U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

FAR GUIDANCE MATERIAL

Subject: AIRCRAFT ENGINE TYPE CERTIFICATION HANDBOOK | **Date:** 06/30/93 | **Initiated by:** ANE-110 | **AC No:** 33-2B | **Change:**

1. PURPOSE. This advisory circular (AC) provides methods acceptable to the Administrator for showing compliance with the type certification requirements of aircraft engines in Part 33, inclusive through amendment 12, of the Federal Aviation Regulations (FAR). The procedures and guidance material provided in this AC may be used by an applicant seeking issuance of a type certificate, an amended type certificate, or a supplemental type certificate for the initial approval of a new type design, or a change in the type design. Consideration will be given to any other method of compliance the applicant elects to present. This information is not in itself mandatory, but serves as a guide to engine manufacturers, engine modifiers, and Federal Aviation Administration (FAA) engine type certification engineers. Individuals should be guided by the intent of the methods provided in this AC.

2. CANCELLATION. This revision supersedes AC 33-2A, "Aircraft Engine Type Certification Handbook," dated June 5, 1972.

3. RELATED FAR SECTIONS. FAR Parts 21, 23, 25, 27, 29, 33, and 45.

4. RELATED READING MATERIAL. FAA Order 8100.5, "Aircraft Certification Directorate Procedures," dated October 1, 1982; and FAA Order 8110.4, "Type Certification," dated December 28, 1967 (Consolidated with Changes 1 through 23, June 1985).

5. BACKGROUND.

a. AC 33-2A, dated June 5, 1972, was published as the "Aircraft Engine Type Certification Handbook." The material therein principally addressed guidance on the procedural aspects of Part 21, but offered very little guidance for Part 33. However, the last sentence of the "PURPOSE" paragraph did state, "The remaining chapters of the handbook pertaining to the design and testing of turbine and reciprocating engines will be issued as they become available."

b. This revision updates and presents the existing procedural information within Chapter 2, and incorporates, within Chapter 3, engine type certification rules and guidance material which has since been developed. The appendixes provide turbine and reciprocating engine model descriptions, an index of guidance material and references, and a glossary of acronyms and abbreviations.

for JACK A. SAIN
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CONTENTS

CHAPTER 1. INTRODUCTION

1. GENERAL. This advisory circular (AC) provides procedural and guidance material for the type certification (TC) of aircraft engines. The AC covers certain sections of Parts 21 and 33 of Subchapter C, Chapter 1, Title 14, of the Code of Federal Regulations (CFR). This AC is considered to be a living document. As such, it will be amended on an as-needed basis to maintain currency, such as with the issuance of Part 33 rules changes, or the development of substantive new guidance material.

2. GUIDANCE. The TC guidance presented is referred to the specific regulatory requirement to which it applies. As a convenience to the user, the FAR Part 33 regulatory requirements, presented in Chapter 3, are reprinted herein to provide a cohesive single-source book for engine type certification; i.e., procedures, rules, and associated guidance. Following each Part 33 section, under "Guidance," is a brief statement of the intent, followed by a listing of documents incorporated as pertinent guidance material; and a second listing of related bibliographic material, followed by specific discussions, where applicable.

CHAPTER 2. GENERAL TYPE CERTIFICATION PROCEDURES

3. PURPOSE. This chapter provides information and guidance material on the certification procedures of FAR Part 21 which may be employed for engine type certification projects.

4. TYPE CERTIFICATE. The type certificate is defined under FAR Section 21.41.

5. TYPE CERTIFICATION OF AIRCRAFT ENGINES. (Reference FAR Sections 21.13, 21.15, 21.16, 21.17, 21.21, 21.27, 21.29, and FAR Part 33).

a. Engines Complying with Parts 21 and 33. Engines tested and approved to the airworthiness standards of FAR Part 33 are eligible to receive a type certificate. Section 21.13 covers applicant eligibility; Section 21.15 covers application for type certificate; Section 21.16 covers the establishment of special conditions; and Section 21.17 covers designation of the applicable version of Part 33 which should be met.

b. Import Engines. Section 21.29 prescribes the conditions for eligibility for type certification of import engines.

c. Military Surplus Engines. Engine type certification may be accomplished for military surplus engines in the same manner as is prescribed in Section 21.21 for other engines, but these engines may also be made eligible for use without being type certificated, in accordance with the provisions of Sections 21.27(c) and (e).

(1) Under Sections 21.27(c) and (e), military surplus engines may be approved for use on military surplus aircraft, if it is shown on the basis of previous military qualifications acceptance and service record, that the engine provides substantially the same level of airworthiness as would be provided if the engine were type certificated under Part 33, with appropriate special conditions and later requirements applied.

(2) The engine characteristics necessary for installation, operation, and identification of the engine should be listed on the pertinent military surplus aircraft type certification data sheet. The following engine technical data are helpful in identifying engine limits and showing compliance with FAR Section 21.27(c):

(i) Military service record summary, including details of mandatory safety changes required for the engine type for military service.

(ii) Military qualification basis, with engine model specifications.

(iii) Military technical orders, comprising manual information for the engine parts list, overhaul, operation, and maintenance.

d. Helicopter Reciprocating Engines. Helicopter reciprocating engines are currently required to meet the specific test requirements of Section 33.49(d), Sections 29.923 and 27.927, or Sections 29.923 and 29.927, as appropriate.

(1) Before this special endurance test was made effective on May 15, 1953, in the Civil Air Regulations (CAR) Part 13, it became evident from service experience that some engines operated in helicopters were hazardous and unreliable, because of the characteristically high steady engine speeds and powers at which overspeeds were often encountered in helicopters.

(2) To provide good reliability in the case of reciprocating engines which were not qualified under Section 33.49(d), or have not been shown to have equivalent capabilities, it is suggested that they be derated. The following method of derating is suggested, as it results in engine ratings which are comparably qualified, as if the helicopter engine test had been the basis for engine qualification:

(i) Limit sea level engines to a maximum power rating (at full throttle), corresponding to an engine speed that is not more than 90 percent of the engine speed at which the original maximum full-throttle power rating was established.

(ii) Limit altitude engines to a maximum power rating of not more than 95 percent of the original maximum power rating, at an engine speed that is not more than 90 percent of the engine speed at which the original maximum power rating was established.

6. TYPE CERTIFICATE DATA. (Reference FAR Sections 21.19 and 21.41). Section 21.19 provides that some types of design changes to engines require a new application for a type certificate.

a. Engine models which are of the same general series, power level, and design characteristics, are usually approved under the same type certificate.

b. A new type certificate is required when the proposed changes in design or limitations are so extensive that a substantially complete investigation of compliance with applicable regulations is required, or when the proposed change is in the principle of operation.

c. The use of engine model number prefixes or suffixes, in lieu of new model designations, is suggested to cover many changes in engines which are important enough to warrant recognition, but which do not involve considerations necessitating that a new model designation be assigned.

d. New model designations are usually assigned in the following instances:

(1) When interchangeability in a given model aircraft is affected significantly by changes of engine weight or performance.

(2) When propeller mounting, propeller vibration damping, or control provisions are changed so as to preclude use of certain types of propellers on all engines of the same model.

(3) When, as a result of design changes, the horsepower or thrust ratings are changed a significant amount (on the order of 20 percent or more), in excess of the accepted tolerance of output measurement.

(4) When special ratings are granted an existing engine model because of incorporation of new design features.

(5) When a significant change is made in the mounting characteristics of an engine, design of cowling or baffles integral with the engine, exhaust port locations, oil supply sump, accessories, or control characteristics.

(6) When a design change results in significant changes in vibration characteristics, heat rejection through oil or coolant, or other operational characteristics.

(7) When special applications, for example, agricultural use, or extended range operations, result in unique maintenance requirements.

7. <u>TYPE CERTIFICATE DATA SHEET (TCDS)</u>. (Reference FAR Section 21.41) The TCDS is part of the type certificate. It includes the type certificate holder, model designation, ratings, limitations, and certification basis. This sheet is prepared by the FAA project engineer, with assistance from the applicant. See FAA Order 8110.4, Paragraph 35, for details on preparations for printing. There is no FAA form provided for TCDSs because of the variations in the required data associated with the various products. The following guidelines provide general information relative to uniform handling of the engine data sheet, with reference to the desired descriptive data content and general arrangement to be considered in the preparation of this sheet.

a. <u>General</u>. Applicable details, as prescribed in following paragraphs, constitute the official status of the engine(s) and serve as a guide for identification, use, and installation of engines in aircraft. The formal arrangement of data, explanatory notes, and extent of detail provided should conform, in general, to that shown for the most recently certificated comparable types of engines. Extensive details of engineering installation data are not desirable and this data may be merely referenced. However, specific data should be indicated, if feasible. The assistance of the applicant is desirable in formulating and assuring the accuracy of the data sheets. Standardization of data sheet format is desirable whenever possible, and specifically for the same generic type engines consistent with the following recommendations. The project engineer should have the draft data sheet completed by the time the type certificate is issued.

b. Detailed Description.

(1) Heading - Numbering. The data sheet number will appear in the upper right-hand corner of page 1. This number will be the same as the type certificate number. When the data sheet is revised, the revision number will be shown as a suffix. The name of the type certificate holder, in abbreviated form, will be included next, together with all the approved models listed in alphabetical, or numerical, order for reference convenience. The issue date will complete this group. The above information will be enclosed in a box to set it off.

(2) Title. The title of the document (Type Certificate Data Sheet No.____) will appear in the center of the page, after the heading box. The title will include the exact, unmodified, type certificate number, as shown on the type certificate.

(3) Sample Preamble. Engines of models described here that conform with this data sheet (which is a part of Type Certificate No. ____) and other approved data on file with the FAA, meet the minimum standards for use in certificated aircraft, in accordance with pertinent aircraft data sheets and applicable portions of the FAR, provided they are installed, operated, and maintained; as prescribed by the FAA approved manufacturer's manuals and other FAA approved instructions.

(4) Type Certificate Holder. Insert the exact name and address of the type certificate holder as shown on the type certificate.

(5) Basic Data. (Main Section).

(i) Model Designation. Show model designations in one or more columns, as necessary to exhibit ratings, limits, or other parameters for each of the models. Reference to recently issued TCDSs will illustrate representative ways of grouping engines in columns, and ways of accomplishing the following instructions.

(ii) Type. Describe engine models in terms of major generic features and processes. For example:

(A) Reciprocating - number of cylinders, cylinder arrangement and cooling method, reduction gear ratio, fuel injection, and supercharging (e.g., 9RA, 6HOA, IGO, TSIO);

(B) Turbojet, turbofan - number of compressor and turbine stages, single or multiple spool, radial or axial flow, bypass, etc., (e.g., 12-stage axial flow compressor, reverse-flow annular combustor, four-stage turbine);

(C) Turboprop, turboshaft - same as in item (B) above, plus free (power) turbine, if appropriate.

(iii) Ratings. State certificated maximum power ratings at control setting, rotational speed, pressure altitude, ambient temperature, or other conditions as applicable for the following generic type engines:

(A) For reciprocating engines:

- Maximum continuous horsepower, r.p.m., in. Hg at:
  - -- Rated pressure altitude ft. __ __ __ __
  - -- Sea level pressure altitude ft. __ __ __ S.L.

- Takeoff (5 minutes) horsepower, r.p.m., in. Hg at:
  - -- Rated pressure altitude ft. __ __ __ __
  - -- Sea level pressure altitude ft. __ __ __S.L.

- Other, if applicable, (e.g., with both low and high impeller gear ratios, anti-detonator injection, or alternate fuels).

(B) For turbojet and turbofan engines:

- Maximum continuous static thrust, lbs. ___ ___ and r.p.m. at sea level.

- Takeoff (5 minutes) static thrust, lbs. ___ ___ and r.p.m. at sea level.

- Other, if applicable, (e.g., with water-alcohol injection, reheat, reverse thrust, or alternate ratings).

(C) For turboshaft and turboprop engines (See Note 1):

- Turboshaft Engine Ratings

  -- Maximum continuous
  --- Output shaft horsepower, SHP
  --- Output shaft speed, r.p.m.

  -- Takeoff (5 minutes)
  --- Output shaft horsepower, SHP
  --- Output shaft speed, r.p.m.

  -- 30-Minute OEI (30 minutes)
  --- Output shaft horsepower, SHP
  --- Output shaft speed, r.p.m.

  -- 2-1/2-Minute OEI (2-1/2 minutes)
  --- Output shaft horsepower, SHP
  --- Output shaft speed, r.p.m.

  -- Continuous OEI
  --- Output shaft horsepower, SHP
  --- Output shaft speed, r.p.m.

- Turboprop Engine Ratings

  -- Maximum continuous
  --- Output shaft horsepower, SHP
  --- Output shaft speed, r.p.m.
  --- Equivalent shaft horsepower, ESHP
  --- Jet thrust, lb.

  -- Takeoff
  --- Output shaft horsepower, SHP
  --- Output shaft speed, r.p.m.
  --- Equivalent shaft horsepower, ESHP
  --- Jet thrust, lb.

  -- Other, if applicable, (e.g., with water-alcohol and/or reverse thrust).

(iv) Reduction Gear Ratio. Output shaft speed to power turbine speed; and fan speed to low turbine speed.

(v) Control System. Manufacturer and model of gas producer fuel control, power turbine governor, and overspeed governor, respectively.

(vi) Fuel.

(A) Fuel - octane, grade, or type, as applicable.

(B) Carburetor, fuel injector, fuel control - manufacturer, model designation, setting, or other relevant information.

(C) Fuel pump (if applicable) - manufacturer and model.

(D) Fuel filtration (if required for fuel at engine inlet) - mesh value.

(vii) Oil.

(A) Oil type or specification.

(B) Oil (sump, dry, or wet) and capacity.

(C) Usable oil - engine in critical positions (degrees from reference).

(viii) Coolant.

(A) Coolant (liquid-cooled engine) type and specification.

(B) Coolant capacity (engine only).

(ix) Ignition.

(A) Ignition (dual) magnetos or ignition supply box - models.

(B) Timing (degrees BTC).

(C) Spark plugs, igniters, and ignition exciters - models. (If extensive, put into a note).

(x) Compressor - Compression.

(A) Bore and stroke (reciprocating).

(B) Displacement (reciprocating).

(C) Compression ratio (reciprocating).

(D) Turbosupercharger - model.

(xi) Principal Dimensions.

(A) Length (in.) -

(B) Width (in.) -

(C) Height (in.) -

(xii) Weight (Dry) Lb. (Note any unusual inclusions or exclusions).

(xiii) Center of Gravity.

(A) Relative to specific longitudinal reference in inches.

(B) Relative to engine center line in inches.

(xiv) Propeller or Power Shaft. Type and size.

(xv) Crankshaft Dampers. Number, order, location, and type.

(xvi) Note List. Listing of note numbers applicable to model group, listed under data column for that group.

(xvii) Legend. Explanation of symbols.

(A) "_ _" indicates "same as preceding model."

(B) "_" indicates "does not apply."

(xviii) Certification Basis.

(A) FAR (CAR), Special Conditions, and Exemptions, as appropriate, effectivity covering type certification of engine.

(B) Engine model and date of type certification application.

(C) Date of type certification.

(D) Date specific models canceled.

(xvix) Production basis. Production certificate number or other production means.

(6) Basic Data. (Notes Section). Variations are so numerous in engine type, and in conditions relative to similar types, that close uniformity in the use of notes for all engines appears impractical. Uniformity for uniformity's sake might well impair the accurate presentation of technical information. The first six notes are assigned to common conditions or parameters and for uniformity should be used solely for these subjects. The remaining notes and contents may be selected according to the data

to be presented. The following examples of engine data sheet notes are presented accordingly.

(i) <u>Common Note Headings Peculiar to All Engines</u>.

NOTE 1. Engine ratings are based on calibrated stand performance, under the conditions specified by the engine type certificate holder. For example:

- Static sea level standard day conditions (59 $^{\circ}$F and 29.92" Hg).

- No customer bleed, no duct losses, no external power extraction.

- Exhaust configuration (as specified by the engine type certificate holder).

NOTE 2. Maximum permissible temperatures or temperature limits.

Maximum Cylinder Head Recip. (Type Thermocouple)	Cylinder Base $^{\circ}$F.($^{\circ}$C.)	Oil inlet $^{\circ}$F.($^{\circ}$C.)

Turbine exhaust gas or turbine inlet

Temperatures measured by ___ thermocouples at ____________________.	Models	Models
Takeoff (5 minutes)	$^{\circ}$F.($^{\circ}$C.)	$^{\circ}$F.($^{\circ}$C.)
Maximum continuous	$^{\circ}$F.($^{\circ}$C.)	$^{\circ}$F.($^{\circ}$C.)
Maximum transient for accel. ( ) sec.	$^{\circ}$F.($^{\circ}$C.)	$^{\circ}$F.($^{\circ}$C.)
Maximum transient for starting ( ) sec.	$^{\circ}$F.($^{\circ}$C.)	$^{\circ}$F.($^{\circ}$C.)
Other temperature limits as applicable	$^{\circ}$F.($^{\circ}$C.)	$^{\circ}$F.($^{\circ}$C.)

NOTE 3. Shaft (or Fan) speed limits.

NOTE 4. Shaft torque limits (or EPR thrust limits).

NOTE 5. Fuel and Oil pressure limits.

NOTE 6. Accessory drive or mounting provisions.

Acc. Drive	Engine RJ 123	Models RJC123	Rotatn Facing Dr Pad	Speed Ratio to Eng	MaxTorq (in.-lb.) Cont. St.	O'hg Mom. in-lb
Strtr (#)	-	*	CC	__:1	-	-
Strtr (#)	-	**	CC	__:1	-	-
Gen (#)	*	**	C	__:1	-	-
Alt (#)	*	*	CC	__:1	-	-
VacPmp (#)	*	*	C	etc.	etc.	etc.
FuelPmp (#)	etc.	etc.	etc.			
Tach (#)	etc.	etc.				
PrpGov (#)	etc.					

"*" - Standard
"**" - Optional
"C" - Clockwise
"CC" - Counterclockwise
"-" means "does not apply"

"#" - Drive source
"P" - Pneumatic
"GP" - Gas Producer rotor
"PT" - Power Turbine rotor
"--" means "same as previous model"

NOTE 7. Model description - similarities, differences, and special characteristics.

RJ123 - Basic Model - Brief Description.

RJC123 - Similar to RJ123 Except ________________.

List major differences.

NOTE 8. The following accessories are provided as part of the engine (or are optional) and comply with the aircraft installation requirements for (make/model) aircraft. Compliance findings need to be determined, or delegated, by the appropriate FAA Aircraft (or Engine) Certification Office (ACO/ECO).

(ii) Uncommon Notes Peculiar to Reciprocating Engines.

NOTE 9. Thrust - tractor or pusher.

NOTE 10. Horizontal or vertical installation - helicopter information.

NOTE 11. Center of gravity tabulation (if not shown in body of data sheet).

NOTE 12. Vibration damper provision limitations.

NOTE 13. Manufacturers bulletins and instructions covering matters of special interest.

NOTE 14. Special ratings.

NOTE 15. Military models note.

NOTE 16. Special equipment.

NOTE 17. Approved propellers - models.

NOTE 18. Other applicable notes.

(iii) Uncommon Notes Peculiar to All Turbine Engines.

NOTE 9. Rotational velocities at standard and overspeed, alternate ratings, etc.

NOTE 10. Bleed air extraction.

NOTE 11. Alternate fuel information.

NOTE 12. Fuel or oil additives.

NOTE 13. Anti-icing, de-icing equipment, requirements.

NOTE 14. Power ratings for non-standard conditions.

NOTE 15. Rotor disk integrity and rotor blade containment (where special provisions apply).

NOTE 16. Operational torques, power settings, and other special limits.

NOTE 17. Engine mount system.

NOTE 18. Power boost, injection.

NOTE 19. Other applicable notes for special equipment, or relating to specific or unique engine installation requirements, such as inlet foreign object protection, lightning protection, HERF protection, thrust reversers, criticality level of software for engine controls, and other electrical/electronic systems, emissions standards, extended range operations, etc.

(iv) Notes Peculiar to Turboprop Engines.

NOTE 20. Approved Propellers - Models (when available).

NOTE 21. Engine - Controls.

NOTE 22. Equivalent shaft horsepower - Jet thrust, lb./2.5 + SHP.

(v) Other Notes Peculiar to Special Conditions Assigned.

(vi) TCDS (For Obsolete Engines). (Reference FAR Sections 21.15, 21.21, 21.31, and 33.5). When an engine model has become obsolete; e.g., if the type certificate holder does not intend to manufacture it, or any of its component parts; approval under the type certificate may be canceled upon request. After cancellation, it is no longer necessary for the [former] type certificate holder to maintain up-to-date type design and type certificate data. The TCDS of the engine will be revised to reflect the change in certification status and, when all models listed under one type certificate have been canceled, the data sheet will be transferred to a combined listing of obsolete engines. The operation of obsolete engines still in service is eligible to be continued under the status of the approval in effect at the time the certificate was canceled. If reinstatement of the type certificate is desired by the former type certificate holder for the purpose of resuming active engine production, a new application for type certificate, to be based on current FAR, is needed.

8. DATA REQUIRED. (Reference FAR Sections 21.15, 21.21, 21.29, 21.31, 21.41, and FAR Part 33).

a. FAA Form 8110-12. "Application for Type Certificate" (OMB 04-R0078) is the form referred to in Section 21.15(a). It should be submitted to the FAA Aircraft Certification Office (ACO), of the region in which the applicant is geographically located.

b. Preliminary Data. Certain technical data are needed to make the initial evaluation of conformity with the specific design requirements and the establishment of detailed qualification testing to be prescribed, in accordance with FAR Part 33. The data most useful for these purposes include a preliminary type design description, technical design data, which are required under Sections 21.21(b) and 21.29(a)(2), together with other useful background information. To facilitate this evaluation of engine design features, the preliminary data may be submitted along with the application for a type certificate. The following preliminary data are suggested:

(1) A preliminary model description, specification, or equivalent, containing at least sufficient information to permit the establishment of the basis for engine certification.

(2) Drawings showing external views and cross-sections of selected components, reflecting unique and typical detailed features.

(3) A review of significant development history, emphasizing the extent of development experience with the engine, with particular emphasis on unique or complex features, or their combinations not used up to now in aircraft engines.

(4) Proposals for substantiating compliance with the requirements of FAR Part 33 for U.S. applicants' engines and Section 21.29 for import engines, by means of technical analyses or testing. Test proposals are desired appreciably before the proposed starting date of the test, in sufficient detail to serve as a guide for testing, whereupon they may be incorporated in the Type Inspection Authorization (TIA). Reference [Handbook] FAA Order 8110.4 for more detailed information on TIAs, including test article pre- and post-test conformity inspection and schedule requirements.

c. Final Type Design and Type Certificate Data for U.S. Manufactured Engines. Acceptable type design and type certificated data, test reports, and computations data, required under Section 21.21(b), cover the engine design that completed the prescribed qualification testing. Acceptable data are described as follows:

(1) Type Design Data. (Reference Section 21.31).

(i) Engine Model Description. The final model description should provide data and information that is all officially verified, to replace the preliminary model description. (Reference Appendixes 1 and 2).

(ii) Engine Parts Drawings, Material, and Process Specifications. Acceptable data will show the configuration of the type design that successfully complied with the required tests and inspections. A numerically arranged drawing list that shows the latest design change identification is recommended to accompany the drawings. Drawings should be sufficiently detailed to identify and completely describe the design features; supply information on dimensions, materials, and processes necessary to define the structural strength of the product; part and serial number locations; and any other data necessary to allow, by comparison, the determination of the airworthiness of later products of the same type.

(2) Type Certificate Data. (Reference Sections 21.21(b), 21.41, and Part 33).

(i) Test Reports and Computations. Test reports and computations to substantiate compliance with the applicable requirements of Part 33. A test report should cover, but not be limited, to the following:

(A) Test equipment. A complete description with photographs, or reference to a previous report in which the same equipment was used; the manner of engine mounting in the test equipment; and the calibration status of instruments.

(B) Test procedure. The name of the test, part of the test sequence, or the FAR; the chronological log of testing; delays in tests and their causes; stops for minor corrections and servicing engine; and time required for starts.

(C) Test data. Graphs showing variations in operating conditions during the endurance test; log sheets and calibration curves for calibration test data; method used in correcting test data to standard atmospheric conditions (Reference Sections 33.45 and 33.85(a)) and substantiation of any correction factors used.

NOTE: All data should be legible, accurate, and when plotted, use scales which are easily read and interpolated.

(D) Teardown inspection. Describe appearance of parts before assembly and after disassembly, prior to cleaning for dimensional inspection. Describe test results with before- and after-test tables of dimensions of major parts of the engine that are likely to incur wear, or change of dimension. Include photographs and descriptions of excessively worn parts. Discuss any unusual wear, burning, overheating, part failure or impending failure, and occurrence of heavy deposits on parts. Indicate the condition of mating, sealing, and friction surfaces; e.g., air-oil seals, each engine case, valve faces, piston rings, oil seals, curvic couplings, etc. Indicate the results of visual, X-ray, magnetic, fluorescent particle, or other inspections of major parts.

(E) Laboratory analyses. Analyses of the types and grades of fuel, lubricants, and hydraulic fluids used in the test. Identify the specification to which the fluids conform. Describe the condition of the lubricant and hydraulic fluids after the test.

(ii) Instruction Manual(s). (Reference Section 33.5). The manual(s) cover information for installing, operating, and continued airworthiness of the engine. Installation and operating manual data that have been substantiated, FAA approved, and are specifically required for engine approval in aircraft, should be so indicated. For convenience, such data may appropriately be contained in a separate portion of the manual(s).

d. Type Design and Type Certificate Data for Import Engines. Certain technical data are required under Section 21.29(a) for import engines when a U.S. type certificate has been applied for. The requirements for such import engines are based on reciprocal airworthiness agreements between the U.S. and the country of manufacture involved, as indicated by Section 21.29. The airworthiness bases, and the exact extent and type of technical data to be supplied the FAA, for showing compliance with the FAA requirements, may vary in accordance with specific agreements between the Administrator and the Airworthiness Authority of the country of manufacture; but includes the usual application and preliminary data already covered, and usually the following:

(1) Type Design Data. Engine model description as discussed above in paragraph c(1) of this section.

(2) Type Certificate Data.

(i) Certification compliance table.

(ii) Engine manuals, in the English language, described above in paragraph c(2)(ii) of this section. Additionally, if not included in the manuals, engine installation and general arrangement drawings are to be submitted.

(iii) Statement of compliance by the Airworthiness Authority of the country of manufacture, with the applicable airworthiness requirements.

(3) Import Requirements Statement. The following statements should be incorporated on the type certificate data sheet (TCDS) for import engines, immediately before "NOTE 1":

"To be considered eligible for installation on U.S. registered aircraft, each engine to be exported to the United States shall be accompanied by a certificate of airworthiness for export, or certifying statement endorsed by the exporting civil airworthiness authority which contains the following language:

(a) This engine conforms to its United States type design (Type Certificate No.-----) and is in a condition for safe operation.

(b) This engine has been subjected, by the manufacturer, to a final operational check and is in a proper state of airworthiness. Reference FAR Section 21.500 which provides for the airworthiness acceptance of aircraft engines manufactured outside the U.S., for which a U.S. type certificate has been issued.

Additional guidance is contained in FAA Advisory Circular 21-23, Airworthiness Certification of Civil Aircraft, Engines, Propellers, and Related Products Imported into the United States."

9. INSTALLATION CONSIDERATIONS OF ENGINES. (FAR Section 21.21).

a. General. An engine type certificate may be obtained upon completion of examination of the type design, completing all engine tests, and applying all applicable provisions of FAR Part 33 and Section 21.21. While it is desirable that the engine applicant cater to all possible aircraft installation characteristics, this is not a requirement for engine certification. This does not obviate the desirability of intimately interrelated installation requirements being introduced into an engine certification program when the aircraft characteristics are known in sufficient time to do so.

b. New Engine. New engines being developed concurrently with new aircraft may be expected to originally meet the applicable aircraft installation requirements. Otherwise, interrelated installation requirements may be met by either engine design changes, or installation features. Such considerations are often specifically related to the engine-aircraft or engine-propeller combination under consideration and require evaluation either apart from or, at times, after engine certification may have been accomplished. While the aircraft applicant is responsible for showing compliance with the aircraft installation requirements, there are occasions when the engine applicant's substantiation data may be utilized for this purpose. It is recommended, therefore, that at the initial engine type board meeting, the engine applicant establish the extent to which he plans to provide substantiation data for the installation. It then becomes desirable that such data be submitted with the engine type certificate data, for later coordination among FAA ACOs.

c. Engine Changes. The foregoing procedure is for new engine models. Refer to the next section for procedures in handling certain design changes to engines that may require changes to the installation. When components of the installation are provided as part of the engine type certification design (e.g., pumps, reversers, coolers, etc.), the engine TCDS should reflect this.

10. ENGINE CHANGES WHICH AFFECT INSTALLATIONS. (FAR Sections 21.19 and 21.97).

a. This section discusses changes in design to certificated engine components whereby the engine operating limits, engine installation details, or aircraft performance characteristics may possibly be significantly altered and require reinvestigation of the aircraft approval. Such major engine changes are to be handled in accordance with Sections 21.19 and 21.97 for engine approval.

b. Extensive changes may result in engine model redesignation, and major changes of a lesser but significant degree may require revisions to the limitation affecting data in TCDSs, operating manuals and/or engine manuals. It is cautioned that seemingly slight changes in engine components may, at times, adversely affect aircraft performance and installation limitations. Some changes that have resulted in certain problems for various engines involve engine fuel metering, surge bleed, and variable geometry control components.

(1) For engine changes, for incorporation in production engines and for general use, that are considered to possibly affect aircraft installations, the degree of compatibility with existing aircraft installation is first established. This involves coordination by the FAA and the engine manufacturer with the responsible aircraft type certificate holder. Suggested procedures are discussed in paragraph 10c below.

(2) If engine interchangeability is adversely affected for existing installations, it is desirable that either the engine or aircraft manufacturer initiate remedial modifications, rather than establishing and qualifying a new model of engine. Proposed engine type design changes should be thoroughly reviewed prior to approval, to ensure they are compatible with the aircraft installations in which the engine is being used, as all engines of the same model designation should be interchangeable in the aircraft.

c. To assist the FAA in evaluating engine type design changes for effects on engine interchangeability in existing aircraft, it is suggested that the engine manufacturer coordinate the changes with affected aircraft manufacturers. It is further suggested that the engine manufacturer establish a written procedure whereby they will notify the FAA engine controlling office of the results, after the completed coordination of each affected engine change. Accomplishment of these steps should reasonably assure thorough evaluation of each design and expedite its approval on the aircraft. If any doubt remains concerning the compatibility status of an engine change, its status should be resolved between the FAA engine and aircraft controlling offices.

11. OFFICIAL ENGINE TESTS. (FAR Section 21.33 and Part 33).

a. Official engine certification tests are to be conducted, in accordance with the authorization directed to the applicant. The tests required for engine certification are as prescribed by pertinent sections of Part 33. The authorization may be a letter or a TIA, in accordance with FAA Order 8120.2A, "Production Approval and Surveillance Procedures," and "TC Handbook," FAA Order 8110.4. Reference these documents and other applicable local FAA Orders, such as NE CD 8110.2A, "Confirmation of Satisfactory Conformity Inspection," and NE CD 8110.1A, "Evaluation and Approval Responsibilities for Manufacturer's Material and/or Process Specifications Specified in the Type Design," when requesting participation of representatives from other than the cognizant FAA engineering office.

b. Witnessing of tests by FAA representatives, as prescribed in Section 21.33, is accomplished, at least, for the engine calibration, endurance, and operation tests; and the teardown inspection following these tests. FAA representatives may also witness such specialized tests as vibration measurement, detonation, rotor integrity, rotor blade containment, icing, and ingestion tests. The engine manufacturer's designated engineering representative (DER) should witness all certification testing and subsequent parts improvement tests conducted by the manufacturer, for the purpose of authenticating the tests and the results. FAA, or delegated designees, must have made a determination prior to testing that engines, parts, and/or components to be tested conform to the appropriate design data.

c. The test authorization identifies the following details relating to official tests:

(1) The engine to be tested and the specific tests, with the schedule of runs and test limits to be employed.

(2) The test equipment, instrumentation (type and accuracy), and facilities (rigs, cells) to be utilized.

(3) The test witnessing desired.

(4) Inspections to be conducted, covering both the engine and the test equipment, as appropriate.

d. For all official FAA tests, test rigs and cells should be inspected for configuration; and data acquisition systems instrumentation for location and calibration.

12. <u>APPROVAL OF ENGINE PARTS AND MATERIALS</u>. (FAR Sections 21.19, 21.113, 21.303, and FAR Part 33).

a. <u>General</u>. All engine parts and materials which have met the design and test requirements of Part 33, for engine type certification, are eligible to be approved parts.

b. <u>Changes by Type Certificate Holder</u>. Changes to the type design of the engine may be made by approval granted to the type certificate holder, when he meets the requirements prescribed under Part 33, and Part 21, Subpart D, discussed in paragraph 13 below.

(1) As indicated for major changes, the parts should undergo testing similar to the original substantiation, unless alternate acceptable substantiation is provided. Minor changes do not usually require testing for their substantiation. Experience has indicated that the cumulative effects of both major and minor changes, especially when groups of new changes are incorporated in production engines, may have significant adverse effects on safety or durability.

(2) Therefore, retesting of engines with all recent design changes appears desirable, when incorporating a design change or group of design changes, in order to assess these effects; and may include development, endurance, vibration, and fatigue testing. Submittal of description data is needed for FAA approval, or for DER approval when appropriately authorized.

c. <u>Replacement or Modification Parts Produced by Other Than the Engine Type Certificate Holder</u>. Design approvals of these parts may be granted as either identical parts to those in the engine type design, or as modifications to the type design. Acceptable means of compliance with Section 21.303 for processing these replacement parts are contained in AC 21.303-1.

(1) When the applicant desires to substantiate parts embodying extensive new design, complete type design data is required, as prescribed in Section 21.19, in the manner applicable to new applications for type certificates.

(2) When the applicant desires to substantiate parts embodying major type design changes, not great enough to require a new application for type certificate, a supplemental type certificate, as prescribed in Section 21.113, may be issued.

13. <u>PROCESSING CHANGES IN TYPE DESIGN</u>. (FAR Part 21, Subparts D and E).

a. <u>Minor Changes</u>. Section 21.95 applies to the approval of minor changes in type design. Such changes normally require only a drawing comparison to substantiate their airworthiness. Typical examples of minor changes are included in the list which follows this paragraph. These changes may be approved by the applicant's appropriately authorized DER. An acceptable method of handling these changes includes submitting to FAA the engineering design change notices, where necessary, to fully describe the changes. Intervals between submittal of each new change, or group of changes, should not exceed six months. Consideration should be given to the possibility that, while certain design changes may well be considered minor when evaluated singly, the cumulative influence of a number of such changes may have an adverse effect, and may have to be evaluated as major changes. The following is a list of typical minor changes:

(1) Slight variations in clearances.

(2) Reasonable increase in radius of fillets.

(3) Increase in thickness, where the design permits it, without adverse effects.

(4) Change to equivalent, or improved material, in minor parts.

(5) Improvements in heat treatments of parts, without reducing elongation of parts subjected to high stress.

(6) Small changes in the design of non-critical parts of the engine.

(7) Improvements in the manufacturing, or processing of parts, without reducing the material properties.

b. Major Changes. Section 21.97 applies to the approval of major changes in the type design. To substantiate major changes to a certificated engine, substantiating data must be submitted. Typical examples of major changes are included in the list which follows this paragraph. Acceptable substantiating data include, at least, technical data and drawings, together with reports of tests, when applicable. As provided in FAR Part 21, Subpart D, a type certificate holder may apply for amendment of the original type certificate for major changes. As provided in FAR Part 21, Subpart E, applicants other than the type certificate holder may apply for a supplemental type certificate for major changes, when appropriate. The applicant should meet at least the minimum airworthiness standards applicable to the original engine, when qualifying design changes. When an unsafe condition has developed, special substantiation may be required to demonstrate that the unsafe condition has been overcome by the proposed type design change. Changes that will contribute to improved safety are often developed as a result of service experience, and may be approved as constituting the current type design standard in compliance with Section 21.99(b). Major changes may be recommended for approval by the type certificate holder's appropriately designated DER, but may not be introduced into service use until approved by the FAA. The following is a list of typical major changes:

(1) A change of either compression ratio, or supercharger gear ratio.

(2) Establishing the eligibility of engines for either an increase of a temperature limit, or a speed limit, such as: oil inlet temperature, turbine inlet or exhaust gas temperature, cylinder base or head temperature, fan engine minimum idle speed, or power turbine maximum speed.

(3) A change in the material or design of highly stressed parts; either rotating, reciprocating, or non-rotating; likely to adversely affect the airworthiness of such parts.

(4) A change involving the method of clamping or attaching rotating, reciprocating, or non-rotating parts.

(5) Any change that measurably affects the engine's fit, function, or compatibility with existing aircraft installations, such as those defined in the preceding paragraph 10b.

(6) Any change to a life-limited part leading to a change of approved life.

(7) Any change providing corrective action for Airworthiness Directives (ADs).

14. IDENTIFICATION PLATE. (FAR Part 33 and Part 45, Subpart B).

a. General. An acceptable method of complying with the fireproof and location requirements of Section 45.11(a) is to meet the following conditions:

(1) The data thereon is legible after the application of a 2,000 ^{o}F flame, for at least 15 minutes.

(2) The plate is located in an accessible place on the engine and engine modules for easy viewing, and is not expected to be easily defaced or dislodged.

b. Identification Data. The type of information to be included on the identification plate, and the persons authorized to install and remove identification plates, are prescribed in Section 45.13.

c. Identification Plate Attachment. AC 43-17,"Methods, Techniques, and Practices Acceptable to the Administrator Governing the Installation, Removal, or Change of Identification

Data and Identification Plates," dated September 5, 1979, is incorporated herein. Compliance with Section 33.19 must be shown, in that the means of attaching the identification plate will not cause cracks, induce fluid leaks, or be susceptible to dislodgement within the interior of the engine, or otherwise adversely affect the engine and module durability, or introduce design features shown to be hazardous or unreliable.

CHAPTER 3. TYPE CERTIFICATION GUIDANCE MATERIAL
SECTION 1. SUBPART A--GENERAL

15. Section 33.3, General.

Section 33.3 General:

Each applicant must show that the aircraft engine concerned meets the applicable requirements of this part.

***

Guidance: The INTENT of this section is self-evident.

Incorporations: None.

References: None.

Generally speaking, FAA will approve an applicant's engine within those conditions and limits which are satisfactorily substantiated. The applicant's assumed data and information for the specific engine design, for which type certification is requested, are initially (in part) provided to FAA with submittal of the application for TC. FAA then, and throughout the TC process, evaluates and validates the assumptions by analyses and tests. The conclusions result in statements of ratings, operating limitations, and instructions for continued airworthiness, installing, and operating the engine - all to assure safe operation of the engine in service.

16. Section 33.4, Instructions for Continued Airworthiness.

Section 33.4 Instructions for Continued Airworthiness.

The applicant must prepare Instructions for Continued Airworthiness in accordance with Appendix A to this Part [immediately following] that are acceptable to the Administrator. The instructions may be incomplete at type certification if a program exists to ensure their completion prior to delivery of the first aircraft with the engine installed, or upon issuance of a standard certificate of airworthiness for the aircraft with the engine installed, whichever occurs later.

APPENDIX A TO PART 33 -- INSTRUCTIONS FOR CONTINUED AIRWORTHINESS

A33.1 GENERAL

(a) This Appendix specifies requirements for the preparation of Instructions for Continued Airworthiness as required by Section 33.4.

(b) The Instructions for Continued Airworthiness for each engine must include the Instructions for Continued Airworthiness for all engine parts. If Instructions for Continued Airworthiness are not supplied by the engine part manufacturer for an engine part, the Instructions for Continued Airworthiness for the engine must include the information essential to the continued airworthiness of the engine.

(c) The applicant must submit to the FAA a program to show how changes to the Instructions for Continued Airworthiness made by the applicant or by the manufacturers of engine parts will be distributed.

A33.2 FORMAT

(a) The Instructions for Continued Airworthiness must be in the form of a manual or manuals as appropriate for the quantity of data to be provided.

(b) The format of the manual or manuals must provide for a practical arrangement.

A33.3 CONTENT

The contents of the manual or manuals must be prepared in the English language. The Instructions for Continued Airworthiness must contain the following manuals or sections as appropriate, and information:

(a) Engine Maintenance Manual or Section.

(1) Introduction information that includes an explanation of the engine's features and data to the extent necessary for maintenance or preventive maintenance.

(2) A detailed description of the engine and its components, systems, and installations.

(3) Installation instructions, including proper procedures for uncrating, deinhibiting, acceptance checking, lifting, and attaching accessories, with any necessary checks.

(4) Basic control and operating information describing how the engine components, systems, and installations operate, and information describing the methods of starting, running, testing, and stopping the engine and its parts including any special procedures and limitations that apply.

(5) Servicing information that covers details regarding servicing points, capacities of tanks, reservoirs, types of fluids to be used, pressures applicable to the various systems, locations of lubrication points, lubricants to be used, and equipment required for servicing.

(6) Scheduling information for each part of the engine that provides the recommended periods at which it should be cleaned, inspected, adjusted, tested, and lubricated, and the degree of inspection, the applicable wear tolerances, and work recommended at these periods. However, the applicant may refer to an accessory, instrument, or equipment manufacturer as the source of this information if the applicant shows that the item has an exceptionally high degree of complexity requiring specialized maintenance techniques, test equipment, or expertise. The recommended overhaul periods and necessary cross references to the Airworthiness Limitations section of the manual must also be included. In addition, the applicant must include an inspection program that includes the frequency of the inspections necessary to provide for the continued airworthiness of the engine.

(7) Troubleshooting information describing probable malfunctions, how to recognize those malfunctions, and the remedial action for those malfunctions.

(8) Information describing the order and method of removing the engine and its parts and replacing parts, with any necessary precautions to be taken. Instructions for proper ground handling, crating. and shipping must also be included.

(9) A list of the tools and equipment necessary for maintenance and directions as to their method of use.

(b) Engine Overhaul Manual or Section.

(1) Disassembly information including the order and method of disassembly for overhaul.

(2) Cleaning and inspection instructions that cover the material and apparatus to be used and methods and precautions to be taken during overhaul. Methods of overhaul inspection must also be included.

(3) Details of all fits and clearances relevant to overhaul.

(4) Details of repair methods for worn or otherwise substandard parts and components along with the information necessary to determine when replacement is necessary.

(5) The order and method of assembly at overhaul.

(6) Instructions for testing after overhaul.

(7) Instructions for storage preparation, including any storage limits.

(8) A list of tools needed for overhaul.

A33.4 AIRWORTHINESS LIMITATIONS SECTION

The Instructions for Continued Airworthiness must contain a section titled Airworthiness Limitations that is segregated and clearly distinguishable from the rest of the document. This section must set forth each mandatory replacement time, inspection interval, and related procedure required for type certification. If the Instructions for Continued Airworthiness consist of multiple documents, the section required by this paragraph must be included in the principal manual. This section must contain a legible statement in a prominent location that reads: "The Airworthiness Limitations Section is FAA approved and specifies maintenance required under Sections 43.16 and 91.163 of the Federal Aviation Regulations unless an alternative program has been FAA approved."

***

Guidance: The INTENT of this section is to assure that Instructions for Continued Airworthiness are available prior to service introduction of the engine.

Incorporations: None.

References: None.

The overhaul section, or manual portion of the instructions for continued airworthiness, may not be available at time of type certification of the engine. In such cases, the engine TCDS should incorporate a "NOTE" prohibiting the overhaul of engines until the overhaul instructions are available; and that, meanwhile, the manufacturer may provide rebuilt engines utilizing new engine tolerances. Overhauled engines must deliver, at least, the TC rated powers, or thrusts, within the ratings' associated limitations.

17. Section 33.5, Instruction Manual for Installing and Operating the Engine.

Section 33.5 Instruction manual for installing and operating the engine.

Each applicant must prepare and make available to the Administrator prior to the issuance of the type certificate, and to the owner at the time of delivery of the engine, approved instructions for installing and operating the engine. The instructions must include at least the following:

(a) Installation instructions.

(1) The location of engine mounting attachments, the method of attaching the engine to the aircraft, and the maximum allowable load for the mounting attachments and related structure.

(2) The location and description of engine connections to be attached to accessories, pipes, wires, cables, ducts, and cowling.

(3) An outline drawing of the engine including overall dimensions.

(b) Operation Instructions.

(1) The operating limitations established by the Administrator.

(2) The power or thrust ratings and procedures for correcting for nonstandard atmosphere.

(3) The recommended procedures, under normal and extreme ambient conditions for--

(i) Starting;

(ii) Operating on the ground; and

(iii) Operating during flight.

***

Guidance: The INTENT of this section is to assure that the engine installation and operating instructions are approved by the time the type certificate for the engine is issued.

Incorporations: None.

References: SAE Document ARP 1507, "Helicopter Engine/Airframe Interface Document and Checklist," issued September 1985. This reference offers further guidance on the types and formats of engine installations and operations information. Although this document is oriented to helicopter (turboshaft) engines, it may be useful as additional general guidance to authors of installation and operating instruction manuals.

a. The installation and operating instructions should incorporate all relevant and complete information on the characteristics, performance, and physical interfaces of the engine. A type certificated engine may include some external lines, equipment mountings, diaphragms, or firewalls which do not meet all certification requirements of some installations. Added line shrouding, relocation of fluid lines, or other changes constitute engine type design changes which may be required for the aircraft installation. Such FAA-approved changes are accomplished preferably by the engine type certificate holder, as approval based on engine compatibility and endurance qualification is usually necessary. However, upon achieving satisfactory coordination with the engine type certificate holder, accomplishment of such changes by the aircraft applicant is often acceptable as an alternative.

b. The engine type certificate holder or applicant may elect to incorporate items of equipment or accessories which are oftentimes handled as part of the aircraft installation responsibility. Examples of such items are engine mounted oil tanks, oil coolers, fuel heaters, generators, thrust reversers, inlet and exhaust nozzles, and various fluid pumps.

(1) When the engine manufacturer elects to furnish such accessories, it is basically implied that he will substantiate

them for engine compatibility, and be responsible for dealing with service difficulties.

(2) If the engine type certificate holder elects to establish aircraft installation compliance, he should develop and provide the necessary installation data in accordance with applicable aircraft requirements.

(3) If the engine type certification effort incorporates findings of compliance for aircraft installation items (i.e., to FAR Part 23, 25, 27, or 29 requirements) then such should be identified on the engine TCDS.

c. The engine installation instructions should incorporate information on the means of limiting, and on the quality of engine compressor bleed air available for airframe use. Design bleed air quality, limit(s), and the means of limiting should be verified by the failure modes and effects analysis and by testing, as appropriate. An example of the need for such information is seen in the certification of FAR Part 23 turbine powered aircraft: Turbine engine bleed air systems of turbine powered airplanes must be investigated to determine that, if the bleed air system is used for direct cabin pressurization, it is not possible for hazardous contamination of the cabin air system to occur in the event of lubrication system failure.

d. The engine installation instructions should incorporate statements of instrumentation types, ranges, required precision, and accuracies for those engine parameters required for safe operation. These statements should be based upon the applicant-selected ratings for the specific engine design, as verified and substantiated throughout the type certification process, particularly the block tests.

18. Section 33.7, Engine Ratings and Operating Limitations.

Section 33.7 Engine ratings and operating limitations.

(a) Engine ratings and operating limitations are established by the Administrator and included in the engine certificate data sheet specified in Section 21.41 of this chapter, including ratings and limitations based on the operating conditions and information specified in this section, as applicable, and any other information found necessary for safe operation of the engine.

(b) For reciprocating engines, ratings and operating limitations are established relating to the following:

(1) Horsepower or torque, r.p.m., manifold pressure, and time at critical pressure altitude and sea level pressure altitude for--

(i) Rated maximum continuous power (relating to unsupercharged operation or to operation in each supercharger mode as applicable); and

(ii) Rated takeoff power (relating to unsupercharged operation or to operation in each supercharger mode as applicable).

(2) Fuel grade or specification.

(3) Oil grade or specification.

(4) Temperature of the--

(i) Cylinder;

(ii) Oil at the oil inlet; and

(iii) Turbosupercharger turbine wheel inlet gas.

(5) Pressure of--

(i) Fuel at the fuel inlet; and

(ii) Oil at the main oil gallery.

(6) Accessory drive torque and overhang moment.

(7) Component life.

(8) Turbosupercharger turbine wheel r.p.m.

(c) For turbine engines, ratings and operating limitations are established relating to the following:

(1) Horsepower, torque, or thrust, r.p.m., gas temperature, and time for--

(i) Rated maximum continuous power or thrust (augmented);

(ii) Rated maximum continuous power or thrust (unaugmented);

(iii) Rated takeoff power or thrust (augmented);

(iv) Rated takeoff power or thrust (unaugmented);

(v) Rated 30 Minute OEI power;

(vi) Rated 2-1/2 Minute OEI power;

(vii) Rated Continuous OEI power; and

(viii) Auxiliary power unit (APU) mode of operation.

(2) Fuel designation or specification.

(3) Oil grade or specification.

(4) Hydraulic fluid specification.

(5) Temperature of--

(i) Oil at a location specified by the applicant;

(ii) Induction air at the inlet face of a supersonic engine, including steady state operation and transient over-temperature and time allowed;

(iii) Hydraulic fluid of a supersonic engine;

(iv) Fuel at a location specified by the applicant; and

(v) External surfaces of the engine; if specified by the applicant.

(6) Pressure of--

(i) Fuel at the fuel inlet;

(ii) Oil at a location specified by the applicant;

(iii) Induction air at the inlet face of a supersonic engine, including steady state operation and transient overpressure and time allowed; and

(iv) Hydraulic fluid.

(7) Accessory drive torque and overhang moment.
(8) Component life.
(9) Fuel filtration.
(10) Oil filtration.
(11) Bleed air.
(12) The number of start-stop stress cycles approved for each rotor disc and spacer.
(13) Inlet air distortion at the engine inlet.
(14) Transient rotor shaft overspeed r.p.m., and number of overspeed occurrences.
(15) Transient gas overtemperature, and number of overtemperature occurrences.
(16) For engines to be used in supersonic aircraft engine rotor windmilling rotational r.p.m.

***

Guidance: The INTENT of this section is to publicly document the engine ratings and limitations data and other information necessary for safe operation of the engine.

Incorporations: AC 91-33A, "Use of Alternate Grades of Aviation Gasoline for Grade 80/87 and Use of Automotive Gasoline," dated July 1984.

References:

1. RTCA Document DO-160B.

2. SAE Committee Report No. AE4EL.

3. AC 21-6A, "Production Under Type Certificate Only", dated July 1, 1982.

4. AC 21-1B, "Production Certificate", dated May 10 1976.

a. Tests. Specific block tests are conducted to establish the various rated powers and thrusts, and the maximum and minimum operating limitations.

(1) The effects of altitude on engine ratings and operating limitations should be determined acceptably. This may be accomplished by means of altitude chamber testing, flight testing, simulated altitude testing, or analytical data using proven methodology.

(2) The ratings' limiting maximum operating parameters should be qualified by operation as indicated in the 150-hour FAA endurance test. Other limitations may be qualified by testing in which the limiting values may be the average attained for appropriate durations.

(3) Special or additional tests may be necessary, at times, to qualify some limitations for either complex engines, such as turbine engines with several rotor systems when limiting test conditions cannot be easily maintained for all rotors simultaneously, or where limits for components may be tested separately on rig tests. Specific examples are:

(i) Under certain ambient conditions, it may not be possible to simultaneously exercise to its respective speed limitation, each rotor of a multiple rotor engine during endurance test running. In such a case, and if approved by the cognizant FAA project manager or engineer, the test may be replicated as necessary to demonstrate each respective limitation, as also discussed under the "Section 33.87, Endurance Test" paragraph of this AC.

(ii) Engine electronic control devices such as full authority digital electronic controls (FADECs), require substantiation of tolerance to the effects of lightning strikes. This substantiation is interpreted to be necessary under the general requirements of FAR Section 33.91(a). Current practice is to require an installations simulation of the complete engine-furnished FADEC system, including cables and connectors, to be subjected to direct and induced lightning strike tests. This effort is typically conducted in accordance with the guidance information provided in References 1 and 2 above. The primary expected outcomes of this testing are definition of the lightning energy levels which the FADEC system can tolerate without adverse affects, and the level of shielding or other protection which the airframer will need to provide upon installation of the FADEC system in the aircraft.

(4) Military test data and reports may be used for certification purposes, if they are determined by the FAA type certification project manager or engineer to satisfy the criteria of the appropriate FAR Part 33 section, and of the conformity inspection requirements of Section 21.53.

b. <u>Ratings and Limitations</u>. Rated engine powers and thrusts are usually established on the basis of engine operation on a test stand, in its normal operating configuration; but usually with, at least, a test stand inlet in place of the aircraft installation hardware.

(1) Ratings are included on the engine TCDS.

(2) All operating limitations that may be considered by the applicant to affect flight safety, if exceeded, are to be noted in the model description and should include such items as the maximum values of: Engine pressure ratio (EPR); torque; rotorspeeds; powers; gas path temperatures; component temperatures; manifold pressure; vibration levels; fuel and

lubricant pressures and temperatures; time at ratings; and number of excursions at ratings.

c. Production and Overhauled Engines. Although discussion of production engines would normally be considered beyond the scope of type certification, the following information may be useful:

(1) Each engine newly produced under a type certificate (TC) only, or under a production certificate, must be tested to assure that engine output is not less than the TC ratings and within each rating's respective associated operating limitations. (See References 3 and 4 above).

(2) It should be recognized that engine manufacturers and overhaulers will typically deliver engines with some degree of performance margin. This margin is usually based on a business agreement between the engine supplier and the installer or user.

(i) The important point is that there is no regulatory basis for engines to have more than minimum type certificated (specification) power/thrust available at delivery, whether in new or overhauled condition.

(ii) A further point is that in-service engines must always be capable of delivering the type certificate rating minimum performance, again, within the respective rating's operating limitations. Otherwise, the engine must be removed from further service and minimum performance restored before return to service.

(3) There are special cases wherein some in-service engine applications have been approved for subsequent operations to lesser performance levels than established during initial type certification. These cases are known as having deteriorated power operation approvals. Such cases have been approved only following extensive reevaluation of the engine and the aircraft to the deteriorated performance level, against the original type certification basis. This approval is limited to the specific initial operator's route structure.

19. Section 33.8, Selection of Engine Power and Thrust Ratings.

Section 33.8 Selection of engine power and thrust ratings.

(a) Requested engine power and thrust ratings must be selected by applicant.

(b) Each selected rating must be for the lowest power or thrust that all engines of the same type may be expected to produce under the conditions used to determine that rating.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

The objective of this requirement is to establish, on a uniform basis, the power or thrust ratings which new engines, and engines restored to new condition, are required to produce. These ratings are used in establishing aircraft performance for which consistent minimum performance is desired. Ratings selected by the applicant are established by FAA block tests. Ratings are typically based on specific atmospheric conditions, for the static case, with no customer bleed, no power extraction, and 100 percent recovery of inlet and exhaust losses. The applicant's experience on the calibrated output of a number of engines, of both the applicable new model and of engines of closely similar design characteristics, should be reviewed to evaluate the range of output expected in all other engines of that type. The selected ratings should be consistent with the output of the lowest output engine anticipated.

SECTION 2. SUBPART B--DESIGN AND CONSTRUCTION; GENERAL

20. Section 33.14, Start-Stop Cyclic Stress (Low-Cycle Fatigue).

Section 33.14 Start-stop cyclic stress (low-cycle fatigue).

By a procedure approved by the FAA, operating limitations must be established which specify the maximum allowable number of start-stop stress cycles for each rotor structural part (such as discs, spacers, hubs, and shafts of the compressors and turbines), the failure of which could produce a hazard to the aircraft. A start-stop stress cycle consists of a flight cycle profile or an equivalent representation of engine usage. It includes starting the engine, accelerating to maximum rated power or thrust, decelerating, and stopping. For each cycle, the rotor structural parts must reach stabilized temperature during engine operation at maximum rated power or thrust and after engine shutdown, unless it is shown that the parts undergo the same stress range without temperature stabilization.

***

Guidance. The INTENT of this section is to establish cyclic life limits using FAA-approved methodology for rotating structural components whose failure could produce a hazard to the aircraft.

Incorporations: AC 33.3, "Turbine and Compressor Rotors Type Certification Substantiation Procedures," dated September 9, 1968.

References: None.

The guidance embodied in the "Incorporations" above, with respect to determination of service life limits, is still considered valid.

a. Some applicants have pre-approved procedures on file with the FAA for establishing initial (and increases of) low cycle fatigue (LCF) lives. Such procedures should be utilized where they exist.

b. The FAA requires the applicant to define the LCF verification test cycle, based on the most severe mission cycle expected in service. The determination of the most severe mission cycle expected in service is based on the concurrence of the FAA engine certification project manager with the applicant's proposed definition.

(1) It is determined logically, based on the type of engine, types of airframe applications, and anticipated service

usage. In rare cases, specific airframe applications during the time of the engine certification program are not known, and, therefore, more speculative, but conservative, approaches may need to be used. In all cases, the FAA's installation office may be consulted to assist in determining the mission cycle.

(2) The test cycle basis should, in part, incorporate some excursions to the redline limits of gas path temperature, rotational speeds, torques, pressures, etc., associated with the maximum ratings used in the mission cycle. Consider such excursions that could reasonably be expected to occur within the extremes of ambient temperature and takeoff altitude conditions encountered during the engine's service life.

(3) The supporting data required for LCF qualification includes mechanical and thermal stress analyses and tests, and material analyses and tests. Since there are various acceptable methods of determining maximum temperature gradients, the FAA does not advocate that any particular methodology be applied for thermal analyses. Test engine rotor structural parts should attain a stabilized temperature for each applied test cycle.

c. Increases in service life limits, similar to the determination of initial life limits, will need to be based on a representative severe operating cycle, identified from service experience. Programs to increase service life limits should be based on further cyclic testing and analysis of in-service parts that have attained a reasonable percentage of their life limits.

d. FAA findings of compliance with existing FAR Section 33.14 are based, in part, on the applicant's definition of the flight cycle profile, or equivalent representation of engine usage. Implementation of this aspect of the rule, in the case of OEI rated engines, requires addressing the use of OEI ratings at a realistic frequency representative of actual (expected) in-service use.

(1) To date, the service experience with OEI rated engines is that use of OEI ratings, following a true case of one engine having failed, is an extremely rare event. Thus, it is considered totally unrealistic to mandate the use of OEI ratings as a constituent of each flight cycle.

(2) However, the applicant is still required, in all cases, to account for low cycle fatigue effects, based on the anticipated usage of OEI ratings during the life of the engine. This could be accomplished, for example, by adding a reasoned finite number of cycles to the expended life of the appropriate components for each OEI power excursion.

21. Section 33.15, Materials.

Section 33.15 Materials.

The suitability and durability of materials used in the engine must--

(a) Be established on the basis of experience or tests; and

(b) Conform to approved specifications (such as industry or military specifications) that ensure their having the strength and other properties assumed in the design data.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: AC 33-4, "Design Considerations Concerning the Use of Titanium in Aircraft Turbine Engines," dated July 28, 1983.

References: None.

The applicant should select approved specification materials in the design and construction of the engine to minimize the development of an unsafe condition of the engine. Although the regulations do not specifically address corrosion and deterioration, these factors need to be considered in the type certification process, particularly in the design stage. Examples are proposed use of non-corrosion resistant alloys in corrosion-susceptible areas and proposed use of galvanic materials in contact.

22. Section 33.17, Fire Prevention.

Section 33.17 Fire prevention.

(a) The design and construction of the engine and the materials used must minimize the probability of the occurrence and spread of fire. In addition, the design and construction of turbine engines must minimize the probability of the occurrence of an internal fire that could result in structural failure, overheating, or other hazardous conditions.

(b) Except as provided in paragraphs (c), (d), and (e) of this section, each external line, fitting, and other component, which contains or conveys flammable fluid must be fire resistant. Components must be shielded or located to safeguard against the ignition of leaking flammable fluid.

(c) Flammable fluid tanks and supports which are part of and attached to the engine must be fireproof or be enclosed by a fireproof shield unless damage by fire to any non-fireproof part will not cause leakage or spillage of flammable fluid. For a reciprocating engine having an integral oil sump of less than 25-quart capacity, the oil sump need not be fireproof nor be enclosed by a fireproof shield.

(d) For turbine engines type certificated for use in supersonic aircraft, each external component which conveys or contains flammable fluid must be fireproof.

(e) Unwanted accumulation of flammable fluid and vapor must be prevented by draining and venting.

***

Guidance. The INTENT of this section is to assure that design, materials, and construction techniques are used to minimize the occurrence and spread of fire.

Incorporations: AC 33-4, "Design Considerations Concerning the Use of Titanium in Aircraft Turbine Engines", dated July 28, 1983.

References:

1. SAE AS1055B, "Fire Testing of Flexible Hose, Tube Assemblies, Coils, Fittings, and Similar System Components," March 1, 1978.

2. SAE AIR 1377A, "Fire Test Equipment for Flexible Hose and Tube Assemblies," January 1980.

3. FAA Powerplant Engineering Report No. 3A, "Standard Fire Test Apparatus and Procedure," Revised March 1978.

4. FAA Report No. FAA-RD-79-51, "Titanium Combustion in Turbine Engines," dated July 1979; and JAR-E, Section 2, Paragraph ACJE530(c), "Titanium Fires."

5. SAE Report No. 690436, "Ignition of Aircraft Fluids on High Temperature Engine Surfaces," by W.T. Westfield of the FAA.

6. FAA Report No. FAA-RD-75-155, "Ignition and Propagation Rates for Flames in a Fuel Mist," October 1975, by C.E. Polymeropoulos.

7. AC 20-135, "Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards and Criteria," dated February 6, 1990.

a. The FAR Part 1 definitions of "fire resistant" and "fire proof" are very broad and are not quantified in terms of flame temperature and time of immersion. For purposes of engine certification, fire resistant should be associated with a test flame temperature of 2000 °F, for at least a 5-minute duration;

fireproof should be associated with a test flame temperature of 2000 °F, for at least a 15-minute duration.

b. Fire test conditions to be applied should be established consistent with the intended use of the engine component or subsystem being evaluated. Examples of this are: sheet stock designed to be firewalls or fireshrouds; formed parts designed as oil tanks; castings designed as fuel pump bodies; seamless tubing designed as fuel and oil supply lines; etc.

c. The test flame should be applied at the component or subsystem location that is determined by analysis and/or inspection to be most critical to fire susceptibility. Additionally, the operating characteristics of the component or subsystem should be established consistent with those which would normally be expected to exist during actual engine fire conditions.

d. Fire susceptibility means not only the probable location of a fire, but also the specific location of the component or subsystem within the fire zone that may be least likely to survive the effects of a fire. Such a determination should consider, at least, the following potential factors: materials characteristics; parts geometry; local torching effects; joint seals; vibration characteristics; internal fluid levels, pressures, and flows; wicking of surface coatings; engine design requirement for installed engine, through nacelle exhaust ejector driven component cooling airflows; characteristics of probable leakage in forms of sprays, drops, streams; etc.

e. The fire test burner to be used should provide the desired 2000 °F flame temperature of sufficient size, and at an energy level (BTU/hr) appropriate to the geometry of the engine component or subsystem being evaluated. Further general guidance on burner configuration can be found in References 1, 2, and 3 above.

f. In all cases, fire test acceptance criteria should show no support of combustion by the constituent material being tested; no burn-through; no leakage of fluid-carrying or fluid-holding parts sufficient to increase the fire hazard; and fire-protecting parts should be capable of satisfactorily performing the functions for which they were designed.

g. Compliance with the requirements of Section 33.17(a) requires that the design and construction of turbine engines must minimize the probability of the occurrence of an internal fire that could result in structural failure, overheating, or other hazardous conditions. (See also Reference 4 above).

h. Available references relating to hot surface ignition (HSI) criteria for fuels are consistent in that the HSI temperature for JP-type fuels is in the range of 425-500 ^{o}F (minimum) for the non-ventilated case. HSI temperature increases dramatically with increasing airflow. It is also influenced by the characteristics of the secondary cooling air and engine surface geometry, ventilation rates of the engine nacelle, direction and changes of direction of the cooling air, and changes in engine power while leakage is occurring. Further information on this topic is available in References 5 and 6 above.

23. Section 33.19, Durability.

Section 33.19 Durability.

(a) Engine design and construction must minimize the development of an unsafe condition of the engine between overhaul periods. The design of the compressor and turbine rotor cases must provide for the containment of damage from rotor blade failure. Energy levels and trajectories of fragments resulting from rotor blade failure that lie outside the compressor and turbine rotor cases must be defined.

(b) Each component of the propeller blade pitch control system which is a part of the engine type design must meet the requirements of Section 35.42 of this chapter.

***

Guidance. The INTENT of this section is self-evident

Incorporations:

1. AC 33-4, "Design Considerations Concerning the Use of Titanium in Aircraft Turbine Engines," dated July 28, 1983.

2. AC 33-5, "Turbine Engine Rotor Blade Containment/Durability," dated June 18, 1990.

References: None.

a. This section addresses the generic safety requirement of engines between "overhaul" periods, in addition to specific design requirements for rotor blade containment and for propeller blade pitch control.

(1) The generic requirement is fulfilled by compliance not only to each of the appropriate sections of FAR Part 33, but also to the "grandfather" Sections of 21.33, "Inspection and tests," and 21.16, "Special conditions."

(2) Collectively, these speak to not only the basis for type certification, but more specifically to: (1) materials and products specifications; (2) conformance of parts to the drawings in the type design; (3) specification of manufacturing processes; and (4) construction and assembly specifications in the engine type design (drawings). Each of these items should be traceable in the type certification design documentation from the engine top assembly drawing.

b. This section also addresses the specific design requirements for rotor blade containment, whereas FAR Section 33.94 addresses the demonstration requirements; both are addressed in Incorporation 2. Essentially, the design (analysis) is borne out by testing to substantiate that the potential energy of the containment structure is greater than the kinetic energy of the released rotor blade debris.

24. Section 33.21, Engine Cooling.

Section 33.21 Engine cooling.

Engine design and construction must provide the necessary cooling under conditions in which the airplane is expected to operate.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

a. Interpretations of this regulation have historically been limited to operating fluid, external engine surface, and component heat rejection considerations, particularly of reciprocating engines. However, inasmuch as the rule applies to "Design and Construction-General," it should be interpreted to apply to both reciprocating and turbine engines, and to all engine cooling considerations.

b. Evaluation of the engine cooling systems design should not only address operating fluid and external component cooling, but also internal flow path cooling of turbochargers, rotors, spacers, nozzles, combustors, cases, etc. Particular attention should be given to ensure that continued safe operation and integrity of the critical structural components, while operating in the intended environment, is maintained throughout the design life and/or time to inspection, as appropriate.

25. Section 33.23, Engine Mounting Attachments and Structure.

Section 33.23 Engine mounting attachments and structure.

(a) The maximum allowable limit and ultimate loads for engine mounting attachments and related engine structure must be specified.
(b) The engine mounting attachments and related engine structure must be able to withstand--
(1) The specified limit loads without permanent deformation; and
(2) The specified ultimate loads without failure, but may exhibit permanent deformation.

***

Guidance. The INTENT of this section is to specify the allowable limit and ultimate loads, as defined, for the engine mounting attachments and related engine structure.

Incorporations: None.

References: None.

a. Engine attachment (mount) limit loads are the maximum loads to be expected in service and include, in combination, static mount loads, operating engine maximum reactive torque loads, gyroscopic loads, and maximum ground and flight loads. Ultimate load capability of the engine attachment mount structure is substantiated by analysis and by limited rig and component testing, which should also serve to validate the applicant's analytical methodology.

b. Engine mounting attachments and structure design should include consideration of deterioration, and corrosion effects expected during the design life of the engine. Suitable methods of detection of pending faults and failures at, or between, inspection intervals to be approved, should also be given consideration.

26. Section 33.25, Accessory Attachments.

Section 33.25 Accessory attachments.

The engine must operate properly with the accessory drive and mounting attachments loaded. Each engine accessory drive and mounting attachment must include provisions for sealing to prevent contamination of, or unacceptable leakage from, the engine interior. A drive and mounting attachment requiring lubrication for external drive splines, or coupling by engine oil, must include provisions for sealing to prevent unacceptable loss of oil and to prevent contamination from sources outside the chamber enclosing the drive connection. The design of the engine must allow for the examination, adjustment, or removal of each accessory required for engine operation.

***

Guidance. The INTENT of this section is that design and construction of engine accessory drives and their mount pads permit proper engine operation when loaded; prevent contamination and excessive loss of oil; and permit inspection, adjustment, and removal of accessories.

Incorporations: None.

References: None.

If engine accessory drives are designed to protect the engine from potential unsafe conditions, such as those due to accessory seizure overtorque, by designed failure of a drive shaft shear section; then, it should be shown that the shear section will not fail under all normal operating load conditions, or otherwise result in damage or hazard to the engine or its subsequent aircraft installation.

27. Section 33.27, Turbine, Compressor, Fan and Turbosupercharger Rotors.

Section 33.27 Turbine, compressor, fan and turbosupercharger rotors.

(a) Turbine, compressor, fan, and turbosupercharger rotors must have sufficient strength to withstand the test conditions specified in paragraph (c) of this section.

(b) The design and functioning of engine control devices, systems, and instruments must give reasonable assurance that those engine operating limitations that affect turbine, compressor, and turbosupercharger rotor structural integrity will not be exceeded in service.

(c) The most critically stressed rotor component (except blades) of each turbine, compressor, and fan, including integral drum rotors and centrifugal compressors in an engine or turbosupercharger, as determined by analysis or other acceptable means, must be tested for a period of 5 minutes--

(1) At its maximum operating temperature, except as provided in paragraph (c)(2)(iv) of this section; and

(2) At the highest speed of the following, as applicable:

(i) 120 percent of its maximum permissible r.p.m. if tested on a rig and equipped with blades or blade weights.

(ii) 115 percent of its maximum permissible r.p.m. if tested on an engine.
(iii) 115 percent of its maximum permissible r.p.m. if tested on a turbosupercharger driven by a hot gas supply from a special burner rig.
(iv) 120 percent of the r.p.m. at which, while cold spinning, it is subject to operating stresses that are equivalent to those induced at the maximum operating temperature and maximum permissible r.p.m.
(v) 105 percent of the highest speed that would result from failure of the most critical component or system in a representative installation of the engine.
(vi) The highest speed that would result from the failure of any component or system in a representative installation of the engine, in combination with any failure of a component or system that would not normally be detected during a routine preflight check or during normal flight operation.
Following the test, each rotor must be within approved dimensional limits for an overspeed condition and may not be cracked.

***

Guidance. The INTENT of this section is to assure engine rotor structural integrity, by design and functioning of engine control and instrumentation systems, to inhibit exceedances of operating limitations; and, to demonstrate that each engine rotor has sufficient strength to withstand a maximum overspeed condition without cracking.

Incorporations: None.

References: None.

a. If the engine bill-of-material includes instrumentation (including sensors), then such must be designed and must function so as to assure safe operation, (structural integrity of the in-service engine). Note that the rule requires the most critically stressed rotor component (including discs, spacers, cooling plates) of each turbine, compressor, and fan to be tested at a maximum overspeed condition for 5 minutes. Determination of the maximum overspeed condition needs to consider the 6 cases defined in the rule -- including shaft failures which decouple a turbine rotor from its load. Rotor shafts are not considered "prime reliable" in that it is assumed that shaft failures will occur, both as a single failure and in combination with another undetected or dormant failure.

b. A rotor burst test, in lieu of the presently required 5-minute overspeed test, could be found as an acceptable equivalent means of compliance. In the case of output shaft (low) turbines, the rotor burst test would be performed, in conjunction with an abrupt load decouple test, to demonstrate the existence of adequate margin between the peak speed and the burst speed. The actual burst speed must be corrected to account for the effects of gas path temperature (i.e., actual engine at maximum operating temperature versus spin pit temperature at burst), and test specimen actual material properties versus specification minimum material properties. Acceptance criteria must show at least a 5.0 percent speed margin between the abrupt decouple peak speed and the corrected burst speed.

c. The following table, provided as a historical reference, correlates the rotor integrity regulation and its guidance, including significant differences:

TABLE 27-1. ROTOR INTEGRITY REGULATIONS/GUIDANCE

REGULATION & EFFECTIVITY DATE		CORRESPONDING GUIDANCE & ISSUE DATE	SIGNIFICANT GUIDANCE DIFFERENCES
FAR 33-13, FAR 33-12, FAR 33-11, FAR 33-10, FAR 33-9, FAR 33-8, FAR 33-7, FAR 33-6,	08/18/89 10/03/88 04/24/86 03/26/84 10/14/80 05/02/77 02/01/77 10/31/74	AC 33-3, 09/09/68	o POST-TEST ACCEPTANCE CRITERIA OF THE FAR TAKES PRECEDENCE OVER THAT OF THE AC.
FAR 33-5, FAR 33-4,	03/01/74 04/23/71	AC 33-3, 09/09/68	o FAR DOES NOT IDENTIFY POST-TEST ACCEPTANCE CRITERIA.
FAR 33-3, FAR 33-2,	04/03/67 07/06/66	AC 20-26, CH.2 07/08/65	o POST-TEST ACCEPTANCE CRITERIA OF THE AC REVISED BY CH.2. (PARAGRAPH 4C).
FAR 33 & 33-1,	02/01/65	AC 20-26 CH.1, 09/18/64; AC 20-26, 07/22/64	o SUPERSEDES FAA MEMORANDUM OF 02/09/59. o OVERSPEED TEST CONDITION ANALYSIS BASED ON FAILURE(S).
CAR 13-6, CAR 13-5, CAR 13-4, CAR 13-3,	04/22/64 02/12/63 05/03/62 10/01/59	FAA POLICY MEMORANDUM, 02/09/59	o ESTABLISHES REQUIREMENTS FOR SUBSTANTIATION OF TURBINE & COMPRESSOR ROTOR INTEGRITY. NOTE THAT THE OVERSPEED TEST CONDITION TO BE RUN IS BASED ON ANALYSIS OF CONTROL SYSTEM FAILURE(S) AND ON A FACTOR OF TAKEOFF R.P.M., WHICHEVER YIELDS THE GREATEST STRESS. o MUST DEMONSTRATE OVERSTRESS MARGIN, BUT DOES NOT OFFER ACCEPTANCE CRITERIA.
CAR 13-2, CAR 13-1, CAR 13,	05/17/58 08/12/57 06/15/56	NONE	N/A

28. Section 33.29, Instrument Connection.

Section 33.29 Instrument connection.

(a) Unless it is constructed to prevent its connection to an incorrect instrument, each connection provided for powerplant instruments required by aircraft airworthiness regulations or necessary to insure operation of the engine in compliance with any engine limitation must be marked to identify it with its corresponding instrument.

(b) A connection must be provided on each turbojet engine for an indicator system to indicate rotor system unbalance.

***

Guidance. The INTENT of this section is to prevent misconnections of engine-required instrumentation, and to provide a drawing location for rotor unbalance sensing.

Incorporations: None.

References: None.

An acceptable method of complying with FAR Section 33.29(b) is to identify, on the engine installation drawing, the flange location for installation of the unbalance indicator transducer. Historically, "turbojet" has been interpreted to also include fan engines.

SECTION 3. SUBPART C--DESIGN AND CONSTRUCTION; RECIPROCATING AIRCRAFT ENGINES

29. Section 33.33, Vibration.

Section 33.33 Vibration.

The engine must be designed and constructed to function throughout its normal operating range of crankshaft rotational speeds and engine powers without inducing excessive stress in any of the engine parts because of vibration and without imparting excessive vibration forces to the aircraft structure.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

30. Section 33.35, Fuel and Induction System.

Section 33.35 Fuel and induction system.

(a) The fuel system of the engine must be designed and constructed to supply an appropriate mixture of fuel to the cylinders throughout the complete operating range of the engine under all flight and atmospheric conditions.

(b) The intake passages of the engine through which air or fuel in combination with air passes for combustion purposes must be designed and constructed to minimize the danger of ice accretion in those passages. The engine must be designed and constructed to permit the use of a means for ice prevention.

(c) The type and degree of fuel filtering necessary for protection of the engine fuel system against foreign particles in the fuel must be specified. The applicant must show that foreign particles passing through the prescribed filtering means will not critically impair engine fuel system functioning.

(d) Each passage in the induction system that conducts a mixture of fuel and air must be self-draining, to prevent a liquid lock in the cylinders, in all attitudes that the applicant establishes as those the engine can have when the aircraft in which it is installed is in the static ground attitude.

(e) If provided as part of the engine, the applicant must show for each fluid injection (other than fuel) system and its controls that the flow of the injected fluid is adequately controlled.

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

31. Section 33.37, Ignition System.

Section 33.37 Ignition system.

Each spark ignition engine must have a dual ignition system with at least two spark plugs for each cylinder and two separate electric circuits with separate sources of electrical energy, or have an ignition system of equivalent in-flight reliability.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

The engine installation instructions should define the characteristics and interface requirements of all aircraft sources of electrical power required by the engine ignition system.

32. Section 33.39, Lubrication System.

Section 33.39 Lubrication system.

(a) The lubrication system of the engine must be designed and constructed so that it will function properly in all flight attitudes and atmospheric conditions in which the airplane is expected to operate. In wet sump engines, this requirement must be met when only one-half of the maximum lubricant supply is in the engine.

(b) The lubrication system of the engine must be designed and constructed to allow installing a means of cooling the lubricant.

(c) The crankcase must be vented to the atmosphere to preclude leakage of oil from excessive pressure in the crankcase.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

SECTION 4. SUBPART D--BLOCK TESTS; RECIPROCATING AIRCRAFT ENGINES

33. Section 33.42, General.

Section 33.42 General.

Before each endurance test required by this subpart, the adjustment setting and functioning characteristic of each component having an adjustment setting and a functioning characteristic that can be established independent of installation on the engine must be established and recorded.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

34. Section 33.43, Vibration Test.

Section 33.43 Vibration test.

(a) Each engine must undergo a vibration survey to establish the torsional and bending vibration characteristics of the crankshaft and the propeller shaft or other output shaft, over the range of crankshaft speed and engine power, under steady state and transient conditions, from idling speed to either 110 percent of the desired maximum continuous speed rating or 103 percent of the maximum desired takeoff speed rating, whichever is higher. The survey must be conducted using, for airplane engines, the same configuration of the propeller type which is used for the endurance test, and using, for other engines, the same configuration of the loading device type which is used for the endurance test.

(b) The torsional and bending vibration stresses of the crankshaft and the propeller shaft or other output shaft may not exceed the endurance limit stress of the material from which the shaft is made. If the maximum stress in the shaft cannot be shown to be below the endurance limit by measurement, the vibration frequency and amplitude must be measured. The peak amplitude must be shown to produce a stress below the endurance limit; if not, the engine must be run at the condition producing the peak amplitude until, for steel shafts, 10 million stress reversals have been sustained without fatigue failure and, for other shafts, until it is shown that fatigue will not occur within the endurance limit stress of the material.

(c) Each accessory drive and mounting attachment must be loaded, with the loads imposed by each accessory used only for an aircraft service being the limit load specified by the applicant for the drive or attachment point.

(d) The vibration survey described in paragraph (a) of this section must be repeated with that cylinder not firing which has the most adverse vibration effect, in order to establish the conditions under which the engine can be operated safely in that abnormal state. However, for this vibration survey, the engine speed range need only extend from idle to the maximum desired takeoff speed, and compliance with paragraph (b) of this section need not be shown.

***

Guidance. The INTENT of this section is to demonstrate that the engine is free of potentially harmful vibration under all normal operating conditions.

Incorporations: None.

References: None.

When the engine is used to drive a propeller, the engine vibration investigation must be conducted with a representative propeller, including the propeller governor and spinner. A satisfactory finding from the engine vibration survey will serve to permit certification of the engine, as far as its vibration is concerned.

35. Section 33.45, Calibration Tests.

Section 33.45 Calibration tests.

(a) Each engine must be subjected to the calibration tests necessary to establish its power characteristics and the conditions for the endurance test specified in Section 33.49. The results of the power characteristics calibration tests form the basis for establishing the characteristics of the engine over its entire operating range of crankshaft rotational speeds, manifold pressures, fuel/air mixture settings, and altitudes. Power ratings are based upon standard atmospheric conditions with only those accessories installed which are essential for engine functioning.

(b) A power check at sea level conditions must be accomplished on the endurance test engine after the endurance test. Any change in power characteristics which occurs during the endurance test must be determined. Measurements taken during the final portion of the endurance test may be used in showing compliance with the requirements of this paragraph.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

36. Section 33.47, Detonation Test.

Section 33.47 Detonation test.

Each engine must be tested to establish that the engine can function without detonation throughout its range of intended conditions of operation.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: AC 33.47-1, "Detonation Testing in Reciprocating Aircraft Engines," dated June 27, 1988.

References: None.

37. Section 33.49 Endurance Test.

Section 33.49 Endurance test.

(a) General. Each engine must be subjected to an endurance test that includes a total of 150 hours of operation (except as provided in paragraph (e)(1)(iii) of this section) and, depending upon the type and contemplated use of the engine, consists of one of the series of runs specified in paragraphs (b) through (e) of this section, as applicable. The runs must be made in the order found appropriate by the Administrator for the particular engine being tested. During the endurance test the engine power and the crankshaft rotational speed must be kept within ± 3 percent of the rated values. During the runs at rated takeoff power and for at least 35 hours at rated maximum continuous power, one cylinder, must be operated at not less than the limiting temperature, the other cylinders must be operated at a temperature not lower than 50 degrees F. below the limiting temperature, and the oil inlet temperature must be maintained within ± 10 degrees F. of the limiting temperature. An engine that is equipped with a propeller shaft must be fitted for the endurance test with a propeller that thrust-loads the engine to the maximum thrust which the engine is designed to resist at each applicable operating condition specified in this section. Each accessory drive and mounting attachment must be loaded. During operation at rated takeoff power and rated maximum continuous power, the load imposed by each accessory used only for an aircraft service must be the limit load specified by the applicant for the engine drive or attachment point.

(b) Unsupercharged engines and engines incorporating a gear-driven single speed supercharger. For engines not incorporating a supercharger and for engines incorporating a gear-driven single-speed supercharger the applicant must conduct the following runs:

(1) A 30-hour run consisting of alternate periods of 5 minutes at rated takeoff power with takeoff speed, and 5 minutes of maximum best economy cruising power or maximum recommended cruising power.

(2) A 20-hour run consisting of alternate periods of 1-1/2 hours at rated maximum continuous power with maximum continuous speed, and 1/2 hour at 75 percent rated maximum continuous power and 91 percent maximum continuous speed.

(3) A 20-hour run consisting of alternate periods of 1-1/2 hours at rated maximum continuous power with maximum continuous speed, and 1/2 hour at 70 percent rated maximum continuous power and 89 percent maximum continuous speed.

(4) A 20-hour run consisting of alternate periods of 1-1/2 hours at rated maximum continuous power with maximum continuous speed, and 1/2 hour at 65 percent rated maximum continuous power and 87 percent maximum continuous speed.

(5) A 20-hour run consisting of alternate periods of 1-1/2 hours at rated maximum continuous power with maximum continuous speed, and 1/2 hour at 60 percent rated maximum continuous power and 84.5 percent maximum continuous speed.

(6) A 20-hour run consisting of alternate periods of 1-1/2 hours at rated maximum continuous power with maximum continuous speed, and 1/2 hour at 50 percent rated maximum continuous power and 79.5 percent maximum continuous speed.

(7) A 20-hour run consisting of alternate periods of 2-1/2 hours at rated maximum continuous power with maximum continuous speed, and 2-1/2 hours at maximum best economy cruising power or at maximum recommended cruising power.

(c) Engines incorporating a gear-driven two speed supercharger. For engines incorporating a gear-driven two-speed supercharger the applicant must conduct the following runs:

(1) A 30-hour run consisting of alternate periods in the lower gear ratio of 5 minutes at rated takeoff power with takeoff speed, and 5 minutes at maximum best economy cruising power or at maximum recommended cruising power. If a takeoff power rating is desired in the higher gear

ratio, 15 hours of the 30-hour run must be made in the higher gear ratio in alternate periods of five minutes at the observed horsepower obtainable with the takeoff critical altitude manifold pressure and takeoff speed, and five minutes at 70 percent high ratio rated maximum continuous power and 89 percent high ratio maximum continuous speed.

(2) A 15-hour run consisting of alternate periods in the lower gear ratio of 1 hour of rated maximum continuous power with maximum continuous speed, and 1/2 hour at 75 percent rated maximum continuous power and 91 percent maximum continuous speed.

(3) A 15-hour run consisting of alternate periods in the lower gear ratio of 1 hour at rated maximum continuous power with maximum continuous speed, and 1/2 hour at 70 percent rated maximum continuous power and 89 percent maximum continuous speed.

(4) A 30-hour run in the higher gear ratio at rated maximum continuous power with maximum continuous speed.

(5) A 5-hour run consisting of alternate periods of 5 minutes in each of the supercharger gar ratios. The first 5 minutes of the test must be made at maximum continuous speed in the higher gear ratio and the observed horsepower obtainable with 90 percent of maximum continuous manifold pressure in the higher gear ratio under sea level conditions. The condition for operation for the alternate 5 minutes in the lower gear ratio must be that obtained by shifting to the lower gear ratio at constant speed.

(6) A 10-hour run consisting of alternate periods in the lower gear ratio of 1 hour at rated maximum continuous power with maximum continuous speed, and 1 hour at 65 percent rated maximum continuous power and 87 percent maximum continuous speed.

(7) A 10-hour run consisting of alternate periods in the lower gear ratio of 1 hour at rated maximum continuous power with maximum continuous speed, and 1 hour at 60 percent rated maximum continuous power and 84.5 percent maximum continuous speed.

(8) A 10-hour run consisting of alternate periods in the lower gear ratio of 1 hour at rated maximum continuous power with maximum continuous speed, and 1 hour at 50 percent rated maximum continuous power and 79.5 percent maximum continuous speed.

(9) A 20-hour run consisting of alternate periods in the lower gear ratio of 2 hours at rated maximum continuous power with maximum continuous speed, and 2 hours at maximum best economy cruising power and speed or at maximum recommended cruising power and speed.

(10) A 5-hour run in the lower gear ratio at maximum best economy cruising power and speed or at maximum recommended cruising power and speed.

Where simulated altitude test equipment is not available when operating in the higher gear ratio, the runs may be made at the observed horsepower obtained with the critical altitude manifold pressure or specified percentages thereof, and the fuel-air mixtures may be adjusted to be rich enough to suppress detonation.

(d) Helicopter engines. To be eligible for use on a helicopter each engine must either comply with paragraphs (a) through (j) of Section 29.923 of this chapter, or must undergo the following series of runs:

(1) A 35-hour run consisting of alternate periods of 30 minutes each at rated takeoff power with takeoff speed, and at rated maximum continuous power with maximum continuous speed.

(2) A 25-hour run consisting of alternate periods of 2-1/2 hours each at rated maximum continuous power with maximum continuous speed, and at 70 percent rated maximum continuous power with maximum continuous speed.

(3) A 25-hour run consisting of alternate periods of 2-1/2 hours each at rated maximum continuous power with maximum continuous speed, and at 70 percent rated maximum continuous power with 80 to 90 percent maximum continuous speed.

(4) A 25-hour run consisting of alternate periods of 2-1/2 hours each at 80 percent rated maximum continuous power with takeoff speed, and at 80 percent rated maximum continuous power with 80 to 90 percent maximum continuous speed.

(5) A 25-hour run consisting of alternate periods of 2-1/2 hours each at 80 percent rated maximum continuous power with takeoff speed, and at either rated maximum continuous power with 110 percent maximum continuous speed or at rated takeoff power with 103 percent takeoff speed, whichever results in the greater speed.

(6) A 15-hour run at 105 percent rated maximum continuous power with 105 percent maximum continuous speed or at full throttle and corresponding speed at standard sea level carburetor entrance pressure, if 105 percent of the rated maximum continuous power is not exceeded.

(e) Turbosupercharged engines. For engines incorporating a turbosupercharger the following apply except that altitude testing may be simulated provided the applicant shows that the engine and supercharger are being subjected to mechanical loads and operating temperatures no less severe than if run at actual altitude conditions:

(1) For engines used in airplanes the applicant must conduct the runs specified in paragraph (b) of this section, except--

(i) The entire run specified in paragraph (b)(1)of this section must be made at sea level altitude pressure;

(ii) The portion of the runs specified in paragraphs (b)(2) through (7) of this section at rated maximum continuous power must be made at critical altitude pressure, and the portions of the runs at other power must be made at 8,000 feet altitude pressure; and

(iii) The turbosupercharger used during the 150 hour endurance test must be run on the bench for an additional 50 hours at the limiting turbine wheel inlet gas temperature and rotational speed for rated maximum continuous power operation unless the limiting temperature and speed are maintained during 50 hours of the rated maximum continuous power operation.

(2) For engines used in helicopters the applicant must conduct the runs specified in paragraph (d) of this section, except--

(i) The entire run specified in paragraph (d)(1) of this section must be made at critical altitude pressure;

(ii) The portions of the runs specified in paragraph (d)(2) and (3) of this section at rated maximum continuous power must be made at critical altitude pressure and the portions of the runs at other power must be made at 8,000 feet altitude pressure;

(iii) The entire run specified in paragraph (d)(4) of this section must be made at 8,000 feet altitude pressure;

(iv) The portion of the runs specified in paragraph (d)(5) of this section at 80 percent of rated maximum continuous power must be made at 8,000 feet altitude pressure and the portions of the runs at other power must be made at critical altitude pressure;

(v) The entire run specified in paragraph (d)(6) of this section must be made at critical altitude pressure; and

(vi) The turbosupercharger used during the endurance test must be run on the bench for 50 hours at the limiting turbine wheel inlet gas temperature and rotational speed for rated maximum continuous power operation unless the limiting temperature and speed are maintained during 50 hours of the rated maximum continuous power operation.

***

Guidance. The INTENT of this section is demonstrate a minimum level of operability of the complete engine, within its (to be) approved ratings, limitations, inspection, and maintenance requirements.

Incorporations: None.

References: None.

38. Section 33.51, Operation Test.

Section 33.51 Operation test.

The operation test must include the testing found necessary by the Administrator to demonstrate backfire characteristics, starting, idling, acceleration, overspeeding, functioning of propeller and ignition, and any other operational characteristic of the engine. If the engine incorporates a multi-speed supercharger drive, the design and construction must allow the supercharger to be shifted from operation at the lower speed ratio to the higher, and the power appropriate to the manifold pressure and speed settings for rated maximum continuous power at the higher supercharger speed ratio must be obtainable within 5 seconds.

***

Guidance. The INTENT of this section is to assure that demonstration of the above characteristics is also conducted.

Incorporations: AC 23.909-1, "Installation of Turbochargers in Small Airplanes With Reciprocating Engines," dated February 3, 1986.

References: None.

The incorporation above primarily addresses small airplane approval procedures for turbocharger installations. It is incorporated herein, however, since it also provides useful guidance for approval of engine modifications to accommodate turbocharger installations.

39. Section 33.53, Engine Component Tests.

Section 33.53 Engine component tests.

(a) For each engine that cannot be adequately substantiated by endurance testing in accordance with Section 33.49, the applicant must conduct additional tests to establish that components are able to function reliably in all normally anticipated flight and atmospheric conditions.

(b) Temperature limits must be established for each component that requires temperature controlling provisions in the aircraft installation to assure satisfactory functioning, reliability, and durability.

***

Guidance. The INTENT of this section is to assure test substantiation of all engine components, functions, and features that would not otherwise have been evaluated by endurance or other testing.

Incorporations: None.

References: None.

40. Section 33.55, Teardown Inspection.

Section 33.55 Teardown inspection.

After completing the endurance test--

(a) Each engine must be completely disassembled;

(b) Each component having an adjustment setting and a functioning characteristic that can be established independent of installation on the engine must retain each setting and functioning characteristic within the limits that were established and recorded at the beginning of the test; and

(c) Each engine component must conform to the type design and be eligible for incorporation into an engine for continued operation, in accordance with information submitted in compliance with Section 33.4.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

41. Section 33.57, General Conduct of Block Tests.

Section 33.57 General conduct of block tests.

(a) The applicant may, in conducting the block tests, use separate engines of identical design and construction in the vibration, calibration, detonation, endurance, and operation tests, except that, if a separate engine is used for the endurance test it must be subjected to a calibration check before starting the endurance test.

(b) The applicant may service and make minor repairs to the engine during the block tests in accordance with the service and maintenance instructions submitted in compliance with Section 33.4. If the frequency of the service is excessive, or the number of stops due to engine malfunction is excessive, or a major repair, or replacement of a part is found necessary during the block tests or as the result of findings from the teardown inspection, the engine or its parts may be subjected to any additional test the Administrator finds necessary.

(c) Each applicant must furnish all testing facilities, including equipment and competent personnel, to conduct the block tests.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

SECTION 5. SUBPART E--DESIGN AND CONSTRUCTION; TURBINE AIRCRAFT ENGINES

42. Section 33.62, Stress Analysis.

Section 33.62 Stress analysis.

A stress analysis must be performed on each turbine engine showing the design safety margin of each turbine engine rotor, spacer, and rotor shaft.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

43. Section 33.63, Vibration.

Section 33.63 Vibration.

Each engine must be designed and constructed to function throughout its operating range of rotational speeds and engine power without inducing excessive stress in any engine part because of vibration and without imparting excessive vibration forces to the aircraft structure.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

44. Section 33.65, Surge and Stall Characteristics.

Section 33.65 Surge and stall characteristics.

When the engine is operated in accordance with operating instructions required by Section 33.5(b), starting, a change of power or thrust, power or thrust augmentation, limiting inlet air distortion, or inlet air temperature may not cause surge or stall to the extent that flameout, structural failure, overtemperature, or failure of the engine to recover power or thrust will occur at any point in the operating envelope.

***

Guidance. The INTENT of this section is to assure that the engine be designed and fabricated to preclude harmful surge and stall characteristics.

Incorporations: AC 33.65-1, "Surge and Stall Characteristics of Aircraft Turbine Engines," dated December 1985.

References: None.

Note that this section addresses design and construction requirements; correlating block test requirements are prescribed in "Section 33.89, Operation Test".

45. Section 33.66, Bleed Air System.

Section 33.66 Bleed air system.

The engine must supply bleed air without adverse effect on the engine, excluding reduced thrust or power output, at all conditions up to the discharge flow conditions established as a limitation under Section 33.7(c)(11). If bleed air used for engine anti-icing can be controlled, provision must be made for a means to indicate the functioning of the engine ice protection system.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

The need to restrict bleed airflow, such as by orifice(s), should either be incorporated in the type design of the engine hardware, or be noted as appropriate in the engine installation instructions (and drawings) and in the engine type certificate data sheet (TCDS).

46. Section 33.67, Fuel System.

Section 33.67 Fuel system.

(a) With fuel supplied to the engine at the flow and pressure specified by the applicant, the engine must function properly under each operating condition required by this Part. Each fuel control adjusting means that may not be manipulated while the fuel control device is mounted on the engine must be secured by a locking device and sealed, or otherwise be inaccessible. All other fuel control adjusting means must be accessible and marked to indicate the functioning of the adjustment unless the function is obvious.

(b) There must be a fuel strainer or filter between the engine fuel inlet opening and the inlet of either the fuel metering device or the engine-driven positive displacement pump whichever is nearer the engine fuel inlet. In addition, the following provisions apply to each strainer or filter required by this paragraph.

(1) It must be accessible for draining and cleaning and must incorporate a screen or element that is easily removable.

(2) It must have a sediment trap and drain except that it need not have a drain if the strainer or filter is easily removable for drain purposes.

(3) It must be mounted so that its weight is not supported by the connecting lines or by the inlet or outlet connections of the strainer or filter, unless adequate strength margins under all loading conditions are provided in the lines and connections.

(4) It must have the type and degree of fuel filtering specified as necessary for protection of the engine fuel system against foreign particles in the fuel. The applicant must show:

(i) That foreign particles passing through the specified filtering means do not impair the engine fuel system functioning; and

(ii) That the fuel system is capable of sustained operation throughout its flow and pressure range with the fuel initially saturated with water at 80 degrees F (27 °C) and having 0.025 fluid ounces per gallon (0.20 milliliters per liter) of free water added and cooled to the most critical condition for icing likely to be encountered in operation. However, this requirement may be met by demonstrating the effectiveness of specified approval fuel anti-icing additives, or that the fuel system incorporates a fuel heater which maintains the fuel temperature at the fuel strainer or fuel inlet above 32 degrees F (0 °C) under the most critical conditions.

(5) The applicant must demonstrate that the filtering means has the capacity (with respect to engine operating limitations) to ensure that the engine will continue to operate within approved limits, with fuel contaminated to the maximum degree of particle size and density likely to be encountered in service. Operation under these conditions must be demonstrated for a period acceptable to the Administrator, beginning when indication of impending filter blockage is first given by either:

(i) Existing engine instrumentation; or

(ii) Additional means incorporated into the engine fuel system.

(6) Any strainer or filter bypass must be designed and constructed so that the release of collected

contaminants is minimized by appropriate location of the bypass to ensure that collected contaminants are not in the bypass flow path.

(c) If provided as part of the engine, the applicant must show for each fluid injection (other than fuel) system and its controls that the flow of the injected fluid is adequately controlled.

***

Guidance. The INTENT of this section is to assure that the engine fuel system is designed and fabricated to operate satisfactorily under all applicable operating conditions.

Incorporations: None.

References: Military Specification MIL-E-5007E(AS), "Engines, Aircraft, Turbojet and Turbofan, General Specification For," dated September 1, 1983.

a. An acceptable means of compliance with Section 33.67(b)(5) can be that the applicant show that the engine will continue to operate satisfactorily, for at least one-half of the maximum flight time (of the intended aircraft applications), beginning at first indication of impending filter blockage. Actual, or rig-simulation of, test engine operation should be at the most critical mission fuel flows expected to be used in service.

b. Table X of the reference provides an example of typical fuel contaminants, particle sizes, and quantities.

47. Section 33.68, Induction System Icing.

Section 33.68 Induction system icing.

Each engine, with all icing protection systems operating, must--

(a) Operate throughout its flight power range (including idling) without the accumulation of ice on the engine components that adversely affects engine operation or that causes a serious loss of power or thrust in continuous maximum and intermittent maximum icing conditions as defined in Appendix C of Part 25 of this chapter; and

(b) Idle for 30 minutes on the ground, with the available air bleed for icing protection at its critical condition, without adverse effect, in an atmosphere that is at a temperature between 15 degrees and 30 degrees F (between -9 degrees and -1 degrees C) and has a liquid water content not less than 0.3 grams per cubic meter in the form of drops having a mean effective diameter not less than 20 microns, followed by a momentary operation at takeoff power or thrust. During the 30 minutes of idle operation the engine may be run up periodically to a moderate power or thrust setting in a manner acceptable to the Administrator.

***

Guidance. The INTENT of this section is to assure that the engine induction icing protection system be designed and fabricated to operate satisfactorily during the icing conditions specified.

Incorporations: AC 20-73, "Aircraft Ice Protection," dated April 21, 1971.

References: None.

a. Certification of engine icing protection systems is conducted to the criteria of continuous icing. That is, engine certification for induction system icing does not recognize time-limited approvals for inadvertent icing encounters.

b. There may be instances where the engine manufacturer elects to design an aircraft induction system as part of the engine bill-of-material and then perform icing analyses and tests of the complete engine/aircraft induction system configuration. This, of course, "locks in" the induction system design, as part of the engine type design for all future applications of the engine. Subsequent deviations from this approved design configuration would invalidate the engine's anti-icing approval and, therefore, would violate the type certificate limitations of the engine.

c. The guidance material for icing protection of engines embodied in AC 20-73, dated April 21, 1971, is still considered valid and useful. In particular, the "two point" test method (Icing Conditions 1 and 2 in the Table of Paragraph 33b(2)) is considered adequate substantiation--when supported by design analysis of the critical conditions for icing protection.

d. The analysis should consider, in part:

(1) for engine bleed air systems, the requirements and limitations of the bleed air characteristic.

(2) the corresponding need to establish operating limitations (and/or minimums) of rotational speed, power or thrust, etc., to maintain the minimum required anti-icing bleed air characteristic.

(3) the affect of ice accretion on engine instrumentation probes or sensors located in the induction air stream.

(4) the maximum customer bleed air extraction on engines which utilize bleed air anti-ice systems.

e. The third test point of the Icing Conditions Table of Paragraph 33b(2) of AC 20-73 refers to the ground fog icing condition. Note that it has been modified by Amendment 10 of Part 33. Accordingly, column 3 of the table now reads "≥ 0.3", "15-30", and "≥ 20", respectively. Also note that Amendment 10 permits periodic engine accelerations during the idle icing condition of Section 33.68(b) to shed ice build-ups.

f. The icing test periods of 10 and 30 minutes suggested in the AC, Paragraphs 33b(2)(a) and (b) respectively, should be understood to be minimum test times. Nonstabilized engine operation, or continued ice build-up at the conclusion of the test period, would be cause to extend the basic 10 or 30 minute test period. Testing should continue until an ice build-up and shed cycle is established, or until engine operation is stabilized, or until the engine will no longer safely operate within limits.

g. Normal engine parameters of EPR, torque, high pressure rotor speed, low pressure rotor speed, gas path temperature, and fuel flow should be monitored to verify stability of engine operation during the icing test. Closed circuit television monitoring of the critical areas during the test is a useful method to verify the icing characteristics and ice build/shed cycle. Post test point icing characteristics are also typically documented by photographic means, immediately following engine shutdown after each test point of interest.

h. The characteristics and calibration of the icing test facility should be documented to substantiate proper liquid water content (LWC), droplet diameter, and atmospheric temperature.

i. Note that anti-icing certification of engines to FAR Part 33 does not include snow ingestion testing. The snow ingestion test requirements of subsection .1093(b)(ii) of FAR Parts 23, 25, 27, and 29 cannot be included in Part 33 since the principal purpose of snow testing is to evaluate the complete engine installation within the airplane or rotorcraft environment. For rotorcraft installations, this includes evaluation of the influences of engine inlet duct geometry and placement, bypass ratio, rotor-wash effects, etc., which are impossible to evaluate at the bare engine level.

48. Section 33.69, Ignition System.

Section 33.69 Ignition system.

Each engine must be equipped with an ignition system for starting the engine on the ground and in flight. An electric ignition system must have at least two igniters and two separate secondary electric circuits, except that only one igniter is required for fuel burning augmentation systems.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

The engine installation instructions should define the characteristics and the interface requirements of all aircraft sources of electrical power required by the engine ignition system.

49. Section 33.71, Lubrication System.

Section 33.71 Lubrication system.

(a) General. Each lubrication system must function properly in the flight attitudes and atmospheric conditions in which an aircraft is expected to operate.

(b) Oil strainer or filter. There must be an oil strainer or filter through which all of the engine oil flows. In addition:

(1) Each strainer or filter required by this paragraph that has a bypass must be constructed and installed so that oil will flow at the normal rate through the rest of the system with the strainer or filter element completely blocked.

(2) The type and degree of filtering necessary for protection of the engine oil system against foreign particles in the oil must be specified. The applicant must demonstrate that foreign particles passing through the specified filtering means do not impair engine oil system functioning.

(3) Each strainer or filter required by this paragraph must have the capacity (with respect to operating limitations established for the engine) to ensure that engine oil system functioning is not impaired with the oil contaminated to a degree (with respect to particle size and density) that is greater than that established for the engine in subparagraph (2) of this paragraph.

(4) For each strainer or filter required by this paragraph, except the strainer or filter at the oil tank outlet, there must be means to indicate contamination before it reaches the capacity established in accordance with paragraph (b)(3) of this section.

(5) Any filter bypass must be designed and constructed so that the release of collected contaminants is minimized by appropriate location of the bypass to ensure that the collected contaminants are not in the bypass flow path.

(6) Each strainer or filter required by this paragraph that has no bypass, except the strainer or filter at an oil tank outlet or for a scavenge pump, must have provisions for connection with a warning means to warn the pilot of the occurrence of contamination of the screen before it reaches the capacity established in accordance with subparagraph (3) of this paragraph.

(7) Each strainer or filter required by this paragraph must be accessible for draining and cleaning.

(c) Oil tanks.

(1) Each oil tank must have an expansion space of not less than 10 percent of the tank capacity.

(2) It must be impossible to inadvertently fill the oil tank expansion space.

(3) Each recessed oil tank filler connection that can retain any appreciable quantity of oil must have provision for fitting a drain.

(4) Each oil tank cap must provide an oil-tight seal.

(5) Each oil tank filler must be marked with the word "oil."

(6) Each oil tank must be vented from the top part of the expansion space, with the vent so arranged that condensed water vapor that might freeze and obstruct the line cannot accumulate at any point.

(7) There must be means to prevent entrance into the oil tank or into any oil tank outlet, of any object that might obstruct the flow of oil through the system.

(8) There must be a shutoff valve at the outlet of each oil tank, unless the external portion of the oil system (including oil tank supports) is fireproof.

(9) Each unpressurized oil tank may not leak when subjected to maximum operating temperature and an internal pressure of 5 p.s.i., and each pressurized oil tank may not leak when subjected to maximum operating temperature and internal pressure that is not less than 5 p.s.i. plus the maximum operating pressure of the tank.

(10) Leaked or spilled oil may not accumulate between the tank and the remainder of the engine.

(11) Each oil tank must have an oil quantity indicator or provisions for one.

(12) If the propeller feathering system depends on engine oil--

(i) There must be means to trap an amount of oil in the tank if the supply becomes depleted due to failure of any part of the lubricating system other than the tank itself;

(ii) The amount of trapped oil must be enough to accomplish the feathering operation and must be available only to the feathering pump; and

(iii) Provision must be made to prevent sludge or other foreign matter from affecting the safe operation of the propeller feathering system.

(d) Oil drains. A drain (or drains) must be provided to allow safe drainage of the oil system. Each drain must--

(1) Be accessible; and

(2) Have manual or automatic means for positive locking in the closed position.

(e) Oil radiators. Each oil radiator must withstand, without failure, any vibration, inertia, and oil pressure load to which it is subjected during the block tests.

***

Guidance. The INTENT of this section is to assure that the engine lubrication system is designed and constructed to operate satisfactorily under all applicable operating conditions.

Incorporations: None.

References: None.

50. Section 33.72, Hydraulic Actuating Systems.

Section 33.72 Hydraulic actuating systems.

Each hydraulic actuating system must function properly under all conditions in which the engine is expected to operate. Each filter or screen must be accessible for servicing and each tank must meet the design criteria of Section 33.71.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

51. Section 33.73, Power or Thrust Response.

Section 33.73 Power or thrust response.

The design and construction of the engine must enable an increase--

(a) From minimum to rated takeoff power or thrust with the maximum bleed air and power extraction to be permitted in an aircraft, without overtemperature, surge, stall, or other detrimental factors occurring to the engine whenever the power control lever is moved from the minimum to the maximum position in not more than 1 second, except that the Administrator may allow additional time increments for different regimes of control operation requiring control scheduling; and

(b) From the fixed minimum flight idle power lever position when provided, of if not provided, from not more than 15 percent of the rated takeoff power or thrust available to 95 percent rated takeoff power or thrust in not over 5 seconds. The 5-second power or thrust response must occur from a stabilized static condition using only the bleed air and accessories loads necessary to run the engine. This takeoff rating is specified by the applicant and need not include thrust augmentation.

***

Guidance. The INTENT of this section is to assure that the engine is designed and fabricated with a minimum standard of power/thrust response characteristics.

Incorporations: AC 33.65-1, "Surge and Stall Characteristics of Aircraft Turbine Engines," dated December 1985.

References: None.

52. Section 33.75, Safety Analysis.

Section 33.75 Safety analysis.

It must be shown by analysis that any probable malfunction or any probable single or multiple failure, or any probable improper operation of the engine will not cause the engine to--

(a) Catch fire;

(b) Burst (release hazardous fragments through the engine case);

(c) Generate loads greater than those ultimate loads specified in Section 33.23(a); or

(d) Lose the capability of being shut down.

***

Guidance. The INTENT of this section is to assure that the engine is designed and fabricated to preclude probable failure, malfunction, or operating conditions resulting in the hazards specified.

Incorporations: None.

References: SAE ARP926A, "Fault/Failure Analysis Procedure," Revised November 15, 1979.

a. The safety analysis should support the engine design goals, such that there would not be a likely single failure or failures that would result in fire, uncontained event, exceedance of engine ultimate loads, or prevent the engine from being shutdown.

b. The guidance provided in the reference above would be an acceptable methodology. The top-down technique is suggested based on the four critical failure modes identified in the rule. The analysis should cover:

(1) all major static and rotating components including mounts, seals, spacers, shafts, and bearings;

(2) all subsystems and components including fuel, lubrication, pneumatic, electronic, cooling, instrumentation, speed reduction, and fire protection.

c. A by-product of the safety analysis should be an assessment of all potentially hazardous conditions, individually and in combination including consideration of dormant failures, and the elimination of such conditions by redesign, required inspections, inspection intervals, specialized instrumentation, and/or finite lifing to support FAA findings of acceptable safety and durability levels.

53. Section 33.77, Foreign Object Ingestion.

Section 33.77 Foreign object ingestion.

(a) Ingestion of a 4-pound bird, under the conditions prescribed in paragraph (e) of this section, may not cause the engine to--

(1) Catch fire;

(2) Burst (release hazardous fragments through the engine case);

(3) Generate loads greater than those ultimate loads specified in Section 33.23(a); or

(4) Lose the capability of being shut down.

(b) Ingestion of 3-ounce birds or 1-1/2 pound birds, under the conditions prescribed in paragraph (e) of this section, may not--

(1) Cause more than a sustained 25 percent power or thrust loss;

(2) Require the engine to be shut down within 5 minutes from time of ingestion; or

(3) Result in a potentially hazardous condition.

(c) Ingestion of water, ice, or hail under the conditions prescribed in paragraph (e) of this section, may not cause a sustained power or thrust loss or require the engine to be shut down. It must be demonstrated that the engine can accelerate and decelerate safely while inducting a mixture of at least 4 percent water by weight of engine airflow following stabilized operation at both flight idle and takeoff power settings with at least a 4 percent water-to-air ratio.

(d) For an engine that incorporates a protection device, compliance with this section need not be demonstrated with respect to foreign objects to be ingested under the conditions prescribed in paragraph (e) of this section if it is shown that--

(1) Such foreign objects are a size that will not pass through the protective device;

(2) The protective device will withstand the impact of the foreign objects; and

(3) The foreign object, or objects, stopped by the protective device will not obstruct the flow of induction air into the engine with a resultant sustained reduction in power or thrust greater than those values required by paragraphs (b) and (c) of this section.

(e) Compliance with paragraphs (a), (b), and (c) of this section must be shown by engine test under the following ingestion conditions:

Foreign Object	Test Quantity	Speed of Foreign Object	Engine Operation	Ingestion
BIRDS:				
3-Ounce Size..	One for each 50 square inches of inlet area or fraction thereof up to a maximum of 16 birds. Three-once bird ingestion not required if a 1-1/2-pound bird will pass the inlet guide vanes into the rotor blades.	Liftoff speed of typical aircraft.	Takeoff........	In rapid sequence to simulate a flock encounter and aimed at selected critical areas.
1-1/2-pound size..	One for the first 300 square inches of inlet area, it can enter the inlet, plus one for each additional 600 square inches of inlet area or fraction thereof up to a maximum of 8 birds.	Initial climb speed of typical aircraft.	Takeoff........	In rapid sequence to simulate a flock encounter and aimed at selected critical areas.

Foreign Object	Test Quantity	Speed of Foreign Object	Engine Operation	Ingestion
4-pound size..	One, if it can enter the inlet......................	Maximum climb speed of typical aircraft if the engine has inlet guide vanes.	Maximum cruise.........	Aimed at critical area.
		Liftoff speed of typical aircraft, if the engine does not have inlet guide vanes.	Takeoff........	Aimed at critical area.
Ice..........	Maximum accumulation on a typical inlet cowl and engine face resulting from a 2-minute delay in actuating anti-icing system, or a slab of ice which is comparable in weight or thickness for that size engine.	Sucked in.............	Maximum cruise.........	To simulate a continuous maximum icing encounter at 25 °F.
HAIL: (0.8 to 0.9 specific gravity)	For all engines: With inlet area of not more than 100 square inches: one 1-inch hailstone. With inlet area of more than 100 square inches: one 1-inch and one 2-inch hailstone for each 150 square inches of inlet area or fraction thereof.	Rough air flight speed of typical aircraft.	Maximum cruise at 15,000 feet altitude.	In a volley to simulate a hailstone encounter. One-half the number of hailstones aimed at random area over the face of the inlet and the other half aimed at the critical face area.
	For supersonic engines (in addition): 3 hailstones each having a diameter equal to that in a straight line variation from 1 inch at 35,000 feet to 1/4 inch at 60,000 feet using diameter corresponding to the lowest supersonic cruise altitude expected.	Supersonic cruise velocity. Alternatively, use subsonic velocities with larger hailstones to give equivalent kinetic energy.	Maximum cruise........	Aimed at critical engine face area.
Water........	At least 4 percent of engine airflow by weight.	Sucked in..........	Flight idle, acceleration, takeoff, deceleration.	For 3 minutes each at idle and takeoff, and during acceleration and deceleration in spray to simulate rain.

NOTE:--The term "inlet area" as used in this section means the engine inlet projected area at the front face of the engine. It includes the projected area of any spinner or bullet nose that is provided.

***

Guidance. The INTENT of this section is to assure that the engine is designed, fabricated, and tested to be structurally and operationally tolerant, to the degrees specified, following the specified ingestion events.

<u>Incorporations</u>: AC 33-1B, "Turbine Engine Foreign Object Ingestion and Rotor Blade Containment Type Certification Procedures," dated April 22, 1970.

<u>References</u>: None.

a. Previous to the Amendment 6 engine certification rules, the foreign object ingestion test requirements were generalized from Sections 33.13 and 33.19, Design Features and Durability, respectively. The incorporation above, and its earlier versions, in fact, provided the ingestion test requirements and procedures for the pre-Amendment 6 engines.

b. The certification rules subsequent to Amendment 5 are definitive. Although they have evolved to the current rules, the guidance embodied in the incorporation may be considered applicable, except where the AC conflicts with the rules. On this basis, the incorporation, with regard to ingestion testing (not containment), coupled with Amendment 10's Section 33.77 Preamble, and the following clarifying information should be useful.

c. It has become clear, through recent certification programs of various engine manufacturers, that the medium bird ingestion test procedures are not being uniformly conducted. Specifically, variations have occurred in the length of time required before throttle adjustments are allowed following ingestion.

d. Paragraph 10b(1)(e) of the incorporation states, "Duration of the engine running following ingestion of any Group II objects should be at least 5 minutes to determine whether the engine is in a condition of imminent failure but, in case of doubt as to actual engine condition or evident engine damage, longer post-ingestion test runs should be conducted."

e. Similarly, paragraph 11b(2) states, "The engine is acceptable if tests demonstrate...its continued safe operation after the ingestion tests. There should be no indication of need for immediate shutdown or imminent failure during the ingestion tests...." Also, FAR Section 33.77 was recently revised (Amendment 33-10) to specify the 5-minute minimum running period from the time of ingestion. If an engine is allowed to be manually throttled-back (to just over 75 percent power) prior to 5 minutes following ingestion, some conditions of imminent failure, which may be present, are much less likely to be detected. Since one of the purposes of the ingestion test is to demonstrate the absence of imminent failure, manual intervention within 5 minutes should not be accepted.

f. A question concerning foreign object ingestion testing is, "What is the definition of the term 'inlet area' as used in FAR Section 33.77, as applied to turbofan engines?" Amendment 10 added the definition of this term at the end of the table in Section 33.77. For the typical turbofan engine, this is the bare-engine inlet area calculated from D_e shown in Figure 1 (which follows paragraph 53j). D_s is the propulsion system feature that usually determines ingestion; that is, foreign object strikes outboard (relative to the duct centerline) of the highlight will usually be repelled, and strikes inboard of the highlight will usually be ingested. However, the nacelle design is not always known at time of engine certification testing and can change from one installation to another. Therefore, since D_e is a rough approximation of D_s for the typical turbofan engine, and since D_e is controlled by the engine manufacturer, it was chosen as the determinant of inlet area in the current rule.

g. Unfortunately, the definition in Amendment 33-12 is not without problems. For example, it is not clearly applicable to an aft-fan engine. Also, the nacelle inlet lip stagnation point area, A_s, (which as explained above, is the functional feature that normally determines ingestion, also known as the capture area) can be much larger than A_e, the bare-engine inlet area; and A_e is not particularly significant if the air inlet duct incorporates an inertial separator. Hence, judgement is required, and the following guidelines are recommended until a rule establishing an improved definition is promulgated.

(1) Typical turbofan engines should use A_e, as defined herein and in Amendment 33-10 for calculating foreign object ingestion quantities. Other engines should use the capture area of the installed engine, if that area is known at the time of engine certification testing. If the nacelle design is not known, or if the manufacturer elects to do so, the engine inlet area, A_e, or estimated nacelle inlet, A_s, may be used, as has been done historically.

(2) The TCDS or the FAA-approved engine installation manual (or similar document for non-domestic engines) should indicate which area was used for ingestion calculations. This area should be considered an installation limit. If a later engine installation results in a larger capture area, the foreign object ingestion test (quantities) should be re-evaluated for possible additional certification testing.

(3) In no case should the nacelle inlet throat area $A\{(f)D_t\}$, see Figure 1, be used for ingestion calculations as this may result in an invalid test.

h. The inlet area question is also most germane for the smaller mass-flow turboshaft (and some turboprop) engines. As in the turbofan engine case, the inlet area determinant for ingestion testing should be the free-stream capture area. This needs to be assumed as the front face area for the bare-engine case. If the engine design incorporates an inlet air separator system, then engineering judgement will need to be applied to define the ingestion area for calculating ingestion quantities and for determining target areas.

i. The guiding principle should be the same in all cases; the induction air stream projected area exposed to the ingestion hazard should be the determinant area. This area must include the projected areas of spinners, inertial separator housings, starter housings, inlet nose cones, etc., if it is possible for the foreign object(s) to still be ingested after impacting such devices. One expected outcome of the ingestion test of such inlet configurations is to ensure that they are ingestion impact tolerant and do not, of themselves, become ingestion objects in the engine flow path.

j. The engine manufacturer may elect to require that the airframe manufacturer install the engine, such that it is impossible for free-stream ingestion objects to enter the engine inlet. In such a case, the TCDS and the installation instructions will need to specify this as an installations limitation. This approach has mostly been applied to rotorcraft engine installations wherein there is no direct line-of-sight between the ambient free-stream and the engine's front face. This arrangement effectively creates a zero ram-recovery plenum for the engine flow stream. The airframers would need to demonstrate that this produces no unairworthy or undesirable characteristic, in accordance with the certification rules for the installation.

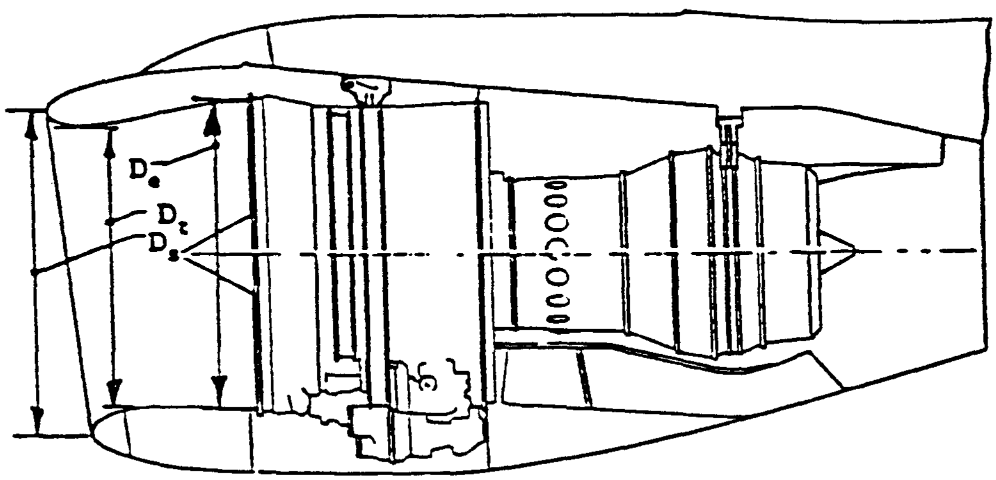

FIGURE 1. GENERIC TURBOFAN AND NACELLE CONFIGURATION

D_s = nacelle inlet lip stagnation point equivalent diameter, (a.k.a. highlight equivalent diameter).

D_t = nacelle inlet throat equivalent diameter.

D_e = engine front face inlet equivalent diameter, (a.k.a. bare-engine inlet equivalent diameter).

A = $nD^2/4$, where n=pi.

54. Section 33.79, Fuel Burning Thrust Augmenter.

Section 33.79 Fuel burning thrust augmenter.

Each fuel burning thrust augmenter, including the nozzle, must--

(a) Provide cutoff of the fuel burning thrust augmenter:

(b) Permit on-off cycling;

(c) Be controllable within the intended range of operation;

(d) Upon a failure or malfunction of augmenter combustion, not cause the engine to lose thrust other than that provided by the augmenter; and

(e) Have controls that function compatibly with the other engine controls and automatically shut off augmenter fuel flow if the engine rotor speed drops below the minimum rotational speed at which the augmenter is intended to function.

***

Guidance. The INTENT of this section is to assure that the afterburner system is designed and constructed to function satisfactorily and not impair the functioning of the rest of the engine.

Incorporations: None.

References: None.

SECTION 6. SUBPART F--BLOCK TESTS; TURBINE AIRCRAFT ENGINES

55. Section 33.82, General.

Section 33.82 General.

Before each endurance test required by this subpart, the adjustment setting and functioning characteristic of each component having an adjustment setting and a functioning characteristic that can be established independent of installation on the engine must be established and recorded.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

Collectively, the results of the block tests, combined with the design and analytical substantiation data, form the basis for the engine type certificate data sheet and engine instruction manuals statements concerning: ratings, steady-state and transient operating limits, critical parts retirement life, environmental envelope, inspection requirements, maintenance/overhaul requirements, operational requirements, and engine/airframe interface requirements.

56. Section 33.83, Vibration Test.

Section 33.83 Vibration test.

(a) Each engine must undergo a vibration survey to establish the vibration characteristics of the rotor discs, rotor blades, rotor shafts, stator blades, and any other components that are subject to vibratory exciting forces which could induce failure at the maximum inlet distortion limit. The survey is to cover the range of rotor speeds and engine power or thrust, under steady state and transient conditions, from idling speed to 103 percent of the maximum permissible speed. The survey must be conducted using the same configuration of the loading device which is used for the endurance test, except that the Administrator may allow the use of a modified configuration if that loading device type is incompatible with the necessary vibration instrumentation.

(b) The vibration stresses (or strain) of rotor and stator components determined under paragraph (a) of this section must be less, by a margin acceptable to the Administrator, than the endurance limit of the material from which these parts are made, adjusted for the most severe operating conditions.

(c) Each accessory drive and mounting attachment must be loaded, with the load imposed by each accessory used only for an aircraft service being the limit load specified by the applicant for the engine drive or attachment point.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

a. The engine vibration survey should be conducted with a representative inlet duct, or equivalent, if such is identified and available by time of test, while inducing the maximum inlet air distortion to be allowed by the engine installation instructions, for evaluating those components influenced by inlet distortion.

(1) The engine speed range to be surveyed is minimum idle speed to 103 percent of the maximum permissible speed. The maximum permissible speed is the highest rpm, including transients, for which the engine is to be approved.

(2) The principal result of the vibration survey is to demonstrate that an acceptable margin exists between the measured stresses and the endurance limit of the material being tested. Acceptable stress margins should exist throughout the operating envelope of the engine, including the worst case inlet air distortion levels to be approved for the engine. If inlet air distortion levels are found to be limiting, when correlated to vibratory stresses, then the engine installation instructions should specify those limits.

(3) Correspondingly, the recommended instrumentation, data acquisition and reduction methods, and coordination needs should also be provided in the engine installation instructions.

b. There are some engine designs which operate at such high rotor speeds and gas path temperatures that existing technology strain gages cannot survive this environment for very long. In such cases, the full stress survey should still be the goal and the test designed accordingly.

(1) If it becomes physically impossible to achieve the testing to 103 percent speed, then some form of analysis could be used to make up any difference.

(2) Additionally, if any significant resonances are found in the operating range of the engine, then the engine should be run, at least, 10 million cycles at each resonant point and at points bracketing the resonances to assure the stress endurance limit is not exceeded. This is normally covered as part of the endurance test's incremental running.

57. Section 33.85, Calibration Tests.

Section 33.85 Calibration tests.

(a) Each engine must be subjected to those calibration tests necessary to establish its power characteristics and the conditions for the endurance test specified in Section 33.87. The results of the power characteristics calibration tests form the basis for establishing the characteristics of the engine over its entire operating range of speeds, pressures, temperatures, and altitudes. Power ratings are based upon standard atmospheric conditions with no airbleed for aircraft services and with only those accessories installed which are essential for engine functioning.

(b) A power check at sea level conditions must be accomplished on the endurance test engine after the endurance test and any change in power characteristics which occurs during the endurance test must be determined. Measurements taken during the final portion of the endurance test may be used in showing compliance with the requirements of this paragraph.

***

Guidance. The INTENT of this section is to determine the engine power characteristics by test calibrating the engine either before and during, or after, the endurance test.

Incorporations: None.

References: None.

The engine calibration tests, in combination with the other block test requirements, form the basis for the engine instrumentation statements to be included in the engine installation instructions. These statements should encompass types, ranges, precision (readability), and accuracies of those parameters required for safe in-service engine operation, including reverse thrust operations, for each of the ratings.

58. Section 33.87, Endurance Test.

Section 33.87 Endurance test.

(a) General. Each engine must be subjected to an endurance test that includes a total of 150 hours of operation and, depending upon the type and contemplated use of the engine, consists of one of the series of runs specified in paragraphs (b) through (f) of this section, as applicable. For engines tested under paragraph (b), (c), (d), or (e) of this section, the prescribed 6-hour test sequence must be conducted 25 times to complete the required 150 hours of operation. The following test requirements apply:

(1) The runs must be made in the order found appropriate by the Administrator for the particular engine being tested.

(2) Any automatic engine control that is part of the engine must control the engine during the endurance test except for operations where automatic control is normally overridden by manual control or where manual control is otherwise specified for a particular test run.

(3) Except as provided in paragraph (a)(5) of this section, power or thrust, gas temperature, rotor shaft rotational speed, and, if limited, temperature of external surfaces of the engine must be at least 100 percent of the value associated with the particular engine operation being tested. More than one test may be run if all parameters cannot be held at the 100 percent level simultaneously.

(4) The runs must be made using fuel, lubricants and hydraulic fluid which conform to the specifications specified in complying with Section 33.7(c).

(5) Maximum air bleed for engine and aircraft services must be used during at least one-fifth of the runs. However, for these runs, the power or thrust or the rotor shaft rotational speed may be less than 100 percent of the value associated with the particular operation being tested if the Administrator finds that the validity of the endurance test is not compromised.

(6) Each accessory drive and mounting attachment must be loaded. The load imposed by each accessory used only for aircraft service must be the limit load specified by the applicant for the engine drive and attachment point during rated maximum continuous power or thrust and higher output. The endurance test of any accessory drive and mounting attachment under load may be accomplished on a separate rig if the validity of the test is confirmed by an approved analysis.

(7) During the runs at any rated power or thrust the gas temperature and the oil inlet temperature must be maintained at the limiting temperature except where the

test periods are not longer than 5 minutes and do not allow stabilization. At least one run must be made with fuel, oil, and hydraulic fluid at the minimum pressure limit and at least one run must be made with fuel, oil, and hydraulic fluid at the maximum pressure limit with fluid temperature reduced as necessary to allow maximum pressure to be attained.

(8) If the number of occurrences of either transient rotor shaft overspeed or transient gas overtemperature is limited, the number of the accelerations required by paragraphs (b), (c), (d), and (e) of this section must be made at the limiting overspeed or overtemperature. If the number of occurrences is not limited, half the required accelerations must be made at the limiting overspeed or overtemperature.

(9) For each engine type certificated for use on supersonic aircraft, the following additional test requirements apply:

(i) To change the thrust setting, the power control lever must be moved from the initial position to the final position in not more than 1 second except for movements into the fuel burning thrust augmenter augmentation position if additional time to confirm ignition is necessary.

(ii) During the runs at any rated augmented thrust, the hydraulic fluid temperature must be maintained at the limiting temperature except where the test periods are not long enough to allow stabilization.

(iii) During the simulated supersonic runs, the fuel temperature and induction air temperature may not be less than the limiting temperature.

(iv) The endurance test must be conducted with the fuel burning thrust augmenter installed, with the primary and secondary exhaust nozzles installed, and with the variable area exhaust nozzles operated during each run according to the methods specified in complying with Section 33.5(b).

(v) During the runs at thrust settings for maximum continuous thrust and percentages thereof, the engine must be operated with the inlet air distortion at the limit for those thrust settings.

(b) <u>Engines other than certain rotorcraft engines</u>. For each engine, except a rotorcraft engine for which a rating is desired under paragraph (c), (d), or (e) of this section, the applicant must conduct the following runs:

(1) <u>Takeoff and idling</u>. One hour of alternate 5-minute periods at rated takeoff power and thrust and at idling power and thrust. The developed powers and thrusts at takeoff and idling conditions and their corresponding rotor speed and gas temperature conditions must be established by the power control in accordance with the schedule established by the manufacturer. The applicant

may, during any one period, manually control the rotor speed, power, and thrust while taking data to check performance. For engines with augmented takeoff power ratings that involve increases in turbine inlet temperature, rotor speed, or shaft power, this period of running at takeoff must be at the augmented rating. For engines that do not materially increase operating severity, the amount of running conducted at the augmented rating is determined by the Administrator. In changing the power setting after each period, the power control lever must be moved in the manner prescribed in subparagraph (5) of this paragraph.

(2) Rated maximum continuous and takeoff power and thrust. Thirty minutes at -

(i) Rated maximum continuous power and thrust during fifteen of the twenty-five 6-hour endurance test cycles; and

(ii) Rated takeoff power and thrust during ten of the twenty-five 6-hour endurance test cycles.

(3) Rated maximum continuous power and thrust. One hour and 30 minutes at rated maximum continuous power and thrust.

(4) Incremental cruise power and thrust. Two hours and 30 minutes at the successive power lever positions corresponding to at least 15 approximately equal speed and time increments between maximum continuous engine rotational speed and ground or minimum idle rotational speed. For engines operating at constant speed, the thrust and power may be varied in place of speed. If there is significant peak vibration anywhere between ground idle and maximum continuous conditions, the number of increments chosen may be changed to increase the amount of running made while subject to the peak vibrations up to not more than 50 percent of the total time spent in incremental running.

(5) Acceleration and deceleration runs. Thirty minutes of accelerations and decelerations, consisting of 6 cycles from idling power and thrust to rated takeoff power and thrust and maintained at the takeoff power lever position for 30 seconds and at the idling power lever position for approximately 4-1/2 minutes. In complying with this subparagraph, the power-control lever must be moved from one extreme position to the other in not more than 1 second, except that, if different regimes of control scheduling of the power-control lever motion in going from one extreme position to the other, a longer period of time is acceptable, but not more than 2 seconds.

(6) Starts. One hundred starts must be made, of which 25 starts must be preceded by at least a 2-hour engine shutdown. There must be at least 10 false engine starts, pausing for the applicant's specified minimum fuel drainage time, before attempting a normal start. There

must be at least 10 normal restarts with not longer than 15 minutes since engine shutdown. The remaining starts may be made after completing the 150 hours of endurance testing.

(c) Rotorcraft engines for which a 30-minute OEI power rating is desired. For each rotorcraft engine for which a 30-minute OEI power rating is desired the applicant must conduct the following series of tests:

(1) Takeoff and idling. One hour of alternate 5-minute periods at rated takeoff power and at idling power. The developed powers at takeoff and idling conditions and their corresponding rotor speed and gas temperature conditions must be as established by the power control in accordance with the schedule established by the manufacturer. During any one period the rotor speed and power may be controlled manually while taking data to check performance. For engines with augmented takeoff power ratings that involve increases in turbine inlet temperature, rotor speed, or shaft power, this period of running at rated takeoff power must be at the augmented power rating. In changing the power setting after each period, the power-control lever must be moved in the manner prescribed in subparagraph (c)(5) of this paragraph.

(2) Rated 30-minute OEI power. Thirty minutes at rated 30-minute OEI power.

(3) Rated maximum continuous power. Two hours at rated maximum continuous power.

(4) Incremental cruise power. Two hours at the successive power-lever positions corresponding with not less than 12 approximately equal speed and time increments between maximum continuous engine rotational speed and ground or minimum idle rotational speed. For engines operating at constant speed, power may be varied in place of speed. If there are significant peak vibrations anywhere between ground idle and maximum continuous conditions, the number of increments chosen must be changed to increase the amount of running conducted while being subjected to the peak vibrations up to not more than 50 percent of the total time spent in incremental running.

(5) Acceleration and deceleration runs. Thirty minutes of accelerations and decelerations, consisting of 6 cycles from idling power to rated takeoff power and maintained at the takeoff power lever position for 30 seconds and at the idling power-lever position for approximately 4-1/2 minutes. In complying with this subparagraph, the power-control lever must be moved from one extreme position to the other in nor more than 1 second, except that, if different regimes of control operations are incorporated necessitating scheduling of the power-control lever motion in going from one extreme

position to the other, a longer period of time is acceptable, but not more than 2 seconds.

(6) Starts. One hundred starts, of which 25 starts must be preceded by at least a 2-hour engine shutdown. There must be at least 10 false engine starts, pausing for the applicant's specified minimum fuel drainage time, before attempting a normal start. There must be at least 10 normal restarts with not longer than 15 minutes since engine shutdown. The remaining starts may be made after completing the 150 hours of endurance testing.

(d) Rotorcraft engines for which a continuous OEI rating is desired. For each rotorcraft engine for which a continuous OEI power rating is desired, the applicant must conduct the following series of tests:

(1) Takeoff and idling. One hour of alternate 5-minute periods at rated takeoff power and at idling power. The developed powers at takeoff and at idling conditions and their corresponding rotor speed and gas temperature conditions must be as established by the power control in accordance with the schedule established by the manufacturer. During any one period the rotor speed and power may be controlled manually while taking data to check performance. For engines with augmented takeoff power ratings that involve increases in turbine inlet temperature, rotor speed, or shaft power, this period of running at rated takeoff power must be at the augmented power rating. In changing the power setting after each period, the power control lever must be moved in the manner prescribed in paragraph (c)(5) of this section.

(2) Rated maximum continuous and takeoff power. Thirty minutes at-

(i) Rated maximum continuous power during fifteen of the twenty-five 6-hour endurance test cycles; and

(ii) Rated takeoff power during ten of the twenty-five 6-hour endurance test cycles.

(3) Rated continuous OEI power. One hour at rated continuous OEI power.

(4) Rated maximum continuous power. One hour at rated maximum continuous power.

(5) Incremental cruise power. Two hours at the successive power lever positions corresponding with not less than approximately 12 equal speed and time increments between maximum continuous engine rotational speed and ground or minimum idle rotational speed. For engines operating at constant speed, power may be varied in place of speed. If there are significant peak vibrations anywhere between ground idle and maximum continuous conditions, the number of increments chosen must be changed to increase the amount of running conducted while being subjected to the peak vibrations up to not more than 50 percent of the total time spent in incremental running.

(6) Acceleration and deceleration runs. Thirty minutes of accelerations and decelerations, consisting of six cycles from idling power to rated takeoff power and maintained at the takeoff power lever position for 30 seconds and at the idling power lever position for approximately 4-1/2 minutes. In complying with this paragraph, the power control lever must be moved from one extreme position to the other in not more than 1 second, except that if different regimes of control operations are incorporated necessitating scheduling of the power control lever motion in going from one extreme to the other, a longer period of time is acceptable, but not more than 2 seconds.

(7) Starts. One hundred starts, of which 25 starts must be preceded by at least a 2-hour engine shutdown. There must be at least 10 false engine starts, pausing for the applicant's specified minimum fuel drainage time, before attempting a normal start. There must be at least 10 normal restarts with not longer 15 minutes since engine shutdown. The remaining starts may be made after completing the 150 hours of endurance testing.

(e) Rotorcraft engines for which a 2-1/2 minute OEI power rating is desired. For each rotorcraft engine for which a 2-1/2 minute OEI power rating is desired the applicant must conduct the following series of tests:

(1) Takeoff, 2-1/2 Minute OEI, and idling. One hour of alternate 5-minute periods at rated takeoff power and at idling power except that, during the third and sixth takeoff power periods, only 2-1/2 minutes need be conducted at rated takeoff power and the remaining 2-1/2 minutes must be conducted at rated 2-1/2 minute OEI power. The developed powers at takeoff, 2-1/2 minute OEI, and idling conditions and their corresponding rotor speed and gas temperature conditions must be as established by the power control in accordance with the schedule established by the manufacturer. The applicant may, during any one period, control manually the rotor speed and power while taking data to check performance. For engines with augmented takeoff power ratings that involve increases in turbine inlet temperature, rotor speed, or shaft power, this period of running at rated takeoff power must be at the augmented rating. In changing the power setting after or during each period, the power control lever must be moved in the manner prescribed in paragraph (d)(6) of this section.

(2) The tests required in paragraphs (b)(2) through (b)(6), or (c)(2) through (c)(6), or (d)(2) through (d)(7) of this section, as applicable, except that in one of the 6-hour test sequences, the last 5 minutes of the 30 minutes at takeoff power test period of paragraph (b)(2) of this section, or of the 30 minutes at 30-minute OEI power test period of paragraph (c)(2) of this section, or

of the 1-hour at Continuous OEI power test period of paragraph (d)(3) of this section, must be run at 2-1/2 minute OEI power.

(f) Supersonic aircraft engines. For each engine type certificated for use on supersonic aircraft, the applicant must conduct the following:

(1) Subsonic test under sea level ambient atmospheric conditions. Thirty runs of 1 hour each must be made, consisting of--

(i) Two periods of 5 minutes at rated takeoff augmented thrust each followed by 5 minutes at idle thrust;

(ii) One period of 5 minutes at rated takeoff thrust followed by 5 minutes at not more than 15 percent of rated takeoff thrust;

(iii) One period of 10 minutes at rated takeoff augmented thrust followed by 2 minutes at idle thrust, except that if rated maximum continuous augmented thrust is lower than rated takeoff augmented thrust, 5 of the 10-minute periods must be at rated maximum continuous augmented thrust; and

(iv) Six periods of 1 minute at rated takeoff augmented thrust each followed by 2 minutes, including acceleration and deceleration time, at idle thrust.

(2) Simulated supersonic test. Each run of the simulated supersonic test must be preceded by changing the inlet air temperature and pressure from that attained at subsonic condition to the temperature and pressure attained at supersonic velocity, and must be followed by a return to the temperature attained at subsonic condition. Thirty runs of 4 hours each must be made, consisting of--

(i) One period of 30 minutes at the thrust obtained with the power control lever set at the position for rated maximum continuous augmented thrust followed by 10 minutes at the thrust obtained with the power control lever set at the position for 90 percent of rated maximum continuous augmented thrust. The end of this period in the first 5 runs must be made with the induction air temperature at the limiting condition of transient overtemperature, but need not be repeated during the periods specified in subdivisions (ii)through (iv) of this subparagraph;

(ii) One period repeating the run specified in subdivision (i) of this subparagraph, except that it must be followed by 10 minutes at the thrust obtained with the power control lever set at the position for 8 percent of rated maximum continuous augmented thrust;

(iii) One period repeating the run specified in subdivision (i) of this subparagraph, except that it must be followed by 10 minutes at the thrust obtained with the power control lever set at the position for 60 percent of rated maximum continuous augmented thrust and then 10 minutes at not more than 15 percent of rated takeoff thrust;

(iv) One period repeating the runs specified in subdivisions (i) and (ii) of this subparagraph; and

(v) One period of 30 minutes with 25 of the runs made at the thrust obtained with the power control lever set at the position for rated maximum continuous augmented thrust, each followed by idle thrust and with the remaining 5 runs at the thrust obtained with the power control lever set at the position for rated maximum continuous augmented thrust for 25 minutes each, followed by subsonic operation at not more than 15 percent of rated takeoff thrust and accelerated to rated takeoff thrust for 5 minutes using hot fuel.

(3) Starts. One hundred starts must be made, of which 25 starts must be preceded by an engine shutdown of at least 2 hours. There must be at least 10 false engine starts, pausing for the applicant's specified minimum fuel drainage time before attempting a normal start. At least 10 starts must be normal restarts, each made no later than 15 minutes after engine shutdown. The starts may be made at any time, including the period of endurance testing.

***

Guidance. The INTENT of this section is to demonstrate a minimum level of operability of the complete engine, within its to be approved ratings, limitations, inspection, and maintenance requirements.

Incorporations: AC 20-18A, "Qualification Testing of Turbojet Engine Thrust Reversers," dated March 16, 1966.

References: None.

a. Although endurance testing rules for propeller-driving engines do not require an intended propeller be installed, it is recommended that such test engines be so equipped, when feasible. This practice would provide additional operating data/information on which to assess engine-to-propeller compatibility.

b. Approval of transient limitations of measured gas temperature, speeds, torques, engine pressure ratios, oil temperature, etc., should be based on those transient excursions (parameter level and time) consistently demonstrated during the endurance test's acceleration runs. Being transients, such limitations should not be approved for times greater than approximately 30 seconds for transients associated with the Maximum Continuous, Takeoff, Continuous OEI, and 30-Minute OEI ratings. Transients associated with the 2-1/2-Minute OEI rating should be limited to very brief periods, on the order of 5 to 10 seconds maximum.

c. Approvals of turboprop and turboshaft engine limits of torque and output shaft speed, as with other limits, are based on those limits having been demonstrated during the engine block tests, particularly the endurance test. Further, approval of simultaneous usage of both the torque and the output shaft speed limits should be based on demonstration of simultaneous excursions of both parameters. For example, each required acceleration to the Takeoff, 30-Minute OEI, Continuous OEI, and 2-1/2 Minute OEI power ratings of the appropriate endurance test schedule should be conducted to the respective torque and output shaft speed limits (value and time) to be requested for approval.

d. In all cases, approval should be granted only to the extent demonstrated. Of principal concern is that approved individual limits of overtorque and overspeed, if applied together, could, for some engine designs, result in a shaft horsepower level which would not have been evaluated during the engine TC process and, thus, may be an unairworthy condition.

e. Under certain ambient conditions, it may not be possible to simultaneously exercise, to its respective speed limitation, each rotor of a multiple rotor engine during endurance test running. During such a case, and if approved by the cognizant FAA project manager or engineer, the required substantiation may be shown by test replication as necessary, and/or by valid analysis.

59. Section 33.88, Engine Overtemperature Test.

Section 33.88 Engine overtemperature test.

Each engine must be run for 5 minutes at maximum permissible r.p.m. and with the gas temperature at least 75 °F (42 °C) higher than the maximum operating limit. Following this run, the turbine assembly must be within serviceable limits.

***

Guidance. The INTENT of this section is to demonstrate a minimum overtemperature capability of the engine.

Incorporations: AC 33-3, Turbine and Compressor Rotors Type Certification Procedures," dated September 1968.

References: None.

a. This rule requires the test to be demonstrated on a complete engine, not a rig. The test should be set up on an engine without mismatching component flow capacities, if possible. For example, the maximum rpm and maximum gas path temperature could be set up on the engine by means of an inlet heater. Then, by modulating compressor bleed, the 75 °F (42 °C) overtemperature (above the maximum rating steady-state limit) would be obtained, under circumstances close to what could be experienced in service. Note that "maximum permissible r.p.m." means the highest rotor speed for power-on engine operation (non-windmill, non-autorotative), whether steady-state or transient, which will be specified on the engine type certificate data sheet (TCDS). Also, note that the critical parameter is turbine inlet gas temperature, not exhaust gas temperature.

b. The overtemperature test condition should be based on the engine's maximum steady-state operating temperature limit. For example, if an engine's maximum steady-state gas temperature for the takeoff rating is 850 °C, the test should be run at 892 °C; however, if this same engine also has a 2-1/2-Minute OEI rating with a steady-state temperature of 900 °C, then this test should be conducted at 942 °C.

c. Post test acceptance criteria is that the engine turbine assembly, which includes blades, discs, drums, spacers, shafts, seals, stators, nozzles, and support structure, must be within serviceable limits. Serviceable limits, including dimensional limits, are determined during the type certification process and as published per "Appendix A to Part 33 -- Instructions for Continued Airworthiness" (See Section 33.4, Instructions for Continued Airworthiness).

60. Section 33.89, Operation Test.

Section 33.89 Operation test.

(a) The operation test must include testing found necessary by the Administrator to demonstrate--

(1) Starting, idling, acceleration, overspeeding, ignition, functioning of the propeller (if the engine is designated to operate with a propeller);

(2) Compliance with the engine response requirements of Section 33.73; and

(3) The minimum power or thrust response time to 95 percent rated takeoff power or thrust, from power lever positions representative of minimum idle and of minimum flight idle, starting from stabilized idle operation, under the following engine load conditions:

(i) No bleed air and power extraction for aircraft use.

(ii) Maximum allowable bleed air and power extraction for aircraft use.

(iii) An intermediate value for bleed air and power extraction representative of that which might be used as a maximum for aircraft during approach to a landing.

(4) If testing facilities are not available, the determination of power extraction required in paragraph

(a)(3)(ii) and (iii) of this section may be accomplished through appropriate analytical means.

(b) The operation test must include all testing found necessary by the Administrator to demonstrate that the engine has safe operating characteristics throughout its specified operating envelope.

***

Guidance. The INTENT of this section is to demonstrate safe operating characteristics and a minimum standard of power/thrust response characteristics.

Incorporations: AC 33.65-1, "Surge and Stall Characteristics of Aircraft Turbine Engines," dated December 6, 1985.

References: None.

Note: Although the incorporation applies to large high bypass ratio turbofan engines, the guidance material therein may also be useful for other engine applications.

a. This section addresses the block test requirements covering surge and stall characteristics. The correlating design and construction requirements are addressed in Section 33.65, "Surge and stall characteristics."

b. Engine transient characteristics at altitude should be defined by testing. However, steady state testing in an altitude test facility, in addition to component and engine analysis, is acceptable, when facility limitations preclude altitude transient testing, if accomplished as follows:

(1) Qualitatively determine, by sea level testing, the transient operating characteristics, including acceleration, deceleration, surge, stall, and flameout.

(2) Considering the limitations of the available altitude test facility, perform a quantitative analysis of the operating characteristics, identified by the above testing, over the complete operating range of the engine.

(3) Select, on the basis of the analysis, those critical conditions which may provide a problem in projected aircraft usage; and demonstrate quantitatively, on a quasi-steady basis, the validity of the analysis in the altitude test facility. "Quasi-steady" means that disturbances of short duration will be applied to the engine when operating on the steady-state operating line, such that the effect of the transient on the engine is determined before the test facility conditions are disturbed.

(4) As a part of the sea level demonstration, the ability of the engine to withstand takeoff surge, without damage, should be shown.

(5) The testing and analysis should show that margins are adequate to tolerate likely variations in fuel schedule, variable geometry schedule, anticipated installations and environmental (temperature, pressure, humidity) effects.

C. The operation test should also include:

(1) Low temperature and high temperature tests (fluids and carcass) for starting and operating the engine.

(2) Substantiation of the ignition system design duty cycle.

(3) Substantiation of the propeller parking brake, if the engine is so equipped.

(4) Substantiation of the engine ground and, where feasible, the in-flight starting envelopes. This substantiation should address all possible combinations of ignition system operation and power sources to be approved, and should result in defined acceptable start times, from initiation of the starting sequence to stabilized idle conditions.

(5) Substantiation of the propeller parking brake, if the engine is so equipped.

(6) Substantiation of all engine operating attitudes, and additionally, for powered-lift engines rotationally displaceable along their longitudinal axis, slue angles, and rates.

61. Section 33.90, Initial Maintenance Inspection.

Section 33.90 Initial maintenance inspection.

Each engine, except engines being type certificated through amendment of an existing type certificate or through supplemental type certification procedures, must undergo an approved test run that simulates the conditions in which the engine is expected to operate in service, including start-stop cycles, to establish when the initial maintenance inspection is required. The test run must be accomplished on an engine which substantially conforms to the final type design.

***

Guidance. The INTENT of this section is to demonstrate the ability of new type certificate engines to operate in a simulation of expected service conditions, for a specified number of cycles and/or hours before requiring maintenance inspection.

Incorporations: None.

References: None.

The requirements of this section are separate and distinct from those of Section 33.14, "Start-stop cyclic stress."

a. The use of an abbreviated flight cycle could satisfy Section 33.90, when supported by analytical data and/or supplemental test data. Applicants may submit existing data, such as from development tests and service experience where applicable and when creditable. The following information should be supplied to permit assessment of the inspection/overhaul period in support of the abbreviated flight cycle:

(1) The design flight cycle for the engine should identify the time history of engine power, or thrust usage including reverse thrust, if applicable, from engine start-up through shutdown, during a typical flight of a representative aircraft which uses the engine.

(2) The design analysis should identify those features of the engine for which initial life limitations will be established, or which will require threshold maintenance inspection; and whether a limitation is based on low cycle fatigue (cycles) or total engine or part-time (hours).

(3) A substantiation of the validity of the limitations and the acceptability of the test procedure as a valid representation of the design flight cycle, with regard to stress, temperature, and vibration (simulating the maximum rotor imbalances to be approved for production acceptance).

b. The initial maintenance inspection test run of engines designed to drive a propeller should be equipped with a propeller representative of the intended application, and include propeller parking brake usage and APU-mode operations, if so equipped.

62. Section 33.91, Engine Component Tests.

Section 33.91 Engine component tests.

(a) For those systems that cannot be adequately substantiated by endurance testing in accordance with the provisions of Section 33.87, additional tests must be made to establish that components are able to function reliably in all normally anticipated flight and atmospheric conditions.

(b) Temperature limits must be established for those components that require temperature controlling provisions in the aircraft installation to assure satisfactory functioning, reliability, and durability.

(c) Each unpressurized hydraulic fluid tank may not fail or leak when subjected to maximum operating temperature and an internal pressure of 5 p.s.i., and each pressurized hydraulic fluid tank may not fail or leak when subjected to maximum operating temperature and an internal pressure not less than 5 p.s.i. plus the maximum operating pressure of the tank.

(d) For an engine type certificated for use in supersonic aircraft, the systems, safety devices, and external components that may fail because of operation at maximum and minimum operating temperatures must be identified and tested at maximum and minimum operating temperatures and while temperature and other operating conditions are cycled between maximum and minimum operating values.

***

Guidance. The INTENT of this section is to assure test substantiation of all engine components, functions, and features which would not otherwise have been evaluated by endurance or other testing.

Incorporations: None.

References: None.

Engine component tests may include, but are not limited to, the following:

a. Fire proof/resistance tests of flammable fluid carrying or holding components.

b. Sea level and altitude pressure conditions testing/calibration of electronic control, fuel, lube, pneumatic, and starting systems.

c. Cold and hot ambient temperature conditions testing/calibration of fuel, lube, pneumatic, and starting systems.

d. Other environmental testing, such as salt spray, humidity, fungus, explosive atmosphere, etc.

e. Electromagnetic compatibility (EMC/HERF) testing.

f. Testing of engine electronic control lightning tolerance, as discussed under Section 33.7 of this AC.

g. Engine thrust reverser systems tests.

h. Engine mount structure loads tests.

i. Engine ignition systems (duty cycles) tests.

j. Compressor mapping tests.

k. Engine control and monitoring systems software validations; and

l. Tests of electronic control integrity, while operating with various combinations of intended dispatchable control subsystem failures.

63. Section 33.92, Windmilling Tests.

Section 33.92 Windmilling tests.

(a) For engines to be used in supersonic aircraft, unless means are incorporated in the engine to stop rotation of the engine rotors when the engine is shut down in flight, each engine rotor must either seize or be capable of rotation for 3 hours at the limiting windmilling rotational r.p.m. with no oil in the engine system, without the engine--

(1) Catching fire;

(2) Bursting (releasing hazardous uncontained fragments); or

(3) Generating loads greater than those ultimate loads specified in Section 33.23(a).

(b) A turbojet or turbofan engine incorporating means to stop rotation of the engine rotors when the engine is shut down in flight must be subjected to 25 operations under the following conditions:

(1) Each engine must be shut down while operating at rated maximum continuous thrust.

(2) For engines certificated for use on supersonic aircraft, the temperature of the induction air and the external surfaces of the engine must be held at the maximum limit during the tests required by this paragraph.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

The FAA dropped the pre-Amendment 10 requirement for windmilling tests of subsonic turbine engines, on the basis that it imposed an unnecessary burden on the engine manufacturer, and that service experience showed no reported incidents involving windmilling hazards resulting from loss of engine oil.

64. Section 33.93, Teardown Inspection.

Section 33.93 Teardown inspection.

After completing the endurance test, each engine must be completely disassembled, and--

(a) Each component having an adjustment setting and a functioning characteristic that can be established independent of installation on the engine must retain each setting and functioning characteristic within the limits that were established and recorded at the beginning of the test; and

(b) Each engine part must conform to the type design and be eligible for incorporation into an engine for continued operation, in accordance with information submitted in compliance with Section 33.4.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

65. Section 33.94, Blade Containment and Rotor Unbalance Tests.

Section 33.94 Blade containment and rotor unbalance tests.

(a) Except as provided in paragraph (b) of this section, it must be demonstrated by engine tests that the engine is capable of containing damage without catching fire and without failure of its mounting attachments when operated for at least 15 seconds, unless the resulting engine damage induces a self shutdown, after each of the following events:

(1) Failure of the most critical compressor or fan blade while operating at maximum permissible r.p.m. The blade failure must occur at the outermost retention groove or, for integrally-bladed rotor discs, at least 80 percent of the blade must fail.

(2) Failure of the most critical turbine blade while operating at maximum permissible r.p.m. The blade failure must occur at the outermost retention groove or, for integrally-bladed rotor discs, at least 80 percent of the blade must fail. The most critical turbine blade must be

determined by considering turbine blade weight and the strength of the adjacent turbine case at case temperatures and pressures associated with operation at maximum permissible r.p.m.

(b) Analysis based on rig testing, component testing, or service experience may be substituted for one of the engine tests prescribed in paragraphs (a)(1) and (a)(2) of this section if--

(1) That test, of the two prescribed, produces the least rotor unbalance; and

(2) The analysis is shown to be equivalent to the test.

***

Guidance. The INTENT of this section is to demonstrate engine blade containment by test, or by test and, in part, by proven analytical methodology.

Incorporations: AC 33-5, "Turbine Engine Rotor Blade Containment Durability," dated November 7, 1989.

References: None.

66. Section 33.95, Engine-propeller Systems Tests.

Section 33.95 Engine-propeller systems tests.

If the engine is designed to operate with a propeller, the following tests must be made with a representative propeller installed by either including the tests in the endurance run or otherwise performing them in a manner acceptable to the Administrator:

(a) Feathering operation: 25 cycles.

(b) Negative torque and thrust system operation: 25 cycles from rated maximum continuous power.

(c) Automatic decoupler operation: 25 cycles from rated maximum continuous power (if repeated decoupling and recoupling in service is the intended function of the device).

(d) Reverse thrust operation: 175 cycles from the flight idle position to full reverse and 25 cycles at rated maximum continuous power from full forward to full reverse thrust. At the end of each cycle the propeller must be operated in reverse pitch for a period of 30 seconds at the maximum rotational speed and power specified by the applicant for reverse pitch operation.

***

Guidance. The INTENT of this section is to assure that the engine, if designed to operate with a propeller, has been minimally tested with a representative propeller installed.

Incorporations: None.

References: None.

67. Section 33.96, Engine Tests in Auxiliary Power Unit (APU) Mode.

Section 33.96 Engine tests in auxiliary power unit (APU) mode.

If the engine is designed with a propeller brake which will allow the propeller to be brought to a stop while the gas generator portion of the engine remains in operation, and remain stopped during operation of the engine as an auxiliary power unit ("APU mode"), in addition to the requirements of Section 33.87, the applicant must conduct the following tests:

(a) Ground locking: A total of 45 hours with the propeller brake engaged in a manner which clearly demonstrates its ability to function without adverse effects on the complete engine while the engine is operating in the APU mode under the maximum conditions of engine speed, torque, temperature, air bleed, and power extraction as specified by the applicant.

(b) Dynamic braking: A total of 400 application-release cycles of brake engagements must be made in a manner which clearly demonstrates its ability to function without adverse effects on the complete engine under the maximum conditions of engine acceleration/deceleration rate, speed, torque, and temperature as specified by the applicant. The propeller must be stopped prior to brake release.

(c) One hundred engine starts and stops with the propeller brake engaged.

(d) The tests required by paragraphs (a), (b), and (c) of this section must be performed on the same engine used for the tests required by Section 33.87.

(e) The tests required by paragraphs (a), (b), and (c) of this section must be followed by engine disassembly to the extent necessary to show compliance with the requirements of Section 33.93(a) and Section 33.93(b).

***

Guidance. The INTENT of this section is to assure that turboprop engines incorporating propeller brake (APU-mode) features are tested to ensure compatibility of those features with the rest of the engine.

Incorporations: None.

References: None.

a. These tests are intended to provide for the assessment of:

(1) Hot section tolerance for locked rotor operations effects on combustor stability/coking, turbine nozzle integrity, turbine blade integrity, vibration, etc.; and

(2) Engine drive system stability/response, including the power turbine rotors, shafting, bearings and supports, reduction and accessory gear trains, and rotor brake components.

b. These propeller brake tests may be conducted in conjunction with the required tests of Section 33.87, where conditions permit, and if found appropriate by the Administrator.

c. The existing airworthiness standards concerning engine installations in FAR Parts 23 and 25, are considered adequate to assure a minimum level of airworthiness for certification installations of engines designed with propeller brakes for APU mode operations.

(1) In this case, the engine manufacturer will be required to perform a safety analysis, in accordance with the existing requirements of Section 33.75, which addresses APU mode operations.

(2) It is intended that the results of this analysis be applied, as necessary, to the installed engine safety analysis, at the airframe level by the airframe manufacturer, to demonstrate compliance with Sections 23.1309 or 25.1309, as appropriate.

68. Section 33.97, Thrust Reversers.

Section 33.97 Thrust reversers.

(a) If the engine incorporates a reverser, the endurance, calibration, operation, and vibration tests prescribed in this subpart must be run with the reverser installed. In complying with this section, the power control lever must be moved from one extreme position to the other in not more than 1 second except, if regimes of control operations are incorporated necessitating scheduling of the power-control lever motion in going from one extreme position to the other, a longer period of time is acceptable but not more than 3 seconds. In addition, the test prescribed in paragraph (b) must be made. This test may be scheduled as part of the endurance run.

(b) One hundred seventy-five reversals must be made from flight-idle forward thrust to maximum reverse thrust and 25 reversals must be made from rated takeoff thrust to maximum reverse thrust. After each reversal, the reverser must be operated at full reverse thrust for a period of 1 minute, except, that, in the case of a reverser intended for use only as a braking means on the ground, the reverser need only be operated at full reverse thrust for 30 seconds.

***

Guidance. The INTENT of this section is to assure that engines incorporating thrust reversers are tested to ensure reverser airworthiness and compatibility with the rest of the engine.

Incorporations: AC 20-18A "Qualification Testing of Turbojet Engine Thrust Reversers," dated March 16, 1966.

References: None.

Note that the published volume of the Code of Federal Regulations, Aeronautics and Space Title 14, Parts 1 to 59, has an omission in Section 33.97. This publication omits the comma in Section 33.97(a) following "endurance". Thus, some interpretations have been made that an endurance test with the reverser installed is not required; but rather a calibration test as that associated with pre- and post-endurance testing is the requirement (in addition to operation and vibration tests). The point of clarification herein is that an endurance test, a calibration test, an operation test, and a vibration test are all required to evaluate thrust reversers.

69. Section 33.99, General Conduct of Block Tests.

Section 33.99 General conduct of block tests.

(a) Each applicant may, in making a block test, use separate engines of identical design and construction in the vibration, calibration, endurance, and operation tests, except that, if a separate engine is used for the endurance test it must be subjected to a calibration check before starting the endurance test.

(b) Each applicant may service and make minor repairs to the engine during the block tests in accordance with the service and maintenance instructions submitted in compliance with Section 33.4. If the frequency of the service is excessive, or the number of stops due to enngine malfunction is excessive, or a major repair, or replaccemennbf a part is found necessary during the block tests or as the result of findings from the teardown inspection, the engine or its parts must be subjected to any additional tests the Administrator finds necessary.

(c) Each applicant must furnish all testing facilities, including equipment and competent personnel, to conduct the block tests.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

70. Section 33.13, Design Features.

Section 33.13 Design features.

The engine may not have design features that experience has shown to be hazardous or unreliable. The suitability of each questionable design detail or part must be established by tests.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

This rule applies to engines having a type certification basis of FAR Part 33, Amendment 5, or earlier. This rule was deleted by Amendment 6 on the basis that the regulations contain adequate and appropriate safety standards for aircraft engines. The preamble for the deletion further stated that testing of questionable design features may be required under the provisions of Section 21.33 and special conditions may be prescribed under Section 21.16 for novel or unusual design features.

APPENDIX 1. TURBINE ENGINE MODEL DESCRIPTION

1. PURPOSE. This appendix outlines the turbine engine model descriptive information that should be submitted in order to establish those features of the engine that are involved in the certification and safe operation of the engine.

2. DISCUSSION. The applicant should submit, where applicable, the following information, plus any additional information which, in the applicant's opinion, is essential to the certification and safe operation of the engine.

a. Applicant's name.

b. Engine model, type, number of rotors, stages and their arrangement.

c. Performance ratings as defined in FAR Part 1 (See Table 1 of this appendix).

d. Performance charts consistent with the ratings.

e. Maximum structural loading envelope, including mounting attachments and allowable loads.

f. Maximum time the engine may be operated under negative and zero "g" conditions.

g. Maximum permissible temperature limits and cooling criteria for engine components and accessories.

(1) Type and location of thermocouple to use for cooling test, as applicable.

(2) Description of temperature sensing provisions, if incorporated.

h. Bleed air characteristic including temperature, pressure, and flow limits, and the extent and nature of contaminants that may be present and possibly harmful, if breathed.

i. Maximum permissible air inlet duct attachment loads.

(1) Shear loads.

(2) Loads normal to mounting surfaces.

(3) Overhang moment.

j. Inlet air requirements.

(1) Maximum limits of radial and circumferential distortion.

(2) Maximum limits of velocity distribution.

(3) Correction factors for inlet pressure losses.

k. Lubrication system.

(1) Oil grade, type, and specification.

(2) Oil consumption rate (normal and maximum).

(3) Oil inlet pressure limits.

(4) Oil system vent pressure limits.

(5) Oil inlet and scavenge temperature limits.

(6) Inlet oil flow rate.

(7) Usable oil capacity, if oil tank is part of engine.

(8) Maximum heat rejection to oil.

(9) Oil pump outlet pressure limits for normal operation and idle, if oil tank is not part of the engine.

(10) Oil filter provisions and requirements.

l. Fuel system.

(1) Fuel, grade, type, and specification.

(2) Fuel inlet pressure limits.

(3) Fuel inlet temperature limits, where applicable, for external connection.

(4) Fuel return pressure limits.

(5) Inlet fuel flow rate.

(6) Method of preventing filter icing.

(7) Fuel filter provisions and requirements.

m. Maximum permissible exhaust flange attachment loads.

(1) Shear loads.

(2) Loads normal to mounting surfaces.

(3) Overhang moment.

n. Bleed air duct/port attachment loads.

(1) Shear loads.

(2) Loads normal to mounting points.

(3) Overhang moment.

o. Accessory attachments. For each accessory drive, give the following information:

(1) Type of drive and mounting arrangement.

(2) Direction of rotation.

(3) Static torque (maximum limit).

(4) Continuous torque (limit).

(5) Drive shaft speed ratio with rotor or crankshaft.

(6) Maximum overhang moment.

(7) Vibration limits.

p. Output shaft. For turboprop or turboshaft engine.

(1) Maximum steady state allowable torque or power limits of the output shaft.

(2) Maximum allowable transient power output torque.

(3) Maximum bending load limits on the output shaft.

(4) The type and dimensions of the output shaft, direction of rotation, and speed ratio, with main rotor and nominal drive shaft speed.

q. Instrumentation. Describe all instrumentation provisions, including required range, accuracy, readability, and assumptions of precision in detail. Describe provisions for connecting permanent and optional instrumentation, including provisions for trend or condition monitoring equipment.

r. External accessory units (Ref. NOTE 8 of TCDS, Paragraph 5(b)(6)). List the function, model designation, setting numbers, or any other pertinent identifying information relative to the following categories of major engine accessories, controls, and special equipment that comprise externally located separate assemblies or units:

(1) Fuel control and subsystems.

(2) Ignition system and subsystems.

(3) Propeller, air bleed, or anti-icing control units.

(4) Safety devices.

(5) Other engine accessories or components to be furnished as part of, or with the engine.

(6) Optional aircraft or engine accessories available with the engine for mounting on, or for use with the engine.

s. Performance data. Data should be presented in the form of suitable plots, charts, tables, or acceptable electronic media form, and should portray the relationship of the various parameters of a "minimum" engine of the model. Data covering the effects of varying ram pressure ratio, ambient temperature, power extraction, air bleed, and altitude should be provided, and the data basis indicated (e.g., estimated, test, minimum, mean, maximum).

t. Installation drawing. The applicant should provide an installation drawing of the engine showing all the dimensions and details necessary for proper installation of the engine in an aircraft.

u. Radiated electromagnetic interference (EMI/HERF) protection requirements of the engine.

v. Lightning protection requirements of the engine.

w. Induction icing protection system description, requirements, and limitations.

x. Engine vibration (include pickup locations and planes) characteristics and limits (where applicable); acceleration; velocity; and/or displacement; and frequency for installation and maintenance considerations.

y. Operating and installation limitations. The applicant should specify any additional information needed to adequately describe the operational and installational limitations of the engine, including the engine reference parameter used to set thrust, where applicable.

z. Electrical supply required. The applicant should specify the engine requirements for any externally supplied electricity.

aa. Weight data.

(1) Dry weight of complete engine, with all required equipment and no residual fuel or oil.

(2) Weights of optional external equipment and accessories.

(3) Estimated weight of residual fuel and lube oil.

(4) Center of gravity location of engine (dry).

ab. Mass moment of inertia of rotating system.

(1) Estimated effective mass moment of inertia of those engine rotating components involved in starting, when using the designated engine starting system.

(2) Estimated mass moment of inertia of main engine rotating component assemblies.

(3) Estimated effective mass moment of inertia of only the power turbine rotor (for a shaft power type engine).

TABLE 1. PERFORMANCE RATINGS AT STANDARD DAY SEA LEVEL STATIC CONDITIONS

RATINGS	Shaft Horse-power (min-rated)	Jet Thrust -lbs. (min-rated)	Rotor r.p.m. (max.)	Measured Gas Temperature °C, °F (max)
Takeoff (wet)				
Takeoff (dry)				
Maximum Continuous				
30-Minute OEI power				
2-1/2 Min OEI power				
Continuous OEI power				
Maximum Reverse (Operating parameter)				
Flight Idle				
Ground Idle				

APPENDIX 2. RECIPROCATING ENGINE MODEL DESCRIPTION

1. PURPOSE. This appendix outlines the reciprocating engine model descriptive information that should be submitted in order to establish those features of the engine that are involved in the certification and safe operation of the engine.

2. DISCUSSION. The applicant should submit, where applicable, the following information, plus any additional information which, in the applicant's opinion, is essential to the certification and safe operation of the engine.

a. Applicant's name.

b. Engine model, cylinder arrangement, number of cylinders, valve arrangement, cycle used, and type of cooling, etc.

c. Performance ratings as defined in FAR Part 1 (See Table 1 of this appendix).

d. Performance charts consistent with the ratings.

e. Design structural loading envelope for mounting attachments and maximum allowable loads.

f. Maximum time the engine may be operated under negative and zero "g" conditions.

g. Maximum permissible temperature limits and cooling criteria for engine components and accessories.

(1) Type and location of thermocouples used for cooling test.

(2) Description of temperature sensing provisions.

h. Maximum carburetor air inlet duct attachment loads.

(1) Shear load.

(2) Loads normal to mounting surfaces.

(3) Overhang moment.

i. Lubrication system.

(1) Oil grade, type, and specification.

(2) Oil consumption rate (normal and maximum).

(3) Oil inlet pressure limits.

(4) Oil system vent pressure limits.

(5) Oil inlet and scavenge temperature limits.

(6) Inlet oil flow rate.

(7) Usable oil capacity, if oil tank is part of engine.

(8) Maximum heat rejection to oil, including turbosuperchargers.

(9) Oil pump outlet pressure limits for normal operation and idle, if oil tank is not part of engine.

(10) Oil filter provisions and requirements.

(11) Oil pressure limits for propeller governing engine oil passages.

j. Fuel system.

(1) Grade, type, and specification.

(2) Fuel inlet pressure limits.

(3) Inlet fuel flow rate (maximum).

(4) Method of providing for carburetor icing precautions.

(5) Fuel filter provisions and requirements.

k. Maximum permissible exhaust attachment loads.

(1) Shear loads.

(2) Loads normal to mounting surfaces.

(3) Overhang moment.

l. Accessory attachments. For each aircraft accessory drive, give the following information:

(1) Type of drive and mounting arrangement.

(2) Direction of rotation.

(3) Static torque (maximum limit).

(4) Continuous torque (limit).

(5) Drive speed ratio with crankshaft.

(6) Maximum overhang moment.

(7) Vibration limits (if applicable).

m. Output shaft.

(1) Maximum steady state allowable torque, or power limits, of the output shaft.

(2) Maximum allowable transient power output torque.

(3) Maximum bending load limits on the output shaft.

(4) The type and dimensions of the output shaft, direction of rotation, speed ratio with crankshaft, and nominal speed.

n. Describe all instrumentation in detail. Describe provisions for connecting permanent and optional instrumentation, including provisions for trend or condition monitoring equipment.

o. Give model designation, setting numbers, or other pertinent identifying information relative to the engine accessories or controls and special equipment, such as:

(1) Carburetor, injectors, and subsystems.

(2) Ignition system.

(3) Spark plugs.

(4) Safety devices.

(5) Other accessories or components to be furnished as part of, or with the engine.

(6) Optional accessories available with the engine for mounting on, or for use with the engine.

p. Performance data should be presented in the form of suitable curves in order to portray the relationship of the various parameters of a minimum engine of the model, including the effects of varying ambient temperature and altitude. The maximum, or limiting air intake temperature(s), should be specified together, with all other engine performance limitations.

(1) For engines incorporating manual mixture controls, performance charts should include recommended data on rich and lean operation.

(2) For engines to be used with variable pitch propellers and in helicopters, performance charts should include manifold

pressure variations, starting from several representative full throttle points, in the engine operating speed range.

(3) For all engines, include altitude performance charts.

q. The applicant should include, in the engine description, an installation drawing of the engine showing all the dimensions and details necessary for proper installation of the engine in an aircraft, including mounting, mounting provisions, and accessory and component installation/removal envelopes.

r. Radiated electromagnetic interference (EMI/HERF) protection requirements of the engine.

s. Lightning protection requirements of the engine.

t. Any additional information to adequately describe the operational and installation limitations of the engine.

u. Engine requirements for any externally supplied electricity.

v. Weight:

(1) Dry weight of complete engine, with all required equipment and no residual fuel or oil.

(2) Weights of optional external equipment and accessories.

(3) Estimated weight or residual fuel and lube oil.

(4) Center of gravity location of engine (dry).

w. Mass moment of inertia of rotating system - frictional horsepower.

(1) Estimated effective mass moment of inertia of those engine rotating components involved in starting.

(2) Estimated mass moment of inertia of main engine rotating component assemblies.

TABLE 1. PERFORMANCE RATINGS AT STANDARD SEA LEVEL CONDITIONS

RATINGS	Shaft Horse-power (min-rated)	Speed r.p.m. (max)	Cylinder Head & Base Temperature °C, °F (max)	Manifold Pressure Limit in. Hg.
Takeoff Wet				
Takeoff Dry				
Maximum Continuous				
Idle				

APPENDIX 3. INDEX OF INCORPORATED GUIDANCE MATERIAL AND REFERENCES

Incorporated Guidance Material and References		Related FAR
AC 20.18A	"Qualification Testing of Turbojet Engine Thrust Reversers," 3/16/66	33.87, 33.97
AC 20.26	"Turbine and Compressor Rotors Type Certification Substantiation Procedures," 7/22/64	33.27
AC 20.73	"Aircraft Ice Protection," 4/21/71	33.68
AC 20-135	"Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards and Criteria," 2/6/90	33.68
AC 21.1B	"Production Certificates," 5/10/76	33.7
AC 21.6A	"Production Under Type Certificate Only," 7/1/82	33.7
AC 21.23	"Airworthiness Certification of Civil Aircraft, Engines, Propellers, and Related Products Imported to the United States," 7/7/87	21.29
AC 21.303-1A	"Certification Procedures for Products and Parts," 8/10/72	21.303, 21.19, 21.113
AC 23.909-1	"Installation of Turbochargers in Small Airplanes With Reciprocating Engines," 2/3/86	33.51
AC 33.1B	"Turbine Engine Foreign Object Ingestion and Rotor Blade Containment Type Certification Procedures," 4/22/70	33.77
AC 33.3	"Turbine and Compressor Rotors Type Certification Substantiation Procedures," 9/9/68	33.14, 33.27, 33.88
AC 33.4	"Design Considerations Concerning the Use of Titanium in Aircraft Turbine Engines," 7/28/83	33.15, 33.17, 33.19
AC 33.5	"Turbine Engine Rotor Blade Containment/Durabilit," 11/7/89	33.19, 33.94

APPENDIX 3. INDEX OF INCORPORATED GUIDANCE MATERIAL AND REFERENCES

Incorporated Guidance Material and References		Related FAR
AC 33.47-1	"Detonation Testing in Reciprocating Aircraft Engines," 6/27/88	33.47
AC 33.65-1	"Surge and Stall Characteristics of Aircraft Turbine Engines," 12/6/85	33.65, 33.73
AC 43.17	"Methods, Techniques, and Practices Acceptable to the Administrator Governing the Installation, Removal, or Change of Identification Data and Identification Plates," 9/5/79	43.3, 45.13
AC 91.33A	"Use of Alternate Grades of Aviation Gasoline for Grade 80/87 and Use of Automotive Gasoline," 7/84	33.7
FAA Order (Handbook) 8110.4	"Type Certification," 6/85	21.21, 21.29, 21.41
FAA Order 8120.2A	"Production Approval and Surveillance Procedures," Rev. 3/12/87	21.33
FAA Order NE CD 8110.1A	"Evaluation and Approval Responsibilities for Manufacturer's Material and/or Process Specifications Specified in the Type Design," 5/28/86	21.33
FAA Order NE CD 8110.2A	"Confirmation of Satisfactory Conformity Inspection," 8/7/86	21.33
FAA Policy Memo	"Turbine and Compressor Rotor Integrity Substantiation," 2/9/59	33.27
FAA Powerplant Engineering Report No. 3A	"Standard Fire Test Apparatus and Procedure (for Flexible Hose Assemblies)," Rev. 3/78	33.17
FAA Report FAA-RD-75-155	"Ignition and Propagation Rates for Flames in a Fuel Mist," 10/75	33.17

APPENDIX 3. INDEX OF INCORPORATED GUIDANCE MATERIAL AND REFERENCES

Incorporated Guidance Material and References		Related FAR
FAA Report FAA-RD-79-51	"Titanium Combustion in Turbine Engines," 7/79	33.17
JAR-E, Section 2, Paragraph ACJ E 530 (c)	"Titanium Fires"	33.17
{RTCA DO-160B}		{33.28}
{RTCA DO-178}		{33.28}
SAE AIR 1377A	"Fire Test Equipment for Flexible Hose and Tube Assemblies," 1/80	33.17
SAE ARP 1507	"Helicopter Engine/Airframe Interface Document and Checklist," 9/85	33.5
SAE ARP 926A	"Fault/Failure Analysis Procedure," Rev. 11/15/79	33.75
SAE AS 1055B	"Fire Testing of Flexible Hose, Tube Assemblies, Coils, Fittings, and Similar System Components," Rev. 3/1/78	33.17
{SAE Committee Report No. AE4EL}		{33.28}
SAE Paper No 690436	"Ignition of Aircraft Fluids on High Temperature Engine Surfaces," William T. Westfield, 4/21/69	33.17

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NOTE: {33.28} is pending.

APPENDIX 4. GLOSSARY OF ACRONYMS AND ABBREVIATIONS

AC	Advisory Circular
ACO	Aircraft Certification Office
AIR	Aerospace Information Report (SAE)
APU	Auxiliary Power Unit
ARP	Aerospace Recommended Practice (SAE)
AS	Aerospace Standard (SAE)
BTC	Before Top Center
BTU	British Thermal Unit
CAR	Civil Aviation Regulations (predecessor of FAR)
CRes	Corrosion Resistant
D_e	Engine front face inlet equivalent diameter
DER	Designated Engineering Representative
D_s	Nacelle inlet lip stagnation point equivalent diameter
D_t	Nacelle inlet throat equivalent diameter
ECO	Engine Certification Office
EEC	Engine Electronic Control
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
"ft.," "'"	Feet (measurement)
g	Gravitational constant
HERF	High Energy Radiated Fields
hr.	Hour (time)

APPENDIX 4. GLOSSARY OF ACRONYMS AND ABBREVIATIONS

HSI	Hot Surface Ignition
"in.," "′′"	Inch (measurement)
in. Hg	Inches of Mercury
JAR-E	Joint Airworthiness Requirements-Engines (European)
JP	Jet Propellant (turbine) fuel
lbs.	Pounds (force or mass)
LCF	Low Cycle Fatigue
max.	Maximum
min.	Minimum
o'hg. mom.	Overhang moment
°C	Degrees Celsius
OEI	One-Engine-Inoperative
°F	Degrees Fahrenheit
p.s.i./psi	Pounds per Square Inch
r.p.m./rpm	Revolutions Per Minute
S.L.	Sea Level
SAE	Society of Automotive Engineers
SHP	Shaft Horse Power
TC	Type Certificate
TCDS	Type Certificate Data Sheet
TIA	Type Inspection Authorization

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