Civil Aeronautics Manual 14

Aircraft Propeller Airworthiness

Revised May 1, 1946

U. S. DEPARTMENT OF COMMERCE
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Civil Aeronautics Manual 14

AIRCRAFT PROPELLER AIRWORTHINESS

Contains all requirements of Part 14 of the Civil Air Regulations and the CAA interpretation

Revised May 1, 1946

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INTRODUCTORY NOTE

This edition of Civil Aeronautics Manual 14 includes all revisions up to May 1, 1946, and for ease of reference incorporates Part 14 of the Civil Air Regulations (small type) immediately preceding the corresponding section of the Manual.

The Manual material herein is not mandatory and is intended only to explain and to show acceptable methods of complying with the pertinent requirement. Alternative methods of showing compliance may be used at the option of the applicant. The function of the Civil Aeronautics Administration is to examine such technical data and to conduct or witness such inspection and testing as may be necessary to demonstrate compliance with the Regulations.

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Aircraft Propeller Airworthiness

14.0 GENERAL

14.00 Provision for rating. Pursuant to the provisions of the Civil Aeronautics Act of 1938, as amended, empowering and requiring the Civil Aeronautics Board to prescribe such minimum standards governing the design, materials, workmanship, construction, and performance of propellers as may be required in the interest of safety, and to provide for the rating of aircraft as to airworthiness, the requirements hereinafter set forth shall be used as the minimum standards for establishing such rating for propellers for use in certificated aircraft.

Part 14 concerns the rating of propellers as to airworthiness specifically, and in aircraft only insofar as the complete power plant unit is eventually installed and operated in an airplane. Accordingly, the operation limit, determined under Part 14, approves the propeller structurally, provided the certificated power rating or speed rating is not exceeded.

14.01 Scope.

To simplify references and to avoid unnecessary repetition, the terms "approved" and "approval" are used in this manual to mean "originally eligible for use in certificated aircraft." The approval of a propeller (or the establishment of its original eligibility for use in certificated aircraft) is intended to cover only its design, construction, and block testing characteristics. *This is determined by means of ground testing based upon the previous experience of the Civil* Aeronautics Administration with propellers which have been used satisfactorily in flight. However, when a metal propeller is installed in a certificated aircraft, such propeller is investigated for its vibration and operating characteristics under the ground and flight testing requirements of Parts 03 or 04. If the propeller model or type is listed on the pertinent aircraft specification, it has met these latter requirements.

14.010 Airworthiness Requisites. To show eligibility of a propeller for certification, the propeller shall meet the requirements herein as to design, construction, and testing. The manufacturer shall comply with the requirements by the submission of technical data and by conducting tests with suitable test equipment. The applicable requirements are set forth in §§ 14.1 through 14.4.

14.011 Type Certificate. The general requirements for the issuance of a type certificate are set forth in Part 02. The procedure relative to type certification of propellers is set forth in § 14.5.

A. General

Recommended practices requisite for the fabrication of wood and metal propellers are discussed separately below. A semiannual report of the production under a type certificate is required in January and July of each year in accordance with CAR 02.35.

B. Wood Propellers

1. Due to the stabilized nature of fixed-pitch wood propeller construction the procedure and equipment have evolved to the point where certain minimum standards may be set forth. The following items are intended to present such standards in materials, processes, manufacturing tolerances, and inspection methods.

2. The materials of construction should be of the highest quality obtainable because of the highly stressed condition of a propeller and its relative importance as a primary power plant item. The following details should be noted:

a. Wood used should be purchased from a reputable lumber company under a detailed specification as to its characteristics. It is recommended that all lumber from which propeller laminae are to be cut should be kiln dried. Propeller lumber should have a moisture content of between 5 and 7 percent at the time of gluing. Propellers should be made only of sweet or yellow birch, sugar maple, black cherry, or black walnut. Spiral or diagonal grain should have a slope of less than 1 in 10 when measured from the longitudinal axis of the laminae. Propeller lumber should be free from checks, shakes, excess of pin worm holes, unsound and loose knots, and decay. Sap stain is considered a defect. To reduce the effect of internal variations present in all wood, the importance of selecting a high grade of material cannot be overemphasized.

b. Glue used should be of a high quality. Blood albumin glues, marine glues, and the various phenol-alde-hyde adhesives are not considered satisfactory due either to their peculiar properties or method of application.

c. The protective covering used should be a high quality spar varnish or its equivalent.

d. Tipping materials should be of a good grade brass, monel metal, stainless steel, or the equivalent. The recommended thickness is 0.020 inch. A linen fabric is frequently applied to the surface for additional strengthening at the tip and for protection against abrasion and splintering. It should be finished with transparent dope or varnish but metal tipping need not be.

3. Processes and methods employed in the fabrication of the propeller shall be those definitely known to yield the best construction. The following sequence of operations and methods employed is presented because, if carefully followed, it will result in an airworthy product. Methods of propeller manufacture outlined in Bulletin ANC–19 are equally satisfactory.

a. Laminations should be laid out with the longitudinal axis parallel to the grain of the boards from which they are to be cut. Boards may be glued edge to edge to provide laminations or hub sections of the desired width. The edges to be joined should be approximately parallel to the direction of the grain as indicated on the face of the board and in no case should the slope of the grain with respect to the edge to be glued be greater than 1 in 15. Edge joints may be plain or serrated. The edges should be smoothly and accurately fitted not more than 4 hours before gluing. If serrated, the pitch should be not less than ⅛ inch and not greater than ¼ inch. The gluing technique employed in making these edge-to-edge joints should be the same as later used in gluing the laminations together. Edge-glued laminations should remain in the clamps at least 4 hours after gluing. After removal from the clamps, such laminations should be conditioned for a period of not less than 72 hours at temperatures of not less than 70° F. before the final surfacing operation. Laminae thickness may vary from ½ inch to 1 inch, but any further variation should be shown on the sealed drawings. Laminae of the same thickness should be used in a propeller, except for outside ones. Prior to assembly for gluing, the laminae should be separated into three classes: light, medium, and heavy. Only laminae of one class should be assembled in a single propeller. These should be individually balanced and assembled with the heavy ends of adjacent laminae at opposite ends to facilitate balancing. Laminae should be prepared for gluing by smoothly and accurately planing all surfaces to be glued not more than 4 hours before gluing.

(1) *Defects in Laminae.* Laminae containing checks, shakes, rot, dotes, pronounced burls or curls, worm holes, discoloration streaks, and other similar defects should be considered cause for rejection.

(2) *Knots.* Round knots over ½ inch in diameter, or small knots that are not as sound as the surrounding wood and which are present in large numbers, and knots in parts of the finished blade less than ½ inch thick or within 18 inches of the tip of either blade, should be cause for rejection.

b. Glue should be applied in accordance with the manufacturer's instructions. The gluing should be done in an enclosed room which is light, clean, and free from draughts and dust. No gluing should be done when the temperature of the gluing room or wood is below 21° C. (70° F.). Particular care should be taken to spread the glue evenly and to correct thickness. The use of a glue spreader is recommended.

c. The manufacturer should so control the temperature of the gluing room, the amount of glue spread, the time that elapses between the time the glue is spread and the pressure applied, and the pressure so that glue joints of maximum strength will be obtained. Pressing may be accomplished manually by the use of C clamps or by a jack-press. A conditioning period of at least 2 days should be allowed after removal from the press or clamps.

d. After conditioning, the propeller should be roughed out not closer than $\frac{1}{8}$ inch of the finished surface, either by hand or with a profiling machine. After this operation the propeller should be conditioned for an additional 7 days or more at approximately 70° F. or not less than 3 days at 120° F.

e. The propellers should be carved and worked to a final size using suitable templates and a protractor. Final operations should include a smooth sanding. The propeller should be rigidly mounted for these operations. The change in pitch angle from station to station should be smooth and true throughout the blade length with no irregularities in contour. A set of metal templates suitably stamped should be available for this stage. All checking with templates should be accomplished with the propeller in the "white" and before applying the metal tips.

f. The hub holes should be drilled with extreme accuracy, using a suitable jig and taking care to insure that the holes are perpendicular to the hub faces.

g. The metal tip should be applied over at least one coat of finish. The small piece of metal should be applied to the camber face of the tip first. The ends of the large piece should then be so lapped over the small piece as to effect a continuous piece of metal along the leading edge. The metal should be secured by No. 4 brass or plated steel flat head wood screws $\frac{1}{2}$ and $\frac{3}{8}$ inch long except in the thin section near the blade tip where $\frac{3}{32}$-inch diameter brass or copper rivets should be used. The blade should be bored for the screws and countersunk for the screw heads. The countersunk holes should be coated with a protective finish. The metal should not be countersunk to take the screw heads, but should be dimpled into the countersunk holes in the wood by a method that avoids splitting or compressing the wood. The holes for the rivets should be drilled through the metal and wood with the tip in place. Countersinking of the metal tipping should not be permitted, but the metal should be removed and the holes in the wood countersunk and a protective coating applied as in the case of the screws. The metal should then be replaced and be carefully dimpled into the countersunk holes before heading. Rivet holes should be drilled to the exact size of the rivet, so that the rivets may be pressed in by hand. Rivets should not be driven in. When completed, the metal tip should fit snugly against the wood. Buckling or lifting of the metal should be cause for rejection. Solder should be filled in over the heads of these rivets and screws, and filed down to the smooth surface of the metal tip. Care should be exercised in soldering screws and rivets to avoid undue heating or charring of the wood. The metal tipping should be vented by drilling three No. 60 (0.030) holes $\frac{3}{16}$ inch deep in the tip end after assembly.

h. At least one coat of finish should be applied prior to, and at least two coats after, tipping. A priming coat of valoil or a paste wood filler may be applied initially. The hub bore should also receive several coats of finish.

i. The propeller should be balanced after shaping and after each successive operation that might affect the balance. Final balance should be accomplished on a rigid knife-edge balancing stand in a room free from air currents. No persistent tendency to rotate from any position on the balance stand should be present. Horizontal unbalance may be corrected by the application of finish or solder to the light blade. The light blade may be coated with a high grade of primer allowing for a finishing coat. After allowing each coat to dry 48 hours, the balance should be checked. Then, as may be necessary, either the required amount of finish should be removed by carefully sandpapering or an additional coat applied. The balance should be rechecked and sandpaper or additional finish applied as may be required to effect final balancing.

j. Vertical unbalance may be corrected by applying putty to the light side of the wood hub at a point on the circumference approximately 90 degrees from the longitudinal centerline of the blades. The putty should be weighed and a brass plate weighing slightly more than the putty should be cut out. The thickness of the plate will be from 1/16 to 1/8 inch depending on the final area, which must be sufficient for the required number of flat head attaching screws. The plate may be made to fit on the hub face or to fit the shape of the light side of the wood hub, and drilled and countersunk for the required number of screws. The plate should be attached and all of the screws tightened. After the plate is finally attached to the propeller, the screws should be secured to the plate by soldering the screw heads. The balance should be checked and all edges of the plate beveled to reduce its weight. The drilling of holes in the propeller and the insertion of lead or other material to assist in balancing will not be permitted.

4. An inspection system should be established to accomplish adequate checks on material being used, tolerances on the finished product, and balance. Recommended tolerances and forms are shown in Table I and discussed in items a, b, and c.

TABLE I.—Wood Propeller Tolerances

Blade length		±1/16″
Blade width	shank to 24-inch station	±3/32″
	30-inch station to tip	±1/16″
Blade thickness	shank to 24-inch station	+1/8″, −1/16″
	30-inch station to tip	+3/64″, −0″
Edge alignment		±1/16″
Face alignment		±1/8″
Template fit	shank to 24-inch station	3/32″
	30-inch station to tip	1/32″
Blade angle	shank to 18-inch station	±1.0°
	24- to 30-inch station	±0.5°
	36-inch station to tip	±0.4°
Track		1/16″
Thickness of hub		±1/32″
Diameter of hub		±3/32″
Hub bolt holes in white		+0.005″ −0.000″
Hub bore in white		+0.015″ −0.000″

Blades of the same propeller should be identical within the limits given, disregarding the plus and minus sign.

a. Definitions:

(1) *Track.* Track is defined as the corresponding points on two or more blades of a propeller lying in the same plane perpendicular to the axis of rotation within the required track tolerances.

(2) *Face Alignment.* Face alignment is defined as the distance from the centerline of the blade to its thrust or working face as measured perpendicular to the chords of the cross sections of the blade at the various stations. Optional use of projected face alignment is permitted when specified on the drawing.

(3) *Edge Alignment.* Edge alignment is defined as the distance parallel to the respective chords of the sections from the centerline of the blade to the leading edge of the cross sections as designated on the drawing. Optional use of projected edge alignment is permitted when specified on drawing.

b. Blade thickness may be checked with a pair of calipers. The hub bolt holes should be checked with an exact size "go" gage and a 0.015 inch oversize "no-go" gage. Tolerance on roundness of hub holes minus nothing, plus 0.020 inch.

c. A suitable final inspection form should be completed and filed for every propeller produced. A suggested form for this purpose is shown below. This form should be signed by some responsible person designated as chief inspector by the company. On the back of the form the production tolerances (see Table I) should be printed.

Suggested Fixed-Pitch Wood Propeller Inspection Form

Shipped to________________ Date Mfd________ Des. No.________

Address________________ Serial No.________

Wood Source________________ Date rec'd________

Hub Drilled________________ by________________

Hub Installed________________ by________________

Station	Angle	Plus or minus	Width	Plus or minus	Maximum thickness	Plus or minus	Template fit	Remarks

	Measured	Plus or minus
Prop. diameter		
Hub diameter		
Hub thickness		

Balance________________

Track________________

Finish________________

Inspected by________________

Approved by________________

C. Metal Propellers

1. Because the art of producing an airworthy metal propeller of the various types is highly individualistic and because such production may properly be accomplished on a variety of machinery and equipment, this section will be confined to indicating what is acceptable in the way of manufacturing tolerances and balancing and inspection methods. Forged solid aluminum alloy blades, forged solid steel blades, or welded hollow steel blades retained in a forged steel hub construction have proven acceptable types of construction thus far and will be discussed in order. The workmanship and material of all types should be of a high quality. All blades and hubs should be finished smooth and free from defects, visible scratches, and tool marks. The effect of surface roughness in creating high local stress concentrations and promoting fatigue failure is such as to be easily critical in any design.

2. Forged solid aluminum alloy blades or one-piece propellers may be forged solid or machined from a forged billet. Great care should be exercised in securing a high quality of material and a sound forging. It is recommended that a check be made in the physical and chemical properties of each forging or billet used by extracting a test piece and subjecting it to a complete physical and chemical test.

a. For inspection purposes each blade should be etched in a 20 percent caustic soda solution and cleaned in a 20 percent nitric acid solution and warm water. The blades should be carefully examined with a three-power magnifying glass for the presence of cracks and other defects. Suspected defects should be repeatedly etched until their nature is determined. A crack will appear as a distinct black line. Transverse cracks of any size or description are sufficient cause for rejection provided they cannot be worked out within the tolerance limits as given in 14.011–C2 (b). Longitudinal cracks which increase in size as the surface metal is removed are also considered cause for rejection provided they cannot be worked out within the above-mentioned tolerance. Small longitudinal inclusions, if relatively few in number, may be passed at the inspector's discretion. Blades which show excessive amounts of inclusions, scabbiness, or other abnormal conditions which cannot be worked out within the tolerance limits, must be rejected.

b. Blades of the same design should be interchangeable in all respects. This dictates to a large extent the necessary production tolerances and balancing requirements. The recommended tolerances for forged aluminum alloy blades are given below in Tables II and III.

Edge and face alignments are defined in 14.011–B4 (a).

TABLE II.—Aluminum Alloy Blade Tolerances

Basic Diameter—10 feet 6 inches, or less		
Blade length		±1/16"
Blade width	shank to 24-inch station	±3/64"
	30-inch station to tip	±1/32"
Blade thickness		±0.025"
Edge alignment		±1/32"
Face alignment		±1/32"
Template fit	shank to 24-inch station	1/32"
	30-inch station to tip	0.020"
Blade angle	shank to 18-inch station	±0.5°
	24- to 30 inch station	±0.25°
	36-inch station to tip	±0.20°
Longitudinal location of stations		±0.015"

TABLE III.—Aluminum Alloy Blade Tolerances

Basic Diameter—Over 10 feet 6 inches to less than 14 feet 0 inches		
Blade length		±1/16"
Blade width	shank to 24-inch station	±1/16"
	30-inch station to tip	±1/32"
Blade thickness	shank to 24-inch station	±0.030"
	30-inch station to tip	±0.025"
Edge alignment		±1/16"
Face alignment	shank to 24-inch station	±1/16"
	30-inch station to tip	±1/32"
Template fit	shank to 24-inch station	3/64"
	30-inch station to tip	0.020"
Blade angle	shank to 24-inch station	±0.5°
	30-inch station to tip	±0.25°
Longitudinal location of stations		±0.015"

c. The interchangeability recommended in the preceding paragraph provides that all blades of the same design balance against each other throughout the entire range of blade angles. This may be accomplished by checking each blade against a master blade or a master cylinder. It is recommended that the balancing equipment for this operation be within a sensitivity of 0.04 inch-pounds in horizontal balance and 0.2 inch-pounds in vertical balance. *The finished propeller should balance both horizontally and vertically at both 0 and 90 degrees* to the plane of rotation without showing a persistent tendency to rotate in any direction. Final balancing should be done on a knife-edge balancing stand in a room free from air currents. Horizontal balance may be corrected by drilling a concentric hole in the base of the blade which hole must conform with the specifications of Table IV. Vertical balance may be corrected by drilling an eccentric hole not greater than ⅜ inch in diameter to a depth not exceeding that specified in Table IV. The outer edge of this hole shall not be closer than ¼ inch to the nearest external blade surface and not more than one eccentric hole should be drilled per blade. These holes may be left open or filled with lead. Leaded holes should be corked.

TABLE IV.—Size and Depth of Balancing Holes

Shank size	Maximum concentric hole diameter	Maximum concentric hole depth	Maximum eccentric hole depth (⅜-inch maximum diameter)
	Inch	*Inches*	*Inches*
00	7/16	2½	2¼
0–V2	19/32	3⅜	3
½	⅝	3⅝	3½
1	¾	4¼	4
1½	13/16	4⅞	4½
2	⅞	5½	5
3	31/32	6⅛	6

As an alternative to drilling the two holes mentioned above, a single eccentric hole having a diameter and depth conforming to the concentric hole dimension given in Table IV may be drilled and filled with lead. The outer edge of this hole should not be closer than 1 inch to the nearest external blade surface. The ends of all balancing holes should be finished with a full size drill having a spherical end to eliminate corners. The sharp edges of the hole should be removed by a 1/32-inch chamfer. Blades having special hub ends which are designed for use in controllable pitch propellers should not be drilled with this eccentric balancing hole.

3. Forged solid steel blades may be forged solid or machined from a forged or rolled billet of suitable alloy steel. A check should be made of the physical properties by taking a test specimen from each and subjecting it to complete physical tests after heat-treating. An ample check should also be made of the chemical content of the material.

a. All blades should be subjected to magnetic inspection for discontinuities, cracks, and other defects. Any unsatisfactory indications which cannot be worked out within the tolerance limit below should be sufficient cause for rejection. The magnetic inspection should be under the direct supervision of highly experienced personnel.

b. Acceptable tolerances for solid steel blades are given in Table V on page 8.

Edge and face alignments are defined in 14.011–B4 (a).

c. Blades of the same design should be interchangeable in all respects. They should, therefore, balance against each other throughout the operating range of blade angles. This may be accomplished by checking each blade against a master blade or cylinder. The balancing apparatus should have a sensitivity of approximately 0.04 inch-pounds in horizontal balance and 0.2 inch-pounds in vertical balance and should be used in a room free from air currents.

TABLE V.—Solid Steel Blade Tolerances

Blade length		±1/16"
Blade width	from shank to 24-inch station	±1/16"
	from 30-inch station to tip	±1/32"
Blade thickness	from shank to 24-inch station	±0.030"
	from 30-inch station to tip	±0.025"
Edge alignment	from shank to 24-inch station	±1/16"
	from 30-inch station to tip	±1/32"
Face alignment	from shank to 24-inch station	±1/16"
	from 30-inch station to tip	±1/32"
Template fit	from shank to 24-inch station	3/64"
	from 30-inch station to tip	0.020"
Blade angle	from shank to 24-inch station	±0.50°
	from 30-inch station to tip	±0.25°
Longitudinal location of stations		±0.015"

The blades should balance both horizontally and vertically when set at both 0 and 90 degrees to the plane of rotation. Inserts or balancing plugs used in the blade shanks for the correction of unbalanced conditions will be considered individually. In all cases they should be shown on the sealed drawing.

4. Welded hollow steel blades should be welded up from suitable sheets or strips of steel alloy. The material used in this type blade should be heat-treated to obtain the following minimum physical properties:

Ultimate tensile strength	125,000 p. s. i.
Yield strength	110,000 p. s. i.
Elongation	12%

Blades of this type should be made from blanking dies, forming dies, welding jigs, heat-treat jigs and similar production tools with a minimum of filing, grinding, wedging, or other hand operations. A standard tension test sample should be cut from each sheet of steel used and subjected to physical tests to determine the above properties. Sufficient chemical analyses should also be run to determine the chemical properties of the material and to assure a uniform composition.

a. All blades should be subjected to X-ray and magnetic inspection at various times during the production process. A frequent number of inspections will be found desirable in order to eliminate a large number of rejections in the final stage of production. Any unsatisfactory indications which cannot be eliminated by removing a maximum of 10 percent of the plate thickness at this stage are considered sufficient cause for rejection. The magnetic inspections should be under the direct supervision of highly experienced personnel. Adequate visual inspection should also be accomplished to detect incomplete welds, concentration of welding material, and the abrupt termination of a weld in such a manner as to constitute a stress concentration point.

b. Recommended tolerances for hollow steel blades are given in Table VI on page 9.

Edge and face alignments are defined in 14.011–B4 (a). The surfaces and edges between stations should be of fair contour.

5. Forged steel hubs should be forged in a die from medium carbon, chrome-vanadium, or chrome-nickel-steel bars or the equivalent. Adjustable pitch propeller hubs should have a Brinell hardness of 295±20 (10 mm. ball, 3,000 kg.) in the center of the thickest portion.

TABLE VI.—Hollow Steel Blade Production Tolerances

Blade length		±1/16″
Blade width	from shank to 24-inch station	±1/16″
	from 30-inch station to tip	±3/64″
Blade thickness	Maximum ordinate	±0.045″
Edge alignment		±1/8″
Face alignment		±0.045″
Template fit	from shank to 24-inch station	1/16″
	from 30-inch station to tip	0.045″
Blade angle	from shank to 24-inch station	±1.0°
	from 30-inch station to tip	±0.5°
Longitudinal location of stations		±1/16″
Plate thickness	0. 375 to 0. 562	−0. 004, +0.015
	0. 156 to 0. 375	−0. 003, +0.010
	0. 060 to 0. 156	−0. 002, +0.005

Controllable pitch propeller hubs should have a Brinell hardness of 305±20. Either material should show at least the following minimum physical properties:

Ultimate tensile strength	135,000 p. s. i.
Yield strength	115,000 p. s. i.
Elongation	15%
Reduction in area	50%

Suitable test specimens should be taken from each hub forging to check these physical properties. Sufficient chemical analyses should also be run to determine the chemical properties of the material and to assure a uniform composition. One or more forgings from each new die should be examined for the proper grain flow.

a. All hubs should be subjected to magnetic inspection. Any unsatisfactory indications which cannot be eliminated within the tolerance limit of the design are considered sufficient cause for rejection of the part. The magnetic inspection should be made under the direct supervision of highly experienced personnel.

b. There are no general recommended tolerances for forged steel hubs.

c. The correctly balanced hub should stand at any angle in the balancing apparatus without displaying a persistent tendency to move in any direction. In order to obtain final balance of the hub, metal may be removed from the portions of the hub where a surplus has been left for balancing purposes. The tolerance limit, however, must not be exceeded in any case.

d. Hub holes, threads, and splines should be checked with suitable "go" and "no-go" gages made up on the basis of the allowable manufacturing tolerances.

14.012 Production Certificate. The requirements for the issuance of a production certificate are set forth in Part 02.

14.013 Deviations. When a propeller embodies a feature of design or construction which deviates from the practice in conventional screw-propeller types, application shall be made to the Administrator for special rulings covering the feature in question.

The term unconventional, as used in 14.013, refers to deviations from the conventional with respect to general design and design details. Materials and types of construction, other than those mentioned herein, are considered unconventional and applications should be made accordingly to the Civil Aeronautics Administration for special rulings covering the design.

If there exists any doubt in the mind of the designer as to whether his design is conventional or not, the entire design should be discussed prior to making active preparations for a test program.

In the case of a new type propeller with detachable blades, data are required to substantiate the hub and blade retention arrangement to withstand a centrifugal load equal to twice the centrifugal force to which the propeller will be subjected in normal operation. Either of the two following methods may in general be used:

1. A successful 1-hour (minimum) whirl test at 1.41 times the maximum (except take-off) r. p. m. rating of the propeller. This can be accomplished by mounting the propeller on a jack-shaft driven by an electric motor. The propeller may be depitched for this test.

2. *Static pull tests.* A stub blade or blades may be incorporated in the hub for this test. Because of the fact that the test is primarily to investigate the strength of the blade retention arrangement, the outboard section of the stub blade need not be formed into air-foil sections but may be flared out to accommodate adequate holding means so as to insure that any failure will occur in the blade retention arrangement. The report of such tests should fully describe the results obtained together with pictures or sketches of the method of testing. In order to be satisfactory in lieu of the overspeed test, the test results should show a positive margin of strength over the calculated double centrifugal forces acting on critical portions of the hub or blade shank sections.

14.02 Hubs and Blades. Interchangeable propeller hubs and blades are certificated as separate units and the word "propeller" as herein used applies, where applicable, to a propeller hub and to a blade as well as to a complete propeller.

A propeller with detachable blades is certificated as a complete unit. Accordingly, separate ratings are not assigned to interchangeable hubs and blades and the rating assigned to any hub-blade combination is dependent upon the rating substantiated with that particular combination.

14.03 Testing Facilities. A manufacturer submitting a propeller for certification shall conduct all of the tests and supply or arrange for the testing facilities necessary to show compliance with the requirements contained herein. When, in the opinion of the Administrator, adequate and satisfactory methods of testing other than those outlined herein are available, propellers tested by such methods may be eligible for certification.

1. It is necessary that the manufacturer conduct all propeller tests and supply or arrange for the proper testing facilities. This normally requires the following equipment:

a. A new engine (or one in good repair) of at least the power and speed for which certification of the propeller is desired. If it has not been overhauled recently, a top inspection or overhaul may be warranted.

b. A suitable engine mount.

c. An accurate tachometer, which should be calibrated before and after testing and checked with a stop watch and revolution counter during testing.

d. A suitable manifold pressure gage if the test is not run at full throttle. (Not required for fixed-pitch wood propeller tests.)

e. Sufficient vibration equipment to measure the vibratory stresses that the propeller will encounter during test. (Necessary only in the case of metal propellers.) Such equipment should consist of suitable vibration stress pick-ups and recorders, the former to be mounted on the blades and used to record the vibration stresses during operation; a suitable torsiograph to determine the torsional characteristics of the propeller-crankshaft system; and suitable linear pick-ups to determine the motion of the engine in space.

14.04 Military Propellers. A propeller of a type which has passed the regular endurance tests of and is approved by the United States Army Air Corps or the Bureau of Aeronautics, Navy Department, may be certificated in accordance with § 14.3.

14.05 Propeller Operation Limits. A certificated propeller shall not be operated at a power or propeller shaft speed, or in conjunction with an engine bore, greater than the limits assigned thereto by the Administrator. The Administrator may specify short-time operation in excess of these limits for take-off purposes except that neither the power nor the speed limits will be raised by more than 10 percent without further testing.

Upon completion of the necessary testing, the propeller is certificated for a specified horsepower, r. p. m., and engine bore limit (when applicable) with a certain diameter and pitch range. Due to the difference in vibration characteristics with different crankshaft systems and gear ratios, it is necessary in the case of metal propellers to supplement these general factors with a qualifying statement regarding subsequent investigation of the vibration characteristics of each proposed propeller-engine-airplane combination prior to certification of the particular airplane model involved. Unless definitely stated to the contrary, the propeller is assigned a take-off operation limit of 10 percent in excess of the maximum, except take-off limit in power and in speed. Fixed-pitch wood propellers are normally certificated only for a horsepower and r. p. m. with no further qualifications other than diameter and pitch. Due to the type of testing employed (see 14.22) the horsepower is often an approximation with the result that the propeller is essentially certificated for operation not in excess of a given r. p. m.

14.06 Propeller Identification Data. A certificated propeller, propeller blade, or propeller hub shall have the following information conspicuously displayed upon it: Manufacturer's name; name model designation, and serial number of the propeller. The identification data shall be permanently attached by means of a plate, stamping, engraving, etching, or other such method upon a non-critical surface of the propeller blade or hub. When such data are not visible when the propeller is assembled or installed on an aircraft, they shall also be painted or printed on the propeller blade or hub.

In addition to the data specified in 14.06 some manufacturers have found it desirable to stamp the approval number on the propeller. This has little advantage since the model designation gives the inspector or owner a basic reference to the current specification for the applicable operation limits. In the case of a propeller with removable blades, the fact that an approval number is stamped on the hub may give the impression that the propeller is approved without investigating whether eligible blades are installed.

14.07 Previously Approved Propellers. These regulations supersede the requirements for approval of propellers set forth in previous regulations. However, propellers rated as suitable for use in approved aircraft in accordance with previous requirements may be used in certificated aircraft at the discretion of the Administrator.

14.1 Design Requirements.

14.10 Propellers shall be so designed as to operate without excessive vibration or flutter and shall be constructed of materials which are suitable for service conditions.

14.11 The surface of a propeller blade shall be smooth and the blade shall be faired with respect to the thickness and the moments of inertia about the major and minor axes, with no abrupt curvature changes or irregularities along the blade. Critical surfaces of a metal propeller hub shall be machined smooth without tool marks and any change in cross-section shall be faired with as large a fillet as possible.

14.12 It is recommended that a propeller be so designed that the weakest portion of the propeller blade or hub may be inspected without disassembly and that excessive wear or a partial failure will precede a serious type of failure.

A. General

Design requirements and recommendations will be discussed separately for wood and metal propellers. CAR 14.10, 14.11, and 14.12 are covered in this general discussion.

B. Wood Propellers

1. Finishes, materials, tolerances, and balancing have previously been discussed for wood propellers. Problems of a design nature will be considered under this topic as quantitatively as possible.

2. Blades should be laid out with a faired contour in plan form and thickness. Abrupt changes in cross-section are to be avoided. Curves of maximum thickness and of minor and major moments of inertia versus radius should be developed and submitted to check this point on new designs. The center of gravity of the blade sections may have a slight forward tilt to relieve the aerodynamic load on the blade. The condition of take-off and climb probably subjects this type of propeller to the most severe steady loads due to the small relieving action

of the centrifugal force at the low revolution speeds combined with the high thrust loadings.

3. Blade tip sections should be designed with great care. In general, thin tip sections have caused trouble in wood propellers and are to be avoided. The designer might well use a slightly thicker tip section at the expense of some propulsive efficiency. Markedly thin tips with their accompanying flexibility tend to promote flutter and resonance conditions. It does not follow that a thick tip insures against flutter and resonance, however, a thick tip on a well-designed blade is preferable structurally if not aerodynamically.

4. Some trouble has been experienced with blade tipping due to poor location of the attaching screws and rivets. These attachments should not be in a straight line parallel to the grain of the wood as this promotes cracking along sections in line with the screws.

5. The finish of the wood propeller may be either transparent or opaque.

6. To promote a standardization of propeller hub, it is recommended that steel hubs for wood propellers be designed according to the AN or SAE standard dimensions.

7. The extensive service use of the fixed-pitch wood propeller has made it possible to investigate portions for quantitative design criteria. The following analysis of this type propeller has been made from the viewpoint of experience.

a. The boss (or hub portion) is stressed chiefly by the steady air loads and centrifugal loads with the engine torque impulses superimposed. The torque impulses prove the most severe for the boss, and service failures give a definite indication of this in burned and elongated bolt holes. Once these holes are elongated and the propeller starts to rock on its hub the bolts are subjected to abrupt eccentric loads which tend to shear the bolt heads.

b. For the majority of designs the rear flange of the steel hub is integral with the splined portion which mates with the crankshaft, while the front flange may be splined to the hub or simply serve as a collar. Assuming the engine torque to be resisted only by the bearing area of the hub bolts and neglecting the effect of friction between the wood and metal surfaces*, it is possible to calculate the "propeller resisting torque" for a specific design. This must be modified for some designs to account for the added strength of splining the front flange. If the hub bolts were rigidly supported at each end, their bearing strength would increase 100 percent over the cantilever type. Because of the varying amounts of play in the splined front flange, this 100 percent increase has been arbitrarily reduced to 25 percent.

c. The "propeller resisting torque" may be expressed in a formula as follows:

$$T_p = F_b ARf$$

where T_p = propeller resisting torque (foot-pounds)

F_b = elastic limit allowable crushing stress (pounds per square inch)

A = total hub bolt bearing area (square inches)

R = bolt circle radius (feet)

f = front flange factor (1.25 for splined flange, 1.00 for floating flange).

In case rear flange incorporates driving bushings, a factor of $f=2$ may be used for the bushing bearing area and $f=1.00$ or 1.25 (as the case may be) for the remainder of the bolt bearing area.

d. T_p has been plotted against rated engine torque multiplied by the bore in figure 1 for representative designs. 790 p. s. i. has been used for F_b for birch. (See Trayer, "Wood in Aircraft Construction," pp. 212–218.) Torque multiplied by the bore was used as a good criterion of the severity of the torque impulses from the engine.

e. The straight line in figure 1 is a recommended minimum safe value for use in the conventional steel hub and wood propeller design. It may be expressed by the equation:

$$T_p = 1.4\ (T_E B) - 110$$

where T_E = rated engine torque (foot-pounds)

B = cylinder bore (inches).

*Neglected for several reasons: First, the actual amount of friction will vary considerably with the humidity of the air and tightness of the bolts; second, service failures have indicated the number and size of hub bolts rather than the size of the flanges to be critical.

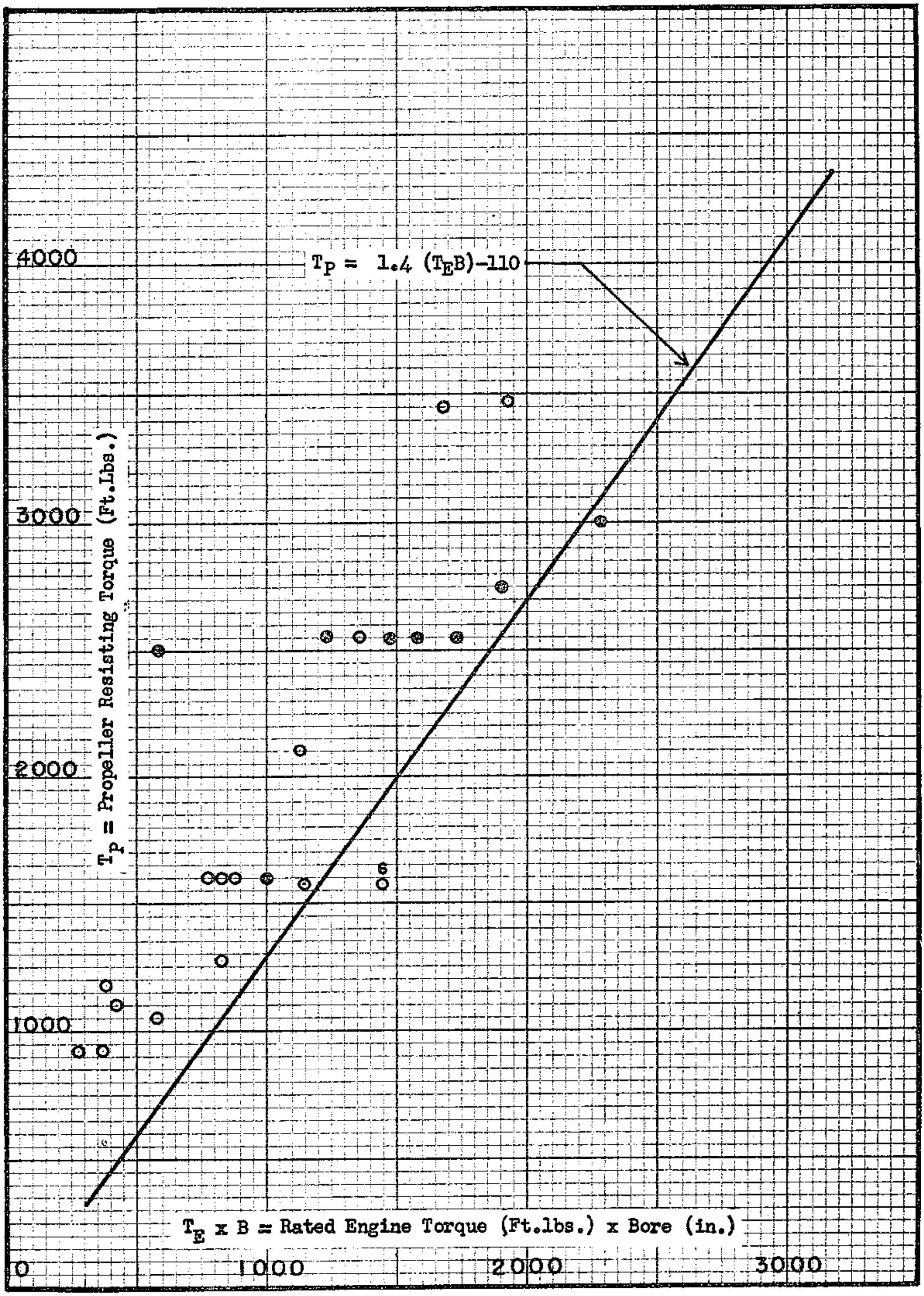

FIGURE 1.—Woodpropeller boss strength criteria.

f. Each circle in figure 1 represents a propeller and hub combination. The solid circles are those designs with a splined front flange and the open circles are those with a floating front flange. The number above the circle indicates the number of failures reported. In all cases the most highly stressed design is shown.

g. Those few isolated cases of single failure may be disregarded since many identical designs are satisfactory. Faulty maintenance, such as loose hub bolts, may have been a contributing cause. However, the series of six failures for the one design is a definite indication of an unsafe condition and this particular design had to be completely changed before satisfactory results were obtained. For design purposes the material presented in figure 1 and the equation in 14.1–B 7 (e) should determine the number, size, and disposition of the hub bolts.

h. To further aid in determining the boss dimensions, it is recommended that the length/diameter ratio of the hub bolts not exceed 11 and that the clearance from the center of the bolts to the outer surface of the boss be a minimum of 2½ times the bolt diameter. Center-to-center bolt spacing on the bolt circle should be 5½ times the bolt diameter (minimum) and the center of the hub bolts should clear the center bore by 3 times the bolt diameter.

i. In considering design improvements it is well to recognize the critical portions of the design and the possibilities of relieving them. The highest local value of bearing stress is experienced in the wood at the hub bolts where they enter the rear flange of the hub and where the load deflection is least.

j. To relieve this portion of the material some designs incorporate a bushing at the rear flange to increase the bearing area of the bolts at this point.

8. The subject of propeller model designation is discussed here because the designer usually assigns such a designation. For the purposes of field identification it is essential that each model be assigned a distinguishing number. For example, model 89B could be designated as 89B–48, 89B–52, and 89B–56 referring to pitches of 48, 52, and 56 inches, respectively. The "89" as used could refer to the diameter in inches, and "B" to the basic air-foil section. (See also 14.4–1.)

C. Metal Propellers

The wide variation in metal propeller design, both in type and material of construction, makes it impossible to advance many quantitative design criteria. The recommended tolerances and balancing methods have been given in 14.011–C. The following discussion will of necessity be somewhat generalized but specific recommendation is made whenever possible.

1. Blades of this type should conform to 14.11. The contour should be faired with respect to the plan form. Abrupt changes in cross-section are to be avoided. Curves of maximum thickness and of minor and major moments of inertia versus radius may be necessary to check new designs. The center of gravity of the blade sections for controllable pitch propellers should lie on, or nearly on, a straight line along the axis of rotation. This line may have a slight forward tilt to relieve the aerodynamic loading of the blade. The blade fairing should avoid abrupt changes and the shank should be designed with this in mind. When the design incorporates an abrupt change of section, as in the butt-end attaching portion, as large a fillet as possible is recommended to reduce stress concentration at that point. Neglect of this has been a source of trouble in many designs.

2. All surfaces subjected to wear and corrosion should be suitably plated for protection against both. Cadmium has proven satisfactory as a steel hub plating with zinc and chromium among the possible alternatives. Cadmium has a somewhat higher salt water spray resistance than zinc in thin coatings (0.010 inch) but zinc plating is slightly superior to cadmium when exposed to air containing sulphur (city atmosphere). Both cadmium and chromium plated steel blades have given satisfactory wear. Aluminum alloy blades ordinarily have no protective coating but a chromic-acid anodic treatment increases their salt-water corrosion resistance.

3. Metal propellers are inherently susceptible to resonance conditions and every effort should be made in the design to avoid such a condition in the operating range. All parts should be designed to minimize the effect of vibration upon their operation. This applies to the control mechanism as well as to the hub and blade structure. The pitch change mechanism for automatic and controllable pitch propellers should be so designed that in case of a failure in the pitch actuating mechanism the blades will either lock in fixed pitch with the blade angle in use at the moment of failure or will assume some other angle between low and high pitch. Low pitch is defined as the minimum blade angle used for take-off. High pitch is defined as the maximum angle used in flight not including feathering.

4. Blade tip sections should be designed with great care. Thin tip sections have caused trouble in metal blades and extreme thinness is to be avoided because the accompanying flexibility tends to promote resonance conditions. It does not follow that a thick tip insures against resonance, but a thick tip on a well-designed blade is preferable structurally if not aerodynamically.

5. In order to facilitate the interchangeability of parts, it is recommended that the propeller design conform so far as possible to Army and Navy or SAE standards.

14.2 Commercial Propellers.

14.20 Data Required. In the case of a propeller of a type which has not been previously approved by the Army or Navy, and for which the manufacturer desires the certification of the Administrator, the following information shall be submitted:

14.200 (a) Application for type certificate on a form which will be supplied for the purpose by the Administrator.

The application for a propeller-type certificate should be submitted on Form ACA 312 supplemented by Form ACA 335. The latter form should enumerate all the engines for which the propeller is designed.

14.201 (b) A complete set of drawings descriptive of the propeller, which drawings shall be numbered and dated and shall include change letters for each revision. All details of the propeller shall be shown, including the profile and plan form of the blade, the size of blade cross-sections at frequent stations, the hub design and the materials of construction. The material shall be specified on the drawings by reference to specification numbers of the Army, Navy, SAE, or other recognized standard whenever possible. If the manufacturer refers to his own specification numbers, details of such specifications shall be furnished the Administrator. All drawings shall be folded to a size of approximately 9 by 12 inches, with the title showing. In order to eliminate a possible source of controversy, the Administrator will not accept drawings which may be altered after approval. Blueprints, photostats, or the equivalent are acceptable. If certain of the drawings required for a particular propeller are identical with drawings previously submitted and approved in connection with a prior type of propeller made by the same manufacturer, such drawings need not be again submitted.

1. Drawings submitted should be complete in all important dimensions, specifications, and identification data. The minimum essential details of a propeller drawing should incorporate the following information:

a. Title block details. (Locate in lower right-hand corner.)
   (1) Company name and address.
   (2) Model or identifying number of propeller or part.
   (3) Date of drawing.
   (4) Initials of draftsman and checker.
   (5) All drawing change letters with date of change and description thereof.

b. Boss dimensions for fixed-pitch wood propeller.
   (1) Diameter of engine shaft bore.
   (2) Diameter of bolt hole circle.
   (3) Size and location of bolt holes.
   (4) Diameter and thickness of boss.
   (5) Cross-section of boss.

c. Blade dimensions and details.

(1) Side elevation not dimensioned but with the line of centers of gravity.

(2) Plan view with the line of centers of gravity and detailed dimensions sufficient to check the general contour of the leading and trailing edges.

(3) Curve of maximum section thickness plotted against radius.

(4) Blade cross-section at frequent intervals (preferably every 6 inches).

(5) Chord and angle at each cross-section. (The section ordinates should also be given at the 10 percent stations of the blade chord. The leading edge section should be further divided into four equal sections and the ordinates given.)

(6) When tipping is used, all details thereof.

(7) If the material is laminated, the extent and thickness of the laminations.

(8) A desired diameter reduction indicated on the blade plan form by dotted lines.

(9) When a different pitch distribution from that of the basic model is desired, the stations and blade angles listed in a table on the drawing, and the model designation which applies to that pitch distribution.

2. A complete material specification list should be noted or referred to on the drawing. The standard Army, Navy or SAE specification should be referred to whenever possible. The exact finish to be used on each part of the propeller should be noted.

3. All dimensional tolerances should be specified or reference made to a table of these tolerances.

4. Drawings should preferably be accordion-folded to a 9- by 12-inch size with the title block showing.

5. Altered blueprints or altered photostats are not acceptable as they are a possible source of controversy.

14.202 (c) A complete parts list in duplicate, showing the drawing number, change letter, and name of each component part of the propeller. The drawing numbers shall be listed in numerical order. When only one or two drawings are submitted for compliance with § 14.201, it is permissible for the manufacturer to submit these drawings in duplicate in which case a parts list is not required.

If a small number of drawings is submitted, they may be in duplicate in which case a sealed set will be returned by the Civil Aeronautics Administration upon certification. Where a large number of drawings is involved, much simplification is effected by submitting one set of drawings and a duplicate parts list. The parts list should be headed with the model number and date of issuance. It should show the drawing number, last change letter, and the name of each component part. Drawing numbers should be arranged numerically. Upon certification of the propeller, the parts list will be sealed and returned for inclusion in the manufacturer's files. The drawings are filed in a general drawing file for each manufacturer, hence identical drawings for different models need not be resubmitted.

14.203 (d) A complete log certified to by the person making the test or signed by a witnessing inspector of the Administrator, at the discretion of the Administrator, describing the manufacturer's tests of the propeller in accordance with §§ 14.21 or 14.22, as the case may be. The log shall include a detailed record of the test with dates; names of persons involved; name and model number of engine, or name, model number, and identification mark of the airplane issued by the Administrator of Civil Aeronautics; and hours of testing with corresponding engine speeds. The report shall also include the results of a detailed inspection of the propeller after the test in accordance with § 14.23.

The log should either be supported by the manufacturer's affidavit or signed by the witnessing inspector. A graphical or tabular engine log with 15-minute readings is acceptable. All stops should be noted and accounted for. Tests on other than fixed-pitch wood propellers must be witnessed by a CAA inspector or an authorized agent (see 14.21–1) and the test log will be signed by such witness. Tests on conventional fixed-pitch wood propellers will ordinarily not be witnessed by an inspector. A new manufacturer's initial test will always be witnessed.

The essential items for this type of test report are given below. This type of report or its equivalent should be used.

FIXED-PITCH WOOD PROPELLER TEST REPORT

1. *Test Data:*
   (a) Propeller Model No. ______________________ Serial No. ______________________
   (b) *Airplane License No. ____________________
   (c) Engine Model No. ________________________ Serial No. ______________________
   (d) *Total period of testing ____________ hours, including hours at ___________ r. p. m.
   (e) **Total period of testing__________________ hours at__________________ r. p. m.

2. *Test Report:*
   (a) Comment on any evidence of excessive flutter or vibration during test ____________
   ____
   ____
   (b) Comment on any forced stops occurring during test ___________________________
   ____
   ____
   (c) Describe tachometer calibrations made ______________________________________
   ____

3. *Inspection after test:*
   (a) Tipping and attachment:
   Tipping cracked excessively______________ ______________________________
   Rivets or screws loose____
   Satisfactory____
   Comments____
   ____
   (b) Condition of all wood joints:
   Blade lamination joints opened up____
   Hub lamination joints opened up____
   Satisfactory____
   Comments____
   ____
   (c) Condition of hub bolt holes.
   Elongated or burned____
   No distortion____
   Comments____
   ____
   (d) Condition of wood in general:
   Longitudinal cracks____
   Transverse cracks____
   Comments____
   ____

*Applies to flight test only and must be supported by the airplane log.
**Applies to block test only and must be supported by the test.

4. *Conformity check:*

Item	Drawing	Measured
Over-all diameter	----------	----------
Hub diameter	----------	----------
Hub thickness	----------	----------
Diameter of hub bolt circle	----------	----------
Station ----: chord	----------	----------
max. thickness	----------	----------
blade angle	----------	----------
Station ----: chord	----------	----------
max. thickness	----------	----------
blade angle	----------	----------
Station ----: chord	----------	----------
max. thickness	----------	----------
blade angle	----------	----------

I HEREBY CERTIFY that the above testing, inspection, and conformity check was supervised by myself and that the data presented herein is true.

State of --------------------

County of ------------------

(SIGNED) ----------------------

14.204 (e) A stress analysis when required by § 14.210 or when, in the judgment of the Administrator, the design is sufficiently unconventional to require it.

A stress analysis is usually requested if the propeller is of a new design. While this is of minor value in itself it is useful as a check of future design changes and as a general indication of steady stress conditions. Such an analysis need not be exact in its treatment of blade deflection, but all assumptions should be of a conservative nature and the analysis should include the basic aerodynamic and centrifugal loadings.

14.21 Tests required for propellers other than fixed-pitch wood propellers. A propeller of such type shall be subjected to a 50-hour endurance block test on an internal-combustion engine rigidly mounted and of the same characteristics as the engine or engines in conjunction with which the propeller will be certificated for use, or on another engine acceptable to the Administrator. The test shall be witnessed by an authorized inspector of the Administrator and may be run without a stop or in periods of 5 hours or more each. The cylinder bore of the engine used for the test will determine the maximum bore of the engine with which identical propellers of this type will be certificated for use. The test shall be run at the proposed rated speed of the propeller with the propeller so adjusted as to absorb its proposed rated power. If the engine is not run at full throttle, and horsepower measurements are not possible during the test, manifold pressure readings shall be taken at frequent intervals. A suitable calibration curve shall be used to determine the power absorbed by the propeller during the test. The power rating assigned to the propeller by the Administrator may correspond to the corrected horsepower developed by the engine if the engine used for the test is of the type on which the propeller is to be certificated for use. In the case of a controllable or automatic pitch propeller, the pitch-changing mechanism shall be operated throughout the usable power range at least once for each hour of the test or the equivalent. The engine may be throttled to prevent overspeeding when changing pitch. After such 50 hours of testing, a controllable or automatic pitch propeller shall also be operated at as close to rated power and speed as possible for periods of 5 minutes each at various pitch settings; i. e., at 1-degree intervals throughout the operating range when the design so permits. All variations in running characteristics of the propellers shall be recorded.

1. The Civil Aeronautics Administration should be notified of the expected starting of a test sufficiently in advance to provide an inspector to witness the test. Items in the test program about which there is any doubt should be discussed with the Civil Aeronautics Administration at an early date.

2. Service failures and stress measurements available to date have indicated the necessity for obtaining vibration stress measurements of metal propellers under operating conditions.

This is to determine the magnitude of the vibration stresses existing in operation and to determine if a critical resonance condition exists at any point in the operating range of the propeller. The essential equipment has been previously listed in 14.03–1 (e). The resultant oscillogram from the stress pick-up may be calibrated to read stress directly and therefore give the magnitude and frequency of the vibration stress at the pick-up location. These pick-ups should be mounted at points on the blade tip where the stress is anticipated to be a maximum and at several points on the blade shank. Sufficient runs should be taken to establish the phase relationship between stresses at corresponding points of different blades and to determine the magnitude and predominant frequency of the vibration stresses over as wide an r. p. m. range as possible; i. e., from take-off r. p. m. down to 25 percent of that speed.

3. Crankshaft torsiograph records should also be obtained in order to determine the torsional characteristics of the propeller-crankshaft system. These runs should be made with the engine rigidly mounted in order to eliminate from the record any secondary vibration due to engine oscillations. The torsiometer should preferably be mounted at the propeller hub. The complete operating range should be investigated.

4. Linear pick-ups of the magnetic type should be suitably mounted on the engine to record the motion along the three axes and such displacement records correlated with the blade vibration-stress measurements for future installation problems. This material is considered secondary but very helpful.

5. The investigations discussed in the preceding three items should be completed as an essential preliminary to any actual endurance running and the results discussed with the Civil Aeronautics Administration before such endurance testing will be authorized. Based on such preliminary investigations the following conditions will apply:

a. If the vibration-stress survey shows no marked resonance conditions in the cruising or take-off regimes, the 50-hour endurance test may be run at either maximum, except take-off power and speed with a 10 percent increase granted for the take-off operation or at 91 percent take-off power and speed with a 10 percent increment granted for take-off operation. It is recommended that 10 hours of the test be conducted at the take-off power and speed.

b. If the preliminary stress survey shows a marked resonance condition in the cruising regime it will be necessary to run a 50-hour test at the critical speed in addition to the testing outlined under item "a" above.

c. If the preliminary stress survey shows a marked resonance condition at take-off power and speed it will be necessary to run an added test under those conditions in addition to the testing mentioned under item "a" above. The amount of this testing will be based upon the amount of take-off operation to be expected in the normal service life of the propeller.

d. As an alternative to running the added test of item "c," the entire 50-hour endurance test may be run at take-off power and speed in which case no additional testing would be required. Tests mentioned under items "b" and "c" can, of course, be omitted by restricting operation of the propeller to avoid the critical conditions.

e. A correlation of stresses in new designs with those measured on designs with a satisfactory service record will be considered acceptable and helpful in a study of vibration-stress measurements.

6. The actual endurance test should be run on an engine of the power and speed for which certification is desired. Because of the vibration problems previously discussed it will ordinarily be possible to assign only a general power, speed, and bore limitation to a propeller. The test should be run in minimum 5-hour increments, except that forced stops in these periods due to engine trouble will not affect acceptance of the test. A definite test schedule should be set up and adhered to as closely as possible. The propeller should be held to within 25 r. p. m. of its proposed rated speed at all times during the test. If the engine is operated at part throttle during the test, suitable arrangements should be made to record the manifold pressure and a

curve should be obtained showing the horsepower variation with manifold pressure at the proposed rated speed of the propeller. At each stop the propeller should be wiped off, examined, and a thin coating of used engine oil rubbed on. This applies to both steel and aluminum alloy propeller blades. The carbon and the trace of acid in the oil both clean the propeller and tend to work in and darken any crack which may have started.

7. It is essential that the pitch-changing mechanism of a controllable or automatic pitch propeller be operated throughout its usable range at least once for every hour of testing. These 50 cycles provide a check of the propeller operating mechanism throughout its full range. Any roughness in the operation of the propeller should be noted. Runs of 5-minute duration should also be made at approximately 1-degree intervals on this type of propeller whenever possible, and any variations in running characteristics should be noted. In addition to these required tests of the pitch-changing mechanism it is suggested that it be further subjected to a vigorous operation test of 500 cycles in the case of a manual control mechanism and 1,500 cycles in the case of an automatic control mechanism.

14.210 A propeller of the above type which, in the opinion of the Administrator, is sufficiently similar to a previously certificated propeller of the same manufacturer may be subjected to a 50-hour flight test in lieu of the test outlined in 14.21 provided that its airworthiness is demonstrated to the satisfaction of the Administrator by a comparative stress analysis submitted by the manufacturer. The stress analysis shall compare the pertinent aerodynamic, centrifugal, vibration, and torque impulse load difference between the respective propellers by a mathematical comparison, when possible, and by suitable curves plotted with the radius of the propeller as abscissa. Curves descriptive of the fairing of the propellers shall also be included when applicable. Such 50-hour flight test shall be conducted on an engine of equal or greater power and speed than that in conjunction with which the rating is requested. At least 5 hours of the test shall be run at the proposed rated speed of the propeller.

14.211 It is recommended that metal propellers of this type also be tested by suitable methods to determine their natural frequencies within all ranges of major vibrations which are produced by the operation of the engines in conjunction with which such propellers are to be certificated for use. Such frequencies should be determined at all blade angles within the desired operating pitch range of propellers. Data covering these tests should be submitted to the Administrator in the form of curves and tables. The type of frequency should be described and the nodes located for each frequency.

1. Although the static vibration tests mentioned in 14.211 are not considered essential data in view of tests discussed in 14.21–1 through 4, it is desired that such tests be run and submitted for possible correlation with the actual stress measurements taken. Static vibration data should be adjusted for the effect of centrifugal force by use of the formula:

$$F^2_r = F^2_o + CN^2$$

where F_r = resonant frequency of the rotating propeller.
F_o = resonant frequency at zero r. p. m.,
N = propeller r. p. m., and
C = vibration mode coefficient.

Suggested values of C for various loop and node conditions are:

C = 1.7 − 2.0 for 1–L and 1–N
C = 6.0 − 6.2 for 2–L and 2–N
C = 12.0 − 12.2 for 3–L and 3–N.

2. A static vibration study should include a wide range of blade angles from 0 to 90 degrees in order to determine the possibility of resonance conditions due to a forced vibration about the major axis. The effects of end fixity have been found to be important, hence a suitable pre-loaded condition at the blade butt should be obtained to duplicate the effect of centrifugal force on that factor.

14.22 Tests required for fixed-pitch wood propellers. A propeller of such type shall be subjected to a 10-hour endurance block test on an internal-combustion engine, or to a 50-hour flight test. The testing shall be witnessed by an authorized inspector of the Administrator at the discretion of the Administrator. In the case of a block test, the entire test shall be run at the proposed rated speed of the propeller. In the case of a flight test, at least 5 hours shall be run at the proposed rated speed of the propeller. Such flight test shall be conducted with an engine of equal or greater power and speed than that in conjunction with which the propller is to be certificated for use.

1. The 10-hour endurance block test should be run with the maximum diameter and pitch for which certification is desired. These dimensions may then ordinarily be reduced and approved without additional testing, provided that no other dimensions are materially altered and provided no increase in rating is desired. The test may be run on any internal combustion engine that may be available, provided that the proposed rated r. p. m. is maintained throughout the test. Since r. p. m. is the only observed factor upon which approval is based, it is essential that it be accurately determined. The tachometer should be calibrated before and after the test and checked with a stop-watch and revolution-counter during testing. This calibration should be noted on the test log. The speed should be held to within plus or minus 25 r. p. m. of the proposed rating. The test may be made in suitable increments, provided that all stops are adequately explained in the test log.

2. The 50-hour flight test should be run on the same general type of airplane on which the propeller will be used, and the specific diameter and pitch for which certification is desired should be installed. The engine power and speed should be equal to or greater than those for which the propeller is to be certificated, and at least five hours should be run at the proposed rated speed. As the r. p. m. is the only observed factor upon which approval is based, it is essential that it be accurately determined. Suitable checks, as discussed in the preceding paragraph, should be made and noted on the test report.

14.23 Inspection of a tested propeller. As prescribed in § 14.203, the log of the flight or block test shall include the results of a detailed inspection of the propeller after the test. Photographs of any failures or suspected failures shall be included. A propeller which fails during the testing is not eligible for certification unless the failure is of a nature such that the strength of the propeller is not impaired and a minor modification to the propeller will preclude the probability of future failures of the same type. Aluminum-alloy propellers shall be etched at all critical portions and then examined for minute cracks with a magnifying glass. Steel propellers shall be subjected to both a magnetic and visual inspection for signs of failure.

1. The propeller should be thoroughly inspected at the conclusion of the testing for any unsatisfactory conditions that may have developed. Pitch-control mechanisms should be thoroughly inspected for excessive wear and for clearances. A complete inspection report, considering all applicable items discussed in the following paragraphs, should be submitted.

a. Aluminum-alloy propeller blades should be etched at the tip and shank portions and at any other critical sections. Fillets, and points of abrupt curvature, are critical sections. The blades should then be examined for cracks with a 4- to 6-power magnifying glass. Particular attention should be paid within the tip portion to the region approximately one-third back from the leading edge on the lower surface of the blade. Any transverse cracks or scratches near this location should be thoroughly investigated. The region of the shank in line with the leading or trailing edge of the blade should also be examined minutely.

b. Hollow steel blades, solid steel blades, and forged steel hubs should be thoroughly inspected visually and magnetically by the wet process. Any pronounced magnaflux indication should be reported and discussed in detail as it may warrant a complete metallurgical examination. This inspection should be made by a highly skilled operator with a long service experience.

c. The blade control mechanism should be inspected for excessive wear, fatigue cracks, and any other unsatisfactory condition. All ferrous parts should be subjected to a magnetic inspection by the wet process.

d. The hub cones should be carefully inspected for any signs of wear which are an indication of torsional vibration condition.

e. Fixed-pitch wood propellers should be thoroughly examined for evidences of loosened or excessively cracked tipping, opened glue joints, cracks in the wood, and local failure or cracking around the hub bolt holes. These items are adequately covered in the sample test report, pages 17 and 18. A certain amount of flexural cracks in the metal tipping is considered normal.

2. The Civil Aeronautics Administration inspector will inspect the torn-down propeller for conformity with the drawings. This inspection should be conducted and certified to by the manufacturer in the case of conventional fixed-pitch wood propeller tests. Several blade sections and other major dimensions of the blades and hub should be checked. Only a representative number of parts need be checked when a large number are involved, as in the hub control mechanism. A notation and record of the conformity inspection should be incorporated in the inspection report.

14.230 A failure of a metal propeller is defined as actual breakage, cracking or permanent set of any part of any blade, hub, bolt, lock nut, spline or keyway; slipping of a blade in its clamping socket; seizing or pitting of any bearing; or jamming of an automatic or controllable pitch mechanism. A wood propeller will be deemed to have failed if the tipping pulls or cracks, if a glue joint opens, or if there is any local failure or crushing around the hub or a bolt. Similar considerations will apply to propellers of any patented composition or of other than conventional wood or metal construction.

14.3 Military Propellers. In the case of a propeller of a type which has previously been approved by the Army or Navy and for which the manufacturer desires certification by the Administrator, the following data shall be submitted:

(a) An application as described in § 14.200.

(b) A copy of the official Army or Navy endurance test report which was the basis for the military approval, signed by the Army or Navy representative who witnessed the test. It is not necessary for the manufacturer to submit this report when such report was been previously forwarded to the Administrator through official channels. When the report is being prepared by the military agency the Administrator, to expedite approval, may in the interim accept a copy of the official letter of approval of the propeller which letter shall include the military rating, the length of test, and the output and model designation of the test engine.

(c) Drawings as described in § 14.201.

1. A requisite to certification of propellers of this type is the submittal of the proper forms and necessary drawings as discussed in the previous paragraphs 14.200 and 14.201, respectively.

2. A copy of the official report which forms the basis of the military approval or a copy of the official letter of approval from the military agency is required. The manufacturer's responsibility with respect to obtaining the letter is the same as in the case of the report. The propeller must be approved for service use. A restricted approval for additional flight test purposes is not considered sufficient.

14.4 Modified Propellers. When a manufacturer desires the certification by the Administrator of a propeller which embodies only minor modifications of a certificated propeller of the same manufacturer, data shall be submitted as follows:

(a) An application as described in § 14.200.

(b) Drawings as described in § 14.201.

(c) Technical data which demonstrate conclusively that the airworthiness of the modified propeller is at least equal to that of the certificated propeller.

1. Small changes in pitch and diameter are ordinarily permissible in the case of fixed-pitch wood propellers without additional testing. For the purposes of field identification it is necessary that a new model number be assigned with each change in pitch and diameter. A change in dash number in conjunction with the basic model number is recommended to designate a change in pitch. (See 14.1–B (7).) A change in pitch distribution should be noted in a suitable tabular form on the basic model drawings. Small changes in diameter which involve only the tip sections may be denoted by dotted lines on the basic model drawing. The necessary Forms 312 and ACA 335 should be submitted for each model.

2. Minor modifications to a metal propeller blade structure may result in major changes in the vibration stresses of the blade. This point must therefore be suitably covered if a modification is submitted as minor. In general, appreciable changes in the structure of a metal propeller will be considered a major change and subject to the test requirements of 14.2.

14.5 Procedure relative to type certification.

14.50 General. The procedure and general requirements for the issuance of a type certificate shall be as prescribed in Part 02.

14.51 Sealed Drawing List. When a type certificate is granted, a drawing list representative of the certificated propeller is impressed with the seal of the Administrator of Civil Aeronautics and is returned to the manufacturer. Sealed copies of the drawings may be used for this purpose in lieu of a drawing list. Inspectors of the Administrator may call for, and must have access to, the sealed drawing list or drawings together with any other pertinent drawings when making an inspection of the manufacturer's plant to determine whether the propellers as built conform to the approved data.

The sealed drawing list and sealed drawings should be kept adequately and conveniently filed at the manufacturer's office so that they are readily available for such conformity checks as may be made by Civil Aeronautics Administration representatives. It is preferable to file each model separately in numerical order.

14.52 Major Changes. Any major change from the approved drawings must be approved in advance by the Administrator. A change will be deemed major within the meaning of these regulations if it adversely affects the reliability or airworthiness of the propeller. In general, a change will be deemed major when it decreases the airworthiness of a part the failure of which might prevent the aircraft from continuing flight. In all doubtful cases the decision of the Administrator shall establish the category within which a specific change will be included.

14.520 Information accompanying a request for approval of a change to a certificated propeller shall include technical data, including (when necessary) stress analyses and reports of tests sufficient to demonstrate to the satisfaction of the Administrator that the changed propeller is airworthy. The report shall be signed and certified to by the responsible representative of the manufacturer. If the change is to a different blade shank size, engine shaft size, blade airfoil or propeller material, application shall be made for a new type certificate.

Major changes to a propeller, as discussed in previous paragraph 14.4, will necessitate compliance with the test requirements of 14.2 and are treated as creating new designs. If there is any doubt as to whether a change is minor or major in nature, the decision should in all cases be referred to the Civil Aeronautics Administration.

14.53 Minor Changes. On January 1 and July 1 of each year the holder of a propeller-type certificate shall submit, for approval and file, drawings pertaining to all the minor changes made to the propeller during the preceding 6-month period.

Drawings including the minor changes made to the propeller during the preceding 6 months should be submitted during January and July of each year. If a drawing list was originally submitted the revised drawing list should also be included. If a drawing list was not originally submitted a duplicate set of drawings should be forwarded so that either a sealed drawing list or set of sealed drawings may be returned for file.

14.54 Reductions in Diameter. A type certificate may provide for reduction in diameter from that of the propeller tested, provided that no increase in rating is involved. The diameter of a propeller blade may be reduced by cutting off the tip of a blade and fairing the immediate vicinity, or by telescoping the outer sections of the blade. The drawings submitted shall show the details of each blade smaller in radius by 6-inch steps, which details may be shown superimposed on a drawing of the original blade.

Reductions in diameter made by cutting off the tip or by telescoping will generally be certificated without additional testing, provided the original design has no critical resonance conditions and it is shown that no additional critical resonance conditions are encountered in the smaller diameter blade.