



Technical Standard Order

PROPOSED TSO

Subject: *Gas Turbine Auxiliary Power Units*

1. **PURPOSE**. This Technical Standard Order (TSO) prescribes the minimum performance standards (MPS) that gas turbine auxiliary power units (APUs) must meet to be identified with the applicable TSO marking.

2. **APPLICABILITY**.

a. This TSO is effective for new applications submitted after the effective date of this TSO. All prior revisions to this TSO are no longer effective and these applications will not be accepted after the effective date of this TSO.

b. APUs approved under a previous TSO authorization may continue to be manufactured under the provisions of their original approval. However, under § 21.611(b) of the Federal Aviation Regulations, all major design changes to APUs approved under previous versions of this TSO now require a new authorization under this TSO.

3. **GENERAL REQUIREMENTS**. TSO qualification programs for new models of APUs, or for previously approved models undergoing a major change, that are to be so identified and that are manufactured on or after the effective date of this TSO, must be in accordance with the following requirements:

a. **Functionality**. The standards of this TSO apply to gas turbine engines intended to provide auxiliary electrical, pneumatic, or mechanical power to support airplane systems operations. These standards do not apply to gas turbines intended for aircraft propulsion, nor do they address the integration of the APU into the design of the airplane.

b. **Minimum Performance Standards**. The design and construction of the APU must be shown to meet the MPS of Appendix 1 to this TSO.

c. **Deviations**. The Federal Aviation Administration (FAA) has provisions for using alternative or equivalent means of compliance to the criteria set forth in the MPS of this TSO. Applicants invoking these provisions shall demonstrate that an equivalent level of safety is maintained and shall apply for a deviation in accordance with § 21.609.

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4. MARKING.

a. In compliance with § 21.607(d), each article manufactured under this TSO must be equipped with a fireproof plate that is permanently and legibly marked with:

- (1) Name and address of the manufacturer.
- (2) Part number, serial number, and model designation.
- (3) Applicable TSO number (TSO-C77b).

b. In addition to the requirements of § 21.607(d), each article manufactured under this TSO must be equipped with a fireproof identification plate that is permanently and legibly marked with:

- (1) Maximum allowable dry weight to the nearest pound.
- (2) Fuel type and specification.
- (3) Lubricating oil type and specification.
- (4) Category 1 or category 2 APU type, whichever is applicable.

c. In addition to the requirements of § 21.607(d), each separate component that is easily removable and each separate subassembly of the article must be permanently and legibly marked with at least the part number.

d. In addition to the requirements of § 21.607(d), if the APU includes a digital computer, the part number must include hardware and software identification, or a separate part number may be utilized for hardware and software. Either approach must include a means for showing the modification status. Note that similar software versions that have been approved to different software levels must be differentiated by part number.

5. DATA REQUIREMENTS. The manufacturer must furnish to the FAA Aircraft Certification Office (ACO) that is responsible for overseeing the manufacturer's facilities one copy each of the following data items to support the FAA design and production approval:

a. TSO Program Data. In addition to the requirements of § 21.605, the following data must be submitted to the responsible FAA- ACO. Items 1 through 3 must be submitted with the application for TSO approval and item 4 must be submitted upon completion of the program:

(1) A compliance plan must be developed that describes the methods of compliance according to the MPS requirements specified in Appendix 1 of this TSO. This plan

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must identify any new or novel design features, or both, that will require a deviation from the MPS in accordance with paragraph 3.c. of this TSO, and must identify qualification data and specifications in accordance with paragraph 5.b of this TSO.

(a) The plan will identify any additional performance requirements, such as analyses or tests, that are deemed necessary by the responsible FAA ACO.

(b) The plan will identify tests performed in accordance with the compliance plan, and will identify which of these tests are to be witnessed by the responsible FAA ACO.

(2) A description of the procedures utilized to ensure qualification test hardware is in compliance with the TSO design.

(3) A description of production design change control procedures. These procedures must address all levels of design changes.

(4) A compliance checklist that documents satisfactory completion of all of the requirements specified in paragraph 5.a.(1) above.

b. TSO Technical Data. In compliance with § 21.605(a)(2), the following data must be submitted to the responsible FAA ACO upon completion of the TSO design approval program:

(1) Manufacturer's TSO qualification data, such as test reports or analyses that were designated for submittal in the compliance plan of paragraph 5.a.(1) of this TSO.

(2) Material and process specifications that were designated for submittal in the compliance plan of paragraph 5.a.(1) of this TSO.

(3) A list of all the parts and equipment, including references to the relevant drawings and software design data, that defines the qualified design configuration of the APU.

(4) A model specification, that specifies the APU ratings and operating limitations established when demonstrating compliance with the requirements of this TSO. The model specification should include the data shown in Appendix 2 of this TSO, as appropriate.

(5) Manual(s) that contain instructions for installing and operating the APU must include, as a minimum, the following:

(a) The information specified in Appendix 3 of this TSO, as appropriate.

(b) Instructions sufficient to ensure that the APU, when installed in accordance with these instructions, continues to meet the requirements of this TSO. Any limitations shall also be sufficient to identify unique aspects of the installation and shall include the following:

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(i) A note with the following statement: "The conditions and tests required for TSO approval of this article are minimum performance standards. It is the responsibility of those installing this article either on or within a specific type or class of aircraft to determine that the aircraft installation conditions are within the TSO standards. TSO articles must be approved for installation per the applicable airworthiness requirements."

(6) Manual(s) containing instructions for continued airworthiness of the APU. Updates are required if the existing instructions or the APU definition changes. The manual(s) must include at least the following:

(a) A section titled "Airworthiness Limitations" that is set apart and clearly distinguishable from the rest of the document(s). This section must describe each mandatory replacement time, inspection interval and related procedures required to meet the requirements of this TSO.

(b) The information specified in Appendix 4 of this TSO, as appropriate.

(c) The instructions for continued airworthiness may be incomplete at the time of the TSO authorization, provided that a program exists to ensure their completion prior to issuance of a standard certificate of airworthiness for the aircraft with the APU installed.

(d) Availability of the manual or portion of the instructions for continued airworthiness that deals with overhaul or other forms of heavy maintenance may be delayed until after the APU has entered service. In such cases, the APU model specification will incorporate a note prohibiting the corresponding heavy maintenance of APUs until the instructions are available.

(7) The quality control system must be described, as required under §§ 21.605(a)(3) and 21.143(a). This would include designated functional test specifications to test each production article to ensure compliance with this TSO.

(8) Nameplate drawing.

c. Manufacturer Data. In addition to the data furnished directly to the responsible ACO, the following technical data must be available for review by both the responsible ACO and the responsible FAA Manufacturing Inspection District Office (MIDO):

(1) The functional test specifications to be used to accept each production article to ensure compliance with this TSO.

(2) All drawings, specifications, software data, and information on dimensions, materials, and processes, necessary to define the configuration and the design features of the product shown to comply with the MPS of this TSO.

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(3) All qualification data including test plans, test reports, test hardware configuration control data, and analyses specified in the compliance plan of paragraph 5.a.(1) of this TSO, and the compliance checklist of paragraph 5.a.(4) of this TSO.

(4) All design changes, with evidence of the required approvals, processed in accordance with the procedures specified in paragraph 5.a.(3) of this TSO.

d. Furnished Data.

(1) One copy of the technical data and the associated information specified in paragraphs 5.b.(4) through 5.b.(6) of this TSO must be provided to each person receiving for use one or more APUs manufactured under this TSO. Also include any other data and information that pertains to the continued airworthiness, operation, proper installation and certification of the APU.

6. AVAILABILITY OF REFERENCED DOCUMENTS.

a. Copies of RTCA Document Nos. DO-160D and DO-178B may be purchased from the RTCA Inc., 1140 Connecticut Avenue, N.W., Suite 1020, Washington, D.C. 20036.

b. Copies of Title 14 of the Federal Aviation Regulations (14 CFR) part 21, Subpart O, may be purchased from the Superintendent of Documents, Government Printing Office, Washington, DC 20402-9325. AC 20-110, "Index of Aviation Technical Standard Orders," and AC 20-115B, "Radio Technical Commission for Aeronautics, Inc. Document RTCA/DO-178B" may be obtained from the U.S. Department of Transportation, Utilization and Storage Section, M-443.2, Washington, DC 20590.

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APPENDIX 1 FEDERAL AVIATION ADMINISTRATION MINIMUM PERFORMANCE STANDARD FOR GAS TURBINE AUXILIARY POWER UNITS

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1.0 Purpose. This appendix provides the minimum performance standards (MPS) for gas turbine APUs.

2.0 Scope. This appendix covers category 1 and category 2 APUs, defined as follows:

2.1 A category 1 APU is any APU that meets the requirements of sections 4.0, 5.0, 6.0, and 7.0 of this Appendix.

2.2 A category 2 APU is any APU that meets the requirements of sections 4.0, 5.0, and 6.0 of this Appendix.

3.0 Definitions. The following are definitions of terms applicable to this standard:

3.1 Accessory drives. Any drive shaft or utility mounting pad, furnished as a part of the APU, that is used for the extraction of power to drive accessories, components, or controls essential to the operation of the APU or any of its associated systems.

3.2 APU. Any gas turbine-powered unit delivering rotating shaft power or compressor air, or both that is not intended for direct propulsion of an aircraft.

3.3 Blade. An energy transforming element of the compressor or turbine rotors whether integral or attached design.

3.4 Compressor air. Compressed air that is provided by the APU to do work whether it is extracted or bled from any point of the compressor section of the gas turbine engine or produced from a compressor driven by the APU.

3.5 Containment. Retention within the APU of all high-energy rotor fragments resulting from the failure of a high-energy rotor.

3.6 Critical rotor stage. The compressor and turbine stages whose rotors have the smallest margin of safety under the conditions of speed and temperature shown in paragraph 6.8.2 of this Appendix.

3.7 Demonstrate. To prove by physical test under the conditions specified in this standard.

3.8 High-energy rotor. A rotating component or assembly that, when ruptured, will generate high kinetic energy fragments.

3.9 Major part. A part whose failure might adversely affect the operational integrity of the unit.

3.10 Maximum allowable speed. The maximum rotor speed that the APU would experience under overload or transient conditions and is limited by installed safety devices.

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3.11 Maximum allowable temperature. The maximum exhaust gas temperature (EGT) or turbine inlet temperature (TIT) that the APU would experience during overload or transient conditions and is limited by installed safety devices.

3.12 Minor part. A part that is not a major part.

3.13 Model. Each unique configuration of a specific APU type.

3.14 Output provisions. Any drive pad or compressed air output flange intended for aircraft use to extract usable shaft or pneumatic power from the APU.

3.15 Rated output. The approved shaft power or compressed air output, or both, that is developed statically at standard sea level atmospheric conditions for unrestricted periods of use.

3.16 Rated speed. The maximum approved speed at which the engine can operate at rated output.

3.17 Rated temperature. The maximum turbine inlet or exhaust gas temperature at which the engine can operate at rated output and speed.

3.18 Rotor. A rotating component or assembly including blades with the exception of accessory drive shafts and gears.

3.19 Start. An acceleration from the initiation of operation or starter torque to a stabilized speed and temperature in the governed ranges without exceeding approved limits.

3.20 Substantiate. To prove by presentation of adequate evidence obtained by demonstration or analysis or both.

3.21 Type. All of a series of units each one of which was developed as an alternate configuration or refinement of the same basic unit.

4.0 Requirements: General.

4.1 APU Ratings and Operating Limitations. The APU ratings and operating limitations must be substantiated by test or analysis and included in the APU Model Specification.

4.2 Materials. Each material must conform to approved specifications. The suitability and durability of the materials used in manufacturing the APU must be established by testing or on the basis of experience, or both.

4.3 Durability. All parts of the APU must be constructed, arranged, and installed so as to ensure their continued safe operation between inspection intervals specified in Appendix 4 of this TSO, Instructions for Continued Airworthiness.

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4.4 Operating Characteristics.

4.4.1 The overall range for APU operating characteristics must be substantiated. This includes the envelopes within which the APU can be started and operated without detrimental effects (such as stall, surge, or flameout).

(a) Operation During Negative “g” Conditions. The maximum duration of time during which the APU can operate without hazardous malfunction during negative “g” conditions may be substantiated by test or analysis and must be specified in the model specification.

4.4.2 The effects of the inlet temperature, air bleed, exhaust back pressure, inlet pressure recovery, and ram pressure ratio upon performance parameters such as speed, power output, air flow, exhaust gas temperature, and pressure ratio must be provided for the operating envelope.

4.5 APU Control System.

4.5.1 The APU control system must be designed to ensure that it performs its intended functions under the declared operating conditions and automatically maintain the APU speed(s) and gas temperature(s) within the declared limits.

4.5.2 The APU control system functioning must not be adversely affected by the declared environmental conditions, including Electromagnetic Interference (EMI), High Intensity Radiated Fields (HIRF), and lightning. The limits to which the system has been qualified shall be documented in the instructions for installation.

4.6 Provisions for Instruments.

4.6.1 The APU must have provisions for providing a signal for any instrumentation necessary to ensure continued safe operation of the APU, and that established APU limits are not exceeded.

4.6.2 In addition to the instrumentation provisions of paragraph 4.6.1 above, automatic features may be provided.

4.7 Extreme Attitude Operation. It must be demonstrated that the APU is capable of functioning satisfactorily within the attitude limits specified in the instructions for installation.

4.8 Mount Loads. The maximum static and dynamic loads must be established. This includes those that result from APU seizure, imbalance under a failed blade condition, and the critical vibration amplitudes and frequencies that could be transmitted by the APU from the mounting points to the airframe through the normal operating range of the APU.

4.9 Flight Loads. The APU mounting attachments and related APU structure must be able to withstand:

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4.9.1 The specified limit loads without permanent deformation; and

4.9.2 The specified ultimate loads without failure, but may exhibit permanent deformation.

4.10 Accessibility. The design of the APU must allow for the examination, adjustment, or removal of each accessory required for APU operation.

5.0 Description: All APUs Design and Construction.

5.1 Safety Analysis. It must be shown by analysis that any probable malfunction or any probable single or multiple failure will not cause the APU to:

5.1.1 Catch fire;

5.1.2 Burst (release hazardous fragments through the APU case);

5.1.3 Generate loads greater than those ultimate loads specified in paragraph 4.8 of this Appendix;

5.1.4 Lose the capability of being shut down, or;

5.1.5 Generate an unacceptable concentration of toxic products in the bleed air.

5.2 Fire Prevention.

5.2.1 Design and construction of the APU and materials used must minimize the probability of the occurrence and spread of fire during either normal operation or failure conditions and must minimize the effects of such a fire.

5.2.2 Except as provided by 5.2.3 and 5.2.4, each external line, fitting, and other external component that contains or conveys flammable fluids, must be at least fire resistant. These components must be shielded or located to safeguard against ignition of leaking flammable fluid.

5.2.3 Flammable fluid tanks and any associated shut-off means and supports, that are part of and attached to the APU must be fireproof either by construction or by protection, unless damage by fire will not cause leakage or spillage of a hazardous quantity of flammable fluid.

5.2.4 If by construction an APU component acts as a firewall and this component shall be:

(a) Fireproof;

(b) Constructed so that no hazardous quantity of air, fluid, or flame can pass across the firewall;

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(c) Protected against corrosion.

5.2.5 Those features of the APU that form part of the mounting structure or APU attachment points must be fireproof, either by construction or by protection.

5.2.6 When parts of the APU control system are located in a designated fire zone, it must be substantiated that a fire affecting these parts will not lead to effects identified under paragraph 5.1 of this Appendix.

5.2.7 Unintentional accumulation of hazardous quantities of flammable fluid and vapor within the APU shall be prevented by draining and venting.

5.2.8 Any components, modules, equipment, and accessories that are susceptible to, or are potential sources of static electricity, induced currents, lightning discharges or other electrical currents, must be designed and constructed in order to be electrically bonded to minimize the risk of ignition in external areas where flammable fluids or vapors could be present.

5.3 Air Intake.

5.3.1 Flammable fluid carrying lines, fittings or components located in the air intake within the APU must be designed so that leakage from the lines, fittings, or components cannot enter the intake air stream. Shrouds must have provisions for attaching external drains.

5.3.2 The effect of inlet air pressure drop and inlet blockage on APU operation must be substantiated. Inlet distortion limits must be specified in the instructions for installation.

5.3.3 If an air intake duct is provided as part of the APU, it must be fireproof.

5.4 Lubrication System.

5.4.1 The lubrication system must function satisfactorily at all the APU operating attitudes specified in paragraph 4.7 of this Appendix, and throughout the operating envelope established in accordance with paragraph 4.4 of this Appendix. Approved APU lubricant(s) must be specified in the APU Model Specification.

5.4.2 The lubrication system when furnished as part of the APU must have at least one accessible drain that allows a safe drainage of the oil system and has manual or automatic means for positive locking in the closed position.

5.4.3 An oil tank or integral oil sump, when supplied with the APU, must have the following features:

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- (a) An adequate expansion space.
- (b) A tank filler located so that the expansion space cannot be inadvertently filled when the APU is serviced at the normal ground attitude.
- (c) A vent from the top part of the expansion space. The venting must be effective throughout the range of extreme attitude specified in paragraph 4.6 of this Appendix and throughout the normal operating envelope established in accordance with paragraph 4.3 of this Appendix. The vent must be sized to accommodate the maximum anticipated rates of ascent and descent in flight.
- (d) The oil tank must be capable of withstanding the application of a differential pressure of at least 5 psi more than the maximum differential pressure that might be encountered during operations throughout the normal operating envelope established in accordance with paragraph 4.3 of this Appendix, and under the maximum flight loads specified in paragraph 4.8 of this Appendix.
- (e) Suitable means for determining the level of oil in the tank when the APU is in the normal ground attitude.

5.4.4 Where there is a filter in the APU lubrication system through which all the oil flows, it must be constructed and installed so that oil may flow at an acceptable rate through the rest of the system with the filter element completely blocked. An impending filter by-pass indication is required.

5.5 Fuel System.

5.5.1 The fuel specification, rate, pressure, and temperature range of fuel flow to the inlet of the APU fuel system and the degree of filtration necessary for satisfactory unit functioning must be established and listed in the APU model specification.

5.5.2 A drain must be provided in the APU to prevent accumulation of fuel in the event of a false start. APU drains in the fuel system must be suitable for connecting to overboard drain lines.

5.6 Exhaust System.

5.6.1 The exhaust system of the APU must be designed and constructed to prevent leakage of exhaust gases into the aircraft.

5.6.2 The exhaust piping must be constructed of fireproof and corrosion resistant materials.

5.7 Cooling. Operating temperature limits must be established for those components that require temperature limitations and provided in the instructions for installation.

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5.8 Overspeed Safety Devices. For any safety device incorporated to prevent a hazardous overspeed condition, a means must be provided for ascertaining that these devices are functioning properly.

5.9 Rotor Containment. For each high-energy APU rotor, the APU must be designed to provide containment of either:

5.9.1 The largest blade section as specified in paragraph 6.8.3(a) of this Appendix; or

5.9.2 Maximum kinetic energy fragments from the hub failure as specified in paragraph 6.8.3(b) of this Appendix.

5.10 Vibration. The APU must be designed and constructed to function throughout its declared operating envelope, including the declared inlet air distortion limits, so that the compressor, turbine, and other highly stressed parts are free from vibration stresses that could be harmful to these parts and other components.

5.11 Life Limitations. All APU rotors must have limitations established, by a procedure approved by the responsible FAA ACO, that specify the maximum allowable number of start-stop stress cycles (low cycle fatigue) or hours representative of typical APU usage. A cycle includes, as a minimum, starting the APU, operating at specific power settings, and stopping.

5.12 Bleed Air Contamination. For APUs that provide compressor bleed air, the applicant must:

5.12.1 Provide characteristics of APU generated bleed air contaminants in the instructions for installation.

5.12.2 Substantiate, if an air intake duct is provided as part of the APU, that under the fireproof requirement specified in paragraph 5.3.3 of this Appendix, the duct will not release hazardous amounts of toxic gases into the bleed air.

5.13 Continued Rotation. Any limitations on APU continued rotation in either direction must be specified in instructions for installation.

6.0 Requirements: All APUs Type Substantiation.

6.1 General. The requirements of this section are applicable to both category 1 and category 2 APUs.

6.2 Calibration Tests.

6.2.1 The APU must be subjected to the calibration tests necessary to establish the APU's power (shaft, bleed, or both) prior to the endurance test specified in paragraph 6.3 of this Appendix.

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6.2.2 An APU power (shaft, bleed, or both) check must be accomplished on the APU after the endurance test of paragraph 6.3 of this Appendix. Any change in power characteristics that occurs during the endurance test must be determined. This data must demonstrate that, at the rated output, the APU does not exceed its declared limits.

6.3 Endurance Test.

6.3.1 The APU must successfully complete the 150-hour endurance test specified in this section. The speed and gas temperature control devices must maintain these parameters within the specified tolerances during the rated output portions of this test. Rated output as used in this section is defined as maximum output of shaft power and compressor bleed air for which approval is sought.

6.3.2 Test periods. Twenty periods of seven and one-half hours each must be run using the following schedule.

(a) Five minutes at or above rated output, 5 minutes at no load, 1 hour at or above rated output, and 5 minutes at no load.

(b) Five minutes at or above rated output, 5 minutes at no load, 1 hour at 75% rated output, and 5 minutes at no load.

(c) Five minutes at or above rated output, 5 minutes at no load, 1 hour at or above rated output, and 5 minutes at no load.

(d) Five minutes at or above rated output, 5 minutes at no load, 1 hour at 50% rated output, and 5 minutes at no load.

(e) Five minutes at or above rated output, 5 minutes at no load, 1 hour at or above rated output, and 5 minutes at no load.

(f) Five minutes at or above rated output, 5 minutes at no load, 1 hour at 25% rated output, and 5 minutes at no load.

6.3.3 Test conditions. The following conditions must be observed during the endurance test:

(a) Speed. The speed of each rotor may not be less than the rated speed during the rated output portions of the tests. No specific rotor speed need be maintained during other portions of the endurance test.

(b) Temperatures. The specified temperature limits, including the rated turbine inlet or exhaust gas temperature and oil temperature, must be substantiated by maintaining the

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temperatures of the affected components at or above these limits during all rated output portions of the endurance test. The temperature of the inlet air may be controlled to match the turbine temperature, speed, and power output to avoid exceeding temperature, speed, or power limits during this test.

(c) Pressures. The minimum regulated oil and fuel pressures must be maintained during all rated output portions of the endurance test.

6.3.4 Adjustments and repair or replacement of parts. During the endurance test, repair and replacement of minor parts or infrequent adjustments not requiring disassembly of major parts may be made. Major parts may not be repaired or replaced during the endurance test.

6.3.5 Starts. At least 100 starts must be made. A minimum of 2 hours shutdown must precede each of at least 25 of the starts.

6.4 Teardown Inspection. After completing the endurance test of paragraphs 6.3 and the recalibration test of paragraph 6.2.2 of this Appendix:

6.4.1 The APU must be completely disassembled.

6.4.2 A detailed inspection must be made of each part and critical dimensions must be reinspected.

6.4.3 Each APU component must be eligible for incorporation into an APU for continued operation, in accordance with instructions for continued airworthiness required by paragraph 5.b.(6) of this TSO.

6.5 Functional Test of Limiting Devices. If limiting devices are provided, the same APU device must be tested on an APU or representative test stand in such a manner that each is made to function satisfactorily 10 times without failure.

6.6 Overspeed Test. For APUs that contain rotors which do not comply with the containment requirements of paragraph 5.9.2 of this Appendix, an APU test must be conducted. This APU test must demonstrate the ability of all compressor and turbine rotors to withstand operation for 5 minutes at the higher of the rotational speeds specified under the operating conditions listed in paragraphs 6.6.1 or 6.6.2 below. This test must be conducted at the turbine inlet or exhaust gas temperature that would prevail during operations under the fault conditions of paragraph 6.6.2 below.

6.6.1 A speed equal to 115% of the rated speed.

6.6.2 The speed resulting from (a) or (b) below, whichever is applicable:

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(a) If overspeed limiting devices are incorporated, a speed of not less than 105% of the highest speed which would result from any single failure of the APU control system.

(b) If overspeed limiting devices are not incorporated, the highest speed which would result from (i) or (ii) below:

(i) Any single failure of the APU control system.

(ii) Any probable combination of failures of the APU.

6.7 Overtemperature Test. For APUs that contain rotors which do not comply with the containment requirements of paragraph 5.9.2 of this Appendix, an APU test must be conducted. This APU test must demonstrate the ability of all turbine rotors to withstand operation for a minimum of 5 minutes at a turbine inlet temperature or exhaust gas temperature of not less than 75°F (42°C) greater than the rated turbine inlet temperature or exhaust gas temperature, while at or above the rated speed. This test may be combined with paragraph 6.6 above.

6.8 Containment.

6.8.1 Compliance with paragraph 5.9 of this Appendix of each high-energy rotor, critical and non-critical, must be substantiated by test, analysis, or combination thereof, as specified in paragraphs 6.8.1(a) and 6.8.1(b) below, under the conditions of paragraphs 6.8.2, 6.8.3, and 6.8.4.

(a) The critical rotor of each compressor and turbine rotor assembly must be substantiated by an APU test. Analyses, component test, rig tests, or any combination of those, may be substituted only if they are validated by an APU test.

(b) Non-critical rotors may be substantiated by validated analysis.

6.8.2 Containment must be demonstrated at the following speed and temperature conditions:

(a) The highest speed which would result from any single failure of the APU control system.

(b) The temperature of the containing components shall not be lower than the temperature during operation of the APU at rated output.

6.8.3 Containment must be substantiated in accordance with either (a) or (b) below.

(a) Blade containment under the following conditions:

(i) For centrifugal compressors and radial turbines, one whole blade, unless it is substantiated that failure of a smaller portion of the blade is more likely to occur.

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(ii) For axial compressor or turbine rotors, the blade fragment resulting from failure at the outermost retention groove, or, for integrally bladed rotor, at least 80% of the blade.

(b) Hub containment under the following condition:

(i) For all types of compressors and turbines, fragments resulting from a failure which produces the maximum translational kinetic energy.

6.8.4 It must be shown that the following requirements were met:

(a) The APU did not experience a sustained external fire.

(b) The APU did not release hazardous fragments radially through the APU casings.

(c) If hazardous debris was ejected from the APU inlet or exhaust, the maximum size, weight, energy, and trajectory of the debris must be defined in the APU instructions for installation.

6.9 Electronic Control Components. For APUs equipped with an electronic control system, the following must be provided for the components of that system:

6.9.1 The acceptability of the declared environmental conditions of paragraph 4.4 of this Appendix must be substantiated to the test conditions specified in RTCA Document No. RTCA/DO-160D, "Environmental Conditions and Test Procedures for Airborne Equipment", Change 4, dated July 29, 1997, or the most current revision, or by a method acceptable to the FAA ACO that is responsible for overseeing the manufacturers facility.

6.9.2 Where applicable, all associated software must be developed in accordance with RTCA Document No. RTCA/DO-178B, "Software Considerations in Airborne Systems and Equipment Certification", dated December 1, 1992, or the most current revision, or by a method acceptable to the FAA ACO that is responsible for overseeing the manufacturers facility.

7.0 Requirements: Category I APUs: Additional Requirements.

7.1 General. The requirements of this section are applicable only to category 1 APUs.

7.2 Icing Protection.

7.2.1 The APU must be designed and constructed to prevent the accumulation of ice in quantities sufficient to cause a substantial loss of APU power or shutdown during operation throughout its operating range within the icing envelopes that are specified in Appendix C to part 25 of the Federal Aviation Regulations.

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7.2.2 Operation of the APU under the conditions of paragraph 7.2.1 above must be substantiated by test, analysis, or combination thereof. Any limitations for operation must be documented in the instructions for installation.

7.3 Foreign Object Ingestion.

7.3.1 It must be substantiated that the ingestion of foreign matter such as water, ice, sand, gravel, and other hard objects likely to enter the APU will not create hazardous effects on APU operation.

7.3.2 Any provision found to be necessary for adequate protection against ingestion of foreign objects or effects on operation must be documented in the instructions for installation.

7.4 Automatic Shutdown. If automatic features are provided, provision must be made to limit automatic shutdown in flight to those failure occurrences that could result in a potentially hazardous condition.

7.5 Ignition System. It must be substantiated by test or analysis, or combination thereof, that the ignition system operates satisfactorily between the inspections and maintenance actions specified in the instructions for continued airworthiness.

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APPENDIX 2

GAS TURBINE AUXILIARY POWER UNIT Model Specification

1.0 The following information must be considered, as appropriate, for inclusion into the model specification required by paragraph 5.b.(4) of this TSO:

1.1 Manufacturers name and address.

1.2 Part number, serial number, and model designation.

1.3 Category for which approved.

1.4 Maximum allowable dry weight to the nearest pound.

1.5 The following performance information and limitations at standard sea level atmospheric conditions:

1.5.1 Rated output shaft power (if applicable).

1.5.2 Rated output speed (if applicable).

1.5.3 Maximum turbine inlet or exhaust gas temperature at rated output.

1.5.4 Maximum allowable speed.

1.5.5 Maximum Allowable turbine inlet or exhaust gas temperature.

1.5.6 Minimum compressor bleed airflow (if applicable).

1.5.7 Minimum compressor bleed air pressure ratio (if applicable).

1.5.8 Maximum fuel consumption at rated output.

1.6 The temperature and speed control tolerances at rated output.

1.7 The maximum duration of time the APU is capable of operating without hazardous malfunction when the APU is subjected to negative “g” conditions.

1.8 The following lubrication system specification:

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- 1.8.1** Type, grade, and specification of oil.
- 1.8.2** Maximum oil consumption rate.
- 1.8.3** Maximum inlet oil temperature.
- 1.8.4** Minimum inlet oil pressure (if applicable).
- 1.8.5** Inlet oil flow rate (if applicable).
- 1.8.6** Maximum oil system outlet pressure (if applicable).
- 1.9** The following fuel system specifications:
 - 1.9.1** Type, grade, and specification of fuel.
 - 1.9.2** Minimum inlet fuel pressure.
 - 1.9.3** Maximum and minimum fuel inlet temperatures.
 - 1.9.4** Inlet fuel flow rate.
 - 1.9.5** The type and degree of fuel filtering necessary for protection of the APU fuel system against foreign particles in the fuel.
 - 1.9.6** Method of preventing filter icing (if applicable).
- 1.10** Maximum loads, including shear, axial, and overhang moment, that the exhaust attachment provisions are capable of withstanding.
- 1.11** The output shaft configuration, direction of shaft rotation, and maximum allowable overhang moment for the main power output pad (if applicable).
- 1.12** Maximum loads, including shear, axial, and overhung moment, that the compressor bleed air attachment provisions are capable of withstanding (if applicable).
- 1.13** The following accessory drive specifications:
 - 1.13.1** Configuration of drive shaft and mounting pad.
 - 1.13.2** Direction of drive shaft rotation.
 - 1.13.3** Maximum static torque.

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1.13.4 Rated torque.

1.13.5 Ratio of accessory drive shaft RPM to power turbine RPM.

1.13.6 Maximum overhung moment the mounting pad is capable of withstanding.

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APPENDIX 3

**GAS TURBINE AUXILIARY POWER UNIT
Installation and Operating Instructions**

1.0 The information contained in this Appendix must be considered, as appropriate, for inclusion into the manual(s) required by paragraph 5.b.(5)(a) of this TSO.

1.1 Definitions of the physical and functional interfaces with the aircraft and the limiting conditions on those interface, including, but not limited to, the following:

1.1.1 Performance.

1.1.2 Cooling system.

1.1.3 Air inlet system.

1.1.4 Exhaust system.

1.1.5 Mounting system.

1.1.6 Fuel system.

1.1.7 Lubrication system.

1.1.8 Electrical system.

1.1.9 Starting system.

1.1.10 Bleed air system.

1.1.11 Accessory drives.

1.1.12 Cockpit interface (instrumentation and controls).

1.1.13 Safety and Protective Provisions.

1.2 The above sub-system sections should include, but not be limited to, the following:

1.2.1 The APU operating envelope including extreme attitude limits and environmental conditions throughout which the APU may be started and operated for unrestricted periods of time.

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1.2.2 The limit and ultimate loads of the APU mounting structure and related APU structure.

1.2.3 Maximum allowable component and surrounding ambient temperatures and heat rejection rates from components where such limits are established. If applicable, the type and location of each thermocouple used to meet installation requirement cooling tests must be specified and a description of ambient temperature sensing provisions must be provided.

1.2.4 Maximum loads, including shear, axial, and overhand moment, that the air duct attachment provisions are capable of withstanding.

1.2.5 The following inlet air specifications:

- a. Maximum inlet air pressure drop.
- b. Distortion limits across the APU inlet.
- c. Effect of inlet air pressure drop on rated power.
- d. Provisions for protection against ingestion of foreign objects.

1.2.6 The type and degree of oil filtering necessary for protection of the APU lubrication system against foreign particles in the oil (if applicable).

1.2.7 Maximum heat rejection rate.

1.2.8 Useable oil capacity.

1.2.9 Oil pressure limits for normal and idle operation.

1.2.10 Lubrication system specifications for components not supplied with the APU.

1.2.11 Operating limitations for integral oil cooling (if applicable).

1.2.12 The maximum exhaust system back pressure and the effect on power output of variations in back pressure.

1.2.13 Maximum conducted and radiated electromagnetic interference that may be generated by the APU during any normal continuous operation.

1.2.14 If applicable, the maximum size, weight, energy, and trajectory of hazardous debris ejected from the APU inlet or exhaust, in accordance with section 6.8.4 of Appendix 1.

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

3.0 Installation conditions which specify the airplane operating characteristics and parameters from that the data from paragraphs 1.1 and 1.2 of this Appendix were derived.

4.0 Proper procedures for uncrating, deinhibiting, acceptance checking, lifting, and attaching accessories, with any necessary checks.

5.0 Acceptable conditions for installation of those aircraft parts and equipment that may be mounted on, or driven by, the APU, which are not part of the declared APU configuration, and substantiate that these conditions are acceptable for safe operation of the APU.

6.0 The following APU drawings, as appropriate:

6.0.1 APU installation drawing, including overall dimensions, envelope definition, installation interfaces, service interfaces, and major component identification.

6.0.2 Outline drawings of APU major external accessories, including overall dimensions.

6.0.3 Electrical system schematic, including interface connections.

6.0.4 Other system schematics, such as pneumatic, lubrication, fuel, and vent and drain systems.

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APPENDIX 4

GAS TURBINE AUXILIARY POWER UNIT Instructions for Continued Airworthiness

1.0 The following information contained in this Appendix must be considered, as appropriate, for inclusion into the manual(s), as required by paragraph 5.b.(6)(b) of this TSO.

1.1 A description of the APU and its components, systems, and installations.

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

1.3 Scheduling information for each part of the APU 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. Necessary cross-references to the Airworthiness Limitations section must also be included. In addition, the applicant must include, if appropriate, an inspection program that includes the frequency of the inspections necessary to provide for the continued airworthiness of the APU.

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

1.5 Information describing the order and method of removing and replacing parts, the order and method of disassembly and assembly, with any necessary precautions to be taken. Instructions for proper ground handling, crating, and shipping must also be included.

1.6 Cleaning and inspection instructions that cover the material and apparatus to be used and methods and precautions to be taken. Methods of inspection must also be included.

1.7 Details of repair methods for worn or otherwise substandard parts and components along with the information necessary to determine when replacement is necessary. Details of all relevant fits and clearances.

1.8 Instructions for testing including test equipment and instrumentation.

1.9 Instructions for storage preparation, including any storage limits.

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

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