TM 1-408

WAR DEPARTMENT TECHNICAL MANUAL

AIRCRAFT POWER PLANT OPERATION

WAR DEPARTMENT • 16 MARCH 1944

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This manual supersedes TM 1-408, Aircraft Engine Operation and Test, 24 December 1941

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TM 1-408, Aircraft Power Plant Operation, is published for the information and guidance of all concerned.

[A. G. 300.7 (4 Feb 44).]

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

J. A. ULIO,
Major General,
The Adjutant General.

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(For explanation of symbols see FM 21-6.)

TECHNICAL MANUAL

AIRCRAFT POWER PLANT OPERATION

Changes No. 1

WAR DEPARTMENT
Washington, March 1945

TM 1-408, 16 March 1944, is changed as follows:

6. ENGINE STARTING. a. General.

* * * * * * *

(2) (Superseded.) Make sure that the ignition switch is in the OFF position and pull the propeller through in the normal direction of rotation four or five revolutions. This is particularly important in radial and inverted type engines during both winter and summer operation. If an excessive amount of oil or fuel is present in the cylinders, the crew will be unable to rotate the propeller. Starting engines with excessive oil and fuel in the combustion chambers must be avoided, as it may result in bent or broken connecting rods.

(3) If the propeller cannot be rotated **as prescribed above,** remove the spark plugs (see fig. 23) and the intake pipes of the bottom cylinder so that the liquid will drain out. Then remove the * * * during their reinstallation.

* * * * * * *

[AG 300.7 (2 May 45)]

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Refer to FM 21-6 for explanation of distribution formula.

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This manual supersedes TM1-408, Aircraft Engine Operation and Test, 24 December 1941.

SECTION I
POWER PLANT OPERATION

1. GENERAL. The power plant is considered as one unit. It includes the engine, propellor, all engine accessories and equipment such as starter, generator, coolers, cowling supports, fixed fire extinguisher, and all engine instruments.

a. In early airplanes, the engine, propeller, and accessories were quite simple and were usually mounted in the same position on all airplanes. However, modern installations vary widely because each type of airplane is designed for specific performance requirements. Figure 1 shows an airplane with engines mounted in the wing nacelles and supported by a welded steel engine mount. Installations of this kind are common to the bombardment type of aircraft which employs high horsepower-output engines. Figure 2 shows the installation of a power plant in the fuselage proper, behind the cockpit. This provides greater range of vision for the pilot and permits the installation of a propeller through which a cannon may be fired. Figure 3 illustrates a radial type engine mounted in the nose section. The liquid-cooled engine is also readily adapted to use in this location. Even though the aircraft engine is a complex unit, it is so constructed that comparatively few bolts and connections need to be handled in the process of removal and installation.

(1) In some installations the position of the engine is reversed from the normal position of mounting. An installation of this kind is shown in figure 4. The propeller mounted in this position is known as a pusher type and is driven by means of an extension shaft.

(2) The number of cylinders is dependent upon the required horsepower output, cost, limitations, the necessary maintenance, and other factors.

b. Personnel safety precautions. Safe operation of high horsepower output engines necessitates strict adherence to safety regulations. If the airplane mechanic is constantly alert and keeps in mind that hazards are always present, many serious accidents will be avoided. Specific instructions cannot be given in this paragraph because various installations have different requirements. The following rules should be used as a general guide for all personnel operating and maintaining aircraft. Their use, together with good judgment and common sense, will greatly reduce the possibilities of injury.

(1) Perform all possible inspections and maintenance when the engine

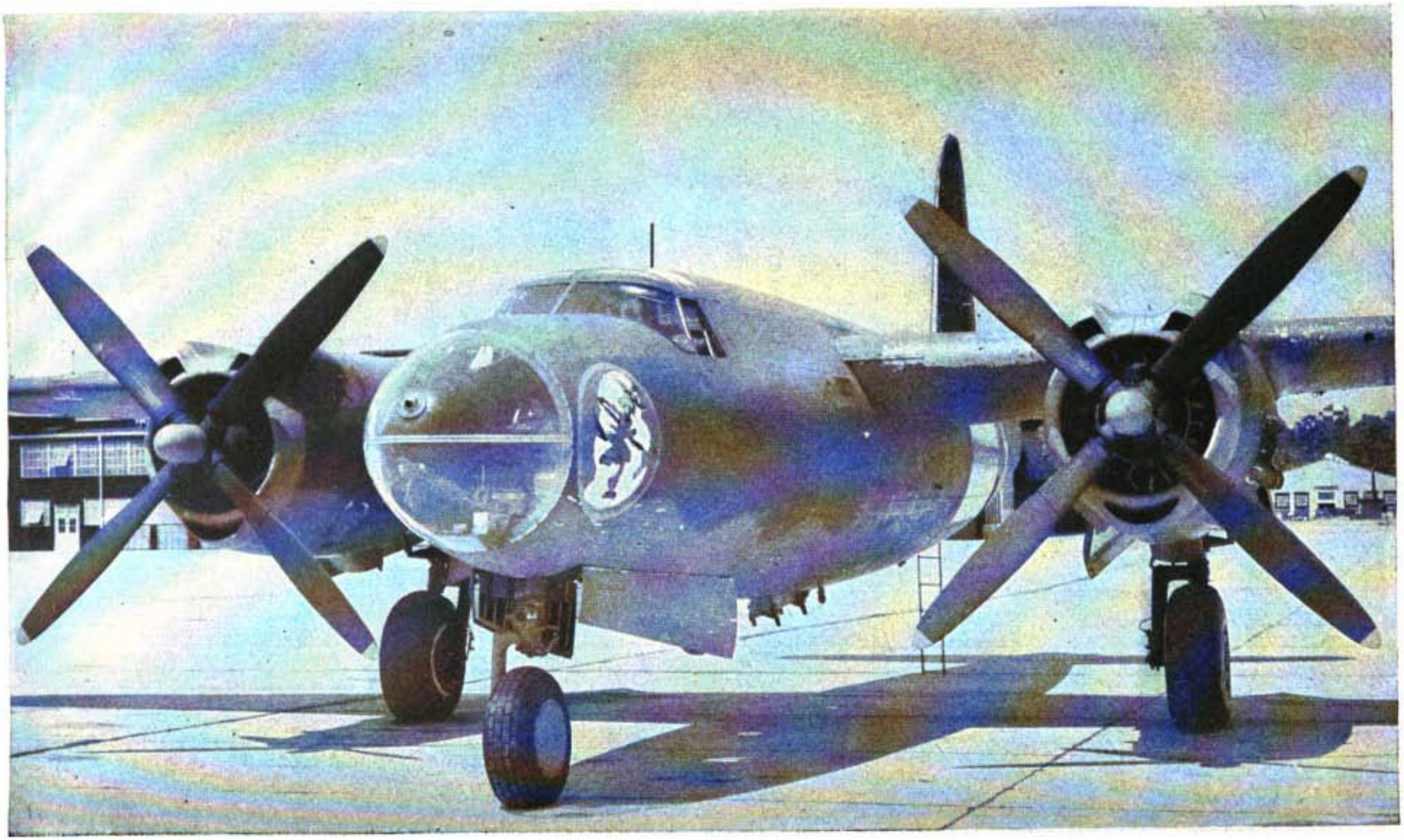


Figure 1. Engines mounted in wing nacelles.

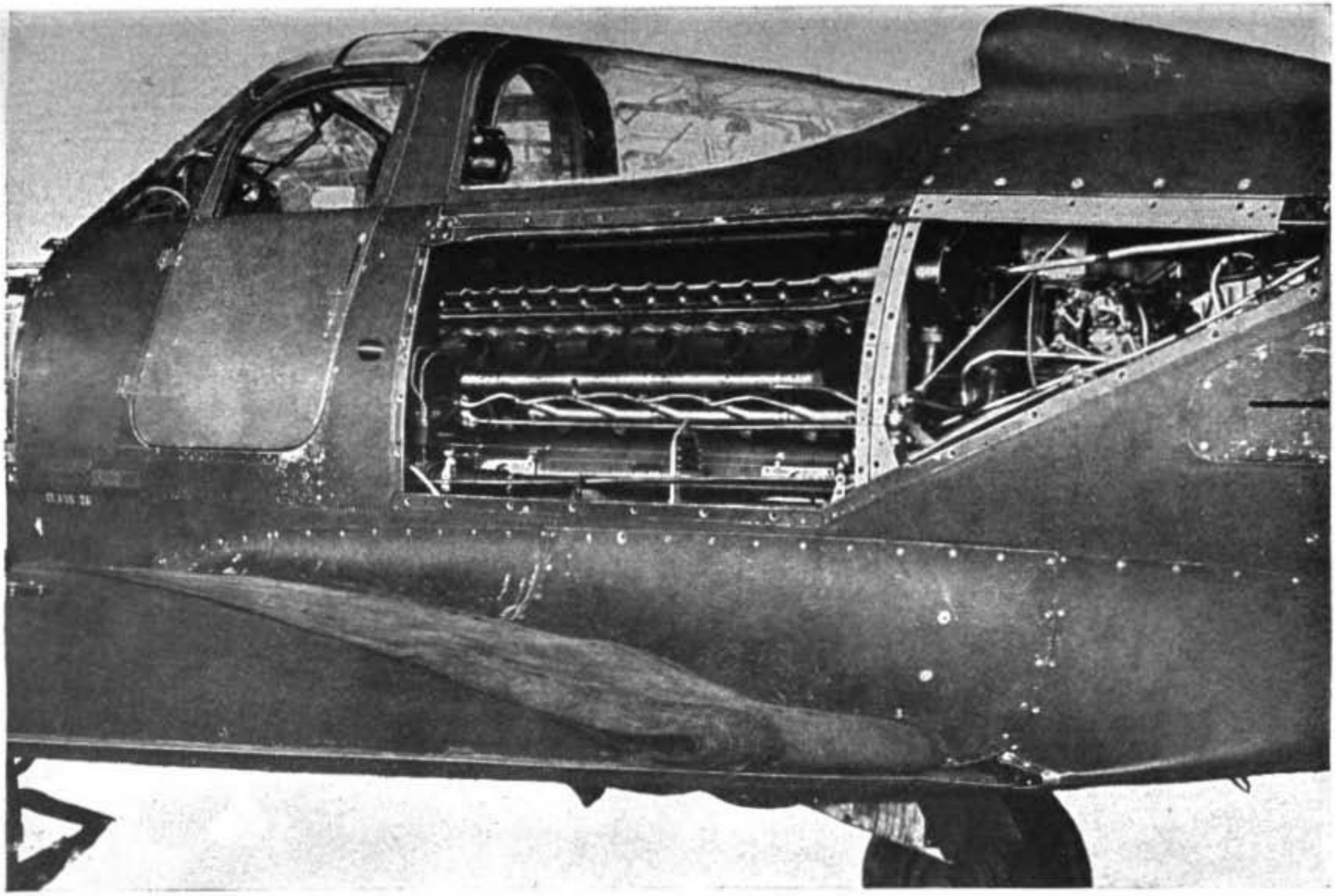


Figure 2. Engine mounted in the fuselage.

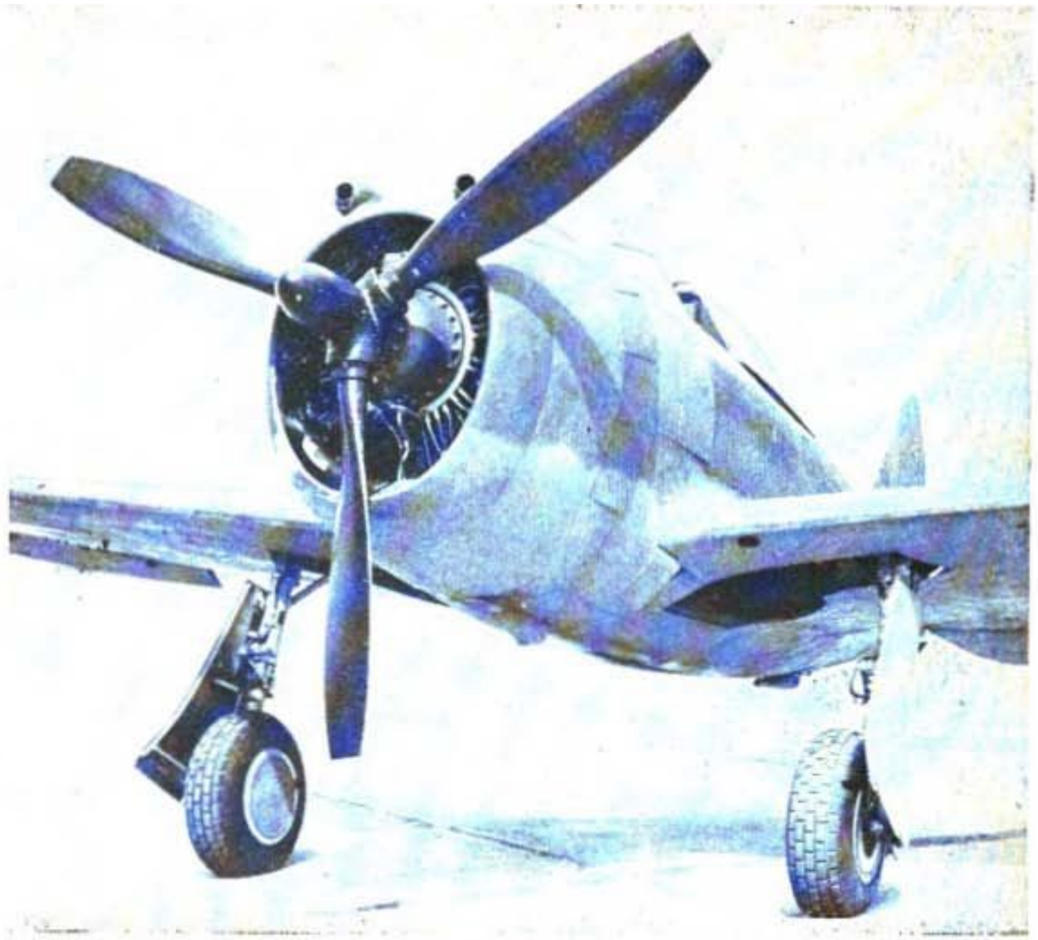


Figure 3. Radial type engine mounted in the nose.

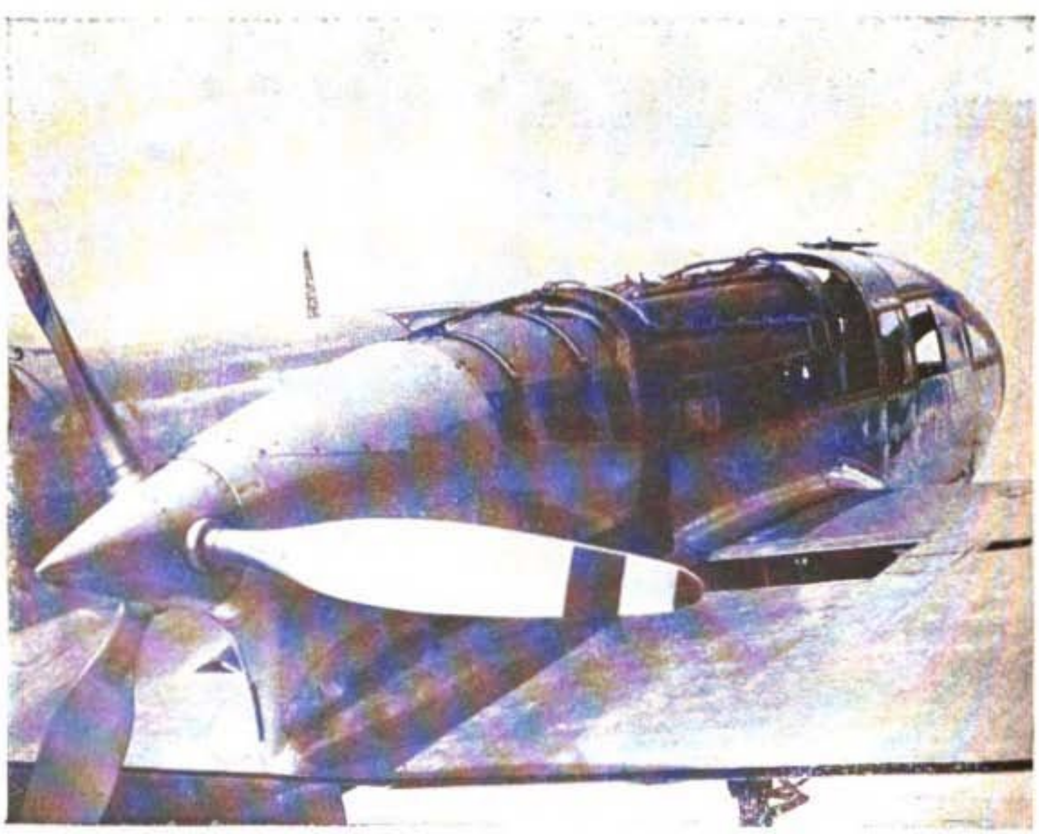


Figure 4. Pusher type propeller installation.

is not running. When it is necessary to work on a running engine, do so with the aid of another crew member. Upon completion of any work, check and recheck.

(2) Be constantly on guard against walking into rotating propellers or moving aircraft.

(3) Before starting the engine, shout the words "All clear" to notify crew members to stand clear of the propeller. Wait until some designated member of the crew returns the same signal before starting the engine.

(4) Be alert and notice irregularities before and after starting the engine. Discovery of irregularities before the engine is started will save time because other damage may result when the engine is operated.

(5) Remove all tools, parts, and tool kits from the airplane and place them in their respective places before starting the engine. This will prevent these objects from being blown around by the propeller blast.

(6) Always be positive that the ignition switch is in the OFF position before any attempt is made to rotate the propeller by hand.

(7) When taxying to and from the flying line, travel in a zigzag path because the view from the cockpit is somewhat obstructed.

(8) Figure 5 illustrates the approved procedure to be used when two or more men are pulling the propeller through on a high horsepower-output engine. Figure 6 shows the recommended grip when executing this operation. Notice that the hands are gripped around the wrist. Smaller engines will not necessarily require more than one man. (See fig. 7.) In all cases be sure that the ignition switch is off. If possible, one man should be in the cockpit at the controls when the propeller is pulled through in its normal direction of rotation.

c. Equipment safety precautions. Specific directions for operating an aircraft engine within its recommended limits are given in Technical Orders. The following precautions are applicable to any power plant installation.

(1) Remove all tools, nuts, loose bolts, washers, etc., from the airplane so that they will not interfere with the rotating propeller and other moving parts. It is a good practice to replace the tools in their proper places or count the number to be sure that none have been forgotten or left lying on the engine.

(2) Before the first flight of the day and if the engine has been inoperative for more than 2 hours (see Technical Order for special cases), pull the propeller through three or four revolutions in order to check for the presence of liquid in the combustion chamber, "loosen up" a cold engine, check for "frozen" pistons, etc. Upon discovery of liquid in the cylinders of an engine, it is permissible to pull the propeller through in the opposite direction. The spark plugs in the lower cylinders of radial engines may be removed to allow the liquid to drain. Failure to observe

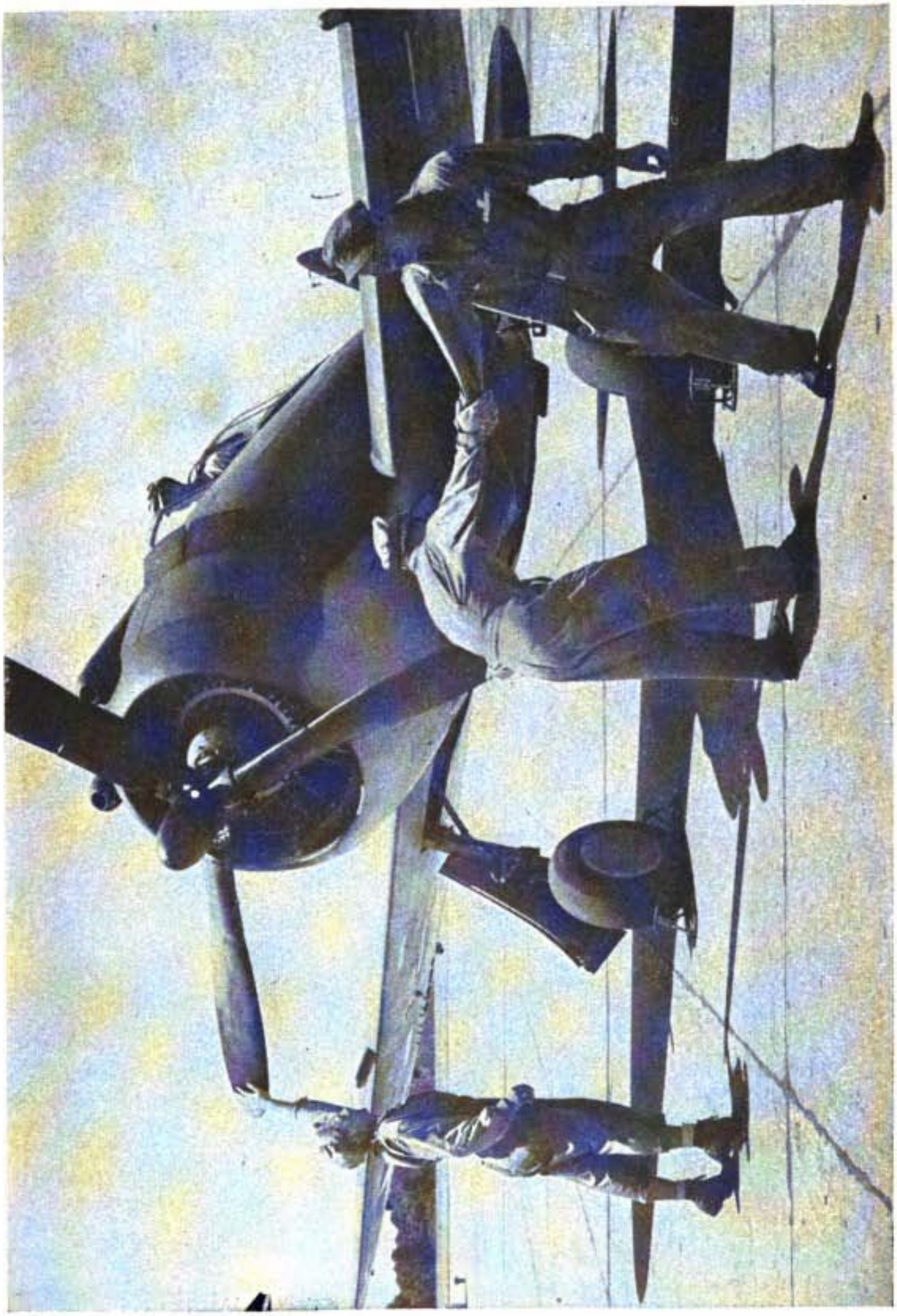


Figure 5. Pulling a propeller through, using three men.

Figure 6. Recommended hand grip.

this rule has often resulted in bent or broken connecting rods, cracked cylinder and piston heads, and distorted crankshafts.

(3) When the engine is started, the oil pressure gauge indication must be observed immediately. It must indicate a rise in pressure within 30 seconds. If no indication is observed, stop the engine immediately. This will prevent burned out bearings, scored pistons and cylinder walls, and other internal damage.

(4) Overheating the engine during ground operation is one of the most common mistakes made by airplane mechanics. It must constantly be borne in mind that the airplane engine is designed primarily for operation in the air and the provisions made for cooling are operative to their full extent only when the airplane is in flight. It is therefore necessary that the temperature readings of the cylinder head temperature gauge, coolant thermometer gauge, and oil temperature gauge be closely observed. If the readings of any of these gauges approach the maximum permissible temperature, the engine should be stopped immediately.

2. CONTROL OF ENGINE OPERATION—COCKPIT CONTROLS.

The operation of the power plant is controlled from the cockpit by numerous control handles and levers which are connected to the engine by means of rods, cables, bell cranks, pulleys, etc. The control handles or levers are in most cases conveniently mounted on quadrants in the cockpit. Labels are placed on the levers or quadrants to indicate the limits and positions of the levers. The linkage from the cockpit to the engine is made in such a way as to allow full and free movement of all controls. In some installations, friction clutches are installed to provide means of holding the controls in place. Overtravel is required in all cases to insure full operation of the units. By manipulating the cockpit engine controls, the operator is able to control the rpm, manifold pressure, engine temperature, carburetor air temperature, oil temperature, and the fuel-air ratio. The coordination of the movement of the controls with the instrument readings provides the necessary guard against the

Figure 7. Pulling a propeller through by one man.

dangers of exceeding operation limits. The operating limits of the engine and the functioning of all the controls must be clearly understood by the operator before he starts the engine.

3. ENGINE INSTRUMENTS. **a.** Aircraft instruments may be divided into three classes: power plant instruments, flight and navigation instruments, and miscellaneous instruments. The discussion in this manual will be limited to the instruments which indicate to the operator the condition of the engine and its accessories and which help him to operate the engine properly. Many of the miscellaneous gauges and devices show whether or not the various accessories are functioning; thus on some airplanes a warning signal lights when the fuel pressure is low. A similar device is in use for oil-pressure systems.

b. Typical engine instrument installation. The term "engine instruments" usually includes all instruments required to measure and indicate the functioning of the power plant. The engine instruments are generally installed on the panel in such a way that all of them can easily be observed at one time. (See fig. 8.) Most installations will have the following instruments:

(1) Oil pressure gauge.
(2) Oil temperature gauge.
(3) Fuel pressure gauge.
(4) Carburetor mixture temperature.
(5) Cylinder head temperature or coolant temperature indicators.
(6) Free air thermometer.
(7) Manifold pressure gauge.
(8) Tachometer.
(9) Liquidometer or fuel level gauge.
(10) Fuel mixture indicator.
(11) Engine synchronism indicator.

c. Interpretation of instrument readings. One of the most important of the skills which the airplane mechanic must develop is the ability to read and properly interpret engine instruments. The general operating principles of these instruments have previously been studied; therefore, this discussion will be devoted to the interpretation of the readings in checking for proper functioning of the engine and its accessories.

(1) The oil pressure gauge indicates the pressure (in pounds per square inch) under which the oil of the lubricating system is being supplied to the moving parts of the engine. Failure to register pressure whenever the engine is operating is a positive indication that remedial measures must be taken immediately. Excessive oscillation of the gauge pointer indicates that the oil lines are obstructed or that some unit of the oil system is functioning improperly.

(2) The oil temperature gauge is used primarily to indicate the temperature of the oil as it is about to enter the engine from the tank. The importance of noting changes in temperature as registered by this gauge cannot be overemphasized because the temperature of the oil affects its lubrication qualities and has a direct bearing on the operating efficiency of the engine.

(3) The fuel pressure gauge indicates the pressure (in pounds per square inch) at which the fuel is being furnished to the carburetor. Any obstruction in the lines or the failure of any unit of the fuel system will be indicated by an abnormal reading of this instrument.

(4) The carburetor mixture thermometer records the temperature of the fuel-air mixture as it leaves the carburetor. The temperature bulb is located between the supercharger and the carburetor.

(5) The carburetor air intake temperature gauge guides the operator in the use of the carbuetor air heater control when icing conditions are present. It indicates the temperature of air at the carburetor intake or scoop.

(6) The coolant temperature gauge indicates the temperature of the coolant at a point between the engine outlet and radiator inlet. By watching this gauge the operator is guided in his adjustment of the position of the radiator shutters, thus preventing dangerous overheating or underheating.

(7) The cylinder head temperature gauge is installed in aircraft radial engines to measure and indicate the temperature of the hottest running cylinder. The reading of this gauge is extremely important in determining whether or not the engine is sufficiently warm for take-off. It also indicates dangerous conditions of combustion within the cylinder. Detonation and improper mixture adjustment will produce radical changes in cylinder temperature.

(8) The free air thermometer registers the temperature of the air or atmosphere outside of the cockpit. The reading of this gauge is particularly important in determining when conditions are such that carburetor icing may occur.

(9) Manifold pressure gauges indicate the pressure (in inches of Hg) of the fuel-air mixture as it enters the combustion chamber. The limits of the manifold pressure are specified for each particular engine installation to insure safe operation. Operating an engine at excessive manifold pressures will raise the compression pressure, resulting in excessive stresses on the pistons and cylinders. Detonation often results when pressure is excessive for fuel of a given octane rating. A direct result will be an immediate rise in cylinder temperature. This may also cause failure of piston heads, cylinder heads, or other structural parts of the engine. The reading of the manifold pressure gauge also gives an immediate indication of icing conditions in the carburetor and thus serves

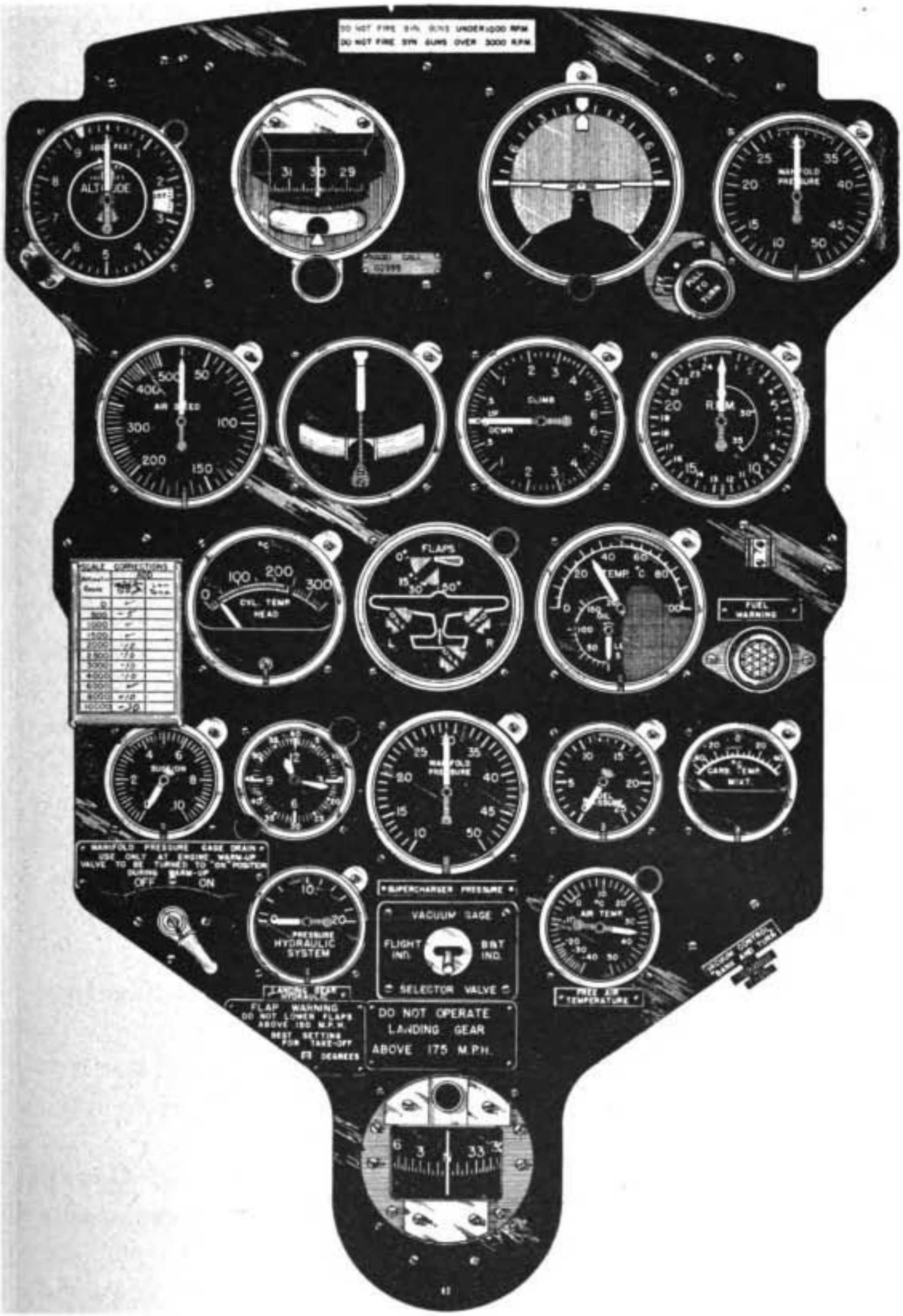


Figure 8. Single-engine airplane instrument panel.

as a warning device for determining when to use the carburetor air heater.

(10) The tachometer is one of the most important of the engine instruments. It measures the engine crankshaft speed in rpm and measures engine performance on the ground as well as in the air. Tachometer indications assist in determining the probable causes of engine trouble. They also permit the operator to adjust the engine speed to the most economical setting during flight.

(11) The liquidometer or fuel level gauge furnishes the operator with constant and accurate indications of the amount of fuel in each tank. This information will enable him to judge flight distances by noting the amount of fuel the power plant has consumed. It will also inform him when it is necessary to switch to another tank.

(12) The fuel mixture indicator furnishes the operator with a constant indication of the ratio of fuel to air which is being consumed by the engine. Maintaining this ratio within certain desired limits will help to insure economical and proper operation of the engine. If the fuel mixture indicator shows an excessively rich mixture when a comparatively lean mixture is normally expected, detonation is taking place.

(13) The engine synchronism indicator is used on multi-engine airplanes in order to synchronize more closely the speeds of the engines. By its use, the speeds of the engines may be synchronized within a few rpm, thus insuring smooth and economical operation.

d. Instrument operation markings. Power plant operation is limited by specific instructions for the particular model of engine. In order to make these limits readily available to the operator, markings are placed on the cover glass of various instruments to indicate the maximum and minimum permissible operating points. The markings on the cover glass may be distinguished by their colors. (See fig. 9.)

(1) Green arcs denote the desired operating range.

(2) Short red radial lines indicate either a minimum or maximum permissible point of operation.

(3) A short white radial line placed partly on the case and partly on the instrument cover glass reveals any movement of the glass in the case.

4. OPERATING FACTORS AND THEIR CONTROL. a. Quantity of fuel-air mixture. Considering an airplane engine not equipped with a turbo-supercharger, the throttle valve, commonly called the butterfly valve, is located in the entrance of the induction system. It controls the flow of fuel-air mixture entering the cylinder on the intake stroke. When the engine is operating on a correctly proportioned mixture, this control either increases or decreases the power of the engine by allowing more or less of the mixture to enter the cylinders. The greater the amount of the mixture admitted into the combustion chamber the greater will be the pressure on the piston, hence, the greater will be the power output. The illustrations in figure 10 show the effect of throttle position on the quantity of mixture entering the combustion chamber. In the two illustrations, notice the similarity of the air density in the intake scoop before the throttle valve and the difference after passing the valve.

(1) THROTTLE CONTROL LEVER. This lever is the most con-

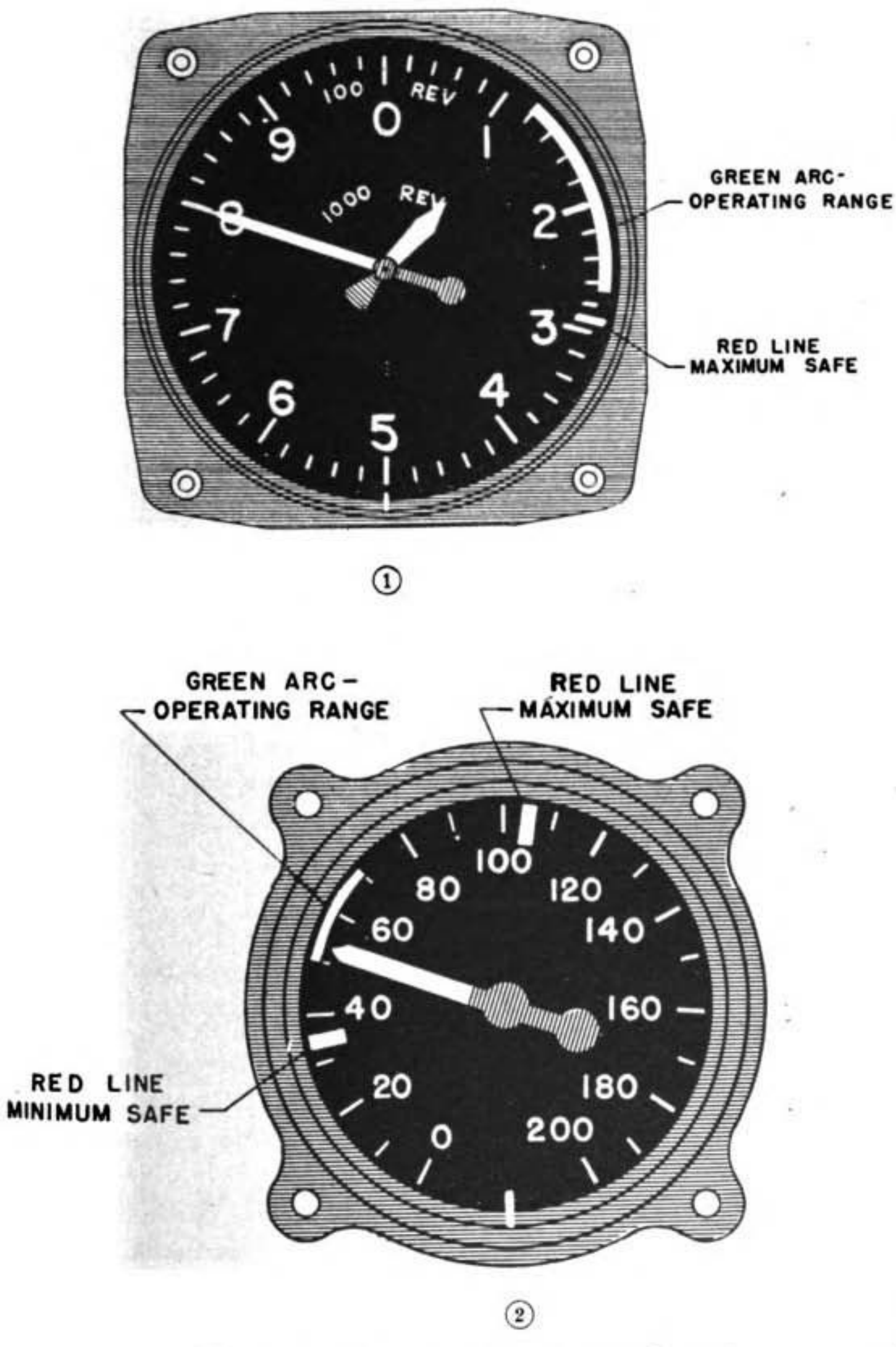
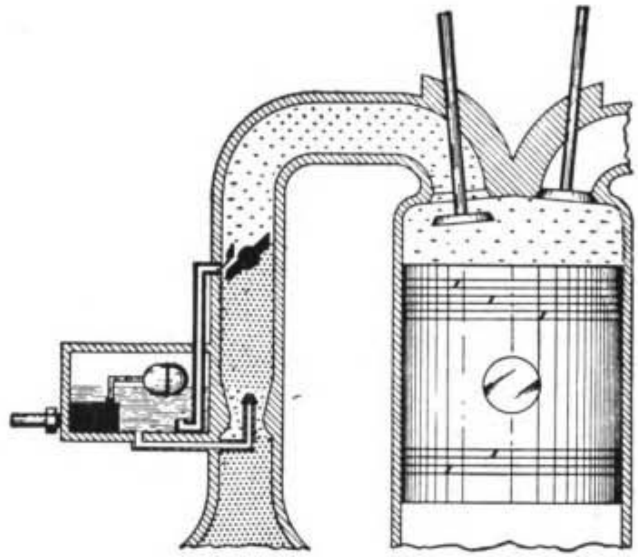
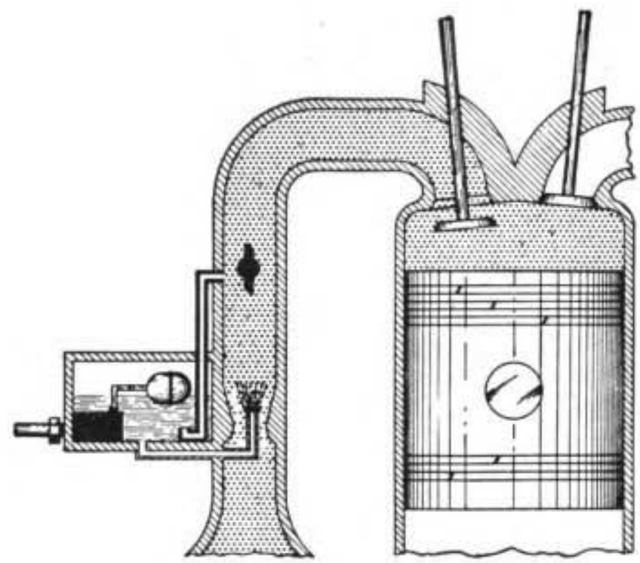


Figure 9. Instrument cover-glass markings.



① *Partly open.*



② *Wide open.*

Figure 10. Effect of throttle opening on density of fuel-air mixture (float type carburetor).

spicuous in the cockpit and is clearly designated by markings on the lever knob (a letter "T") and on the control quadrant. Movement of this control either increases or decreases the size of the induction system entrance by opening or closing the butterfly valve.

(2) FUEL-AIR MIXTURE. The amount of fuel-air mixture used by an engine is expressed in terms of weight of fuel per brake horsepower. When excessive amounts of the charge are admitted, the engine is compressing into the combustion chamber more than it was designed to accommodate. Excessively high readings noted on the manifold pres-

sure gauge indicate this condition. It should be interpreted immediately to mean that structural stresses and strains are present in many parts of the engine as a result of the excessive pressure, and the throttle should be adjusted accordingly. Adjustable throttle stops may be installed with highly supercharged engines to warn the operator to limit the opening of the throttle below the critical altitude of the engine; but throttle stops are a poor substitute for a clear knowledge of the manifold pressure limits of the engine. Low manifold pressure also affects engine operation. At sea level 169 cubic feet of air will weigh 13 pounds. (See fig. 11①.) This is the amount required to burn completely 1 pound of fuel for maximum power. However, at 18,000 feet, 169 cubic feet of air weigh only 6.5 pounds, because the air is about one-half as dense. (See fig. 11②.) As altitude increases and density of air decreases, an over rich

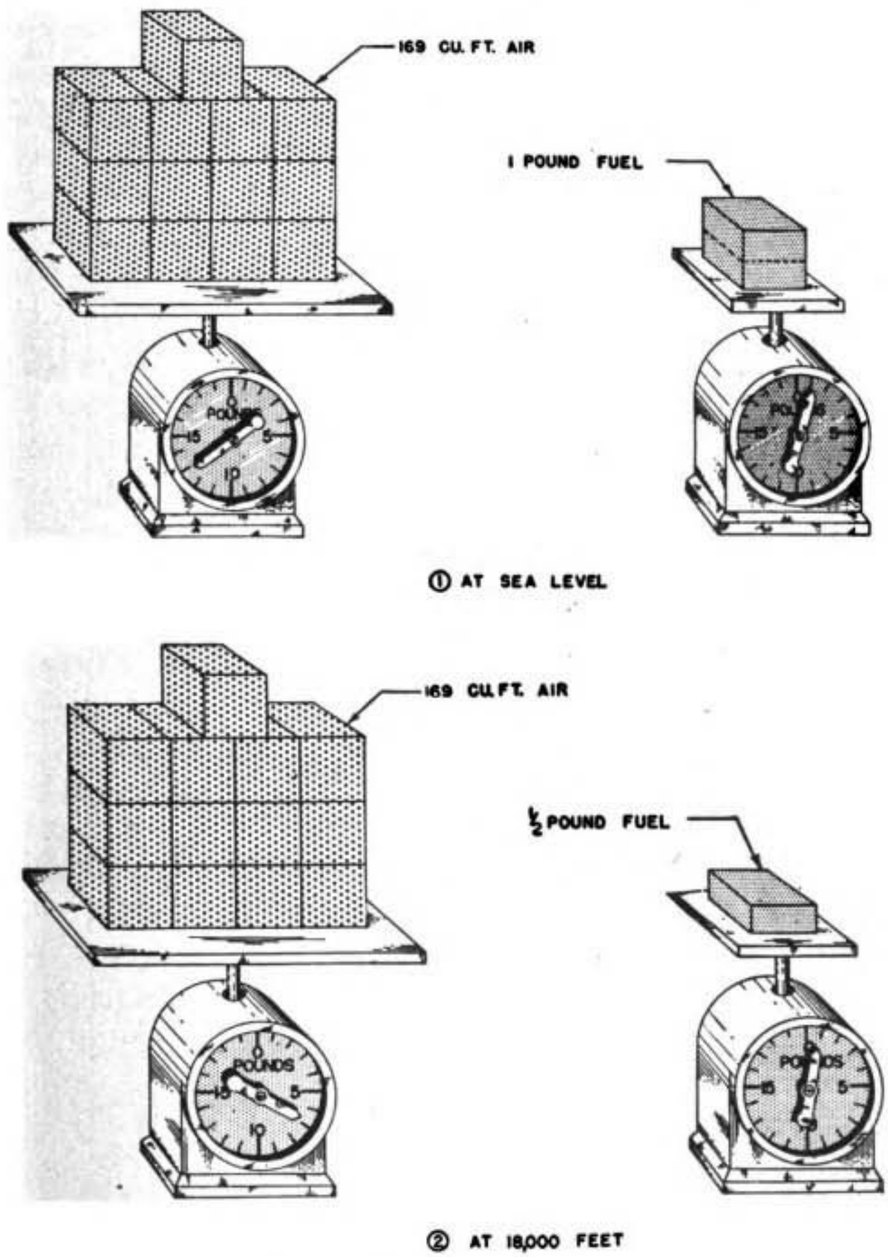


Figure 11. Fuel-air mixture.

mixture and loss of power and speed result. To operate smoothly (but with a loss of power) at 18,000 feet the weight of the fuel must be decreased to one-half its original weight to maintain a correct mixture ratio of 13 to 1. This loss of power is overcome by the installation of superchargers which pack the fuel-air mixture into the cyclinders, thereby maintaining or increasing (if required) the horsepower available from a specified engine.

(3) SUPERCHARGERS. The supercharger operates as a centrifugal fan which forces additional air, together with fuel, into the induction system. The forced induction may be used to increase the power of an engine at low altitudes or it may be used by the engine at high altitudes to make up for the deficiency in pressure due to the lower density of air. It was previously stated that the fuel consumption varies directly with the horsepower delivered. The curve in figure 12 illustrates the quantity of fuel consumed at full power compared to the amount consumed at half power. Assuming a full-rich mixture and sea-level operation, the graph indicates that at high speed, level flight, the engine is delivering 95 percent of its rated power and consuming 100 gallons of fuel per hour.

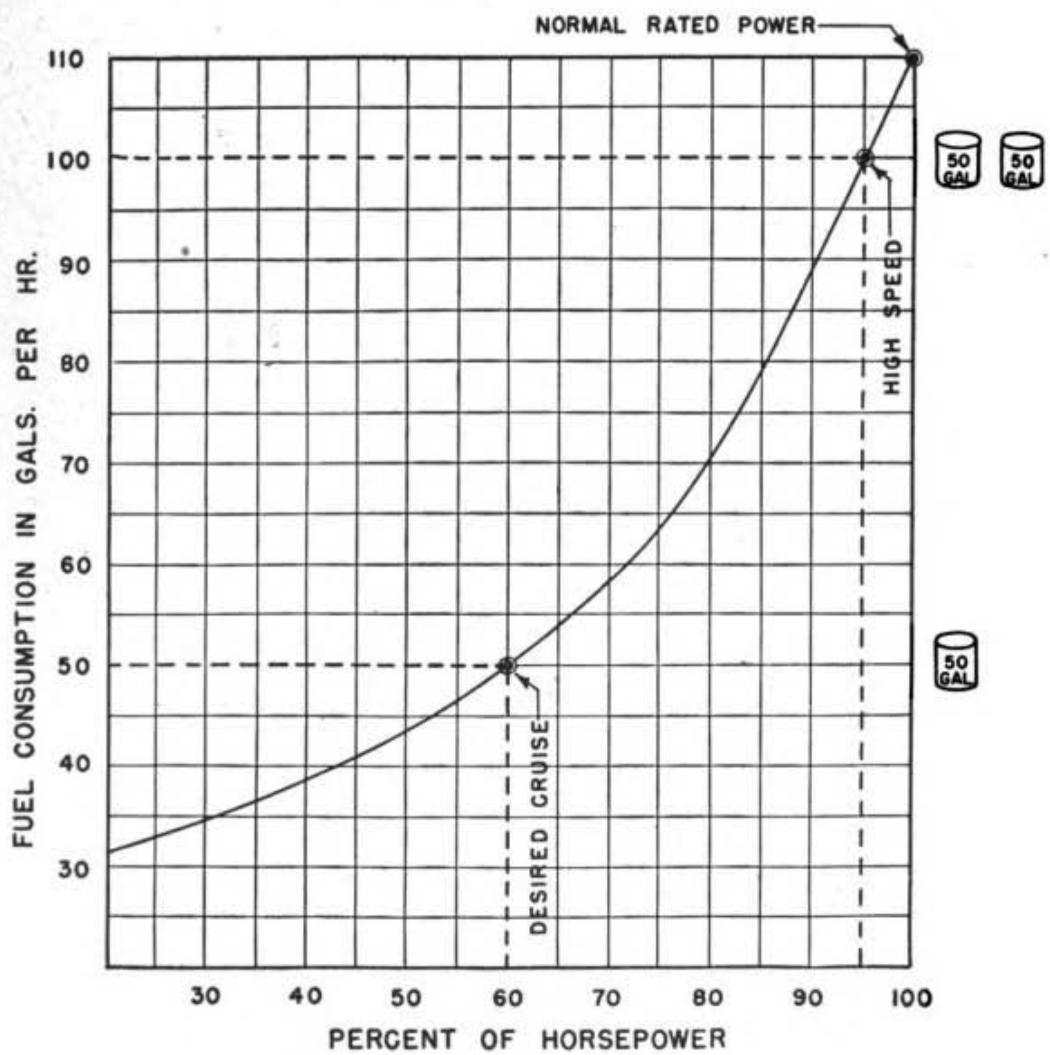


Figure 12. Fuel consumption-horsepower curve.

At desired cruising, the engine fuel consumption is only 50 gallons per hour or a 50 percent saving in the amount consumed at high speed, with only a 35 percent reduction in horsepower. The reason for this saving in fuel is that at full power, a rich fuel-air mixture must be used to prevent overheating of the engine, whereas at reduced power a leaner fuel-air mixture may be used.

b. Quality of fuel-air mixtures. To provide for variations in fuel, atmospheric pressure, and other operating variables, the carburetor is set to provide a slightly richer mixture than that which will give the best power. Adjustment of the mixture control lever from the FULL RICH position toward the LEAN or IDLE CUT-OFF position varies the amount of fuel delivered by the carburetor by controlling the fuel-air ratio. Intelligent use of the mixture control is of vital importance in maintaining safe and economical operation of the engine. The mixture control should never be used without a full understanding of its effect on engine operation, a knowledge of the characteristics of the fuel being used, and the general conditions under which the engine is operating. It is possible to damage an engine beyond repair in a few minutes by improper use of the mixture control. Too lean a mixture will overheat the engine and will possibly cause piston rings, pistons, and valves to stick or "freeze." Correct fuel-air ratio, that is the number of parts of air by weight as compared to the parts of fuel by weight, lies between 11 to 1 and 16 to 1. This ratio gives the proper mixture to produce maximum power. A ratio of 13 to 1 is generally selected as the desired ratio for normal operation. This weight proportion of air and fuel is necessary to promote proper combustion. With the mixture control lever as shown in figure 13①, the throttle in a fixed position, and the propeller pitch fixed, a movement of the mixture control from its FULL RICH position to a leaner position will cause an increase in engine rpm. The point at which this increase ceases is called the RICH BEST POWER position, figure 13②. Further leaning will maintain the rpm at the same value for an appreciable movement of the control. Still further leaning will cause a loss in rpm. The position of the mixture control at which this loss in rpm begins is called the LEAN BEST POWER position (see fig. 13③.) Figure 13④ shows the control set to produce further leaning of the mixture. This will cause detonation and result in horsepower and speed losses, proportional rises in engine failure. In this illustration it should be noted that the mixture ratio has risen tremendously. It must be understood that the illustrations in figure 13 show movement and not definite positions of the control lever. A knowledge of the various fuel-air mixtures is of importance to the operator. Those mixtures, their use and control are discussed in the following paragraphs:

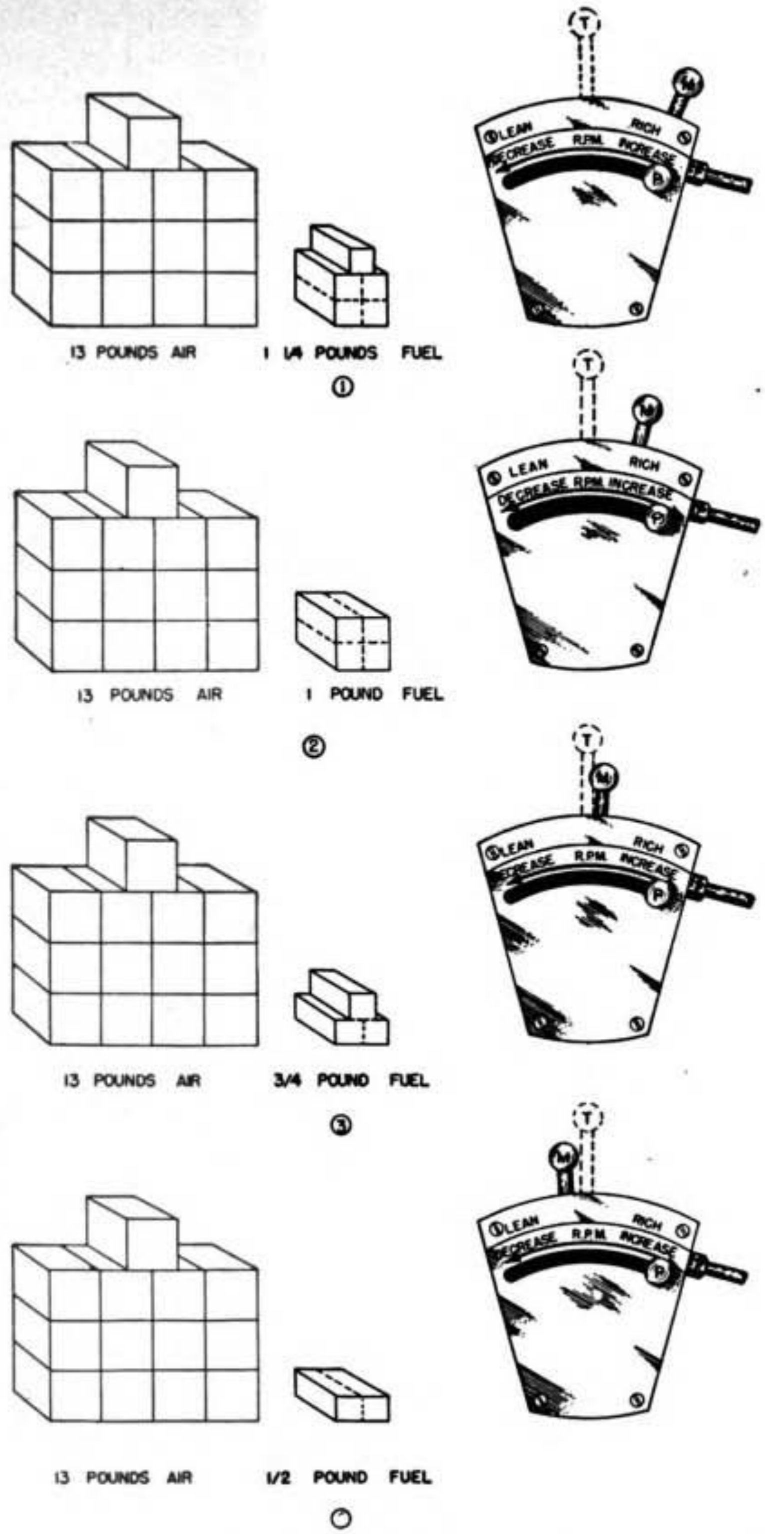


Figure 13. Effect of mixture control movement on fuel-air ratio.

(1) Excessively rich mixtures (ratios less than 11 to 1) will not produce full power because proper combustion will not take place. They will result in excessive fuel consumption and more or less sluggish engine operation, depending upon the extent of richness. This condition is indicated by heavy black smoke and red flame issuing from the exhaust ports. (See fig. 14.)

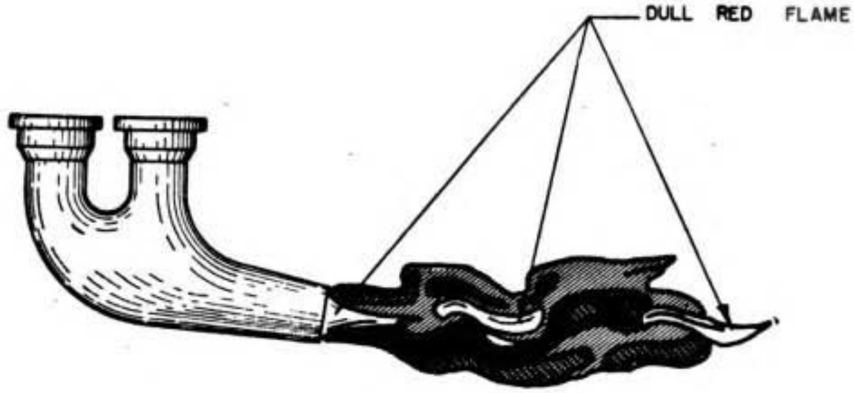


Figure 14. Excessively rich mixture indicated by exhaust flame.

(2) Rich mixtures are best suited for maximum horsepower output. All oxygen particles are removed by combustion but enough fuel particles remain in the combustion chamber to absorb the excess heat and help cool the engine. The color of the exhaust flame is blue with a yellow tip. (See fig. 15.)

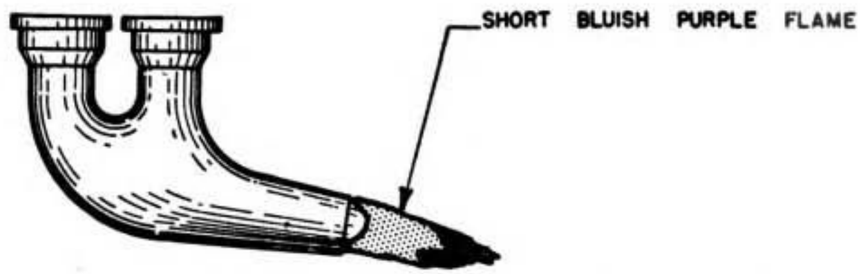


Figure 15. Rich mixture indicated by exhaust flame.

(3) Cruising lean mixtures are used for maximum economy. The ratio is about 16 to 1 and is used when long-range operation, medium power output, and maximum fuel economy are required. Care must be taken to prevent detonation.

(4) Lean mixtures of approximately 17 to 1 ratio and higher will result in decreased power. Detonation and excessive operating temperatures are produced since the speed of the combustion flame is retarded. If the flame is still burning in the combustion chamber when the intake valve opens, "popping back" will occur. Flame color will be predominately yellowish white with a tinge of light blue. (See fig. 16.)

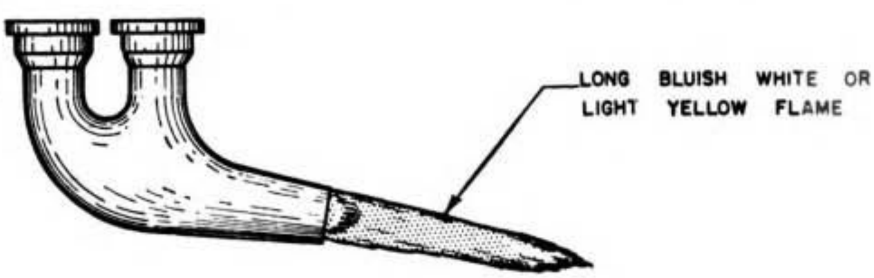


Figure 16. Lean mixture indicated by exhaust flame.

(5) As has been previously stated, the mixture control setting for various altitudes has a decided effect upon engine performance. For a given throttle opening and a given position of the mixture control, the mixture will become enriched as high altitude is attained. Conversely, with loss in altitude, the mixture becomes leaner with unchanged mixture and throttle settings. Therefore, the mixture control should be readjusted for each 1,000 feet of change in altitude. For take-off, climb, or landing, at or near sea level, the mixture control should be in the FULL RICH or AUTOMATIC RICH position as specified for the particular engine. At high-altitude fields, the mixture control should be placed as close to the FULL RICH position as possible, and only leaned to obtain smooth running of the engine. At high manifold pressures, the mixture control should be set at FULL RICH, although at extreme altitudes it is permissible to lean out the mixture just enough to obtain smooth running of the engine. At approximately 80 percent of the rated rpm of the engine, it is recommended that the mixture control be used as an economy device. At this time the mixture control may be moved to LEAN BEST POWER or lower, depending upon the type of engine. However, great care must be exercised when using the mixture control as a fuel economy device, because lean mixtures tend to increase engine operating temperatures.

(6) With the advent of fuel-air ratio indicators installed in the aircraft cockpit, the proper use of the mixture control was greatly simplified. This instrument has eliminated guess work in obtaining desired mixtures for any condition of engine operation.

(7) There are various automatic mixture controls which eliminate the use of the manual control, except as an optional device to be used at the discretion of the operator in an emergency.

(8) On an engine equipped with constant-speed propeller, the propeller assembly must be placed in the fixed position in order to adjust the mixture control when a fuel mixture indicator is not provided.

c. Spark position. Most American manufacturers of high-output aircraft engines have discontinued the use of a spark control. Theoretically, the firing of the spark plug should occur at a particular point during the compression stroke, so that a complete burning of the fuel-air charge occurs just as the power stroke begins. A good ignition spark must be an intensely hot flame which will penetrate and ignite the compressed charge. The magneto generates a low-voltage primary current and a high-voltage induced secondary current which is directed (by the distributor) through high-tension leads to the individual spark plugs. A very high voltage (approximately 20,000 to 25,000 volts) is required because of the increased resistance built up by the high compression.

(1) FIXED ADVANCE SPARK. Fixed advance-spark position is used on nearly all modern aircraft engines. The charge is ignited during

the compression stroke at a point from 15° to 35° of crankshaft travel before the piston reaches top dead center. The exact position varies with different types of engines.

(2) STAGGERED SPARK. Since exhaust systems are not 100 percent efficient, some of the exhaust gases from the previous charge remain in the vicinity of the exhaust valve. The new charge entering combines with these gases and forms a slow-burning mixture in this area. *Staggered spark* is designed to eliminate "lopsided" burning. With this arrangement, the spark plug nearest to the exhaust valve fires 4° to 8° of crankshaft travel before the other spark plug, as shown in figure 17.

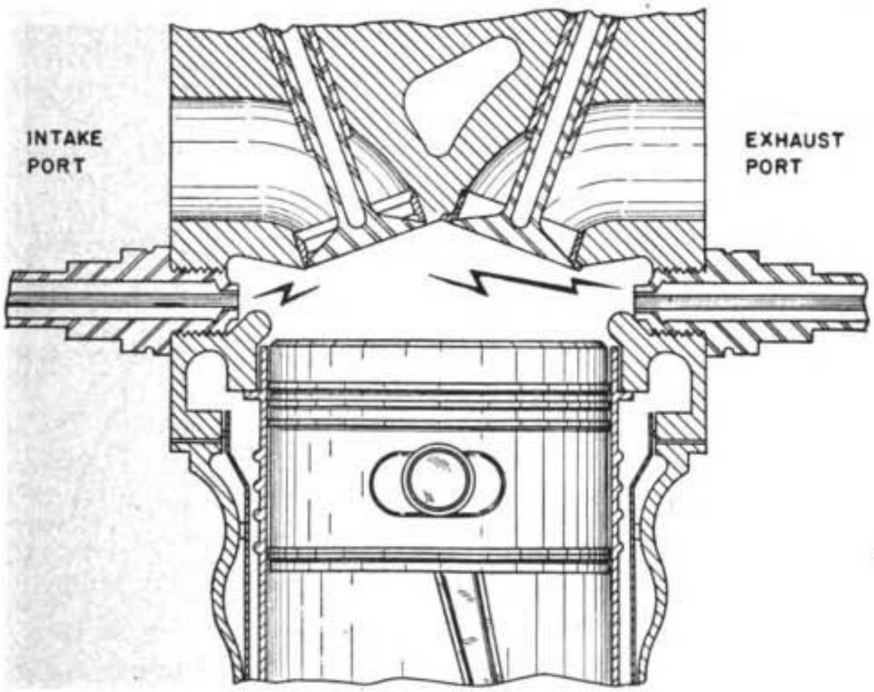


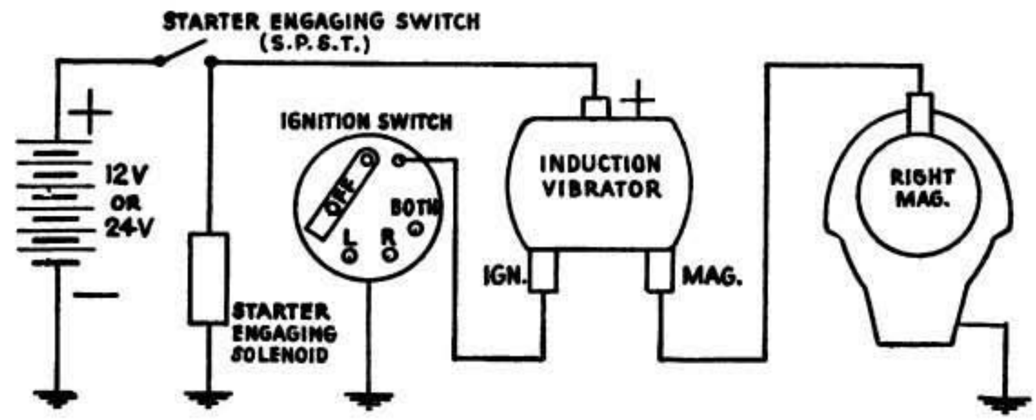
Figure 17. Staggered spark.

This makes it possible for the flames of the slow-burning and fast-burning mixtures to meet in the center of the piston and exert their greatest pressure there.

(3) SYNCHRONIZED SPARK. *Synchronized spark* results from synchronized timing of the breaker points. The spark plug and valve locations are so fixed that the spark from each spark plug ignites the charge at the same time and flame travel is equal in both directions.

(4) RETARDED SPARK. *Retarded spark* is the result of the breaker points opening late so that the piston is approximately at top center or after when the spark ignites the charge. When this occurs the engine is said to be firing "late." Retarded spark is commonly used in the booster-coil system to aid engine starting. The spark from the booster coil is discharged through the trailing booster segment. This is purposely set to fire the charge when the piston is very near top center, in order to eliminate "kick back."

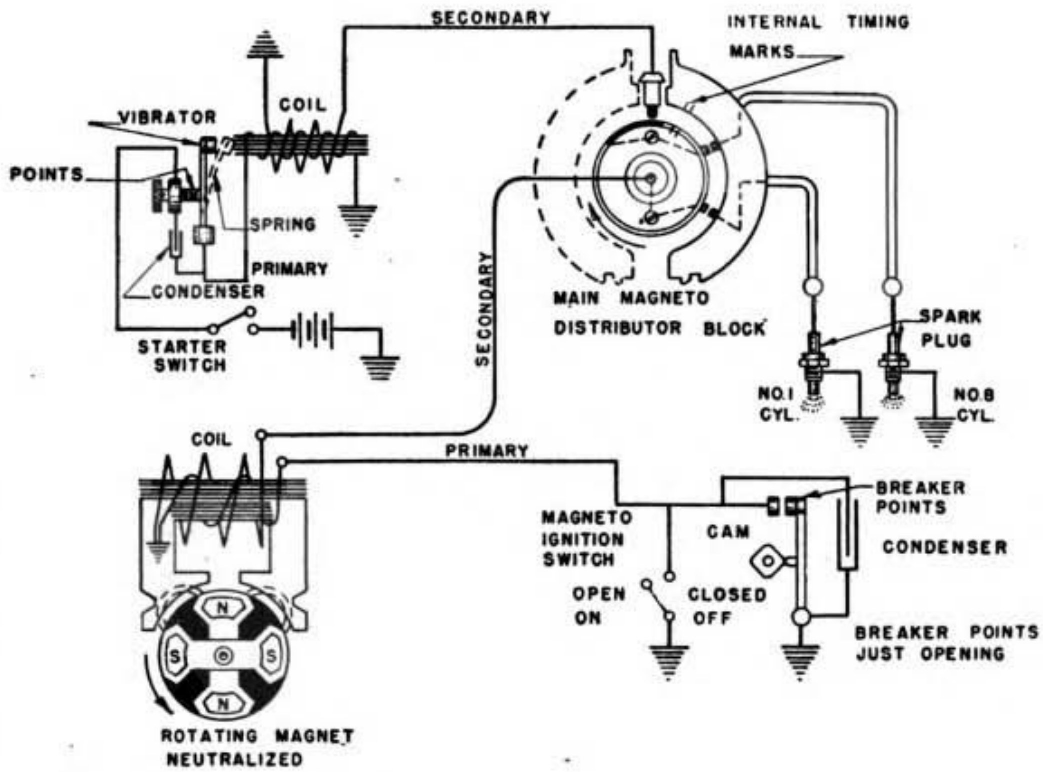
(5) BOOSTER COIL SPARK. This spark is produced by an auxiliary unit which supplies high voltage to the spark plugs during starting. It is delivered when the starter switch is placed in the MESH position. Simultaneously, the meshing solenoid operates the starter engaging device, causing the engine starter dog to engage the engine dog and turn the engine over. Booster current passes through the booster cable (which is connected to the booster terminal marked H), to the booster electrode, and then to the booster collector ring. It is then conducted to the booster segment and across the distributor block electrodes and spark plugs. The booster segment in the distributor finger trails the high tension segment and consequently gives a retarded spark. In other words, when the high tension segment is in position to fire No. 1 cylinder the booster segment is in position to fire No. 8 cylinder (in a nine-cylinder engine). (See fig. 18.)



① *Induction vibrator.*

Figure 18. External wiring diagram.

(6) INDUCTION VIBRATOR. (*a*) The *induction vibrator,* which is replacing the booster coil, functions as an auxiliary source of ignition power to facilitate starting of aircraft engines. It supplies an interrupted battery current through the primary winding of the regular magneto coil, which then acts like a battery ignition coil, producing sparks or electric impulses which are distributed through the distributor rotor, distributor block, and cables to the spark plugs. This action takes place during the entire period that the magneto contact points are open. During the period the magneto contact points are closed, no spark can be generated, although the vibrator continues to send interrupted current impulses through the magneto contact points to ground with no harm to itself or any other part of the system. The unit is composed of a vibrator and a relay. The relay automatically connects and disconnects the induction vibrator to the circuit, the vibrator being active only during the cranking period of the engine. The relay also prevents grounding of the magneto in installations where



② *Booster coil operation.*

Figure 18. External wiring diagram.

the induction vibrator is operated in parallel with a starting-motor engaging coil.

(*b*) The induction vibrator operates from a storage battery (fig. 18). When the engine ignition switch is in the ON position and the starter is engaged to the engine, the current from the battery is sent through the coil of the relay causing the relay points to close. The closing of the relay points completes the circuit to the vibrator coil and the vibrator produces a rapidly interrupted current. This current is sent through the primary winding of the magneto coil where, by induction, a high voltage is created in the secondary winding of the magneto coil. This produces a shower of high-tension sparks which are delivered to the spark plugs through the magneto distributor rotor and distributor block electrodes, when the magneto contact points are open. This action continues until the magneto contact points close and the current is bypassed to the ground. This action is repeated each time the magneto contact points are seperated, sending the interrupted current again through the primary of the magneto coil where the action oulined again occurs. This action continues until the engine is firing under the regular magneto spark and the engaging switch is released.

d. Engine temperatures. The heat produced by the combustion of the fuel-air mixture is very necessary to the functioning of the internal combustion engine. From this process is obtained the necessary increase of temperature and pressure to force the piston downward and to rotate the crankshaft. If it were possible to confine the heat in the combustion chamber and allow none to escape into the cylinder walls and other metal parts of the engine, more power could be derived from the same amount of fuel consumed. Since it is not mechanically possible to use all of the heat energy expended by the burning mixture, it is essential that some medium, such as air or some specified liquid, be used to remove the excess heat. (The lubricating oil also assists in removing surplus heat from the engine.) It has been found that maximum economy and power output are available at a certain temperature. In order to reach this temperature, engines must be operated during a warm-up period after they are started. The principal purpose of warming up is to expand the numerous engine parts to their proper clearances to obtain smooth operation. Lubricating oil is also affected by temperature changes and must be thoroughly warmed before it will flow freely between the moving parts. Indications of engine temperatures are shown on the cockpit instrument panel by the oil temperature gauge, coolant temperature indicator, and the cylinder head temperature gauge. Temperatures are kept within the desired operating ranges by proper adjustment of the throttle, mixture control, oil cooler shutters, coolant shutters, cowling flaps, and the carburetor air heater or intercooler shutters.

(1) The throttle position, in part, controls the rate of combustion events in the cylinder, which in turn governs the heat generated. When the throttle is nearly closed, combustion events are fewer per unit of time. Opening the throttle increases engine power output, and also causes the engine to develop more heat.

(2) The mixture control adjustment has a very decided effect on the operating temperature. Leaning a mixture to excess admits a greater quantity of oxygen particles into the combustion chamber and as a result all of the fuel particles, which would tend to cool the engine, are burned. Excessively rich mixtures are not as dangerous, although they do possess the slow burning characteristics of a lean mixture. During the combustion of a normal-burning rich mixture, most of the oxygen is eliminated but some fuel particles (which absorb heat) are left in the chamber.

(3) Cowling flaps control the amount of air that passes over and around the cylinder fins (air-cooled engines). The opening of the flaps will decrease cylinder head temperature.

(4) The flow of air through the core of the radiator is regulated by the coolant shutters. This controls the temperature of the liquid passing through the cooling system of the engine.

(5) To maintain safe "oil-in" temperatures, oil cooler shutters are regulated manually or automatically. There are two types of automatic controls: the temperature regulator incorporating a thermostatic valve which operates the shutters in order to maintain a constant oil temper-

ature; and the viscosity regulator which tends to maintain the oil at a constant viscosity.

(6) The use of the carburetor air heater always increases engine temperature. If an excessive amount of heat is introduced into the engine through the use of this heater, detonation, preignition, and a great loss of power will result. Only the amount of heat necessary to prevent icing and effect sufficient warming of the air for smooth operation should be used. More power and lower engine temperatures can be obtained with lower carburetor inlet temperatures.

e. Oil-cooling control. The indications of the oil temperature gauge are transmitted from the thermometer bulb (in the oil inlet passage to the engine) to the gauge on the instrument panel. In addition to its primary purpose of eliminating metal-to-metal contact, the oil also serves as a cooling medium for the engine. The use of a radiator cooler is required because much of the engine heat is given up to the oil. The cooler is generally located in the line between the scavenging pumps and the oil tank, and is usually fitted with a spring-loaded thermostatic valve which bypasses the oil around the jacket when the oil is thick and cold. This is desirable because it produces quick warming of the oil when the engine is first started. Shutters, either of the manually or automatically operated type, control the air flow through the core and tend to maintain the oil at nearly a constant temperature and viscosity. Automatically controlled shutters have a distinct advantage over the manual type in that the operator is relieved of another of his many duties. Many of the high-engine temperature troubles will be eliminated if the mechanic always services the oil system with a sufficient supply of the proper grade of oil.

f. Engine cooling. All aircraft engines may be classified as liquid-cooled or air-cooled. Since internal combustion engines are not 100 percent thermally efficient, some means of removing the excess heat must be incorporated in the design of the power plant. The greater part of the heat is removed by a liquid medium or by air. In either type of engine, a portion of the internal heat developed in the engine itself is conducted to the atmosphere by the oil of the lubrication system; therefore, it is very important that the grade and supply be that specified for the particular engine.

(1) Liquid-cooled installations employ a coolant medium known as ethylene glycol to dissipate the heat. The coolant conducts the heat to the radiator where it is transferred to the atmosphere. Adjustment of the radiator shutters varies the flow of incoming air through the radiator core. The greater the difference between the coolant temperature and the temperature of the surrounding air, the more rapid will be the cooling. The use of ethylene glycol, which has a high boiling point, permits a higher and more efficient operating temperature than water.

The size of the radiator is reduced tremendously when ethylene glycol is used instead of water. This results in less head resistance for the airplane.

(2) Air-cooled engines are equipped with an arrangement of finned surfaces, cast or machined with the cylinder head and cylinder barrel. The cowl arrangement forces the air over the engine. The amount of air passing over the power plant is controlled by the movement of the cowling flaps. Baffles are provided to decrease the speed of the air passing over the finned area and thus permit an even cooling by eliminating the low-pressure area behind the cylinder.

g. Carburetor icing and control. A thorough understanding of ice formation and a practical knowledge of the carburetor air-heater control are vitally important if an engine is to be operated properly when icing conditions exist. Carburetor icing may cause engine failure, hence.

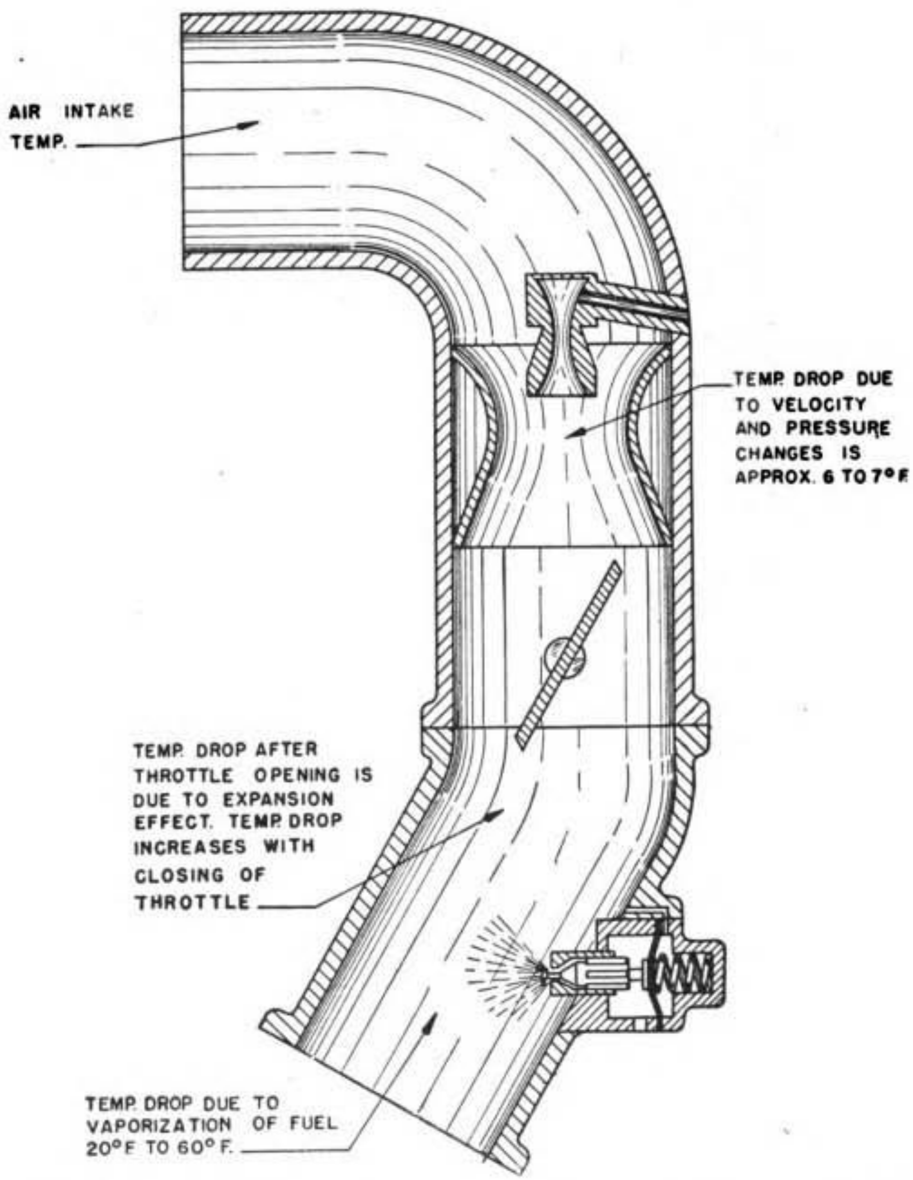


Figure 19. Mixture temperature drop in the induction manifold.

it must be detected immediately. Ice formation in the carburetor is caused by the reduction of temperature due to the pressure drop in the venturi, the pressure drop at the throttle (see fig. 19), and the evaporation of fuel. The temperature drop due to vaporization alone is from 20°F. to 60°F. The drop in temperature causes the moisture in the air within the carburetor to condense and freeze. This form of icing is much more hazardous than ice formation on the structure of the airplane. It may occur at any time during the year, choking the air-fuel passage and sometimes causing the throttle to jam. Carburetor icing is most likely to occur during damp or rainy weather, when the humidity is high and the ground temperature is between 30°F. and 70°F. (—1° and 21°C.) Carburetor air-heater control valves are installed in the air intake as a means of maintaining the incoming air at high enough temperature to avoid a drop below 32°F. in the carburetor and induction system when water vapor is present. Several types of heaters are used.

(1) EXHAUST HEATERS. An exhaust heater generally consists of a muff or shroud around the exhaust piping to conduct air from around the exhaust pipes to the induction system where it may be mixed with the air from the normal cold air inlet if needed. The valve may be adjusted to any desired opening depending upon the quantity of warm air required.

(2) ALTERNATE AIR-INLET HEATERS. This type installation for carburetor air heat consists of a two-position valve arrangement in the air scoop. The operator may close the cold air entrance and at the same time open an entrance to the engine compartment to let the warm air heated by the engine enter the induction system. The air heat in this case depends upon free-air temperature, engine operating temperature, cowl flap position, and other variables of the airplane engine installation.

(3) OTHER TYPES OF HEATERS. Other types of carburetor air heaters are hot spots, intensifier tubes, and systems in which warm air from the coolant and oil coolers is utilized.

(4) The operation of the carburetor air-heat control lever is essentially the same as the operation of the throttle and mixture controls. Smaller installations are sometimes equipped with push-pull rods. Placing the control in the COLD position sets the heater valve in a position that allows only the cold air to enter into the induction system. When the lever is moved to the HOT position, the cold air passage is closed and the incoming air must pass through the heating chamber. During starting it is of great importance that the carburetor heat control be placed in the COLD or OFF position to eliminate the possibility of damaging the heater control valve if the engine backfires. During ground operation and warm-up the heater control will be kept in the COLD position. The carburetor air-intake thermometer and mixture thermometers should indicate temperatures within the desired ranges. There is a possibility of

icing during extended ground operation prior to take-off. When this condition occurs, the following procedure may be followed (if it does not conflict with Technical Orders) to eliminate ice from—and prevent ice formation in—the induction system: when the moisture of the air is nearing freezing point, apply full carburetor heat, then maintain the desired temperature. If the temperature cannot be maintained, place the heater control in full COLD position.

(5) INSTRUMENT INDICATIONS OF CARBURETOR HEAT CONTROL. The manifold pressure gauge will indicate almost immediately the movement of the carburetor heat control. If ice is forming in the carburetor and the heat control is moved to the HOT position, the manifold pressure gauge will show an increase in manifold pressure because the constriction in the intake is being removed. If no ice is forming, and the heat control is moved to the HOT position, the manifold pressure gauge will indicate a loss in pressure. The unnecessary heat and the reduced intake-air pressure (due to the slight pressure drop in the air heater) decrease the speed and power. As the manifold pressure increases, a corresponding increase will be indicated on the tachometer and vice versa. Some installations are equipped with carburetor air temperature thermometers, while others are equipped with carburetor mixture thermometers. The use of these instruments greatly simplifies the setting of the carburetor air-heater control. Because the hot air tends to build up in layers and because of the nature of the ramming intake, it may be necessary to move the exhaust-heater control about two-thirds travel before the hot air affects the thermometer bulb. However, once the bulb is affected, a greater range of temperature change will occur with small movements of the heater control. Engines equipped with the various types of temperature indicators should have the carburetor heat controls adjusted to maintain temperatures as shown in table I. Intercooler shutters, installed with turbine-driven superchargers, will be used to maintain the temperatures shown in table I. Turbo-supercharger installations not equipped with intercooler shutters should use the carburetor air-heat control to satisfy the necessary temperature requirements.

(6) Several limitations and precautionary measures increase safety of operation of the carburetor air-heater control. In starting an aircraft engine, the carburetor air-heat control should be placed in the COLD position to eliminate the possibility of the control valve being damaged by backfire. Under nonicing conditions, unnecessarily high intake-air temperatures may cause overheating of the engine with resultant danger of detonation and engine failure if air intake and carburetor temperatures are not observed closely. When conditions warrant the use of the heater during warm-up, the air-heat control must be used intelligently to avoid carburetor temperatures above 35° C. (95° F.), thus helping prevent detonation. Use of the carburetor air heater may cause ice and snow to

melt and then freeze on the induction system walls. This condition might be avoided if the air-heat control were left in the COLD position. The alcohol de-icing equipment, if installed, should not be used for ground operation because of its limited supply and because it forms very rich mixtures at low engine speeds which may cause the engine to stop. It is evident that ice will form when the heat absorbed reduces the temperature of the air-fuel mixture below 32° F. (0° C.) and water vapor is present. This may occur when atmospheric temperature is as high as 85° F. (30° C.) with the atmospheric moisture in a liquid or vapor form. The moisture freezes on the walls of the induction system, the venturi throat, and the butterfly valves. Icing may also occur on clear days when the atmospheric temperature is between 30° F. and 75° F. (—1° C. and 24° C.) if the relative humidity is very high. Clouds are always saturated with water vapor and will cause carburetor icing if the temperature is below 85° F. When atmospheric temperature is below 20° F. the probability of icing is very slight due to the low content of water vapor at such temperatures. Normally, the formation of ice may be recognized by a gradual loss of rpm at cruising manifold pressure without change of throttle or flight attitude. At greater throttle openings, it is more difficult to detect except from irregularities of engine operation. However, the most hazardous time for carburetor icing to occur is probably during take-off or while flying at low altitudes where the time element prevents removal. It is possible that sudden icing on take-off will result in engine failure; therefore, precautions must be taken to prevent its formation.

Table I.

Type of thermometer installed	Type of heater installed	Fuel pressure	Desired temperature °C.	Desired temperature °F.
Air temperature ...	Exhaust heater (adjustable control).	Above 6 pounds per square inch	10° to 30°	50° to 86°
Air temperature ...	Exhaust heater (adjustable control).	Below 6 pounds per square inch	30° to 35°	86° to 95°
Air temperature ...	Alternate air-inlet heater (two-position)		Full Heat to 40°	104°
Mixture temperature	Exhaust heater (adjustable control).		2° to 5°	35° to 41°
Mixture temperature	Alternate air-inlet heater (two-position)		Full Heat to 10°	50°

h. Fuel pressure requirements and control. (1) A mechanically driven fuel pump is incorporated in the fuel system to insure a constant flow of fuel to the carburetor. If the engine is to operate satisfactorily, this flow must be maintained regardless of the fuel level in the tanks or the position of the tank relative to the engine, and must not be affected by airplane maneuvers. Other necessary requirements for a constant fuel flow are reliable pumps and other fuel system units, and fuel which is free of dirt, water, and other impurities. Engine fuel pumps must be able to deliver far greater quantities of fuel to the carburetor than the engine will consume. The hand wobble pump also insures constant fuel pressure to the carburetor. The fuel pressure relief valve is designed to maintain constant pressure by relieving the excessive pressures in the line between the pump and carburetor. Fuel pressure relief valves are adjusted according to the pressures needed for specific types of carburetors. Float type carburetors generally require a fuel pressure of 3 to 5 pounds per square inch; the Chandler-Evans (Ceco) and Holley type carburetors require a pressure of 6 to 8 pounds per square inch; and the Stromberg pressure injection type carburetor requires a pressure of 12 to 17 pounds per square inch.

(2) FUEL SUPPLY. When an airplane has a reserve fuel supply, the engines will be started and warmed up on the ground with the fuel cock on RESERVE. During the warm-up, the functioning of all the tanks and lines will be tested by switching the fuel valve to each tank long enough to insure that the fuel from the tank has an opportunity to flow to the engine. Proper performance of the engine or engines during this test will insure that the entire fuel system is free from water, dirt, and restrictions, and is functioning properly.

i. Oil pressure requirements and control. High speed, high power output, and high operating temperatures are characteristic of modern aircraft engines. The potential friction between the rapidly moving parts is very great, and successful operation of the power plant is dependent largely upon the reduction of this friction by proper lubrication. The oil system, therefore, must maintain a supply of oil to the moving parts of the engine. The reduction of friction between the parts is accomplished by forcing a thin film of oil between them, so that they actually "ride" on this oil layer instead of against each other. Space, correctly termed clearance, is always provided in engines to allow for this film of oil. A gear type pump forces oil under pressure to all bearings and bearing surfaces. Oil spray thrown off by the crankshaft and connecting rods lubricates the piston pins, pistons, cylinder walls, and gears. In addition to reducing friction, the oil also provides a certain amount of cooling. This is accomplished as the oil absorbs the heat from the metal parts and transfers it through the cooler to the surrounding air. The control of pressure in the oil system is largely dependent upon the oil pressure relief valve, although the pressure will vary with engine speed and oil pump output. Adjustment of the oil pressure relief valve must be made when the engine has reached its normal operating temperature. Settings made when the oil is cold and thick will result in low oil pressure when the oil assumes its normal viscosity. Setting the valve when the oil is at a high temperature will give an extremely high pressure at normal oil temperatures. Generally, the oil pressure maintained by the oil pressure relief valve is between 60 and 80 pounds per square inch for engine speeds from 1,600 to 3,000 rpm, with the oil temperature between 50° and 85° C. During extremely cold weather operation, preheating the oil before starting the engine will aid in lubrication, decrease the warm-up time, and eliminate the possibility of engine damage and failure. During extremely cold weather operation, it is also recommended that the oil pressure gauge line be filled with light oil. This will prevent congealing of the oil in the line, which would result in slow gauge response. In all cases the engine oil pressure should normally be established within a maximum of 30 seconds after starting. Should the oil pressure fail to register within this period of time, stop the engine immediately and investigate the trouble. Failure to do this may result in burned-out bearings and serious damage to the engine.

j. Propeller control. The propeller governor-control lever is generally located on the control pedestal or near it. The lever (marked with the letter "P") may be moved forward to the INCREASE RPM position to decrease the blade angle and increase engine speed, or backward to the DECREASE RPM position to increase the blade angle and decrease the speed of the engine. The travel toward INCREASE RPM is limited by a stop on the quadrant which should be so adjusted that the engine speed does not exceed the maximum rpm when the throttle is wide open for take-off. The toggle switch for an electrically controlled propeller is usually mounted on the instrument panel. If the selector switch is put in the automatic position, the engine rpm will be held constant, unless varied by means of the governor control lever. However, the propeller may be controlled manually by placing the selector switch in either the DECREASE RPM or INCREASE RPM position. This will decrease or increase the blade angle by operating the pitch-changing electric motor of the propeller.

(1) FEATHERING. When an engine fails while the airplane is in flight, the propeller will "windmill" and cause drag. This may be eliminated by "feathering" the propeller—changing the blade angle so that the propeller will not be rotated by the wind. To accomplish this during practice feathering the throttle must be closed, the mixture control moved to IDLE CUT-OFF, the feathering control moved to FEATHER, the fuel turned OFF, and the ignition switch placed in the OFF position. However, in case of emergency, the feathering control will be put in the FEATHERING position immediately, after which the procedure outlined will be followed.

Table II. Propeller chart for mechanics

Propeller	Start	Reason	Warm-up	Taxi	Stop	Reason
Hamilton Standard constant-speed.	High pitch, low rpm.	Prevents starving of main bearings.	Low pitch	Low pitch	High pitch	Prevent corrosion of propeller piston.
Hamilton Standard two-position.	High pitch, low rpm.	Prevents starving of main bearings.	Low pitch	Low pitch	High pitch	Prevent corrosion of propeller piston.
Hydromatic and Aero-products.	Low pitch, high rpm.	Reduces starting load and torque.	Low pitch	Low pitch	Low pitch	Easier starting.
Curtiss Electric.	Selector switch in automatic, low pitch, high rpm.	Reduces starting load and torque.	Low pitch	Low pitch	Low pitch	Easier starting.

(2) UNFEATHERING. To unfeather a propeller, adjust the throttle to a "cracked" position (one-tenth open), leave the mixture control in IDLE CUT-OFF, and hold the feathering control at UNFEATHER until the tachometer shows 700 to 900 rpm. With the engine windmilling and fuel pressure registering 4 to 5 pounds per square inch, turn the fuel ON, place the ignition switch in the BOTH position (indicating that both magnetos should operate), move the mixture control to AUTO RICH position, and the engine should start. Watch the tachometer to make sure the engine is operating. If the engine should backfire, work the wobble pump or electric booster pump to remove all the air from the fuel lines and carburetor.

k. Intercooler control. Compressing air by a supercharger, or by any other means, increases its temperature considerably. It is desirable to cool this compressed air before it reaches the carburetor intake, thus preventing detonation, preignition, and reduction of the density of the intake mixture. This is accomplished by means of an intercooler (fig. 20), usually in the form of a radiator between the carburetor intake and the supercharger. The radiator core is exposed to the slipstream, and air passes through the core and cools the warm compressed air in the same manner as water is cooled in a radiator. Adjustment of the intercooler shutters controls the temperature of the compressed air. Carburetor mixture temperature and carburetor air-intake temperatures should be as specified in paragraph 4g.

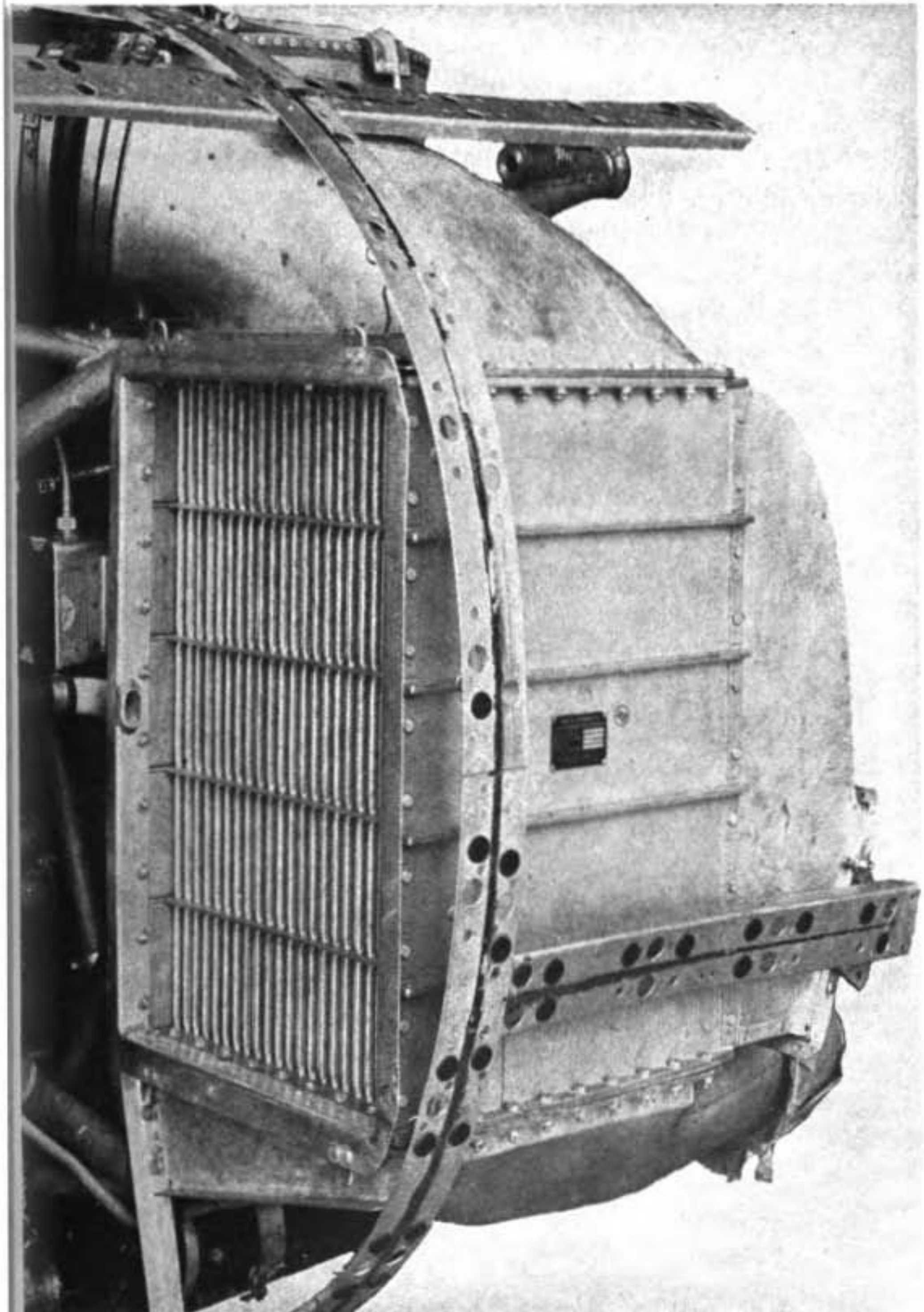


Figure 20. Intercooler.

l. Carburetor air-filter control. (1) PURPOSE OF CARBURETOR AIR FILTER. Excessive engine wear due to dust and sand entering the engine through the carburetor air intake has made it necessary to incorporate an air filter in the induction system. Sand and dust conditions create serious maintenance problems. Although such conditions are most troublesome on the ground, while the engine is idling "on the line" or during taxying or take-off, they are also present during flying, as air in circulation is capable of carrying the dust and sand to great heights. The carburetor air filter is designed to remove dust and sand from the air entering the engine.

(2) OPERATION OF CARBURETOR AIR FILTER. One type of carburetor air-filter valve is operated by an electric motor. The motor is controlled by a double-throw toggle switch located on the instrument panel. When the switch is placed in the CLOSED position, atmospheric air bypasses the filters as shown in figure 21①. When the switch is held in the OPEN position the atmospheric air must be drawn through the filters before entering the supercharger as shown in figure 21②. An

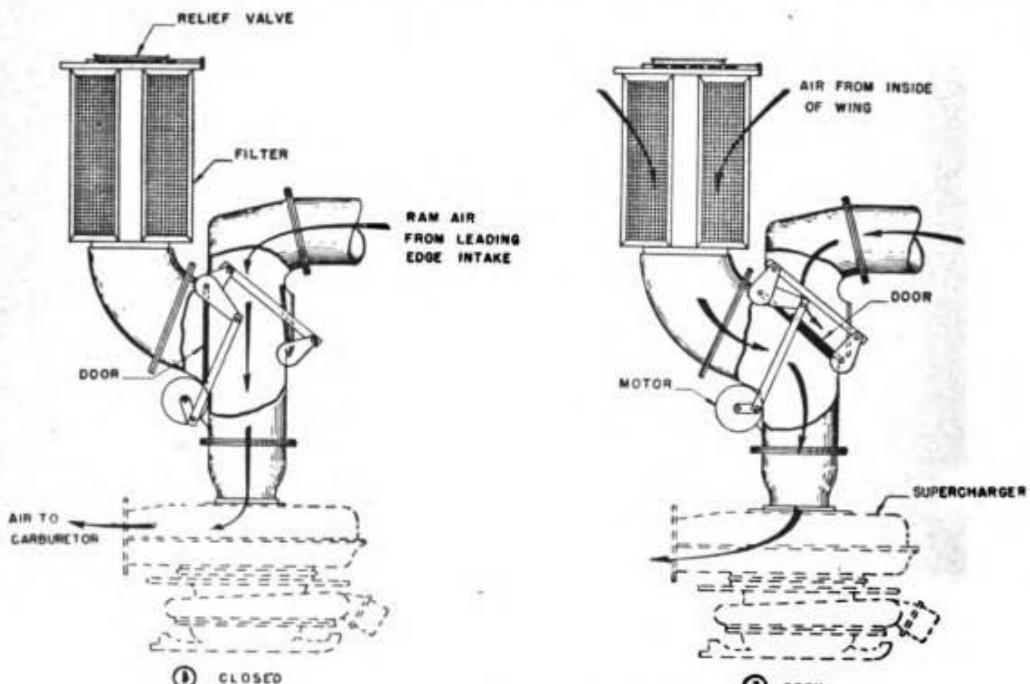


Figure 21. Carburetor air filter.

indicator lamp is generally located on the instrument panel, near the switch, to indicate when the valve is open or closed. When the valve is completely open, permitting only filtered air to enter the supercharger intake, an amber lamp is lighted. If the green lamp is illuminated the control valve is fully closed. If neither lamp is lighted, the valve has not completed its travel to either position. During all engine operation on the ground, the air filter should be placed in the OPEN position, and for dust conditions up to 8,000 feet, it should remain in that position.

Setting the carburetor air-filter switch to the OPEN setting before take-off restricts the air-intake opening; therefore, a slight power reduction will be observed, as indicated by a decrease on the manifold pressure gauge of approximately 1 to 2 inches of Hg. This drop may be overcome by readjusting the supercharger control-lever stops until the desired manifold pressure is obtained.

(3) PRECAUTIONARY MEASURES. It should be pointed out that the use of the air filter will not completely eliminate sand and dust from the engine. Other precautionary measures should be taken at any operating base where sand and dust conditions exist. The period of engine idling should be reduced to a minimum. Airplanes should not be left near the take-off strip where dust and sand are blown around by other planes taking off. Every precaution should be taken to prevent sand and dust from entering the fuel and oil system during servicing. Where good hangar facilities are not available, tight covering should be placed over the entire engine. If a large cover is not available, suitable covers should be installed over the carburetor air scoop, exhaust stacks, engine breathers, and other openings.

5. OPERATION LIMITS. a. General. Many factors affect the speed, manifold pressure, power output, and temperature of an engine. A change in any one of these factors without a compensating change in some other or others will vary the speed, manifold pressure, horsepower,

SPECIFIC OPERATING INSTRUCTIONS

ENGINE: R-1820-87

CONDITION	FUEL PRESSURE LB/IN²	OIL PRESSURE LB/IN²	OIL TEMP °C	COOLANT TEMP °C
DESIRED	14	70	50-70	
MAXIMUM	16	75	85	
MINIMUM	12	65		
IDLING		15		

MAX. PERMISSIBLE ENGINE OVER SPEED: 2760 R.P.M.

MAX ALLOWABLE OIL CONSUMPTION AT:

NORMAL RATED POWER 15 QTS./HR.
MAXIMUM CRUISING 10 QTS./HR.
MINIMUM SPECIFIC FUEL FLOW 5 QTS./HR.

FUEL GRADE 100 OCTANE

⊕ OPERATING CONDITION	HORSE POWER	R.P.M.	MAN. PRESS. (IN. HG)	PRESSURE ALTITUDE (IN FEET)	BLOWER CONTROL POSITION	USE LOW BLOWER BELOW	MIXTURE CONTROL POSITION	MIN. F/A RATIO	FUEL FLOW GAL/HR	MAX. CYL. HD. TEMP °C	REMARKS
TAKE-OFF	1200	2500	45.5	S.L.	Low	Always Use Low Blower	Auto-Rich	-	144	260	5 min. duration only.
MILITARY RATED POWER	1200 1000	2500 2500	43.0 44.5	4200' 14,200'	Low High	10,000	Auto-Rich	-	144 127	260	5 min. duration only.
⊕ NORMAL RATED POWER (100%)	1000 900	2300 2300	37.2 40.0	6900' 15,200'	Low High	10,500	Auto-Rich	-	112 114	232	
MAX CRUISING (75%)	750 675	2020 2020	30.5 32.0	6900' 15,200'	Low High	14,000	Auto-Rich	-	63 66	205	
DESIRED CRUISE (67%)	670 603	2020 2020	28.0 29.0	6900' 15,200'	Low High	16,500	Auto-Lean	-	53 55	205	
DESIRED CRUISE (60%)	600 540	1940 1940	26.0 26.5	6900' 15,200'	Low High	17,500	Auto-Lean	-	46 47	205	
CRUISE FOR MIN. SPECIFIC FUEL FLOW	285 307 332 360 390	1300 1300 1300 1300 1500	23.0 22.0 21.0 20.5 22.0	S.L. 5000 10,000 15,000 20,000	Low Low Low Low High	17,000	Auto-Lean	-	24 26 28 30 33	205	

⊕ REFER TO T.O. NO. 00-10 FOR DEFINITION OF EACH OPERATING CONDITION ⊕ MAXIMUM PERMISSIBLE CONTINUOUS HORSE POWER REVISED [illegible]

NOTE: The data on this chart are the result of dynamometer tests and are adaptable for flight purposes in the absence of the Pilot's Handbook of Operating Instructions.

Figure 22. Sample engine operating instructions.

or the operating temperature. Technical Orders specify definite operating limits and instructions for each engine model. (See fig. 22.) These limits are based on the design characteristics of the engine and on rigid operation tests.

b. Engine power output. For a given engine, horsepower output is a function of crankshaft rpm and manifold pressure. The greater the rpm, the greater the horsepower output; and the greater the manifold pressure, the greater will be the horsepower output. Thus, an increase in engine horsepower output will occur whenever the crankshaft rpm or the manifold pressure, or both, increase. However, it must be clearly understood that for every engine there are definite limitations to the manifold pressure, crankshaft rpm, and therefore to the horsepower output permissible during the operation of that engine.

(1) MANIFOLD PRESSURE LIMITS. When the throttle is opened to a greater extent, a larger charge enters the combustion chamber, and a rise in compression pressure results. This charge may be forced into the chamber by atmospheric pressure (30 inches Hg. at sea level), or, if superchargers are employed, the charge is packed into the combustion chamber at pressures much higher than atmospheric. A correspondingly increased compression pressure and a greater horsepower output result. However, there is a definite limit to the amount of pressure the piston and cylinder assemblies can withstand without being damaged. This limit is determined and specified for each engine.

(2) ENGINE SPEED LIMITS. When an engine is equipped with a fixed pitch propeller, crankshaft speed is controlled directly by the throttle. When a constant-speed propeller is used, however, the engine speed is regulated by a propeller governor control. In either case, it is extremely important not to exceed the maximum engine rpm (permissible for a short period of time only) specified for a particular engine. Mechanical stresses and internal structural failures, some of which may not be visually apparent, will result if this maximum limit is exceeded. The desired speed range is specified for all around purposes, and it is within this range that the engine will operate during most of its useful service.

(3) POWER RATINGS. Normal rated power is the highest permissible power which may be delivered continuously at a given altitude. This power output may be exceeded only for short periods of time, such as at take-off and in military emergency. During these times, the engine delivers its maximum power output; that is, the highest output which the engine is designed to deliver. To deliver this horsepower, the engine must operate at its maximum manifold pressure and maximum rpm. An engine should be operated at maximum power output for as short a period as possible, since the high manifold pressure and high rpm result in excessive stresses on the piston and cylinder assemblies, and on the entire engine structure. It is extremely important never to exceed either the

maximum permissible manifold pressure or maximum permissible rpm. Operating the engine at excessive manifold pressures is likely to result in detonation if pressures exceed the limit of the octane rating of the fuel. Structural parts have been known to fail when this trouble occurred and in cases of severe detonation scoring and freezing of the cylinders is highly probable. Aircraft engines exceed the maximum rpm limit only at the expense of safety and economy of operation. Friction losses and loads on the pistons, bearings, etc., increase tremendously and excessive heat will be encountered as the speeds approach and exceed the maximum. Careful manipulation of the engine controls is necessary to avoid operating the engine in excess of its specified limits.

c. Minimum engine speeds. In many instances minimum speeds are not specified; however, the mechanic should be familiar with the conditions that take place when high power output engines are operated at low speeds. Spark plug fouling is one of the most common troubles which occur when the engine is operating at low rpm for a fairly long period of time.

d. Engine temperature limits. (1) Certain definite temperature limits must be observed in order to guard the engine against unnecessary damage. As has been previously stated, instruments have been provided to inform the operator of these conditions.

(2) It is as important to heed the minimum temperature limits as it is to observe the maximum limits. Operating an engine at too low a temperature will sometimes result in serious damage, such as scored bearings, because of lack of proper lubrication.

6. ENGINE STARTING. a. General. It is important that the mechanic determine the type of fuel system that is installed in the airplane and the function of its various units. Starting an engine is not difficult if the proper procedure is followed in setting the controls and in the use of the primer and starter. The following general instructions will be followed by mechanics when starting an aircraft engine during the preflight inspection.

(1) All necessary inspection and maintenance must be performed before the engine is started.

(2) Make sure that the ignition switch is in the OFF position and pull the propeller through four or five revolutions. This is particularly important in radial and inverted type engines during both winter and summer operation. If an excessive amount of oil or fuel is present in the cylinders, the crew will be unable to rotate the propeller. Often rotation of the propeller in the opposite direction will remove the accumulation in the cylinders and make it unnecessary to remove the spark plugs and intake pipes. Starting engines with excessive oil and fuel in the combus-

tion chambers must be avoided, as it may result in bent or broken connecting rods.

(3) If the propeller cannot be rotated in either direction, remove the spark plugs (see fig. 23) and the intake pipes of the bottom cylinder so

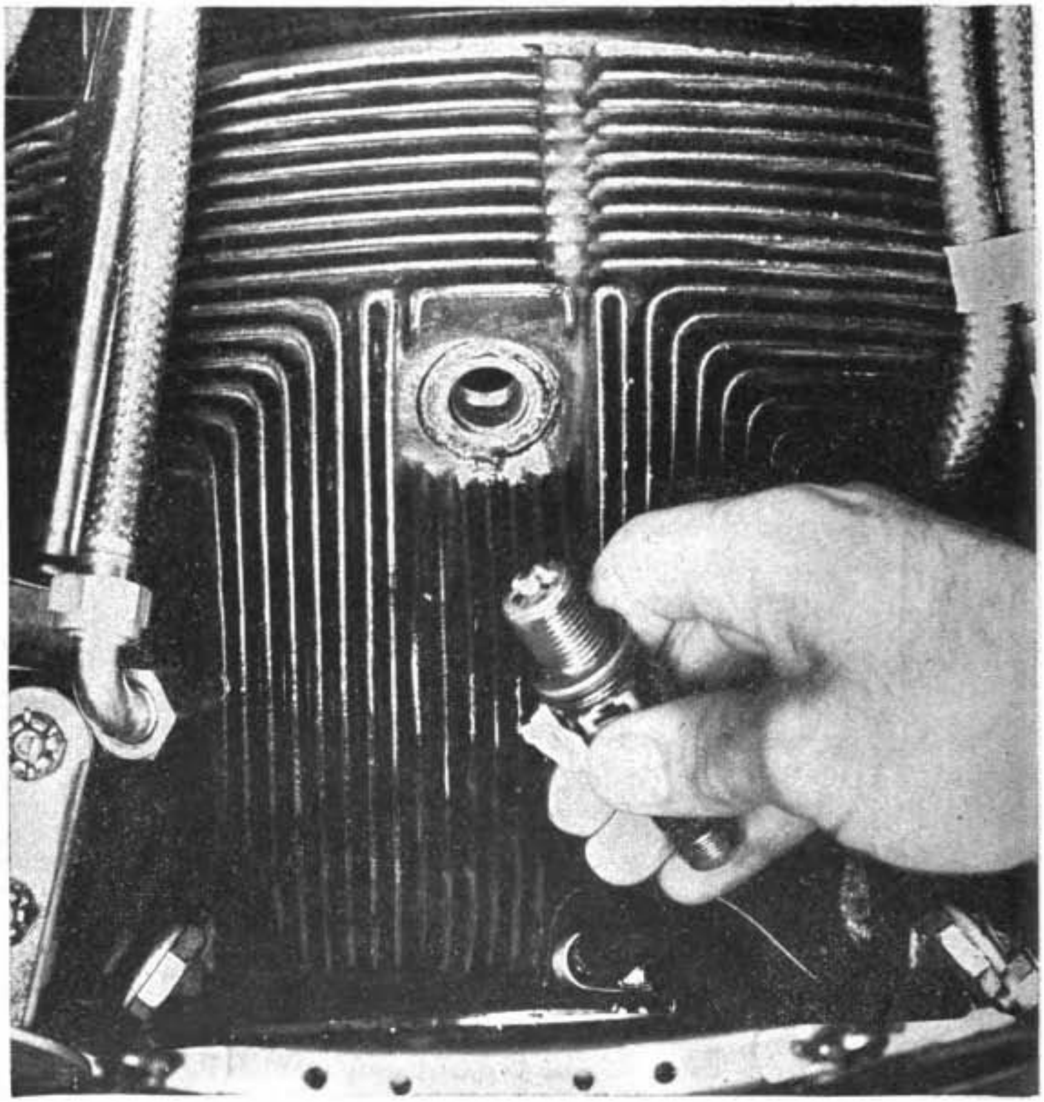


Figure 23. Removing liquid from the combustion chamber.

that the liquid will drain out. Then remove the intake pipes and spark plugs on either side of the ones already checked. Continue this procedure until all liquid has been removed. Spark plugs should be thoroughly dried before being reinstalled. Care should be exercised during their reinstallation.

(4) Warn the crew members by shouting "All clear," then stop the flywheel rotation by engaging the starter flywheel to the engine. If energy is stored in the flywheel, it will be noticed by rotation of the propeller.

b. Control settings. As aircraft engines have improved, more units and controls have been added, until now it is impossible for an operator to adjust the controls during the time of actual starting of the engine. For this reason and for safety of operation, all of the manually controlled units must be in the correct position before starting the engine. More automatic controls are also being used. These controls are examined only to be certain that they are in the proper position. Before starting the engine, the controls are generally set as shown in table III.

Table III

Control	Comments	Starting position
Fuel selector valve	....	Reserve.
Cross-feed valve	(If applicable)	Off.
Carburetor mixture control:		
Float type carburetor	(If applicable)	Full rich.
Ceco or Holley type carburetor	(If applicable)	Full rich.
Bendix Stromberg injection type carburetor	(If applicable)	Idle cut-off.
Throttle (800 to 1,000 rpm)	....	Cracked to one-tenth open.
Propeller:		
Hamilton Standard two-position	(If applicable)	High pitch (low rpm).
Hamilton Standard constant-speed	(If applicable)	High pitch (low rpm).
Hamilton Standard hydromatic	(If applicable)	Low pitch (high rpm).
Aeroproducts	(If applicable)	Low pitch (high rpm).
Curtis Electric:	(If applicable)	
Thermal overload safety switch	....	On.
Propeller selector switch	....	Automatic.
Pitch control	....	Low pitch (high rpm).
Carburetor air heater	....	Cold.
Carburetor air filter	....	Open.
Oil cooler shutters	....	See engine Technical Order.
Cooling system:		
Coolant-radiator shutters	....	Open.
Cowling flaps	....	Open.
Supercharger:		
Turbine-driven supercharger waste gauge	(If applicable)	Open.
Supercharger regulator	....	Off.
Intercooler shutters	....	Open.
Two-speed supercharger	(If applicable)	Low blower.
Automatic manifold pressure regulator	....	Take-off pressure.
Fuel mixture indicator	(If applicable)	On.
Priming pump	....	On.
Fuel system:		
Hand wobble pump	....	Maintain fuel pressure.
Electric booster pump	....	On.
Battery disconnect switch	....	On.
Generator main-line switch	....	Off.
Ignition switch	....	On, or Both.

c. Priming. Nearly every airplane engine requires some priming for starting. The amount of priming required depends upon the length and size of the primer lines, the temperature of both the engine and atmosphere, the size of the engine, and the capacity of the priming pump. Much more priming will be needed during cold weather than during warm weather. If the engine is overprimed, as indicated by an excessive amount of raw fuel flowing from the supercharger drain valve, place the ignition switch in the OFF position, place the throttle in FULL OPEN position, and pull the propeller through three or four times. In temperate climates and when the engine is warm, priming will usually be unnecessary. Do not prime through the exhaust ports or the spark plugs with raw fuel and avoid the use of the throttle as a priming device except where authorized in special operating instructions in Technical Orders. After the engine is primed, lock the primer plunger in the OFF position and energize and mesh the starter to the engine. The following information applies to two types of primers, namely, the hand primer and the electrically operated priming pump.

(1) HAND PRIMER. To obtain a high efficiency from the hand primer, first unlock it (turn the handle from the OFF position to the ON position), then draw the plunger out slowly, and hold it out long enough to be sure that the pump cylinder is filled with fuel. When the cylinder is full, force the plunger in abruptly to atomize the fuel as it is discharged into the intake port of the engine cylinder. Two or three strokes are usually sufficient for starting in moderate temperatures. After priming, the plunger must be locked in the OFF position (fig. 24) or the engine

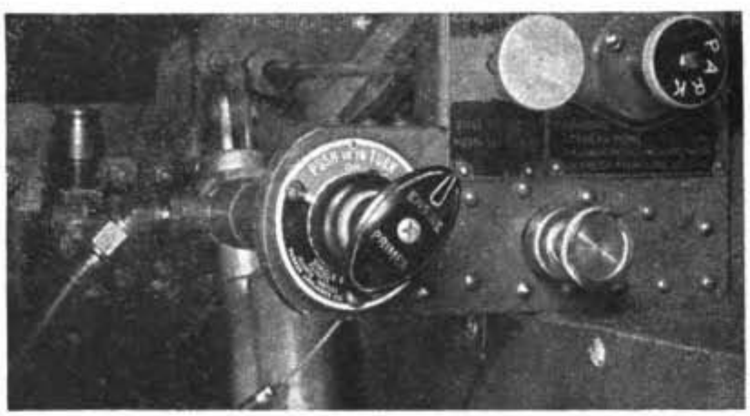


Figure 24. Primer pump in the OFF position.

will syphon the fuel through the primer, resulting in an overly rich mixture. Starting of the engine should take place immediately after priming. When the inertia starter is installed, this may be accomplished by priming while the starter is being energized, and timing the last stroke of the pump so that it is made just before placing the ignition switch in the BOTH position and engaging the starter flywheel.

(2) ELECTRIC PRIMERS. Electric primers serve the same purpose as hand-operated primers. The priming pump is operated by closing the switch located on the cockpit instrument panel. Holding the switch closed for 1 second is equivalent to one stroke of the hand primer.

d. Starter operation. In the operation of inertia starters, hand or electric, the mechanic must learn by experience to determine when sufficient flywheel speed is attained before engaging the flywheel to the engine. Excessive speeds should be avoided, particularly when energizing the starter by an external electrical power unit. In starting a very cold engine, energy stored in the starter flywheel is dissipated to a large extent in the starter clutch if the engine is not loosened up before using the starter. This may be eliminated, to some extent, by pulling the propeller through three or four revolutions. At the same time a check for liquid accumulation in the combustion chambers should be made. Starters cannot be expected to rotate the propeller on a cold engine as rapidly as when the engine is warm. If engine conditions are found satisfactory, starting may be performed by using any one of the following methods:

(1) PORTABLE FIELD ENERGIZER. Whenever possible, use the portable field energizer to energize the starter flywheel in order to save the battery on the airplane as much as possible. The portable energizer is simply an electric motor, adapted so that it may be connected to the starter extension shaft by a cranking pin. The direction of rotation of this pin may be reversed by interchanging the cranking pin and the metal cap which is on the opposite end of the drive shaft. Before inserting the cranking pin in the opening in the extension shaft, check to be certain that the energizer rotates in the right direction. This is done by depressing the trigger switch and observing the cranking pin. The direction of rotation of the starter extension shaft may be determined by examining the spiral slot in the shaft. When the energizer is properly set, the cranking pin of the energizer should be inserted into the starter extension opening and the trigger on the energizer handle depressed. (See fig. 25.) As soon as the desired cranking speed is attained, the trigger switch is released and the energizer is removed from the starter extension shaft before engaging the starter. The ignition switch in this case remains in the OFF position until the mechanic operating the portable energizer gives the "all clear" signal. He will remove the energizer before giving the signal.

(2) HAND INERTIA STARTER. To energize the flywheel, the hand crank should be rotated slowly at first, and gradually faster until the desired speed is attained. (See fig. 26.) This procedure will prevent damage to the spiral slot and shear pin. Remove the hand crank, stand away from the propeller, and inform the operator, by shouting "All clear," that everything is in readiness for an engine start. The operator then moves a switch or control rod handle to engage the starter flywheel to the engine. It is important that the switch remain in this position until the engine begins to fire evenly. With the switch in the ENGAGED position the booster coil is able to furnish the necessary spark for the start. As a safety feature, an automatic spring release is incorporated to release the

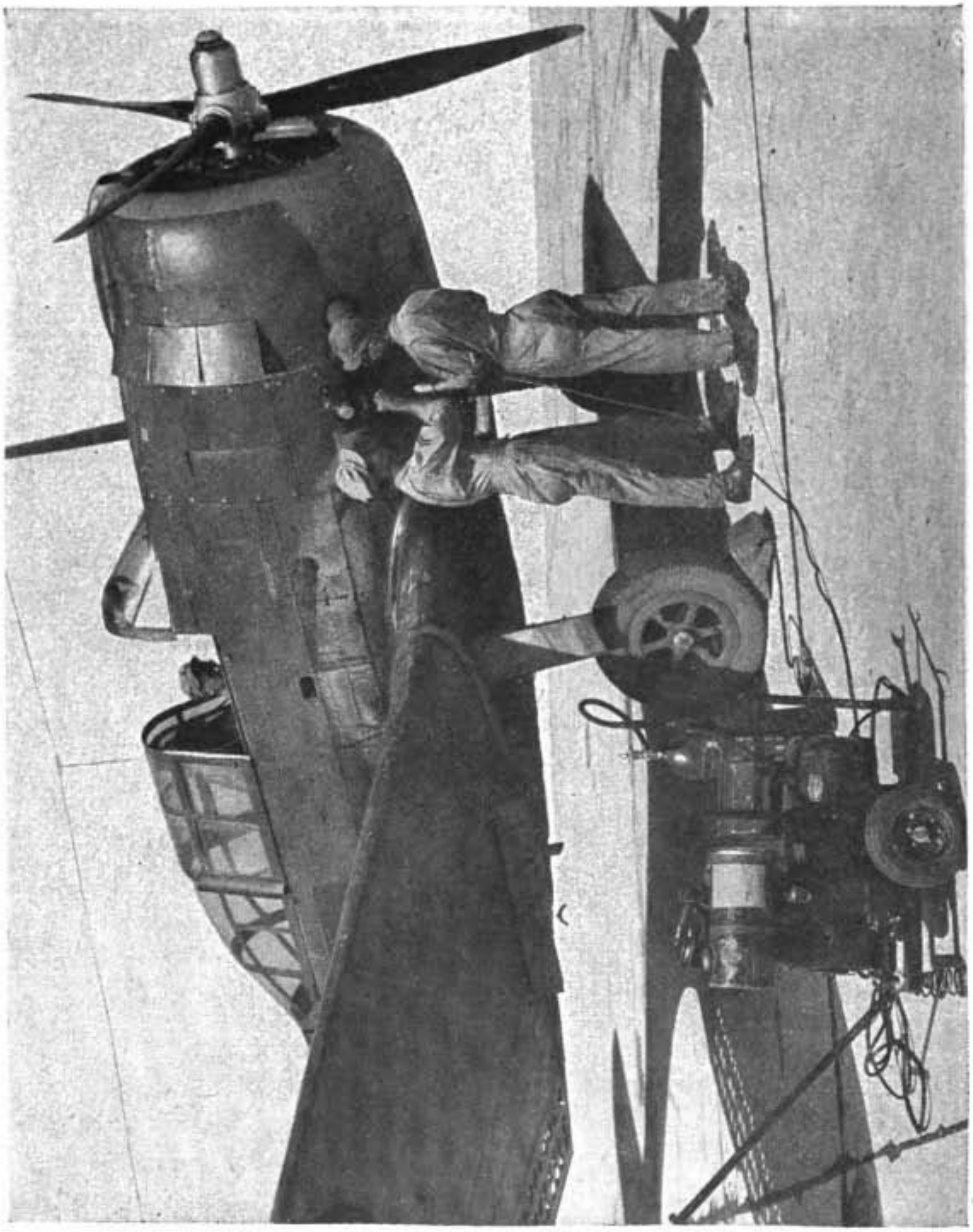


Figure 25. Energizing the starter flywheel with a portable energizer.

Figure 26. Energizing the starter flywheel with a hand crank.

starter jaws as the engine builds up speed. If the engine does not start and the starter jaw does not disengage, place the ignition switch and other controls in the OFF position and pull the propeller through one or two times.

(3) ELECTRIC INERTIA-STARTER OPERATION. Set all the controls and switches for starting. Shout "All clear," as a warning for all crew members to stand clear, then place the starter motor switch in the ENGAGE or MESH position. If any energy is present in the flywheel, it will be evidenced by propeller rotation. To energize a rotating flywheel without first stopping it will sometimes result in damage to the starter mechanism. Energize the flywheel by placing the switch in the START position and keeping the circuit closed from 10 to 20 seconds, depending upon the state of the charge of the battery. The second hand of the cockpit clock may be used for determining the time the switch is kept in the START position. After the flywheel has reached the proper speed, shift the toggle switch to the ENGAGE position and hold it there until the engine starts. If the engine does not start, determine whether

trouble exists, then repeat the operations described. When the engine fires, perform the necessary steps to continue the operation of the engine. Do not release the starter switch until the engine begins to fire evenly.

(4) COMBINATION ELECTRIC-INERTIA DIRECT-CRANKING STARTER OPERATION. Set all the controls and switches for starting. Shout "All clear" to warn crew members to stand clear. Step 1, figure 27, indicates the position of the switch to stop any flywheel rotation.

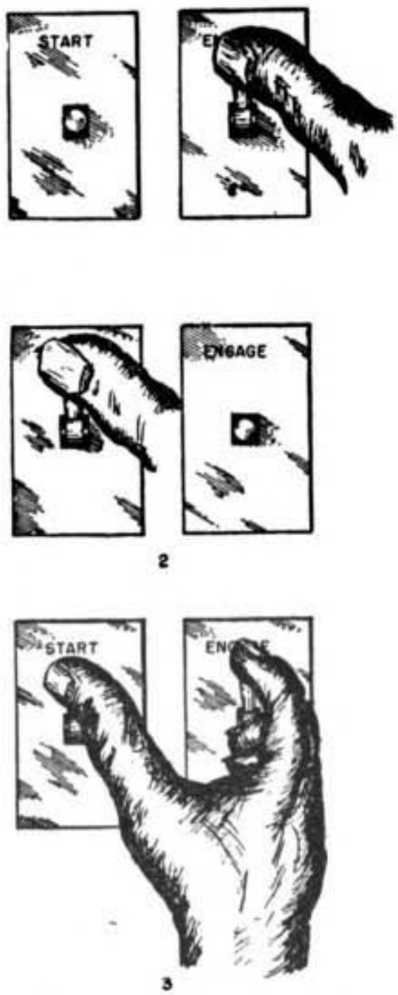


Figure 27. Positions of direct-cranking electric inertia starter switches

Energize the flywheel by placing the switch in the START position as shown in step 2. After the flywheel is sufficiently energized, close the ENGAGE switch with the forefinger, at the same time keeping the thumb in the original position, as shown in step 3. It is permissible to hold both switches in this position as a direct-cranking starter to turn the engine over. If the engine fails to fire, repeat the procedure. If trouble is indicated after the engine starts, stop the engine and perform necessary corrective maintenance.

e. Starting of an engine equipped with float type carburetor. Starting an engine equipped with a float type carburetor, with or without an idle cut-off unit, is accomplished as follows:

(1) Make sure the ignition switch is in the OFF position and pull the propeller through four or five revolutions.

(2) After the foregoing operation is performed, the operator should shout "All clear" to warn the crew members to stand away from the propeller. He should then proceed to stop the flywheel rotation by engaging the starter to the engine.

(3) Place the mixture control lever in the FULL RICH position. There is very little danger of engine flooding if the needle valve in the float chamber functions properly.

(4) Set the remaining controls in proper position for starting.

(5) Operate the wobble pump to produce 3 to 5 pounds per square inch fuel pressure.

(6) Prime the engine three to four strokes.

(7) Energize the starter flywheel and engage it to the engine.

(8) When the engine fires, maintain the required 3 to 5 pounds pressure by using the wobble pump. Keep the starter flywheel engaged to the engine until the engine begins to fire evenly. Releasing the switch momentarily when starting will cause the dogs of the flywheel and engine to disengage and possibly damage the dog teeth by causing them to ride on each other instead of properly meshing when the switch is closed again.

(9) As the engine begins to fire evenly, release the starter switch, and check the oil pressure gauge reading. If no pressure is indicated within 30 seconds, shut the engine off immediately.

(10) If sufficient oil pressure is indicated, check all instruments for proper indications and adjust the throttle for the desired warm-up rpm.

f. Starting of an engine equipped with Chandler-Evans or Holley type carburetor. This carburetor is also known as Chandler-Groves, "Ceco," or as the floatless variable-venturi carburetor. It is particularly important in starting an engine equipped with this type of carburetor not to advance the throttle to more than the CRACKED position. No attempt should be made to prime with the throttle; the accelerating pump is not connected mechanically to the throttle, but functions automatically when the engine is in operation.

(1) Make sure the ignition switch is in the OFF position and pull the propeller through three or four revolutions.

(2) Shout "All clear" to warn the crew members to stand clear of the propeller and place the starter switch in the ENGAGE position to stop the flywheel rotation.

(3) Set the mixture control in the FULL RICH position.

(4) Adjust the remaining controls in the proper position for starting.

(5) Operate the wobble pump or the electric booster pump to produce 6 to 8 pounds per square inch pressure.

(6) Prime the engine three or four strokes with the hand primer or hold the electric primer switch closed 3 or 4 seconds.

(7) Energize the starter flywheel to the proper speed and engage it to the engine.

(8) When the engine fires, maintain the desired fuel pressure of 6 to 8 pounds and be sure to keep the starter flywheel engaged to the engine. Momentarily releasing the switch may result in damage to the starter and also open the booster-coil circuit that furnishes most of the starting spark.

(9) As the engine begins to fire smoothly, release the starter switch and check the oil pressure. Oil pressure must register within 30 seconds or the engine must be stopped immediately.

(10) All instruments should be checked for proper indications and the throttle control set for the desired warm-up speed.

g. Starting an engine equipped with Bendix Stromberg injection type carburetor. The procedure for starting engines equipped with this type carburetor is as follows:

(1) INSTALLATIONS EQUIPPED WITH HAND TYPE PRIMER AND HAND WOBBLE PUMP. Place the carburetor mixture control in the IDLE CUT-OFF position. With the control set in this position, fuel cannot be discharged through the discharge nozzle. While maintaining fuel pressure with the hand wobble pump, prime the engine with three or four strokes of the hand primer. Prime the engine as little as possible thus reducing the likelihood of washing the oil from the cylinder walls and thereby causing scored cylinder barrels or piston seizure. After the engine is primed, lock the priming plunger in the OFF position. When the engine starts firing, raise the fuel pressure between 12 and 16 pounds by using the wobble pump, and quickly move the carburetor mixture control to AUTOMATIC RICH position. Keep the starter engaged until the engine begins to fire evenly. As the engine builds up speed, check the oil pressure gauge reading. If no pressure is indicated within 30 seconds, stop the engine immediately. If pressure is indicated, check the remaining engine instruments for proper indications and position the throttle for the proper warm-up rpm. If starting difficulties are encountered in emergencies such as operating during subzero weather, set the carburetor mixture control in the AUTOMATIC RICH position, and raise fuel pressure to 12 to 17 pounds by operating the hand wobble pump at the same time the starter is engaged to the engine. Stop using the wobble pump if the engine will not start or overpriming may result.

(2) INSTALLATIONS EQUIPPED WITH HAND TYPE PRIMER AND ELECTRIC BOOSTER OR ELECTRICALLY DRIVEN EMERGENCY FUEL PUMP. Place the carburetor mixture control in the IDLE CUT-OFF position. Start the booster fuel pump or emergency fuel pump for the engine to be started. Energize the starter, and immediately before meshing the starter to the engine, operate the primer through two strokes to fill the primer lines with fuel. This

is not intended as a priming operation, but it fills the primer lines so that priming will occur immediately when the primer is next operated. Mesh the starter to the engine and at the same time prime the engine with three or four strokes of the primer and return the primer to the locked or OFF position. As a precautionary measure, hold the primer in (toward the locked position) when not pumping, since boost pressure may be sufficient to release the handle and cause flow of fuel in the primer lines resulting in a flooding condition. When the engine starts firing, move the carburetor mixture control to the AUTOMATIC RICH position. During subzero weather, if starting difficulty is encountered move the mixture control from IDLE CUT-OFF to the AUTO RICH position at the same time the starter is engaged to the engine. If the engine does not start on the fourth revolution, move the mixture control to the IDLE CUT-OFF position. Overpriming will result if this is not followed. If overpriming has already occurred, follow the instructions listed in paragraph 6c.

(3) In an installation equipped with an electric primer and an electrically driven booster pump or auxiliary pump, move the mixture control to the IDLE CUT-OFF position. Start the booster pump or emergency fuel pump for the engine to be started. Energize the starter, and immediately before meshing the starter to the engine turn the primer switch to the ON position for a period not to exceed 2 seconds. This fills the primer lines with fuel, so that priming will occur immediately when the primer is next operated. Mesh the starter to the engine and at the same time turn the primer ON and prime the engine. After the engine starts, release the switches and move the mixture control to the AUTOMATIC RICH position. During subzero weather, if starting difficulty is encountered, move the mixture control out of IDLE CUT-OFF position at the same time the starter is engaged with the engine. If this practice is used it is essential that the mixture control be moved back to the IDLE CUT-OFF position if the engine does not start during the fourth revolution of the propeller. This procedure will result in overpriming if extreme caution is not used. Normally, the engine will start on the second or third revolution. However, if the engine does not start, turn off the ignition switch, place the throttle in wide open position, and pull the propeller through to clear the engine of excess fuel.

h. Cold weather starting and operation. When the temperature falls below 40° F., the lubricating oil in the power plant becomes so stiff that the movement of the various parts, such as pistons, bearings, etc., is hindered. When a cold weather start is necessary, various methods of reducing starting time and eliminating starting difficulties are used. The following aids may be used either singly or together:

(1) OIL DILUTION. (*a*) Cold oil will provide satisfactory lubrication at starting when diluted to a lower viscosity by the addition of fuel. The diluted oil allows the engine to be turned over freely even when it is

exposed to subzero temperatures. In addition, the oil dilution system provides proper lubrication immediately after starting and does away with the usual warm-up period. The oil dilution or thinning of the oil is accomplished before stopping the engine when a cold weather start is anticipated by setting the throttle to about 800 to 1,800 rpm and holding the oil dilution control in the ON position for the period of time indicated in table IV.

Table IV. Dilution time in minutes for specific airplanes

Airplane	4.0° to —12°C. (39 to 10°F.)	—12° to —29°C. (10 to —20°F.)	—29° to —46°C. (—20 to —51°F.)
B–24	2	4	6
B–17	2	4	7
B–26	3	5	8
B-25*	6	10	14
P-38	3	5	7
P-39	3	5	7
P-40	4	8	12
P-47	3	5	7
P-51*	4	8	12
A-36*	4	8	12
C-47	3	5	7
C-48	3	5	7
C-49	3	5	7
C-50	3	5	7
C-51	3	5	7
C-52	3	5	7
C-53	3	5	7

* The time periods shown apply only to those airplanes of this type that are not winterized. On winterized airplanes shown by yellow dot on the Y-casting (restricted) fitting, part No. 37A3528, before the dilution solenoid, use the time indicated in the airplane manual or as shown under general procedure, section II, TO 02–1–29, 21 October 1943.

(*b*) The dilution of the engine while the oil temperatures are above 50°C. is not particularly effective. If oil dilution is to be accomplished and engine oil temperatures are too high, stop the engine and after the oil has cooled to below 40°C., restart the engine and proceed with oil dilution. In some instances, particularly during subzero temperature, where a long dilution period is required, the engine oil temperatures may rise above the maximum desired values for oil dilution 50°C. (122°F.). If this occurs, it may be necessary to dilute the oil in two or more short periods. Breaking up the oil dilution period into several short periods is neither detrimental nor beneficial to the general dilution procedure. If it is necessary to service the oil tank, the oil dilution procedure must be divided so that some dilution is accomplished before servicing the oil tank, and the remainder is accomplished after the oil tank is serviced. After dilution has been accomplished, shut off the engine in normal manner (with the exception of an engine which must be stopped by shutting off the fuel to prevent after firing), continuing to hold dilution valve on until the engine stops. Where an engine must be stopped by shutting off the fuel, the engine will first be stopped in this manner and allowed to cool, then restarted and the oil diluted as prescribed in the foregoing. After the oil has been diluted, the engine will be stopped, by shutting off the switch, the dilution valve being held on until the engine stops.

(2) COLD WEATHER OPERATION OF HYDRAULIC PROPELLERS. Because engine oil is used to actuate the propeller mechanism, the oil must be diluted to provide satisfactory propeller operation during cold weather. During the last 2 minutes of the last oil dilution period the throttle will be moved slowly from its original position of 800 rpm to a position to obtain a manifold pressure of 26 inches Hg and then moved back to its original position. This procedure will be accomplished twice before the oil dilution is completed. Any slight amount of oil leakage that may occur through the blade packings of a hydromatic propeller following an oil dilution is considered normal. If leakage becomes excessive or continues in flight, it must be corrected.

(3) COLD WEATHER OPERATION OF TURBO-SUPERCHARGER REGULATOR. During the procedure of oil dilution, the supercharger regulator will be operated to expel the undiluted oil from the piston chamber. During the last 2 minutes of the last period of oil dilution, the regulator control is moved from the LOW to the HIGH boost position in a minimum period of 8 seconds.

(4) COLD WEATHER OPERATION OF OIL PRESSURE GAUGE. During cold weather operation of the airplane with temperatures below 0° C. (32° F.) engine oil will congeal in the oil pressure gauge line and may cause sluggish response on the gauge when the engine is started. To prevent this, the oil gauge line is filled with a lighter oil (the specification number should be checked in Technical Orders). Disconnect the oil pressure gauge line at the instrument and at the engine and drain out all of the heavy oil. Compressed air may be used to force out the oil. If the oil gun pump is not equipped with a fitting, solder one on the nozzle and connect the engine side of the line to the soldered fitting. With the oil gun, force oil through the line until a small amount drips from the opposite end. (See fig. 28.) Connect this end to the instrument without withdrawing the plunger of the pump and carefully tighten the connection. Remove the oil gun and connect the line to the engine. Normally, the light oil mixes very slowly with the engine oil. The oil gauge will operate satisfactorily for as long as 60 to 90 days after the line is filled with light oil.

(5) COLD WEATHER START WITHOUT PREVIOUS OIL DILUTION. If a cold weather start is necessary and oil dilution previous to engine stopping has not been accomplished, a normal start should be made. After starting the engine, if a heavy viscous oil is indicated, the

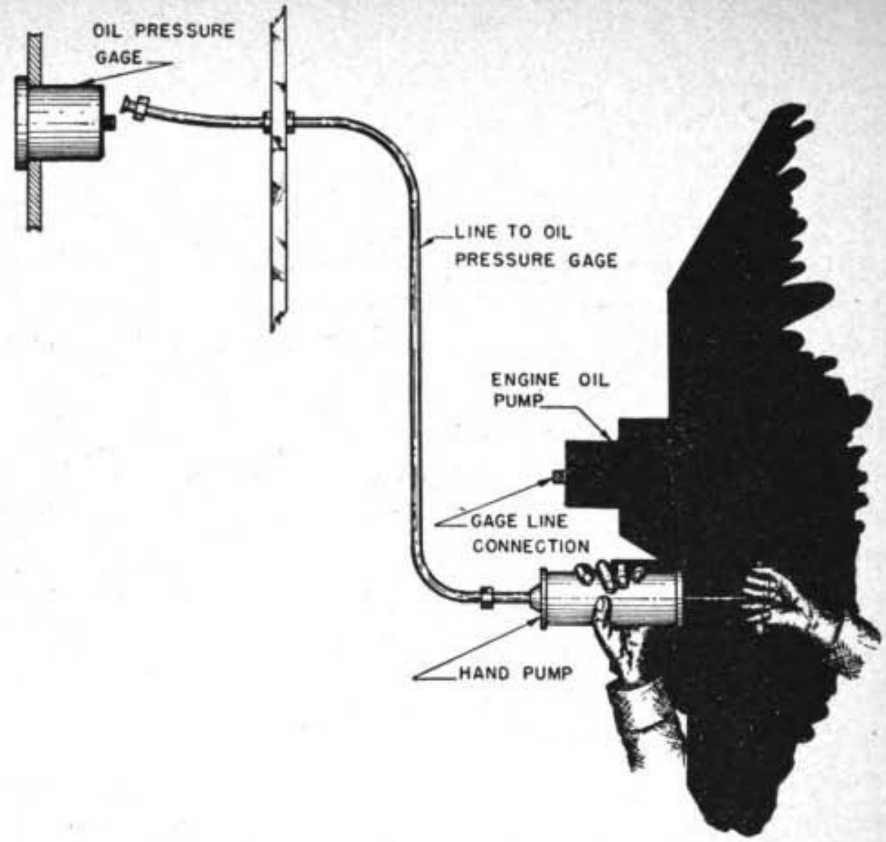


Figure 28. Filling the oil pressure gauge line with light oil.

oil dilution control may be placed in the ON position to correct this condition. This method should be used only if time and extreme temperature conditions do not permit the engine to warm up in the normal manner. Because of slow oil flow and a cold engine, the fuel will not evaporate very readily and overdilution is likely to result. If dilution is used during warm-up, close observation of the oil pressure will be necessary during the time of dilution and through the remainder of the warm-up to determine whether or not the oil has been overdiluted. This will be indicated by a low oil pressure.

(6) STARTING WITH PROPANE GAS. When the temperature drops below —65° F., ordinary 100-octane fuel will not vaporize; therefore, a highly volatile fuel, propane gas, is used. This gas becomes a liquid at approximately —39° F. It is easily handled in case of fire and its use eliminates the danger of overpriming and washing the oil from the cylinder walls. The gas is stored under pressure in a seamless steel cylinder to which is connected a length of tubing leading to the carburetor adapter. Later models of larger airplanes are factory-equipped with a complete unit—bottle, cockpit control, and connections—for propane gas starting. On earlier types and on smaller airplanes, an accessible location, to which the portable propane bottle may be easily attached, is provided. This is usually located inside a small door in the lower part of

the cowling. (See fig. 29.) Propane bottles are included on the portable cart with the battery and the auxiliary power unit. The procedure for engine starting with propane fuel at low temperatures is the same as that used with regular fuel priming. When a start is to be made with propane,

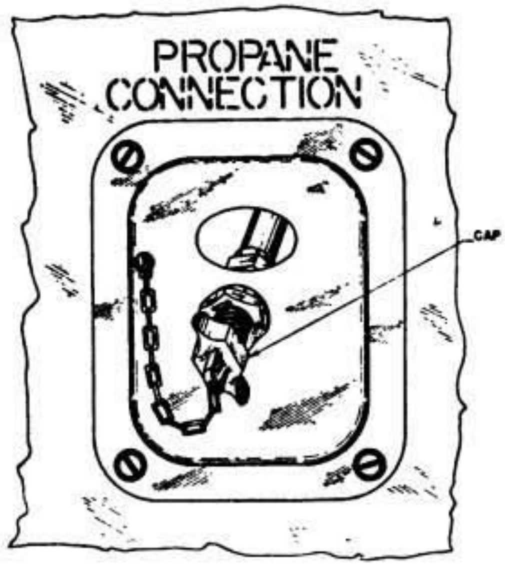


Figure 29. Attachment for propane gas cylinder.

no previous fuel priming is required. The throttle is set at an rpm between 800 and 1,200 rpm where smooth firing will occur. (In order that future starting difficulties may be eliminated, it is suggested that the throttle quadrant be marked when this position is determined.) The carburetor mixture control is left in the IDLE CUT-OFF position. The starting procedure for both the permanent installation and the portable outfit is generally the same. The preliminary step of attaching the propone fuel supply line to the fitting is necessary with a portable outfit. Energize the starter flywheel and during the energizing period, depress the propane primer control for 1 second and release. At the instant that the starter flywheel is engaged to the engine, press the propane primer again and hold until the engine begins to fire regularly. Simultaneously release the propane primer and push the carburetor mixture control to the AUTOMATIC RICH position. After a satisfactory start is made, discontinue the propane gas supply. If the portable type is used, replace the cap on the propane supply line fitting and seal the opening in the cowl. The engine must not be operated above 1,200 rpm when using propane, or too much of the gas will be used. Ordinarily, a bottle of propane is good for 8 to 10 starts.

(7) CARBURETOR DE-ICING. Carburetor icing may occur when the outside temperature is between 30° F. and 70° F., with humidities greater than 50 percent. As was previously stated, no carburetor is non-icing. Provisions are made in some airplanes for the installation of an

alcohol de-icing unit. This unit injects alcohol into the air intake between the supercharger and the carburetor inlet just above the venturi. The system consists of a tank for the isopropyl alcohol, an electrically driven pump, and an ON-OFF toggle switch located on the instrument panel. The amount of alcohol used depends mainly on the amount of ice that is formed. Generally, holding the switch on from 20 to 60 seconds will be sufficient to remove the ice formation. Usually the supply of alcohol is sufficient for only 1 hour of continuous operation. Its use should be limited to emergencies when the carburetor heater cannot eliminate the ice formation. When there is any indication of icing conditions, the alcohol de-icing system will be turned on just before take-off, since take-off must be performed with the carburetor air heater placed in the COLD position. Due to the enrichment of the mixture by the alcohol, a slight loss in power will occur. When a safe altitude is reached, the carburetor air-heater control will be adjusted to maintain the correct carburetor temperature and the alcohol de-icing switch placed in the OFF position. The alcohol de-icer system may serve other purposes besides acting as a de-icing agent to maintain full power. It may be used to start an engine after severe carburetor icing which has resulted in engine stoppage. It may act as a trouble-shooting agent in determining the cause of power loss or engine roughness. For example, if both de-icing methods (adjusting the engine controls and using the alcohol system) do not eliminate the trouble, it can be assumed that carburetor icing is not the trouble. During glides at low power through icing conditions, it may be used to clear out the engine quickly. However, the operator must exercise caution when using alcohol at low engine speed and power, because it may result in excessively rich mixtures and may stop the engine.

(8) PORTABLE GROUND ENGINE HEATERS. Portable ground engine heaters are available in two types. These are the type D–1 heater, which incorporates a small gasoline engine, and the portable hand-operated heater. When the temperature is below —23° C. (—10° F.) these heaters are used to preheat the engine and accessory units before starting. The heaters are provided with oil burners. In the D–1 type portable heater a small gasoline engine provides the power to drive the blower which forces cold air from the atmosphere to the burner for combustion. Other air is forced over the heated jacket (oven) and is used for the actual engine heating process. The outlet ports are provided with flexible heat-resistant canvas tubes designed for easy connection to the airplane. (See fig. 30.) The hand-operated portable heater consists of a burner and a hand crank to rotate the blower. A length of flexible tubing is attached to the outlet of the heater to carry the heated air to the various parts of the engine as shown in figure 31. During the preheating operation the cowl flaps should be closed and the

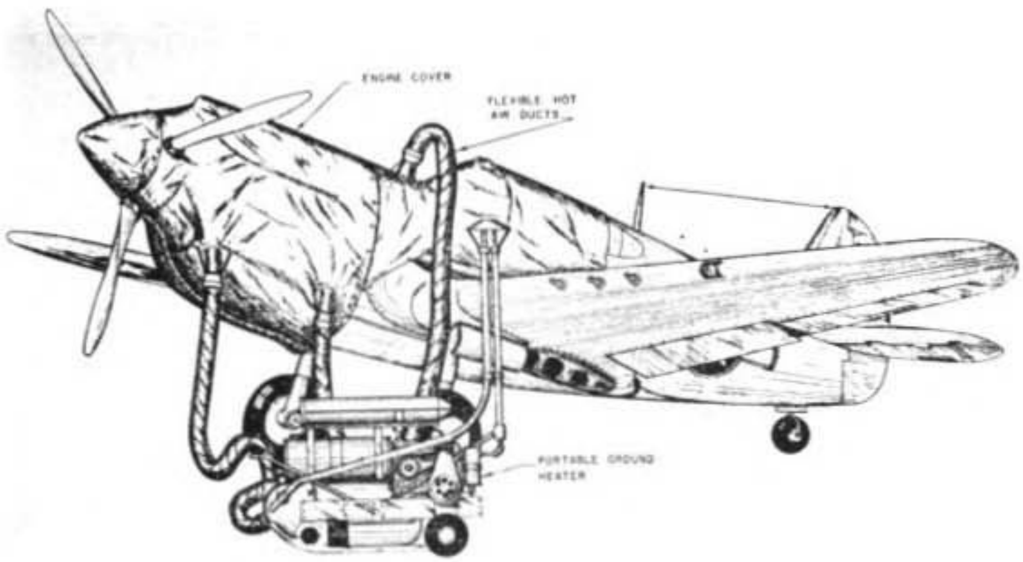


Figure 30. Heater tubes attached to engine cover.

Figure 31. Portable heater in operation.

heated air allowed to enter the cowl covers both at the nose of the engine and at the accessory section. At least 2 hours are generally required to heat an engine during low temperatures. If oil dilution has not been performed it may be necessary to preheat the oil coolers and the oil lines. Care is necessary to prevent excessively hot air from blasting against the ignition harness, flexible hose, self-sealing tanks, and other rubberized or fabric materials. The temperature should be low enough so that a bare hand may be held in front of the blast for about a minute.

(9) OIL IMMERSION HEATERS.—An immersion heater is a 110-volt electrical unit which supplies heat to the oil in the tank. Some airplanes are equipped with permanent units in the tank. They need only to be connected to a 110-volt current supply, (fig. 32). When a portable

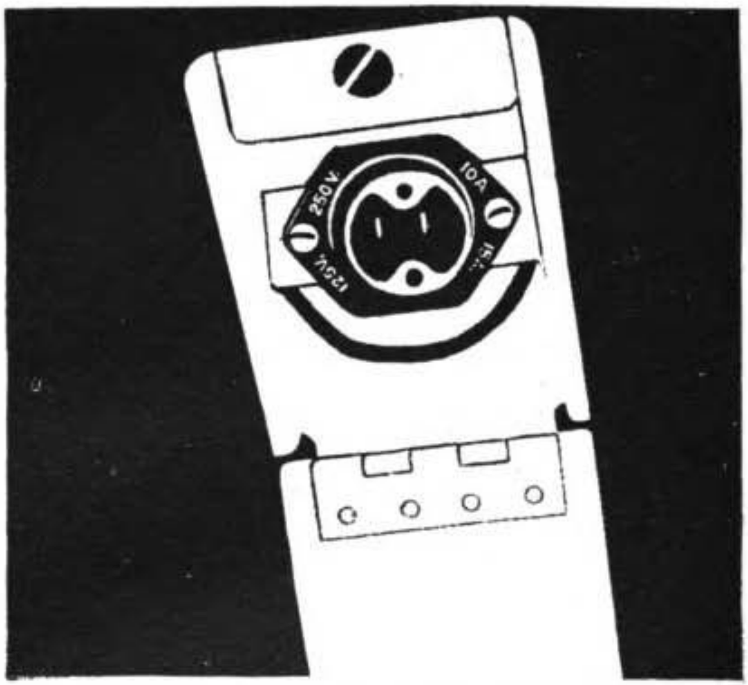


Figure 32.—Oil immersion-heater receptacle.

immersion heater is used on an airplane not equipped with a permanent unit, the heater is inserted through the oil-filler cap and the end of the cord is plugged in some source of electrical power. To permit the heater to warm the oil sufficiently it should remain in the tank from 2 to 5 hours. The portable heater must be removed prior to engine starting, and should be cleaned each time it is used. This method of oil heating may also be used when oil dilution is performed.

(10) PREHEATING COOLANT. When the temperature falls below —5° to —10° C., the coolant may be drained from a liquid-cooled engine into clean containers and heated. The drain cocks must be left open until just before the coolant is returned to the system.

(11) PROTECTIVE CANVAS ENGINE HOODS. Engine covers (fig. 33) are provided for each engine installation. These close-fitting

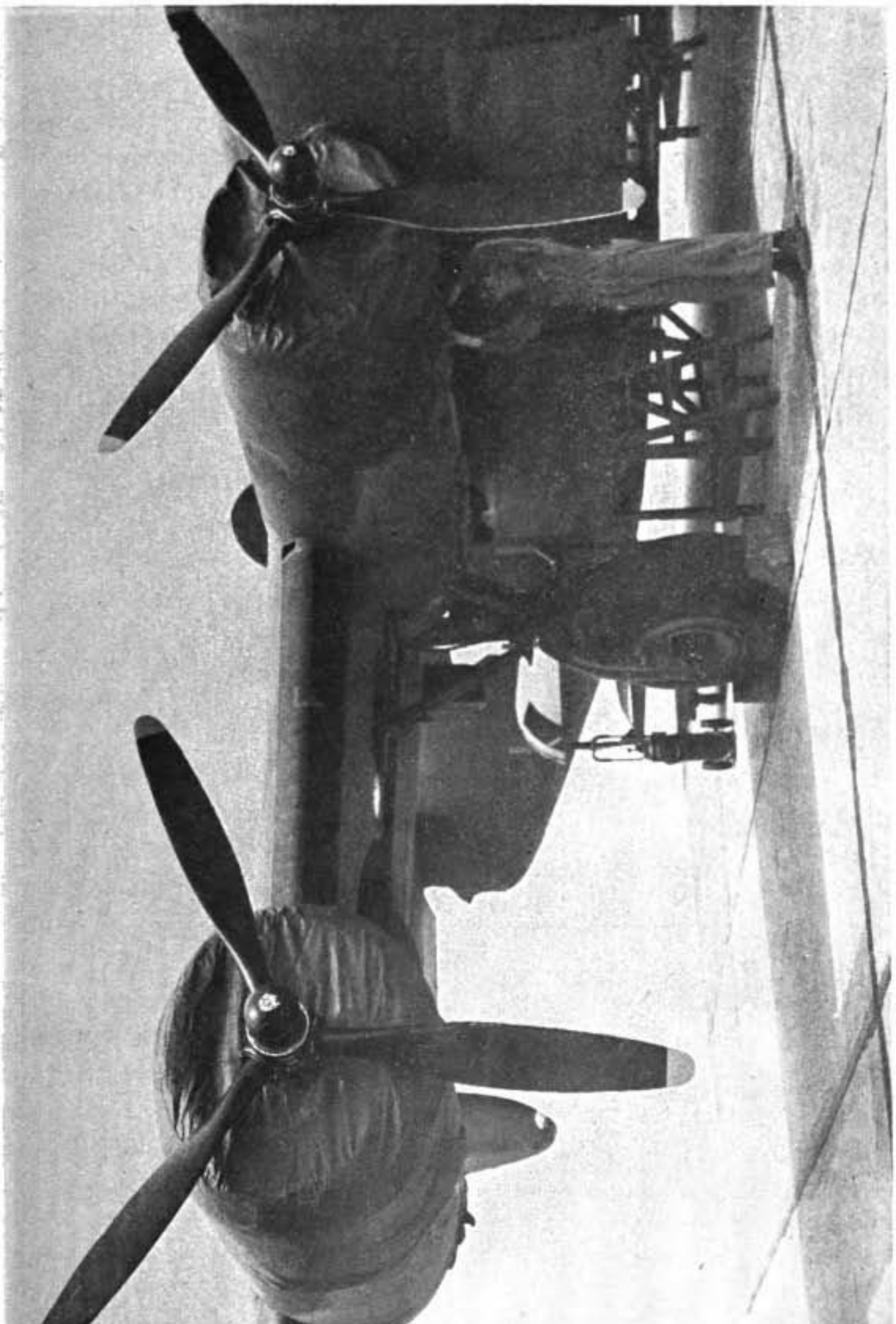


Figure 33. Protective engine canvas hood.

covers can be securely fastened and extend from the propeller hub, around the cowl, to a point behind the firewall. In each cover are two openings, one at the accessory section and one at the front, to allow for the connection of the flexible extensions from portable ground heaters.

(12) OPERATION OF ENGINE-COWL NOSE SHUTTERS. Cowl nose shutters are generally installed only on the air-cooled engines of airplanes at bases where the average atmospheric temperatures are 20° F. (—7° C.) or below. The purpose of the shutter assembly is to control the amount of air that flows over the engine. The shutters are controlled manually by levers located in the cockpit. Figure 34 shows the shutters in the OPEN position and figure 35 shows them in the CLOSED

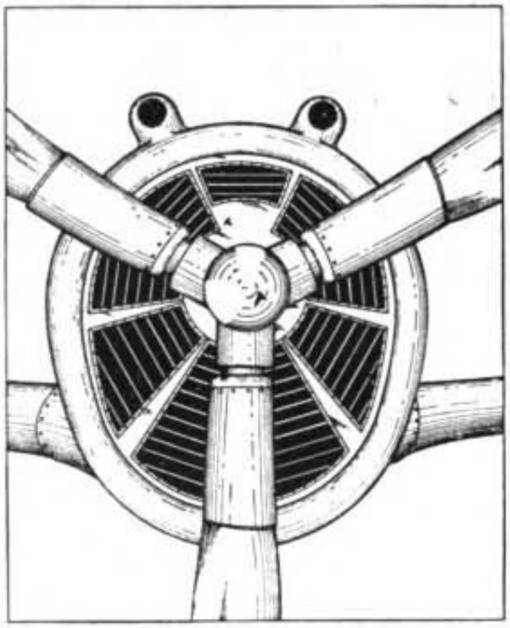


Figure 34. Engine cowl nose shutters—open.

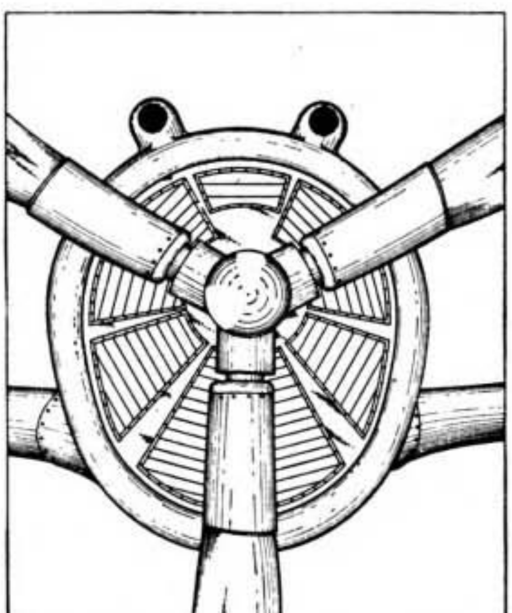


Figure 35. Engine cowl nose shutters—closed.

positions. Specific information concerning position of the shutters during starting, stopping, and flight operation will be furnished by local authority. These data were gathered by running tests in that particular locality to determine the proper operating instructions for each specific engine equipped with nose shutters. However, ground operation, if not prolonged and if 1,200 rpm is not exceeded, will usually be satisfactory.

(13) OIL TANK WATER DRAINS. In order to prevent condensation and freezing of water in the coil tanks during cold weather, the newer tank installations incorporate a tank drain valve. The drain, usually located in the tank sump, is a simple on-off type valve. During the preflight ground check the valve is turned to the ON position and left open until the water is eliminated. It is then turned to the OFF position. If the operation is performed during freezing temperatures and no water flow occurs it will be necessary to heat the tank in order to thaw the ice.

(14) SELF-THAWING OIL TEMPERATURE REGULATORS. The construction of the self-thawing oil temperature regulator is about the same as that of the older type units except for the construction of the core, which is made in such a manner that it allows the warm oil from the engine to flow through predetermined portions of the core in large quantities at lower pressures. Because of these low-pressure paths more heat may be dissipated by the oil to the surrounding areas of the core, thus serving two purposes: first, it shortens the time for oil warm-up during cold weather operation; and second, it keeps the oil from congealing during flight.

(15) ABSENCE OF EXTERNAL HEAT SUPPLY. When no external heating unit such as the portable ground heater or the oil immersion heater is available, the oil should be drained into clean containers and placed in some warm location where it will not congeal. Before it is replaced in the engine, the oil should be heated over a fire to insure free flow. If the temperature is expected to fall below —20° F., the airplane is not expected to be used for a considerable period of time, and no clean containers are available, it is permissible to drain the oil on the ground. It is much easier and quicker to drain the oil and service with fresh oil than it is to warm up the oil system after the oil has once congealed.

(16) BATTERIES. If a temperature of 0° C. (32° F.) or below is expected and the airplane will not be used for some time, the battery will be removed and placed in a warm location to prevent freezing of the electrolyte.

7. ENGINE WARM-UP. The engine must be warmed up to operating temperature before flight. Aircraft engine oils are heavy and viscous at low temperatures and circulate very slowly. A careful warming up of the power plant and oil is required to heat the oil to a temperature at which it will flow in adequate quantity to the various bearing surfaces, particularly to the crankshaft bearings where heavy loads are imposed. Oil is also needed when excessive priming has washed the film of oil from the cylinder walls. Pistons, bearing journals, bearings, metals, and many other parts must be warmed up so that they will expand to the proper operating clearances. This is very important in the radial type engine, since the cylinders are elongated to provide for proper valve timing. Warm-up procedures for different types of engines vary to some extent. Detailed instruments must be obtained from the handbook for the specific engine.

a. Precautions. Generally speaking, an engine should be run on the ground only long enough to warm it thoroughly and to give the operator an opportunity to check for proper functioning of the various engine instruments.

(1) When adjusting the throttle for warm-up, the engine will not be permitted to exceed one-half of the maximum permissible ground rpm until the engine maintains, without fluctuation, at least two-thirds of the minimum full-power oil pressure, and the oil temperature gauge shows a definite increase, thereby indicating that the oil is circulating properly. A cold engine should never be raced in an attempt to shorten the warm-up period.

(2) When operating high-output aircraft engines, it is necessary to operate at a high enough speed to prevent oil fouling of the spark plugs. Operation at very low idling speeds does not allow the engine to develop enough heat to burn the oil entering the combustion chamber.

(3) Tightly baffled engines quickly reach excessive engine temperatures when operated at a high ground rpm. This will cause high oil temperatures which may cause sticking pistons and rings.

(4) A radial type engine is dependent upon the forward motion of the airplane for sufficient cooling. When an engine is operated on the ground, the flow of air is very much reduced and may possibly reverse at some engine speeds. Unless the power output and warm-up time are limited, the cylinders will overheat. During prolonged ground operation, the ring cowling should be removed. If the installation is equipped with cowling flaps, they should be in the FULL OPEN position. Propeller cuffs, as shown in figure 36, streamline the root of the blade, reduce drag, and increase engine efficiency by forcing additional cool air over the cylinders.

b. Instrument check. When safe operating conditions are obtained, the speed may be increased to check the engine performance for proper functioning at a higher rpm. Maximum permissible ground speed will not be maintained for periods in excess of 20 to 30 seconds. On supercharged engines, this maximum permissible ground rpm is determined by a throttle stop or indicated by a red limiting mark on the manifold pressure-gauge cover glass.

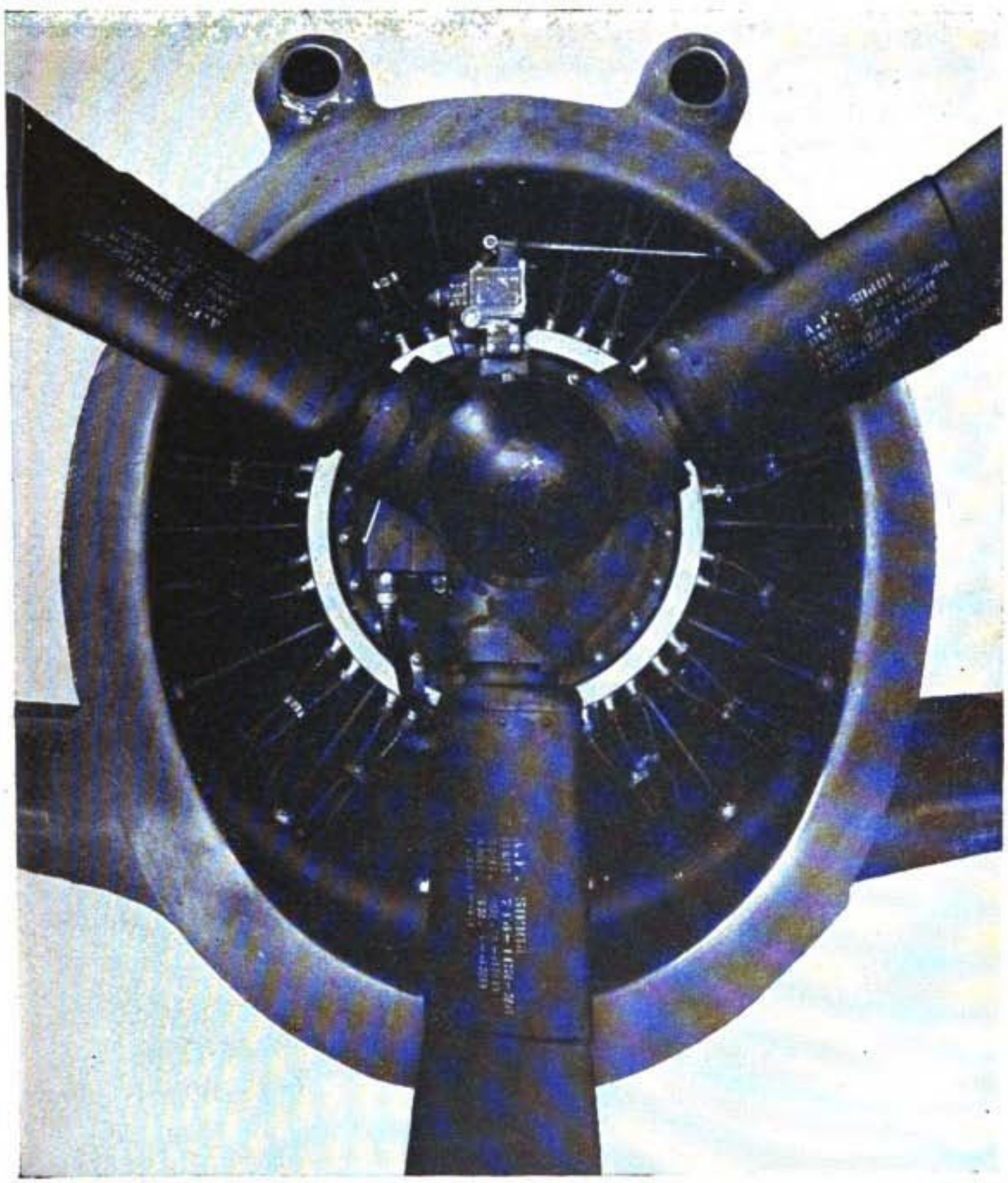


Figure 36. Propeller-blade cuffs.

c. Control adjustment. (1) The engine should be started with the throttle set for a low rpm. Upon starting, the engine should be operated at a moderate speed to allow the lubrication system to function properly. At low speeds the oil pressure is slight. An increase in speed builds up the pressure so that a sufficient amount of oil is sprayed on the cylinder walls, pistons, and other spray-lubricated parts.

(2) To prevent the main bearings from being oil-starved, engines equipped with hydraulically controlled counterweight propellers should remain in the HIGH PITCH position until a steady oil pressure is indicated. This usually requires approximately from 30 to 60 seconds at normal idling speeds. Engines equipped with Hamilton Standard hydromatic or Curtiss Electric propellers are started with the propellers in the LOW PITCH position to reduce the load on the engine and also to provide better cooling.

d. Taxying. (1) High-powered, tightly baffled engines are taxied during warm weather with the cowling flaps placed in the FULL OPEN position. When the engine and oil temperatures approach the maximum limits the airplane is taxied as quickly as possible to the hangar line and the engine stopped immediately. In cases where an airplane must take off again soon after a landing, prolonged ground operation must be avoided. The oil shutters, coolant shutters, and the cowling flaps must be opened, the mixture control must be in the FULL RICH position, and the intercooler shutters FULL OPEN in order to maintain normal ground temperatures.

(2) During cold weather, when the engine and oil temperatures are subnormal, prolonged ground operation is permitted, provided normal engine temperatures are maintained and engine speed is periodically increased to clear the cylinders of accumulated exhaust gases and oil.

8. ENGINE OPERATION CHECK. The engine check is made after the warm-up period. It consists of checking operation of the power plant and accessory equipment by ear, by visual inspection, and by proper interpretation of instrument readings, control movements, and switch reactions. Visual inspection for adequte supply of fuel, oil, and coolant and for proper security of cowling and tank caps, free movement of controls, etc., should be made prior to the engine check. The procedures outlined in the Army Air Forces Visual Inspection System will be followed, except where they conflict with instruction in Technical Orders pertaining to the operation of a specific engine.

a. Ignition. (1) At the end of the engine warm-up period, the ignition switch should be checked. The propeller should be in LOW PITCH (INCREASE RPM) position and the engine should be operating at approximately 700 rpm. The switch should be snapped to the OFF position momentarily to note whether or not the engine stops firing. Two or three seconds is sufficient time for it to remain in the OFF position and it should immediately be returned to the BOTH position. (See fig. 37.) Performing this check quickly at a low engine speed prevents high structural stresses on the parts of the power plant.

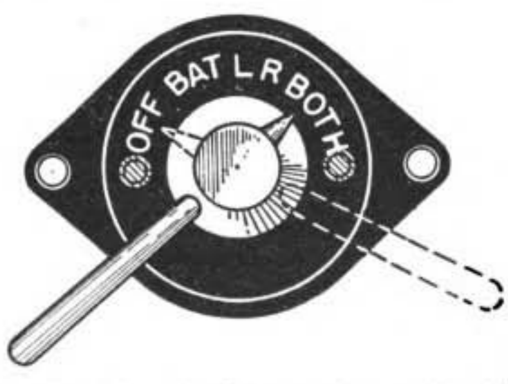


Figure 37. Checking the OFF position of ignition switch.

(2) Before checking the operation of the engine on each magneto, advance the throttle slowly until the rpm reaches that specified for the particular engine. Maximum cruising manifold pressure must not be exceeded. Detonation is likely to occur when firing on only one set of spark plugs at a manifold pressure higher than that specified. Move the switch quickly from the BOTH ON position to one magneto (see fig. 38) and observe the rpm drop. Ordinarily, the check requires 3 or 4

Figure 38. Checking engine operation on left magneto.

seconds. The switch is then returned to BOTH ON and the engine is allowed to assume its original speed. Snap the switch to the unchecked magneto and observe the rpm drop on the tachometer. (See fig. 39.)

Figure 39. Checking engine operation on right magneto.

An engine can normally be expected to lose between 40 and 100 rpm when operated on one magneto. The difference in rpm of the two magnetos is caused by the difference in timing of the two units. Normal rpm drop can be determined by experience with the particular power plant.

(3) When an engine is not equipped with a manifold pressure gauge or when cruising manifold pressure is not known, the foregoing check is performed with 85 percent of the rpm developed when the throttle is opened to the throttle stop. If no throttle stop and manifold pressure gauge are installed, the magnetos are checked with the engine operating at 85 percent full rpm.

b. Two-speed superchargers. To prevent the accumulation of centrifuge sludge and dirt in the supercharger clutch mechanism, set the engine speed at 1,500 rpm, the propeller in full Low Pitch, and move the supercharger control lever to the HIGH position and lock. Open the throttle to obtain not more than 30 inches Hg manifold pressure. When the engine speed is steady, observe the manifold pressure and immediately shift the supercharger control to LOW position without moving the throttle. A sudden decrease in manifold pressure is an indication that the two-speed supercharger drive is operating properly. This operation is performed immediately after engine warm-up and the control must be left in the LOW BLOWER position for take-off. Technical Orders should be consulted for additional instructions about the specific supercharger installation.

c. Turbo-driven superchargers. Place the waste gate control in FULL AUTOMATIC position. While operating the engine at maximum allowable ground rpm, check to see that the supercharger waste gas operates automatically and that the manifold pressure is held within the specified limits. To prepare an engine for take-off, set the propeller at the rpm specified, open the throttle wide, and raise the manifold pressure to that specified for take-off. This should be done as quickly as possible by using the supercharger regulator control. Then lock the regulator control and retard the throttle. The airplane may then be taxied out for the take-off. When all throttles are fully opened for take-off, the supercharger regulator will raise the manifold pressure to the predetermined value.

d. Controllable pitch propellers. The operation of a controllable pitch propeller is checked by the indications of the tachometer and manifold pressure gauge when the propeller governor control is moved from one position to another. To prevent overheating of the engine while operating in HIGH PITCH (LOW RPM) position, the manifold pressure during the test should not exceed that specified for maximum cruising. In order to insure proper lubrication immediately after starting an engine equipped with a hydraulically operated counterweight propeller, the propeller control should not be moved to its LOW PITCH (HIGH RPM) position until a steady oil-pressure reading is obtained. This usually requires approximately 30 to 60 seconds of operation.

(1) HAMILTON TWO-POSITION PROPELLER. The Hamilton two-position propeller is checked after the engine has warmed up. The

pitch change should be performed at an engine speed of approximately 1,400 rpm except where limitations have been listed for specific engines.

(2) HAMILTON CONSTANT-SPEED PROPELLER. A constant-speed propeller is tested at approximately 1,600 rpm after the engine has warmed up except where limitations have been listed for specific engines. The pitch-changing action is tested by moving the control to the POSITIVE HIGH PITCH position and observing the corresponding change (drop in rpm); then move the control to TAKE-OFF RPM position and observe the tachometer indication of an increase in rpm.

(3) HAMILTON HYDROMATIC PROPELLER. The preflight check for range of operation of a hydromatic propeller is performed after the engine is warmed up. The throttle should be set to obtain about *1,800 rpm,* except where limitations are listed on specific engines. The propeller control is then moved to the HIGH PITCH (LOW RPM) position and the drop in rpm noted (manifold pressure increases). Without changing the throttle setting, move the propeller control to LOW PITCH (HIGH RPM) position. The engine should assume its original rpm. When both increase and decrease in engine rpm are indicated on the tachometer (during the foregoing operations), the propeller is functioning properly.

(4) CURTISS ELECTRIC PROPELLER. After engine warm-up, the electric propeller is checked at approximately 1,000 to 1,200 rpm. Hold the selector switch in the DECREASE RPM position until a reduction in speed occurs and note the manifold pressure increase; then move the switch to the INCREASE RPM position. When the engine rpm ceases to increase, the propeller has reached its positive low blade angle. The ignition switch may be used to test individual magneto operation while the selector switch is in the OFF position. Constant-speed operation is checked by placing the selector switch in AUTOMATIC position and the governor control in TAKE-OFF position. Open the throttle until the engine speed is approximately 70 percent of the rated rpm and pull the governor control lever back until a reduction in engine rpm is noted. Return the control again to TAKE-OFF position noting that the original rpm is again resumed.

(5) AEROPRODUCTS CONSTANT-SPEED PROPELLER. At preflight warm-up, the propeller operation is checked with the propeller control set in the INCREASE RPM position. Move the throttle until approximately 2,300 rpm are obtained. While retarding the throttle with one hand to maintain constant manifold pressure, use the other to pull the propeller control to the full DECREASE RPM position and still hold the original manifold pressure. Then move the propeller control back to the full INCREASE RPM position (2,300 rpm). The other hand should be setting the throttle back to its original position to estab-

lish the original manifold pressure. If the engine assumes a speed of 2,300 rpm, it indicates that the propeller is functioning properly.

e. Oil pressure gauges. The oil pressure gauge should indicate pressure between the minimum and maximum oil pressures specified for the particular engine. The gauge needle should show very little pressure fluctuation at a fixed rpm.

f. Fuel pressure gauges. Fuel pressure gauges should show the specified pressures, and the pointer should not oscillate excessively. Note the pressure with the engine operating at different rpm, and closely observe the gauge when the selector valve is rotated to each tank.

g. Fuel-warning light. Press the test light switch to check the condition of the light bulb. (See fig. 40.) Closely observe the fuel pressure

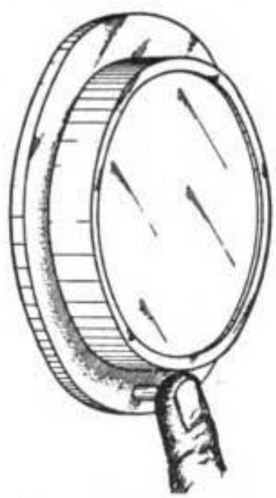


Figure 40. Checking the fuel system warning light.

gauge and the warning light when checking the operation of the selector valve and the setting of the fuel-warning light switch.

h. Fuel-contents gauge. During this check, the functioning of all tanks is tested by rotating the selector cock valve to each tank and observing the effect on the fuel contents gauge and warning light. Each tank will be tested long enough to allow fuel to flow to the carburetor.

i. Manifold pressure gauge. At idling speed, open the gauge vent-line cock to allow vapors in the gauge line to be carried into the engine by the inflow of atmospheric air. Check the gauge by opening the engine throttles. The indicator needle should move freely.

j. Tachometer. Ability to check tachometer indications with or without corresponding manifold pressures may be gained only from experience with the particular engine installation when operating under normal conditions. The pointer should show a fairly steady indication.

k. Fuel-selector cock valves. Fuel cocks should not bind when rotated. A noticeable drag should occur when the handle is turned, and a click should be felt as the selector valve falls into proper position. The proper operation of the fuel system should be checked for each tank.

l. Thermometers. Oil, coolant, and cylinder thermometers should indicate an increase in temperature (up to operating temperatures) from the time the engine is started. The pointers should not oscillate.

m. Voltmeters. Voltage will vary during the warm-up period. It will be high when the regulator is cold and decrease as it warms up. Therefore, adjustment should not be made until after the engine has warmed up and the ignition check has been made.

(1) With the main-line switch in its OFF position and the engine speed approximately 1,500 rpm, the voltmeter should indicate 14.25 volts in a 12-volt system and 28.5 volts in a 24-volt system. The voltmeter pointer should not oscillate excessively. Low voltmeter indications and discharge or no charge shown on the ammeter signify malfunction of the generator or control system. Excessive generator voltage will seriously damage auxiliary electrical equipment, especially radio equipment; therefore, it is essential that the voltage regulator be adjusted to give the specified voltage on the voltmeter.

(2) Placing the main line switch in the ON position, the mechanic determines the voltage at which the current cut-out relay completes the circuit between the battery and the generator by slowly opening and closing the throttle and observing the voltmeter. The current cut-out points should close at 13.5 volts in a 12-volt system and at 27 volts in the 24-volt system. Closing of the points will be indicated by a slight drop-back of the voltmeter pointer. (See fig. 41.)

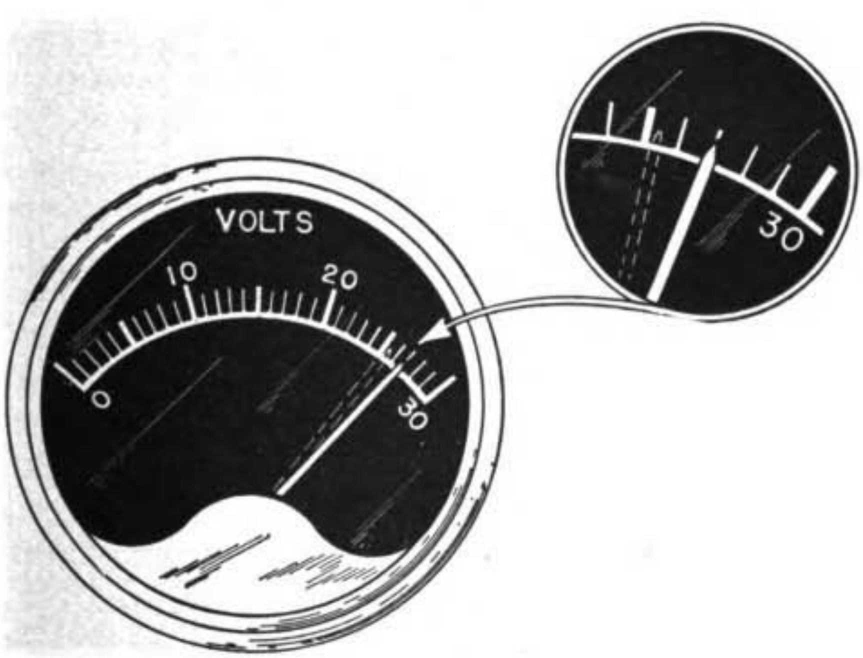


Figure 41. Indications of voltmeter when checking reverse-current cut-out.

n. Ammeter. (1) With the main line switch OFF, check the pointer for zero setting.

(2) With the main-line switch ON and the engine running at cruising rpm, make certain that the ammeter indicates a normal charge, and that the pointer does not oscillate excessively.

9. FLIGHT OPERATION OF ENGINE. If the engine mechanic is to understand the operation of the airplane and do his work properly, he must understand the effects of actual flight conditions upon the power plant.

a. Take-off and climb. During take-off and climb, the engine is being forced to develop its maximum output (110 to 120 percent of normal rated power, as shown in fig. 42) and maximum amounts of fuel and oil are being consumed. Engine power, speed, and temperatures have reached, or are approaching, their maximum limits. Because of these conditions, operating time at maximum power output must be limited to periods of short duration to prevent danger of structural break-down. The following instructions pertain to take-off operations under all conditions:

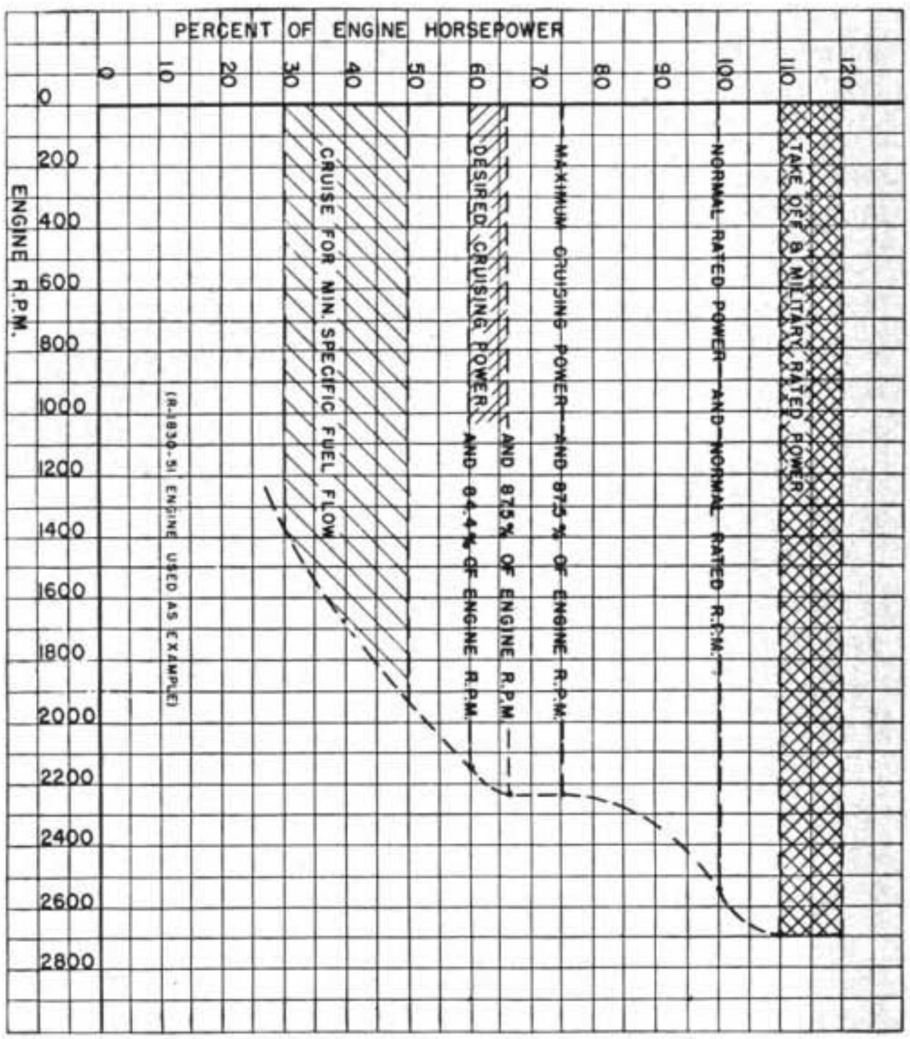


Figure 42. Range of engine flight operating conditions.

(1) Constant-speed propellers must be adjusted to the TAKE-OFF RPM position. Multiple or two-position controllable propellers must be set in the LOW-PITCH (HIGH RPM) position for take-off and climb. This is necessary to obtain maximum propeller efficiency and permit the engine to develop full power.

(2) Place the fuel cock in the RESERVE position to insure that fuel from the reserve tank will be used during take-off and climb. This precaution eliminates the possibility of engine failure from a lack of fuel supply to the carburetor because of the change in attitude of the airplane.

(3) As a general rule, on highly supercharged engines, a higher manifold pressure is permitted for emergency take-off and climb than permitted for flight below certain altitudes. These high manifold pressures are not normally used for take-off or climb, as they impose abnormally high stresses on the engine. They may be used in emergencies, such as take-offs from a small landing field, or with a heavy load, or where obstacles must be cleared, etc. Under no circumstances should maximum rpm be exceeded in take-off or climb.

(4) Aircraft engines are usually subjected to their highest operating temperatures during take-off and climb. Temperatures should be kept within the specified ranges indicated on the instruments. This may be done, to a great degree, by proper use of the cockpit controls. For maximum cooling, open the cowling flaps and radiator shutters, adjust the carburetor air heater to the COLD or OFF position, and place the mixture control in its FULL RICH position. Some tightly baffled engine installations give considerable trouble until the airplane is in flight and the forward speed of the airplane permits proper cooling of the power plant. In such cases, it is recommended that the engine be started and the airplane taxied to the flying line immediately. At that point the engine is checked for proper operation. As soon as the operator is satisfied with the operation of the engine, an immediate take-off can be accomplished with minimum possible engine operating temperatures and with maximum power output. As a last resort when abnormally high temperatures are present, manifold pressures must be reduced on take-off and climb to prevent detonation and possible engine failure.

(5) SEA LEVEL SUPERCHARGING. This method is sometimes used to increase the power output above the normal maximum at sea level. It also increases the temperatures, pressures, and mechanical stresses in the engine. The principal purpose for "boosting" the engine power at sea level is to gain maximum power for limited periods of time only, as for take-off and climb of modern military interceptor type airplanes. With superchargers of large capacities, some form of mechanical stop is usually installed in the system to prevent extreme pressures during sea level operation.

b. Cruising. An airplane engine operates during most of its useful life at cruising rpm with medium power output. The cruising operation may be subdivided into three phases: cruising for minimum specific fuel flow (low-speed cruising), desired cruising, and maximum (or high-speed) cruising. During all cruising operations, multiple-position and two-position controllable propellers are set in HIGH PITCH (DECREASE RPM) position to obtain maximum efficiency of the propeller and engine. On an engine with a constant-speed propeller, the throttle control is set to give the desired manifold pressure and the cockpit propeller governor control is then adjusted to the desired rpm.

(1) CRUISING FOR MINIMUM SPECIFIC FUEL FLOW. The horsepower indicated on the graph (fig. 42) is not determined from a fixed percentage of normal rated power but represents the highest horsepower possible when the engine rpm, manifold pressure, and other conditions are adjusted to a point where the fuel consumption per brake horsepower per hour is at a minimum. As shown in figure 42, the setting of the controls will generally be positioned to have the engine deliver between 30 and 50 percent of the normal rated power under the conditions stated. (This range was arrived at by selecting the average of the specifications of several commonly used engines.) During low-speed cruising, the engine operates at the rpm that will permit a reasonable forward speed of the aircraft with minimum fuel consumption per hour of engine operation. Within the limits mentioned, the mixture control is set in the LEAN BEST POWER position or leaner if permitted for the particular engine. Low-speed cruising is recommended for maximum air-mile range with a given fuel supply. The usefulness of low-speed cruising may be offset in cold weather or at high altitudes by poor fuel vaporization, even though the carburetor heater is utilized. When carburetor icing conditions exist, low-speed cruising may not produce enough heat for the carburetor air heater effectively to prevent or eliminate ice formation in the induction system. (See par. 4g.)

(2) DESIRED CRUISING. Desired cruising is that engine speed which permits the use of a reliable engine horsepower to give efficient aircraft performance consistent with economical fuel consumption per hour of engine operation. By reference to figure 42, it may be seen that desired cruising is between 60 and 67 percent of normal rated power and 84.4 and 87.5 percent of normal rated engine rpm. The power plant will operate the majority of hours during its useful life within this range. Within the limits given, the mixture control is set in the best power range or at RICH BEST POWER. The manifold pressure for this condition is specified in the Technical Orders for each particular engine. Desired cruising is recommended when good engine performance and low fuel consumption are required. Intelligent use of the mixture control and

proper operation of the carburetor air heater, radiator shutters, and cowling flaps will help to accomplish the purpose of desired cruising.

(3) MAXIMUM CRUISING. Maximum cruising is that condition which permits the use of a high, reliable, delivered horsepower to give maximum prolonged aircraft performance with a reasonable fuel consumption per hour of engine operation. Reference to figure 42 shows that maximum cruising is determined by taking 75 percent of the normal rated power and 87.5 percent of the normal rated engine rpm. Within the limits mentioned, the engine is usually operated with the mixture control adjusted halfway between the RICH BEST POWER and FULL RICH positions. The manifold pressure used is specified in the Technical Orders for each particular engine. Maximum cruising is recommended where high engine performance is needed without particular consideration of fuel consumption. Under severe carburetor icing conditions, maximum cruising is desirable to furnish sufficient heat with the carburetor air heater to remove or prevent ice formation. (See par. 4g.)

c. Normal rated power. Normal rated power is the maximum continuous power at which the engine may be operated with safety. As shown in figure 42, normal rated power is that setting of the engine controls which furnishes continuously 100 percent power at normal rated engine rpm.

d. Maximum permissible operation or military rated power. This is the condition of engine operation (at a designated speed) which permits the use of the entire available horsepower of the particular engine. Normally, this operating condition should be avoided and used only as a power reserve in case of emergency. As shown in figure 42, maximum permissible operation is that setting of the engine controls which permits the engine to deliver 110 to 120 percent of the normal rated power of a specified engine rpm. Within the limits mentioned, the engine is usually operated at the maximum permissible manifold pressure. This pressure is limited as specified in Technical Orders for each particular engine installation. The mixture control should be placed in the FULL RICH position. Very high fuel consumption can be expected when operating under these conditions. Under no circumstances should the maximum permissible rpm and manifold pressure be exceeded. During this condition of engine operation, high engine temperatures are to be expected; however, the engine speed and power must be reduced when temperatures approach or reach maximum permissible limits.

e. High altitude operation. Modern military aircraft, with the exception of trainers and other light airplanes, are usually equipped with highly supercharged power plants. Either the turbine or the internal type may be used. In some installation, both types are utilized.

(1) Each particular engine installation has a definite critical altitude rating. This is defined as the maximum altitude at which the power

plant will deliver maximum rated horsepower. Above this altitude the throttle must be advanced toward the FULL OPEN position (as the airplane climbs) to maintain manifold pressure, until the celing of the aircraft is reached. Although the engine must not be operated at full throttle for long periods of time at low altitudes, continuous full-throttle operation is usually permissible above the critical altitude. When the engine is operating under these conditions, the mixture control should be adjusted to smooth out any tendency toward rough running. It should be used as an altitude control and, under certain conditions, as an economy device.

(2) In an engine equipped with an internal supercharger, the selection of the supercharger ratio is governed by the required manifold pressure; that is, the low blower ratio should be utilized as long as the required manifold pressure can be maintained, even though the carburetor throttle approaches the FULL OPEN position.

(3) In an installation incorporating an external or turbo type supercharger, the automatic regulator is adjusted to maintain approximately 31 inches of manifold pressure at full throttle from sea level to approximately the critical altitude of the supercharger. Above cruising manifold pressures or speeds the mixture control should be placed in the FULL RICH position. At or below cruising manifold pressures or speeds, the mixture control should be placed in the LEAN BEST POWER or RICH BEST POWER position, as specified for the particular engine installation. Above the critical altitude of the supercharger the mixture control should be used as an altitude control.

f. Descent. When the airplane assumes a gradual inclined path downward, with just sufficient speed to keep flying, it is in a glide. Steeper "nose down" descents are called dives, and steep descent under power, a "power dive." In a steep glide the controls should be adjusted as follows:

(1) If no automatic manifold-pressure regulator is installed, the fuel-air mixture must be enriched until the control is in the FULL RICH position and the throttle must be closed gradually to avoid excessive manifold pressures.

(2) Set the propeller constant-speed control in CRUISING RPM position. This setting will prevent overspeeding of the engine if the throttle is opened suddenly.

(3) Adjust the manifold pressure-regulator control for take-off pressure and use the throttle to control the engine.

(4) The carburetor air heater should be placed in the COLD position. The use of the carburetor air heater is recommended in long glides at reduced power when icing conditions exist.

(5) In descending from a high altitude, the manifold pressure gauge indication should be closely observed even though engine speed is gradu-

ally decreased, since it is possible to obtain an excessive manifold pressure with correspondingly low rpm. This condition should be avoided.

g. Landing. Landing operation of the power plant is interpreted to mean operation before the airplane actually touches the ground.

(1) In installations incorporating controllable-pitch or constant-speed propellers, the landing should be effected with the propeller set in LOW PITCH (HIGH RPM) position in the event an immediate climb or take-off becomes necessary.

(2) The mixture control should always be placed in its FULL RICH position prior to landing.

(3) The throttle should be retarded gradually to decrease engine rpm and power. A sudden drop in engine speed tends to cause very rapid cooling of certain engine parts and will probably result in spark plug fouling. It is advisable to open the throttle periodically to clear the cylinders of exhaust gases which accumulate in the combustion chambers, and to remove the accumulated oil films on the spark plug electrodes.

(4) Aircraft equipped with a reserve fuel supply should be landed with the fuel cock placed in the RESERVE position. This precautionary measure insures a positive supply of fuel to the fuel pump in case an immediate climb or take-off becomes necessary.

(5) After the landing operation is completed, ground operating procedures must be followed.

10. ENGINE STOPPING. With each type of carburetor installation, specific procedures are employed in stopping the engine. The general procedure outlined in the following paragraphs reduces the time required for stopping, minimizes backfiring tendencies, and, most important of all, prevents overheating of tightly baffled air-cooled engines during operation on the ground.

a. Control settings. In stopping any aircraft engine the controls are set as follows, irrespective of carburetor type or fuel system installation.

(1) Cowling flaps are always placed in the FULL OPEN position to avoid overheating of the engine and left in that position after the engine is stopped to prevent the residual heat of the engine from deteriorating the wiring of the ignition system.

(2) Radiator shutters are also left in the FULL OPEN position.

(3) Oil cooler shutters should be FULL OPEN to allow the oil temperature to return to normal.

(4) Intercooler shutters are kept in the FULL OPEN position.

(5) Carburetor air-heater control is left in the COLD position to prevent damage which may occur from backfire when the engine is stopped.

(6) Exhaust gas analyzer should be placed in the OFF position after the engine is stopped.

(7) Turbo-driven supercharger waste gates are set in the FULL OPEN position.

(8) Supercharger regulators are generally automatically controlled and require very little attention during engine stopping.

(9) Two-speed supercharger control is placed in the LOW BLOWER position.

(10) The automatic manifold-pressure regulator should be left in the ON (take-off) position.

(11) PROPELLERS. A Hamilton Standard two-position or a constant-speed propeller will usually be stopped with the control set in the HIGH PITCH (DECREASE RPM) position. All taxying will be done with the propeller in the LOW PITCH (INCREASE RPM) position. After reaching the hangar line, open the throttle to approximately 1,200 rpm and shift the propeller control to HIGH PITCH (DECREASE RPM) position. This operation will decrease the engine speed. Allow the engine to operate approximately 1 minute before stopping, in order that the oil dumped into the engine from the propeller may be properly scavenged and returned to the oil tank. However, to inspect the propeller piston for galling and wear and for other special purposes, this propeller may be stopped with the propeller control in LOW PITCH (INCREASE RPM). A Hamilton Standard hydromatic and the Aeroproducts propeller will be left in the LOW PITCH (INCREASE RPM) position when the engine is stopped. The Curtiss Electric propeller control is set in the LOW PITCH (INCREASE RPM) position and the selector switch in AUTOMATIC position.

(12) No mention is made of the throttle, mixture control, fuel selector valve, and ignition switches in the preceding set of directions because the operation of these controls varies with the type of carburetor used with the engine.

b. Float type carburetor. Engines equipped with a float type carburetor without an IDLE CUT-OFF unit are stopped as follows:

(1) Adjust the throttle to obtain an idling speed of approximately 600 to 800 rpm, depending on the type of engine.

(2) Close the fuel selector valve.

(3) Open the throttle slowly until the engine is operating at approximately 800 to 1,000 rpm.

(4) Observe the fuel pressure. When it drops to zero, turn the ignition switch to the OFF position and simultaneously move the throttle slowly to the FULL OPEN position. This operation will remove the accelerating charge from the induction system and avoid the possibility of accidental starting.

(5) When the engine has stopped, place the fuel selector cock valve in the ON position and refill the carburetor and fuel lines by using the wobble pump.

c. Carburetors equipped with idle cut-off. An engine equipped with a carburetor incorporating an IDLE CUT-OFF is stopped as follows:

(1) Idle the engine by setting the throttle for 800 to 1,000 rpm.

(2) Move the mixture control to the IDLE CUT-OFF (FULL LEAN) position. In a pressure type carburetor, this causes the cut-off valve to stop the discharge of fuel through the discharge nozzle. In a float type carburetor, it equalizes the pressure in the float chamber and at the discharge nozzle.

(3) When stopping an engine equipped with a Bendix Stromberg injection type carburetor, the throttle will be moved to the FULL OPEN position (speed of throttle movement is dependent upon the type of engine). This should be done just as the mixture control reaches IDLE CUT-OFF position. This is necessary to remove the accelerating charge from the induction system and prevent accidental starting.

(4) After the propeller has stopped rotating, place the ignition switch in the OFF position.

d. Stopping engines equipped with fuel injector. (1) Throttle the engine to approximately 600 to 800 rpm to allow the power plant to cool.

(2) Move the mixture control lever to the IDLE CUT-OFF (FULL LEAN) position, but do not move the throttle.

(3) Place the ignition switch in the OFF position only after the engine has completely stopped.

(4) Leave the fuel selector valve in the ON position in order that the fuel lines will remain filled, thereby avoiding undue cranking when starting the engine. The valve will never be shut off except in an emergency.

e. Oil dilution. (1) In starting an engine employing oil dilution, a normal start should be made without regard to the oil dilution system. After starting the engine, if a heavy viscous oil is indicated by oil pressure that is too high, or by oil pressure that fluctuates or falls back when the engine rpm is increased, the dilution control may be pushed momentarily several times to decrease the viscosity of the oil as a means of correcting this condition. Pratt and Whitney R–1830, R–2000, and R–2800 type engines are equipped with a thermostatic oil-pressure relief valve which is arranged so that on cold starting, the relief valve does not function and oil pressure as high as 200 pounds per square inch is encountered. As soon as the oil temperature reaches 40°C., the relief valve begins to operate and regulates the oil pressure in the normal manner. On these types of Pratt and Whitney engines, therefore, when high oil pressures are encountered on starting, it is not advised to push the dilution switch as mentioned, in an effort to correct this high pressure. The dilution switch, therefore, should only be pushed on those airplanes equipped with other than the Pratt and Whitney R–1830, R–2000, and R–2800 type of engines after engine starting. This procedure must be used with caution as it is possible to cause an engine failure by supplying the engine pump with pure gasoline in case the oil is sufficiently viscous or stopped by ice so as not to permit flow; the oil pressure gauge may indicate sufficient pressure due to the gasoline to cause operating personnel to believe oil is flowing, which may not be the case. This method is suggested only if time and extreme temperature conditions do not permit engine warm-up in the normal manner.

(2) If desired, it is safe to make immediate take-offs, after oil dilution has been used, without normal warm-up, provided there has been a rise in oil temperature, oil pressure is steady, and the engine is running smoothly. Cold oil properly diluted has the same viscosity as hot undiluted oil and, therefore, the same ability to circulate and properly lubricate an aircraft engine.

11. REFUELING. One of the most important phases of the airplane mechanic's work is the refueling and servicing of the airplane's fuel tanks. Refueling involves many hazards, the most important of which result from carelessness. These hazards must be carefully guarded against in order to eliminate the possibility of fires, explosions, and engine failures during flight.

a. Correct grade of fuel. When refilling fuel tanks, the correct octane-rating fuel must be used. Failure to use the correct fuel will result in detonation and excessive loss in engine power. To prevent the accidental use of incorrect fuel, the octane rating of the fuel to be used is stenciled in ½-inch letters near the filler neck. (See fig. 43.)

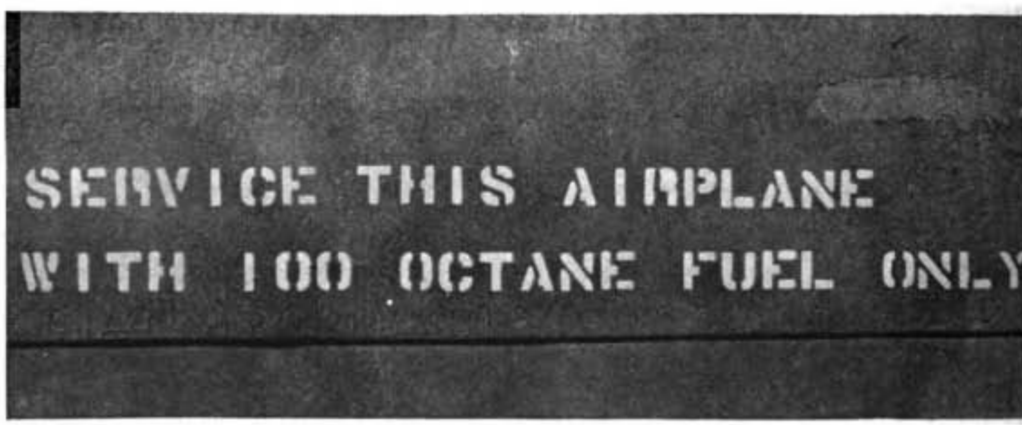


Figure 43. Fuel octane-rating label.

b. Surface damage. A fuel hose will usually reach a number of tanks on the airplane. The mechanic should not scratch or damage the wing and structure surfaces as he moves from one tank to another. De-icer shoes should be protected from injury when the fuel hose is pulled over the leading edge of the wing.

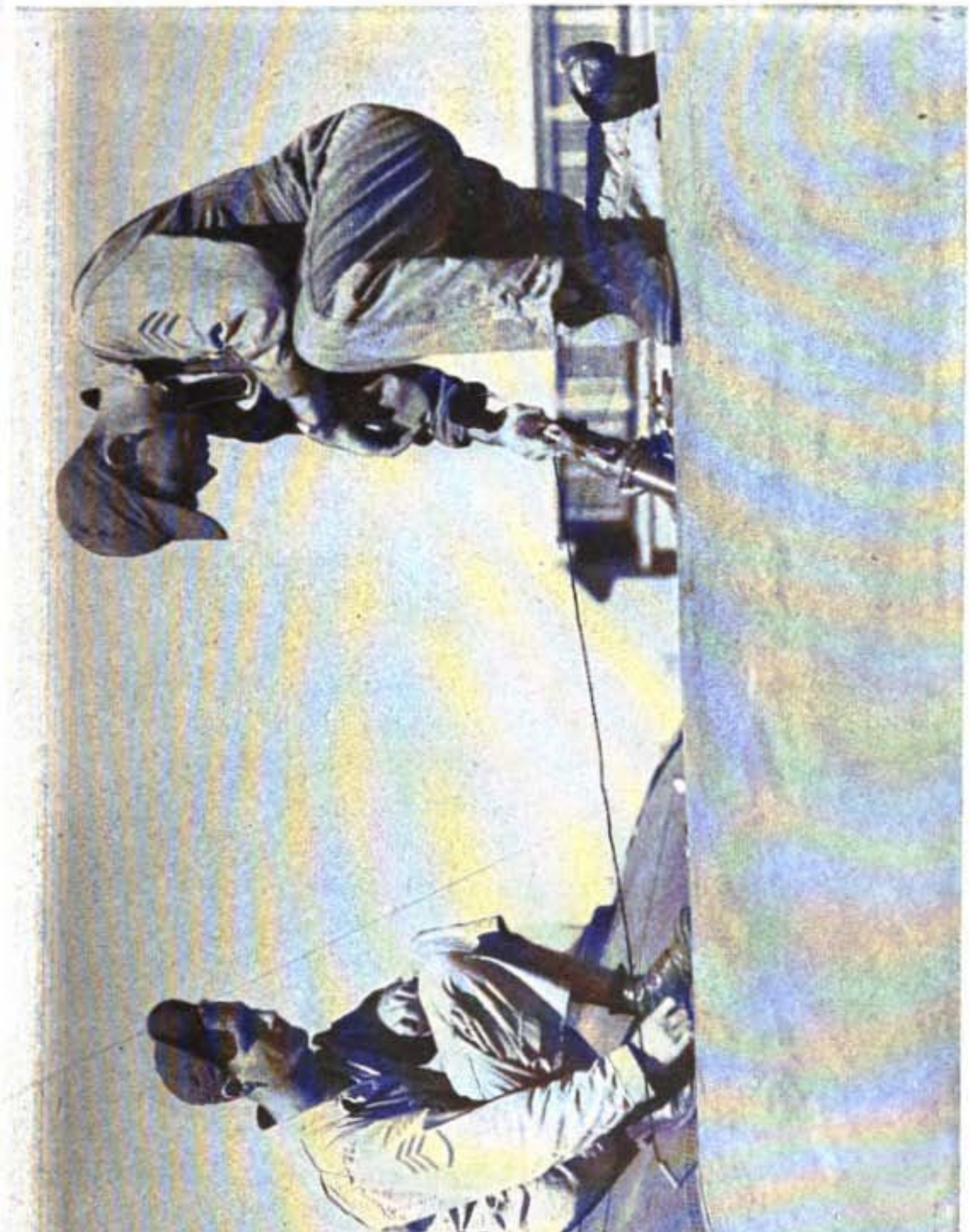


Figure 44. Fuel-hose bonding wire and clamp.

c. Fuel filters. Water and other foreign matter should be prevented from entering the fuel tank. Some of the fuel passages of the carburetor are very small; fuel will pass through these openings, whereas foreign matter may not. To make certain that only clean fuel enters the tank, chamois skins are always used when refueling with small containers and a funnel. Fuel systems are equipped with filters, screens, drain cocks, and other devices to eliminate foreign matter that may enter the fuel tanks in spite of the precautions taken.

d. Avoidance of exposure of fuel. Heat, age, and exposure to the air will rob the fuel of its more volatile fractions, thus reducing the octane rating. In deserts and very hot climates it is essential that fuel be stored in some location where the temperature can be kept below 102°F. If possible, refueling should be done at night, because pouring the fuel under extreme heat into a heated tank will result in a considerable loss of fuel and a lowering of the octane rating. Unnecessary transfer of fuel from one container to another must also be avoided.

e. Discharge of static electricity. Static electricity is generated by an airplane in flight. If not eliminated prior to refueling, this charge may cause a spark that will ignite the fuel.

(1) HOSE GROUNDING. A metal-lined or otherwise bonded hose is provided to furnish a path through which a static charge may reach the ground. A length of flexible bonding wire and a clamp are permanently attached to the discharge nozzle as shown in figure 44. Whenever the fuel tank is to be filled, the free end of the bonding wire will always be clamped to a convenient uninsulated metallic part of the airplane. This will insure an electrical bond between the tank and the delivery hose. The bonding wire should not be attached next to the filler neck of the tank and it should always be attached to the aircraft before the fuel tank cap is removed. After refueling, the bond will be removed after the cap has been replaced. When possible, filling or draining of fuel tanks will be performed in the open.

(2) GROUNDING OF DE-ICER SHOES. To discharge static electricity properly from de-icer shoes, a wire brush, properly grounded, is passed carefully over the entire surface of the shoes (see fig. 45). Rubber is not a conductor of electricity and therefore the entire surface must be touched with the brush to remove completely the charge from the shoes.

(3) GROUNDING BODY. Since a static charge is also built up in the human body, and since clothes and shoes will act as insulators, the mechanic should, prior to refueling, drag his bare hand over the wing surface for a considerable distance before touching the filler cap. By following this procedure, he will discharge or ground the charge stored in his body, and prevent a spark jump as he reaches for the tank cap.

Figure 45. Grounding de-icer shoes.

f. Refueling with small containers. One of the most difficult maintenance problems in combat zones is the handling of fuel and servicing of the airplane's fuel tanks. The conditions under which this is done may often be most undesirable. The operation may be performed in the open, exposed to dirt and sandstorms, and under constant enemy interruption. Often it is not safe nor even possible to refuel from pits and trucks. In such cases, the fuel is stored in 50-gallon drums and refueling is done with 5-gallon cans (or any small container), a chamois to filter the liquid, and a funnel. The chamois is attached to the funnel by means of copper safety wire and the fuel is poured through the chamois. During the actual pouring of the fuel, the mechanic should make certain that the funnel is in constant contact with the filler neck and the container is resting on the chamois around the top of the funnel. (See fig. 46.)

Figure 46. Using a small container for refueling.

g. Other precautions. Precautions will always be taken to avoid spilling fuel. Smoking in the refueling area is strictly forbidden. Open flames and anything that might cause ignition of the fuel must be kept at least 100 feet from the refueling operation. This includes matches and cigarette lighters, which on occasion have fallen from a mechanic's pocket and ignited the fuel.

SECTION II

POWER PLANT INSPECTION AND MAINTENANCE

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12. SCOPE. a. General. The precision construction of modern airplanes requires that high and exacting standards of maintenance and inspection be set up for every part of the aircraft and its engine. Power plant inspection is that phase of aviation activity which pertains to maintenance necessary for satisfactory engine operation during the period between major overhauls. The performance of these inspections includes all activities essential for the prevention of engine failure. The general instructions given here are based on instructions found in Technical Orders. Applicable Technical Orders should be consulted for each type of airplane, engine, or unit of accessory equipment.

b. Purpose of engine inspection. Only by constant and conscientious inspection can the mechanic insure flight reliability of an aircraft engine. The primary purposes of inspection are to prevent failure of the engine while in operation and reduce to a minimum the necessity of removing the airplane from service due to minor troubles. An engine requires frequent adjustments and many minor repairs while in use. Systematic periodic inspections constitute the best method of detecting the need for adjustments and repairs. These periodic inspections simplify the work of the ground crews by arranging their duties into a regular routine. All material and equipment used by the Amy Air Forces is put through experimental test runs to determine approximately how long they may operate before mechanical service or attention will normally be needed. The operating time betwen inspections is based on these tests, and the inspection of a particular part or parts is set to be accomplished before the critical point is reached. The responsibility for keeping the engine airworthy at all times lies directly with the maintenance personnel. Complete and accurate data of all routine inspection, maintenance, servicing, changes, and replacements must, therefore, be kept by the crew chief. (See fig. 48.) These records must be kept up to date and must be available for inspection by supervisory personnel at all times.

Figure 47. Inspecting the engine.

Figure 48. Recording data on the Maintenance Inspection Record form.

c. Extent of inspection and maintenance. The inspection and maintenance requirements given here for the power plant are to be considered as minimum and general. In all cases, conditions permitting, the detailed procedures given in Technical Orders and the orders of local authority take precedence. First and second echelon maintenance is the function of all Army Air Forces units operating or maintaining aircraft. Normally, the work consists of cleaning and servicing aircraft and aircraft equipment, and of making periodic inspections, minor repairs, adjustments, and replacements. Most of the tools and equipment required to accomplish this work are transportable by air. It is difficult to place definite limits on the maintenance and repair operations that constitute the work performed by these echelons. During periods of emergency, each unit does everything it possibly can, leaving only what it cannot do to be accomplished by the next higher echelon. In this way, the burden on higher echelons is lessened. In some cases, the duties of the first and second echelons may be determined by the length of time required to perform the operation, and by the initiative, ability, and aggressiveness of the maintenance personnel. The power plant inspection periods are as follows:

(1) Preflight inspection, which is accomplished prior to the first flight of the day.

(2) Daily inspection, which is performed once each calendar day, except on occasions as listed in paragraph 14.

(3) 25-hour inspection (accomplished between the 20th and 30th flying hours) which includes the preflight and daily inspections and is designed to be thorough and searching.

(4) 50-hour inspection (accomplished between the 40th and 60th flying hours) which includes the preflight, daily, and 25-hour inspections. It is accomplished during regular maintenance without withdrawing a plane from regular service.

(5) 100-hour, 200-hour, 300-hour, and subsequent inspections are performed concurrently with the applicable 50-hour inspections due.

(6) SPECIAL INSPECTIONS. Weekly inspections are performed at 7-day intervals regardless of flying time. A special inspection is performed 5 hours after engine change. Every 10 hours the supercharger and oil Cuno are inspected. The 25-hours-after-engine-change inspection will be performed between the 20th and 30th flying hours following engine change.

13. PREFLIGHT INSPECTION. a. General. Prior to the first flight of the day, a visual check of the airplane power plant will be made. Inspecting personnel will make the proper entries on W.D., A.C. Form No. 41B. If the daily inspection is performed before the first flight of the day, it should be accomplished in conjunction with the preflight inspection before the airplane is rolled to the flying line. This eliminates the necessity of performing two separate inspections. The preflight inspection is performed—

(1) Prior to the first flight each day, or at least once every 7 days, except on airplanes in "in storage" status, undergoing engine change, or in the engineering shops.

(2) On all transient aircraft, prior to departure from any station, whether or not a preflight inspection has been accomplished the same day at another station.

b. Purpose of preflight inspection. During the preflight inspection of the power plant, the mechanic determines that the engine, the engine accessories, and the engine controls are functioning properly; that all cowlings, fuel and oil tank caps, etc., are in place and properly safetied; that all accessible fuel strainers (including tank drains where drain cocks are provided) are drained and safetied; and that the engine installation is ready for flight operation.

c. Outline of procedure. The procedure for performing the preflight inspection will be listed in two parts: the inspection prior to starting the engine, and the engine operation check during engine warm-up. The instructions given in this paragraph are by no means complete, but are to be considered as minimum. The engine handbook and local authority should always be consulted for instructions concerning specific installations. The following items are listed as aids in conducting periodic inspections. Although they may not be universally applicable, additions and slight modifications will make them apply to all types of engines and engine equipment.

(1) Examine for security of installation and mounting.

(2) Check for proper safetying.

(3) Inspect the external portion of the unit for dents, cracks, bends, nicks, and damage to the protective coating.

(4) Check all lines, leads, and control rods, where applicable.

(5) Inspect tanks for fluid levels, where applicable.

(6) Check for operation, when necessary.

d. Preflight procedure before starting engine. (1) Perform all routine periodic inspections before rolling the airplane to the flying line.

(2) Become familiar with the operation and service instruction handbook for the particular installation; read TO 02–1–29 and all other pertinent Technical Orders.

(3) Examine all flight reports for completeness, and, if incomplete, make necessary additions.

(4) Check the quantity of fuel and oil in the tanks and enter the amounts on W.D., A.A.F. Form No. 1A. Tanks of oil-lubricated superchargers must also be checked for proper oil level.

(5) Be sure that fuel and oil tank caps are secure and properly safetied.

(6) Drain and resafety all accessible fuel tank drains and system strainers. To prevent airlocks in the fuel line, the fuel cock should be turned on and the drain cock tightened as fuel drips from the drain. This will eliminate the possibility of trapping air in the strainer. (See fig. 49.)

(7) Check all oil drain cocks and plugs for proper safetying.

(8) On liquid-cooled installations, check the coolant system for correct fluid and proper level and make certain the tank caps and drain plugs are properly safetied.

(9) Inspect all cowlings for proper installation and safetying.

(10) See that the hand crank is in its proper place. (See fig. 50.)

(11) Check the fuel pressure gauge for correct zero setting ±0.3 pounds per square inch. The oil pressure gauge has a maximum allowable tolerance at zero of ±5 pounds per square inch. Mechanically driven tachometers should be checked for zero setting ±15 rpm; the tolerance for electrically driven tachometers is ±30 rpm.

(12) Check manifold pressure gauge against station barometer.

(13) Check thermometer gauges against station thermometer.

(14) Wind and set the clock. (Get correct time from operations tower.)

(15) Check operation of fuel pressure warning light by placing the switch in ON position and operating the wobble pump.

(16) Inspect all engine instruments for security, broken cover glasses, correct pointer positions, and other visible defects.

(17) Check the throttle, mixture, propeller governor, oil and coolant temperature regulator, carburetor air heater, supercharger, and cowling flap controls for proper range of operation.

(18) Before starting an engine which has not been operated within the past 2 hours, pull the propeller through at least four or five revolutions in the direction of rotation. This should be done before using the starter in order to check for accumulation of liquid in the combustion chambers.

(19) Set the propeller control for engine starting.

(20) See that other maintenance personnel are familiar with ground operation of aircraft engines.

e. Preflight inspection after starting and during engine warm-up. After starting the engine the following observations and operation checks should be made:

(1) OIL PRESSURE. Check the oil pressure gauge reading. If there is no indication of pressure within 30 seconds, stop the engine immediately. If conditions are satisfactory, the engine rpm should not exceed one-half of the maximum permissible ground speed until the engine maintains (without fluctuation) at least two-thirds of the minimum full power oil pressure specified, and the oil temperature shows a definite increase, indicating proper circulation of oil.

Figure 49. Draining the main-line strainer.

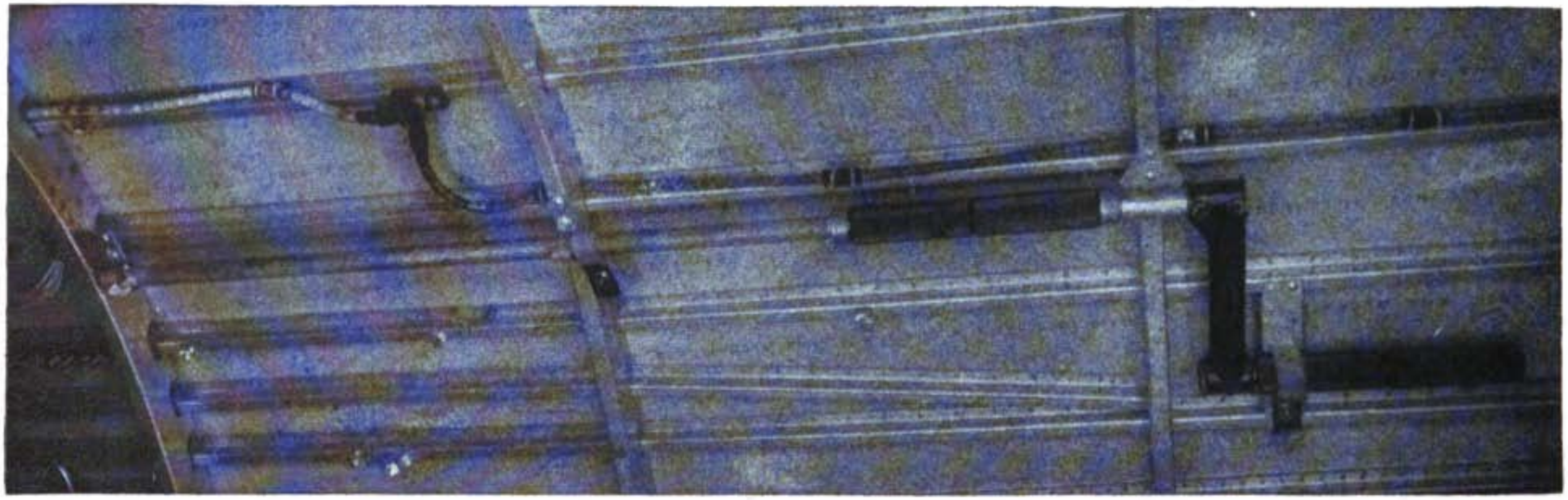

Figure 50. Starter hand crank in proper place.

(2) INSTRUMENTS. Check all instruments for readings consistent with engine requirements and for excessive pointer oscillation and vibration.

(3) MANIFOLD PRESSURE GAUGE LINE. Open the manifold pressure gauge vent cock and allow it to remain open a few seconds.

(4) PROPELLER. Adjust the propeller to the proper position for engine warm-up and watch for excessive vibration.

(5) AMMETERS. With the generator main-line switch off, check the pointer for zero. Place the generator main-line switch in the ON position, and check for normal charge and excessive fluctuation.

(6) VOLTMETERS. Operate engine at a manifold pressure which does not exceed maximum cruising manifold pressure. With generator main-line switch off, note the reading. The pointer should show a voltage between 14.2 and 14.3 for a 12-volt system and between 27.9 and 28.1 for a 24-volt installation. Set the main-line switch in the ON position, and determine the voltage at which the current cut-out relay closes the circuit between the battery and generator by slowly opening and closing the throttle and observing the voltmeter. The current cut-out points should close at 13.5 volts in a 12-volt system and 27 volts in a 24-volt system. Closing of the circuit will be indicated by a slight "drop-back" of the voltmeter pointer.

(7) MAGNETOS. Operate the engine at a manifold pressure which does not exceed maximum cruising manifold pressure. If no manifold pressure gauge is used, the throttle movement should not exceed 85 percent of the travel between closed throttle and the throttle stop. An installation which does not have a manifold pressure gauge or throttle stop will be checked with the throttle set to give an engine speed which does not exceed 85 percent of the full throttle rpm. If a controllable-pitch propeller is used, it should be in LOW PITCH position. Check each magneto for proper operation, and note the loss in rpm when switching from the BOTH position.

(8) TURBO-SUPERCHARGERS. Place the waste gate control in AUTOMATIC position. While operating at maximum allowable ground rpm, check the operation of the supercharger waste gate. The manifold pressure should be held within specified limits.

(9) TWO-SPEED SUPERCHARGERS. To check the supercharger drive, set the engine speed at 1,500 rpm (propeller in HIGH RPM position), move the supercharger control lever to HIGH position, and lock. Open the throttle to obtain not over 30 inches Hg manifold pressure. When the engine speed has stabilized, observe the manifold pressure, and shift the supercharger control to the LOW position without moving the throttle. (At least 3 minutes should elapse between shifts. This will allow the clutches to cool.) A sudden decrease in manifold pressure is an indication that the two-speed supercharger drive is oper-

ating properly. If no decrease occurs, the clutch may be "frozen" in the high-ratio position.

NOTE. Consult operation and flight instructions of specific engines for further details and additional instructions.

(10) IGNITION SWITCH. While operating the engine at approximately 700 rpm, check the ignition switch to insure that the ground wires are properly connected. The switch should be turned to the OFF position momentarily (to determine whether the engine or engines stop firing), and immediately returned to the ON or BOTH position.

14. ENGINE DAILY INSPECTION. **a.** If practical, the daily inspection should be made either at the end of a day's flying, or in conjunction with the preflight check the next day. It is not performed if flights have not been made since the last daily inspection, or if the airplane is in storage, undergoing repairs, or is stationed where there are no enlisted or civilian mechanics. This inspection is not designed to be sufficiently thorough and searching to detect slight wear and early stages of deterioration, but includes only a visual check of the engine's general condition to detect damage or any maladjustment that might interfere with flight reliability.

b. The daily inspection consists of checking the following:

(1) IGNITION AND ELECTRICAL SYSTEM. Ignition and electrical systems require very little inspection because of their high dependability. A daily check for oil leaks around the starter and generator is required. Leakage around the generator may mean that the oil seal is defective and if so the unit must be replaced. Oil seepage in the starter, if not excessive, may be remedied by drilling a $\frac{3}{16}$-inch hole at the lowest point of the starter housing to provide drainage. Because a great amount of twist and torsion occurs in a starter, it is necessary to check it for security of mounting, for cracks and defects, and the housing bolts for tightness. On the hand inertia type starter, the hand-cranking extension brackets and supports are inspected.

(2) COWLING AND FAIRING. All cowling and fairing must be checked for general condition, security of attachment, dents, and bends. (See fig. 51.)

(3) CARBURETOR AND MANIFOLD AIR HEATERS. Inspect the manifold and carburetor air heater for blown gaskets and security of mounting.

(4) TURBO-SUPERCHARGERS AND REGULATORS. Turbo-supercharger and regulator units must be completely checked for security of mounting, proper clearances, excessive play, cracks, lubrication, and general condition of the complete system. An operation check of the controls must also be made. Such thoroughness is necessary because of

the high operational speeds and high temperature conditions under which the unit operates.

.(5) COOLING SYSTEM. Air-cooled power plants are checked daily for any rubbing of the cowling against the cylinder fins. Check for

Figure 51. Checking the engine cowling for security.

broken fins which may interfere with proper cooling. (See fig. 52.) Cylinders having an excessixe number of broken fins must be replaced. An operation check of the cowl flaps should be made. The plumbing system of liquid-cooled engines must be inspected for leaks, proper safetying, and general condition. If shutters are provided for the coolant radiator, they must be checked for proper operation.

(6) ENGINE CONTROLS. Engine controls are examined throughout the control linkage for creeping, lost motion, general condition, and proper safetying. A check is made for full working range both in the cockpit and at the engine. Figure 53 illustrates the proper position of the

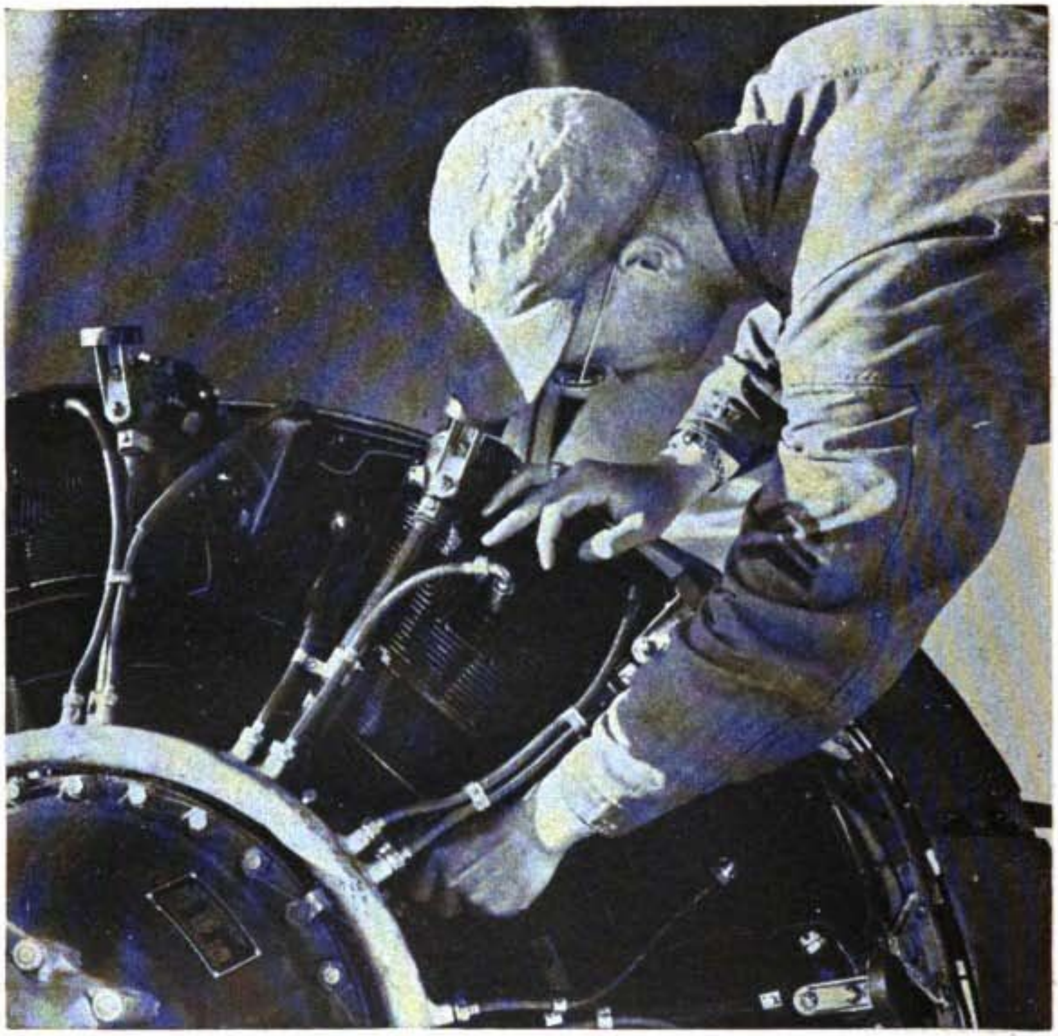

Figure 52. Inspecting cylinder fins.

carburetor mixture control when the cockpit lever is placed in the FULL RICH position.

(7) LUBRICATION SYSTEM. Oil system inspections should be made to detect any excess amount of oil that may appear around the engine. Determine the cause, as this may be an indication of damage. All drain plugs should be checked for proper safetying. During cold weather operation, check the blanketing of the cooler.

(8) FUEL SYSTEM. Turn the fuel valve to the ON position and check the complete system for leaks and general condition. Rotate the fuel cock handle one complete revolution to check for binding. Inspect the safety wiring on the carburetor and fuel injectors (when used).

(9) PROPELLERS. The propeller is inspected for security of mounting. The hub retaining nut must be tight. Not only may looseness cause scoring or galling of the rear cone, but vibration caused by looseness may damage the crankshaft and other parts of the engine. A check for proper safetying of all bolts, nuts, pins, and screws must be made. Inspect the blades and hubs for cracks, nicks, bends, and other damage. All defects should be corrected before engine operation. Check hydraulically operated propellers for oil leakage. Controllable propellers (except the hydromatic) are checked for grease leakage. At the end of each day's flying, all metal propellers will be wiped off and coated with thin films of engine oil to prevent corrosion. (See fig. 54.)

Figure 53. Mixture control in FULL RICH position (at the carburetor).

(10) ENGINE INSTRUMENTS. Engine instruments are inspected for looseness of mounting, cracked glass, and proper marking of the gauges. The pointer error must be within the maximum allowable limits. Lighting systems provided for any individual instrument or panel must be examined for proper operation.

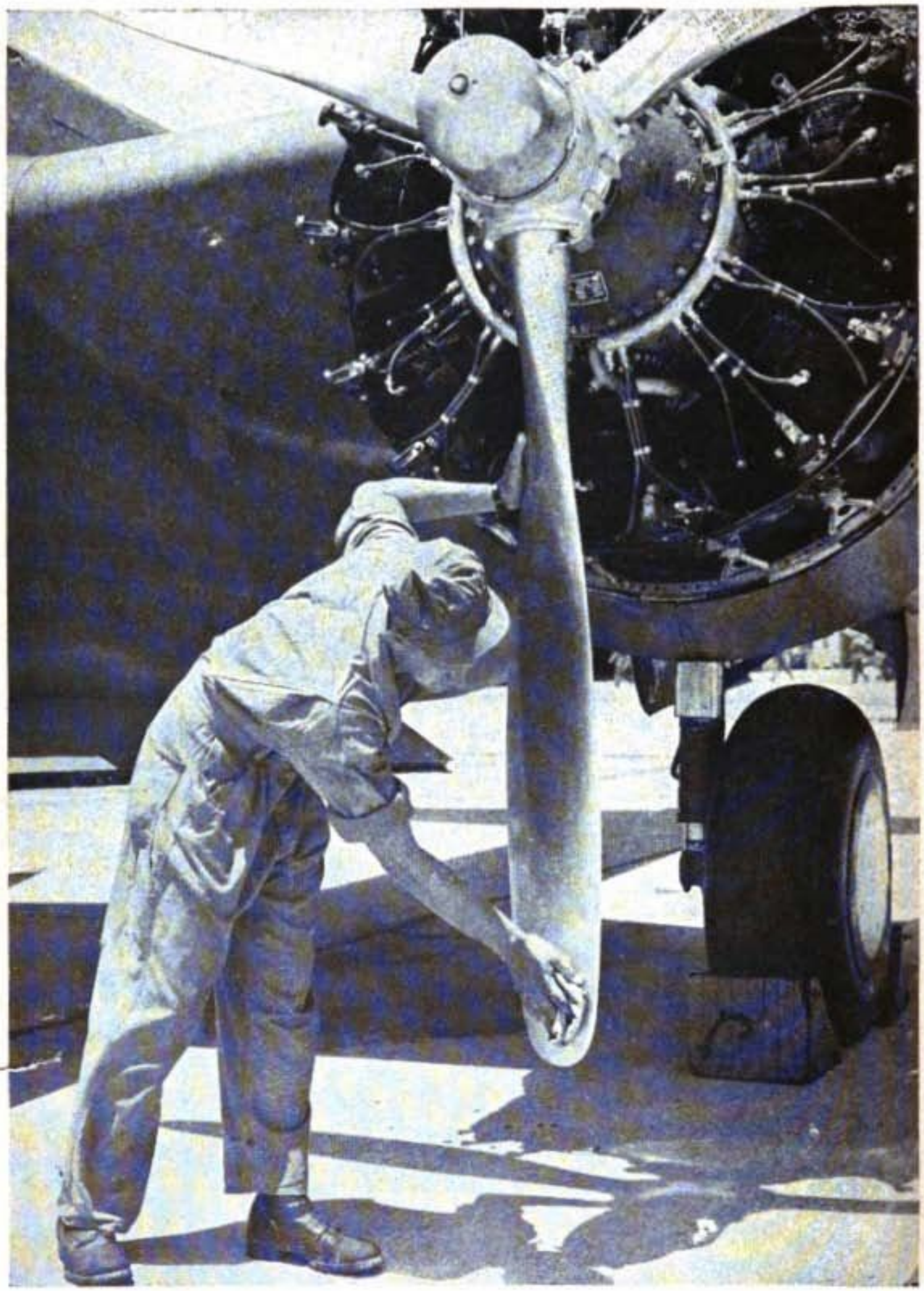

Figure 54. Coating the propeller with engine oil.

(11) AIRCRAFT BATTERIES. Check the specific gravity of each cell by taking a daily hydrometer reading. Hold the hydrometer in a vertical position if the location of the battery permits. In locations where the vertical position cannot be maintained, draw in a satisfactory amount of electrolyte, pinch the hose near the end, hold the hydrometer in a

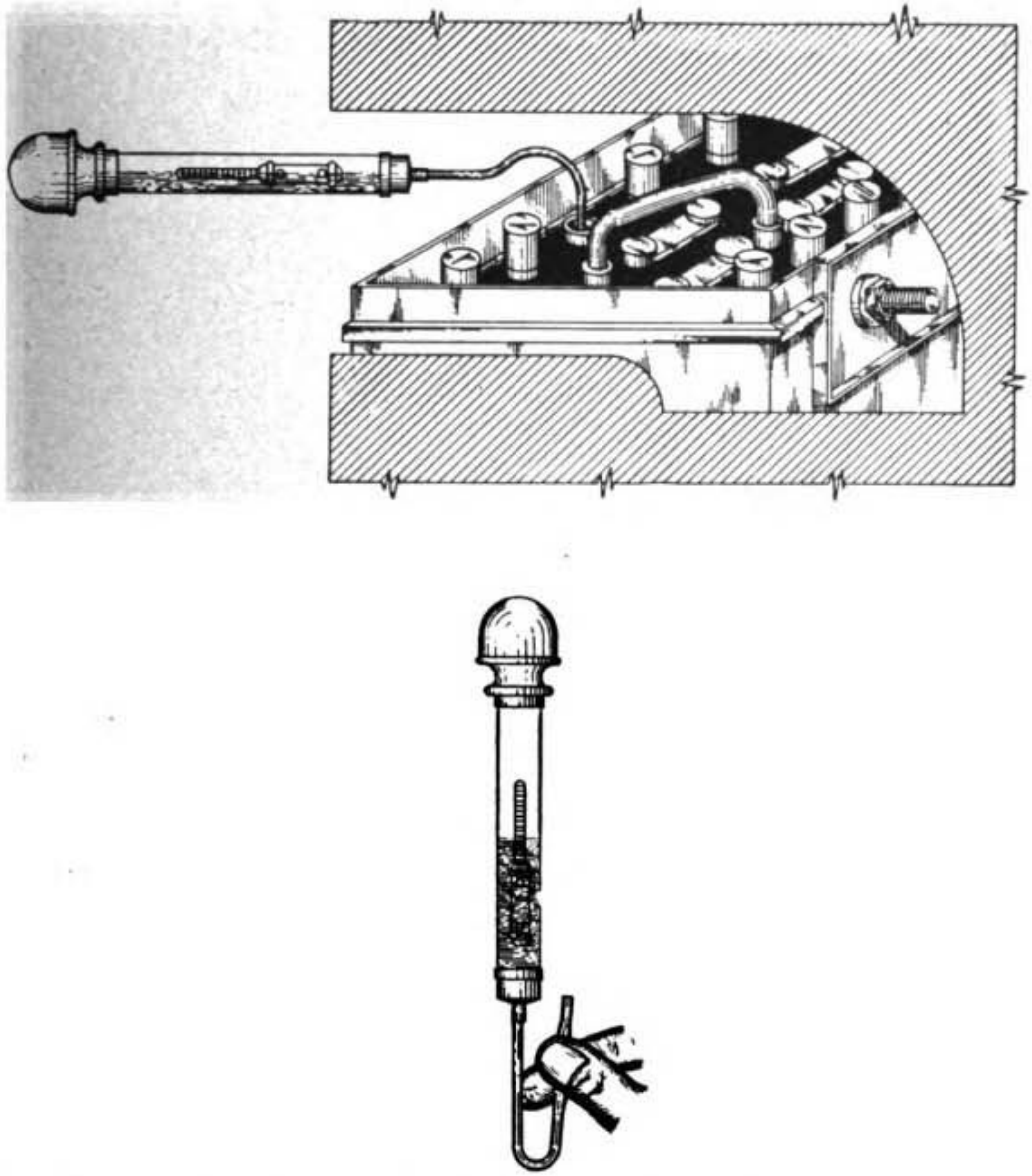

Figure 55. Checking the specific gravity when it is difficult to reach the battery.

vertical position so that the float is free, and obtain the specific gravity reading. (See fig. 55.) Be certain that too much electrolyte is not drawn into the hydrometer. This will permit the float to touch the rubber stop at the top of the glass and indicate an incorrect reading. After checking the reading, return the electrolyte to the cell from which it was obtained. Make the necessary correction for temperature. Consult the Technical Order titled *Aircraft Storage Batteries* for this procedure. Replace the battery as soon as practicable when the specific gravity is found below

1.240 or above 1.310. Add only distilled water when needed and the water added must not rise above ⅜ inch over the plates. If the battery is exposed to temperatures below freezing, do not add water unless the battery will be charged immediately after the addition. If this procedure is not followed, the water will not become thoroughly mixed with the electrolyte, but will remain on the top and freeze. (See cold weather operation, par. 6h(16).)

15. 25-HOUR INSPECTION. The 25-hour inspection, which includes the daily inspection, is designed to be thorough and searching. All parts are inspected to make certain that they are in good condition, that they function properly, and that routine maintenance operations have been performed. This inspection is accomplished during normal working hours, and without withdrawing the airplane from regular service. A period of 10 hours (between the 20th and 30th flying hours) is allotted to permit the accomplishment of this inspection. In addition to the daily inspections, the following checks are made every 25 hours:

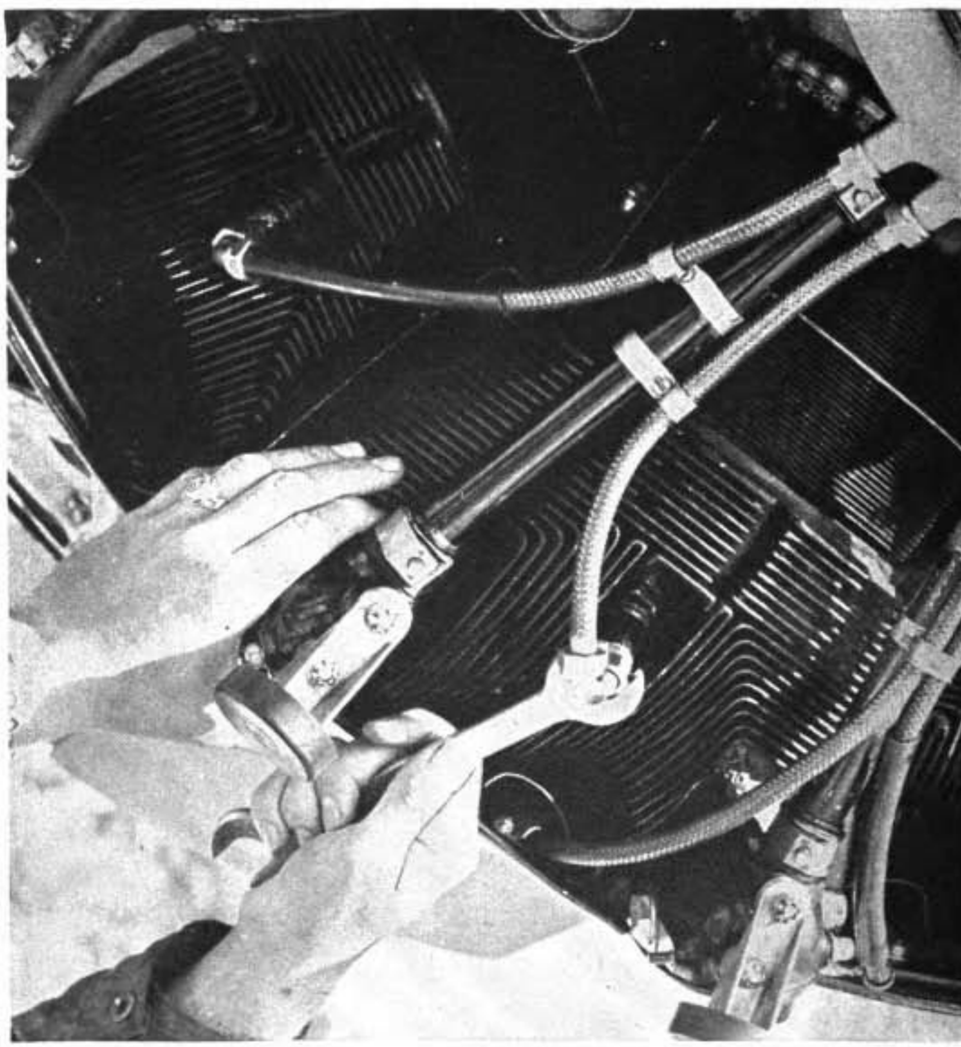

Figure 56. Tightening loose spark plug connection.

a. Ignition and electrical system. The terminal connections of unshielded plugs and the elbow terminals and shielding nuts of shielded plugs are examined for proper tightness. (See fig. 56.) Care must be exercised to tighten only to a snug fit. The barrels of shielded plugs are checked for looseness. If found to be loose, they are tightened with a special wrench. On airplanes that operate at high altitudes, the spark plugs are removed and examined for burned electrodes. The gap clearances should also be checked and reset. (See fig. 57.)

Figure 57. Checking spark plug gap clearance.

b. Engine general. A general inspection of the liquid-cooled engine includes a check of the cylinder hold-down and coolant-jacket stud nuts for tightness. This is required on some installations only at the inspection after the first 5 hours' flying time following engine overhaul.

c. Cooling systems. The inspections of the liquid- and air-cooled systems are as follows:

(1) On liquid-cooled engines the cowl flaps or shutter assemblies and controls are lubricated according to the instructions given in the individual handbooks. Inspect the drain holes (at the parting surface of the crankcase) that drain off any coolant that leaks past the cylinder liner coolant seals. Inspect all lines for proper identification markings, anchorage, and wear. Cooling systems filled with ethylene glycol are marked with a white band on each side of a black band. Systems containing water are marked with a single white band. Coolant pumps are examined for leakage; if a packing adjustment screw is tightened to the last thread, a new pellet coated with oil will be installed. Some models of liquid-cooled engines incorporate a spring-loaded type packing which will not require manual tightening. If leakage is excessive, do not attempt to replace the packing or any part of the pump. Replace the entire pump as a unit.

Where a fitting is provided, the pump shaft bearing is lubricated. Radiators, expansion tanks, lines, and other connections are inspected for leaks. Hose clamps are examined for condition and safetying. All drain cocks must be secure and properly safetied.

(2) Cylinder fins of an air-cooled engine are vital to proper operating temperatures. Damaged fins therefore constitute a serious hazard. Check the cowl flaps and ring cowls for general condition and for proper operation and adjustment. Magneto and other cooling tubes are inspected for cleanliness, breaks, cracks, and security of attachment.

d. Engine controls. Examine the control assemblies, including all rods, cables, linkage supporting brackets, guides, pulleys, etc., for free and full movement, lost motion, creeping, bent rods, frayed cables, loose or missing bolts, and proper safetying. Make any necessary adjustments. All moving connections will be cleaned and lubricated with the proper oil. Sealed bearings will not be lubricated or washed out. The throttle shaft and bearings are oiled with a light grade of lubricating oil.

e. Oil systems. Inspect oil lines for dents, leaks, wear due to chafing, and condition of connections. All connections must be examined

Figure 58. Coating a Cuno with engine oil before replacement.

for security, proper location, and safetying of clamps. All oil lines will be properly identified with single bands of yellow. Examine the oil cooler for clogged core, dents, leaks, security of mounting, and proper operation of the shutters. Remove and clean the oil, screens, and oil Cuno (manual and automatic types). The Cuno unit must be washed in gasoline, inspected, and coated with clean engine oil before it is reinstalled. (See fig. 58.)

f. Fuel system. Turn the fuel selector valve to the ON position, build up fuel pressure with the hand pump or booster pump, and check the entire system for leaks, cracks, security of lines and fittings, and wear at the mounting points. The lines should be marked with single red bands. Place the proper size drill in the vent opening of the relief valve to check for a restriction. Inspect the fuel pump for security of mounting. Examine all fuel drains and overflow lines for security, breaks, and stoppage. Remove and clean all removable strainers. (See fig. 59.)

g. Carburetors. Aircraft carburetors must be inspected for fuel leakage at the parting surfaces and at fuel line connections. Drain the float and strainer chamber and flush the carburetor with clean gasoline. Lubricate the throttle, shaft bearings, exposed economizer, and operating parts of the accelerating pump with machine-gun oil.

h. Propellers. The counterweight bearings of both the Hamilton Standard two-position and constant-speed propellers must be lubricated with high melting point grease. The exposed portion of the pistons will be cleaned, and then lubricated with clean engine oil.

i. Aircraft batteries. Batteries are inspected at the 25-hour or at 7-day intervals, whichever comes first. Most battery installations are easily accessible and adequately protected from fuel, oil, and exposure. The surfaces adjacent to the battery boxes are usually protected by a coating of acidproof paint. In cases where the battery is completely inclosed, suitable vents are provided. Provisions are also incorporated to keep spilled liquid from coming in contact with the airplane proper.

(1) Inspect the battery drain sump (on installation so equipped). Remove the cover and inspect the felt pad. If it is covered with a flaky deposit, it should be removed, washed in clear water, saturated with bicarbonate of soda solution, and reinstalled. If the sump body is corroded, it should be cleaned and then painted with acidproof paint.

(2) Check for leakage of acid due to a cracked case or defective sealing compound. If leakage is found, the battery will be removed, the container repainted with acidproof paint, and a new battery installed. Connect terminals as shown in figure 60.

(3) The specific gravity of the electrolyte in each cell must be checked with a hydrometer. (See par. 14b(11).) Figure 61 illustrates the correct position of the hydrometer when this operation is performed.

Figure 59. Removing main-line strainer for cleaning.

(4) Terminals must be checked for security. Corrosion may be removed with a solution of baking soda or diluted ammonia; a light coat of vaseline should then be applied to any terminals which are exposed to battery gases. The condition of the leads should be carefully noted.

(5) The general condition of the battery container (its security of mounting and cleanliness) and the vent system must be examined at this period.

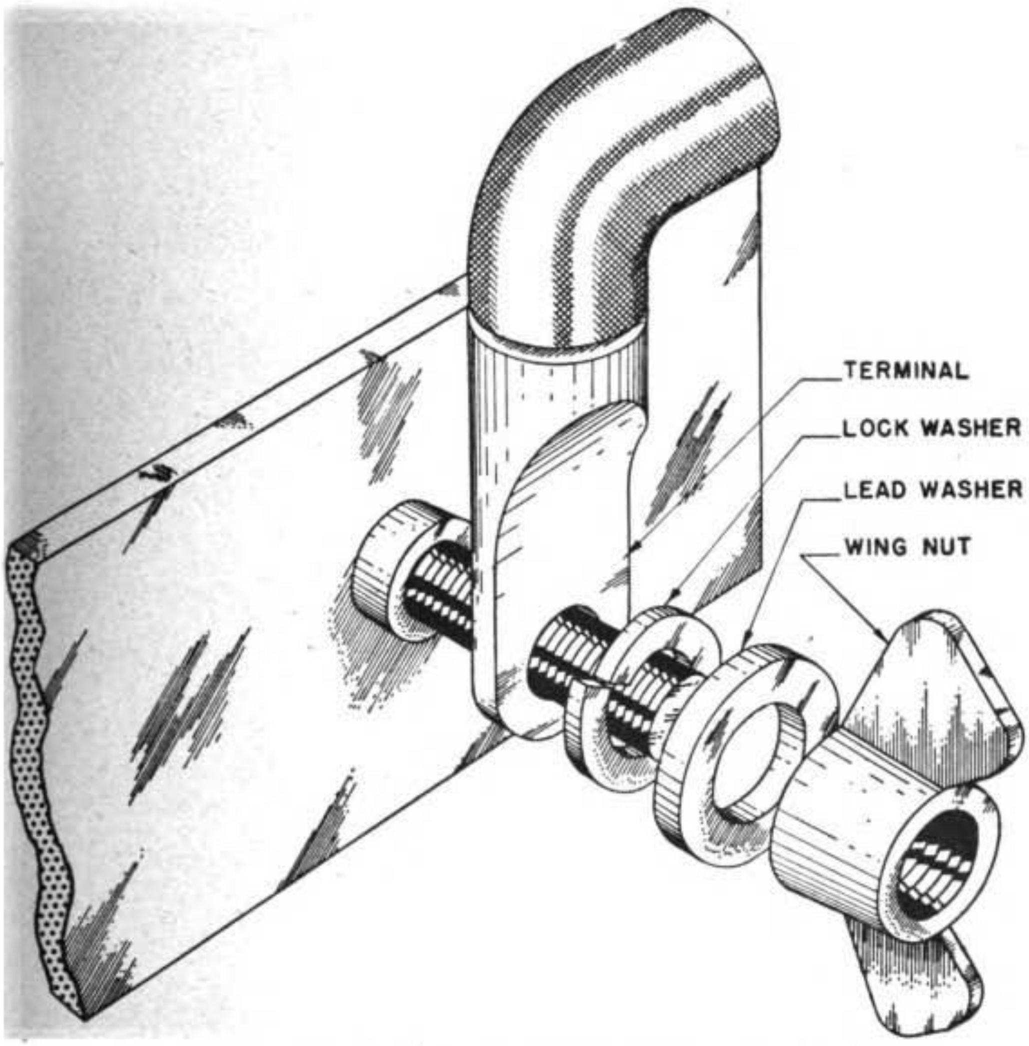

Figure 60. Proper method of connecting battery terminals.

(6) Check the mounting of the battery and tighten the hold-down clamps if they are found to be loose.

(7) When an airplane is to remain idle for more than a week, the battery is removed and returned to the battery shop for storage.

16. 50-HOUR INSPECTION. The 50-hour check is a very thorough, complete, and searching examination of the whole airplane. It includes all operations performed during the daily and 25-hour inspections. This inspection need not be made in one continuous operation. It may be accomplished any time between the 40th and 60th hours to avoid ground-

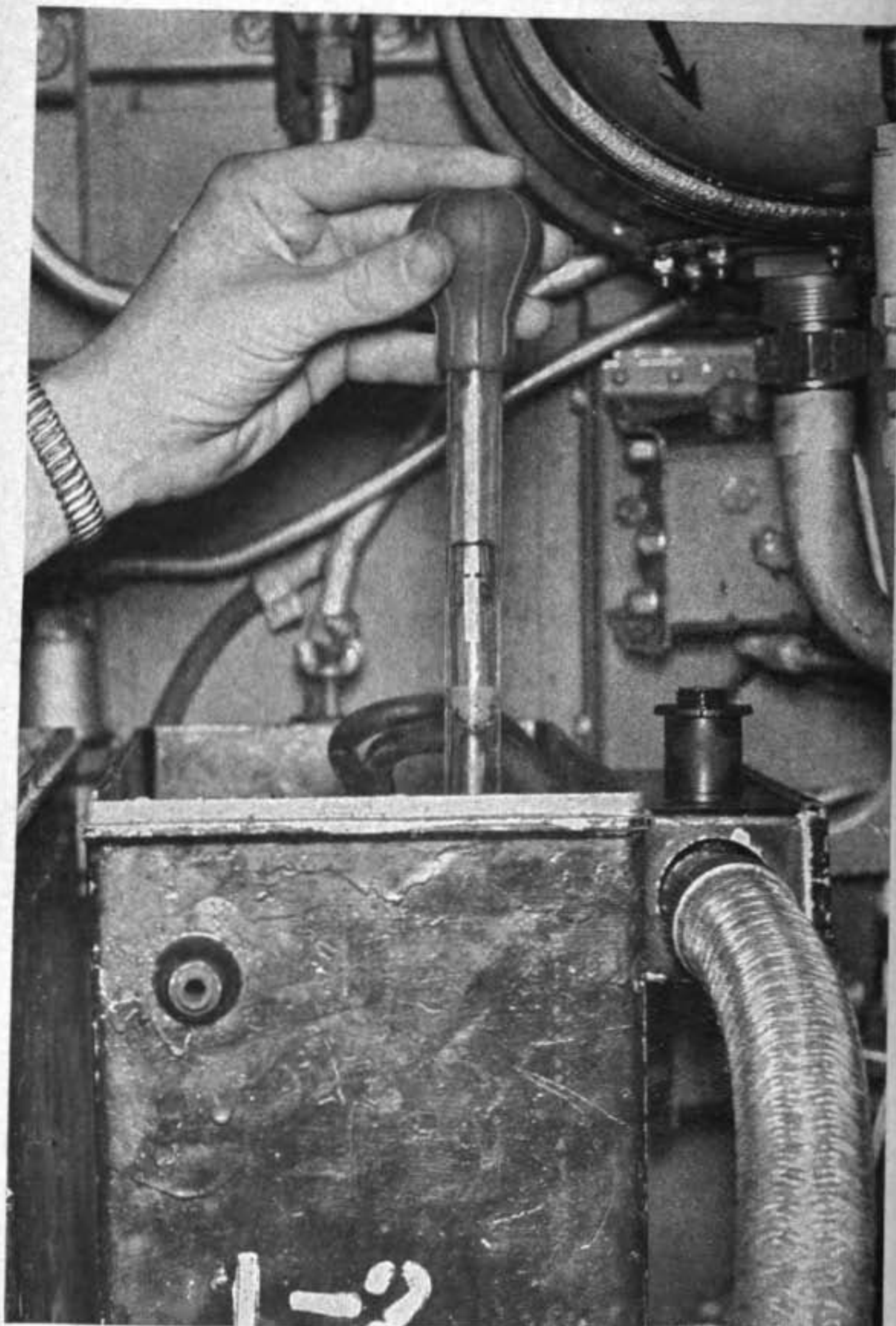

Figure 61. Checking specific gravity of electrolyte in a storage battery.

ing the airplane. The 50-hour power plant check includes the items which follow.

a. Magneto ignition system. In servicing the magneto ignition system the following operations are performed:

(1) MAGNETO. Remove the breaker cover, clean the breaker housing, and inspect the breaker mechanism for a damaged cam follower, damaged breaker felts or cushions, and a weak or broken breaker-arm spring. Use a scale for testing the breaker-arm spring. (See fig. 62.)

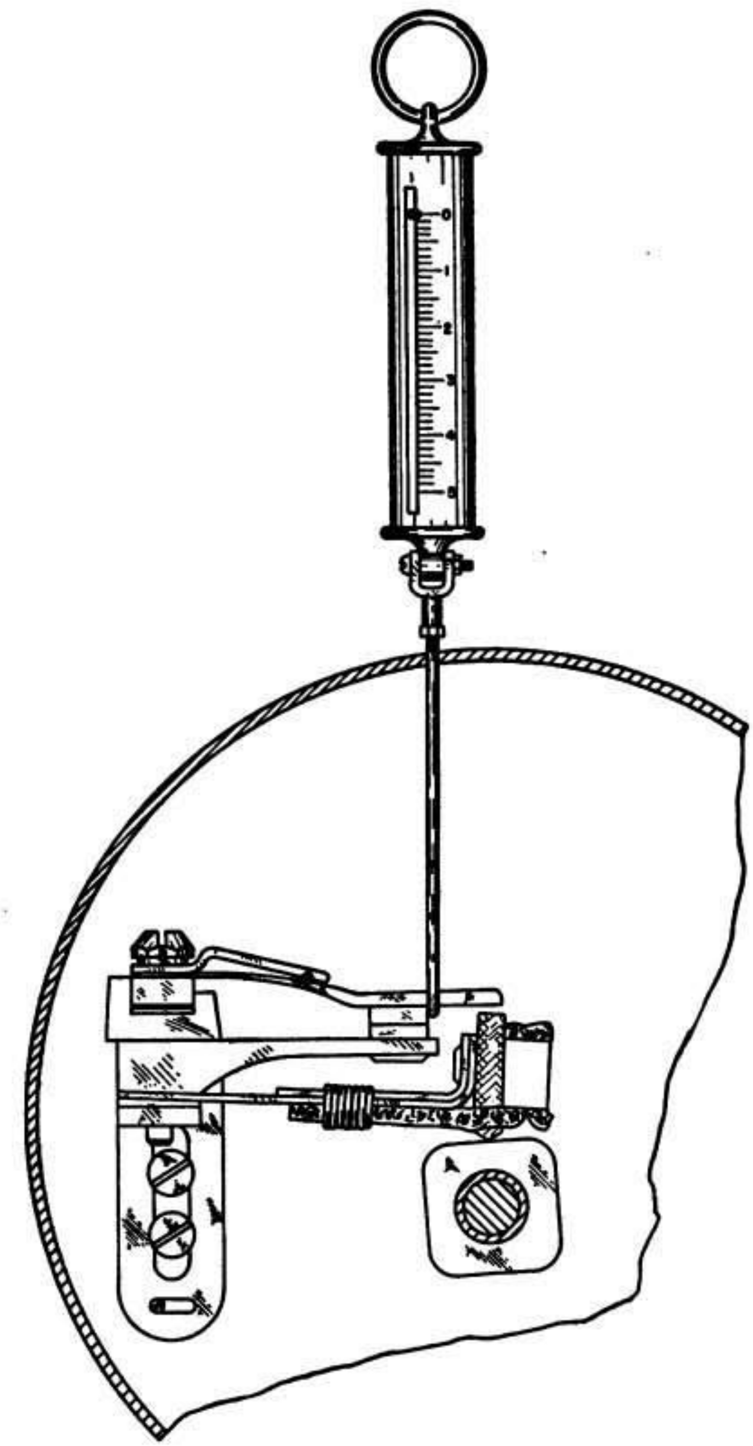

Figure 62. Testing the magneto breaker-arm spring for proper tension.

Check the felt on the cam follower for proper lubrication. If it is dry, it should be moistened with the specified grade of oil. Be certain that it is not lubricated excessively, because the excess oil will be thrown on the contact points and cause them to burn. On lever type breaker magnetos, in addition to the foregoing, lubricate the bearings if oil cups are provided. Bearings in magnetos not equipped with oil cups are packed with grease and need no lubrication between overhaul periods.

Figure 63. Oiling magneto by pressing oiler button.

In some magneto installations, an oiler is incorporated. Pressing the oiler button once during the 50-hour inspection will furnish the proper amount of cam lubricant. (See fig. 63.) This is done when the engine is not operating.

(2) LEVER TYPE BREAKER MECHANISM. On a lever type breaker mechanism check for proper breaker-stop clearance, worn or loose breaker-arm bushings or support pins, excessive lubrication, cleanliness, security of mounting, and proper clearance between the lever bushings and axle.

(3) PIVOTLESS TYPE BREAKER POINTS. Inspect and adjust the breaker points. Pivotless type breaker points must always be adjusted so that the contacts open at the proper position of the cam in relation to the timing marks on the rim of the breaker cup. These points do not have any fixed clearance.

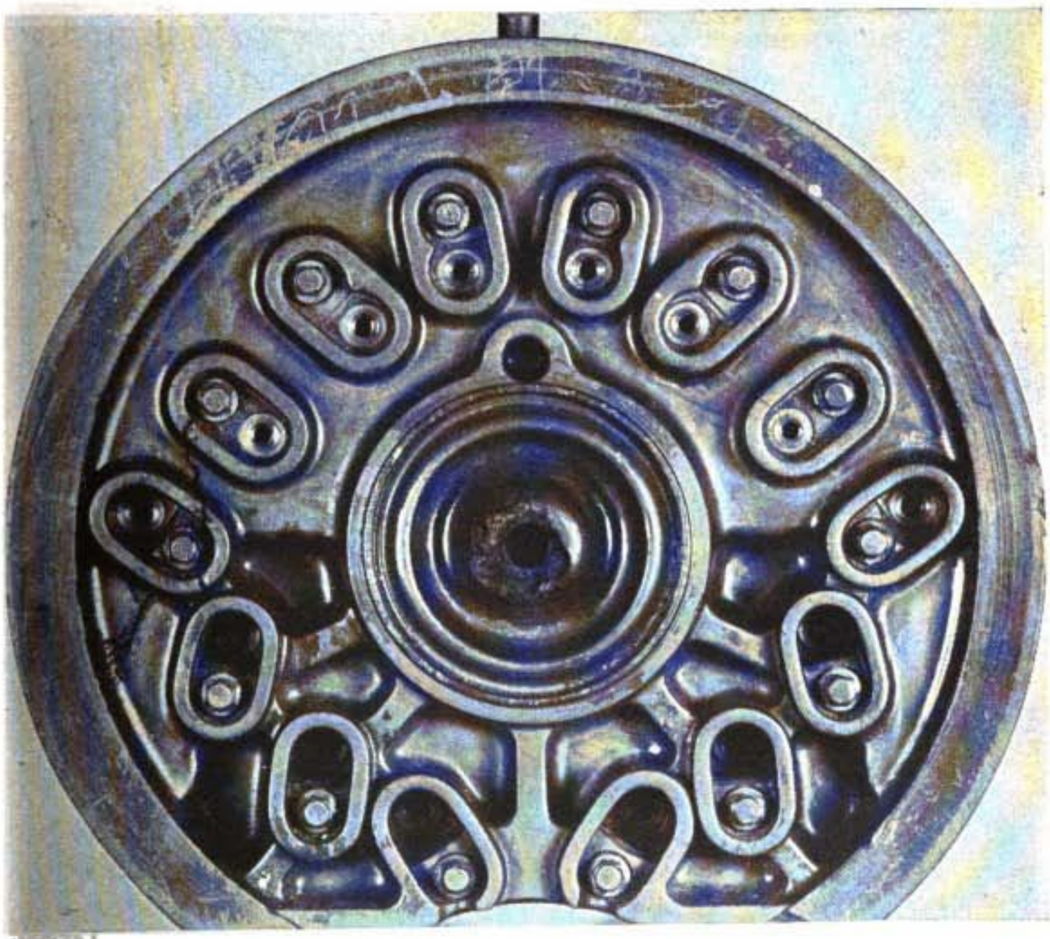

Figure 64. Cracked distributor.

(4) DISTRIBUTOR. Inspect the distributor for a cracked head (fig. 64) or rotor, sticking or broken brushes, signs of arcing, tightness of the mounting screws, and cleanliness. If one or more of the conditions mentioned are present, replace the head, brush, or rotor, or clean and tighten the parts as required.

(5) IGNITION CABLE. Examine the ignition cable for condition of connections and terminals, exposed ends, chafing due to vibration, and for deterioration due to heat.

(6) INDUCTION VIBRATOR (OR BOOSTER COIL PROVIDED ON OLDER PLANES). See that the induction vibrator (or ignition booster coil if plane is thus equipped) is securely mounted.

(7) IGNITION SWITCH. Check the ignition switches for security of mounting, condition, and proper connection of all electrical leads and terminals.

b. Generator and generator control panel. The condition of electrical equipment is of vital importance to the operation of the airplane. There is the ever present possibility that it may not function properly due to some apparently slight oversight; therefore, the mechanic must constantly maintain the electrical installation in perfect working condition.

(1) CONTROL PANEL. Inspect the generator control panel for security of mounting, general cleanliness, and proper safetying. Examine all leads, terminals, and contact points for condition and proper clearance. Check the condition of the vibration absorbing mount of the control panel.

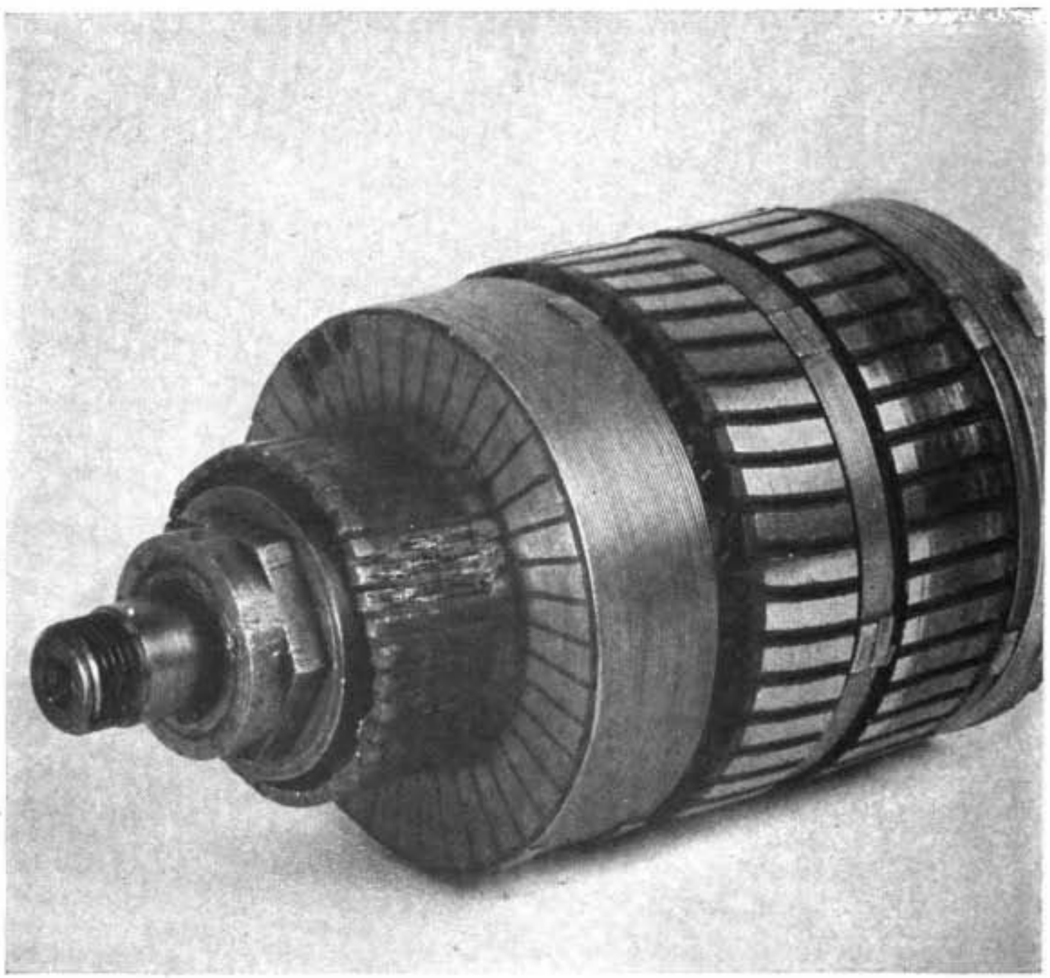

Figure 65. Burned, pitted, and out-of-round commutator.

(2) GENERATOR. Examine the generator for cleanliness and security of mounting. Check the generator commutator for rough, coated, pitted, worn, or eccentric surfaces. (See fig. 65.) Clean dirty or coated commutators with No. 000 sandpaper. Replace the generator if the commutator is found rough, pitted, or "out of round." An eccentric commutator may be detected by holding the pointed end of a pencil on top of the brush while the generator is operating. If the pencil vibrates excessively, replace the generator.

(3) BRUSH ASSEMBLY. Check the generator brush assembly for loose connections, worn or sticking brushes, and low spring tension. Replace brushes which are worn to less than the minimum allowable length. When a worn brush is replaced, the new brush must be properly seated by using No. 000 sandpaper, as shown in figure 66. Clean sticking brushes and holders with a gasoline-saturated rag.

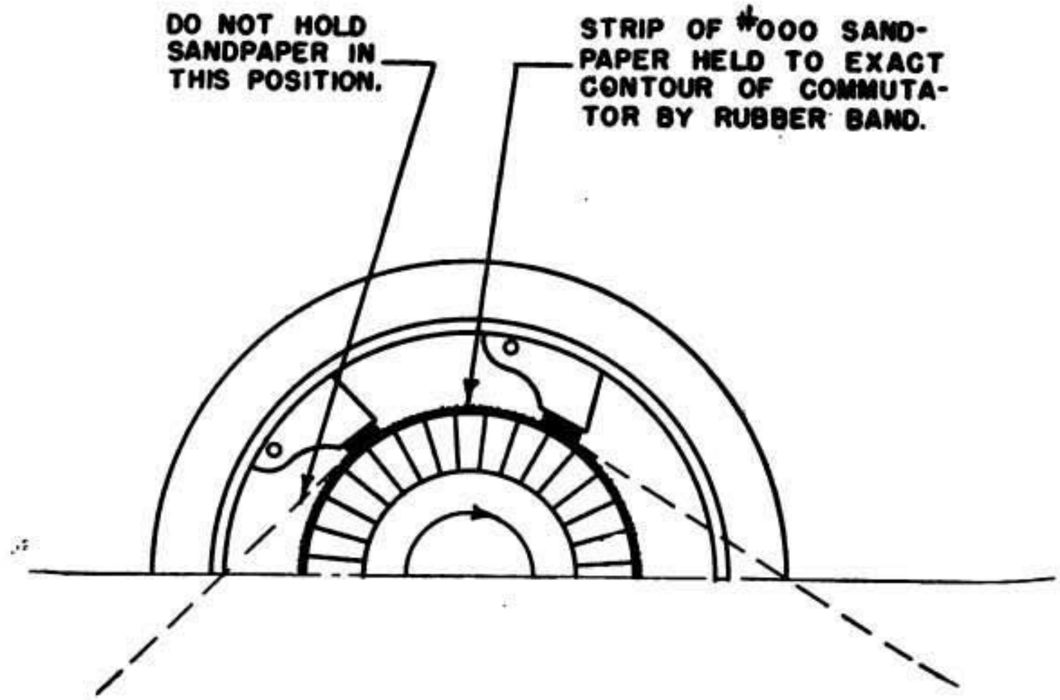

Figure 66. Correct method of seating generator brushes.

c. Starters, inertia, and direct cranking. The inspection of the mechanism of all starters (except the motors and switches of electrical starters) is the same.

(1) STARTER UNIT. Inspect the electric motor for a dirty or rough commutator. If the commutator is rough or badly burned, replace the motor. If it is dirty, clean it with No. 000 sandpaper and use compressed air to blow the dirt out of the housing. Check the condition of the brush holders and clean all binding brushes and brush holders with a gasoline-saturated cloth. Check the brushes to be sure that they are bearing properly on the commutator. Remove and replace worn brushes when the maximum permissible brush wear is exceeded. All new brushes must

be properly seated by using No. 000 sandpaper. Lubricate the hand crank system with the specified grade of engine oil.

(2) STARTER SOLENOIDS AND SWITCHES. Check all solenoids for security of mounting and condition of the leads. When adjusting the starter solenoids, first make certain that the starter jaw is completely retracted against the baffle plate; then with the oil seal and solenoid plunger in the outermost position (see fig. 67) adjust the cable so that

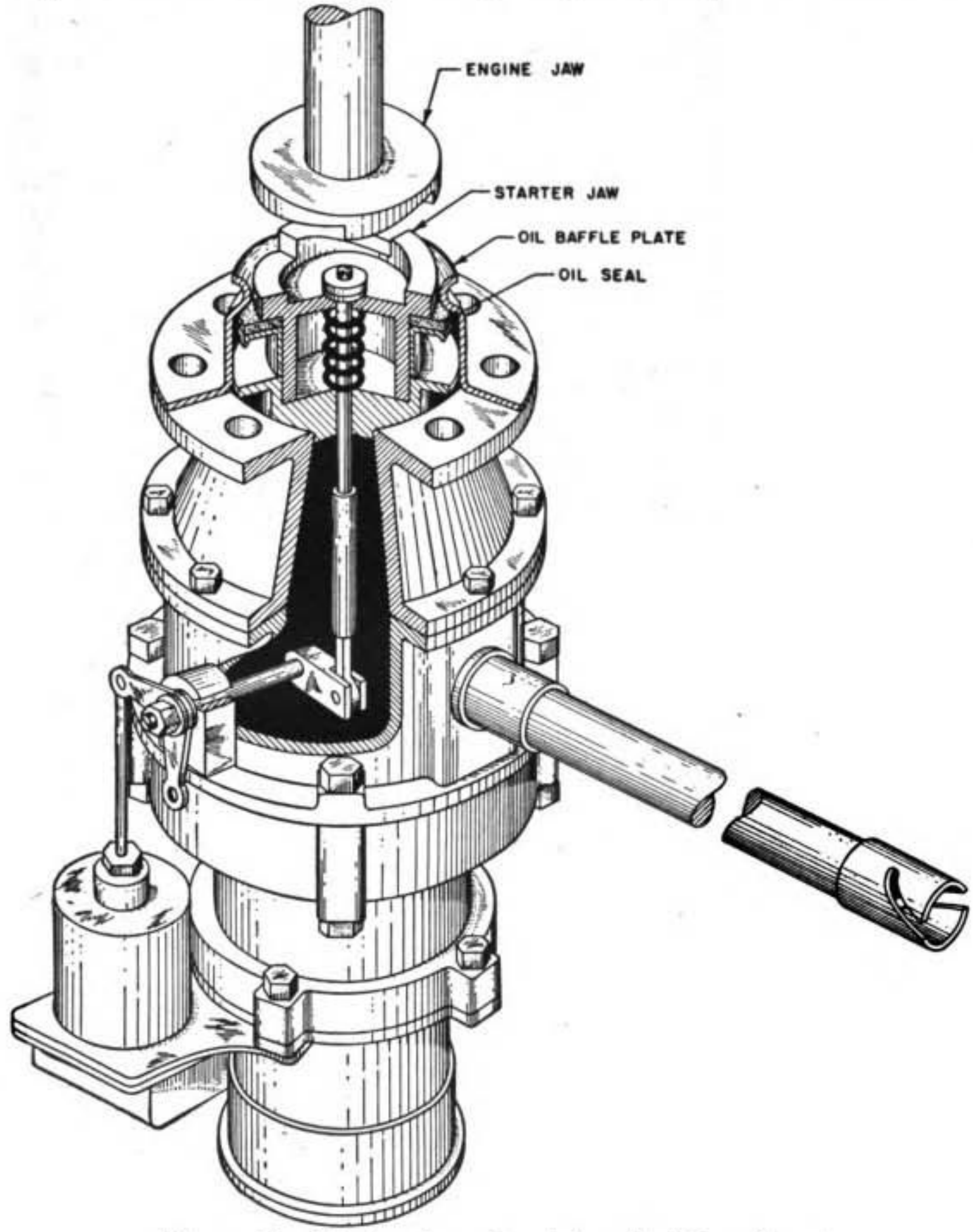

Figure 67. Starter jaw retracted against the oil seal.

it has 1/32 inch of free play. All defective switches and solenoids should be replaced.

d. Wiring systems. Connecting wiring and cables must be flexible and long enough to prevent undue pull on terminal connections of any electrical unit.

(1) WIRING. Inspect all wiring for proper anchorage and security of union nuts, bonding, shielding, and terminal box covers. Check to make certain that no leads are swinging in such a manner as to cause undue wear or fatigue.

(2) CONNECTIONS. Examine all connections, terminals, exposed ends, and contacts, including ground connections, for condition.

e. Engine general. (1) Engine installations have become so complex that the inspection of some parts of the power plant is very difficult. Many of these parts, however, may be examined with the aid of a flashlight or drop cord and a mirror.

(2) Inspect the engine for missing bolts, nuts, or studs, and for proper safetying. Examine all parts of the engine for cracks, broken parts, and oil leakage. On some installations, the ends of the crankshaft must be inspected for oil leakage. Where applicable, lubricate the center bearing of the extension shaft, making certain that the proper grade of grease is used.

f. Engine mounts. In earlier installations, engines were mounted as rigidly as possible. Since no elasticity was provided, severe stresses were transmitted throughout the entire airplane structure. The present day engine is mounted on rubber bushings. These are usually installed between the engine mount and the airplane, and between the engine mount and the engine. This type mounting is now standard. When elastic mountings are used, the engine must be held firmly enough to permit satisfactory attachment of the plumbing, the controls, and the cowling. The 50-hour check of the engine mount is accomplished as follows:

(1) Check the entire mounting frame for cracks (particularly at the welded joints) and for bent or broken structural members.

(2) Check the protective coating for proper condition.

(3) Check the mounting clamps and bolts for tightness.

(4) Closely examine the vibration absorbers for deterioration. If oil or grease is found on them, it should be removed with unleaded gasoline.

g. Valves and manifolds. Extreme care should be exercised in checking valves and manifolds. If the engine is operated when valve clearances are incorrect, rough running will be the result. The alignment of the stacks is important. If each section is not aligned with its mating section, strains and eventual cracking will result.

(1) VALVES. Inspect and adjust the valve mechanism, if called for by TO 02–1–7, as specified for each particular engine.

(2) MANIFOLDS. Exhaust gases contain poisonous carbon monoxide. The exhaust system prevents this gas from reaching the operator. Examine the exhaust system for blown gaskets, loose or broken studs, and damaged manifolds. Tap the outside of the exhaust collector ring with a wooden mallet to loosen any scale formation. Without removing the collector ring, brush out the inside of the ring with a wire brush.

h. Turbo-supercharger and regulator. Regular inspection of the supercharger will disclose small defects before they lead to serious engine trouble. Proper care of the supercharger will reduce the maintenance required between overhauls and lengthen the useful life of the engine.

(1) SUPERCHARGER. Check the structural and mechanical condition of the supercharger very carefully.

(2) PRESSURE REGULATOR. Inspect the regulator for oil leaks, security of mounting, and for proper attachment of the oil pressure and drain lines. The air pressure line from the engine induction system to the regulator must be checked for leakage. Draw off a small amount of oil and examine it. If the oil contains sediment, drain the system and flush the tank and lines before refilling with new oil. If the oil is clean, it may be used indefinitely.

i. Cooling system (liquid). (1) All cooling systems should give dependable and satisfactory service if the coolant is kept free from dirt and foreign matter and the engine operated within specified limits.

(2) Some types of liquid-cooled engines are drained and flushed at this period. If the coolant is ethylene glycol, it is strained and replaced in the system. Examine the ball check valve in the expansion tank and check it for freedom of movement. A specific gravity check of the coolant used in other types of liquid-cooled power plants is required. For specific instructions on ethylene glycol when used as an aircraft engine coolant, reference should be made to TO 24–25–1.

j. Cooling system (air). (1) Pressure-type baffles are now standard equipment on most air-cooled engines. Pressure baffling forces large quantities of cooling air through and around the fins. Excessive engine heat is thus efficiently dissipated.

(2) Inspect the entire control assembly of the engine cowl flaps, including all joints, for excessive wear and proper adjustment. Check for proper fastening and condition of the pressure baffles.

k. Engine controls. (1). The successful operation of the engine through the use of engine controls is absolutely dependent upon the attention given to every detail in inspection and maintenance of the linkage.

(2) Lubricate the firewall guides with grease as specified in Technical Orders.

l. Oil systems. Proper operation of an engine depends largely upon satisfactory lubrication. Only those oils specified by Technical Orders should be used. The utmost care should be taken to keep the oil, tanks, and lines free from any dirt and foreign materials.

(1) TANKS. Examine the tanks for security, freedom from leakage, condition of padding, proper tension of the support straps, and proper anchorage of all lines. Normally, aircraft engine lubricating-oil tanks (hopper and nonhopper types) will be drained only at engine change, except where some unusual circumstances such as dust conditions, failure

of minor engine parts, etc., make it advisable to change oil before that time. Wet sump engines (engines not equipped with a separate oil tank) will be drained after each approximate 25 hours of flight—immediately upon completion of flight while the oil is hot.

(2) OIL DILUTION VALVE. Examine the oil dilution control linkage for binding and check for proper closing of the valve.

(3) SCREENS AND CUNOS. All screens and filters will be removed and cleaned. Each screen is inspected for breaks and tears.

(4) PRESSURE-WARNING SIGNAL. When a pressure-warning signal is installed, examine all connections for tightness and leaks. Check the security of mounting of the unit and the condition of the electrical wiring.

m. Fuel systems. Satisfactory operation of any airplane engine is dependent upon the proper functioning of its accessories, particularly its fuel system.

(1) SELECTOR VALVE. Check the fuel-selector valve-control linkage for excessive backlash and drag. The taper pins in the linkage must be examined for looseness and proper safetying. Fuel cocks having a friction release and a short control rod assembly with one universal joint may not have more than 15° of free movement. On longer control rod assemblies having more than one universal joint, a free movement of 30° is permitted. The maximum permissible free movement on any other type is 10°.

(2) FUEL PUMPS. When remotely driven fuel pumps are installed, the flexible drive will be lubricated with the proper grade of grease.

n. Carburetors. (1) The proper functioning of the engine is dependent upon the efficient operation of the carburetor. Without a constant and sufficient supply of fuel, no engine can give its best performance.

(2) BENDIX STROMBERG CARBURETOR. Drain the air, fuel, regulator, and control unit chambers of the Bendix Stromberg injection type carburetor to remove any accumulation of sludge. Lubricate the latch mechanism of the mixture control unit with the proper grade of grease.

o. Fuel tanks. Because many fuel tanks are manufactured from rubber or synthetic materials, certain fuel compounds may cause deterioration of the inner tank walls. Careful, close, and frequent inspection of the tanks for deterioration is therefore required.

(1) ALL TANKS. Inspect the fuel tanks for security, leakage, condition of the padding, tension on the supporting straps, and the condition of the gaskets.

(2) DROPPABLE TANKS. Examine the mounting brackets of the droppable fuel tanks carefully. Inspect the release mechanism of the tanks for condition and operation. Check the alignment of pulleys, cables, and other moving parts.

(3) CONNECTIONS AND LINES. Remove the fuel access doors of the self-sealing tanks and inspect for leakage at all fittings and fuel duct connections. Inspect all fuel lines for proper anchorage near the cells.

(4) CAPACITY CHECK. Drain the fuel cells and refill to check the existing capacity of each cell. If it is less than 95 percent of the original capacity, remove the cell and check for defects and swollen places in the lining. All repairs to self-sealing cells should be made as soon as possible to prevent further swelling of the lining.

p. Propellers and governors. Any propeller unit should render dependable service for a long period of time without disassembly if it is correctly adjusted, properly operated, and kept clean.

(1) HAMILTON STANDARD TWO-POSITION PROPELLER. Examine the exterior of the propeller for cracks and other defects; use a magnifying glass and perform local etching if necessary. Inspect all markings and antiglare coatings for deterioration. Check the control linkage for security of mounting and free operation. Check the piston for looseness. Lubricate the spider hub with the specified grease only.

(2) HAMILTON STANDARD CONSTANT-SPEED PROPELLER. Inspect the external parts of the propeller unit for cracks, nicks, scars, and dents. All markings and antiglare coatings are checked for deterioration. Check the piston for looseness. Carefully examine the propeller and governor controls for security of mounting. Check the counterweight bearings and shaft for proper clearance, and make certain that the correct grade of grease is used for lubrication of the counterweight bearings.

(3) HAMILTON STANDARD HYDROMATIC PROPELLER. A magnifying glass must be used to examine all defects found on the blades of the propeller. Local etching will be performed to determine if defects are cracks or scratches. Check for deterioration of the propeller markings and the antiglare coating or camouflage. Check the complete installation for security of mounting and operation.

(4) HAMILTON STANDARD PROPELLER GOVERNORS. Inspect the control system and the governor for security of mounting. Check for proper safetying of the exposed nuts, clevis pins, and other fastening devices.

(5) AEROPRODUCTS CONSTANT-SPEED PROPELLER. Check the retaining nut for signs of looseness. Carefully examine the exterior of the propeller for cracks and other defects, using a magnifying glass. Check for any signs of deterioration of the painted markings on the blade and hub. Inspect the installation for security of mounting and operation. Lubricate the hub with the approved grade of grease and wipe the outside of both the hub and regulator with an oil-soaked rag. Examine the propeller spinner for dents, nicks, loose rivets and dowels. Remove all dents.

(6) CURTISS ELECTRIC PROPELLERS—THREE-BLADE (CONVENTIONAL) AND FOUR-BLADE MODELS. Inspect the propeller for deterioration of painted markings on the blades and hub. Check the retaining nut for looseness. Remove the brush cap assembly and inspect the slip rings and brushes for cleanliness and wear. Examine the brushes for frayed or broken leads. Brushes of the molded type holder are inscribed on the side with an arrow which points toward the front of the brush. When the point of wear of a brush reaches the tip of the arrow, that brush must be replaced. Brushes used in the early type holder do not have arrows; they should extend at least 3/8 inch from the block. Inspect carefully for worn brushes, permanently compressed springs, and dirty brush guides. Check the oil level in the speed reducer by rotating the filler plug opening to 20° below the horizontal when the airplane is at a ground angle of 12° or 8° when the airplane is level. Fill with the approved oil. Inspect the safety, selector, and feathering switches to make certain that they make positive contact and that they are free from looseness and sluggish operation of the handles. Lubricate the hub with the specified grade of grease. Remove the motor cover and examine the general condition of the electric motor (the terminals and wire connections, tightness and condition of the brush rigging). Check the condition of the brake and check the brake clearance. Both the inner and outer brake clearance must be checked on the four-blade model.

(7) CURTISS ELECTRIC PROPELLERS—HOLLOW SHAFT MODEL. To check the oil level in the speed reducer of the hollow shaft models, rotate the propeller until the large filler plug, located in the rear housing, is at the highest point. If the oil is below the plug opening, fill the assembly to the level of the opening. The hub of the hollow shaft propeller is not lubricated with grease. The general condition of the electric motor should be checked, and the brake should be checked for possible warping and proper clearance.

q. Instruments. (1) The repair of instruments is like the repair of watches—it requires the skill of a specialist. The best that a line mechanic can do is keep dust, moisture, and gases of any sort from entering the delicate mechanism and causing the instruments to malfunction.

(2) Examine all instruments and lines for security of mounting. All lines should be properly anchored and provided with the proper amount of flexibility. Check all connections for leaks. Inspect the dials and pointers for luminosity and be certain that the operation limits are correctly painted on each instrument glass.

17. ENGINE CHANGE INSPECTION. This inspection is made at the time the engine is removed from the airplane. (Fig. 68.) The expected time of operation, in flying hours, for each type and model of engine is specified in Technical Orders. Where failures have occurred or where serious malfunctioning is detected, the time may be reduced. On the other hand, if no serious malfunction has occurred and the engine is operating satisfactorily, an extension of the time between engine changes is permitted. (See TO 00-25-4.) Such variations are determined by local authority as directed by Technical Orders. At the time of engine change, all the inspections listed in the Technical Orders for the power plant must be made. As these inspections vary widely with the type and model of engine, they will not be listed here.

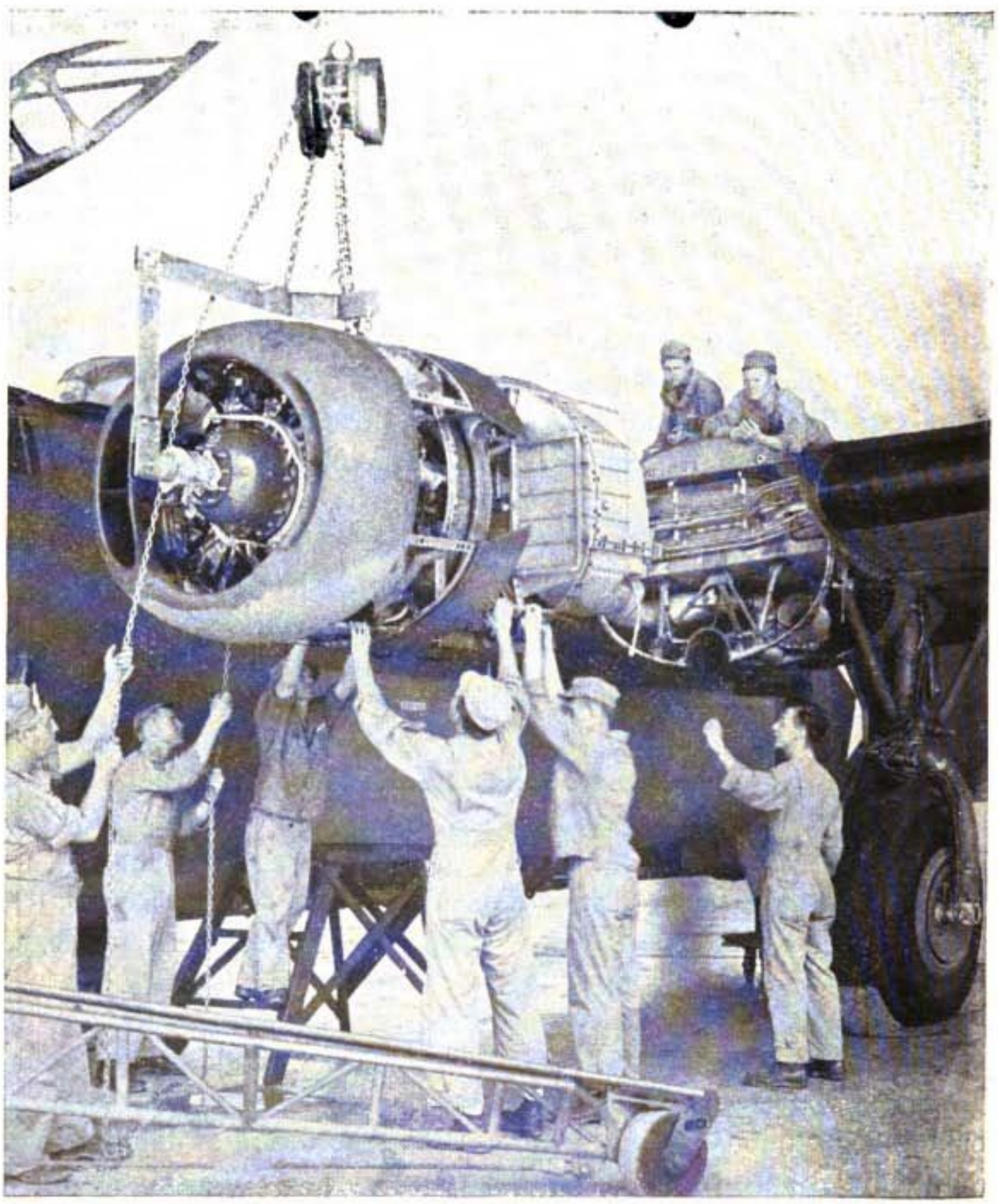

Figure 68. Engine change.

18. SPECIAL INSPECTIONS. Special inspections are prescribed to include necessary checks that do not fall under a regular daily, 25-hour, or 50-hour examination. These inspections include one-time examinations of units after installations, and periodic examinations of installed units that require checks which are more or less frequent than the inspection periods previously discussed.

a. 100-, 200-, 300-, etc., hour inspections. These inspections are equally as important as the previously discussed checks. However, since these inspections vary greatly in detail, they will not be listed here. Reference will have to be made to the specific Technical Order for them. The inspections are accomplished between flights, concurrently with the applicable 50-hour inspection.

b. Weekly. If the weekly battery check becomes due before the 25-hour period is reached the items listed under paragraph 15i. will be inspected.

c. After first 5 hours' flying time. At the end of the first 5 hours' flying time, the following inspections are made:

(1) Cylinder hold-down nuts of a liquid-cooled engine will be checked for tightness. No further check is necessary.

(2) The oil system Cuno of newly installed engines will also be cleaned and reinstalled. The same method of cleaning is used as during normal inspection.

d. 10-hour inspection. At every 10-hour period the following inspections are performed:

Figure 69. Checking the operation of a manual Cuno.

(1) Grease-lubricated superchargers are lubricated with grease as specified in the Technical Order. During summer operation grade 275 is used and grade 375 is used for winter conditions.

(2) Both the manual and automatic Cunos are checked. The handle of the manual type Cuno is rotated one turn counterclockwise (fig. 69). To check the automatic Cuno, remove the pinion shaft nut, turn it upside down, and screw it back on. Mark one face of the pinion nut, and note the position of the face. Operate the engine at idling speed for approximately 5 minutes, and then note the position of the marking on the pinion nut. Movement of this nut is an indication that the automatic filter turning mechanism is operating. If the nut appears as not having moved, restart the engine and operate for about 1½ minutes and recheck the position of the marking, because the marking may have returned to its original position. If the pinion nut has not turned, remove and replace the filter with one the operation of which is known to be satisfactory. To check the automatic Cuno without operating the engine, use the proper wrench and check to see if the disks turn freely. (See fig. 70.) After checking the filter, reinstall the pinion nut in its original position.

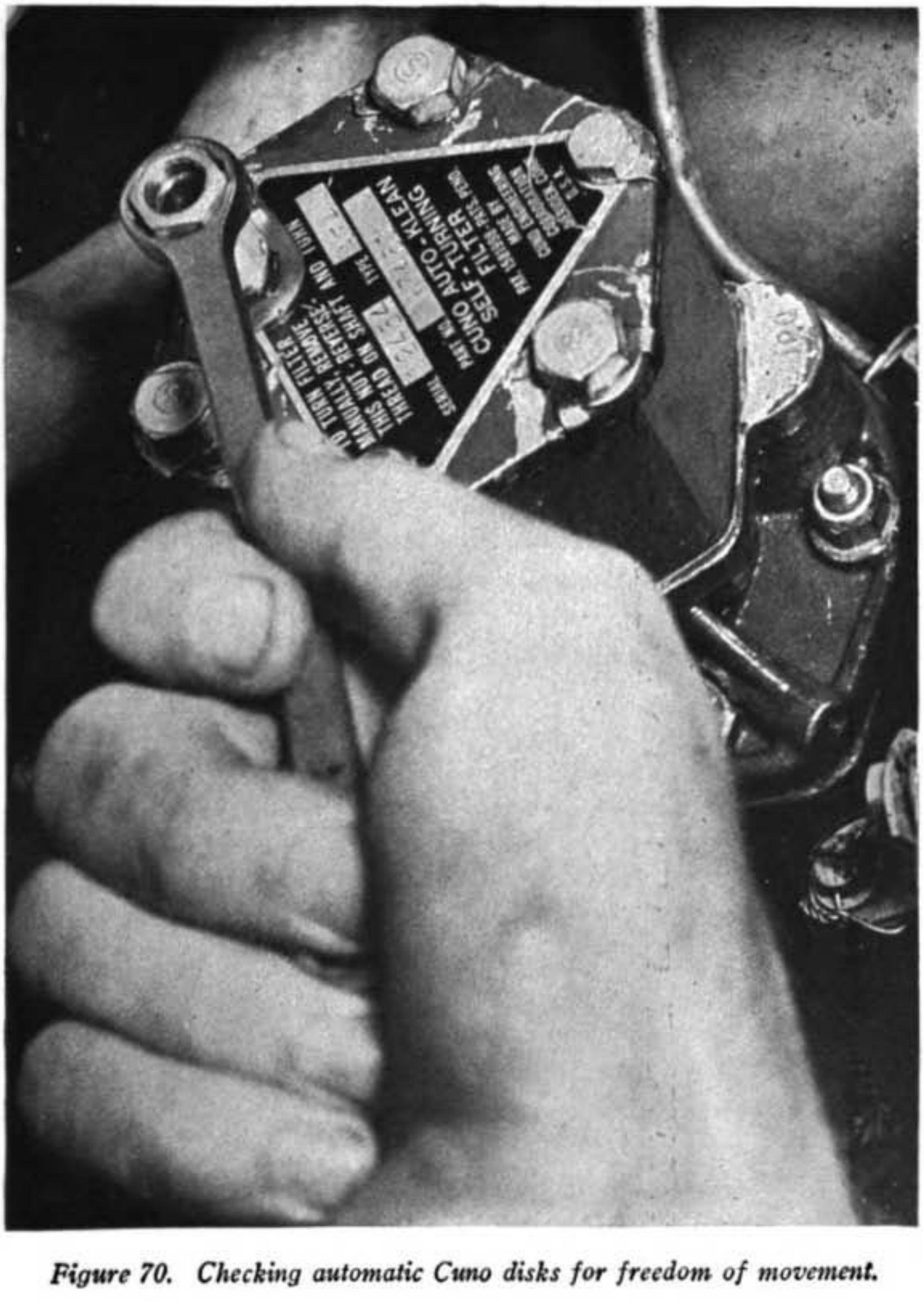

Figure 70. Checking automatic Cuno disks for freedom of movement.

SECTION III
POWER PLANT TROUBLE ANALYSIS

19. TROUBLE RECOGNITION. a. Engine trouble is a condition which causes abnormal or inefficient operation at a power plant. The existence of malfunctioning is indicated or pointed out by one or more signs of abnormal operation called symptoms. The aircraft mechanic faces the difficult problem of being able to recognize, diagnose, and locate trouble, and then prescribe the method of treatment when a power plant fails to operate properly. The mechanic must make careful note of the trouble and then in his mind analyze the *symptoms* and build a plan to diagnose and locate the malfunction.

b. Interpretation of operation indications. Skill in trouble shooting requires logical reasoning, a thorough knowledge of the principles

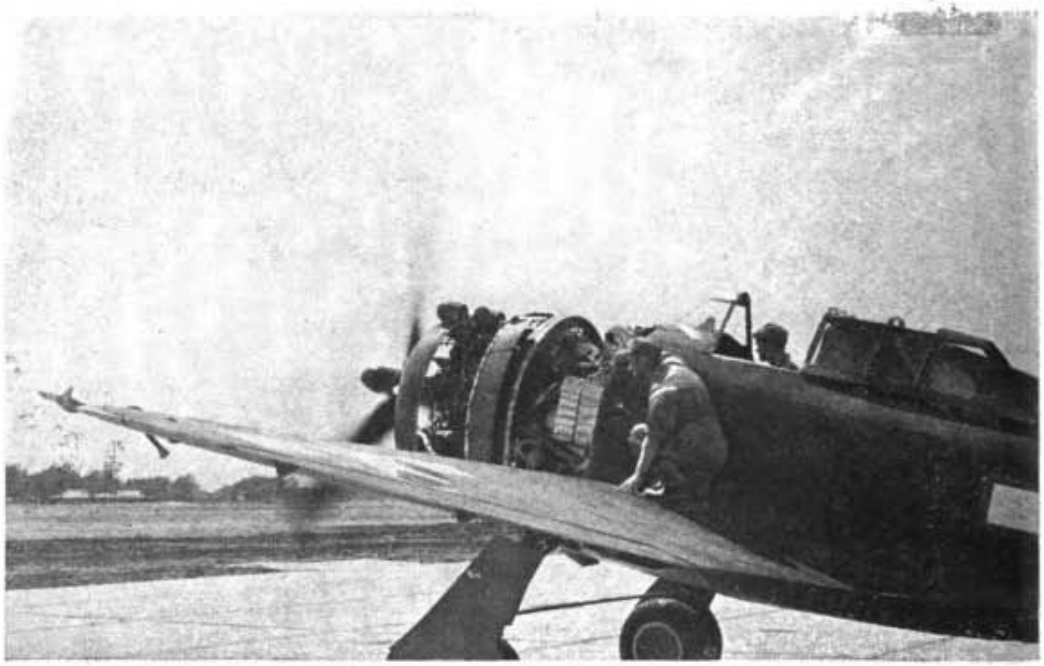

Figure 71. Trouble shooting.

of engine operation, and accurate operating information which is available from the pilot, crew chief, airplane flight records, and the engine itself. The greater the experience of the mechanic and the more familiar he becomes with an engine and its operating characteristics, the quicker and more efficiently he can remedy troubles. Delay in locating and correcting engine trouble is always very costly. There are a number of instances where certain troubles (which could have been avoided by the proper manipulation of the various engine controls and observance of certain operating limits and precautions) have developed in the power plant. Some troubles which cannot be avoided by ordinary operation and maintenance will occur; hence, trouble analysis and elimination are necessary.

(1) INSTRUMENT READINGS. Instruments furnish the most important indications which enable an airplane mechanic to analyze engine malfunctions. Excessively high or low temperatures or pressures are readily detected by the instruments. However, the presence of other symptoms may also aid in the successful location and correction of the trouble.

(2) EXHAUST FLAMES. Exhaust characteristics are indications of probable causes of engine troubles. They are sometimes difficult to interpret and distinguish because many variables may cause distinct changes of color under various operating conditions. When an engine is equipped with individual exhaust stacks, flame colors can be readily observed; however, where an installation has an exhaust collector ring or manifold it is difficult to make any analysis because the flame is dampened by the collector ring. Exhaust characteristics are generally analyzed in various degrees of exhaust colors. Dull red flame and heavy puffs of black smoke are generally the signs of an excessively rich mixture and overloaded engine. This may be due to overpriming, a carburetor leak into the induction system, or other troubles which allow excessive amounts of fuel to enter the intake manifold. In this case, engine operation is rather sluggish at low and medium speeds. Long bluish white or whitish yellow flame from the exhaust stacks indicate a lean mixture. Other indications of a lean charge are loss of power, detonation, preignition, and backfiring, or "popping back" through the induction system. Bluish gray smoke, frequently seen at the exhaust of an automobile, may be a general indication that the engine is consuming excessive amounts of oil because of worn piston rings and bearings.

(3) ENGINE SOUNDS. Sometimes the parts of an engine that are not functioning properly give a warning by sime peculiar sound or knock, usually at regular intervals of time. These noises or sounds usually exist in two classes; those created by the mechanical or structural condition of the engine, and those produced by the combustion conditions. The sounds due to mechanical condition may originate from the piston, piston pin and rings, valve mechanism, connecting rods, bearings, gears, or mounting. Troubles indicated by combustion noises are due to detonation, poor fuel, preignition, carbon, or overload. The first step in determining the cause of abnormal noises is to make certain that the engine is firing on all

cylinders. The analysis should be made when the engine is warm. Before any attempt is made to repair or replace any part, make certain that the cockpit controls are in their proper positions. Often an engine malfunction may be corrected by simply changing the mixture or readjusting the carburetor air heater.

(4) ENGINE VIBRATION. Because the airplane is more or less suspended in air it is extremely sensitive to vibrations set up by the engine. Excessive vibrations play havoc with the units installed in the airplane and cause fatigue of metals which results in structural failures and rapid wearing of parts. A limited amount of vibration is normal, but it must be held within low limits by the balancing of rotating units, and by the use of flexible or dynamic mountings for various related parts. Experience and familiarity with the engine will be of great help to the mechanic in determining the amount of vibration allowable in a specific engine installation. Generally, excessive vibration or operational roughness is caused by preignition, misfiring of one or more cylinders, detonation, propeller trouble, or mounting defects.

(5) CONTROL ADJUSTMENTS. Spotting trouble is sometimes very difficult since a single symptom may be due to a great many separate causes. Also, a single defective part may produce more than one symptom. Manipulation of the controls and switches may be used at times to find and isolate failures in the various engine systems. The need for thorough knowledge of operation principles cannot be overemphasized because some troubles may be controlled or corrected to a certain extent by resetting the controls. For example, it is quite possible to notice the presence of too lean a mixture during engine operation and, through a readjustment of the mixture control, completely eliminate the trouble.

20. TROUBLE ANALYSIS. To diagnose engine trouble successfully, an accurate understanding of the symptoms of engine operation is necessary. The diagnosis may require operation of the engine at various speeds for a period of time, at different control settings, and on all switch positions. When this operation is performed, the instruments are checked, exhaust characteristics are analyzed, and abnormal vibrations and sounds are noted. Engine trouble exists in two forms, structural and operational. The reliability of engines has increased tremendously in the last 30 years. This has resulted in a rapid decline in structural failures. They still occur, but usually result from engine operation at excessively high temperatures or excessive engine speeds. Occasionally a hidden defect may escape detection and cause trouble during service. Operational troubles can be located through the abnormal operation of the engine and unusual indications of the engine instruments. The aircraft engine is made up of a number of interrelated, yet separate, systems which are known as the ignition system, the lubrication system, the carburetion and fuel system, the cooling system, and the compression system. Most troubles can be diagnosed to fall into one or more of the foregoing systems with the exception of some structural failures which may be listed as mechanical troubles. When the symptom (or symptoms) of the trouble is determined, the engine may be stopped and the trouble diognosed.

a. Classification. Engine troubles, regardless of the system in which they occur, are classified into two groups, local and general.

(1) LOCAL TROUBLES. Local troubles are those which affect the operation of a limited number of cylinders without affecting the operation of the remaining cylinders. They generally occur after the point of distribution of the system. For example, malfunctioning of the two spark plugs installed in a cylinder affects the operation of that cylinder without affecting the operation of the remaining cylinders. When the symptoms of operation classify a trouble as local and affecting only a limited number of cylinders, it is evident that if the trouble is in the ignition system, it must be after the distributor, either in the spark plug leads, or spark plugs; if the trouble is in the carburetion system it must be in some part of the system where all cylinders cannot be affected, usually after the carburetor.

(2) GENERAL TROUBLES. General troubles are those which affect the operation of all cylinders and occur somewhere between the source and point of distribution. For example, a restricted fuel flow between the fuel tank and carburetor affects the operation of all cylinders, particularly of the higher engine speeds. When a trouble is classified as general, if in the ignition system it must be before the distributor, either in the magneto, ground wiring, or switch. The majority of the troubles that occur in the lubrication, cooling, and compression systems are general in nature.

b. Systematic symptom study and elimination. Troubles are usually indicated by a loss of engine speed or power, excessive temperatures, vibration or rough operation, incorrect mixture-control setting, or misfiring in one or more of the cylinders. A mechanic has to learn to "feel" when something is wrong. Only long experience will enable him to locate engine troubles quickly and accurately. Realizing this, the apprentice mechanic should follow a plan of systematic symptom study and elimination in order to reduce confusion and avoid undue delay in maintenance.

(1) OBSERVATION AND STUDY OF SYMPTOMS. Locating a defective part or faulty system with minimum delay is sometimes made rather difficult by the fact that one symptom may indicate trouble in one or more of several systems. Again, at times a symptom may lead a mechanic to believe there are as many as three or four causes. Symptoms can be obtained by studying any unusual conditions while the engine is operated on each switch position and at low, idling, medium, and high

speeds. This will prove a great aid, because some malfunctions are only noticeable at one speed or on one switch position. The operator or pilot is in a position to furnish very important information concerning the operation of the engine. From him determine at what speed or speeds the trouble was outstanding, whether engine operation was excessively rough, whether the engine backfired, and if movement of the controls affected the symptoms. Find out if the movement of the mixture control caused a change in the indications and what reaction was indicated when the engine was accelerated and decelerated. Just as important are the indications of the instruments while the engine performed under the troubled conditions. To have many symptoms, all of which indicate one particular trouble, is an aid in trouble shooting, but these conditions are not always probable. Since the same symptom may be caused by several different systems or units, the malfunction, after being carefully studied, will be diagnosed, first, by eliminating all unrelated systems.

(2) SYSTEM ANALYSIS. Internal combustion engines all work on the same principle and malfunctions of engine operation which affect smooth and satisfactory operation are very much the same, regardless of the type of engine. There are differences between the air- and liquid-cooled power plants as to the general location of the systems, but essentially they function in the same manner. It is not an easy matter to determine the exact cause of improper engine operation since it may arise from several sources. Therefore, the primary objective is to take into account all systems from which the trouble may arise and eliminate them in logical order.

(3) UNIT ANALYSIS. When the search has been narrowed to a definite system, the next step is to locate the defective unit by a process of elimination within that particular system. After determining the system in which the malfunction may lie, the various units are then eliminated one by one as possible causes of the trouble indicated by the symptoms. Begin by checking the easiest and most probable.

(4) PART ANALYSIS. After the trouble has been traced to a certain unit of the system it can usually be found by using a similar process of elimination. The most probable trouble is checked first. If the trouble is not located, it will be necessary to recheck the possible causes or to "rerun" the engine and again study the symptoms of the trouble. The mechanic soon learns that every pilot is in a hurry to fly the airplane, but it should be remembered that speed which results from a "patched up" job can never take the place of the safety that results from thoroughness.

c. Example. Systematic elimination, when diagnosing malfunctions, will greatly reduce time and effort in locating troubles. The following is a typical example of systematic trouble elimination:

(1) SYMPTOMS OF ENGINE TROUBLE.

Idling speed (500 to 1,000 rpm)	Engine operates satisfactorily.
Low speed (1,000 to 1,400 rpm)	Engine operates satisfactorily.
Cruising speed (1,400 to 2,200 rpm)	Engine operates satisfactorily.
High speed (maximum permissible manifold pressure)	Regular misfiring in a limited number of cylinders. Instruments indicate normal readings.

(2) CLASSIFICATION OF TROUBLE.

General	No.
Local	Yes, only a few cylinders are affected.

(3) SYSTEM DIAGNOSIS.

Ignition	Yes.
Carburetion	Not probable.
Lubrication	Not probable.
Compression	Not probable.
Cooling	Not applicable.

(4) SYSTEM UNIT CHECK.

Distributor	Not probable, because trouble occurs only at one speed.
Ignition leads	Not probable, for same reason.
Spark plugs	Probable. Defective or excessively wide spark gap in the spark plugs of cylinders affected.

21. TROUBLE ELIMINATION. a. Extent of repair operation. When failures and malfunction have occurred, the engine must be restored to its original condition with the least amount of time and delay. Regardless of the type of engine, trouble elimination includes one or more of the following: disassembly, removal, cleaning, inspection, repair or replacement, reassembly, and installation followed by an operation test and adjustment of the unit and engine. In the interest of safety, when necessary repairs are made, it is logical that other replacements be made if the condition of a related part may be a cause of future trouble. It is particularly important to learn at just what point in the engine the trouble exists, and what the cause is likely to be. With this idea in mind, no unnecessary part or parts need to be removed, and much time will be saved. An engine is always more or less disfigured and marred during repair operations. One should always analyze the symptoms of the trouble first, and thus avoid doing the wrong job. As previously stated, it is difficult to establish a definite set of instructions as to the extent of the maintenance and repair that must be performed by first echelon. Determining the nature and extent of work required rests upon the organization whose responsibility it is to keep the airplanes in operating condition.

b. Eliminating repetition of trouble. In order that a great many repetitions of the same trouble may be avoided, it is well that the mechanic extend his maintenance beyond the point of just replacing the part. It is a good idea to search thoroughly to determine where the fault exists; whether it was due to the incompleteness of the work at a former inspection, or due to faulty repair during previous maintenance; whether it was caused by the structural break-down of the metal, or possibly due to the failure to detect a flaw or defect at the last overhaul period (or during the manufacture of the unit in question). It is important to note whether the unit is exposed to dirt and dust, and to take necessary steps to eliminate this condition if found. One of the most difficult probabilities of the cause of troubles to "pin down" is that failure may have been caused by engine operation above the specified limits. A careful inspection may often reveal that failure may be the result of an excessive force which has been applied to the particular unit. Most of the modern aircraft engines render dependable service for long periods of time without many major repairs if they are kept clean, adjusted properly, and operated as recommended. It is desirable and practical to disassemble any part of an engine only when absolutely necessary. Unless an engine is of an unusually complicated design, many troubles can be overcome by external adjustments.

c. Use of interchangeable parts. Whenever engines can be kept in operating condition by utilizing serviceable interchangeable parts, such as instruments, accessories, and engine parts from other nearby power plants awaiting repair or shipment, it is permissible to use any needed part until others are received from supply. However, immediate steps must be taken to obtain the parts necessary for the repair of the grounded engine.

SECTION IV

COMMON POWER PLANT TROUBLES AND POSSIBLE CAUSES

22. GENERAL. Many symptoms and the possible causes of engine troubles have been grouped together under the one heading, "Common Power Plant Troubles and Possible Causes." In the following paragraphs, common symptoms are listed first. These are followed by some of the most probable causes. To "trouble shoot" an engine, the mechanic must understand the various signs and symptoms created by the different conditions of engine performance. The mechanic of the past was severely handicapped in this work by the lack of accurate measuring devices. In recent years, rapid advances have been made in the development of engine instruments, and it is now possible to obtain reliable indications of the many phases of engine operation. The mechanic, however, must use common sense in interpreting the meaning of these indications.

23. TROUBLES REVEALED PRIOR TO OPERATION. The symptoms and the possible causes listed in the following subparagraphs are easily detected when the engine is not operating. They are generally discovered during the daily or preflight inspection of the installation. To discover trouble prior to flight, to know what caused it, and to remove the causes will avoid further damage and the possibility of engine failure during flight.

a. Warped or damaged supercharger turbine wheel and buckets. A preflight inspection reveals warped or damaged condition of the supercharger turbine wheel or buckets. (Technical Order instructions will be followed concerning the replacement and disposition of superchargers having warped or damaged turbine wheels or buckets.)

(1) EXCESSIVE SUPERCHARGING. Supercharging to a pressure higher than safe continuous manifold pressure is generally due to an operator's carelessness in operating below the specified altitude with the supercharger FULL ON. This will cause the turbine wheel to overspeed. Overboosting is detrimental to both the engine and the supercharger and therefore must be avoided.

(2) EXCESSIVELY RICH MIXTURES. When the engine is operating at or near rated power where the mixture must necessarily be rich, "afterburning" may occasionally occur. This afterburning is a

result of the mixing and igniting of the outside air and unburned fuel particles in the exhaust gases. The burning occurs as the exhaust gases pass through the buckets of the turbine wheel and the resultant temperatures are generally much higher than the normal temperature of the exhaust gases.

(3) EXCESSIVELY LEAN MIXTURES. The slow burning tendency of the excessively rich mixture is also characteristic of the excessively lean charge. The slow burning flame of a lean charge passes into the exhaust manifold and ignites the unburned particles of fuel deposited there by the discharge of other cylinders.

(4) FOREIGN OBJECTS. Spark plug electrodes, or thermocouples used to measure exhaust gas temperature, may sometimes break and be blown into the turbine wheel. Other foreign objects, such as nuts, cotter pins, etc., may pass through the nozzles and be blown into the turbine wheel.

(5) IMPROPER NOZZLE BOX AND TURBINE WHEEL CLEARANCE. The clearance between the turbine wheel and the nozzle box should be maintained as specified in Technical Orders. (See fig. 72.) Adjustment of the clearance is obtained by replacing or removing shims under the nozzle box supports.

(6) LEAK IN INDUCTION SYSTEM. When a leak in the induction system occurs, the supercharger will attempt to maintain the supply of air required by driving the supercharger turbine wheel faster. Turbine wheel speed will ultimately become unsafe; at this point, normal operation can no longer be maintained. When a condition of this nature is reported, examine the induction system thoroughly for leaks and, if necessary, pressure test the system as directed in Technical Orders. Check the exhaust clamp bolts. These bolts should be tightened very little beyond finger-tight. They must not be drawn too tight or a tension failure will occur when the collar heats up and expands in operation.

b. Oil leak in vicinity of oil cooler. At a daily inspection it is discovered that oil is leaking from the oil temperature regulator.

(1) COLLAPSED CORE TUBE. Excessive pressure in the system, loose mounting, or vibration may cause a collapsed core tube. In some installations it is necessary to remove and replace the cooler when this occurs. In other types, the core tube may be removed and replaced by using special tools and following the directions listed in Technical Orders.

(2) OVERTIGHTENING OF MOUNTING CLAMPS. An excessive tightening of the mounting clamps may cause the cooler to leak at the junction of the core and the shell. To avoid overtightening, draw the mounting clamps only tight enough to insure a snug fit.

c. Engine controls not operating freely. During a preflight inspection it is discovered that excessive force is necessary to move a control lever.

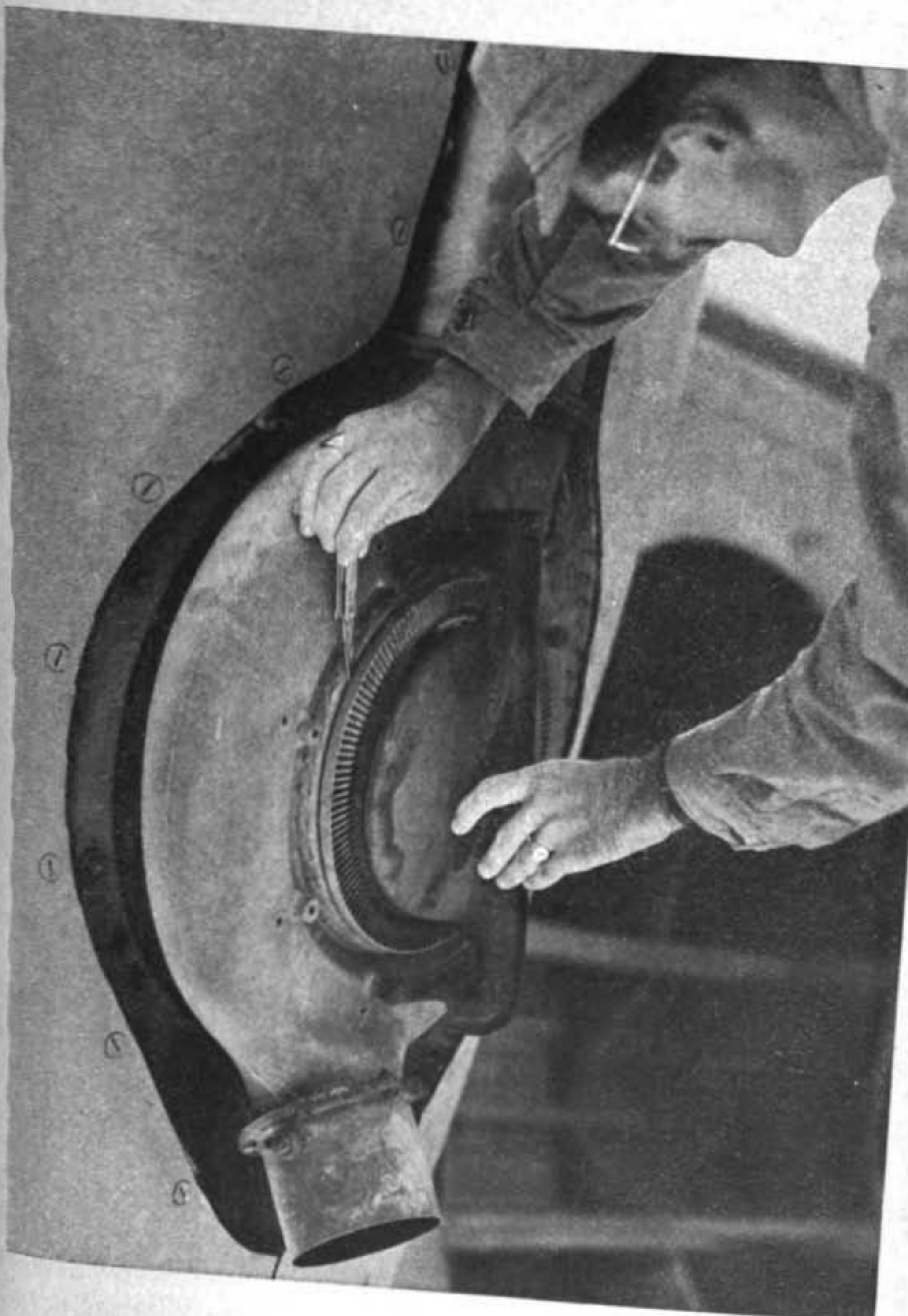

Figure 72. Checking the clearance between nozzle box and turbine wheel.

(1) LACK OF LUBRICATION. Remove the suspected part and examine carefully. Remove any suspected bearing and check the operation by hand. If any bearing of the unit has misshapen balls, pitted bearing races, or is damaged in any other way, it must be replaced.

(2) MISALIGNMENT. Hold the clevis yokes in alignment while readjusting the clevis lock nuts to insure that the control is installed in the correct position.

(3) BENT CONTROL RODS. Slightly bent control rods or tubes may be straightened, but extreme care should be taken in this operation. Severely bent control tubes or rods should be replaced with new parts.

(4) OBSTRUCTION OF LINKAGE. The control mechanism may become fouled with foreign objects. Make sure that loose equipment, hidden bolts or nuts, and other objects are removed or securely and properly fastened so that they will not interfere with the linkage.

(5) DEFECTIVE PULLEYS. Examine for loose or broken pulleys, and for pulleys out of alignment with the cables. Defective units will be repaired or replaced.

(6) OVERTIGHTENED BALL JOINTS. Ball joints must be adjusted properly. Screw the adjustable socket down on the ball pin until just tight, then unscrew one-quarter turn and tighten the lock nut.

(7) BINDING IN CONTROL QUADRANT. Friction in the quadrant may be excessive. This may be caused by the shifting of the friction-clutch adjustment due to vibration. If this condition is present, readjustment is necessary.

(8) BINDING IN CONTROL GUIDES OR FAIRLEADS. This is generally due to bent rods, frayed cables, or collection of dirt and grease. Repair or replace bent rods and cable. Remove the dirt and grease with kerosene.

(9) DEFECTIVE BELL CRANKS. Examine the parts carefully and replace any suspected unit. Make certain that tension and adjustment are correct and that the unit moves freely.

(10) COLD WEATHER. The lubricant of the linkage units becomes too heavy and "gummy" at extremely low temperatures. To correct this condition, wash the control linkage with kerosene. No lubrication other than that supplied by the kerosene is required until warmer temperatures prevail.

(11) FRAYED OR SNAGGED CABLES. An inspection of the cables near points of contact will generally reveal the existence of frayed wires and signs of wear. Replace any defective cable if more than the allowable number of wires are broken.

d. Fuel pressure warning-light failure. Prior to starting the engine for a preflight warm-up check it was found that the fuel warning-light signal did not function.

(1) DEFECTIVE LAMP BULB. Remove the outer glass and remove and replace the bulb with one known to be satisfactory.

(2) POOR CONTACT. If the lamp base and the socket fail to make proper contact the lamp will not light. Make certain that a lamp with the proper base is installed.

(3) FAULTY WIRING. All connections should be clean and free from dirt. Binding posts, screws, and terminal ends must be attached firmly.

(4) UNIT OUT OF ADJUSTMENT. To adjust the setting of the warning signal, first remove the signal cover, then place the fuel cock in the ON position. Increase the fuel pressure with the wobble or booster pump to the desired setting, place the battery switch on, and adjust the fuel light until the light flickers. Check the setting by increasing the fuel pressure above the setting pressure and allow the pressure to decrease slowly. The lamp should light at the desired setting. A tolerance of ± 0.25 pound per square inch is allowed.

e. Oil pressure warning-light failure. When the switches were placed in the ON positions prior to starting, it was discovered that the oil pressure warning signal failed to light.

(1) DEFECTIVE LAMP BULB. Check the condition of the bulb by replacing it with one known to be good.

(2) POOR CONTACT. Check the condition of the socket and determine whether the contacts are corroded. Be certain that the lamp has the proper base.

(3) FAULTY WIRING. Check the warning-light terminal posts for security of leads. See that all terminal connections are clean and free from dirt.

(4) UNIT OUT OF ADJUSTMENT. For adjustment of the internal mechanism of the warning signal, the unit must be removed from the airplane and returned to a repair depot.

f. Spark plug indication of excessive operating temperatures. At a 25-hour inspection, when gap clearances were checked, the spark plug electrodes were found to be in an extremely clean condition. Neither carbon, formed by lubricating oil, nor white powder, formed by the burning of leaded fuel, was present. Upon a closer examination, the spark plug body and electrodes were found to be discolored. This indicates that they had been exposed to excessive heat, which tends to make the ceramic insulation more porous, thus allowing current leakage and a resultant loss of engine efficiency.

(1) EXCESSIVE MANIFOLD PRESSURES. High manifold pressures are accompanied by high operating temperatures, and therefore should always be avoided.

(2) INCORRECT INSTALLATION AND INSUFFICIENT SPARK PLUG COOLING. These troubles may be caused by any

one of the following: The replacement of a spark plug without a gasket allows the plug body to penetrate further into the combustion chamber and become exposed to more of the burning charge. (See fig. 73.) If

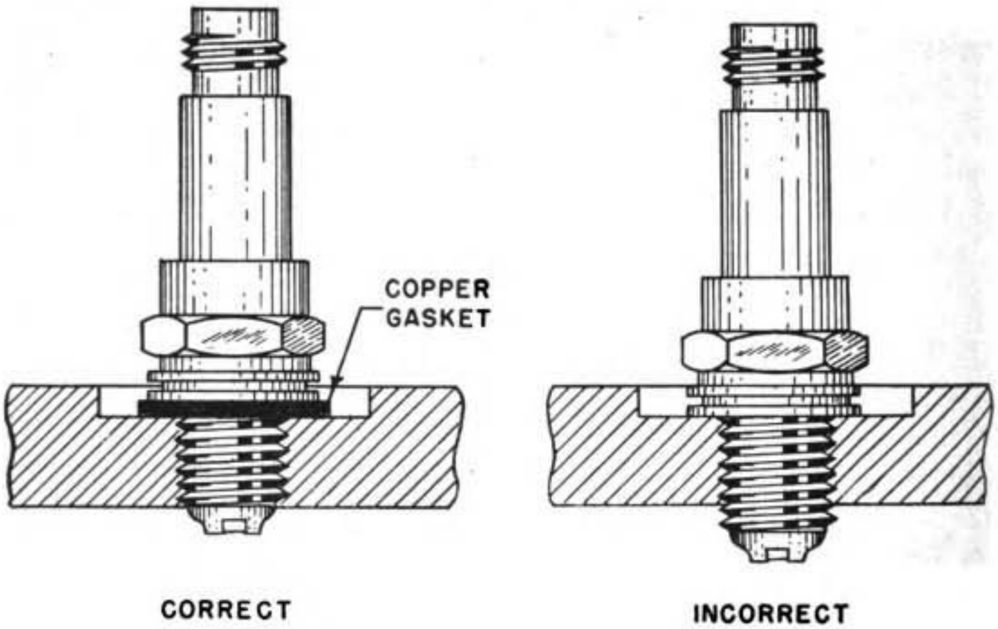

Figure 73. Proper and improper spark plug installation.

the wrong type of plug is installed, it may be of a kind that is unable to withstand the high pressures and temperatures developed in the engine. Insufficient air flow over the outside of the spark plug may often be caused by a damaged or distorted baffle plate. The elimination of these causes should improve engine performance.

(3) DETONATION DUE TO POOR FUEL. The recommended grade of fuel only must be used. Most of our high-powered engines have a very high compression ratio and thus require a fuel with correspondingly high antiknock properties.

(4) INADEQUATE SPARK PLUG COOLING. When the plug cannot dissipate the heat at a rate sufficiently rapid to avoid overheating it, other troubles, such as detonation and preignition, may result. High-output engines require a spark plug with a short insulator and less exposed insulating surface which will dissipate the heat rapidly and yet retain sufficient heat to burn carbon, or maintain a "self-cleaning" temperature.

g. Leakage near battery compartment. A seepage of liquid is noticeable in the vicinity of the battery compartment and upon inspection the leak is traced to a cracked battery case. The acid in the electrolyte will cause rapid deterioration of metal parts. It should be removed as soon as possible by flushing the exposed parts with a solution of baking soda and water.

(1) LOOSE BATTERY HOLD-DOWN CLAMPS. The battery must be held firmly in the battery compartment so that it cannot shift

around during maneuvers of the aircraft. Remove and replace the battery, making sure that the hold-down clamps are properly tightened.

(2) FROZEN BATTERY. The battery must be removed and replaced.

h. Frozen battery. A weekly inspection during extremely cold weather reveals a number of frozen cells in the battery.

(1) DISCHARGED BATTERY. When the specific gravity of a battery is 1.275, the outside temperature must drop to —85° F. to freeze it; at 1.200 the battery will freeze at —16°F.; but at 1.150, freezing of the electrolyte will occur at 5° F. In order to avoid damage due to freezing, keep the battery well charged or remove it from the airplane to a warm location.

(2) RECENT ADDITION OF WATER. Newly added distilled water will not mix thoroughly with the electrolyte in the cell until the battery is charged, hence, it will freeze at or near the freezing point of water. About ½-hour charge is necessary to mix the added water with the electrolyte.

i. Corrosion in battery box. Excessive corrosion on the inside of the battery compartment is noted during the periodic weekly inspection.

(1) OVERCHARGING. Overcharging produces an overheated condition of the battery cells. Liberation of oxygen and hydrogen and a violent boiling of the electrolyte, known at gassing, results from this condition.

(2) ELECTROLYTE SPILLAGE. The electrolyte causing the corrosion may have spilled when too much water was added by the mechanic who last checked the battery. Check also for leakage from defective sealing compound or cracked cell.

(3) DEFECTIVE VENTS. Leaking or clogged vents may cause an accumulation of electrolyte in the compartment. Check the vent tubing and note the condition of the outlet to see that the protruding tube end has not been damaged.

j. Melted battery sealing compound. At a weekly battery inspection it is discovered that the compound on the top of the battery is melted.

(1) HIGH CHARGING RATE. An excessive charging rate produces violent boiling of the electrolyte. This may result in an overheated condition of the battery cells.

(2) COMPARTMENT TEMPERATURE TOO HIGH. Excessive battery compartment temperature may occur during operation in hot climates. During such operation, the proportion of acid to water is reduced to lengthen the normal service period of the battery. (This is not performed by a line mechanic.)

k. Spark plug condition—coated with white film. A 25-hour spark plug inspection reveals that some of the units are coated with a hard grayish white film. When the spark plugs are removed from the engine they should be set out in a row for comparison, and care should be exercised to identify each spark plug with the cylinder from which it wa removed.

OXIDATION OF LEAD. The chemical combination of oxygen wit the lead in the fuel forms lead oxide (lead rust). This coating of lea oxide on the electrodes will increase the resistance of the secondary circuit thereby reducing the high-tension current (amperage). This weakens th spark and may cause missing. If this condition is found, the spark plu will be removed and replaced.

l. Spark plug condition—black gummy deposit. By a proces of elimination the mechanic finds that the fuel system functions normally and that misfiring exists in only a few cylinders. This indicates the trouble to be in the ignition system. After stopping the engine, he places his bare hand near the cylinders and notices that a few cylinders do not "feel" as hot as the others. A visual check of the most probable causes reveals that the wiring is in good condition and the connections at the terminals properly tightened. When the spark plugs are removed from the cooler cylinders, an inspection reveals that the electrodes and the exposed portions of the plugs are coated with a black gummy deposit and fresh oil. (See fig. 74.)

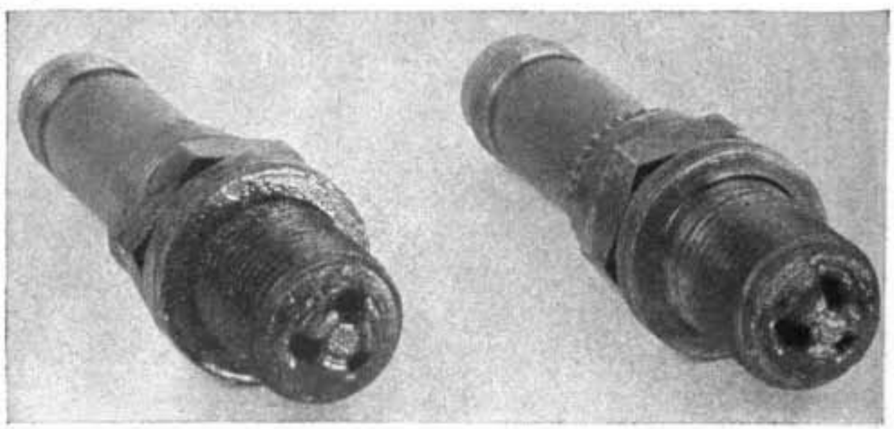

Figure 74. Fouled spark plugs.

(1) LOW ENGINE SPEED. Permitting a high-output engine to operate at low speeds for long periods of time, either in flight or on the ground, may not allow the power plant to develop sufficient heat to burn the accumulation of oil that seeps into the cylinders.

(2) EXCESSIVE OIL CONSUMPTION. Worn rings allow excessive amounts of oil to get by the rings and into the combustion chamber. Oil and carbon will bridge the gap clearance and furnish an easy path for the current, thus preventing the formation of the spark necessary for combustion.

(3) EXCESSIVE GAP CLEARANCE. The space between the electrodes acts as an insulator. When this space is too wide the resistance

created by the distance will prevent the production of the necessary spark. It is therefore important that the gap clearance be maintained within the specified limits.

m. External surface covered with oil. Excessive quantities of oil are spilled from the crankcase breather and blown over the engine and airplane by the propeller airstream.

(1) EXCESSIVE OIL SUPPLY. Servicing the tank with too much oil overloads the lubrication system. In the process of servicing, refill only to the point specified by the engine Technical Order.

(2) DEFECTIVE INVERTED FLIGHT VALVE. The proper operation of the inverted flight valve in the crankcase breather should normally prevent oil loss during inverted flight.

(3) DEFECTIVE SCAVENGER SYSTEM. Air leaks in the scavenging system of the engine or propeller governor may result in an accumulation of oil in the crankcase causing spillage from the breather.

(4) WORN CYLINDER ASSEMBLY. Worn rings and scored cylinder walls allow the cylinder pressure to escape into the crankcase. This builds up excessive crankcase pressure and forces the oil out of the power section.

(5) OIL DILUTION VALVE STUCK OPEN. The malfunction of the oil dilution valve allows fuel to seep into the oil system, therefore causing an excessive dilution of the oil. This condition will be indicated by a drop in fuel pressure and oil pressure with probable increases in engine temperature during flight.

n. Starter oil leakage. A daily inspection reveals an accumulation of oil in the vicinity of the starter housing. When making an attempt to start the engine, it is found that the starter motor does not function. When the starter switch is in the MESH position, the customary "buzz" of the contact points and "click" of the solenoid plunger are heard, indicating that current is available at the booster coil.

(1) WORN LEATHER OIL SEAL IN BAFFLE PLATE. A worn leather oil seal allows engine oil to seep into the starter and starter motor. If this is the trouble, remove and replace the starter.

(2) INSUFFICIENT CABLE SLACK. Insufficient slack in the engaging linkage, preventing complete retraction of the starter jaw against the oil seal, allows engine oil to seep into the starter. To eliminate this a minimum of 1/32-inch slack is permitted so that proper seating of the starter jaw against the seal is provided. (See fig. 65.)

(3) EXCESSIVE FRICTION. To eliminate excessive friction in the engaging linkage and allow the starter jaw to completely retract from the engine jaw, an auxiliary spring may be attached to the linkage to aid in the retraction.

24. HARD STARTING ENGINES. In many cases, hard starting of th engine occurs because the operator does not follow the proper startin procedure. That is, the engine controls may not be correctly "set" fo starting; the starter flywheel may not be rotating at the correct speed the engine may be flooded, etc. It is impossible to state all the minut details of how to start the engine. They may be learned by each individu from experience with a particular engine. Every time the engine i started, remember how many shots of the primer were necessary, ho long it was necessary to energize the starter, etc. If starting trouble i encountered, vary the procedure slightly. In this way, a definite pro cedure for starting each engine may be discovered.

a. Propeller cannot be pulled through. During the preflight in spection, the propeller cannot be pulled through in the normal manner.

(1) LIQUID IN COMBUSTION CHAMBER. Excessive seepag of oil or coolant into the combustion chamber of an engine will restric the movement of the piston. When this condition is encountered, th accumulation must be removed before starting. (See par. 6a(2) and (3).)

(2) CONGEALED OIL. During extremely cold weather the oil be comes cold and viscous, and may offer enough resistance to prevent th rotation of the propeller by hand. Preheating the oil and the engin will generally remedy this condition.

(3) "FROZEN" PISTONS AND RINGS. Overheating sometime causes the pistons and ring assemblies to jam or stick after cooling off The excessive heat removes the oil from the cylinder walls and pisto rings, thus creating a metal-to-metal contact. If this condition is en countered, engine overhaul is necessary.

(4) MECHANICAL DEFECTS. When it is suspected that there ar broken parts of any kind, no further attempt should be made to pull th propeller through until the trouble is determined and corrected.

b. Compression leak. During the process of pulling the propelle through, a hissing sound is noted as each piston passes through it compression stroke. Leaks of this nature may be located by installin a compression gauge in the spark plug opening. (See fig. 75.)

(1) LEAKING INTAKE VALVE. A leak by the intake valve ma be heard in the carburetor induction system.

(2) LEAKING EXHAUST VALVE. Leaky exhaust valves will allow the mixture to escape through the valve into the exhaust collector ring A distinct odor of fuel will be present.

(3) DEFECTIVE CYLINDER ASSEMBLY. If the sound of escap ing pressure is heard in the crankcase, this may indicate defective rings scored cylinder walls, or a cracked piston. Excessive crankcase pressure will force the fumes to escape through the breathers.

c. **Hand-cranking difficulty.** During an attempt to use the hand ank of a hand inertia starter (starter brushes raised), it is discovered at the crank can be rotated only by applying excessive force.

l) MISALIGNMENT OF CRANK EXTENSION SHAFT. Dis-rtion of the extension shaft generally occurs when excessive force is plied to the hand crank during the starting operation.

2) INSUFFICIENT BEARING LUBRICATION. A dry or frozen tension shaft bearing will cause restricted movement of the shaft. The aring should be lubricated with engine oil, grade 1100.

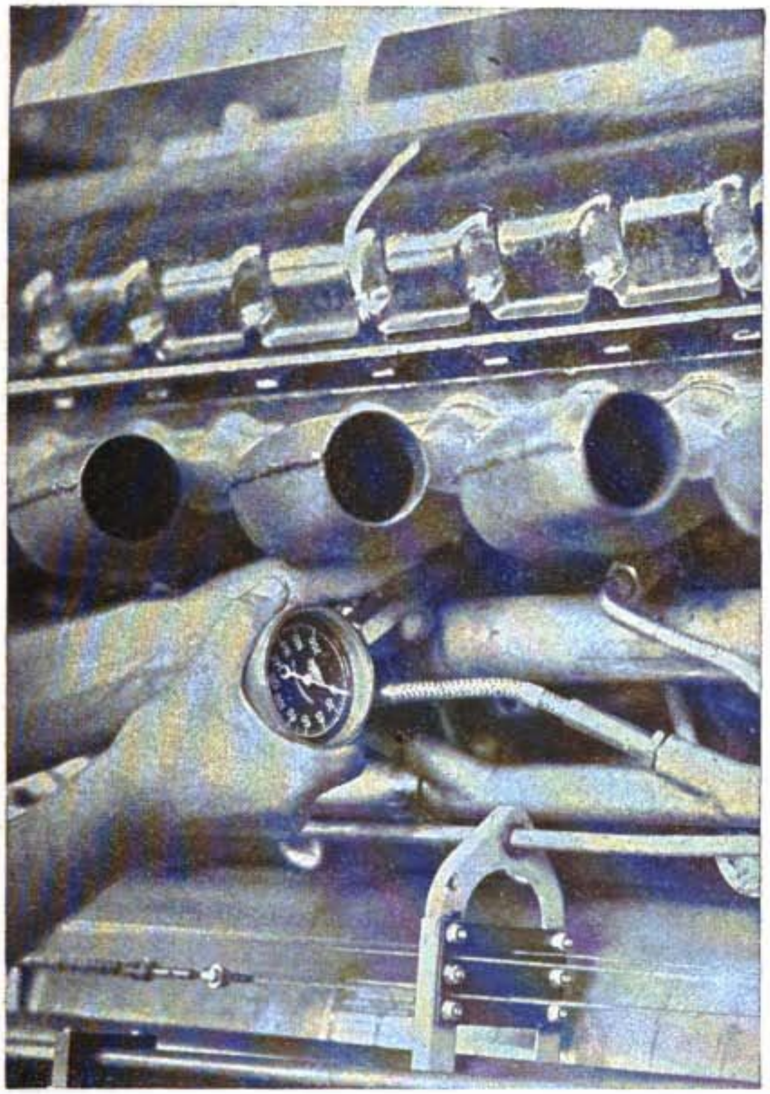

Figure 75. Checking cylinder pressure with a compression gauge.

3) IMPROPER STARTER LUBRICATION. Heavy greases and ils may become unusually stiff during cold weather. Preheating the tarter will usually correct this condition.

4) DRIED LUBRICANT IN STARTER. This trouble may occur f the starter is not periodically inspected while it is in storage. It makes and cranking difficult and results in poor starter performance.

(5) BARREL ADJUSTING NUT TOO TIGHT. The barrel a justing nut should be tightened until snug, then backed off one full ho Clearance between the nut and the ball rack should be at least 0.003 inc

(6) WORN STARTER PARTS. Worn or rough ball bearings, shaf and other parts may cause excessively hard or unusually loose turnin Unusual noises may also be heard. When this condition exists, remo and replace the starter.

d. Starter fails to energize. During an attempt to start the e gine, a chattering noise is heard and the starter fails to energize wh the starter switch is placed in the START (or ENERGIZE) positio

(1) PARTIALLY DISCHARGED BATTERY. A battery in a lo state of charge will not furnish sufficient power to close the startin solenoid switch, but will cause the plunger to produce a noise similar that caused by slipping gear teeth. Replace if the specific gravity below 1.250 or above 1.310.

(2) FAULTY TERMINAL CONNECTIONS. Defective termin connections may cause complete or partial failure by preventing full cu rent flow. The noise listed in (1) above will occur.

(3) DEFECTIVE STARTER SWITCH. A defective starter switc will cause the same action as faulty terminal connections. Place heav jumpers across the starting switch terminals. If the starter motor op erates, the switch is defective and should be replaced.

(4) DEFECTIVE STARTER MOTOR JAWS. If the teeth of th starter motor jaw or the flywheel jaws are damaged, abnormal grindin noises will probably be heard. The starter should be stopped immediatel or further damage may result.

e. Starter flywheel not engaged. During single-engine starting the "whir" of the starter motor is heard, indicating that the starter moto is functioning. If the pitch of the noise rapidly increases, the motor i carrying no load. If this condition exists, the starter motor should b stopped at once as the speed of the armature may increase enough to caus it to fly apart.

(1) STICKING STARTER JAW. If the motor jaw binds on th armature shaft it may be due to gummed oil, which prevents the moto dog from moving forward into position to engage the flywheel. In som cases, releasing the switch and closing it again will remedy the trouble If the trouble remains, the starter motor should be replaced with on which has been properly lubricated.

(2) FLYWHEEL IS ROTATING. In some starters, when the starte switch is closed and the flywheel is still rotating, the motor jaw override the flywheel jaw, and no engagement is made. To avoid this malfunction mesh the flywheel to the engine to remove any energy that may b stored in the flywheel.

(3) INCORRECT MOTOR ROTATION. When the starter motor rotates in the wrong direction, remove and replace it with the proper unit.

f. Engine fails to "turn over." The starter is fully energized, but the engine fails to turn over when the starter switch is placed in the MESH position.

(1) FAULTY MESHING SOLENOID CABLE OR MECHANICAL CONNECTION. Broken linkage or extremely loose adjustment caused by excessive vibration may prevent meshing of the flywheel dog to the engine dog. Adjust the cable to permit proper operation of the engaging mechanism and allow 1/32-inch slack.

(2) DEFECTIVE TERMINAL CONNECTIONS. Check and make certain that all terminal connections are securely fastened. Terminal connections must be kept very clean, as otherwise contact resistance will cause a voltage drop that will impair the efficient operation of the system.

(3) DEFECTIVE MESHING SOLENOID. This may be due to improper electrical connections or an open or grounded coil. To check the coil for an open circuit, place a 110-volt test lamp across the coil contact terminals (not the battery connections); if the lamp fails to light, replace the coil. To test for a shorted or grounded circuit, connect one test lead to one terminal, remove the grounding bushing from the other terminal, and touch the other test lead to the coil housing. If the lamp lights, replace the coil.

(4) DEFECTIVE SWITCH. Switch troubles usually result from poor terminal connections, loose parts, or burned contacts. Check the switch by placing a heavy jumper cable across the switch terminals. If the switch is found to be defective, it must be replaced.

(5) DEFECTIVE GEAR ASSEMBLY, CLUTCH MECHANISM, OR ENGINE STARTER JAW. A grinding or rattling noise will occur as the flywheel is meshed to the engine. Remove the starter and inspect it. If it is damaged, replace it with another starter unit.

g. Engine fails to start. Several unsuccessful attempts to start are accompanied by weak or intermittent explosions and clouds of black smoke issuing from the exhaust manifold. These indicate a partially burned charge.

(1) OVERPRIMING. When the mixture is overly rich, normal combustion cannot take place. Overpriming or flooding is remedied by placing the ignition switch in the OFF position, setting the throttle full open, and pulling the propeller through three or four revolutions.

(2) INCORRECT MIXTURE-CONTROL SETTING. On installations equipped with a Stromberg injection type carburetor, the mixture control must be in the IDLE CUT-OFF position when the hand wobble pump or electric booster pump is used to build up pressure. When this procedure is not followed, fuel is permitted to flow into the supercharger impeller sec-

tion, causing a flooded condition. Follow the procedure stated in (1) above to remove the excess fuel.

(3) DEFECTIVE BOOSTER COIL. The contacts of the booster coil are subject to a moderate amount of burning and should be inspected if this trouble occurs. If the points are badly pitted or burned as shown in figure 76, the coil must be replaced.

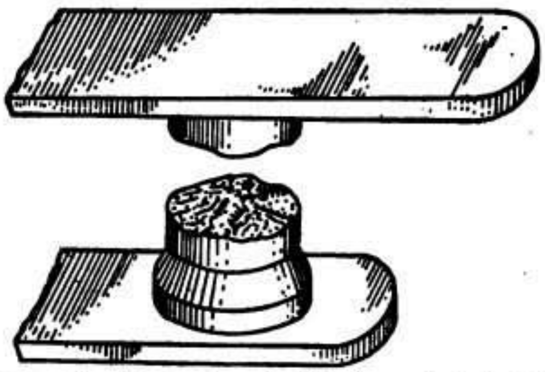

Figure 76. Burned and pitted contact points.

h. Lack of booster spark when engine fails to start. An attempt to start during warm weather results in failure, but the engine rotates with sufficient speed for normal starting. When the starter switch is placed in the MESH position to stop the starter flywheel rotation, the customary "buzz" of the booster coil is not heard. Releasing the switch and closing it again reveals the same condition.

(1) IMPROPER ADJUSTMENT OF BOOSTER COIL CONTACTS. To check the booster coil for operation, disconnect the booster high-tension lead at the magneto (or disconnect the lead at the coil and use a test lead), place the end of the lead approximately ⅜ inch from a grounded structure of the airplane, set the ignition switch in the BOTH position, and close the starter switch in the Mesh position. The spark should jump the gap. (See fig. 77.) In the event that trouble is discovered during this check, replace the unit with one known to operate satisfactorily.

(2) ROUGH, PITTED, OR DIRTY BOOSTER POINTS. One or more of these conditions may add sufficient resistance to prevent the normal flow of current. Slide a piece of hard paper between the contact points to clean them. Replace the coil when the contact points are found badly pitted or burned.

(3) DEFECTIVE WIRING. Check the wiring and insulating bushings for signs of arcing and for loose or broken connections. If the insulation is defective it may produce a spark leak at the point where the insulation is damaged. Replace all defective leads and properly install all connections.

(4) DEFECTIVE SOLENOID SWITCH. If the switch fails to function properly, examine it for corroded contacts or an open circuit. A good, clean, smooth surface contact is necessary. If defective, the switch must be removed and replaced. (See par. 24f.)

(5) DEFECTIVE COIL. The simplest method of testing for a faulty coil is to substitute a good coil for the suspected one, and compare the behavior under similar operating conditions.

i. Engine fails to start during cold weather. After meshing the starter flywheel to the engine it is noticed that the engine fails to turn over as it normally does. The starter flywheel lacks the characteristic high-pitch sound when energized. Atmospheric temperature is near 20° F.

(1) FLYWHEEL NOT FULLY ENERGIZED. The switch must be held on long enough for the flywheel to be energized (holding the switch closed for 10 to 20 seconds is usually sufficient).

(2) WEAK OR DISCHARGED BATTERY. Check the state of charge of the battery. If the specific gravity is below 1.250, replace the battery with a fully charged one.

Figure 77. Checking booster-coil spark strength.

3) COLD BATTERY. A battery is less efficient during cold weather ecause the electrolyte becomes thicker or more dense. This retards cirulation of the electrolyte and the battery does not respond as quickly as vhen it is warm. If this is the trouble, remove the battery and place it in warm location until it becomes warm enough to operate properly.

(4) CONGEALED OIL. If oil seeps into the starter and becomes too stiff to allow the flywheel to be fully energized, it will be necessary to preheat the engine and oil to reduce starting torque. To reduce starter failure caused by seepage and accumulation of oil in the starter and flywheel housing, a $\frac{3}{16}$-inch diameter hole is drilled at the lowest point of the flywheel housing to permit drainage of oil.

j. Combustion failure. The engine fails to start after several repeated attempts. Fumes (a moderate amount) escape from the exhaust manifold, but there are no signs of occasional combustion.

(1) IGNITION SWITCH IN "OFF" POSITION. With the switch in this position, both magnetos remain grounded, the booster coil circuit is open, and high-tension current to produce spark is not furnished to the spark plugs.

(2) DEFECTIVE BOOSTER MAGNETO COIL. Examine and test the booster coil. Bits of dirt or other foreign material between the points are generally the troubles affecting proper operation. Check the ground connections and make sure that they are clean and securely tightened.

(3) FAULTY IGNITION HARNESS. Moisture, deterioration, or loose and improper connection will short the ignition circuit. Replace the ignition harness when it is found defective. Examine all connections for condition and proper tightness.

(4) DEFECTIVE MAGNETO BREAKER POINTS OR CONDENSER. Trouble may be caused by points that are sticking open, by worn or pitted points, by incorrectly adjusted points, or by a shorted condenser. Check the breaker points for proper opening and readjust if necessary. If the points are excessively worn or pitted, replace the magneto or replace or dress the points, whichever is specified in Technical Orders. If condenser trouble is suspected, remove the condenser and if the engine operates, install a new condenser.

(5) FOULED SPARK PLUGS. When all spark plugs are fouled, combustion failure will occur. To check for this condition plug in an air-cooled engine, remove and inspect the spark plugs. If they are lead fouled, replace them. If the plugs are oil fouled, wash them in gasoline, dry them thoroughly with compressed air, check and reset the gap clearances, and reinstall them. To check for this condition in an in-line engine, remove one of the spark plug leads and expose the sleeve insulator and spring. Have someone attempt a start of the engine, then cautiously place the end of the spring approximately ⅛ inch from some spot or ground on the engine and check the spark jump. If this is satisfactory, clean or replace plugs as herein directed. (See fig. 78.) If no spark is obtained, check the magneto for dirty or inaccurately spaced contact points or defective distributor. (See (4) above.) (Be careful of the rotating propeller and be certain that secure footing is available before performing the check.)

(6) DEFECTIVE IGNITION SWITCH OR LEADS. Check the leads to and from the switch. Be sure that the insulation is not burned or chafed off, permitting the conducting wire to rub against some part of the engine. This would ground the magneto. If the internal mechanism of the switch is thought to be defective, disconnect the magneto ground leads at the switch, and then attempt an engine start.

(7) IMPROPER TIMING. After the possibilities mentioned are exhausted, the valve and ignition timing should be checked. Reference should be made to the Technical Order concerning valve and ignition timing of the particular engine.

k. Insufficient fuel in mixture. During the starting procedure, the engine fires a short burst and suddenly stops. Repeated attempts give the same results. Occasional flashes of yellowish white flames are observed issuing from the exhaust.

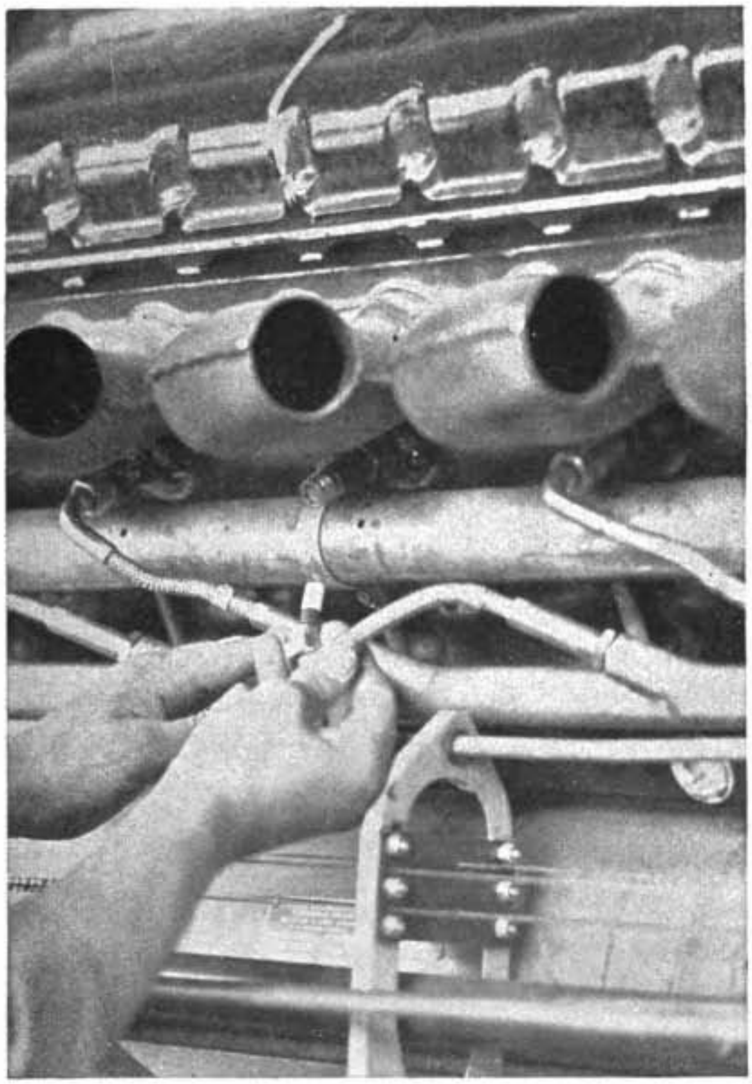

Figure 78. Checking ignition harness.

(1) UNDERPRIMING. This condition is due to either a defective priming pump or to an insufficient number of priming strokes. In either

case, the necessary amount of priming charge for starting is not supplied to the engine. Attempt another start providing additional strokes of the primer. After several tries, if the same trouble occurs, remove a priming line and check the pump for discharge. Check the primer line jets for stoppage by inserting a proper size drill to remove any restriction. If pump discharge is low, replace the plunger washer or replace the pump.

(2) INCORRECT SETTING OF MIXTURE CONTROL. When the mixture control of a pressure type carburetor is positioned in or near FULL LEAN (IDLE CUT-OFF), normal fuel flow is restricted. Float type carburetor installations are started with the mixture control in FULL RICH position. On engines equipped with Stromberg injection type carburetors the mixture control is in the IDLE CUT-OFF position prior to starting and as the engine fires it must be placed in the AUTO RICH position.

(3) INCORRECT SETTING OF THROTTLE. The throttle lever adjusts the butterfly valve which controls the air flow into the induction system. During starting, this valve should be positioned so that the carburetor idle system will function and a proper fuel-air mixture is obtained for starting.

(4) RESTRICTION IN SYSTEM. Stoppage in the fuel system will not affect the firing of the priming charge, but will allow insufficient fuel flow from the carburetor for continuous operation.

(5) WATER IN SYSTEM. Water will obstruct the small passages (jets), because it cannot flow readily through them. Drain all fuel system sumps until water is removed. Clean all strainers before replacing.

(6) DEFECTIVE FUEL PUMP. Even though the engine-driven fuel pump is not operating properly, engine starting can be accomplished by using the wobble pump or booster pump to maintain pressure. Replace the pump if it is found defective.

l. Fuel booster pump pressure low. Prior to starting, with the fuel booster pump switch ON and the pump operating, the fuel pressure warning light flickers on, and the fuel pressure gauge indicates a low pressure.

(1) LOW BATTERY VOLTAGE. This condition may be checked by attempting to operate other electric motors. When the battery is suspected, check the state of charge with hydrometer. If the charge is low, replace the battery.

(2) WORN MOTOR BRUSHES. When the brushes become excessively short the pressure on them decreases and proper contact with the commutator may be impossible. Replace the worn brushes and properly seat them on the commutator. (See (4), below.)

(3) BRUSHES BINDING IN HOLDERS. Brushes must slide up and down easily in the holders. Remove and clean both the brushes and

the holders to remove any gum formed by grease and carbon dust. Use a gasoline-saturated rag.

(4) BRUSHES NOT PROPERLY SEATED. After installation of new brushes, the pump and motor should be run under load for 2 hours to aid in seating the brushes. Brushes may also be fitted by inserting a strip of No. 000 sandpaper between the brush and the commutator (with the abrasive side next to the brush) and pulling the paper over the contour of the commutator. (See fig. 64.)

(5) LOOSE OR DIRTY CONNECTIONS. The high resistance caused by loose or dirty connections will keep the motor from rotating at the specified rpm for normal pump pressure discharge. Clean and tighten all connections.

(6) DIRTY COMMUTATOR. An occasional cleaning of commutators is necessary because they frequently become coated with carbon and copper dust, and grease. No. 000 sandpaper is used to clean the unit and the dust is removed with a compressed air blast.

(7) ROUGH OR PITTED COMMUTATOR. When the commutator is slightly pitted it may be smoothed by using No. 000 sandpaper. If the commutator is excessively rough or pitted, the complete unit must be replaced.

(8) FUEL SEEPAGE INTO MOTOR. This condition may be determined by removing the vent plug. If fuel is present in the motor, remove the pump and replace with a new unit.

(9) EXCESSIVE CLEARANCE BETWEEN IMPELLER AND THROAT. If this condition is present, pump pressure will be low and the pump unit must be replaced.

(10) BENT SHAFT. If the shaft is bent or distorted, replace the complete pump unit.

(11) IMPELLER RUBBING ON THROAT OR PUMP BODY. When this occurs, friction prevents the impeller from rotating as it normally would. Replace the pump.

(12) SHORTED, GROUNDED, OR OPEN COMMUTATOR. This will usually result in complete failure, but partial failure (which causes low fuel pressure) is possible. Replace the complete assembly.

(13) SHORTED, GROUNDED, OR OPEN MOTOR COILS. Same as in (12) above. Replace the complete unit.

(14) GROUNDED BRUSH HOLDERS. When this condition exists, remove and replace the unit.

m. Fuel booster pump noisy. Prior to starting, a noise occurs only when the fuel booster pump switch is closed; the sounds are then localized in the fuel booster pump.

(1) LOOSE MOUNTING ON TANK. Check the pump for security of mounting. If found loose, tighten and safety the unit properly.

(2) LOOSE PARTICLES OF FOREIGN MATTER IN PUMP.

Remove the pump from the mounting and clean out all foreign objects. If the pump shows no indication of damage, it may be reinstalled.

(3) PUMP PROPELLER RUBBING THROAT. When this condition occurs, remove the pump and replace it with a new or overhauled unit.

(4) IMPELLER RUBBING THROAT. Field servicing includes only the replacement of the pump unit when the impeller is found rubbing against the throat.

(5) LOOSE SLINGER. The line mechanic must replace the complete unit when this trouble is encountered.

n. Fuel booster pump motor noisy. At a preflight inspection it is discovered that abnormal sounds occur only when the fuel booster pump switch is CLOSED and the pump is operating. Closer inspection localizes the noise in the pump motor.

(1) LOOSE PARTS. Check the unit for tightness and if internally loose parts are evident, replace the complete pump unit.

(2) WORN OR MARRED BEARING AND LACK OF GREASE. Bearings become worn due to a lack of lubrication or from fuel seepage that washes the lubricant from the bearing surfaces. If this condition is found, replace the pump.

(3) BENT SHAFT. Excessive load or torque of the shaft may sometimes cause distortion. If this occurs, replace the pump unit.

o. Booster pump fuel pressure fluctuates. At starting and prior to engine warm-up (with the fuel booster pump switch ON and the booster pump operating) a surging of fuel pressure is indicated on the fuel pressure gauge.

(1) INSUFFICIENT FUEL IN TANK. Switch to another tank and check the suspected tank for contents.

(2) CLOGGED SCREEN. A clogged screen due to pieces of rubber or foreign material in the pump may result in complete or partial failure. Remove the screen and clean it.

(3) FLUCTUATING VOLTAGE. It is important that the electrical power be maintained at full voltage since the speed and the discharge pressure of the pump are affected by variations in voltage.

(4) LOOSE CONNECTIONS. The normal vibration of the engine will cause variations of voltage when the connections are loose. Carefully clean and tighten all terminal leads.

(5) FUEL SEEPAGE INTO MOTOR. Remove the vent plug in the motor and examine for fuel seepage. If seepage is present, remove the unit and replace it.

(6) UNVENTED TANK. Partial clogging or complete restriction of the air vent will generally result in fluctuating pressure. Check vents and open if necessary.

p. Fuel booster pump failure. Prior to starting, it is observed that the fuel warning light remains burning, the fuel pressure gauge registers no pressure, and no sound of pump operation is heard when the booster pump switch is held in the ON position.

(1) WIRING NOT PROPERLY CONNECTED. Check the wiring of the electric motor against the installation wiring diagram.

(2) LOW PRESSURE. All causes listed in l above are to be considered in diagnosing this trouble.

25. ENGINE TROUBLES DURING OPERATION. If the mechanic understands the principle of operation and the construction of the various parts of an aircraft engine, he should be able to determine the causes of troubles by thought and reasoning. The mechanic should always keep in mind the two main conditions necessary for engine operation: first, fuel must be provided at the proper place (combustion chamber); and second, a spark must be furnished at the spark plug gap in order to produce combustion. Proper timing and the correct quantity and mixture of fuel are also essential to efficient combustion. Lubrication, cooling, compression, etc., must be provided if the engine is to operate smoothly and efficiently. As electrical power is used to operate many engine units, a source of electricity is also necessary. Lack of one or more of the essentials listed is the cause of engine troubles during operation. If engine troubles occur during operation, try to establish some basic cause for the trouble encountered before removing any unit. The wiring diagram of the airplane's electrical system will help to locate points of connection and aid in tracing the continuity of the wiring system. Before removing any terminal connection to an electrical unit, be certain that the battery disconnect switch is in the OFF position, and that it remains off until the unit is satisfactorily repaired. This paragraph gives a list of some of the troubles, electrical and otherwise, which may be encountered during engine operation under various conditions.

a. Engine will not idle. Satisfactory operation is obtained at medium and high speeds. Abnormal vibration is present only at idling speeds. All pressure gauges indicate desired readings, but the engine temperature increases.

(1) INCORRECT IDLING SPEED AND MIXTURE ADJUSTMENT. The mixture adjustment controls the engine speed and mixture ratio of the charge for idling speeds only. Adjustment is made by turning the adjusting screw to make the mixture either leaner or richer as desired. On a pressure type carburetor, the knurled adjusting screw turns hard because of the spring lock and may require the use of a screw driver.

(2) DEFECTIVE IDLE SYSTEM. Restriction of the idle jets, caused by foreign material or water, will affect the operation of the en-

gine at lower speeds. Drain all fuel system strainers and tank sumps. Examine the discharge to determine whether the fuel contains an excessive amount of foreign matter.

(3) INDUCTION SYSTEM AIR LEAKS. The effect of leaks in the induction manifold will depend upon their size and location. Generally, in the case of a small leak, erratic operation is noticeable at idling and low engine speeds, with the possibility of "smoothing out" at higher speeds. Leaks often occur at the synthetic rubber packings on the crankcase end of the intake manifold and between the intake manifold and the cylinders. These packings become hard with age and heat, and fail to maintain an airtight seal.

(4) CLOGGED SUPERCHARGER REGURGITATION TUBE. When this tube is restricted, the mixture will have a tendency to become alternately rich and lean. This effect may only occur during the first few minutes of engine operation and the condition may be removed by continued running of the engine.

(5) FOULED OR DEFECTIVE SPARK PLUG. A spark plug has to fire unfailingly, many times a second in an intensely hot chamber containing soot, carbon, and oil. It is also exposed to continuous changes in temperature and pressure. Fouled plugs must be cleaned and defective ones replaced.

b. Fluctuating tachometer needle. An unsteady reading is indicated on the tachometer; however, the engine rpm appear to be as required, and all other conditions of engine operation are satisfactory.

(1) LOOSE TERMINALS AND CONNECTIONS (AT INSTRUMENT). The electrical terminal connections are sometimes shaken loose by engine vibration. The "make and break" condition set up by the loose terminals will cause the fluctuation in the tachometer pointer. Clean and securely fasten all leads and connections.

(2) OIL OR LIQUID SEEPAGE. Seepage of liquids at the tachometer generator binding posts or into the lead conduit will often cause the above listed trouble. Examine the generator unit and replace it if oil is present.

(3) WORN OR LOOSE CONNECTION (AT GENERATOR). A "make and break" condition will also result from this defect. If the leads or terminals are worn excessively, replace them.

(4) DEFECTIVE GAUGE. Replace the unit with one known to operate satisfactorily. If this corrects the trouble, replacement of the indicator is required.

c. Reversed reading on tachometer. After starting the engine it is found that the tachometer needle moves in the wrong direction. Engine operation is normal and desired readings are recorded on all other gauges.

(1) REVERSED TERMINALS. The terminal connections should be checked against the wiring diagram furnished with each specific unit. First check at the tachometer generator and then at the indicator.

(2) DEFECTIVE TACHOMETER GAUGE. If the trouble is definitely traced to a defective unit, it will be replaced. The new unit will be checked for correct indication.

d. Erratic operation of manifold pressure gauge. A malfunction was described by the operator as a sudden erratic increase of manifold pressure followed by a fixed setting of the manifold pressure gauge needle. An attempt to increase the power output by increasing the manifold pressure through the movement of the waste gate control had no effect. Otherwise, engine operation was normal.

DAMAGED WASTE GATE CONTROL CABLE. A spring cartridge is installed in the supercharger regulator system. If the supercharger control cables become severed or disconnected, this spring places the supercharger regulator in a position to deliver 65 percent rated power (at a specified altitude and rpm). When the cable is repaired or replaced, be sure that the controls move freely.

e. Fuel pressure suddenly drops to zero. The engine "spits and sputters," and fuel pressure drops to zero. Quick action by the operator in changing from one tank to another and in using the wobble pump or booster pump keeps the engine operating. The power plant operates normally on all tanks when wobble pump use is continued, but pressure drops when it is discontinued. Possibility of an empty tank is eliminated; therefore, some defect in the fuel pump system is indicated.

(1) DEFECTIVE FUEL PUMP. A defective fuel pump must be replaced.

(2) BROKEN FUEL PUMP DRIVE. Failure to lubricate the flexible cable of remotely driven fuel pumps may cause the cable to overheat and freeze. Replace broken cable and lubricate according to existing instructions.

(3) CLOGGED FUEL LINE. A restriction that affects the engine pump only must be in the fuel pump line between the **T**-fittings to which the lines to the hand wobble pump (or booster pump) are attached. Remove the suspected fitting and line and blow through it to check for stoppage.

f. Fuel pressure indication excessive. The needle of the fuel pressure gauge indicates a fuel pressure which is considerably higher than normal. This pressure remains unchanged at all engine speeds. Smooth and normal operation of the engine is not affected.

(1) INCORRECT RELIEF VALVE SETTING. When the spring tension is adjusted too high the relief valve will not open at the desired pressure. In this case, pressure in the whole system is abnormally high. Adjust relief valve to "kick out" at the desired pressure.

(2) DEFECTIVE FUEL PRESSURE GAUGE. Excessive pumping of the wobble pump may sometimes destroy the accuracy of the gauge. In order to check the operation of the gauge, replace the old one with a

fuel pressure gauge known to be in good condition. If the gauge is defective, it must be replaced.

g. Fuel pressure fluctuation. Engine operation is normal at times but is accompanied by intermittent periods of "spitting and sputtering." During these periods, the fuel pressure gauge pointer fluctuates violently.

(1) WATER IN FUEL. If this condition exists, tank drain sumps and system strainers should be drained.

(2) RESTRICTION IN LINES. Many line troubles would be eliminated if proper care were taken to keep all dirt and other foreign material from entering the tank. Disconnect the suspected line and blow it out.

(3) CLOGGED SCREEN. A system strainer of fine mesh is installed at the lowest point in the system. If it becomes clogged it may cause fuel pressure fluctuation. Dirty screens must be removed and thoroughly cleaned.

(4) FAULTY CARBURETOR DISCHARGE NOZZLE. Check the discharge nozzle for correct pressure discharge and be certain that the nozzle is not sticking open. Fuel under a high vacuum will boil and cause erratic metering of the fuel. If the nozzle is defective, the carburetor must be replaced.

(5) IMPROPER RELIEF VALVE OPERATION. Small particles of dirt sometimes get lodged intermittently between the valve seat and valve face and produce fluctuation of fuel pressure.

(6) DEFECTIVE FUEL PUMP. Any malfunction to the "heart" of the system would be indicated by the fuel pressure gauge and the operation of the engine. If during operation, the wobble or booster pump were used and normal engine operation resulted, the trouble would be confined to the fuel pump. It would then be necessary to remove and replace this unit.

h. No oil pressure indication. The engine operates normally after starting, but the oil pressure gauge indicates zero pressure. *In every case, shut down the engine within 30 seconds.*

(1) INSUFFICIENT SUPPLY. Stop the engine and check the oil level in the tank. If it is low, examine the flight report and note whether the system had been serviced after previous flight. If it had been serviced, inspect the system for other troubles. Otherwise, fill the tank to the proper level.

(2) LEAK IN OIL LINES OR TANK. Any leak in the system can be easily detected by the greasy surface in the vicinity of the leak. Trace all oil leaks to their source. Check hose clamps for security and examine the hose connection for deterioration. Repair or replace all defective units.

(3) CONGEALED OIL. In zero weather the oil pressure gauge is slow in responding to an indication. Technical Orders specify methods of correcting this condition. (See par. 6h(4).)

(4) CLOGGED OIL FILTER RELIEF VALVE. A relief valve is incorporated in the filter to bypass unfiltered oil to the engine in case of an emergency. Remove and clean the filter and integral relief valve with gasoline, coat the filter disks with clean engine oil, and reinstall the unit.

(5) RESTRICTION IN SYSTEM. Restrictions in the system may be caused by foreign matter, gummed oil, or vapor lock which may be due to foaming in the tank or failure to preoil after engine change. If this condition occurs, it will be necessary to drain and flush the complete system.

(6) IMPROPER SETTING OF RELIEF VALVE. The valve should be set to obtain the correct pressure. Before adjusting the relief valve, the Technical Order for the specific engine should be consulted. Adjustments are made only after the possibilities listed are eliminated and the oil is at normal operating temperature.

(7) MECHANICAL. A defective pump or pump drive would cause complete loss of pressure. In either case, replace the pump assembly.

i. No oil pressure indication after engine change. Upon completion of the installation and servicing the oil tank, the engine is started and it is found that the oil pressure gauge indicates zero pressure. Steps must be taken to stop the engine if no oil pressure is indicated in 30 seconds.

(1) VAPOR LOCKS. Air trapped in the inlet line to the oil pump must be bled out at the oil pump outlet. TO 02–1–22 specifies the procedure required for preoiling after engine change.

(2) MECHANICAL DEFECTS. Failure to seal the drain plug opening, a disconnected oil pump, incorrect relief valve setting, failure to replace the oil filters, and numerous other troubles may cause the foregoing symptoms. Examine the whole system and correct any defects before restarting the engine.

j. Fluctuating oil pressure gauge needle. During warm-up, it is noted that the oil pressure gauge fluctuates excessively. (This symptom is usually noticeable in engines nearing their maximum operating time before overhaul.)

(1) PARTIALLY CLOGGED OIL FILTER OR SCREEN. This is generally due to the accumulation of soft carbon particles and other foreign materials in the oil. Remove filter or screen, wash with unleaded gasoline, coat with clean engine oil, and replace.

(2) MALFUNCTIONING OF OIL PRESSURE RELIEF VALVE. A defective valve spring or particles of foreign matter may cause a surging or pressure by not allowing the relief valve to function normally. Before replacing or adjusting this unit, be certain that some other defect is not responsible for malfunction.

(3) FOAMING OR VAPOR LOCK IN OIL LINES. This may be caused by a leak in the line from the sump to that tank or by a leak in

the suction side of the pump. Check carefully for leaks and repair or replace any faulty lines or fittings. Drain and refill the system.

(4) DEFECTIVE PRESSURE GAUGE. Excessive vibration, shocks, or overpressure may cause the gauge to register an unsteady reading. Check for the above troubles before replacing the gauge.

(5) DEFECTIVE OIL PUMP. Check the installation carefully. If the fault lies in the pump, replace the unit. Before starting, be certain that some other defect in the installation is not responsible for pump failure.

k. Low oil pressure. Soon after starting the engine it is noted that the oil pressure is lower than that specified for the particular engine. Other operating conditions are normal.

(1) LOW OIL SUPPLY. See h(1) above.

(2) LEAK IN SYSTEM. See h(2) above.

(3) IMPROPER GRADE OF OIL. In order to provide correct lubrication pressure, the oil must be of sufficient viscosity to establish a seal between the rings and cylinder wall. If this is the trouble, drain the oil system and refill with the proper grade of oil.

(4) RESTRICTION IN SYSTEM. See h(5) above.

(5) PARTIALLY CLOGGED CUNO OR SCREEN. See j(1) above.

(6) OVERDILUTION. An excessive dilution of the oil may make it too thin to maintain a seal between the rings and the cylinder. In most cases, overdilution may be corrected by continued operation of the engine. If not, check the oil dilution valve and control for proper operation.

(7) OIL FOAMING. See j(3) above.

(8) DEFECTIVE OIL PRESSURE GAUGE. If this trouble is suspected, tap the instrument glass with the ends of the fingers to check for sticking of the pointer. Next, remove the instrument and replace with one which is known to operate satisfactorily.

(9) WORN BEARINGS. See an(3) below.

(10) WORN PISTON RINGS. See an(3) below.

l. Low oil pressure during cold weather. During warm-up, the oil pressure gauge records a low reading, but other features of engine operation are normal. Atmospheric temperature is near freezing.

(1) OVERDILUTION. This is the most likely cause. (See k(6) above.)

(2) INSUFFICIENT OIL SUPPLY. See h(1) above.

(3) LEAK IN OIL LINES. See h(2) above.

m. Low fuel pressure and low oil pressure. During the engine warm-up prior to the first flight of the day it is noted that the fuel and oil pressures are both below the values specified as normal. The oil was diluted after the last flight on the preceding day. Free-air temperature is 30° F.

(1) DEFECTIVE OR OPEN OIL DILUTION VALVE. If this is the trouble, continued operation may result in serious damage to the engine. Stop the engine and check the operation of the oil dilution valve and controls.

(2) LINE LEAKS. If both the fuel and oil lines are leaking, the foregoing symptoms will be indicated. (See h(2) above.)

(3) FROZEN WATER AND CONGEALED OIL. The presence of ice in the fuel system may show only a low reading on the gauge without indications of erratic operation. The congealed state of the oil may have resulted because of an overheated condition of the engine occuring at previous operation which vaporized the fuel that was intended for oil dilution.

(4) DEFECTIVE GAUGES. See k(8) above.

n. Excessive oil temperature. After flight, the pilot reports excessively high indications on all engine temperature gauges and an excessively low indication on the oil pressure gauge.

(1) OIL COOLER SHUTTERS CLOSED. Proper operation of the oil shutters will regulate and maintain the correct oil temperatures. Closing the shutters limits the amount of cooling air passing through the cooler core.

(2) DAMAGE TO OIL-COOLING SYSTEM. Inspect the oil-cooling system for proper operation. This inspection should include an operation check for full movement of the cockpit control lever and the shutters.

(3) RESTRICTED AIR FLOW THROUGH COOLER. A coating of dirt and grease will affect the efficiency of the cooler. Remove the coating with a suitable cleaning fluid.

(4) INCORRECT GRADE OF OIL. (See k(3) above.)

(5) RESTRICTION IN SYSTEM. Clogged oil lines and strainers will cause indications of low pressure before a temperature rise is noticed. If the oil pressure remains near normal and excessive temperatures exist, examine the return line to the supply tank. Make the necessary adjustments and repairs to allow free flow and proper cooling of the oil.

(6) RELATED ENGINE UNITS. Overheating of other engine parts or units will cause high oil temperatures. Careful analysis is required to trace this condition to its source. Repair or replace any unit which is overheating.

o. Excessive oil temperature at high altitudes. Excessively high oil temperature during high-altitude flight is reported by the pilot. Oil pressure and operation of the engine remain normal and satisfactory. At ground run-up this symptom is not evident.

CONGEALED OIL IN COOLER. The congealing of oil in the cooler may be due to the faulty operation of the oil cooler flap. Examine the override valve and piston to make certain that they move freely and do not leak. If a leak is found, remove and replace the override valve.

p. Low oil temperature. After flight the pilot reports an abnormally low oil temperature. Engine operation and all the other instrument indications are normal.

(1) INSUFFICIENT BLANKETING OF OIL COOLER. Some heat is necessary for the efficient operation of the engine. To retain some of the heat during engine operation and to prevent overcooling, a covering or blanket is placed over one end of the radiator core to restrict air flow through the core. If the amount of blanketing used proves insufficient, increase the area of blanketing to maintain proper temperature.

(2) DEFECTIVE OIL-COOLER SHUTTER CONTROL. Low oil temperature may result from an inoperative or improperly set thermostatic valve assembly. When the charge is lost from the bellows, the safety release operates. The bellows and valve are held down on the seat, acting as a spring-loaded relief valve. This results in overcooling of the oil. If this has occurred, replace the oil temperature regulator.

(3) DEFECTIVE TEMPERATURE INDICATOR. Check the electrical connections at the gauge and at the point of installation on the engine. (See k(8) above.)

q. Low reading on cylinder head temperature gauge. During warmup, it is noted that the cylinder head temperature is below that specified for the engine. Other instrument indications are normal.

(1) POOR CONNECTIONS. The location of faulty connections may lie in either the binding posts, thermocouple, or at the indicator. These terminals should be clean and tight.

(2) SHORT CIRCUIT. Leads, thermocouple, and the indicator binding posts should be examined to see that they are in good condition. Repair any trouble if found in the system.

(3) INCORRECT SETTING. Reset the zero corrector shift and check the setting against the correct value secured from operations.

r. Excessive cylinder head temperature. When operating the engine, it is noted that the cylinder head temperature is near or beyond the specified limit. It is also noted that engine speed drops off just after being brought up to speed from idling. Rapidly rising indications are also noticeable on the other engine temperature gauges.

(1) PROLONGED GROUND OPERATION. Aircraft engines are designed to be cooled during flight, so lengthy ground checks should be avoided in order to maintain safe engine temperatures.

(2) INCORRECT SETTING OF COWLING FLAPS. The control must be adjusted to keep the flaps open during ground operation. Sufficient air flow over the finned cylinders is obtainable only during flight.

(3) EXCESSIVE MANIFOLD PRESSURE. Increases in engine temperature are closely related to increases in manifold pressure. Engines are built to withstand only certain pressures safely, therefore, operation above specified limits should be avoided as much as possible.

(4) CARBURETOR AIR-INLET TEMPERATURES TOO HIGH. The carburetor air-heater control should be placed in the full COLD position. If the valve leaks, hot air will enter the induction system and lean out the charge, overheat the engine, and eventually reduce the speed and power of the engine.

(5) LEAK IN INDUCTION MANIFOLD. This may cause excessive cylinder head temperatures by leaning the mixture. Examine the induction system. If leaks are found, make the necessary repairs.

(6) OVERHEATED OIL. When this condition is present, an indication should be recorded by the oil temperature gauge. Excessive oil temperature cannot be disregarded as a possible cause of an overheated condition of the engine.

(7) BROKEN OR DAMAGED FINS AND BAFFLES. Any change in the amount of cooling fins will affect the dissipation of excess cylinder heat. The disturbance of air flow over and around the cylinder may cause local hot spots as well as general overheating of the whole engine. Install the thermocouple on the cylinder and check the operating temperature. If this is found to be excessive, replace the cylinder. (This replacement is made only on orders from local authority.)

(8) RETARDED IGNITION. Due to the piston being farther down in the cylinder when the mixture is burned, more cylinder surface is exposed to the greater heat, thereby causing overheating of the engine. If this is the trouble, retime the engine.

s. Cylinder head temperature gauge registers atmospheric temperature. During the operation of a radial engine, it is found that all instruments except the cylinder head temperature gauge show satisfactory and desired indications. This instrument indicates atmospheric temperture, which is near 80°F.

(1) OPEN CIRCUIT AT INSTRUMENT BINDING POST. Examine the terminal connections for cleanliness and security.

(2) OPEN CIRCUIT AT THERMOCOUPLE CONNECTIONS. Faulty maintenance or engine vibration may have caused the connections to become loose or disconnected. Check the circuit and tighten all loose connections.

(3) BROKEN LEAD. A clean break can probably be blamed on engine vibration or swaying of the leads. Broken leads must be replaced; they cannot be spliced. Properly secure the leads at a number of intervals to eliminate swaying.

(4) DEFECTIVE INSTRUMENT. See k(8) above.

t. Excessive coolant temperature. During engine operation, high coolant temperatures are noted. They are accompanied by increases in engine and oil temperatures.

(1) COOLANT SHUTTERS CLOSED. Failure to observe ground operation instruction or faulty control linkage may be the cause.

(2) RESTRICTED AIR PASSAGE. Foreign matter in front of the opening will limit the amount of cooling air passing through the radiator. Check the front of the radiator for obstructions.

(3) INSUFFICIENT COOLANT SUPPLY. The coolant must be maintained at the proper level to obtain the correct degree of cooling. Check the coolant level and replenish if necessary.

(4) LEAK IN COOLANT SYSTEM. A leak may occur in the pump packing gland, lines, line connections, radiator, and in the cylinder assembly. If a leak is found, it must be repaired before flight.

(5) IMPROPER LIQUID USED. The engine is manufactured to meet certain requirements with a specified coolant as the heat dissipator. Any change in the quality of the coolant, medium will necessarily mean changes in the engine operating temperatures. If the system contains the wrong liquid, drain and refill with the correct kind.

(6) DEFECTIVE PUMP. The pump must at all times maintain a large capacity of coolant flow through the system at a low pressure. Any change in the coolant flow will affect the coolant and engine temperature. (See h(7) above.)

(7) DEFECTIVE GAUGE. See k(8) above.

u. High coolant temperature when operating at high altitudes. On a turbo-supercharged engine, excessively high coolant temperatures are recorded at high altitudes. A loss in coolant is noted when the airplane returns to the ground. After the coolant system has been replenished, a thorough ground check reveals satisfactory operation on the ground, but reptition of the trouble is reported after the next flight.

(1) CONTINUED OPERATION AT HIGH ALTITUDES. A loss of coolant may occur because ethylene glycol will boil at lower temperatures at extremely high altitudes.

(2) LEAKS IN SYSTEM. Because of the higher pressures in the line and the lower pressures at high altitudes, some connections may leak. The appearance of coolant in the vicinity of the leak will aid in locating it. Tighten all connections and replace defective hoses or fittings.

(3) DEFECTIVE PRESSURE RELIEF VALVE. Incorrect adjustment of the sniffler valve may cause the loss of coolant. Properly adjust the valve setting as directed in the Technical Order for the airplane.

v. Engine surging. With the controls in a fixed position, the engine operates as though the throttle were advanced and retarded intermittently. The tachometer and manifold pressure gauge reflect this fluctuation.

(1) DEFECTIVE THROTTLE VALVES. Throttle valves are sometimes damaged by violent backfire. If this is the trouble, replace the carburetor. Defective or disconnected throttle linkage may be the trouble. Carefully examine the linkage for damage and freedom of movement and repair or replace any defective parts.

(2) DEFECTIVE MANIFOLD PRESSURE REGULATOR. A defect in the regulator will cause surging. The throttle valves will oscillate, opening and closing intermittently. If this unit is defective, it must be replaced.

(3) FAULTY PROPELLER GOVERNOR. Dirt or carbon in the oil entering the constant-speed propeller governor may clog the small oil passages. A faulty governor pressure-relief valve, dirty contact points (electric propeller governor), or a galled metering valve will also cause faulty governor action. If any of these conditions are found they must be corrected or the governor removed and replaced.

(4) TRAPPED AIR IN PROPELLER GOVERNOR LINES. Air trapped in the oil system of the propeller causes "hunting" and surging of the governor. The propeller pitch will thus be constantly changing. Moving the control several times will eliminate air from the system and allow accurate governing and rapid response.

w. Unusual roughness. Extremely rough engine operation is accompanied by the following symptoms: an increase in cylinder head temperature; an erratic reading of the exhaust analyzer (movement of the mixture control to a leaner position fails to show a leaner mixture or causes the pointer of the instrument to move toward the richer side); and intermittent puffs of dense black smoke, often accompanied by sparks or glowing carbon particles. The additional symptoms of knocking and pinging sounds and a drop in manifold pressure are noted.

(1) LEAN MIXTURE OPERATION. A yellowish white flame, accompanied by backfiring at high engine speeds, precedes the symptoms given above. Weak or lean mixtures burn slowly. This causes engine temperatures to increase and results in detonation. Readjust the mixture control.

(2) OPERATION ABOVE SPECIFIED LIMITS. When the manifold pressure exceeds the limits of the octane rating of the fuel, detonation (an explosion of the mixture) results. Operation must be within the limits specified for the engine.

(3) EXCESSIVE CARBURETOR HEAT. The symptoms of this condition are similar to those listed in (1) above. They are generally accompanied by an increase in carburetor mixture temperature or carburetor air-intake temperature. Adjust the carburetor heat control to the proper position.

(4) LOW OCTANE-RATING FUEL. In addition to producing detonation, a low octane-rating fuel increases the fuel consumption appreciably. Drain the fuel system and refill with the correct fuel.

x. Engine suddenly stops. The power plant "spits and sputters" and suddenly cuts out. Prior to the failure, everything operated normally and there were no signs of malfunction.

(1) NO FUEL. Service the airplane fuel tanks.

(2) WATER IN SYSTEM. Water in the fuel system may cause only slight interruption of engine operation, but in some cases it may cause complete engine failure. Drain all fuel system screens and strainers.

(3) FUEL LINES TOO NEAR EXHAUST SYSTEM. The heat of the exhaust system will cause the fuel to vaporize in the line, thus restricting the fuel flow.

(4) SHARP BENDS IN LINE. Sharp bends are generally the spots where fuel may vaporize and form a vapor lock that will restrict the fuel flow to the carburetor.

(5) INSUFFICIENT COLD AIR CIRCULATION. Sufficient air must circulate around the engine and the fuel lines to avoid vapor-locking tendencies.

(6) RESTRICTION IN LINE. See g(2) above.

(7) IGNITION DEFECTS. It is unusual for both magnetos to become defective at one time. An ignition defect would have to occur at a point where both magnetos could become inoperative. Check the ignition switch and the ground leads. Trouble shoot in the ignition only after the above possibilities are eliminated. (See ac(5) below.)

y. Backfiring through carburetor. It was reported that continual backfiring through the carburetor, abnormal vibration, and an increase in engine temperature interfere with engine operation during flight. When the engine was ground checked, the same symptoms plus occasional bursts of flames in the carburetor intake were present. This condition is similar to backfiring experienced when starting a cold engine. If trouble of this nature is allowed to occur repeatedly, it may result in serious fire hazard and engine failure.

(1) LEAN MIXTURES. Because of its slower rate of burning, a lean charge may continue to burn after the intake valve opens. This will set fire to the incoming charge before it enters the combustion chamber and thus cause exploding back through the carburetor.

(2) INSUFFICIENT FUEL DISCHARGED FROM CARBURETOR NOZZLE. Insufficient supply or low fuel pressure is the same as a lean mixture. The reaction is also the same. (See (1) above.)

(3) DEFECTIVE OR EARLY IGNITION TIMING. When a defect occurs in the ignition system that permits the spark to reach the charge at a time when the intake valve is open, the mixture is ignited, causing an explosion through the intake manifold. If this is the trouble, the engine must be retimed.

(4) INTAKE VALVE NOT CLOSED COMPLETELY. Perfect closing of the intake valve is necessary to maintain proper compression pressure and power. When this valve does not close completely, the hot burning charge is permitted to escape into the intake manifold. This ignites the fuel particles there. Some of the causes of a faulty intake valve are warped, sticking, or gummed valve stems, worn and pitted

valve seats and valve faces, embedded carbon particles, foreign particles between the valve face and seat, and insufficient clearance between the rocker arm and valve stem.

(5) EXHAUST VALVE OPENS LATE AND CLOSES EARLY. When this condition exists, all of the hot exhaust gases cannot escape. The carbon dioxide in the exhaust gases left in the combustion chamber mixes with the fresh charge, thus creating a slower burning mixture. To remedy this condition, adjust the valve clearances.

(6) INCORRECT VALVE TIMING. It is not very likely that the valve timing order may change once it is set at overhaul. When an engine is not properly operated and suffers intense backfires, it is possible that correct valve timing may be changed because of extremely high pressures exerted on the engine. If this condition exists, an engine change should be recommended.

z. Backfiring through exhaust. Continual backfiring interferes with normal engine operation and increases in engine temperature are evident. The condition was reported as occurring during flight and prevails at a ground check. This condition may be more noticeable when the throttle is retarded suddenly.

(1) MIXTURE TOO LEAN. A weak or lean mixture burns at a slower rate than a correct fuel-air charge. Therefore, the mixture will still be burning when the exhaust valve opens and the burning mixture will escape into the collector ring. Readjust the mixture control lever to obtain a richer mixture.

(2) MISFIRING OF CYLINDERS. If the charge in any cylinder is not ignited it will enter the collector ring and be ignited by the hot exhaust gases. This trouble is usually caused by defects in the ignition system. Any malfunction, which produces a weak spark or no spark resulting in partial burning or no burning of the charge, can be found by trouble shooting in the ignition system.

(3) EXHAUST VALVE CLEARANCE INADEQUATE. When too little clearance is provided between the rocker arm and the valve stem, the exhaust valve is held open, permitting the burning mixture to escape into the exhaust manifold. Check the valve clearances and adjust them as specified in Technical Orders.

(4) LATE IGNITION TIMING. Late timing or retarded spark means that the spark to ignite the mixture occurs after the specified time. If this spark is delivered as the exhaust valve opens, combustion will occur in the exhaust collector ring. Check the ignition timing and make the necessary adjustments.

(5) DEFECTIVE VALVE SPRINGS. If the exhaust valve springs become weak or broken from heat and use, part of the charge is allowed to escape into the exhaust, because the valve is not drawn tightly on its seat. Report this condition to the engineering officer.

(6) EXHAUST VALVE LEAKAGE. Leakage through the exhaust port may be due to sticking or gummed valve guides, warped valve stems, pitted, worn, and improper valve seats, or embedded foreign particles between the valve seat and valve face. If any of these troubles are present, the valve wiil not seal the burning charge in the cylinder. Check the compression of each cylinder and report the information to the local authority.

(7) INCORRECT VALVE TIMING. See y(6) above.

(8) MECHANICAL OR STRUCTURAL DEFECTS. A broken impeller will be indicated by noises and low manifold pressure. A slipping drive clutch is indicated by a low reading on the manifold pressure gauge. An engine change will be recommended by local authority.

aa. Operation rough at idling speed. At ground run-up, power plant operation is found to be rough at idling speeds. There are no signs of backfire or "popping back" in the carburetor or exhaust. The roughness disappears at higher speeds. All temperature and pressure gauges record normal readings. A magneto check indicates satisfactory operation at higher speeds.

(1) IMPROPER SETTING OF IDLE MIXTURE (IDLE SPEED) ADJUSTMENT. Movement of this adjustment controls the mixture for idling speeds only. Turn the adjustment in the direction which permits more fuel to the carburetor, and note whether this improves running conditions. If so, move the adjustment one more notch toward the rich side; if not, reverse the direction of the adjustment until smooth running is obtained. This adjustment must be made when the engine is warm.

(2) DEFECTIVE INTAKE MANIFOLD. Any leak in the induction manifold causes rough operation and high engine temperatures because the mixture is made lean. (See a(3) above.)

(3) THROTTLE VALVE CLOSING TOO FAR. The throttle valve is never entirely closed when the throttle is in the full retarded position. When the cockpit control lever is completely retarded the throttle valve stop is so adjusted that a small quantity of air will enter the induction system and engine will idle evenly.

(4) IMPROPER VALVE CLEARANCES. If the valves are adjusted to open too soon or too late, the engine will not absorb the full power of the charge because some of it will escape. Also, if part of the charge remains, it will affect the combustion process. Adjust the valve clearances.

(5) POOR COMPRESSION. Poor compression may cause the engine to "jerk" at low speeds. If this trouble is present, it may be impossible to get smooth running with any fuel-air mixture. Check the pressure (with a compression gauge) of each individual cylinder and report the findings to the engineering officer in charge.

ab. Engine operating on one magneto. The flight report states that the engine operated with a loss in power and a tendency to overheat. During a ground run-up, the engine operates on one magneto but stops when switched over to the other. The power plant is stopped in order to avoid further danger of overheating and detonation. Because the malfunction affects all cylinders, it is classified as general and therefore exists somewhere between the distributor and the inoperative magneto.

(1) DEFECTIVE GROUND LEAD. If the insulation of the lead becomes burned or chafed and the lead makes contact with the airplane structure, the magneto will be grounded. The lead may be checked by disconnecting the ground connection and operating the engine. If it runs satisfactorily, install a new ground lead.

(2) POINTS NOT CORRECTLY ADJUSTED. If the magneto contact points are set so that they do not open or so that they do not close, there will be no spark at the spark plugs. Adjust the contact points.

(3) WORN OR PITTED BREAKER POINTS. The contact points are made of platinum and do not oxidize easily. However, heat produced by arcing between the points will eventually cause pitting. If the contacts are excessively pitted or worn, in some instances remove and replace the magneto and in other cases they may be either replaced or properly dressed according to specific directions stated in Technical Orders.

(4) OIL ON CONTACT POINTS. A film of oil on the breaker assembly and points provides a path for the current to follow to ground. It will also cause burning of the contact points. Never overlubricate the magneto or these troubles will occur. Remove the excess oil with a flexible cleaner (a common pipe cleaener is ideal).

(5) DEFECTIVE BREAKER ASSEMBLY. A shorted or grounded breaker assembly or contact points will make the magneto inoperative. Consult the applicable Technical Order for the proper maintenance.

(6) DEFECTIVE CONDENSER. A grounded or shorted condenser affords the current a low resistance path to ground. This condition may be checked by removing the condenser and attempting to operate the engine. If the engine operates and there is excessive arcing at the points, install a new condenser.

(7) DEFECTIVE DISTRIBUTOR. A cracked or faulty distributor assembly permits carbon, dust, grease, and moisture to collect in the cracks, thus short-circuiting the high-tension current. Replace all defective parts.

(8) DEFECTIVE COIL. The insulation of the coil may in time break down because of excessive heat or high voltage. When the spark plug gap is too wide, an excessively high voltage is required to jump the gap because of the greater resistance. If the gap is wide enough, the spark may arc through the insulation instead of jumping the spark plug gap. Replace the coil if it is found to be defective.

(9) DEFECTIVE SWITCH. A contact grounding one magneto may be defective. Disconnect the ground lead at the switch and attempt to operate the engine. If the engine operates, replace the switch or ground lead connection.

(10) MECHANICAL DEFECTS. Mechanical defects may exist in such forms as worn or frozen bearings, a worn cam follower, armature out of round, loose screws, etc. If any of these conditions exist, remove and replace the magneto.

ac. Misfiring at high engine speeds only. Misfiring is present in all cylinders. Occasional "spits and sputters" are noticeable. Intermittent knocks or "pinging" noises are heard when the mechanic stands very close to the engine. A loss in speed and power accompanies rapidly rising engine temperatures.

(1) LEAN MIXTURE OPERATION. See w(1) above.

(2) IMPROPER GRADE OF FUEL. See w(4) above.

(3) RESTRICTED FUEL FLOW. A restriction in the line beyond the fuel pressure gauge take-off affects normal flow of fuel from the discharge nozzle, and yet will not affect the fuel pressure gauge reading. Disconnect the fuel line at the carburetor, start the booster pump (or wobble pump), and check the fuel flow. Inspect the main-line strainer and if dirt and foreign materials are evident, the whole system must be cleaned and flushed.

(4) IMPROPER SPARK PLUG GAP CLEARANCE. The resistance between the electrodes increases as the pressure in the combustion chamber increases. If the gap clearance is too great the resistance may reach a value (during operation at high speeds) which will cause misfiring. Remove the plugs and regap. Defective plugs must be replaced.

(5) IGNITION DEFECTS. If the trouble is not caused by any of the foregoing possibilities, check the ignition system. Examine the ignition harness for deterioration, inspect the distributor for cracks, check the coil by replacing it with one known to operate satisfactorily, and examine the contact points for proper adjustment. Repair or replace any parts found to be defective. If the contact points are found to be badly pitted, replace the magneto.

ad. Inability to obtain take-off rpm. During ground run-up, it is impossible to obtain take-off rpm even though the propeller cockpit control is in the FULL LOW PITCH position and the throttle lever is in FULL OPEN position. The engine is operating smoothly.

(1) THROTTLE VALVE LINKAGE DEFECTIVE OR OUT OF ADJUSTMENT. Check the throttle linkage for movement, and check the positions of the cockpit lever against corresponding positions of the butterfly valves. Make any necessary adjustments.

(2) EXTERNAL CONDITIONS. The full-throttle speed of an engine may vary under different atmospheric conditions. The plane's position on the ground in relation to wind direction will affect engine speed.

The airplane should be headed into the wind during all ground operation.

(3) CONSTANT-SPEED GOVERNOR OUT OF ADJUSTMENT. When the constant-speed unit is governing at an rpm lower than that which must be obtained for take-off, its action does not permit the propeller blades to move to their LOW PITCH position. To correct this condition, stop the engine and readjust the adjustable take-off rpm stop to give a higher rpm. In general, the LOW PITCH limits should be such that, with the propeller governor control in FULL LOW PITCH and the throttle FULL OPEN, the engine rpm will be that specified for take-off.

ae. Excessive take-off rpm. Prior to take-off, with the propeller control in its LOW PITCH position and the throttle wide open, more than take-off speed is obtained.

IMPROPER SETTING OF CONSTANT-SPEED GOVERNOR. The improper setting allows a higher take-off rpm than is specified. To correct this condition, pull the governor control lever slowly back until the tachometer indicates take-off rpm, then stop the engine. Without disturbing the cockpit control lever, fix the adjustable stop at the constant-speed governor to limit the rotation of the control shaft to this exact position. Then readjust the linkage so that the cockpit control lever is approximately 1/8 inch from its full forward position when the pin on the pulley is against the stop.

af. Rough operation and abnormal vibration. This condition is present at all speeds, but is more pronounced at high rpm. All other conditions are normal and no signs of misfiring are present at any speed.

(1) PROPELLER VIBRATION. If the propeller is "out of track," abnormal engine vibration will be created. Check the propeller. If any blade is "out of track" more than the specified amount, replace the complete unit.

(2) LOOSE MOUNTING. Broken or loose mounting bolts and worn rubber shock absorbers may cause erratic operation. The engine is permitted some freedom of oscillation, but it is limited depending on the type of installation. Tighten any loose mounting bolts. Examine the rubber absorbers for deterioration and replace when necessary.

(3) ENGINE MECHANICAL DEFECTS. A bent crankshaft or other mechanical defect which creates an unbalanced condition in the moving parts will necessarily mean an engine overhaul. Report the condition to the local authority.

ag. Engine fails to accelerate properly. When the throttle is moved quickly forward, the engine is slow in "picking up" speed, but with slow throttle movement, the engine operates satisfactorily at any desired rpm.

(1) FAULTY CARBURETOR LINKAGE. Faulty linkage may not allow the unit to travel freely and provide the necessary fuel needed for

quick acceleration. Examine the linkage for binding and slipping. Replace defective units and lubricate the bearings.

(2) DEFECTIVE ACCELERATING PUMP. The carburetor accelerating pump may not be adjusted to give the required full travel. A restriction of the fuel inlet to the accelerating pump may also cause this trouble. Replace the carburetor when either condition is evident.

(3) DEFECTIVE REGULATOR UNIT. Leaks into the air chamber of the regulator unit may be found by removing the drain plug at the bottom of the chamber. If fuel seepage is present, the complete carburetor unit must be replaced.

(4) CLOGGED AIR SCOOP. Birds and other foreign objects sometimes obstruct the opening in the scoop. This results in restricted air flow. Remove any foreign material which has collected on the air scoop screen or the carburetor intake screen.

ah. Failure to develop full power shortly after starting. Heavy clouds of black smoke and occasional bursts of red flame are noticeable from the exhaust. Engine operation is sluggish and the engine shows signs of "choking up." All temperature and pressure gauges indicate normal readings.

(1) MIXTURE TOO RICH. An overrich mixture contains insufficient oxygen to promote complete combustion. Readjustment of the mixture control will correct the situation.

(2) ENGINE TOO COLD. Heat is necessary to aid in the vaporization of fuel and to cause the engine parts to expand to their proper clearances. All cooling system units should be inspected for proper condition and operation.

(3) FUEL LEAKING FROM CARBURETOR. If the engine is equipped with a float type carburetor, a leaky float or faulty seating of the needle valve will cause a flooded condition. Remove and inspect the float. Consult the applicable Technical Order when float repairs are necessary. Examine the needle valve for proper seating and reseat if necessary.

ai. Misfiring at all engine speeds. Misfiring and abnormal vibration are noted at all engine speeds. All pressure gauges record normal readings but the temperature gauges indicated engine overheating. When the mixture control lever is moved, it has no effect on the condition except for a greater degree of misfiring as the control is moved toward LEAN. The operation check of each magneto does not reveal any changes in the symptoms which may aid in localizing the trouble.

(1) DEFECTIVE SPARK PLUGS. A weak spark will result in a retarded burning of the mixture. No spark allows the unburned fuel to explode in the collector ring. (See z(2) above.) Examine the spark plugs for condition and reset to proper gap clearances. Defective plugs must be replaced.

(2) FAULTY IGNITION HARNESS. Arcing from the ignition harness to the ground ("spark leak") will keep the high-tension current from reaching the spark plugs. This is due to the rubber insulation on the cables becoming old, hardened, and porous. Atmospheric dampness and moisture are likely to produce the same reaction. Replace all deteriorated leads.

(3) DEFECTIVE MAGNETO COIL. See ab(8) above.

(4) CRACKED DISTRIBUTOR. See ab(7) above.

(5) DEFECTIVE BREAKER CONTACT POINTS. Contact points should be kept clean and free from pits and burns in order to avoid added resistance to the flow of current. Examine the contact points for proper adjustment and readjust if necessary.

(6) MECHANICAL DEFECTS. Sticking valves which cause a lagging action, despite the pull of the spring, may be due to lack of lubrication, carbon deposit on the stem, warpage, or bending of the stems. Loss in compression may result from loosely mounted spark plugs. A cracked cylinder or piston are other possibilities.

aj. Engine operates roughly at high speeds. Engine operation at high altitudes and at high power output is reported to be abnormally rough. The engine is found to operate satisfactorily at lower speeds. Ground run-up reveals that all pressure and temperature gauges give normal readings. Operation at low and medium engine speeds is satisfactory. At maximum permissible rpm and manifold pressure, the engine shows signs of misfiring intermittently.

(1) DEFECTIVE SPARK PLUGS. Too wide a spark plug gap will allow the engine to operate satisfactorily at low and medium speeds, but because of the added resistance induced by the higher pressure, rough running will result at high speeds. (See ai(1) above.)

(2) DETERIORATED IGNITION WIRING. See ai(2) above.

(3) DEFECTIVE DISTRIBUTOR. Minute cracks in the distributor may allow high-tension current to "leak" only when the engine is operating at high power output. To check the distributor, replace it with one known to operate satisfactorily and recheck engine operation.

ak. Loss in power and speed. The engine suddenly loses speed and "sputters" during flight. Carburetor mixture records 0°C. Exhaust characteristics are normal.

(1) CARBURETOR ICING. Ice will often form in the carburetor and cause the engine to lose rpm. Ice formation has the same effect as suddenly closing the throttle and choking the engine. This condition can be corrected by careful application of carburetor air heat. (See par. 4g.)

(2) DEFECTIVE IGNITION HARNESS. See ai(2) above.

(3) STICKING VALVES. Overheating an engine by operating it above the specified limits may cause warping, binding, and sticking of

the valve stems in the guides. Excessive heat also causes the valve stems to become coated with carbon and thus produces a "gummed up" condition. Report the condition to the local authority.

al. Failure to develop full power. During operation, operating conditions are normal for the power and speed obtained. However, forward movement of the throttle lever does not effect an increase in engine speed.

(1) DEFECTIVE THROTTLE LINKAGE. Faulty linkage will not allow full opening of the butterfly valves. Examine the control linkage thoroughly and repair or replace any damaged or defective parts. Most recent types of airplanes incorporate an automatic device which will set the throttle valve at a predetermined position in case of complete failure of the throttle control linkage.

(2) CLOGGED AIR SCOOP. See ag(4) above.

am. Throttle sticking. A tendency of the throttle to stick is noticed when the air temperature is around 0°C. (32°F.) and the relative humidity is high. The engine begins to operate roughly and there is a drop in manifold pressure.

(1) THROTTLE ICING. Ice formation in the adapter at the fuel nozzle or on the butterfly valves will restrict the movement of the throttle. If ice is forming in the carburetor, an indication of low temperature on the air or mixture thermometer will accompany the foregoing symptoms. Icing is eliminated by proper application of carburetor air heat or alcohol de-icing. (See par. 4g.)

(2) DEFECTIVE THROTTLE LINKAGE. Check the units of the throttle linkage to be sure that full movement of the controls in the cockpit results in full movement of the butterfly valves. Remove and replace any faulty unit and lubricate the bearings to insure free movement.

an. Steady gray smoke stream from exhaust. During operation of an engine a light bluish gray (or white) smoke accompanied by a distinctive odor of burning oil is present. A check of the flight report reveals that the pilot noted a gradual decrease in oil pressure accompanied by a steady increase in engine temperature. The engine's Maintenance Inspection record shows that the rate of oil consumption has gradually increased since last overhaul.

(1) INCORRECT GRADE OF OIL. Oil of a low viscosity will easily escape around the rings and into the combustion chamber. In addition, a low grade of oil will usually have a low flash point. (See k(3) above.)

(2) WORN PISTON RINGS. When the piston ring expansion force becomes insufficient to hold the ring firmly against the cylinder wall, oil will pass between the cylinder wall and the worn ring. To check the condition of the rings, pull the propeller through and observe the "feel" of compression. This will give an approximate indication of the condition. An accurate pressure reading may be obtained by installing a compression

in the spark plug hole. Overhaul is necessary to remedy this tion.

VORN CONNECTING ROD BEARINGS. Loose and worn ngs permit an excessive amount of oil to be sprayed on the cylinder The piston rings will not return all of the oil to the scavenging n, therefore much of it will be swept into the combustion chamber urned.

OIL TEMPERATURE TOO HIGH. Any condition which per- the engine temperature to increase will normally be indicated by the ments. When an overheated condition exists, the sealing ability of ngs is reduced, because heated oil becomes thin. Check the entire oling system and eliminate all defects.

EXCESSIVE OIL PRESSURE. High oil pressure causes a large nt of oil to be splashed and sprayed on the cylinder walls. (See bove.) To correct this condition, adjust the relief valve to main- he specified pressure recommended for the particular engine. This tment must be made when the engine and oil are at normal operating rature. Consult the Technical Order for the engine for specific ions concerning the oil pressure relief valve setting.

DEFECTIVE SCAVENGING SYSTEM. Too much oil in the case allows an excessive amount of oil to be thrown on the cylinder and therefore increases the amount of oil that seeps into the com- n chamber. Examine the oil in the tank; if it is found to be d with excess foam, there is probably some defect in the scavenging n. Correct any defect in the external portion of the system. In- l defects will necessitate an engine change.

OVERDILUTION. See k(6) above.

DEFECTIVE SUPERCHARGER OIL SEALS. A faulty super- ger seal permits the oil of the lubrication system to seep into the charger and be mixed with the fuel-air charge. Engine overhaul is ssary to remedy this condition.

CLOGGED SUPERCHARGER VENT. If the supercharger vent (on one type of engine) is clogged, oil will be forced through the ercharger seal and into the supercharger and the induction system. ck the supercharger vent by blowing through it. If air does not pass ugh it freely, remove some of the packing wool until free air passage ssured.

) PISTON RINGS INCORRECTLY INSTALLED. If the wiper s are inverted on the piston during assembly, oil from the cylinder will be forced upward into the combustion chamber. Oil system sure may remain normal until the supply becomes insufficient.

o. Heavy black smoke from exhaust. Rich mixtures are indi- d by heavy puffs of black smoke, a dark red flame coming out of the aust stacks, and an odor of raw fuel. (See fig. 14.) (On installations equipped with a collector ring there may be an absence of the red flame.) This condition is accompanied by uneven operation, "galloping" or "loping" of the engine, a loss in power, and an eventual increase in fuel consumption. Overheating will usually occur only when the power is considerably reduced.

(1) MIXTURE CONTROL SETTING TOO RICH. Operation of the airplane at high altitude with mixture control set in FULL RICH position creates an overly rich mixture because the air is less dense than at sea level. Readjust the mixture control for a leaner mixture.

(2) PARTIALLY CLOGGED INDUCTION MANIFOLD. Excessively rich mixtures are present because the air flow is restricted so that sufficient air cannot enter the system.

(3) PRIMER PUMP IN "ON" POSITION OR LEAKING. An unlocked priming pump allows fuel to be drawn into the combustion chamber during the downward movement of the pistons. Be certain that the pump is placed in the OFF position during engine operation. In case of leaks, check the pump packing and the locking mechanism. If found defective, replace the pump.

(4) FUEL PRESSURE TOO HIGH. In addition to the symptoms stated, if the fuel pressure gauge functions properly, an indication of excessive pressure will be shown on the gauge. In case of a defective instrument and maladjusted relief valve, replace the instrument and adjust the relief valve to obtain desired pressure.

(5) MECHANICAL DEFECTS. Some mechanical defects that may also cause this trouble are: economizer set to open too early, float level too high, jets too large, and air bleeds too small or clogged. Any trouble of this nature will allow too much fuel to flow into the induction system. If any of the foregoing troubles are found, replace the carburetor.

ap. Low voltage reading. The engine is operating at the rated rpm but the voltage is below the desired amount. The generator main line switch is in the OFF position, and temperature and pressure indications are normal.

(1) LOOSE OR DIRTY CONNECTIONS. Poor connections add resistance to the circuit and thus cause a voltage drop. All connections must be clean and sufficiently tight to insure good contact.

(2) FAULTY VOLTAGE REGULATOR. Check the generator voltage output. Place the generator main-line switch in the OFF position and remove the voltage regulator from the mounting base. Connect the power terminal (the lead from the armature—marked A on some types of generators, B on other types) to the field terminal (F+ or A). Increase the generator speed slowly and watch the voltmeter on the instrument panel. If the voltage builds up to approximately the desired voltage with the engine speed less than rated rpm, the generator is satisfactory and the regulator should be checked. Decrease the speed, remove the test

lead between the two terminals, install and adjust the voltage regulator as specified in Technical Orders, or replace the unit.

(3) BINDING BRUSHES. Brushes should move freely in their holders. Remove and clean binding brushes, preferably with an unleaded fuel.

(4) LOW BRUSH SPRING TENSION. Brush springs become weakened with age and use. A spring balance is used to check the springs. (See fig. 79.) Adjust spring tension to the proper setting as

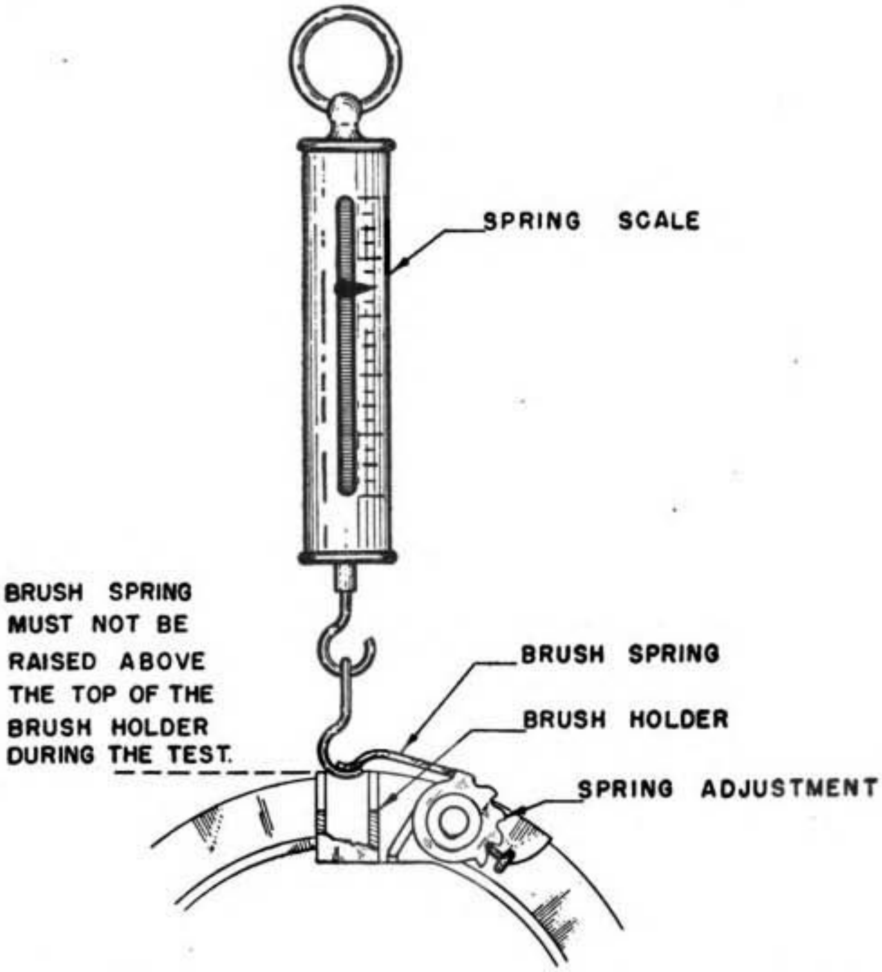

Figure 79. Testing the spring tension of generator brush springs.

given in Technical Orders. If readjustment is not possible, replace the generator.

(5) WORN-OUT BRUSHES. If brushes are found to be worn to less than the minimum allowable length, they must be replaced. To seat a new generator brush against the commutator, insert a piece of No. 000 sandpaper or 7–0 garnet paper (do not use emery cloth) between the brush and the commutator (with the sanded side next to the brush). Pull the sandpaper in the direction of rotation, being careful that it is kept against the surface of the commutator. Repeat the operation until the brush is seated. Blow dust out with compressed air.

(6) DIRTY OR DEFECTIVE COMMUTATOR. When the co mutator is found to be rough or dirty, clean and smooth with No. 0 sandpaper, and blow the dust out with compressed air. If the co mutator is badly scored or eccentric, remove and replace the generato

(7) WRONG OR FAULTY CONNECTIONS. Check the extern circuit between the generator, the control panel, and the voltmet against a diagram of the airplane's electrical circuit, being certain th all leads are properly connected to the correct terminals.

(8) BROKEN OR DISCONNECTED LEADS. Check all leads b tween the generator, the control panel, and the voltmeter. If defecti restore them to the proper condition.

(9) FAULTY OR DAMAGED VOLTMETER. Check the readi and lightly tap the glass with the finger tips if pointer shows indicati of sticking. To check the instrument, replace it with one known to fun tion correctly. If a test voltmeter is available, connect one lead to t power (armature) terminal (A+ or B) on the regulator and atta the other lead to the ground. If voltage is indicated it shows that t generator is operating satisfactorily and indicates a defective instrume on the panel. Replace the unit.

(10) INTERNAL DEFECTS OF GENERATOR. If the generat has an internal defect not listed in the foregoing paragraphs it must replaced.

aq. Zero indication on voltmeter. The engine is operating rated rpm but no voltage is indicated on the voltmeter. The generat main-line switch is in the OFF position. Normal readings are record by the other instruments.

(1) LOSS OF RESIDUAL MAGNETISM. Leave the generat main-line switch in the OFF position and remove the voltage regulat from the mounting base. Remove the connector plug at the generato Place one lead of a test voltmeter on the armature terminal of the ge erator (marked B on some types of generators and A+ on others Attach the other test lead to the ground terminal E or A—. A readi of ½ to 2 volts should be obtained. If the foregoing reading is not o tained, the cause may be due to a loss of residual magnetism and it wi be necessary to flash the field of the generator. If the generator r peatedly loses its residual magnetism, replace the generator.

(2) All troubles, causes, and remedies listed in as above are applicable.

ar. Excessive voltmeter reading. A warm-up check at rated rp reveals an excessive reading on the voltmeter although engine operatio is normal. (Excessive voltage is not caused by a defective generato but it does result from a maladjusted or defective voltage regulator.)

(1) VOLTAGE REGULATOR NOT PROPERLY ADJUSTE The voltage regulator automatically regulates the voltage by controlli the amount of resistance inserted into the field circuit of the generato

To adjust the regulator, place the generator main-line switch in the OFF position so that the adjustment is made at "no load" (no electrical units operating). Connect a *precision test voltmeter* in the circuit as directed in the Technical Order. For some types of regulators the engine must be operated for a definite length of time in order to allow for the warming up of the unit. Set the engine throttle to obtain approximately rated rpm. Then check the voltage reading and proceed to set the voltage regulator adjustment (follow directions as specified in Technical Orders) to obtain a reading of 14.25 volts for a 12-volt system or 28 volts for a 24-volt system. Reduce the speed of the engine and then raise it to rated rpm and note the reading on the voltmeter. The indication should remain constant at any speed after that voltage is reached. Except in an emergency, the voltmeter located on the generator instrument panel of the airplane should never be used to adjust the regulator because it is only put on the panel to indicate that the generator is producing voltage.

(2) SHORT CIRCUIT BETWEEN ARMATURE AND FIELD TERMINALS. An internal short circuit between these terminals or a short between the two wires will allow the current to flow directly through the field coil instead of following the normal path through the regulator coil and the resistor. This increases the field strength and results in an excessive voltage output. A continuity tester cannot be used to check for an internal short in the generator between the field positive A or F+ and the generator positive B or A+, since both the armature and the field are connected together inside the generator. Shut off the engine, remove the voltage regulator, and remove the cannon plug. Using a continuity tester, check for shorts between the positive field and armature positive leads from the generator cannon plug to the voltage regulators. Replace all defective leads. (If an ohmmeter is available, check the resistance of the internal circuit between the field positive and the generator positive. Consult Technical Orders for the specified resistance. Replace the generator if the check reveals internal generator trouble.)

(3) FAULTY VOLTAGE REGULATOR. See ap(2) above.

(4) DEFECTIVE INSTRUMENT PANEL VOLTMETER. See ap(9) above.

as. Fluctuating voltmeter needle. The generator is operating at rated rpm and generator main-line switch is in the OFF position. All instruments record normal or desired reading with the exception of the voltmeter, which fluctuates excessively.

(1) FAULTY CONNECTIONS. Engine vibration will cause loose connections to vibrate. This causes variations in the resistance in the system, thereby causing the voltmeter needle to fluctuate. Tighten all loose connections.

(2) ARCING AT BRUSHES. When this condition exists, the probable causes listed in ax below should be checked.

at. Off-scale reading on voltmeter. The generator is operating at the rated rpm, but the voltmeter needle moves in the wrong direction. Engine operation is normal.

POLARITY OF GENERATOR IS REVERSED. If the polarity of the generator is reversed, the direction of current flow through the voltmeter will be reversed. This will cause the needle to move in the wrong direction.

au. Generator not charging battery. An inspection after flight reveals that the battery is not maintained at its full state of charge. It is known that the generator main-line switch was in the ON position during flight.

(1) ELECTROLYTE LOW. The liquid content of the battery should be about 3/8 inch above the top of the plates. Drinkable water may be added to the battery if distilled water is not available.

(2) DEFECTIVE BATTERY TERMINAL CONNECTIONS. Battery terminals must be kept clean and free from corrosion. The greenish white growth so often found on the terminals is usually due to acid leakage, caused by overfilling of one or more cells. Corrosion may be removed by using a solution of baking soda or diluted ammonia. Apply a light coat of vaseline or petroleum to retard further corrosion.

(3) REVERSE-CURRENT RELAY POINTS OUT OF ADJUSTMENT. If the relay points cannot close, the line remains open and the generator is unable to charge the battery. Make the correct adjustment by following the directions given in the Technical Order for the installation.

(4) DAMAGED OR WORN-OUT BATTERY. Examine the external surface of the battery for cracks, defects, etc., which would allow the electrolyte to escape. A damaged or worn-out battery must be replaced.

av. Excessive arcing at generator brushes. The generator is operated at or near maximum output. After removal of the cover plate, it is noted that excessive arcing is present between the brushes and the commutator.

(1) POOR CONNECTIONS. Faulty electrical connections sometimes leave the evidence of arcing in the form of burned and pitted commutator bars. Examine all connections. Correct all defective external connections. If defective internal connections in the generator are evident, replace the generator.

(2) BRUSHES WORN TOO SHORT. When the brushes are too short to be held against the commutator, a gap is provided across which a spark will jump. (See ap(5) above.)

(3) BINDING BRUSHES. See ap(3) above.

(4) LOW BRUSH SPRING TENSION. See ap(4) above. The spring tension is tested by means of a spring scale. (See fig. 78.) Too little spring tension on the brushes causes them to "float" and the result is an arcing that creates undesirable heat resulting in the melting of solder and burning of the commutator. If the springs cannot maintain tension, replace the generator.

(5) DIRTY OR DEFECTIVE COMMUTATOR. See ap(6) above.

(6) CONTROL PANEL UNITS OUT OF ADJUSTMENT. When the charging rate is too high, arcing is produced between the brushes and commutator. This often raises the temperature of the commutator enough to cause the solder to be melted and slung out. See ap(2) above.

(7) IMPROPER GENERATOR AND CONTROL PANEL CONNECTION. The voltage regulator must be correctly connected in the system to allow the regulator to insert more or less resistance in the generator field circuit. Check the wiring of the circuit against the electrical wiring diagram of the airplane electrical system.

(8) SHORT CIRCUIT BETWEEN ARMATURE AND FIELD TERMINALS. See ar(2) above.

aw. Generator throwing solder. A burning odor is present. After the cowling is removed, the external surface of the generator is found to be hot. Upon removing the cover plate, evidence of melted solder is seen in the generator.

EXCESSIVE ARCING AT BRUSHES. See aw above.

ax. Ammeter indicates discharge. After flight, the condition of the engine was reported satisfactory. At ground run-up in preparation for the next flight, with the generator main-line switch in the ON position, the ammeter indicated discharge only when the power plant was idled and at low speeds.

REVERSE-CURRENT RELAY POINTS STUCK. Normally the relay points are open. When the generator is operating, the contacts close and permit current to flow to the battery for charging purposes. When the generator output is below the output of the battery, the points open and prevent the current flowing from the battery to the generator. Clean the contact points with an India oilstone, and polish the surfaces with an Arkansas oilstone. Never use oil on the stones for this operation. Clean the contacts with carbon tetrachloride and adjust them. If the above does not remedy the trouble, replace the relay.

ay. Propeller will not unfeather. On an airplane equipped with Hamilton hydromatic propellers, a propeller was feathered during flight. The operator, following correct procedure, discovered that the unfeathering operation could not be performed. At a ground run-up check, the mechanic finds the same conditions.

(1) DISCHARGED BATTERY. Sufficient battery voltage is necessary to operate the feathering pump in order that full pressure may be

supplied to the propeller unit for unfeathering. An approximate bat check may be made by operating other motors on the airplane. Rep the battery if it is in a low state of charge.

(2) DEFECTIVE CONTROL UNITS. Check the switch by c necting a heavy jumper across its terminals. If it is defective, it m be replaced. Examine all leads and terminals for cleanliness and tig ness.

(3) DEFECTIVE GOVERNOR CUT-OFF VALVE. If the gov nor cut-off valve is defective, it may allow auxiliary oil pressure to l back through the governor into the engine oil system. If this occu the auxiliary oil pump may be unable to deliver sufficient oil pressure the outboard side of the piston. If the cut-off valve leaks, replace governor unit.

(4) DEFECTIVE DISTRIBUTOR VALVE ACTION. Excess spring tension at the distributor valve will restrict the movement of valve unit, and thereby restrict the flow of oil to the outboard end the dome. If this condition is suspected, replace the distributor va assembly.

(5) RESTRICTION IN FEATHERING LINE. Oil lines so times become clogged at the fittings. Remove the line and inspect interior for obstructions. If the trouble is caused by dirt, sludge, or ot foreign substances in the oil, flush the system and refill it with new o

(6) DEFECTIVE FEATHERING PUMP. A "frozen" bearing other defect of the pump prevents oil under pressure being supplied the cylinder in order that the piston may be moved inward for the feathering operation. If this condition is suspected, remove and repl the pump.

(7) DEFECTIVE FEATHERING-PUMP MOTOR. If the pu motor is found defective, locate the trouble. Be certain to check complete system.

(8) EXTERNAL DOME LEAK. External damage to the dome s tion causing an oil pressure loss may usually be discovered by vis inspection. Propeller unfeathering is impossible when excessive leaka exists. Defective gaskets may be replaced by the line mechanic, but da age requiring replacement of the dome will necessitate replacement of complete propeller assembly.

(9) INTERNAL LEAK IN DOME. This may result from a def tive piston gasket. Replacement of the propeller unit is necessary.

ba. Sluggish operation during change of propeller pitch. T pilot reports that the propeller reacted sluggishly to the movement of cockpit propeller control during pitch change. A thorough ground che reveals the same condition, although engine operation is normal.

(1) FAULTY GOVERNOR CONTROL CABLE. The general rangement and installation of the control cable linkage is such that

cable does not interfere with the other parts of the engine. When interference, broken strands, worn pulleys, or a defective or loose cable does not permit proper operation of the system, propeller control becomes erratic. Low tension and stretching of the cable may be caused by abnormal engine vibration or by interference which results in excessive backlash. Replace all defective units and check for full operation and freedom of movement.

(2) AIR IN PROPELLER OIL SYSTEM. Faulty propeller operation may be caused by air in the propeller oil system. Air, being compressible, causes a slower action of the pitch-in changing operation. Move the governor control through the quadrant several times to eliminate the air from the system.

(3) FAULTY GOVERNOR RELIEF VALVE. A governor relief valve stuck in the open position will cause a drop in the pressure available to operate the propeller, thereby causing sluggish pitch-changing action. Replace the governor if the trouble is located in this unit.

(4) STICKY PILOT VALVE OR FLY BALL. Faulty operation of the pilot valve or fly ball operation will affect the sensitivity of the constant-speed control and cause a delay in the correction of an "off-speed" condition. Check the pilot valve to see that it slides easily and inspect the fly balls to see that they rotate with the drive gear. The valve should also be examined to see that it is free from carbon.

(5) OIL LEAKAGE. Gaskets are provided to establish a seal between the dome and the propeller hub. If the dome head gasket leaks, the cylinder or dome will be covered with oil and it may drip from the head. Excessive leakage at the transfer rings when the pressure is correct will cause the propeller to shift normally from low pitch to high pitch, although the change from high pitch to low pitch is slow. This gets worse as the engine oil warms up and oil becomes thin. Replace the gasket and properly resafety the dome.

(6) LOW OIL PRESSURE. If this trouble occurs with a constant-speed propeller it may be caused by a defective pump in the governor. Low oil pressure in a controllable propeller may be caused by defects in the engine lubrication system. (See k above.)

(7) COUNTERWEIGHT BEARING DEFECTS. On engines equipped with Hamilton Standard two-position or constant-speed propellers, inspect the retainers and races for damage. Check the clearance between the counterweight brackets and the cylinders and examine the cap races for correct installation. If the parts are found to be defective, replace the propeller assembly.

bb. Oil leak at propeller dome. During a preflight ground check of an engine equipped with a Hamilton Standard hydromatic propeller the mechanic discovers that the dome, the adjacent parts of the propeller, and the engine are covered with engine oil. A pool of oil is found under

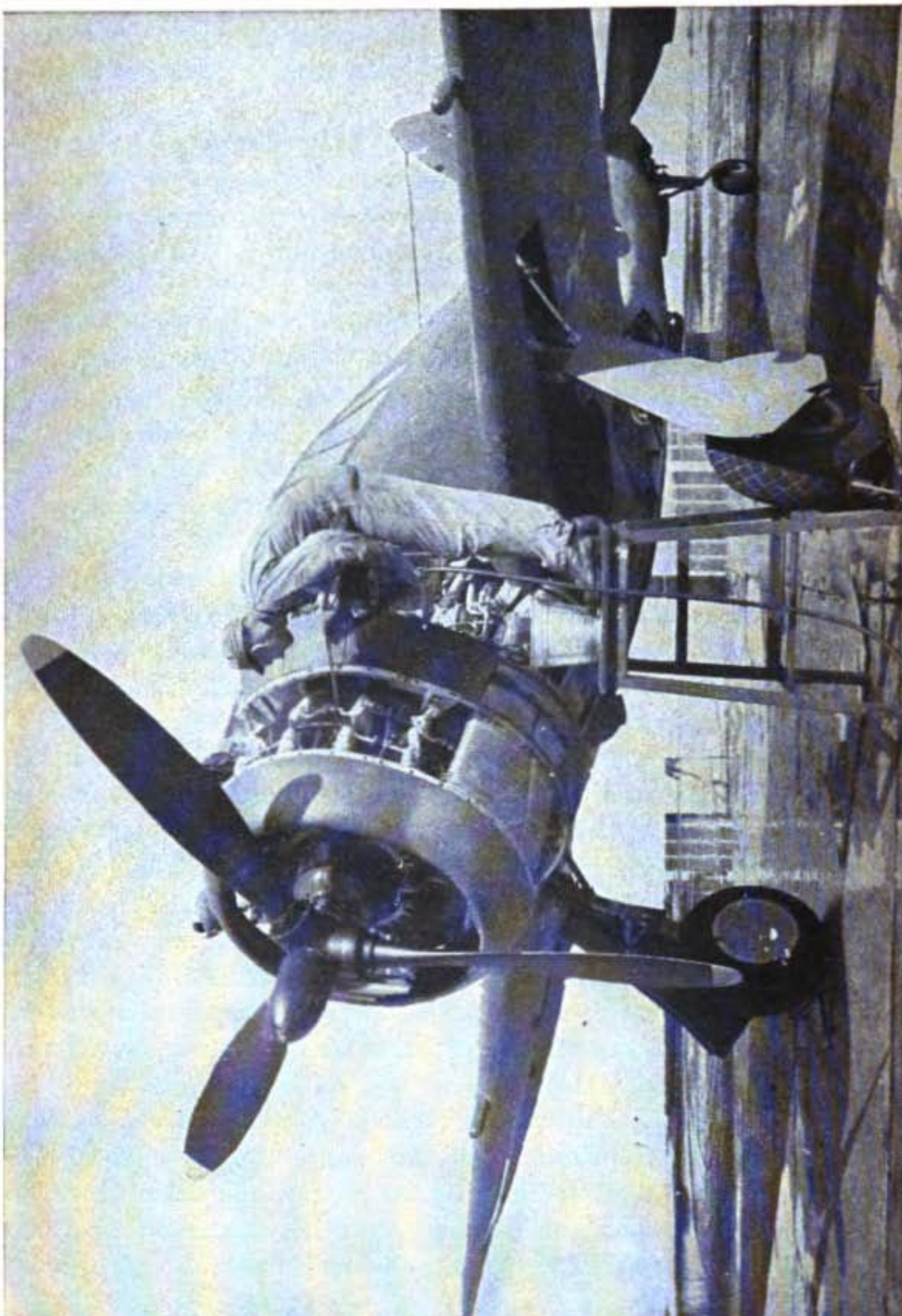

Figure 80. Cleaning the engine.

the nose section. (Fig. 80 shows a method of cleaning the engine after the trouble has been remedied.)

(1) DOME NOT TIGHT. The dome may not be tight enough to compress the gasket into an oiltight seal. Examine the dome for looseness and see that all fastening devices are properly safetied.

(2) DEFECTIVE DOME GASKET. A damaged, loose, or worn gasket will allow the oil to seep through. Remove and replace the gasket to correct this condition.

(3) LOOSE DOME SEAL NUT OR BREATHER CUP. If the leak occurs at this point it may be easily distinguished, because the dome will be covered with oil and oil may drip from the head after the propeller stops rotating. A tightening of the nut or cup, or replacement of the seal will usually correct the condition.

26. ENGINE STOPPING DIFFICULTIES. Most of the later type engines are being equipped with pressure type carburetors incorporating idle cut-off units. To stop an engine equipped with this type carburetor, set the mixture control lever in the FULL LEAN position. This will actuate the idle cut-off needle and restrict fuel flow to the carburetor. The symptoms of engine-stopping troubles are not difficult to analyze, but in many cases, carelessness in handling engine controls during stopping is a direct cause for the engine's failure to start. Proper operation of the controls and careful interpretation of the instrument readings will eliminate many stopping troubles.

a. Engine fails to stop. When the switch is placed in the OFF position, there is no change in operation. Operating on either the left or right magneto does not affect the rpm. All other instrument indications are normal. Cockpit control levers operate satisfactorily.

(1) BROKEN OR DISCONNECTED GROUND LEAD. One or both magneto ground leads may be broken or disconnected. When this condition is present the magneto cannot be grounded by the switch. The engine may be stopped by placing the mixture control in the IDLE CUT-OFF position or by placing the fuel selector valve in the OFF position. Check the lead and terminal connection, and replace if found defective.

(2) DEFECTIVE SWITCH. See paragraph 25ab(9).

b. Idle cut-off does not operate. During the preflight operation check, the ignition switch operation is satisfactory and the engine conditions are normal, but the engine will not stop when the mixture control lever is placed in IDLE CUT-OFF position.

(1) FAULTY CONTROL LINKAGE. Check the position of the manual mixture control to see that the control is correctly positioned in the IDLE CUT-OFF position. Examine the linkage for binding, disconnected parts, and for incomplete movement. Perform the maintenance required.

(2) MIXTURE CONTROL NEEDLE NOT SEATING PROPERLY. Remove the plug on the side of the fuel control unit, next to the cruise jet, and check to see if the washer seats in the IDLE CUT-OFF position. If not, replace the carburetor.

(3) INTERNAL CARBURETOR FAILURES. If the trouble is definitely located in the carburetor, remove and replace the carburetor.

c. Backfire through carburetor at stopping. When an engine equipped with a pressure type carburetor incorporating an IDLE CUT-OFF unit is stopped, it backfires violently through the carburetor intake. Experience has shown that when the backfires are intense, fire is often present after the engine ceases to function.

(1) THROTTLE MOVEMENT TOO FAST. Shutting off the fuel and opening the throttle too suddenly allows a blast of air to enter the induction manifold, and momentarily create a lean mixture. The lean charge continues to burn until the valve reopens, thereby causing a backfire through the induction system. Experiment in stopping the engine to determine satisfactory procedure.

(2) OVERHEATED ENGINE. An overheated condition of the engine will generally cause conditions explained in (1) above. It is recommended that the engine be idled with the mixture control in FULL RICH position to decrease the engine temperature before stopping.

d. Prior to stopping, engine "feels" as if it is operating under load. After the airplane (equipped with a hydromatic or electric propeller) lands and is returned to the hangar line, the engine "feels" as if it is operating under a braking load. The rpm is low for the throttle setting and the manifold pressure is higher than normal.

(1) PROPELLER IN HIGH PITCH. Check the propeller cockpit control to see if it is properly positioned. All hydromatic and electric propellers are stopped in LOW PITCH.

(2) DEFECTIVE PROPELLER CONTROL LINKAGE. After stopping the engine, examine the control linkage for binding, misalignment, defective cable, or broken pulleys. Perform the necessary maintenance and check for freedom of movement.

(3) DEFECTIVE GOVERNOR UNIT. If a defect is suspected in the governor unit, remove and replace the unit with one known to operate satisfactorily.

(4) MECHANICAL DEFECTS. Mechanical defects in the propeller are not necessarily frequent. If internal defects are evident or suspected, remove and replace the propeller.

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