Propeller Installation, Inspection, and Maintenance

21

INTRODUCTION

Propellers are essential aircraft parts, providing the thrust necessary to move the aircraft through the air. Propellers require the highest degree of care and attention to detail in their installation, inspection, and maintenance.

The propeller installation procedures and maintenance requirements discussed in this chapter are representative of those currently in widespread use. No attempt has been made to include detailed maintenance procedures for any one particular propeller; all pressures, figures, and specifications are presented solely for the purpose of illustration and do not have specific application. *For maintenance information on a specific propeller, always refer to applicable manufacturer's instructions.*

PROPELLER INSTALLATION AND REMOVAL

Types of Hubs

The propeller is mounted on its shaft by means of several attaching parts. The types of hubs generally used to mount propellers on engine crankshafts are (1) a forged steel hub fitting a splined crankshaft, (2) a tapered forged steel hub connected to a tapered crankshaft, and (3) a hub bolted to a steel flange forged on the crankshaft.

Hubs Fitting Tapered Shafts. For some models on which the hub fits a tapered shaft, the hub is held in place by a retaining nut that screws onto the end of the shaft. A locknut safeties the retaining nut, and a puller is required for removing the propeller from the shaft. The locknut screws into the hub and bears against the retaining nut. The locknut and the retaining nut are then safetied together with either a cotter pin or a lockwire.

A newer design employs a snap ring instead of a locknut. When the propeller is to be removed, the retaining nut is backed off and bears against the snap ring, and the propeller is thus started from the shaft. Holes in the retaining nut and the shaft are provided for safetying.

Hubs Fitting Splined Shafts. On splined-shaft propellers, a retaining nut that screws onto the end of the shaft is used to hold a hub fitting the splined shaft, as shown in

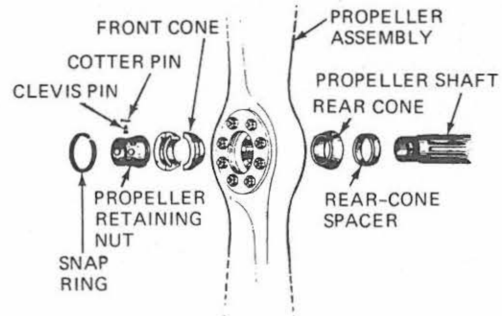


FIG. 21–1 Installation parts for a splined-shaft propeller.

Fig. 21–1. Front and rear cones are provided to seat the propeller properly on the shaft. The **rear cone** is made of bronze and is of one-piece construction. It seats in the **rear-cone seat** of the hub. The **front cone** is a two-piece split-type steel cone. A groove around its inner surface makes it possible to fit the cone over a flange of the propeller retaining nut.

The front cone seats in the **front-cone seat** of the hub when the retaining nut is threaded into place. A snap ring is fitted into a groove in the hub forward of the front cone so that the front cone will act against the snap ring and pull the propeller from the shaft when the retaining nut is unscrewed from the propeller shaft. This snap ring must not be removed when the splined-shaft propeller is removed from its shaft, because the snap ring provides a puller for the propeller.

When a hub with a bronze bushing instead of a front cone is used, a puller may be required to start the propeller from the shaft.

A **rear-cone spacer** is provided in some designs to prevent the front cone from bottoming on the forward ends of the splines. If the rear cone is too far back, the front cone will come in contact with the splines before the propeller is secure.

The principal purpose of a retaining nut is to hold the propeller firmly on its shaft. A secondary purpose, in some designs, is to function as a puller with the snap ring to aid in removing the propeller.

Integral-Hub Flange-Type Crankshaft. The integral-hub flange-type crankshaft is manufactured with the propeller mounting hub forged on the front end of the crankshaft, as shown in Fig. 21–2. The flange includes inte-

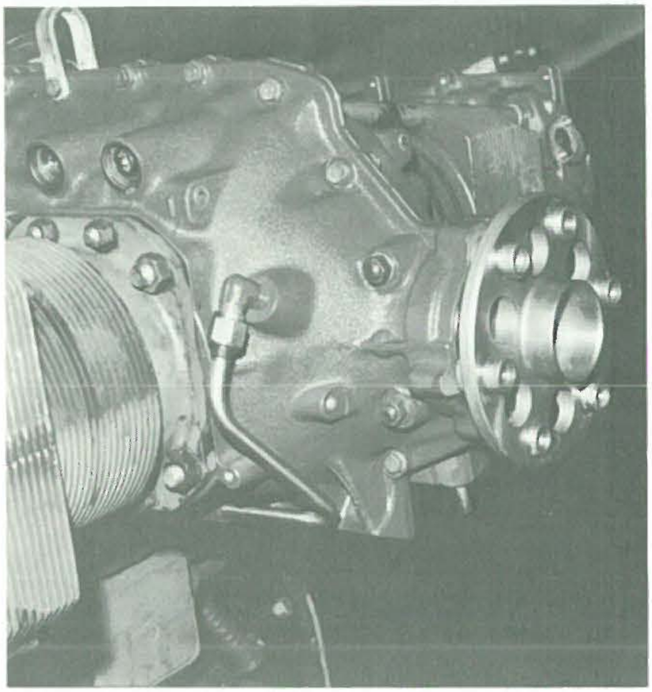


FIG. 21–2 Integral-hub flange-type crankshaft.

gral bushings that fit into counterbored recesses in the rear face of the propeller hub. The recesses are concentric with the bolt holes. A stub shaft on the front end of the crankshaft forward of the flange fits the propeller bore and ensures that the propeller is correctly centered.

Propeller Installation Preparation

Before installing any propeller, inspect the shaft and hub for corrosion, nicks, and other surface defects. Wipe the shaft and the inside of the hub with a clean, dry rag until they are free of dirt, grease, and other foreign substances. Small burrs or rough spots which might prevent the hub from sliding onto the shaft may be removed with a fine file or fine sandpaper. Inspect bolt holes for cleanness and thread condition, and inspect the attaching bolts for cracks and elongation.

A thin coat of light engine oil or antiseize compound is normally applied to the shaft prior to installation of the propeller.

Specific Propeller Installations, Removals, and Related Concerns

Installation of a Propeller on a Flange-Type Shaft. Flange-type shafts (see Fig. 21–2) are currently used on most opposed-type reciprocating engines. If the flanged propeller shaft has dowel pins, the propeller can be installed in only one position. In the absence of dowel pins, consult the manufacturer's maintenance manual for the proper position for installation. The propeller installation position may affect such factors as vibration, engine life, and positioning for hand propping. In the absence of dowel pins, position the propeller so that the blades are at the two o'clock and eight o'clock positions when the engine is stopped. Place the propeller on the flanged shaft with enough force to mate the recesses in the back of the propeller with the bushings on the flanged shaft. Install the propeller bolts into the holes and turn the bolts until they are finger-tight. Use a torque wrench for final tightening, and tighten in an alternating sequence so that all the bolts are pulled down evenly. Torque to the specified value, and safety the bolts.

A propeller on a flanged shaft is removed simply by unscrewing the retaining bolts and lifting the propeller from the shaft.

Installation of a Propeller on a Tapered Shaft. Before a propeller is installed on a tapered shaft, the fit of the propeller to the shaft should be checked. This may be done with Prussian blue. First, both the hub and the shaft are cleaned and all roughness is removed. Then a thin coating of Prussian blue is applied to the shaft. The propeller hub is installed, and the retaining nut is tightened to the proper torque for normal installation. The hub is then removed, and the degree of surface contact inside the hub is shown by the transfer of Prussian blue. If the contact area is 70 percent or more, the fit is satisfactory. Some authorities recommend a fit of 85 or 90 percent. If the area of contact is less than 70 percent, the fit may be improved by lapping with a fine lapping compound. When the correct fit is attained, the lapping compound must be completely removed from both the hub and the shaft, and then both surfaces should be coated with light engine oil.

The procedure used to install a propeller on a tapered shaft depends on the type of hub. If a locknut is used, lift the propeller into position. Be sure that the key on the shaft lines up with the keyway on the hub. Slide the propeller well back on the shaft. Unless there is something wrong, the hub will not bind as it slides on the tapered shaft. Screw the retaining nut onto the end of the shaft. Note that a shoulder on the retaining nut bears against a shoulder in the hub and forces the hub onto the shaft. Use the wrenches designated by the manufacturer for the final tightening, and do not apply any extra leverage.

Next, screw the locknut into the hub. Be careful in starting the nut to ensure that there is no "cross threading," because the thread on this nut is comparatively fine. Pull the locknut tight, but do not tighten it as much as the retaining nut. One of the lockwire holes must be in line with a hole in the retaining nut. Finally, use either a lockwire or a cotter pin to secure the retaining nut and the locknut.

If the propeller is designed with a snap-ring puller, simply place the propeller in the proper position on the shaft, install and tighten the retaining nut, install the snap ring, and install the safety clevis pin or bolt.

Removal of a Propeller from a Tapered Shaft. The most prevalent problem in removing a tapered-shaft propeller is that the hub often sticks to the shaft, perhaps because of overtorquing during installation or because the shaft has not been properly lubricated. If, after the retaining nut has been removed, the propeller cannot be removed from the shaft with reasonable force, it will be necessary to employ a propeller puller. Propellers that are designed with a snap ring and puller nut are easier to remove because the nut applies pulling force against the snap ring as the nut is backed off.

Removal of a Propeller from a Splined Shaft. In order to remove a propeller from a splined shaft, remove the cotter pins and clevis pin that secure the propeller retaining nut and then unscrew the propeller retaining nut. The front cone over the flange of the retaining nut presses against the snap ring in the hub and pulls the propeller away from the shaft for a short distance. When the propeller is loose, it is usually slipped off easily by hand; but if this is not possible with a reasonable amount of force, remove the snap ring, nut, and front cone. Then clean the threaded portion of the shaft and nut; lubricate the cone, nut, and shaft with clean engine oil; reassemble; and finally apply force to unscrew the nut. The rear cone and spacer are left with the engine if a new propeller is to be installed. A propeller puller is used to start the propeller from the shaft if there is a bronze bushing instead of a front cone.

Shaft and Hub Splines. The splines on the propeller shaft and inside the propeller hub should be carefully inspected for damage and wear. Wear of the splines should be checked with a single-key no-go gage made to +0.002 in [0.05 mm] of the base drawing dimensions for spline land width. If the gage enters more than 20 percent of the spline area, the part should be rejected.

Installation of a Propeller on a Splined Shaft. To install a propeller on a splined shaft, first install the rear-cone spacer if there is one on the assembly (see Fig. 21–1). Install the rear cone on the propeller shaft. Match the wide spline on the shaft with the wide groove in the hub, and slide the propeller well back against the rear cone. Next, assemble the front cone and the retaining nut, and screw the nut onto the propeller shaft. Before the propeller is tightened down and safetied, the front and rear centering cones must be inspected for bottoming.

Front Cones. Since hub front-cone halves are machined in pairs, the original mated halves are always used together in the same installation. If one half becomes unserviceable, both halves are rejected. Before installation and use, the two halves of a front cone are held together by a thin section of metal left over from the manufacturing process. This metal must be sawed through with a hacksaw and the two separated halves gone over carefully with a handstone to remove all rough and fine edges and to round off the sharp edges where the cones have been cut apart. After this process is completed, the two halves are always taped together when not installed.

Front-Cone Bottoming. A front cone sometimes **bottoms** against the outer ends of the propeller-shaft splines; that is, the apex of the front cone hits the ends of the splines before the cone properly seats in its cone seat in the hub. The hub is loose because it is not seated properly and held tight by the cones, even though the retaining nut may be tight.

Whenever a splined hub is found to be loose, even though the retaining nut is tight, an inspection is made for front-cone bottoming unless there is a more probable cause of the trouble. Also, this condition may be manifested by excessive propeller vibration during preflight operations.

Inspection for Front-Cone Bottoming. To check for front-cone bottoming, first apply a thin coating of Prussian blue to the apex of the front cone. Then install the propeller on the shaft and tighten the propeller retaining nut. Next, remove the retaining nut and front cone. See if the Prussian blue has been transferred to the ends of the splines of the propeller shaft. If it has not been transferred, the front cone is not bottoming and the Prussian blue can be cleaned off.

If the Prussian blue has been transferred to the ends of the shaft splines, install a steel spacer behind the rear cone to correct the condition of front-cone bottoming (see Fig. 21–3). Spacers for this purpose are generally made in any shop adjacent to the place where the work is being performed and are ⅛ in [3.18 mm] thick.

The presence of the spacer moves the entire propeller assembly forward, causing the front cone to seat in the hub before its apex hits the end of the shaft spline. After the installation of the spacer, the Prussian-blue test should be made again. If bottoming is still indicated, inspect the hub-shaft end and all attaching parts for excessive wear or any other condition that might cause improper fit. Worn or defective parts should be replaced.

Rear-Cone Bottoming. Occasionally a situation will exist where the front edge of a rear cone bottoms against the ends of the splines in the propeller hub, as shown in Fig. 21–3. This condition is caused by wear of both the cone and the cone seat in the hub due to prolonged service and will prevent the cone and cone seat from being firmly engaged. If inspection shows that the front of the rear cone is touching the splines, the condition can be corrected by carefully removing not more than 1⁄16 in [1.59 mm] of material from the front edge (apex) of the cone or replacing the

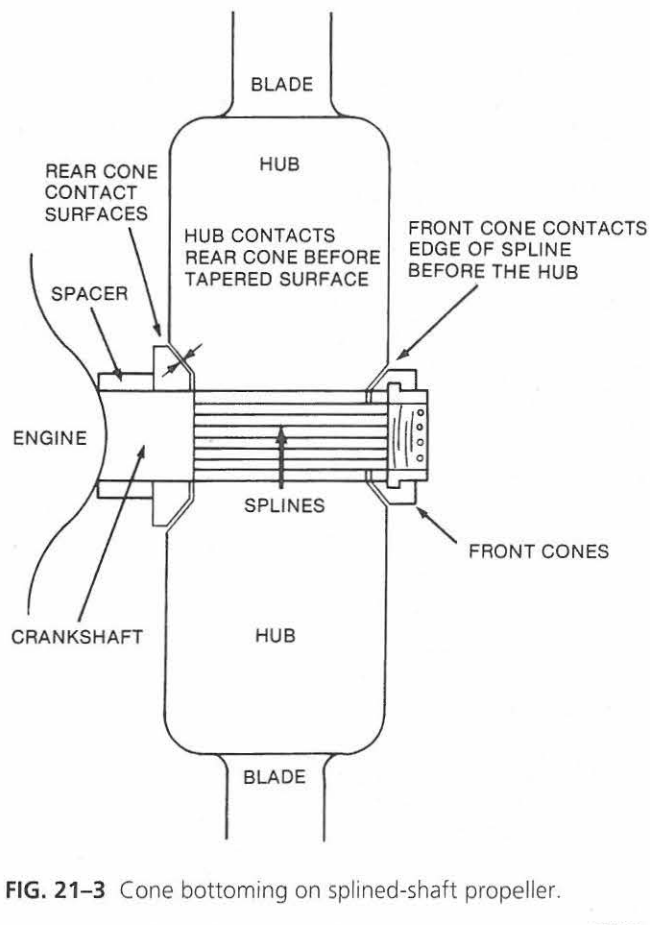


FIG. 21–3 Cone bottoming on splined-shaft propeller.

cone with a new one. After proper fit of the cones has been established, the propeller can be installed.

A bar about 3 ft [0.9 m] long is placed through the holes in the nut for the final tightening, as specified in the maintenance manual. It is not necessary to pound the tightening bar. The snap ring is then installed in its groove in the hub. The retaining nut is safetied with a clevis pin and a cotter pin. If the propeller retaining nuts have elongated locking holes, a washer is placed under the cotter pin. The clevis-pin head should be to the inside, and the washer and cotter pin should be to the outside.

Installation and Adjustment of Ground-Adjustable Propellers. The installation of ground-adjustable propellers follows the practices previously described for fixed-pitch propellers. The following steps may be considered typical for such an installation:

1. Make sure that the propeller being installed has been approved for the engine and aircraft on which it is being installed.
2. See that the propeller has been inspected for proper blade angle and airworthiness.
3. See that the propeller shaft and the inside of the propeller are clean and covered with a light coat of engine oil.
4. Install the rear-cone spacer (if used) and the rear cone.
5. Lift the propeller into place carefully, and slide it onto the shaft, making sure that the wide splines are aligned and that the splines are not damaged by rough handling of the propeller.
6. See that the split front cone and the retaining nut are coated with engine oil, assemble them, and install them as a unit. (This step in the procedure will vary according to the design of the retaining devices. With some propellers the front-cone halves are installed, then the retainer nut, and finally a snap ring.)
7. Tighten the retaining nut to the proper torque, as specified by the manufacturer or according to other pertinent directions. Usually a 3-ft [0.9-m] bar will enable the technician to apply adequate torque for small propeller installations.
8. Install the safety pin or other safetying device.

Adjustment of the blade angle for a ground-adjustable propeller may be done on a propeller surface table, as shown in Fig. 21–4. The propeller is mounted on a mandrel of the correct size, and the blade angle is checked with a large propeller protractor, as shown in the illustration. The blade clamps or retaining nuts are loosened so that the blades can be turned; after the correct angle is established, the blades are secured in the hub by the clamps or blade nuts. The blade angle must be checked at a specified blade station as given in the pertinent instructions.

The method for checking the blade angle when the propeller is installed on the engine is the same as that used for other propellers and is described later in this chapter.

Removal of a Hartzell Compact Flanged Propeller. To remove a compact flanged propeller, it is usually necessary to remove the engine cowling. When the propeller is removed for overhaul, the blades should be feathered and the spinner removed.

A typical compact propeller installation is shown in Fig. 21–5. Remove the spinner nose cap by removing the attaching screws. Remove the spinner by removing the safety wire and check nut from the propeller at the forward end of the forward spinner bulkhead and also the screws that secure the spinner to the aft bulkhead. Place a drip pan under the propeller to catch oil spillage. Cut the safety wire around the propeller mounting studs, and remove the studs from the engine crankshaft flange. The nuts are frozen and pinned to the studs, so the studs should turn with the nuts. Pull the propeller from the engine shaft.

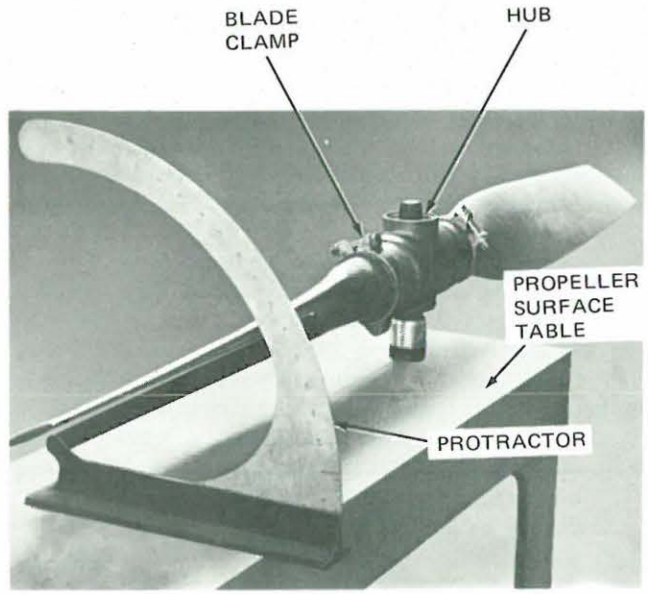


FIG. 21–4 Adjustment of blade angle on a ground-adjustable propeller.

Installation of a Hartzell Compact Flanged Propeller. Clean the propeller and the engine crankshaft flange. Lubricate and install the O-ring on the engine crankshaft. Install the sleeve, spring, and thimble in the engine crankshaft, as shown in Fig. 21–5. Mount the propeller on the engine crankshaft. Screw each bolt into its mating engine flange bushing a few threads at a time until all are tight. Torque the studs to the proper specifications. Safety the bolts by inserting safety wire through the roll pins. Install the spinner, and torque the spinner screws and check nut to the proper specifications. Safety the check nut with safety wire. Charge the cylinder through the air valve with dry air or nitrogen gas to the prescribed pressure. Refer to the placard in the spinner cap or to the appropriate maintenance manual for an exact pressure value for the ambient temperature. It is very important to maintain an accurate air charge. *Note:* Do not check the pressure with the propeller in the feathered position.

Always use the amount of air pressure required for the ambient temperature, as shown by the placard or manual. If excessive pressure is used in the propeller, there is a possibility of feathering taking place at idle speed when the engine is warm and the oil is very thin. An accurate air pressure gage is an important tool. A typical pressure check kit is shown in Fig. 21–6. **Dry air** or **nitrogen gas** should be used to recharge the propeller. It is important not to allow moisture to enter the air chamber, because this could cause the piston to freeze during cold-weather operation. A test for gas leakage may be performed by applying a soap solution or equivalent around the valve and stop adjustment

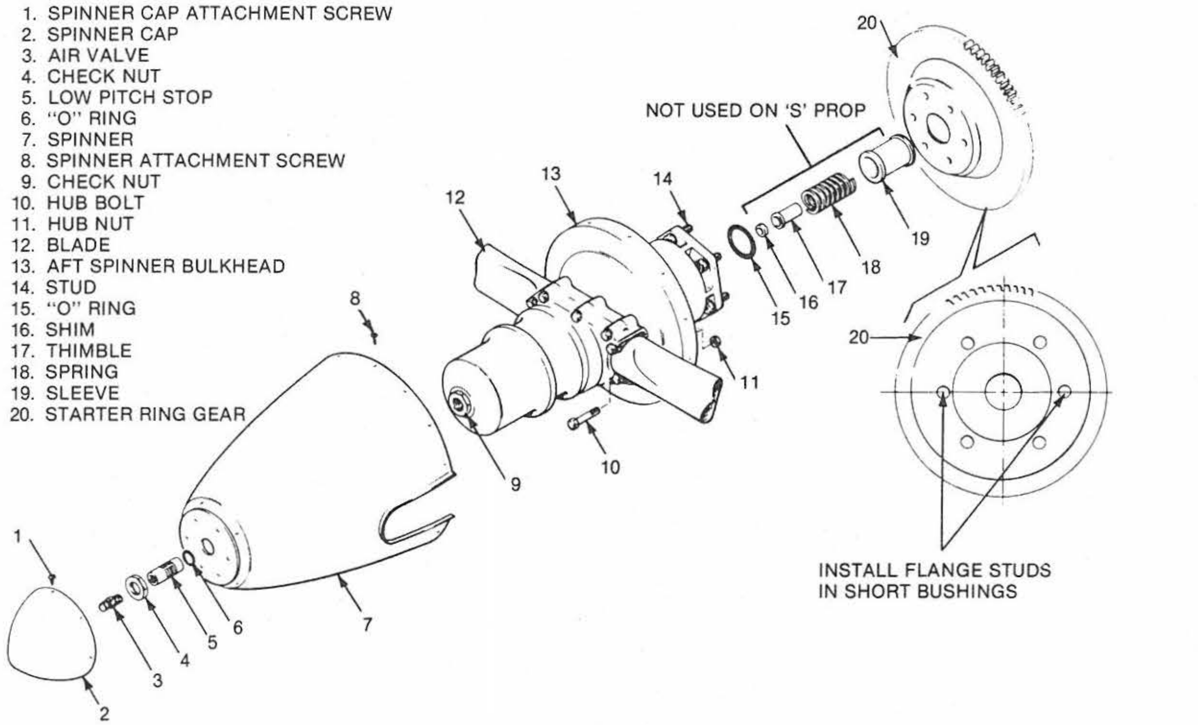


FIG. 21–5 Compact propeller installation. *(Hartzell Propeller)*

nut. If the propeller is in feather on the ground, it is possible that starting the engine will cause the blades to come out of feather position. This is often an undesirable practice because of engine roughness, which will occur during unfeathering. The blades may be removed from feather without engine operation by removing the air charge, turning the blades by hand, and replacing the air charge. Install the engine cowling and spinner cap.

Installation of a McCauley Flanged Propeller. If the spinner bulkhead has been removed, position the bulkhead so that the propeller blades will emerge from the spinner with ample clearance. Install the spinner bulkhead on the propeller or engine shaft using attaching parts (lugs, screws, etc.) as applicable. Clean the front face of the crankshaft flange, including the mounting-bolt holes, using a clean, lint-free cloth dampened in solvent. Tightly adhering dirt may be removed with fine steel wool, but be certain to wipe off any metal particles left by the steel wool. Remove any dirt and particles from the crankshaft bore. Inspect the mating flange surface and bore of the hub, and, if necessary, clean with a solvent-dampened cloth, particularly the counterbore or groove into which the O-ring packing is to be installed. Lightly lubricate a new O-ring and the crankshaft pilot with clean engine oil and install the O-ring in the propeller hub (all other surfaces should be clean and dry).

CAUTION: *The propeller must be seated against the crankshaft flange with a straight push. Rotation, cocking, or wiggling of the propeller to seat it is likely to damage the O-ring groove, and oil leakage may result.*

Align the propeller mounting studs or bolts (threads must be clean and dry) with the proper holes in the engine crankshaft flange, and slide the propeller carefully over the crankshaft pilot until the mating surfaces of the propeller and crankshaft flanges are approximately ¼ in [6.35 mm] apart. Install the propeller attaching bolts, washers, and nuts, as applicable, and work the propeller aft as far as possible; then tighten the nuts evenly and torque as specified in the appropriate aircraft maintenance manual.

Install shims and the plastic spinner shell support on the propeller cylinder as illustrated in Fig. 21–7. If shims are not mechanically centered (piloted), center the parts visually and hold them in place until the spinner support is forced firmly in place. Lightly press the shell to hold it snugly against the support and check the alignment of the holes in the shell with the holes in the bulkhead. Adjust the number of shims until the holes are approximately 3/64 in [1.19 mm] out of alignment. Push hard on the spinner shell until the holes are in alignment and screws and fiber washers can be installed. The number of shims used should allow just

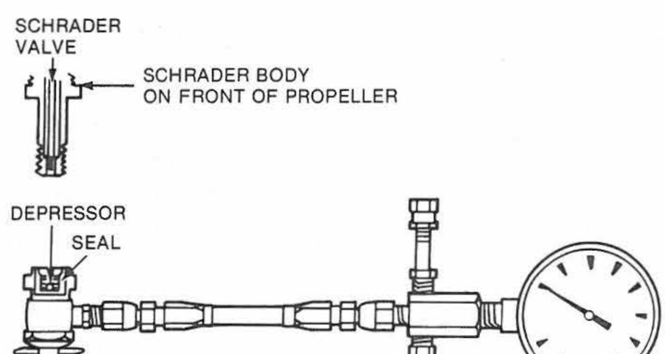


FIG. 21–6 Air charge pressure check kit. *(Hartzell Propeller)*

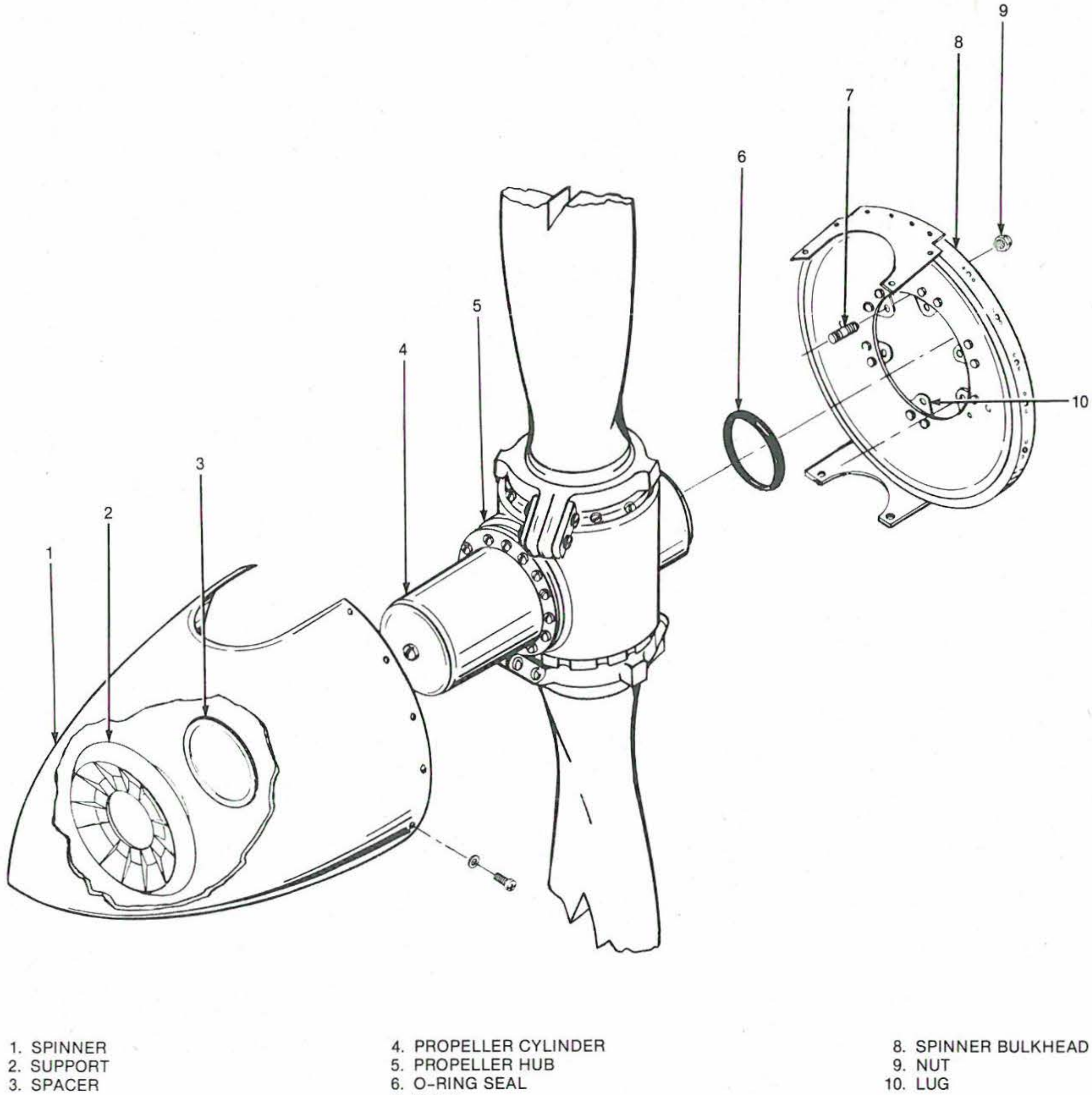


FIG. 21–7 McCauley flanged propeller installation.

enough alignment for you to install the screws while simultaneously pushing hard against the shell. Maintain force against the shell to hold the holes in alignment and install four screws and washers (approximately equally spaced). Relax force and install the remaining screws and washers.

Installation of a Turbopropeller PT6A Engine (Reversing). The turbopropeller is installed on the PT6A engine according to the instructions that follow. Place a new O-ring seal over the engine shaft. Pull the low-pitch stop collar fully forward with the puller, as shown in Fig. 21–8.

CAUTION: *To avoid damaging the propeller, make sure that the tool is not cocked. Be careful to avoid bending or otherwise damaging the spring-loaded rods and the low-pitch* ***stop collar*** *(brass ring).*

Install the propeller on the engine by inserting the two mounting studs on the propeller into the mounting holes in the drive shaft of the engine. Install the propeller mounting bolts and washers and torque to the specifications illustrated in Fig. 21–9. Secure the carbon block and arm assembly to the mounting bracket, as shown in Fig. 21–10. *Note:* To protect the low-pitch stop collar against scoring, there should be a clearance between the bottom of the collar and the head of the carbon block retaining pin, as shown in Fig. 21–10. Remove the puller and connect the propeller reversing lever to the propeller control linkage.

Installation of a Hamilton Standard Hydromatic Propeller. The Hamilton Standard hydromatic propeller is installed as follows:

1. Install the rear cone, dry, on the splined propeller shaft.

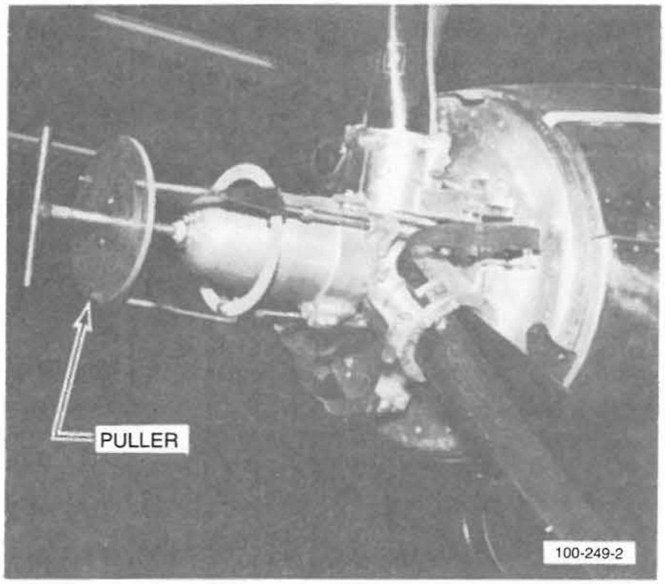


FIG. 21–8 Puller installed on PT6A propeller. *(Beech Aircraft Corp.)*

2. Install the propeller (hub and blades) on the shaft.

3. Install the split front cone on the retaining nut and install both with required seals on the shaft. Torque according to instructions.

4. Install the distributor valve in the dome and secure with a snap ring and lock ring.

5. Place the adapter flange with copper gasket on each side of the inside gear at the base of the dome. Install the dome on the propeller with necessary preload shims and tighten the dome retaining nut to the correct torque.

6. With the propeller in low pitch, fill the dome with engine oil and install the dome-seal nut with the dome-seal washer and dome seal. Secure with lockwire.

Installation instructions and some maintenance instructions will vary among different types of propellers. The technician must always follow the instructions provided for the particular installation.

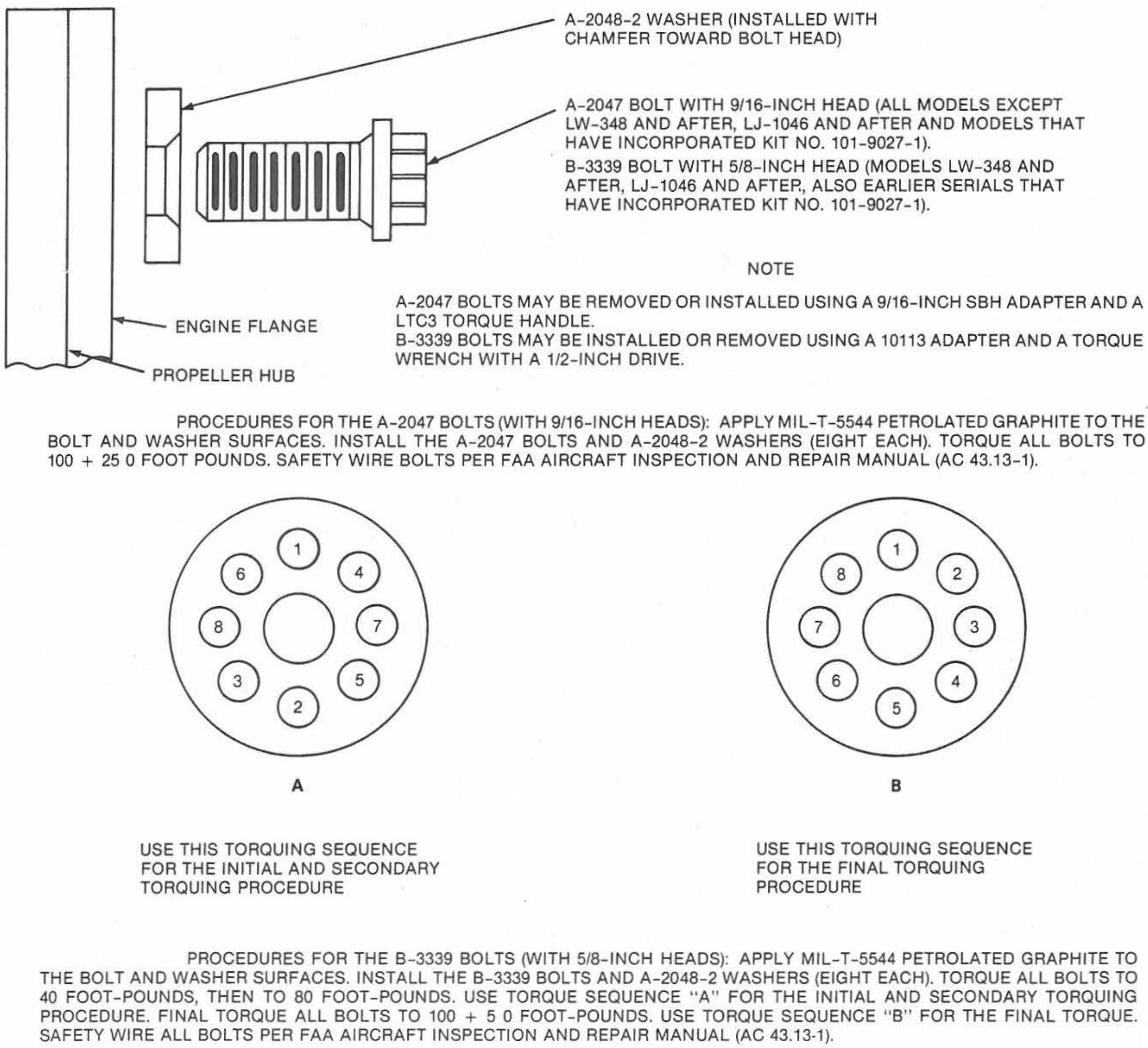


FIG. 21–9 Torque procedure for PT6A propeller installation (for training purposes only). *(Beech Aircraft Corp.)*

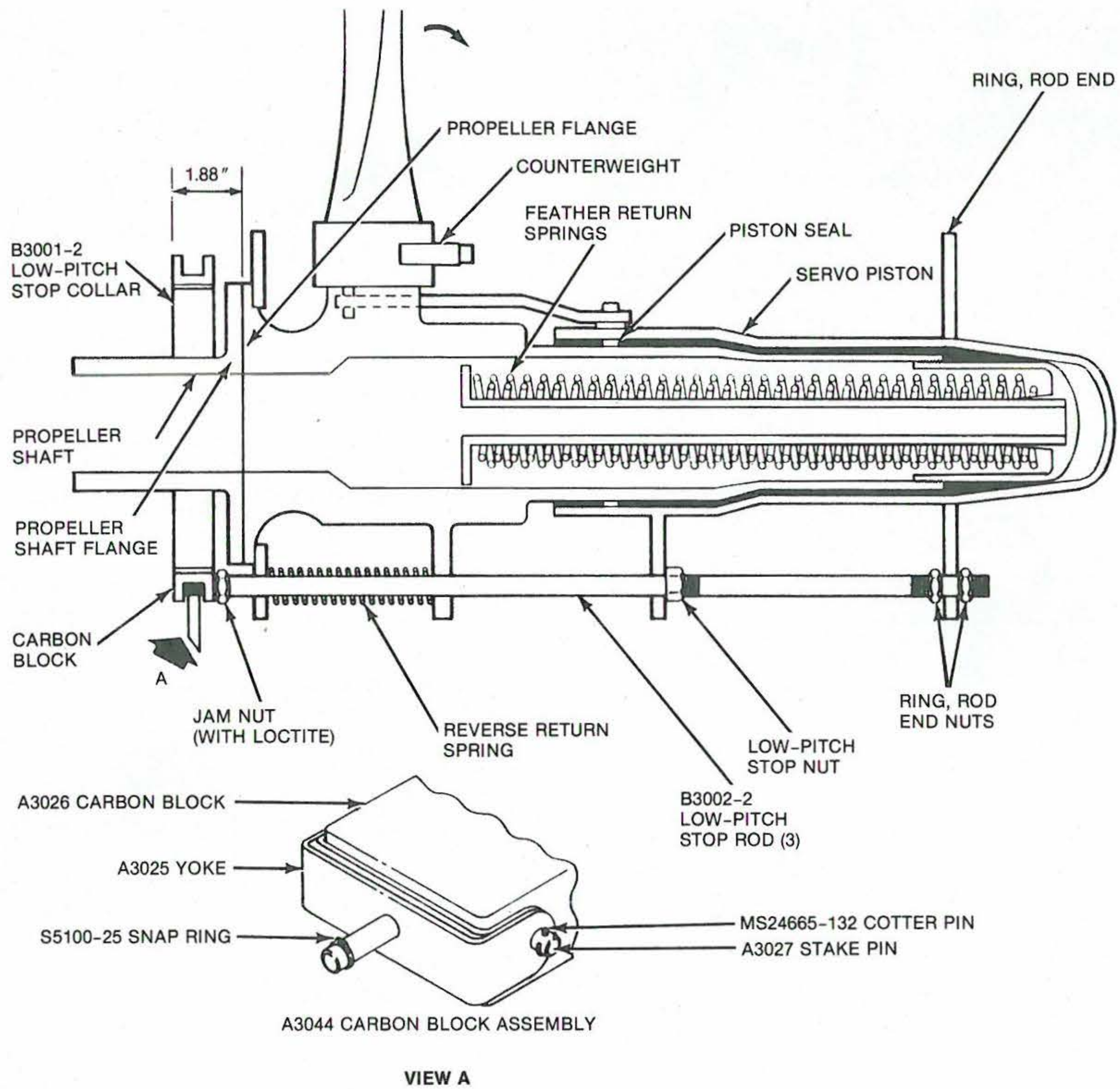


FIG. 21–10 PT6A propeller installation. *(Beech Aircraft Corp.)*

Inspection of a New Propeller Installation

When a new fixed-pitch propeller has been installed and operated, the hub bolts should always be inspected for tightness after the first flight and after 25 h of flying. Thereafter, the bolts should be inspected and checked for tightness at least every 50 h of operation, unless otherwise specified in the appropriate maintenance manual.

No definite time interval between inspections can be specified for wood propellers, since bolt tightness is affected by changes in the wood caused by the moisture content in the air where the airplane is flown and stored. During wet weather, some moisture is apt to enter the propeller wood through the drilled holes in the hub. The wood swells, but since expansion is limited by the bolts extending between the two flanges, some of the wood fibers are crushed. Later, when the propeller dries out during dry weather, a certain amount of propeller hub shrinkage takes place and the wood no longer completely fills the space between the two hub flanges. Accordingly, the shrinkage of the wood also results in loose hub bolts.

AIRCRAFT VIBRATIONS

Most aircraft vibrations are caused by rotating elements that are out of balance, and by aerodynamic forces in propellers. These vibrations may be classed as **"correctable"** and **"uncorrectable."**

Correctable vibrations relate primarily to propeller track and balance and to the balance of shafting, accessories, etc. Track and balance disturbances are generally at the one-per-rev (once-per-revolution) rate of the propeller.

Uncorrectable vibrations are vibrations that are inherent in the aircraft, such as "n-per-rev" vibrations (where n = number of blades) and vibrations that are harmonically related to propeller rates. These are generally aerodynamically induced force inputs at rates that excite natural resonances in blades, airframes, mounts, etc. They are truly characteristic of the aircraft components and are changeable only by changes in design parameters by the factory. Certain worn or loose parts will aggravate these vibrations, and correction of such problems may help, but will not cure, inherent vibrations.

Purpose of Checking Track and Balance

The purpose of propeller balancing is to reduce the one-per-rev vibration induced by the out-of-balance propeller. This vibration is transmitted to the airframe to a varying degree, depending on the engine mounts, and causes discomfort to crew and passengers. It also causes shortened component life and other problems, such as premature failures in lines and fittings, cracks in structure, bearing and seal failures, and avionics problems.

The purpose of checking propeller **track** is to ensure that all blades of a propeller are flying in the same plane of rotation. Track may change with power if pitch angle, blade contour, and stiffness are not exactly matched. Changing track may make it appear that balance is changing, but it is really caused by the "lift" of one blade that is different from the others. Vibration from the out-of-track condition, which changes with power and blade-angle settings, interacts with vibration from the out-of-balance condition, making it extremely difficult or impossible to achieve acceptable balance under all flight regimes.

Propeller Track

For the **track** of a propeller to be correct, corresponding points on the two blades must lie in the same plane, perpendicular to the axis of rotation. Checking the track of either a wood propeller or a metal propeller can be done on a propeller surface table, as shown in Fig. 21–11. Each corresponding point on each blade should have the same height from the table surface as indicated by the height gage.

When a propeller is installed on an airplane engine on the aircraft, the track can be checked by rotating the tip of the propeller past a fixed reference point attached to the aircraft. This method is shown for a metal propeller in Fig. 21–12. The track of one blade should normally be within 1/16 in [1.59 mm] of the other blade. Constant-speed and controllable propellers should be placed in low pitch before checking for track unless otherwise specified by the manufacturer.

Propeller tracking may also be accomplished through the use of a strobelight in a process called dynamic propeller tracking, which will be discussed later in this chapter.

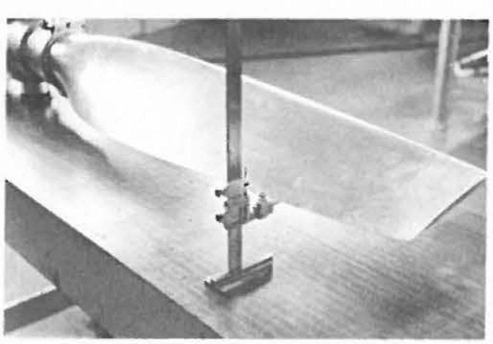


FIG. 21–11 Checking propeller track on a surface table.

FIG. 21–12 Checking the track of a metal propeller on an airplane.

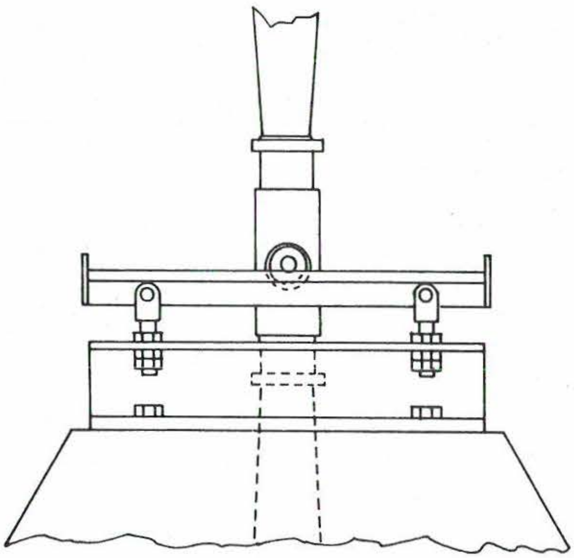
Static Propeller Balance

A propeller is balanced both horizontally and vertically, as illustrated in Fig. 21–13. A propeller on a balance stand is shown in Fig. 21–14. **Horizontal imbalance** can be adjusted on a wooden propeller by adding or removing solder from the blade tips. When balance is achieved, the solder must blend in with the contour of the tip. The metal at the tip is vented by drilling a few 0.040-in [1.016-mm] holes at the extreme tip. These holes help to eliminate any moisture which might condense under the metal tipping.

Vertical imbalance is corrected by attaching a metal weight to the light side of the hub. The size of the weight is determined by first applying putty at a point 90° from the horizontal centerline. When the propeller balances, the putty is removed and weighed. A metal plate is then cut to a size which will approximate the weight of the putty. The weight of the metal plate must be adjusted for the weight of the screws and solder which are used for attachment. The plate is attached to the hub at the 90° location with counter sunk screws. The heads of the screws are soldered and then smoothed with a file. Finally, varnish is applied to match the finish of the rest of the propeller.

Balancing of Controllable Propellers. Upon completion of repairs, the horizontal and vertical balance of a propeller must be checked. If any unbalanced condition is found, correction must be made according to the manufacturer's instructions. Balancing methods include the installation of weights in the shanks of the blades, packing of lead wool into holes drilled in the ends of the blades, packing of lead into hollow bolts, and others. In any event, the manufacturer's recommendations must be followed for any specific type of propeller. For some propellers, only the manufacturer is permitted to perform the balancing operations.

To balance a three-bladed constant-speed propeller, attach the propeller to a balance arbor and place the propeller and arbor on the balance stand, as shown in Fig. 21–15. Place each of the three blades alternately in the horizontal position. Locate the blade that has the greatest tendency to move up from horizontal; this is the lightest blade.



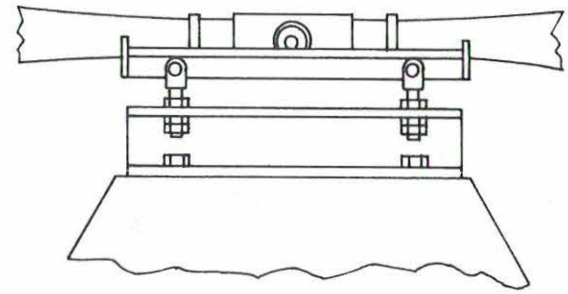


FIG. 21–13 Positions of two-bladed propeller during balance check.

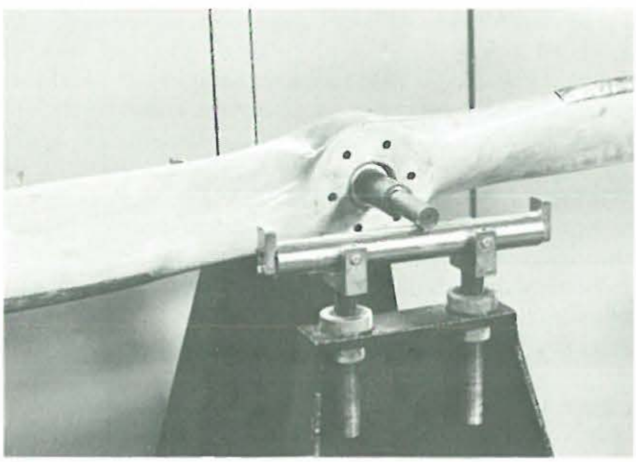


FIG. 21–14 Propeller on a balance stand.

The propeller is balanced when all three blades stay in the horizontal position without any tendency to move up or down.

Dynamic Propeller Balance

If a rotating disk is perfectly balanced, no vibration will be passed on to the supporting structure. If a weight is added to the edge of the disk, the support will be forced up and down once per revolution as the disk rotates, generating a one-per-rev vibration (see Fig. 21–16). Even when the propeller is properly statically balanced and the engine is in perfect condition, tolerances allow the propeller/engine combination to produce a one-per-rev vibration. This residual imbalance can produce significant vibration energy that can stress engine mounts, seals, accessory brackets, etc. Electronic vibration-measuring equipment can be used to sense this out-of-balance condition with the engine running and provide information on where and in what amount to add trim weights to eliminate the vibration.

A vibration-measuring system consists of a vibration transducer for converting the vibration into a measurable electrical signal; a photocell, magnetic pickup, or strobelight for sensing the angular position of the propeller; and an electronic instrument for filtering, measurement, and readout of the amplitude and phase of the vibration signal. The Micro-Vib aircraft vibration analyzer/balancer is shown in Fig. 21–17.

The vibration transducer most commonly used is a piezoelectric accelerometer. This type of sensor uses a crystal material that produces an electrical charge in proportion to the force applied to it. This type of sensor is sensitive to vibration in one axis only. For propeller balance, the sensor is mounted on the engine or gearbox as close as possible to the propeller, as shown in Fig. 21–18. The vibration produced by propeller imbalance causes a circular motion at all points on the end of the engine, so accelerometer mounting orientation is not critical.

A photocell can be used to sense the phase angle of the propeller. The photocell produces a beam of light that is modulated at a high frequency. If the beam of light strikes a retroreflector, the return beam is sensed by the photocell and a signal pulse is generated. By attaching the photocell (photo-tach) to the engine or engine cowling (see Fig. 21–19), and placing a patch of retroreflective tape on a propeller blade, a simple phase detector is installed. The high-frequency modulation of the light beam allows the photocell to ignore other sources of ambient light. Common photocells can sense a reflector at distances from 2 to 40 in [5.08 to 101.6 cm], and universal mounting brackets provide easy alignment, making photocells easy to use.

A magnetic pickup can also be used to sense the phase angle of the propeller. A magnetic pickup consists of a bar magnet wrapped with a coil of wire. The housing of the pickup nearly completes the magnetic circuit, leaving a gap at the end of the pickup. Whenever a ferromagnetic object is introduced into this gap, the magnetic flux increases dra-

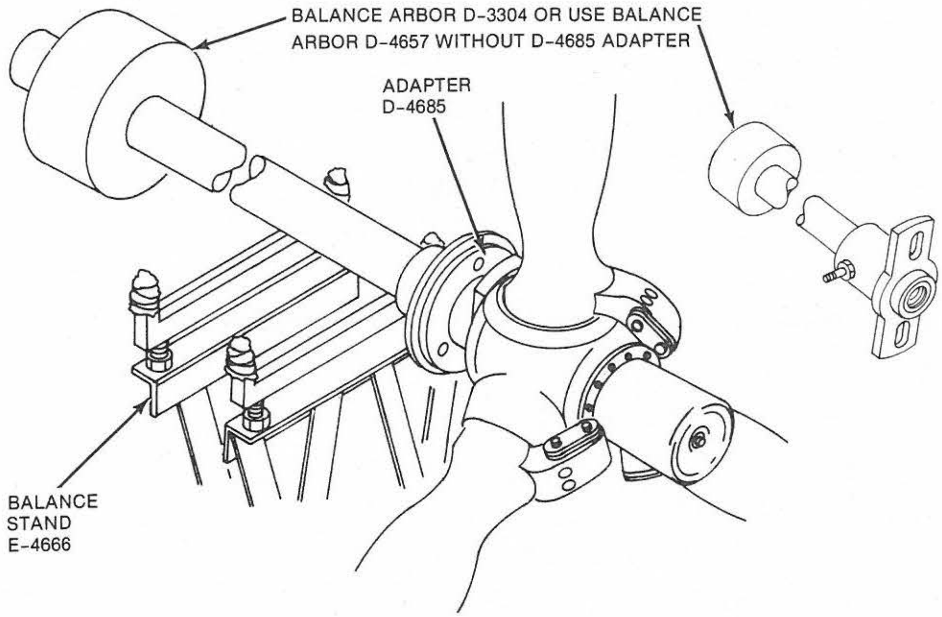


FIG. 21–15 Balancing a three-bladed propeller.

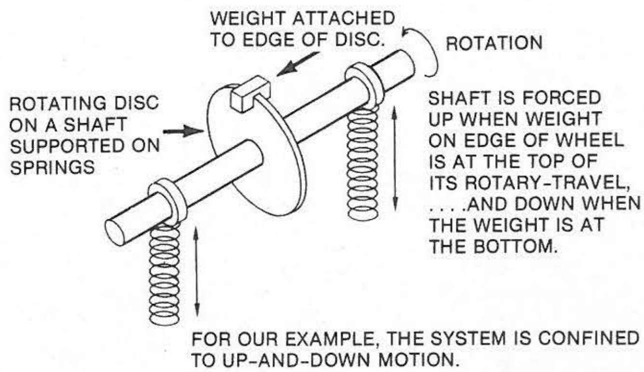


FIG. 21–16 Up-and-down motion caused by an out-of-balance condition. *(Chadwick-Helmuth Co.)*

FIG. 21–17 Micro-Vib aircraft vibration analyzer/balancer. *(Dynamic Solutions Systems, Inc.)*

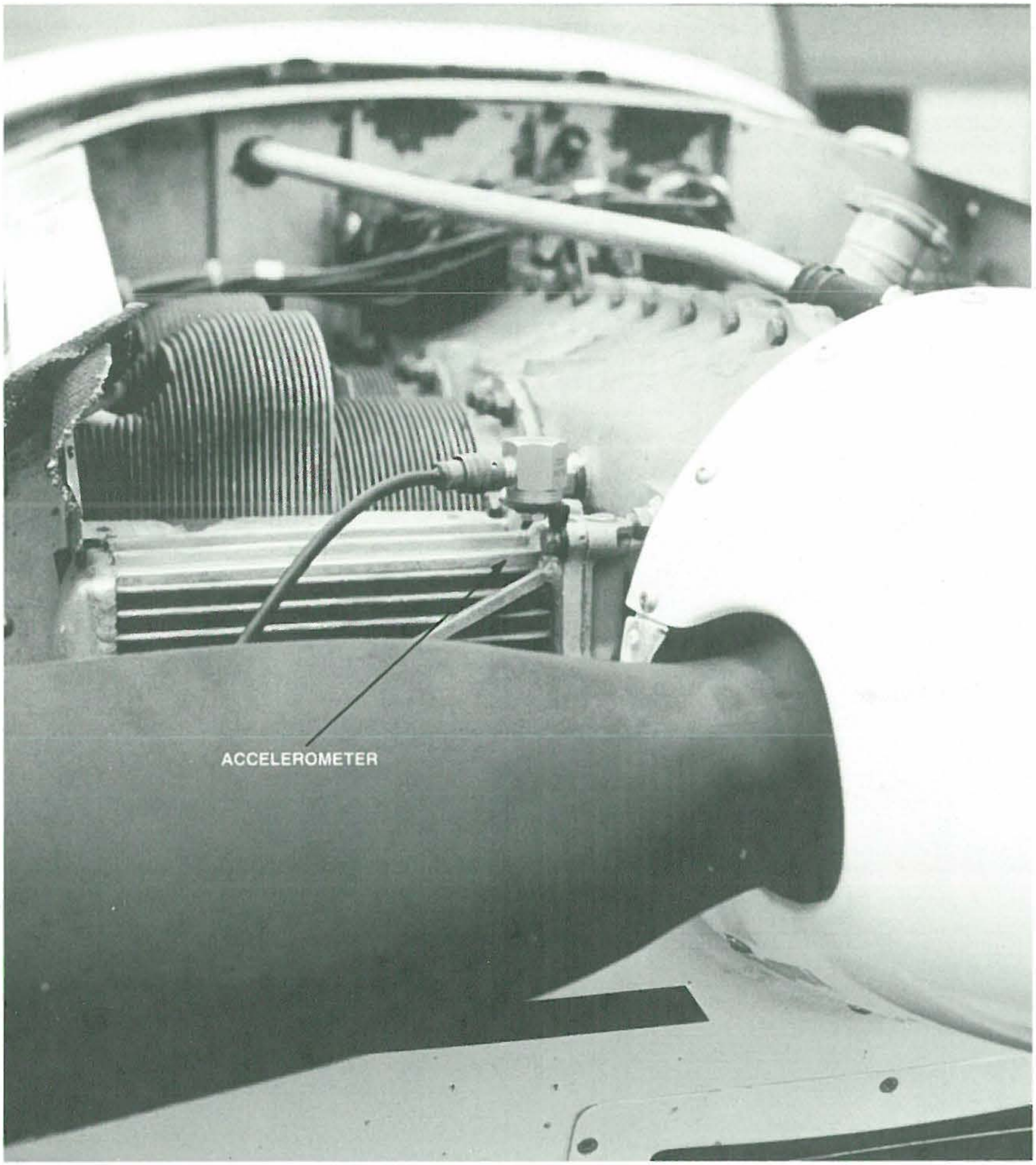


FIG. 21–18 Accelerometer installation for balancing. *(Dynamic Solutions Systems, Inc.)*

matically. This change in magnetic flux induces a voltage in the coil that is proportional to the rate of change of the magnetic flux. Magnetic pickups are inexpensive and very rugged, but they require a small, accurately controlled gap between the end of the pickup and the "interrupter" (blade of steel) that passes by the pickup. This controlled gap requires that special brackets and interrupters be produced for each type of aircraft.

A strobelight can also be used to measure the vibration phase angle. After the vibration signal is filtered, a zero-crossing detector circuit is used to create a pulse and trigger the strobelight. A piece of retroreflective tape is placed on the root of one of the propeller blades. Directing the strobe at the propeller will make the retroreflective tape appear to have stopped. The phase angle can be estimated visually by the user. This method has several disadvantages. It usually requires two people, one to operate the aircraft and one to stand in front of the prop and operate the strobe. Also, there is no way to average the phase angle data except by human skill level. In addition, a strobe requires a lot of power,

FIG. 21–19 Photo-tach installation for balancing. *(Dynamic Solutions Systems, Inc.)*

which is usually drawn from the aircraft battery. Attachment of wires to aircraft power systems takes time and can be dangerous.

The electronic instrument that completes the dynamic balancing system must include at minimum a tuneable filter circuit for removing all but the one-per-rev signal produced by the propeller, an accurate amplitude-measuring circuit and display (similar to a voltmeter), and a phase-measuring circuit for measurement and display of the phase angle between the photocell or mag pickup signal and the accelerometer signal. The balancing process is accomplished during a ground run-up with the cables and balancer positioned as shown in Fig. 12–20 and 12–21.

Data Averaging

With older balancers, the raw amplitude and phase data were presented to the user. The user was left to manually tune the filter and watch the needle on a meter waver back and forth. Digital balancers can automatically tune the filter and mathematically compute the average of several readings. This method can provide repeatable, accurate measurements of data that were difficult to interpret on the older equipment. This allows dynamic balancing to much lower levels to be done with ease.

Computing a Balance Solution

Determining how much weight to add and where to add it based on the amplitude and phase angle data was commonly done with older balancers using nomographs often called "charts." The amplitude and phase readings were manually plotted on a graph of concentric circles and radial lines. An overlay of lines could be followed out to the recommended solution weight and location. More modern balancing systems compute the solution using digital computations. These balancers eliminate the need to manually plot the data on, and to read, these "charts." These "computer balancers" display the amount of weight to add and the location in degrees.

Attaching Dynamic Balance Weights

Some aircraft have locations designed to accept dynamic balance weights. Many aircraft have no built-in provision for attaching these weights. Several propeller and airframe manufacturers have authorized drilling of the spinner backing plate for attachment of standard aircraft screws, nuts, and washers. The hole should be drilled slightly undersize and reamed to final size. The hole should be deburred with emery cloth to reduce the possibility of a stress concentration. The maximum amount of weight to be added at one location is strictly limited by manufacturer standards. When a stack of washers is used, at least one should be placed on either side of the bulkhead to reduce stress.

Balancers that Learn

The latest technology in computer balancers is a balancer that continuously learns during the balancing process.

FIG. 21–20 Cable and transducer installation for balancing. *(Dynamic Solutions Systems, Inc.)*

FIG. 21–21 Collection of balancing data during ground run-up. *(Dynamic Solutions Systems, Inc.)*

Nonlinear response to weight addition is commonly found in many types of aircraft. Only by learning from each step in the balancing process can the balancer reduce vibrations to a minimum in the fewest possible moves. Earlier versions of "computer balancers" learn the response of the aircraft on the first trial run only, and assume thereafter that the response is linear. This can lead to a phenomenon referred to as the "Black Hole," wherein vibration apparently cannot be reduced below a moderate level.

Dynamic Propeller Tracking

A strobelight can be used to observe the visual track of the blade tips on a propeller. Small strips of retroreflective tape must be placed securely and accurately at the tip of each blade. The shape, color, or orientation of each target should be varied for identification. If the strobe has an internal oscillator, it can be set to the blade rate while the engine is running. If a mag pickup or photocell signal is available, this can be used as a synchronizing pulse if the strobe has a "sync oscillator" (or "locking oscillator").

A propeller that is out of track will usually induce a one-per-rev vibration similar to the vibration from an out-of-balance prop. This vibration will increase with thrust power (pitch), whereas an out-of-balance vibration will remain constant with increasing thrust. An out-of-track prop can also induce an axial vibration that can be sensed by reorienting the vibration sensor axis parallel with the prop shaft.

Engine Vibration Analysis

Modern computer balancers usually can provide an accurate "spectrum analysis" of the vibration of the aircraft engine. This can be done during the balancing process and requires only a few extra seconds. The engine vibration is a good indicator of the "health" of the engine. By comparing the vibrations of several engines of the same type, it is easy to see when an engine has a problem. One computer balancer maker (Dynamic Solutions Systems, Inc.) is building a large database of common engine types. These data will be shared with the aircraft industry to help improve engine reliability and flight safety.

MAINTENANCE AND REPAIR OF PROPELLERS

General Nature of Propeller Repairs

When objects, such as stones, dirt, birds, etc., strike against the propeller blades and hub during flight or during takeoff and landing, they may cause bends, cuts, scars, nicks, scratches, or other defects in the blades or hub. If a defect is not repaired, local stresses are established which may cause a crack to develop, resulting eventually in the failure of the propeller or hub. For this reason, propellers are carefully examined at frequent intervals, and any defects that are discovered are repaired immediately according to methods and procedures that will not further damage the propeller.

The terminology of propeller inspection, maintenance, and repair is very precise. Repairs and alterations are rigidly classified and assigned to certain types of repair agencies. After the work is assigned to the correct individuals or organizations, the propeller must be carefully cleaned before work is performed on it. Then the necessary inspections, repairs, alterations, and maintenance procedures may be carried out.

Authorized Repairs and Alterations

The technician contemplating repair, overhaul, or alteration should be thoroughly familiar with the approved practices and regulations governing the operation which he or she expects to perform. All repairs and alterations of propellers must be performed in accordance with the regulations set forth in Federal Aviation Regulations (FAR) and the pertinent manufacturers' manuals.

Repairs and alterations on propellers are divided into four main categories: (1) major alterations, (2) minor alterations, (3) major repairs, and (4) minor repairs.

A **major alteration** is an alteration which may cause an appreciable change in weight, balance, strength, performance, or other qualities affecting the airworthiness of a propeller. Any alteration which is not made in accordance with accepted practices or cannot be performed by means of elementary operations is also a major alteration.

A **minor alteration** is any alteration not classified as a major alteration.

A **major repair** is any repair which may adversely affect any of the qualities noted in the definition of a major alteration.

A **minor repair** is any repair other than a major repair.

Classification of Repairs and Alterations

Changes such as those in the following list are classified as major alterations unless they have been authorized in the propeller specifications issued by the Federal Aviation Administration (FAA).

1. Changes in blade design
2. Changes in hub design
3. Changes in governor or control design
4. Installation of a governor or feathering system
5. Installation of a propeller deicing system
6. Installation of parts not approved for the propeller
7. Any change in the design of a propeller or its controls

Changes classified as minor alterations are those similar to the types listed below.

1. Initial installation of a propeller spinner
2. Relocation of changes in the basic design of brackets or braces of the propeller controls
3. Changes in the basic design of propeller control rods or cables

Repairs of the types listed below are classified as propeller major repairs, since they may adversely affect the airworthiness of the propeller if they are neglected or improperly performed.

1. Any repairing or straightening of steel blades
2. Repairing or machining of steel hubs
3. Shortening of blades
4. Retipping of wood propellers
5. Replacement of outer laminations on fixed-pitch wood propellers
6. Inlay work on wood propellers
7. All repairs of composition blades
8. Replacement of tip fabric
9. Repair of elongated bolt holes in the hubs of fixed-pitch wood propellers
10. Replacement of plastic covering
11. Repair of propeller governors
12. Repair of balance propellers of rotorcraft
13. Overhaul of controllable-pitch propellers
14. Repairs involving deep dents, cuts, scars, nicks, etc., and straightening of aluminum blades
15. Repair or replacement of internal elements of blades

Propeller repairs such as those listed below are classified as propeller minor repairs.

1. Repairs of dents, cuts, scars, scratches, nicks, and leading-edge pitting of aluminum blades if the repair does not materially affect the strength, weight, balance, or performance of the propeller

2. Repairs of dents, cuts, scratches, nicks, and small cracks parallel to the grain of wood blades

3. Removal and installation of propellers

4. The assembly and disassembly of propellers to the extent necessary to permit (*a*) assembly of propellers partially disassembled for shipment and not requiring the use of balancing equipment, (*b*) routine servicing and inspection, and (*c*) replacement of parts other than those which normally require the use of skilled techniques, special tools, and test equipment

5. Balancing of fixed-pitch and ground-adjustable propellers

6. Refinishing of wood propellers

Persons and Organizations Authorized to Perform Repairs and Alterations on Propellers

The regulations governing the persons and organizations authorized to perform propeller repairs and alterations are subject to change, but in general, maintenance, minor repairs, or minor alterations must be done by a certificated repair station holding the appropriate ratings, an airframe and powerplant technician (A&P) or a person working under the direct supervision of such a technician, or an appropriately certificated air carrier. Major repairs or alterations on propellers may be performed only by an appropriately rated repair station, manufacturer, or air carrier in accordance with the regulations governing their respective operations.

Requirements governing persons or organizations authorized to perform maintenance and repairs on propellers are set forth in FAR Part 65.

Remember that minor repairs and alterations are those which are not likely to change the operating characteristics of the propeller or affect the airworthiness of the propeller. All other repairs and alterations are major in nature and must be performed by properly authorized agencies.

General Repair Requirements

Propellers should be repaired in accordance with the best accepted practices and the latest techniques. Manufacturers' recommendations should always be followed if such recommendations are available. It is recognized that the manuals may not be available for some of the older propellers; in such cases, the propellers should be repaired in accordance with standard practices and FAA regulations.

When a propeller is repaired or overhauled by a certificated agency, the repair station number or the name of the agency should be marked indelibly on the repaired propeller. It is recommended that a decal giving both the repair agency's name and repair station number be used for this purpose. If the original identification marks on a propeller are removed during overhaul or repair, it is necessary that they be replaced. These marks include the name of the manufacturer and the model designation.

General Inspection and Repair of Wood Propellers

Wood propellers are inspected for such defects as cracks, bruises, scars, warping, oversize holes in the hub, evidence of glue failure, evidences of separated laminations, sections broken off, and defects in the finish. The tipping should be inspected for such defects as looseness or slippage, separation of soldered joints, loose screws, loose rivets, breaks, cracks, eroded sections, and corrosion. Frequently, cracks do appear across the leading edge of the metal tipping between the front and rear slits where metal has been removed to permit easier forming of the tip curvature. These cracks are considered normal and are not cause for rejection.

The steel hub of a wood or composite propeller should be inspected for cracks and wear. When the hub is removed from the propeller, it should be magnetically inspected. Any crack in the hub is cause for rejection. The hub should also be inspected for wear of the bolt holes.

All propellers should undergo regular and careful inspection for any possible defect. Any doubtful condition such as looseness of parts, nicks, cracks, scratches, bruises, or loss of finish should be carefully investigated and the condition checked against repair and maintenance specifications for that particular type of propeller.

Causes for Rejection. Propellers worn or damaged to such an extent that it is either impossible or uneconomical to repair them and make them airworthy should be rejected and scrapped. The following conditions are deemed to render a wood propeller unairworthy and are therefore cause for rejection.

1. Cracks or deep cuts across the grain of the wood
2. Split blades
3. Separated laminations, except the outside laminations of fixed-pitch propellers
4. More screw or rivet holes, including holes filled with dowels, than are used to attach the metal leading-edge strip and tip
5. Appreciable warping
6. An appreciable portion of wood missing
7. Cracks, cuts, or other damage to the metal shanks or sleeves of blades
8. Broken lag screws which attach the metal sleeve to the blade
9. Oversize shaft holes in fixed-pitch propellers
10. Cracks between the shaft hole and the bolt holes
11. Cracked internal laminations
12. Excessively elongated bolt holes

Repair of Minor Damage. Small cracks parallel to the grain in a wood propeller should be filled with an approved glue thoroughly worked into all portions of the cracks, dried, and then sanded smooth and flush with the surface of the propeller. This treatment is also used with small cuts. Dents or scars which have rough surfaces or shapes that will hold a filler and will not induce failure may be filled with a mixture of approved glue and clean, fine sawdust, thoroughly worked and packed into the defect, dried, and then sanded smooth and flush with the surface of the propeller. It is very important that all loose or foreign matter be removed from the place to be filled so that a good bond of the glue to the wood is obtained.

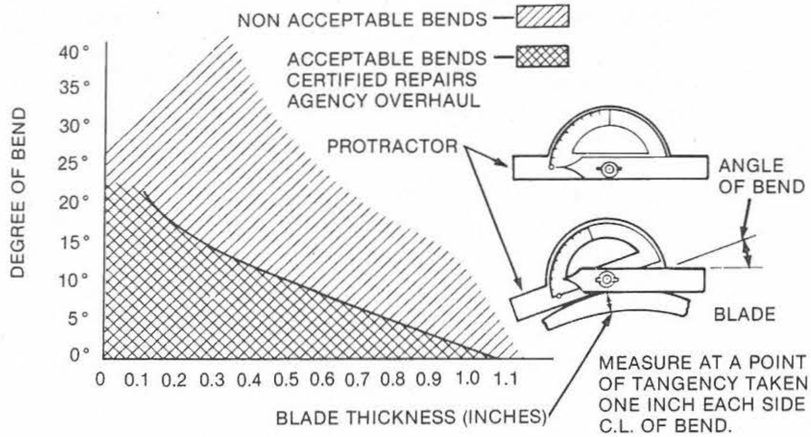


FIG. 21–22 Blade straightening limits. *(Hartzell Propeller)*

Repair of Major Damage. As explained previously, the aviation technician rarely is involved with the major repair of a wood propeller. For this reason, such repairs are not described in this section. If an A&P technician should be confronted with the need to have a wood propeller reconditioned or repaired, a properly certificated propeller repair station would be able to perform the necessary work. Help and advice in such a matter can be obtained from the FAA General Aviation District Office.

General Inspection and Repair of Metal Propellers

Hollow and Solid Steel Propellers. Major damage on steel propeller blades should not be repaired except by the manufacturer. Welding or straightening is not permissible on such blades, even for very minor repairs, except by the manufacturer, because of the special process employed and the heat treatment required. A blade developing a crack of any nature in service should be returned to the manufacturer for inspection.

Inspection of Steel Blades. The inspection of steel blades may be either visual or magnetic. Visual inspection is easier to perform if the steel blades are covered with engine oil or rust-preventive compound. The full length of the leading edge, especially near the tip; the full length of the trailing edge; the grooves and shoulders on the shank; and all dents and scars should be examined with a magnifying glass to determine whether defects are scratches or cracks.

In the magnetic inspection of steel blades and propeller parts, the blade or part to be inspected is mounted in a machine, and then the blade is magnetized by passing a current through the blade or part. Either a black or a red mixture of an iron-base powder and kerosene is poured over the blade or part at the time that it is magnetized. North and south magnetic poles are established on either side of any crack in the metal. The iron filings arrange themselves in lines within the magnetic field thus created. A black or a red line, depending on the color of the mixture, will appear wherever a crack exists in the blade or part.

Repair of Minor Damage in Steel Blades. Minor injuries to the leading and trailing edges only of steel blades may be smoothed by handstoning, provided that the injury is not deep.

Aluminum-Alloy Propellers. A seriously damaged aluminum-alloy propeller blade should be repaired only by the manufacturer or by repair agencies certificated for this type of work. Such repair agencies should follow manufacturers' instructions.

Definition of Damaged Propellers. A damaged metal propeller is one that has been bent, cracked, or seriously dented. Minor surface dents, scars, nicks, etc. which are removable by field maintenance technicians are not considered sufficient to qualify the propeller as damaged.

If the model number of a damaged blade appears on the manufacturer's list of blades which cannot be repaired, the blade should be rejected.

Blades bent in face alignment The extent of a bend in the face alignment of blades should be carefully checked by means of a protractor similar to the one illustrated in Fig. 21–22.

Manufacturers often specify the maximum bends which can be repaired by cold-straightening on specific models of propellers. Figure 21–23 is a chart which shows the maximum allowable bend for cold repair of McCauley 1A90, 1B90, and 1C90 fixed-pitch metal propellers. From the chart, for example, it can be determined that if the propeller is bent at the 16-in [40.64-cm] radius, the maximum degree of bend which can be straightened cold is 9°. At the 32-in [81.28-cm] radius, the blade can be repaired by cold-straightening if the bend is as great as 18.5°. After straightening, the affected portion of the blade must be etched and thoroughly inspected for cracks and other flaws. Blades with bends in excess of this amount require heat treatment and must be returned to the manufacturer or an authorized agent for repair.

Blades bent in edge alignment Blades which are bent in edge alignment should be repaired by the manufacturer or a certificated repair station holding the appropriate rating.

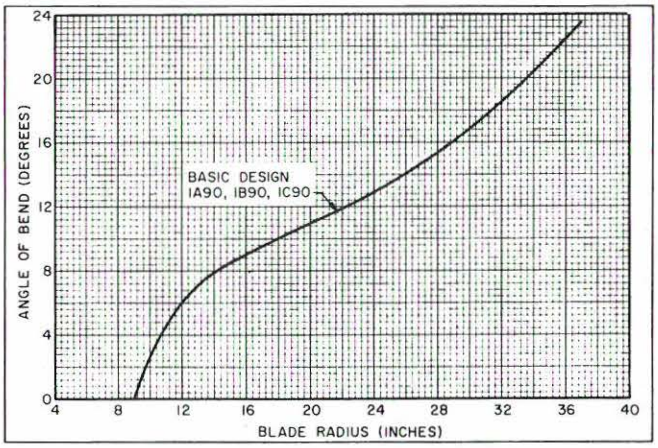


FIG. 21–23 Chart showing the maximum allowable bend for a cold repair.

Aluminum Blade Fatigue Failure

An investigation of a representative number of propeller blades disclosed that failures usually occurred because of **fatigue cracks** which started at mechanically formed dents, cuts, scars, scratches, nicks, or leading-edge pits. Blade material samples in most cases did not reveal evidence of failure caused by material defects or surface discontinuities existing before the blades were placed in service. Often fatigue failure occurs at a place where previous damage has been repaired, which may be a result of the failure actually having started prior to the repair or of the repair having been performed improperly.

The stresses that normally occur in a propeller blade may be envisioned as being produced by lines of force that run within the blade approximately parallel to the surface, as shown in Fig. 21–24. When a defect occurs, it tends to squeeze together the lines of force in the defect area, thereby increasing the stress. This increase in stress may be sufficient to cause a crack to start. Even a small defect such as a nick or dent may develop into a crack. The crack, in turn, results in an even greater stress concentration in the area. The resulting growth of the crack will almost inevitably result in blade failure. This condition is so common, and the results are so serious, that great emphasis should be placed on the daily and preflight inspections of propeller blades for defects.

Experience indicates that fatigue failures normally occur within a few inches of the blade tip; however, failures also can occur in other portions of the blade when dents, cuts, scratches, or nicks are ignored. Failures have also been reported in blades near the shank and at the propeller hub, well out of the critical areas; therefore, no damage should be overlooked or allowed to go without correction.

When performing an inspection on the propeller, especially during the preflight inspection, inspect each complete blade—not just the leading edge—for erosion, scratches, nicks, and cracks. Regardless of how small a surface irregularity may be, consider it as a stress intensifier that makes the area subject to fatigue failure.

Propeller manufacturers' manuals, service letters, and bulletins specify methods and limits for blade maintenance, inspection service, and repair. The proper service information should always be consulted.

Prevention and Treatment of Minor Surface Defects

To prevent propeller surface defects, avoid operating the aircraft in areas with loose stone or gravel that could be pulled into the blades and cause damage to the blade face or leading edge. When takeoff from a nonhard surface runway is initiated, blade damage can be minimized by allowing the aircraft to move prior to fully opening the throttle. Keep the blade clean of stains and foreign matter, and *do not move aircraft by pulling on propeller blades.*

Propeller blades with nicks, gouges, scratches, and leading-edge pitting can be repaired most often by a qualified technician in the field. Normally there is sufficient material available to allow a number of minor repairs to be made prior to replacement. Blades with larger nicks, gouges, etc., that may affect the structure, balance, or operation of the propeller should be referred to a qualified propeller repair station for repair or replacement.

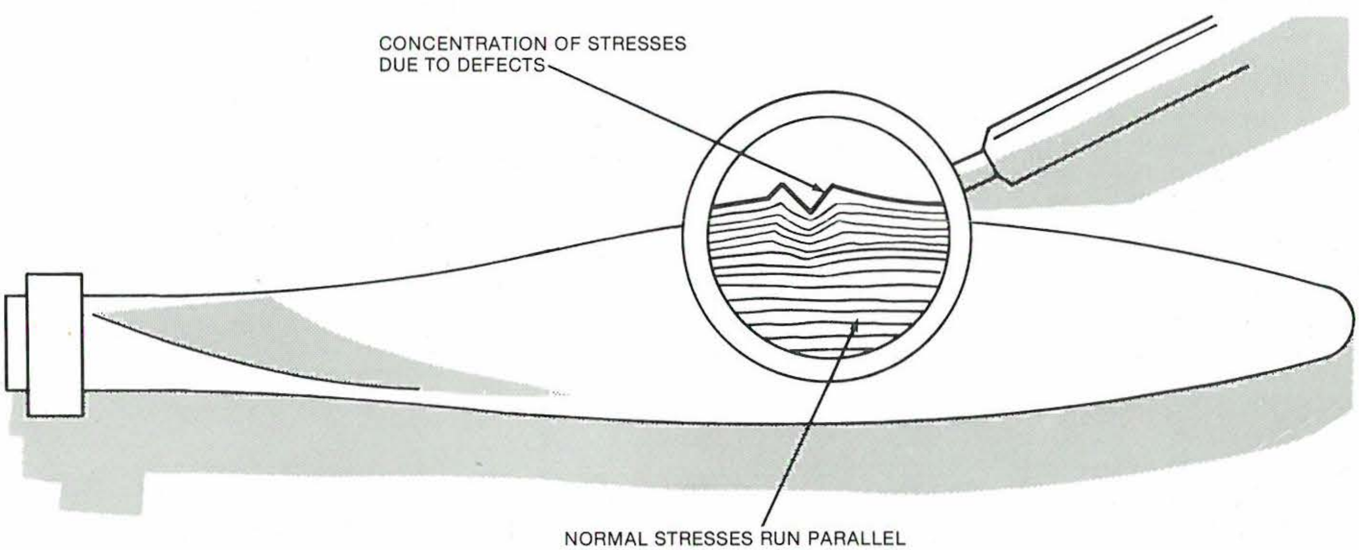


FIG. 21–24 Fatigue stresses in a propeller.

Repair may be made using files or small air- or electric-powered equipment with suitable grinding and polishing attachments. All repairs must be made parallel to the blade axis. The manufacturer's manual should be consulted to ensure that correct information is used in the repair of specific models of propellers.

For damaged areas in the leading or trailing edge, begin with a round file and remove damaged material down to the bottom of the damaged area. Remove material from this point out on both sides, providing a smooth, faired depression, and maintaining the original airfoil concept, as shown in Fig. 21–25. The area should be smoothly faired using **emery cloth,** to remove all traces of initial filing and rework. **Crocus cloth** is used to polish the area. When all rework has been completed, inspect the reworked area with a 10× magnifying glass and dye penetrant to make sure that no indications of the damage or cracks remain.

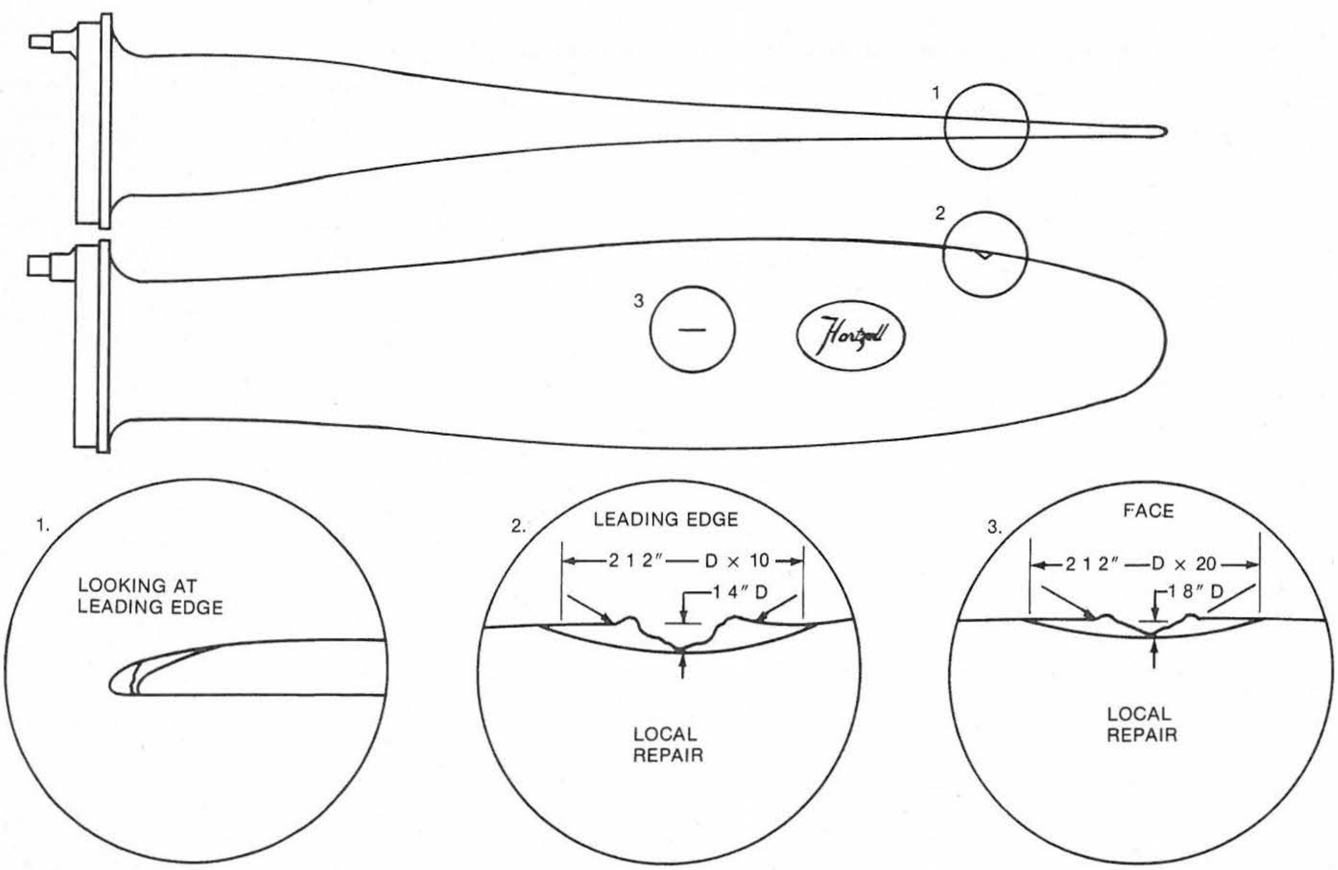
Damaged areas on the face or camber sections of the blade should be reworked employing the same methods used for the leading edge (see Fig. 21–25).

All repaired areas should be chemically treated to prevent corrosion. Alodine or an approved paint should be properly applied to the repaired area prior to return of the blade to service.

Number of Defects Allowable in Blades. More than one defect falling within the above limitations is not sufficient cause alone for the rejection of a blade. A reasonable number of such defects per blade is not necessarily dangerous, if within the limits specified, unless the locations of the defects with respect to each other are such as to form a continuous line of defects that would materially weaken the blade.

Repair of Pitted Leading Edges. Blades whose leading edges are pitted from normal wear in service may be reworked by removing sufficient material to eliminate the defects. In this case, the metal should be removed by starting at approximately the thickest section, as shown in Fig. 21–26, and working well forward over the nose camber so that the contour of the reworked portion will remain substantially the same, avoiding abrupt changes in section or blunt edges. Blades requiring removal of more material than the permissible reductions in width and thickness from the minimum drawing dimensions should be rejected.

Inspection and Treatment of Defects. Scratches and suspected cracks should be given a local etch, as explained below, and then examined with a magnifying glass. *The*



TO DETERMINE THE NEEDED AMOUNT OF REWORK, USE THE FOLLOWING FORMULA
- LEADING AND TRAILING EDGE = DEPTH OF NICK × 10
- FACE AND CAMBER DEPTH OF NICK × 20

NOTE: LOCAL WIDTH OR THICKNESS REPAIR DEPTH MAY NOT EXCEED THE MANUFACTURERS MINIMUM REPAIR TOLERANCE

FIG. 21–25 Blade repair. *(Hartzell Propeller)*

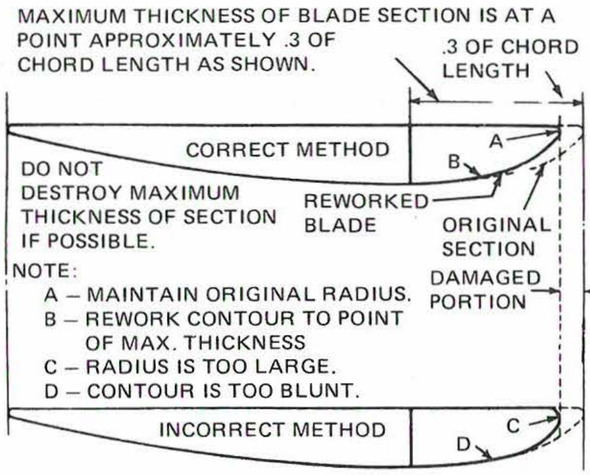


FIG. 21-26 Rework of a propeller's leading edge.

shank fillets of adjustable-pitch blades and the front half of the undersurface of all blades from 6 to 10 in [15.24 to 25.40 cm] from the tip are the most critical portions.

Adjustable-pitch blades should be etched locally on the clamping portion of the shank at points ¼ in [6.35 mm] from the hub edge in line with the leading and trailing edges and should be examined with a magnifying glass for circumferential cracks. Any crack is cause for rejection. The Micarta shank bearing on controllable and hydromatic propeller blades should not be disturbed, except by the manufacturer. Blades requiring removal of more material than is permissible (See "Repair of Pitted Leading Edges," above) should be scrapped.

Local Etching. To avoid dressing off an excess amount of metal, checking by local etching should be performed at intervals during the progress of removing cracks and double-back edges of metal. Suitable sandpaper or fine-cut files may be used for removing the necessary amount of metal, after which, in each case, the surfaces involved should be smoothly finished with No. 00 sandpaper. Each blade from which any appreciable amount of metal has been removed should be properly balanced before being used.

When aluminum-alloy blades are inspected for cracks or other failures and for bends, nicks, scratches, and corrosion, the application of engine oil to the blades helps the inspector to see the defects, especially with a magnifying glass. If there is any doubt about the extent of the defects, local etching is then performed.

Purposes Local etching has four principal purposes: (1) it shows whether visible lines and other marks within small areas of the blade surfaces are actually cracks or only scratches; (2) it determines, with a minimum removal of metal, whether or not shallow cracks have been removed; (3) it exposes small cracks that might not be visible otherwise; and (4) it provides a simple means of inspecting the blades without removing or disassembling the propeller.

The caustic soda solution is a 20 percent solution prepared locally by adding to the required amount of water as much commercial caustic soda as the water will dissolve and then adding some soda pellets after the water has ceased to dissolve the caustic to be sure that the solution is saturated. The quantity required depends on the amount of etching to be done. This caustic soda solution should reveal the presence of any cracks.

An acid solution is used to remove the dark corrosion caused by the application of the caustic soda solution to the metal. The acid solution is a 20 percent nitric acid solution prepared locally by adding one part commercial nitric acid to each five parts of water.

Keep the solutions in glass or earthenware containers. Do not keep them in metal containers, since they attack metal. If any quantity of either the caustic soda or the acid solution is spilled, flush the surface it hits with fresh water, especially if it is a metal surface.

Procedures Clean and dry the area of the aluminum-alloy blade to be locally etched. Place masking tape around the area under suspicion to protect the adjoining surfaces. Smooth the area containing the suspected defect with No. 00 sandpaper. Apply a small quantity of the caustic soda solution with a small swab to the suspected area. After the suspected area becomes dark, wipe it off with a clean cloth dampened with clean water, but do not slop too much water around the suspected area or the water will remove the solution from the defect and spoil the test. The dark stain that appears on an aluminum-alloy blade when the caustic solution is applied is caused by the chemical reaction between the copper in the alloy and the caustic soda (sodium hydroxide). If there is any defect in the metal, it will appear as a dark line or other mark. Examination under a microscope will show small bubbles forming in the dark line or mark.

It may require several applications of the caustic soda to reveal whether or not a shallow defect has been removed since a previous local etching was performed and a defect discovered. Immediately after the completion of the final test, all traces of caustic soda must be removed with the nitric acid solution. The blade is rinsed thoroughly with clean water, and then it is dried and coated with clean engine oil.

The inspection of aluminum-alloy propeller blades for cracks and flaws may be accomplished by means of a chromic acid anodizing process. This is superior to the caustic etching process and should therefore be used if facilities are available.

The blades should be immersed in the anodizing bath as far as possible, but all parts not made of aluminum alloy must either be kept out of the chromic acid bath or be separated from the blade by nonconductive wedges or hooks. The anodizing treatment should be followed by a rinse in clear, cold, running water for 3 to 5 min, and the blades should be dried as soon as possible after the rinse, preferably with an air blast. After the blades are dried, they should stand for at least 15 min before examination. Flaws, such as cold shuts and inclusions, will appear as fine black lines. Cracks will appear as brown stains caused by chromic acid bleeding out onto the surface.

The blades may be sealed for improved corrosion resistance by immersing them in hot water (180 to 212°F [82 to 100°C]) for ½ h. In no case should the blades be treated with hot water before the examination for cracks, since heating expands any cracks and allows the chromic acid to be washed away.

Inspection of aluminum-alloy propeller blades for cracks and other defects may also be accomplished by means of the fluorescent penetrant process or the dye penetrant process. These methods for the inspection of nonferrous metals are explained in Chap. 10.

Tolerances Listed in Blade Manufacturing Specifications. Tolerances listed in the blade manufacturing specifications govern the width and thickness of new blades. These tolerances are to be used with the pertinent blade drawing to determine the minimum original blade dimensions to which the reductions shown in Fig. 21–27 may be applied.

For repairing blades, the permissible reductions in width and thickness from the minimum original dimensions allowed by the blade drawing and blade manufacturing specifications are shown in Fig. 21–27 for locations on the blade from the shank to 90 percent of the blade radius. In this instance, the outer 10 percent of blade length may be modified as required.

Shortening of Blades to Remove Defects. When the removal or treatment of defects on the tip necessitates shortening of a blade, each blade used with it must likewise be shortened. Such sets of blades should be kept together. Figures 21–28 and 21–29 illustrate acceptable methods of blade shortening.

With some propeller blades, the length may be reduced substantially and the propeller can then be given a new model number in accordance with the manufacturer's specifications. The reduction in length may require an increase in the blade angle, and the length must agree with the specification for the new model number.

Causes for Rejection. Unless otherwise specified in this text, a blade having any of the following defects must be rendered unserviceable: (1) irreparable defects, such as longitudinal cracks, cuts, scratches, scars, etc., that cannot be dressed off or rounded out without materially weakening or unbalancing the blade or materially impairing its performance; (2) general unserviceability due to removal of too much stock by etching, dressing off defects, etc.; (3) slag inclusions in an excessive number or cold shuts in an excessive number, or both; and (4) transverse cracks of any size.

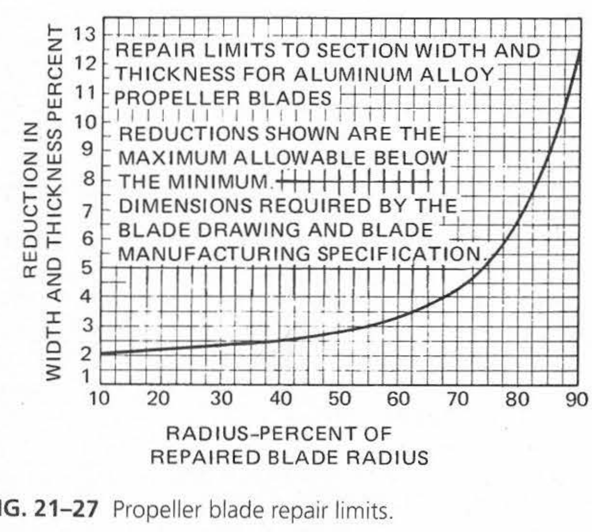


FIG. 21–27 Propeller blade repair limits.

Composite Propeller Blade Damage Limits

To determine the damage limits and make repairs on composite propeller blades, the technician must be familiar with the terminology and equipment used to make these repairs. The appropriate current manufacturer's maintenance manual should always be consulted in the assessment of airworthy damage. This is also required for repair of composite propeller blades. The information contained in this text is presented solely for the purpose of familiarizing the technician with composite blade repair. It is also recommended that the technician seek factory training before performing maintenance on composite propeller blades.

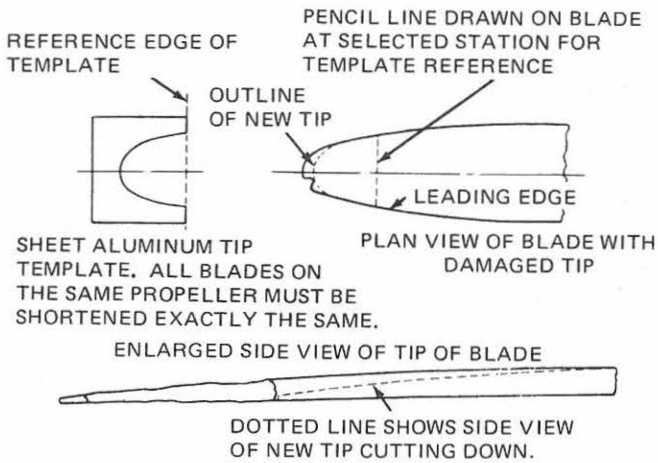


FIG. 21–28 Repair of a damaged propeller tip.

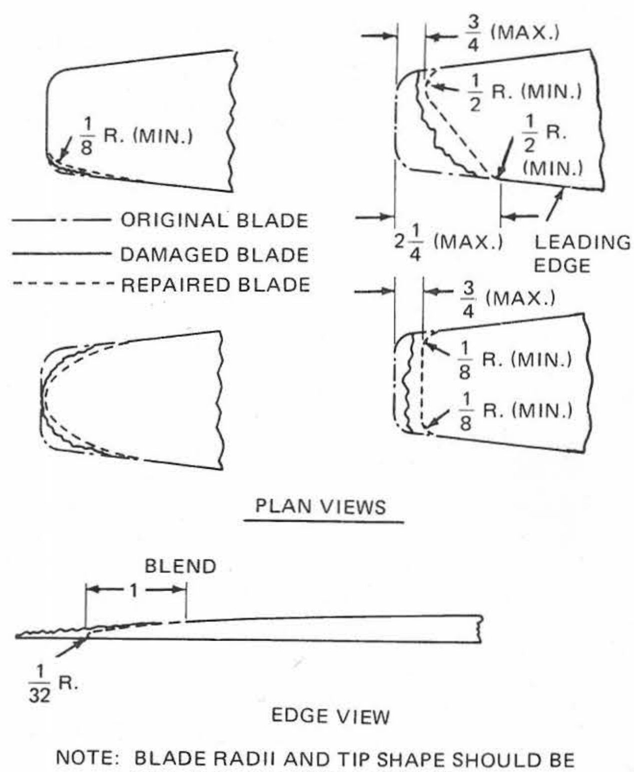


FIG. 21–29 Repair of a damaged square tip.

Blade Life. Blade life is expressed in terms of total hours of service (TT, or total time), time between overhauls (TBO), and hours of service since overhaul (TSO, or time since overhaul). Overhaul returns the blade assembly to zero hours TSO, but not to zero hours TT. Occasionally, a part may be "life limited," which means that it must be replaced after a specified period of use. All references are necessary in defining the life of the propeller.

Blade Damage. Damage to composite propeller blades can be divided into airworthy and unairworthy damage, and it is important that the technician be able to determine the difference between these two types of damage. Airworthy damage repairs can normally be made in the field.

Damage to composite blades can take many forms. Some of the terms used to describe blade damage are as follows:

Corrosion is a gradual wearing away or deterioration due to chemical action.

A **crack** is an irregularly shaped separation within a material, usually visible as a narrow opening at the surface. Refer to Fig. 21–30.

Debond is a separation of the metal erosion shield from the composite material in the blade. Refer to Fig. 21–31.

Delamination is an internal separation of the layers of composite material.

A **depression** is a surface area where the material has been compressed, but not removed, by contact with a sharp object.

Distortion is an alteration of the original shape or size of a component.

Erosion is a gradual wearing away or deterioration due to action of the elements.

Exposure is the condition in which material is left open to the action of the elements.

A **gouge** is a small surface area from which material has been removed by contact with a sharp object.

Impact damage occurs when the propeller blade or hub assembly strikes or is struck by an object, either in flight or on the ground.

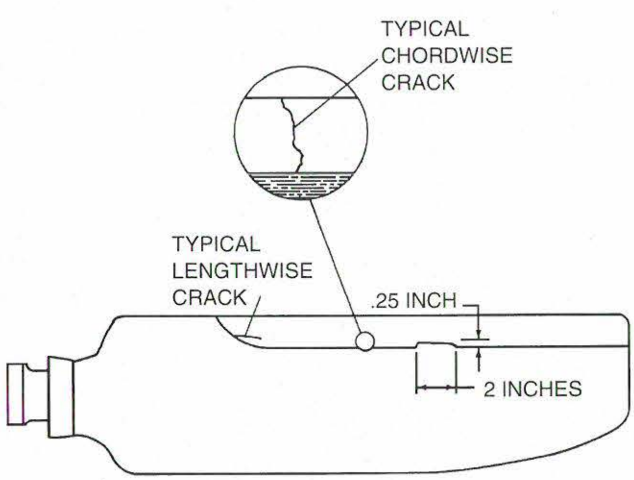


FIG. 21–30 Missing portions of nickel erosion shield (trailing edge side) and typical cracks. *(Hartzell Propeller)*

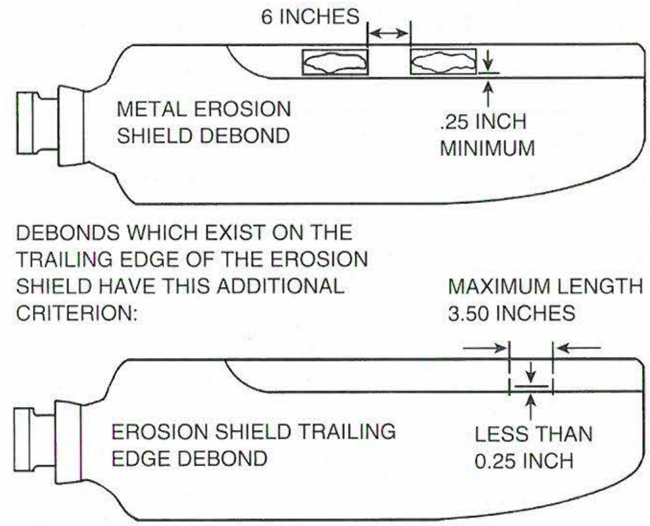


FIG. 21–31 Limits of airworthy damage in metal erosion shield debond. *(Hartzell Propeller)*

Overspeed damage occurs when the propeller hub assembly rotates at a speed more than 10 percent in excess of the maximum for which it is designed. Overspeed damage may not produce visible indications.

A **scratch/nick** is removal of paint and possibly a small amount of the composite material not exceeding one layer (approximately 0.010 in [0.254 mm]).

A **split** is a delamination of the blade extending to the blade surface, normally found near the trailing edge or tip.

Normal airworthy damage does not affect flight safety characteristics of the blades, although areas of airworthy damage should be repaired to maintain aerodynamic efficiency. Airworthy damage should be monitored until repaired, with the repair being accomplished as soon as possible. To determine if the damage is airworthy or unairworthy, the technician should refer to the information contained in the current blade-repair manual. The following is a list of airworthy damage limits for Hartzell composite propeller blades.

Erosion Shield Airworthy Damage. The following types of damage cannot be resolved without replacement of the erosion shield, but, within these limits, do not render the blade unairworthy:

Any gouge that does not penetrate through to the surface of composite material.

Any full-width chordwise crack as long as the erosion shield is not debonded within 3.5 in [8.89 cm] of the crack (Fig. 21–30).

No two full-width chordwise cracks may occur within 6 in [15.24 cm] of each other.

Chordwise cracks less than 0.5 in [1.27 cm] in length that are not debonded within 1 in [2.54 cm].

Portions of the trail side of the erosion shield may be missing as a result of erosion or removal by sanding (see Fig. 21–30 for limits).

Lengthwise cracks less than 2 in [5.08 cm] long that are not debonded within 3.5 in [8.89 cm] of the crack (see Fig. 21–30 for limits).

For blades with attached counterweight clamps, cracks within 1 in [2.54 cm] of counterweight clamp that are not debonded.

Minor deformations due to impact damage that does not greatly affect the airfoil shape.

The following types of damage do not render the blade unairworthy but should be repaired as soon as practical to prevent degradation of the condition:

Debonds located along the trailing side of the erosion shield that together total less than 10.5 in [26.67 cm] in length. No individual debond may exceed 3.5 in [8.89 cm] in length and 0.25 in [0.64 cm] in width (Fig. 21–31).

Debond which is located at least 0.25 in [0.64 cm] from the erosion shield trail side and has total area less than 2.5 in^2 [16.13 cm^2], and is separated by at least 6 in [15.24 cm] from any other debond area on the same blade surface. The total debonded area of all debonds may not exceed 10 in^2 [64.52 cm^2].

Blade Cuff Airworthy Damage. The types of blade cuff damage that are considered to be airworthy damage are as follows:

Nicks, scratches.

Depressions less than 1 in^2 [6.45 cm2] in area and less than 0.25 in [6.35 mm] deep.

Delaminations less than 2 in^2 [12.90 cm^2] in area.

Cracks at the root end are airworthy, but should be sealed to protect the foam from contamination (Fig. 21–32) until the next overhaul, during which these cracks can be permanently repaired.

Cracks located in the area where the cuff and blade meet must be within the limits, as shown in Fig. 21–33.

No more than two other cracks may be located elsewhere on the cuff. These cracks must be less than 3 in [7.62 cm] in length.

No more than two damaged areas per side are permitted within 6 (linear) in [15.24 cm] of each other. Root end cracks and cracks where the blade and cuff meet are not included in this requirement.

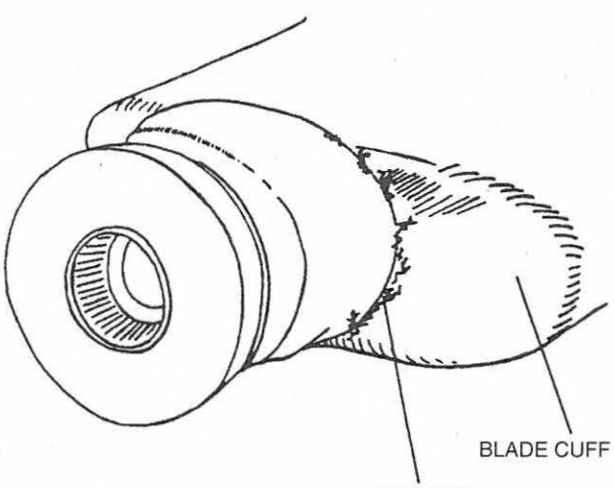


FIG. 21–32 Blade cuff damage. *(Hartzell Propeller)*

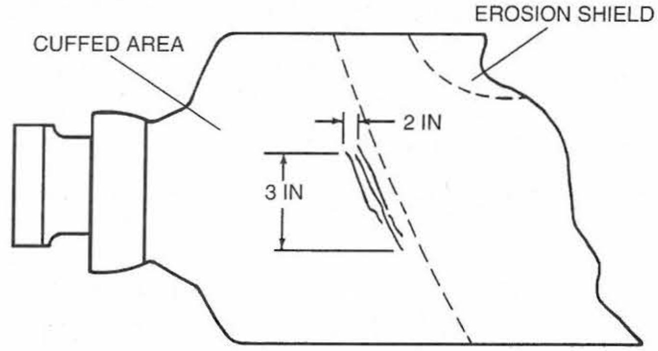


FIG. 21–33 Cracks in the area where cuff meets blade. *(Hartzell Propeller)*

Cuffs with no boot or erosion shield covering the leading edge may have no cracks within 2 in [5.08 cm] of leading edge.

Blade Airworthy Damage. Types of blade damage that are considered airworthy are:

Gouges or loss of material. Gouges less than 0.500 in [12.7 mm] in diameter or of equivalent area and no more than 2.5 in [6.35 cm] long and less than 0.020 in [0.508 mm] deep anywhere on the outboard half of the blade.

Delamination. Delamination on the outboard half of the blade totaling less than 2 in^2 [12.90 cm^2] in area and with no dark brown or black stain which would indicate the presence of grease.

Gouges, loss of material, or delaminations. Any of these on the inboard half of the blade can be unairworthy, and the factory should be consulted.

Paint erosion. The exposure of less than 5 in^2 [32.26 cm^2] of the composite material and/or the primer filler.

Crushed blade trailing edge. The crushed area can be no larger than 0.25 in [6.35 mm] deep by 1 in [2.54 cm] long on the outer half of the blade with no broken strands of composite material (epoxy crushed only, see Fig. 21–34).

Split trailing edge. A split trailing edge with an area less than 0.25 in [6.35 mm] deep by 1 in [2.54 cm] long on the outer half of the blade.

Erosion screen. Airworthy damage to erosion screens should be repaired using limits and procedures for blade gouge minor repair.

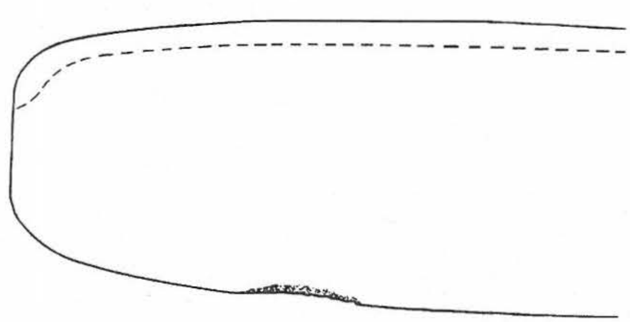


FIG. 21–34 Crushed trailing edge. *(Hartzell Propeller)*

Blade retention windings. Cracks apperaring in the paint over the blade retention windings are airworthy. These cracks should be repaired as soon as practical.

Repair of Composite Blades

Repair procedures can be categorized as either minor repair or major repair. Minor repair is the correction of damage that may be safely performed in the field by a certified aircraft technician. Major repair is the correction of damage that cannot be performed by elementary operations. Major repairs must be performed by a propeller shop that has been approved by Hartzell for the specific type of major repair.

Repair of Unairworthy Damage. **Unairworthy damage** is defined as any damage of the composite blade which exceeds the limits of the airworthy damage as previously described. Unairworthy damage to a composite blade must be repaired before the blade can be used on another flight. This requires returning the blade to a factory-designated facility for evaluation and repair with factory consultation.

Composite propeller blades are not subject to fatigue cracks, as are aluminum propellers, because of their composite construction. The factory or factory-approved repair station can repair many types of unairworthy damage of composite blades.

Lightning strikes usually enter a composite blade through the metal erosion shield; however, some strikes can hit the hub directly. A direct strike on the hub of a composite blade propeller results in unairworthy damage. The blades must then be overhauled according to prescribed procedures before the propeller can be used for further service. A lightning strike on the metal erosion shield leaves a darkened area and sometimes pitting near the tip of the composite blade, as shown in Fig. 21–35. If evidence of a lightning strike is found, it will require a careful debond/delamination inspection to determine the extent of the damage and whether it is airworthy or unairworthy. To determine this, perform a "coin-tap" test immediately to test for debond and/or delamination. The **"coin-tap" test** is shown in Fig. 21–36. Use of an **impactoscope flaw detector** is an approved optional method, in conjunction with a coin-tap test, for detecting delaminated areas on the blade. If only a darkened area is present on the erosion shield from the lightning strike, and all blade damage is within limits specified, the damage is considered airworthy. If the damage is determined to be unairworthy damage, return the blade to the factory.

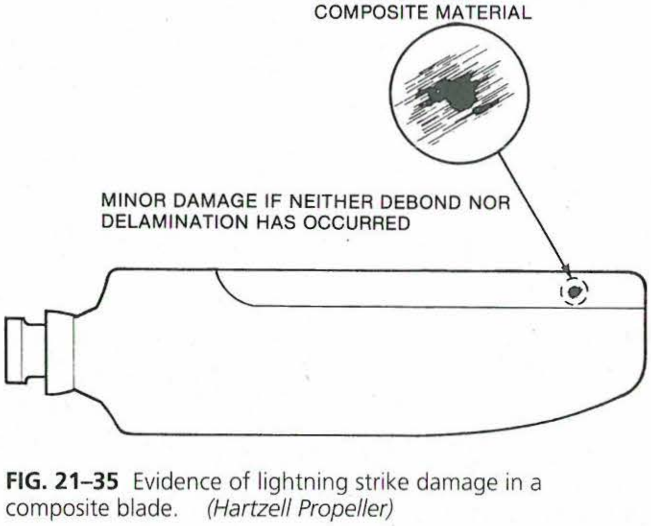


FIG. 21–35 Evidence of lightning strike damage in a composite blade. *(Hartzell Propeller)*

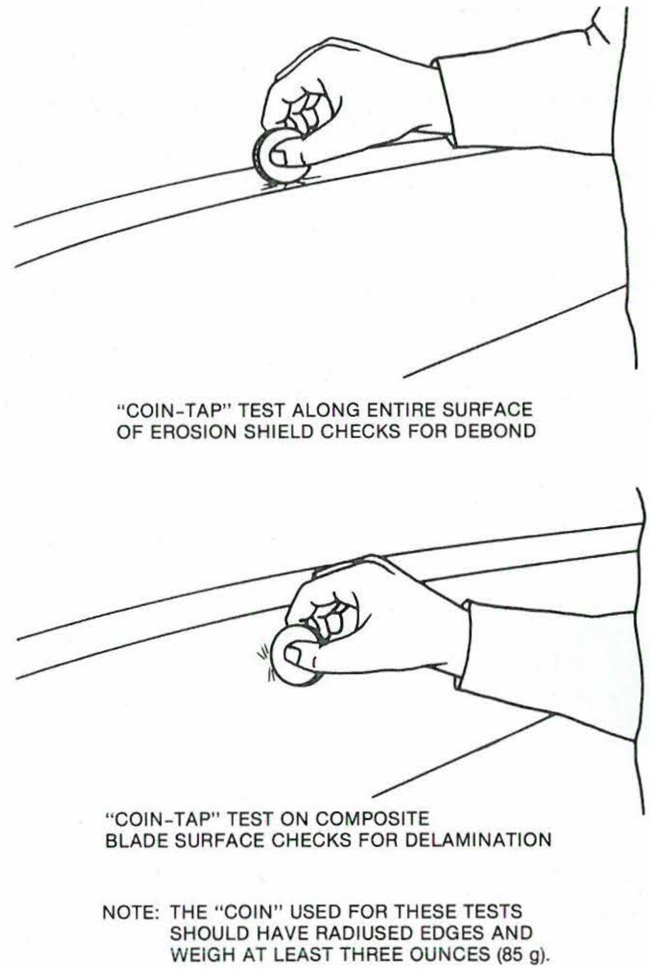


FIG. 21–36 Use of coin-tap test to check for debond and delamination. *(Hartzell Propeller)*

Repair of Airworthy Damage. There are many different types of airworthy damage, and therefore there are several methods used to repair this type of damage. Repair of a composite propeller blade is usually performed by cleaning the damaged area, removing the paint, and sanding. The damaged area is then filled with laminated fiberglass cloth and epoxy. It is normally necessary to use C-clamps to apply pressure as the epoxy sets up, as shown in Fig. 21–37. After the epoxy has hardened, the area is sanded for conformance with the contour of the blade. Examples of repaired erosion shield areas are shown in Fig. 21–38. The repaired blade receives a final finish of approved primer and polyurethane paint.

Records of Repair. In the performance of repairs of composite blades, record keeping is very important. Records should indicate whether a particular instance of damage was unairworthy or airworthy, and a description of

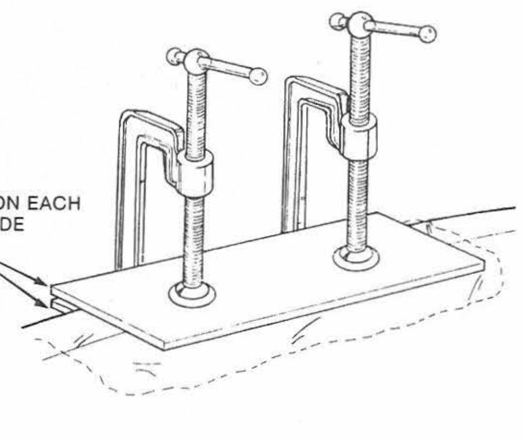


FIG. 21–37 Use of C-clamps to apply pressure to erosion shield debond repair. *(Hartzell Propeller)*

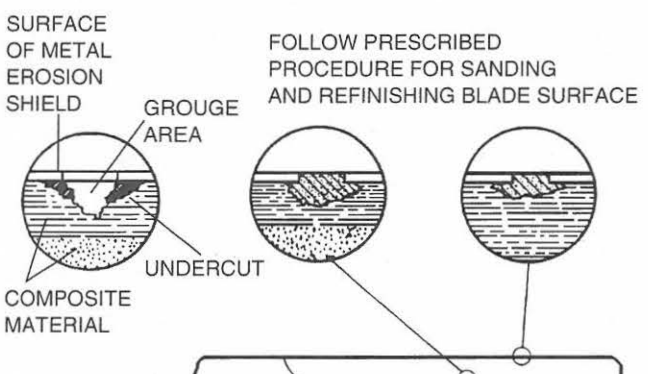


FIG. 21–38 Field repair of airworthy (minor) damage in erosion shield. *(Hartzell Propeller)*

the resulting repair should be recorded on the proper form. Figure 21–39 shows a typical form for recording composite blade repairs. The date, flight hours, degree of damage, description of repair, and person performing the work are recorded on the form. It is also important to show the location of the repair, because repairs may be made close to other repairs or on top of previous repairs.

CHECKING BLADE ANGLES

The blade angles of a propeller may be checked by using any precision protractor which is adjustable and is equipped with a spirit level. Such a protractor is often called a **bubble protractor.**

Universal Propeller Protractor

The blade angles of a propeller may be accurately checked by the use of a **universal propeller protractor,** which is the same instrument used to measure the throw of control surfaces. An accurate check of blade angles cannot be made by referring to the graduations on the ends of the hub barrels or on the shanks of the blades of propellers; such references are suitable only for rough routine field inspections and emergency blade settings.

A **protractor** is merely a device for measuring angles. The propeller protractor consists of an aluminum frame in which a steel ring and a disk are mounted, as shown in Fig. 21–40. The principal, or "whole-degree," scale is on the disk. The vernier, or "fractional-degree," scale is on the ring. The zeros on these two scales provide reference marks which can be set at the two sides of an angle, thereby enabling the operator to read from zero to zero to obtain the number of degrees in the angle.

Two adjusting knobs provide for the adjustment of the ring and disk. The ring adjuster is in the upper right-hand corner of the frame; when it is turned, the ring rotates. The disk adjuster is on the ring; when this knob is turned, the disk rotates.

There are two locks on the protractor. One is the disk-to-ring lock, located on the ring. It is a pin that is held by a spring when engaged, but it engages only when the pin is pulled out and placed in the deep slot and when the zeros on the two scales are aligned. Under these conditions, the ring and disk rotate together when the ring adjuster is turned and when the ring-to-frame lock is disengaged. To hold the spring-loaded pin of the disk-to-ring lock in the released position, it is first pulled outward and then turned 90°.

The other lock, the ring-to-frame lock, is on the frame. It is a right-hand screw with a thumb nut. The disk can be turned independently of the ring by means of the disk adjuster when the ring is locked to the frame and the disk-to-ring lock is released.

There are two spirit levels on the protractor. One is the center, or disk, level. It is at right angles to the zero graduation mark on the whole-degree scale of the disk; therefore, the zero graduation mark will lie in a vertical plane through the center of the disk whenever the disk is "leveled off" in a horizontal position by means of the disk level.

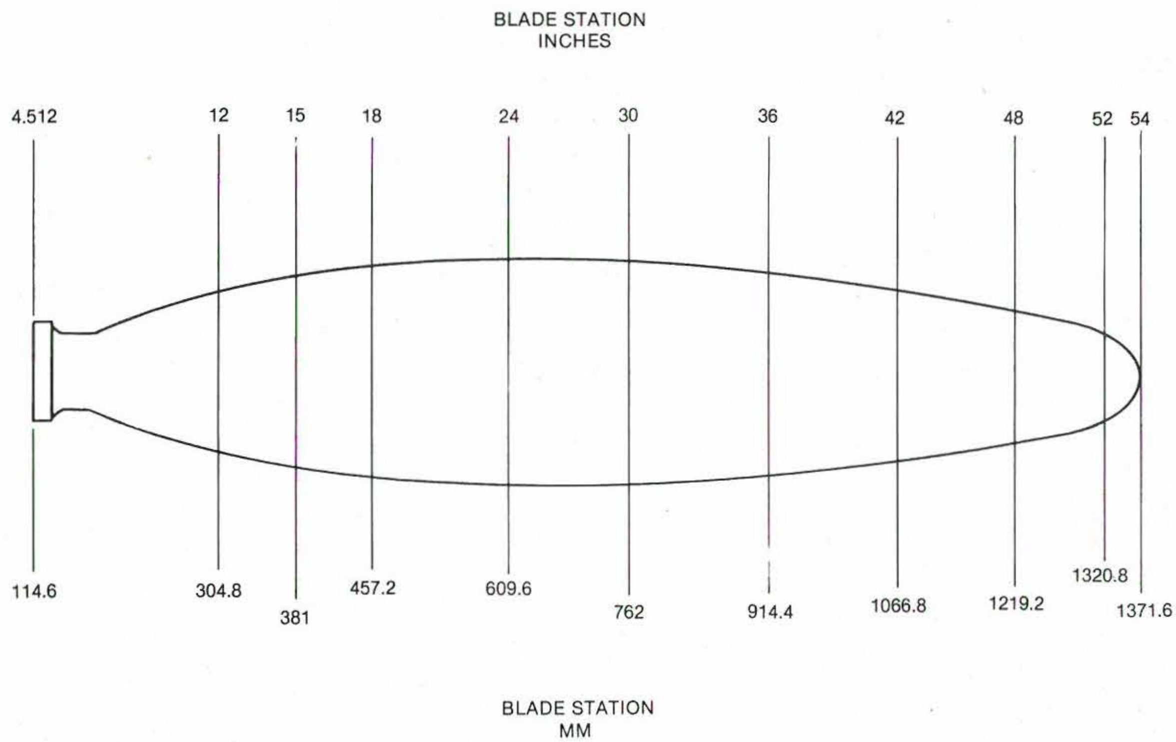
The other level is the corner spirit level, located at the lower left-hand corner of the frame and mounted on a hinge. This level is swung out at right angles to the frame whenever the protractor is to be used. It is used to keep the protractor in a vertical position for the accurate checking of the blade angle.

As described earlier, the degree scale for the protractor (Fig. 21–40) is on the center disk and the vernier scale is on the ring just outside the disk. The vernier graduations have a ratio of 10 to 9 with the degree graduations; that is, ten graduations on the vernier scale will match with nine graduations on the degree scale. As shown in Fig. 21–41, the reading between the 0° point on the degree scale and the 0° point on the vernier scale is somewhat more than 15°.

RECORD OF MODEL M10877 COMPOSITE BLADE DAMAGE REPAIR

BLADE DESIGN ______________________________

BLADE SERIAL NUMBER ______________________________



DATE OF ENTRY	FLIGHT HOURS	DEGREE OF DAMAGE (MAJOR OR MINOR) DESCRIPTION OF DAMAGE	DESCRIPTION OF REPAIR	REPAIRED BY

FIG. 21–39 Composite blade damage and repair record form. *(Hartzell Propeller)*

To find the amount in tenths of a degree, the vernier scale is read in the same direction from the 0° point on the vernier scale to the point where a vernier-scale graduation coincides approximately with a degree-scale graduation. In Fig. 21–41, this is a point eight graduations to the left of the 0° point of the vernier scale and is read 0.8°. The total angle shown by the protractor is therefore 15.8°.

As pointed out above, the number of tenths of a degree in the blade angle is found by observing the number of vernier-scale spaces between the zero of the vernier scale and the vernier-scale graduation that comes closest to being in perfect alignment with a degree-scale graduation line. Always read tenths of degrees on the vernier scale in the same direction as the degrees are read on the degree scale.

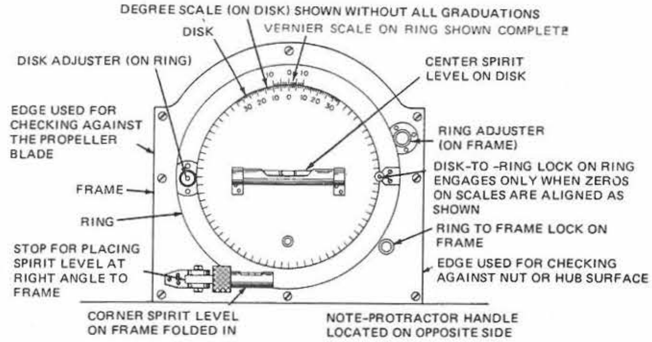


FIG. 21–40 Propeller protractor.

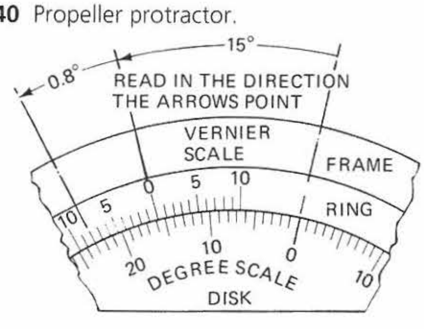


FIG. 21–41 Reading the protractor scale.

How to Measure the Propeller Blade Angle

To measure the propeller blade angle, determine how much the flat side of the blade slants from the plane of rotation. If a propeller shaft is in the horizontal position when the airplane rests on the ground, the plane of propeller rotation, which is perpendicular to the axis of rotation or the propeller shaft, is vertical. Under these conditions, the blade angle is simply the number of degrees that the flat side of the blade slants from the vertical, as illustrated in Fig. 21–42. However, an airplane may rest on the ground with its propeller shaft at an angle to the horizontal. The plane of propeller rotation, being perpendicular to the propeller axis of rotation, is then at the same angle to the vertical as the propeller shaft is to the horizontal, as represented by angle A in Fig. 21–43.

Under these conditions, the number of degrees that the flat side of the propeller blade slants from the vertical is the blade angle minus the ground angle of the airplane, or angle B in the same illustration. To obtain the actual blade angle, the ground angle of the airplane (which is also the angle at which the plane of rotation slants from the vertical) must be added to the angle at which the flat side of the blade slants from the vertical in the opposite direction, as represented by angle C in the same illustration.

Angles A and B are measured with a universal protractor and added in two related operations. It is then possible to read the total angle, or blade angle C, from the degree and vernier scales of the protractor.

Checking and Setting Blade Angles when the Propeller is on the Shaft

The following steps are recommended when a universal propeller protractor is available for checking propeller blade angles while the propeller is installed on the shaft of the engine. If it is necessary to use another type of protractor, the procedure to be followed will be modified.

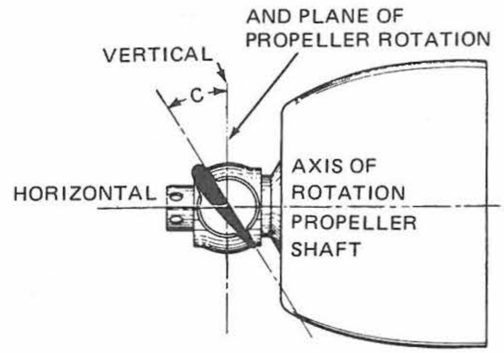


FIG. 21–42 Measuring a propeller's blade angle.

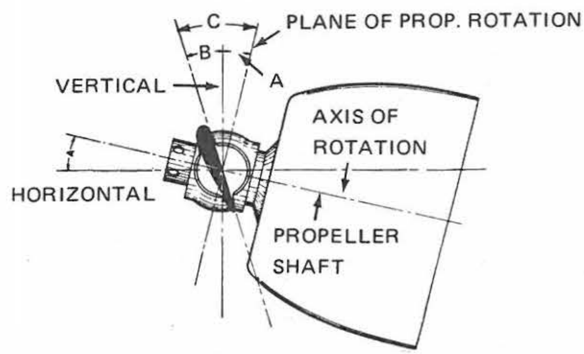


FIG. 21–43 Effect of ground angle on the measurement of blade angle.

1. Mark the face of each blade with a lead pencil at the blade station prescribed for that particular blade.

2. Turn the propeller until the first blade to be examined is in a horizontal position with its leading edge up.

3. Using a universal propeller protractor, swing the corner spirit level out as far as it will go from the face of the protractor.

4. Turning the disk adjuster, align the zeros of both scales and lock the disk to the ring by placing the spring-loaded pin of the disk-to-ring lock in the deep slot.

5. See that the ring-to-frame lock is released. By turning the ring adjuster, turn both zeros to the top. Refer to Fig. 21–40, which shows the universal propeller protractor.

6. Hold the protractor in the left hand, by the handle, with the curved edge up. Place one vertical edge of the protractor across the outer end of the propeller retaining nut or any hub flat surface which is parallel to the plane of propeller rotation, which means that it is placed at right angles to the propeller-shaft centerline. Using the corner spirit level to keep the protractor vertical, turn the ring adjuster until the center spirit level is horizontal. The zeros of both scales will now be set at a point that represents the plane of propeller rotation. This step can be understood better by referring to the illustration of the measurement of the blade angle in Fig. 21–44.

7. Lock the ring to the frame to fix the vernier zero so that it continues to represent the plane of propeller rotation.

8. Release the disk-to-ring lock by pulling the spring-loaded pin outward and turning it to 90°. This completes what is often called the **first operation,** shown at the left in Fig. 21–44.

9. Change the protractor to the right hand, holding it in the same manner as before, and place the other vertical edge of the protractor, which is the edge opposite the first edge used, against the blade at the mark which was made

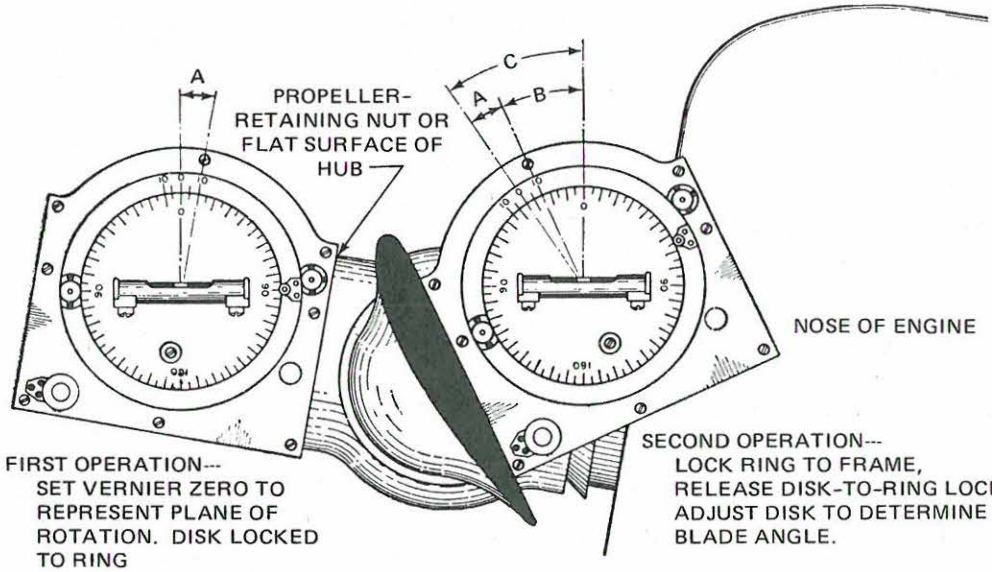


FIG. 21–44 Measurement of the blade angle in two operations.

with a pencil on the face of the blade. This is the beginning of the **second operation**, which is shown at the right in Fig. 21–44. Keep the protractor vertical by means of the corner spirit level. Turn the disk adjuster until the center spirit level is horizontal, as shown in the illustration. In this manner, the angle at which the flat side of the blade slants from the vertical is added to the angle at which the plane of rotation slants from the vertical in the opposite direction.

10. Read the number of whole degrees on the degree scale between the zero of the degree scale and the zero of the vernier scale. Read the tenths of a degree on the vernier scale from the vernier zero to the vernier-scale graduation that comes the closest to lining up with a degree-scale graduation. In this manner the blade angle is determined.

11. Obtain the required blade angle by making any necessary adjustments of the blade or the propeller pitch-changing mechanism.

12. Repeat this procedure for each of the remaining blades to be checked.

INSPECTIONS AND ADJUSTMENTS OF PROPELLERS

There are many types of propeller inspections, including daily inspections, 100-h inspections, and inspections performed during overhaul. Although inspection procedures will vary among the different types of propellers, some examples of inspection procedures on a compact propeller 100-h inspection are as follows:

1. Check for oil and grease leaks.
2. Clean the spinner, propeller hub interior and exterior, and blades with a noncorrosive solvent.
3. Inspect the hub parts for cracks.
4. Steel hub parts should not be permitted to rust. Use aluminum paint to touch up, if necessary, or replate during overhaul.
5. Check all visible parts for wear and safety.
6. Check blades to determine whether they turn freely on the hub pivot tube. This can be done by rocking the blades back and forth through the slight freedom allowed by the pitch-change mechanism.
7. Inspect blades for damage or cracks. Nicks in the leading edges of blades should be filed out and all edges rounded. Use fine emery cloth for finishing.
8. Check condition of propeller mounting nuts and studs.
9. For severe damage, internal repairs, or replacement of parts, transport the propeller to a certified propeller repair station.
10. Sand each blade face lightly and paint with a flat black paint to retard glare, when necessary. A light application of oil or wax may be applied to the surfaces to prevent corrosion.
11. Grease the blade hub through the zerk fittings, as shown in Fig. 21–45. Remove one of the two fittings for each propeller blade. Apply grease through the zerk fitting until fresh grease appears at the fitting hole of the removed fitting. Care should be taken to avoid blowing out hub gaskets.
12. Check for air leaks by applying soap solution around the air valve and stop adjustment nut. Internal leakage will show up as air flow through the piston rod.
13. Record the appropriate information in the propeller records.

Propeller Static RPM (Fixed-Pitch Propeller)

Normally, a fixed-pitch propeller will not develop its maximum rpm while the aircraft is sitting static, or still, because of the lack of air passing through the propeller blades. As discussed in Chap. 19, as the airspeed of the aircraft increases, the angle of attack of the propeller blades decreases, thus allowing the propeller to turn faster. As the aircraft approaches flying speed, with throttles full open,

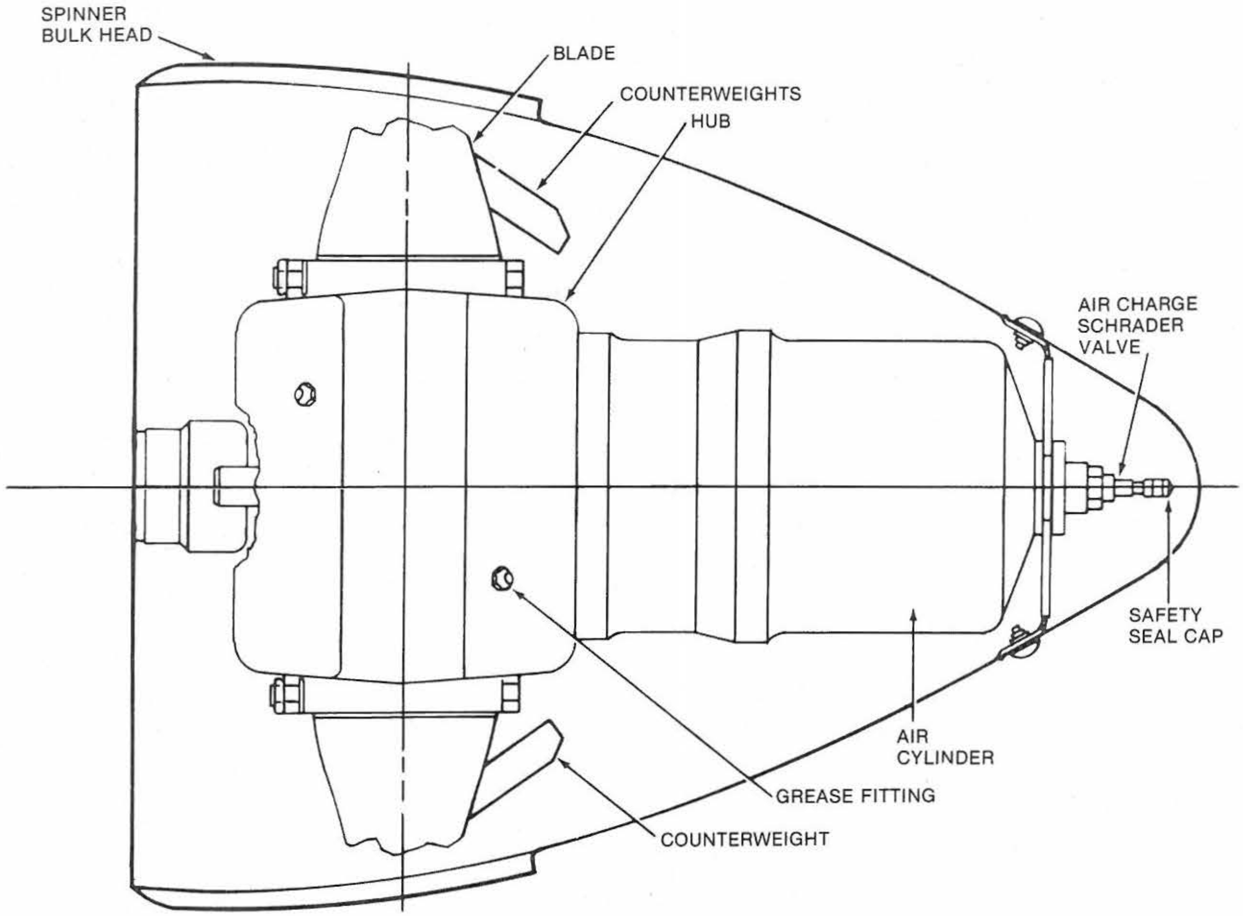


FIG. 21–45 Grease and air charge fittings. *(Hartzell Propeller)*

the propeller should approach the red-line rpm as noted on the tachometer.

The **static rpm** is checked during a power run-up to determine whether the engine is developing its rated power. The static rpm is generally found in the aircraft's Type Certificate Data Sheet. For example, for an aircraft that is red-lined at 2750 rpm, static rpm may range from 2100 to 2200 rpm. If an aircraft does not produce its static rpm, this could be a signal that the engine or propeller is in need of maintenance. On a fixed-pitch propeller, there is no means of adjusting the static rpm.

Constant-Speed Propeller Adjustments

Some propeller models have items which may have to be adjusted after installation, such as low-pitch stop for static rpm, high-rpm stop, high-pitch stop, and feathering pitch stop. These adjustments are described in the proper manufacturer's manuals. The **low-pitch stop** on the Hartzell Compact propeller should be set to obtain takeoff rpm, or about 50 rpm below takeoff rpm, during engine run-up on the ground. This stop is normally set for each specific engine application at the factory. In the event that an adjustment is required, it can be made by adjusting the screw in the nose of the cylinder. Backing the screw out one-half turn will increase the static rpm by about 100 rpm; conversely, turning the screw in one-half turn will decrease the static rpm by about 100 rpm.

CAUTION: *Before adjusting the low stop screw on the feathering propeller, the air pressure must be dropped to zero. Unless this is done, it is possible to unscrew the low stop far enough to disengage the threads, allowing the pressure to blow the low stop screw out with great force. There must be at least four threads engaged during normal operation. Replace the air charge as per applicable charging instructions.*

The high-rpm stop on the governor should be set for takeoff rpm.

There is no high-pitch stop adjustment for either constant-speed or feathering propellers.

The feathered blade angle for some models of propellers can be adjusted by adding or removing shims. Adding shims increases the feathered angle.

In order to test whether the governor or the propeller low-pitch stop is limiting the static rpm, the operator can run the engine up on the ground. With the throttle wide open, increase rpm slowly with the rpm control. If the propeller low-pitch stop is limiting the rpm, the rpm will stabilize before the rpm control reaches the limit of its travel. If the rpm increases continuously during the entire movement of the rpm control, the governor is limiting the static rpm and not the propeller low-pitch stop. As mentioned before, it is desirable that the propeller stop limit the rpm to about 50 rpm below the engine rating, so that, in the event the governor malfunctions during takeoff, the propeller will overspeed a minimum amount.

TROUBLE	PROBABLE CAUSE	CORRECTION
Propeller does not respond to movement of propeller pitch lever.	Governor speeder spring broken	Overhaul or replace governor
	Screen in governor mounting gasket clogged	Remove Governor & replace gasket
	Governor drive shaft sheared	Overhaul or replace governor
Engine speed will not not stabilize.	Governor relief valve sticking	Overhaul or replace governor
	Excessive clearance in pilot valve	Overhaul or replace governor
	Excessive governor oil pump clearance	Overhaul or replace governor
Failure of propeller to go full low pitch (high rpm).	Governor arm reaches stop before maximum rpm is obtained	Adjust governor
	Defective governor	Overhaul or replace governor
Sluggish propeller movement to either high or low pitch	Excessive propeller blade friction	Grease blade bearing
Failure of propeller to feather.	Attempting to feather from too low an engine rpm	Increase rpm and attempt to feather again
	Automatic high pitch stop pin in the engaged position	Disengage stop pin. Check for freedom of operation & correct cause of pin sticking
	Feathering spring weak or broken	Overhaul propeller
Oil leaking around propeller mounting flange	Damaged hub O-ring seal	Remove propeller and replace O-ring seal

FIG. 21-46 Example of a troubleshooting chart for a constant-speed propeller.

Special Inspections After Accidents

If the propeller strikes or is struck by any object (sudden stoppage), examine it for damage. Disassemble any propeller that has been involved in an accident, and carefully inspect the parts for damage and misalignment before using the propeller again. Examine all steel parts and otherwise serviceable steel propeller blades for airworthy damage by means of a magnetic inspection supervised by trained personnel. Have aluminum-alloy blades which are otherwise serviceable given a general etching.

Any accident which severely damages the propeller may also damage the engine. It is good practice, therefore, to check the alignment of the crankshaft after an accident in which the propeller has been damaged. Crankshaft alignment **runout** may be checked as follows:

1. Remove the propeller.
2. Install a dial gage on a mounting attached to the nose of the engine with the finger of the dial gage touching the smooth area on the outer rim of the flange on either the aft side or the forward face of the flange. (For a spline or taper shaft, install a dial gage on the nose of the engine and place the finger of the gage on the smooth surface forward of the spline or taper.)
3. Rotate the propeller shaft through a complete revolution and observe the movement of the gage indicating needle. If the shaft runout is out of limits according to the manufacturer's specifications, the engine must be removed and overhauled. It is good practice to disassemble and inspect any engine that has suffered sudden stoppage.

Propeller Troubleshooting

Because there are so many different types of propellers, it is very difficult for a textbook to cover all the troubleshooting problems that can potentially occur. Propellers, for the most part, are fairly trouble-free; the problems that do occur usually center around either the pitch-changing mechanisms or oil and grease leaks. Sometimes engine surging can be caused by the propeller blades sticking or by very sluggish propeller operation.

Although vibration may be caused by the propeller, there are numerous other possible sources of vibration which can make troubleshooting difficult. The dynamic track and balance procedures previously outlined should be followed in troubleshooting of propeller vibrations.

The propeller spinner can contribute to an out-of-balance condition. An indication of this would be a noticeable spinner "wobble" while the engine is running. This condition is normally caused by inadequate shimming of the spinner front support or a cracked or deformed spinner.

A typical troubleshooting chart for propeller problems is shown in Fig. 21–46.

REVIEW QUESTIONS

1. What types of hubs are generally used to mount propellers on engine crankshafts?

2. What is the purpose of the cones used in the installation of a propeller on a splined shaft?

3. How does the retaining nut for a propeller serve as a puller when the propeller is removed?

4. Why is a rear-cone spacer used with some installations?

5. What items should be checked prior to the installation of a propeller on a crankshaft?

6. What sequence should be followed during tightening of propeller attachment bolts?

7. Explain how the fit of a tapered hub and shaft is checked.

8. What special tool is needed for installation of a PT6A turbopropeller?

9. What is meant by the term "correctable vibration"?

10. What is the purpose of checking propeller track?

11. What components comprise a dynamic vibration measuring system?

12. What are three methods of measuring the phase angle of the propeller during dynamic balancing?

13. Define the term "major alteration" as it applies to propellers.

14. Who is authorized to perform major repairs and alterations of propellers?

15. Describe the repair of small cracks parallel to the grain in a wood propeller.

16. Who is authorized to repair damaged steel propeller blades?

17. How may minor damage of the leading and trailing edges of a steel blade be repaired?

18. Define a damaged metal propeller blade.

19. What should be done to aluminum-alloy blades that have pitted leading edges as a result of normal wear?

20. What is the purpose of local etching?

21. Define the terms "debond" and "delamination" as they apply to composite propellers.

22. How may a composite propeller blade be tested for debond and delamination?

23. What device is used for checking propeller blade angle?

24. Can static rpm be adjusted on a fixed-pitch propeller?

25. After a propeller is damaged in an accident, what inspections should be made?