FEDERAL AVIATION AGENCY
Washington 25, D.C.

TECHNICAL STANDARD ORDER

Regulations of the Administrator

Part 514

Subject: GAS TURBINE AUXILIARY POWER UNITS TSO-C77

Technical Standards Orders for Aircraft Materials, Parts and Appliances

Part 514 which contains minimum performance standards and specifications for materials, parts, and appliances used in aircraft consists of two subparts. Subpart A contains the general requirements applicable to all Technical Standard Orders. Subpart B contains the technical standards and specifications to which a particular product must conform.

ANY TECHNICAL STANDARD ORDER MAY BE OBTAINED BY SENDING A REQUEST TO FAA, WASHINGTON 25, D.C.

Subpart A—GENERAL

§ 514.0 Definition of terms.

As used in this part:

(a) "Administrator" means the Administrator of the Federal Aviation Agency or any person to whom he has delegated his authority in the matter concerned.

(b) "FAA" means Federal Aviation Agency.

(c) "Manufacturer" means a person who controls the design and quality of an article produced under the TSO system, including all parts thereof and processes and services related thereto obtained from outside sources.

(d) "Article" means the materials, parts, or appliances for which approval is required under the Civil Air Regulations for use on civil aircraft.

§ 514.1 Basis and purpose.

(a) *Basis.* Section 601 of the Federal Aviation Act of 1958, and §§ 3.18, 4a.31, 4b.18, 5.18, 6.18, 7.18, 10.21, 13.18, and 14.18 of this title (Civil Air Regulations).

(b) *Purpose.* (1) This part prescribes in individual Technical Standard Orders the minimum performance and quality control standards for FAA approval of specified articles used on civil aircraft,[1] and prescribes the methods by which the manufacturer of such articles shall show compliance with such standards in order to obtain authorization for the use of the articles on civil aircraft.

(2) The performance standards set forth in the individual Technical Standard Orders are those standards found necessary by the Administrator to assure that the particular article when used on civil aircraft will operate satisfactorily, or accomplish satisfactorily its intended purpose under specified conditions.

§ 514.2 TSO authorization.

(a) *Privileges.* No person shall identify an article with a TSO marking unless he holds a TSO authorization and the article meets the applicable TSO standards prescribed in this part.

(b) *Letters of acceptance issued prior to July 1, 1962.* An FAA letter of acceptance of a statement of conformance issued for an article prior to July 1, 1962, is an authorization within the meaning of this part and the holder thereof may continue to manufacture such article without obtaining an additional TSO authorization, but shall comply with the requirements of § 514.3 through § 514.10.

(c) *Application.* The manufacturer or his duly authorized representative shall submit an application for a TSO authorization together with the following documents (See Appendix A of this subpart for sample application) to the Chief, Engineering and Manufacturing Branch, Flight Standards Division, in the region in which the manufacturer is located.[2]

(1) A statement of conformance certifying that the applicant has complied with the provisions of Subpart A and the article meets the applicable performance standards established in Subpart B of this part (See Appendix B of this subpart for sample statement of conformance);

(2) Copies of the technical data required in the performance standards set forth in Subpart B of this part for the particular article;

(3) A description of his quality control system in the detail specified in § 1.36 of this title (Civil Air Regulations). In complying with this provision the manufacturer may refer to current quality control data filed with the Agency, as a part of a previous application.

NOTE: When a series of minor changes in accordance with § 514.5 is anticipated, the manufacturer may set forth in his application the basic model numbered article with open brackets after it to denote that suffix change letters will be added from time-to-time e.g., Model No. 100 ( ).

(d) *Issuance.* (1) Upon receipt of the application and adequate supporting documents specified in paragraph (c) of this section to substantiate the manufacturer's statement of conformance with the requirements of this part and his ability to produce duplicate articles in accordance with the provisions of this part, the applicant will be given an authorization to identify his article with the applicable TSO marking.

(2) If the application is deficient in respect to any requirements, the applicant shall, upon request by the Chief, Engineering and Manufacturing Branch, submit such additional information as may be necessary to show compliance with such requirements. Upon the failure of the applicant to submit such additional information within 30 days after the date of the request therefor, his application will be denied and he will be so notified by the Chief, Engineering and Manufacturing Branch.

NOTE: The applicant will be issued an authorization or notified of the denial of his application within 30 days after the date of receipt of such application or, in the event that additional information has been requested, within 30 days after the date of receipt of such additional information.

[1] Articles may also be approved and manufactured for use on civil aircraft as a part of the type design of a type certificate for an aircraft engine or propeller.

[2] Regional Offices are located at New York, Atlanta, Kansas City, Fort Worth, Los Angeles, Anchorage.

§ 514.3 Conditions on authorizations.

The manufacturer of an article under an authorization issued under the provisions of this part shall—

(a) Manufacture such article in accordance with the requirements of Subpart A and the performance standards contained in the applicable TSO of Subpart B of this part;

(b) Conduct the required tests and inspections, and establish and maintain a quality control system adequate to assure that such article, as manufactured, meets the requirements of paragraph (a) of this section and is in a condition for safe operation;

(c) Prepare and maintain for each type or model of such article a current file of complete technical data and records in accordance with § 514.6; and

(d) Permanently and legibly mark each such article with the following information:

(1) Name and address of the manufacturer,

(2) Equipment name, or type or model designation,

(3) Weight to the nearest tenth of a pound,

(4) Serial number and/or date of manufacturer, and

(5) Applicable Technical Standard Order (TSO) number.

§ 514.4 Deviations.

Approval for a deviation from the performance standards established in Subpart B may be obtained only if the standard or standards for which deviation is requested are compensated for by factors or design features which provide an equivalent level of safety. A request for such approval together with the pertinent data shall be submitted by the manufacturer to the Chief, Engineering and Manufacturing Branch of the Region in which the applicant is located.

§ 514.5 Design changes.

(a) *By Manufacturer*—(1) *Minor changes.* The manufacturer of an article under an authorization issued pursuant to the provisions of this part may make minor design changes to the article without further approval by the FAA. In such case the changed article shall retain the original model number and the manufacturer shall forward to the Chief, Engineering and Manufacturing Branch such revised data as may be necessary for compliance with § 514.2(c).

(2) *Major changes.* If the changes to the article are so extensive as to require a substantially complete investigation to determine compliance with the performance standards established in Subpart B, the manufacturer shall assign a new type or model designation to the article and submit a new application in accordance with the provisions of § 514.2(c).

(b) *By persons other than the manufacturer.* Design changes to an article by a person other than the manufacturer who submitted the statement of conformance for such article are not eligible for approval under this part, unless such person is a manufacturer as defined in § 514.0 and applies for authorization under § 514.2(c).

NOTE: Persons other than a manufacturer may obtain approval for design changes to a product manufactured under a TSO pursuant to the provisions of Part 18 or the applicable airworthiness regulations.

§ 514.6 Retention of data and records.

(a) A manufacturer holding an authorization issued pursuant to the provisions of this part shall, for all articles manufactured under such authorization on and after July 1, 1962, maintain and keep at his factory:

(1) A complete and current technical data file for each type or model of article which shall include the design drawings and specifications. This technical data shall be retained for the duration of his operation under the provisions of this part.

(2) Complete and current inspection records to show that all inspections and tests required to ensure compliance with this part have been properly accomplished and documented. These records shall be retained for at least two years.

(b) The data specified in paragraph (a)(1) of this section shall be identified and copies transferred to the FAA for record purposes in the event the manufacturer terminates his business or no longer operates under the provisions of this part.

§ 514.7 Inspection and examination of data, articles or manufacturing facilities.

The manufacturer shall, upon request, permit an authorized representative of the FAA to inspect any article manufactured pursuant to this part, and to observe the quality control inspections and tests and examine the manufacturing facilities and technical data files for such article.

§ 514.8 Service difficulties.

Whenever the investigation of an accident or a service difficulty report shows an unsafe feature or characteristic caused by a defect in design or manufacture of an article, the manufacturer shall upon the request of the Chief, Engineering and Manufacturing Branch, report the results of his investigation and the action, if any, taken or proposed by him to correct the defect in design or manufacture (e.g., service bulletin, design changes, etc.). If the defect requires a design change or other action to correct the unsafe feature or characteristic, the manufacturer shall submit to the Chief, Engineering and Manufacturing Branch, the data necessary for the issuance of an airworthiness directive containing the appropriate corrective action.

§ 514.9 Noncompliance.

Whenever the Administrator finds that a manufacturer holding an authorization issued pursuant to the provisions of this part has identified an article by a TSO marking and that such article does not meet the applicable performance standards of this part, the Administrator may, upon notice thereof to the manufacturer, withdraw the manufacturer's authorization and, where necessary, prohibit any further certification or operation of a civil aircraft upon which such article is installed until appropriate corrective action is taken.

§ 514.10 Transferability and duration.

An authorization issued pursuant to the provisions of this part shall not be transferred and is effective until surrendered, or withdrawn, or otherwise terminated by the Administrator.

APPENDIX A

SAMPLE APPLICATION FOR TSO AUTHORIZATION

_____
(Date)

(Addressed to: Chief, Engineering and Manufacturing Branch, Federal Aviation Agency, Region.)

Application is hereby made for authorization to use the Technical Standard Order procedures.

Enclosed is a statement of conformance for the article to be produced under TSO–C_____.

The required quality control data [1] are transmitted: (herewith) (under separate cover).

Signed _____

APPENDIX B

SAMPLE STATEMENT OF CONFORMANCE

_____
(Date)

(Addressed to: Chief, Engineering and Manufacturing Branch, Flight Standards Division, Federal Aviation Agency.)

The undersigned hereby certifies that the article listed below by model, type or part number has been tested and meets the performance standards of Technical Standard Order C_____. In addition, all other applicable provisions of Part 514 of the Regulations of the Administrator have been met.

The technical data required by the TSO in the quantity specified are transmitted: (herewith) (under separate cover).

Authorization to use TSO identification on this article is requested.

Signed _____

[1] Reference may be made to data already on file with the FAA.

§ 514.83 Gas turbine auxiliary power units - TSO-C77.

(a) Applicability. Minimum performance standards are hereby established for gas turbine auxiliary power units for use on civil aircraft of the United States. New models of gas turbine auxiliary power units manufactured for use on civil aircraft on or after the effective date of this section shall meet the standards specified in the Federal Aviation Agency Standard, "Gas Turbine Auxiliary Power Units", dated January 3, 1963.

(b) Marking. Articles shall be marked in accordance with the requirements of § 514.3(d) except that the weight need only be shown to the nearest pound. In addition, the following shall also be shown:

(1) Maximum rated speeds and temperature;

(2) Maximum allowable speeds and temperature;

(3) Maximum rated output;

(4) Category and class of service;

(5) Fuel grade and specification; and

(6) Lubricating oil grade and specification.

(c) Data requirements. In accordance with the provisions of § 514.2, the manufacturer shall furnish to the Chief, Engineering and Manufacturing Branch, Flight Standards Division, Federal Aviation Agency, in the region in which the manufacturer is located, the following technical data:

(1) Instruction manual containing instructions for the installation, operation, servicing maintenance, repair, and overhaul of the unit; and

(2) Model specification.

(d) Effective date. May 20, 1963.

January 3, 1963

Federal Aviation Agency Standard

for

Gas Turbine Auxiliary Power Units

1.0 Purpose. To specify minimum requirements for gas turbine auxiliary power units for use in civil aircraft.

2.0 Scope. This standard covers gas turbine auxiliary power units intended to be used as a power source for the driving of generators, hydraulic pumps, and other aircraft accessories and equipment, or to provide compressed air for aircraft pneumatic systems. This standard establishes minimum design and performance standards for the following categories and classes of gas turbine auxiliary power units:

Category I. Essential Power

Class A. A source of shaft power.

Class B. A source of compressor bleed air.

Class C. A combination source of shaft power and compressor bleed air.

Category II. Nonessential Power

Class A. A source of shaft power.

Class B. A source of compressor bleed air.

Class C. A combination source of shaft power and compressor bleed air.

This technical standard order does not specify installation standards; therefore, consideration should be given for the inclusion of design features desirable for complying with applicable requirements for installing the unit in an aircraft. Regulations pertaining to the design and performance standards of applicable aircraft are Civil Air Regulations, Parts 3, 4b, 6, and 7.

3.0 Definitions. As used in this standard, terms are defined as follows:

3.1 Auxiliary Power Unit. Any gas turbine power units delivering shaft horsepower or bleed-air power, or both, exclusive of direct propulsion of the aircraft.

3.2 Essential Power. Power which is used to drive accessories necessary for maintaining safe operation of the aircraft either on the ground or in flight.

3.3 Nonessential Power. Power which may be discontinued without jeopardizing safe operation of the aircraft either on the ground or in flight.

3.4 Standard Atmosphere. The standard atmosphere is an atmosphere as defined by Federal Aviation Regulation Part 1, Sec. 1.1.

3.5 Type and Model. An auxiliary power unit type includes all of a series of units each one of which was developed as an alternate configuration to or a refinement of the same basic unit. Each configuration of such a series is a model.

3.6 Fireproof. As defined by Federal Aviation Regulation Part 1, Sec. 1.1.

3.7 Fire-resistant. As defined by Federal Aviation Regulation Part 1, Sec. 1.1.

3.8 Demonstrate. To prove by actual physical test or experience under the conditions to be satisfied.

3.9 Substantiate. To prove on the basis of adequate evidence obtained by demonstration or analysis or both.

3.10 Containment. Parts being contained may penetrate containing components but shall not have passed clear through such components.

3.11 Rotor. The entire rotating assembly with exception of accessory drive shafts and gears.

3.12 Hub. The inner portion of the rotor.

3.13 High Energy Rotor. A rotating component or assembly which, if it ruptures, will generate particles with sufficient energy as to cause secondary damage to the rotor housing.

3.14 Maximum Rated Temperature. The maximum exhaust gas or turbine inlet temperature that can be maintained for periods of unrestricted duration while operating at the maximum rated output and speed. This temperature shall be specified in the model specification.

3.15 Maximum Allowable Temperature. The maximum exhaust gas or turbine inlet temperature which the unit would experience under overload or transient conditions and which is limited by a safety device, if applicable. This temperature shall be specified in the model specification.

3.16 Maximum Rated Speeds. The maximum speed at which the engine can operate for periods of unrestricted duration at the maximum rated output. These speeds shall be specified in the model specification.

3.17 Maximum Allowable Speeds. The maximum speed of the gas producer rotor and the maximum speed of the output shaft, if applicable, which the unit would experience under overload or transient conditions and which are limited by safety devices, if applicable. These speeds shall be specified in the model specification.

3.18 Maximum Rated Output. The maximum shaft horsepower or bleed air output or both that the unit will deliver for periods of unrestricted duration. This output shall be specified in the model specification.

3.19 Blade. The energy transforming elements of the compressor or turbine rotor whether of integral or attached design.

3.20 Output Drives. Any drive pad or bleed-air output flange intended for customer use to extract usable shaft or pneumatic power from the unit.

3.21 Accessory Drives. Any accessory drive or utility pad furnished as a part of the unit for extraction of power to drive accessories, components, or controls essential to operation of the unit or any of its associated systems.

3.22 Start. A successful start shall be defined as a complete start and acceleration from starter torque initiation to stabilized speed and temperature in the governed range without exceeding allowable limits.

3.23 Critical Stage. In testing for rotor integrity the stage(s) of the compressor and/or turbine section determined by the manufacturer as having the least margin of safety when subjected to the conditions of speed and temperature shown in paragraph 7.3.1. In testing for containment the stage(s) whose casing is most susceptible to penetration.

4.0 General Requirements.

4.1 Materials and Processes. The suitability and durability of all materials and processes used in manufacturing the unit shall be established on the basis of tests or experience, or both. These materials and processes shall conform to specifications selected or prepared by the manufacturer which will insure that the strength and other properties assumed in the design data are valid.

4.2 Accessibility. Parts of the unit requiring routine service checking, adjustment, or replacement shall be made readily accessible for servicing without teardown of the unit or removal of any major part, component, or accessory.

4.3 Attitude Conditions. The manufacturer shall specify in the model specification the attitude limits at which the unit will function satisfactorily. These limits shall be substantiated by actual tests.

4.4 Magnetic and Electronic Interference. The conducted and radiated magnetic and electronic interference limits of the unit, where appropriate, shall be specified in the model specification as well as the testing procedure.

4.5 Operating Characteristics. The overall range of engine operation and environmental conditions shall be specified by the manufacturer. Starting envelopes and operational envelopes within which the unit can be operated without detrimental effects such as stall, surge, flameout, etc., shall be specified. For essential units, these envelopes shall be substantiated by test or by equivalently reliable analysis.

Data showing the effects of inlet temperature, altitude, air bleed, exhaust back pressure, inlet pressure recovery, and ram pressure ratio upon performance parameters such as r.p.m. power output, airflow, fuelflow, exhaust gas temperature, compressor temperature, and pressure ratio shall be provided for the desired operating envelope.

4.6 Flight Maneuver Loads. The manufacturer shall establish the maximum translational, rotational, and combined accelerations in all three principal directions, which the unit including all accessories and its mounting provisions can withstand without permanent deformation or failure or adversely affecting its operating characteristics. These loads shall be included in the model specification as installation design limitations.

4.7 Negative Acceleration. The manufacturer shall specify and substantiate the maximum duration of time under negative acceleration conditions for which the unit will function satisfactorily. This time will appear in the model specification as an installation design limitation.

5.0 Design and Construction. The unit shall not incorporate design features or details which are hazardous or unreliable. The suitability of all design details and parts shall be established by tests, experience, or analysis as prescribed herein. All parts of the unit shall be designed and constructed to minimize the development of unsafe conditions in the unit between overhaul periods.

5.1 Fire Prevention. The design and construction of the unit and materials used shall be such as to minimize the possibility of occurrence and spread of fire because of structural failure, overheating, leaking flammables or other causes.

5.1.1 Hose Assemblies. Fuel and oil system hose assemblies shall meet the appropriate fire-resistant standards of Technical Standard Order C53 in effect on the date that the manufacturer certifies conformity to this standard.

5.1.2 Isolation of High Temperature Components. Components, lines and fittings carrying flammable fluid shall be located, shielded, shrouded, or otherwise separated or isolated so as to prevent any leakage of the fluid from contacting surfaces hot enough to ignite the fluid. Surface temperatures below 500° F. are not considered to be sources of ignition.

5.2 Air Intake. The air intake passages within essential units shall be designed and constructed so as to prevent accumulations of ice in sufficient quantities as to cause malfunctioning of the unit during continuous operation throughout the icing envelope defined by CAR, Sections 4b.1(b) (7) and (8). If applicable the maximum permissible shear load, axial load, and moment which may be applied to the intake connection shall be specified in the model specification. The presence of flammable fluid carrying lines, fittings, and components in the air intake should be avoided wherever possible. When flammable fluid carrying lines, fittings, or components must be in the air intake, they shall be protected by shrouds so that leakage from such lines, fittings, or components cannot enter the unit intake airstream. Shrouds shall be fitted with provisions for attaching external drains.

5.2.1 Foreign Object Ingestion. For essential units the effect on engine functioning, performance, or reliability of ingesting foreign objects such as sand, gravel, dust, insects, and other environmental objects shall be investigated by the manufacturer. Necessary provisions for protection from ingestion of foreign objects, if required, shall be specified in the model specification.

5.2.2 Inlet Air Pressure Drop. The affect of inlet air pressure drop on the rated power of the unit shall be specified in the model specification. For essential units, if velocity distribution at the inlet of the unit has an adverse effect on the vibration characteristics of the unit, the manufacturer shall specify maximum permissible limits.

5.3 Lubrication System. The auxiliary power unit lubrication system shall be designed to function satisfactorily under all of the normal operating conditions defined by paragraphs 4.3 and 4.5 of this standard. The applicable lubricant specification shall be specified in the model specification. The lubrication system, when furnished as part of the auxiliary power unit, shall incorporate the following features:

5.3.1 Oil Drains. Accessible drains shall be provided to permit safe drainage of the entire oil system. The oil drains shall be located at the lowest points of the system.

5.3.2 Breather. A breather or other suitable means shall be provided to prevent detrimental differential pressure in the oil tank.

5.3.3 Filters. If the unit is equipped with an oil filter, the filter shall be constructed in such a manner that complete blocking of the flow through the filter element will not prevent the safe operation of the engine oil supply system.

5.3.4 Oil Tank. The oil tank or sump type oil reservoir shall incorporate the following features:

5.3.4.1 Oil Tank Material. The oil tank and its supports shall be fireproof.

5.3.4.2 Expansion Space. The oil tank shall incorporate an expansion space of at least 10 percent of the total tank capacity. The tank filler shall be so located that the expansion space cannot be inadvertently filled when serviced at the normal ground attitude. The tank vent shall be located at the top of the expansion space.

5.3.4.3 Negative Acceleration. Provisions shall be made in the oil tanks of essential units for supplying the unit with a continuous flow of oil during operation with both positive and negative acceleration unless the unit has been demonstrated capable of operation at rated power without adverse effects with interruption of oil flow for the time specified by paragraph 4.7 of this standard.

5.3.4.4 Oil Tank Pressure Test. The oil tank shall be demonstrated capable of withstanding a differential pressure of 5 p.s.i. more than the maximum differential pressure which would be encountered during operation throughout the normal operating envelope defined by paragrpah 4.5 of this standard.

5.3.4.5 Oil Level Gage. The oil tank shall be provided with a marked dipstick or other suitable means for determining the level of oil in the tank when the unit is in the normal installed attitude.

5.3.4.6 Oil Tank Strainer. The oil tank shall have a provision to prevent entrance into the tank of any foreign object which might obstruct the flow of oil through the system.

5.3.5 Nonintegral Systems. If any portion of the lubrication system is not supplied with the unit, the manufacturer shall specify all oil system requirements in the model specification.

5.4 Fuel System. The fuel specification, rate, pressure, and temperature range of fuel flow to the inlet of the auxiliary power unit fuel system and the degree of filtration necessary for satisfactory unit functioning shall be established by the manufacturer and specified in the model specification.

5.4.1 Fuel System Drains. A drain shall be supplied in the combustor to prevent the accumulation of fuel in the event of a false start. The combustor drain and any other drains in the fuel system shall have fittings suitable for connecting overboard drainage lines.

5.4.2 Fuel Resistance. All materials used in the fuel system shall be sufficiently resistant to fuels used in the unit as to permit continuous normal operation of the fuel system and all its components throughout the overall range of engine operation and environmental conditions as defined by paragraph 4.5 of this standard.

5.5 Exhaust System. The exhaust system of the unit shall be so designed and constructed as to prevent the leakage of exhaust gases into the aircraft. The unit shall incorporate suitable fittings for the connection of exhaust ducts. The maximum permissible shear and axial loads and moments that may be applied to the exhaust connection of the unit shall appear in the model specification.

5.5.1 Exhaust Piping. Exhaust piping shall be constructed of fireproof, heat and corrosion resistant material and shall incorporate provisions to prevent failure due to expansion when heated to operating temperatures.

5.5.2 Turbine Exhaust Back Pressure. The model specification shall specify changes upon output power resulting from exhaust back pressure.

5.6 Cooling. Temperature limits shall be established for those components which require temperature controlling provisions in the aircraft installation to assure satisfactory functioning, reliability, and durability. These limits together with the heat rejection rates shall appear in the model specification.

5.7 Instrumentation. Provisions shall be made for attaching a turbine inlet or exhaust gas temperature probe, a tachometer generator for each independent rotor assembly, and the sensing elements of any other instrumentation necessary to monitor the continued safe operation of the unit. These provisions shall be specified in the model specification.

5.8 Drive Attachments. Accessory drives and mounting attachments shall be designed and constructed to that the unit will operate properly with the accessories attached. The design of the unit shall incorporate provisions for the examination, adjustment, or removal of all accessories. For output drives other than accessory drives limiting conditions of torque speed, direction of rotation, and overhanging moment shall be determined and substantiated and, together with a description of the type of pad and drive, shall be specified in the model specification.

5.9 Temperature Control: Essential units shall be provided with an automatic temperature control capable of maintaining all critical gas temperatures within the limits specified by the manufacturer. The temperature control shall be so designed and constructed as to prevent the maximum allowable turbine temperature from being exceeded under any of the specified operating conditions.

5.10 Speed and Acceleration Control: The speed and acceleration control systems shall maintain the unit speed and acceleration within the limits specified by the manufacturer. The control systems shall be designed so that the unit rotational speed shall be automatically controlled to prevent the predetermined maximum allowable speed from being exceeded under the specified operating conditions.

5.11 Safety Devices. When safety devices are incorporated to prevent a hazardous overspeed or overtemperature condition and if it is desired to consider these devices in testing per paragraph 7.2, means shall be provided for ascertaining from the control panel on the ground or during normal flight operation that these devices are functioning properly.

5.12 Bleed-Air Provisions. Units of a type permitting the extraction of compressor bleed air shall incorporate suitable fittings for the connection of bleed-air ducts. The manufacturer shall specify in the model specification the amount, cleanliness, and characteristics of bleed-air available and the maximum permissible shear and axial loads and moments which may be applied to the bleed-air connection.

5.13 Rotor Blade Failure Protection. Except for those nonessential units for which rotor containment will be demonstrated in accordance with paragraph 7.3, compressor and turbine rotor cases shall be designed to provide for containment of damage from rotor blade failure. Whole vanes from radial flow rotors shall be contained unless smaller portions of these vanes are substantiated by the manufacturer as the largest portions likely to occur. The entire airfoil section of the blade of exducers, inducers, and axial flow rotors shall be contained. Blade containment shall be demonstrated in accordance with paragraph 7.3. For rotors incorporating more than one stage, containment need be demonstrated for the critical stage only. The manufacturer shall substantiate which stage is the critical stage.

5.14 High Energy Rotors. The compressor and turbine rotor cases of non-essential units shall be designed to contain maximum energy failed rotor fragments unless compliance with paragraphs 5.15, 5.16, and 7.2 is established. Containment, if applicable, shall be demonstrated in accordance with paragraph 7.3. All rotors of essential units shall be capable of overtemperature and overspeed operation in accordance with paragraph 7.2.

5.15 Vibration. The manufacturer shall investigate the vibration amplitudes and frequencies which could be transmitted to the airframe throughout the normal operating range of the unit. Critical frequencies and amplitudes shall be specified in the model specification. The manufacturer shall demonstrate by actual measurement under operating conditions or equivalently reliable techniques that the compressors, turbines, and other highly stressed parts of essential units and nonessential units complying with paragraph 7.2 are free from harmful vibration stresses.

5.16 Stress Rupture and Start/Stop Cycle Fatigue. For essential auxiliary poeer units and nonessential power units complying with paragraph 7.2, the stress rupture and start/stop cycle fatigue characteristics shall be investigated and substantiated. Based on the results of these investigations, life and/or growth limits, if applicable, shall be established. These life and/or growth limits shall be specified in the model specification.

5.17 Control of Unit Rotation. In the event that unit windmilling in either direction could have adverse effects on the unit, provisions shall be made to prevent such rotation. The capabilities of any antirotation device shall be substantiated by test or equivalently reliable analysis and shall be specified in the model specification.

5.18 Ignition System. The unit shall provide for satisfactory ignition during starting and restarting under all of the conditions specified in the model specification.

6.0 Block Tests. A complete unit representative of production units shall be subjected to the following tests and whatever additional tests the manufacturer deems necessary to demonstrate compliance with these standards.

a. Essential units shall comply with paragraphs 6.1 to 6.5.

b. Nonessential units shall comply with paragraph 6.1.

6.1 Unit Calibration. The unit shall be subjected to such calibration tests as are necessary to establish its power characteristics and the conditions for the endurance test. Calibration shall be conducted prior to the endurance test. Calibration data shall be presented in the form of curves of output shaft power or torque and speed, fuel flow and bleed-air flow, temperature and pressure versus turbine inlet or exhaust gas temperature and turbine speed.

6.2 Endurance Test. Essential power units shall be subjected to and satisfactorily pass a 150-hour endurance test in accordance with paragraphs 6.2.1, 6.2.2, and 6.2.3. To have satisfactorily passed this test, there must be no indication of impending failure, or excessive wear in any of the unit's

major components. The unit must be functioning properly and be in such condition that it could be overhauled without the replacement of major components. During the maximum rated portions of this test, the normal speed and gas temperature control devices shall maintain these parameters within the tolerances specified in the model specification.

6.2.1 Test Periods. Twenty periods of seven and one-half hours each shall be run in accordance with the following schedule:

Note: Maximum rated output in the following schedule means the maximum shaft power output for which approval is desired for Class A units, the maximum bleed-air output (mass and pressure) for which approval is desired for Class B units and the maximum simultaneous combination of shaft power output and bleed-air output for which approval is desired for Class C units.

a. Five minutes at or above maximum rated output, five minutes at no load, one hour at or above maximum rated output and five minutes at no load.

b. Five minutes at or above maximum rated output, five minutes at no load, one hour at seventy-five percent maximum rated output and five minutes at no load.

c. Five minutes at or above maximum rated output, five minutes at no load, one hour at or above maximum rated output and five minutes at no load.

d. Five minutes at or above maximum rated output, five minutes at no load, one hour at fifty percent maximum rated output and five minutes at no load.

e. Five minutes at or above maximum rated output, five minutes at no load, one hour at or above maximum rated output and five minutes at no load.

f. Five minutes at or above maximum rated output, five minutes at no load, one hour at twenty-five percent maximum rated output and five minutes at no load.

6.2.2 Test Conditions. The following test conditions shall be observed during the endurance test:

6.2.2.1 Speed. During the maximum rated output portions of the endurance test, the speed of each rotor must be at least equal of the maximum rated speed. During all other portions of the endurance test, definite rotor speeds need not be maintained.

6.2.2.2 Temperatures. During the endurance test, all temperature limits including the maximum rated turbine inlet or exhaust gas temperature and oil temperature limits shall be substantiated by maintaining the temperatures of the affected components at or above these limits during all maximum rated output portions of the endurance test. The temperature of the inlet air may be controlled in order to match the turbine temperature, speed, and power output and avoid unnecessarily exceeding either temperature, speed, or power during this test.

6.2.2.3 Pressures. The minimum oil and fuel pressures specified by the manufacturer in the model specification shall be maintained during all maximum rated output portions of the endurance test.

6.2.2.4 Output Drives. During the endurance test, all output drives shall be subjected to the maximum torque and overhang moment loadings for which approval is desired. These loadings shall appear in the model specification.

6.2.3 Adjustments and Repair or Replacement of Parts. During the endurance test, repair, or replacement of minor parts or infrequent adjustment not requiring disassembly of major components shall be permissible. Minor parts are parts the failure of which could not affect the performance, operating characteristics, reliability, or integrity of the unit. All other parts are major parts. Major parts may not be repaired or replaced during the endurance test.

6.3 Starts. For essential power units a minimum of 100 starts shall be made on the unit of which at least 25 starts shall be preceded by a minimum of two hours shutdown.

6.4 Recalibration. After completion of the endurance test, a recalibration check run shall be made in accordance with paragraph 6.1. During this run the output shall be not less than 95 percent of the values obtained during calibration and fuel consumption shall not exceed 105 percent of the values obtained during calibration.

6.5 Teardown Inspection. After completion of the recalibration test, essential power units shall be completely disassemblied, and a detailed inspection shall be made of auxiliary power unit parts to check for fatigue and wear. Redesign and testing of components shall be accomplished as necessary.

7.0 Special Tests. The following special tests shall be conducted:

a. Essential units shall comply with paragraphs 7.1 and 7.2.

b. Nonessential units shall comply with either paragraphs 7.1 and 7.2 or paragraphs 7.1 and 7.3.

7.1 Test of Safety Devices. If overspeed and/or overtemperature limiting devices are provided, the unit shall be operated in such a manner that each such device is called upon to function ten times. Each device shall demonstrate its ability to limit the speed and/or temperature of the unit to no more than the maximum allowable value specified in the model specification each of the ten times it is called upon to function.

7.2 Rotor Integrity Substantiation. The overspeed and overtemperature capabilities of rotor assemblies, when applicable, shall be substantiated for the critical stage(s) only by complying with the following test:

7.2.1 Test. The overstress margin for compressor and turbine rotors shall be substantiated to be adequate to withstand operation for five minutes at the critical rotational speed which is the highest of the speeds specified by subparagraphs a. through c. while at the turbine inlet or exhaust gas temperature which would prevail during actual operation under the fault conditions of b. or c.

The overstress margin for compressor and turbine rotor shall also be substantiated to be adequate to withstand operation for five minutes at a turbine inlet or exhaust gas temperature 75° F. more than the maximum rated turbine inlet or exhaust gas temperature while at not less than the maximum rated speed.

Note: If the critical overspeed condition is accompanied by a turbine inlet or exhaust gas temperature at least 75° F. greater than the maximum rated turbine inlet or exhaust gas temperature, then both the overspeed and the overtemperature capabilities will have been substantiated simultaneously. If the critical overspeed condition is accompanied by a turbine inlet or exhaust gas temperature less than 75° F. greater than the maximum rated turbine inlet or exhaust gas temperature, then the overspeed and overtemperature capabilities will not have been substantiated simultaneously and must, therefore, be substantiated separately.

a. A speed equal to 115 percent of the maximum rated speed.

b. If safety devices per paragraph 5.11 are incorporated a speed equal to 105 percent of the highest speed which would result from failure of any one of the normal engine control systems.

c. If no safety devices per paragraph 5.11 are incorporated, a speed equal to the highest speed which would result from the failure of any one of the normal engine control systems.

7.2.1.1 Methods for Substantiating the Overstress Margin. Acceptable methods for substantiating the overstress margin on turbine and compressor rotors as covered by paragraph 7.2.1 are:

a. Testing a full scale rotor at speed and temperature in a complete unit.

b. Testing a full scale rotor at speed and temperature in a spin pit.

c. Testing a modified rotor in a complete unit at a speed and temperature which will induce stresses equal to or greater than those required.

d. Calculation of the overstress margin of the rotor at speed and temperature from basic data obtained by cold spinning.

7.3 Rotor and Rotor Blade Containment Demonstration. Rotor and rotor blade containment shall be demonstrated for the critical stage(s) only under the conditions specified in the following paragraphs.

7.3.1 Speed. Containment shall be demonstrated at the maximum obtainable speed defined by subparagraphs a. and b.

a. If safety devices per paragraph 5.11 are incorporated, a speed equal to the highest speed which would result from failure of any one of the normal engine control systems.

b. If no safety devices per paragraph 5.11 are incorporated, a speed equal to the highest speed which would result from the failure of any one of the normal engine control systems.

7.3.2 Temperature. Containment shall be demonstrated with the containing components at the temperature prevalent during operation at maximum rated power.

8.0 Ratings. The performance ratings shall be listed in the model specification. These data contemplate no restriction of the air inlet or exhaust and no loading of the output drives. The ratings shall be based on the data obtained by paragraph 6.1 and the atmospheric conditions specified in paragraph 3.4.

9.0 Model Specification. The manufacturer shall prepare a model specification in which the following information shall be included:

a. Manufacturer's name.

b. Model designation.

c. Category and class of service for which approved (IC, IIA, etc.).

d. Sea level output ratings.

(1) R.P.M. (each rotor) - maximum rated and maximum allowable.

(2) Rated output shaft power - minimum (if applicable).

(3) Rated output shaft speed (if applicable).

(4) Bleed-air flow - nominal (if applicable).

(5) Bleed-air pressure ratio - nominal (if applicable).

(6) Bleed-air temperature rise ratio - nominal (if applicable).

(7) Fuel consumption - maximum.

(8) Turbine inlet or exhaust gas temperature - maximum rated and maximum allowable.

e. The normal temperature (if applicable) and speed control tolerances under maximum rated output conditions.

f. The life and/or growth limits of all parts for which such limits have been established.

g. Operating envelope throughout which the operating characteristics have been found to be free of detrimental effects per paragraph 4.5 (essential units only).

h. Maximum structural loading envelope per paragraph 4.6.

i. Maximum time unit may be operated satisfactorily under negative "g" conditions per paragraph 4.7.

j. Maximum permissible component and surrounding ambient temperature limits where such limits are established.

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

(2) Description of temperature sensing provisions if incorporated.

k. Maximum permissible air inlet duct attachment loads.

(1) Shear.

(2) Axial.

(3) Overhung moment.

1. Inlet air requirements per paragraph 5.2.2.

   (1) Maximum air pressure drop.

   (2) Air velocity distribtuion limits.

   (3) Effect of air pressure drop on rated power.

m. Lubrication system requirements.

   (1) Grade of oil and specification.

   (2) Maximum oil consumption rate.

   (3) Minimum inlet oil pressure (if applicable).

   (4) Maximum inlet oil temperature.

   (5) Inlet oil flow rate (if applicable).

   (6) Degree of aircraft installed filtering necessary (if applicable).

   (7) Usable oil capacity (if applicable).

   (8) Maximum heat ejection (if applicable).

   (9) Maximum oil system outlet pressure (if applicable).

   (10) Oil pressure limits for normal and idle operation.

n. Fuel system requirements.

   (1) Grade of fuel and specification.

   (2) Minimum inlet fuel pressure.

   (3) Maximum and minimum inlet fuel temperatures.

   (4) Inlet fuel flow rate.

   (5) Degree of aircraft installed filtering necessary.

   (6) Method of preventing filter icing (if applicable).

o. Exhaust system requirements.

   (1) Maximum permissible back pressure.

   (2) Effect of exhaust back pressure on rated power.

p. Maximum permissible exhaust attachment loads.

(1) Shear.

(2) Axial.

(3) Overhung moment.

q. Main shaft power output pad (if applicable). See ratings for output shaft speed and power.

(1) Output shaft configuration.

(2) Direction of rotation.

(3) Overhung moment.

r. Bleed air attachment loads (if applicable).

(1) Shear.

(2) Axial.

(3) Overhung moment.

s. Accessory attachments.

(1) Type of drive and mounting pad.

(2) Direction of rotation.

(3) Maximum static torque.

(4) Maximum continuous torque.

(5) Drive shaft speed ratio.

(6) Maximum permissible overhang moment.

t. Monitoring instrumentation attachments - describe all instrumentation attachments i detail.

u. Give model designation, setting numbers or any other pertinent information relative to the engine accessories or controls such as:

(1) Fuel control.

(2) Igniter system.

(3) Igniter plug.

(4) Safety devices.

(5) Any other accessories or components furnished as a part of the unit.

v. Performance data shall be presented in the form of suitable curves and shall portray the relationships of the various parameters obtained by paragraph 6.1. The effects of ram pressure ratio, ambient temperature, and altitude shall be ascertained and included with the performance data.

w. The manufacturer shall include an installation drawing of the unit showing all dimensions and details necessary for proper installation of the unit in an aircraft.

x. The manufacturer shall identify the axes of the unit and shall specify the maximum displacement in each direction or combined displacements under which the unit will function satisfactorily.

y. The manufacturer shall specify the maximum conducted and radiated electronic and magnetic interference present in the unit.

z. The manufacturer shall specify any additional information necessary to adequately describe the unit's operating and/or installation limitations.

aa. Necessary provisions for protection from ingestion of foreign objects (if applicable).

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