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U. S. CIVIL AERONAUTICS ADMINISTRATION

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AIRCRAFT PROPELLER AIRWORTHINESS

U.S. DEPARTMENT OF COMMERCE

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INTRODUCTORY NOTE

This edition of Civil Aeronautics Manual 14 includes all revisions up to June 1, 1945, 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.

CONTENTS

		Page
14.0	General	1
14.00	Provision for rating	1
14.01	Scope	1
14.02	Hubs and blades	14
14.03	Testing facilities	14
14.04	Military propellers	14
14.05	Propeller operation limits	15
14.06	Propeller identification data	15
14.07	Previously approved propellers	15
14.1	Design requirements	15
14.2	Commercial propellers	21
14.20	Data required	21
14.21	Tests required for propellers other than fixed-pitch wood propellers	25
14.22	Tests required for fixed-pitch wood propellers	28
14.23	Inspection of a tested propeller	29
14.3	Military propellers	30
14.4	Modified propellers	30
14.5	Procedure relative to type certification	31
14.50	General	31
14.51	Sealed drawing list	31
14.52	Major changes	31
14.53	Minor changes	32
14.54	[illegible]	32

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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 ENGINES AS TO AIRWORTHINESS, THE FOLLOWING PERFORMANCE SET FORTH SHALL BE USED AS THE BASIS OF SUCH RATING FOR ESTABLISHING SUCH RATINGS FOR PROPELLERS FOR USE IN CERTIFICATED AIRCRAFT.

Part 14 concerns the rating of propellers as to airworthiness specifically, and in aircraft only in so far as the complete powerplant unit is eventually installed and operated in an airplane. Accordingly, the operation limit, determined under Part 14, approves the propeller numerically, provided the certificated power rating or speed rating is not exceed-

14.1 [illegible].

To simplify references and to avoid unnecessary repetition, the terms "approved" and "approval" are used in this manual to mean "properly 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 [illegible] based upon the previous experience of the Civil Aeronautics [illegible] with propellers which have been used satisfactorily in flight [illegible], when a metal propeller is installed in a certificated aircraft, such propeller is investigated [illegible] its vibration and operating characteristics under the ground and flight testing requirements of Part 04, Airplane Installation. Part [illegible] provides that [illegible] combination [illegible] model [illegible] met these latter requirements.

[illegible]
[illegible]
[illegible]
§§ 14.1 [illegible] 14.4

[illegible]
[illegible]
[illegible]
[illegible] 4.5.

A. [illegible]

[illegible] propellers [illegible] metal and metal-[illegible] propellers [illegible] [illegible] [illegible]

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 five and seven per cent 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 over emphasized.

b. Glue used should be of a high quality. Blood albumin glues, marine glues, and the various phenol-aldehyde 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, [illegible] metal, stainless steel, or the equivalent. The recommended thickness is 0.[illegible]19 inch. A linen fabric is frequently applied to the surface for additional strengthening at the tip [illegible] for protection against abrasion and splintering. It should be finished with transparent [illegible] 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.

. . 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 four hours before gluing. If serrated, the pitch should be not less than 1/8 inch and not greater than 1/4 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 four 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 1/2 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 four 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 1/2 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 1/2 inch thick or within 18 inches of the tip of either blade, should be cause for rejection.

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.

. 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 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 two days should be allowed after removal from the press or clamps.

d. After conditioning, the propeller should be roughed out not closer than 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 seven days or more at approximately 70°F, or not less than three 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 [illegible] of finish. The small piece of metal should be applied to the camber face of the tip first. The ends of the large [illegible] should then [illegible] wrapped over the small piece as to [illegible] continuous piece of metal along the leading edge. [illegible] should be [illegible] by No. 4 brass or plated steel [illegible] screws, 1/2 and 3/8 inch long except in the thin section [illegible] the [illegible] 1/16-inch diameter brass or copper [illegible] should be [illegible]. The blade should be [illegible] countersunk for the screw heads. The countersunk [illegible] be coated [illegible] filled. The metal should [illegible] countersunk to take the screw heads, but should be [illegible] the countersunk holes in the wood by a method that [illegible] splitting or compressing the wood. The holes for [illegible] should be [illegible] through the metal and wood with [illegible] place. [illegible] of the metal tipping [illegible] mitted, but the metal should be removed and [illegible] wood countersunk and a protective coating [illegible] of the screws. The metal should then be [illegible] carefully dimpled into the countersunk holes before [illegible] Rivet holes should be drilled to the exact size of [illegible] that the rivets may be pressed in by hand. Rivets [illegible] be driven [illegible] completed, the metal tip should [illegible] against the wood. Buckling or lifting of the metal [illegible] cause for rejection. Solder should be filled [illegible] of these rivets and screws, and filed down to the [illegible] surface of the metal tip. Care should be exercised [illegible]

and rivets to avoid undue heating or charring of the wood. The metal tipping should be vented by drilling three No. 60 (.030) holes 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 varnish 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.

A-N-A 1 - WOOD PROPELLER TOLERANCES

[illegible] width	(shank to 24-inch station)	± 3/32"
	(30-inch station to tip)	± 3/16"
[illegible] thickness	(shank to 24-inch station)	± 1/8"
	(30-inch station to tip)	[illegible]
[illegible] alignment		± 1/16"
[illegible] alignment		± 1/8"
Angle of [illegible]	(shank to 24-inch station)	3/32"
	(30-inch station to tip)	7/32"
[illegible] angle	(shank to 16-inch station)	± 1.0°
	(24-inch to 30-inch station)	± 0.5°
	(30-inch station to tip)	± 0.4°
[illegible]		1/16"
Thickness of hub		± 1/32"
Diameter of hub bolt holes in white		± 3/32"
		-.005"
		.000"
[illegible] bore in white		+.005"
		-.000"

[illegible] 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.

[illegible]

c. A suitable [illegible] completed and filed for every [illegible] purpose is shown below. [illegible] by some responsible per[illegible] designated [illegible] by the company. On the back of [illegible] should be printed.

SUGGESTED [illegible] FORM

Shipped to _____ Dest. [illegible]

Address _____ [illegible] No. _____

Wood Source _____ [illegible]

Hub Drilled _____ by _____

Hub Installed _____ by _____

Station	Angle	Plus or Minus	Width	Plus or Minus	Max. Thickness	Plus or Minus	Tee Rate [illegible]	Remarks

	Measured	Plus or Minus
Prop. Diameter		
Hub Diameter		
Hub Thickness		

Balance _____
Track _____
Finish _____
Inspected by _____
Approved by _____

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 information which 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% caustic soda solution and cleaned in a 20% 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 14.01)-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 on the following page in Tables II and III.

TABLE II - ALUMINUM ALLOY BLADE TOLERANCES

Basic Diameter -- 10 ft, 6 in., or less		
Blade length		± 1/16"
Blade width	(shank to 24-inch station)	± 3/64"
	(30-inch station to tip)	± 1/32"
Blade thickness		± .025"
Edge alignment		± 1/32"
Face alignment		± 1/32"
Template fit	(shank to 24-inch station)	1/32"
	(30-inch station to tip)	.020"
Blade angle	(shank to 18-inch station)	± 0.5°
	(24-inch 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 ft, 6 in. to less than 14 ft, 0 in.		
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"

*Edge and face alignment are defined in 14.011-B4(a).

c. The interchangeability recommended in the preceding paragraph provides that all blades of the [illegible] shall agree 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 sensitive to [illegible] inch-pounds in horizontal balance and [illegible] in vertical balance. The finished propeller should be [illegible] horizontally and vertically at both 0 and 90 degrees [illegible] of rotation without showing a persistent tendency [illegible] direction. Final balancing should be done [illegible] indicator stand in a room free from [illegible] may be corrected by drilling a concentric [illegible] case of [illegible] blade which hole must conform with the [illegible] Table [illegible]. Vertical balance may be corrected [illegible] hole not greater than 3/8 inch in diameter [illegible] as specified in Table IV. The [illegible] not greater than 1/4 inch to the [illegible] and not more than one eccentric hole [illegible]. These holes may be left open [illegible] corked.

TABLE IV [illegible]

Shank Size	Maximum concentric hole diameter	[illegible] eccentric depth.
00	[illegible]	[illegible]
0-V2	[illegible]	
2/2	[illegible]	
1	[illegible]	
1 1/2	[illegible]	
2	[illegible]	
3	[illegible]	

As an alternate [illegible] single eccentric [illegible] the concentric hole [illegible] and filled with [illegible] closer than one [illegible] ends of all holes [illegible] drill having a [illegible] edges of the [illegible] Blades having [illegible] available [illegible] eccentric [illegible]

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.

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)	.004
	(from 30-inch station to tip)	.020"
Blade angle	(from shank to 24-inch station)	± 0.50°
	(from 30-inch station to tip)	± 0.25°
Longitudinal location of stations		± .014"

Edge and face alignment 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. 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. [illegible] standard tension test sample should be cut from each [illegible] of steel used and subjected to physical tests to determine [illegible] properties. Sufficient chemical analyses should [illegible] the chemical properties of the material and [illegible] composition.

a. All [illegible] should be subjected to [illegible] at various times during the production process. [illegible] number of inspections will be found desirable in order to [illegible] a large number of rejections in the final stage of production. Any unsatisfactory indications which cannot be eliminated [illegible] a maximum of 10% of the plate thickness at this stage are considered sufficient cause for rejection. The [illegible] 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 [illegible] concentration point.

[illegible] tabulation [illegible]

[illegible]

Blade [illegible]		[illegible]
Blade width	(from shank to 24-inch station)	[illegible]
	(from 30-inch station to tip)	[illegible]
Blade [illegible]	(Maximum ordinate)	[illegible]
Edge alignment		[illegible]
Face alignment		[illegible]
Template fit	(from shank to 24-inch station)	[illegible]
	(from 30-inch station to tip)	[illegible]
Blade angle	(from shank to 24-inch station)	[illegible]
	(from 30-inch station to tip)	[illegible]
Longitudinal [illegible] of stations		[illegible]

Plate thickness:

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

Edge and face alignment 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, 3000kg) in the center of the thickest portion. 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 32.

14.013 DEVIATIONS. WHEN A PROPELLER PROCESS A FEATURE OF DESIGN OR CONSTRUCTION WHICH DEVIATES FROM THE PRACTICE IN CONVENTIONAL AIRCRAFT 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.

14.02 Hubs and blades. [illegible] 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 applicable endurance tests of and is accepted 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 [illegible] POWER OR PROPELLER SHAFT SPEED, [illegible] WITH AN ENGINE [illegible], GREATER THAN THE LIMITS ASSIGNED THERETO BY THE ADMINISTRATOR. THE [illegible] 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 [illegible] propeller is certificated for a specified horsepower, [illegible] limit with a certain diameter and pitch range. [illegible] in vibration characteristics with different crankshaft [illegible] 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. Unless definitely stated to the contrary, the propeller is assigned a take-off operation limit of 10% 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 rpm 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 rpm.

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; AND MAXIMUM POWER AND MAXIMUM SPEED FOR WHICH CERTIFICATION HAS BEEN GRANTED. 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 PRINTED OR PAINTED 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 [illegible] 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.

[illegible]

[illegible]

[illegible]

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% over the cantilever type. Because of the varying amounts of play in the splined front flange this 100% increase has been arbitrarily reduced to 25%.

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

$$T_p = F_b AHf$$

where T_p = propeller resisting torque (ft.lbs.)
F_b = elastic limit allowable crushing stress (p.s.i.)
A = total hub bolt bearing area (sq.in.)
H = bolt circle radius (ft.)
f = front flange [illegible]

d. T_p has been plotted against rated engine torque [illegible] the bore in figure 1 for representative designs. [illegible] has been used for F_b for birch. (See Drayer, "Wood in Aircraft Construction," pp. [illegible].) [illegible] was used as a good criterion of the severity of the torque impulses from the engine.

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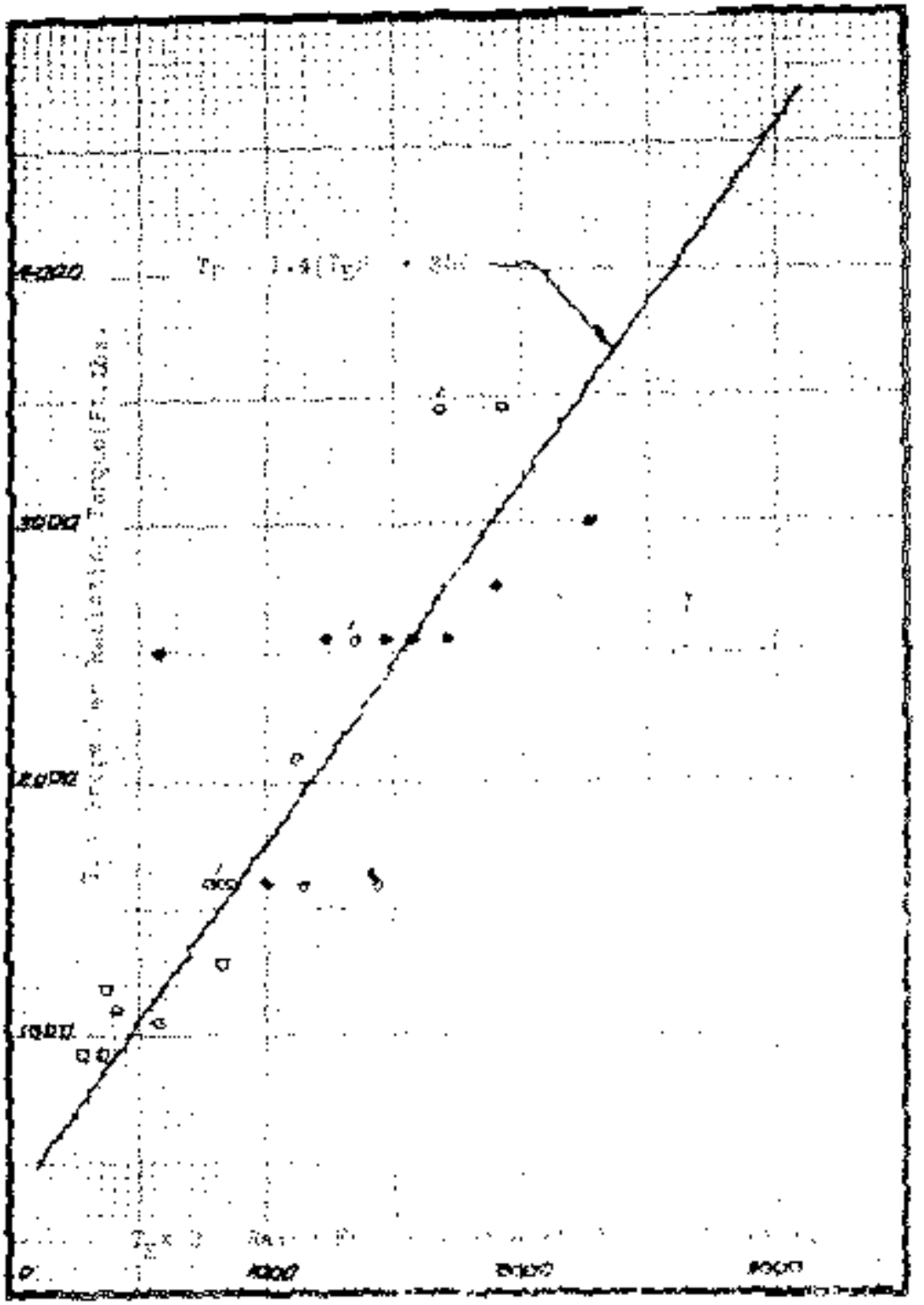
* Neglected for several reasons: [illegible] will vary considerably with the humidity of the air and tightness of the bolts; second, service failures have indicated the number and size of hub bolts rather than the size of the flanges to be critical.



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:

$$T_p = 1.4\ (T_E B) + 350$$

where T_E = rated engine torque (ft.lbs.)
B = cylinder bore (inches)

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. The three isolated cases of circle 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 14.1-8 [illegible] should determine the number, size, and disposition of the hub bolts.

h. [illegible] dimensions, it is recommended [illegible] of the hub bolts not exceed eleven [illegible] from the center of the bolts [illegible] minimum of 2 1/2 times the bolt diameter. [illegible] on the bolt circle should be 5 1/2 times the bolt diameter minimum and the center of the [illegible] times the bolt diameter.

i. [illegible] recognize the critical [illegible] possibilities of relieving them. [illegible] value of bearing stress is experienced in the wood [illegible] bolts where they enter the rear flange of the [illegible] where the load deflection is least.

j. [illegible] designs incorporate a bushing at the rear [illegible] 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 [illegible] example, model 89B could be designated as 89B-48, 89B-52 and [illegible] referring to [illegible] of 48, 52 and 56 inches respectively. The [illegible] as used could refer to the diameter in inches and 89B to the [illegible] airfoil 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 planform. 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 rub plating with zinc and chromium among the possible alternatives. Cadmium has a somewhat higher salt water spray resistance than zinc in thin coatings (0.001 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 good wearing qualities. Aluminum alloy blades ordinarily have no protective coating but a [illegible] shot-blast treatment increases [illegible] salt water corrosion [illegible].

3. Metal propellers are inherently [illegible] 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 engine operation. This applies to the control mechanism as well as to the hub and blade structure. The pitch change mechanism of automatic and controllable pitch propellers should be so designed that in case of a failure in the pitch changing mechanism the blade will either lock in fixed pitch with the blade angle in case of 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. Metal tip sections should be designed with great care. Thin tip sections have caused trouble in metal propellers and extreme thinness is to be avoided because the [illegible] tends to promote

[illegible]

14.2
14.201 (a)

[illegible]

[illegible]

[illegible]

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 the quarter intervals (preferably every 6 inches).
Chord and angle at each cross-section. (The section ordinates should also be given at the 10% stations of the blade chord. The leading edge section should be further divided into four equal sections and the ordinates given.)
(5) When tipping is used, all details thereof.
(6) If the material is laminated, the extent and thickness of the laminations.
(7) A desired diameter reduction indicated on the blade planform by dotted lines.
(8) 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 [illegible] 9 [illegible] 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 are 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 are 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 [illegible] the drawing number, [illegible] component part. Drawing numbers should be [illegible] the propeller the [illegible] in the manufacturer's [illegible] general drawing file for each manufacturer [illegible] different models need not be re-submitted.

14.203 (a) A [illegible] PERSON MAKING THE TEST OR SIGNED BY A WITNESSING INSPECTOR OF THE ADMINISTRATOR, [illegible] THE ADMINISTRATOR, DESCRIBING THE MANUFACTURER'S TESTS OF THE PROPELLER [illegible] §§ 14.23 OR 14.22, AS THE CASE MAY BE. THE LOG SHALL [illegible] NAMES OF PERSONS INVOLVED; NAME AND MODEL [illegible] IDENTIFICATION MARK OF THE AIRPLANE ISSUED [illegible] WITH CORRESPONDING ENGINE [illegible] THE RESULTS OF A DETAILED INSPECTION OF THE PROPELLER AFTER [illegible] WITH § 14.23.

The log should [illegible] affidavit or signed by the [illegible] or tabular engine log with 15-minute [illegible] stops should be noted and accounted for. Tests [illegible] pitch wood propellers must be witnessed by a CAA [illegible] (see 14.21-1) and the test log will be [illegible] on conventional fixed-pitch wood propellers will [illegible] be witnessed by an inspector. A new manufacturer's [illegible] test will always be witnessed. The essential items for this type [illegible] report are given below. This type of report or its equivalent [illegible] be used.

FIXED-PITCH WOOD [illegible]

1. Test Data

(a) Propeller Model No. _____ Serial No. _____
(b) *Airplane License [illegible]
(c) Engine Model No. _____ Serial No. _____
(d) *Total Period of [illegible] _____ hrs., including _____ rpm.
(e)**Total Period of [illegible] _____ hrs. at _____ rpm.

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 _____

* 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 log.

3. Inspection after test

(a) Tipping and attachments
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
Worn, oval or burred _____
Satisfactory _____
Comments _____

(d) Condition of wood in general
Longitudinal cracks _____
Transverse cracks _____
Comments _____

4. Conformity check

Item	Drawing	Measured
Overall 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) _____

Subscribed and sworn to before me this_____day of_____

19___.

14.204 (a) A STRESS ANALYSIS MAY BE 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 on 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 EACH TYPE SHALL BE SUBJECTED TO A 50-HOUR ENDURANCE BLOCK TEST ON AN INTERNAL-COMBUSTION ENGINE DIRECTLY MOUNTED AND OF THE SAME CHARACTERISTICS AS THE ENGINE ON 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 AS PERIODS OF 5 HOURS OR MORE EACH. THE CYCLICAL MODE OF THE ENGINE USED FOR THE TEST WILL DETERMINE THE MAXIMUM MODE OF THE PROPELLER 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 HOT RUN AT FULL THROTTLE, AND HORSEPOWER MEASUREMENTS ARE NOT REQUIRED 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 BRAKEPOWER 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 EACH 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 INTERVALS THROUGHOUT THE OPERATING RANGE WHEN THE DESIGN SO PERMITS. ALL VARIATIONS IN RUNNING CHARACTERISTICS OF THE PROPELLERS SHALL BE RECORDED.

a. 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.

b. 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 oscillograph 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 rpm range as possible, i.e., from take-off rpm down to 25% 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% increase granted for the take-off operation or at 91% take-off power and speed with a 10% 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 measurement.

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 run to within 25 rpm 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 power-speed 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 aids in both finding aluminum alloy propeller cracks. The rubbing in of the oil helps 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 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 [illegible] Runs of 5-minute duration should also be made at [illegible] intervals on this type of propeller. Similarly, [illegible] times in running characteristics should be obtained. In addition these required tests of the pitch-changing mechanism should be such that it be further subjected to a reasonable number of [illegible] cycles in the case of a manual [illegible] the case of an automatic [illegible]

14.210 A PROPELLER OF THE SAME TYPE AS, A DESIGN IDENTICAL TO, OR A DESIGN CLOSELY SIMILAR TO A PREVIOUSLY CERTIFICATED PROPELLER OF THE SAME MANUFACTURE MAY BE GIVEN A 50-HOUR FLIGHT TEST IN LIEU OF THE TEST OUTLINED IN 14.211 PROVIDED THIS CAN BE DEMONSTRATED TO THE SATISFACTION OF THE ADMINISTRATOR BY A COMPARISON OF DATA SUBMITTED BY THE MANUFACTURER. SUCH STRESS ANALYSIS DATA SUBMITTED IN SUPPORT OF A NEW PROPELLER CERTIFICATE, VIBRATION, AND TORQUE IMPULSE DATA OBTAINED DURING FLIGHT TESTS OF A NEW PROPELLER, A MATHEMATICAL COMPARISON, WHICH PERMITS, AND AT SUITABLE POINTS PLOTTED AGAINST PROPELLER AS ABSCISSAS. CURVES DESCRIPTIVE OF THE FAILURE OF THE PROPELLER SHALL BE SUBMITTED WHEN APPLICABLE. SUCH 50-HOUR FLIGHT TEST SHALL BE CONDUCTED AT A SETTING OF POWER AND SPEED THAT THAT IS CONJUNCTION WITH WHICH THE RATING IS REQUESTED. AT LEAST THE TEST SHALL BE RUN AT THE PROPOSED RATED SPEED OF THE PROPELLER.

14.211 IT IS RECOMMENDED THAT METAL PROPELLERS OF THIS TYPE BE TESTED BY [illegible] METHODS TO DETERMINE THEIR NATURAL FREQUENCIES WITHIN ALL RANGES OF [illegible] RECORDED BY THE OPERATION OF THE ENGINE IN CONJUNCTION WITH WHICH THE PROPELLER ARE TO BE CERTIFICATED FOR USE. SUCH FREQUENCIES SHOULD BE DETERMINED AT ALL [illegible] WITH A VIEW OPERATING WITH BANDS OF FREQUENCIES. DATA COVERING THESE [illegible] ADMINISTRATOR IN THE FORM OF CURVES AND TABLES. THE TYPE [illegible] THE WORDS 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:

$$F_r^2 = f_o^2 + CN^2$$

where F_r = resonant frequency of the rotating propeller,

F_o = resonant frequency at zero rpm,

N = propeller rpm, and

C = vibration mode coefficient.

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

C = 1.2 - 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 degrees to 90 degrees in order to determine the susceptibility 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.

14.23 Tests required for propellers. A propeller of such type shall be subject to a 10-hour endurance block test on an engine-dynamometer engine, or to a 50-hour flight test. The testing shall be witnessed by an authorized inspector of the Administration or a representative of the Administrator. In the case of a block test the entire test shall be run at the 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 in an aircraft of equal or greater power and speed load than that in connection with which the propeller is to be certificated for use.

1. The 10-hour endurance block tests 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 rpm is maintained throughout the test. Since rpm 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 within plus or minus 2% rpm of the proposed rating. The test may be made in suitable increments, provided that all stops are adequately explained in the test log.

[illegible] The 50-hour flight test should be run on the same [illegible] of airplane on which the propeller will be used and the [illegible] diameter and pitch for which certification is desired should be [illegible]. The engine power and speed should be equal to or [illegible] speed those for which the propeller is to be certificated and [illegible] hours should be run at the proposed rated speed. As the [illegible] observed factor upon which approval is based [illegible] be accurately determined. Suitable checks, as [illegible] the preceding paragraph, should be made and noted on the [illegible]

[illegible] INSPECTION OF A TESTED PROPELLER. AS PRESCRIBED IN § 14.203, THE [illegible] OF THE [illegible] ON THE [illegible] TEST SHALL INCLUDE THE RESULTS OF A DETAILED INSPECTION OF THE PROPELLER [illegible] PHOTOGRAPHS OF ANY FAILURES OR SUSPECTED FAILURES SHALL BE INCLUDED. A PROPELLER WHICH [illegible] COVERS THE TESTING IS NOT ELIGIBLE FOR CERTIFICATION UNLESS THE FAILURE IS OF A [illegible] THE [illegible] OF THE PROPELLER IS NOT IMPAIRED AND A MINOR MODIFICATION TO THE PROPELLER [illegible] PRECLUDE THE PROBABILITY OF FUTURE FAILURES OF THE SAME TYPE. ALUMINUM-ALLOY PROPELLERS [illegible] STEMPS 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 [illegible]

[illegible] 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.

... fixed-pitch wood propellers should be thoroughly examined ... evidences of loosened or excessively cracked tipping, opened ... joints, cracks in the wood and local failure or cracking ... and the hub bolt holes. These items are adequately covered ... the sample test report, pages 23 and 24. A certain amount ... flexural cracks in the metal tipping is considered normal.

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

(a) (iv) 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 internal fails or cracks, if a glue joint opens, or if there is any local failure or cracking around the hub or a bolt. Similar considerations will apply to propellers of any patented construction or of other than conventional wood or metal construction.

(b) 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 has been previously furnished 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 manufacture, 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.

[illegible]

[illegible] each model.

[illegible] major [illegible] must therefore be [illegible] as minor. In [illegible] tal propeller will [illegible] est requirements of [illegible]

[illegible]

[illegible]

[

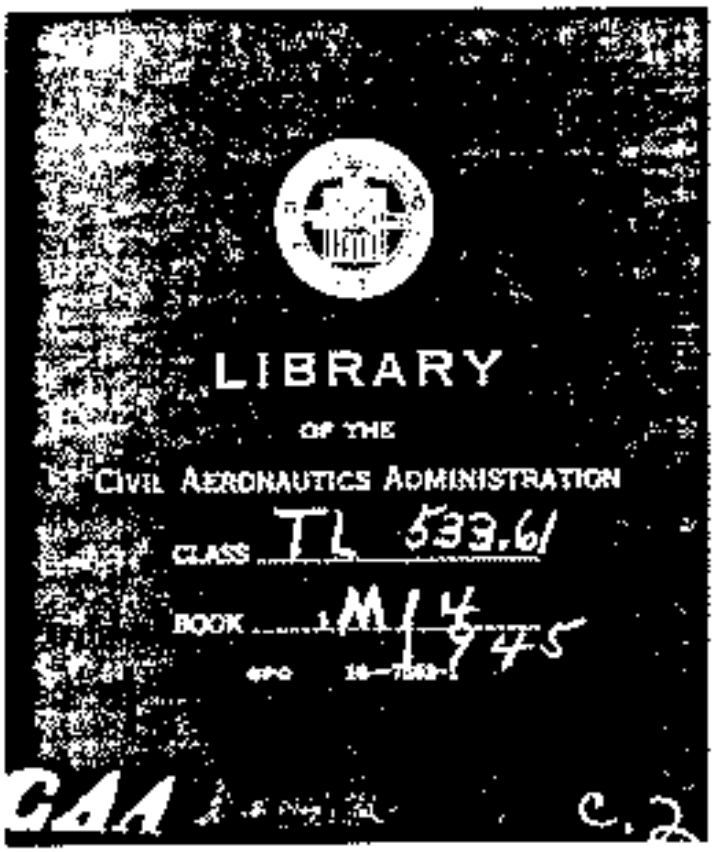
chan[illegible] minor or major in nature, [illegible] should in all cases be referred to the Civil Aeronautics [illegible]tration.

14.53 MINOR CHANGES. [illegible] JANUARY 1 [illegible] 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 six months should be submitted during January and July of each year. If a drawing list was origi[illegible]ly 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.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