Department of Transportation
Federal Aviation Administration
Office of Airworthiness
Washington, D.C.

TSO-C77a

Date 7/20/81

Technical Standard Order

Subject: Gas Turbine Auxiliary Power Units

(a) Applicability

Minimum Performance Standard. This Technical Standard Order (TSO) prescribes the minimum performance standard which gas turbine auxiliary power units (APUs) must meet in order to be identified with this TSO marking. New models of gas turbine auxiliary power units that are to be so identified and which are manufactured on or after the date of the TSO must meet the requirements of Appendix 1, Federal Aviation Administration Standard for Gas Turbine Auxiliary Power Units, of this TSO.

(b) Marking. Each APU must be legibly and permanently marked on a fireproof identification plate with the following information:

(1) Name and address of the manufacturer.

(2) Part number, serial number, and model designation.

(3) Maximum allowable dry weight to the nearest pound.

(4) Applicable TSO number (TSO-C77a).

(5) Essential or nonessential category of service for which approved.

(6) Fuel type and specification.

(7) Lubricating oil type and specification.

(c) Data Requirements. The manufacturer must furnish the following technical data to the Chief of the Aircraft Engineering Office in the region of the Federal Aviation Administration in which the manufacturer is located:

(1) One or more manuals containing instructions for the installation, operation, servicing, maintenance, repair, and overhaul of the APU.

(2) Model specifications containing the following information:

i. Manufacturer's name and address.

DISTRIBUTION: ZVS-326;A-X(FS)-3;A-X(CD)-3;A-W(WS)-3; A-FFS-1,2,3,7,8(LTD)

ii. Part number, serial number, and model designation.

iii. Essential or nonessential category of service for which approved.

iv. Maximum allowable dry weight to the nearest pound.

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

(A) Rated output shaft power (if applicable).

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

(C) Maximum turbine inlet or exhaust gas temperature at rated output.

(D) Maximum allowable speed.

(E) Maximum allowable turbine inlet or exhaust gas temperature.

(F) Minimum compressor bleed air flow (if applicable).

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

(H) Maximum fuel consumption at rated output.

vi. The temperature and speed control tolerances at rated output.

vii. 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.

viii. The maximum translational, rotational, and combined accelerations along all three major axes which the APU, including all of its accessories and mounting provisions, is capable of withstanding.

ix. The maximum duration of time the APU is capable of operating without hazardous malfunction when the oil system is subjected to negative "g" conditions.

x. 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.

xi. Maximum loads, including shear, axial, and overhang moment, that the air inlet duct attachment provisions are capable of withstanding.

xii. The following inlet air specifications:

(A) Maximum inlet air pressure drop per paragraph 6.4.3.

(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.

xiii. The following lubrication system specifications:

(A) Type, grade, and specification of oil.

(B) Maximum oil consumption rate.

(C) Maximum inlet oil temperature.

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

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

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

(G) Usable oil capacity.

(H) Maximum heat rejection rate.

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

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

(K) Lubrication system specifications for components not supplied with the APU.

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

xiv. The following fuel system specifications:

(A) Type, grade, and specification of fuel.

(B) Minimum inlet fuel pressure.

(C) Maximum and minimum inlet fuel temperatures.

(D) Inlet fuel flow rate.

(E) The type and degree of fuel filtering necessary for protection of the APU fuel system against foreign particles in the fuel.

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

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

xvi. Maximum loads, including shear, axial, and overhang moment, that the exhaust attachment provisions are capable of withstanding.

xvii. The output shaft configuration, direction of shaft rotation, and maximum allowable overhang moment for the main power output pad (if applicable).

xviii. Maximum loads, including shear, axial, and overhang moment, that the compressor bleed air attachment provisions are capable of withstanding (if applicable).

xix. The following accessory drive specifications:

(A) Configuration of drive shaft and mounting pad.

(B) Direction of drive shaft rotation.

(C) Maximum static torque.

(D) Rated torque.

(E) Ratio of accessory drive shaft RPM to power turbine RPM.

(F) Maximum overhang moment the mounting pad is capable of withstanding.

xx. Detailed description of attachments for APU monitoring instrumentation.

xxi. Information regarding accessories or controls necessary for proper operation of the APU including the model designation or part number, and calibration or setting numbers of each accessory or control, such as the fuel control, igniter system, and safety devices.

xxii. Maximum conducted and radiated electronic and magnetic interference generated by the APU throughout its normal operating range and the procedure used to determine the amount of interference generated.

xxiii. An installation drawing of the APU which identifies its three major axes and the maximum displacement in each direction, or combined displacements, under which the APU will meet the operating characteristics requirements of paragraph 5.5, Appendix 1, of this TSO.

xxiv. Characteristics of the APU compressor bleed air and the maximum amount of contamination in the compressor bleed air.

xxv. Critical frequencies and amplitudes determined in accordance with the vibration requirements of paragraph 6.19, Appendix 1, of this TSO.

xxvi. Life or creep growth limits or both, of components, determined in accordance with the rupture and fatigue requirements of paragraph 6.20, Appendix 1, of this TSO.

xxvii. Trajectory envelopes and energy levels of uncontained rotor fragments resulting from the rotor containment demonstration requirements of paragraph 7.10, Appendix 1, of this TSO.

xxviii. Installation restrictions determined to be necessary on the basis of the degree of compliance with the ice protection demonstration requirement of paragraph 7.11, Appendix 1, of this TSO (if applicable).

xxix. Installation provisions determined to be necessary on the basis of the degree of compliance with the foreign object ingestion demonstration requirements of paragraph 7.12, Appendix 1, of this TSO.

xxx. Limitations on APU windmilling and capabilities of antirotation devices provided under paragraph 6.22, Appendix 1, of this TSO.

xxxi. Calibration data obtained under paragraph 7.2, Appendix 1, of this TSO.

xxxii. Other information and limitations as specifically required by this TSO.

(3) One copy of the Qualification Test Reports.

(d) Data to be Furnished With Manufactured Units. A copy of the information specified in paragraphs (c)(1) and (c)(2) must be furnished to each person receiving for use one or more APUs manufactured under this TSO.

(e) Previously Approved Equipment. APU equipment approved prior to the date of this TSO may continue to be manufactured under the provisions of its original approval.

M. C. Beard
Director of Airworthiness

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

1.0 Purpose. This document provides minimum design and performance standards for gas turbine auxiliary power units (APUs) intended for use as power sources for driving generators, hydraulic pumps, and other aircraft accessories and equipment or to provide compressed air for aircraft pneumatic systems.

2.0 Scope. This standard covers the following categories of gas turbine auxiliary power units:

Category I - Essential APU
Category II - Nonessential APU

3.0 Installation. This standard does not specify APU installation standards. However, the standard specifies requirements for the establishment of APU installation limitations relating to APU performance and design.

4.0 Definitions. The following are definitions of terms applicable to the standard:

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

4.2 Auxiliary Power Unit (APU). Any gas turbine-powered unit delivering rotating shaft power, compressor air, or both which is not intended for direct propulsion of an aircraft.

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

4.4 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.

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

4.6 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 7.10, Appendix 1, of this TSO.

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

4.8 Essential APU. An APU which produces bleed air and/or power to drive accessories necessary for the dispatch of the aircraft to maintain safe aircraft operation.

4.9 High energy rotor. A rotating component or assembly which, when ruptured, will generate high kinetic energy fragments.

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

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

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

4.13 Minor part. A part which is not a major part.

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

4.15 Nonessential APU. An APU which may be used on the aircraft as a matter of convenience, either on the ground or in flight, and may be shutdown without jeopardizing safe aircraft operations.

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

4.17 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.

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

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

4.20 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.

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

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

5.0 General Requirements.

5.1 Materials and Processes. The suitability of the materials and processes and the durability of the materials used in manufacturing the APU must be established by tests or on the basis of experience or both. Each material and process must conform to approved specifications (such as industry or military specifications, or technical standards) to ensure that the strength and other properties assumed in the design data are valid.

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

5.3 Extreme Attitude Operation. It must be demonstrated that the APU is capable of functioning satisfactorily over its full range of operating conditions, up to and including rated output, within the attitude limits specified by the manufacturer in the model specifications.

5.4 Electromagnetic Interference. The maximum conducted and radiated electromagnetic interference which may be generated by the APU during any normal continuous operation must be substantiated by tests and specified in the model specifications.

5.5 Operating Characteristics. The overall range of APU operation and environmental conditions for which approval is requested must be specified in the model specifications. These include the starting and operating envelopes within which the APU can be started and operated without detrimental effects (such as stall, surge, or flame-out). The starting and operating envelopes for essential APUs must be substantiated by tests or an equivalent analysis.

The effects of inlet temperature, air bleed, exhaust back pressure, inlet pressure recovery, and ram pressure ratio upon performance parameters such as r.p.m. power output, airflow, fuel flow, exhaust gas temperature, and pressure ratio shall be provided for the operating envelope.

5.6 Flight Maneuver Loads. The applicant must select and substantiate the maximum translational, rotational, and combined accelerations in all three major axes which the APU, including mounting provisions and all accessories, is capable of withstanding without permanent deformation, failure, or impairment of operation. The accelerations must be specified in the model specifications.

5.7 Operation During Negative "g" Conditions. The maximum duration of time during which the APU can operate without hazardous malfunction during negative "g" conditions must be specified in the model specifications. The duration may not be less than 5 seconds.

6.0 Design and Construction.

6.1 General. The APU may not have design features or details which are

hazardous or unreliable. The suitability of all design features and parts must be established by tests, experience, or analysis. All parts of the APU must be constructed, arranged, and installed so as to ensure their continued safe operation between normal inspections and overhauls. The APU must have provisions for electrical bonding to the aircraft.

6.2 Safety Analysis. A failure analysis must be made to show that no single failure or malfunction or probable combination of failures in any critical system of the APU will result in an unsafe condition.

6.3 Fire Prevention. The design and construction of the APU and materials used must be such as to minimize the probability of the occurrence and spread of fire because of structural failure, overheating, leaking flammable fluids, or other causes. In addition--

(a) Each line, fitting, and external component, including fluid shutoff valves carrying flammable fluids, must be fire resistant; and

(b) Each line, fitting, and external component carrying flammable fluid in an area subject to fire conditions must be located, shielded, or shrouded to safeguard against the ignition of any leaking flammable fluid.

6.4 Air Intake

6.4.1 Ice Protection. For essential APUs, the air intake passages within the APU must be designed and constructed to prevent the accumulation of ice in quantities sufficient to cause malfunctioning of the APU during operation throughout its operating range within the icing envelopes specified in Appendix C of Part 25 of the Federal Aviation Regulations. The degree of ice protection capability must be demonstrated as specified in paragraph 7.11 of this standard. For nonessential APUs, compliance with paragraph 7.11 is optional.

6.4.2 Shrouding of Lines. Flammable fluid carrying lines, fittings, or components located in the air intake within the APU must be protected by shrouds so that leakage from the lines, fittings, or components cannot enter the intake airstream. Shrouds must have provisions for attaching external drains.

6.4.3 Inlet Air Pressure Drop. The effect of inlet air pressure drop and inlet blockage on APU operation must be substantiated. Inlet distortion limits must be listed in the APU model specification.

6.4.4 Foreign Object Ingestion. For essential APUs, the degree of foreign object ingestion capability must be established as specified under paragraph 7.12 of this standard. For nonessential APUs, compliance with paragraph 7.12 is optional.

6.5 Lubrication System. The lubrication system must function satisfactorily at all the APU operating attitudes specified in paragraph 5.3 and throughout the operating envelope established in accordance with paragraph 5.5

of this standard. The applicant must specify the approved engine lubricant in the model specifications. The lubrication system, when furnished as part of the APU, must have the following:

6.5.1 Oil Drains. There must be 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.

6.5.2 Oil Filters. If 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. A means must be provided to indicate when this filter is being bypassed.

6.5.3 Oil Tank. The oil tank or integral oil sump must have the following features:

(a) The oil tank and its supports must be fireproof.

(b) An expansion space of not less than 10 percent of the total tank capacity must be provided.

(c) The tank filler must be so located that the expansion space cannot be inadvertently filled when the APU is serviced at the normal ground attitude.

(d) A vent from the top part of the expansion space must be provided. The venting provided must be effective throughout the range of extreme attitudes specified in paragraph 5.3 and throughout the operating envelope established in accordance with paragraph 5.5 of this standard. The vent must be sized to accommodate the maximum anticipated rates of ascent and descent in flight.

(e) Provision must be made to ensure adequate oil flow during operation when the oil system is subjected to a negative "g" condition for a 5-second interval.

(f) 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 which might be encountered during operations throughout the normal operating envelope established in accordance with paragraph 5.5 and under the maximum flight maneuver loads specified in paragraph 5.6 of this standard.

(g) Suitable means must be provided for determining the level of oil in the tank when the APU is in the normal ground attitude.

(h) A means to prevent entrance into the tank or the tank outlet of any object that might obstruct the flow of oil through the system must be provided. The tank outlet may not be enclosed by any screen or guard

that would reduce the flow of oil below a safe value at any operating temperature.

6.6 Fuel System. 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 model specifications.

6.7 Fuel Drains. A drain must be provided in the APU to prevent accumulation of fuel in the event of a false start. The combustion chamber drain and any other drains in the fuel system must have fittings suitable for connecting to overboard drain lines.

6.8 Fuel System Materials. All materials used in the fuel system must be sufficiently resistant to fuels approved for use in the APU to permit continuous normal operation of the fuel system and components throughout the overall range of APU operation and environmental conditions established in accordance with paragraph 5.5 of this standard.

6.9 Exhaust System. The exhaust system of the APU must be designed and constructed so as to prevent leakage of exhaust gases into the aircraft. The maximum permissible shear, axial loads, and moments that may be applied to the exhaust connection of the unit must be specified in the model specifications. In addition, the following apply:

6.9.1 The APU must incorporate suitable means for the connection of exhaust ducts (if any).

6.9.2 Exhaust piping must be constructed of fireproof materials that are heat and corrosion resistant and must incorporate provisions to prevent failure due to expansion when heated to operating temperatures.

6.9.3 The changes of output power that result from exhaust back pressure must be specified in the model specifications.

6.10 Cooling. Operating temperature limits must be established for those components which require temperature control provisions to ensure satisfactory functioning, reliability, and durability. These limits, together with the heat rejection rates, must be specified in the model specifications.

6.11 Instrumentation. The APU must have provisions for attaching a means for measuring turbine inlet or exhaust gas temperature, a speed indicator for each independent rotor assembly, and the sensing elements of all other instrumentation necessary for operation of the unit. These provisions must be specified in the model specifications.

6.12 Drive Attachments. Each accessory drive and mounting attachment must be designed and constructed so that the APU will operate properly with the accessories attached. The APU must have provisions for the examination and removal of all accessories. For output drives, limiting conditions of torque,

speed, direction of rotation, shear and axial loads, and overhang moment must be determined and substantiated. These conditions, with a description of the type of pad and drive, must be specified in the model specification.

6.13 Temperature Control. Each APU must be provided with automatic temperature devices which will control temperatures within the limits specified in the model specifications and must provide for a signal to applicable monitoring devices. The temperature control must prevent the maximum allowable temperature from being exceeded under the operating conditions specified in the model specifications.

6.14 Speed and Acceleration Controls. The speed control system and acceleration control system must maintain the APU speed and acceleration within the limits specified in the model specifications and must provide for a signal to applicable monitoring devices. The speed must be automatically controlled to prevent the maximum allowable speed from being exceeded under the operating conditions specified in the model specifications.

6.15 Safety Devices. If safety devices are incorporated to prevent a hazardous overspeed or overtemperature condition, means must be provided for ascertaining from the control panel, on the ground or during normal flight operation, that these devices are functioning properly.

6.16 Automatic Shutdown. For essential APUs, if an automatic shutdown feature is provided, only APU overspeed must be used to initiate an automatic shutdown. For nonessential APUs, automatic shutdown may be initiated by overspeed or other failure conditions.

6.17 Rotor or Rotor Blade Failure Containment. Both essential and nonessential APUs must be designed for compliance with the special test requirements specified in paragraph 7.7 of this standard to contain either:

6.17.1 Maximum kinetic energy fragments from compressor and turbine rotor failures, or

6.17.2 Whole vanes from radial flow rotors unless failure of smaller portions of these vanes is substantiated to be the largest portions likely to occur, and

6.17.3 Entire airfoil sections of blades of exducers, inducers, and axial flow rotors.

6.18 Mount Loads. The maximum static and dynamic loads, including those that result from an inbalance under a failed blade or failed rotor condition; and the vibration amplitudes and frequencies which could be transmitted by the APU from the mounting points to the airframe through the normal operating range of the APU must be determined. Critical amplitudes and frequencies and maximum static and dynamic loads which can be generated and absorbed by the APU must be specified in the model specifications.

6.19 Vibration Stresses in Highly Stressed Components. It must be demonstrated by measurements under operating conditions up to the declared inlet air distortion limits, or by equally reliable methods, that the compressor, turbine, and other highly stressed parts are free from vibration stresses that could be harmful to these parts and other components.

6.20 Stress Rupture and Start/Stop Cycle Fatigue. The stress rupture and start/stop cycle fatigue characteristics must be substantiated for the critical stages of APU rotor assemblies complying with paragraph 7.9. Cyclic or hourly life limits and/or creep growth limits, if applicable, of rotating components must be established. These limits must be specified in the model specifications.

6.21 Bleed Air Provisions. APUs with provisions for the extraction of compressor bleed air must incorporate suitable fittings for the connection of bleed air ducts. The characteristics of the compressor bleed air, the maximum amount of contamination in the compressor bleed air, and the maximum permissible shear and axial load and moments which may be applied to the bleed air connection must be specified in the model specifications.

6.22 Control of Unit Rotation. Any limitations on APU windmilling in either direction must be specified in the model specifications. Any antirotation device must be substantiated and listed in the model specifications.

6.23 Ignition System. The ignition system of the APU must provide satisfactory ignition during starting and restarting throughout the full range of conditions specified in the model specifications.

7.0 Tests.

7.1 Block Tests. A complete APU must be subjected to the tests specified in:

7.1.1 Paragraphs 7.2 through 7.6 of this standard to be qualified as an essential APU.

7.1.2 Paragraph 7.2 of this standard to be qualified as as nonessential APU.

7.2 Unit Calibration. The APU's power and/or bleed air characteristics and (for essential APUs) the conditions for the endurance test specified in paragraph 7.3 of this standard must be established by calibration tests. The data obtained from the calibration tests must be presented in the model specifications in the form of curves of output shaft power, output shaft torque, output shaft speed, fuel flow, compressor bleed air flow, compressor bleed air temperature and pressure versus turbine inlet or exhaust gas temperature and turbine speed.

7.3 Endurance Test. The APU must successfully complete the 150-hour endurance test specified in this paragraph. Upon completion of this test, there must not be any indication of impending failure or excessive wear in any of the APU's major components. The unit must be functioning properly and be in a condition that it can be overhauled without replacement of major components. The speed and gas temperature control devices must maintain these parameters within the tolerances specified in the model specifications during the rated output portions of this test:

7.3.1 Test Periods. Twenty periods of seven and one-half hours each must be run using the following schedule. Rated output as used in this paragraph means maximum output of shaft power and compressor bleed air for which approval is sought.

(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 percent 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 percent 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 percent rated output, and 5 minutes at no load.

7.3.2 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 temperature limits specified in the model specifications, including the rated turbine inlet or exhaust gas temperature and oil temperature, must be substantiated by maintaining the 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 oil and fuel pressures specified in the model specifications must be maintained during all rated output portions of the endurance test.

(d) Output Drives. Each output drive must be subjected during the endurance test to the maximum power and overhang moment loading compatible with the loads specified in paragraph 7.3.1 of this standard. These loadings must be listed in the model specifications.

7.3.3 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.

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

7.5 Recalibration. After completion of the endurance test in accordance with paragraph 7.3, a recalibration test must be made as specified in paragraph 7.2 of this standard. During this recalibration test, the APU output may not be less than 95 percent of the output and the fuel consumption rate may not exceed 105 percent of that obtained during the first calibration test.

7.6 Teardown Inspection. After completing the recalibration test, the APU must be completely disassembled, a detailed inspection must be made of each part, and critical dimensions must be reinspected. Components found to have excessive fatigue and wear must be redesigned and tested.

7.7 Special Tests. Essential and nonessential APUs must meet either the limiting device functional test requirements specified in paragraph 7.8, the rotor assembly integrity test specified in paragraph 7.9, and the rotor blade containment requirements specified in paragraph 7.10 of this standard, or the rotor containment requirements specified in paragraph 7.10. Essential APUs must also meet the ice protection test requirements specified in paragraph 7.11 and the foreign object ingestion test requirements specified in paragraph 7.12.

7.8 Functional Test of Limiting Devices. If speed or temperature limiting devices or both are provided, the APU must be operated in such a manner that each limiting device is made to function 10 times. Each device must limit the speed or temperature to not more than the values specified in the model specifications each of the 10 times it is made to function.

7.9 Rotor Assembly Integrity Test. The overspeed and overtemperature capabilities of the critical stages of compressor and turbine rotor assemblies must be substantiated by complying with the following:

7.9.1 Overspeed Test. The overstress margin for compressor and turbine rotors must be substantiated to be adequate to withstand operation for 5 minutes at the rotational speed which is the highest of the speeds specified in paragraphs 7.9.1(a) through 7.9.1(c) of this standard while at the turbine inlet or exhaust gas temperature which would prevail during operations under the fault conditions of paragraphs 7.9.1(b) or (c) of this standard.

(a) A speed equal to 115 percent of the rated speed.

(b) If safety devices are incorporated, a speed of not less than 105 percent of the highest speed which would result from failure of any one of the normal engine control systems.

(c) If safety devices are not incorporated, a speed equal to the highest speed which would result from the failure of any one of the normal engine control systems.

7.9.2 Overtemperature Test. The overstress margin for the turbine rotors must be substantiated to be adequate to withstand operation, for not less than 5 minutes, at a turbine inlet or exhaust gas temperature of not less than 75 degrees F. (42 degrees C.) higher than the rated turbine inlet or exhaust gas temperature, while at not less than rated speed. If the critical overspeed condition is accompanied by a turbine inlet or exhaust gas temperature of at least 75 degrees F. (42 degrees C.) greater than the rated turbine inlet or exhaust gas temperature; both the overspeed and overtemperature capabilities may be substantiated simultaneously. If the critical overspeed condition is accompanied by a turbine inlet or exhaust gas temperature less than 75 degrees F. (42 degrees C.) greater than the rated turbine inlet or exhaust gas temperature; the overspeed and overtemperature capabilities must be substantiated separately.

7.9.3 Method for Conducting Overspeed and Overtemperature Tests. The overspeed and overtemperature tests required by paragraphs 7.9.1 and 7.9.2 of this standard must be accomplished by testing a complete APU.

7.10 Rotor or Rotor Blade Containment Demonstration. APU rotor or rotor blade containment capability must be demonstrated for the critical stages under the following conditions:

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

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

7.10.2 Temperature. The containing components at a temperature not lower than the temperature during operation of the APU at rated output.

Parts attached adjacent to the rotor casing may be credited for containing rotor fragments. If the containment demonstration does not result in containment of all rotor fragments, information on trajectory envelopes and energy levels of the uncontained rotor fragments must be provided in the model specifications.

7.11 Ice Protection Demonstration. For essential APUs, the capability of the APU to meet the requirements of the icing conditions specified in Appendix C of Part 25 of the Federal Aviation Regulations must be demonstrated as specified in paragraph 6.4.1 of this standard. Any restrictions found to be necessary as a result of exposure to these icing conditions must be stated in the model specifications in such a manner that they can be followed during APU installation.

7.12 Foreign Objects Ingestion Demonstration. For essential APUs, the effects on APU functioning and performance from ingestion of hazardous quantities of foreign matter such as water, ice, sand, gravel, and other hard objects must be established by testing a complete APU. Any provisions found to be necessary for adequate protection against ingestion of foreign objects must be stated in the model specifications in such a manner that they can be followed during APU installation.