U.S. Department
of Transportation
Federal Aviation Administration

Advisory Circular

Subject: CERTIFICATION OF PROPELLERS **Date:** 12/29/08 **AC No:** AC 35-1
Initiated by: ANE-110 **Change:**

1. Purpose. This advisory circular (AC) provides guidance and describes acceptable methods, but not the only methods, that may be used to demonstrate compliance with provisions of the requirements of part 35 of Title 14 of the Code of Federal Regulations (14 CFR part 35).

2. Applicability.

a. The guidance provided in this document is directed to propeller manufacturers, modifiers, foreign regulatory authorities, and Federal Aviation Administration (FAA) propeller type certification engineers and their designees.

b. This material is neither mandatory nor regulatory in nature and does not constitute a regulation. It describes acceptable means, but not the only means, for demonstrating compliance with the applicable regulations. We ("the FAA") will consider other methods an applicant may present to demonstrate compliance. Terms such as "should," "shall," "may," and "must" are used only in the sense of ensuring applicability of this particular method of compliance when the method in this document is used. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. If we find that following this AC would not result in compliance with the applicable regulations, we will not be bound by this AC, and we may require additional substantiation as the basis for finding compliance.

c. This material does not change, create any additional, authorize changes in, or permit deviations from existing regulatory requirements.

3. Cancellation. This AC cancels the following policy memoranda.

a. ANE-2002-35.15-R0, Policy for Propeller Safety Analysis, October 30, 2003.

b. ANE-2001-35.13-R0, Policy for Propeller-Level Failure Effects, March 12, 2003.

c. ANE-2001-35.31-R0, Policy for Bird Strike, Lightning, and Centrifugal Load Testing for Composite Propeller Blades and Spinners, March 12, 2003.

4. Related Regulations and Documents.

a. Related Regulations.

(1) 14 CFR Part 21, Certification Procedures for Products and Parts.

(2) 14 CFR Part 23, Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes.

(3) 14 CFR Part 25, Airworthiness Standards: Transport Category Airplanes.

(4) 14 CFR Part 33, Airworthiness Standards: Aircraft Engines.

(5) 14 CFR Part 45, Identification and Registration Marking.

(6) European Aviation Safety Agency (EASA) Certification Specifications for Propellers (CS-P) Amendment 1, November 16, 2006.

b. Related Documents.

(1) AC 20-66A, Vibration and Fatigue Evaluation of Airplane Propellers, September 17, 2001.

(2) AC 20-107A, Composite Aircraft Structure, April 25, 1984.

(3) AC 35.4-1, Propeller Instructions for Continued Airworthiness, November 3, 2003.

(4) AC 35.37-1A, Guidance Material for Fatigue Limit Tests and Composite Blade Fatigue Substantiation, September 17, 2001.

(5) ANE-2007-35.23-1, Policy for Electronic Propeller Control Systems, §§ 35.21 and 35.23, August 22, 2007.

(6) Order 8110.4C, Type Certification, October 26, 2005.

5. Background. This AC was developed in conjunction with the FAA's revision to the airworthiness standards for the issuance of original and amended type certificates (TCs) for airplane propellers. The previous amendment of propeller requirements did not adequately address the technological advances of the past twenty years. The standards for part 35, published in the Federal Register on October 24, 2008 (73 FR 63339), address the current advances in technology and harmonize the FAA requirements with the EASA certification specifications. This amendment will establish nearly uniform standards for airplane propellers certified by the FAA and by the EASA, thereby simplifying airworthiness approvals for imports and exports.

//signed by Peter A. White//
Peter A. White
Acting Manager, Engine and Propeller Directorate

TABLE OF CONTENTS

CHAPTER 1. INTRODUCTION

1.1 General. This AC provides procedures and guidance for the type certification of propellers.

1.2 Definitions. The following terms and definitions apply in this AC.

a. Analysis and assessment. The two terms are, to some extent, interchangeable. However, “analysis” generally implies a specific and detailed evaluation, while “assessment” implies a general or broader evaluation that may include one or more types of analysis. In practice, the distinction comes from the specific application (for example, Functional Hazard Analysis (FHA), Fault Tree Analysis (FTA), Markov Analysis, or Preliminary System Safety Assessment (PSSA)).

b. Beta control. A system whereby the propeller blade angle is directly selected. For constant speed propellers, beta control is normally used during ground handling, including reverse pitch angles.

c. Check. An examination, inspection, or test that determines physical integrity, functional capability, or both.

d. Conventional. The same as, or closely similar to, that of previously approved systems, components or attributes that are commonly used.

e. Dormant failure. A failure the effect of which is not detected for a given period of time.

f. Failure condition. A condition with direct, consequential propeller-level effects caused or contributed to by one or more failures.

g. Failure mode. The mechanism of the failure or the manner in which an item or function can fail.

h. Feather. Moving the blade angle to feathered pitch.

i. Feathered pitch. The pitch setting that corresponds to an in-flight windmilling torque and rotational speed of approximately zero.

j. Fixed pitch wood propellers of conventional design. A propeller that has the following physical properties:

- One piece laminated wood construction
- Two or four blades
- The surface coating does not contribute to the propeller strength
- The surface coating only provides environmental protection

A fixed pitch propeller with a composite shell over a wood core is not a conventional design when the composite shell contributes to the strength and frequency response of the propeller. A fixed pitch wooden propeller with a fabric or composite covering that does not alter the structure for environmental protection is of conventional design.

k. Fixed pitch metal propellers of conventional design**.** A propeller that has the following physical properties:

- One piece solid metal construction
- Two blades

l. Ground adjustable-pitch propeller. A propeller whose pitch setting can be changed during field maintenance but not when the propeller is rotating.

m. Ground idle. The power lever position which results in zero or nearly zero thrust while the aircraft is on the ground and not moving.

n. In-flight low-pitch position. The minimum pitch permitted in flight by the control system in normal operation.

o. Pitch. The propeller blade angle, measured in a manner and at a radius declared by the manufacturer and specified in the appropriate propeller manual.

p. Pitch control system. The components of the propeller system that control pitch position, including but not limited to governors, pitch change assemblies, pitch locks, mechanical stops, and feathering system components.

q. Propeller. The propeller as defined in § 35.1(d) consists of those components listed in the propeller type design.

r. Propeller system. The propeller system as defined in § 35.1(d) consists of the propeller plus all the components necessary for its functioning but not necessarily included in the propeller type design.

s. Reverse pitch. The propeller blade angle used for producing reverse thrust with a propeller. Typically this is any blade angle below ground idle blade angle.

t. Reversible pitch propeller. A propeller in which blades can be rotated to a reverse pitch blade angle while operating.

CHAPTER 2. GENERAL

2.1. Propeller System and Propeller Type Design. Part 35 distinguishes between the propeller and the propeller system because components required to operate the propeller may not be part of the propeller type design. These components have typically been hydraulic controls, electronic controls, overspeed governors, spinners, deicing boots, and deicing components. When components are not included in the propeller type design, they are not under the design control of the propeller type certificate holder but, instead, are controlled by the aircraft or engine type certificate holders. Even though these components are not within the scope of the propeller type design, compliance with some part 35 regulations requires that representative or typical components be included and, to some extent, evaluated during the design and testing phases of propeller certification.

2.2. Components Approved for Use with the Propeller. These components are typically governors, pitch control units, de-icing equipment, spinners and other accessories that are substantiated by the applicant to operate with the propeller system and approved for use with the propeller by the certificate management Aircraft Certification Office (CMACO). They may or may not be included in the propeller type design. These components are referenced on the propeller type certificate data sheet (TCDS) notes as approved components. When not included in the propeller type design, design control of these components resides with the engine or airplane type certificate holder. A reference in Note 10 is included on the TCDS to ensure that the propeller installation with these components is approved as part of the airplane type certificate and that it complies with applicable airplane airworthiness requirements. The format for a propeller TCDS, along with the statement to be included in Note 10, is found in order 8110.4C.

2.3. De-icing Equipment. Propeller type certification does not verify compliance with part 23 or 25 airplane requirements to show that the de-icing equipment will provide acceptable ice protection performance on the airplane. Airplane icing capability is demonstrated on the airplane in accordance with applicable airplane airworthiness requirements. The deicing system on the propeller is required to meet the applicable structural and durability requirements of part 35.

2.4. Propeller-Level Failure Conditions.

a. Part 35 certification procedures address a single propeller. Therefore, the effects of failures should be assessed at the propeller level. Once the propeller passes into the certification environment of the airplane, specifics of the particular installation are used to address the issues of power plant redundancy or the effects of various failure conditions as they affect the airplane. FAA Aircraft Certification Offices (ACOs) or Directorates with airplane certification authority (under parts 23 or 25) regulate the airplane-level effects of all parts of the airplane, including the propellers.

b. Airplane-level failure classifications do not apply directly to propeller failure classifications because the airplane may have features that decrease or increase the consequences of a propeller failure effect. Additionally, the same type-certificated propeller may be used in a variety of installations, each with different airplane-level failure classifications.

c. Due to possible installation differences, airplane-level requirements for individual failure conditions may be more severe than the propeller-level requirements. Therefore, the propeller manufacturer and the airplane manufacturer should coordinate with each other, and with the appropriate FAA certification offices, to ensure that the propeller installation is acceptable to the FAA for airplane certification. Applicants should be aware that a propeller certified for a given airplane may not be eligible for operation and installation on a different airplane.

2.5. Hazardous Propeller Effects. The hazardous propeller effects are defined in § 35.15(g)(1) and are discussed in the following paragraphs.

a. Propeller failures resulting in excessive drag or significant thrust in the direction opposite to that commanded by the pilot could, depending on the flight phase, result in loss of control of the airplane. Failures that could be classified as hazardous propeller effects include unwanted low or reverse propeller pitch in flight and high forward thrust when reverse thrust is commanded. Unwanted low or reverse propeller pitch in flight, in addition to causing high drag, may result in severe overspeed of the propeller or disruption of the airflow over the wing potentially leading to increased airplane stall speed.

b. A release of the propeller, blades, hubs, counterweights, erosion shields, or other similar large rotating components with sufficient energy to penetrate a fuselage represents a hazardous propeller effect since these objects could cause damage to the airplane structure or systems or cause injury or fatality.

c. Propeller failures resulting in excessive unbalance could result in a hazardous condition related to the aircraft and to engine damage. Failures that result in excessive unbalance may include:

(1) Release of a blade;

(2) Release of a major portion of a blade;

(3) Release of a counterweight; or

(4) Unwanted pitch change of individual blades.

d. Although each of the defined propeller hazardous effects represents a compromise of safety, the propeller may have mitigating features, such as counterweights, that drive the propeller to a fail safe condition or the ability to feather the remaining blades and reduce the unbalance of the propeller.

2.6. Major Propeller Effects. The major propeller effects are defined in § 35.15(g)(2) and are discussed in the following paragraphs.

a. Feathering propellers should be able to reach the established feather angle. The rate of pitch change to reach the feather angle should not be substantially lower than that of the normally operating system.

b. Variable pitch propellers are considered unable to change pitch when the rate of pitch change is substantially lower than that of the normally operating system.

c. A significant uncommanded change in pitch would require pilot corrective action or would significantly degrade aircraft performance. To facilitate propeller system design and certification in the absence of an application-specific definition, significant uncommanded change in pitch is defined as a change that would result in change in thrust of more than 10 percent of the typical climb thrust. However, final determination of the installation requirement is based on aircraft controllability requirements and should be evaluated during aircraft certification.

d. A significant uncontrollable torque or speed fluctuation would require pilot corrective action or would significantly degrade aircraft performance. To facilitate propeller system design and certification in the absence of an application-specific definition, significant uncontrollable torque or speed fluctuation is defined as the loss of the capability to modulate rotational speed or torque within 3 percent of reference torque or speed at all normal operating conditions.

CHAPTER 3. GUIDANCE FOR SUBPART A – GENERAL

3.1. Section 35.1 Applicability.

a. Under part 35, we issue a propeller type certificate independent of the airplane and engine. Part 35, therefore, accommodates a modular propeller system concept, which allows companies to produce propellers for a variety of engine/aircraft installations. Part 35 does not require that all the potential engine/aircraft applications be listed on the propeller's TCDS, and this is not required for propeller certification. Therefore, applicants may request later that different models of a propeller that incorporate modular features, such as different flange configurations, blade models, or control configurations, be added to the propeller type certificate.

b. The phrase "or compliance is not required for installation on that airplane" in § 35.1(c) refers to airplanes that are issued special airworthiness certificates. These airplanes include those with primary, restricted, surplus aircraft of the Armed Forces, limited, light-sport, and provisional airworthiness certificates; special flight permits; and experimental certificates. Exceptions to this may apply if the Administrator finds that compliance to §§ 23.907 or 25.907 is required. These exceptions may include primary, restricted, surplus aircraft of the Armed Forces, and limited category airplanes. An airplane with a special (experimental) airworthiness certificate as defined in § 21.191, Experimental certificates, does not need to show compliance with the requirements of §§ 23.907 or 25.907.

3.2. Section 35.2 Propeller Configuration. The list of components does not need to be reduced to a piece part level. Component assemblies, such as blades or controls, may be listed by the part number of the assembly with references to the appropriate drawings.

3.3. Section 35.3 Instructions for Propeller Installation and Operation. A typical installation manual for a constant speed, feathering, and reversing propeller generally contains items listed below, as applicable. The installation manual may apply to a specific propeller model or to a family of propellers. Information listed on the propeller TCDS does not need to be repeated in the installation manual.

a. A reference to the propeller TCDS and any applicable supplemental type certificates.

b. A list of components and accessories.

c. A description of the overall propeller system.

d. A brief control system description that may reference a more detailed system description. The description should include control system characteristics and define operation in primary and all alternate operational modes. If applicants anticipate any changes in operating characteristics when transitioning between modes, or in backup mode(s), then they should describe those characteristics.

e. Interface and rigging requirements.

f. A list of propeller specifications and limitations, such as:

- Diameter
- Number of blades
- Power and r.p.m. limits
- Torque limits
- Overspeed and overtorque limits
- Propeller shaft loads
- Propeller system mounting instructions and bolt torque's
- Propeller balance (as delivered)
- Vibration environment
- Altitude versus ambient temperature limitations
- Ground deicing limitations
- Propeller system component weights
- Moments of inertia
- Center of gravity

g. Pitch change information, such as:

- Settings
- Slew rates
- Beta sensor position
- Limits on intended movement below the in-flight low-pitch-position
- Feathering limitations
- Start lock engagement and disengagement r.p.m.

h. Recommended operating procedures for the following operations, such as:

- Ground
  - Starting
  - Propeller brake
  - Overspeed governor check
  - Secondary low pitch stop check
  - Limitations and restrictions
- Deicing
- Flight
- Emergency
  - Loss of hydraulic pressure
  - Loss of electrical power
- Fault detection, isolation and accommodation

i. Ice protection system description.

j. Electrical system description, such as:

- Power requirements
- Loss of aircraft electrical power effects

k. EMI/Lightning protection information, such as:

- System description
- Qualification results
- Limitations

l. Actuation and lubrication system information, such as:

- Actuating/lubrication fluids
- Propeller pump fluid requirements
- Fluid filtration
- Lubricating fluid
- Hub lubricating fluid
- Auxiliary motor and pump
- Hydraulic system pressure requirements

m. Assumptions, such as:

- Safety analysis
- Design
- Operation

3.4. Section 35.4 Instructions for Continued Airworthiness. See AC 35.4-1, Propeller Instructions for Continued Airworthiness, for guidance**.**

3.5. Section 35.5 Propeller Ratings and Operating Limitations.

a. The rated power, rotational speed, and torque are those values declared by the applicant and substantiated to meet the requirements of part 35. The applicant may elect to conduct certification tests, analysis, and evaluation at values greater than the declared rated values. The regulations do not currently require that takeoff power and r.p.m. be greater than maximum continuous power and r.p.m., although they typically are. Propeller takeoff power and r.p.m. and maximum continuous power and r.p.m. are validated during the endurance test required by § 35.39.

(1) The power and r.p.m. ratings declared on the propeller TCDS do not apply to any given airplane installation. They only apply to the propeller. The propeller may have multiple ratings depending on the specific configuration definition. The propeller may only be suitable for operation on some aircraft at a lower power or r.p.m. Appropriate aircraft installation limitations are established by parts 23 or 25 for normal, utility, acrobatic, commuter, and transport category aircraft and are referenced in the aircraft TCDS and Aircraft Flight Manual (AFM). The

propeller power and r.p.m. listed in the aircraft TCDS and AFM cannot be greater than that listed on the propeller TCDS.

(2) The overspeed and overtorque limits established in § 35.41 are independent of the maximum power and rotational speeds. These limits are not intended to be used routinely. They are to be used for service checks, and unplanned exceedence of torque and speed.

3.6. Section 35.7 Features and Characteristics. To meet the requirements of this section, applicants should review the development and service history of earlier model propellers. For a new model, applicants should review the development and service experience of models with similar design features.

CHAPTER 4. GUIDANCE FOR SUBPART B - DESIGN AND CONSTRUCTION

4.1. Section 35.15 Safety Analysis.

a. Overview. The objective of the safety analysis is to ensure that the risk to the aircraft from all propeller failure conditions is within an acceptable range. An acceptable total propeller design risk can be achieved by managing the individual major and hazardous risks to acceptable levels. This emphasizes reducing the likelihood or probability of an event in proportion to the severity of the hazard the event occurrence presents. The safety analysis should support the regulatory compliance goals so that major or hazardous propeller effects do not exceed an established probability of occurrence.

(1) The depth and scope of an acceptable safety assessment depends on the following elements:

(a) The complexity and criticality of the functions performed by the system(s);

(b) The components or assemblies under consideration;

(c) The severity of related failure conditions;

(d) The uniqueness of the design;

(e) The extent of relevant service experience;

(f) The number and complexity of the identified causal failure scenarios; and

(g) The ability to detect contributing failures.

(2) Various methods of analysis for assessing the causes, severity levels, and likelihood of potential failures are available to support experienced engineering judgment. Common methods, based on inductive or deductive approaches, include Fault Tree Analysis, Failure Mode and Effects Analysis (FMEA), and Markov Analysis. These are discussed further in paragraph 4.1.f.

(3) Aircraft-level failure classifications do not apply directly to the propeller safety analysis since the aircraft may have features that reduce or increase the consequences of a propeller failure condition. Additionally, the same type-certificated propeller may be used in a variety of installations, each with different aircraft-level failure classifications. Therefore, in the absence of an actual safety classification from aircraft and engine manufacturers, the classification of the consequences of propeller failures should only be based on assumptions for a typical propeller/engine/aircraft combination.

(4) Section 35.15 defines the propeller-level failure conditions and the probability of failure for hazardous propeller effects as extremely remote (probability of occurrence of 10^{-7} or less per propeller flight hour). Since aircraft-level requirements for individual failure conditions

may be more severe than propeller-level requirements, the propeller manufacturer, engine manufacturer and aircraft manufacturer should coordinate early to ensure propeller, engine, and aircraft compatibility. See paragraph 2.4 for additional guidance.

(5) The probability of failure for major propeller effects is not defined by regulation because a defined maximum failure rate may be too severe for some simple fail safe control systems on single reciprocating engine airplanes and not severe enough for transport category airplanes. To be consistent with airplane requirements, we recommend that the probability of failure for major propeller effects for propellers installed on multiple turbine engine applications be defined as remote (probability of occurrence of 10^{-5} or less per propeller flight hour).

b. Scope of the Safety Analysis.

(1) The propeller system components may include the following:

- Hydraulic controls
- Electronic controls
- Overspeed governors
- Spinners
- Deicing boots
- Deicing components
- Lightning protection devices

Some components may not be in the propeller type design. When components are not in the propeller type design, they are under the design control of the aircraft or engine TC holder not the propeller TC holder. Although these components are not within the scope of the propeller type design, the safety analysis should assume representative components to assess the system safety as a typical installation.

(2) The phrase “typical installation” does not imply that the aircraft-level effects are known. It implies that assumptions of typical aircraft or engine devices, such as governors or annunciation devices, are stated in the analysis. The typical installation does not imply an average installation. A typical installation may be the initial aircraft installation or one that requires a higher level of safety if the initial aircraft installation requires a lower level of safety than other potential aircraft applications.

(3) Parts 23 and 25 provide airplane requirements for aircraft-level devices.

(4) Applicants should integrate the specific requirements of § 35.23, Propeller control system, if applicable, into their propeller safety analysis. We recommend, however, that applicants are careful to ensure that critical elements of the analysis are not left out during incorporation.

(5) The probabilistic calculations of failure rates should include the possible dormancy period of failures.

(6) The failure summary may be formatted as a list or table.

(7) Probability of failures.

(a) The occurrence rate of hazardous propeller effects applies to each individual effect. The defined probability rate of 10^{-7} or less per propeller flight hour for each hazardous propeller effect applies to the sum of the probabilities of this hazardous propeller effect arising from individual failures and combinations of failures other than failure of critical components. For example, if the fatigue failure of a connector combined with the failure of a pump could lead to reverse pitch in flight, then the total probability of failure is the probability of failure of the connector multiplied by the probability of failure of the pump. This total probability of failure cannot exceed 10^{-7}. Some probability of failure rates may not be as well understood as others. In this example, the pump failure rate may be well known from past reliability data, but the individual failure rate of the connector due to fatigue may not be well known. In this case, applicants should use engineering judgment or analysis to estimate the probability of connector failure. Some aircraft may require a rate of occurrence of reverse pitch in flight that does not exceed 10^{-9}.

(b) When considering primary failures of certain single elements, such as critical components, the numerical failure rate cannot be estimated. When the failure of such elements is likely to result in hazardous propeller effects, reliance is placed on meeting integrity requirements, such as §§ 35.4, 35.35 and 35.37. The regulation does not require that applicants include the estimated primary failure rates of such single elements in the summary of failures for each hazardous effect due to the difficulty of producing and substantiating such estimates.

c. Verification of Assumptions. Predicting the likely progression of some propeller failures may rely extensively upon engineering judgment. When the validity of such engineering judgment is questioned, to the extent that the conclusions of the analysis could be invalid, the judgment should be substantiated. Additional substantiation may consist of previous relevant service experience, engineering analysis, material, component, rig or propeller test, or a combination of these. When there is significant doubt of the validity of the substantiation, applicants should consider additional testing or other validation.

d. Single Elements. The integrity requirements include structural testing such as the tests required by §§ 35.35 and 35.37. When appropriate, applicants may develop additional integrity requirements under § 21.16.

e. Additional Considerations. The analysis should include general statements when the safety analysis depends on the elements listed in § 35.15(e)(1) through (4).

(1) The general statements in the analysis summary should refer to regular maintenance in a shop as well as maintenance on the line, as applicable. When specific failure rates rely on special or unique maintenance checks, the analysis should state this.

(2) The propeller maintenance manual, overhaul manual, or other relevant manuals

may provide the appropriate documentation for these maintenance actions.

(3) The Airworthiness Limitations section of the Instructions for Continued Airworthiness must include mandatory replacement times, inspection intervals, and related procedures required for type certification.

(4) Improper maintenance has often contributed to hazardous or catastrophic effects at the aircraft level. Accordingly, applicants should develop their propeller designs keeping in mind that their propellers may be subject to improper maintenance and, to some degree, still be required to operate satisfactorily. For some maintenance practices, applicants may consider requiring a two-man quality assurance check of major repairs or alterations or avoiding maintenance of both propellers on twin installations at the same time.

(5) If specific failure rates rely on special or unique maintenance checks for protective devices, those maintenance checks should be stated in the analysis.

(6) Improper propeller operation has also resulted in hazardous or catastrophic effects at the aircraft level. These effects would have been less serious if constrained to the propeller level. The applicant, therefore, should consider mitigating the effects of improper operation or providing operating instructions that reduce the likelihood of improper operation.

(7) If the incorrect assembly of parts could result in hazardous propeller effects, applicants should design parts to minimize the risk of incorrect assembly. If this is not practical, applicants should consider indicating that these parts should be permanently marked to indicate their correct position when assembled.

f. Analytical Techniques.

(1) This section describes various analytic techniques for performing a safety analysis. Variations or combinations of these techniques are also acceptable. For derivative propellers, the scope of the analysis may be limited to modified components or operating conditions and their effects on the rest of the propeller. The applicant and the project manager from the ACO that manages the original propeller TC should agree early in the certification program on the scope of the analysis and the methods of assessment.

(2) Common methods include:

(a) Functional Hazard Analysis. An FHA is a systematic, comprehensive examination of the propeller system to identify potential major and hazardous propeller effects that may arise, not only as a result of malfunctions or failure to function, but also as a result of normal responses to unusual or abnormal external factors. FHA is concerned with the operational vulnerabilities of systems instead of a detailed analysis of the actual implementation. The FHA is an engineering tool that may be used early in the design and updated as necessary.

(b) Failure Modes and Effects Analysis. An FMEA is a structured, inductive, bottom-up analysis that evaluates the effects of each possible element or component failure on the propeller system. When properly formatted, the FMEA aids in identifying dormant failures and the possible causes of each failure mode.

(c) Fault Tree or Dependence Diagram (Reliability Block Diagram) Analyses. These analyses are structured, deductive, top-down analyses that identify the conditions, failures, and events that cause each defined failure condition. They are graphical methods of identifying the logical relationship between each particular failure condition and the primary element or component failures, other events, or combinations of these that can cause the failure condition. An FTA is failure-oriented and is conducted from the perspective of which failures must occur to cause a defined failure condition. A Dependence Diagram Analysis is success-oriented and conducted from the perspective of which failures must not occur to preclude a defined failure condition.

(d) For more detailed descriptions of analytical techniques, refer to the following SAE Documents:

- SAE Document No. ARP 4754, Certification Considerations for Highly Integrated or Complex Aircraft Systems, issued November 1996.
- SAE Document No. ARP 4761, Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment, issued December 1996.

4.2. Section 35.17 Materials and Manufacturing Methods.

a. Metallic Materials and Processes for Propellers. The metallic materials used in propeller production and the fabrication processes employed should be established on the basis of experience and/or tests. We recommend applicants use the following guidelines.

(1) Material Selection. Selected materials should be suitable for their intended mechanical and/or physical function and be resistant to degradation by atmospheric corrosion and the chemical environment encountered in the specific application. When the use of inherently resistant materials is not practical, consider the use of adequate coating systems. Avoid alloy-temper combinations that are susceptible to stress corrosion cracking (SCC). Coatings may delay, but not prevent, the onset of SCC. As much as possible, avoid designs that involve active galvanic coupling of dissimilar metals/alloys. When such coupling becomes the logical design choice, consider the use of coatings, films or sealants.

(2) Specifications. Materials should be procured to adequately detailed specifications. Such specifications should be acceptable to the Administrator, either specifically, or by having been prepared by an organization that the Administrator accepts as having the necessary credentials. The detail of the specification should be related to the criticality of the application.

(3) Design Values. The assumed design values of properties of materials should be suitably related to the minimum (conservative) properties stated in the material specification or some other recognized document.

(4) Process Specifications. Manufacturing processes should be performed according to detailed process specifications. Such specifications should be acceptable to the Administrator either specifically or by having been prepared by an organization which the Administrator accepts as having the necessary credentials. The detail of the process specification should be related to the criticality of the application.

(5) Special Manufacturing Methods. Casting, forging, welding, and brazing are regarded as custom manufacturing methods, requiring precautions not ordinarily applicable to the manufacture from mill products (bar, sheet, plate and the like). The following are typical steps taken to ensure the quality of these manufacturing methods:

(a) Classification. Classify materials requiring special manufacturing methods according to their functional criticality. This classification becomes the basis for establishing the non-destructive inspection and testing requirements to be listed on the drawing.

(b) Testing. Materials requiring special manufacturing methods should have provisions for testing the material. The applicant should develop a reasonable plan for testing these materials to verify their properties.

(c) Inspection. Materials requiring special manufacturing methods should be subjected to a suitable non-destructive and destructive inspection process at an appropriate stage and with an appropriate sampling rate.

b. Composite Materials and Processes for Propellers. See AC 20-107A, Composite Aircraft Structure, for guidance.

4.3. Section 35.19 Durability. Reserved for future guidance.

4.4. Section 35.21 Variable and Reversible Pitch Propellers. The extent of any intended travel must account for backlash, tolerances, secondary stops and in-service wear. For example, a hydraulic failure of a dual acting propeller system with pitch lock operating at the in-flight low-pitch positions may permit a small decrease in blade angle due to system backlash. The pitch lock may require a small blade angle change before it engages. This value is documented in the instructions for propeller installation and operation. To facilitate propeller system design and certification in the absence of an application-specific definition, the maximum backlash should not be greater than three degrees to prevent excessive loss of thrust or propeller overspeed. However, final determination of the installation requirement is based on aircraft controllability requirements and should be evaluated during aircraft certification.

4.5. Section 35.22 Feathering Propellers.

a. The feathering and unfeathering characteristics and limitations may include parameters such as:

- feather angle
- rate of pitch change
- rotational speed where start locks engage or disengage
- airspeed limits above which the propeller may not feather completely or may feather at a slower rate

Such data should be made available to airframe TC holders, as necessary.

b. Feathered pitch is the pitch setting which corresponds in flight to a windmilling torque and rotational speed of approximately zero. A counterweighted propeller typically needs additional force from a spring or from oil pressure to feather the propeller. A propeller operating at the angle provided by the counterweight would not be considered a feathered propeller; it would be a propeller windmilling at a high pitch angle provided by the counterweight.

c. Evaluation at the minimum declared outside temperature may be verified in a cold chamber or by flight test. If a maximum diversion time has been established for the airplane installation, it is appropriate to use this as the time for stabilization to a steady state temperature. There is no requirement to define a minimum unfeathering rate.

4.6. Section 35.23 Propeller Control System. See ANE-2007-35.23-1, Policy for Electronic Propeller Control Systems, §§ 35.21 and 35.23, for guidance.

4.7. Section 35.24 Strength. Compliance with the regulation may be shown by an auditable part of the design process, provided that the following information may be found in the propeller TC holder design documentation:

- Design definition
- Design requirements
- Design loads
- Stress analysis
- Test results
- Material specifications
- Verification that the component tested and/or analyzed represents the type design
- A process that reviews this requirement for each design change

CHAPTER 5. GUIDANCE FOR SUBPART C - TYPE SUBSTANTIATION

5.1. Section 35.33 General. Applicants may run some tests without automatic controls or safety systems. For example, a primary system may have to be disabled to test a backup system or a governing function may need to be disabled to test an overspeed condition.

5.2. Section 35.34 Inspection, Adjustments and Repairs. Reserved for future guidance.

5.3. Section 35.35 Centrifugal Load Tests.

a. Hub, Retention and Counterweight.

(1) The maximum centrifugal load to which the propeller may be subject to during operation, within the limitations established for the propeller, is based on the maximum rated rotational speed declared in the TCDS. Overspeed limits and overspeeds such as would occur at the overspeed governor setting are not considered normal and do not constitute the maximum r.p.m. to be used for establishing test conditions.

(2) Test the hub, blade retention, and counter weights as an assembly either by whirl testing to twice the centrifugal load, or by applying twice centrifugal load to the assembled components to simulate the centrifugal load, as appropriate.

(3) The blade retention is that area of the blade that transmits blade centrifugal and bending loads to the hub. Included in the retention are bearing races and other associated components used for the transmission of loads to the hub.

(4) This test does not need to include the complete blade. Stub blades, with weights to establish the correct centrifugal load during whirl tests, can be used. The stub blades must have the same blade retention so that similarity to the full blade retention is maintained.

b. Blade Features. Blade features such as those associated with transitions from a composite blade to a metallic retention can be tested during the hub and retention test or with a separate component test. Blade features are typically associated with the transition from a composite blade to a metallic retention. But other applicable configurations may exist, such as the transition associated with a configuration where the blade of any material construction is bonded, or otherwise attached, to the portion of the blade retained in the hub.

c. Propeller Components. Propeller components not requiring twice centrifugal load tests should be subjected to test or analysis equal to the centrifugal load generated at 159 percent of the maximum centrifugal load to which the component would be subjected during operation at the maximum rated rotational speed for a period of 30 minutes. These components may also be shown to be acceptable by similarity to existing components with applicable service history. Testing can involve whirl testing or static testing with the assembly or on a component or sub-component level. The component test, such as a peel test, need not be 30 minutes in duration. These supporting tests may be combined with analysis to show that the components will be acceptable for 30 minutes duration if a full scale test were to be conducted. Analysis methods used to demonstrate compliance for these components should be accepted by the Administrator.

5.4. Section 35.36 Bird Impact. Compliance may be based on similarity and service history to existing propeller installations, bird impact testing, or analysis combined with similarity and testing. Both static and rotating tests are acceptable.

a. Selection of Critical Operating Conditions. The selection of critical operating conditions is based on an evaluation of the intended use of the propeller, the operating conditions when the propeller will most likely encounter bird populations, and the impact geometry of the propeller. Typically, this condition occurs at takeoff and landing.

b. Selection of Impact Site.

(1) Blade. Choose the impact site to produce maximum blade retention loads. This site should show that the entire blade will not separate and, at the same time, should test for local structural integrity to show any local or tip blade damage.

(2) Spinner. Choose the impact site that produces maximum loads. The site selected should show that the entire spinner would not separate.

c. Selection of the Bird. Natural or artificial birds may be used.

d. Static or Rotating Testing. Either static or rotating testing is acceptable. The objective is to simulate a bird strike in a controlled manner to assess the resulting blade response and damage. When appropriate, include blade hub, retention, and pitch change hardware as part of the static test set up for assessment of the effect of bird strike on these components.

e. Damage Evaluation. Evaluate the blades, including composite blades, after the impact testing. Typical areas reviewed include:

(1) Visual examination

(2) Frequency response tests

(3) Blade tap tests for delamination evaluation of composite components

(4) Ultrasonic inspection for delamination and internal damage of composite components

(5) X-ray inspection for internal damage; and

(6) Fluorescent penetrant inspection or magnetic particle inspection of metallic components.

f. Composite fixed pitch or ground adjustable-pitch propellers have inherent mitigating features. Specifically, these propellers may offer relief from hazardous propeller effects associated with the release of a portion of the propeller. Since these blades tend to be lightweight, that lower weight may produce unbalance that is not excessive when a large portion is lost. Similarly, propeller fragments caused by bird impact on single engine tractor airplanes would not hit the fuselage and cause damage to the airplane. So, for fixed pitch or ground adjustable-pitch propellers, when showing compliance with the bird impact requirements of § 35.36, we recommend that the applicant identify the amount of blade loss, if any, and include that information in the installation manual provided to airframe manufacturers for their aircraft testing.

5.5. Section 35.37 Fatigue Limits and Evaluation. See AC 35.37-1A, Guidance Material for Fatigue Limit Tests and Composite Blade Fatigue Substantiation, for guidance.

5.6. Section 35.38 Lightning Strike. This guidance provides an overview of test methodology used to determine the effect of a lightning strike on a propeller. The reference documents, listed below in paragraph 5.6.c., include detailed methods, test set-up information on voltage waveforms, current waveforms, and data collection for conducting a lightning strike test. ANE-2007-35.23-1, Policy for Electronic Propeller Control Systems, §§ 35.21 and 35.23, addresses the effects of lightning on electronic controls.

a. Consider all components of the propeller assembly that could be in the lightning path. These include, but are not limited to, the spinner, blade, hub, blade bearings, and the pitch change mechanism. Additionally, consider electrical/electronic components that could be influenced by the indirect effects. These include propeller blade and spinner de-icing system components as well as any other propeller mounted electrical or electronic components.

b. The damage caused by lightning is characterized as direct or indirect. The direct effects associated with lightning depend on the structural component involved, the attachment point, and the current path through the structure. The indirect effects are classified as damage to electrical equipment by the current or voltages either by the associated electromagnetic field, surges, or by current directly injected into the electrical wires.

(1) Testing for indirect effects determines the conducted currents, surge voltages, and induced voltages entering the aircraft electrical system through systems such as the propeller de-icing system. Testing involves measurement of voltages at the terminals of the de-icing system or of other electrical/electronic systems where they connect to the aircraft electrical system.

(2) The direct effect of lightning is physical damage. This damage depends on the strength of the strike and on the construction of the propeller races and bearings.

c. The references below provide information regarding test setup, simulated lightning wave forms, and other general procedures to conduct a lightning strike test.

(1) AC 20-136A, "Protection of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning," December 21, 2006.

(2) AC 20-53B, "Protection of Airplane Fuel Systems Against Fuel Vapor Ignition

Due to Lightning," June 5, 2006.

(3) RTCA DO-160F/EUROCAE ED-14F, "Environmental Conditions and Test Procedures for Airborne Equipment," December 6, 2007.

(4) SAE ARP5414A, "Aircraft Lightning Zoning," February 2005.

(5) SAE ARP5412A, "Aircraft Lightning Environment and Related Test Waveforms," February 2005.

(6) AC 20-155, "SAE Documents to Support Aircraft Lightning Protection Certification," April 28, 2006.

d. Damage Evaluation. The damage evaluation for blades, including composite blades, after a lightning strike typically includes a combination of:

(1) Visual examination

(2) Frequency response tests

(3) Blade tap tests for delamination evaluation of composite components

(4) Ultrasonic inspection for delamination and internal damage of composite components

(5) X-ray inspection for internal damage; and

(6) Fluorescent penetrant inspection or magnetic particle inspection of metallic components.

e. The effects of lightning strike on composite fixed pitch or ground adjustable-pitch propellers are the same as those noted for bird impact in paragraph 5.4.f. So, for fixed pitch or ground adjustable-pitch propellers, when showing compliance with the lightning strike requirements of § 35.38, we recommend that the applicant identify the amount of blade loss, if any, and include that information in the installation manual provided to airframe manufacturers for their aircraft testing.

5.7. Section 35.39 Endurance Test.

a. Test Configuration. Testing should be conducted with the propeller system. The engine power output should be at least equal to the propeller takeoff and maximum continuous power ratings. The rated rotational speed is typically the takeoff rotational speed. Spinner and de-ice components should be installed during the endurance test. However, in lieu of this for spinner and de-ice components, conducting a spin-rig test or similarity to a previously tested configuration may be acceptable.

b. Propeller Diameter. When the propeller being certified includes more than one acceptable blade design, the diameter of the propeller tested need not be the blades that give maximum propeller diameter. The blades tested should be ones for which certification is sought, and the applicant should show that testing with these blades represents all other similar blades included in the type design. If the blades differ from the ones for which certification is sought, the applicant should supply engineering data to show that the blades used during the endurance test have similar loading and vibration characteristics and will result in the same test results. In addition, testing with blades of different construction than blades for which certification is sought may not be acceptable. For example, if both composite and aluminum blade options are included in the type design, then both the composite and aluminum blades should be tested.

c. Representative Engine. The engine must be capable of developing the power and speed for which certification of the propeller is sought. The engine vibration should be similar to the intended application for the propeller. For example, testing on a turbine engine may not be applicable to show that the propeller is acceptable on a piston engine.

d. Continuity of Test. The endurance test may be continuous or in increments agreed upon between the propeller applicant and the Administrator.

e. Controls. Controls must be operated in accordance with the applicant's instructions (with such minor alterations as the Administrator may permit). The applicant's instructions should be those which are proposed for incorporation in the propeller manuals.

f. Stops. The test should be run in accordance with the approved test plan unless agreed to by the Administrator. Each period should be run non-stop. In the event of a stop during any period, the period should be repeated unless the Administrator considers this to be unnecessary. The Administrator reserves the right to require the complete test to be repeated if an excessive number of stops occurs.

5.8. Section 35.40 Functional Test.

a. General. The functional tests are intended to substantiate the control function in the propeller system. These tests can be performed in conjunction with § 35.39, Endurance test, and § 35.42, Components of the propeller control system.

b. Governing Propellers. The following is an example of a simulated flight cycle that may be used for § 35.40(b) and it is a representative flight cycle:

(1) Ground idle (GI) – stabilize

(2) Acceleration from GI to takeoff power – transition

(3) Takeoff power – stabilize

(4) Takeoff power to maximum continuous power – transition

(5) Maximum continuous power – stabilize

(6) Maximum continuous power to cruise power – transition

(7) Cruise power – stabilize

(8) Cruise power to descent power – transition

(9) Descent power – stabilize

(10) Descent power to reverse power – transition

(11) Reverse power – stabilize; and

(12) Reverse power to GI – transition.

c. Feather Cycle. The following is an example of a feather cycle that may be used:

(1) GI - stabilize

(2) GI to feather – transition

(3) Feather - stop rotation; and

(4) Unfeather to GI – transition.

d. Reverse Cycle. The following is an example of a reverse cycle that may be used:

(1) GI – stabilize

(2) GI to maximum reverse power – transition

(3) Maximum reverse power – stabilize; and

(4) Maximum power to GI – transition.

5.9. Section 35.41 Overspeed and Overtorque.

a. The maximum propeller overspeed is the rotational speed that will not require rejection of the propeller from service or maintenance action other than to correct the cause. This rotational speed should only be caused by some inadvertent or maintenance action.

b. The maximum propeller overtorque is the torque that will not require rejection of the propeller from service or maintenance action other than to correct the cause. This torque should only be caused by some inadvertent or maintenance action.

c. Section 35.41 does not preclude the applicant from specifying other overspeed and overtorque levels in the appropriate manuals that would require maintenance actions. An example would be an overspeed level that would require the propeller to be removed and sent to a repair shop for inspection.

5.10. Section 35.42 Components of the Propeller Control System. Tests should explore all the operating conditions applicable to propeller components used in the control (including governors, pitch change assemblies, pitch locks, mechanical stops, and feathering system components, beta control and reverse thrust) of the propeller. The tests may be carried out on suitable rigs or in conjunction with the § 35.39, Endurance tests and § 35.40, Functional tests. Section 35.42 testing identifies the functionality and wear of the propeller pitch control system's components for the purpose of establishing appropriate instructions for continued airworthiness. The tests should represent the hours of operation which would arise within the initially declared overhaul period, but not be less than the 1000 hours of operation defined in the rule. Compliance with this section may be shown by analysis based on the results of tests or service experience on similar components.

5.11. Section 35.43 Propeller Hydraulic Components. Tests should verify the structural adequacy of the hydraulic components in the event of over-pressurization of the system. The burst pressure test should demonstrate structural integrity with no significant fracture. Verification that unacceptable permanent deformation did not take place may be shown by comparing dimensional part measurements before and after the test.