Australian Government
Civil Aviation Safety Authority

ADVISORY CIRCULAR
AC 35-01 v1.1

Wooden propellers

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Advisory circulars are intended to provide advice and guidance to illustrate a means, but not necessarily the only means, of complying with the Regulations, or to explain certain regulatory requirements by providing informative, interpretative and explanatory material.

Advisory circulars should always be read in conjunction with the relevant regulations.

Audience

This advisory circular (AC) applies to propeller designers and manufacturers.

Purpose

The purpose of this AC is to provide guidance relating to the manufacture of fixed pitch wooden propellers.

For further information

For further information on this AC, contact CASA's Airworthiness and Engineering Branch (telephone 131 757).

Status

This version of the AC is approved by the Manager, Airworthiness and Engineering Branch.

Version	Date	Details
v1.1	December 2022	Administrative review only.
v1.0	December 2017	Initial issue

Unless specified otherwise, all subregulations, regulations, Divisions, Subparts and Parts referenced in this AC are references to the *Civil Aviation Safety Regulations 1998 (CASR)*.

Contents

1 Reference material

1.1 Acronyms

The acronyms and abbreviations used in this AC are listed in the table below.

Acronym	Description
AC	Advisory Circular
CAO	Civil Aviation Order
CAR	*Civil Aviation Regulations 1988*
CASA	Civil Aviation Safety Authority
CASR	*Civil Aviation Safety Regulations 1998*
CS-P	Certification Specifications - Propellers
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration (of the USA)
FAR	Federal Aviation Regulation (of the USA)
SWG	Standard Wire Gauge

1.2 Definitions

Terms that have specific meaning within this AC are defined in the table below. Where definitions from the civil aviation legislation have been reproduced for ease of reference, these are identified by 'grey shading'. Should there be a discrepancy between a definition given in this AC and the civil aviation legislation, the definition in the legislation prevails.

Term	Definition
Blushing	Trapped solvent or moisture in the finish that gives a white/grey cloud look to the coating. It can appear in spots or across the entire piece.
Wane	A defect in a plank or board characterised by bark or insufficient wood at a corner or edge, generally due to the curvature of the log.
Want	The absence of bark or surface wood from the log caused by anything other than wane.
Callus tissue	Undifferentiated tissue developing in response to a wound.

1.3 References

Legislation

Legislation is available on the Federal Register of Legislation https://www.legislation.gov.au/

Document	Title
Part 21	Certification and airworthiness requirements for aircraft and parts

Document	Title
Part 35	Airworthiness standards for aircraft propellers
Civil Aviation Order (CAO) 108.28	*Civil Aviation Order 108.28 Instrument 2007*
CAO 108.29	*Civil Aviation Order 108.29 Instrument 2007*

Advisory material

CASA's advisory materials are available at https://www.casa.gov.au/publications-and-resources/guidance-materials

Document	Title
AC 21-14	Production Certificates

Additional advisory material

Document	Title
FAA[1] FAR[2] Part 35	Airworthiness standards: Propellers
EASA[3] CS-P	Certification Specification Propellers

[1] Federal Aviation Administration (of the USA).
[2] Federal Aviation Regulation (of the USA).
[3] European Aviation Safety Agency.

2 Background

Propellers are a Class 1 product and require a type certificate to be approved for use on a type certificated aircraft. A type certificate can be obtained under Part 21 for a propeller that meets the airworthiness standards mentioned in Part 35. Part 35 includes recognition of the Federal Aviation Administration (FAA) Federal Aviation Regulation (FAR) Part 35 and European Aviation Safety Authority (EASA) Certification Specifications for Propellers (CS-P).

Repealed Civil Aviation Order (CAO) 108.28 contained standards relating to the practices used in the manufacture of fixed pitch wooden propellers. Requirements regarding the selection of timber for use in the manufacture of laminated wooden propellers were contained in CAO 108.29.

The information previously contained in CAOs 108.28 and 108.29 that is still useful for the manufacture of wooden propellers, as well as for the selection of timber for the use in manufacture of wooden propellers, has been reproduced as guidance material within this AC.

NOTE

The information in this AC does not supersede the requirements specified in any applicable airworthiness standards or approved design.

3 Manufacturing processes for wooden propellers

3.1 Lamina

3.1.1 Wooden propellers are typically of laminar construction. Each lamina should be cut from the planks so that the direction of its grain is as parallel to its length as possible. The inclination of the grain on the edges of the short lamina used at the front and back faces of a propeller must not exceed 1-in-12 on the edges relative to the glued faces, and on the faces relative to the longitudinal axis of each lamina, as determined by the splitting test or alternatively, as described in Appendix A.1.

3.1.2 The thickness and number of lamina to be used in a propeller should be specified on the approved drawing.

Note: Where it is permitted to depart from the thickness given on the drawing, the dimensions adopted must be such that at least two laminations extend the full length of the blade, i.e. from tip to tip.

3.1.3 After being cut to shape and reduced to the required thickness, the lamina should be kept in the gluing room (or under similar atmospheric conditions to the gluing room) for a period of at least 24 hours before being glued to stabilise or maintain moisture content as per paragraph 4.4. Any laminae found to be warped or split at the expiration of this period should be rejected.

3.1.4 Side-by-side jointing of lamina may be used if the joint(s) in adjacent lamina in the assembled block are discontinuous by at least 20 mm at the centre of the propeller.

3.1.5 The lamina, which comprise the basic propeller block, should be selected and arranged so as to ensure (as far as possible) that the static balance of the complete assembly is easily achievable (refer paragraph 3.8).

3.2 Gluing

3.2.1 Adhesives are to be used strictly in accordance with the adhesive manufacturer’s instructions, unless specified otherwise in the approved design.

Note: Resorcinol formaldehyde or epoxy adhesives prepared specifically for timber are acceptable. Whereas, acid catalysed phenolics and/or urea formaldehyde type adhesives are not acceptable, being subject to fungal attack or deterioration in hot, moist environments.

3.2.2 The base on which the laminae are to be glued together should be flat and rigid, and should provide continuous support for the entire length of the block of wood being laminated.

3.2.3 Clamping of the laminae should be started at the centre of the block, after which the additional clamps should be fixed alternately on either side until the ends of the block are reached. The distance between adjacent clamps should not exceed 300 mm.

3.2.4 Clamp pressures should be in accordance with the requirements of the selected adhesive.

3.2.5 The block should be left with the clamps in place until the adhesive has completely cured in accordance with the conditions specified in the data for the adhesive used.

3.2.6 After the clamps have been removed, the block should be left for at least 48 hours before further operations are commenced. When the block has been removed from the gluing base, it should be stored in a horizontal position, lying on one of the boss faces.

3.2.7 Samples of the bonded wood, either from coupons made during manufacture of each propeller using the same wood and adhesive, or from off cuts from the glued propeller block, should be used for destructive testing to verify the strength of the bond. The wood should break away from the glue line.

3.2.7 The manufacturing records for each propeller should include the details of the adhesive used (i.e. adhesive brand and batch number).

3.3 Boring and drilling

3.3.1 The bore and bushing holes should be straight, circular, smooth and parallel to the axis of rotation. The bolt holes should be jig drilled.

3.3.2 The boss or hub faces should be flat, smooth and perpendicular to the axis of the bore.

3.3.3 To prevent exposure of the end grain, a suitable protective covering should be applied immediately upon completion of the drilling operations.

3.3.4 Unless otherwise stated on the approved drawing, the manufacturing limits, dimension tolerances and clearances should be as specified in Table 1:

Table 1: Dimension tolerances

Dimension	Tolerance
Bore	-0.0 to +0.5 mm
Diameter of bolt holes	-0.0 to 0.4 mm on nominal bolt diameter
Position of bolt holes	Within 0.5 mm of specified dimensions
Distances between the boss faces	±2.0 mm
Diameter of counter boring (if any)	-0.0 to +2.0 mm
Diameter of boss	-3.0 to +4.0 mm

3.4 Shaping

3.4.1 After being roughly shaped, unless otherwise specified, the propeller should be stored for at least 10 days under atmospheric conditions similar to those existing in the final shaping shop (i.e. under conditions that will achieve or maintain 10-15% moisture content and typically at a temperature greater than 15°C).

3.4.2 To prevent exposure of the end grain, a suitable protective covering should be immediately applied to the end grain exposed by shaping operations in the area where the blade roots blend into the boss.

3.4.3 The propeller should be carefully examined during the shaping process for faults or defects.

3.5 Inspection

3.5.1 On completion of the final shaping, the propeller should be inspected for accuracy of angles, dimensions, track and balance, and for general finish against the approved drawing.

3.5.2 Unless otherwise stated on the approved drawing, the allowable tolerances on angles, chords, maximum thickness, diameter and track should be as stated in Table 2:

Table 2: Allowable tolerances

Item	Allowable tolerances
Angles	± 1° throughout the inner third of the blade length. ± ½° throughout the outer two-thirds of the blade length.
Chords	± 1 mm for chords up to 50 mm increasing by ± 0.5 mm for each 50 mm of chord, or part thereof, in excess of 50 mm.
Maximum thickness	± 0.5 mm for thickness up to 10 mm increasing by ± 0.2 mm for each 10 mm, or part thereof, in excess of 10 mm.
Diameter	± 5 mm.
Track	± 1 mm for propellers of up to 1.5 m diameter, increasing by ± 0.5 mm for each 1 m, or part thereof, in excess of 1.5 m diameter.
Plan form	For propellers of up to 1.5 m in diameter, a tolerance of 2 mm is allowed on the distances (as given in the approved drawing) between the trailing edge of all sections (except that nearest the tip) and a datum plane containing the axis of the bore and the centre line of the section nearest the tip. This tolerance may be increased by ± 1 mm for each 1 m, or part thereof, by which the diameter exceeds 1.5 m

3.6 Protective treatment

3.6.1 The propeller should be finished in accordance with the instructions specified on the approved drawing.

3.6.2 Where lacquering is to be used, the following processes should be applied:

- prior to lacquering: the surfaces of the propeller should be smooth, even, dry and clean. Any small depressions remaining after the propeller has been rubbed down with fine sand paper may be filled up with plastic wood or similar filling.
- to prevent blushing: the lacquering should be carried out at a temperature typically between 20 - 30°C, at the required wet bulb/dry bulb relative humidity in a room, which should be free from draughts.
- on completion of the lacquering: the propeller surfaces should be smooth and entirely free from bubbles and pin holes, and the film of lacquer should typically be between 0.10 - 0.15 mm thick.

3.6.3 Where fabric covering is to be used, the following processes should be applied:

- fabric intended for covering propeller blades should comply with the specification provided in the approved drawing
- the covering for each blade should be in one piece and should be applied and extend to the position as stated on the approved drawing
- the covering process should ensure that the adhesive or coating used to bond the fabric to the propeller achieves complete penetration of the fabric, and that the fabric is laid down with minimum 'waviness' of the cloth, and be without bubbles and pinholes
- all coatings are applied and allowed to dry at a temperature typically not less than 20°C at the required relative humidity, and in a room which should be free from draughts
- after being allowed to dry for at least 12 hours, the fabric covering should be given one coat of undercoating varnish complying with a specification as provided in the approved drawing.

3.7 Metal sheathing

3.7.1 The metal leading edge sheathing (if specified) should be fitted in accordance with the instructions on the approved drawing.

3.7.2 Localised reduction of the thickness of sheath segments (e.g. by filing) to achieve correct fit or static balance etc. is prohibited. The segments should be worked in accordance with the approved drawing and in a way as to make such re-working unnecessary.

3.7.3 Sheaths should be attached in accordance with the approved drawings, typically using countersunk wood screws (suitably plated or dipped) except where the blade is less than 10 mm thick, in which region 14 SWG tinned copper rivets should be used. The position and spacing of screws and rivets should be as indicated on the approved drawing.

3.7.4 To prevent any movement of sheath segments relative to the blades, the edges of the screw and rivet holes in the segments should be punched or spun into the timber. This forms a countersink for the screw or rivet head that, when in place, should be slightly below the surface of the sheath. Care should be taken to prevent bulging or buckling of the sheath and/or damage to the covering and timber during the punching or spinning processes.

3.7.5 Slots in screw heads should be thoroughly cleaned before the screws are inserted. After insertion, screw and rivet heads should be flooded over with soft solder.

3.7.6 The application of solder to the whole or to any segment of a sheath for the purpose of securing balance is prohibited unless permitted in the approved drawing.

3.7.7 Drainage of the propeller blades should be provided for by filing slots or drilling holes in the tip segments after they have been lapped over and secured.

3.7.8 Care should be taken to avoid damage to the blade structure, surface or protective coverings when installing and forming the edges of the sheaths.

3.8 Static balance

3.8.1 The propeller should be tested for static balance at the following stages:

- during final stages of shaping
- after final shaping has been completed
- after sheaths have been fitted
- when it is in the finished state (except for any small alteration necessary to secure balance)
- after any necessary alterations, as required by the preceding tests.

3.8.2 The static propeller balance tests should be made using a balancing stand and adapting mandrills etc. that have been tested and shown to be capable of detecting an imbalance significantly less than the maximum permitted imbalance (refer to Table 2) with the known errors documented.

3.8.3 During the tests specified in paragraph 3.8.1, and making allowance for the known error for the balancing apparatus as determined by testing it with the propeller in position, any lack of balance detected in the propeller should not exceed the following limit whatever the position of the propeller in the plane of rotation:

- 1,500 mm-g for propellers of up to 2 m diameter
- increasing by 750 mm-g for each 1 m, or part thereof, for propellers in excess of 2 m diameter.

3.8.4 If the propeller does not satisfy the requirements stated in paragraph 3.8.3, the error should be corrected in the following manner:

- during final shaping and after the final shaping has been completed—by removing the timber from the propeller to the extent permitted by the tolerances stated in Table 1 and Table 2.
- when it is in the finished state—by the application of cellulose, lacquer, varnish or other specified coating (whichever is appropriate).

3.8.5 Any other method of securing balance is prohibited unless otherwise specified in the approved drawing.

3.9 Identification markings

3.9.1 Propellers must be marked in accordance with the requirements of Subpart 21.Q.

3.9.2 Each propeller should be marked with all of the details indicated below:

- the manufacturer's name
- the diameter and pitch in metres or feet (preceded by the letters D and P, respectively) according to the metrics nominated in the applicable aircraft flight manual
- the identification number of the type certificate (if any) of the propeller
- the identification number of the production certificate (if any) under which the propeller was manufactured
- the model designation of the propeller, hub or blade
- the serial number.

3.9.3 Information marked on a propeller, blade or hub should be marked in a way such that it is not likely to be defaced.

3.9.4 If a data plate is to be attached to a propeller, blade or hub, the plate should be attached to a non-critical surface, in a way that ensures as far as possible that the plate cannot be detached.

3.9.5 Care should be taken to ensure that all stamp impressions are and should remain legible and not liable to misinterpretation.

4 Timber for use in aircraft propellers

4.1 Acceptable timbers

4.1.1 Acceptable types of timber used for aircraft propellers are listed in Table 3.

Table 3: Acceptable timbers for use in wooden propeller manufacture

	Approved timber	Minimum density (kg/m^3)
1	Ash, Mountain/Ash Alpine *(Eucalyptus regnans/ Eucalyptus delegatensis)*	601
2	Ash, Silver, Northern *(Flindersia pubescens)*	633
3	Ash, Silver Queensland *(Flindersia bourjotiana)*	577
4	Beech, Myrtle *(Nothofagus cunninghamii)*	671
5	Birch, White *(Schizomeria ovate)*	604
6	Bollywood *(Litsea reticulate)*	449
7	Coachwood *(Ceratopetalum apetalum)*	577
8	Mahogany Honduras *(Swietenia macrophylia)*	513
9	Maple, Queensland *(Flindersia brayleyana/pimenteliana)*	513
10	Oak, Silky Southern *(Grevillea robusta)*	615
11	Pine, Bunya *(Araucaria bidwillii)*	420
12	Pine, Hoop *(Araucaria cunninghamii)*	455
13	Pine, Klinki *(Araucaria hunsteinii)*	385
14	Sassafras *(Doryphora sassafras)*	543
15	Spruce, Sitka *(Picea sitchensis)*	384

4.1.2 Timber for use in wooden propellers should be quarter sawn, unless otherwise approved by the approved drawing.

4.2 Quality

4.2.1 The timber should be clearly identified with respect of species and should be of known origin.

4.2.2 The timber should be in the form of selected planks, which should be free from warp. Sloping grain is permitted but not exceeding 1-in-12, as determined by the splitting test or alternatively as described in Appendix A.1.

Note: Deviation of grain due to knots of permissible size may be disregarded as per paragraph 4.2.4.

4.2.3 The timber should be clean and free from:

- obvious and incipient decay
- knots (as per 4.2.4)
- shakes
- splits
- seasoning checks
- internal checks
- fractures
- brittle heart
- compression failures
- bark pockets, gum pockets or gum veins
- callus tissue
- insect attack, wane or want.

4.2.4 The following imperfections are permitted:

- pin-knots not exceeding 3 mm diameter and not closer than 50 mm to each other
- pin-holes not exceeding 1.5 mm diameter and not more than 3 in any 10 000 square mm of surface area, and no two should be closer than 50 mm to each other
- small, isolated imperfections that do not significantly affect the strength of the timber (i.e. wavy grain, interlocked grain, flecks, spots, fine drying checks and blemishes).

4.3 Seasoning

4.3.1 The timber should have been either air-dried or kiln-dried to a moisture content within the limits specified in section 4.4. Mountain ash and alpine ash after seasoning to 12% moisture content should be reconditioned for 6 hours at 100°C (saturated conditions). The material should then be air or kiln dried.

4.4 Moisture content

4.4.1 The moisture content of each plank should be determined by means of an electrical resistance type moisture meter or other approved method (see Appendix A.2). Tests should be made at points approximately 300 mm from each end and at the mid length.

4.4.2 The 3 readings should lie between 10% - 15%, and the individual readings should not vary more than 2% moisture content in any one plank. The average moisture content should not vary more than 3% between planks.

4.5 Density

4.5.1 With moisture content within the limits specified in section 4.4, the measured density of each plank should not be less than the value given in Table 3 for the particular timber.

4.5.2 An acceptable method for determining density is given in Appendix A.3.

4.6 Brittleness

4.6.1 In order to detect brittleness, two samples from each plank should be tested for impact resistance in an Izod testing machine. Details of the Izod test method are given in Appendix A.4. The Izod values obtained for the standard specimen should not be less than 6.5 joules.

4.7 Marking

4.7.1 Each acceptable plank should be ink stamped with the standard name of the timber (i.e. Maple, Queensland, Coachwood, Mahogany, Honduras, etc.)

4.7.2 The manufacturing records for each propeller should include the details of the planks used, as the markings of each plank will be lost during manufacture.

Appendix A

Acceptable testing methods for wood

A.1 Methods for the determination of the direction and slope of grain

A.1.1 The following are some methods to determine the direction and slope of grain in the selected wood:

- the direction of splitting is usually the best guide to the slope of the grain
- splinters pulled out from the surface of a piece of wood with a pocket knife will also reveal the grain direction
- a drop of ink placed on a face of the piece of wood will spread most readily in the direction of the grain
- a swivel handled scribe may also be used to determine the slope of grain in wood.

A.2 Method for the determination of moisture content

A.2.1 Take a small sample of the timber from the appropriate position, weigh it (W1) to an accuracy of 1% of its weight and then desiccate it in an oven at a temperature of 100°C-105°C until the weight is constant (WO), taking great care to prevent any change in moisture content between the cutting of the sample and the first weighing and also between removal from the oven and the subsequent weighing. Calculate the moisture content as follows:

$$Moisture\ content\ (\%) = \frac{100(W_1 - W_0)}{W_0}$$

A.3 Method for the determination of density

A.3.1 Cleanly cut a sample, approximately 2.5 cm long and of the full cross-section of the board or plank, from each end of the piece at a position clear of weathering, where the moisture content is known or is about to be determined. Make a series of measurements of the length, width and thickness of each sample, obtain the arithmetic mean of each dimension and calculate the volume (V) of the samples in cubic centimetres. From each sample take the weight (W) in grams to an accuracy of ± 1% of its weight. Calculate the density as follows:

$$Density = \frac{1000\,W}{V}\ (kg/m^3)$$

where: W is in grams
V is in cubic metres.

A.4 Brittleness (Izod) test

A.4.1 Test specimens

A.4.1.1 Two samples should be cut from diagonally opposite edges from one end of the plank. A notched specimen, the sides of which are cut radially and tangentially, of the form and dimensions shown in Figure 1, must be prepared from each of the samples.

A.4.2 Procedure

A.4.2.1 The test specimens must be broken in an Izod impact testing machine, the blow being applied in the direction tangential to the growth rings. The testing machine must be of a type which will permit the test results being determined to within 0.3 joule. The Izod values obtained for the standard specimen shown in Figure 1 must not be less than 6.5 joules.

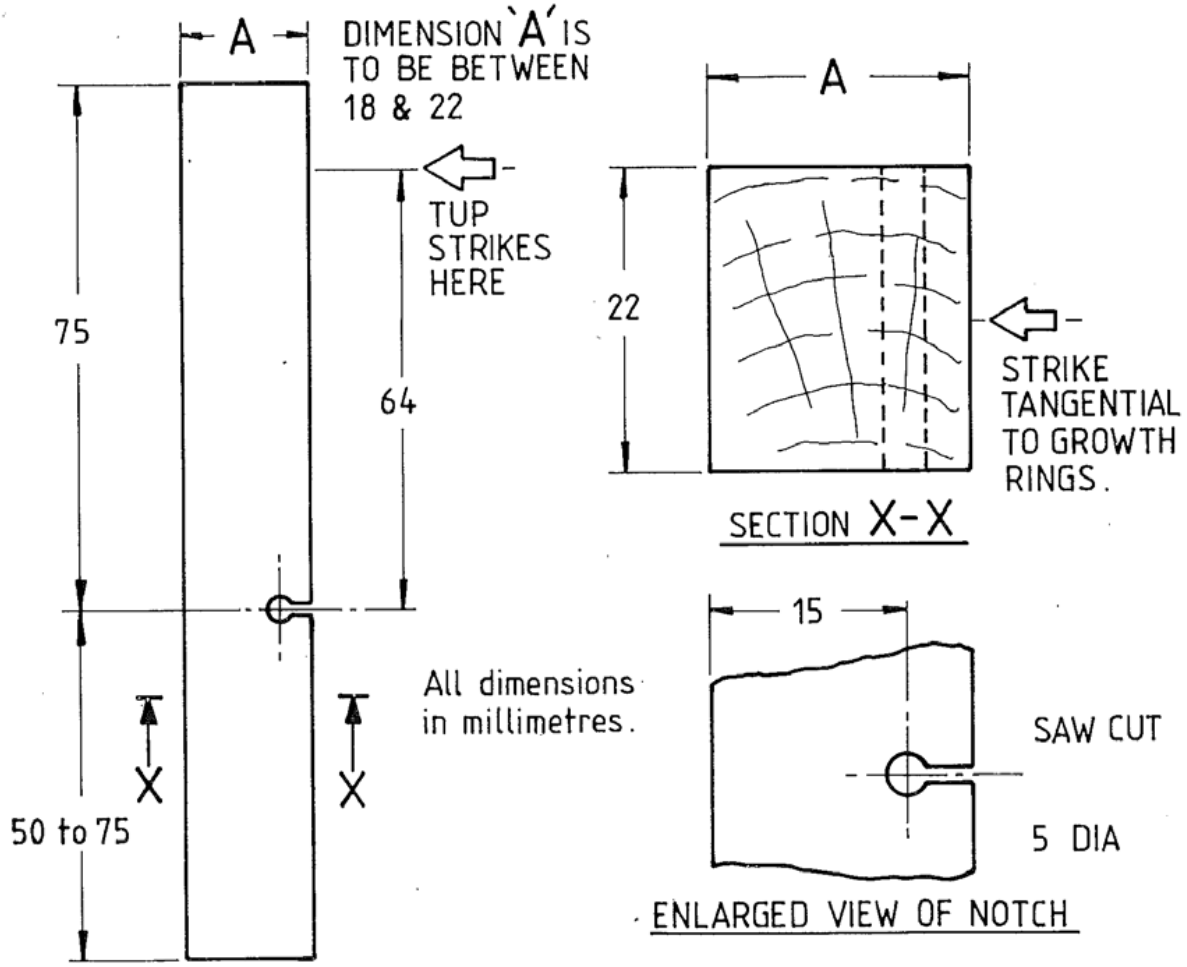

Figure 1: Impact test specimen