European Aviation Safety Agency

The Executive Director

DECISION NO. 2003/5/RM

OF THE EXECUTIVE DIRECTOR OF THE AGENCY

of 17 October 2003

on certification specifications, including airworthiness codes and acceptable means of compliance, for auxiliary power units (« CS-APU »)

THE EXECUTIVE DIRECTOR OF THE EUROPEAN AVIATION SAFETY AGENCY

Having regard to Regulation (EC) No 1592/2002 of the European Parliament and of the Council of 15 July 2002 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency[1] (hereinafter referred to as the "Basic Regulation"), and in particular Articles 13 and 14 thereof,

Having regard to the Commission Regulation (EC) No 1702/2003 of 24 September 2003[2] laying down implementing rules for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations, in particular 21A.16A of Part 21 thereof;

Whereas :

(1) The Agency shall issue certification specifications, including airworthiness codes and acceptable means of compliance, as well as guidance material to be used in the certification process.

(2) The Agency has, pursuant to Article 43 of the Basic Regulation, consulted widely interested parties on the matters which are subject to this Decision and following that consultation provided a written response to the comments received,

HAS DECIDED AS FOLLOWS:

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[1] OJ L 240, 7.09.2002, p. 1.

[2] OJ L 243, 27.09.2003, p. 6.

Article 1

The certification specifications, including airworthiness codes and acceptable means of compliance, for auxiliary power units are those laid down in the Annex to this Decision.

Article 2

This Decision shall enter into force on 17 October 2003. It shall be published in the *Official Publication of the Agency*.

Done at Brussels, 17 October 2003.

For the European Aviation Safety Agency,

Patrick GOUDOU

Executive Director

European Aviation Safety Agency

Certification Specifications for Auxiliary Power Units

CS-APU

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Book 1

Airworthiness code

SUBPART A - GENERAL

CS-APU 10 Applicability

(a) This CS-APU contains airworthiness specifications for the issue of certificates, and changes to those certificates, for Auxiliary Power Units (APUs), in accordance with Part 21.

(b) This Book 1 is applicable to Category 1 and Category 2 Auxiliary Power Units.

(1) A Category 1 APU is any APU that meets the specifications of subparts A, B, C and D.

(2) A Category 2 APU is any APU that meets the specifications of subparts A, B and C.

CS-APU 15 Terminology

(a) The terminology of this CS-APU 15 must be used in conjunction with the issue of CS-Definitions current at the date of issue of this CS-APU. Where used in CS-APU, the terms defined in this paragraph and in CS-Definitions are identified by initial capital letters.

(b) (reserved)

CS-APU 20 APU Configuration, Installation and Interfaces

(a) The list of all the parts and equipment, including references to the relevant drawings and software design data, which defines the proposed type design of the APU must be established.

(b) Manuals that contain the following instructions must be provided:

(1) Instructions for installing the APU which must specify the physical and functional interfaces with the aircraft and define the limiting conditions on those interfaces,

(2) Instructions for operating the APU which must specify all procedures necessary for operating the APU,

(3) Installation conditions which must specify the aircraft operating characteristics and parameters from which the data of CS-APU 20 (b)(1) and (2) were derived.

(c) The conditions for installation of those aircraft parts and equipment that are mounted on or driven by the APU, which are not part of the declared APU configuration, must be established and it must be substantiated that these conditions are acceptable for safe operation of the APU.

CS-APU 30 Instructions for Continued Airworthiness

(a) Manual(s) must be established containing instructions for continued airworthiness of the APU. They must be up-dated as necessary according to changes to existing instructions or changes in APU definition.

(b) The instructions for continued airworthiness must contain a section titled airworthiness limitations that is segregated and clearly distinguishable from the rest of the document(s). This section must set forth each mandatory replacement time, inspection interval and related procedure required for issuance of the certificate.

For APU Critical Parts, this section must also include any mandatory action or limitation for maintenance and repair identified in the Service Management Plan, as required under CS-APU 150

(c) The following information must be considered, as appropriate, for inclusion into the manual(s) required by CS-APU 30 (a).

(1) A description of the APU and its components, systems and installations.

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

(3) 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.

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

(5) 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 programme that includes the frequency of the inspections necessary to provide for the continued airworthiness of the APU.

(6) Trouble shooting information describing probable malfunctions, how to recognise those malfunctions and the remedial action for those malfunctions.

(7) Information describing the order and method of removing the APU and its parts 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.

(8) 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.

(9) 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.

(10) Instructions for testing including test equipment and instrumentation.

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

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

CS-APU 40 APU Ratings and Operating Limitations

The APU ratings and operating limitations must be substantiated by test or analysis and included in the APU instructions for installation. Applicable data must be included in the APU mo del specification.

CS-APU 50 Identification

(a) The APU identification must comply with 21A.805 21A.807 (c).

(b) APU modules that can be changed independently in service must be suitably identified so as to ensure traceability of parts and to enable proper control over the interchangeability of such modules with different APU variants.

CS-APU 60 Materials

Each material must conform to established 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.

CS-APU 80 Operating Characteristics

(a) 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).

(b) 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.

(c) The maximum time during which the APU can operate without hazardous effect during negative « g » conditions must be substantiated by test or analysis and must be specified in the APU instructions for installation. The continuous duration must not be less than 5 seconds.

CS-APU 90 APU Control System

(a) 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.

(b) The APU Control System functioning must not be adversely affected by the declared environmental conditions, including Electromagnetic Interference (EMI) and lightning. The limits to which the system has been qualified must be documented in the APU instructions for installation.

(c) For APU electronic Control Systems, all associated software must be designed and implemented by an approved method consistent with the criticality of the functions performed.

CS-APU 100 Provisions for Instruments

(a) 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.

(b) Instrumentation provisions per CS-APU 100 (a) need not be provided if automatic features of the APU and its instructions for installation provide a degree of safety equal to that intended by compliance with CS-APU 100 (a).

CS-APU 110 Extreme Attitude Operation

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

CS-APU 120 Mounts Loads

The maximum static and dynamic loads, including those that result from APU seizure or imbalance under a failed blade condition, and the critical 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 established and included in the instructions for installation.

CS-APU 130 Mounts Strength

(a) Limit loads and ultimate loads must be specified. Limit loads are the maximum loads occurring under normal APU operation. Ultimate loads are the maximum loads resulting from APU failures which can occur at a rate in excess of that defined as Extremely Remote.

(b) The APU mounting attachments and related APU structure must be able to withstand:

(1) The specified limit loads without permanent deformation, and

(2) The specified ultimate loads without failure, but could exhibit permanent deformation.

CS-APU 140 Accessibility

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

CS-APU 150 Critical Parts

The integrity of the APU Critical Parts identified under CS-APU 210 must be established by:

(a) An Engineering Plan, the execution of which establishes and maintains that the combinations of loads, material properties, environmental influences and operating conditions, including the effects of parts influencing these parameters, are sufficiently well known or predictable, by validated analysis, test or service experience, to allow APU Critical Parts to be withdrawn from service at an Approved Life before Hazardous APU Effects can occur. Tolerance assessments must be performed to address the potential for failure from material, manufacturing and service-induced anomalies within the Approved Life of the part. The Approved Life must be published as required in CS-APU 30 (b).

(b) A Manufacturing Plan, which identifies the specific manufacturing constraints necessary to consistently produce the APU Critical Parts with the Attributes required by the Engineering Plan.

(c) A Service Management Plan which defines in-service processes for maintenance and repair of APU Critical Parts which will maintain Attributes consistent with those required by the Engineering Plan. These limitations will become part of the Instructions for Continued Airworthiness.

CS-APU 210 Safety Analysis

(a) (1) An analysis of the APU, including the control system, must be carried out in order to assess the likely consequence of all failures that can reasonably be expected to occur. This analysis must take account of:

(i) Aircraft-level devices and procedures assumed to be associated with a typical installation. Such assumptions must be stated in the analysis.

(ii) Consequential secondary failures and dormant failures.

(iii) Multiple failures referred to in CS-APU 210 (d) or that result in the Hazardous APU Effects defined in CS-APU 210 (g)(2).

(2) A summary must be made of those failures that could result in Major APU Effects or Hazardous APU Effects as defined in CS-APU 210 (g), together with an estimate of the probability of occurrence of those effects. Any APU Critical Part must be clearly identified in this summary.

(3) It must be shown that Hazardous APU Effects are predicted to occur at a rate not in excess of that defined as Extremely Remote (probability less than 10^{-7} per APU operating hour). The estimated probability for individual failures may be insufficiently precise to enable the total rate for Hazardous APU Effects to be assessed. For APU certificates, it is acceptable to consider that the intent of this paragraph is achieved if the probability of a Hazardous APU Effect arising from an individual failure can be predicted to be not greater than 10^{-8} per APU operating hour (see also CS-APU 210 (c)).

(4) It must be shown that Major APU Effects are predicted to occur at a rate not in excess of that defined as Remote (probability less than 10^{-5} per APU operating hour).

(b) If significant doubt exists as to the effects of failures and likely combination of failures, any assumption may be required to be verified by test.

(c) It is recognised that the probability of primary failures of certain single elements (for example, disks) cannot be sensibly estimated in numerical terms. If the failure of such elements is likely to result in Hazardous APU Effects, reliance must be placed on meeting the prescribed integrity specifications of CS-APU in order to support the objective of an Extremely Remote probability of failure. These instances must be stated in the safety analysis as required by CS-APU 210 (a)(2).

(d) If reliance is placed on a safety system to prevent a failure progressing to cause Hazardous APU Effects, the possibility of a safety system failure in combination with a basic APU failure must be included in the analysis. Such a safety system may include safety devices, instrumentation, early warning devices, maintenance checks, and other similar equipment or procedures. If items of a safety system are outside the control of the APU manufacturer, the assumptions of the safety analysis with respect to the reliability of these parts must be clearly stated in the analysis and identified in accordance with CS-APU 20 (b)(3).

(e) If the acceptability of the safety analysis is dependent on one or more of the following items, they must be identified in the analysis and appropriately substantiated.

(1) Maintenance actions being carried out at stated intervals. This includes the verification of the serviceability of items which could fail in a dormant manner. When necessary for preventing the

occurrence of Hazardous APU Effects at a rate in excess of Extremely Remote, these maintenance actions and intervals must be published in the instructions for continued airworthiness required under CS-APU 30. If errors in maintenance of the APU, including the control system, could lead to Hazardous APU Effects, appropriate procedures must be included in the relevant APU manuals.

(2) Verification of the satisfactory functioning of safety or other devices at pre-flight or other stated periods. The details of this verification must be published in the appropriate manual.

(3) The provision of specific instrumentation not otherwise required.

(4) Flight crew actions. These actions must be identified in the operating instructions required under CS-APU 20.

(f) If applicable, the safety analysis must also consider, in particular, investigation of

- Indicating equipment,
- Aircraft-supplied data or electrical power,
- Compressor bleed systems,
- Refrigerant injection systems,
- Gas temperature control systems,
- APU speed, power governors and fuel control systems,
- APU over-speed, over-temperature or topping limiters,

(g) For compliance with CS-APU the following failure definitions apply to the APU:

(1) An APU failure in which the only consequence is partial or complete loss of power (and associated APU services) from the APU must be regarded as a Minor APU Effect.

(2) The following effects must be regarded as Hazardous APU Effects:

(i) Non containment of high-energy debris;

(ii) Concentration of toxic products in the APU bleed air for the cabin sufficient to incapacitate crew or passengers;

(iii) Uncontrolled fire;

(iv) Failure of the APU mount system leading to inadvertent APU separation;

(v) Axial ejection of substantially whole rotors retaining high energy.

(3) An effect falling between those covered in (g)(1) and (2) must be regarded as a Major APU Effect.

CS-APU 220 Fire Prevention

(a) The design and construction of the APU and the materials used must minimise the probability of the occurrence and spread of fire during normal operation and failure conditions and must minimise the effects of such a fire. In addition, the design and construction of APUs must minimise the probability of the occurrence of an internal fire that could result in structural failure or Hazardous Effects.

(b) Except as provided by CS-APU 220 (c), each external line, fitting and other component which contains or conveys flammable fluids during normal APU operation, must be at least Fire Resistant. Components must be shielded or located to safeguard against ignition of leaking flammable fluid.

(c) Tanks which contain flammable fluid and any associated shut-off means and supports, which 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.

(d) An APU component designed, constructed and installed to act as a firewall must be –

(1) Fireproof, and,

(2) Constructed so that no hazardous quantity of air, fluid or flame can pass around or through the firewall, and,

(3) Protected against corrosion.

(e) Those features of the APU which form part of the mounting structure or APU attachment points must be Fireproof, either by construction or by protection, unless not required for the particular aircraft installation and so declared in accordance with CS-APU 20 (b)(3).

(f) In addition to specifications of CS-APU 220 (a) and (b), APU Control System components which are located in a designated fire zone must be at least Fire Resistant.

(g) Unintentional accumulation of hazardous quantities of flammable fluid and vapour within the APU must be prevented by draining and venting.

(h) Any components, modules, equipment and accessories which are susceptible to or are potential sources of static discharges or electrical fault currents must be designed and constructed so as to be properly grounded to the APU reference in order to minimise the risk of ignition in external areas where flammable fluids or vapours could be present.

CS-APU 230 Air Intake

(a) 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.

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

(c) If an air intake duct is provided as part of the APU, it must be Fireproof.

CS-APU 240 Lubrication System

(a) The lubrication system must function satisfactorily at all the APU operating attitudes specified in CS-APU 110 and throughout the operating envelope established in accordance with CS-APU 80. The approved APU lubricant(s) must be specified in the APU instructions for installation.

(b) 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.

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

(1) An adequate expansion space,

(2) A tank filler located so that the expansion space cannot be inadvertently filled when the APU is serviced at the normal ground attitude,

(3) A vent from the top part of the expansion space. The venting must be effective throughout the range of extreme attitude specified in CS-APU 110 and throughout the operating envelope established in accordance with CS-APU 80. The vent must be sized to accommodate the maximum anticipated rates of ascent and descent in flight.

(4) The oil tank must be capable of withstanding the application of a differential pressure of at least 10 kPa more than the maximum differential pressure which might be encountered during operations throughout the normal operating envelope established in accordance with CS-APU 110, and under the maximum flight loads specified in CS-APU 130.

(5) Suitable means for determining the level of oil in the tank when the APU is in the normal ground attitude.

(d) 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 can 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.

CS-APU 250 Fuel System

(a) 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 instructions for installation.

(b) 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.

CS-APU 260 Exhaust System

(a) The exhaust system of the APU must be designed and constructed so as to prevent leakage of exhaust gases into the aircraft.

(b) The exhaust piping must be constructed of Fireproof and corrosion resistant materials.

CS-APU 270 Cooling

Operating temperature limits must be established for those components which require temperature limitations and provided in the APU instructions for installation.

CS-APU 280 Over-speed Safety Devices

For any safety device incorporated to prevent a hazardous over-speed condition, a means must be provided for ascertaining that these devices are functioning properly.

CS-APU 290 Rotor Containment

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

(a) The largest blade section as specified in CS-APU 470 (c)(1) or

(b) Maximum kinetic energy fragments from the hub failure as specified in CS-APU 470 (c)(2).

CS-APU 300 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.

CS-APU 310 Life Limitations

All APU rotors must have limitations established by an acceptable procedure which 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.

CS-APU 320 Bleed Air Contamination

For APUs which provide compressor bleed air, the applicant must:

(a) Provide the characteristics of APU generated bleed air contaminants in the APU instructions for installation,

(b) Substantiate, if an air intake duct is provided as part of the APU, that under the fire specifications of CS-APU 230 (c), the duct will not release hazardous amounts of toxic gases into the bleed air.

CS-APU 330 Continued Rotation

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

SUBPART C - ALL APUs. TYPE SUBSTANTIATION

CS-APU 410 Calibration Tests

(a) The APU must be subjected to the calibration tests necessary to establish the APU's power (shaft and / or bleed) prior to the endurance test specified in CS-APU 420.

(b) An APU power (shaft and / or bleed) check must be accomplished on the APU after the endurance test of CS-APU 420. Any change in power characteristics which 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.

CS-APU 420 Endurance Test

(a) The APU must successfully complete the 150-hour endurance test specified below. 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 paragraph means maximum output of shaft power and compressor bleed air for which approval is sought.

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

(1) 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.

(2) Five minutes at or above Rated Output, 5 minutes at no load, 1 hour at 75% Rated Output, and 5 minutes at no load.

(3) 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.

(4) Five minutes at or above Rated Output, 5 minutes at no load, 1 hour at 50% Rated Output, and 5 minutes at no load.

(5) 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.

(6) Five minutes at or above Rated Output, 5 minutes at no load, 1 hour at 25% Rated Output, and 5 minutes at no load.

(c) Test conditions. The following conditions must be observed during the endurance test:

(1) Speed. The speed of each rotor must 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.

(2) Temperatures. The specified temperature limits 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.

(3) Pressures. The minimum regulated oil and fuel pressures must be maintained during all Rated Output portions of the endurance test.

(d) 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 can be made. Major parts must not be repaired or replaced.

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

CS-APU 430 Tear down Inspection

After completing the endurance test of CS-APU 420 and the calibration test of CS-APU 410 (b) -

(a) The APU must be completely disassembled;

(b) A detailed inspection must be made of each part, and critical dimensions must be re-inspected, and

(c) Each APU component must be eligible for incorporation into an APU for continued operation, in accordance with the information required under CS-APU 30.

CS-APU 440 Functional Test of Limiting Devices

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

CS-APU 450 Over-Speed Test

For APUs which contain rotors not complying with the containment specifications of CS-APU 290 (b), an 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 CS-APU 450 (a) or (b). The test must be conducted at the turbine inlet or exhaust gas temperature which would prevail during operations under the fault conditions of CS-APU 450 (b).

(a) A speed equal to 115% of the rated speed,

(b) The speed resulting from (1) or (2), whichever is applicable:

(1) If over-speed 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.

(2) If over-speed limiting devices are not incorporated, the highest speed which would result from (i) or (ii):

(i) Any single failure of the APU Control System.

(ii) Any single failure or combination of failures of the APU not considered to be Extremely Remote.

CS-APU 460 Over-Temperature Test

For APUs which contain rotors not complying with the containment specifications of CS-APU 290 (b), an APU test must demonstrate the ability of all turbine rotors to withstand operation, for a minimum of 5 minutes, at a turbine inlet or exhaust gas temperature of not less than 42°C higher than the rated turbine inlet or exhaust gas temperature, while at or above the Rated Speed.

CS-APU 470 Containment

(a) Compliance with CS-APU 290 of each high-energy rotor, critical and non-critical, must be substantiated by test, analysis or combination thereof as specified in CS-APU 470 (a)(1) and (a)(2), under the conditions of CS-APU 470 (b), (c) and (d).

(1) The critical rotor of each compressor and turbine rotor assembly must be substantiated by APU test. Analyses and / or component or rig tests may be substituted only if they are validated by APU test.

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

(b) Containment must be demonstrated at the following speed and temperature conditions:

(1) The highest speed which would result from either:

(i) Any single failure of the APU Control System, or

(ii) Any single failure or combination of failures not considered to be Extremely Remote.

(2) The temperature of the containing components must not be lower than the temperature during operation of the APU at Rated Output.

(c) Containment must be substantiated in accordance with either (1) or (2) below:

(1) 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.

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

(2) Hub containment under the following condition: for all types of compressors and turbines, fragments resulting from a failure which produces the maximum translational kinetic energy.

(d) It must be shown that the following specifications were met:

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

(2) The APU did not release high-energy fragments radially through the APU casings

(3) The APU did not axially release any substantially whole rotors with residual high energy.

(4) If debris were ejected from the APU inlet or exhaust, the approximate reported maximum size, weight, energy and trajectory of the debris must be estimated and provided in the APU instructions for installation.

CS-APU 480 Electronic Control System Components

For APUs equipped with an electronic control system, the acceptability of the declared environmental conditions of CS-APU-90 (b) must be substantiated by an approved method.

SUBPART D - CATEGORY 1 APUs. ADDITIONAL SPECIFICATIONS

CS-APU 510 Ice Protection

(a) 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 specified in CS-1.

(b) Operation of the APU under the conditions of CS-APU 510 (a) must be substantiated by test, analysis or combination thereof. Any limitations for operation must be documented in the APU instructions for installation.

CS-APU 520 Foreign Objects Ingestion

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

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

CS-APU 530 Automatic Shutdown

If automatic features are provided, provision must be made to limit automatic shutdowns in flight to those failure occurrences which could result in a potentially hazardous condition.

CS-APU 540 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

EASA Certification Specifications
for
Auxiliary Power Units

CS-APU
Book 2

Acceptable means of compliance

SUBPART A - GENERAL

In addition to the AMCs in Book 2 of this Certification Specification, AMCs in AMC-20 may also provide acceptable means of compliance to the specifications in Book 1 of this CS-APU.

AMC CS-APU 20 APU Configuration and Interface

(1) The components and equipment listed in the APU type definition declared under CS-APU 20 (a) should include those items necessary for the satisfactory functioning and control of the APU.

It is not necessary to include any items required to provide non mechanical inputs to the APU if the characteristics of these inputs (e.g. voltage, current, timing, fuel, air, etc.) can be clearly specified.

(2) The manuals required under CS-APU 20 (b) should include, where applicable, details of the division of the APU into modules, giving the nomenclature and clearly defining the boundaries for each module.

(3) The APU manufacturer should give the aircraft manufacturer the information on the assumptions which were made for the issuance of the APU certificate and which need to be taken into account when designing the installation (see CS-APU 20 (b)(3)).

The APU manufacturer should ensure that APU design considerations which might be imposed by the assumed installation certification specifications are taken into account. For example, all necessary provision should be made in the APU for the fitment and operation of at least the mandatory items of equipment prescribed in the assumed applicable aircraft specifications.

(4) Model specification. The following information should be considered, as appropriate, for inclusion into the model specification required by CS-APU 20 (b)(4):

(a) Manufacturers name and address.

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

(c) Category for which approved.

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

(e) The following performance information and limitations at standard sea level atmospheric conditions:

- Rated output shaft power (if applicable).
- Rated output speed (if applicable).
- Maximum turbine inlet or exhaust gas temperature at rated output.
- Maximum allowable speed.
- Maximum allowable turbine inlet or exhaust gas temperature.

- Minimum compressor bleed airflow (if applicable).

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

- Maximum fuel consumption at rated output.

(f) The temperature and speed control tolerances at rated output.

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

(h) The following lubrication system specification:

- Type, grade, and specification of oil.

- Maximum oil consumption rate.

- Maximum inlet oil temperature.

- Minimum inlet oil pressure (if applicable).

- Inlet oil flow rate (if applicable).

- Maximum oil system outlet pressure (if applicable).

(i) The following fuel system specifications:

- Type, grade, and specification of fuel.

- Minimum inlet fuel pressure.

- Maximum and minimum fuel inlet temperatures.

- Inlet fuel flow rate.

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

- Method of preventing filter icing (if applicable).

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

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

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

(m) The following accessory drive specifications:

- Configuration of drive shaft and mounting pad.

- Direction of drive shaft rotation.

- Maximum static torque.

- Rated torque.

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

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

AMC CS-APU 90 APU Control System

The AMC 20-2 in the CS-20 document provides specific interpretative material for APU electronic control systems.

AMC CS-APU 150 APU Critical Parts

Until a dedicated text is prepared for this AMC CS-APU 150, the principles of AMC CS-E 515 may be used for interpreting CS-APU 150.

SUBPART B - ALL APUs - DESIGN AND CONSTRUCTION

AMC CS-APU 210 Safety analysis

(1) Introduction.

Compliance with CS-APU 210 requires a safety analysis which should be substantiated, when necessary, by appropriate testing and/or comparable service experience.

The depth and scope of an acceptable safety assessment depend on the complexity and criticality of the functions performed by the systems, components or assemblies under consideration, the severity of related failure conditions, the uniqueness of the design and extent of relevant service experience, the number and complexity of the identified failures, and the detectability of contributing failures.

Examples of methodologies are Fault Tree Analysis (FTA), Failure Mode and Effects Analysis (FMEA) and Markov Analysis.

(2) Objective.

The ultimate objective of a safety analysis is to ensure that the risk to the aircraft from all APU failure conditions is acceptably low. The basis is the concept that an acceptable overall APU design risk is achievable by managing the individual major and hazardous APU risks to acceptable levels. This concept emphasises reducing the likelihood or probability of an event proportionally with the severity of its effects. The safety analysis should support the APU design goals such that there would not be Major or Hazardous APU Effects that exceed the required probability of occurrence as a result of APU failure modes. The analysis should consider the full range of expected operations.

(3) Specific guidance.

(a) Classification of effects of APU failures.

Aircraft-level failure classifications are not directly applicable to APU assessments since the aircraft may have features that could reduce or increase the consequences of an APU failure condition. Additionally, the same APU may be used in a variety of installations, each with different aircraft-level failure classifications.

CS-APU 210 defines the APU-level failure conditions and presumed severity levels.

Since aircraft-level specifications for individual failure conditions may be more severe than the APU-level specifications, there should be early co-ordination between the APU manufacturer and the aircraft manufacturer to ensure APU and aircraft compatibility, especially for assessing cases where APU availability is essential to the continued safe flight.

(b) Component Level Safety Analysis.

In showing compliance with CS-APU 210 (a), a component level safety analysis may be an auditable part of the design process or may be conducted specifically for demonstration of compliance with this rule.

The specific specifications of CS-APU for the APU Control System should be integrated into the overall APU safety analysis.

(c) Typical installation

The reference to "typical installation" in CS-APU 210 (a)(1)(i) does not imply that the aircraft-level effects are known, but that assumptions of typical aircraft devices and procedures, such as fire-extinguishing equipment, annunciation devices, etc., are clearly stated in the analysis.

CS-APU 210 (f) requires the applicant to include in the APU safety analysis consideration of some aircraft components.

It is recognised that, when showing compliance with CS-APU 210 (a)(3) and (4) for some APU effects, the applicant may not be in a position to determine the detailed failure sequence, the rate of occurrence or the dormancy period of such failures of the aircraft components.

In such cases, for APU certification, the applicant will assume a failure rate for these aircraft components. Compliance with CS-APU 210 (e) requires the APU manufacturer to provide, in the installation instructions, the list of failures of aircraft components that may result in or contribute to Hazardous or Major APU Effects. The mode of propagation to this effect should be described and the assumed failure rates should be stated.

During the aircraft certification, the APU effect will be considered in the context of the whole aircraft. Account will be taken of the actual aircraft component failure rate.

Such assumptions should be addressed in compliance with CS-APU 20 (b)(3).

(d) Hazardous APU Effects

(i) The acceptable occurrence rate of Hazardous APU Effects applies to each individual effect. It will be accepted that, in dealing with probabilities of this low order of magnitude, absolute proof is not possible and reliance should be placed on engineering judgement and previous experience combined with sound design and test philosophies.

The probability target of not greater than 10^{-7} per APU operating hour for each Hazardous APU Effect applies to the summation of the probabilities of this Hazardous APU Effect arising from individual failure modes or combinations of failure modes other than the failure of APU Critical Parts (e.g., discs, hubs, spacers). For example, the total rate of occurrence of uncontrolled fires, obtained by adding up the individual failure modes and combination of failure modes leading to an uncontrolled fire, should not exceed 10^{-7} per APU operating hour. The possible dormant period of failures should be included in the calculations of failure rates.

If each individual failure is less than 10^{-8} per APU operating hour then summation is not required.

(ii) When considering primary failures of certain single elements such as APU Critical Parts, the numerical failure rate cannot be sensibly estimated. If the failure of such elements is likely to result in Hazardous APU Effects, reliance must be placed on their meeting the prescribed integrity specifications. These specifications are considered to support a design goal that, among other goals, primary LCF (Low Cycle Fatigue) failure of the component should be Extremely Remote throughout its operational life. There is no specification to include the estimated primary failure rates of such single elements in the summation of failures for each Hazardous APU Effect due to the difficulty in producing and substantiating such an estimate.

(iii) Non-containment of high-energy debris.

Uncontained debris cover a large spectrum of energy levels due to the various sizes and velocities of parts released in an APU failure. The APU has a containment structure which is designed to withstand the consequences of the release of a single blade (see CS-APU 290), and which is often adequate to contain additional released blades and static parts. The APU containment structure is not always required (see CS-APU 290) to contain major rotating parts should they fracture. Discs, hubs, impellers, rotating seals, and other similar rotating components should therefore always be considered to represent potential high-energy debris when containment means are not provided.

(iv) Toxic products.

CS-APU 210 (g)(2)(ii) addresses generation and delivery of toxic products caused by abnormal APU operation sufficient to incapacitate the crew or passengers during the flight. Possible scenarios include:

- Rapid flow of toxic products impossible to stop prior to incapacitation

- No effective means to prevent flow of toxic products to crew or passenger compartments.

- Toxic products impossible to detect prior to incapacitation.

The toxic products could result, for example, from the degradation of abradable materials in the compressor when rubbed by rotating blades or the degradation of oil leaking into the compressor air flow.

No assumptions of cabin air dilution or mixing should be made in this APU-level analysis; these can only be properly evaluated during aircraft certification. The intent of CS-APU 210 (g)(2)(ii) is to address the relative concentration of toxic products in the APU bleed air delivery. The Hazardous APU Effect of toxic products relates to significant concentrations of toxic products, with „significant“ defined as concentrations sufficient to incapacitate persons exposed to those concentrations.

Since these concentrations are of interest to the installer, information on delivery rates and concentrations of toxic products in the APU bleed air for the cabin should be provided to the installer as part of the installation instructions.

(v) Uncontrolled fire.

An uncontrolled fire should be interpreted in this context as an extensive or persistent fire which is not effectively confined to a designated fire zone or which cannot be extinguished by using the aircraft means identified in the assumptions. Provision for flammable fluid drainage, fire containment, fire detection, and fire extinguishing may be taken into account when assessing the severity of the effects of a fire.

(vi) Axial ejection of substantially whole rotors retaining high energy.

In-service experience has shown cases of ejection of complete turbine wheels through the APU exhaust. Although in some aircraft there is no aircraft part in the trajectory of the expulsed rotor, this is considered as a hazard for people around the aircraft if the event occurs on ground or for people on ground when the event occurs in flight. In other aircraft installation the exhaust is not straight and therefore this high-energy part is likely to damage the aircraft with an unpredictable trajectory and effect of debris.

(e) Major APU Effects

Compliance with CS-APU 210 (a)(4) can be shown if the individual failures or combinations of failures resulting in Major APU Effects have probabilities not greater than 10^{-5} per APU operating hour. No summation of probabilities of failure modes resulting in the same Major APU Effect is required to show compliance with this rule.

Major APU Effects are likely to significantly increase crew workload, or reduce the safety margins. Not all the effects listed below may be applicable to all APUs or installation, owing to different design features, and the list is not intended to be exhaustive.

Typically, the following may be considered as Major APU Effects:

- Controlled fires (i.e., those brought under control by shutting down the APU or by on-board extinguishing systems).

- Case burn-through where it can be shown that there is no propagation to Hazardous APU Effects.

- Release of low-energy parts where it can be shown that there is no propagation to Hazardous APU Effects.

- Concentration of toxic products in the APU bleed air for the cabin sufficient to degrade crew performance.

- Loss of integrity of the load path of the APU supporting system without actual APU separation.

The concentration of toxic products in the APU bleed air may be interpreted as the generation and delivery of toxic products as a result of abnormal APU operation that would incapacitate the crew or passengers, except that the products are slow-enough acting and/or are readily detectable so as to be stopped by crew action prior to incapacitation. Possible reductions in crew capabilities due to their exposure while acting in identifying and stopping the products must be considered, if appropriate. Since these concentrations are of interest to the installer, information on delivery rates and concentrations of toxic products in the APU bleed air for the cabin should be provided to the installer as part of the installation instructions.

(f) Minor APU Effects.

It is generally recognised that APU failures involving complete loss of power can be expected to occur in service, and that the aircraft should be capable of continued safe flight following such an event. For the purpose of the APU safety analysis and APU approval, APU failure with no external effect other than loss of power and services may be regarded as a failure with a minor effect. This assumption may be revisited during aircraft certification, where installation effects may be fully taken into consideration as well as the aircraft's type of operations (ETOPs in particular). This re-examination applies only to aircraft certification and is not intended to impact APU approval.

The failure to achieve any given power rating for which the APU is approved should be covered in the safety analysis and may be regarded as a minor APU effect. Similarly, this assumption may be revisited during aircraft certification.

(g) Determination of the effect of a failure.

Prediction of the likely progression of some APU failures may rely extensively upon engineering judgement and may not be proved absolutely. If there is some question over the validity of such engineering judgement, to the extent that the conclusions of the analysis could be invalid, additional substantiation may be required. Additional substantiation may consist of reference to APU test, rig test, component test, material test, engineering analysis, previous relevant service experience, or a combination thereof. If significant doubt exists over the validity of the substantiation so provided, additional testing or other validation may be required under CS-APU 210 (b).

(h) Reliance on maintenance actions.

For compliance with CS-APU 210 (e)(1) it is acceptable to have general statements in the analysis summary that refer to regular maintenance in a shop as well as on the line. If specific failure rates rely on special or unique maintenance checks, those should be explicitly stated in the analysis.

In showing compliance with the maintenance error element of CS-APU 210 (e)(1), the APU maintenance manual, overhaul manual, or other relevant manuals may serve as the appropriate substantiation. A listing of all possible incorrect maintenance actions is not required in showing compliance with CS-APU 210 (e)(1).

Precautions should be taken in the APU design to minimise the likelihood of maintenance errors. However, completely eliminating sources of maintenance error during design is not possible; therefore, consideration should also be given to mitigating the effects in the APU design.

Components undergoing frequent maintenance should be designed to facilitate the maintenance and correct re-assembly.

In showing compliance with CS-APU 210 (e)(2), it is expected that, wherever specific failure rates rely on special or unique maintenance checks for protective devices, those must be explicitly stated in the analysis.

(4) Analytical techniques.

This paragraph describes various techniques for performing a safety analysis. Other comparable techniques exist and may be proposed by an applicant. Variations and/or combinations of these techniques are also acceptable. For derivative APUs, it is acceptable to limit the scope of the analysis to modified components or operating conditions and their effects on the rest of the APU. Early agreement between the applicant and the Agency should be reached on the scope and methods of assessment to be used.

Various methods for assessing the causes, severity levels, and likelihood of potential failure conditions are available to support experienced engineering judgement. The various types of analyses are based on either inductive or deductive approaches. Brief descriptions of typical methods are provided below. More detailed descriptions of analytical techniques may be found in the documents referenced in paragraph (5) of this AMC.

- Failure Modes and Effects Analysis. This is a structured, inductive, bottom-up analysis which is used to evaluate the effects on the APU of each possible element or component failure. When properly formatted, it will aid in identifying latent failures and the possible causes of each failure mode.

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

(5) Related documents.

- AMC 25.1309 of CS-25, “System Design and Analysis”.

- Taylor Young Limited, „Systematic Safety“ by E Lloyd & W Tye

- Society of Automotive Engineers (SAE), Document No. ARP4754, Certification Considerations for Highly Integrated or Complex Aircraft Systems.

- Society of Automotive Engineers (SAE), Document No. ARP 926A, "Fault/Failure Analysis Procedure".

- Society of Automotive Engineers (SAE), Document No. ARP 4761, "Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment".

- Carter, A.D.S., Mechanical Reliability (2nd ed.). Macmillan, 1986.

(6) Definitions.

The following definitions are applicable to this AMC. They should not be assumed to apply to the same or similar terms used in other specifications or AMCs.

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

Failure condition. A condition with direct, consequential APU-level effect, caused or contributed to by one or more failures. Examples include limitation of power to idle or oil exhaustion.

Failure mode. The cause of the failure or the manner in which an item or function can fail. Examples include failures due to corrosion or fatigue, or failure in jammed open position.

Toxic products. Products that act as or have the effect of a poison when humans are exposed to them.

AMC CS-APU 220 Fire prevention

(1) Definitions

(a) Drain and Vent Systems: Components which are used to convey unused or unwanted quantities of flammable fluid or vapour away from the APU.

(b) External Lines, Fittings and Other Components: APU parts conveying flammable fluids and which are external to the main APU casings, frames and other APU major structure. These parts include, but are not limited to, fuel or oil tubes, accessory gearbox, pumps, heat exchangers, valves and APU fuel control units.

(c) Fire Hazard: (i) The unintentional release or collection of a hazardous quantity of flammable fluid, vapour or other substances; or (ii) a failure or malfunction which results in an unintentional ignition source within a fire zone; or (iii) the potential for a Hazardous APU Effect as the result of exposure to a fire.

(d) Hazardous quantity: An amount of fluid, vapour or other substance which could sustain a fire of sufficient time and severity to create damage potentially leading to a Hazardous APU Effect. In the absence of a more suitable determination of a hazardous quantity of flammable fluid, this can be assumed to be 0.25 litre or more of fuel (or a quantity of flammable material of equivalent heat content).

(2) General

(a) Intent

The intent of CS-APU 220 is to give assurance that the design, materials and construction techniques utilised will minimise the probability of the occurrence, the consequences and the spread of fire.

(b) Objectives

With respect to the above intent, the primary objectives are to (i) minimise the probability of a fire, (ii) prevent any sources of flammable substance or air from feeding an existing fire and (iii) ensure that the APU Control System and accessories will permit a safe shutdown of the APU and subsequently maintain that condition.

(c) Determination of level of fire protection

CS-APU 220 (b) requires that all flammable fluid conveying parts or components be at least Fire Resistant, whereas CS-APU 220(c) requires flammable fluid tanks and associated shutoff means to be Fireproof. It should then be determined which level of fire protection should be shown for each component requiring a fire protection evaluation.

The 5 minute exposure which is associated with a "Fire Resistant" status provides a reasonable time period for the flight crew to recognise a fire condition, shut down the APU and close the appropriate fuel shut-off valve. This cuts off the source of fuel.

Oil system components of APUs, however, may continue to flow oil after the APU has been shut down because of continued rotation. The supply of oil to the fire might exist for as long as the continued rotation effects (duration is dependent on flight level of aircraft) are present or until the oil supply is depleted.

According to these assumptions, in general, components which convey flammable fluids can be evaluated to a Fire Resistant standard provided the normal supply of flammable fluid is stopped by a shut-off feature.

Oil system components may need to be evaluated from the standpoint of fire hazard (quantity, pressure, flow rate, etc.) to determine whether Fire Resistant or Fireproof standards should apply. It should be noted that, historically, most oil system components have been evaluated to a Fireproof standard.

Other flammable fluid conveying components (except flammable fluid tanks), such as hydraulic systems, should be evaluated in a similar manner. Flammable fluid tanks must be Fireproof as required by CS-APU 220 (c).

(d) Pass / fail criteria

When a fire test is performed, the following acceptance criteria should be considered:

- To maintain the ability to perform those functions intended to be provided in case of fire,
- No leakage of hazardous quantities of flammable fluids, vapours or other materials,
- No support of combustion by the constituent material of the article being tested,
- No burn through of firewalls,
- No other conditions which could produce Hazardous APU Effects.

(i) Functions

The functions intended to be provided in case of fire will be determined on a case by case basis. For example, APU Control Systems should not cause a Hazardous APU Effect while continuing to operate but should allow or may cause a safe shutdown of the APU at any time within the required exposure time period.

A safe APU shutdown at any time during the fire resistance test is an acceptable outcome for this type of component, provided the safe condition is maintained until the end of the 5 minutes test period.

For a flammable fluid tank shutoff valve, the valve should be operable (to close) or should default closed, and be capable of maintaining this position without leakage of a hazardous quantity of flammable fluid until the end of the 15 minute test period.

The above examples are included to illustrate the case by case nature of making this determination.

(ii) Leakage of flammable fluid

At no time during or at the end of the test should the test article leak a hazardous quantity of flammable fluid.

(iii) Support of combustion

Consideration should be given to non-self-extinguishing fire test events. This type of event could be either combustion of the constituent material of the test article or combustion of flammable fluid leaking from the component. In general, these events should continue to be cause for failure of the test, unless it can be shown that the constituent material supporting combustion is not a hazardous quantity of flammable fluid, vapour, or material as defined in this AMC.

This has been the case for certain electronic components. Current technology electronic components often use circuit board potting compounds internal to the control system casings that may support combustion when heated sufficiently or when exposed to fire. These compounds can also flow under high heat and may leak through the casings. Therefore, such materials may support a small intensity fire internal and / or external to the casing for a limited period of time after the test flame is removed.

(iv) Firewall

At no time during or at the end of the test should a firewall component fail to contain the fire within the intended zone or area. Implied with this outcome is the expectation that the firewall component will not develop a burn through hole and will not fail in any manner at its attachment or fire seal points around the periphery of the component and will not continue to burn after the test flame is removed. There should not be backside ignition.

(v) Other conditions

At no time during or at the end of the test should a Hazardous APU Effect result.

(3) Materials

(a) Experience has shown that when using materials such as magnesium and titanium alloys, appropriate design precautions may be required to prevent an unacceptable fire hazard. Consideration should be given to the possibility of fire as a result of rubbing or contact with hot gases.

Any material used for abradable linings needs to be assessed to ensure that fire or explosion hazards are avoided. Consideration should also be given to the effects of mechanical failure of any APU component and to the effects of dimensional changes resulting from thermal effects within the APU.

(b) Use of Titanium

Many titanium alloys used for manufacturing APU rotor and stator blades will ignite and may sustain combustion, if the conditions are appropriate. In general, titanium fires burn very fast and are extremely intense. The molten particles in titanium fires generate highly erosive hot sprays which have burned through compressor casings with resulting radial expulsion of molten or incandescent metal. In such cases, depending on the installation, the aircraft could be hazarded.

In showing compliance with CS-APU 220 (a) the applicant should assess the overall design for vulnerability to titanium fires. If this assessment cannot rule out the possibility of a sustained fire, then it should be shown that a titanium fire does not result in a Hazardous APU Effect.

Based on experience, the following precautions can reduce the susceptibility of APUs to titanium fires:

The type of alloy i.e. its constituents other than titanium;

Blade / casing coatings or mechanical linings which inhibit ignition or subsequent combustion;

The way in which the design minimises potentially dangerous rubs by such methods as:

- Large inter blade row clearances;
- The use of appropriate abradable materials in areas of potential rub of sufficient depth to accommodate predicted rotor or stator deflections including those likely to occur in fault conditions;
- Not using titanium for adjacent rotating and static parts;
- Taking full account of rotor movements under transient and bearing failure conditions;
- Ensuring that thin, easily ignited titanium sections are unlikely to be shed at the front of the APU.

(c) Use of Magnesium

Many magnesium alloys used in the manufacture of components are highly combustible when in finely divided form, such as chips or powder. Therefore the use of magnesium alloys in thin sections or where they are exposed to corrosion, rubbing or high scrubbing speeds should be carefully evaluated.

In showing compliance with CS-APU 220 (a), the applicant should assess the overall design for vulnerability to magnesium fires. If this assessment cannot rule out the possibility of a sustained fire, then it should be shown that a magnesium fire does not result in a Hazardous APU Effect.

(d) Abradable Linings

Many compressor and turbine modules have abradable linings between rotating blade tips and stator casings. Depending upon the material used in the abradable lining, experience has shown that fire or explosion can occur in the presence of an ignition source if a significant amount of lining is removed during rubs between rotor and stator. Under certain conditions, auto-ignition can occur in the mixture of small particles extracted from the abradable linings and hot flow path gases.

These situations should be evaluated for each compressor and turbine stage which has an abradable lining.

(e) Absorbent Materials

Absorbent materials should not be used in close proximity to flammable fluid system components unless they are treated or covered to prevent the absorption of a hazardous quantity of such fluid.

(4) Specific interpretations

(a) Test equipment and calibration

Acceptable procedures for calibration of the relevant burners for the tests, and the standard flame, are defined in the ISO 2685 standard.

A pre test calibration to verify that the standard flame temperature and heat flux is achieved is necessary for each test. To ensure that flame conditions are constant throughout the test either the flow parameters should be shown to be constant throughout the test or a post-test calibration should be performed to show equivalency with pre-test values.

(b) Flame impingement location

The test flame generally should be applied to the test article feature(s) that is determined by analysis or test to be the most critical with respect to surviving the effects of the fire.

For this approach, determination of the flame impingement location(s) should consider, as a minimum, the following potential factors: materials; geometry; part features; local torching effects; vibration; internal fluid level, pressure and flow rate; surface coatings; fire protection features; etc.

Alternatively, the applicant may consider all potential sources of fire in the intended installation when determining test flame impingement location specifications.

The intent is to identify locations or features which cannot be directly impinged by fire, and evaluating critical features which can be directly impinged. If the applicant chooses this installation analysis approach, it should be based on the actual intended installation, and should consider, as a minimum, the factors noted above, plus the following potential installation specific factors: surrounding aircraft structure and hardware; cooling airflow; etc.

Such installation analyses should avoid simple generalities, such as “the most likely flame direction is vertical assuming fuel collects at the bottom of the APU compartment”, and should be co-ordinated with the installer. If this approach is utilised, each new installation will need to be re-evaluated against the original fire protection substantiation to confirm its applicability to the new installation. Lastly, due consideration should be given to fire protection features such as fire shields, fire protective coatings or other methods so as not to discourage or invalidate their use with respect to compliance with CS-APU 220.

(c) Operating parameters for test articles

The operating characteristics and parameters of the test article should be consistent, but conservative, with respect to the conditions which might occur during an actual fire situation. For example, where a high internal fluid flow increases the heat sink effect, and is less conservative with respect to fire susceptibility, a minimum flow condition should be specified for the test. The same is true for examples relating to internal fluid temperatures or quantity or other parameters.

(d) Electrical Systems components

For compliance with CS-APU 220 (f), the effects of fire on components of the electrical system should be evaluated. Electrical cables, connectors, terminals and equipment, installed in or on the APU, in designated fire zones must be at least Fire Resistant.

(5) Fire tests

(a) Flammable fluid tank fire test

In the absence of an acceptable installation assessment, the fire test flame should be applied to the tank location(s) or feature(s) that has been determined by analysis or test to be the most critical with respect to fire susceptibility (i.e. the location or feature least likely to survive the test conditions or meet the test pass / fail criteria).

In selecting the flame application location, the tank installation and all features of the tank assembly should be considered. Typical tank features include, but are not limited to tank body, inlet and outlet assemblies, sight glass, drain plug, magnetic chip detector, quantity sender assembly, vent line assembly, filler cap and scupper, mounts, shut-off valve, temperature sensor, and air/fluid separator assembly. Tanks can be designed and manufactured with any combination of the above features, or other features not listed, and of varying materials.

Therefore, in some instances, compliance with CS-APU 220 may need to be supported by data from other fire tests, multiple location testing, sub component level tests, or service experience, to cover all tank assembly features.

Also, other aspects of determining impingement location should be considered, such as vent system performance (experience has shown that oil tank fire tests have failed due to high internal pressure and inadequate venting), the lack of heat sink effect for tank features at or above the operating level of the tanks fluid contents and the effect of any special protective features (shields, coatings, feature placement, etc.) incorporated into the design.

With respect to fluid quantity, the tank quantity at the start of the test should be no greater than the minimum dispatchable quantity, unless a greater quantity is more severe. Relative to flow rate, the first 5 minutes of the test should be conducted at the most critical operating condition and the subsequent 10 minutes should be conducted at an APU shutdown flow rate with consideration of the effect of any continued rotation. The test may be run, at the applicant’s option, for 15 minutes at the most critical condition (worst case of APU operating or in flight shutdown conditions).

With respect to fluid temperature, this should be at its maximum value (the greatest of steady state or transient limit) at the start of the test, unless a lower temperature is more severe. The tank internal pressure should be the normal working pressure for the operating conditions at the start of the test. It is understood that these values may change due to the test conditions.

The tank design and its intended application should be reviewed to provide reasonable assurance that the test set-up reflects the most critical flame impingement orientation and operating conditions for the intended application.

(b) Drain and Vent Systems

CS-APU 220 (b) allows certain parts to be exempt from the specifications because they do not typically contain or convey flammable fluids during normal APU operation. This refers to normal operation in a typical flight mission. It is not intended to impose a fire resistance demonstration for all parts of the APU which might contain, convey or be wetted by flammable fluids in all possible failure scenarios.

An example of parts which might be exempted is a combustor drain system which typically drains off residual fuel after an aborted APU start. This might also be the case of the majority of individual drains and vents.

However, a shrouded fuel line is considered as being a single assembly which cannot be dissociated into the main fuel line and its envelope (acting as a drain in case of a failure in the main fuel line) and should comply with CS-APU 220 as a component carrying flammable fluid. In this particular case, after the exposure to the flame, the external envelope may be destroyed provided the general pass / fail criteria described in paragraph (2)(d) of this AMC are complied with.

In the case of a drain and vent system which would flow a hazardous quantity of flammable fluid during continued rotation after shut down of the APU, then a fireproof standard may be appropriate. The function of each drain or vent should be carefully reviewed in making these determinations

(c) Electrical Bonding

The overall intent of CS-APU 220 (h) is to show that an electrical current path exists between certain components that are mounted externally to the APU and the APU carcass.

These components are those which, with respect to fire protection, are susceptible to or are potential sources of static discharge or electrical fault current. To comply with this specification, the applicant should show that the modules, assemblies, components and accessories installed in or on the APU are electrically grounded to the APU reference.

This may be accomplished by examination of the type design drawings, electrical continuity check, or actual inspection of an APU. The type design should provide protection for probable failure cases.

(d) Air Sources

In accordance with CS-APU 220 (a), the applicant should evaluate the effect of fire on components conveying bleed air and evaluate whether failure of such components could further increase the severity or duration of a fire within a fire zone.

(e) Firewall

The overall intent of CS-APU 220 (d)(2) is to provide specifications for the proper functioning of a firewall which are consistent with the aircraft specifications on firewalls. In no case should a hazardous quantity of flammable fluid or vapour pass around the firewall. Also, the firewall should contain the fire without resulting in a Hazardous APU Effect.

(f) Shielding

The overall intent of CS-APU 220 (b) specification concerning the shielding and location of components is to minimise the possibility of liquid flammable fluids contacting ignition sources and igniting. Ignition sources include hot surfaces with temperatures at or above typical flash points for aviation fuels, oils, and hydraulic fluids, or any component that produces an electrical discharge. Compliance with this specification may be shown by installation of drainage shrouds around flammable fluid lines or fittings; installation of spray shields to deflect leaking fuel away from ignition sources, and general component location on the APU which minimises the possibility of starting and supporting a fire. Therefore, the overall substantiation should show that leaked flammable fluid would be unlikely to impinge on an ignition source to the extent of starting and supporting a fire.

AMC CS-APU 460 Over-Temperature Test

(1) Running the test of CS-APU 460 at 42°C above the turbine inlet temperature is the minimum required. It has been assumed that running the test at 42°C above the exhaust gas temperature, if this represents for the applicant the easiest way to conduct the test, would give a greater margin above the turbine inlet temperature. Nevertheless, if the applicant chooses to consider the exhaust gas temperature, it should be demonstrated that this assumption is valid for the particular APU design and that the APU would run at least 42°C above the rated turbine inlet temperature.

(2) The test of CS-APU 460 may be combined with the test of CS-APU 450 if the objectives of both specifications can be simultaneously met.

AMC CS-APU 470 Containment

(1) An analysis must determine which rotors are critical. The other rotors will be considered as non-critical.

(2) With respect to blade or hub containment, a critical rotor is a rotor for which the APU design provides the smallest margin for containment in the defined conditions. The margin for containment addresses the direct containment of the failed part (blade or hub) as well as potential secondary effects which could produce an end effect identified under CS-APU 210.

(3) Any analytical tool used in place of a test should be validated by APU test(s) and all appropriate rig or component testing or service experience and shown to be equivalent to an APU test and able to predict test results. Therefore, substitution of an analysis to an APU test would normally not be accepted for a totally new product.

(4) Testing of the gas generator alone for containment may be considered as an acceptable APU test for the relevant rotors if it is shown that the presence of the other parts would not change the test results.