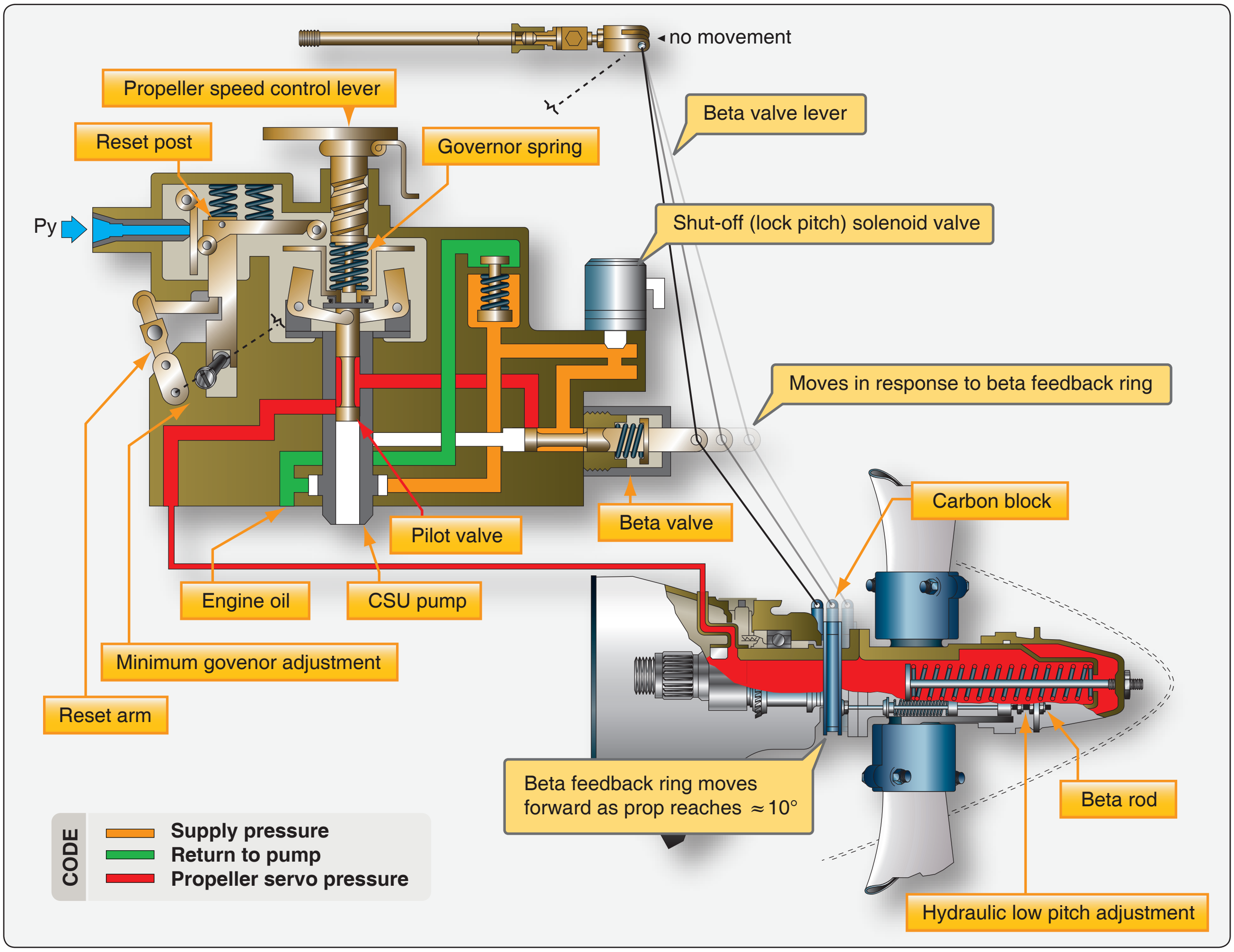


Figure 7-51. *Beta mode forward operation.*

The distributor valve or engine-shaft-extension assembly provides oil passages for governor or auxiliary oil to the inboard side of the piston and for engine oil to the outboard side. During unfeathering operation, the distributor shifts under auxiliary pressure and reverses these passages so that oil from the auxiliary pump flows to the outboard side of the piston and oil on the inboard side flows back to the engine. The engine-shaft-extension assembly is used with propellers that do not have feathering capabilities.

The hydromatic propeller *[Figure 7-55]* is composed of four major components:

1. The hub assembly,
2. The dome assembly,
3. The distributor valve assembly (for feathering on single-acting propellers) or engine-shaft-extension assembly (for nonfeathering or double-acting propellers), and
4. The anti-icing assembly.

The hub assembly is the basic propeller mechanism. It contains both the blades and the mechanical means for holding them in position. The blades are supported by the spider and retained by the barrel. Each blade is free to turn about its axis under the control of the dome assembly.

The dome assembly contains the pitch-changing mechanism for the blades. Its major components are the:

1. Rotating cam,
2. Fixed cam,
3. Piston, and
4. Dome shell.

When the dome assembly is installed in the propeller hub, the fixed cam remains stationary with respect to the hub. The rotating cam, which can turn inside the fixed cam, meshes with gear segments on the blades. The piston operates inside the dome shell and is the mechanism that converts engine and

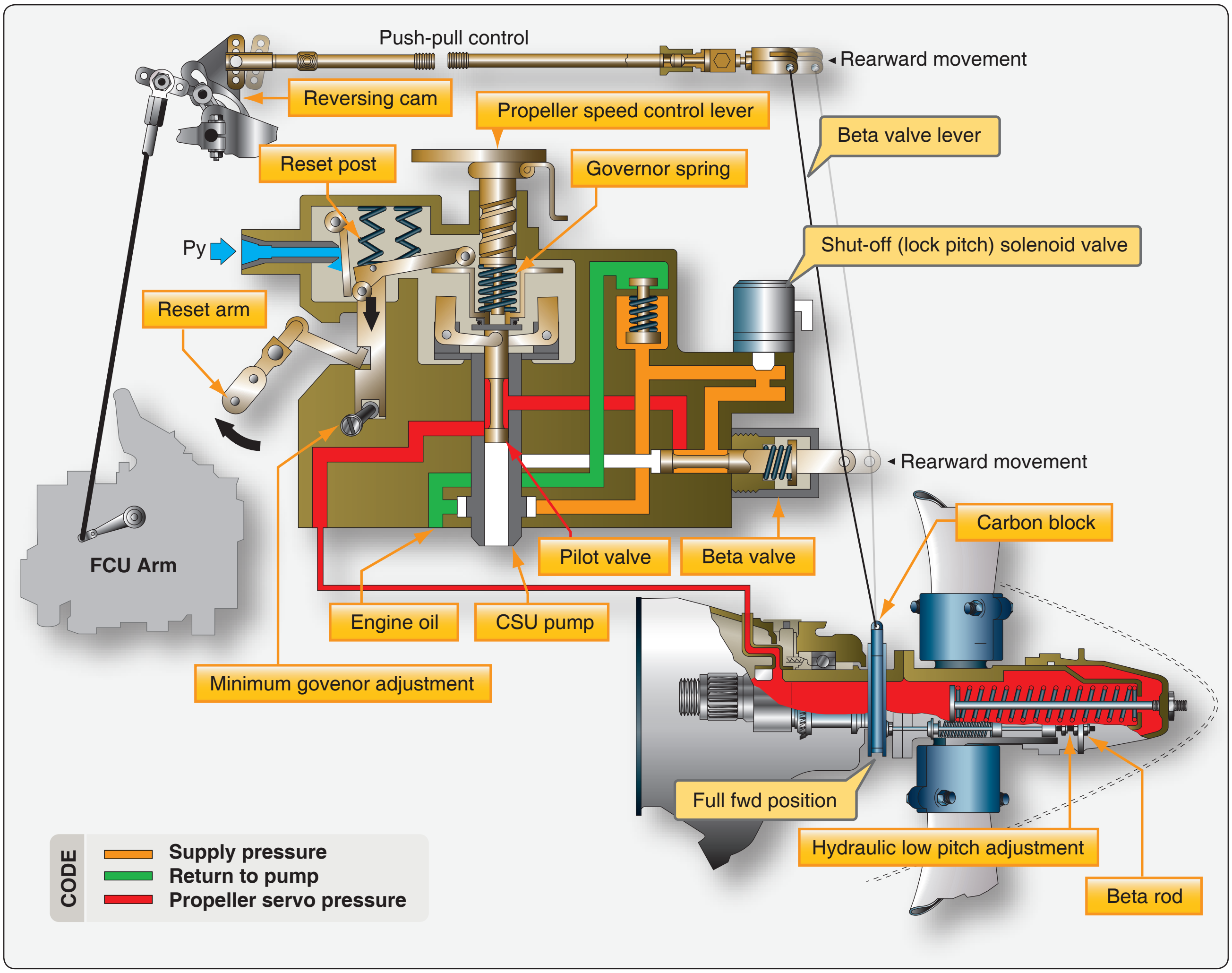


Figure 7-52. *Beta mode reverse operation.*

governor oil pressure into forces that act through the cams to turn propeller blades.

Principles of Operation

The pitch-changing mechanism of hydromatic propellers is a mechanical-hydraulic system in which hydraulic forces acting on a piston are transformed into mechanical twisting forces acting on the blades. Linear movement of the piston is converted to rotary motion by a cylindrical cam. A bevel gear on the base of the cam mates with bevel gear segments attached to the butt ends of the blades, thereby turning the blades. This blade pitch-changing action can be understood by studying the schematic in *Figure 7-56*.

The centrifugal force acting on a rotating blade includes a component force that tends to move the blade toward low pitch. As shown in *Figure 7-56*, a second force, engine oil pressure, is supplied to the outboard side of the propeller piston to assist in moving the blade toward low pitch.

Propeller governor oil, taken from the engine oil supply and boosted in pressure by the engine-driven propeller governor, is directed against the inboard side of the propeller piston. It acts as the counterforce, which can move the blades toward higher pitch. By metering this high-pressure oil to, or draining it from, the inboard side of the propeller piston by means of the constant-speed control unit, the force toward high pitch can balance and control the two forces toward low pitch. In this way, the propeller blade angle is regulated to maintain a selected rpm.

The basic propeller control forces acting on the Hamilton Standard propeller are centrifugal twisting force and high pressure oil from the governor. The centrifugal force acting on each blade of a rotating propeller includes a component force that results in a twisting moment about the blade center line that tends, at all times, to move the blade toward low pitch. Governor pump output oil is directed by the governor to either side of the propeller piston. The oil on the side of

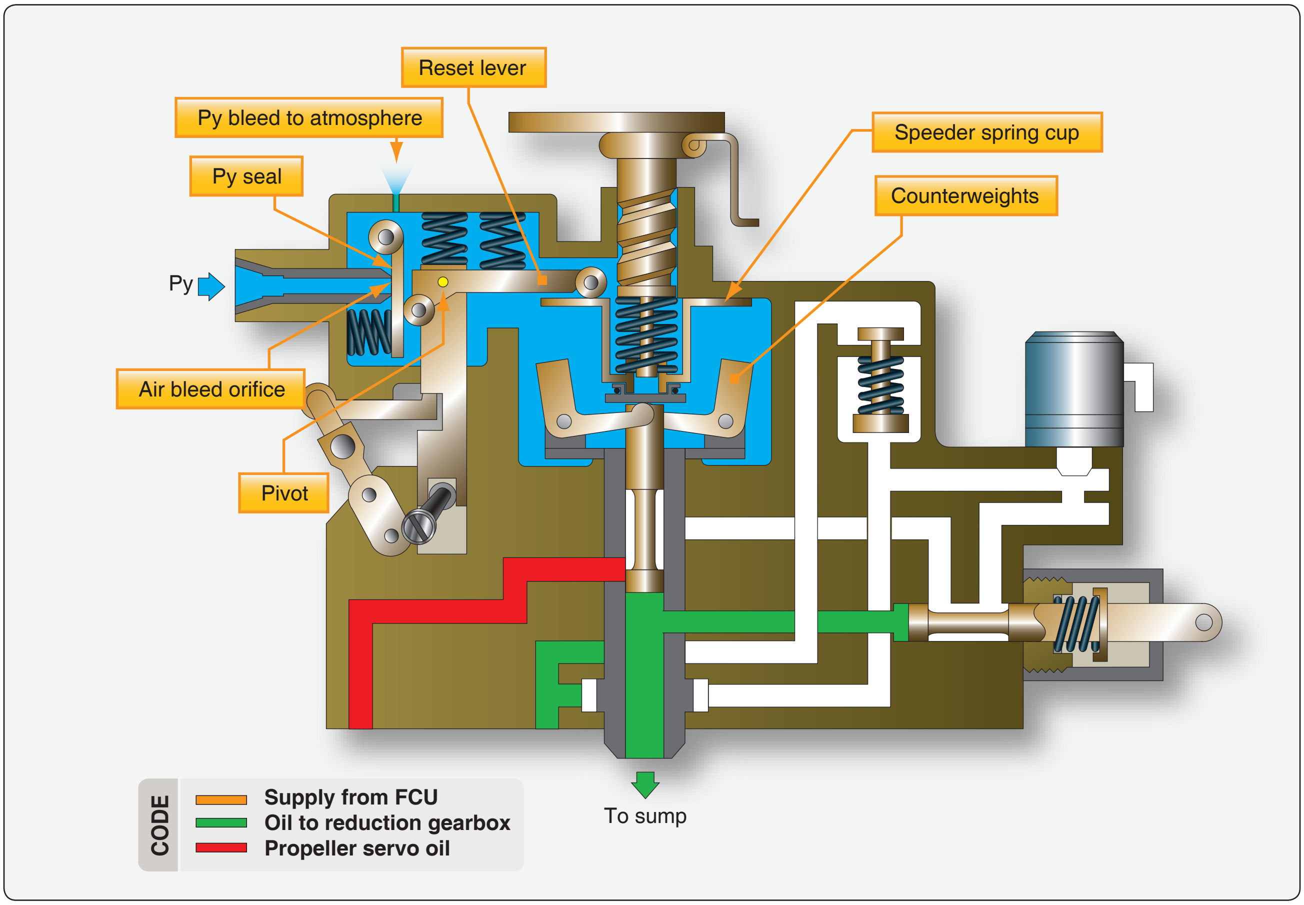


Figure 7-53. *Nf overspeed governor.*

the piston opposite this high-pressure oil returns to the intake side of the governor pump and is used over again. Engine oil at engine supply pressure does not enter the propeller directly but is supplied only to the governor. During constant-speed operations, the double-acting governor mechanism sends oil to one side or the other of the piston as needed to keep the speed at a specified setting.

Feathering Operation

A typical hydromatic propeller feathering installation is shown in *Figure 7-57*. When the feathering push-button switch is depressed, the low current circuit is established from the battery through the push-button holding coil and from the battery through the solenoid relay. As long as the circuit remains closed, the holding coil keeps the push button in the depressed position. Closing the solenoid establishes the high current circuit from the battery to the feathering motor pump unit. The feathering pump picks up engine oil from the oil supply tank, boosts its pressure, if necessary, to the relief valve setting of the pump, and supplies it to the governor high-pressure transfer valve connection. Auxiliary oil entering the high-pressure transfer valve connection shifts the governor transfer valve, which hydraulically disconnects the governor from the propeller and at the same time opens the propeller governor oil line to auxiliary oil. The oil flows through the engine transfer rings, through the propeller shaft governor oil passage, through the distributor valve port, between lands, and finally to the inboard piston end by way of the valve inboard outlet.

The distributor valve does not shift during the feathering operation. It merely provides an oil passageway to the inboard piston end for auxiliary oil and the outboard piston end for engine oil. The same conditions described for underspeed operation exist in the distributor valve, except that oil at auxiliary pressure replaces drain oil at the inboard end of the land and between lands. The distributor-valve spring is backed up by engine oil pressure, which means that at all times the pressure differential required to move the piston is identical with that applied to the distributor valve.

The propeller piston moves outboard under the auxiliary oil pressure at a speed proportional to the rate the oil is supplied. This piston motion is transmitted through the piston rollers operating in the oppositely inclined cam tracks of the fixed cam and the rotating cam and is converted by the bevel gears into the blade-twisting moment. Only during feathering or unfeathering is the low mechanical advantage portion of the

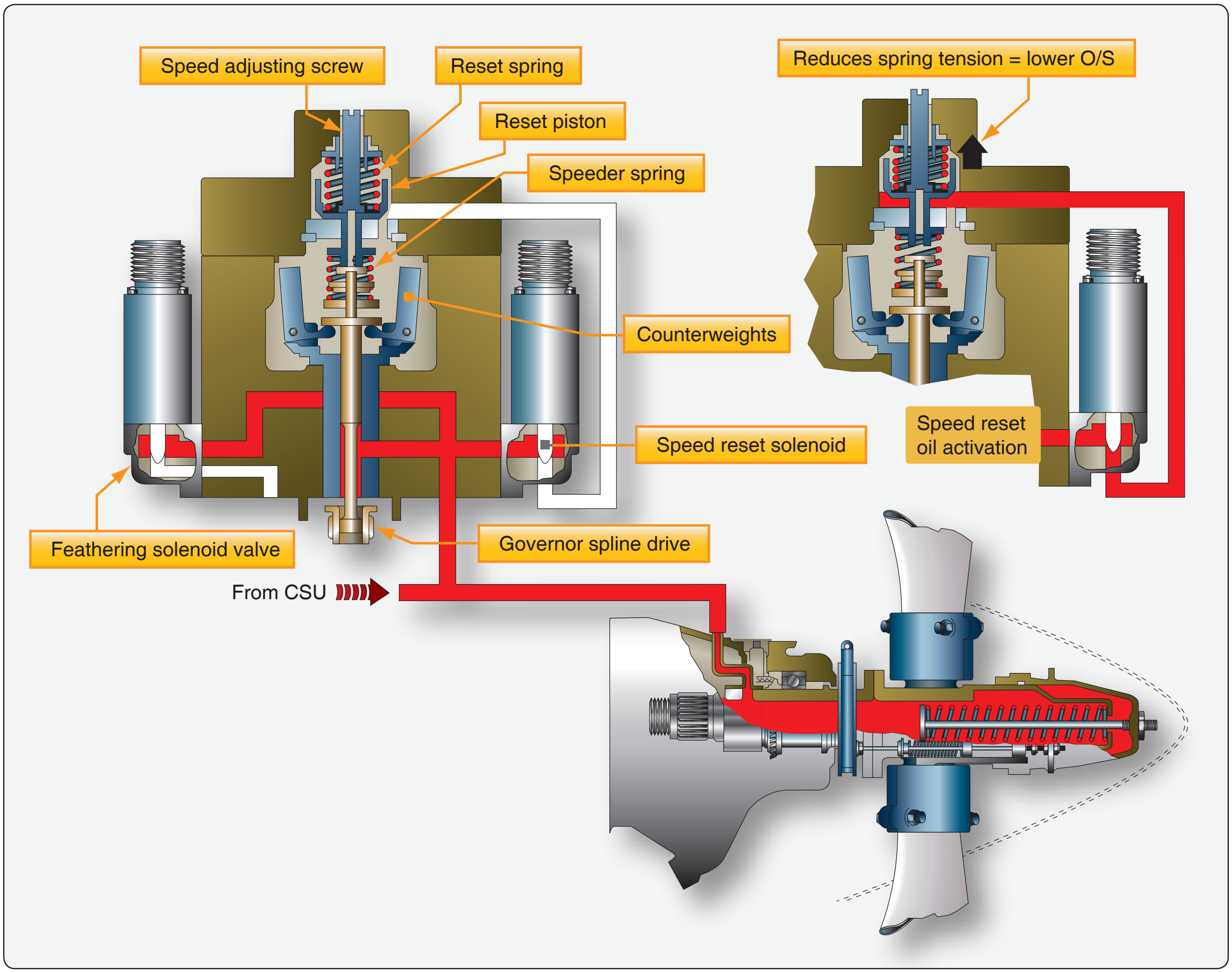


Figure 7-54. *Propeller overspeed governor.*

cam tracks used. (The low mechanical advantage portion lies between the break and the outboard end of the track profile.) Oil at engine pressure, displaced from the outboard piston end, flows through the distributor valve outboard inlet, past the outboard end of the valve land, through the valve port, into the propeller shaft engine oil passage, and is finally delivered into the engine lubricating system. Thus, the blades move toward the full high-pitch (or feathered) angle.

Having reached the full-feathered position, further movement of the mechanism is prevented by contact between the high-angle stop ring in the base of the fixed cam and the stop lugs set in the teeth of the rotating cam. The pressure in the inboard piston end now increases rapidly, and upon reaching a set pressure, the electric cutout switch automatically opens. This cutout pressure is less than that required to shift the distributor valve.

Opening the switch deenergizes the holding coil and releases the feathering push-button control switch. Release of this switch breaks the solenoid relay circuit, which shuts off the feathering pump motor. The pressures in both the inboard and outboard ends of the piston drop to zero, and, since all the forces are balanced, the propeller blades remain in the feathered position. Meanwhile, the governor high-pressure transfer valve has shifted to its normal position as soon as the pressure in the propeller governor line drops below that required to hold the valve open.

Unfeathering Operation

To unfeather a hydromatic propeller, depress and hold in the feathering switch push-button control switch. As in the case of feathering a propeller, the low-current control circuits from the battery through the holding coil and from the battery through the solenoid are completed when the solenoid closes. The high-current circuit from the battery starts the motor-pump unit, and oil is supplied at a high pressure to the governor transfer valve.

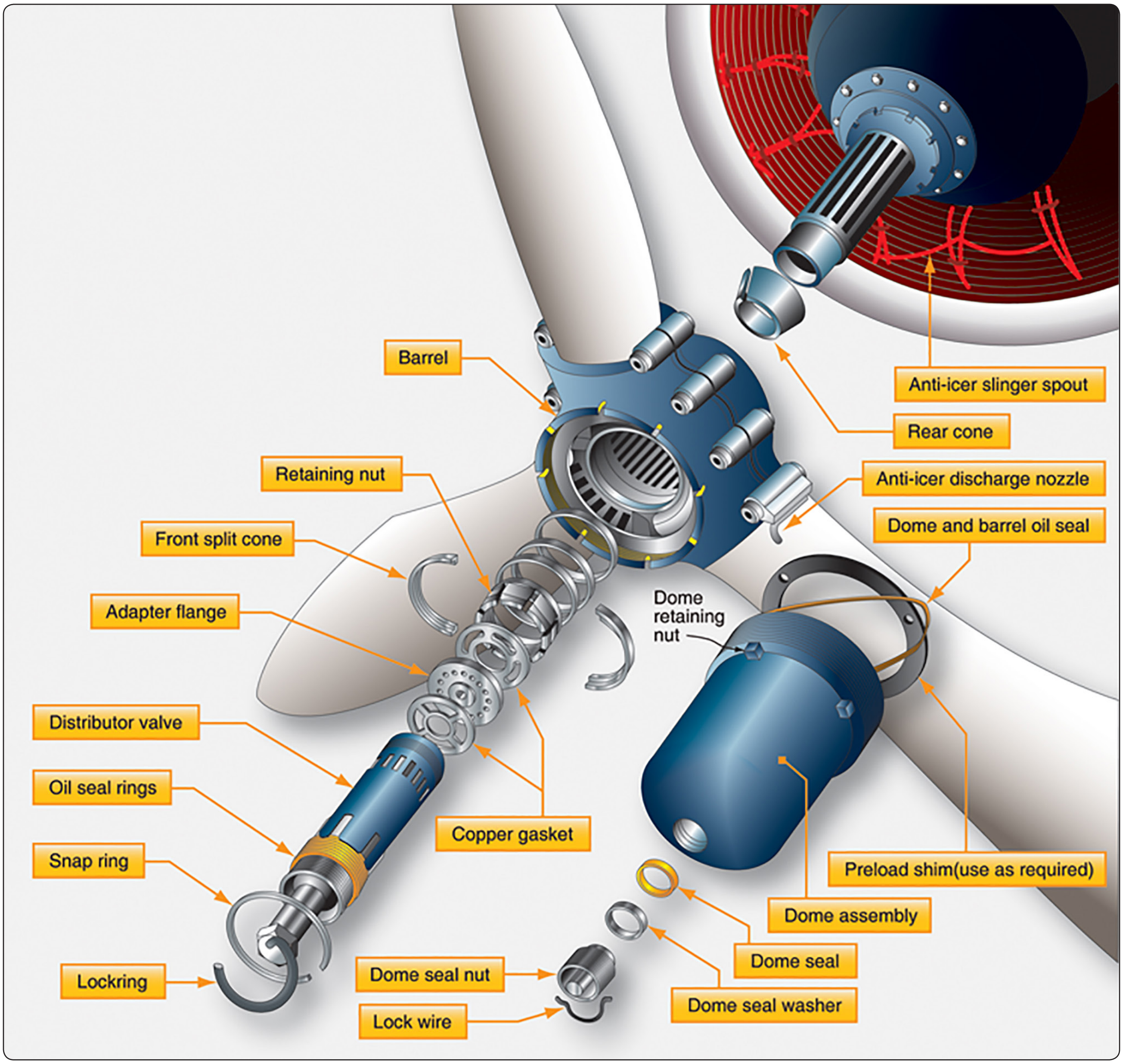


Figure 7-55. *Typical hydromatic propeller installation.*

Auxiliary oil entering through the high-pressure transfer valve connection shifts the governor transfer valve and disconnects the governor from the propeller line; in the same operation, auxiliary oil is admitted. The oil flows through the engine oil transfer rings, through the propeller shaft governor oil passage, and into the distributor valve assembly.

When the unfeathering operation begins, the piston is in the extreme outboard position. The oil enters the inboard piston end of the cylinder by way of the distributor valve inboard outlet. As the pressure on the inboard end of the piston increases, the pressure against the distributor valve land builds up. When the pressure becomes greater than the combined opposing force of the distributor valve spring and the oil pressure behind this spring, the valve shifts. Once the valve shifts, the passages through the distributor valve assembly to the propeller are reversed. A passage is opened between lands and through a port to the outboard piston end by way of the distributor valve outlet. As the piston moves inboard under the auxiliary pump oil pressure, oil is displaced from the inboard piston end through the inlet ports between the valve lands, into the propeller shaft engine oil lands, and into the propeller shaft engine oil passage where it is discharged into the engine lubricating system. At the same time, the pressure at the cutout switch increases and the switch opens. However, the circuit to the feathering pump and motor unit remains complete as long as the feathering switch is held in.

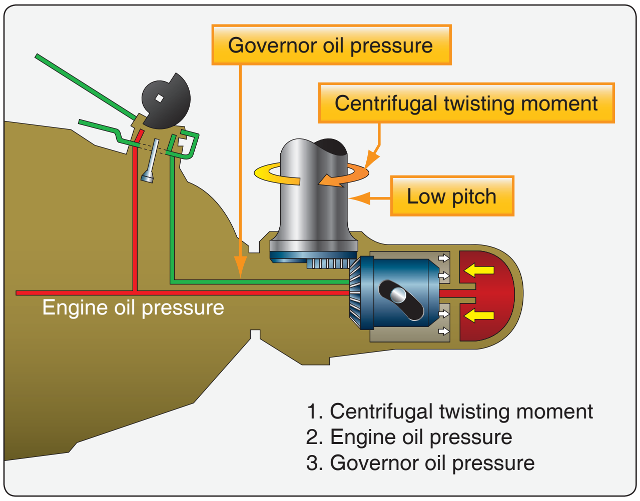


Figure 7-56. *Diagram of hydromatic propeller operational forces.*

With the inboard end of the propeller piston connected to drain and auxiliary pressure flowing to the outboard end of the piston, the piston moves inboard, unfeathering the blades. As the blades are unfeathered, they begin to windmill and assist the unfeathering operation by the added force toward low pitch brought about by the centrifugal twisting moment.

When the engine speed has increased to approximately 1,000 rpm, the operator shuts off the feathering pump motor. The pressure in the distributor valve and at the governor transfer valve decreases, allowing the distributor valve to shift under the action of the governor high-pressure transfer valve spring. This action reconnects the governor with the propeller and establishes the same oil passages through the distributor valve that are used during constant-speed and feathering operations.

Setting the Propeller Governor

The propeller governor incorporates an adjustable stop that limits the maximum speed at which the engine can run. As soon as the takeoff rpm is reached, the propeller moves off the low-pitch stop. The larger propeller blade angle increases the load on the engine, thus maintaining the prescribed maximum engine speed. At the time of propeller, propeller governor, or engine installation, the following steps are normally taken to ensure that the powerplant obtains takeoff rpm. During ground runup, move the throttle to takeoff position and note the resultant rpm and manifold pressure. If the rpm obtained is higher or lower than the takeoff rpm prescribed in the manufacturer's instructions, reset the adjustable stop on the governor until the prescribed rpm is obtained.

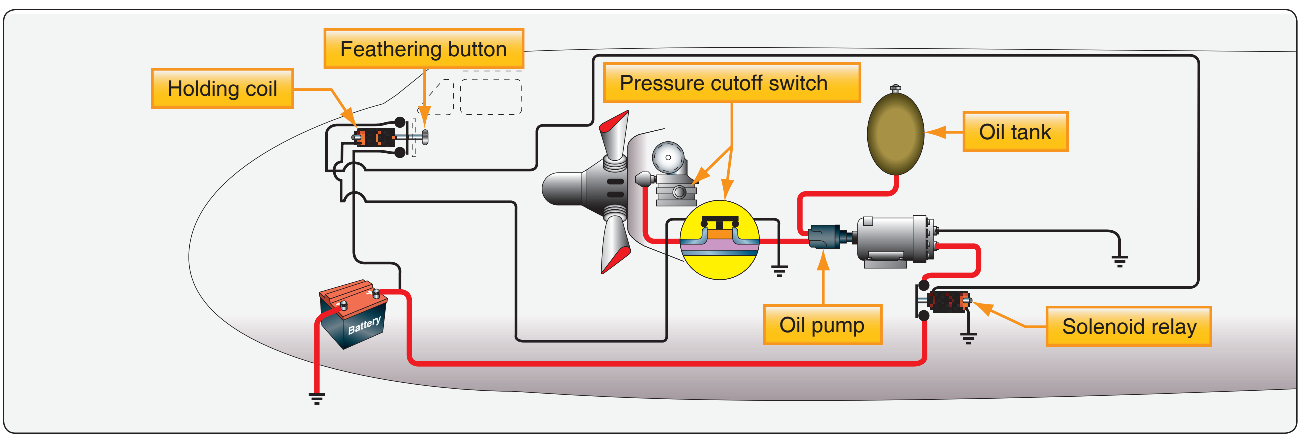


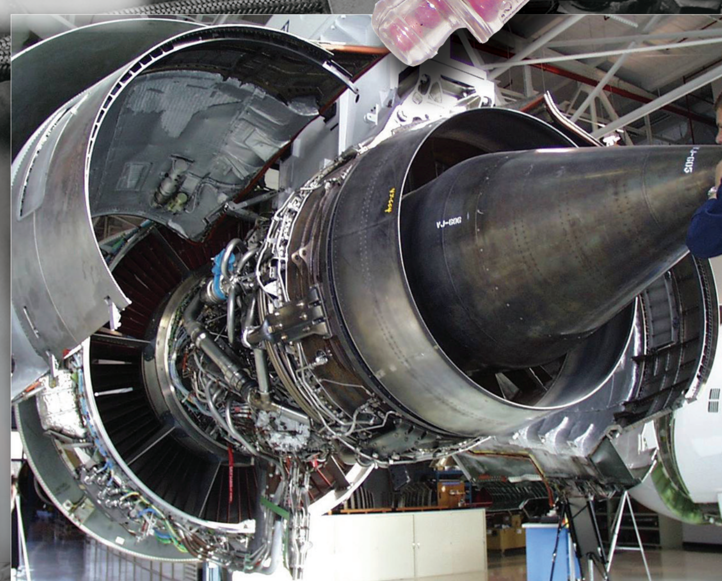
Figure 7-57. *Typical feathering installation.*

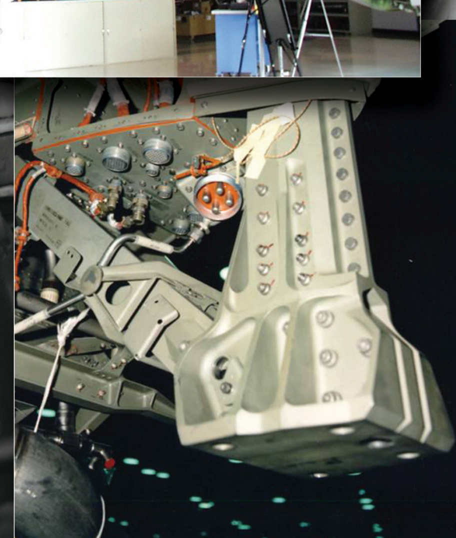
Chapter 8

Engine Removal and Replacement

Introduction

Procedures for removing or installing an aircraft engine usually vary widely with the type of aircraft and the type of engine. Thus, no single list of instructions can be provided as a guideline for all engines. Because of the many types of engine and aircraft installations and the large number of design variations within each type or category, representative examples have been selected to illustrate the most typical installation procedures for reciprocating, turboprop, and turbofan engines. There are some common tasks that must be accomplished when replacing an aircraft engine. Most engines require disconnecting and reconnecting electrical, hydraulic, fuel supply, intake and exhaust air path components, engine controls, and engine mounting connections to the airframe.





Reciprocating engines and gas turbine engines are used in this chapter to describe and represent general and typical procedures for engine buildup, removal, preservation, storage, and installation. Although these two types of engines have some common areas, each procedure has been included to ensure adequate coverage of the engines used in both heavy and light aircraft. It should be emphasized that while procedures for specific engines and aircraft are included in this chapter, many pertinent or mandatory references have been omitted because of their irrelevance to a general discussion. For this reason, always reference the applicable manufacturer's instructions before performing any phase of engine removal or installation.

Reasons for Removal of Reciprocating Engines

The following paragraphs outline the most common reasons for removing and replacing an engine. Information to aid in determining engine conditions that require removal is included; however, in every case, consult applicable manufacturer's instructions as the final authority in establishing the basis for engine replacement.

Engine or Component Lifespan Exceeded

Engine life is dependent upon such factors as operational use, the quality of manufacture or overhaul, the type of aircraft in which the engine is installed, the kind of operation being carried out, and the degree to which maintenance is accomplished. Thus, the manufacturer sets engine removal times. Based on service experience, it is possible to establish a maximum expected time before overhaul (TBO) or span of time within which an engine needs to be overhauled. Certain critical components of turbine engines such as turbine blades, turbine disks or combustion liners may have shorter life limits established by the manufacturer due to the stresses imposed on those parts during operation. The FAA requires that the manufacture identify and establish which parts have mandatory replacement times.

Sudden Stoppage

Sudden stoppage is a very rapid and complete stoppage of the engine. It can be caused by engine seizure or by one or more of the propeller blades striking an object in such a way that revolutions per minute (rpm) goes to zero in less than one complete revolution of the propeller. Sudden stoppage may occur under such conditions as complete and rapid collapse of the landing gear, nosing over of the aircraft, or crash landing. Sudden stoppage can cause internal damage, such as cracked propeller gear teeth, gear train damage, crankshaft counterweights becoming detuned or misalignment, or damaged propeller bearings. When sudden stoppage occurs, the engine usually requires replacement or disassembly and inspection as per manufacturer's instructions.

Sudden Reduction in Speed

Sudden reduction in engine speed can occur when one or more of the propeller blades strike an object at a low engine rpm. After impact, the foreign object is cleared and the engine recovers rpm and continues to run unless stopped to prevent further damage. While taxiing an aircraft, sudden reduction in speed can occur when the propeller strikes a foreign object, such as a raised section in the runway, a tool box, or a portion of another airplane. When the accident occurs at high engine rpm, shocks are much more severe. When sudden reduction in rpm occurs, the following procedure can be used as a general rule, but you must comply with the manufacturer's information.

Make a thorough external inspection of the engine mount, crankcase, and nose section to determine whether any parts have been damaged. If damage is found that cannot be corrected by line maintenance, remove the engine. Internal components can be damaged, especially counter weights on the crankshaft.

Remove the engine oil screens or filters. Inspect them for the presence of metal particles. Remove the engine sump plugs, drain the oil into a clean container, strain it through a clean cloth, and check the cloth and the strained oil for metal particles. Heavy metal particles in the oil indicate a definite engine failure, and the engine must be removed. However, if the metal particles present are similar to fine filings, continue the inspection of the engine to determine its serviceability. If there are no heavy metal particles in the engine oil, check again for metal in the oil system after operating the engine. Metal in the screens is a sign that the bearings have been compromised and are in the process of failing.

Remove the propeller and check the crankshaft, or the propeller drive shaft on reduction-gear engines, for misalignment. Clamp a test indicator to the nose section of the engine. Use the dial-indicator that has $\frac{1}{1,000}$-inch graduations. Remove the spark plugs from all the cylinders. Then, turn the crankshaft, and observe if the crankshaft, propeller shaft, or flange turns straight without any bending taking place. If there is an excessive runout (bend in the crankshaft or propeller flange) reading at the crankshaft or propeller-drive shaft at the front seat location, the engine should be removed. Consult the applicable manufacturer's instructions for permissible limits. If the crankshaft or propeller drive shaft runout does not exceed these limits, install a serviceable propeller. Make an additional check by tracking the propeller at the tip in the same plane, perpendicular to the axis of rotation, to assure that blade track tolerance is within the prescribed limits.

Start the engine to see if operation is smooth, without vibration, and the power output adequate. If the engine operates properly during this ground check, shut the engine down and repeat the inspection for metal particles in the oil system.

Metal Particles in the Oil

Metal particles in the engine oil screens or the magnetic chip detectors are generally an indication of partial internal failure of the engine. Carbon tends to break loose from the interior of the engine in rock-like pieces that have the appearance of metal. It is necessary to consider these possibilities when foreign particles are found on the engine oil screens or magnetic chip detectors.

Before removing an engine for suspected internal failure, as indicated by foreign material on the oil screens or oil sump plugs, determine if the foreign particles are ferrous metal by placing them close to a magnet to see if they are magnetic. If the material is not magnetic, it is not attracted by the magnet. Any ferrous metal in the oil screens is cause for concern. Very small amounts of nonferrous metal, especially after major engine maintenance, can sometimes be normal. If the particles are metal, determine the probable extent of internal damage. For example, if only small particles are found that are similar in nature to filings, drain the oil system, and refill it. Then, ground-run the engine and reinspect the oil screens and magnetic chip detectors. If no further evidence of foreign material is found, continue the engine in service or per the manufacturer's instructions. However, engine performance should be closely observed for any indication of difficulty or internal failure.

Spectrometric Oil Analysis Engine Inspection Program

Spectrometric oil analysis program allows an oil sample to be analyzed and searched for the presence of minute metallic elements. Due to oil circulation throughout an aircraft engine, every lubricant that is in service contains microscopic particles of metallic elements called wear metals. As the engine operates over a certain amount of time, the oil picks up very small particles that stay suspended in the oil. Oil analysis programs identify and measure these particles in parts per million (PPM) by weight. The analyzed elements are grouped into categories, such as wear metals and additives, and their measurement in PPM provides the data that expert analysts can use as one of many tools to determine the engine's condition. If certain metals have an increase in PPM, it can be a signal of component wear or pending failure of the engine. The amount of wear metals is recorded and noted each time a sample is taken. If the amount of wear metals increases beyond a normal rate, then the operator can be notified quickly so repair, a recommended specific maintenance procedure, or inspection can be ordered. The advantage of oil analysis is an increase in safety by noticing an engine problem before engine failure. It also saves money by finding engine problems before they become large problems or complete engine failure. This procedure can be used for both turbine and reciprocating engines. Oil analysis can be used to diagnose impending engine failure and would be a reason for removing the engine from the aircraft and sending it to overhaul.

Turbine Engine Condition Monitoring Programs

Many turbine engines are monitored by an engine condition program that helps determine the health of the engine in service. This can also be called trend analysis performance monitoring, but it consists mainly of monitoring certain engine parameters daily and watching for trend shifts or changes in the engine parameters. A shift in key parameters (change over time) could be a warning that the engine has serious internal deterioration and should be overhauled.

Engine Operational Problems

Engines are usually removed when there are consistent engine operational problems. Engine operational problems generally include, but are not limited to, one or more of the following conditions:

1. Excessive engine vibration; this is especially true with turbine engines.
2. Backfiring, or misfiring, either consistent or intermittent due to valve train or other mechanical defect in reciprocating engines.
3. Turbine engines that exceed normal operating parameters or life limited components exceeding maximum time in service or cycles.
4. Low power output, generally caused by low compression, with reciprocating engines and internal engine deterioration or damage with turbines.

General Procedures for Engine Removal and Installation

Preparation of Engines for Installation

After the decision has been made to remove an engine, the preparation of the replacement engine must be considered. The maintenance procedures and methods used vary widely. Commercial operators, whose maintenance operations require the most efficient and expeditious replacement of aircraft engines, usually rely on a system that utilizes the quick-engine-change assembly (QECA), also sometimes referred to as the engine power package. The QECA is essentially a powerplant and the necessary accessories installed in the engine.

Other operators of aircraft equipped with reciprocating engines sometimes use a different replacement method in these repair facilities because engine changes often occur at random intervals. Such replacement engines may be partially or wholly built up with the necessary accessories and subassemblies, or they may be stored as received from the manufacturer in packing boxes, cases, or cans and are uncrated and built up for installation only when needed to replace an engine.

QECA Buildup Method for Changing of Engines

Because the QECA system is most commonly used with large turbine engines used in the airlines, such engines are used to describe QECA buildup and installation procedures. Many of these procedures are applicable to all other methods of engine buildup and installation.

The following study of QECA buildup is not designed to outline procedures to follow in a practical application; always use those recommended by the manufacturer. The procedures included in this chapter provide a logical sequence in following a QECA and its components through the stages of a typical buildup to gain a better understanding of units and systems interconnection. The components of a QECA are illustrated in *Figure 8-1.* As shown, the QECA consists of several units. On many aircraft, the engines are mounted in streamlined housings called nacelles that extend from the wings. These nacelles are divided into two main sections: wing nacelle and engine nacelle. The wing nacelle is that portion of the nacelle that is attached to the wing structure. The engine nacelle is that portion of the nacelle that is constructed separately from the wing. Also, the wing nacelles normally contain lines and units of the oil, fuel, and hydraulic systems, as well as linkages and other controls for the operation of the engine.

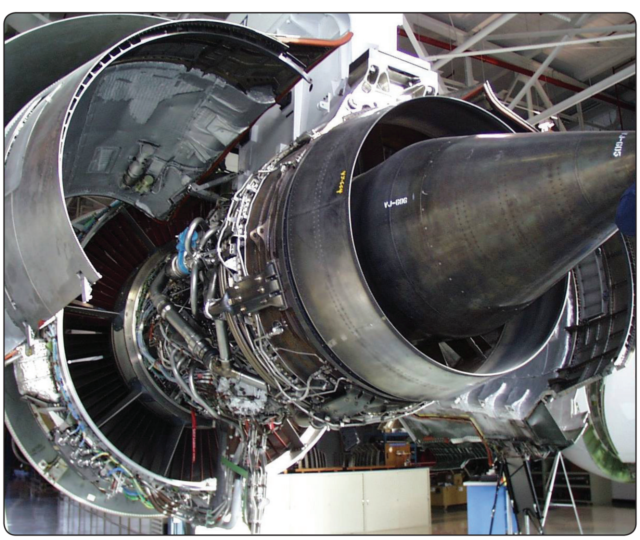


Figure 8-1. *Open cowling view of a typical power package.*

The firewall is usually the foremost bulkhead of the engine nacelle and differs from most other aircraft bulkheads in that it is constructed of stainless steel or some other fire-resistant material. *[Figure 8-2]* The primary purpose of the firewall is to confine any engine fire to the engine nacelle. It also provides a mounting surface for units within the engine nacelle and a point of disconnect for lines, linkages, and electrical wiring that are routed between the engine and the aircraft. Without this firewall, an engine fire would have ready access to the interior of the aircraft. Since the consequences of an engine fire are obvious, the necessity of sealing all unused openings in the firewall cannot be overstressed.

An aircraft engine and its accessories that have been in storage must undergo careful depreservation and inspection before they may be installed in an aircraft. This involves more than removing an engine from its container and bolting it to the aircraft. If the engine is stored in a pressurized metal container, the air valve should be opened to bleed off the air pressure. Depending upon the size of the valve, the air pressure should bleed off in somewhat less than 30 minutes.

Prepare the container for opening by removing the bolts that hold the two sections together. Then, attach a hoist to the "hoisting points" and lift the top section clear of the container and place it away from the work area. If the engine is installed in a wooden shipping case, it is necessary to carefully break the seal of the protective envelope and fold it down around the engine. Remove the dehydrating agent or desiccant bags and the humidity indicator from the outside of the engine. Also, remove and set safely aside any accessories that are not installed on the engine but are mounted on a special stand or otherwise installed inside the protective envelope with the engine.

Figure 8-2. *Typical firewall with components mounted on it.*

Depreservation of an Engine

After the engine has been secured to an engine stand, all covers must be removed from the points where the engine was sealed or closed with ventilatory covers, such as the engine breathers, exhaust outlets, and accessory mounting-pad cover plates. As each cover is removed, inspect the uncovered part of the engine for signs of corrosion. Also, as the dehydrator plugs are removed from each cylinder, make a very careful check of the walls of any cylinder for which the dehydrator plug color indicates an unsafe condition. Care is emphasized in the inspection of the cylinders, even if it is necessary to remove a cylinder.

On radial engines, the inside of the lower cylinders and intake pipes should be carefully checked for the presence of excessive corrosion-preventive compound that has drained from throughout the interior of the engine and settled at these low points. This excessive compound could cause the engine to become damaged from a hydraulic lock (also referred to as liquid-lock) when a starting attempt is made.

The check for excessive corrosion-preventive compound in the cylinders of reciprocating engines can be made as the dehydrator plugs are removed from each cylinder. Much of the compound drains from the spark plug holes of the lower cylinders of a radial engine when the dehydrator plugs are removed. But some of the mixture remains in the cylinder head below the level of the spark plug hole and can be removed with a hand pump. *[Figure 8-3]* A more positive method is to remove the lower intake pipes and open the intake valve of the cylinder by rotating the crankshaft. This latter method allows the compound to drain from the cylinder through the open intake valve. If excessive compound is present in an upper cylinder, it can be removed with a hand pump.

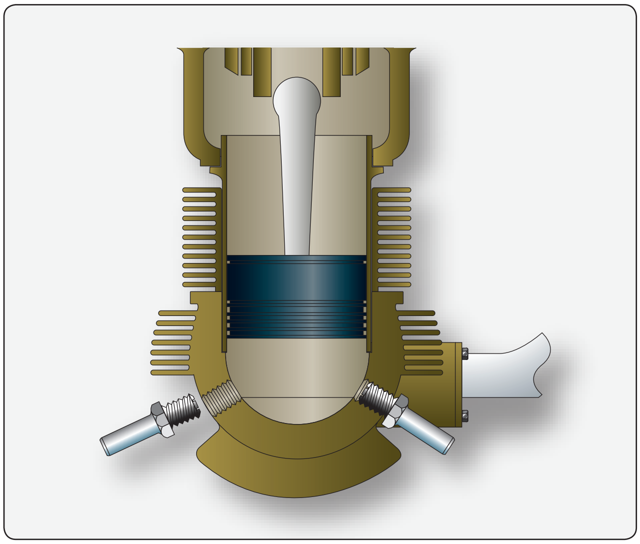


Figure 8-3. *Draining corrosion preventive compound.*

The oil screens should be removed from the engine and thoroughly washed in an approved solvent to remove all accumulations that could restrict the oil circulation and cause engine failure. After the screens are cleaned, immerse them in clean oil and then reinstall them in the engine.

When the cover has been removed from the intake area, the silica gel desiccant bags (used to remove moisture from the engine in storage) must be removed from the engine area. If the engine uses a propeller, remove the protective covering from the propeller shaft and wash all corrosion-preventive compounds from both the inside and outside surfaces of the shaft. Then, coat the propeller shaft lightly with engine oil. Turbine engines require the removal of several covers on many external areas on the engine.

As a final check, see that the exterior of the engine is clean. Usually a quantity of compound runs out of the engine when the dehydrator plugs and oil screens are removed. To clean the engine, spray it with an approved commercial solvent.

Inspection and Depreservation of Accessories

An engine's performance is no better than that of its accessories. Though the engine has been completely overhauled and is in top condition, any oversight or error in installing the accessories can result in improper engine operation or even irreparable damage to it.

Before depreserving any of the accessories enclosed with the engine, consult the storage data usually stenciled on the outside of the engine container or the records enclosed with the engine to determine how long the engine and accessories were in storage. Certain accessories that normally accompany an engine from overhaul are considered unsafe for use if their time in storage has exceeded a specified period. This time varies according to the limits prescribed by the manufacturer.

Any accessory that has been removed from an old engine that can be installed on the new one must be given a thorough inspection to determine its condition. This inspection includes a check for general condition, cleanliness, absence of corrosion, and absence of wear as evidenced by excessive play in the moving parts.

Some accessories must be replaced, regardless of their operating time, if the engine is being changed because of internal failure. Such accessories may have been contaminated by metal particles carried into their operating mechanisms by the engine oil that lubricates them.

Before installing any replacement accessory, check it visually for signs of corrosion and for freedom of operation.

Always wipe the mounting pad, flange, and coupling clean before mounting the accessory, and install the proper gasket between the mounting pad and the accessory mounting flange. Lubricate the accessory drive shaft if so indicated in the manufacturer's instructions.

Inspection and Replacement of Powerplant External Units and Systems

The engine nacelle must be cleaned thoroughly before it is inspected. The design of an engine nacelle varies with different aircraft. Basically, it is a framework covered with removable cowling, in which the engine is mounted. This assembly is attached to the aircraft and incorporates an insulating firewall between the engine and the airframe. The interconnecting wiring, tubing, and linkages between the engine and its various systems and controls pass through the firewall.

Inspect the complete engine nacelle for condition of the framework and the sheet-metal cowling and riveted plates that cover the nacelle. The engine mounting frame assembly should be checked for any distortion of the steel tubing, such as bends, dents, flat spots, corrosion, or cracks. Use the dye penetrant inspection method to reveal a crack, porous area, or other defects.

The engine mounting bolts are usually checked for condition by magnetic particle inspection or other approved process. While the bolts are removed, the bolt holes should be checked for elongation caused by the movement of an improperly tightened bolt.

Check the outer surface of all exposed electrical wiring for breaks, chafing, or other damage. Also, check the security of crimped or soldered cable ends. In addition, carefully inspect connector plugs for overall condition. Any item that is damaged must be repaired or replaced, depending on the extent of the damage.

Before installing an engine, inspect all tubing in the nacelle for dents, nicks, scratches, chafing, or corrosion. Check all tubing carefully for indications of fatigue or excessive flatness caused by improper or accidental bending. Thoroughly inspect all hoses used in various engine systems. Weather checking (a cracking of the outside covering of the hose) sometimes penetrates to the hose reinforcement. Replace any length of hose that shows indications of the cover peeling or flaking or has exposed fabric reinforcement. Replace a hose that shows indications of excessive cold flow. Cold flow is a term used to describe the deep and permanent impressions or cracks caused by hose clamp pressure.

Always replace a control rod if it is nicked or corroded deeply enough to affect its strength. If the corrosion cannot be removed by rubbing with steel wool, the pitting is too deep for safety.

On older aircraft, check the pulleys in the control system for freedom of movement. It is easy to spot a pulley that is not turning freely, for both it and the cable are worn from the cable sliding over the pulley instead of rolling free. The bearings of a pulley may be checked by inspecting the pulley for excessive play or wobble with the tension removed from the cable. The cable must also be inspected for corrosion and broken strands. Locate any broken strands by wiping the cable with a cloth.

Check bonding for fraying, loose attachment, and cleanness of terminal ends. The electrical resistance of the complete bond must not exceed the resistance values specified in the applicable manufacturer's instructions.

Inspect the exhaust stacks, collector ring, and tailpipe assembly for security, cracks, or excessive corrosion. Depending on the installation, these units, or parts of them, may be mounted on the engine before it is installed in the aircraft.

Check all air ducts for dents and for the condition of the fabric or rubber anti-chafing strips at the points where sections of duct are joined. The dents may be pounded out; the anti-chafing strips should be replaced if they are pulled loose from the duct or are worn to the point at which they no longer form a tight seal at the joint.

Thoroughly inspect the engine oil system and perform any required special maintenance upon it before installing a replacement engine. If an engine is being changed at the end of its normal time in service, it is usually necessary only to flush the oil system; however, if an engine has been removed for internal failure, usually some units of the oil system must be replaced and others thoroughly cleaned and inspected.

If the engine has been removed because of internal failure, the oil tank is generally removed to permit thorough cleaning. Also, the oil cooler and temperature regulator must be removed and sent to a repair facility for overhaul. The vacuum pump pressure line and the oil separator in the vacuum system must also be removed, cleaned, and inspected. Internal failure also requires that the propeller governor and feathering pump mechanism be replaced if these units are operated by engine oil pressure.

Preparing the Engine for Removal

Before starting to work on the aircraft or reciprocating engine, always be sure that the magneto switch is in the off position. Aircraft engines can be started accidentally by turning the propeller if the magneto switch is on.

Check to see that all fuel selectors or solenoid-operated fuel shutoff valves are closed. The fuel selector valves are either manually or solenoid operated. If solenoid-operated fuel shutoff valves are installed, it may be necessary to turn the battery switch on before the valves can be closed, since the solenoid depends on electricity for operation. These valves close the fuel line at the firewall between the engine and the aircraft. After ensuring that all fuel to the engine is shut off, disconnect the battery to eliminate the possibility of a hot wire starting a fire. If it is anticipated that the aircraft will be out of service for more than 6 days, the battery is usually removed and taken to the battery shop and placed on charge.

Also, a few other preparations should be made before starting to work on the engine removal. First, make sure that there are enough fire extinguishers near at hand to meet any possible emergency. Check the seals on these extinguishers to be sure the extinguishers have not been discharged. Then, check the wheel chocks. If these are not in place, the aircraft can, and probably will, inch forward or back during some crucial operation. Also, if the aircraft has a tricycle landing gear, be sure that the tail is supported so that the aircraft cannot tip back when the weight of the engine is removed from the forward end. It is not necessary to support the tail on some multiengine aircraft if only one engine is to be removed. In addition, the landing gear shock struts can be deflated to prevent them from extending as the engine weight is removed from the aircraft.

After taking these necessary precautions, begin removing the cowling from around the engine. As it is removed, clean it and check for cracks so that the necessary repairs can be made while the engine change is in progress. Place all cowling that does not need repair on a rack where it can be readily found when the time comes to reinstall it on the new engine. After removing the cowling, the propeller should be removed for inspection or repair.

Draining the Engine

Place a large metal pan (drip pan) on the floor under the engine to catch any spilled mixture or oil. Next, secure a clean container in which to drain the oil or corrosion-preventive mixture. Place the container beneath the engine, open the drain valve, and allow the oil to drain. *Figure 8-4* shows the points at which a typical aircraft engine oil system is drained. Other points at which the oil system is drained can typically include the oil cooler, oil return line, and engine sumps. All valves, drains, and lines must remain open until the oil system has been completely drained. After draining the oil, reinstall all drain plugs and close all drain valves. Then, wipe all excess oil from around the drain points.

Electrical Disconnects

Electrical disconnections are usually made at the engine firewall. When the basic engine is being removed, the electrical leads to such accessories as the starter and generators are disconnected at the units themselves. When disconnecting electrical leads, it is a good safety habit to disconnect the magnetos first and immediately ground them at some point on the engine or the assembly being removed. Most firewall disconnections of electrical conduit and cable are simplified by use of (Army/Navy) AN or (Military Standard) MS connectors. Each connector consists of two parts: a plug assembly and a receptacle assembly. To prevent accidental disconnection during airplane operation, the outlet is threaded to permit a knurled sleeve nut to be screwed to the outlet and then fastened with safety wire, if necessary.

A typical plug fitting assembly is shown in *Figure 8-5*. It also shows a typical junction box assembly, which is used as a disconnect on some aircraft engine installations. After the safety wire is broken, remove all of it from the sleeve nuts that hold the conduit to the junction boxes, as well as from the nuts

Figure 8-4. *Oil system drain points.*

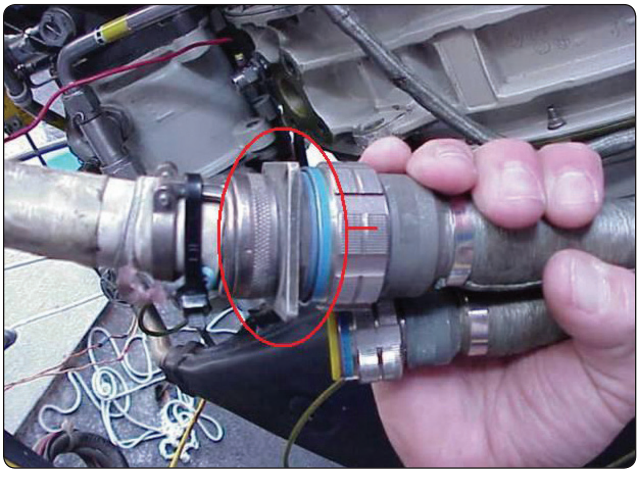


Figure 8-5. *Electrical connections.*

on the connectors. Wrap moisture proof tape over the exposed ends of connectors to protect them from dirt and moisture. Also, do not leave long electrical cables or conduits hanging loose, since they may become entangled with some part of the aircraft while the engine is being hoisted. It is a good practice to coil all lengths of cable or flexible conduit neatly, and tie or tape them to some portion of the assembly being removed.

Disconnection of Engine Controls

The engine control rods and cables connect such units as the carburetor or fuel control throttle valve and the mixture control valve with their manually actuated control in the cockpit. The controls are sometimes disconnected by removing the turnbuckle that joins the cable ends. *[Figure 8-6]* A typical reciprocating engine control linkage consisting of a control rod attached to a bell crank is illustrated in *Figure 8-7.*

The control rod in the linkage shown has two rod-end assemblies, a clevis, and an eye screwed onto opposite ends. These rod-end assemblies determine the length of the control rod by the distance they are screwed onto it, and they are locked into position by cheek nuts. An antifriction bearing is usually mounted in the eye end of a rod. This eye is slipped over a bolt in the bell crank arm and is held in position by a castle nut safety with a cotter pin. The clevis rod end is slipped over the end of a bell crank arm, which also usually contains an antifriction bearing. A bolt is passed through the clevis and the bell crank eye, fastened with a castle nut, and safetied with a cotter pin.

Sometimes linkage assemblies do not include the antifriction bearings and are held in position only by a washer and cotter pin in the end of a clevis pin that passes through the bell crank and rod end. After the engine control linkages have been disconnected, the nuts and bolts should be replaced in the rod ends or bell crank arms to prevent their being lost. All control rods should be removed completely or tied back to prevent them from being bent or broken if they are struck by the replacement engine or QECA as it is being hoisted.

Disconnection of Lines

The lines between units within the aircraft and the engine are either flexible hose or aluminum-alloy tubes joined by lengths of hose clamped to them. Lines that must withstand high pressure, such as hydraulic lines, are often made of stainless steel tubing.

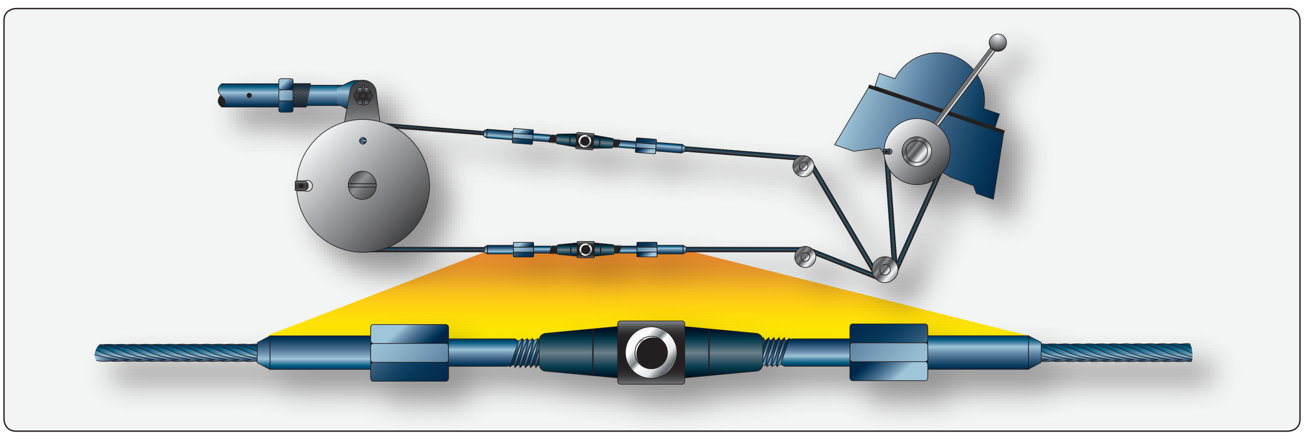


Figure 8-6. *Engine control cable and turnbuckle assembly.*

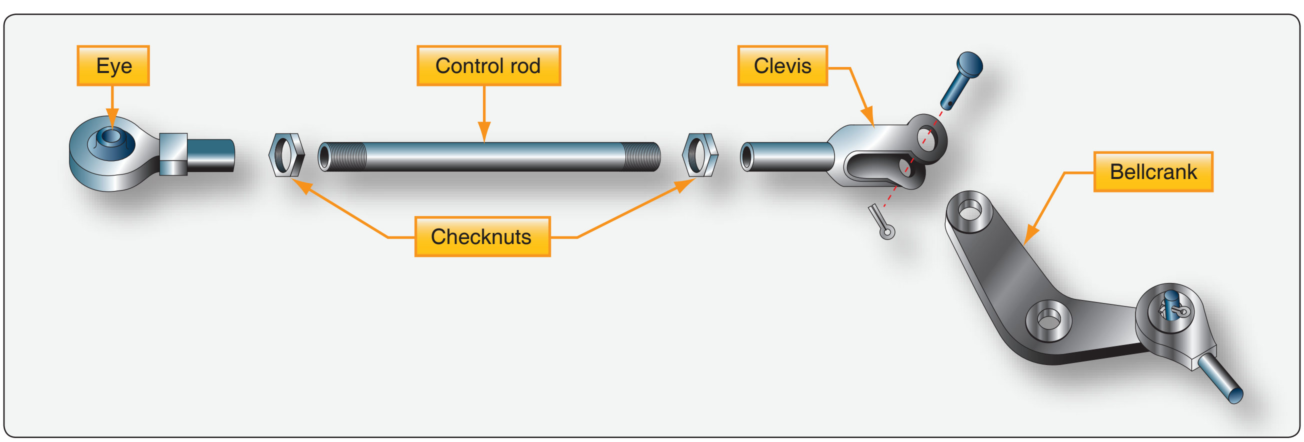


Figure 8-7. *Engine control linkage assembly.*

Figure 8-8 shows the basic types of line disconnects. Most lines leading from a QECA are secured to a threaded fitting at the firewall by a sleeve nut around the tubing. Hoses are sometimes secured in this manner but may also be secured by a threaded fitting on the unit to which they lead, or by a hose clamp. The firewall fittings for some lines have a quick-disconnect fitting that contains a check valve to prevent the system from losing fluid when the line is disconnected. Metal tubing on some installations may also be disconnected at a point at which two lengths of it are joined together by a length of rubber hose. Such a disconnection is made by loosening the hose clamps and sliding the length of rubber hose over the length of tubing that remains on the aircraft. There may be some further variations in these types of disconnections, but they follow the same basic pattern.

Some type of a container should be used to collect any fuel, oil, or other fluid that may drain from the disconnected lines. After the lines have drained, they should be immediately plugged or covered with moisture-proof tape to prevent foreign matter from entering them, as well as to prevent any accumulated fluid from dripping out.

Other Disconnections

The points at which the various air ducts are disconnected depend upon the engine and the aircraft in which it is installed. Usually, the air intake ducts and the exhaust system must be disconnected so the basic engine or the QECA can be removed. After the engine connections are free (except the engine mounts) and all the disconnections are entirely clear so they do not bind or become entangled, the engine can be prepared for hoisting.

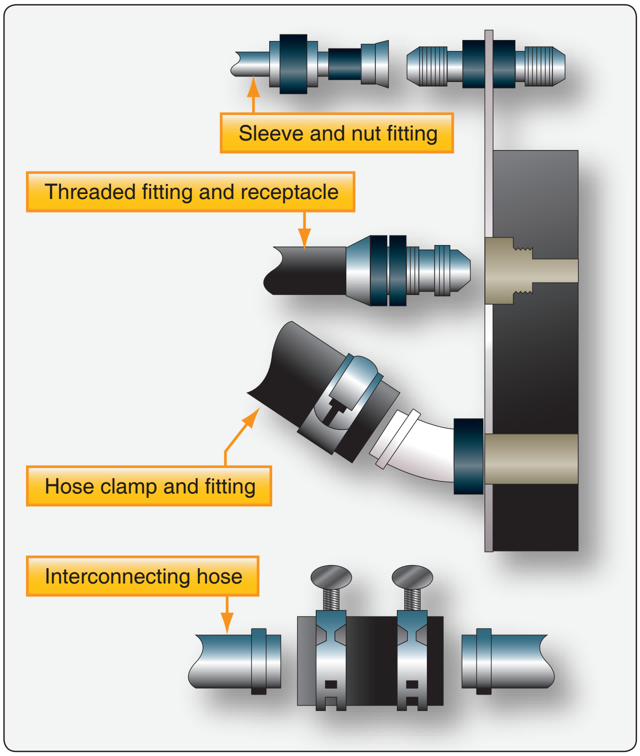


Figure 8-8. *Types of line disconnects.*

Removing the Engine

If a QECA is being removed, the engine mount accompanies the engine. The mount remains on the aircraft if only the engine is being removed. Before the engine can be freed from its attachment points, a sling must be installed so the engine's weight can be supported with a hoist when the mounting bolts are removed.

Aircraft engines, or QECAs, have marked points for attaching a hoisting sling. The location of these attaching points varies according to the size and weight distribution of the engine. *Figure 8-9* shows a sling supporting an engine that has two attaching points. As a matter of safety, carefully inspect the sling for condition before installing it on the engine.

Before attaching the sling to the hoist, be sure that the hoist has sufficient capacity to lift the engine safely. The engine's center of gravity (CG) should also be taken into account as the engine is hoisted. A manually operated hoist mounted in a portable frame is shown in *Figure 8-10.* This hoist assembly is specifically manufactured for the purpose of removing engines and other large assemblies from aircraft. Some frames are fitted with power-operated hoists. These should be used with care, since considerable damage can be done if an inexperienced operator allows a power-operated hoist to overrun. The hoist and frame should also be checked for condition before being used to lift the engine.

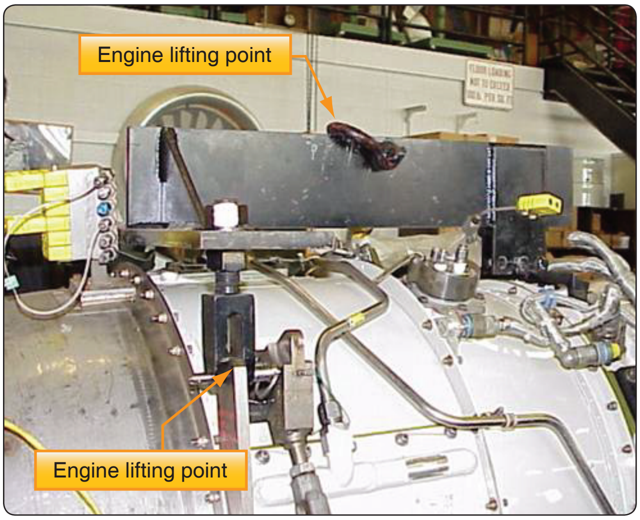


Figure 8-9. *Hoisting sling attached to engine.*

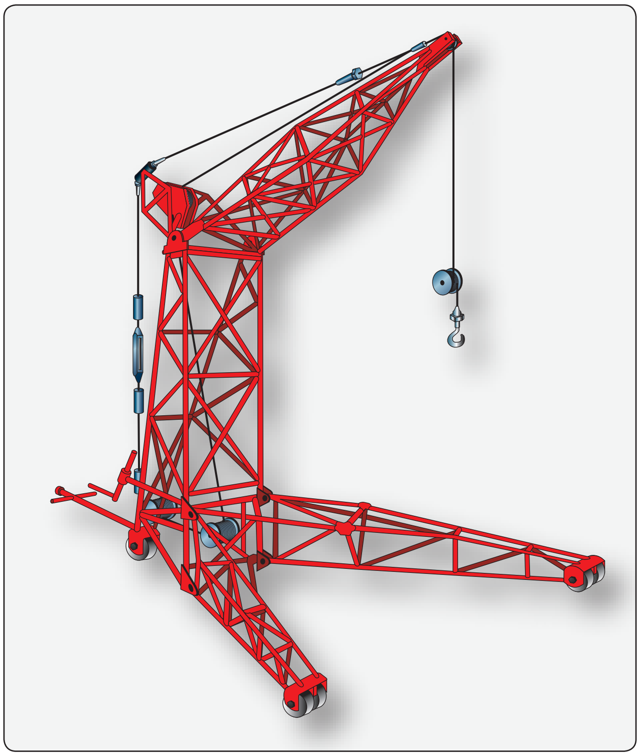


Figure 8-10. *Hoist and frame assembly used for engine removal.*

Hoisting the Engine

Before the hoist is hooked onto the engine sling, recheck the aircraft tail supports and the wheel chocks. Fasten lines to the engine, at points on the sides or rear, so that the engine can be controlled as it is being hoisted. Hook the hoist onto the sling and hoist the engine just enough to relieve the engine weight from the mount attachments. Remove the nuts from the mount attachments in the order recommended in the manufacturer's instructions for the aircraft. As the last nuts are being removed, pull back on the lines fastened to the engine (or force it back by other means if lines are not being used), thus steadying the engine. If bolts must be removed from the mount attachments, be sure the engine is under control before doing so. If the bolts are to remain in the mount attachments, the hoist can be gently maneuvered upward or downward as necessary after all the nuts have been removed. Meanwhile, gently relax the backward force on the engine just enough to allow the engine gradual forward movement when it is free from the mount attachments. When the hoist has removed all engine weight from the mount attachments, the engine should be eased gently forward, away from the aircraft. If the engine binds at any point, maneuver it with the hoist until it slips free.

The procedure just discussed applies to removal of most reciprocating and turbine aircraft engines. Any variation in details is outlined in the manufacturer's instructions. Before attempting any engine removal, always consult these instructions for the aircraft concerned. When the engine has been removed, it can be carefully lowered onto a stand. The engine should be fastened to the stand and prepared for the removal of accessories.

Hoisting and Mounting the Engine for Installation

When the new or overhauled engine is ready to be hoisted for installation, move the engine stand as close as possible to the nacelle in which the replacement is to be installed. Then, attach the sling to the engine and hook the hoist to the sling. Take up the slack until the hoist is supporting most of the engine weight. Next, remove the engine attaching bolts from the stand and hoist the engine clear.

The engine stand may be moved and the hoist frame positioned so the engine can be hoisted easily into the nacelle. To prevent injury to the crew or damage to the aircraft or engine, be sure that the engine is steadied when moving the hoist frame.

Engine nacelles are rarely designed for the engine to be fitted and bolted into place as though it were being mounted on a bare wall. The engine must be guided into position and mated with its various connections, such as the mounting bolt holes and the exhaust tailpipe. This must be done despite such obstacles as the nacelle framework, ducts, or firewall connections and without leaving a trail of broken and bent parts, scratched paint, or crushed fingers.

When the engine has been aligned correctly in the nacelle, insert the mounting bolts into their holes and start all of the nuts on them. Always use the type of bolt and nut recommended by the manufacturer. Never use an unauthorized substitution of a different type or specification of nut and bolt than that prescribed.

The nuts on the engine mount bolts must be tightened to the torque recommended by the aircraft manufacturer. While the nuts are being tightened, the hoist should support the engine weight sufficiently to allow alignment of the mounting bolts. If the engine is permitted to exert upward or downward pressure on the bolts, it is necessary for the nuts to pull the engine into proper alignment. This results in nuts being tightened to the proper torque value without actually holding the engine securely to the aircraft.

The applicable manufacturer's instructions outline the sequence for tightening the mounting bolts to ensure security of fastening. After the nuts are safetied and the engine sling and hoist are removed, bonding strips should be connected across each engine mount to provide an electrical path from the mount to the airframe.

Mounting the engine in the nacelle is, of course, only the beginning. All the ducts, electrical leads, controls, tubes, and conduits must be connected before the engine can be operated.

Connections and Adjustments

There are no hard-and-fast rules that direct the order in which units or systems should be connected to the engine. Each maintenance organization normally supplies a worksheet or checklist to be followed during this procedure. This list is based upon past engine installations on each particular aircraft. If this is followed carefully, it serves as a guide for an efficient installation. The following instructions are not a sequence of procedures but a discussion of correct methods for completing an engine installation.

The system of ducts for routing air to the engine varies with all types of aircraft. In connecting them, the goal is to fit the ducts closely at all points of disconnect so that the air they route does not escape its intended path. The duct systems of some aircraft must be pressure checked for leaks. This is done by blocking the system at one end, supplying compressed air at a specified pressure at the other end, and then checking the rate of leakage.

The filters in the air induction system must be cleaned to ensure an unrestricted flow of clean air to the engine and its units. Because methods for cleaning air filters vary with the materials used in the filtering element, clean them in accordance with the technical instructions for the aircraft being serviced.

The exhaust system should also be carefully connected to prevent the escape of hot gases into the nacelle. When assembling the exhaust system, check all clamps, nuts, and bolts, and replace any in doubtful condition. During assembly, the nuts should be gradually and progressively tightened to the correct torque. The clamps should be tapped with a rawhide mallet as they are being tightened to prevent binding at any point. On some systems, a ball joint connects the stationary portion of the exhaust system to the portion that is attached to the engine. This ball joint absorbs the normal engine movement caused by the unbalanced forces of the engine operation. Ball joints must be installed with the specified clearance to prevent binding when expanded by hot exhaust gases.

Hoses used inside low-pressure systems are generally fastened into place with clamps. Before using a hose clamp, inspect it for security of welding or riveting and for smooth operation of the adjusting screw. A clamp that is badly distorted or materially defective should be rejected. Material defects include extremely brittle or soft areas that may easily break or stretch when the clamp is tightened. After a hose is installed in a system, it should be supported with rubber-lined supporting clamps at regular intervals.

Before installing metal tubing with threaded fittings, ensure the threads are clean and in good condition. Apply sealing compound, of the correct specification for the system, to the threads of the fittings before installing them. While connecting metal tubing, follow the same careful procedure for connecting hose fittings to prevent cross-threading and to ensure correct torque.

When connecting the starter, generator, or various other electrical units within the nacelle, make sure that all lead connections are clean and properly secured. On leads that are fastened to a threaded terminal with a nut, a lock washer is usually inserted under the nut to prevent the lead from working loose. When required, connector plugs can be safetied with steel wire to hold the knurled nut in the full-tight position.

Electrical leads within the engine nacelle are usually passed through either flexible or rigid conduit. The conduit must be anchored, as necessary, to provide a secure installation and bonded when required.

All engine controls must be accurately adjusted to ensure instantaneous response to the control setting. For flexibility, the engine controls are usually a combination of rods and cables. Since these controls are tailored to the model of aircraft in which they are installed, their adjustment must follow exactly the step-by-step procedure outlined in the manufacturer's instructions for each particular model of aircraft.

Figure 8-11 illustrates a simplified schematic drawing of a throttle control system for a reciprocating aircraft engine. Follow a general procedure for adjusting throttle controls. First, loosen the serrated throttle control arm at the carburetor and back off the throttle stop until the throttle valve is in the fully closed position. After locking the cable drum into position with the locking pin, adjust the control rod to a specified length. Then, attach one end of the control rod to the locked cable drum, and reinstall the throttle control arm on the carburetor in the serrations that allow the other end of the control rod to be attached to it. This correctly connects the control arm to the cable drum.

Now, loosen the cable turnbuckles until the throttle control can be locked at the quadrant with the locking pin. Then, with both locking pins in place, adjust the cables to the correct tension as measured with a tensiometer. Remove the locking pins from the cable drum and quadrant.

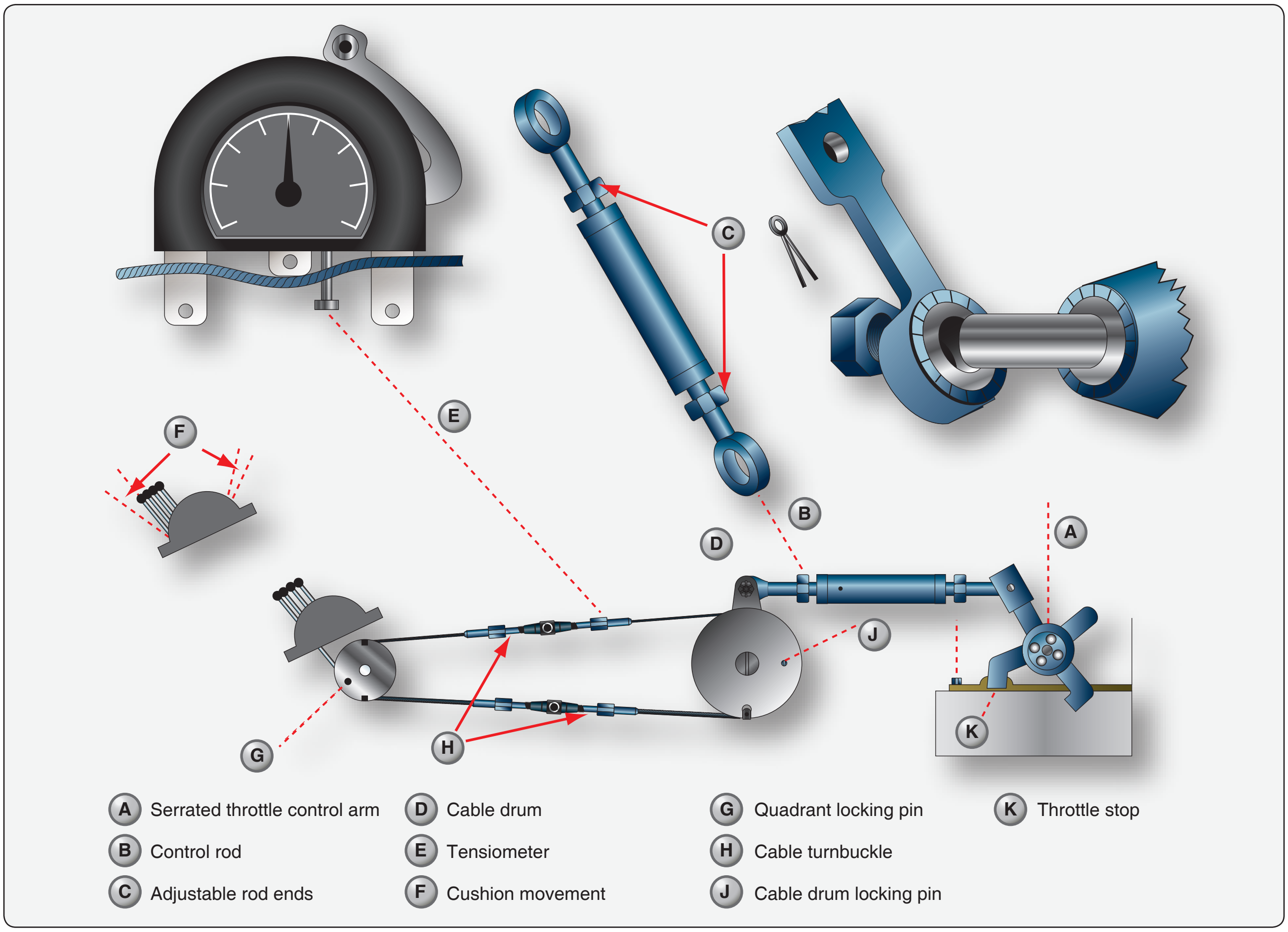


Figure 8-11. *Schematic drawing of throttle control system.*

Next, adjust the throttle control so that it has a slight cushion action at two positions on the throttle quadrant: one when the carburetor throttle valve is in the full-open position and the other when it is closed to the idle position (stop to stop).

Adjust the cushion by turning the cable turnbuckles equally in opposite directions until the throttle control cushion is correct at the full-open position of the throttle valve. Then, when the throttle arm stop is adjusted to the correct idle speed setting, the amount of cushion should be within tolerance at the idle speed position of the throttle valve. The presence of this cushion ensures that the travel of the throttle valve is not limited by the stops on the throttle control quadrant, but that they are opening fully and closing to the correct idle speed as determined by the throttle arm stop.

Adjustment of the engine controls is basically the same on all aircraft regarding the linkage adjustment to a predetermined length for a specific setting of the unit to be controlled. Then adjust cables, if used in the control system, to a specific tension with the control system locked. Finally, the full travel of the unit to be controlled is ensured by establishing the correct cushion in the controls. In general, the same basic procedure is used to connect the linkage of the remaining engine controls. After rigging the engine controls, safety the turnbuckles and castle nuts, and make certain the jam nuts on all control rods are tightened.

On multiengine aircraft, the amount of cushion of all engine controls on each quadrant must be equal so that all are aligned at any specific setting chosen. This eliminates the necessity of setting each control individually to synchronize engine operations.

After the engine has been installed, it is necessary to adjust the cowl flaps, if installed, so that the passage of the cooling air over the engine can be regulated accurately. Operate the system and recheck for opening and closing to the specified limits. Also, check the cowl flap position indicators, if installed, to ensure that they indicate the true position of the cowl flaps. Cowl flaps are doors at the bottom of the rear cowling that are used to control air flow through the cowling.

The oil cooler doors are adjusted in a manner similar to that used to adjust the cowl flaps. In some cases, the procedure is reversed in so far as the door is first adjusted to retract to a specified point, and the limit switch on the motor is set to cut out at this point. Then, the jackscrew is adjusted to permit the door to open only a specified distance, and the open limit switch is set to stop the motor when this point is reached.

After the engine has been completely installed and connected, install the propeller on the aircraft. Before doing so, the thrust bearing retaining nut should be checked for correct torque. If required, the propeller shaft must be coated with light engine oil before the propeller is installed; the propeller governor and anti-icing system must be connected according to applicable manufacturer's instructions.

Preparation of Engine for Ground and Flight Testing

Pre-Oiling

Before the new engine is flight tested, it must undergo a thorough ground check. Before this ground check can be made, several operations are usually performed on the engine.

To prevent failure of the engine bearings during the initial start, the engine should be pre-oiled. When an engine has been idle for an extended period of time, its internal bearing surfaces are likely to become dry at points where the corrosion-preventive mixture has dried out or drained away from the bearings. Hence, it is necessary to force oil throughout the entire engine oil system. If the bearings are dry when the engine is started, the friction at high rpm destroys the bearings before lubricating oil from the engine-driven oil pump can reach them.

There are several methods of pre-oiling an engine. The method selected should provide an expeditious and adequate pre-oiling service. Before using any pre-oiling method, remove one spark plug from each cylinder to allow the engine to be turned over more easily with the starter. Also, connect an external source of electrical power (auxiliary power unit) to the aircraft electrical system to prevent an excessive drain on the aircraft battery.

In using some types of pre-oilers, such as that shown in *Figure 8-12,* the oil line from the inlet side of the engine-driven oil pump must be disconnected to permit the pre-oiler tank to be connected at this point. Then, a line must be disconnected, or an opening made in the oil system at the nose of the engine, to allow oil to flow out of the engine.
Oil flowing out of the engine indicates the completion of the pre-oiling operation, since the oil has now passed through the entire system.

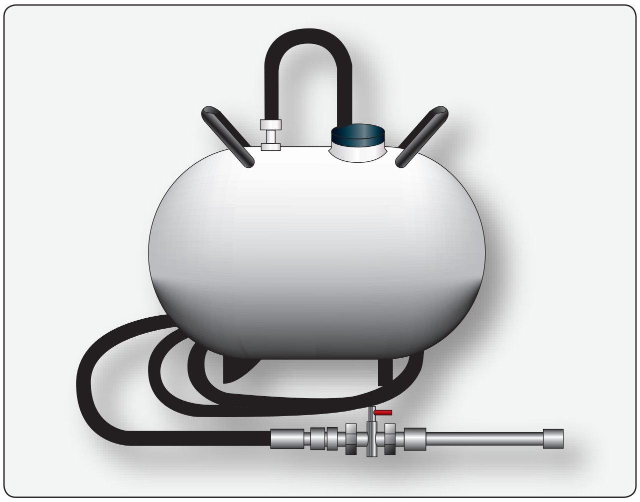


Figure 8-12. *Pre-oiler tank.*

In order to force oil from the pre-oiler tank through the engine, apply air pressure to the oil in the tank while the engine is being turned through with the starter. When this action has forced oil through the disconnection at the nose of the engine, stop cranking the engine and disconnect the pre-oiler tank. A motor-driven oil pump can also be used to pump oil through the engine during the pre-oiling operation.

When no external means of pre-oiling an engine are available, the engine oil pump may be used. Fill the engine oil tank, or crankcase, to the proper level. Then, with the mixture in the idle cutoff position (reciprocating engine), the fuel shutoff valve and ignition switches in the off position, and the throttles fully open, crank the engine with the starter until the oil pressure gauge mounted on the instrument panel indicates oil pressure.

After the engine has been pre-oiled, replace the spark plugs and connect the oil system. Generally, the engine should be operated within 4 hours of being pre-oiled; otherwise, the pre-oiling procedure normally must be repeated.

Fuel System Bleeding

To purge the fuel system of air locks, and to aid in flushing any traces of preservative oil from a pressure carburetor, fuel injector unit, or fuel control (turbine), remove the drain plug in the fuel unit chamber that is farthest from the fuel inlet to the fuel unit. In its place, screw a threaded fitting to a length of hose leading to a suitable container. Then, set the fuel control unit to flow fuel so that fuel is permitted to flow through the system. After ensuring the fuel shutoff and main fuel tank valves are open, turn on the fuel boost pump until there are no traces of preservative oil in the fuel being pumped through the system. The passage of air is indicated by the absence of air mixed in the fuel emerging from the end of the hose submerged in the container of fuel. Air trapped in the system should not be confused with the numerous small air bubbles that may appear as a result of the velocity of the fuel being ejected from the engine's fuel unit. Usually, after approximately a gallon of fuel has been bled off, the system can be considered safe for operation. After completing the bleeding operation, return all switches and controls to their normal, or off, position, and replace and safety all fuel unit connections disturbed.

Propeller Check

The propeller, if equipped, must be checked before, during, and after the engine has been ground operated. The propeller should be checked for proper torque on the mounting bolts, leaks, vibration, and for correct safety.

A propeller whose pitch-changing mechanism is electrically actuated may be checked before the engine is operated. Propellers whose pitch-changing mechanisms are oil actuated must be checked during engine operation after the normal operating oil temperature has been reached. In addition to checking the increase or decrease in rpm, the feathering cycle of the propeller should also be checked.

Checks and Adjustments After Engine Runup and Operation

After the engine has been ground operated, and again after flight test, operational factors must be adjusted, as necessary, and the entire installation given a thorough visual inspection. These adjustments often include fuel pressure and oil pressure, as well as rechecks of such factors as ignition timing, valve clearances, and idle speed and mixture. If these rechecks are indicated by the manner in which the engine performs.

After both the initial ground runup and the test flight, remove the oil sump plugs and screens and inspect for metal particles. Clean the screens before reinstalling them.

Check all lines for leakage and security of attachment. Especially, check the oil system hose clamps for security as evidenced by oil leakage at the hose connections. Also, inspect the cylinder holddown nuts or cap screws for security and safety. This check should also be performed after the flight immediately succeeding the test flight.

Rigging, Inspections, and Adjustments

The following instructions cover some of the basic inspections and procedures for rigging and adjusting fuel controls, fuel selectors, and fuel shutoff valves.

1. Inspect all bellcranks for looseness, cracks, or corrosion.
2. Inspect rod ends for damaged threads and the number of threads remaining after final adjustment.
3. Inspect cable drums for wear and cableguards for proper position and tension.

While rigging the fuel selector, power controls, and shutoff valve linkages, follow the manufacturer's step-by-step procedure for the particular aircraft model being rigged. The cables should be rigged with the proper tension with the rigging pins installed. The pins should be free to be removed without any binding; if they are hard to remove, the cables are not rigged properly and should be rechecked. The power lever should have the proper cushion at the idle and full-power positions. The pointers, or indicators, on the fuel control should be within limits. The fuel selectors must be rigged so that they have the proper travel and do not restrict the fuel flow to the engines.

Rigging Power Controls

Many older conventional turbofan engines use various power lever control systems. One of the common types is the cable and rod system. This system uses bellcranks, push-pull rods, drums, fairleads, flexible cables, and pulleys. All of these components make up the control system and must be adjusted or rigged from time to time. On single-engine aircraft, the rigging of the power lever controls is not very difficult. The basic requirement is to have the desired travel on the power lever and correct travel at the fuel control. On multiengine turbojet aircraft, the power levers must be rigged so that they are aligned at all power settings.

Most computer controlled engines have an electronic connection from the flight deck to the engine. This eliminates the need for any type of cable or linkages. In the computer controlled system, the computer sends electronic information through wires or buses to the fuel control to command it to follow pilot inputs from the flight deck.

On older style aircraft the power lever control cables and push-pull rods in the airframe system to the pylon and nacelle are not usually disturbed at engine change time and usually no rigging is required, except when some component has been changed. The control system from the pylon to the engine must be rigged after each engine change and fuel control change. *Figure 8-13* shows the control system from the bellcrank in the upper pylon to the fuel control.

Before adjusting the power controls at the engine, be sure that the power lever is free from binding and the controls have full throw on the console. If they do not have full throw or are binding, the airframe system should be checked, and the discrepancies repaired. After all adjustments have been made, move the power levers through their complete range,

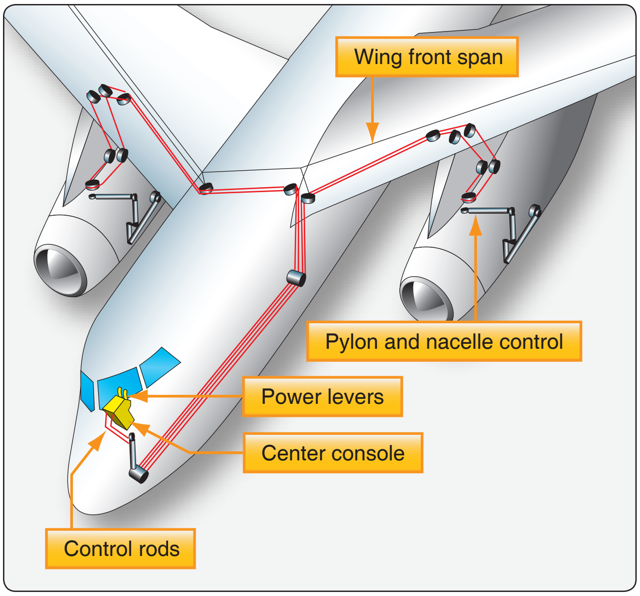


Figure 8-13. *Power lever control system.*

carefully inspecting for adequate clearance between the various push-pull rods and tubes. Secure all locknuts, cotter pins, and safety as required.

Adjusting the Fuel Control

The fuel control unit of the typical turbofan on older aircraft can be a hydromechanical device that schedules the quantity of fuel flowing to the engine so that the desired amount of thrust can be obtained. The amount of thrust is dictated by the position of the power lever in the cockpit and the particular operation of the engine. Thus, the thrust of the engine and the consequent rpm of its turbine are scheduled by fuel flow.

The fuel control unit of the engine is adjusted to trim the engine to obtain maximum thrust output of the engine when desired. The engine must be retrimmed after a fuel control unit is replaced, the engine does not develop maximum thrust, engine change, or excessive throttle stagger.

After trimming the engine, the idle rpm can be adjusted. The idle rpm is adjusted by turning the INC. IDLE screw an eighth of a turn at a time, allowing sufficient time for the rpm to stabilize between adjustments. Retard the power lever to idle and recheck the idle rpm.

If wind velocity is a factor, the aircraft should be headed into the wind while trimming or checking the trim on an engine. Since trimming accuracy decreases as windspeed and moisture content increase, the most accurate trimming is obtained under conditions of no wind and clear, moisture-free air. Do not trim when there is a tailwind because hot exhaust gases may be reingested. As a practical matter, the engine should never be trimmed when icing conditions exist because of the adverse effects on trimming accuracy. To obtain the most accurate results, the aircraft should always be headed into the wind while the engine is being trimmed.

With the aircraft headed into the wind, verify that the exhaust area is clear. Install an engine trim gauge to the T-fitting in the turbine discharge pressure line. Start the engine and allow it to stabilize for 5 minutes before attempting to adjust the fuel control. Refer to the applicable manufacturer's instructions for correct trim values. Compensate for temperature and pressure during the trimming process. If a hydromechanical fuel control is not within limits, turn the INC. MAX screw *[Figure 8-14]* about one-eighth turn in the appropriate direction. Repeat, if necessary, until the desired value is attained. If the aircraft is equipped with a pressure ratio gauge, set it to the correct value.

An example of a trim check using an electronic controlled fuel control must take into account temperature and pressure for each parameter measured. The parameters checked can include:

1. Minimum idle (percent N_2)
2. Approach idle (percent N_2)
3. 2.5 bleed open (percent N_1)
4. 2.5 bleed closed (percent N_1)
5. Takeoff engine pressure ratio (EPR)
6. 95 percent takeoff thrust (EPR)
7. 90 percent thrust change decal (EPR)

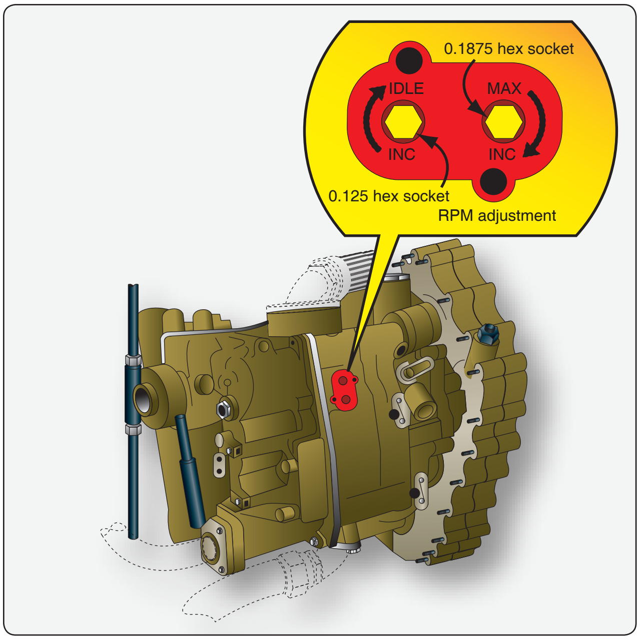


Figure 8-14. *Typical fuel control adjustments.*

The actual trim check would be done based on a temperature and pressure, such as the example in *Figure 8-15.* For these given temperature and pressures, the target parameter values can be derived from a chart in the manufacturer's manual. The engine is run up, and these values are checked against the tolerances given in the manual.

Turboprop Powerplant Removal and Installation

Since most turboprop powerplant removal and installation instructions are developed for QECA, the following procedures reflect those used for a typical QECA. The procedures for turboprop engine removal and installation are similar to those presented in the section of this chapter for turbojet engines, except for those systems related to the turboprop propeller.

Open the engine side panels and remove the nacelle access panels. Disconnect the engine thermocouple leads at the terminal board. Before disconnecting any lines, make sure that all fuel, oil, and hydraulic fluid valves are closed. Plug all lines as they are disconnected to prevent entrance of foreign material.

Remove the clamps securing the bleed-air ducts at the firewall. Then, disconnect the electrical connector plugs, engine breather and vent lines, and fuel, oil, and hydraulic lines.

Disconnect the engine power lever and propeller control rods or cables. Remove the covers from the QECA lift points, attach the QECA sling, and remove slack from the cables using a suitable hoist. The sling must be adjusted to position the hoisting eye over the QECA CG. Failure to do so may result in engine damage.

Remove the engine mount bolts. The QECA is then ready to be removed. Recheck all of the disconnect points to make certain they are all disconnected prior to moving the engine. Move the engine forward, out of the nacelle structure, until it clears the aircraft. Lower the QECA into position on the QECA stand and secure it prior to removing the engine sling.

The installation procedures are essentially the reverse of the removal procedures. Move the QECA straight back into the nacelle structure and align the mount bolt holes and the firewall. Start all the bolts before torqueing. With all the

ASSUME

1. Ambient temperature: OAT = 12 °F
2. Barometric pressure = 29.0 inches of mercury

SELECT TRIM TARGETS FOR THE FOLLOWING

1. Minimum idle (%N2) is 57.7 (+1.5/–0.5)%N2
2. Approach idle (%N2) is 67.6 ±0.5 %N2
3. 2.5 bleed open inc (%N1) 60.4 ±0.5 %N1
4. 2.5 bleed closed inc (%N1) is 63.5 ±0.5 %N1
5. Takeoff (EPR) is 1.50 +0.01/–0.00 EPR
6. 95% takeoff thrust (EPR) is 1.46 EPR
7. 90% thrust change deceleration (EPR) is 1.04 EPR

DAT °F (°C)	Trim targets	Barometer (inches of mercury)									
		31.0	30.0	29.0	28.0	27.0	26.0	25.0	24.0	23.0	22.0
12 (–11)	MIN IDLE (%N2)	57.6	57.6	57.7	58.0	58.3	58.6	58.9	59.5	60.2	60.9
	APP IDLE (%N2)	67.5	67.5	67.6	67.7	67.8	67.9	68.0	68.3	68.8	69.0
	2.5 BLEED OPEN INC (%N1)	60.4	60.4	60.4	60.4	60.4	60.4	60.4	60.4	60.4	60.4
	2.5 BLEED CLOSED INC (%N1)	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
	TAKEOFF (EPR)	1.45	1.48	1.50	1.51	1.53	1.54	1.56	1.57	1.59	1.61
	95% TAKEOFF THRUST (EPR)	1.42	1.45	1.46	1.47	1.48	1.50	1.51	1.52	1.53	1.54
	90% THRUST CHANGE DECEL (EPR)	1.03	1.03	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
16 (–9)	MIN IDLE (%N2)	57.9	57.9	58.0	58.2	58.5	58.8	59.2	59.8	60.4	61.2
	APP IDLE (%N2)	67.8	67.8	67.9	68.0	68.1	68.2	68.3	68.6	68.9	69.3
	2.5 BLEED OPEN INC (%N1)	60.6	60.6	60.6	60.6	60.6	60.6	60.6	60.6	60.6	60.6
	2.5 BLEED CLOSED INC (%N1)	63.8	63.8	63.8	63.8	63.8	63.8	63.8	63.8	63.8	63.8
	TAKEOFF (EPR)	1.45	1.48	1.50	1.51	1.53	1.54	1.56	1.57	1.59	1.61
	95% TAKEOFF THRUST (EPR)	1.42	1.45	1.46	1.47	1.48	1.50	1.51	1.52	1.53	1.54
	90% THRUST CHANGE DECEL (EPR)	1.03	1.03	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
20 (–7)	MIN IDLE (%N2)	58.1	58.1	58.2	58.5	58.8	59.1	59.4	60.0	60.7	61.4
	APP IDLE (%N2)	68.1	68.1	68.2	68.3	68.3	68.5	68.6	68.9	69.2	69.6
	2.5 BLEED OPEN INC (%N1)	60.9	60.9	60.9	60.9	60.9	60.9	60.9	60.9	60.9	60.9
	2.5 BLEED CLOSED INC (%N1)	64.0	64.0	64.0	64.0	64.0	64.0	64.0	64.0	64.0	64.0
	TAKEOFF (EPR)	1.45	1.48	1.50	1.51	1.53	1.54	1.56	1.57	1.59	1.61
	95% TAKEOFF THRUST (EPR)	1.42	1.45	1.46	1.47	1.48	1.50	1.52	1.52	1.53	1.54
	90% THRUST CHANGE DECEL (EPR)	1.03	1.03	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04

Figure 8-15. *Trim check data (Boeing).*

bolts started, and using the correct torque wrench adapter, tighten the mount bolts to their proper torque. Remove the sling and install the access covers at the lift point. Using the reverse of the removal procedures, connect the various lines and connectors. New O-ring seals should be used. The manufacturer's instructions should be consulted for the proper torque limits for the various clamps and bolts.

After installation, an engine runup should be made. In general, the runup consists of checking proper operation of the powerplant and related systems. Several functional tests are performed to evaluate each phase of engine operation. The tests and procedures outlined by the engine or airframe manufacturers should he followed.

Reciprocating Helicopter Engine and QECA

The engine is installed facing aft with the propeller shaft approximately 39° above horizontal. The engine is supported by the engine mount, which is bolted to the fuselage structure. The installation of the engine provides for ease of maintenance by allowing easy access to all accessories and components when the engine access doors are opened. The QECA contains the engine, engine mount, engine accessories, engine controls, fuel system, lubrication system, ignition system, cooling system, and hydromechanical clutch and fan assembly.

Removal of Helicopter QECA

Prior to removing the helicopter QECA, the engine should be preserved if it is possible to do so. Then, shut off the fuel supply to the engine and drain the oil. Make the disconnections necessary to remove the QECA, and then perform the following steps:

1. Attach the engine lifting sling to a hoist of at least a two-ton capacity.
2. Raise the hoist to apply a slight lift to the QECA. Loosen both engine mount lower attachment bolt nuts before leaving the upper attachment bolts.
3. Remove the bolts from the sway braces and remove both engine upper attachment bolts. Then, remove both engine mount lower attachment bolts and remove the QECA from the helicopter. Mount the power package in a suitable workstand and remove the sling.

Installation, Rigging, and Adjustment of Helicopter QECA

The installation of a new or an overhauled engine is in reverse of the removal procedure. The manufacturer's instructions for the helicopter must be consulted to ascertain the correct interchange of parts from the old engine to the new engine. The applicable maintenance instructions should be followed. Refer to the Maintenance Instructions Manual and associated technical publications for detailed information concerning rigging the throttle, mixture control, cable tensions, and related data.

Testing the Engine Installation

Normal engine run-in procedures must be followed in accordance with the manufacturer's instructions. A flight test is usually performed after the engine has been installed and the engine controls have been adjusted.

Engine Mounts

Mounts for Reciprocating Engines

Most aircraft equipped with reciprocating engines use an engine mount structure made of welded steel tubing. The mount is constructed in one or more sections that incorporate the engine mount ring, bracing members (V-struts), and fittings for attaching the mount to the wing nacelle.

The engine mounts are usually secured to the aircraft by special heat-treated steel bolts. The importance of using only these special bolts can be readily appreciated, since they alone support the entire weight of, and withstand all, the stresses imposed by the engine and propeller in flight. The upper bolts support the weight of the engine while the aircraft is on the ground, but when the aircraft is airborne another stress is added. This stress is torsional and affects all bolts, not just the top bolts. A typical engine mount ring shown in *Figure 8-16* discloses fittings and attachment points located at four positions on the engine mount structure. Each fitting houses a dynamic engine mount.

Figure 8-16. *Engine mounting ring.*

The section of an engine mount where the engine is attached is known as the engine mount ring. It is usually constructed of steel tubing having a larger diameter than the rest of the mount structure. It is circular in shape so that it can surround the engine, which is near the point of balance for the engine. The engine is usually attached to the mount by dynafocal mounts, attached to the engine at the point of balance forward of the mount ring. Other types of mounting devices are also used to secure the different engines to their mount rings.

As aircraft engines became larger and produced more power, some method was needed to absorb their vibration. This demand led to the development of the rubber and steel engine-suspension units called shock mounts. This combination permits restricted engine movement in all directions. These vibration isolators are commonly known as flexible, or elastic, shock mounts. An interesting feature common to most shock mounts is that the rubber and metal parts are arranged so that, under normal conditions, rubber alone supports the engine. Of course, if the engine is subjected to abnormal shocks or loads, the metal snubbers limit excessive movement of the engine. Dynafocal engine mounts, or vibration isolators, are units that give directional support to the engines. Dynafocal engine mounts have the mounting pad angled to point to the CG of the engines mass. *[Figure 8-16]*

Mounts for Turbofan Engines

The engine mounts on most turbofan engines perform the same basic functions of supporting the engine and transmitting the loads imposed by the engine to the aircraft structure. Most turbine engine mounts are made of stainless steel and are typically located as illustrated in *Figure 8-17.* Some engine mounting systems use two mounts to support the forward end of the engine and a single mount at the rear end.

Turbine Vibration Isolation Engine Mounts

The vibration isolator engine mounts support the power plants and isolate the airplane structure from adverse engine vibrations. Each power plant is generally supported by forward vibration isolator mounts and an aft vibration isolator mount.

The forward vibration isolator engine mounts carry vertical, side, and axial (thrust) loads and allow engine growth due to thermal expansion. The aft mounts take only vertical and side loads; however, they will also accommodate thermal expansion of the engine without applying axial loads to the engine flanges.

The vibration isolators consist of a resilient material permanently enclosed in a metal case. As an engine vibrates, the resilient material deforms slightly, thereby dampening the vibrations before they reach the airplane structure. If complete failure or loss of the resilient material occurs, the isolators will continue to support the engine.

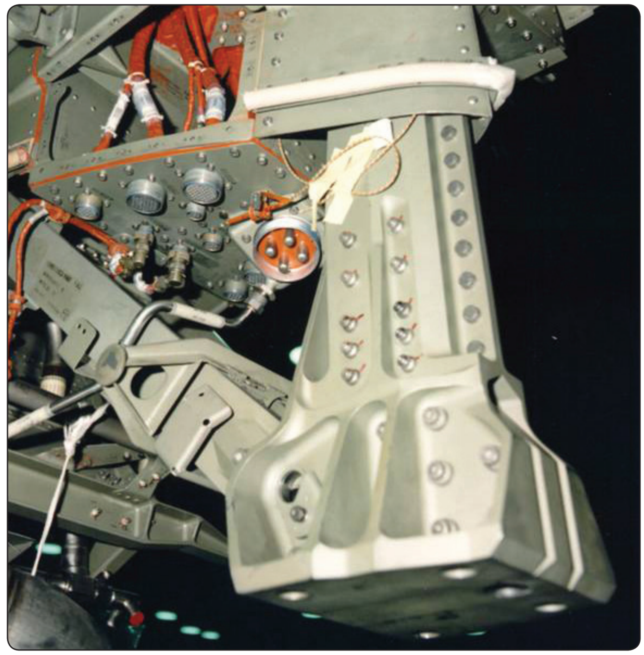


Figure 8-17. *Turbine engine front mount.*

Preservation and Storage of Engines

An engine awaiting overhaul or return to service after overhaul must be given careful attention. It does not receive the daily care and attention necessary to detect and correct early stages of corrosion. For this reason, some definite action must be taken to prevent corrosion from affecting the engine. Engines that are not flown regularly may not achieve normal service life because of corrosion in and around the cylinders. The normal combustion process creates moisture and corrosive by-products that attack the unprotected surfaces of the cylinder walls, valves, and any other exposed areas that are unprotected. In engines that have accumulated 50 hours or more time in service in a short period, the cylinder walls have acquired a varnish that tends to protect them from corrosive action; engines under favorable atmospheric conditions can remain inactive for several weeks without evidence of damage by corrosion. This is the best-case scenario, but aircraft that operate close to oceans, lakes, rivers, and humid regions have a greater need for engine preservation than engines operated in dry low humid areas.

Corrosion-Preventive Materials

An engine in service is in a sense self-purging of moisture, since the heat of combustion evaporates the moisture in and around the engine, and the lubricating oil circulated through the engine temporarily forms a protective coating on the metal it contacts. If the operation of an engine in service is limited or suspended for a period of time, the engine is preserved to a varying extent, depending upon how long it is to be inoperative. There are three types of engine storage: active engine, temporary, and indefinite. An engine in active storage is defined as having at least one continuous hour of operation with an oil temperature of at least 165 °F to 200 °F and storage time not to exceed 30 days. Temporary storage describes an aircraft and engine that is not flown for 30 to 90 days, and indefinite storage is for an aircraft not to be flown for over 90 days or is removed from the aircraft for extended time.

Corrosion-Preventive Compounds

The preservation materials discussed are used for all types of engine storage. Corrosion-preventive compounds are petroleum-based products that form a wax-like film over the metal to which they are applied. Several types of corrosion-preventive compounds are manufactured according to different specifications to fit the various aviation needs. The type mixed with engine oil to form a corrosion-preventive mixture is a relatively light compound that readily blends with engine oil when the mixture is heated to the proper temperature.

The light mixture is available in three forms: MIL-C-6529C type I, type II, or type III. Type I is a concentrate and must be blended with three parts of MIL-L-22851 or MIL-L-6082C (SAE J1966) grade 1100 oil to one part of concentrate. Type II is a ready-mixed material with MIL-L-22851 or grade 1100 oil and does not require dilution. Type III is a ready-mixed material with grade 1010 oil for use in turbine engines only. The light mixture is intended for use when a preserved engine is to remain inactive for less than 30 days. It is also used to spray cylinders and other designated areas.

The desired proportions of lubricating oil, and either heavy or light corrosion-preventive compound, must not be obtained by adding the compound to the oil already in the engine. The mixture must be prepared separately before applying to the engine or placing in an oil tank.

A heavy compound is used for the dip treating of metal parts and surfaces. It must be heated to a high temperature to be sufficiently liquid to effectively coat the objects to be preserved. A commercial solvent, or kerosene spray, is used to remove corrosion-preventive compounds from the engine or parts when they are being prepared for return to service.

Although corrosion-preventive compounds act as an insulator from moisture, in the presence of excessive moisture, they eventually break down and corrosion begins. Also, the compounds eventually dry because their oil base gradually evaporates. This allows moisture to contact the engine's metal and aids in corroding it. Therefore, when an engine is stored in a shipping case or container, some dehydrating (moisture removing) agent must be used to remove the moisture from the air in and around the engine.

Dehydrating Agents

There are a number of substances (referred to as desiccants) that can absorb moisture from the atmosphere in sufficient quantities to be useful as dehydrators. One of these is silica gel. This gel is an ideal dehydrating agent since it does not dissolve when saturated.

As a corrosion preventive, bags of silica gel are placed around and inside various accessible parts of a stored engine. It is also used in clear plastic plugs, called dehydrator plugs, that can be screwed into engine openings, such as the spark plug holes. Cobalt chloride is added to the silica gel used in dehydrator plugs. This additive makes it possible for the plugs to indicate the moisture content, or relative humidity, of the air surrounding the engine. The cobalt-chloride-treated silica gel remains a bright blue color with low relative humidity; as the relative humidity increases, the shade of the blue becomes progressively lighter, becoming lavender at 30 percent relative humidity and fading through the various shades of pink *[Figure 8-18],* until at 60 percent relative humidity it is a natural or white color. Some types of dehydrator plugs can be dried by removing the silica gel and heating the gel to dry it out, returning it to its original blue color. *[Figure 8-19]* When the relative humidity is less than 30 percent, corrosion does not normally take place. Therefore, if the dehydrator plugs are bright blue, the air in

Figure 8-18. *Dehydrator plug "pink" showing high humidity (Sacramento Sky Ranch).*

Figure 8-19. *Dehydrator plug "blue" showing low humidity (Sacramento Sky Ranch).*

the engine has so little moisture that internal corrosion is held to a minimum. This same cobalt-chloride-treated silica gel is used in humidity indicator envelopes. These envelopes can be fastened to the stored engine so that they can be inspected through a small window in the shipping case or metal engine container. All desiccants are sealed in containers to prevent their becoming saturated with moisture before they are used. Care should be taken never to leave the container open or improperly closed.

Engine Preservation and Return to Service

Before an engine is placed in temporary or indefinite storage, it should be operated and filled with a corrosion-preventive oil mixture added in the oil system to retard corrosion by coating the engine's internal parts. Drain the normal lubricating oil from the sump or system and replace with a preservative oil mixture according to the manufacturer's instructions. Operate the engine until normal operating temperatures are obtained for at least one hour.

Always take the appropriate precautions when turning or working around a propeller. After the flight, remove all the spark plug leads and the top spark plugs.

To prevent corrosion, spray each cylinder interior with corrosion-preventive mixture to prevent moisture and oxygen from contacting the deposits left by combustion. Spray the cylinders by inserting the nozzle of the spray gun into each spark plug hole and playing the gun to cover as much area as possible. Before spraying, each cylinder to be treated should be at the bottom center position and the oil at room temperature. This allows the entire inside of the cylinder to become coated with corrosion-preventive mixture. After spraying each engine cylinder at bottom center, respray each cylinder while the crankshaft is stationary with none of the cylinder's pistons at top dead center.

The crankshaft must not be moved after this final spraying, or the seal of corrosion-preventive mixture between the pistons and cylinder walls are broken. Air can then enter past the pistons into the engine. Also, the coating of corrosion-preventive mixture on the cylinder walls is scraped away, exposing the bare metal to possible corrosion. The engine should have a sign attached similar to the following: "DO NOT TURN CRANKSHAFT—ENGINE PRESERVED PRESERVATION DATE ____________."

When preparing the engine for storage, dehydrator plugs are screwed into the spark plug opening of each cylinder. If the engine is to be stored in a wooden shipping case, the ignition harness leads are attached to the dehydrator plugs with lead supports. *[Figure 8-20]* Special ventilatory plugs are installed in the spark plug holes of an engine stored horizontally in a storage container. Any engine being prepared for storage must receive thorough treatment around the exhaust ports. Because the residue of exhaust gases is potentially very corrosive, a corrosion-preventive mixture must be sprayed into each exhaust port, including the exhaust valve. After the exhaust ports have been thoroughly coated, a moisture-proof and oil-proof gasket backed by a metal or wooden plate should be secured over the exhaust ports using the exhaust stack mounting studs and nuts. These covers form a seal to prevent moisture from entering the interior of the engine through the exhaust ports. Engines stored in metal containers usually have special ventilatory covers. Another point at which the engine must be sealed is the intake manifold. If

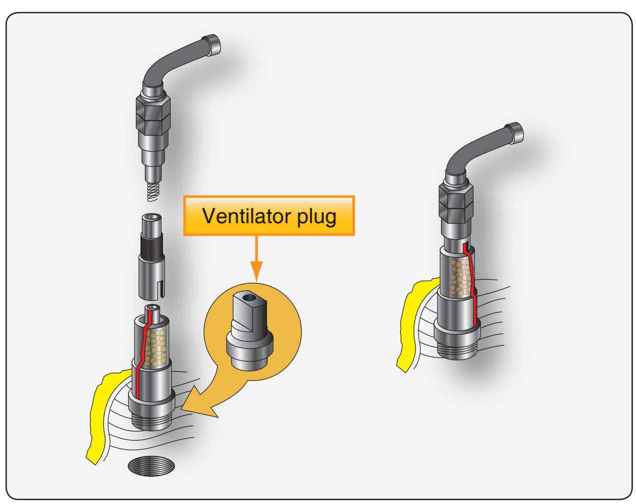


Figure 8-20. *Ignition harness lead support installation.*

the carburetor is to remain on the engine during storage, the throttle valve should be wired open and a seal installed over the air inlet. But, if the carburetor is removed and stored separately, the seal is made at the carburetor mounting pad. The seal used in either instance can be an oil-proof and moisture-proof gasket, backed by a wooden or metal plate securely bolted into place. Silica gel should be placed in the intake manifold to absorb moisture. The silica gel bags are usually suspended from the cover plate. This eliminates the possibility of forgetting to remove the silica gel bags when the engine is eventually removed from storage. A ventilatory cover, without silica gel bags attached, can be used when the engine is stored in a metal container.

After the following details have been taken care of, the engine is ready to be packed into its container. If the engine has not been spray coated with corrosion-preventive mixture, the propeller shaft and propeller shaft thrust bearing must be coated with the compound. Then, a plastic sleeve, or moisture-proof paper, is secured around the shaft, and a threaded protector cap is screwed onto the propeller retaining nut threads.

All engine openings into which dehydrator plugs (or ventilatory plugs if the engine is stored in a metal container) have not been fitted must be sealed. At points where corrosion-preventive mixture can seep from the interior of the engine, such as the oil inlet and outlet, oil-proof and moisture-proof gasket material backed by a metal or wooden plate should be used. At other points moisture-proof tape can be used if it is carefully installed.

Before its installation in a shipping container, the engine should be carefully inspected to determine if the following accessories, which are not a part of the basic engine, have been removed: spark plugs and spark plug thermocouples, remote fuel pump adapters (if applicable), propeller hub attaching bolts (if applicable), starters, generators, vacuum pumps, hydraulic pumps, propeller governors, and engine-driven fuel pumps.

1. Remove seals and all desiccant bags.
2. Remove cylinder dehydrators and plugs or spark plugs from upper and lower spark plug holes.
3. Remove oil sump drain plug and drain the corrosion preventive mixture. Replace drain plug, torque and safety. Remove oil filter. Install new oil filter, torque and safety. Service the engine with oil in accordance with the manufacturer's instructions.

   WARNING: To prevent serious bodily injury or death, accomplish the following before moving the propeller:

   a. Disconnect all spark plug leads.
   b. Verify that magneto switches are connected to magnetos and that they are in the off position and P-leads are grounded.
   c. Throttle position CLOSED.
   d. Mixture control IDLE-CUT-OFF.
   e. Set brakes and block aircraft wheels. Ensure that aircraft tiedowns are installed and verify that the cabin door latch is open.
   f. Do not stand within the arc of the propeller blades while turning the propeller.
4. Rotate propeller by hand several revolutions to remove preservative oil.
5. Service and install spark plugs and ignition leads in accordance with the manufacturer's instructions.
6. Service engine and aircraft in accordance with the manufacturer's instruction.
7. Thoroughly clean the aircraft and engine. Perform visual inspection.
8. Correct any discrepancies.
9. Conduct a normal engine start.
10. Perform operational test in accordance with operational inspection of the applicable Maintenance Manual.
11. Correct any discrepancies.
12 Perform a test flight in accordance with airframe manufacturer's instructions.
13. Correct any discrepancies prior to returning aircraft to service.
14. Change oil and filter after 25 hours of operation.

Engine Shipping Containers

For protection, engines are sealed in plastic or foil envelopes and can be packed in a wooden shipping case or in pressurized metal containers.

The engine is lowered into the shipping container so that the mounting plate can be bolted into position. The protective envelope is attached directly to the base of the shipping case. Then, the engine is lowered vertically onto the base and bolted directly to it. A carburetor not mounted on its reciprocating engine (or no provision is made to seal it in a small container to be placed inside the shipping case) can, in some cases, be fastened to a specially constructed platform bolted to the engine.

Before the protective envelope is sealed, silica gel should be placed around the engine to dehydrate the air sealed into the envelope. The amount of silica gel used is determined by the size of the engine. The protective envelope is then carefully gathered around the engine and partially sealed, leaving an opening at one end from which as much air as possible is exhausted. A vacuum applied to the container is very useful for this purpose and is also an aid in detecting any leaks in the envelope. The envelope is then completely sealed, usually by pressing the edges together and fusing them with heat.

Before lowering the shipping case cover over the engine, a quick inventory should be made. Be sure the humidity indicator card is placed so that it can be seen through the inspection window and that everything required is enclosed in the container. While lowering the wooden shipping case cover into position, be careful that it does not twist and tear the protective envelope. Secure the cover and stencil or mark the date of preservation on the case. Also, indicate whether the engine is repairable or serviceable.

There are several types of shipping containers in use. *[Figure 8-21]* Another type allows horizontal installation of an engine, thus eliminating the need for an extra hoist. The engine is simply lowered onto the base portion of the container and secured. Then, silica gel bags are packed into the container, usually in a special section. The amount of silica gel required in a metal container is generally greater than that needed in a wooden shipping case, since the volume of air in the metal container is much greater than that in the protective envelope installed around an engine in a wooden shipping case. Also, in the metal container the silica gel bags must dehydrate the interior of the engine, since ventilatory plugs are normally installed in the engine openings in place of dehydrator plugs. All records of the engine should be enclosed inside the shipping container or on the outside for accessibility. A humidity indicator should be fastened inside the containers with an inspection window provided. Then, the rubber seal between the base and the top of the container must be carefully inspected. This seal is usually suitable for re-use several times. After the top of the container has been lowered into position and fastened to the base of the container, dehydrated air at approximately 5 pounds per square inch (psi) pressure is forced into the container. The container should be checked for leaks by occasional rechecks of the air pressure, since radical changes in temperature affect the air pressure in the container.

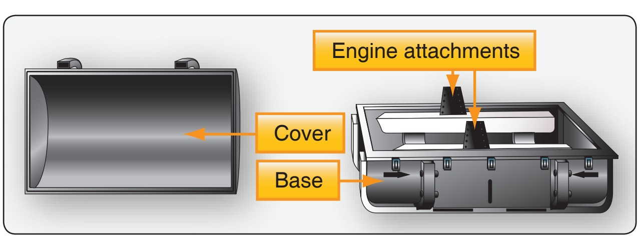


Figure 8-21. *Turbine engine shipping container.*

Inspection of Stored Engines

Most maintenance shops provide a scheduled inspection system for engines in storage. Normally, the humidity indicators on engines stored in shipping cases are inspected every 30 days. When the protective envelope must be opened to inspect the humidity indicator, the inspection period may be extended to once every 90 days, if local conditions permit. The humidity indicator of a metal container is inspected every 180 days under normal conditions.

If the humidity indicator in a wooden shipping case shows by its color that more than 30 percent relative humidity is present in the air around the engine, all desiccants should be replaced. If more than half the dehydrator plugs installed in the spark plug holes indicate the presence of excessive moisture, the interior of the cylinders should be resprayed. If the humidity indicator in a metal container gives a safe blue indication, but air pressure has dropped below 1 psi, the container needs only to be brought to the proper pressure with dehydrated air. However, if the humidity indicator shows an unsafe (pink) condition, the engine should be represerved.

Preservation and Depreservation of Gas Turbine Engines

The procedures for preserving and depreserving gas turbine engines vary depending upon the length of inactivity, the type of preservative used, and whether or not the engine may be rotated during the inactive period. Much of the basic information on corrosion control presented in the section on reciprocating engines is applicable to gas turbine engines. However, the requirements for the types of preservatives and their use are normally different.

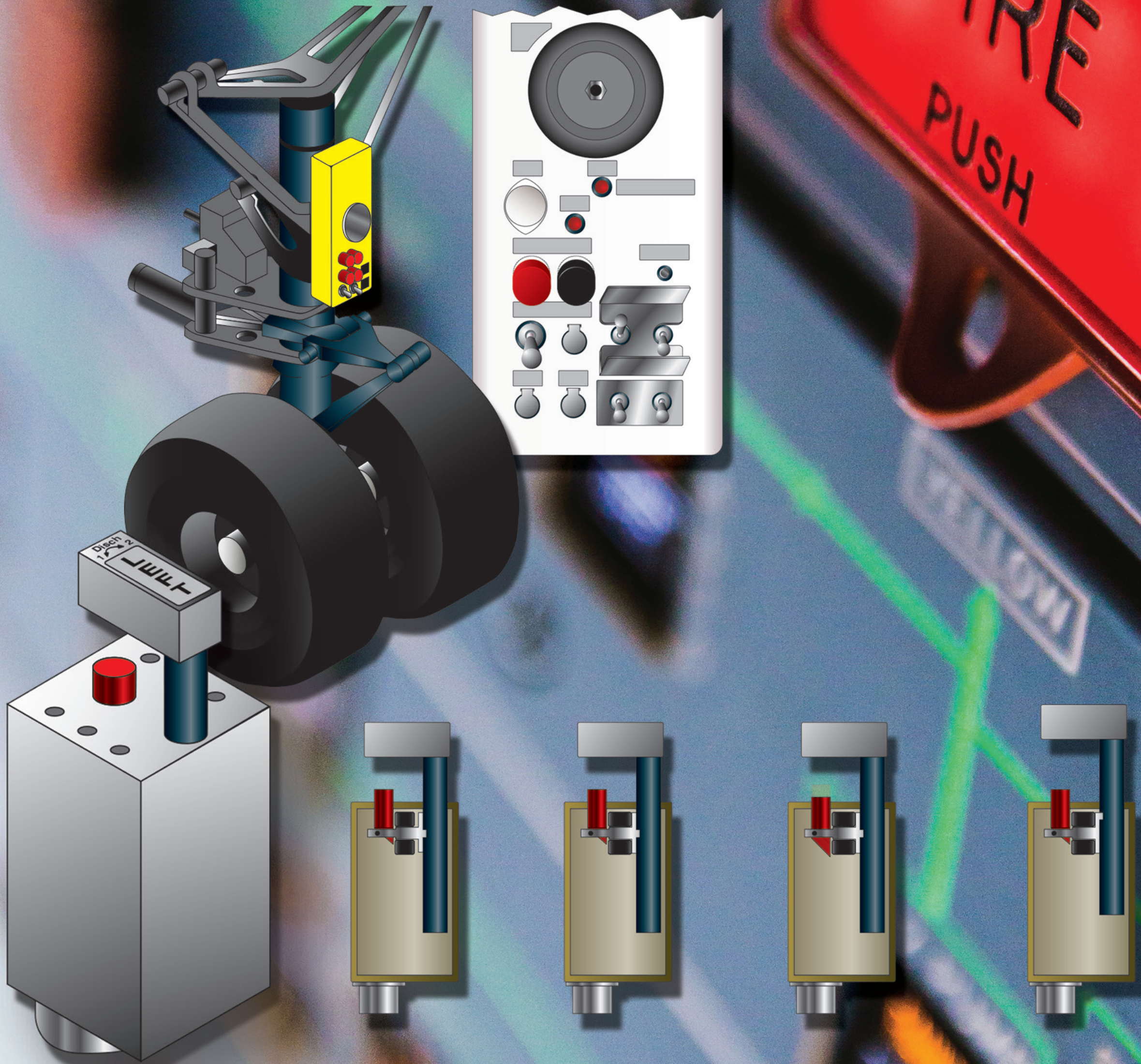
The lubrication system is usually drained and may or may not be flushed with preservative oil. The engine fuel system is generally filled with preservative oil, including the fuel control. Before the engine can be returned to service, the preservative oil must be completely flushed from the fuel system by motoring the engine and bleeding the fuel system. Always follow the manufacturer's instructions when performing any preservation or depreservation of gas turbine engines.

Chapter 9

Engine Fire Protection Systems

Introduction

Because fire is one of the most dangerous threats to an aircraft, the potential fire zones of all multiengine aircraft currently produced are protected by a fixed fire protection system. A "fire zone" is an area or region of an aircraft designated by the manufacturer to require fire detection and/or fire extinguishing equipment and a high degree of inherent fire resistance. The term "fixed" describes a permanently installed system in contrast to any type of portable fire extinguishing equipment, such as a hand-held fire extinguisher.



In accordance with Title 14 of the Code of Federal Regulations (14 CFR) parts 23 and 25, engine fire protection systems are mandatory on: multiengine turbine powered airplanes, multiengine reciprocating engine powered airplanes incorporating turbochargers, airplanes with engine(s) located where they are not readily visible from the cockpit, all commuter and transport category airplanes, and the auxiliary power unit (APU) compartment of any airplane incorporating an APU. Fire protection systems are not mandatory for many single and twin reciprocating engine general aviation (GA) aircraft.

Several general failures or hazards can result in overheat conditions or fires peculiar to turbine engine aircraft because of their operating characteristics. The two major types of turbine failure can be classified as 1) thermodynamic and 2) mechanical.

Thermodynamic causes upset the proportion of air used to cool combustion temperatures to the levels that the turbine materials can tolerate. When the cooling cycle is upset, turbine blades can melt, causing a sudden loss of thrust. The rapid buildup of ice on inlet screens or inlet guide vanes can result in severe overheating, causing the turbine blades to melt or to be severed and thrown outward. Such failure can result in a severed tail cone and possible penetration of the aircraft structure, tanks, or equipment near the turbine wheel. In general, most thermodynamic failures are caused by ice, excess air bleed or leakage, or faulty controls that permit compressor stall or excess fuel.

Mechanical failures, such as fractured or thrown blades, can also lead to overheat conditions or fires. Thrown blades can puncture the tail cone, creating an overheat condition. Failure of forward stages of multi-stage turbines usually is much more severe. Penetration of the turbine case by failed blades is a possible fire hazard, as is the penetration of lines and components containing flammable fluids.

A high flow of fuel through an improperly adjusted fuel nozzle can cause burn-through of the tail cone in some engines. Engine fires can be caused by burning fluid that occasionally runs out through the exhaust pipe.

Components

A complete fire protection system includes both a fire detection and a fire extinguishing system. To detect fires or overheat conditions, detectors are placed in the various zones to be monitored. Fires are detected in aircraft by using one or more of the following: overheat detectors, rate-of-temperature-rise detectors, and flame detectors. In addition to these methods, other types of detectors are used in aircraft fire protection systems but are not used to detect engine fires. For example, smoke detectors are better suited to monitor areas such as baggage compartments or lavatories, where materials burn slowly or smolder. Other types of detectors in this category include carbon monoxide detectors.

Fire protection systems on current-production aircraft do not rely on observation by crewmembers as a primary method of fire detection. An ideal fire detector system includes as many of the following features as possible:

1. A system that does not cause false warnings under any flight or ground condition.
2. Rapid indication of a fire and accurate location of the fire.
3. Accurate indication that a fire is out.
4. Indication that a fire has reignited.
5. Continuous indication for duration of a fire.
6. Means for electrically testing the detector system from the aircraft cockpit.
7. Detectors that resist damage from exposure to oil, water, vibration, extreme temperatures, or handling.
8. Detectors that are light in weight and easily adaptable to any mounting position.
9. Detector circuitry that operates directly from the aircraft power system without inverters.
10. Minimum electrical current requirements when not indicating a fire.
11. Each detector system should turn on a cockpit light, indicating the location of the fire, and have an audible alarm system.
12. A separate detector system for each engine.

Engine Fire Detection Systems

Several different types of fire detection system are installed in aircraft to detect engine fires. Two common types used are spot detectors and continuously loop systems. Spot detector systems use individual sensors to monitor a fire zone. Examples of spot detector systems are the thermal switch system, the thermocouple system, the optical fire detection system, and the pneumatic-based thermal fire detection system. Continuous loop systems are typically installed on transport type aircraft and provide more complete fire detection coverage by using several loop-type sensors.

Thermal Switch System

A number of detectors or sensing devices are available. Many older model aircraft still operating have some type of thermal switch system or thermocouple system. A thermal switch system has one or more lights energized by the aircraft