

CHAPTER 8

TURBOPROP ENGINES AND PROPELLERS

There are a variety of turboprop aircraft in the Navy inventory. The C-130 Hercules, a cargo transport aircraft, is the workhorse of naval aviation. The E-2 Hawkeye is the fleet's airborne early warning aircraft. The C-2 Greyhound is a fleet logistics support aircraft. The P-3 Orion is our fleet antisubmarine warfare (ASW) aircraft (*Figure 8-1*).

In this chapter, the T56 engine and the Hamilton Sundstrand 54H60-77, or the NP2000 model propellers, are examples of common turboshaft engine and propeller systems. There are differences in the turboprop aircraft mentioned above, but the basic operation, assemblies, and maintenance are similar.

The turboprop engine section of this chapter discusses the operating principles, parts, and systems unique to turboprop engines. After learning about the turboprop engine, we will discuss propellers. The propeller section describes basic propeller parts, operating principles, and maintenance procedures.

LEARNING OBJECTIVES

When you have completed this chapter, you will be able to do the following:

1. Identify the major components of the turboprop engine systems.
2. Discuss the turboprop safety systems.
3. Recognize the turboprop control systems.
4. Describe the basic propeller operating principles.
5. Identify basic propeller operations.
6. Recognize propeller assemblies and subassemblies.
7. Discuss propeller maintenance checks.
8. Recognize propeller balancing and leakage tests.

TURBOPROP ENGINES

If the exhaust gas from the basic part of a turbojet rotates an additional turbine that drives a propeller through a speed-reducing system, it is a turboprop engine. The aircraft turboprop is more complicated and heavier than a turbojet engine of equal size and power. The turboprop delivers more thrust at low subsonic airspeeds. This advantage decreases as flight speed increases, so in normal cruising speed ranges, the propulsive efficiency of a turboprop decreases as speed increases. In a turbojet, the propulsive efficiency increases as speed increases. The ability of a propeller to accelerate a large mass of air at low airspeed results in the unusual high performance of a turboprop during takeoff and climb. This low-speed performance also enables a turboprop aircraft to carry heavier payloads, making them ideal cargo aircraft. At approximately Mach 1 airspeed, the turboprop engine can deliver more thrust than the turbojet engine of the same gas turbine design. For a given amount of thrust, the turboprop engine requires a smaller gas turbine with lower fuel consumption than the turbojet engine.

The turboprop engine produces thrust indirectly through the propeller. A characteristic of the turboprop is that changes in power do not change engine speed. Changes in power change the turbine inlet temperature (TIT). During flight, the propeller maintains a constant 100-percent engine speed. This speed is the design speed where power and maximum efficiency is obtained. Changes in fuel flow affect power changes. An increase in fuel flow causes an increase in turbine inlet



Figure 8-1 — Four types of turboprop aircraft. (1-P-3), (2-E-2), (3-C-2), (4-C-130)

temperature and a corresponding increase in energy available at the turbine. The turbine absorbs more energy and sends it to the propeller in the form of torque. The propeller, in order to absorb the increased torque, increases blade angle to maintain constant engine revolutions per minute (rpm).

These changes occur through coordination between the propeller governor and the turboprop engine fuel control. Together they establish the correct combination of rpm, fuel flow, and propeller blade angle to create the propeller thrust required to provide the requested power.

Turboprop Engine Systems

The turboprop engine consists of three major assemblies. They are the power section assembly, the torquemeter assembly, and the reduction gear assembly (RGA) (*Figure 8-2*). We will discuss the power section assembly first.

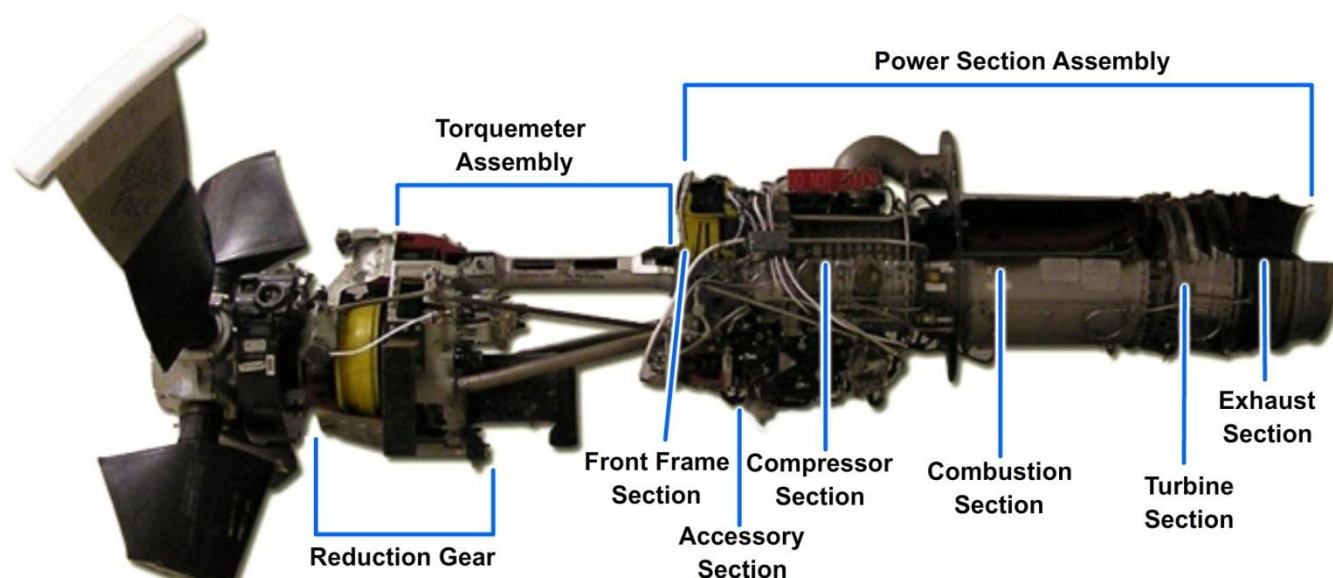


Figure 8-2 — Turboprop engine major assemblies.

Power Section Assembly

The power section assembly is essentially a constant-speed turbojet engine (*Figure 8-3*). The major assembly consists of an axial flow compressor assembly, a can-annular combustion section, a turbine assembly, and accessory drive housing. The power section assembly contains oil, fuel, ignition, control, and cooling air systems. It also has a compressor extension shaft to which the torquemeter attaches.

Torquemeter Assembly

The torquemeter assembly is located between the power section and reduction gear assemblies. Its purpose is to transmit and measure the shaft output from the power section to the reduction gear assembly.

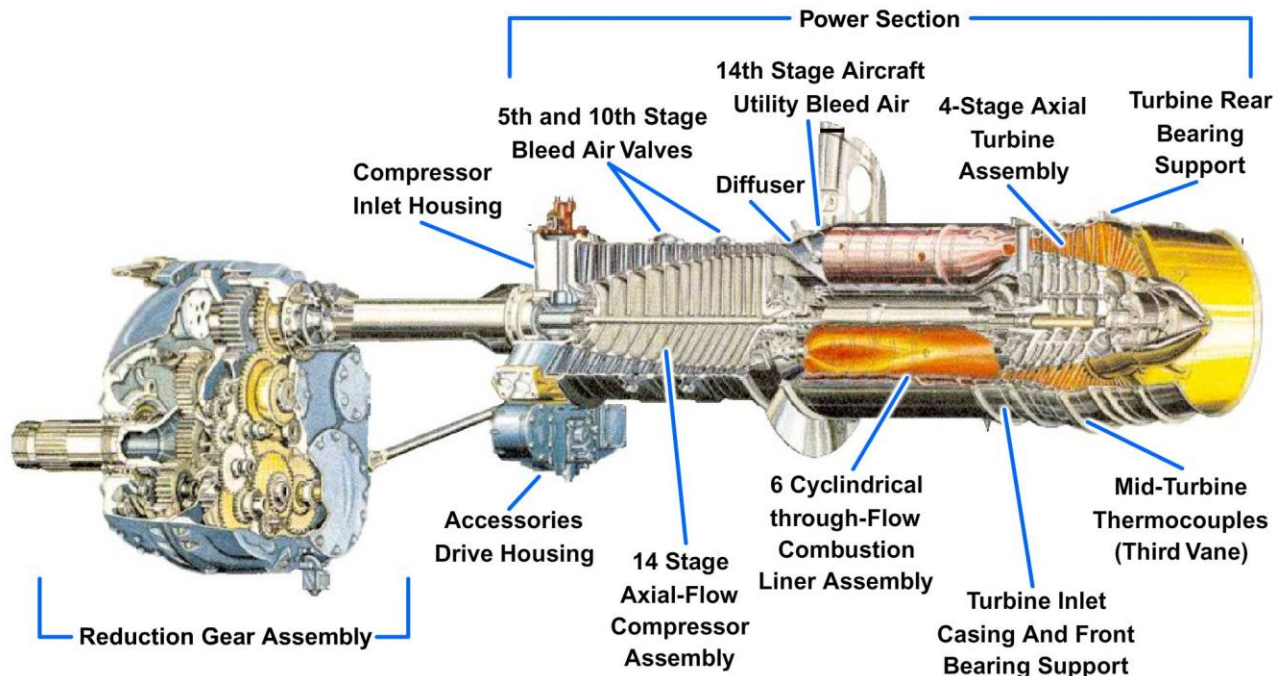


Figure 8-3 — Power section assembly.

The torquemeter operates on the principle of accurate measurement of torsional deflection (twist) that occurs in any power transmitting shaft. This torsional deflection is detected by magnetic pickups. The deflection is measured electronically, and displayed in the flight station instrument panel in terms of inch-pounds of torque, or shaft horsepower (SHP). The principle parts of the torquemeter assembly are shown in *Figure 8-4*.

Two concentric shafts make up the torquemeter assembly. The inner shaft (torque shaft) carries the load and produces the measured twist. The outer shaft (reference shaft for measuring purposes) is rigidly connected to the torque shaft at the drive input end only. There are separate flanges on both the torque and reference shafts at the reduction gear assembly end. Rectangular exciter “teeth” are machined in line on each flange, which enable the pickups to detect the relative displacement of the two flanges.

The torquemeter housing serves as a rigid lower support between the power unit and the reduction gear assembly. It provides a mounting for the pickup assembly at the reduction gear end.

The pickup assembly consists of electromagnetic pickups mounted radially over the teeth of the torque and reference shaft flanges. These pickups produce electrical impulses at the passage of each exciter tooth. The pickups are displaced so that the reference flange impulse from its pickup and the torque flange impulse from its pickup are slightly out of phase at zero load. Because zero torque

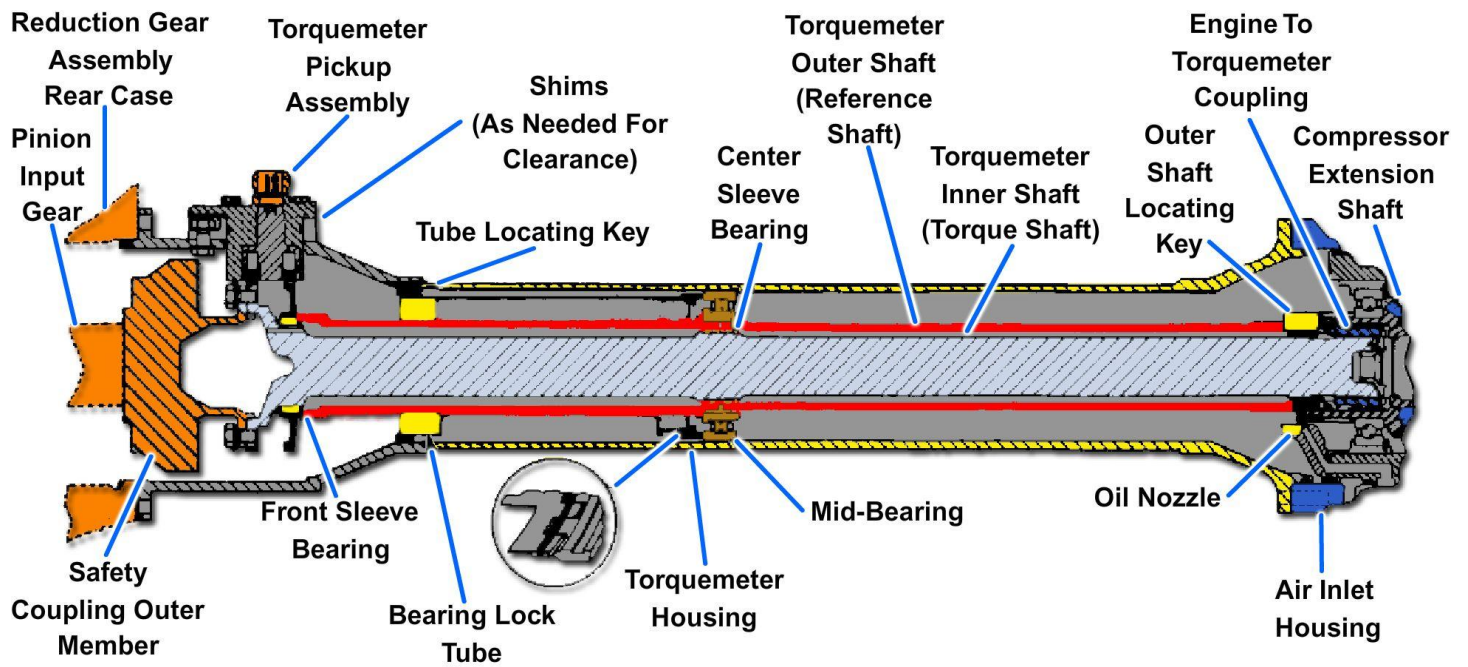


Figure 8-4 — Torquemeter assembly.

indications are not at the electrical zero of the indicator, both positive and negative torque conditions are measured.

Reduction Gear Assembly (RGA)

The reduction gear assembly changes the high rpm, low torque of the turbine section to the low rpm, high torque necessary for efficient propeller operation. This change is made through a two-stage reduction system of sun and planetary gears (*Figure 8-5*). The two stages of reduction provide an overall speed reduction of 13.54 to 1; for example, when power section rpm is 13,820, the propeller shaft rpm is 1,020. The reduction gear case also provides the drive and location to mount the propeller and accessories.

Accessories mounted on the case include a

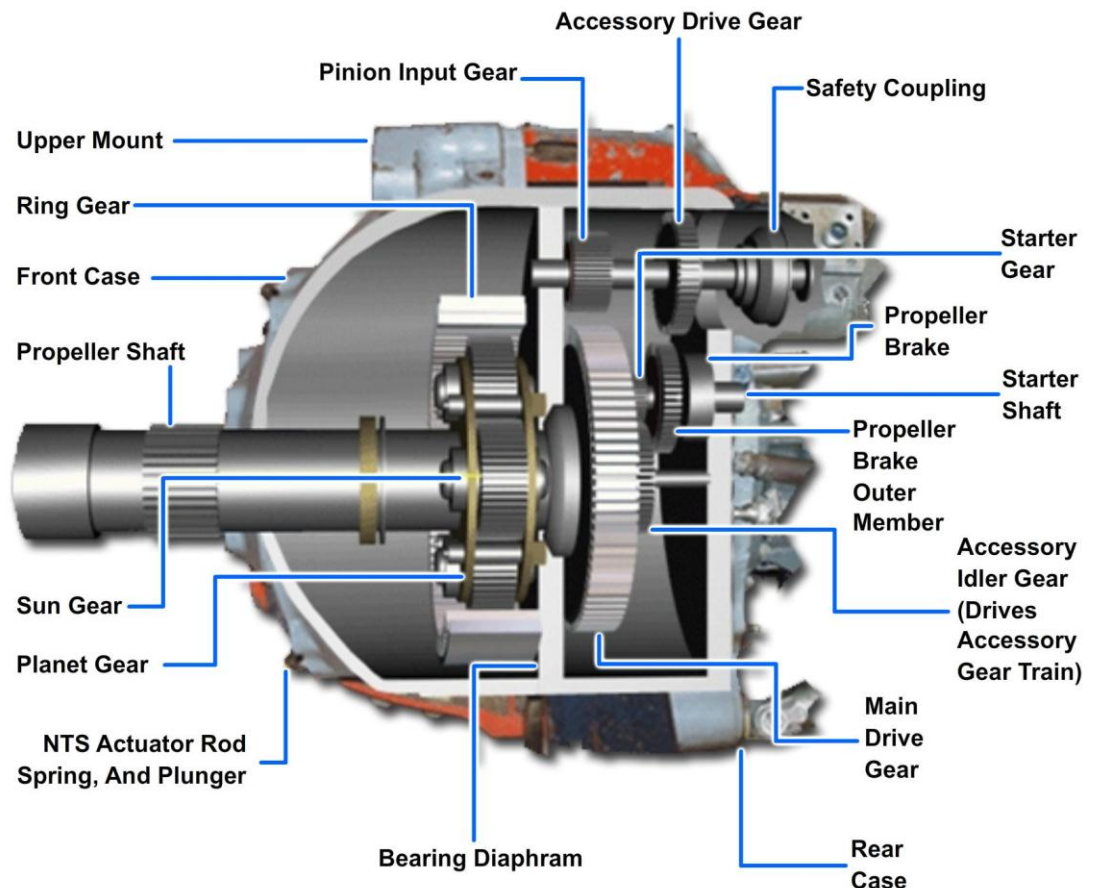


Figure 8-5 — Reduction gear assembly (RGA).

starter, generator, engine-driven compressor (EDC), oil pump, and tachometer generator. The reduction gear assembly also uses safety systems that we will discuss next.

TURBOPROP SAFETY SYSTEMS

The complexity of the turboprop configuration brings the possibility of certain hazardous in-flight situations. Safety features have been designed into the system to activate automatically whenever a system-related hazard occurs. One shall not rely on safety features and should always follow safety precautions when working on or around a turboprop.

The following text discusses some of the hazards and their related safety features (*Figure 8-6 frames 1-7*).



Figure 8-6 — Turbo prop safety systems frames 1-7.

Thrust Sensitive Signal (TSS)

The thrust sensitive signal system (TSS) is a safety device used during takeoffs. The TSS automatically initiates propeller feathering and shuts down the turboprop engine in case of power loss. This allows the pilot to concentrate on flying the aircraft during the critical takeoff period. Feathering the propeller reduces the yawing action (caused by drag) and asymmetric flight characteristics on multi-engine aircraft. The TSS system is on the reduction gear assembly, and it is armed through a switch in the flight station.

Negative Torque Signal (NTS)

The negative torque signal system (NTS) momentarily prevents the propeller from driving the engine during in-flight conditions. The NTS system is mechanically locked out during engine operation in the

ground range. The system's mechanical linkage and plunger are inside the front case of the reduction gearbox. They work with the propeller valve housing assembly to increase propeller blade angle during negative torque conditions. When a predetermined negative torque is applied to the reduction gearbox, a stationary (nonrotating) ring gear moves forward against spring force. This action results in a rod moving forward through the reduction gear nose case. The rod positions the feather valve in the valve housing to an increased blade angle. When the propeller blade angle has increased enough to relieve negative torque conditions, the plunger retracts and the propeller returns to normal operation.

The NTS system functions in flight during temporary fuel interruptions, air gust loads on the propeller, normal descents with lean fuel scheduling, or high compressor bleed-air conditions at low-power settings.

Safety Coupling

The safety coupling is an automatic mechanical device that decouples (disconnects) the power section from the reduction gear assembly when negative torque exceeds the setting of the safety coupling. The safety coupling is between the main input pinion gear shaft on the reduction gearbox and the outer member of the torquemeter drive shaft. Any transfer of torque, positive or negative, between the power section and the reduction gear assembly transmits through the safety coupling. Positive torque occurs when the power section drives the propeller through the reduction gear assembly. Negative torque occurs when the propeller drives the power section. The safety coupling backs up the NTS system to prevent engine compressor and turbine damage. If the NTS system fails to limit negative torque, the safety coupling protects the engine from extensive damage by decoupling.

Propeller Brake

The propeller brake is used when a turboprop engine is not in operation. Since the compressor and turbine rotors can rotate easily when the engine is shut down, a propeller brake is needed. The propeller brake prevents the propeller from wind-milling on the ground or when it is feathered in flight. It also decreases the time needed for the propeller to come to a complete stop after engine shutdown. The brake is in the reduction gearbox assembly between the rear case and rear case inner diaphragm. It is part of the accessory drive gear train. The propeller brake has three positions. They are the released, applied, and locked positions.

The propeller brake is a friction-cone type, consisting of a stationary inner member and a rotating outer member. During normal engine operation, reduction gear oil pressure holds the brake in the released position. This is accomplished by oil pressure, which holds the outer member away from the inner member. When the engine is shut down, reduction gear oil pressure drops. A spring force moves the outer member into contact with the inner member or to the applied position. The propeller brake locks when it is moved in a direction opposite normal rotation. When locked, it acts upon the reduction gearbox primary stage reduction gearing to prevent movement along with the friction-cone brake.

TURBOPROP CONTROL SYSTEMS

The control of a turboprop engine involves the control of engine speed, temperature, and torque. The turboprop fuel control and the propeller governor are connected and operate in coordination with each other. Together they establish the correct combination of rpm, fuel flow, and propeller blade angle to create sufficient propeller thrust to provide the desired power.

Manual control of the system is provided by the power levers and the emergency shutdown handles mounted in the flight station (*Figure 8-7*). The control systems are divided into two operational ranges. They are the flight control range (alpha) and ground handling range (beta).

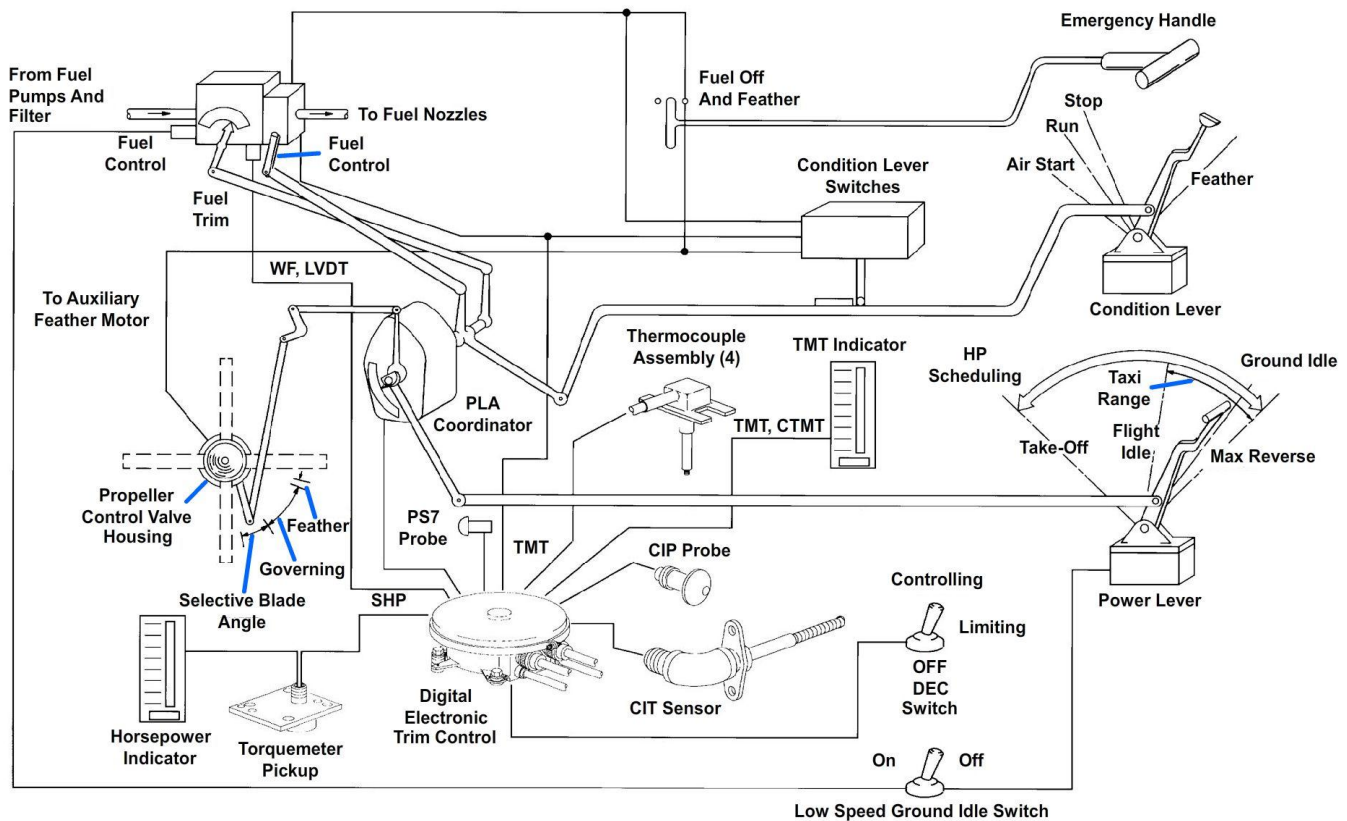


Figure 8-7 — Control schematic.

For airborne operation, the propeller blade angle and fuel flow for any given power lever setting are governed automatically according to a predetermined schedule. Below the flight idle power lever position, the coordinated rpm blade angle schedule becomes incapable of handling the engine efficiently. Here the ground handling or beta range is encountered. In this range of the throttle quadrant, the propeller blade angle is controlled by the power lever position. Next, we will discuss the engine's control system components—power levers, fuel control, and coordinator.

Power Levers

The power lever controls power delivered by the engine. There are six positions marked on the power lever quadrant (*Figure 8-8*). Listed below are the corresponding degrees as read from the engine coordinator.

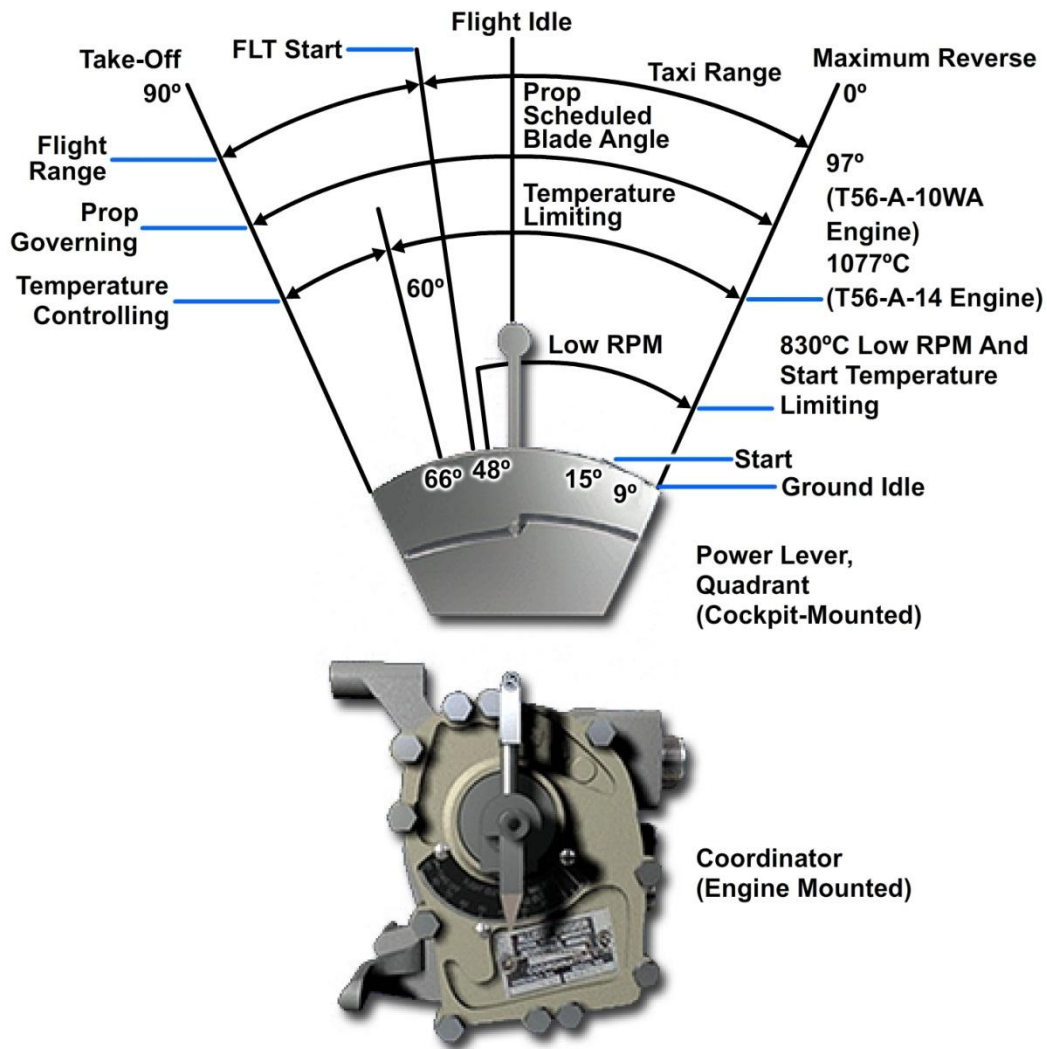


Figure 8-8 — Coordinator quadrant markings.

Max reverse — 0°
Ground idle — 9°
Start — 15°
Flight idle — 34°
Air start — 48 °
Takeoff — 90° (max power)

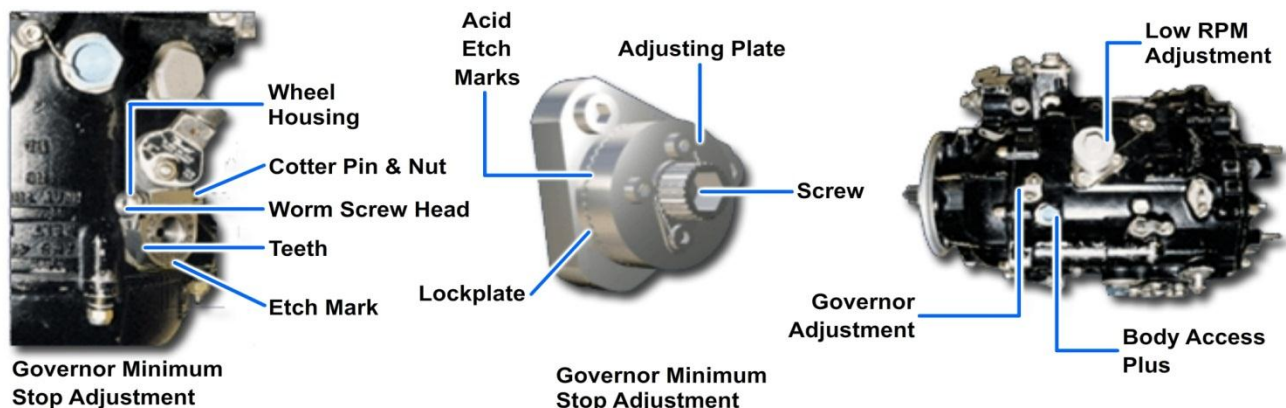
The two ranges of operation of the power lever quadrants are the alpha and beta ranges. The beta range is the portion of the quadrant from max reverse (0°) to flight idle (34°). With the power lever set at ground idle, the propeller is at a 5 degree-negative blade angle to compensate for power section thrust. Movement of the power lever toward flight idle increases fuel flow and blade angle. Movement from ground idle towards max reverse increases fuel flow, but causes the propeller to schedule reverse blade angle. In the flight range alpha, the power lever schedules fuel flow only.

Fuel Control

A turboprop fuel control is similar to a turbojet fuel control. The difference is the turboprop fuel control operates in conjunction with a propeller governor. The fuel control mounts on the engine accessory drive housing, which is mechanically linked to the coordinator. The fuel control is designed to perform the following functions:

- Provide a means of varying fuel flow to permit a selection of power that is coordinated with propeller blade angle and engine speed.
- Regulate the rate of fuel metering during acceleration to prevent excessive turbine inlet temperature.
- Control the rate of fuel metering during deceleration to prevent flameout.
- Control engine and propeller speed outside the limits of operation of the propeller governor. This includes reverse thrust, low speed ground idle, flight idle, and high speed ground idle.
- Provide a measure of engine protection during overspeed conditions by reducing fuel flow and turbine inlet temperature.
- Provide a starting fuel flow schedule that, with the temperature datum valve, avoids over-temperature and compressor surge.
- Compensate for changes in air density due to variations in compressor inlet air temperature and pressure.
- Provide a means of cutting off fuel flow electrically and manually.

The fuel control senses compressor inlet pressure, compressor inlet temperature, and engine speed. Using these three factors and the setting of the power lever, the fuel control meters the proper amount of fuel. Pressure and temperature compensating systems are designed to maintain constant turbine inlet temperature as the compressor inlet conditions vary.



Governor Minimum Stop Adjustment

1. Adjust If "Lean Blow-Out Occurs During Reset To Low Speed Ground Idle
2. Counterclockwise To Increase Fuel Flow
3. Maximum Permissible Adjustment To Increase Fuel Flow is 90PPH

Governor Adjustment

1. Adjust If Overspeed Governor Setting Is Found To Be Out-Of-Limits during an Overspeed Governor And Propeller Pitch Lock Check
2. One 360° Turn Of Adjustment Will Change Engine Speed Approximately 140 RPM (1%)
3. Turn Counterclockwise To Increase RPM

Low Speed Ground Adjustment

1. Adjust If RPM Is Out-Of-Limits During Low-Speed Ground Idle Operation
2. One Detent (Cuck) Equals Approximately 70 RPM (.5%)
3. Turn Clockwise To Increase RPM

Figure 8-9 — Fuel Control.

The fuel control includes a cutoff valve for stopping fuel flow to the engine. This valve operates both electrically and manually. Electrical control is made possible by moving the fuel and ignition switch to the off position. This signals the cutoff valve motor to close the valve. Actuation of the emergency shutdown control closes the valve mechanically through a cable and control rod system from the flight station (*Figure 8-9*).

Coordinator

Mounted on the rear face of the fuel control is the engine coordinator. The function of the engine coordinator is to coordinate the propeller, temp control, and fuel control. A system of levers, bell cranks, and linkages connect the coordinator with the fuel control and the propeller control. Refer to the system schematic (*Figure 8-7*).

PROPELLERS

The propeller converts the power output of the engine into forward thrust to move the aircraft through the air. A propeller is essentially a “rotating wing,” or airfoil. When the aircraft engine turns the propeller, relative motion is developed between the wing-like propeller blades and the air. As it pulls itself through the air, the propeller carries along anything that is attached to it, within the limitations of the power developed. The faster the propeller spins, within certain limits, the greater the resulting thrust.

Basic Propeller Parts

There are different propeller manufacturers and many varied designs. These designs include the experimental multi-curved blade for propellers. All propellers have the same basic parts, and terms for the parts of one propeller are applicable to other propellers. The basic parts of a propeller are as follows:

- **BLADE.** One arm of a propeller from the butt to the tip. Propellers usually have two or more blades (*Figure 8-10*).
- **BLADE BACK.** The surface of the blade as seen by standing in front of the propeller (*Figures 8-10*).
- **BLADE FACE.** The surface of the blade as seen by standing directly behind the propeller (*Figure 8-11*).
- **SHANK.** The thickened portion of the blade near the hub of the propeller. The shank is sometimes referred to as the root (*Figure 8-10*).
- **TIP.** The portion of the blade furthest from the hub (*Figure 8-10*).



Figure 8-10 — NP 2000 (8) propeller blades.

- **HUB.** The central portion of the propeller that is fitted to the propeller shaft, securing the blades by their roots (Figure 8-10).
- **LEADING EDGE.** The forward or “cutting edge” of the blade that leads in the direction the propeller is turning. The other edge (rear edge) is called the **TRAILING EDGE** (Figure 8-10).
- **PROPELLER RETAINING NUT.** The nut that locks the propeller hub to the propeller shaft. It is part of the propeller rather than the engine.



Figure 8-11 — 54H60-77 (4) propeller blades.

- **BLADE STATIONS.** These are reference lines, usually designed as measurements, made from the hub. These lines are numbered and locate positions on the propeller blade. They are usually designated at 6-inch intervals. The first station is normally 12 inches from the hub. Figure 8-12 shows the blade stations of a propeller blade.
- **BLADE ANGLE (PITCH).** Blade angle is the angle formed by the chord of a section of the blade and a plane perpendicular to the axis of rotation. The blade angles in Figure 8-13 are representative of standard low- and high-pitch as well as the feather angles. These angles will vary with different propeller installations.
- **BLADE CHORD.** Blade chord is the distance between the leading and trailing edges. This is an imaginary line extending from the center of the leading edge to the center of the trailing edge. It is important for blade balancing.
- **FEATHERING.** Feathering is streamlining the propeller blade with the relative wind. This feature is found in most multi-engine propeller installations. Feathering serves to reduce the drag caused by a wind-milling propeller on a dead engine and to stop rotation that could cause further damage (Figure 8-13).

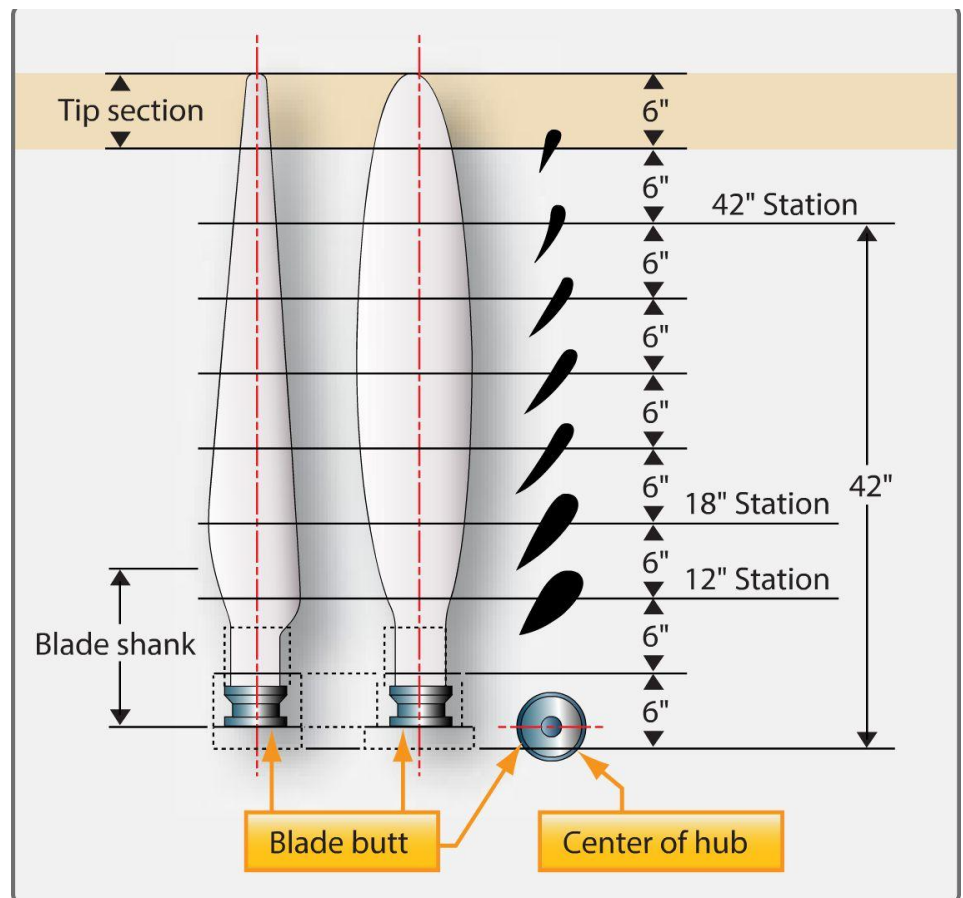


Figure 8-12 — Blade stations.

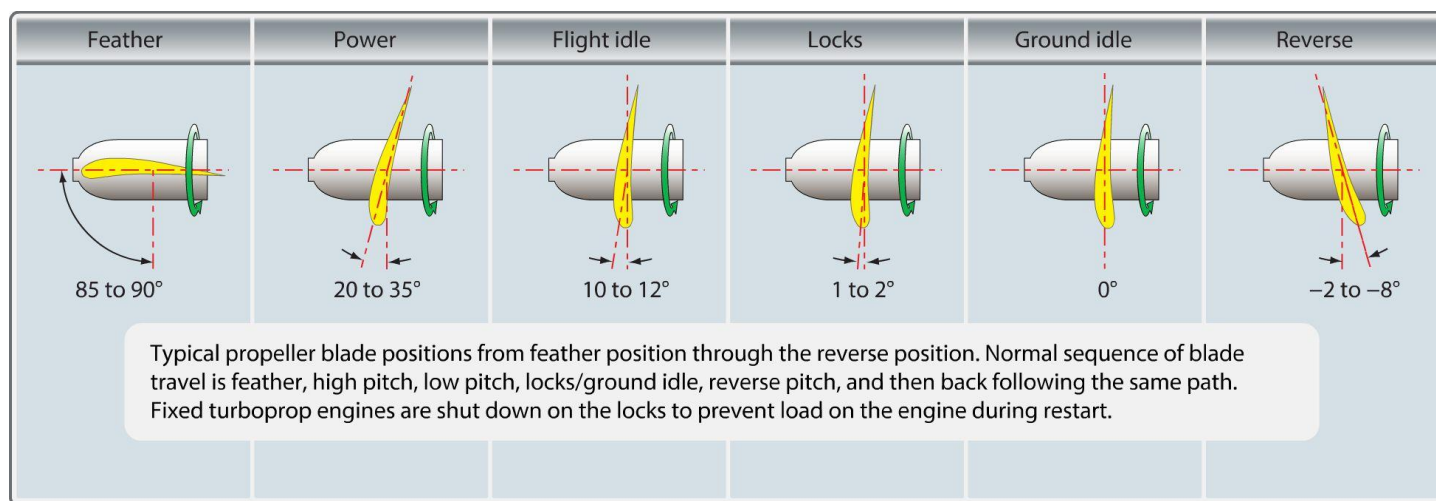


Figure 8-13 — Propeller blade angles.

- **REVERSING.** A reversing propeller allows for a negative blade angle. With a negative blade angle, a propeller produces reverse thrust (thrust in a direction opposite to that normally produced by the propeller in flight). Reverse thrust produces a braking action used during landing to reduce the landing roll-out distance. It can also be used to taxi an aircraft backwards.

Propeller Model Designation

The model designation for the propeller assembly, shown by markings on the barrel, identifies the type of propeller. The number and letter group describes the basic model, and the number group that follows the dash indicates the number of minor modifications.

A breakdown of the designation of the 54H60-77 propeller is as follows:

- 5—Indicates the number of major changes incorporated in the propeller.
- 4—Indicates the number of blades.
- H—Describes the blade shank size. (The use of a LETTER here also indicates that the blades are made of aluminum. A NUMBER here would indicate the shank size and that the blades were made of steel, as in model 24260.)
- 60—Indicates the spline size of the propeller shaft.
- 77—Indicates minor modifications made to the propeller.

BASIC PROPELLER OPERATION

The first propellers were fixed-pitch and designed mainly to get the aircraft off the ground. The pitch (blade angle) was small so that the engine could quickly turn over to its full rpm and use its full horsepower for takeoff. Once an aircraft with a fixed-pitch propeller of low blade angle is in the air, forward speed of the aircraft is limited. The low blade angle allows the propeller to turn too fast to take a big enough bite of the onrushing air. As a result, the engine must be throttled to prevent excessive over speeding.

The first improvement over the fixed-pitch propeller was the ground-adjustable-pitch type. On this type, the blade angle (pitch) could be changed or adjusted on the ground by manually twisting the blades in the hub to the desired angle. When the angle was increased to improve cruising conditions, takeoff conditions suffered. An aircraft taking off from the ground with the propeller at a high blade angle position is much the same as a car set into motion in high gear. The engine is not able to

produce full horsepower because the high blade angle loads the propeller too much to enable it to turn over at the full rpm of the engine.

The next design was the two-position propeller. It enabled a pilot to use a low blade angle (high rpm setting) for takeoff, climb, and necessary operational acceleration. The pilot could then change the propeller blade angle in flight to a higher blade angle (low rpm setting) for cruise. With this propeller, full engine rpm could be developed for takeoff. Aircraft speed could be increased at cruise with a decrease in engine power because the high-pitch propeller takes larger bites out of the air. The two-position propeller did not, however, produce the most efficient and economical use of engine horsepower for all of the numerous intermediate flight conditions encountered by aircraft.

Constant-speed propellers were eventually designed to maintain a preselected rpm automatically. Suppose the aircraft is heading into a gradual climb. The constant-speed propeller maintains the selected rpm automatically by turning the propeller blades to a lower angle. That is, the propeller takes a smaller bite of air when the load on the engine is increased. Now, should the aircraft assume a nose-down attitude, the propeller blades move automatically to a higher blade angle; hence, the propeller takes a larger bite of air. In other words, increase the load on the engine and the propeller takes a smaller bite of air. Decrease the engine load and the propeller takes a larger bite of air. This function will keep the turboprop engine at 100-percent rpm.

On constant-speed propellers, the blade angle must be adjusted to provide the most efficient angle of attack at all engine and aircraft speeds. The most efficient angle of attack is very small; it varies from 1 to 4 degrees positive angle. The actual blade angle necessary to maintain this small angle of attack varies with the forward speed of the aircraft. With constantly increasing aircraft speeds and high-altitude operations, it is necessary to have a wide range of blade angle settings. This range of settings must adapt the propeller to conditions encountered in takeoff, climb, and cruising.

Forces Acting on the Propeller

One of the main requirements of any propeller is its ability to withstand severe stresses. We will discuss these stresses, which are greatest near the hub, in the following paragraphs. *Figure 8-14* shows the forces acting on propeller blades.

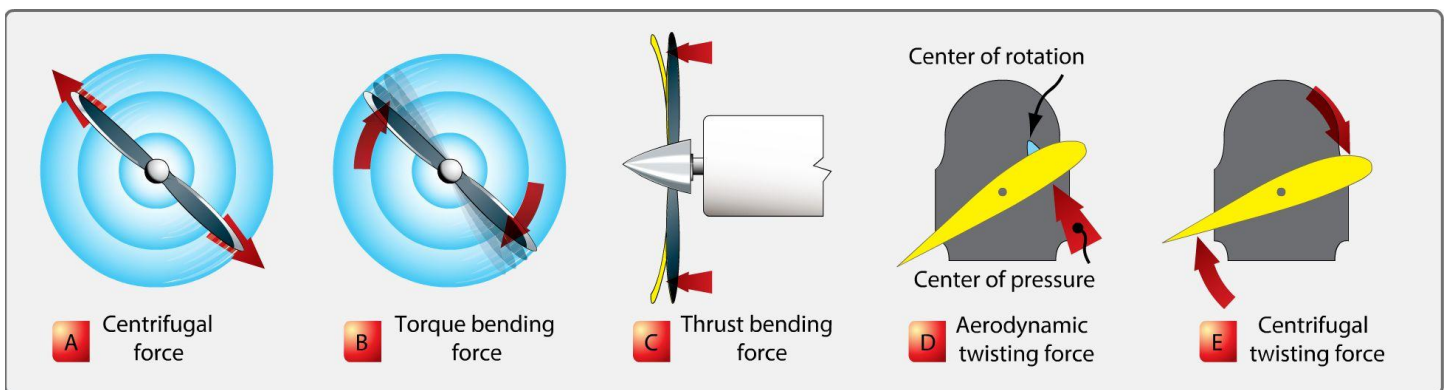


Figure 8-14 — Natural forces acting upon propeller blades.

Centrifugal Force

The greatest force acting upon the propeller blade is centrifugal force. This force tends to pull the blade of a spinning propeller out of its hub. To prevent the blades from breaking into fragments or flying off into space, the blade is thicker near the hub. The hub is made from a strong steel forging.

Thrust Bending Force

Thrust bending force causes a rotating propeller to try to pull away from the aircraft. Because it is held back by the hub and the load of the aircraft it is pulling, the blade tips, which are thinner and lighter than the blade shank, bend forward. The sum of these bending forces on the blades is carried at or near the hub. Hence, the section of the blade at the hub must be proportionately thicker. Centrifugal force counteracts thrust bending force by its tendency to pull the blades in a straight line.

Torque Bending Force

Torque bending force is the tendency for a blade to bend backwards, throughout its length, in a direction opposite rotation. This bending force is created by the density of the air.

Aerodynamic Twisting Force

Aerodynamic twisting force tries to rotate the blades in the hub to an increased blade angle. The point at which this force is exerted most strongly on the chord of the airfoil is known as the center of pressure. During normal cruise conditions, this center of pressure is nearer the leading edge of the propeller, so the force tends to rotate the blades to a higher pitch.

Centrifugal Twisting Force

The centrifugal twisting force on the blades tends to twist them to a lower pitch angle. This occurs because all parts of the propeller try to remain in a plane parallel to the plane of rotation.

Propeller Vibration

Sometimes, in the face of these forces, a propeller loses some of its rigidity. The result is a flutter, a type of vibration in which the tips of the blades attempt to twist rapidly back and forth while the propeller is turning. Fluttering causes a distinctive noise, which is nearly drowned out by the exhaust noises of the engine. Fluttering will weaken the propeller and may result in structural failure unless detected early and corrected.

PROPELLER ASSEMBLIES

The propeller system has one primary function—increasing or decreasing pitch as required by power lever movement. Safety features incorporated in the 54H60-77 (4-bladed) propeller system includes automatic mechanical pitchlock, automatic negative torque control. Some of the important features incorporated in the NP 2000 (8-bladed) propeller system include all composite blades with individual blade replacement, runs quieter containing an active inflight balancing system, and an Electronic Propeller Control System (EPCS).

Spinners and Afterbody Assemblies

The main purpose of the front and rear spinners are to streamline the airflow around the outside of the propeller assembly for cooling. The front and rear spinner assemblies improve the aerodynamic characteristics of the whole propeller assembly. They enclose the dome, barrel, and oil control assemblies. The front spinner has an air inlet in the middle of it. Cooling ram air enters to cool the dome, barrel, and oil control assemblies. The rear spinner has electrical deicing wires to prevent ice buildup on the backside of the propeller assembly. The propeller after-body assembly streamlines airflow into the engine air inlet. The after-body assembly has a top and bottom half.

Hub Mounting Bulkhead Assembly and Propeller Assembly

The hub mounting bulkhead is the mounting surface for the front and rear spinner assemblies. The variable pitch aircraft propeller (propeller assembly) has four major subassemblies. They are the barrel assembly, the blade assembly, the dome assembly, and the pitchlock regulator assembly (*Figure 8-15*).

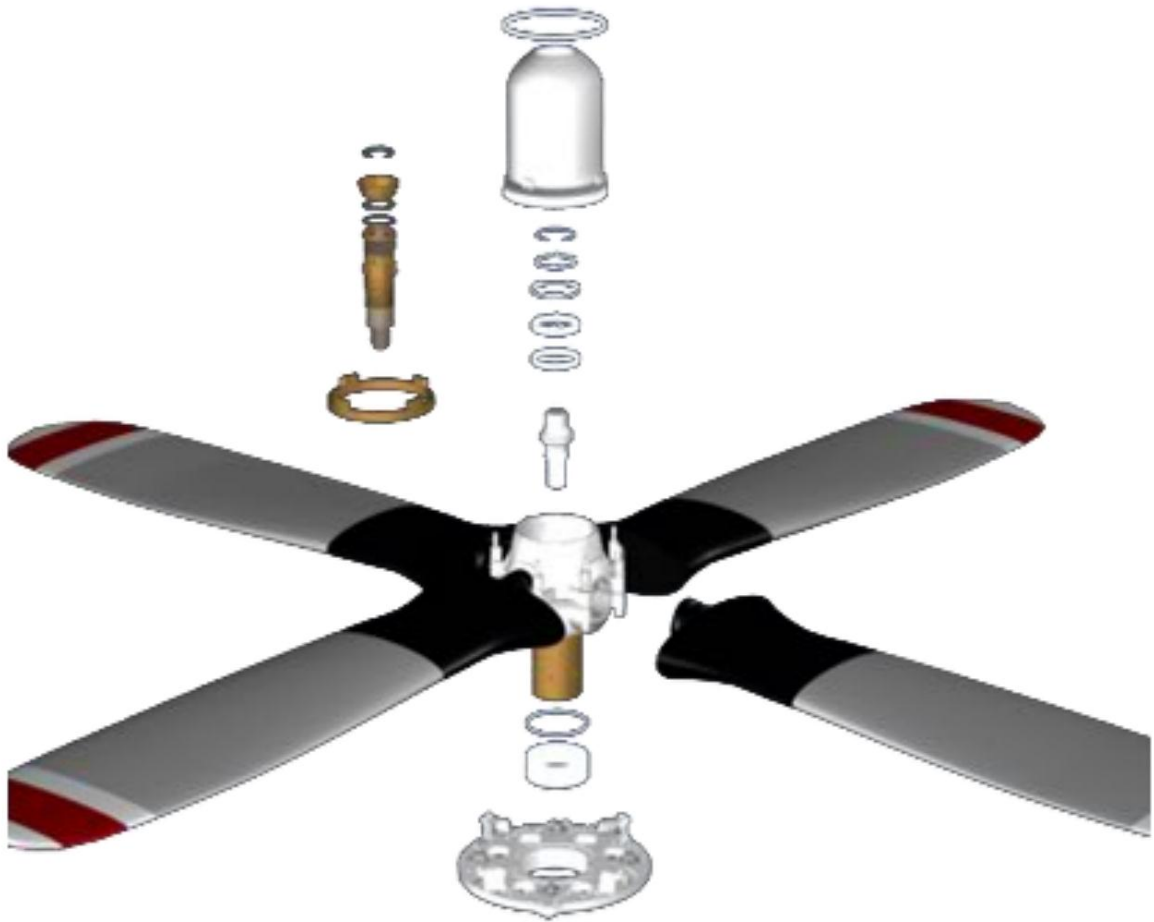


Figure 8-15 — Propeller system.

Barrel Assembly

The propeller barrel assembly serves several functions. It retains the four propeller blades and also supports the dome assembly and the propeller control assembly. Engine torque is transmitted to the propeller by the barrel assembly, which mounts and secures to the front of the reduction gear assembly propeller shaft.

The barrel assembly is a split type; the front and rear barrel sections are manufactured and balanced as a matched pair. These sections are kept together throughout the service life of the propeller. The high centrifugal blade loads are carried by the barrel shoulders and lips at each blade position.

A machined integral extension on the rear barrel half is splined internally and has seats at both ends. The front and rear cones are beveled to match the extension seats for centering and securing the propeller on the propeller shaft. The extension is splined externally for driving pumps in the propeller control assembly. A propeller hub nut locks the barrel assembly to the reduction gearbox propeller shaft. The propeller hub nut has a flange on its inboard end that butts against the front cone.

Blade Assembly

The 54H60-77 model is a broad, lightweight 4-blade propeller forged from a solid aluminum alloy or composite, which gives it the strength necessary to obtain the high thrust capability at low aircraft speeds. The blade butt is partially hollow to allow for installation of the blade bushing and blade balancing assembly. Propeller balancing is discussed in the balancing section of this chapter.

The blade shank has a molded fairing that is composed of a plastic foam material covered with a nylon-reinforced neoprene material. The heater assembly is bonded to the leading edge of the fairing. It contains the necessary blade deicer elements to prevent ice buildup on the blade assembly. Blade heater element damage, involving cut or broken heater wires because of weather corrosion or foreign object damage (FOD) strikes, can be repaired if no more than four wires are damaged. If more than four wires are damaged, the heater assembly must be replaced. The purpose of the blade fairing cuff is to streamline and direct the airflow to the engine intake.

The NP2000 model is an all-composite 8 propeller blade system with the capability to do on-wing blade replacement, improving aircraft reliability. It also reduces maintenance propeller man hours by half and fuel consumption by 3 percent. Although there are other propeller blade systems in aviation, these are the two types prominently used in today's Navy.

Dome Assembly

The propeller dome assembly is the blade angle changing mechanism of the propeller system. The dome assembly is mounted on the front barrel shelf and held in position by the dome retaining nut. The principal components of this pitch-changing mechanism are the rotating cam, the stationary cam, the piston assembly, and the low pitch stop assembly. The low pitch-stop assembly is screwed into the lever sleeve bushing at the front of the dome.

Preformed packings are used throughout the dome assembly for internal leakage control and to seal the piston assembly in order to separate the inboard and outboard hydraulic pressure necessary for blade movement. Shims are used to establish the proper clearance between the rotating cam and the blade segment gears. The dome assembly is mounted in position on the front barrel shelf. It is held in place by the dome retaining nut that is locked in place by a special head screw.

The low pitch-stop assembly screws into the dome assembly. It sets the desired low pitch-stop blade angle. In the flight range of operation, the low pitch-stop lever assembly prevents the propeller blade angle from going below 13 degrees. In the ground range, extra high hydraulic fluid pressure actuates the low pitch-stop assembly, allowing the piston to move further outboard. This turns the blades from the low pitch-stop position towards the reverse blade angle.

Pitchlock Regulator Assembly

The propeller pitchlock regulator assembly mounts within the propeller barrel and is splined to the propeller hub nut. The pitchlock regulator assembly directs hydraulic pressure to the outboard and inboard sides of the dome piston. It also serves as a safety feature by preventing a decrease in blade angle by pitch-locking, under certain conditions. Pitchlock occurs if hydraulic control pressure is lost or during an overspeed of 103 to 103.5 percent.

The pitchlock regulator assembly contains two ratchet rings that are spring loaded together, but are held apart by hydraulic pressure. One ratchet ring is splined to the rotating cam of the dome assembly. The other ratchet ring is splined to the propeller rear barrel half and does not rotate. If hydraulic pressure is lost, the ratchet rings come together, and their teeth mesh to prevent a decreased blade angle. This is referred to as pitchlock, and can only occur between approximately 15 to 60 degrees of blade angle. Pitchlock is mechanically cammed out below 15 and above 60 degrees. When in pitchlock, the propeller operates as a fixed-pitch propeller. However, the reverse rake of the

pitchlock ratchet teeth allows rotating of the propeller into higher blade angles for feathering or to regain control.

Propeller Control Assembly (Integral Oil Control Assembly)

The propeller control assembly is a nonrotating integral oil control mechanism. It mounts on the rear extension of the propeller barrel (*Figure 8-16, frames 1 and 2*). The control assembly contains two major components—the pump housing assembly and the valve housing assembly. The pump housing assembly contains the hydraulic reservoirs, pumps, and valves. The valve housing assembly is where all mechanical and electrical connections necessary for propeller operation are made. The mechanical connections include the linkages between the engine control system and NTS. The electrical connections are for the pulse generator coil, the auxiliary pump motor, the synchrophasing system, and the anti-icing and deicing systems.



Interaction Available

Propeller Control Assembly

Figure 8-16 — Propeller control assembly frames 1 and 2.

Pump Housing Assembly

The pump housing assembly forms the lower parts of the propeller control assembly. The pump housing contains five positive displacement gear-type pumps (three mechanically driven and two electrically driven). An externally mounted alternating current (ac) electric motor drives the two common shafted auxiliary pumps. Two hydraulic fluid sumps are contained in the pump housing assembly. One is a pressurized sump with a capacity of 6 quarts. The other is an atmospheric sump with a capacity of 4.5 quarts. A pressure cutout switch located in the pump housing serves to terminate the action of the auxiliary pumps. This action occurs when the feather blade angle is reached.

The three mechanically driven gear-type pumps are the main pump, the main scavenge pump, and the standby pump. The electrical pumps are the auxiliary scavenge pump and the feather pump. The feather pump is used for static ground operations. It also serves to complete the feather operation in flight. An electrical motor driven pump is needed since the output pressure of the mechanically driven pumps is reduced in proportion to the decaying propeller rpm.

Valve Housing Assembly

The valve housing assembly is considered the brains of the propeller system. It mounts to the upper part of the pump housing assembly, forming the propeller control assembly. The valve housing assembly is the most complex assembly of the propeller system. Major units of the valve housing

assembly are the speed servo governor assembly, flyweights, speeder spring, pilot valve, feather valve, feather solenoid valve, main and standby regulating valves, high-pressure relief valve, beta and speed-setting lever assembly, alpha and beta pinion shafts, linkage support assembly, and electrical branch cable.

The two ranges of operation controlled through the valve housing assembly are the governing range and the taxi range. The governing range is commonly called the alpha or the flight range. The taxi range is commonly called the beta scheduling or the ground-handling range. All primary propeller operations, except for feathering and unfeathering the propeller, are determined by the position of the pilot valve in the speed servo governor. Hydraulic fluid for blade angle change operation is pumped from the pressurized sump by the main pump (and standby pump if needed) to the pilot valve chamber.

Flyweights are geared to the propeller shaft. This causes their rotation to develop centrifugal force in direct relation to the engine speed. The centrifugal force extends the flyweights outward and pushes the pilot valve toward the increased pitch position. This movement of the pilot valve opposes the speeder-spring force, which pushes the pilot valve toward the pitch change valve spool centers in the pitch change sleeve to block pitch change hydraulic pressure from the propeller dome. Any change in the engine speed will change the outward position of the flyweight. The flyweight shifts the pilot valve to direct pitch change hydraulic pressure to the dome.

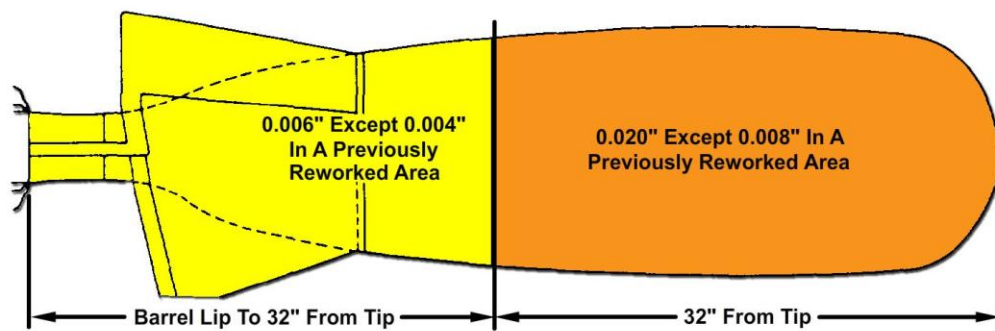
Constant-speed governing is blocked out in the ground handling range. The propeller blade angle is coordinated with the position of the power lever. Interaction of the cams on the alpha and beta shaft controls the position of the pilot valve in the speed servo governor. When the power lever is moved, a cam on the alpha shaft positions the pilot valve to obtain a corresponding blade angle. As the blade pitch changes, a cam on the beta shaft returns the pilot valve to a position that will maintain the blade pitch at the angle scheduled by the power lever.

Rigging pin holes are located on the valve housing assembly for rigging the valve housing to the propeller assembly and power lever. Adjustments are provided to set the mechanical governor speed and the reverse and ground handling blade angles.

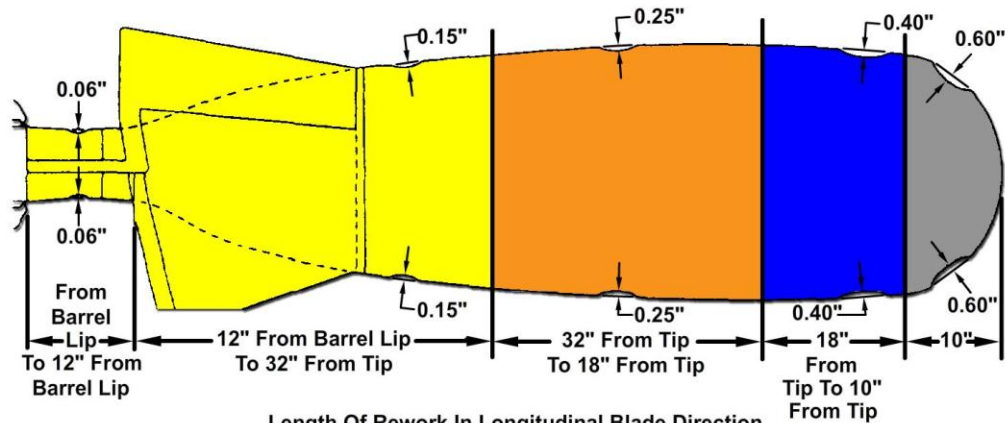
PROPELLER MAINTENANCE

In today's Navy, comprehensive and systematic means of maintaining a multi-engine propeller system is essential. You, as an Aviation Machinist's Mate, must know the procedures for day-to-day maintenance. You must know the procedures for removal and installation of a propeller, rigging, adjustment, and troubleshooting of propeller systems. You should also be familiar with the procedures for propeller balancing and leakage test requirements. The modern-day propeller system is a complex and durable system, and, with proper maintenance, a highly reliable aircraft system.

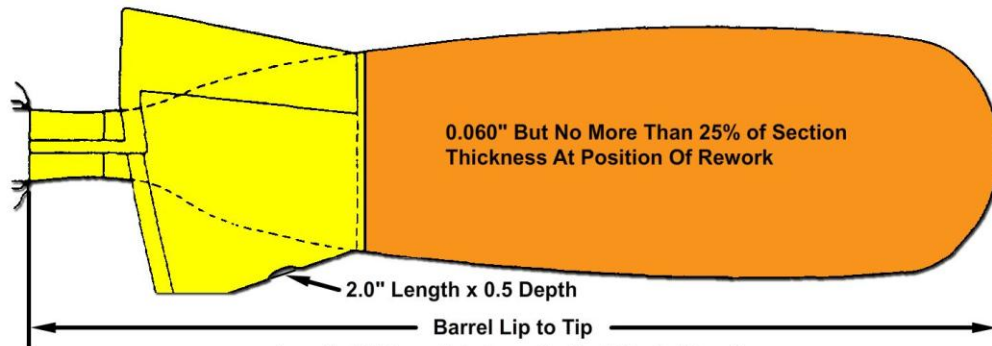
Inspect the blades daily for any gouges, nicks, scratches, or gross damage. If the propeller has struck any object (static or rotating), inspect the blades carefully for damage. For example, yellow paint marks on a blade indicate that the propeller could have possible damage from hitting a piece of support equipment (*Figure 8-17*).



A. Blade Damage Requiring No Rework



Length Of Rework In Longitudinal Blade Direction
Shall Be No Less Than Ten Times Depth Of Rework
B. Local Rework Limits Leading And Trailing Edges



Length Of Rework In Longitudinal Blade Direction
Shall Be No Less Than Thirty Times Depth Of Rework
**C. Local Rework Limits On Face, Camber Sides,
And Cuff Trailing Edges**

Figure 8-17 — Propeller blade damage rework limits.



WARNING

The blade damage repair limits shown in *Figures 8-16 and 8-17* are examples of repair limits found in maintenance instruction manuals (MIMs). Refer to the specific maintenance instruction manual for the propeller that you are working on.

Propeller Cleaning

If you disassemble the propeller, clean all the parts with approved cleaning solution (except the deicing brushes and slip rings). Thoroughly dry all parts after cleaning. Vapor blasting is NOT permitted on this propeller. The use of rags or paper for cleaning or wiping internal parts of the propeller and control assembly is NOT permitted. The use of these materials may cause lint or minute particles to enter the hydraulic system. Malfunctioning of parts is possible. Unused parts or parts not reassembled within a reasonable time should be preserved with a corrosion-preventive compound. Exact procedures for the cleaning and prevention of corrosion on propellers are found in the applicable maintenance instructions.

Rigging and Adjustment

During the initial engine/propeller installation, or whenever a fuel control, coordinator, or linkage has been replaced, make a complete rigging check. The final propeller control linkage rigging and valve housing adjustment is done with the propeller installed. In most cases, when a T56 engine is ready for issue (RFI) from an Aircraft Intermediate Maintenance Department (AIMD), Fleet Readiness Center (FRC) to a squadron, the fuel-control-to-coordinator rigging has been completed.

A minimum of five rigging pins are necessary to rig and adjust the propeller control linkage and valve housing. Refer to the appropriate technical publication for the special tool requirements. Check for freedom of movement for both power levers and emergency shutdown handles (E-handles). There must be NO binding or interference. Check cable tension with a tensiometer. Insert rigging pins in slots. Rig pins should go in with slight finger pressure. Adjust control rod lengths if needed. Remove rig pins. Check rigging at max reverse, takeoff, and flight idle by comparing coordinator readings and inserting rig pins in appropriate engine or valve housing slots. After mechanical rigging checks agree, adjust valve housing assembly for setting blade angles (*Figure 8-18*).

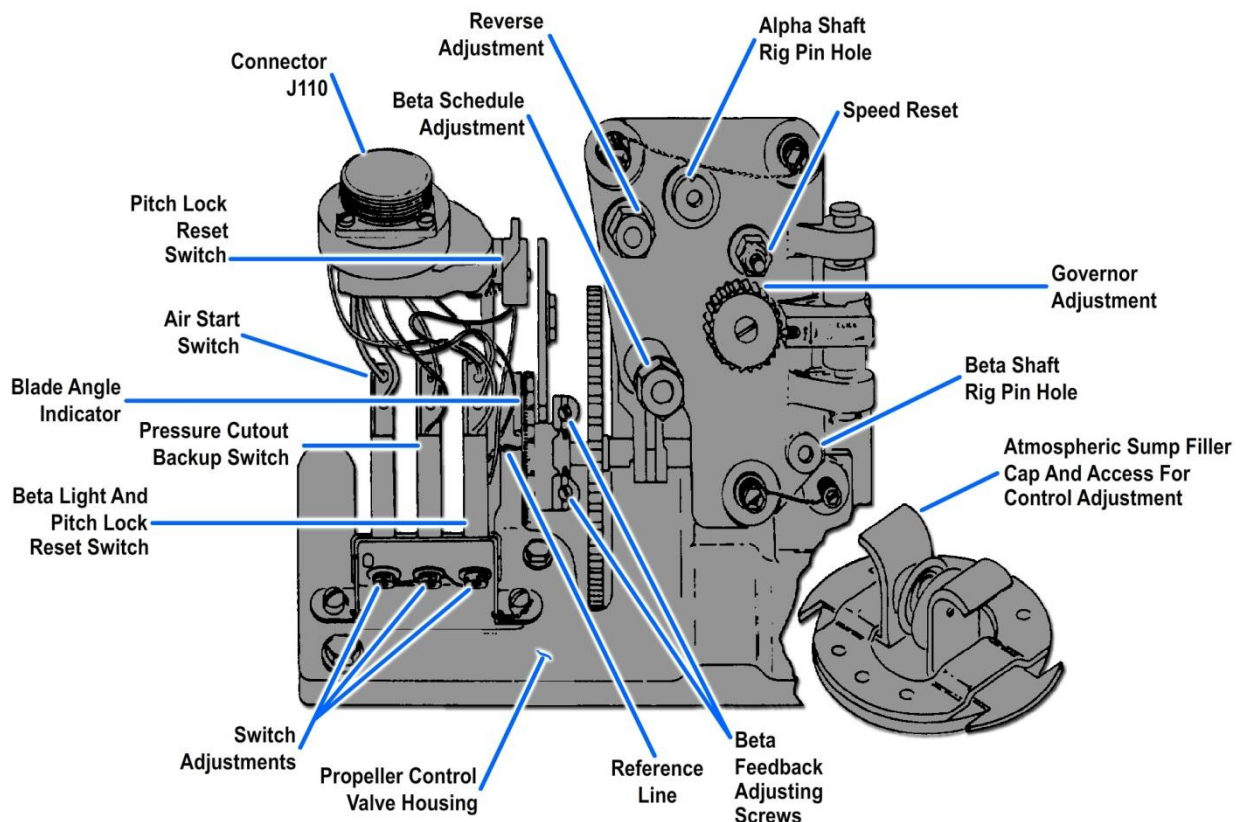


Figure 8-18 — Valve housing assembly (adjustments).

After all rigging has been completed, check for installation of bolts, nuts, and safety wire. Torque all bolts and nuts and safety wire all rod ends, as required by the appropriate technical manual. At this point, you should remove all rigging pins and install the valve housing atmospheric sump filler cap. Now complete propeller and engine checks to test for proper operation.

Feathering Check

Depressing the feather button in the flight station causes normal feathering. This action supplies voltage to the holding coil of the feathering switch, auxiliary pump, and feather solenoid. Hydraulic fluid positions the propeller control feather valve to feather the propeller. When the propeller has fully feathered, pressure buildup will operate a pressure cutout switch. The switch causes the auxiliary pump and feather solenoid to become de-energized through a relay system. Feathering also occurs by pulling the E-handle. This action mechanically positions the feather valve and electrically energizes the feather button holding coil to send the propeller to feather.

Unfeathering Check

To unfeather the propeller, pull the feather button and hold in the unfeather position. This action causes the auxiliary pump to come on. Fluid pressure flows to the decrease side of the pitch change piston in the dome. This action unlatches the feather latches. The propeller will start to unfeather. Upon reaching the air start pitch angle (45 to 48 degrees), the air start beta switch closes. Closing the switch energizes the air start control relay. This relay energizes the feather valve solenoid, which sends the blades back towards feather. The return of the blades toward feather opens the air start beta switch to reenergize the air start relay. Now the blades are cycling around the air start blade angle to stabilize the propeller speed and engine speed. These stabilized speeds prevent an NTS condition from occurring during an air start. The air start blade angle for unfeathering will cut out ground unfeathering when you depress the pressure cutout override (PCO) button. This button is usually adjacent to the feather button. Depressing the PCO button prevents the blades from cycling around the air start switch. The PCO button allows the blades to go to a lower blade angle setting.

Increase the blade angle before trying a decrease, so the pitchlock teeth will disconnect. The pitchlock teeth will engage upon release of the feather button. Failure to increase the blade angle will cause damage to the pitchlock teeth.



Stopping a decreasing blade angle during ground operations may cause a problem. If stoppage occurs above the low pitch stop, do NOT, under any circumstances, attempt to decrease the blade angle any further.

Fuel Governor, Pitchlock, and Reverse Horsepower Checks

The purpose of the fuel governor check is to be sure that the fuel control governor will limit the engine speed if the propeller governor fails. The pitchlock check makes sure that the propeller pitchlock will engage to prevent the propeller from going to a lower blade angle. The reverse horsepower check will ensure that the reverse horsepower will operate normally.

NTS Check on Shutdown

With the engine running at low rpm, place the NTS/feather valve check switch in the NTS check position. Turn the fuel/ignition switch to OFF. NTS action should develop and illuminate the NTS light. If unsuccessful, maintenance action is necessary.

PROPELLER BALANCING AND LEAKAGE TESTS

Accomplish all propeller balancing in a horizontal plane using the propeller balancing kit 7A100, or its equivalent (*Figure 8-19*). Before performing actual propeller assembly buildup and balancing, you must always refer to the appropriate technical publication.



Figure 8-19 — Propeller balancing.

NOTE

The final balance check can be erroneous because of residual hydraulic fluid in the propeller dome assembly. You must make sure the dome assembly is completely drained of any residual hydraulic fluid before installing the dome assembly for the final balance check.

Preliminary and final balance has already been completed on new and overhauled propellers before they are disassembled and shipped to an AIMD/FRC. Do not perform preliminary balance if final balance can be obtained first.

You must obtain horizontal balancing on all propellers during assembly. Horizontal balancing must be performed in a room free of air currents and with the propeller assembly clean and dry. The plane of the blades must be horizontal, and the blade pitch must be set at 45 degrees.

Do not install the dome cap, low pitch stop assembly, pitchlock regulator assembly, propeller hub nut, hub mounting bulkhead assembly, and their associated parts. These units are not included as part of the balancing procedure. Install the dome assembly without the dome-to-barrel preformed packing and gear preload shims. Tighten the dome retaining nut snugly past its normal locking position. Use masking tape to hold the dome retaining nut special head screw (without its cotter pin) in place at its normal locking position.

Final Balance Check

The final balance check is obtained by adding bolts, washers, and nuts to balancing holes in the deicer contact ring holder assembly near the outer edge. If possible, bolts, washers, and nuts should be divided equally on each side of the deicer contact ring holder assembly. Do not disturb similar bolts, washers, and nuts, which are painted red and already located in the balancing holes. They are used for balance of the holder assembly itself, not the propeller. Use special bolts, washers, and nuts on the deicer contact ring holder assembly installed on the propeller. For the plastic molded holder assembly, use no more than six AN960-10 washers on one bolt; use no more than six NAS514P1032-16 bolts and six MS20364-1032A nuts.

Obtain final balance with the propeller assembly mounted on the horizontal balance machine, with the plane of the blades horizontal and the dome assembly installed. The sensitivity of the balance machine must be calibrated so that any unbalance shown by the machine may be corrected or reversed by applying a restraining moment of 6 inch-ounces.

If final balance cannot be obtained because of the maximum limit on the number of bolts, washers, and nuts that can be added to the deicer contact ring holder assembly, it is necessary to obtain preliminary balance first, and then final balance. Remove the final balance bolts, washers, and nuts from the holder assembly, if they are installed.

If final balance cannot be obtained, preliminary balance must be obtained by installing balance washers on the blade balancing plugs of the light blades.

NOTE

The propeller must be balanced to minimize vibration levels, ensuring longevity and service life.

With the propeller suspended on the balancing stand, you should place the balance washers on the shanks of the light blades next to the outboard electric contact rings (*Figure 8-20*). Preliminary balance has been obtained when the propeller shows no tendency to tilt, or when tilting may be stopped or reversed by the addition of the lightest balance washer to one or more blades on the light side of the propeller.

After you have determined the number of washers to install, remove the propeller from the balancing stand. Disassemble the propeller until the light blades have been removed. Install the required washers on the blade balance plugs. Reassemble and reinstall the propeller on the balancing stand. Recheck the preliminary balance and obtain the final balance check, as previously described.

After you obtain final balance, remove the special head screw taped on the dome assembly. Remove the dome assembly from the propeller, using care not to disturb the 45-degree setting of the rotating cam. Remove the balancing arbor from the propeller.

Remove the propeller from the balancing stand. Remove the deicer contact ring assembly and the packing seal ring with its preformed packing. The propeller must be reassembled prior to performing the external and internal hydraulic leakage test.

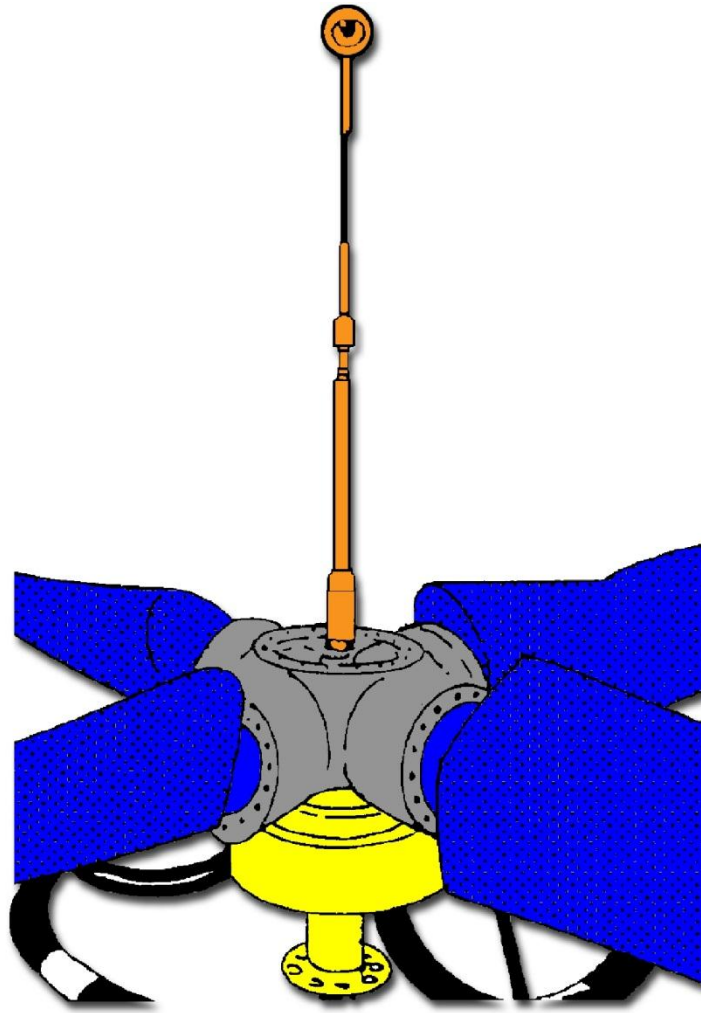


Figure 8-20 — Propeller suspended for balancing.

External and Internal Hydraulic Leakage Test

Before you begin the propeller test, first verify that the propeller test equipment has been inspected, serviced, and properly assembled. This must be done prior to the installation of the propeller. Install the propeller on the test equipment in accordance with the appropriate technical publication before beginning the hydraulic leakage test.

After the hydraulic fluid is warmed up, exercise the propeller between the high and the low blade angles several times to purge air from both the test equipment and propeller system. Purging will avoid erratic operation during the external and internal leakage tests.

⚠ CAUTION ⚠

Attempting to initiate a decrease in propeller blade angle when the propeller is in a range from about 60 degrees to 15 degrees may cause the pitchlock to engage or cause damage to the ratchet teeth. If it becomes necessary to stop in this range, first increase the blade angle to above the pitchlock range, and then proceed to a decreased blade angle.

External Leakage Test

The test equipment used to supply the various pressures and flow requirements is the hydraulic propeller test stand GS1221. With the test stand maintaining 150 pounds per square inch (psi), cycle the propeller blades between a low blade angle and a high blade angle until a total of eight cycles are completed. No external leakage is permissible during the cycling.

If internal leakage occurs at the junction of the barrel half seals and the blade packings, eliminate the leakage by separating the barrel halves and adding zinc chromate putty, MIL-P-8116, to the junction. You must control the amount and location of the putty to prevent it from getting into the barrel cavity. Leakage from the blade bores can be eliminated by replacing the blade preformed packing. The complete external leakage test must be rerun after any external leakage corrective work has been completed.

Internal Flow And Leakage Test

The internal flow and leakage tests are designed to ensure the proper internal operation of the propeller system. The test equipment will supply the various hydraulic pressures to the inboard and outboard side of the dome piston, surge valve, and pitchlock mechanism, ensuring smooth blade angle movement to the reverse and feather blade angles.

If internal flow and leakage requirements are not in compliance with the appropriate technical publication, you must disassemble the propeller and inspect all visible packings for damage and/or proper location. All internal flow and leakage tests must be completed before you can issue the propeller to an operating activity.

End of Chapter 8

Turboprop Engines and Propellers

Review Questions

- 8-1. How does a turboprop engine produce thrust?
- A. Indirectly through a fuel control
 - B. Indirectly through power converter
 - C. Indirectly through a propeller
 - D. Indirectly through a supercharger
- 8-2. What does the propeller maintain that is 100 percent constant?
- A. Air speed
 - B. Engine speed
 - C. Propeller speed
 - D. Wind speed
- 8-3. How many major assemblies does the turboprop engine consist of?
- A. 1
 - B. 2
 - C. 3
 - D. 4
- 8-4. Which assembly is considered a major assembly of a turboprop engine?
- A. Combustion
 - B. Compressor
 - C. Propeller
 - D. Power
- 8-5. The Thrust Sensitive Signal (TSS) serves what purpose?
- A. As a safety device used for fueling
 - B. As a safety device used for landings
 - C. As a safety device used for takeoffs
 - D. As a safety device used for taxing
- 8-6. What are the two ranges of the power lever quadrant?
- A. Alpha/Beta
 - B. Charlie/Delta
 - C. Echo/Foxtrot
 - D. Gamma/Indigo

- 8-7. What is the portion of the propeller furthest from the hub called?
- A. Blade
 - B. Blade back
 - C. Tip
 - D. Shank
- 8-8. What is feathering of the blade?
- A. Negative blade angle
 - B. Streamlining the propeller blade with relative wind
 - C. The distance between the leading and trailing edges
 - D. The blade angle that is formed by the chord of a section of the blade
- 8-9. How many stresses are acting upon propeller blades?
- A. 2
 - B. 3
 - C. 4
 - D. 5
- 8-10. What is the greatest force acting upon a propeller blade?
- A. Aerodynamic
 - B. Centrifugal
 - C. Thrust bending
 - D. Torque bending
- 8-11. How many positive displacement gear type pumps are located in the pump housing assembly?
- A. 2
 - B. 3
 - C. 4
 - D. 5
- 8-12. What is considered the brains of the propeller system?
- A. Dome assembly
 - B. Pitchlock regulator assembly
 - C. Pump housing assembly
 - D. Valve housing assembly
- 8-13. When is a complete rigging check required?
- A. During fuel control replacement
 - B. During de-fueling process
 - C. During a high power check
 - D. During a weight and balance check

8-14. How is final balance check obtained?

- A. By adding a feathering check
- B. By adding bolts, nuts, and washers to the deicer contact ring holder assembly
- C. By adding a rigging check
- D. By adding weights to the propeller blades

8-15. What is the purpose of the fuel governor?

- A. Limit air speed
- B. Limit engine speed
- C. Limit horsepower
- D. Limit torque

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