European Aviation Safety Agency

The Executive Director

DECISION NO. 2003/9/RM

OF THE EXECUTIVE DIRECTOR OF THE AGENCY

of 24 October 2003

on certification specifications, including airworthiness codes and acceptable means of compliance, for engines (« CS-E »)

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,

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

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

HAS DECIDED AS FOLLOWS:

Article 1

Unless otherwise decided for engines to be installed on powered sailplanes, very light aeroplanes and very light rotorcraft, the certification specifications, including airworthiness codes and acceptable means of compliance, for engines are those laid down in the Annex to this Decision.

Article 2

This Decision shall enter into force on 24 October 2003. It shall be published in the *Official Publication of the Agency*.

Done at Brussels, 24 October 2003.

For the European Aviation Safety Agency,

Patrick GOUDOU

Executive Director

European Aviation Safety Agency

Certification Specifications for Engines

CS-E

CONTENTS (General lay-out)

CS-E BOOK 1 – AIRWORTHINESS CODE

CS-E BOOK 2 - ACCEPTABLE MEANS OF COMPLIANCE

EASA Certification Specifications
for
Engines

CS-E
Book 1

Airworthiness code

SUBPART A – GENERAL

CS-E 10 Applicability

(a) This CS-E contains airworthiness specifications for the issue of type certificates, and changes to those certificates, for Engines, in accordance with Part 21.

(b) CS-E contains the specifications for the approval for use of the Engine with a thrust reverser, if fitted. If compliance is shown, the specific thrust reverser approved for use will be noted in the Engine certification documentation. Otherwise, the documentation will be endorsed to indicate that the use of a thrust reverser is prohibited.

(c) The specifications of subparts A, B and C apply to Piston Engines. Any necessary variations of the specifications of subparts B and C for Piston Engines intended for use in rotorcraft will be decided in accordance with 21A.16.

(d) The specifications of subparts A, D, E and F apply to Turbine Engines.

CS-E 15 Terminology

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

(b) All Engines

Extremely Remote	means unlikely to occur when considering the total operational life of a number of aircraft of the type in which the Engine is installed, but nevertheless, has to be regarded as being possible. Where numerical values are used this may normally be interpreted as a probability in the range 10^{-7} to 10^{-9} per Engine flight hour.
Reasonably Probable	means unlikely to occur often during the operation of each aircraft of the type but which may occur several times during the total operational life of each aircraft of the types in which the Engine may be installed. Where numerical values are used this may normally be interpreted as a probability in the range 10^{-3} to 10^{-5} per Engine flight hour.
Remote	means unlikely to occur to each aircraft during its total operational life but may occur several times when considering the total operational life of a number of aircraft of the type in which the Engine may be installed. When numerical values

are used, this may normally be interpreted as a probability in the range 10^{-5} to 10^{-7} per Engine flight hour.

(c) Turbine Engines

Hazardous Engine Effect	means an effect identified as such under CS-E 510.
Major Engine Effect	means an effect identified as such under CS-E 510.
Minor Engine Effect	means an effect identified as such under CS-E 510.

(d) For piston Engines

Boost Pressure	means the power setting measured relative to standard sea-level atmospheric pressure.
Charge Cooling	means the percentage degree of charge cooling, quantitatively expressed as: $((t2 – t3) / (t2 – t1)) \times 100$ where t1 is the temperature of the air entering the charge cooler coolant radiator in the powerplant, t2 is the temperature of the charge without cooling, and t3 is the temperature of the charge with cooling.
Manifold Pressure	means the absolute static pressure measured at the appropriate point in the induction system.

(e) Terms associated with the Engine Control System

Alternate Mode	means any Control Mode, including Back-up Modes that are not the Primary Mode used for controlling the Engine.
Back-up Mode	means the Control Mode of the Back-up System.
Back-up System	means a part of the Engine Control System where the operating characteristics or capabilities of the Engine control are sufficiently different from the Primary System that the operating characteristics or capabilities of the aircraft, crew workload, or what constitutes appropriate crew procedures may be significantly impacted or changed.
Engine Control System	means any system or device which is part of the Engine type design, which controls, limits or

	monitors Engine operation and is necessary for continued airworthiness of the Engine.
Primary System	means the part of the Engine Control System used for controlling the Engine under normal operation.
Control Mode	means each defined operational state of the Engine Control System where satisfactory Engine control can be exercised by the crew.
Primary Mode	means the mode that is intended to be used for controlling the Engine under normal operation. This is often referred to as the 'normal mode'.
Aircraft-Supplied Data	means all data which are supplied by or via aircraft systems and is used by the Engine Control System.
Electronic Engine Control System (EECS)	means an Engine Control System in which the primary functions are provided using electronics. It includes all the components (e.g. electrical, electronic, hydromechanical and pneumatic) necessary for the control of the power or thrust output of the Engine, within the flight envelope and operating limitations.
Fault or Failure	means an occurrence which affects the operation of a component, part, or element such that it can no longer function as intended.
Fault or Failure Accommodation	means the capability to mitigate, either wholly or in part, the Fault or Failure.
Full-up Configuration	means an EECS that has no known Faults or Failures present.
Loss of Thrust Control (LOTC) or Loss of Power Control (LOPC)	means the loss of ability to modulate power or thrust between given values, or unacceptable thrust or power oscillations. These values are determined by the exact application.
Programmed Logic Device (PLD)	means a component that is purchased as an electronic component and altered to perform an application specific function. PLDs include, but are not limited to, programmable array logic components (PAL), programmable logic array components, general array logic components (GAL), field programmable gate array components, and erasable programmable logic devices.

(f) Terms associated with Engine Critical Parts

Approved Life	means the mandatory replacement life of a part which is approved by the Agency.

Attributes	means inherent characteristics of a finished part that determine its capability.
Damage Tolerance	means an element of the life management process that recognises the potential existence of component imperfections as the result of inherent material structure, material processing, component design, manufacturing or usage and addresses this situation through the incorporation of fracture resistant design, fracture mechanics, process control, and non-destructive inspection.
Engine Critical Part	means a part that relies upon meeting prescribed integrity specifications of CS-E 515 to avoid its Primary Failure, which is likely to result in a Hazardous Engine Effect.
Engine Flight Cycle	means the flight profile, or combination of profiles, upon which the Approved Life is based.
Engineering Plan	means a compilation of the assumptions, technical data and actions required to establish and to maintain the life capability of an Engine Critical Part. The Engineering Plan is established and executed as part of the pre- and post-certification activities.
Manufacturing Plan	means a compilation of the part specific manufacturing process constraints, which must be included in the manufacturing definition (drawings, procedures, specifications, etc.) of the Engine Critical Part to ensure that it meets the design intent as defined by the Engineering Plan.
Primary Failure	means a Failure of a part which is not the result of the prior Failure of another part or system.
Service Management Plan	means a compilation of the processes for in-service maintenance and repair to ensure that an Engine Critical Part achieves the design intent as defined by the Engineering Plan.

CS-E 20 Engine Configuration and Interfaces

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

(b) The aircraft airworthiness code which is assumed as being applicable to the intended installation of the Engine must be identified under CS-E 30.

(c) The aircraft parts and equipment that may be mounted on, or driven by, the Engine, which are not part of the declared Engine configuration and therefore are not covered by the Engine Type Certificate must be identified.

(d) Manuals must be provided containing instructions for installing and operating the Engine. These instructions must contain a definition of the physical and functional interfaces with the aircraft and aircraft equipment. They must also include a description of the Primary and all Alternate Modes, and any Back-up System, together with any associated limitations, of the Engine Control System and its interface with the aircraft systems, including the Propeller when applicable.

(e) Engine performance data, compatible with the Engine acceptance and operating limitations, must be provided for aircraft certification performance, handling and stressing purposes. The data must be such that the power/thrust of a 'minimum' and a 'maximum' Engine can be derived and must include means of determining the effects on performance of variations of Engine bleed and power off-take, forward speed, ambient pressure, temperature and humidity.

(f) For Engines having one or more OEI Ratings, data must be provided on Engine performance characteristics and variability to enable the aircraft manufacturer to establish power assurance procedures.

CS-E 25 Instructions for Continued Airworthiness

(a) In accordance with 21A.61 (a), manual(s) must be established containing instructions for continued airworthiness of the Engine. They must be updated as necessary according to changes to existing instructions or changes in Engine 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).

For Engine Critical Parts, this section must also include any mandatory action or limitation for in-service maintenance and repair identified in the Service Management Plan required under CS-E 515.

(1) For all Engines, the airworthiness limitations section must set forth each mandatory replacement time, inspection interval and related procedure required for type certification.

(2) For Engines having 30-Second OEI and 2-Minute OEI power ratings, in addition to complying with CS-E 25 (b)(1), the airworthiness limitations section must also prescribe the mandatory post-flight inspections and maintenance actions associated with any use of either the rated 30-Second OEI or 2-Minute OEI Power. The adequacy of these inspections and maintenance actions must be validated and an in-service Engine evaluation programme must be established to assure the adequacy of the data of CS-E 20 (f) pertaining to power availability and the instructions for the mandatory post flight inspections and maintenance actions.

The programme must include service Engine tests or equivalent service Engine test experience on Engines of similar design and/or evaluations of service usage of the 30-Second / 2-Minute OEI ratings.

(c) The following information must be considered, as appropriate, for inclusion into the manual(s) required by CS-E 25 (a).

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

(2) Handling 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 Engine components, systems and installations operate. Information describing the methods of starting, running, testing and stopping the Engine or its components and systems 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 Engine that provides the recommended periods at which it should be cleaned, inspected, adjusted, tested and lubricated, and the degree of inspection, the applicable serviceability limits, and work recommended at these periods. Necessary cross-references to the airworthiness limitations section must also be included. In addition, if appropriate, an inspection programme must be included that states the frequency of the inspections necessary to provide for the continued airworthiness of the Engine.

(6) Troubleshooting 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 Engine 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 non-serviceable 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-E 30 Assumptions

(a) In the course of establishing compliance with CS-E certain assumptions have to be made concerning the conditions that may be imposed on the Engine when it is eventually installed in the aircraft. In order that the validity of the conditions assumed in the Engine certification may be assessed for any particular installation, prior to Engine certification, the details of the assumptions made must be submitted. These assumptions must be included in the Engine instructions for installation required under CS-E 20 (d).

(b) Where an Engine system relies on components which are not part of the Engine type design, the interface conditions and reliability specifications for those components upon which the Engine certification is based must be specified in the Engine instructions for installation directly or by reference to appropriate documentation.

CS-E 40 Ratings

(a) Power ratings must be established for Take-off Power and/or Thrust and for Maximum Continuous Power and/or Thrust, for all Engines.

(b) Other ratings may also be established as –

(1) Piston Engines -

(i) Maximum Recommended Cruising Power.

(ii) Maximum Best Economy Cruising Power.

(2) Turbine Engines for Multi-Engine Aeroplanes

(i) 2 1/2-Minute OEI Power or Thrust

(ii) Continuous OEI Power or Thrust

(3) Turbine Engines for Multi-Engine Rotorcraft -

(i) 30-Second OEI Power

(ii) 2-Minute OEI Power

(iii) 2 1/2-Minute OEI Power

(iv) 30-Minute OEI Power

(v) Continuous OEI Power

(c) The Engine thrust and/or power ratings will be based on standard atmospheric conditions, with no air bleed for aircraft services and with only those accessories installed which are essential for Engine functioning, including controls, unless otherwise declared in the Engine Type certificate data sheet.

(d) Operating limitations appropriate to the intended operating conditions for the Engine must be established.

(e) The Engine's rated Powers/Thrusts and any operating limitations established under this CS-E 40 which must be respected by the crew of an aircraft must be listed in the Engine Type certificate data sheet specified in 21A.41. The Engine Type certificate data sheet must also identify, or make reference to, all other information found necessary for the safe operation of the Engine.

(f) The ratings established under this CS-E 40 must be defined for the lowest power/thrust that all Engines of the same type may be expected to produce under the conditions used to determine these ratings. The minimum testing must be defined, together with associated conditions, necessary for ensuring that the Engines will comply with this objective.

(g) In determining the Engine performance and operating limitations, the overall limits of accuracy of the Engine Control System and of the necessary instrumentation as defined in CS-E 60 (b) must be taken into account.

(h) For Piston Engines, each declared rating must be defined in terms of the power produced at a given power setting and Engine rotational speed.

CS-E 50 Engine Control System

(a) *Engine Control System Operation.* It must be substantiated by tests, analysis or a combination thereof that the Engine Control System performs the intended functions in a manner which -

(1) Enables selected values of relevant control parameters to be maintained and the Engine kept within the approved operating limits over changing atmospheric conditions in the declared flight envelope.

(2) Complies with the operability specifications of CS-E 390, CS-E 500 (a) and CS-E 745, as appropriate, under all likely system inputs and allowable Engine power or thrust demands, unless it can be demonstrated that this is not required for non-dispatchable specific Control Modes in the intended application. In such cases, the Engine approval will be endorsed accordingly.

(3) Allows modulation of Engine power or thrust with adequate sensitivity and accuracy over the declared range of Engine operating conditions, and

(4) Does not create unacceptable thrust or power oscillations.

(b) *Control Transitions.* It must be demonstrated that, when a Fault or Failure results in a change from one Control Mode to another, or from one channel to another, or from the Primary System to the Back-up System, the change occurs so that:

(1) The Engine does not exceed any of its operating limitations,

(2) The Engine does not surge, stall, flame-out or experience unacceptable thrust or power changes or oscillations, or other unacceptable characteristics, and

(3) If the flight crew is required to initiate, respond to or be aware of the Control Mode change, there must be provision for a means to alert the crew. This provision must be described in the Engine instructions for installation and the crew action described in the Engine instructions for operation.

The magnitude of any change in thrust or power and the associated transition time must be identified and described in the Engine instructions for installation and operation.

(c) *Engine Control System Failures.* The Engine Control System must be designed and constructed so that :

(1) The rate for Loss of Thrust (or Power) Control (LOTC/LOPC) events, consistent with the safety objective associated with the intended aircraft application, can be achieved,

(2) In the Full-up Configuration, the system is essentially single Fault tolerant for electrical and electronic Failures with respect to LOTC/LOPC events.

(3) Single Failures of Engine Control System components do not result in a Hazardous Engine Effect,

(4) Foreseeable Failures or malfunctions leading to local events in the intended aircraft installation, such as fire, overheat, or Failures leading to damage to Engine Control System components, must not result in a Hazardous Engine Effect due to Engine Control System Failures or malfunctions.

(d) *System Safety Assessment.* When complying with CS-E 210 or CS-E 510, a system safety assessment must be completed for the Engine Control System. This assessment must identify Faults or Failures that result in a change in thrust or power, a transmission of erroneous data, or an effect on Engine operability together with the predicted frequency of occurrence of these Faults or Failures. (See also CS-E 110 (e))

(e) *Protection Systems.*

(1) When electronic over-speed protection systems are provided, the design must include a means for testing the system to establish the availability of the protection function. The means must be such that a complete test of the system can be achieved in the minimum number of cycles. If the test is not fully automatic, the specification for a manual test must be contained in the Engine instructions for operation.

(2) When over-speed protection is provided through hydromechanical or mechanical means, it must be demonstrated by test or other acceptable means that the over-speed function remains available between inspection and maintenance periods.

(f) *Software and Programmed Logic Devices*. All associated software and encoded logic must be designed, implemented and verified to minimise the existence of errors by using an approved method consistent with the criticality of the performed functions.

(g) *Aircraft Supplied Data.*

Single Failures leading to loss, interruption or corruption of Aircraft-Supplied Data, or data shared between Engines must:

(1) Not result in a Hazardous Engine Effect for any Engine.

(2) Be detected and accommodated. The accommodation strategy must not result in an unacceptable change in thrust or power or an unacceptable change in Engine operating and starting characteristics. The effects of these Failures on Engine power or thrust, Engine operability and starting characteristics throughout the flight envelope must be evaluated and documented.

The specification of CS-E 50 (g)(2) does not apply to thrust or power command signals from the aircraft.

(h) *Aircraft Supplied Electrical Power.*

(1) The Engine Control System must be designed so that the loss or interruption of electrical power supplied from the aircraft to the Engine Control System will not -

(i) Result in a Hazardous Engine Effect,

(ii) Cause the unacceptable transmission of erroneous data.

The effect of the loss or interruption of aircraft supplied electrical power must be taken into account in complying with CS-E 50 (c)(1).

(2) When an Engine dedicated power source is required for compliance with CS-E 50 (h)(1), its capacity should provide sufficient margin to account for Engine operation below idle where the Engine Control System is designed and expected to recover Engine operation automatically.

(3) The need for, and the characteristics of, any electrical power supplied from the aircraft to the Engine Control System for starting and operating the Engine, including transient and steady state voltage limits, must be identified and declared in the Engine instructions for installation.

(4) Low voltage transients outside of the power supply voltage limitations, declared under CS-E 50 (h)(3), must meet the specifications of CS-E 50 (h)(1). The Engine Control System must resume normal operation when aircraft supplied electrical power returns to within the declared limits.

(i) *Air Pressure Signal.*

The effects of blockage or leakage of the signal lines on the Engine Control System must be considered as part of the system safety assessment of CS-E 50 (d) and the appropriate design precautions adopted.

(j) Engines having a 30-Second OEI Power Rating must incorporate means or provision for means for automatic availability and automatic control of the 30-Second OEI Power within its operating limitations.

(k) Means for shutting down the Engine rapidly must be provided.

CS-E 60 Provision for Instruments

(a) Provision must be made for the installation of instrumentation necessary to ensure operation in compliance with the Engine operating limitations. Where, in presenting the safety analysis, or complying with any other specification, dependence is placed on instrumentation which is not otherwise mandatory in the assumed aircraft installation, then this instrumentation must be specified in the Engine instructions for installation and declared mandatory in the Engine approval documentation.

(b) A list of the instruments necessary for control of the Engine must be provided in the Engine instructions for installation. The overall limits of accuracy and transient response required of such instruments for control of the operation of the Engine must also be stated so that the suitability of the instruments as installed may be assessed.

(c) The sensors together with associated wiring and signal conditioning must be segregated, physically and electrically, to the extent necessary to ensure that the probability of a Fault propagating from instrumentation and monitoring functions to control functions or vice versa is consistent with the Failure effect of the Fault.

(d) Rotorcraft turbine Engines having 30-Second and 2-Minute OEI Power Ratings must:

(1) Have means, or provision for means, to alert the pilot when the Engine is at the 30-Second OEI and the 2-Minute OEI Power levels, when the event begins, and when the time interval expires.

(2) Have means or provision for means, which cannot be reset in flight, to

(i) Automatically record each usage and duration of power at the 30-Second and 2-Minute OEI Power levels.

(ii) Alert maintenance personnel in a positive manner, that the Engine has been operated at either or both of the 30-Second and 2-Minute OEI Power levels and permit retrieval of recorded data; and

(3) Have means, or provision for means, to enable routine verification of the proper operation of the above means.

(e) Instrumentation enabling the flight crew to monitor the functioning of the turbine cooling system must be provided unless evidence shows that:

(1) Other existing instrumentation provides adequate warning of Failure or impending Failure, or

(2) Failure of the cooling system would not lead to Hazardous Engine Effects before detection, or

(3) The probability of Failure of the cooling system is Extremely Remote.

Appropriate inspections must be promulgated in the relevant manuals.

CS-E 70 Materials and Manufacturing Methods

(a) The suitability and durability of materials used in the Engine must be established on the basis of experience or tests. The assumed design values of properties of materials must be suitably related to the minimum properties stated in the material specification.

(b) Manufacturing methods and processes must be such as to produce sound structure and mechanisms which retain the original mechanical properties under reasonable service conditions.

CS-E 80 Equipment

(a) Equipment Drives and Mountings

(1) Mountings and drives for all equipment installed on the Engine must be designed :

(i) To permit safe operation of the Engine with the equipment fitted, and

(ii) So that Failure of equipment will not result in further damage likely to produce a Hazardous Engine Effect.

(2) Mountings and drives for equipment identified under CS-E 20 (c) must be designed and located so as to minimise the possibility of defective equipment necessitating Engine shut-down as a result of:

(i) Contamination or major loss of the Engine oil supply, or

(ii) Engine malfunctioning through the application of excessive torque, loose parts falling into the Engine, flailing of the drives, etc.

(b) The equipment identified under CS-E 20 (a) must be approved as an integral part of the Engine and must meet the relevant specifications of CS-E. Unless the specifications prescribed in subpart C or E, as appropriate, will subject this equipment to such cycles of operation as to adequately represent all the critical conditions affecting its airworthiness to which it may be expected to be exposed during service, the equipment specification must state those additional airworthiness specifications for which evidence of compliance will be needed.

(c) The equipment identified under CS-E 20 (c) will be accepted for use on an Engine subject to:

(1) The equipment meeting the interface specifications identified under CS-E 20 (d);

(2) Evidence of satisfactory compliance with CS-E 80 (a);

(3) Being approved under the relevant aircraft Type Certificate.

(d) Equipment with high-energy rotors must be such as to meet one of the following:

(1) Failures will not result in significant non containment of high energy debris, or

(2) An acceptable level of integrity of the design, including the high energy parts, has been established, or

(3) An appropriate combination of (1) and (2).

CS-E 90 Prevention of Corrosion and Deterioration

(a) Each Engine component and each item of equipment must be protected from corrosion and deterioration in an approved manner.

(b) Materials which will render the Engine inherently self-protecting against corrosion, without the use of internal and external corrosion inhibitors, must be used wherever possible.

CS-E 100 Strength

(a) The maximum stresses developed in the Engine must not exceed values conforming to those established by satisfactory practice for the material involved, due account being taken of the particular form of construction and the most severe operating conditions. Where a new type of material is involved, evidence must be available to substantiate the assumed material characteristics. For Turbine Engines, due consideration must be given to the effects of any residual stresses in Engine Critical Parts.

(b) The Engine components which form part of the Engine mounting and any other parts of the Engine liable to be critically affected must, when the Engine is properly supported by a suitable Engine-mounting structure, have sufficient strength to withstand the flight and ground loads for the aircraft as a whole in combination with the local loads arising from the operation of the Engine.

(c) Each Engine must be designed and constructed to function throughout its declared flight envelope and operating range of rotational speeds and power/thrust, without inducing excessive stress in any Engine part because of vibration and without imparting excessive vibration forces to the aircraft structure.

CS-E 110 Drawings and Marking of Parts – Assembly of Parts

(a) The drawings for each Engine component and each item of equipment must give full particulars of the design and must indicate the materials used in terms of their specifications. The protective finish and, where applicable, the surface finish, must be indicated. Any tests necessary to establish the manufacturing quality of components or equipment must be quoted on the relevant drawings either directly or by reference to other suitable documents.

(b) Except where otherwise agreed each part must be marked so that it can be identified with the drawing to which it was made. The position of the markings must be indicated on the drawing.

(c) Certain parts (including Engine Critical Parts, see CS-E 515) as may be required by the Agency must be marked and the constructor must maintain records related to this marking such that it is possible to establish the relevant manufacturing history of the parts.

(d) Turbine Engine parts, the incorrect assembly of which could result in Hazardous Engine Effects, must be designed so as to minimise the risk of incorrect assembly or, where this is not practical, permanently marked so as to indicate their correct position when assembled.

(e) As part of the system safety assessment of CS-E 50 (d), the possibility and subsequent effect of incorrect fitment of instruments, sensors or connectors must be assessed. Where necessary, design precautions must be taken to prevent incorrect configuration of the system.

CS-E 120 Identification

(a) The Engine identification must comply with 21A.801 (a) and (b), and 21A.805.

(b) Major Engine 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 Engine variants.

CS-E 130 Fire Protection

(a) The design and construction of the Engine 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 Engines must minimise the probability of the occurrence of an internal fire that could result in structural Failure or Hazardous Engine Effects.

(b) Except as required by CS-E 130 (c), each external line, fitting and other component which contains or conveys flammable fluid during normal Engine operation must be at least Fire Resistant. Components must be shielded or located to safeguard against the 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 Engine, 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. For a Piston Engine having an integral oil sump of less than 23.7 litres capacity, the oil sump need not be Fireproof nor be enclosed by a Fireproof shield but still must comply with CS-E 130 (b).

(d) An Engine 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) In addition to specifications of CS-E 130 (a) and (b), Engine control system components which are located in a designated fire zone must be at least Fire Resistant

(f) Unintentional accumulation of hazardous quantities of flammable fluid within the Engine must be prevented by draining and venting.

(g) 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 grounded to the Engine reference in order to minimise the risk of ignition in external areas where flammable fluids or vapours could be present.

(h) Those features of the Engine which form part of the mounting structure or Engine 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-E 30.

CS-E 140 Tests - Engine Configuration

(a) The configuration of the Engine or components or parts to be tested must be sufficiently representative of the type design for the purpose of the test.

(b) All automatic controls and protections must be in operation unless it is accepted that this is not possible or that they are not required because of the nature of the test.

(c) Variable devices that are not intended to be adjusted during Engine operation must be set in accordance with the type design prior to each test, except when the particular test demands adjustments to be made or as required by paragraphs relating to specific tests. Other variable devices must operate or be operated in a manner consistent with both the type design and the operating instructions to be provided under CS-E 20 (d) unless otherwise necessary for the purpose of the test.

(d) (1) All equipment drives not essential to the satisfactory functioning of the Engine must be disconnected or off loaded during the Calibration Tests of CS-E 350 or CS-E 730. Throughout all other tests, except as required by CS-E 140 (d)(2), they must be suitably loaded, either with the equipment listed in the constructor's declaration or with slave units of a suitable type.

(2) When running the additional endurance test sequence required by CS-E 740 (c)(3)(iii), the accessory drives and mounting attachments need not be loaded if it can be substantiated that there is no significant effect to the durability of any accessory drive or Engine component. However, the equivalent Engine output power extraction from the power turbine rotor assembly must be added to the Engine shaft output.

(e) Certain features prescribed in CS-E 500 and CS-E 560 to CS-E 590 may be incorporated as part of the aircraft installation rather than as part of the Engine type design. In this case, where the performance of the Engine is affected, the features concerned must be satisfactorily represented throughout the Engine tests.

(f) In addition to the combined Engine and Propeller tests required by CS-E 180, other tests prescribed in Certification Specifications for Propellers may be conducted jointly with Engine tests where it is accepted that these combined tests do not constitute a less severe test for either the Engine or the Propeller or both.

CS-E 150 Tests - General Conduct of Tests

(a) The fuel and oil used for all tests must normally be chosen from those specified by the Applicant, but, where it may have relevance to the results of any particular test, the actual fuel and oil to be used (including any additives) must be justified.

(b) During all tests, only servicing and minor repairs must be permitted except that major repairs or replacement of parts may be resorted to, provided that the parts in question are subjected to an agreed level of penalty testing.

(c) Except where declared by the Applicant, no artificial means of increasing the humidity of the ambient air must be employed.

(d) For all tests, parameters relevant to the purpose of the test must be agreed and recorded at appropriate times during the test. Where possible, Engine conditions must be allowed to stabilise before observations are taken. In particular, observations taken less than 3 minutes after a change of Engine conditions must not be included in assessment of performance, unless the rating cannot be used for more than 3 minutes.

(e) Adjustments made in compliance with CS-E 140 (c) must be checked and unintended variations from the original settings recorded after each test.

(f) All test bed equipment and all measuring equipment used for tests must be appropriately calibrated.

CS-E 160 Tests – History

(a) In order to enable compliance with 21A.21 (c)(3) of Part 21, should a Failure of an Engine part occur during the certification tests, its cause must be determined and the effect on the airworthiness of the Engine must be assessed. Any necessary corrective actions must be determined and substantiated.

(b) The development history of the Engine or component or equipment of the Engine must be considered. Any significant event, relevant to airworthiness of the Engine, occurring during development and not corrected before certification tests, must also be assessed under CS-E 160 (a).

CS-E 170 Engine Systems and Component Verification

For those systems or components which cannot be adequately substantiated by other tests of CS-E, additional tests or analyses must be conducted to demonstrate that the systems or components are able to perform the intended functions in all declared environmental and operating conditions.

CS-E 180 Propeller Functioning Tests

(a) If approval of the Engine for use with a Variable Pitch Propeller is sought by the Applicant, a sufficient portion of the tests prescribed in CS-P, must be made either during or on the completion of the endurance test of CS-E 440 or CS- 740 to demonstrate that the Propeller-Engine combination will function satisfactorily. The minimum number of tests which will be acceptable for Engine approval is given below.

(b) The following tests must be carried out:

(1) Pitch change cycles

(i) Turbine Engines

(A) Fifty forward pitch change cycles, by operation of Propeller control. (Only applicable when a separate Propeller control is provided). Each cycle must include the maximum range of pitch likely to be experienced in normal use.

(B) 100 operations with-drawing the flight fine pitch lock. These may be combined with the Engine decelerations prescribed in CS-E 740 for the endurance test.

(ii) Piston Engines – For Engines to be approved for use with a variable pitch Propeller, 100 representative forward pitch change cycles must be made across the range of pitch and rotational speed.

(2) 10 feathering cycles. In addition, for turbine Engines, where the oil tank is to be approved as part of the Engine, the ability to complete one cycle (i.e. one feather and unfeather) when the supply of oil has been reduced to the feathering reserve oil (see CS-E 570 (b)(6)) must be demonstrated.

(3) 200 reverse pitch change cycles (braking or manoeuvring, whichever is greater), and sustaining the appropriate maximum declared Engine conditions for 1 minute during each cycle. In this case, the periods of the endurance test covering the range of cruising conditions may be reduced by a total of 3 hours.

(4) 1 reverse (manoeuvring) pitch change cycle, sustaining the appropriate maximum declared Engine conditions for 5 minutes.

(c) Additional tests with Reversible Pitch Propellers on Piston Engines –

(1) Where approval of an Engine for use with Reversible Pitch Propellers is sought, the appropriate tests of Certification Specifications for Propellers must be run on Engines sufficiently representative of the type design.

(2) After completion of these tests, those parts of the Engines which may be affected by the reversed thrust or air flow, must be removed and examined and must be shown to have suffered no adverse effects.

(d) Any other tests considered necessary to demonstrate that the Propeller-Engine combination will function satisfactorily.

CS-E 190 Engines for Aerobatic Use

Where approval is sought for an Engine intended for use in an aeroplane for which the Flight Manual will approve aerobatics or semi-aerobatic flight, the ability of the Engine to continue to function safely in conditions of inverted flight or for intentional negative g conditions for specified periods must be demonstrated. Where the evidence is considered to be acceptable, and such tests as are necessary have been completed satisfactorily, the Engine Type certificate data sheet will be endorsed by means of a note, e.g. 'the Engine may be used under sustained negative g or inverted flight conditions for continuous periods not exceeding... seconds'.

SUBPART B — PISTON ENGINES, DESIGN AND CONSTRUCTION

CS-E 210 Failure Analysis

(a) A Failure analysis of the Engine, including the control system for a typical installation must be made to establish that no single Fault, or double Fault if one of the Faults may be present and undetected during pre-flight checks, could lead to unsafe Engine conditions beyond the normal control of the flight crew.

(b) In certain cases the Failure analysis will depend on assumed installed conditions. Such assumptions must be stated in the analysis.

CS-E 230 De-Icing and Anti-Icing Precautions

(a) The design of the Engine induction system must be such as to minimise the risk of ice formation adversely affecting the functioning of the Engine and, if necessary, must include provision for the use of a means for ice prevention

(b) Where necessary, provision must be made for the fitting of an induction thermometer or ice indicator, as appropriate for the control of the particular system.

CS-E 240 Ignition

All spark-ignition Engines shall comply with the following:

(a) The Engine shall be equipped either with:-

(1) A dual ignition system having entirely independent magnetic and electrical circuits, including spark plugs, or,

(2) An ignition system which will function with at least equivalent reliability.

(b) If the design of the ignition system includes redundancy :-

(1) The maximum power reduction resulting from loss of redundancy shall be declared in the appropriate manual(s).

(1) Provision shall be made to establish the serviceability of the ignition system. The associated procedures and required inspection intervals shall be specified in the appropriate manual(s).

CS-E 250 Fuel System

(a) Each fuel specification to be approved, including any additive, and the associated limitations in flow, temperature and pressure that ensure proper Engine functioning under all intended operating conditions must be declared and substantiated.

Any characteristic of fuel conforming to the specification(s) to be approved which is likely to adversely affect Engine functioning or durability, must be identified so that, where necessary, Engine or rig testing using appropriate fuel may be conducted.

(c) Filters, strainers or other equivalent means must be provided to protect the fuel system from malfunction due to contaminants. These devices must have the capacity to accommodate any likely quantity of contaminants, including water, in relation to recommended servicing intervals. These means may be provided in the aircraft fuel system; in such case, the characteristics of the means shall be specified in the instructions for installation.

(d) It shall not be possible for fuel to drain into the Engine when it is not running, in such quantities as to introduce a risk of 'hydraulicing' or in any way adversely affect the mechanical reliability of the Engine.

(e) Design precautions must be taken against the possibility of errors and inadvertent or unauthorised changes in setting of all fuel control adjusting means.

CS-E 260 Engine Cooling System

(a) The design and construction of the Engine cooling system must ensure adequate cooling in all normal operating conditions within the flight envelope. Any reliance upon assumed installed conditions shall be declared in the instructions for installation.

(b) For liquid-cooled Engines, it must be shown that the coolant will not boil under any normal operating condition within the flight envelope, under all additive concentrations approved for use.

(c) For liquid-cooled Engines, to prevent Engine malfunction due to overheating, appropriate means or provision for means shall be provided to detect loss of coolant.

CS-E 270 Lubrication System

(a) It shall not be possible for oil to drain into the Engine when it is not running, in such quantities as to introduce a risk of 'hydraulicing' or in any way adversely to affect the mechanical reliability of the Engine.

(b) The oil flow between the Engine lubrication system and the Propeller control system or other system utilising oil supplied by the Engine, shall not prevent oil pressure being maintained within approved limits at all operating conditions within the flight envelope, allowance being made for deterioration of the Engine.

(c) All parts of the oil system that are not inherently capable of accepting contaminants likely to be present in the oil or otherwise introduced into the oil system shall be protected by suitable filter(s) or strainer(s). These shall provide a degree of filtration sufficient to preclude damage to the Engine and Engine equipment and have adequate capacity to accommodate contaminants in relation to the specified servicing intervals. These filters or strainers may be provided as part of the aircraft; in such cases, their characteristics will be specified in the instructions for installation

(d) Adequate oil cooling shall be provided, or the required oil cooling means shall be defined in the instructions for installation, to ensure that temperature limits are not exceeded in any normal operating condition within the flight envelope.

(e) Each type of oil, and brand if appropriate, must be declared and substantiated, along with any associated limitations.

(f) Any oil characteristic which is likely to be critical for Engine functioning or durability must be identified. Where necessary, Engine or rig testing using appropriate oil shall be conducted.

CS-E 290 Hand Turning

It must be possible to rotate the crankshaft in controlled slow motion. Where this is effected by hand-turning gear as distinct from the Propeller, a means of safe guarding the operator against injury, if the Engine starts or kicks back, must be provided. It must not be possible to damage the Engine by use of the hand-turning gear.

SUBPART C — PISTON ENGINES, TYPE SUBSTANTIATION

CS-E 300 Conditions Applicable to All Tests

(a) *Coolant Flow*. (Applicable to liquid-cooled Engines only). Equipment must be provided to permit simultaneous observation of the coolant flow to each bank of cylinders.

(b) *Cylinder Temperatures.* (Applicable to air-cooled Engines only). Cylinder temperature observations must be made on all cylinders throughout the Rating Checks, Detonation, Endurance and Calibration Tests. The location of the point(s) at which the temperature of each cylinder is measured must be recorded.

(c) *Temperatures – General.* Except as prescribed in CS-E 300 (d) and (e), the temperatures must be held throughout each stage, within the limits given in Table 1, to the values declared as the maxima appropriate to the power, where that power is a limiting condition.

TABLE 1

Temperature	Applicable to	Limits (°C)
Oil inlet	All Engines	± 3
Coolant outlet	Liquid-cooled Engines	± 3
Cylinder	Air-cooled Engines	± 5
Charge Cooler (when fitted)	All Engines	± 3

(d) *Temperatures – At High Powers*

(1) For the stages in which the Engine is run at Maximum Continuous Power, the limits of CS-E 300 (c) apply to 50% of the total running period of each stage; the remaining 50% of the period must be run at not less than the Maximum Best Economy Cruising temperatures.

(2) For the stages in which the Engine is run at Take-off Power for not less than 1 hour continuously, the limits of CS-E 300 (c) apply to a continuous period of not less than 15 minutes in each hour only, during which at least one full set of observations must be taken; the remainder of each hour must be run at not less than the Maximum Best Economy Cruising temperatures.

(3) The limits of CS-E 300 (c) are not applicable to stages in which the Engine is run for less than 15 minutes continuously at any one power.

(e) *Temperature - Calibrations Tests*. For the power performance items of the calibration tests in CS-E 350, the limits of CS-E 300 (c) must apply except that the declared temperature may be obtained and set at the commencement of each curve and thereafter be left unadjusted, provided that the temperatures do not vary appreciably from those declared.

(f) *Torque Measurement* - For testing requiring the measurement of Engine power, an acceptable method of establishing the torque of the Engine shall be defined.

CS-E 320 Performance Correction

(a) All performance results shall be corrected to the conditions of the Standard Atmosphere, in accordance with an internationally recognised method.

(b) Where Engine power is affected by cylinder temperature or coolant temperature the performance results shall be corrected to the minimum engine power within the range of temperatures to be approved for use.

CS-E 330 Tests - General

A single Engine must be used for all the tests except that, if so desired, the vibration, calibration, and detonation tests may be made on Engines of the same type as the Engine used for the other tests so long as there is essential similarity to that Engine. The vibration tests may be made during preliminary development of the type provided that the design standard and power rating of the Engine used do not differ essentially from the prototype.

CS-E 340 Vibration Tests

(a) Tests by approved methods must be made on an appropriate mounting to satisfy the Agency that no dangerous torsional or flexural vibration characteristic exists in the dynamic system throughout the operating range of crankshaft rotational speed and Engine power used in flight. In the absence of adequate evidence to the contrary, a maximum stress shown to be safe for continuous use must be regarded as the maximum safe stress. The range must include low power operation and must comprise crankshaft speeds from idling to the highest of the following: 110% of the desired Maximum Continuous speed, 105% of the desired maximum Take-off speed, or the maximum desired Over-speed. Observations must be made at increments of 50 crankshaft rpm throughout this range. Tests covering the range up to the desired maximum take-off speed rating must also be made with that cylinder not firing which is most critical from the point of view of vibration.

(b) A representative flight Propeller must be used for these tests. In the case of a Fixed Pitch Propeller a 'throttle' curve must be run. In the case of a Variable Pitch Propeller the procedure must normally be the same, with the Propeller blade pitch set to a fixed value which will give maximum Engine power at maximum Engine rotational speed. If the results of the tests with a Variable Pitch Propeller show the existence of a serious critical vibration within the operating speed range, a more detailed investigation must be made at speeds within the critical range.

(c) A harmonic analysis of the vibration records must be made by a method approved by the Agency, at each increment of Engine speed and the results plotted against Engine speed so that the predominant orders of vibration and their relative magnitudes are clearly shown throughout the operating speed range of the Engine.

(d) In cases where torsional strain in the Propeller shaft has been measured by means of a torsional strain type of vibration pickup, the torque amplitude of the orders of vibration must be plotted about the mean torque curve for the Engine. In other cases where for practical reasons it is impossible to use the strain type of torsional vibration pickups, and a seismic type of instrument attached to the free end of the crankshaft is used, the angular displacement amplitudes of the various orders of vibration at the free end of the crankshaft must be plotted against Engine speed.

(e) A tabulation based on the theoretical and test results obtained must be made detailing the following information relating to resonant conditions for the most serious criticals: Engine speed, order of vibration, frequency, maximum and minimum values of vibration stress in the crankshaft and Propeller shaft and the region at which they occur. Diagrams showing the displacement curves for the modes of vibration associated with these criticals should also be presented.

(f) If excessive vibration is found to be present in the operating range of the Engine, suitable remedial measures must be taken prior to the endurance test of CS-E 440.

(g) If moderate vibration is found to exist, which is not sufficiently serious to warrant the introduction of modifications but needs proof of its effect on the Engine, a vibration penalty test must be substituted for those stages of the endurance test as are considered most suitable and must include sufficient duration under the most adverse vibration condition to establish the ability of the Engine to resist fatigue Failure.

CS-E 350 Calibration Tests

(a) The power characteristics of the Engine must be established, under all normal operating conditions within the declared flight envelope, by means of sufficient calibration testing.

(b) In order to identify the Engine power changes that may occur during the endurance test of CS-E 440, sea level power calibration curves of the test engine shall be established at the beginning and the end of the endurance test

CS-E 360 Detonation Tests

For spark ignition Engines:

(a) A test shall be conducted to demonstrate that the Engine can function without detonation at all operating conditions within the flight envelope. If the design of the ignition system includes redundancy, this test shall be repeated in degraded operating modes.

(b) During the test of CS-E 360 (a), the Engine shall be operated throughout the range from the lowest Engine rotational speed intended to be used for cruising, to the declared maximum Engine rotational speed, at the conditions of power setting, mixture setting (if applicable), oil temperature, coolant or cylinder-head temperatures, and manifold air temperature, most likely to cause detonation. An agreed method shall be used to determine the degree of detonation.

CS-E 370 Starting Tests

(a) At least 100 successful Engine starts must be made, either during or at the end of the endurance test of CS-E 440, using the normal means of starting and the technique recommended by the Engine constructor. Half the starts must be made with the Engine cold and half with the Engine hot.

(b) Time to start, number of attempts, ambient air temperature, and (in the case of electric starters) current consumption, must be recorded at the beginning of each 10-hour period. In addition, a record must be made of the means and amount of priming, if employed, and whether or not oil dilution is used.

(c) If alternative means of starting are provided for emergency or standby use, not less than 10 additional starts on each of the alternative means of starting provided must be made. These tests may be made either as part of the endurance test of CS-E 440 or separately in which case they must be followed by a suitable strip examination.

CS-E 380 Low Temperature Starting Tests

(a) Tests shall be carried out to demonstrate that the Engine can be started under the lowest temperature conditions to be approved, without causing damage to the Engine. At least 25 Engine starts shall be made at oil inlet temperatures, evenly distributed between + 5°C and the minimum temperature to be declared for starting. Before each start attempt, the oil inlet temperature and the temperature of the Engine shall be substantially the same as the temperature of the ambient air.

(b) The tests shall be carried out using representative aircraft and ground starting equipment and using the starting technique defined in the operating instructions.

(c) The Engine shall be fitted with a representative flight Propeller or its equivalent, and representative aircraft equipment, as defined in CS-E 20 (c).

(d) Both before and after the completion of the low temperature starting tests, the Engine and equipment shall be submitted to a strip examination to demonstrate that the condition of the Engine is satisfactory for continued safe operation. Measurements shall be made of those dimensions liable to change by reason of wear or distortion.

CS-E 390 Acceleration Tests

(a) The tests of CS-E 390 (a)(1) and (2) must be carried out at the end of the endurance test of CS-E 440 without heated intake air and repeated, when applicable, with intake air heated to the maximum temperature likely to be experienced at any operating condition within the flight envelope.

    (1) For all Engines, except two-speed supercharged Engines, five accelerations must be made from idling conditions to Take-off Power.

    (2) For two-speed supercharged Engines, five accelerations must be made from idling conditions up to each condition

        (i) To Take-off Power with supercharger in low gear

        (ii) To Maximum Continuous Power with supercharger in high gear.

    (b) The Engine shall respond without hesitation and accelerate smoothly throughout the range, when the power lever is moved from the minimum flight idle position to the Take-off or Maximum Continuous position, as appropriate, in not more than one second.

(c) If the Engine is to be approved for use with a propeller with variable or adjustable pitch, for the tests of CS-E 390(a) the propeller pitch shall be set such that the Engine will produce not less than rated Take-off power at the Engine rotational speed used to define the Take-off rating (see CS-E 40 (h)).

(d) Each acceleration (except for those with a supercharger in high gear) shall be made starting from the minimum temperatures for acceleration from idle to be declared in the operating limitations. Each acceleration with a supercharger in high gear shall be made from ambient conditions.

CS-E 400 Over-speed Tests

(a) The tests of (1) and (2) shall be completed during or at the end of the endurance test of CS-E 440.

    (1) All Engines, except two-speed supercharged Engines. 20 runs, each of 30 seconds duration, at the declared Maximum Engine Over-speed or at a speed 5% in excess of the declared maximum Engine rotational speed, whichever is greater. The power setting for these runs shall not be less than that declared for the Maximum Continuous rating.

(2) Two-speed Supercharged Engines. 20 runs, each of 30 seconds duration, at the declared Maximum Engine Over-speed or at a speed 5% in excess of the declared maximum Engine rotational speed, whichever is the greater, 10 with the supercharger in low gear and 10 with the supercharger in high gear. The power setting for these runs shall not be less than that declared for the Maximum Continuous rating.

(b) A further test consisting of a total of 10-minutes run in stages of not less than one minute shall be made at the declared Maximum Over-speed or at a speed not less than 5% in excess of the declared maximum Engine rotational speed, whichever is greater. The power for this test shall be not greater than 30% Take-off Power. The oil inlet temperature shall be within 30°C of the declared maximum temperature for take-off. This test may be run on a dynamometer.

CS-E 430 Water Spray Tests

(a) *Installation Conditions.* With the Engine suitably cowled or shielded to be fully representative of an installed Engine, a water spray must be applied throughout three periods of running.

(b) *Running Conditions.* Each period of running must comprise –

- Start
- Warm up
- Ignition checks
- 5 minutes at Take-off Power
- 15 minutes at Maximum Continuous Power
- 15 minutes at Maximum Best Economy Cruising Power
- 25 minutes at 60% of Maximum Continuous Power at 75% of Maximum Best Economy Cruising crankshaft rotational speed
- Ignition check and accelerations.

Two-speed supercharged Engines must run the whole test in low gear.

(c) *Interval Conditions.* An interval of 24 hours must be allowed after each period of running. No adjustment or artificial drying-off must be undertaken from the commencement of the test and, when not running, the Engine must be completely covered in a manner which will fully promote moisture penetration. At the conclusion of the third cycle of running and standing, the Engine must be subjected to 5 minutes running at Take-off Power without the water spray.

(d) *Water Spray Conditions.* The spray must be arranged to deliver water in a manner representative of very heavy rain over the whole frontal area of the Engine including cowling, air intakes, etc., but not necessarily the Propeller tips, throughout the full running time. The rate of delivery, R, must be assessed from the formula –

$R = 12{\cdot}2F$ litres/min

where F, in m^2, is frontal area of nacelle.

CS-E 440 Endurance Test

(a) (1) The test must be made in the order defined in the appropriate schedule and in suitable non-stop parts. In the event of a stop occurring during any part, the part must be repeated unless it is agreed to be unnecessary. The complete test may need to be repeated if an excessive number of stops occur.

(2) The whole of the endurance test must be run with the oil pressure set to give the declared normal operating pressure at Maximum Continuous conditions except that one hour at Take-off conditions and nine hours at Maximum Continuous must be run with the pressure set to give the declared minimum for completion of the flight at Maximum Continuous conditions. The test conditions may be revised, if necessary, to avoid having to stop the Engine during particular parts in order to reset the oil pressure.

(3) Where the operating conditions are prescribed in terms of a percentage of Maximum Continuous Power, the crankshaft rotational speed, power setting and mixture setting (if applicable)mixture setting (if applicable) must be appropriate to the simulation of the most severe cruising conditions at this power. Where in such cases the power setting is not greater than that for Maximum Best Economy Cruising Power Conditions, the mixture setting (if applicable) mixture setting (if applicable) must be compatible with the power setting.

(4) Throughout each part of the endurance test, the crankshaft rotational speed and power setting must be maintained at, or as near as possible to, the declared maximum values appropriate to the Engine operating conditions prescribed. A repeat of the run might be required if, for any reason, the observed crankshaft rotational speed and power setting deviate by more than ± 1.5% from the declared maximum values.

(5) *Propellers*. A representative flight Propeller must be used during this test.

(i) *Variable Pitch Propellers*. The blade setting of the Propeller need not be set precisely as for flight conditions. If, however, the blade setting does not allow the conditions, detailed in the test schedule agreed for the particular Engine, to be achieved, the limitations approved for the Engine will be based on the conditions at which the test is run.

(ii) *Fixed Pitch Propellers*. A sufficient number of Propellers, agreed prior to the commencement of the tests, must be used for reasonable approximations to the various power ratings to be made. The number normally acceptable is two, for instance, one primarily suited to Maximum Best Economy Cruising Power Conditions, and the other primarily suited to Maximum Continuous or Take-off conditions.

(iii) *Limitations not Simultaneously Attainable*. If a fixed pitch Propeller is fitted for the tests, the Engine must be operated at the maximum power setting or maximum crankshaft rotational speed appropriate to the conditions of the tests, whichever limitation is reached first.

(6) The Engine must be subjected to an agreed extent of pre-assembly inspection, and a record must be made of the dimensions liable to change by reason of wear, distortion and creep. A record must also be made of the calibrations and settings of separately functioning Engine components and equipment (e.g. the control system, pumps, actuators, valves).

(b) *Schedules*

(1) *Schedule for Unsupercharged Engines and Engines Incorporating Gear-driven, Single-speed Superchargers*

Part 1 A 30-hour run consisting of alternate 5 minute periods at Take-off Power and speed and Maximum Best Economy Cruising Power or Maximum Recommended Cruising Power conditions.

Part 2 A 20-hour run consisting of alternate periods of 1½ hours at Maximum Continuous Power and speed and ½ hour at 75% Maximum Continuous Power and 91% Maximum Continuous speed.

Part 3 A 20-hour run consisting of alternate periods of 1½ hours at Maximum Continuous Power and speed and ½ hour at 70% Maximum Continuous Power and 89% Maximum Continuous speed.

Part 4 A 20-hour run consisting of alternate periods of 1½ hours at Maximum Continuous Power and speed and ½ hour at 65% Maximum Continuous Power and 87% Maximum Continuous speed.

Part 5 A 20-hour run consisting of alternate periods of 1½ hours at Maximum Continuous Power and speed and ½ hour at 60% Maximum Continuous Power and 84·5% Maximum Continuous speed.

Part 6 A 20-hour run consisting of alternate periods of 1½ hours at Maximum Continuous Power and speed and ½ hour at 50% Maximum Continuous Power and 79·5% Maximum Continuous speed.

Part 7 A 20-hour run consisting of alternate 2½ hour periods at Maximum Continuous Power and speed and Maximum Best Economy Cruising Power or Maximum Recommended Cruising Power conditions.

(2) *Schedule for Engine Incorporating a Gear-driven Two-speed Supercharger.*

Part 1 A 30-hour run in the lower gear ratio consisting of alternate 5 minute periods at Take-off Power and speed and Maximum Best Economy Cruising Power or Maximum Recommended Cruising Power Conditions.

If a Take-off Power rating is desired in the higher gear ratio, 15 hours of the 30-hour run must be made in the higher gear ratio in alternate periods of 5 minutes at the power obtainable with the Take-off Critical Altitude power setting and Take-off speed and 5 minutes at 70% high ratio Maximum Continuous Power and 89% high ratio Maximum Continuous speed.

Part 2 A 15-hour run in the lower gear ratio consisting of alternate periods of one hour at Maximum Continuous Power and speed and ½ hour at 75% Maximum Continuous Power and 91% Maximum Continuous speed.

Part 3 A 15-hour run in the lower gear ratio consisting of alternate periods of one hour at Maximum Continuous Power and speed and ½ hour at 70% Maximum Continuous Power and 89% Maximum Continuous speed.

Part 4 A 30-hour run in the higher gear ratio at Maximum Continuous Power and speed.

Part 5 A 5-hour run consisting of alternate periods of 5 minutes in each of the supercharger gear ratios. The first 5 minutes of each 10-minute period must be made in the higher gear ratio at Maximum Continuous speed and the power obtainable with 90% of Maximum Continuous power setting in the higher gear ratio under sea-level conditions. The condition for operation for the following 5-minute period in the lower gear ratio must be that obtained by shifting to the lower gear ratio at constant speed.

Part 6 A 10-hour run in the lower gear ratio consisting of alternate periods of one hour at Maximum Continuous Power and speed and one hour at 65% Maximum Continuous Power and 87% Maximum Continuous speed.

Part 7 A 10-hour run in the lower gear ratio consisting of alternate periods of one hour at Maximum Continuous Power and speed and one hour at 60% Maximum Continuous Power and 84·5% Maximum Continuous speed.

Part 8 A 10-hour run in the lower gear ratio consisting of alternate periods of one hour at Maximum Continuous Power and speed and one hour at 50% Maximum Continuous Power and 79·5% Maximum Continuous speed.

Part 9 A 20-hour run in the lower gear ratio consisting of alternate 2-hour periods at Maximum Continuous Power and speed and Maximum Best Economy Cruising Power and speed or at Maximum Recommended Cruising Power and speed.

Part 10 A 5-hour run in the lower gear ratio at Maximum Best Economy Cruising Power and speed or Maximum Recommended Cruising Power and speed.

(3) *Schedule for Engine Incorporating a Turbocharger*. For Engines incorporating a turbocharger, the Schedule of CS-E 440 (b)(1) will apply, except that –

(i) Entire run specified in Part 1 must be made at sea-level pressure,

(ii) The portions of the runs specified in Parts 2 to 7 at Maximum Continuous Power must be made at Critical Altitude pressure and the portions of the runs at other powers must be made at 2 500 m altitude pressure, and

(iii) The turbocharger used during the 150-hour endurance test must be run on the bench for an additional 50 hours at a representative inlet pressure and at the limiting turbine wheel inlet gas temperature and rotational speed for Maximum Continuous Power operation unless the limiting temperature and speed are maintained during 50 hours of the rated Maximum Continuous Power operation.

(c) After completion of the test, the Engine must be subject to a strip inspection, and the dimensions measured in accordance with CS-E 440 (a)(6) must be re-measured and recorded. The condition of the Engine must be satisfactory for safe continued operation. Separately functioning Engine components and equipment must be functionally checked prior to strip to ensure that any changes in function or settings are satisfactory for normal operation.

CS-E 450 Ignition Tests

For spark-ignition Engines:

(a) If the design of the ignition system includes redundancy, the reduction in Engine power resulting from loss of redundancy shall be established. Tests shall be carried out with the Engine running at Take-off power setting at the beginning and at the end of each part of the endurance test of CS-E 440.

(b) In no case shall the reduction in power during the test exceed the value declared under CS-E 240 (b)(1).

CS-E 460 Backfire Tests

For spark ignition Engines:

(a) After completion of the endurance test of CS-E 440, functioning tests of the Engine shall be made to determine if there is any tendency for the Engine to backfire when using the normal means of starting and during accelerations effected by any reasonable means.

(b) (1) If after the completion of the endurance test, no tendency for the Engine to backfire is established, three backfires shall be produced artificially on an Engine of the same type. If, however, a tendency to backfire is established, at least twenty backfires shall be produced artificially on an Engine of the same type.

(2) If necessary, mechanical mal-adjustment shall be used to cause backfiring. Maladjustment may include the mixture setting (if applicable) artificially weakened, non-standard ignition timing, an inlet tappet adjusted to hold the valve off its seat, or crossed ignition leads.

(3) The effect of backfires occurring during starting and during running conditions shall be established.

(4) In order to qualify for approval, the Engine shall not suffer serious damage as a result of these tests.

CS-E 470 Contaminated Fuel

Evidence shall be provided that the complete Engine fuel system is capable of operating without Engine malfunctioning under any likely quantities of solid contaminant, water and ice present in the fuel. If compliance relies upon fuel anti-icing additive(s) or other means incorporated in the aircraft fuel system, this shall be declared under CS-E 30 together with a statement of the conditions under which use of additive(s) is approved.

SUBPART D – TURBINE ENGINES; DESIGN AND CONSTRUCTION

CS-E 500 Functioning

(a) The Engine must be free from dangerous surge and instability throughout its operating range of ambient and running conditions within the air intake pressure and temperature conditions declared by the constructor.

(b) [Reserved]

(c) All Engines must be equipped with an igniter system suitable for starting the Engine on the ground and in flight at all altitudes up to a declared altitude.

CS-E 510 Safety Analysis

(a) (1) An analysis of the Engine, 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-E510 (d) or that result in the Hazardous Engine Effects defined in CS-E 510 (g)(2).

(2) A summary must be made of those Failures that could result in Major Engine Effects or Hazardous Engine Effects as defined in CS-E 510 (g), together with an estimate of the probability of occurrence of those effects. Any Engine Critical Part must be clearly identified in this summary.

(3) It must be shown that Hazardous Engine Effects are predicted to occur at a rate not in excess of that defined as Extremely Remote (probability less than 10^{-7} per Engine flight hour). The estimated probability for individual Failures may be insufficiently precise to enable the total rate for Hazardous Engine Effects to be assessed. For Engine certification, it is acceptable to consider that the intent of this paragraph is achieved if the probability of a Hazardous Engine Effect arising from an individual Failure can be predicted to be not greater than 10^{-8} per Engine flight hour (see also CS-E 510 (c)).

(4) It must be shown that Major Engine Effects are predicted to occur at a rate not in excess of that defined as Remote (probability less than 10^{-5} per Engine flight 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 cannot be sensibly estimated in numerical terms. If the Failure of such elements is likely to result in Hazardous Engine Effects, reliance must be placed on meeting the prescribed integrity specifications of CS-E 515 in order to support the objective of an Extremely Remote probability of Failure. These instances must be stated in the safety analysis as required in CS-E 510 (a)(2).

(d) If reliance is placed on a safety system to prevent a Failure progressing to cause Hazardous Engine Effects, the possibility of a safety system Failure in combination with a basic Engine 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 applicant, 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-E 30.

(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 Engine Effects at a rate in excess of Extremely Remote, the maintenance intervals must be published in the airworthiness limitations section of the instructions for continued airworthiness required under CS-E 25. If errors in maintenance of the Engine, including the Engine Control System, could lead to Hazardous Engine Effects, appropriate procedures must be included in the relevant Engine 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-E 20 (d).

(f) If applicable, the safety analysis must also consider, but not be limited to, investigation of -

(1) Indicating equipment,

(2) Aircraft-supplied data or electrical power,

(3) Compressor bleed systems,

(4) Refrigerant injection systems,

(5) Gas temperature control systems,

(6) Engine speed, power or thrust governors and fuel control systems,

(7) Engine over-speed, over-temperature or topping limiters,

(8) Propeller control systems, and

(9) Engine or propeller thrust reversal systems.

(g) For compliance with CS-E, the following Failure definitions apply to the Engine :

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

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

(i) Non-containment of high-energy debris,

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

(iii) Significant thrust in the opposite direction to that commanded by the pilot,

(iv) Uncontrolled fire,

(v) Failure of the Engine mount system leading to inadvertent Engine separation,

(vi) Release of the propeller by the Engine, if applicable,

(vii) Complete inability to shut the Engine down.

(3) An effect falling between those covered in CS-E 510 (g)(1) and (2) must be regarded as a Major Engine Effect.

CS-E 515 Engine Critical Parts

The integrity of the Engine Critical Parts identified under CS-E 510 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 each Engine Critical Part to be withdrawn from service at an Approved Life before Hazardous Engine Effects can occur. Appropriate Damage 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-E 25 (b).

(b) A Manufacturing Plan which identifies the specific manufacturing constraints necessary to consistently produce Engine 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 Engine Critical Parts which will maintain Attributes consistent with those required by the Engineering Plan. These processes must become part of the instructions for continued airworthiness.

CS-E 520 Strength

(a) The major rotating components of the Engine must have adequate strength to withstand both the thermal and dynamic conditions of normal operation and any excessive thermal or dynamic conditions that may result from abnormal speeds, abnormal temperatures or abnormal vibration loads. In assessing the abnormal conditions to be considered, account must be taken of the Failure analysis prescribed in CS-E 510.

(b) Fixed structure in close proximity to rotating parts must be so arranged that any rub caused either by –

(1) Thermal expansion or contraction of parts to the extremes of movement within the operating envelope of the Engine, or

(2) Movement resulting from likely Fault conditions of either the fixed or rotating parts, will occur in a manner not likely to result in a Hazardous Engine Effect. As an alternative, a device giving warning of such unintended movement must be provided.

(c) (1) The strength of the Engine must be such that the shedding of compressor or turbine blades, either singly or in likely combinations, will not result in a Hazardous Engine Effect (e.g. as a long term effect in respect of those Failures which would not be detected by the declared instrumentation, such as vibration detectors) and within the likely shutdown time for those which would be detected, and during any continued rotation after shutdown.

(2) Data must be established and provided for the purpose of enabling each aircraft constructor to ascertain the forces that could be imposed on the aircraft structure and systems as a consequence

of out-of-balance running and during any continued rotation with rotor unbalance after shutdown of the Engine following the occurrence of blade Failure as demonstrated in compliance with CS-E 810. The data must include, but is not limited to, the relevant out-of-balance forces and Engine stiffnesses, together with the expected variations with time of the rotational speed(s) of the Engine's main rotating system(s) after blade Failure.

(d) Design consideration must be given to avoiding the risk of major rupture of Engine casings (particularly those which are subjected to high pressure loads) in the event of a local Failure in the casing or damage to the casing arising, for example, from a torching flame following a combustion system Failure.

CS-E 525 Continued Rotation

If any of the Engine's main rotating systems will continue to rotate after the Engine is shutdown for any reason while in flight, and means to prevent that continued rotation, are not provided, any continued rotation during the maximum period of flight and in the flight conditions expected to occur with that Engine inoperative must not result in effects that would be unacceptable under CS-E 510.

CS-E 540 Strike and Ingestion of Foreign Matter

(a) The Engine must be designed so that the strike and ingestion of foreign matter that is likely to affect only one Engine in any one flight will not cause any Hazardous Engine Effects as defined in CS-E 510 (g), except that events with a probability of occurrence lower than Extremely Remote need not be considered.

(b) The Engine must be designed so that the strike and ingestion of foreign matter that is likely to affect more than one Engine in any one flight will not preclude the continued safe flight and landing of the aircraft as a consequence of a Hazardous Engine Effect or an unacceptable

(1) Immediate or subsequent loss of performance;

(2) Deterioration of Engine handling characteristics;

(3) Exceedence of any Engine operating limitation.

CS-E 560 Fuel System

(a) (1) Each fuel specification to be approved, including any additive, and the associated limitations in flow, temperature and pressure that ensure proper Engine functioning under all intended operating conditions must be declared and substantiated.

(2) Any parameter of the fuel specification which is likely to adversely affect Engine functioning or durability must be identified so that, where necessary, Engine or rig testing using appropriate fuel may be conducted.

(3) The Engine fuel pump must have a margin of capacity over the maximum Engine demand in the flight envelope consistent with the assumed aircraft installation specifications.

(b) (1) Filters, strainers or other equivalent means must be provided to protect the fuel system from malfunction due to contaminants. These devices must have the capacity to accommodate any likely quantity of contaminants, including water, in relation to recommended servicing intervals and, if provided, the blockage or by-pass indication system (see also CS-E 670).

(2) Any main fuel filter or strainer provided between the Engine fuel inlet and any device having a significant function for the control of the thrust or power must have a means to permit indication of impending blockage of the filter or strainer either :

(i) To the flight crew or

(ii) To the maintenance crew, if it can be shown that the Engine will continue to operate normally with the levels of contamination specified, for a period equal to the inspection interval of the impending blockage indicator.

(c) If a by-pass means is provided on any filter or strainer, it must be designed such that, if the filter or strainer element is completely blocked, fuel will continue to flow at an acceptable rate through the rest of the system. In addition :

(1) The design of the by-pass must be such that, when it is in operation, the previously collected contaminants in the filter or strainer will not enter the Engine fuel system downstream of the filter or strainer.

(2) The design of the fuel system must be such that, when the by-pass is open, operation on contaminated fuel does not result in a Hazardous Engine Effect.

(3) If the maintenance action to be taken after by-pass operation is different from that following an indication of impending blockage, then indication of by-pass operation must be provided.

(d) The fuel system must be designed so that any accumulation of likely quantities of water which may separate from the fuel will not cause Engine malfunctioning.

(e) If icing can occur in the fuel system, continued satisfactory functioning of the Engine in such circumstances must be ensured without the need for any action by the flight crew. If compliance relies upon fuel anti-icing additives or other means incorporated in the aircraft fuel system, this must be declared under CS-E 30 together with a statement of the conditions which must be met.

(f) Provision must be made near each fuel pressure connection provided for instrumentation so as to limit the loss of fluid in the event of a pipe Failure.

(g) Design precautions must be taken against the possibility of errors and inadvertent or unauthorised changes in setting of all fuel control adjusting means.

CS-E 570 Oil System

(a) (1) The design of the oil system must be such as to ensure its proper functioning under all intended flight attitudes, installation, atmospheric and operating conditions, including oil temperature and expansion factors.

(2) There must be design precautions -

(i) To minimise the possibility of incorrect fitment of the closing device of the oil filling point or any other access point, or to preclude fluid loss in the event of incorrect fitment, and

(ii) To prevent entrance into the oil tank or into any oil tank outlet of any object that might obstruct the flow of oil through the system,

(3) Tank filler caps must be designed to provide an oil tight seal and designed so that they will not loosen in flight and must be marked with the word ‘oil’.

(4) Provision must be made near each oil pressure connection provided for instrumentation so as to limit the loss of fluid in the event of a pipe Failure.

(b) (1) All parts of the oil system that are not inherently capable of accepting contaminants likely to be present in the oil or otherwise introduced into the oil system must be protected by suitable filter(s) or strainer(s). These must provide a degree of filtration sufficient to preclude damage to the Engine and Engine equipment and have adequate capacity to accommodate contaminants in relation to the specified servicing intervals.

(2) If the most critical main oil filter does not incorporate a by-pass, then it must have provision for appropriate indication to the flight crew of impending blockage.

(c) Each filter or strainer that has a by-pass must be constructed and installed so that, if the filter or strainer element is completely blocked, the oil will flow through the rest of the system at a rate which is within the normal operating range of the system. In addition :

(1) The design of any by-pass must be such that, when the by-pass is in operation, previously collected contaminants in the filter or strainer will not enter the Engine oil system downstream of the filter or strainer.

(2) Indication of by-pass operation must be provided to permit appropriate maintenance action to be initiated. This indication need not be provided if the maintenance instructions require the same action to be taken following an impending blockage indication of the most critical main oil filter.

(d) The oil system, including the oil tank expansion space, must be adequately vented. All atmospheric vents in the oil system must be located, or protected, to minimise ingress of foreign matter that could affect satisfactory Engine functioning. Venting must be so arranged that condensed water vapour which might freeze and obstruct the line cannot accumulate at any point.

(e) (1) Except where the tank, its supports and all oil system components external to the Engine casing are Fireproof, a means must be provided to shut off the oil supply to the Engine. The means must be such that in the event of Failure of any oil system pipe, it will, when operated, prevent the discharge of hazardous quantities of oil.

(2) When applicable, operation of the shut-off means must not prevent the utilisation of any oil supply intended for the Propeller feathering operation.

(f) (1) Each un-pressurised oil tank must not leak when subjected to the maximum operating temperature and a differential pressure of 35 kPa.

(2) Each oil tank must have, or have provision for, an oil quantity indicator.

(3) If a Propeller feathering system depends on Engine oil,

(i) There must be means to trap an amount of oil in the tank if the supply becomes depleted due to Failure of any part of the lubricating system other than the tank itself. The amount of trapped oil must be enough to accomplish one feathering operation taking into account deterioration in service, and must be available only to the feathering pump.

(ii) Provision must be made to prevent sludge or foreign matter from entering the Propeller feathering system.

(iii) The design of the Engine oil system must be such that it is possible to complete the feathering and unfeathering operation under all normal operating conditions.

(g) (1) Each brand and type of oil to be approved, and the associated limitations, must be declared and substantiated.

(2) Any parameter of the oil specification which is likely to be critical for Engine functioning or durability must be identified so that, where necessary, Engine or rig testing using appropriate oil may be conducted.

CS-E 580 Air Systems and Compressor and Turbine Bleeds

(a) Where bleed air is used to cool or to pressurise areas of the Engine the functions of which could be detrimentally affected by the ingress of foreign matter (e.g. sand or dust) the design must be such that the passage of foreign matter of unacceptable quantity or unacceptable size is precluded.

(b) Air ducts external to the Engine must be so designed, routed or arranged that Failure of a duct will not cause an unsafe Engine condition (e.g. by excessive bleed or by secondary damage) before the Engine can be shut down, unless it can be shown that Failure of the duct is Extremely Remote.

CS-E 590 Starter Systems

Where the starter is declared as part of the Engine, its design, and that of its associated drive mechanism, must be such that over-speeding of the starter, to an extent which could result in a Hazardous Engine Effect, cannot occur under any Fault conditions in the Engine which cannot be classified as Extremely Remote. The possibility of the starter remaining connected, or subsequently becoming reconnected, to the Engine resulting from any Failure of the drive system must be considered. Where in showing compliance with this paragraph, dependence is placed on safety provisions to be provided as part of the installation, the need for such provisions must be declared.

SUBPART E – TURBINE ENGINES TYPE SUBSTANTIATION

CS-E 600 Tests – General

(a) All tests must be made with air intakes conforming to an acceptable design that is as representative of the powerplant intakes as is practicable.

(b) All tests must be made with acceptable representative jet pipes and propelling nozzles, except as permitted under CS-E 740 (f)(4)(i). The approval of other jet pipes and / or propelling nozzles for particular installations will be considered individually as necessary.

(c) Unless otherwise required for specific tests, any optional air bleed must be closed during all relevant tests.

(d) In cases where dirt accumulates within the Engine due to the test house environment, it will be acceptable to clean the Engine internally at agreed intervals during the endurance test of CS-E 740 by an agreed method which does not involve stripping any part of the Engine or necessitate the removal of the Engine from the test bed.

(e) Engines for Rotorcraft. All tests must normally be made with the Engine mounted in the attitude in which it will be installed.

CS-E 620 Performance Correction

(a) All performance results must be corrected to the following assumed conditions of atmospheric pressure and temperature at mean sea level:

(1) Pressure. 1013·25 hPa

(2) Temperature. 288 K

(3) Atmosphere. Dry air (if correction is significant).

(b) *Correction of Humidity.* No correction for humidity of the air supply may be made to the power obtained. Humidity corrections appropriate to high atmospheric temperatures, at altitudes up to 4 500 m must be established, however, for each type of turbine Engine, for use in the assessment of aircraft performance in these conditions.

CS-E 640 Pressure Loads

(a) *Static Pressure Loads*

It must be established by test, validated analysis or combination thereof that all static parts which are subject to significant gas or liquid pressure loads will not, for a stabilised period of one minute :

(1) Exhibit permanent distortion beyond serviceable limits or exhibit leakage which could result in a Hazardous Engine Effect when subjected to the greater of the following pressures:

(i) 1.1 times the maximum working pressure or,

(ii) 1.33 times the normal working pressure or,

(iii) 35 kPa above the normal working pressure, and

(2) Exhibit fracture or burst when subjected to the greater of the following pressures :

(i) 1·15 times the maximum possible pressure or,

(ii) 1·5 times the maximum working pressure or,

(iii) 35 kPa above the maximum possible pressure.

(b) Compliance with CS-E 640 (a) must take account of

(1) The operating temperature of the part,

(2) Any other significant static loads in addition to pressure loads,

(3) Minimum properties representative of both the material and the processes used in the construction of the part, and

(4) Any adverse geometry conditions allowed by the type design.

CS-E 650 Vibration Surveys

(a) Each Engine must undergo vibration surveys to establish that the vibration characteristics of those components that may be subject to mechanically or aerodynamically induced vibratory excitations are acceptable throughout the declared flight envelope. The Engine surveys and their extent must be based upon an appropriate combination of experience, analysis and component test and must address, as a minimum, blades, vanes, rotor discs, spacers and rotor shafts.

(b) The surveys must cover the ranges of power or thrust and both the physical and corrected rotational speeds for each rotor system, corresponding to operations throughout the range of ambient conditions in the declared flight envelope, from the minimum rotational speed up to 103% of the maximum physical and corrected rotational speed permitted for rating periods of two minutes or longer and up to 100% of all other permitted physical and corrected rotational speeds, including those that are Over-speeds. If there is any indication of a stress peak arising at the highest of those required physical or corrected rotational speeds, the surveys must be extended sufficiently to reveal the maximum stress values present, except that the extension need not cover more than a further 2 percentage points increase beyond those speeds.

(c) Evaluations must be made of:

(1) The effects on vibration characteristics of operating with scheduled changes (including tolerances) to variable vane angles, compressor bleeds, accessory loading, the most adverse inlet airflow distortion pattern declared by the manufacturer and the most adverse conditions in the exhaust duct(s); and

(2) The aerodynamic and aeromechanical factors which might induce or influence flutter in those systems susceptible to that form of vibration.

(d) Except as provided by CS-E 650 (e), the vibration stresses associated with the vibration characteristics determined under this CS-E 650, when combined with the appropriate steady stresses, must be less than the endurance limits of the materials concerned, after making due allowances for operating conditions and for the materials' permitted variations in properties. The suitability of these stress margins must be justified for each part. If it is determined that certain operating conditions, or ranges, need to be limited, operating and installation limitations must be established.

(e) The effects on vibration characteristics of excitation forces caused by Fault conditions (such as, but not limited to, out-of-balance, local blockage or enlargement of stator vane passages, fuel nozzle blockage, incorrectly scheduled compressor variables, etc.) must be evaluated by test or analysis or by reference to previous experience and be shown not to result in a Hazardous Engine Effect.

(f) Compliance with this CS-E 650 must be substantiated for each specific installation configuration that can affect the vibration characteristics of the Engine. If these vibration effects cannot be fully investigated during Engine certification, the methods by which they can be evaluated and compliance shown must be substantiated and defined in the Engine instructions for installation required under CS-E 20 (d).

CS-E 660 Fuel Pressure and Temperature

A substantiation must be made to establish the minimum and maximum fuel pressure and fuel temperature limits to be approved for the Engine. The details of the substantiation, which may involve rig tests and/or complete Engine tests, must be agreed with the Agency.

CS-E 670 Contaminated Fuel

(a) Evidence must be provided that the complete Engine fuel system is capable of functioning satisfactorily with fuel containing the maximum quantity of liquid/solid contamination, likely to be encountered in service, for a period sufficient to ensure that Engine malfunctioning as a result of this cause will not occur.

(b) The evidence must provide assurance that –

(1) The fuel system is not adversely affected by contamination which can pass through any filtration provided, either immediately or during subsequent running, and

(2) It will be possible for the Engine to complete a period equal to at least half the maximum flight duration of the aeroplane in which it is likely to be installed, with the same contaminant level, from the point at which indication of impending filter blockage is first given.

CS-E 680 Inclination and Gyroscopic Load Effects

It must be demonstrated that the effects of inclination on Engine running are not seriously detrimental and that the Engine is designed to withstand the gyroscopic loads resulting from normal flight manoeuvres.

CS-E 690 Engine Bleed

(a) For an Engine having bleed(s) for aircraft and/or Engine uses, the standard Engine endurance test schedule of CS-E 740 must be varied in accordance with this paragraph CS-E 690 (a) unless the use of the bleed(s) is substantiated by separate test and analysis.

(1) *General*

(i) Exercise the bleed controls at the end of each stage of the endurance test.

(ii) Complete any other tests which may be necessary to demonstrate the satisfactory functioning of the Engine and the bleeds.

(iii) During the tests of CS-E 690 (a)(3) the Engine rotational speed(s) may be reduced if necessary when the bleeds are in operation in order to avoid exceeding the maximum declared jet pipe temperatures. (See CS-E 740 (f)(2).)

(2) *Calibration Tests.* Include a calibration with each bleed in operation separately and one with all bleeds in operation. (See CS-E 730)

(3) *Endurance Test.*

(i) Run Stages 3, 7, 13, 17 and 23 with the bleed(s) in operation during all the conditions of running for which they are intended to be approved for use.

(ii) During the four test sequences of CS-E 740 (c)(3)(iii), an air bleed extraction need not be used where it is shown that the validity of the test is not compromised.

(b) *Contamination Tests of Bleed Air for Cabin Pressurisation or Ventilation.* The specifications of this paragraph (b) are applicable where it is desired to declare that compressor bleed air is suitable for direct use in an aircraft cabin pressurisation or ventilation system.

(1) Tests to determine the purity of the air supply must be made.

(2) An analysis of defects which could affect the purity of the bleed air must be prepared and where necessary the defects must be simulated and tests, as agreed by the Agency, must be made to establish the degree of contamination which is likely to occur. If the defect under consideration is such that the Engine would be shut down immediately, the tests required may be modified accordingly.

CS-E 700 Excess Operating Conditions

Where any of the operating conditions (e.g. air or gas pressure, thrust, gas temperature) substantiated elsewhere in this subpart could be exceeded in any of the normal and likely emergency conditions within the flight envelope declared by the Engine constructor, it must be established to the satisfaction of the Agency that the most severe conditions likely to occur will have no unacceptable effects on the Engine.

CS-E 710 Rotor Locking Tests

If continued rotation is prevented by a means to lock the rotor(s), the Engine must be subjected to a test that includes 25 locking and unlocking operations of this means under the following conditions: the Engine must be shut down from rated Maximum Continuous thrust/power; the means for stopping and locking the rotor(s) must be operated as specified in the Engine operating instructions while being subjected to the maximum torque that could result from continued flight in this condition; and following rotor locking, the rotor(s) must be held stationary under these conditions for five minutes for each of the 25 operations.

CS-E 720 Continuous Ignition

(a) Where approval of an Engine is sought which permits or requires the use of a continuously-operated ignition system, the specifications of CS-E 720 (b) together with either CS-E 720 (c) or (d) must be met.

(b) Separate tests as agreed by the Agency must be conducted to show that continuous ignition systems are safe and effective in the conditions for which their use is permitted or required.

(c) The system must be operated during a suitable Engine endurance test for periods representative of the duration and frequency of operation of the system during likely service usage, and should be agreed by the Agency for individual cases. Generally, the schedule must include the use of continuous ignition for the maximum duration which is likely to be achieved in 1000 hours of service operation.

(d) It is acceptable to conduct an equivalent programme by appropriate rig testing, where this is possible, but in this case final confirmation of suitability of the equipment in the Engine must be obtained by running at least 10 hours (in periods of at least ½ hour duration) of an Engine endurance test with the ignition in operation at the appropriate Engine conditions.

CS-E 730 Engine Calibration Test

In order to identify the Engine thrust or power changes that may occur during the endurance test of CS-E 740, thrust or power calibration curves of the test Engine must be established either by specific tests accomplished immediately before and after the endurance test or by measurements obtained during the first and final stages of the endurance, up to the highest rated powers except for 30-Second and 2-Minute OEI Power ratings.

CS-E 740 Endurance Tests

(a) The specifications of this CS-E 740 must be varied and supplemented as necessary to comply with CS-E 890.

(b) (1) The test must be made in the order defined in the appropriate schedule and in suitable non-stop stages. An alternative schedule may be used if it is agreed as being at least as severe. In the event of a stop occurring during any stage, the stage must be repeated unless it is considered to be unnecessary. The complete test may need to be repeated if an excessive number of stops occur.

(2) The time taken in changing power and / or thrust settings during the entire test must not be deducted from the prescribed periods at the higher settings.

(3) Throughout each stage of the endurance test, the rotational speed must be maintained at, or within agreed limits of, the declared value appropriate to a particular condition. The determination of the necessary rotational speed tolerance will take account of the Engine speed, test equipment and any other relevant factors. [See also CS-E 740 (f)(1)].

(4) On turbo-propeller Engines, a representative flight Propeller must be fitted.

(5) The Engine must be subjected to an agreed extent of pre-assembly inspection, and a record must be made of the dimensions liable to change by reason of wear, distortion and creep. A record must also be made of the calibrations and settings of separately functioning Engine components and equipment (e.g. the control system, pumps, actuators, valves).

(c) *Schedules*

(1) *Schedule for Standard Ratings (Take-off and Maximum Continuous)*

25 six-hour stages, each stage comprising –

Part 1 One hour of alternate 5-minute periods at Take-off Power or Thrust and minimum ground idle, or, for rotorcraft Engines, minimum test bed idle.

Part 2 (A) Stages 1 to 15, each of 30 minutes duration, at Maximum Continuous Power/Thrust.

(B) Stages 16 to 25, each of 30 minutes duration, at Take-off Power/Thrust.

For Engines for Aeroplanes. Where Engine rotational speeds between Maximum Continuous and Take-off may be used in service, e.g. for reduced thrust take-off or due to variations with ambient temperature, and these speeds would not be adequately covered by other Parts of the endurance test, then the following Part 2 must be substituted:

(C) Stages 1 to 10, each of 30 minutes duration at Maximum Continuous Power/Thrust.

(D) Stages 11 to 15, each of 30 minutes duration at Take-off Power or Thrust.

(E) Stages 16 to 25, each of 30 minutes duration covering the range in 6 approximately equal speed increments between Maximum Continuous and Take-off Power/Thrust.

Part 3 One hour and 30 minutes at Maximum Continuous Power/Thrust.

Part 4 2 hours and 30 minutes covering the range in 15 approximately equal speed increments from Ground Idling up to but not including Maximum Continuous Power/Thrust.

Part 5 30 minutes of accelerations and decelerations consisting of 6 cycles from Ground Idling to Take-off Power/Thrust, maintaining Take-off Power/Thrust for a period of 30 seconds, the remaining time being at Ground Idling.

(2) (i) *Schedule for Standard Ratings with 2½-Minute OEI and/or Continuous OEI Rating and/or 30-Minute OEI Rating (when appropriate).*

25 six-hour stages, each stage comprising –

Part 1 One hour of alternate 5-minute periods at Take-off Power or Thrust and minimum ground idle, or, for rotorcraft Engines, minimum test bed idle, except that –

(A) In Stages 3 to 20, in place of two of the 5-minute periods at Take-off Power/Thrust, run 2½ minutes at Take-off Power/Thrust followed by 2½ minutes at 2½-Minute OEI Power/Thrust.

(B) In Stages 21 to 25, in place of three of the 5-minute periods at Take-off Power/Thrust, run 1 minute at Take-off Power/Thrust followed by 2 minutes at 2½-Minute OEI Power/Thrust and 2 minutes at Take-off Power/Thrust.

Part 2 (A) Stages 1 to 15, each of 30 minutes duration at Maximum Continuous Power/Thrust.

(B) Stages 16 to 25, each of 30 minutes duration at Take-off Power/Thrust, except that in one stage a period of 5 minutes in the middle of a 30-minute period must be run at 2½-Minute OEI Power/Thrust.

For Engines for Aeroplanes. Where Engine rotational speeds between Maximum Continuous and Take-off may be used in service, e.g. for reduced thrust take-off or due to variations with ambient temperature, and these speeds would not be adequately covered by other Parts of the endurance test, then the following Part 2 must be substituted:

(C) Stages 1 to 15, each of 30 minutes duration at Maximum Continuous Power/Thrust.

(D) Stages 16 to 20, each of 30 minutes duration at Take-off Power/Thrust except that in Stage 16 a period of 5 minutes in the middle of the 30-minute period must be run at 2½-Minute OEI Power/Thrust.

(E) Stages 21 to 25, each of 30 minutes duration covering the range in six approximately equal speed increments between Maximum Continuous and Take-off Power/Thrust.

Part 3 (A) For Engines for Aeroplanes –

30 minutes at Maximum Continuous Power/Thrust followed by one hour at Continuous OEI Power/Thrust.

(B) For Engines for Rotorcraft –

Either (Engines to be approved with Continuous OEI rating) 30 minutes at Maximum Continuous Power followed by one hour at Continuous OEI Power or (Engines to be approved with 30-Minute OEI Rating) one hour at Maximum Continuous Power followed by 30 minutes at 30-Minute OEI Power. A Continuous OEI Rating and a 30-Minute OEI Rating at a higher power level can be cleared in the same test, if desired, by running 30 minutes at Maximum Continuous Power followed by 30 minutes at Continuous OEI Power and then 30 minutes at 30-Minute OEI Power.

Part 4 2 hours and 30 minutes covering the range in 15 approximately equal increments from Ground Idling, or, for rotorcraft Engines, minimum test bed idle, up to but not including Maximum Continuous Power.

Part 5 30 minutes of accelerations and decelerations consisting of 6 cycles from Ground Idling, or, for rotorcraft Engines, minimum test bed idle, to Take-off Power/Thrust, maintaining Take-off Power/Thrust for a period of 30 seconds, the remaining time being at Ground Idling, or, for rotorcraft Engines, minimum test bed idle.

(ii) If only one additional rating is required, then the periods at the rating not required must be run at the power/thrust level appropriate to the next rating down the scale.

(iii) Where a constructor desires an en-route OEI Rating for 30 minutes only, then the appropriate FAR 33.87 Schedule may be used in place of this Schedule. Where this option is taken and a 2½ Minute OEI Power rating is also desired, then the appropriate Schedule of FAR 33.87 must be used.

(3) For Engines with 30-Second and 2-Minute OEI Power ratings,

(i) If a Continuous OEI Power rating is associated with the 30-Second and 2-Minute OEI Power ratings, the following tests must be conducted and must be complemented by the additional test of CS-E 740 (c)(3)(iii) :

25 six-hour stages, each stage comprising –

Part 1 One hour of alternate 5 minute periods at Take-off Power and minimum test bed idle.

Part 2 (A) Stages 1 to 15, each of 30 minutes duration at Maximum Continuous Power.

(B) Stages 16 to 25, each of 30 minutes duration at Take-off Power.

Part 3 One hour at Maximum Continuous Power, followed by one hour at Continuous OEI Power.

Part 4 2 hours covering the range in 12 approximately equal increments from minimum test bed idle up to, but not including, Maximum Continuous Power.

Part 5 30 minutes of accelerations and decelerations consisting of 6 cycles from minimum test bed idle to Take-off Power, maintaining Take-off Power for a period of 30 seconds, the remaining time being at minimum test bed idle.

(ii) If a 30-Minute OEI Power rating is associated with the 30-Second and 2-Minute OEI Power ratings, the following tests must be conducted and must be complemented by the additional test of CS-E 740 (c)(3)(iii) :

25 six-hours stages, each stage comprising :

Part 1: One hour of alternate 5-minute periods at Take-off Power and minimum test bed idle.

Part 2: (A) Stages 1 to 15, each of 30 minutes duration at Maximum Continuous Power.

(B) Stages 16 to 25, each of 30 minutes duration at Take-off Power.

Part 3: One hour at Maximum Continuous Power, followed by thirty minutes at 30-Minute OEI Power.

Part 4: Two hours and thirty minutes covering the range in 15 approximately equal increments from minimum test bed idle to Maximum Continuous Power.

Part 5: 30 minutes of accelerations and decelerations consisting of 6 cycles from minimum test bed idle to Take-off power, maintaining Take-off Power for a period of 30 seconds, the remaining time being at minimum test bed idle.

(iii) The following test sequence must be performed four times for a total time of not less than 120 minutes. If a stop occurs during this test, the interrupted sequence must be repeated unless it is shown that the severity of the test is not reduced if it were continued :

Part 1: Three minutes at Take-off Power.

Part 2: Thirty seconds at 30-Second OEI Power.

Part 3: Two minutes at 2-Minute OEI Power.

Part 4: Five minutes at whichever is the greatest of, as applicable, 30-Minute OEI Power, Continuous OEI Power and Maximum Continuous Power, except that during the first test sequence this period must be sixty-five minutes. However, where the greatest is the 30-Minute OEI Power, that sixty-five minutes period must consist of thirty minutes at 30-Minute OEI Power followed by thirty-five minutes at whichever is the greater of Continuous OEI Power and Maximum Continuous Power, as applicable.

Part 5: One minute at 50 percent of Take-off Power.

Part 6: Thirty seconds at 30-Second OEI Power.

Part 7: Two minutes at 2-Minute OEI Power.

Part 8: One minute at flight idle.

(d) *Accelerations and Decelerations*

(1) During scheduled accelerations and decelerations in Parts 1 and 5,

(i) For aeroplane Engines, the power or thrust control lever must be moved from one extreme position to the other in a time not greater than one second.

(ii) For rotorcraft Engines, the power demand must be increased to Take-off from the minimum test bed idle in a time not greater than one second.

(2) *Observations*

(i) *Turbine Engines for Aeroplanes.*

(A) Readings of power/ thrust, speed and Exhaust Gas Temperature must be recorded at every significant change of Engine conditions. Following accelerations, the over-run of speed and temperature above the steady conditions at Take-off must be noted.

(B) Observations of all parameters must be recorded on first establishing steady running conditions and thence, during periods of continuous steady running, at approximately 30-minute intervals.

(C) During cyclic or other running, sufficient observations must be made to establish the power/thrust, speed and temperature conditions of the Engine whenever significant readings can be taken.

(ii) *Turbine Engines for Rotorcraft.*

Readings of power, rotational speed, nozzle position and Exhaust Gas Temperature must be taken at idling speed and at the maximum speed obtained on acceleration. The over run of speed and temperature above the steady conditions at Take-off Power must be noted. These observations are likely to be affected by the types of instruments used and must therefore be coupled with this information in the endurance test report.

(e) *Oil Pressure.* The whole of the endurance test must be run with the oil pressure set to a value which is within the limits declared for Engine acceptance, except that –

(1) Stage 22 must be run with the pressure set to give that declared as the minimum for completion of the flight, at Maximum Continuous conditions, and

(2) One other stage must be run with the pressure set to give that declared as the maximum normal, at maximum continuous conditions. During this stage the oil temperature need not be held at its maximum value. Alternatively, this test may be omitted from the endurance test if appropriate evidence is available from other testing.

(f) *Operating Limitations.* The normal Engine operating limitations of power, rotational speed, turbine entry temperature, oil temperature, etc., to be established under CS-E 40 (d) and CS-E 40 (g), will be based on the mean values obtained during the appropriate periods of the endurance test, including, when applicable, the mean values obtained during the applications of the 30-Second and 2-Minute OEI Power conditions in the 2-hour additional endurance test sequence of CS-E 740 (c)(3)(iii).

Similarly, the degrees of compressor and turbine bleed that may be approved are the percentages of the mass flow which have been demonstrated during the endurance test, except as provided by CS-E 690 (a)(3)(ii).

(1) The characteristics of multi-spool Engines may be such that it is not possible to obtain the maximum rotational speed of each spool simultaneously at sea-level test bed conditions, without making the Engine unacceptably non-standard, or running it in a non-representative manner. In such circumstances, the endurance test must be run at the turbine entry temperatures for which approval is sought, and evidence from supplementary endurance testing, to a schedule acceptable to the Agency, must be provided to substantiate the approval of any higher rotational speed limitations desired.

(2) If Stages 3, 7, 13, 17 and 23, with bleed(s) in operation, require the use of a rotational speed less than the maximum without bleed (as permitted by CS-E 690 (a)(1)(iii)), these Stages need not be included in the assessment of the mean rotational speed value, subject to agreement by the Agency.

(3) In the case of Engines incorporating free power-turbines, if the requisite periods are not run at the maximum power-turbine torque for which approval is sought, evidence of additional running will be required. This may be obtained from tests equivalent to the endurance test on a similar Engine, the endurance test Engine or the relevant parts of it. In all such additional running the appropriate periods must be run at the maximum rotational speed for which approval of the maximum torque is required.

(4) *Temperatures.*

(i) All periods of the test corresponding to a rating to be approved must be run at the appropriate maximum declared turbine entry temperature for this rating unless otherwise agreed. The means of achieving this (e.g. by adjustment of the nozzle areas, the use of bleed) must be justified.

(ii) In general, essentially the average of the maximum temperatures achieved during the appropriate periods of the test will be utilised to establish the operating limitations of temperature for the Engine. The average Exhaust Gas Temperatures will be reduced, however, by the amounts necessary to ensure that the turbine entry temperatures in flight do not exceed the turbine entry temperatures established by endurance test at the appropriate rating conditions. During the accelerations and short periods at Take-off Power, attempts must be made to run at maximum temperatures but if, owing to the unstabilised conditions, lower temperature readings are recorded, these need not be included in calculating the average.

(iii) Engines for Aeroplanes. Where the Engine characteristics are such that an acceleration from cold produces a transient over-temperature in excess of that for steady state running, a maximum turbine gas temperature limit for acceleration with a time limitation of 2 minutes may be approved by running at the required temperature for the first 2 minutes of each prescribed period at Take-off Power conditions for 5 minutes or more, and for the whole of all the 30-second periods at Take-off Power. Approval for short period transient conditions at 2½-Minute OEI Power will not be considered and any temperature clearance required must be demonstrated normally during the 2½-Minute OEI periods of the endurance test.

(iv) Engines for Rotorcraft. Where the Engine characteristics are such that an acceleration from cold produces a transient over-temperature in excess of that for steady state running, a maximum Exhaust Gas Temperature limit for acceleration with a time limitation of 2 minutes may be approved by running at the required temperature for the first 2 minutes of each prescribed period at Take-off Power conditions in excess of 2 minutes (and for the whole of all the 30-second Take-off Power periods for single-engined rotorcraft). Approval for short period transient conditions at 2½-Minute OEI Power will not be considered, and any temperature clearance required must be demonstrated normally during the endurance test.

(v) For all Take-off Power/Thrust periods of 5 minutes or greater, 5 minutes must be run at the maximum oil inlet temperature declared for the condition, with the remainder of each 30-minute period at Take-off Power/Thrust being run at the normal oil temperature for take-off. If a 10-minute Take-off Power/Thrust Rating is sought, then 10 minutes of each 30-minute period at Take-off Power/Thrust must be run at the maximum oil temperature. For all Maximum Continuous Power/Thrust periods 30 minutes must be run at the maximum oil inlet temperature declared for the condition, the remainder of each 1½ hour period at Maximum Continuous Power/Thrust being run at the normal oil temperature for climb/cruise.

(vi) Where necessary to cater for short-duration rise of indicated oil temperature under service conditions above the maximum established during the endurance test such higher temperature may be approved as the Maximum Oil Temperature (with an appropriate time limitation) without additional endurance testing, provided that it can be demonstrated that –

(A) The temperature rise under service conditions is the result of a local increase in the oil temperature at the temperature sensing position (e.g. as may occur on reducing power at the top of the climb when fuel is used as the oil cooling medium),

(B) There is no significant increase in the maximum local temperature of either the Engine components or the oil in any Engine Critical Part, and

(C) There is no undue deterioration of the oil in such circumstances and no adverse effect on any system using the oil as a working fluid (e.g. Propeller control).

(g) *Incremental Periods*.

(1) If a significant peak blade vibration is found to exist at any condition within the operating range of the Engine (not prohibited under CS-E 650 (d)), not less than 10 hours, but not exceeding 50%, of the incremental periods of Part 4 of the endurance test must be run with the rotational speed varied continuously over the range for which vibrations of the largest amplitude were disclosed by the vibration survey; if there are other ranges of rotational speed within the operational range of the Engine where approximately the same amplitude exists, a further 10 hours must be run in the same way for each such range. The speed variation must be effected by automatic means using a method acceptable to the Agency.

(2) In the case of Engines operating at constant speed, the thrust and/or power may be varied in lieu of speed, in Part 4 of the endurance test.

(3) In the case of free power-turbine Engines, the normal operating range of power-turbine speed must be covered. This may be run concurrently with the range of gas generator speed.

(4) In the case of a free power-turbine Engine for Rotorcraft, 10 minutes of Part 4 in each stage of the endurance test must be run at the Maximum Power-turbine Speed for Autorotation with the gas generator producing the most critical conditions associated with this flight configuration.

(h) (1) After completion of the test, the Engine must be subject to a strip inspection, and the dimensions measured in accordance with CS-E 740 (b)(5) must be re-measured and recorded. The condition of the Engine must be satisfactory for safe continued operation. Separately functioning Engine components and equipment must be functionally checked prior to strip to ensure that any changes in function or settings are satisfactory for normal operation.

(2) Engines with 30-Second and 2-Minute OEI Power ratings must be subjected to a full strip inspection after completing the additional endurance test of CS-E 740 (c)(3)(iii).

(i) If the Engine was not subject to a strip examination before commencing the additional endurance test then the strip inspection specifications of CS-E 740 (h)(1) apply on completion of the test.

(ii) If it is proposed to subject the Engine to a strip examination before commencing the additional endurance test, the Engine must be reassembled using the same parts used during the 150 hours test run, except those parts described as consumable in the Engine documentation.

(iii) After this additional endurance test, the Engine may exhibit deterioration in excess of that permitted in CS-E 740 (h)(1), and it is accepted that some Engine parts may be unsuitable for further use. It must be shown by inspection, analysis and/or test or by any combination thereof that the structural integrity of the Engine is maintained.

CS-E 745 Engine Acceleration

(a) It must be demonstrated, on a test bed, that:

(1) For aeroplane Engines, the power / thrust increases to rated Take-off when the power or thrust control lever is moved in not more than one second from the minimum flight idle position to the maximum position with the appropriate adverse combination of bleed air and power extraction to be permitted in the aeroplane, without over-temperature, surge, stall, or other detrimental factors occurring to the Engine.

(2) For rotorcraft Engines, the power increases to rated Take-off when the power demand is increased from minimum test bed idle to rated Take-off in not more than one second with the appropriate adverse combination of bleed air and power extraction to be permitted in the aircraft, without over-temperature, surge, stall, or other detrimental factors occurring to the Engine.

(3) For all Engines, an increase can be made from 15% of the rated Take-off Power or thrust, to 95% of the rated Take-off Power or thrust in a time not greater than 5 seconds. A longer time may be accepted if properly justified. This power or thrust response must occur from a stabilised static condition using only the bleed air and accessories loads necessary to run the Engine.

(b) The minimum response time to 95% of the rated Take-off Power or thrust as a result of moving the power lever of aeroplane Engines in not more than one second, from minimum ground idle and from minimum flight idle positions or, for rotorcraft Engines, increasing the power demand in not more than one second from the minimum test bed idle condition, starting from a stabilised condition, must be measured under the following Engine load conditions.

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

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

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

(c) If testing facilities are not available to demonstrate the effects of power extraction required in CS-E 745 (b)(2) and (3), this must be accomplished through appropriate analytical means.

CS-E 750 Starting Tests

(a) Twenty-five cold starts (i.e. after the Engine has been stopped for not less than two hours) and ten hot starts (i.e. within 15 minutes of shutting-down after the previous running) must be specifically made at evenly distributed intervals throughout the endurance test of CS-E 740. Time to light up and accelerate to idling conditions must be recorded.

(b) Ten False Starts, each followed by a normal start immediately on expiry of the declared drainage period, must be made at evenly distributed intervals throughout the endurance test. Failure to start must be simulated on these occasions by rendering the ignition circuit inoperative. Following each False Start, the combustion chambers, air casings, etc., may be drained, by the normal means provided, of any fuel which may have accumulated.

(c) At the conclusion of the endurance test the number of starts must be made up to a total of one hundred. The additional starts necessary to make this aggregate may be 'hot' or 'cold' starts. All attempted starts including those prescribed in CS-E 750 (b) must count towards the total, provided that the normal starting cycle is completed.

(d) In the case of a free power-turbine Engine for Rotorcraft, each normal start must be made with the free power-turbine locked and followed by a run at Ground Idling Conditions for three minutes with the free power-turbine stationary in order to simulate the operation of the Engine in the rotorcraft with the rotor system locked.

(e) Full details of all starts made throughout the endurance test must be recorded. Times to light up and accelerate to idling conditions must be recorded, together with details of all attempted starts, and the reasons for any Failures.

CS-E 770 Low Temperature Starting Tests

(a) The Engine must be shown to be capable of satisfactory starting and acceleration from the appropriate minimum temperatures declared by the constructor, and demonstrated as indicated in CS-E 770 (b) and (c). Unless otherwise agreed, the temperature indicated for service use should be the oil temperature.

(b) *Minimum Engine Carcass/Oil Temperature for Starting.* Evidence must be provided that Engine starting with the Engine carcass and oil at the declared minimum temperature using the minimum and maximum starting torques declared for service use, is feasible and will not damage the Engine. If a non-standard starting procedure is necessary below a certain temperature, this must also be established and the relevant details must be quoted in the Engine operating instructions, in addition to the standard procedure.

(c) *Minimum Oil Temperature for Acceleration.* Evidence must be provided that, with the Engine oil at the declared minimum temperature for the selection of Take-off Power or thrust, smooth acceleration of the Engine is obtained without Engine damage when the power or thrust control lever is moved from the ground idle position (minimum test bed idle for rotorcraft Engines) to the position appropriate to take-off in a time not greater than one second.

CS-E 780 Tests In Ice-Forming Conditions

(a) It must be established by tests, unless alternative appropriate evidence is available, that the Engine will function satisfactorily when operated in the atmospheric icing conditions of CS-Definitions without unacceptable

(1) Immediate or ultimate reduction of Engine performance,

(2) Increase of Engine operating temperatures,

(3) Deterioration of Engine handling characteristics, and

(4) Mechanical damage.

(b) *(Reserved)*

(c) During the tests of CS-E 780 (a), all optional Engine bleeds permitted during icing conditions must be in the position assumed to be most critical. It must be established, however, that other likely use of bleed will not lead to Engine malfunctioning.

(d) Where the Engine is considered to be vulnerable to operation in ice crystal cloud conditions, in mixed ice crystals and liquid water conditions, or in snow, such additional tests as may be necessary to establish satisfactory operation in these conditions must be made.

(e) In showing compliance with the specifications of this paragraph CS-E 780, the conditions associated with a representative installation must be taken into account.

(f) If after the tests it is found that significant damage has occurred, further running or other evidence may be required to show that subsequent Failures are unlikely to occur.

(g) Where an intake guard is fitted, compliance with the specifications of this paragraph CS-E 780 must be established with the guard in position, unless the guard is required to be retracted during icing conditions, in which case it must be established that its retraction is not affected immediately after a representative delay period.

CS-E 790 Ingestion of Rain and Hail

(a) *All Engines*

(1) The ingestion of large hailstones (0·8 to 0·9 specific gravity) at the maximum true air speed, for altitudes up to 4 500 metres, associated with a representative aircraft operating in rough air, with

the Engine at Maximum Continuous power/ thrust, must not cause unacceptable mechanical damage or unacceptable power or thrust loss after the ingestion, or require the Engine to be shut down. One-half the number of hailstones must be aimed randomly over the inlet face area and the other half aimed at the critical inlet face area. The hailstones must be ingested in a rapid sequence to simulate a hailstone encounter and the number and size of the hailstones must be determined as follows:

(i) One 25-millimetres diameter hailstone for Engines with inlet throat areas of not more than 0.0645 m^2.

(ii) One 25-millimetres diameter and one 50-millimetres diameter hailstone for each 0.0968 m^2 of inlet throat area, or fraction thereof, for Engines with inlet throat areas of more than 0.0645 m^2.

(2) In addition to complying with CS-E 790 (a)(1) and except as provided in CS-E 790 (b), it must be shown that each Engine is capable of acceptable operation throughout its specified operating envelope when subjected to sudden encounters with the certification standard concentrations of rain and hail as defined in Appendix A to CS-E. Acceptable Engine operation precludes, during any 3-minute continuous period in rain and during any 30-second continuous period in hail, the occurrence of flameout, rundown, continued or non recoverable surge or stall, or loss of acceleration and deceleration capability. It must also be shown after the ingestion that there is no unacceptable mechanical damage, unacceptable power or thrust loss, or other adverse Engine anomalies.

(b) *Engines for Rotorcraft* – As an alternative to the specifications specified in CS-E 790 (a)(2), but for rotorcraft turbine Engines only, it must be shown that each Engine is capable of acceptable operation during and after the ingestion of rain with an overall ratio of water droplet flow to airflow, by weight, with a uniform distribution at the inlet plane, of at least 4percent. Acceptable Engine operation precludes flameout, rundown, continued or non-recoverable surge or stall, or loss of acceleration and deceleration capability. It must also be shown after the ingestion that there is no unacceptable mechanical damage, unacceptable power loss, or other adverse Engine anomalies. The rain ingestion must occur under the following static ground-level conditions:

(1) A normal stabilisation period at Take-off Power without rain ingestion, followed immediately by the suddenly commencing ingestion of rain for three minutes at Take-off Power; then

(2) Continuation of the rain ingestion during subsequent rapid deceleration to minimum idle power; then

(3) Continuation of the rain ingestion during three minutes at minimum idle power to be certified for flight operation; then

(4) Continuation of the rain ingestion during subsequent rapid acceleration to Take-off Power.

(c) *Engines for Supersonic Aeroplanes* – In addition to complying with CS-E 790 (a)(1) and (a)(2), a separate test for supersonic aeroplane Engines only must be conducted with three hailstones ingested at supersonic cruise velocity, except as provided otherwise in this CS-E 790 (c). The Engine operating conditions of rotor speed(s), component loading and component temperatures for this test must be representative of supersonic cruise flight operation. These hailstones must be aimed at the Engine's critical face area and their ingestion must not cause unacceptable mechanical damage or unacceptable thrust loss after the ingestion, or require the Engine to be shut down. The hailstones must be ingested in a rapid sequence to simulate a hailstone encounter and the size of these hailstones must be determined from the linear variation in diameter from 25 millimetres at 10 500 metres to 6 millimetres at 18 000 metres using the diameter corresponding to the lowest expected supersonic cruise altitude. Alternatively, three larger hailstones may be ingested in a rapid sequence at subsonic velocities provided it can be shown that such an ingestion is equivalent to the applicable supersonic ingestion in respect of Engine component loading and strength, the kinetic energy of hailstones and their depth of penetration into the Engine.

(d) For an Engine that incorporates or requires the use of a protection device, demonstration of the rain and hail ingestion capabilities of the Engine, as required in CS-E 790 (a), (b) and (c), may be waived wholly or in part by the Agency if it is shown that –

(1) The subject rain or hail constituents are of a size that will not pass through the protection device;

(2) The protection device will withstand the impact of the subject rain or hail constituents; and

(3) The subject rain or hail constituents stopped by the protection device will not obstruct the flow of induction air into the Engine resulting in damage, power or thrust loss, or other adverse Engine anomalies in excess of what would be accepted in CS-E 790 (a), (b) and (c).

CS-E 800 Bird Strike and Ingestion

(a) *Objective*. To demonstrate that the Engine will respond in a safe manner following specified encounters with birds, as part of the compliance with CS-E 540.
The demonstration will address the ingestion of large, medium and small birds, and also the effect of the impact of such birds upon the front of the Engine.

(b) *Single large bird ingestion test*. An Engine ingestion test must be carried out using a large bird as specified below. Alternative evidence may be acceptable as provided under CS-E 800 (f)(1).

(1) *Test conditions*.

(i) The Engine operating conditions must be stabilised prior to ingestion at not less than 100% of the Take-off Power or thrust at the test day ambient conditions. In addition, the demonstration of compliance must account for Engine operation at sea level take-off conditions on the hottest day that a minimum Engine can achieve maximum rated Take-off Power or thrust.

(ii) The bird to be used must be of a minimum mass of :-

(A) 1·85 kg for Engine inlet throat areas of less than 1·35 m^2 unless a smaller bird is determined to be a more severe demonstration.

(B) 2·75 kg for Engine inlet throat areas of less than 3·90 m^2 but equal to or greater than 1·35 m^2.

(C) 3·65 kg for Engine inlet throat areas equal to or greater than 3·90 m^2.

(iii) The bird must be aimed at the most critical exposed location on the first stage rotor blades.

(iv) A bird speed of 200 knots for Engines to be installed on aeroplanes or the maximum airspeed for normal flight operations for Engines to be installed on rotorcraft.

(v) Power lever movement is not permitted within 15 seconds following the ingestion.

(2) *Acceptance criteria*. Ingestion of this single large bird must not result in a Hazardous Engine Effect.

(c) *Large flocking bird.* An engine test using a single bird must be carried out at the conditions specified below for Engines with an inlet throat area equal to or greater than 2.5 m^2. Alternative evidence may be acceptable as provided under CS-E 800 (f)(1).

(1) *Test conditions*.

(i) The Engine operating conditions must be stabilised prior to ingestion at not less than the mechanical rotor speed of the first exposed stage(s) that, on an ISA standard day, would produce 90% of the sea level static Rated Take-off Thrust.

(ii) The bird speed must be 200 knots.

(iii) The bird mass must be at least as defined below

Engine Inlet throat Area (A) m^2	Mass of Bird kg
A<2.50	Not applicable
2.50$\leq$ A<3.50	1.85
3.50$\leq$ A<3.90	2.10
3.90$\leq$ A	2.50

(iv) The bird must be targeted on the first exposed rotating stage(s) at a blade airfoil height of not less than 50%, measured at the leading edge.

(v) The following test schedule must be used:

Step 1 - Ingestion followed by 1 minute without power lever movement.

Step 2 - 13 minutes at not less than 50% of Rated Take-off Thrust.

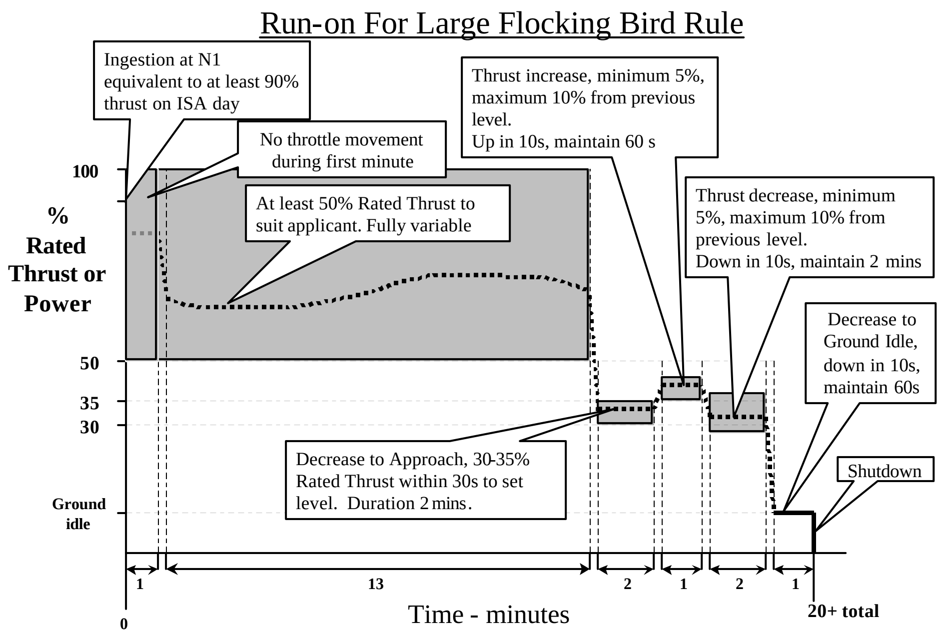
Step 3 - 2 minutes at a thrust set between 30% and 35% of Rated Take-off Thrust.

Step 4 - 1 minute at a thrust increased from that set in step 3 by between 5% and 10% of Rated Take-off Thrust.

Step 5 - 2 minutes at a thrust decreased from that set in step 4 by between 5% and 10% of Rated Take-off Thrust.

Step 6 - At least 1 minute at ground idle followed by Engine shut down.

Each specified step duration is time at the defined step conditions. Power lever movement between each step will be 10 seconds or less, except that power lever movement for setting conditions of step 3 will be 30 seconds or less. Within step 2, power lever movements are allowed and are not limited.



(2) *Acceptance criteria.*

The test of CS-E 800 (c)(1)(v) must not cause:

- The Engine to be unable to complete the required test schedule,
- The Engine to be shut down before end of step 6,
- A sustained reduction of thrust to less than 50% Rated Take-off Thrust during step 1,
- A Hazardous Engine Effect.

(d) *Medium and small birds ingestion tests*. Engine ingestion tests and analysis with medium and small sized birds must be carried out as specified below. Alternative evidence may be acceptable as provided under CS-E 800 (f)(1). The small birds test will not be required if the prescribed number of medium birds pass into the Engine rotor blades during the medium bird test.

(1) *Test Conditions*.

(i) The Engine operating conditions must be stabilised prior to ingestion at not less than 100% of the Take-off Power or thrust at the test day ambient conditions. In addition, the demonstration of compliance must account for Engine operation at sea level take-off conditions on the hottest day at which a minimum Engine can achieve maximum rated Take-off Power or thrust.

(ii) The critical ingestion parameters affecting power loss and damage must be determined by analysis or component tests or both. They must include, but are not limited to, the effects of bird speed, critical target location and first stage rotor speed. The critical bird ingestion speed must reflect the most critical condition within the range of airspeeds for normal flight operations up to 450 m (1 500 feet) above ground level, but not less than V1 minimum for Engines to be installed on aeroplanes.

(iii) Except for rotorcraft Engines, the following test schedule must be used:

- Ingestion to simulate a flock encounter within one second
- 2 minutes without power lever movement
- 3 minutes at 75% of the test conditions of CS-E 800 (d)(1)(i)
- 6 minutes at 60% of the test conditions of CS-E 800 (d)(1)(i)
- 6 minutes at 40% of the test conditions of CS-E 800 (d)(1)(i)
- 1 minute at Approach Idle
- 2 minutes at 75% of the test conditions of CS-E 800 (d)(1)(i)
- Stabilise at idle and shut Engine down.

These durations are times at the defined conditions, the power lever being moved between each condition in less than 10 seconds.

(iv) For rotorcraft Engines, the following test schedule must be used :

- Ingestion to simulate a flock encounter within one second
- 3 minutes at 75% of the test conditions of CS-E 800 (d)(1)(i)
- 90 seconds at minimum test bed idle
- 30 seconds at 75% of the test conditions of CS-E 800 (d)(1)(i)
- Stabilise at idle and shut Engine down.

These durations are times at the defined conditions, the power lever being moved between each condition in less than 10 seconds.

(v) (A) *Medium birds*. Masses and quantities of birds will be determined from column 2 of Table A. When only one bird is specified, it must be aimed at the Engine core primary flow path; the other critical locations on the Engine face area must be addressed by appropriate tests or analysis or both.

When two or more birds are specified, the largest must be aimed at the Engine core primary flow path and a second bird must be aimed at the most critical exposed location on the first stage rotor blades. Any remaining birds must be evenly distributed over the Engine face area.

(B) *Small birds*. One 85 g bird for each 0·032 m^2 of the inlet throat area or fraction thereof with a maximum of 16 birds, distributed to take account of any critical exposed locations on the first stage rotor blades, but otherwise evenly distributed over the Engine face area.

TABLE A

Medium (flocking) birds

	Engine test (CS-E 800 (d)(1))	Additional integrity assessment (CS-E 800 (d)(3))
Engine inlet throat area (A) m^2	Number of birds x mass of birds kg	Number x mass of birds kg
A < 0·05	none	none
0·05 ≤ A < 0·10	1 x 0·35	none
0·10 ≤ A < 0·20	1 x 0·45	none
0·20 ≤ A < 0·40	2 x 0·45	none
0·40 ≤ A < 0·60	2 x 0·70	none
0·60 ≤ A < 1·00	3 x 0·70	none
1·00 ≤ A < 1·35	4 x 0·70	none
1·35 ≤ A < 1·70	1 x 1·15 + 3 x 0·70	1 x 1·15
1·70 ≤ A < 2·10	1 x 1·15 + 4 x 0·70	1 x 1·15
2·10 ≤ A < 2·50	1 x 1·15 + 5 x 0·70	1 x 1·15
2·50 ≤ A < 2·90	1 x 1·15 + 6 x 0·70	1 x 1·15
2·90 ≤ A < 3·90	1 x 1·15 + 6 x 0·70	2 x 1·15
3·90 ≤ A < 4·50	3 x 1·15	1 x 1·15 + 6 x 0·70
4·50 ≤ A	4 x 1·15	1 x 1·15 + 6 x 0·70

(2) *Acceptance criteria*. The ingestion must not cause:

- More than a sustained 25% power or thrust loss
- The Engine to be shut down during the test.

(3) In addition, except for rotorcraft Engines, it must be substantiated by appropriate tests or analysis or both that, when the full first stage rotor assembly is subjected to the quantity and mass of medium birds from Column 3 of Table A fired at the most critical locations on the first stage rotor, the effects will not be such as to make the Engine incapable of complying with the acceptance criteria of CS-E 800 (d)(2).

(e) *Impact*. The impact against the front of the Engine of the largest medium bird required by CS-E 800 (d)(1)(v)(A) and of the large bird required by CS-E 800 (b)(1)(ii) must be evaluated for compliance with CS-E 540 under the Engine conditions specified for the ingestion tests. The bird speed must be the critical bird ingestion speed for the critical locations within the range of airspeeds for normal flight operations up to 450 m (1 500 feet) above ground level, but not less than V_1 minimum for Engines to be installed on aeroplanes or higher than the speeds for the ingestion tests.

The impact evaluation may be carried out separately from the ingestion evaluation; however any damage resulting from the impact on the front of the Engine must be assessed in relation to consequential damage on the rotating blades.

(f) *General*

(1) Engine tests must be performed as required under CS-E 800 (b), (c) and (d) unless it is agreed that alternative evidence such as Engine test, rig test, analysis or an appropriate combination, may come from the Applicant's experience on engines of comparable size, design, construction, performance and handling characteristics, obtained during development, certification or operation.

(2) The Engine test described in CS-E 800 (b)(1), with regard to the single large bird, may be waived if it can be shown by test or analysis that the specifications of CS-E 810 (a) are more severe.

(3) Compliance with CS-E 800 (c), in place of an Engine test, may be shown by:

(i) Incorporating the run-on specifications of CS-E 800 (c)(1)(v) into the Engine test demonstration specified in CS-E 800 (b)(1); or

(ii) Using a component test at the conditions of CS-E 800 (b)(1) or (c)(1), subject to the following additional conditions:

(A) All components critical to achieving the run-on criteria of CS-E 800 (c) are included in the component test; and

(B) The components tested under (A) above are subsequently installed in a representative Engine for a run-on demonstration in accordance with CS-E 800 (c)(1)(v), except that steps 1 and 2 of CS-E 800 (c)(1)(v) are replaced by a unique 14-minutes step at a thrust not less than 50% of Rated Take-off Thrust after the Engine is started and stabilised, and

(C) Dynamic effects that would have been experienced during a full Engine test can be shown to be negligible with respect to meeting the specifications of CS-E 800 (c).

(4) Limit exceedences may be permitted to occur during the tests of CS-E 800 (c) and (d). Any limit exceedence must be recorded and shown to be acceptable under CS-E 700.

(5) For an Engine that incorporates an inlet protection device, compliance with this CS-E 800 must be established with the device functioning and the Engine approval must be endorsed accordingly.

(6) If compliance with all of the specifications of CS-E 800 is not established, the Engine approval will be endorsed accordingly by restricting the Engine installations to those where birds cannot strike the Engine or be ingested by the Engine or adversely restrict the airflow into the Engine.

(7) An Engine to be installed in a multi-engine rotorcraft does not need to comply with the medium or small bird specifications of CS-E 800 (d), but the Engine approval will be endorsed accordingly.

(8) The Engine inlet throat area, as used in CS-E 800 to determine the bird quantity and mass, must be established and identified as a limitation on the inlet throat area in the instructions for installation.

CS-E 810 Compressor and Turbine Blade Failure

(a) It must be demonstrated that any single compressor or turbine blade will be contained after Failure and that no Hazardous Engine Effect can arise as a result of other Engine damage likely to occur before Engine shut down following a blade Failure.

(b) Where, in the Failure analysis of CS–E 510, reliance is placed on the shedding of turbine blades in order to protect the rotating system in over-speed conditions, tests must be made to demonstrate that –

(1) The shedding will occur at a speed which provides a reasonable margin –

(i) Above the maximum Engine speed to be approved (including the Maximum Engine Over-speed) and

(ii) Below the minimum rotor burst speed.

(2) No Hazardous Engine Effect is likely to arise as a consequence of the blades shedding.

CS-E 820 Over-torque Test

(a) If approval of a Maximum Engine Over-torque is sought for an Engine incorporating a free power turbine, compliance with this paragraph must be demonstrated by test.

(1) The test may be run, if desired, as part of the endurance test of CS-E 740. Alternatively, evidence may be provided from tests of a complete Engine or equivalent testing of individual groups of components.

(2) On conclusion of such tests, the stripped condition of the Engine or individual groups of components must be satisfactory for continued running.

(b) The test conditions must be as follows:

(1) A total of 15 minutes run at the Maximum Engine Over-torque to be approved. This may be done in separate runs, each being of at least 2½-minutes duration.

(2) A power turbine rotational speed equal to the highest speed at which the Maximum Engine Over-torque can occur in service, but not more than the limit speed of Take-off or OEI ratings of a duration longer than 2 minutes.

(3) For Engines incorporating a reduction gearbox, a gearbox oil temperature equal to the maximum temperature at which the Maximum Engine Over-torque could occur in service; for other Engines, an oil temperature within the normal operating range.

(4) A turbine entry gas temperature equal to the maximum steady state temperature to be approved for use during periods longer than 20 seconds when operating at conditions not associated with 30-Second or 2-Minute OEI Power Ratings, unless it can be shown that other testing provides substantiation of the temperature effects when considered in combination with the other parameters identified in CS-E 820 (b)(1), (b)(2) and (b)(3).

CS-E 830 Maximum Engine Over-speed

(a) If approval of a Maximum Engine Over-speed is sought for a rotating system of the Engine, a test must be undertaken on a complete Engine. Alternatively, test evidence from an Engine of similar design may be provided.

(b) The test conditions must be as follows:

(1) A total of 15 minutes run at the Maximum Engine Over-speed to be approved. This may be done in separate runs, each being of at least 2.5 minutes duration.

(2) A turbine-entry gas temperature equal to the maximum steady state temperature to be approved for use during periods longer than 20 seconds and not associated with 30-Second or 2-Minute OEI Power Ratings. However, for the shaft system to be approved, if the maximum over--speed cannot occur at the maximum turbine-entry temperature, the highest temperature which could occur at the conditions of Maximum Engine Over-speed must be used.

(3) The declared maximum operating oil temperature.

(c) On conclusion of such tests, the stripped condition of the Engine must be satisfactory for continued running.

(d) The test may be run, if desired, as part of the endurance test of CS-E 740 provided the conditions of CS-E 830 (b) are satisfied.

CS-E 840 Rotor Integrity

(a) For each fan, compressor, and turbine rotor, it must be established by test, analysis, or combination thereof, that a rotor which has the most adverse combination of material properties and dimensional tolerances allowed by its type design will not burst when it is operated in the Engine for five minutes at whichever of the conditions defined in CS-E 840 (b) is the most critical with respect to the integrity of such a rotor.

However, where that required condition is determined by either CS-E 840 (b)(3) or (b)(4), but the associated Failure condition is of a sudden transient nature, such as loss of load, and it precludes any further operation of the affected rotor, then the time period of that Failure condition is an acceptable duration for showing compliance by means of an Engine test provided the required test speeds are achieved. Test rotors which do not have the most adverse combination of material properties and dimensional tolerances must comply at appropriately adjusted test parameters, e.g. speed, temperature, loads.

(b) When determining the operating conditions applicable to each rotor for compliance with CS-E 840 (a) and (c), each of the following speeds must be evaluated in conjunction with their associated temperatures and temperature gradients, throughout the Engine's operating envelope :

(1) 120% of the maximum permissible rotor speeds associated with any of the ratings except OEI ratings of less than 2½-minutes.

(2) 115% of the maximum permissible rotor speeds associated with any OEI ratings of less than 2½-minutes.

(3) 105% of the highest rotor speed that would result from either -

(i) The Failure of the component or system which, in a representative installation of the Engine, is the most critical with respect to over-speeding when operating at any rating condition except OEI ratings of less than 2½-minutes, or

(ii) The Failure of any component or system in a representative installation of the Engine, in combination with any other Failure of a component or system that would not normally be detected during a routine pre-flight check or during normal flight operation that is the most critical with respect to over-speeding, except as provided by CS-E 840 (c), when operating at any rating condition except OEI ratings of less than 2½-minutes.

(4) 100% of the highest rotor speed that would result from the Failure of the component or system which, in a representative installation of the Engine, is the most critical with respect to over-speeding when operating at any OEI ratings of less than 2½-minutes.

(c) The highest over-speed which will result from a complete loss of load on a turbine rotor, unless it can be shown to be Extremely Remote under the provisions of CS-E 850, must be included in the over-speeds considered under each of CS-E 840 (b)(3)(i), (ii) and (b)(4), irrespective of whether it is the result of a Failure within the Engine or external to the Engine.

Over-speeds resulting from any other single Failure must be considered. Over-speeds resulting from multiple Failures must also be considered unless they can be shown to be Extremely Remote.

(d) In addition, for each fan, compressor, and turbine rotor, it must be established by test, analysis, or combination thereof, that a rotor which has the most adverse combination of material properties and dimensional tolerances allowed by its type design and which is operated in the Engine for five minutes at 100% of the most critical speed and temperature conditions resulting from any Failure or combination of Failures considered under CS-E 840 (b)(3) and (b)(4), will meet the acceptance criteria prescribed below in CS-E 840 (d)(1) and (d)(2).

However, where the Failure condition is of a sudden transient nature, such as loss of load, and it precludes any further operation of the affected rotor, the time period of that Failure condition is an acceptable duration for showing compliance by means of an Engine test.

Test rotors which do not have the most adverse combination of material properties and dimensional tolerances must comply at appropriately adjusted test parameters, e.g. speed, temperature, loads.

(1) Growth of the rotor while it is operating at the applicable conditions must not cause the Engine to:

(i) Catch fire,

(ii) Release high energy debris through the Engine's casing or result in a hazardous Failure of the Engine's casing,

(iii) Generate loads greater than those ultimate loads for which the Engine's mountings have been designed in compliance with CS-E 100 (b), or

(iv) Lose the capability of being shut down.

(2) After the applicable period of operation, the rotor must not exhibit conditions such as cracking or distortion which preclude the safe operation of the Engine during any likely continued operation following such an over-speed event in service.

CS-E 850 Compressor, Fan and Turbine Shafts

(a) *Objectives.*

(1) It must be demonstrated that Failures of the shaft systems will not result in Hazardous Engine Effects, except as provided in CS-E 850 (a)(3).

(2) It must be established that the shaft systems are designed so that Failures are predicted to occur at a rate not in excess of that defined as Remote.

(3) If compliance with the objective of CS-E 850 (a)(1) is not achieved for certain elements of a shaft, it must be shown that Failures of these elements are predicted to occur at a rate not in excess of that defined as Extremely Remote.

(b) *Compliance*.

(1) Non-Hazardous Shaft Failures. When it is claimed that Failures of the shaft systems will not result in Hazardous Engine Effects, a test will normally be required to demonstrate the consequences of these shaft Failures unless it is agreed that the consequences are readily predictable.

(2) Hazardous Shaft Failures**.** In complying with CS-E 850 (a)(3), the Failure rate of certain elements of shaft systems will be accepted as Extremely Remote, if :-

(i) The shaft is identified as an Engine Critical Part and compliance is shown with CS-E 515.

and

(ii) Their material and design features are well understood and are conducive to well established and validated stressing techniques.

and

(iii) The surrounding environment of the elements considered is such that it is accepted that a shaft Failure owing to this environment can be judged as sufficiently unlikely that the Failure mode can be discounted. This consideration of the environment must include complexity of design, corrosion, wear, vibration, fire, contact with adjacent components or structure, overheating, and secondary effects from other Failures or combinations of Failures.

and

(iv) In making the assessment described in CS-E 850 (b)(2)(iii), any assumptions regarding the Engine installation are identified and declared in accordance with CS-E 30.

and

(v) Experience with parts of similar design is assessed and taken into account as appropriate.

CS-E 860 Turbine Rotor Over-temperature

(a) The most critical temperature conditions which the turbine rotor(s) can attain in the event of Failures of the cooling air supply must be established by analysis and tests, as appropriate. Failure of individual components of the Engine that can be classified as Extremely Remote need not be included in the analysis or tests.

(b) Evidence to demonstrate that instrumentation is not required under CS-E 60 (e) may be obtained from endurance running in an Engine or on rigs, or, where adequate margins can be demonstrated, by calculation. Where practicable, the duration of endurance running may be reduced by compensating increases in the test temperature.

CS-E 870 Exhaust Gas Over-temperature Test

(a) *General*

(1) Where the Applicant wishes to establish a Maximum Exhaust Gas Over-temperature limit compliance must be shown with this paragraph CS-E 870.

(2) The test may be run, if desired, as part of the endurance test of CS-E 740. Alternatively, test evidence may be provided from an Engine of the same type.

(3) On conclusion of the tests, the stripped condition of the Engine must be satisfactory for continued running.

(b) *Test Conditions*

(1) A 15-minute period at Maximum Exhaust Gas Over-temperature must be run with each spool of the Engine which could be significant to the test, at the ma ximum speed to be approved (excluding the Maximum Engine Over-speed (20 Second)).

(2) Where desired, the test may be made up of separate runs giving a total time of 15 minutes, the time of each individual run being no less than 2½-minutes.

CS-E 880 Tests with Refrigerant Injection for Take-Off and/or 2½-Minute OEI Power

(a) *Engines for Rotorcraft.* The variation of the tests prescribed in this subpart E when using refrigerant injection must be agreed in consultation with the Agency.

(b) *Engines for Aeroplanes.* Refrigerant Injection Used to Increase ISA Take-off and/or 2½-Minute OEI Performance. The following variations to the tests prescribed in this subpart E must be made:

(1) *Calibration Tests.* (See CS-E 730). Add a calibration with refrigerant injection to demonstrate that the predicted power/thrust output will be achieved at the conditions demanding maximum refrigerant flow for each rating. This additional calibration may be made on a separate Engine if desired.

(2) *Endurance Test* (See CS-E 740 (c)). Run all normal Take-off periods (and/or 2½-Minute OEI if applicable) of Part 1 of each of the stages with refrigerant injection to achieve a mean refrigerant flow rate of at least 50% of the maximum, whilst maintaining at least the minimum declared power/thrust output and maximum declared turbine entry temperature.

(3) *Accelerations* (See CS-E 740 (c) and (d)). All the appropriate accelerations of Part 1 of each of the stages must be made with refrigerant injection selected.

(4) *Idle conditions used for power or thrust response* (See CS-E 745). The idle conditions appropriate to the use of maximum refrigerant injection flow, as well as without, must be established.

(5) *Over-speed Test* (See CS-E 830). Two Over-speeds will need to be declared if the Take-off maximum rotational speed with refrigerant injection differs from the Take-off maximum rotational speed without refrigerant injection. Only an Over-speed test with refrigerant injection need be run if all the critical conditions are more severe with refrigerant injection, than without. The 15-minute Over-speed test with refrigerant injection need not be run non-stop, but the duration of the individual periods of running at this condition must be not less than 3 minutes.

(c) *Engines for Aeroplanes*. Refrigerant Injection Used to Restore ISA Take-off and/or 2½-Minute OEI Performance at Higher Ambient Temperature. The following variations to the tests prescribed in this subpart E must be made:

(1) *Calibration Tests*. (See CS-E 730). Add a calibration with refrigerant injection to demonstrate that the predicted power/thrust will be achieved at the maximum declared air intake temperature whilst running within the appropriate operating limitations. This additional calibration may be made on a separate Engine if desired.

(2) *Endurance Test* (See CS-E 740 (c)). Run all the Take-off periods of Part 1 of any 10 of the stages with refrigerant injection to achieve a mean refrigerant flow rate of at least 50% of the maximum, whilst maintaining at least minimum declared power/thrust output and maximum declared turbine entry temperature. If a 2½-Minute OEI Rating is also sought then all the Take-off and 2½-Minute OEI periods of Part 1 in stages 3 to 12 must be run as above.

(3) *Accelerations* (See CS-E 740 (c) and (d)). All the appropriate accelerations of Part 1 of each of the 10 required stages must be made with refrigerant injection selected.

(4) *Idle conditions used for power or thrust response* (See CS-E 745). The idle conditions appropriate to the use of maximum refrigerant injection flow, as well as without, must be established.

(5) *Over-speed* (See CS-E 830). Run either without refrigerant injection at the ambient air intake temperature or with refrigerant injection with the air intake temperature raised to the highest sea-level temperature at which refrigerant is to be used, depending on which involves the more severe running conditions. If the test is run with refrigerant injection, the 15-minute period need not be run non-stop, but the duration of the individual periods of running at this condition must be not less than 3 minutes. The test may be run, if desired as part of the endurance test. Alternatively, test evidence from an Engine of similar design may be provided.

CS-E 890 Thrust Reverser Tests

(a) *Applicability*. CS-E 890 is applicable to thrust reversers intended to be installed on turbine Engines.

(b) The thrust reverser must be fitted to the Engine for the whole of the endurance test of CS-E 740 and a representative control system must be used.

(c) *Thrust reversers intended for ground use only*. The following specific tests must be performed as part of the tests of CS-E 740:

(1) 150 cycles from an Engine rotational speed in the forward thrust range not greater than that which will be achieved in a representative aeroplane under typical landing conditions to the declared maximum reverse thrust conditions, sustaining the maximum reverse thrust conditions during each cycle for the period for which approval at these conditions is sought.

(2) 25 cycles from the Engine rotational speed for rated Take-off conditions to the declared maximum reverse thrust conditions.

(3) One cycle to the declared maximum reverse thrust conditions, from each of ten Engine rotational speeds in the forward thrust range (except Take-off rotational speed and idling), these speeds being such that the forward thrust range is divided into approximately equal increments.

(4) One cycle to the Take-off maximum rotational speed from each of 15 speeds in the declared reverse thrust range, these speeds being such that the reverse thrust range is divided into approximately equal increments.

(d) Where approval is sought for ground and in-flight use, in addition to the tests prescribed under CS-E 890 (c), a test of at least 5 hours must be performed, as part of the tests of CS-E 740, at the maximum reverse thrust conditions declared for in-flight use divided into equal periods each not less than the maximum permitted for in-flight use and including at least 30 operations into reverse thrust.

(e) (1) During the tests of CS-E 890 (c) and (d), the time to complete each scheduled thrust operation must be recorded.

(2) The power control lever movement into reverse thrust must be initiated from the conditions indicated in the schedule, reverse thrust being selected in accordance with the recommended procedure. Immediately the thrust reverser is indicated as being in the reverse thrust position, the power control lever must be moved from the minimum idling position with reverse thrust to the position appropriate to the maximum with reverse thrust in a time not greater than 1 second. During decelerations the power control lever must be moved from the position appropriate to the declared maximum with reverse thrust to the minimum idling position with reverse thrust in a time not greater than 1 second.

(f) After the completion of the tests specified in CS-E 890 (c) and (d), the Engine and the thrust reverser must comply with the specifications of CS-E 740 (h).

(g) Engine tests must be performed as required under CS-E 890 (b), (c) and (d) unless it is agreed that alternative evidence may come from the Applicant's experience on Engines of comparable size, design, construction, performance and handling characteristics, obtained during development, certification or operation, supported by analysis and tests as appropriate.

CS-E 900 Propeller Parking Brake

If a Propeller parking brake is provided it must be operated 100 times during the endurance test. It must be applied at the maximum Propeller speed recommended by the Engine constructor.

CS-E 910 Relighting In Flight

The Engine constructor must recommend an envelope of conditions for Engine relighting in flight, and must substantiate it by appropriate tests or other evidence. The recommendation must state all the conditions applicable, e.g. altitude, air speed, Engine windmilling rotational speed, whether starter assistance is required, the recommended drill.

CS-E 920 Over-temperature Test

For Engines with 30-Second and 2-Minute OEI Power ratings, the Engine must be run for a period of 4 minutes at the maximum power-on rotor speed with the turbine entry gas temperature at least 19 °C higher than the 30-Second OEI Power rating operating temperature limit. Following this test, the turbine assembly may exhibit distress beyond the limits for an over-temperature condition provided the Engine is shown by analysis or test or both to maintain the integrity of the turbine assembly.

SUBPART F — TURBINE ENGINES - ENVIRONMENTAL AND OPERATIONAL DESIGN REQUIREMENTS

CS-E 1000 General

Compliance with the specifications of CS-E 1010 and CS-E 1020 may be mandatory for Engine type certification depending on the specifications referenced under CS-34. Compliance with all or some of the other specifications of this subpart is optional, at the request of the applicant.

Compliance with the specifications of this subpart will be recorded in notes in the Engine type certificate data sheet.

CS-E 1010 Fuel Venting

The design of a turbine Engine must comply or, where the imposed specifications are directed at the aircraft, incorporate provisions enabling the aircraft in which it is intended to be installed to comply with the fuel venting specifications of CS 34.1.

CS-E 1020 Engine Emissions

It must be demonstrated, by test or analysis or combination thereof, that the Engine type design complies with the emission specifications of CS 34.2 in effect at date of Engine certification. The resulting data must be recorded.

CS-E 1030 Time Limited Dispatch

If time limited dispatch is requested, any dispatchable configuration of the Engine, including its control system, must comply with the applicable specifications of CS-E. The length of time allowed prior to rectification of a Fault resulting in degraded operation must be justified as part of the system safety assessment of CS-E 50 (d) or the safety analysis of CS-E 510 and documented as part of the MMEL of the aircraft in which the Engine is installed.

CS-E 1040 ETOPS

(Reserved)

APPENDIX A

CERTIFICATION STANDARD ATMOSPHERIC CONCENTRATIONS OF RAIN AND HAIL.

Figure A1, Table A1, Table A2, Table A3 and Table A4 in this Appendix A specify the atmospheric concentrations and size distributions of rain and hail for establishing certification, in accordance with the specifications of CS-E 790 (a)(2). In conducting tests, normally by spraying liquid water to simulate rain conditions and by delivering hailstones fabricated from ice to simulate hail conditions, the use of water droplets and hailstones having shapes, sizes and distributions of sizes other than those defined in this Appendix A, or the use of a single size or shape for each water droplet or hailstone, can be accepted, provided the substitution does not reduce the severity of the test. [*Source of data in Tables A1 to A4 : Results of the Aerospace Industries Association Propulsion Committee Study, Project PC 338–1, June 1990*].

Note : The unit for altitude has been kept as "feet" to be consistent with the source of data. This is compatible with Annex 5 of ICAO.

FIGURE A1 - Illustration of Rain and Hail Threats.
Certification concentrations are obtained using Tables A1 and A2.

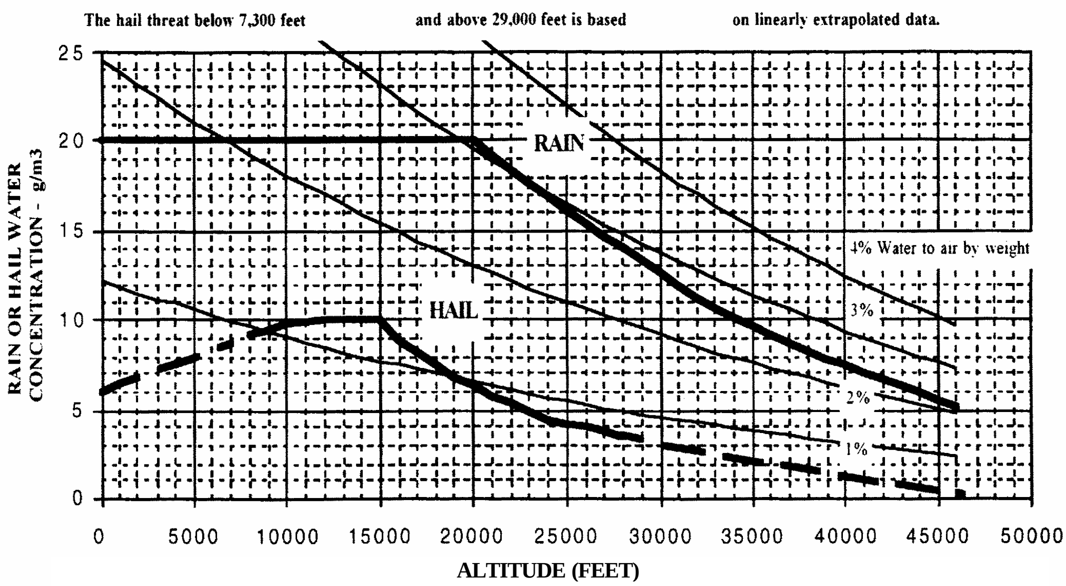


TABLE A1 – CERTIFICATION STANDARD ATMOSPHERIC RAIN CONCENTRATIONS

Altitude (feet)	Rain Water Content (RWC) (grams water/cubic metre air)
0	20·0
20 000	20·0
26 300	15·2
32 700	10·8
39 300	7·7
46 000	5·2

RWC values at other altitudes may be determined by linear interpolation.

TABLE A2 – CERTIFICATION STANDARD ATMOSPHERIC HAIL CONCENTRATIONS

Altitude (feet)	Hail Water Content (HWC) (grams water/cubic metre air)
0	6·0
7 300	8·9
8 500	9·4
10 000	9·9
12 000	10·0
15 000	10·0
16 000	8·9
17 700	7·8
19 300	6·6
21 500	5·6
24 300	4·4
29 000	3·3
46 000	0·2

HWC values at other altitudes may be determined by linear interpolation. The hail threat below 7 300 feet and above 29 000 feet is based on linearly extrapolated data.

TABLE A3 – CERTIFICATION STANDARD ATMOSPHERIC RAIN DROPLET SIZE DISTRIBUTION

Rain Droplet Diameter (mm)	Contribution to total RWC (%)
0 – 0·49	0
0·50 – 0·99	2·25
1·00 – 1·49	8·75
1·50 – 1·99	16·25
2·00 – 2·49	19·00
2·50 – 2·99	17·75
3·00 – 3·49	13·50
3·50 – 3·99	9·50
4·00 – 4·49	6·00
4·50 – 4·99	3·00
5·00 – 5·49	2·00
5·50 – 5·99	1·25
6·00 – 6·49	0·50
6·50 – 7·00	0·25
TOTAL	100·00

Median diameter of rain droplets is 2·66 mm.

TABLE A4 –- CERTIFICATION STANDARD ATMOSPHERIC HAILSTONE SIZE DISTRIBUTION

Hailstone Diameter (mm)	Contribution to total HWC (%)
0 – 4·9	0
5·0 – 9·9	17·00
10·0 – 14·9	25·00
15·0 – 19·9	22·50
20·0 – 24·9	16·00
25·0 – 29·9	9·75
30·0 – 34·9	4·75
35·0 – 39·9	2·50
40·0 – 44·9	1·50
45·0 – 49·9	0·75
50·0 – 55·0	0·25
TOTAL	100·00

Median diameter of hailstones is 16 mm

EASA Certification Specifications
for
Engines

CS-E
Book 2

Acceptable means of compliance

SUBPART A - GENERAL

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

AMC to CS-E 10 (c)
Thrust Reversers

If a thrust reverser is declared as being part of the Engine type design under CS-E 20 (a), it should comply with all appropriate CS-E specifications and therefore be certificated as part of the Engine. However, the thrust reverser itself is, in addition, required to comply with the relevant aircraft specifications during the certification of the aircraft.

The intent of CS-E specifications is to give sufficient confidence that the use of the thrust reverser has no detrimental effects on the Engine itself, such as flutter in a fan, excessive vibrations or loads induced in the Engine carcass, etc.

This is addressed mainly under CS-E 650 and CS-E 890.

If the Engine is intended to be used with a thrust reverser which is not included in the Engine type design, these CS-E specifications should nevertheless be addressed for approval of the use of the Engine with this thrust reverser. If this is not done, then the Engine certification documentation is endorsed so that the use of the thrust reverser is prohibited.

If CS-E is complied with by the Engine / thrust reverser combination, the Engine data sheet would contain a note to the effect that the Engine may be used with the specified thrust reverser.

AMC to CS-E 20
Engine Configuration and Interfaces

(1) The components and equipment listed in the Engine type design (see CS-E 20 (a)) should include those items necessary for the satisfactory functioning and control of the Engine.

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

(3) The components or equipment identified under CS-E 20 (c) constitute interfaces for the purposes of CS-E 20 (d). The effect of these components or equipment on the Engine should be considered during the Engine certification, in normal and Failure cases (see CS-E 80). The Engine instructions for installation required under CS-E 20 (d) should clearly specify the need for such components or equipment to comply with CS-E 80 (c).

(4) The applicant should give the aircraft manufacturer the information on the assumptions which were made during the Engine certification and which need to be taken into account when designing the installation (see CS-E 30). The applicant should ensure, when appropriate in co-ordination with the aircraft manufacturer, that Engine 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 Engine for the fitment and operation of at least the mandatory items of equipment prescribed by the use of the word 'should' in the assumed applicable aircraft specifications.

(5) The Engine instructions for installation should include or make reference to installation interface descriptions, limitations, and specifications for the Engine Control System. For example, the Electronic Engine Control System (EECS) power specifications and quality, including interrupt limitations, should be clearly defined for the installer. Another example is that the impedance and buffering limitations for the signals provided by the EECS for display and instrumentation, or signals used by the EECS, such as air data information, should be specified.

(6) The trend toward system integration may lead to EECS that :

- Have other control functions integrated within the Engine Control System, such as an integrated Engine and Propeller Control System or,

- Depend on aircraft resources.

Examples of these aircraft supplied resources include recording of rotorcraft One Engine Inoperative data and aircraft central computers that perform some or all of the Engine control functions.

The applicant is responsible for specifying the specifications for the EECS for these aircraft supplied resources in the Engine instructions for installation and substantiating the adequacy of those specifications.

(7) The Engine instructions for installation should include a description of all operational modes of the Engine Control System and its functional interface with the aircraft systems including Back-up or Alternate Modes whether dispatchable or not, and including the Propeller when applicable.

AMC to CS-E 20 (f)
Power assurance data for engines with one or more OEI power ratings

(1) For Engines having one or more OEI ratings, the applicant should provide in the instructions for installation the necessary Engine data to support the installer in meeting the power availability specifications of CS-27.45 (f) or CS-29.45 (f).

These data should include the effects of those installation losses that can be defined at the Engine level. Such installation losses should include customer bleed, customer power extraction, and others as appropriate, up to and including the highest power rating.

(2) The safety analysis of CS-E 510 should consider dormant Failures which could lead to non-availability of the OEI ratings and the results of this review should be part of the data required under CS-E 20 (f).

(3) The objective of the power availability procedures is to allow the installer to ensure that the Engine is capable of obtaining and sustaining the OEI ratings within the associated ratings operating limitations. The required Engine data are intended to be used for establishing a procedure for trending of individual Engine performance by the operator. These data should support maintenance procedures, intervals and standards applicable to the Engine, including sensors and indicating systems, to detect those latent or dormant conditions which are not detectable through the normal aircraft power assurance procedures (e.g., fuel control maximum flow capability, turbine section distress), or because the power assurance procedure will not include a topping check to the highest OEI rating power level.

The adequacy of these procedures, intervals and standards should be validated on the basis of the Engine and Engine systems Failure modes and effects analysis (FMEA) required under CS-E 510. The Engine database should include a thermodynamic model, the experience gained during development and certification testing, and the field experience gained with this Engine type or with engines of similar design, when applicable.

(4) In order to satisfy the power availability specifications of CS-27/29.45 (f) the data required under CS-E 20 (f) should enable the installer to establish power assurance procedures in which the extrapolation of power assurance results can be achieved, from a lower power check level, up to the highest OEI rating power. The performance extrapolation may be accomplished by comparing the performance characteristics with the minimum acceptable Engine performance in a deteriorated state. The establishment of the minimum acceptable Engine performance characteristic depends on the existence of a reliable database. In a mature Engine programme, it is possible to use the new production Engine acceptance test data, Engine-to-Engine variation and also testing on engines prior to overhaul to determine the effects of deterioration. Thus, an up-to-date minimum Engine performance characteristic can be maintained.

For a completely new Engine design, or a remote derivative of an existing design, it may be somewhat difficult to establish the initial database. The experience from Engine development and certification tests should be used. This experience usually includes several thousand hours of running time to schedules which are expected to be more rigorous than normal commercial service. The information gathered from these tests could provide a sufficient database for the assessment of in-service engines, including the rate of deterioration. The testing of engines in production will eventually establish Engine-to-Engine variation, but an estimated worst variation should be assumed initially, based on the experience of engines of the same or similar design.

(5) The applicant should also provide information on methods by which to assure that Engine limiter settings would not prevent the Engine from reaching the 30-Second or 2-Minute OEI power which would be automatically available in compliance with CS-E 50 (f). These limiter settings may include Engine speed, measured gas temperature and fuel flow. Particular attention should be given to take-off conditions with a cold-soaked Engine.

AMC to CS-E 25
Instructions for continued airworthiness

(1) The maintenance actions are determined through certification testing, including, where applicable, endurance tests, Over-speed tests, Over-temperature tests, and supplemented by development testing and service experience of engines of the same type or of similar design. Servicing information should cover maintenance details regarding servicing points, inspections, adjustments, tests and replacement of components if required.

The mandatory inspection and maintenance actions considered under CS-E 25 (b)(1) may also evolve after entering service, based on the service experience.

(2) Where it is permitted to carry out certain tests with the engines installed in the aircraft, the relevant manual(s) should provide information on the way in which minimum installed performance levels will be verified (if necessary) and related to the static sea-level test-bed ratings approved for the Engine.

(3) The manuals required under CS-E 25 should include, where applicable, details of the division of the Engine into modules, giving the nomenclature and clearly defining the boundaries for each module.

(4) Inspection and maintenance actions for engines having 30-Second and 2-Minute OEI Power ratings. (See CS-E 25 (b)(2))

(a) For Engines with 30-Second and 2-Minute OEI Power ratings, the airworthiness limitations section of the instructions for continued airworthiness are required to prescribe the mandatory post-flight inspections and maintenance actions which are applicable following the use of either of these two ratings, or both, prior to next flight.

If the 2-Minute OEI Power rating time period is extended to 2 1/2 minutes, as described in paragraph (5) of AMC to CS-E 40 (b), the additional 30 seconds period is considered as a de-rated 30-Second OEI Power rating and the maintenance actions prescribed for the 30-Second OEI rating should be used. Alternatively, the applicant may seek approval for prescribing a different set of inspections and maintenance actions for time exceedence of Engine operation at the 2-Minute OEI Power rating if this is appropriately justified and validated. For instance, if the Engine is essentially the same as one which has a 2 1/2-Minute OEI rating equivalent to the new 2-Minute OEI rating, then the maintenance considerations of the 2 1/2-Minute OEI rating might also be applicable after use of the 2-Minute OEI rating for up to 2.5 minutes.

If only the accumulated usage time is recorded under CS-E 60 (d)(2), the inspection and maintenance action prescribed as required by CS-E 25 (b)(2) should be based on the total recorded time duration regardless of the number of applications at the ratings used in one flight.

(b) The 30-Second and 2-Minute OEI ratings were originally intended to allow brief periods of operation close to the limits of the Engine design. This may result in component deterioration beyond serviceable limits so that they would not be suitable for further use.

The extent to which use of the ratings cause component damage or life reduction, in particular the life of Engine Critical Parts, is primarily a function of Engine design margins, application exposure level and duration, hardware condition prior to use and operating environment. Because Engine operating conditions and time recording are specifications for this rating, the maintenance actions can be related directly to an actual documented usage level, time and, if applicable, known condition prior to rating application (hours / cycles / prior rating exposure, etc.).

Depending on the actual operating parameters such as temperature and time exposure which are recorded during usage of these ratings in accordance with CS-E 60 (d), it is possible to pre-define a maintenance action and decrement of the remaining time before overhaul or component replacement, based on the type, level and duration of exposure. If the mandatory maintenance instructions result in no maintenance action, then the minimum specification would be the interpretation of recorded event data and documentation of the data in the maintenance log(s). The instructions for continued airworthiness should also include the definition of data to be provided by the operator on the Engine during service to support the applicant in completing the Engine in service evaluation programme

(c) Validation of mandatory post-flight inspection and maintenance actions.

(i) Under CS-E 40 (f), at any time during its service life, the Engine should be maintained in a condition which would assure that the 30-Second and 2-Minute OEI ratings can be attained and sustained. This specification has a bearing on both power assurance procedures and instructions for continued airworthiness. The mandatory maintenance following the use of 30-Second or 2-Minute OEI rating should be capable of identifying and correcting any component distress which could significantly reduce subsequent Engine reliability or prevent the Engine from achieving or sustaining further application of the OEI ratings.

The applicant should provide evidence by endurance test results or analysis based on test data of the endurance tests, and/or with other certification tests and service experience of similar type and design of engines, to show that the power at 30-Second and 2-Minute OEI ratings is achievable and can be sustained for the respective duration at any time between overhauls or major maintenance of the Engine.

(ii) Essential to the establishment of mandatory maintenance instructions is a thorough knowledge of the potential damage incurred with use of the 30-Second and 2-Minute OEI ratings and, more importantly, the remaining margin to component Failure or reduced Engine performance due to use of these OEI ratings.

The certification procedures for the 30-Second and 2-Minute OEI ratings emphasise demonstrating design adequacy by endurance testing and by specific margin tests for turbine temperature, rotor speeds, etc. An understanding of operating margins to various Failure modes when operating at the 30-Second and 2-Minute OEI ratings is needed for establishing adequate instructions for continued airworthiness. These Failure modes should be determined and validated by appropriate methods or experience.

(iii) The applicant should undertake the necessary actions, including instructions in Engine manuals, to make sure that the operators are aware of the need and understand the procedures to properly collect and return the information necessary for the applicant to monitor the adequacy of the prescribed mandatory maintenance actions.

(d) In-service Engine evaluation programme

(i) In order to comply with CS-E 25 (b)(2), an in-service Engine evaluation programme to assure the continued adequacy of the instructions for continued airworthiness and of power availability data should be provided and be approved by the Agency prior to certification.

The intent of this programme is to obtain relevant data concerning Engine hardware condition and power availability at various stages in the life of the Engine hardware critical to the achievement of the ratings and to compare that data to corresponding data observed during the certification process that defined the instructions for continued airworthiness.

Differences may exist in hardware condition and power availability characteristics from in-service engines that have not experienced any usage of the 30-Second or 2-Minute OEI ratings versus similar parameters that existed prior to the two-hour additional endurance test of CS-E 740 (c)(3)(iii).

Similarly, differences may exist in hardware condition and power assurance characteristics from in-service engines after usage of the 30-Second or 2-Minute OEI ratings versus similar parameters observed following the two-hour additional endurance test of CS-E 740 (c)(3)(iii).

Proper definition of the instructions for continued airworthiness is expected to have anticipated and accounted for such in-service conditions; this programme should however be structured to validate that such in-service differences are properly accounted for. If the data obtained during the execution of the programme indicates that the in-service differences are not properly accounted for, then the data from the programme or from additional Engine testing should be used to modify the instructions as appropriate.

(ii) The in-service Engine evaluation programme should include some type of service Engine testing and / or evaluations of service usage of the 30-Second / 2-Minute OEI ratings, although equivalent service Engine test experience on engines of similar design is acceptable as an alternative. This part of the programme would consist of, but not be limited to, one or more of the following elements :

- Scheduled tests of in-service Engines imposing three applications of 30 seconds OEI rated power, while either installed in the rotorcraft or in an Engine test cell. For selected representative aged engines, the programme would include number and frequency of samples, as well as inspection and test specifications. Such specifications should include the recording of data on the available power and the identification of the hardware condition before and after 30-Second and 2-Minute OEI rating usage.
- Unscheduled tests of engines of opportunity imposing three applications of 30 seconds OEI rated power. The programme may include actions to be taken when Engines become available that meet certain predetermined criteria. Definition of selection criteria for representative aged engines should be included in the programme. Inspection / test specifications on such engines should include the recording of data on the available power and the identification of the hardware condition before and after 30-Second and 2-Minute OEI rating usage.
- Service usage of 30-second/2 minute OEI rated power. This may include recorded power available data, post usage power available data and / or results of the mandatory maintenance and inspection actions.
- The equivalent service test on engines of similar design is acceptable although it should be demonstrated as being representative.

The aircraft certification testing of the 30-Second and/or 2-Minute OEI ratings could also provide additional recorded data with respect to available power, post-usage power data and results of hardware maintenance and inspection of the Engine, to support the programme.

In addition to the tests on engines from service, the in-service evaluation programme may also include test evidence from development or certification tests to reduce, but not eliminate, the required number of engines from service.

During the execution of the in-service evaluation programme, the instructions for continued airworthiness should be modified as necessary, based on the results. Similarly, if circumstances warrant, the programme itself may be modified, as additional in-service data become available.

(iii) The information or actions needed from the operator to support the in-service evaluation programme may be prescribed in the airworthiness limitation section of the instructions for continued airworthiness.

AMC to CS-E 30
Assumptions

The details required by CS-E 30 concerning assumptions should normally include information on, at least, the items listed in Table 1.

TABLE 1

Specifications/References	*Assumptions*
ALL ENGINES	
Interfaces CS-E 20	Applicable aircraft specifications Flight and ground loads Aircraft components and equipment not included in the Engine definition Attitudes Negative g duration Physical and functional interfaces with the aircraft Mount flexibility
Engine Control System CS-E 50	Type of aircraft installation Conditions on the interfaces with the aircraft or the Propeller Environmental conditions
Instrumentation CS-E 60	Instrumentation required and statement of accuracy. For engines with 30-Second / 2-Minute OEI ratings, conditions imposed to the usage recording system
Strength CS-E 100 CS-E 520, E 640	Ultimate and limit loads – Out of balance loads – Operating envelope
Propeller functioning tests CS-E 180	Propeller system Levels of the Propeller vibrations
Failure Analysis CS-E 210, E 510	Installation aspects and the assumptions made with respect to any safety system that is required for the Engine and which is outside the applicant's control.
Low temperature starting tests,	Minimum and maximum starting torque.

CS-E 380, E 770	
TURBINE ENGINES	
Freedom from surge CS-E 500	Operating envelope, i.e. altitude, temperature, aircraft speed. Permissible intake distortion.
Low cycle fatigue CS-E 515	Engine Flight Cycle
Continued rotation CS-E 525	Aircraft conditions such as airspeed, flight duration and ambient conditions.
Fire precautions CS-E 530	Reliance placed on installation fire-zone partitioning for any part of the mounting structure or Engine attachment points that are not fireproof.
Electrical bonding CS-E 530	Reliance placed on aircraft provisions for electrical bonding of Engine components and for their protection against lightning strikes.
Fuel system CS-E 560	Fuel Specifications approved for use. Need for aircraft fuel anti-ice means or fuel with anti-ice additives. Assumptions made with respect to the maximum levels of contamination in the fuel supplied to the Engine.
Oil System CS-E 570	Oil(s) approved for use.
Starter system CS-E 570	Reliance placed on aircraft provisions for any safety system that is outside the applicant’s control.
Vibration Survey CS-E 650	Intake conditions, exhaust conditions. Propeller or thrust reverser effects.
Contaminated fuel CS-E 670	Duration of flight with contaminated fuel following indication of impending filter blockage, and critical temperature for test of AMC to CS-E 670 Paragraph 2.
Inclination and gyroscopic loads effects CS-E 680	Flight manoeuvres.
Excess operating conditions CS-E 700	Operating envelope.
Rotor locking test CS-E 710	Maximum torque from continued flight.
Thrust or power response CS-E 745	Minimum ground idle Minimum flight idle Flight envelope
Test in ice forming conditions	Intake conditions and configuration. Aircraft speeds and appropriate Engine powers.

CS-E 780	
Ingestion of rain and hail CS-E 790	Aircraft speeds, Engine speeds and altitudes. Intake throat area – Intake configuration.
Bird strikes CS-E 800	Aircraft speeds, Engine speeds and altitudes. Intake throat area – Intake configuration.
Re-light in flight CS-E 910	Flight re-light envelope
PISTON ENGINES	
De-icing and anti-icing CS-E 230	Temperature rise provided.
Filters CS-E 260	Provision to be made in installation.
Vibration tests CS-E 340	Propeller used.
Water Spray tests CS-E 430	Installation details.

AMC to CS-E 40
Ratings

The thrust and / or power ratings to be approved should be adequately justified by the applicant, using as appropriate the results of the calibration tests (CS-E 350 or CS-E 730) and the values substantiated by the endurance test (CS-E 440 or CS-E 740) or other means.

AMC to CS-E 40 (b)(3)
30-Second OEI and 2-Minute OEI Ratings

(1) The 30-Second and 2-Minute OEI Power ratings are two separate ratings. However they are associated in a combined structure of 2.5 minutes duration.

(2) The 30-Second and 2-Minute OEI ratings are optional ratings that may be specifically requested by the applicant and are intended for use only for continuation of the one-flight operation after the Failure of one Engine in multi-Engine rotorcraft during take-off, climb or landing. The 30-Second OEI Power rating provides a short burst of power to complete the take-off or to effect a rejected take-off, should an Engine Failure occur at the critical decision point, so that the rotorcraft can lift clear of any obstruction in the flight path and climb out or, alternatively, to reject the take-off. Similarly, this rating also provides adequate power for the rotorcraft to execute a safe landing, or a baulked landing if an Engine fails at any point down to and including the landing decision point. The 2-Minute OEI Power rating provides a further period of increased power to enable the rotorcraft to complete the climb out from take-off or baulked landing to safe altitude and airspeed.

(3) While the 30-Second and 2-Minute OEI power ratings were originally conceived as high power ratings, using the available margins in the Engine design, and followed by a mandatory Engine overhaul, the experience has shown that the manufacturers provide engines with differing capabilities and different

margins. Therefore some flexibility is possible in defining the mandatory maintenance actions, provided they are appropriately validated during certification. (See also AMC to CS-E 25)

(4) These ratings have been intended for one usage per flight in an emergency during the take-off or landing phases. Nevertheless the certification specifications have been defined around the worst case scenario involving the possible use of these ratings three times in one flight (i.e., the event at take-off, baulked landing and final landing). While not initially intended, it is recognised that the ratings could also be inadvertently used in some unexpected, non-critical conditions like an Engine Failure in a rotorcraft flying at a high-speed cruise. In all cases, the required mandatory maintenance actions apply after any use of the rating powers.

(5) In some circumstances, the highest power used during a 2.5 minute duration OEI event might be lower than the 30-second OEI power band but still inside the certified power band of the 2-Minute OEI power rating. In this case, it is permissible to extend the use of the 2-Minute OEI power rating to a total duration of 2.5 minutes. However, that additional 30 seconds period will be considered as a de-rated 30-Second OEI power rating. For the required mandatory maintenance actions, see CS-E 25 (b)(2) and AMC to CS-E 25.

(6) The 30-Second and 2-Minute OEI power ratings should account for deterioration observed from the applicable portion of the two-hour additional endurance test of CS-E 740 (c)(3)(iii).

Any available information from tests of CS-E 740 (c)(3)(iii) may be used for establishing the Engine characteristics throughout the Engine's operating envelope. In particular, the power ratings for the 30-Second and 2-Minute OEI ratings should reflect the rated power deterioration that is observed from the pre-2 hour test calibration through and including the third application of 30-Second OEI rated power during the additional endurance test. The power deterioration through the third application is expected to be the best indicator of the worst case power deterioration that could occur during actual usage of the rating, and thus should be reflected in the data given to the aircraft manufacturer to define performance characteristics of the aircraft system. In the event of power deterioration exceeding 10% at the 30-Second OEI rating over the course of the 2-hour test, the mode of deterioration should be evaluated to ensure that the availability of 30-Second OEI rated power in service will not be compromised by deterioration variability.

AMC to CS-E 40 (d)
Operating Limitations

The Operating limitations established under CS-40 (d) should normally include those items listed below.

(1) General

(a) Environmental conditions. (Flight envelope)

(b) Maximum declared Engine conditions for reverse pitch Propeller operations. (If applicable)

(c) Types of Propellers approved. (If applicable)

(d) Equipment approved for use on the Engine.

(2) Piston Engines

(i) Maximum Engine rotational speed and power setting for Take-off conditions.

(ii) Maximum Engine rotational speed and power setting for Maximum Continuous conditions.

(iii) Maximum Engine Over-speed

(iv) Fuel, oil, and Engine coolant specifications, including additives.

(v) Maximum oil inlet temperature(s) (appropriate to each operating condition).

(vi) Minimum oil inlet temperature for starting.

(vii) Minimum oil inlet temperature for acceleration from idle.

(viii) Normal operating oil inlet pressure at Maximum Continuous conditions.

(ix) Minimum oil inlet pressure for completion of flight at Maximum Continuous conditions.

(x) Maximum cylinder temperature (if applicable)

(xi) Minimum cylinder temperature for acceleration from idle. (If applicable.)

(xii) Maximum Engine coolant temperature. (If applicable.)

(xiii) Minimum Engine coolant temperature for acceleration from idle. (If applicable.)

(xiv) Maximum intake air temperature. (If applicable)

(xv) Maximum Over-speed and associated time limit.

(xvi) Normal operating fuel inlet pressure.

(xvii) Minimum fuel inlet temperature for starting

(xviii) Maximum fuel inlet temperature

(3) Turbine Engines

(a) RPM, indicated turbine gas temperature and time for:
- Take-off conditions.
- Maximum Continuous conditions.
- Maximum Contingency conditions. (If applicable.)
- Intermediate Contingency conditions. (If applicable.)
- 30-minute Contingency conditions. (If applicable.)

(b) Oil brand(s) and type(s).

(c) Fuel specification(s).

(d) Hydraulic fluid specification(s). (If applicable.)

(e) Inlet air distortion at the Engine inlet.

(f) Maximum and minimum fuel pressure.

(g) Maximum and minimum fuel temperature.

(h) Maximum indicated oil temperature for:
- Take-off conditions.
- Maximum Continuous conditions.
- Contingency conditions.

- Transient conditions and associated time limitation(s).

(i) Minimum indicated oil temperature for starting.

(j) Minimum indicated oil temperature for acceleration from idle.

(k) Minimum oil pressure for completion of flight at Maximum Continuous conditions.

(l) Maximum normal oil pressure at Maximum Continuous conditions.

(m) Use of compressor bleed air.

(n) Maximum Power Turbine speed for Autorotation (if applicable).

(o) Maximum Power Turbine torque and maximum rpm at which use of maximum torque is approved.

(p) Maximum Over-torque transient and time limit.

(q) Maximum Over-speed transient(s) and time limit(s) for each applicable operating condition.

(r) Maximum Over-temperature transient and time limit.

(s) Maximum refrigerant flow rate (if applicable).

(t) Maximum reverse thrust conditions and time limitations (including use in flight if applicable).

(u) Maximum rpm for application of Propeller brake (if applicable.)

AMC to CS-E 50
Engine Control System

(1) Applicability

CS-E 50 is applicable to all types of Engine Control Systems. For instance, these systems might be hydromechanical or hydromechanical with a limited authority electronic supervisor or single channel full authority Engine control with hydromechanical back-up or dual channel full authority Electronic Engine Control System with no back-up or any other combination. The electronic technology may be analogue or digital.

The Engine Control System includes any system or device that controls, limits or monitors Engine operation and is necessary for continued airworthiness of the Engine. This includes all equipment that is necessary for controlling the Engine and ensuring safe operation of the Engine within its limits as specified in CS-E 50 (a). This implies consideration of all Engine Control System components including the electronic control unit(s), fuel metering unit(s), variable-geometry actuators, cables, wires, sensors, etc. The main Engine fuel pump is often Engine-mounted and physically integrated with the fuel metering unit. However, it is not usually considered part of the Engine Control System.

These specifications cover the main Engine Control System as well as protection systems against, for example, over-speed, over-torque or over-temperature.

When blade shedding or Engine design related means is used for over-speed protection, this would not be considered under CS-E 50 as being part of the Engine Control System, as this protection is purely mechanical and is designed to work without influence from the Engine Control System.

Engine monitoring systems are covered by this specification when they are physically or functionally integrated with the Engine Control System or they perform functions that affect Engine safety or are used to effect continued-operation or return-to-service decisions. For instance, low cycle fatigue (LCF) cycle-counters for Engine Critical Parts would be included but most trend monitors and devices providing information for maintenance would not. Where a device is not functionally or physically integrated into the Engine Control System and does not perform a function that affects Engine safety, it should still be considered under CS-E 170.

(2) Objective

The purpose of CS-E 50 is to set objectives for the general design and functioning of the Engine Control System and these specifications are not intended to replace or supersede other specifications, such as CS-E 560 for the fuel system. Therefore, individual components of the Engine Control System, such as alternators, sensors, actuators, should be covered, in addition, under other CS-E paragraphs such as CS-E 80 or CS-E 170, as appropriate.

For EECS, AMC 20-1 provides additional and detailed interpretation of CS-E 50 with special consideration to interfaces with the aircraft, and the Propeller when applicable.

(3) Integrity

The intent of CS-E 50 (c) is to establish Engine Control System integrity specifications consistent with operational specifications of the various applications. In particular, the introduction of Electronic Engine Control Systems should provide at least an equivalent level of safety and reliability for the Engine as achieved by Engines equipped with hydromechanical control and protection systems, and magneto systems.

(4) Aircraft Supplied Power

Engine Control Systems implemented in hydromechanical technology or technology other than electrical and electronic technology should inherently be compliant with CS-E 50 (h). However, if the system has functions implemented electrically or electronically that depend on aircraft-supplied electrical power, the system should be evaluated for compliance with this rule (see AMC 20-1 for relevant interpretation).

(5) Air Signal Lines

CS-E 50 (i) covers cases of ingress of foreign matter (e.g. sand, dust, water, or insects) which could result in blockage of the lines and result in an adverse effect on Engine operation. For example, the experience has shown that lines used for measuring the static pressure in the compressor of turbine Engines could be blocked by frozen water, leading to a loss of power. Precautions should therefore be taken, such as use of protected openings, filters, drains for water, heating of the lines to prevent freezing of condensed water. Corrosion effects should also be addressed.

AMC to CS-E 50 (e)
Rotor integrity

The Engine control devices, systems and instruments referred to in CS-E 50 (e) are usually provided in modern engines by over-speed protection and/or circuits which although they may be provided as independent devices are generally provided as part of the electronic Engine Control System. One acceptable method for showing compliance with the specification for "reasonable assurance" of providing functionality of the protection systems or circuits is to have them periodically tested by built-in test equipment (BITE) or a functional test.

In case of the over-speed protection system, the BITE test should provide complete test of the electrical/electronic part of the protection system. The need for inspections or tests of the mechanical or actuating part of the protection system should be based on the results of the safety analysis for this part.

AMC to CS-E 50 (j)
Controls - Engines having a 30-Second OEI Power Rating

(1) The 30-Second OEI rating is intended to provide a rotorcraft with a power reserve in the event of one Engine becoming inoperative. The flight and operating conditions requiring use of this rating may create a high pilot workload to maintain safe flight. Therefore the 30-Second OEI rating should be applied and controlled by an automatic means that requires no pilot input or control other than termination command. Once activated, it automatically controls the 30-Second OEI power and prevents the Engine from exceeding its limits, specified in the Engine's type certificate data sheet and associated with this rating. Because the 30-Second OEI rating could already use almost all the available margins in the Engine design, it is considered that exceeding the limits associated with this rating would likely result in an Engine Failure, which would be unacceptable in a critical flight condition with an already failed Engine.

The required automatic control of the 30-Second OEI power is intended to avoid the need for monitoring Engine parameters such as output shaft torque or power, output shaft speed, gas generator speed and gas path temperatures. Such means for automatic control within the operating limitations should be effective during normal and abnormal operations.

(2) The means required by CS-E 50 (j) should not prevent the Engine from reaching and maintaining its rated 30-Second OEI Power. See also paragraph (5) of AMC to CS-E 20 (f).

AMC to CS-E 60
Provision for instruments

(1) Under the specifications of CS-E 60 (a), the Engine manufacturer should define the instrumentation which is necessary for Engine operation within its limitations and also make provision for installation of this instrumentation.

In addition to powerplant instrumentation required for aircraft certification, the Engine safety analysis might show the need for specific instrumentation providing information to the flight crew or maintenance personnel for taking the appropriate actions in order to prevent the occurrence of a Failure or to mitigate any associated consequences.

(2) Care should also be exercised in selecting the position on the Engine at which a particular parameter, such as oil pressure, is sensed in order to ensure that the indication is appropriate for the intended protection of relevant components. For example:

(a) The pick-up point on the Engine for the oil pressure gauge and the low oil pressure warning device, where applicable, should be suitably chosen with due regard to all critical components to ensure a satisfactory indication of the oil pressure to the main Engine bearings.

(b) Unless otherwise agreed, there should be no relief valve or other component liable to Failure between the oil pressure gauge and warning device connection and the main Engine bearings. Filters necessary to protect oil jets or metering orifices should be suitably chosen to reduce the possibility of blockage to a minimum and should be accessible for periodic inspection.

(3) In complying with CS-E 60(c), for example, because the inadvertent deployment of a reverser in-flight is a Hazardous Engine Effect, the thrust reverser position control and position indicating systems should be separate, such that Failures which could affect the thrust reverser position would not cause loss of the correct flight deck indication of reverser position.

(4) In complying with CS E 60(d), the recording system should only be able to be reset by the maintenance personnel and not by the flight crew, in order to prevent further Engine operation without having taken the prescribed mandatory post-flight inspection and maintenance action.

AMC to CS-E 60 (d)
Provision for instruments

(1) For the purpose of complying with CS-E 60 (d), the 30-Second OEI power level is considered to be used whenever one or more of the operating limitations applicable to the 2-Minute OEI power level are exceeded. The 2-minute OEI power level is considered to be used whenever one or more of the operating limitations applicable to the next lower OEI power rating or other Engine rating (if applicable) are exceeded.

(2) The required means, provided by the applicant or by the rotorcraft manufacturer, are intended to automatically record the entry into, and the subsequent usage of, the defined power levels, and to enable the pilot to be automatically alerted of the entry into the power levels and the corresponding impending time expiration and the time expiration point. The automatic recording should be compatible with the maintenance instructions prescribed for these ratings. In particular, it should record the number of usages and time of each usage or accumulated time, including any exceedence of 30-Second OEI and/or 2-Minute OEI operating limitations or relevant time limitations. It should also provide a means to alert the maintenance personnel that usage and/or exceedence of 30-Second and/or 2-Minute OEI power have taken place. See also paragraph (5) of AMC to CS-E 40 (b) regarding exceedence of the 2 minute time limitation at 2-Minute OEI power.

(3) The objective is to ensure that the information needed for the mandatory maintenance actions is available after the use of 30-Second and/or 2-Minute OEI power, thus avoiding continued operation of the Engine in a potentially unsafe condition. The overall development assurance level of the recording and retrieval system should be consistent with this objective. The development assurance level(s) of the components of the systems used to record usage and to retrieve the record of the 2-Minute and 30-Second OEI powers should be based on the criticality of the function(s) performed within the recording and retrieval system as determined through the system safety analysis required under CS-E 50 (d). The overall system assurance level can be achieved based on an appropriate combination of system architecture and component assurance levels.

If the recording and/or retrieval system is not part of the Engine, the aircraft should still comply with CS-27/29.1305 specifications. The applicant should specify in the instructions for installation that the objective of this recording/retrieval system is to ensure that the information needed for the mandatory maintenance actions is available after the use of 30-Second and/or 2-Minute OEI power, thus avoiding continued operation of the Engine in a potentially unsafe condition and that the overall development assurance level of the recording and retrieval system should be consistent with this objective.

(4) The recording systems should only be able to be reset by the maintenance personnel and not by the flight crew in order to prevent further Engine operation without having taken the prescribed mandatory post-flight inspection and maintenance actions.

AMC to CS-E 70
Castings, Forgings, Welded Structures and Welded Components

(1) Castings

The means of maintaining the required quality of all castings should be established by such methods as analysis for correct chemical composition, tests of mechanical properties, microscopic examination, break-up examination, strength tests, radiographic examination, etc. While other forms of examination may be adequate for most parts of castings, radiographic examination, where practicable, should be carried out on the more highly stressed portions in order to establish that the foundry technique is satisfactory.

When radiographic examination is called for, this should be continued until a satisfactory standard of quality has been established. Subsequent relaxation may be introduced, in quantity production, at the Engine constructor's discretion using a system acceptable to the Agency.

All castings should be subjected to a suitable flaw-detection process. Such processes should be completed subsequent to any heat treatment.

The drawings of each casting should contain information sufficient to identify the relevant means of manufacture and quality control, either by detailing the necessary information, or quoting the relevant documents. Where necessary, areas of high stress should be identified, but this may be done by a separate drawing.

No change of foundry (i.e. castings constructor) or significant change of foundry technique should be made without the agreement of the Engine constructor, and such agreement should involve review of the need for the repetition of certain tests and/or a revision of the method of quality control.

(2) Forgings

(a) Forgings should be classified as Class 1, Class 2 or Class 3 parts in accordance with the following:

- *Class 1* Those parts, the Failure of which could hazard the aircraft.
- *Class 2* Stressed parts not covered by the terms of Class 1.
- *Class 3* Unstressed or only lightly stressed parts, not covered by the terms of Class 1.

The means of maintaining the required quality of all forgings should be established by such methods as analysis for correct chemical composition, tests of mechanical properties, microscopic examination, fracture examination, strength tests, radiographic examination, etc.

On the drawings of Class 1 parts, the direction of grain required should be indicated clearly in a manner which will ensure that it is brought to the notice of the person responsible for deciding the forging technique to be adopted. The agreed material properties should also be identified.

All forgings should be subjected to a suitable crack-detection process at an appropriate stage. Additional crack-detection tests should be made after any subsequent heat treatment has been completed. Where the level and location of residual stresses in forged Engine Critical Parts could be significant in relation to the intended loads, and cannot be assessed by experience on similar designs using similar materials and forging methods, sufficient physical tests should be carried out to give adequate assurance of the level of residual stress likely to be present and of freedom from unacceptable variability.

When radiographic or ultrasonic examination is called for, this should be continued until a satisfactory standard of quality has been established. Subsequent relaxation may be introduced in quantity production at the Engine constructor's discretion using a system acceptable to the Agency.

The drawings of each forging should contain information sufficient to identify the relevant means of manufacture (e.g. the optimum fabrication method and sequence to obtain the desired level of residual stress and the correct grain flow in the finished forgings) and quality control either by detailing the necessary information or quoting the relevant process control documents.

The strength of forgings classified as Class 1 or Class 2 parts should be proved to be satisfactory by calculation, by test, or comparison with a forging of similar design already proved to be satisfactory.

(b) Tests

Each Class 1 and Class 2 forging should normally incorporate one or more projections which, after heat treatment of the forging, can be used as test piece(s) to establish that the material qualities of the forging are satisfactory.

The location(s) and dimensions of the test piece(s) should be decided in consultation with the forging manufacturer. The forging manufacturer should certify that the test piece(s) achieve the required material properties.

In cases where the incorporation of test pieces is unpractical, or would adversely affect the design, the drawing should indicate that such test pieces are not required. In such cases a suitable technique of sample testing should be agreed.

(c) No change of forging constructor or significant change of forging technique should be made without the agreement of the Engine constructor and such agreement should involve review of the need for the repetition of certain tests and/or a revision of the method of quality control.

(3) Welded Structures and Welded Components

Fusion and resistance welds should be classified in accordance with the following:

- *Group 1* Those welds the Failure or leakage of which could hazard the aircraft.
- *Group 2* Highly stressed welds the Failure or leakage of which would not hazard the aircraft.
- *Group 3* All other welds.

The necessary means of maintaining the required quality of all welded structures and components should be established. This may involve the verification of correct application of the approved preparatory and welding techniques, by destructive and non-destructive inspection of representative test specimens, at prescribed intervals during weld production, visual inspection of each weld produced, and pressure testing of welds, where applicable, etc.

All welds should be subjected to a suitable crack-detection process at an appropriate stage. Additional crack-detection tests should be made after any subsequent heat treatment has been completed.

When radiographic examination is called for, this should be continued until a satisfactory standard of quality has been established. Subsequent relaxation may be introduced in quantity production at the Engine constructor's discretion using a system acceptable to the Agency.

The drawings of each welded structure or component should contain information sufficient to identify the relevant means of welding to be used and the quality control method either by detailing the necessary information or quoting the relevant documents.

No significant change of welding technique should be made without the agreement of the Engine constructor and such agreement should involve review of the need for a revision of the method of quality control or even modification approval action.

AMC to CS-E 80
Equipment

(1) The need for additional specifications in the equipment specifications should be determined when complying with CS-E 80 or be defined by the applicant on a general basis, for example for covering more than one aircraft installation.

Consideration of general conditions, such as those of EUROCAE ED-14 / RTCA/DO-160, allows certification of equipment in a consistent manner, independent from any installation consideration. However, additional testing may be required in order to comply with CS-E 80 (b), dependant on the assumed installation conditions. All equipment, including all electronic units, sensors, harnesses, hydromechanical elements, and any other relevant elements or units, should be shown to operate properly in their declared environment.

(2) The manufacturer should consider the applicability of the items listed in the Tables 1 to 4 below, which are provided as a guide.

Documents that provide acceptable test procedures for each item are referenced in the same table. The manufacturer may define other acceptable appropriate test and analysis procedures. Compliance is normally demonstrated by test or analysis unless the equipment is shown to be sufficiently similar to and operates in an environment which is the same or less severe than previously certified equipment for which similarity is claimed.

The intent and applicability of each item of Tables 1 to 4 are also specified after each table.

The following list of applicable tests or procedures (or their equivalent) is acceptable for evaluating equipment airworthiness.

(a) General Environmental Conditions

The following environmental conditions should be considered for all Equipment.

Table 1

	ENVIRONMENTAL CONDITIONS	ACCEPTABLE TESTS/PROCEDURES
1	High Temperature	EUROCAE ED-14 / RTCA/DO-160, section 4 or Mil-E-5007 paragraph 4.6.2.2.5
2	Low Temperature	EUROCAE ED-14 / RTCA/DO-160, section 4 or Mil-E-5007 paragraph 4.6.2.2.7
3	Room Temperature	EUROCAE ED-14 / RTCA/DO-160, section 4 or Mil-E-5007 paragraph 4.6.2.2.6
4	Contaminated Fluids	As a reminder. See relevant CS-E specifications for fuel/oil/air specifications or Mil-E-5007 paragraph 4.6.2.2.6 (fuel test only)
5	Vibration	EUROCAE ED-14 / RTCA/DO-160, Section 8
6	Operational shock and crash safety	EUROCAE ED-14 / RTCA/DO-160,

		Section 7.2 and 7.3.1
7	Sand and Dust	EUROCAE ED-14 / RTCA/DO-160, Section 12, Category D or MIL-STD-810
8	Fluid Susceptibility	EUROCAE ED-14 / RTCA/DO-160, Section 11, Category F
9	Salt Spray	EUROCAE ED-14 / RTCA/DO-160, Section 14, Category S or MIL-STD-810
10	Fuel System Icing	As a reminder. See CS-E 560 (e)
11	Induction Icing	As a reminder. See CS-E 230 & E 780
12	Fungus	EUROCAE ED-14 / RTCA/DO-160, Section 13, Category F
13	Temperature and altitude	EUROCAE ED-14 / RTCA/DO-160, Section 4

High Temperature

The high temperature demonstration is to verify that the equipment can function properly in its maximum temperature environment and to identify any damage caused by exposure to maximum temperature that could lead to equipment Failure. Maximum conditions should take into account ambient, external and internal fluid temperatures to which the equipment is exposed. Historical specifications can be found in MIL-E-5007 Paragraph 4.6.2.2.5. EUROCAE ED-14 /RTCA/DO-160 Section 4 tests have been used to show compliance.

Low Temperature

The low temperature demonstration is to verify that the equipment can function properly in its minimum temperature environment and identify any damage caused by exposure to minimum temperature that could lead to equipment Failure. Minimum conditions should take into account ambient, external and internal fluid temperatures to which the equipment is exposed. Historical specifications can be found in MIL-E-5007 Paragraph 4.6.2.2.7. EUROCAE ED-14 /RTCA/DO-160 Section 4 tests have been used to show compliance.

Room Temperature

The room temperature demonstration is to identify any damage caused by extended operation at room temperature that could lead to equipment Failure. EUROCAE ED-14 / RTCA/DO-160, section 4 tests have been used to show compliance. Historical specifications can also be found in MIL-E-5007 Paragraph 4.6.2.2.6. This test may be combined with the contaminated fluid tests, if applicable.

Contaminated Fluids

The contaminated fluid demonstration is to verify that the Engine systems can function properly in a contaminated fluid environment. This can be achieved either by system testing or individual item of equipment test/analysis. Refer to the applicable CS-E specifications, such as CS-E 560 for fuel, CS-E 570 for oil and CS-E 580 (a) for air for more details. Testing may be combined with the room temperature demonstration.

Vibration

The vibration demonstration is to verify that exposure to the declared vibration environment does not cause structural Failures and to verify that the equipment functions properly when exposed to that vibration. This can be addressed by either a specific unbalanced Engine test or by equipment test. The equipment may not be required to be operational during equipment testing if the applicant can demonstrate by other means that the equipment operate satisfactorily or do not adversely impact system operation when subjected to the declared vibration environment. EUROCAE ED-14 / RTCA/DO-160, Section 8 tests are appropriate if the equipment vibration environment can be correlated to the DO-160 standards.

Operational shock and crash safety

The operational shock demonstration is to verify that exposure to shocks experienced during normal aircraft operations will allow the equipment to continue to function properly. The crash safety demonstration is to verify that exposure to shocks experienced in crash conditions will not cause Failure of the mounting attachment. This demonstration applies to cases where separation of the equipment could lead to a Hazardous Engine Effect. EUROCAE ED-14 / RTCA/DO-160, Section 7 2 and 7.3.1 tests respectively are appropriate.

Sand and Dust

The sand and dust demonstration is applicable to all equipment that is not environmentally sealed. Testing should be performed according to EUROCAE ED-14 / RTCA/DO-160 section 12, category D.

Fluid Susceptibility

The fluid susceptibility demonstration is to verify that the equipment can function properly after exposure to specified fluids and identify any damage caused by such exposure that could lead to equipment Failure. Normally the fluids to be considered are those likely to be encountered in service, such as fuel, oil, hydraulic fluids, cleaning solvents, etc. Equipment testing may follow the procedures defined in EUROCAE ED-14 / RTCA/DO-160 section 11, category F, paragraph 11.4.1 (Spray Test). At the conclusion of the test, if the design of the unit allows, the unit under test should be opened and inspected for entry of the test fluid. If evidence of fluid entry is detected, the applicant should provide the rationale for accepting the test results based on the criticality of the quantity and location of the fluid entry point.

Salt Spray

The salt spray demonstration is to verify proper equipment operation after exposure to a salt spray environment. For environmentally sealed equipment, the specification may be substantiated by an analysis that shows that the equipment external materials are immune to a salt spray environment. Testing may be performed according to EUROCAE ED-14 / RTCA/DO-160 sections 14, category S.

Fuel System Icing

Fuel system equipment normally substantiate their capability to operate in icing environment through system test or analysis.

Induction Icing

Equipment exposed to Engine gas path or bleed system icing normally substantiate their capability to operate in icing environment through an Engine test or analysis.

Fungus

The fungus demonstration is substantiated by test or an analysis which shows that no materials which support the growth of fungus are used in the equipment. Testing may be performed as defined in EUROCAE ED-14 / RTCA/DO-160, section 13, category F (Fungus Resistance).

Temperature and Altitude

The purpose is to verify by test or an analysis that the equipment operates per design intent throughout the Engine flight envelope. Testing may be performed as defined in EUROCAE ED-14 / RTCA/DO-160, section 4.

(b) General Environmental Conditions for Electrical /Electronic Equipment.

The following environmental conditions should be considered for all electrical / electronic equipment or equipment with electrical / electronic sub-components. Additional advisory material on EMI, HIRF and lightning strikes may be found in AMC 20-1.

Table 2

Electrical General	ENVIRONMENTAL CONDITIONS	ACCEPTABLE TESTS/PROCEDURES
14	Thermal Cycle	EUROCAE ED-14 / RTCA/DO-160, Section 5
15	Explosion Proofness	EUROCAE ED-14 / RTCA/DO-160, Section 9
16	Humidity	EUROCAE ED-14 / RTCA/DO-160, Section 6 or MIL-STD-810
17	Waterproofness	EUROCAE ED-14 / RTCA/DO-160, Section 10 or MIL-STD-810 (RAIN)
18	EMI, HIRF & lightning	See AMC 20-1
19	Power Input	EUROCAE ED-14 / RTCA/DO-160, Section 16 and 17 or MIL-STD-704

Thermal Cycle

The thermal cycle demonstration is to demonstrate that an item of equipment will continue to operate and not fail or be damaged when exposed to temperature cycles and thermal transients consistent with the declared temperature environment. Equipment testing may follow the procedures defined in EUROCAE ED-14 / RTCA/DO-160, Section 5. If the equipment has electrical sub-components, testing of the sub-components only may be acceptable.

Explosion Proofness

The explosion proof demonstration is to verify that an item of equipment cannot cause an explosion of flammable fluids or vapours. If applicable, explosion proof testing may be performed as defined in EUROCAE ED-14 / RTCA/DO-160, section 9 (Explosion Proofness). Environment I defines equipment mounted in fuel tanks or within fuel systems. Environment II is an atmosphere in which flammable mixtures can be expected to occur as the result of a "Fault causing spillage or leakage".

For installations in a Fire zone, the Fire zone will have extinguishing provisions, so that the explosion proof test given by Environment II of DO-160D, section 9 is adequate. However, Flammable Fluid Leakage areas may not have fire extinguishing provisions or any of the other safety specifications associated with Fire zones based on the assumption that there are no ignition sources in these areas. In these cases the explosion proof test given by Environment I of DO-160D, section 9 may be required for aircraft installation.

Humidity

The humidity demonstration is to demonstrate that the equipment is not adversely effected, operationally or structurally, by ingress of moisture. Testing may be performed according to EUROCAE ED-14 / RTCA/DO-160 section 6.

Waterproofness

The waterproofness demonstration is to verify that the equipment can function properly after exposure to water and identify any damage caused by water exposure that could lead to equipment Failure. Water testing may be performed according to EUROCAE ED-14 / RTCA/DO-160 section 10 Category S. Following the test, if the design of the unit allows, the unit under test should be opened and inspected for entry of water. If evidence of water entry is detected, the applicant should provide the rationale for accepting the test results based on the criticality of the quantity and location of the water entry point.

Power Input

The power input demonstration applies only to electrical/electronic equipment or equipment with electrical/electronic sub-components that receive power directly from the aircraft (e.g., EEC, HMU fuel shutoff solenoid). The purpose of this test is to demonstrate that such equipment can accommodate the full range of power inputs declared for the installation. For applicable equipment, the specification may be substantiated by the test defined in EUROCAE ED-14 / RTCA/DO-160, section 16 and 17.

(c) Mechanical Equipment

Other specifications of CS-E may affect some equipment as follows.

Table 3

	SUBJECT	ACCEPTABLE TESTS/PROCEDURES
20	Proof Pressure	CS-E 640 (a)(1)
21	Burst Pressure	CS-E 640 (a)(2)
22	Pressure Cycling	CS-E 640 (b)
23	Fire	CS-E 130 (note : the Engine Control System should also comply with CS-E 130 (e))

The related AMC to CS-E 130 and AMC to CS-E 640 are therefore relevant.

(d) Specialised Equipment Testing

Table 4

	SUBJECT	ACCEPTABLE TESTS/PROCEDURE
24	Overheat for Engine electronic control systems	AMC 20-1

Overheat

The purpose of this test or analysis is to verify that the electrical/electronic portions of the Engine Control System, when subjected to an overheat condition leading to Failure, will not cause a hazardous Engine effect. See also AMC 20-1. If an overheat test/analysis is not completed, this should be declared as an installation limitation in the Engine instructions for installation and the possibility of an overheat should be addressed at aircraft certification.

(3) The provision of a weak link in the drive or the specification of a weak link in the equipment will normally be an acceptable means of limiting excessive torque. However for some equipment which might be included under CS-E 20 (c) (e.g. a high output electrical generator) a weak link might not provide an adequate safeguard against damage to the Engine from overheating and break-up of the equipment. In such a case other means of disconnect would need to be provided or specified in order to permit disengagement of the equipment with the Engine running.

(4) Equipment with high-energy rotors. Compliance with the specifications of CS-E 80 (d) can be demonstrated by reference to the four containment categories in Table 5 relating to a turbine-starter having air or gas supplied from an external source and specifies the specifications appropriate to each category. Other equipment will be considered on a similar basis, using the Fault analysis of the whole system to determine the critical speeds which may result from Failures.

Table 5

CONTAINMENT CATEGORY DEMONSTRATED	SECTION SPECIFICATIONS APPLICABLE (see Table 6)
1. Blade containment only	a, b, c, d and e
2. Tri-hub burst within the normal operating speed (i.e. at the highest permitted speed without Failure of the system but including maximum governor over-swing)	a, b, c (a reduction of the fatigue scatter factor may be permissible), d and e
3. Tri-hub burst at the maximum "no load" speed, under all Fault or combination of Fault conditions (including those affecting fluid supply) other than Extremely Remote Fault conditions	a and b
4. Engine-driven case if more critical than 3. Hub burst containment at the maximum driven speed or the maximum burst speed, whichever is the lesser	a only

Table 6

REFERENCE	SPECIFICATION
a	Quality control of containment means

b	Establishment that drive mechanism will prevent the Engine driving the starter to a dangerous speed, unless such a probability is Extremely Remote (see CS-E 590)
c	Establishment of Approved Life and quality control of rotating Engine Critical Parts (see CS-E 515, E 70 and E 110)
d	Integrity test of rotating parts (see CS-E 840)
e	Clearance between rotating and fixed parts (see CS-E 520 (b))

AMC to CS-E 130
Fire protection

(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 Engine.

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

(c) Fire Hazard : (1) The unintentional release or collection of a hazardous quantity of flammable fluid, vapour or other materials; or (2) a Failure or malfunction which results in an unintentional ignition source within a fire zone; or (3) the potential for a Hazardous Engine Effect as the result of exposure to a fire.

(d) Fire Resistant, Fireproof : the definitions of "Fire Resistant" and "Fireproof" are given in CS-E 15; they imply that the functioning of the part under fire condition should not hazard the aircraft.

(e) Hazardous quantity : An amount of fluid, vapour or other material which could sustain a fire of sufficient time and severity to create damage potentially leading to a Hazardous Engine 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-E 130 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 (1) contain, isolate and withstand a fire or prevent any sources of flammable material or air from feeding an existing fire and (2) increase the probability that the Engine Control System and accessories will permit a safe shutdown of the Engine or feathering of the Propeller (if the Propeller control system is part of the Engine design) and subsequently maintain that condition.

(c) Determination of level of fire protection

CS-E 130 (b) requires that all flammable fluid conveying parts or components be at least Fire Resistant, whereas CS-E 130 (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 appropriate Engine and close the appropriate fuel shut off valve(s). This cuts off the source of fuel.

Oil system components of turbine Engines, however, may continue to flow oil after the Engine 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 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 shutoff feature [also see CS-E 570 (b)(7)(i).

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 and thrust augmentation systems should be evaluated in a similar manner. Flammable fluid tanks should be fireproof as required by CS-E 130 (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 Engine Effects.

(i) Functions

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

A safe Engine shutdown at any time during the fire resistance test is an acceptable outcome for this type of component, provided the safe shutdown 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 casings of the Engine Control System 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 Engine 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 Engine component and to the effects of dimensional changes resulting from thermal effects within the Engine.

(b) Use of Titanium

Many titanium alloys used for manufacturing Engine 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-E 130 (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 Engine Effect.

Based on experience, the following precautions can reduce the susceptibility of Engines 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 Engine.

(c) Use of Magnesium

Many magnesium alloys used in the manufacture of Engine 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-E 130, 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 would be confined to areas within the Engine such that it does not result in a Hazardous Engine Effect.

(d) Abradable Linings

Many fan, 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 fan, 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 : cowling and nacelle structure; under cowl airflow; aircraft Engine build up hardware; 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 cowl,” 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-E 130.

(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-E 130 (c), the effects of fire on components of the electrical system should be evaluated. Electrical cables, connectors, terminals and equipment, installed in or on the Engine, in designated fire zones should 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, shutoff 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-E 130 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 (typically a minimum flight idle flow rate) and the subsequent 10 minutes should be conducted at an Engine 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 Engine 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-E 130 (b) allows certain parts to be exempt from the specifications because they do not typically contain or convey flammable fluids during normal Engine 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 Engine 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 Engine 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 envelop (acting as a drain in case of a Failure in the main fuel line) and should comply with CS-E 130 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 Engine, 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-E 130 (g) is to show that an electrical current path exists between certain components that are mounted externally to the Engine and the Engine 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 Engine are electrically grounded to the Engine reference.

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

(d) Air Sources

In accordance with CS-E 130 (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-E 130 (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 Engine Effect.

(f) Shielding

The overall intent of CS-E 130 (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 Engine 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 to CS-E 140
Test- Engine configuration

For turbine engines, if the power turbine accessory drives are not loaded, the equivalent power should be added as required by CS-E 140 (d)(3) to the required power at the output drive so that the power turbine rotor assembly is operated at or above the same level as it would be if the power turbine accessory drives were loaded.

AMC to CS-E 150 (a)
Tests - General conduct of tests

For piston Engines, where the operating conditions of a test represent Maximum Continuous Power at altitude, a higher grade fuel or any other approved anti-detonant may be used if such is required to suppress detonation during the test.

AMC to CS-E 150 (f)
Endurance tests - Inspection checks and calibration tests

(1) If relevant, the level of Engine disassembly, component cleaning and replacement prior to rebuild for the additional endurance test sequence should be agreed with the Agency (See CS-E 150 (f)(3)(ii)). It should be shown that any cleaning or replacement of consumable parts during the strip examination or replacement of consumable parts will not enhance the Engine's ability to meet the specifications of the additional endurance test of CS-E 740 (c)(3)(iii).

(2) For complying with the structural integrity specification of CS-E 150 (f)(3)(iii), the applicant should show that no Failure of any significant Engine component occurs during test or during shutdown, or

becomes evident during the subsequent tear-down inspection. In the event that any Failure becomes evident, this should be analysed and corrective actions taken, or certain limitations imposed on the Engine as appropriate. For the purpose of this specification, the Engine parts deemed significant are those that can affect the structural integrity, including but not limited to mountings, casings, bearing supports, shafts and rotors.

(3) The Engine condition exhibited after the additional endurance test required by CS-E 740 (c)(3)(iii) may be used to validate the mandatory maintenance actions after use of 30-Second and 2-Minute OEI ratings as required by CS-E 25 (b)(2) and described in the associated AMC material.

(4) For components which are distressed beyond serviceable limits during the test of CS-E 740 (c)(3)(iii), it should be shown that the inspections and mandatory maintenance actions for these components, as specified in the Instruction for Continued Airworthiness, are adequate. The instructions should include means for proper identification of these component conditions, and appropriately defined maintenance actions.

The component deterioration as it affects performance during the test, and the component condition after test, should be determined. The distress seen as a result of the 2-hour test should not create a potentially hazardous condition. In addition to visible physical damage, non-visible damage should be assessed. Such damage may include but not necessarily be limited to the effects of creep, stress rupture, metallurgical effects, life usage, etc. This overall evaluation should then be considered when defining and justifying the inspections and mandatory maintenance actions for instructions for continued airworthiness.

AMC to CS-E 170
Engine systems and component verification

The intent of CS-E 170 is to define the additional tests or analysis which would be necessary for those systems or components which are not necessarily tested during the endurance test of CS-E 440 or CS-E 740.

It is also recognised that the other specifications of CS-E do not always provide sufficient testing to cover all the conditions (pressure, temperature, vibration, etc.) which could affect the airworthiness of a piece of equipment throughout the declared flight envelope and within all the declared installation conditions.

Other reasons for testing under CS-E 170 include, but are not limited to, the following examples:

- When testing is required in support of CS-E 50 (a) for validation throughout the declared flight envelope and within all the declared installation conditions.

- When a pressure relief valve, in the inlet manifold of a turbocharged Engine, and the effect of its operation on the Engine and turbocharger are untested during the scheduled test of CS-E 440.

- When, for example, an over-speed protection system (or a torque limiter) is unlikely to be tested during the scheduled tests of CS-E 740.

- When an Electronic Engine Control System has a mechanical back-up which is not normally used during the endurance test.

- When demonstration that a Failure indicating system, on which dependence is placed in the Engine safety analysis, will function satisfactorily when required.

The Engine manufacturer should define all necessary testing and / or analysis for those accessories or systems that need specific substantiation, in addition to the certification tests performed on a complete Engine, with attention paid to their location and operating conditions. Unless it is necessary to test the functioning of a system itself, substantiation of individual components can be made separately from the system they are part of.

The objective of CS-E 50 (a), in conjunction with CS-E 80 or CS-E 170, is to demonstrate that the Engine Control System can perform its intended function in its installed environment. In particular, Electronic Engine Control Systems are sensitive to lightning and other electromagnetic interference and these conditions can be common to more than one Engine. Advisory material for environmental effects other than lightning and electromagnetic effects can be found in AMC to CS-E 80.

For compliance with CS-E 170, the functional integrity of the Engine Control System should be maintained when subjected to designated levels of electric or electromagnetic induction, including effects from external radiation and lightning. The environment, including radiated and conducted emissions, to which the Engine Control System and its components are qualified should be entered into the Engine instructions for installation, and is considered to be an installation limitation for the installer.

When the installer specifies the environmental conditions of the installation, compliance with this specification may be demonstrated by meeting the specified installation specifications.

When the installation specifications are not specified or not known, environmental conditions of a typical installation may be assumed.

It should be established by analysis or test that all components of the Engine Control System, including all electronics units, sensors, harnesses, hydromechanical elements, and any other relevant elements or units, operate properly in their declared environment. The environmental limits are not imposed by the rules, but should be representative of the environments that are expected to be encountered in the Engine installation.

Additional means may be found in AMC to CS-E 80 or in AMC 20-1 for Electronic Engine Control Systems.

In meeting the above environmental concerns, due consideration should be given to dispatching in each approved degraded state.

See AMC to CS-E 80 for additional specific means.

AMC to CS-E 180
Propeller Functioning Tests

For Propeller approval the remaining tests of CS-P may be conducted on another Engine of the same type providing the same Propeller without further adjustment is used.

For Piston Engines, auxiliary cooling may be used during tests of CS-E 180 (b)(3) and (4).

AMC to CS-E 210
Failure Analysis

(1) The Failure analysis would normally include investigation of those Engine components that could affect the functioning and integrity of the major rotating assemblies, and for the control system, all manual and automatic controls such as refrigerant injection system, Engine and fuel system speed governors, Engine over-speed limiters, Propeller control systems, Propeller thrust reversal systems, etc.

(2) The Failure of individual components of the Engine and its installation need not be included in the analysis if the Agency accepts that the possibility of such Failure is sufficiently remote.

SUBPART C – PISTON ENGINES; TYPE SUBSTANTIATION

AMC to CS-E 300 (f)
Conditions Applicable to all Tests - Torque Measurement

In establishing an acceptable method for determination of the Engine torque, consideration should be given to the following:

(1) Where a method of direct Engine torque measurement is to be used, the overall accuracy of the torque measurement system should be determined.

(2) Where no direct means for measuring Engine torque is available, an appropriate method for establishing the torque will be needed.

(a) Normally this requires the use of suitable Engine parameters (e.g. power setting, and Engine speed) to correlate the Engine torque measured on a dynamometer with the Engine torque achieved in the test configuration.

(b) The correlation should take into account any effect due to environmental changes (e.g. temperature, humidity, ambient pressure) and of test bench configuration changes (e.g. air inlet, exhaustand engine cooling system differences between the dynamometer installation and the test configuration).

(c) The overall accuracy of the method used for determining Engine torque should be determined.

AMC to CS-E 320
Performance correction

(1) An acceptable method for calculating performance corrections is defined in ISO 1585:1992, Road vehicles - Engine test code - Net power.

(2) Since the effect of free water on power output is within ±1% over the range of water/air ratios normally encountered in operation, and the amount of free water is exceedingly difficult to measure, no corrections for free water need to be made.

AMC to CS-E 340
Vibration Tests

(1) Calculations during design of the engine

During the design stage the applicant should make calculations to determine the vibration characteristics of the coupled crankshaft torsional and Propeller flexural vibrations for the Engine and Propeller system. For this purpose, 'admittance' lines for the Propeller should be provided by the Propeller manufacturer.

The scope of these calculations should be wide enough to reveal any serious criticals within the operating speed range of the Engine and their relative magnitudes. These calculations form an essential part of the subsequent analysis and interpretation of the tests required by CS-E 340.

(2) Maximum Acceptable Stress

When considering the maximum stress in the Engine crankshaft and Propeller system the vibration stress at the particular Engine speed and power conditions should be added to the mean stress at the same speed.

In the absence of adequate evidence to the contrary, a maximum stress shown to be safe for continuous use should be regarded as the maximum safe stress for Engine crankshafts and Propeller shafts.

AMC to CS-E 350
Calibration Tests

(1) In complying with CS-E 350 (a), the following calibration testing should normally be considered adequate.

(a) The sea level power characteristics of the Engine should be established against rotational speed and power setting. The following curves should be generated, each consisting of sufficient points for each characteristic to ensure the accuracy of the interpolation. Normally, at least five points in each curve will be required:

(i) Power against rotational speed at constant power setting, starting from each rating to be declared, over the full range of rotational speeds appropriate to that rating.

(ii) Power against power setting at constant speed, in at least five increments of rotational speed between Maximum Take-off rated speed and 60% of best economy cruising speed, over the full range of power settings appropriate to that speed. The increments selected should include all rated rotational speeds.

(b) The effect on Engine power should be established of all parameters that may affect the power produced (e.g. altitude, ambient air temperature, cylinder/coolant temperature, mixture setting, fuel specification.).

(2) In complying with CS-E 350 (b), the calibration testing outlined in paragraph (1)(a) of this AMC should normally be considered adequate.

AMC to CS-E 380
Low Temperature Starting Tests

The minimum tropical and temperate sea-level temperature as defined in CS-Definitions is –20°C. In order not to restrict operation of the aircraft in which the Engine is installed, it is recommended that the minimum temperature declared for starting should be not higher than –20°C.

AMC to CS-E 440 (b)(3)
Endurance Test – Schedule for Engine Incorporating a Turbocharger

Altitude testing may be simulated provided it is shown that the Engine and turbocharger are being subjected to mechanical loads and operation temperatures no less severe than if run at actual altitude conditions.

AMC to CS- 470
Contaminated Fuel

In complying with CS-E-470, the following contaminant specifications and levels are considered acceptable:

(1) Solid Contaminants

(a) Contaminant with the characteristics detailed in MIL–E–5007D.

(b) A contamination rate of 1.0 g of contaminant per 1,000 litres.

(2) Water Contaminant

(a) Contaminated fuel initially saturated with water at a fuel/water temperature of 27°C into which a further 0·2 ml of free water per litre of fuel has been evenly dispersed.

(b) The contaminated fuel mixture should be at the most critical conditions for fuel icing likely to be encountered in operation.

SUBPART D – TURBINE ENGINES; DESIGN AND CONSTRUCTION

AMC to CS-E 500
Functioning – Control of Engines (Turbine Engines for Aeroplanes)

It is normally acceptable that the control of Engines within their limitations may be achieved by manual, as opposed to automatic, means provided that –

(1) The likely rate of change of Engine conditions makes manual control practicable,

(2) Minimum thrust setting parameters for use during all critical flight phases (e.g. take-off or baulked landing) can be predetermined in a manner which will ensure that –

  (a) They are easily set-up,

  (b) The same instrument is used under all ambient conditions,

  (c) They will normally prevent any other limit being exceeded (though normal crew monitoring may be assumed to be adequate for detecting progressive slowly changing excesses which may result from Engine deterioration in service),

(3) The Engine is shown to be safe in the event of inadvertent opening of the throttle to its maximum travel in an emergency situation (see also AMC to CS-E 700 paragraph 3).

AMC to CS-E 510
Safety analysis

(1) Introduction.

Compliance with CS-E 510 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 Engine Failure conditions is acceptably low. The basis is the concept that an acceptable overall Engine design risk is achievable by managing the individual major and hazardous Engine 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 Engine design goals such that there would not be Major or Hazardous Engine Effects that exceed the required probability of occurrence as a result of Engine Failure modes. The analysis should consider the full range of expected operations.

(3) Specific means.

(a) Classification of effects of Engine Failures.

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

CS-E 510 defines the Engine-level Failure conditions and presumed severity levels.

Since aircraft-level specifications for individual Failure conditions may be more severe than the Engine-level specifications, there should be early co-ordination between the applicant and the aircraft manufacturer to ensure Engine and aircraft compatibility.

(b) Component Level Safety Analysis.

In showing compliance with CS-E 510 (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-E 50 for the Engine Control System should be integrated into the overall Engine safety analysis.

(c) Typical installation

The reference to "typical installation" in CS-E 510 (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-E 510 (f) requires the applicant to include in the Engine safety analysis consideration of some aircraft components.

It is recognised that, when showing compliance with CS-E 510 (a)(3) and (4) for some Engine 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 Engine certification, the applicant will assume a Failure rate for these aircraft components. Compliance with CS-E 510 (e) requires the applicant to provide, in the Engine instructions for installation, the list of Failures of aircraft components that may result in or contribute to Hazardous or Major Engine Effects. The mode of propagation to this effect should be described and the assumed Failure rates should be stated.

During the aircraft certification, the Engine 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-E 30.

(d) Hazardous Engine Effects

(i) The acceptable occurrence rate of Hazardous Engine 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 Engine flight hour for each Hazardous Engine Effect applies to the summation of the probabilities of this Hazardous Engine Effect arising from individual Failure modes or combinations of Failure modes other than the Failure of Engine 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 Engine flight 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 Engine flight hour then summation is not required.

(ii) When considering primary Failures of certain single elements such as Engine Critical Parts, the numerical Failure rate cannot be sensibly estimated. If the Failure of such elements is likely to result in Hazardous Engine Effects, reliance should be placed on their meeting the prescribed integrity specifications, such as CS-E 515, among others. 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 Engine 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 Engine Failure. The Engine has a containment structure which is designed to withstand the consequences of the release of a single blade (see CS-E 810 (a)), and which is often adequate to contain additional released blades and static parts. The Engine containment structure is not expected to contain major rotating parts should they fracture. Discs, hubs, impellers, large rotating seals, and other similar large rotating components should therefore always be considered to represent potential high-energy debris.

Service experience has shown that, depending on their size and the internal pressures, the rupture of the high-pressure casings can generate high-energy debris. Casings may therefore need to be considered as a potential for high-energy debris.

(iv) Toxic products.

CS-E 510 (g)(2)(ii) concerns generation and delivery of toxic products caused by abnormal Engine 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 Engine-level analysis; these can only be properly evaluated during aircraft certification. The intent of CS-E 510 (g)(2)(ii) is to address the relative concentration of toxic products in the Engine bleed air delivery. The Hazardous Engine 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 Engine bleed air for the cabin should be provided to the installer as part of the Engine instructions for installation.

(v) Significant thrust in the opposite direction to that commanded by the pilot, Engine Failures resulting in significant thrust in the opposite direction to that commanded by the pilot can, depending on the flight phase, result in a hazardous condition relating to aircraft controllability. Those Failures, if applicable to CS-E certification, that could be classified as hazardous events include :

- Uncommanded thrust reverser deployment;
- Unintended movement of the Propeller blades below the established minimum in-flight low-pitch position;
- High forward thrust when reverse thrust is commanded.

(vi) Uncontrolled fire.

An uncontrolled fire should be interpreted in this context as an extensive or persistent nacelle 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.

(vii) Complete inability to shut the Engine down.

Complete inability to shut down the Engine is regarded as a Hazardous Engine Effect due the potential circumstances where continued running of the Engine, even at low thrust or power, represents a hazard. These circumstances include the inhibition of safe evacuation of passengers and crew, directional control problems during landing due to the inability to eliminate thrust or power, or the inability to ensure safe shut down when required following a Failure.

It is acceptable to take account of aircraft-supplied equipment (fuel cut-off means, etc.) to protect against the "complete inability" to shut down the Engine.

The inclusion of this item within the Hazardous Engine Effects should not preclude hardware or software intended to protect against inadvertent Engine shutdown, including aircraft logic to mitigate against the inadvertent shutdown of all engines.

(e) Major Engine Effects

Compliance with CS-E 510 (a)(4) can be shown if the individual Failures or combinations of Failures resulting in Major Engine Effects have probabilities not greater than 10^{-5} per Engine flight hour. No summation of probabilities of Failure modes resulting in the same Major Engine Effect is required to show compliance with this rule.

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

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

- Controlled fires (i.e., those brought under control by shutting down the Engine or by on-board extinguishing systems).
- Case burn-through where it can be shown that there is no propagation to Hazardous Engine Effects.
- Release of low-energy parts where it can be shown that there is no propagation to Hazardous Engine Effects.
- Vibration levels that result in crew discomfort.
- Concentration of toxic products in the Engine bleed air for the cabin sufficient to degrade crew performance.
- Thrust in the opposite direction to that commanded by the pilot, below the level defined as hazardous.

- Loss of integrity of the load path of the Engine supporting system without actual Engine separation.
- Generation of thrust greater than maximum rated thrust.
- Significant uncontrollable thrust oscillation.

The concentration of toxic products in the Engine bleed air may be interpreted as the generation and delivery of toxic products as a result of abnormal Engine 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 should be considered, if appropriate. Since these concentrations are of interest to the installer, information on delivery rates and concentrations of toxic products in the Engine bleed air for the cabin should be provided to the installer as part of the Engine instructions for installation.

(f) Minor Engine Effects.

It is generally recognised that Engine Failures involving complete loss of thrust or power from the affected Engine can be expected to occur in service, and that the aircraft should be capable of controlled flight following such an event. For the purpose of the Engine safety analysis and Engine certification, Engine Failure with no external effect other than loss of thrust and services may be regarded as a Failure with a minor effect. This assumption may be revisited during aircraft certification, where installation effects such as Engine redundancy may be fully taken into consideration. This re-examination applies only to aircraft certification and is not intended to impact Engine certification.

The Failure to achieve any given power or thrust rating for which the Engine is certificated should be covered in the safety analysis and may be regarded as a minor Engine effect. Similarly, this assumption may be revisited during aircraft certification, particularly multi-Engine rotorcraft certification.

(g) Determination of the effect of a Failure.

Prediction of the likely progression of some Engine 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 Engine 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-E 510 (b).

(h) Reliance on maintenance actions.

For compliance with CS-E 510 (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-E 510 (e)(1), the Engine 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-E 510 (e)(1).

Maintenance errors have contributed to hazardous or catastrophic effects at the aircraft level. Many of these events have arisen due to similar incorrect maintenance actions being performed on multiple engines during the same maintenance availability by one maintenance crew, and are thus primarily an aircraft-level concern. Nevertheless, precautions should be taken in the Engine 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 Engine design.

If appropriate, consideration should be given to communicating strategies against performing contemporaneous maintenance of multiple engines.

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

The following list of Engine maintenance errors was constructed from situations that have occurred in service and have caused one or more serious events :

- Failure to restore oil system or borescope access integrity after routine maintenance (oil chip detector or filter check). Similar consideration should be given to other systems.
- Mis-installation of, or Failure to refit, O-rings,
- Servicing with incorrect fluids,
- Failure to install, omitting to torque, under-torquing, or over-torquing nuts.

Improper maintenance on parts such as discs, hubs, and spacers has led to Failures resulting in Hazardous Engine Effects. Examples of this which have occurred in service are overlooking existing cracks or damage during inspection and Failure to apply or incorrect application of protective coatings (e.g. anti-gallant, anti-corrosive).

In showing compliance with CS-E 510 (e)(2), it is expected that, wherever specific Failure rates rely on special or unique maintenance checks for protective devices, those should 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 engines, it is acceptable to limit the scope of the analysis to modified components or operating conditions and their effects on the rest of the Engine. 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 Engine 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 should occur to cause a defined Failure condition. A Dependence Diagram Analysis is success-oriented, and is conducted from the perspective of which Failures should 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. 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 Engine-level effect, caused or contributed to by one or more Failures. Examples include limitation of thrust 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 to CS-E 515
Engine Critical Parts

(1) *Introduction*

Because the Failure of an Engine Critical Part is likely to result in a Hazardous Engine Effect, it is necessary to take precautions to avoid the occurrence of Failures of such parts. Under CS-E 510 (c), they are required to meet prescribed integrity specifications.

For that purpose, an Engineering Plan, a Manufacturing Plan and a Service Management Plan are required under CS-E 515. These three plans define a closed-loop system which link the assumptions made in the Engineering Plan to how the part is manufactured and maintained in service; the latter two aspects are controlled by the Manufacturing and Service Management Plans respectively. These plans may generate limitations which are published in the Airworthiness Limitation Section of the Instruction for Continued Airworthiness. This AMC provides means for the establishment of such plans.

(2) *General*

(a) *Identification of Engine Critical Parts*

The safety analysis required under CS-E 510 identifies Engine Critical Parts that are required to comply with CS-E 515. An Engine Critical Part is a Critical Part, by definition, with regard to compliance with Part 21.

If a part is made of various sub-parts, which are finally integrated in an inseparable manner into a unique part, and any one of the sub-parts is identified as an Engine Critical Part, the entire part is then treated as an Engine Critical Part.

(b) *Attributes of a part*

'Attributes' include, but are not limited to, material mechanical properties, material microstructure, material anomalies, residual stress, surface condition, and geometric tolerances. Processes such as alloy melting practise, ingot conversion to billet or bar, forging, casting, machining, welding, coating, shot peening, finishing, assembly, inspection, storage, repair, maintenance and handling may influence the Attributes of the finished part. Environmental conditions experienced in service may also affect the Attributes.

(c) *Content of a plan*

The Engineering Plan, Manufacturing Plan and Service Management Plan should provide clear and unambiguous information for the management of the Engine Critical Parts.

'Plan', in the context of this rule, does not necessarily mean having all technical information contained in a single document. If the relevant information exists elsewhere, the plan may make reference to drawings, material specifications, process specifications, manuals, etc., as appropriate. It should be noted that these references should be clear enough to uniquely identify the referenced document. The plan should allow the history of the individual part number to be traced.

(3) *Means for defining an Engineering Plan*

(a) *Introduction*

The Engineering Plan consists of comprehensive life assessment processes and technologies that ensure that each Engine Critical Part can be withdrawn from service at a life before Hazardous Engine Effects can occur. These processes and technologies address the design, test validation, and certification aspects as well as define those manufacturing and service management processes that should be controlled in order to achieve the Engine Critical Part design intent.

(b) *Elements of the Engineering Plan*

The Engineering Plan should address the following subjects:

- Analytical and empirical engineering processes applied to determine the Approved Life.
- Structured component and engine testing conducted to confirm engine internal operating conditions and to enhance confidence in the Approved Life.
- Establishment of the Attributes to be provided and maintained for the manufacture and service management of Engine Critical Parts.
- Development and certification testing, and service experience required to validate the adequacy of the design and Approved Life. Any in-service inspections identified as critical elements to the overall part integrity, should be incorporated into the Service Management Plan.

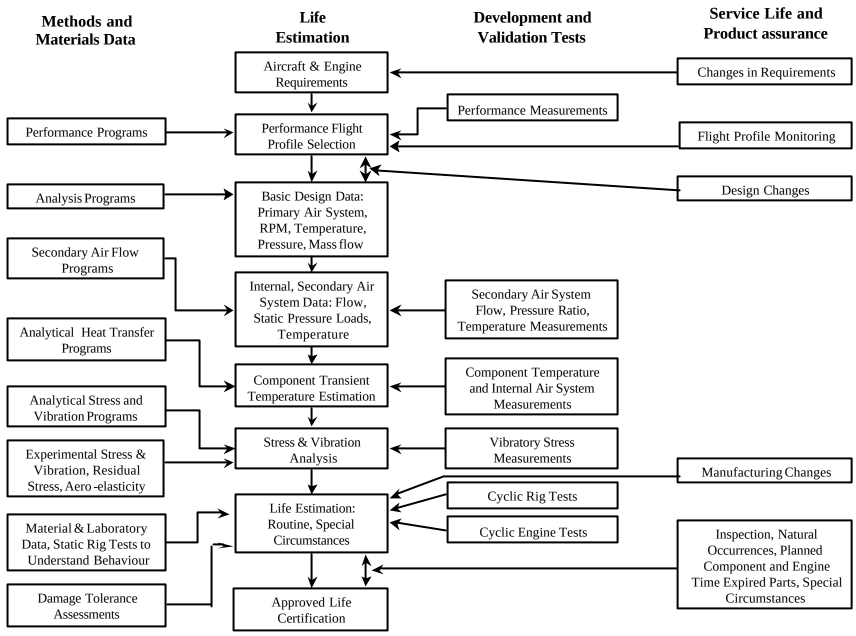
(c) *Establishment of the Approved Life – General*

Determining the life capability of an Engine Critical Part involves the consideration of many separate factors, each of which may have a significant influence on the final results.

It is possible that the final life calculated may be in excess of that considered likely for the associated airframe application. However, the life, in terms of cycles or hours as appropriate, should still be recorded in the airworthiness limitations section in order that the usage of the part may be properly tracked.

(d) *Establishment of the Approved Life - Rotating parts*

The following describes a typical process for establishing the Approved Life of rotating parts:



The major elements of the analysis are:

(i) *Operating conditions.*

For the purposes of certification, an appropriate flight profile or combination of profiles and the expected range of ambient conditions and operational variations will determine the predicted service environment. The Engine Flight Cycle should include the various flight segments such as start, idle, takeoff, climb, cruise, approach, landing, reverse and shutdown. The assumed hold times at the various flight segments should correspond to the assumed limiting installation variables (aircraft weight, climb rates, etc.). A maximum severity cycle that is known to be conservative may be used as an alternative.

The corresponding rotor speeds, internal pressures, and temperatures during each flight segment should be adjusted to account for engine performance variation due to production tolerances and installation trim procedures, as well as engine deterioration that can be expected between heavy maintenance intervals. The range of ambient temperature and takeoff altitude conditions encountered during the engines' service life as well as the impact of cold and hot engine starts should also be considered.

The appropriateness of the Engine Flight Cycle should be validated and maintained over the lifetime of the design. The extent of the validation is dependant upon the approach taken in the development of the Engine Flight Cycle. For example, a conservative flight cycle where all the variables are placed at the most life damaging value would require minimum validation, whereas a flight cycle which more accurately represents some portion of the actual flight profile but is inherently less conservative, would require more extensive validation. Further refinements may be applied when significant field operation data are gathered.

(ii) *Thermal analysis.*

Analytical and empirical engineering processes are applied to determine the engine internal environment (temperatures, pressures, flows, etc.) from which the component steady state and transient temperatures are determined for the Engine Flight Cycle. The engine internal environment and the component temperatures should be correlated and verified experimentally during engine development testing.

(iii) *Stress analysis.*

The stress determination is used to identify the limiting locations such as bores, holes, changes in section, welds or attachment slots, and the limiting loading conditions. Analytical and empirical engineering processes are applied to determine the stress distribution for each part. The analyses evaluate the effects on part stress of engine speed, pressure, part temperature and thermal gradients at many discrete engine cycle conditions. From this, the part's cyclic stress history is constructed. All methods of stress analysis should be validated by experimental measurements.

(iv) *Life analysis.*

The life analysis combines the stress, strain, temperature and material data to establish the life of the minimum property part. Plasticity and creep related effects should also be considered. Relevant service experience gained through a successful programme of parts retirement or precautionary sampling inspections, or both, may be included to adjust the life prediction system.

The fatigue life prediction system is based upon test data obtained from cyclic testing of representative laboratory, sub-component, or specific component specimens and should account for the manufacturing processes that affect low cycle fatigue (LCF) capability, including fabrication from production grade material. Sufficient testing should be performed to evaluate the effects of elevated temperatures and hold times, as well as interaction with other material Failure mechanisms such as high cycle fatigue and creep. The fatigue life prediction system should also account for environmental effects, such as vibration and corrosion, and cumulative damage.

When the fatigue life is based on cyclic testing of specific parts, the test results should be corrected for inherent fatigue scatter. The factors used to account for scatter should be justified. In order to utilise this approach the test should be designed to be representative of the critical engine conditions in terms of the temperature and stress at the specific features, e.g. bore, rim or blade attachment details, of the part being tested. Appropriate analytical and empirical tools should be utilised such that the fatigue life can be adjusted for any differences between the engine conditions and cyclic test. In the event the test is terminated by burst or complete Failure, crack initiation for this particular test may be defined using the appropriate crack growth calculations and/or fracture surface observations. It may also be possible to utilise the number of cycles at the last crack free inspection to define the crack initiation point. This approach requires an inspection technique with a high level of detection capability consistent with that used by the engine industry for rotating parts.

The test data should be reduced statistically in order to express the results in terms of minimum LCF capability (1/1000 or alternately -3 sigma). The fatigue life should be determined as a minimum life to initiation of a fatigue crack, defined typically as a crack length of 0.75mm.

An alternative way of using the data is to base the fatigue life on an agreed safety margin to burst of a minimum strength part. Typically a 2/3 factor has been applied to the minimum (1/1000 or alternatively –3 sigma) burst life, however any factor used should be justified for a particular material.

(v) *Damage Tolerance assessment.*

Damage Tolerance assessments should be performed to minimise the potential for Failure from material, manufacturing and service-induced anomalies within the Approved Life of the part. Service experience with gas turbine engines has demonstrated that material, manufacturing and service-induced anomalies do occur which can potentially degrade the structural integrity of Engine Critical Parts. Historically, life management methodology has been founded on the assumption of the existence of nominal material variations and manufacturing conditions. Consequently, the methodology has not explicitly addressed the occurrence of such anomalies, although some level of tolerance to anomalies is implicitly built-in using design margins, factory and field inspections, etc. A Damage Tolerance assessment explicitly addresses the anomalous condition(s) and complements the fatigue life prediction system. It should be noted that the 'Damage Tolerance Assessment' is part of the design process and not a method for returning cracked parts to service whilst monitoring crack growth.

The Damage Tolerance assessment process typically includes the following primary elements:

Anomaly size and frequency distributions.

A key input in the damage tolerance assessment is the size and rate of occurrence of the anomalies. This type of information may be statistical in nature and can be presented in a form that plots number of inclusions that exceed a particular size in a specified amount of material. Anomalies should be treated as sharp propagating cracks from the first stress cycle unless there is sufficient data to indicate otherwise.

Crack growth Analysis.

This determines the number of cycles for a given anomaly to grow to a critical size. This prediction should be based upon knowledge of part stress, temperature, geometry, stress gradient, anomaly size and orientation, and material properties. The analysis approach should be validated against relevant test data.

Inspection techniques and intervals..

Manufacturing and in-service inspections are an option to address the fracture potential from inherent and induced anomalies. The intervals for each specified in-service inspection should be identified. Engine removal rates and module and piece part availability data could serve as the basis for establishing the inspection interval. The manufacturing inspections assumed in the damage tolerance assessments should be incorporated into the Manufacturing Plan. Likewise, the assumed in-service inspection procedures and intervals should be integrated into the Service Management Plan and included, as appropriate, in the airworthiness limitations section of the instructions for continued airworthiness.

Inspection Probability of Detection (POD).

The Probability of Detection (POD) of the individual inspection processes, such as eddy-current, penetrant fluid or ultrasonic, used to detect potential anomalies should be based upon the statistical review of sufficient quantities of relevant testing or experience. The relevance of these data should be based upon the similarity of parameters such as:

- Size, shape, orientation, location, and chemical or metallurgical character of the anomaly
- Surface condition and cleanliness of the parts
- Material being inspected (such as its composition, grain size, conductivity, surface texture, etc.).
- Variation of inspection materials or equipment (such as the specific penetrant fluid and developer, equipment capability or condition, etc)
- Specific inspection process parameters such as scan index
- Inspector (such as visual acuity, attention span, training, etc.)

In addition, the following should be noted with regard to the above:

- Appropriate Damage Tolerance assessments.

In the context of CS-E 515 (a), "appropriate Damage Tolerance assessments" recognises that industry standards on suitable anomaly size and frequency distributions, and analysis techniques used in the damage tolerance assessment process are not available in every case listed in the paragraphs below. In such cases, compliance with the rule should be based on such considerations as design margins applied, application of damage tolerance design concepts, historical experience, crack growth rate comparisons to successful experience, etc. Anomalies for which a common understanding has been reached within the Engine community and the Authorities should be considered in the analysis.

Material anomalies.

Material anomalies consist of abnormal discontinuities or non-homogeneities introduced during the production of the input material or melting of the material. Some examples of material anomalies that should be considered are hard alpha anomalies in titanium, oxide/carbide (slag) stringers in nickel alloys, and ceramic particulate anomalies in powder metallurgy materials unintentionally generated during powder manufacturing.

Manufacturing anomalies.

Manufacturing anomalies include anomalies produced in the conversion of the ingot to billet and billet to forging steps as well as anomalies generated by the metal removal and finishing processes used during manufacture and/or repair. Examples of conversion related anomalies are forging laps and strain induced porosity. Some examples of metal removal related anomalies are tears due to broaching, arc burns from various sources and disturbed microstructure due to localised overheating of the machined surface.

Service-induced anomalies.

Service-induced anomalies such as non-repaired nicks, dings and scratches, corrosion, etc should be considered. Similarity of hardware design, installation, exposure and maintenance practice should be used to determine relevance of the experience.

(e) *Establishment of the Approved Life - Static, pressure loaded parts*

(i) *General Principles*

The general principles which are used to establish the Approved Life are similar to those used for rotating parts.

However, for static pressure loaded parts, the Approved Life may be based on the crack initiation life plus a portion of the residual crack growth life. The portion of residual life used should consider margin to burst. If the Approved Life includes reliance on the detection of cracks prior to reaching the Approved Life, the reliability of the crack detection should be considered. Any dependence upon crack detection should result in mandatory inspections being included in the Service Management Plan and in the airworthiness limitations section of the instructions for continued airworthiness. Crack growth analysis techniques should be validated experimentally.

Some construction techniques, such as welding or casting, contain inherent anomalies. Such anomalies should be considered as part of the methodology to establish the Approved Life. Fracture mechanics is a common method for such assessments.

In determining the life of the part, the temperature of the part, any temperature gradients, any significant vibratory or other loads (for example flight manoeuvre) should be taken into account in addition to the pressure loads.

Manufacturing and in-service inspections are an option to address the potential for fracture. The intervals for each specified in-service inspection should be identified. Engine removal rates and module and piece part availability data could serve as the basis for establishing the inspection interval. The manufacturing inspections should be incorporated into the Manufacturing Plan. Likewise, the assumed in-service inspection procedures and intervals should be integrated into the Service Management Plan and included, as appropriate, in the airworthiness limitations section of the instructions for continued airworthiness.

(ii) *Tests*

When using testing as part of the substantiation of the life of the part, the basic load cycle should be from substantially zero differential pressure to a value that simulates the most critical operation stress condition and returning to substantially zero differential pressure.

When a test is performed, the test pressure level should be adjusted to include the effects of stress due to thermal gradients in actual operation. When this is impossible, due to over-stress of regions other than the critical location or stress reversal in the Engine Flight Cycle for example, the fatigue capability in operation should be established by an additional analysis.

If the part is subject to loads in addition to those resulting from differential pressure (e.g. flight manoeuvre loads, engine mounting loads, etc.), an analysis should be made of these additional loads and their effect examined. If the effect of these loads is small it may be possible to simulate them by an addition to the test pressure differential. However, if the loads are of significant magnitude or cannot adequately be represented by a pressure increment, the test should be carried out with such loads acting in addition to the pressure loads.

The part should be tested at the temperature associated with the most critical stress case or alternatively the test pressure differential may be increased to simulate the loss of relevant properties as a result of temperature.

Any fatigue scatter factors used should be justified.

During pressure testing the methods of mounting and restraint by the test facility or test equipment of any critical section should be such as to simulate the actual conditions occurring on the engine.

(iii) *Analytical Modelling Methods*

An analytical modelling method may be used to determine adequate fatigue life provided that the modelling method is validated by testing or successful field experience with parts of similar design.

(f) *Establishment of the Approved Life - Other Parts*

It is possible that the Safety Analysis required by CS-E 510 may identify Engine Critical Parts other than rotating parts or static pressure loaded parts. In such instances, a methodology for determining the Approved Life will need to be agreed with the Authority, using the general principles for rotating and static pressure loaded parts as a guideline.

(g) *Maintaining the Approved Life*

At certification, the Approved Life is based on predictions of engine operation, material behaviour, environment etc. which all can be expected to influence the life at which the part should be withdrawn from service to avoid Hazardous Engine Effects.

After certification it may be necessary to check the accuracy of such predictions, recognising that many aspects, for example, the usage of the engine and its operating environment, may change during its operational life, especially with a change of ownership. It is important to use any service feed back to confirm that any assumptions made in the Engineering Plan remain valid, or are modified if required. The Engineering Plan should describe not only the basis of the Approved Life but also those actions subsequent to certification, which will be necessary to ensure that the Approved Life is appropriate throughout the operational life of the engine.

A regular review of the assumptions made when establishing the Approved Life may be required, depending on the conservative nature of the assumptions made when determining the Approved Life. The Engineering Plan should detail when such reviews should occur and what information will be required in order to complete the review.

Aspects which may be considered include, but need not be limited to:

- The frequency of Approved Life reviews
- Detailed inspection of service run parts, including time expired parts
- Review of flight plans
- Findings during maintenance
- Engine development experience
- Lessons learned from other engine projects
- Any service events

(h) *Influencing Parts*

Engine Critical Parts are part of a complex system and other parts of the engine can have an impact on the Engine Critical Parts and their life capability. Therefore, the Engineering Plan needs to address these parts, and particularly changes to them. Examples of influencing parts include a turbine blade, a mating part, and a static part that impacts the environment (temperatures, pressures, etc.) around the Engine Critical Part. Examples of changes to influencing parts include a blade with a different weight, centre of gravity, or root coating; a mating part made from a material having a different coefficient of thermal expansion; and a static part where changes in geometry or material modify the thermal and/or mechanical response of the component and could, as a result, affect the environment around the Engine Critical Part.

(4) *Means for Defining a Manufacturing Plan*

(a) *Introduction*

The Manufacturing Plan is a portion of the overall integrity process intended to ensure the life capability of the part. The Engineering Plan includes assumptions about how Engine Critical Parts are designed, manufactured, operated and maintained: each can have an impact on the part life capability. Therefore, it is essential to ensure that the Attributes required by the Engineering Plan are maintained.

(b) *Elements of a Manufacturing Plan*

The part specific Manufacturing Plan should consider the Attributes of the part delivered by the manufacturing process from raw material to finished part and should highlight all sensitive parameters identified as being significant with regard to part life which should not be changed without proper verification. Such parameters may include, but may not be limited to: material controls, including any zoned areas for special properties, manufacturing method specifications, manufacturing method order of application, inspection method and sensitivity, and any special part rough machining methods or finishing method(s), especially any methods intended to improve fatigue capability or minimise induced anomalies.

(c) *Development and Verification of the Manufacturing Plan*

The Manufacturing Plan should be reviewed and verified by the following key Engineering and Manufacturing skills:

- Engineering (Design & Lifing)
- Material Engineering
- Non-Destructive Inspection
- Quality Assurance
- Manufacturing Engineering (Development & Production)

Hence, this same skill mix should evaluate and approve process validation and the procedures for manufacturing change control and non-conformance disposition to ensure that the product of manufacturing is consistent with the design assumptions of the Engineering Plan. The intent is that:

- Manufacturing processes are developed and applied with the appropriate level of oversight to ensure the part life capability assumed in the Engineering Plan is consistently achieved. Substantiation programmes are agreed up-front and executed as part of the process validation.
- Changes to such manufacturing processes and practices are visible and are not made without cross-functional review and approval.
- When a suspected non-conformance event occurs, it is reviewed with the appropriate skill mix prior to disposition.

The level of detail in the Plan may vary depending on the specific process step being considered, the sensitivity of the particular process step, and the level of control required to achieve the required life capability.

For instance, consider the case where a process specification exists to control the drilling of holes. If the use of this specification produces a hole that meets the life capability specifications for a flange bolt hole, the plan may simply note that the flange bolt hole will be produced per the specification. However, if a rim air hole requires cold expansion, after drilling per the specification, to meet the life capability specifications, it may be necessary to reference the cold expansion process in the plan.

(5) *Means for defining a Service Management Plan.*

(a) *Introduction*

The Service Management Plan forms part of the overall process intended to maintain the integrity of Engine Critical Parts throughout their service life. The Engineering Plan includes assumptions about the way in which the Engine Critical Parts are manufactured, operated and maintained: each can have an impact on the life capability of the part. Therefore, it is essential to ensure that these assumptions remain valid. The Service Management Plan conveys the processes for in-service repair and maintenance to remain consistent with the assumptions made in the Engineering Plan.

(b) *Determining the acceptability of repair and maintenance processes*

Repair and maintenance processes should be reviewed by the following key skills:

- Engineering (Design & Lifing)
- Material Engineering
- Non-Destructive Inspection
- Quality Assurance
- Product Support Engineering
- Repair Development Engineering

The role of this cross-functional review is consistent with that laid out for the Manufacturing Plan. The review should include process validation, change control and non-conformance to ensure the product of any repair or maintenance is consistent with the engineering specification. The intent is that:

- Repair and maintenance processes and practices are developed with the appropriate level of oversight, and with due regard to their possible impact on the life capability of the part. Substantiation programmes are agreed up-front and executed as part of the validation process.
- Changes to such processes and practices are visible to all parties, and are not made without cross-functional review and approval.
- When a suspected non-conformance event occurs, it is reviewed with the appropriate skill mix prior to disposition.

To achieve the necessary control of the application of those processes and practices, the procedures for repair and maintenance should be clearly articulated in the appropriate section(s) of the engine shop manual. These procedures should also include clearly delineated limits to these processes and practices that will ensure that Engine Critical Parts maintain attributes consistent with those assumed in the Engineering Plan.

(c) *Service Management Aspects of Static Pressure Loaded Parts or Other Parts*

The difference in approach to lifing for static pressure loaded parts or other parts means that in addition to the Approved Life, instructions for continued airworthiness may typically contain:

- A defined periodic inspection interval in the airworthiness limitations section.
- The inspection method(s) to be used.
- A detailed description of the area(s) to be inspected.
- Inspection result acceptability limits.
- Acceptable repair methods, if applicable.
- Any other instructions necessary to carry out the required inspection and allowable maintenance procedures.

(6) *Airworthiness Limitations Section*

(a) To ensure a closed-loop between the in-service parts and the Engineering Plan, the importance of the limits to the repair and maintenance of Engine Critical Parts should be highlighted in the Engine manuals required by CS-E 25. Further, since inappropriate repair or maintenance could impact the integrity of the part in a hazardous manner, visibility should be provided through the airworthiness limitations section (ALS) of instructions for continued airworthiness. Wording as, or similar to, that shown below should be placed in the appropriate section of the ALS.

"The following airworthiness limitations have been substantiated based on engineering analysis that assumes this product will be operated and maintained using the procedures and inspections provided in the instructions for continued airworthiness supplied with this product by the Type Certificate holder, or its licensees. For Engine Critical Parts and parts that influence Engine Critical Parts, any repair, modification or maintenance procedures not approved by the Type Certificate holder, or its licensees, or any substitution of such parts not supplied by the Type Certificate holder, or its licensees, may materially affect these limits."

(b) For engines with OEI ratings, the airworthiness limitations section should include a method for accounting for the number of cycles used in operation at the OEI ratings. This may be accomplished by adding a finite number of cycles to the expended life of the affected Engine Critical Parts or by using appropriate life reduction factors for each of the OEI power excursions.

AMC to CS-E 520 (a)
Strength – High Cycle Fatigue

In order to minimise the adverse consequences of Failures due to unpredicted high cycle fatigue it is recommended that, normally, the relative fatigue strengths of the blade/disc are graded such that they lie in the ascending order: blade form, blade root, disc blade attachment, disc rim.

AMC to CS-E 520 (c)(1)
Strength – Shedding of Blades

(1) In order to reduce the risk of a single blade Failure leading to a multiple blade Failure and possible non-containment, particular attention should be paid to such items as blade material, blade root fixing and the design of casing joints in vulnerable areas.

(2) In providing containment for compressor and turbine blades account should be taken of the possibility that the final trajectory of a failed blade may not be directly in the plane of its rotation. This is particularly important when the final containment provisions are external to the Engine casing and lie some distance from it (impact points on the aircraft structure of failed blades have been experienced at

angles up to ± 30° from the point of intersection of the Engine centre line and the plane of rotation) or where the Engine casing containment capability is reduced adjacent to the plane of rotation of the blades, e.g. by virtue of cut-outs for adjacent stator roots, bleed ports, etc. This AMC is not meant to impose an obligation on the Engine constructor to provide containment in the direction of the intake and exhaust, provided the limits of the angles to which containment is assured are made available to the aircraft constructor installing the Engine.

AMC to CS-E 525
Continued rotation

(1) Continued rotation can be either due to windmilling or due to mechanical effects such as clutch drag in the case of a multi-engined rotorcraft. Compliance with this specification may be established by test or analysis and should take into account the conditions imposed on the Engine by a typical aircraft installation.

(2) The conditions imposed on the Engine after in flight shutdown and their maximum duration should include consideration of all expected aircraft applications for the Engine, e.g. rotorcraft, turbopropeller, subsonic aircraft and supersonic aircraft.

(3) Conditions that should be considered and addressed, if determined to be applicable, should include, but are not limited to, those identified below:

- Complete loss of Engine oil,

- Rotor unbalance resulting from blade loss and subsequent rotor damage.

Consideration should be given to extended periods of continued rotation under these conditions in conjunction with the assumed flight envelope with one Engine shut down, including, where applicable, supersonic and supersonic to subsonic transition flight conditions.

(4) The conditions imposed at the Engine-to-aircraft interface as a result of the rotor unbalance and rotational speed associated with continued rotation of an Engine following an Engine blade loss and subsequent rotor damage should be determined by analysis or test or both by the applicant as required by CS-E 520 (c)(2), covering the entire flight envelope, and be provided in the installation documents required by CS-E 20.

AMC to CS-E 540
Strike and ingestion of foreign matter

(1) When complying with CS-E 540 (a), the substantiation of the strike and ingestion effects of foreign objects such as cleaning cloths, hand tools, rivets, bolts and screws needs only to be carried out if these are likely to be more severe than those of the single large bird strike / ingestion.

As well as being part of the demonstration of compliance with CS-E 540 (a), the effects of the large bird ingestion test of CS-E 800 on the spinner or any Engine static part, as a result of a bird strike, should be assessed against the criteria of CS-E 510. Main frame struts or bifurcation strut fairings may be exposed to impact from birds or bird debris. Such frame struts or strut fairings may house fuel, oil, hydraulic, high-pressure bleed air lines, or wiring associated with the engine control system. The applicant should consider the potential for bird induced damage to these ducts, lines or wires with regard to the objective of CS-E 540.

In order to verify the Extremely Remote criteria for Hazardous Engine Effects in case of bird strikes as required in CS-E 540 (a), consideration should be given to the possibility of aircraft operation at speeds higher than 200 knots, associated with the corresponding probability of occurrence of encountering a single bird under such conditions.

(2) CS-E 540 (b) is intended to address for example rain, hail, ice, gravel, sand, small and medium birds. For some threats the interpretation of the specifications of CS-E 540 (b) should be made in relation to other CS-E specifications, such as CS-E 800 for birds or CS-E 790 for rain and hail, which may quantify the safety objectives of CS-E 540 (b). These related paragraphs are therefore intended to be sufficient for demonstrating compliance with CS-E 540 (b) for the considered subject. Nevertheless, any unusual finding made during these demonstrations of compliance should be assessed against the safety objective of CS-E 540 (b) continued safe flight and landing.

AMC to CS-E 560
Fuel system

(1) More than one type of fuel may be allowed : CS-E 560 (a) applies to each type and covers additives in the fuel (for example, fuel system icing inhibitor).

Some engines may use other fluids, such as water methanol : when appropriate, the word "fuel" in CS-E 560 should be interpreted as covering these fluids as well.

If the Engine may be adversely affected by a parameter of the fuel specification, such as sulphur or gum content, this should be identified in the appropriate documentation.

When defining the fuel specifications under CS-E 560 (a), CS-E 90 should also be considered for effects induced in the fuel system by the fuel itself, fuel additives or water in the fuel.

(2) To comply with CS-E 560 (b)(1), contaminants likely to be present in the fuel delivered to the Engine from the aircraft should be considered as well as contaminants resulting from wear of a part or component of the Engine fuel system (such as fuel pump bearing).

(3) In compliance with CS-E 560 (e), any means provided for protection against icing in the fuel system may either be in operation continuously or commence operation automatically when required.

(4) In complying with CS-E 110 (d), because a fuel leakage is considered as a potential fire hazard, design precautions should be taken to minimise possibilities of incorrect assembly of fuel system components, including pipes and fittings, especially if parts of the system have to be removed during the routine maintenance procedures.

(5) For compliance with CS-E 130 (a), in order to minimise the possibility of occurrence and spread of fire, each filter or strainer should be mounted so that its weight is not supported by the connecting lines or by the inlet or outlet connections of the filter or strainer, unless adequate strength margins under all loading conditions are provided in the lines and connections.

(6) Each filter or strainer requiring regular servicing should -

- Be accessible for draining and cleaning or replacement,
- Incorporate a screen or element that is easily removable, and
- Have a sediment trap and drain except if the filter or strainer is easily removable for drain purposes.

(7) Any restriction in by-pass operation condition should be specified in the appropriate manuals.

(8) CS-E 560 (g) is intended to cover any likely changes in settings caused by vibration~~s~~, incorrect maintenance, mechanical interference when installed or during handling, etc. Examples of design precautions are : locking devices, sealing, inaccessible installation.

AMC to CS-E 570
Oil system

(1) Each filter or strainer requiring regular servicing should be accessible for draining and cleaning or replacement. For complying with CS-E 570 (a)(1) in order to avoid possible leakage, each filter or strainer should be mounted so that its weight is not supported by the connecting lines or by the inlet or outlet connections of the filter or strainer, unless adequate strength margins under all loading conditions are provided in the lines and connections.

(2) In complying with CS-E 570 (a)(1), each oil tank should have an expansion space. Experience has shown that 10 percent of the tank capacity is adequate. It should be impossible to fill the oil tank expansion space inadvertently.

(3) In complying with CS-E 570 (a)(2)(i), filling and drainage provisions should be accessible and have manual or automatic means for positive locking in the closed positions. Each oil tank filler connection that can retain any significant quantity of oil should have provision for drainage to the outside of the Engine cowling.

(4) In complying with CS-E 570 (a)(2), access points include, but are not limited to, Magnetic Chip Detectors and gearbox access cover plates.

(5) “Hazardous quantities”, as referred to in CS-E 570 (e)(1), is defined in AMC to CS-E 130.

SUBPART E – TURBINE ENGINES; TYPE SUBSTANTIATION

AMC to CS-E 600 (e)
Test - General

The applicant should justify any difference between the Engine attitude during the tests and the Engine attitude in the intended rotorcraft installations.

AMC to CS-E 620
Performance : Formulae

(1) The following corrections from the observed test conditions to the assumed atmospheric conditions of pressure and temperature should be used within the range of conditions appropriate to the particular type of Engine, i.e. taking into account the characteristics of the Engine Control System, and the possible effect of Reynolds Number, unless more accurate or additional corrections for a particular type of Engine have been agreed or required by the Agency.

Gas Pressures

S.I. Units

$$Pc = Po \text{ x } \frac{1013 \cdot 25}{B}$$

Gas Temperatures

$$Tc = To \text{ x } \frac{288}{\theta}$$

Rotational Speed

$$Nc = No \text{ x } \sqrt{\frac{288}{\theta}}$$

Thrust

S.I. Units

$$Fc = Fo \text{ x } \frac{1013 \cdot 25}{B}$$

Mass Air Flow

S.I. Units

$$Wc = Wo \, x \frac{1013 \bullet 25}{B} \, x \sqrt{\frac{q}{288}}$$

In cases where certain proprietary types of air flowmeter are employed, it should be noted that Wo is the actual air consumption of the Engine during test.

Fuel Flow

S.I. Units

$$Wc = Wo \text{ x } \frac{1013 \cdot 25}{B} \text{ x } \sqrt{\frac{288}{\theta}}$$

Power

S.I. Units

$$Pc = Po \text{ x } \frac{1013 \cdot 25}{B} \text{ x } \sqrt{\frac{288}{\theta}}$$

(2) Notation

B	=	Barometric pressure in test chamber	hPa
θ	=	Observed intake temperature, corrected for instrument temperature and scale errors only	K
P	=	Pressure	hPa
T	=	Temperature	K
N	=	Rotational speed	rpm
F	=	Thrust	kN
W	=	Mass air flow	kg/s
w	=	Fuel flow	kg/h
P	=	Power	kW

(3) Suffixes

Suffix ‘o’ denotes an observed result, corrected for instrument temperature and scale errors only. Suffix ‘c’ denotes a result corrected to the standard atmospheric pressure and temperature conditions of CS-E 620.

AMC to CS-E 640
Static Pressure and Fatigue Tests

(1) Definitions. For the purpose of CS-E 640 (a) the following definitions apply and should be related to the Engine when installed in a typical installation.

Normal Working Pressure. The maximum pressure differential likely to occur on most flights including any pressure fluctuations as a result of the normal operation of valves, cocks, etc, where these could produce significant surge pressures.

Maximum Working Pressure. The maximum pressure differential which could occur under the most adverse operational conditions (e.g. forward speed, altitude, ambient temperature, Engine speed, use of OEI ratings) likely to be encountered in service, including any pressure fluctuations as a result of the normal

	operation of valves, cocks, etc., where these could produce significant surge pressures.
Maximum Possible Pressure.	The maximum pressure differential which could occur under the most adverse combination of operational conditions (e.g. forward speed, altitude, ambient temperature, Engine Speed, use of OEI ratings) likely to be experienced in service, together with Failure of any relevant parts of the Engine or control system, or combinations of Failures which are more likely than Extremely Remote. Consideration should be given to any pressure fluctuations as a result of normal or emergency use of valves, cocks, etc., where these could produce significant surge pressures.
Static Parts subject to significant gas or liquid pressure loads.	The components subject to high-pressure loads or whose design is influenced by the gas or liquid pressure loads to be contained. Examples might include the compressor, combustor and turbine casings, heat exchangers, bleed valve solenoids, starter motors or fuel, oil and hydraulic system components. Special attention should be given to any filler cap.

(2) Static Pressure Tests (see CS-E 640 (a))

The anticipated Engine manual serviceable limits may be used as the criteria to judge the acceptability of any permanent distortion.

When a test is performed on a part which is subjected in service to a varying pressure throughout its length, it is permissible to simulate the pressure conditions by suitably dividing the part into zones and applying the maximum pressure for each zone including the appropriate factors of CS-E 640 (a).

(3) Tests. General

If the part is subject to loads in addition to those resulting from differential pressure (e.g. flight manoeuvre loads, Engine mounting loads, etc.), an analysis should be made of these additional loads and their effect examined. If the effect of these loads is small it may be possible to simulate them by an addition to the test pressure differential. However, if the loads are of significant magnitude or cannot adequately be represented by a pressure increment the test should be carried out with such loads acting in addition to the pressure loads.

The part should be tested at the temperature associated with the most critical stress case or alternatively the test pressure differential may be increased to simulate the loss of relevant properties as a result of temperature.

During pressure testing the methods of mounting and restraint by the test facility or test equipment of any critical section should be such as to simulate the actual conditions occurring on the Engine.

(4) Analytical Modelling Methods

An analytical modelling method may be used to determine adequate strength and fatigue life provided that the model is validated by testing or successful field experience with parts of similar design.

AMC to CS-E 650
Vibration Surveys

(1) Definitions. The following are defined for the purpose of this AMC:

Physical rotational speed (Nr).	The raw uncorrected rotational speed of a rotor system measured in revolutions per minute (rpm).
Corrected rotational speed (Nc).	The rotational speed of a rotor system corrected by normalising the compressor inlet conditions to a standard condition of air at 15°C. The correction values are empirically determined and are applied by the formula: Nc = Nr/(T inlet/288) exponent Where T inlet is the compressor inlet temperature in Kelvin and the exponent is determined empirically but has a typical value of 0.5.
Resonance.	A condition that results when the exciting force frequency coincides with one of the component's natural frequencies. A unique vibratory mode exists for each resonant response.
Endurance limit.	The maximum value of alternating stresses, in combination with the appropriate steady-state stresses, that will not result in material fatigue Failure.
Flight envelope.	All airborne and non-airborne conditions of operation, including start-up and shutdown, both on the ground and in flight, and windmilling rotation in flight.
Flutter.	Flutter in a system having blades or vanes is a self-excited vibration that occurs at one of the system's natural frequencies and at the associated natural vibratory mode. It is independent of any external excitation source but is dependent upon the aerodynamic conditions over the blade and upon the system's aeroelastic properties.

(2) Selection of Components.

Analyses should be conducted to identify the Engine components whose vibration characteristics require verification by Engine test or by other means shown to be equivalent or more appropriate. The selected components would normally include:

- The most critical blades and vanes, from a vibration point of view, in the fan and each compressor and turbine.

- All blade rows adjacent to variable incidence vanes.

- All fan discs, and the most critical disc, from a vibration point of view, in each compressor and turbine.

- All main rotor shaft systems (and gears when included in such systems).

- Any other component specifically identified as requiring Engine test to substantiate analysis and/or to supplement component tests.

(3) Test Conditions.

The following alterations to the test conditions may be necessary to adequately assess the Engine's vibratory characteristics.

(a) Rig testing.

Normally a full Engine test is the preferred means to complete the survey. However, an applicant may elect to use rig tests for overcoming limitations associated with a full Engine test, such as the amount of instrumentation or range of inlet conditions that can be tested. If rig tests are employed, the applicant should demonstrate that all pertinent interface conditions and physical hardware closely model actual Engine operations.

(b) Speed extensions.

The full stress survey should be the goal and the test programme arranged accordingly to cover at least the ranges of conditions required under CS-E 650 (b). Where extensions to those ranges are considered necessary for the identification of the effects of the rising vibratory stress peak, as required under CS-E 650 (b), but it proves physically impracticable to achieve the appropriate extended test conditions, the effects of the rising vibratory stress peak should be adequately assessed by other means to be agreed with the Agency.

(c) Instrumentation survivability.

Where the Engine operates at such high rotor speeds and gas path temperatures that test instrumentation can only survive the environment for short periods of time, some form of analysis acceptable to the Agency would be expected to complete the substantiation.

(4) Altitude Effects.

Engine tests may be conducted by flight test or in altitude facilities or in other facilities such that the effects of flight and altitude are properly represented and can be evaluated. Suitable test equipment and instrumentation should be used for each situation. Any alterations made to the Engine for the purpose of achieving test conditions should be evaluated to show that the alterations are acceptable.

(5) Flutter.

Testing required to demonstrate satisfactory vibratory clearance from flutter boundaries may be accomplished by compressor rig and/or Engine sea-level or altitude test. In both cases the test procedure needs to recognise that some systems' susceptibilities to flutter will not be revealed during tests if the relevant operating conditions are not sustained long enough for the flutter to develop.

(a) The hardware standard, the intake conditions and margins to account for Engine deterioration should be taken into consideration. Further, the methods used to verify the absence of damaging levels of flutter throughout the declared flight envelope should include consideration of applicable combinations of the following:

(i) The ranges of physical and corrected rotational speeds for each rotor system.

(ii) The simultaneous occurrence of maximum compressor inlet air total temperature and maximum corrected rotational speed (i.e. maximum reduced velocity).

(iii) The range of compressor operating lines within the flight envelope; and

(iv) The most adverse of other compressor inlet air conditions encountered within the flight envelope (e.g. applicable combinations of total air pressure, density, temperature, and inlet distortion).

(b) As flutter is a phenomenon which can be sensitive to small variations in those factors which could influence the response of the system, due consideration should be given to possible variations, between the nominal and extreme values of, for example, tip clearances, mechanical damping, operating lines, bleed flows, etc…Experience has also shown that there are differences in susceptibility to flutter from one blade set to another and that 'tuned' blade sets might be more sensitive.

(6) Variations in Material Properties and Natural Frequencies.

Allowance should be made for the usual variations in material properties and natural frequencies of production components when interpreting test results or analytical predictions.

(7) Resonant Dwell.

If any significant resonance is found within the operating conditions prescribed in CS-E 650, then the relevant components should be subjected to sufficient cycles of vibration close to, and/or on, the resonance peak to demonstrate compliance with CS-E 650 (d). This resonant dwell testing would normally be incorporated into the incremental periods of the CS-E 740 Endurance Test as required by CS-E 740 (g)(1). Components subjected to such resonant dwell testing should subsequently also meet the specifications of CS-E 740 (h) endurance test final strip inspection.

(8) Instrumentation Incompatibility.

If the dimensions of the blades or vanes are incompatible with the necessary instrumentation, instrumented Engine tests to substantiate the vibration characteristics of compressor and turbine blades and vanes and the variation of the Endurance Test incremental running as prescribed in CS-E 740 (g)(1) may be waived wholly or in part if the Agency is satisfied that the total hours of operation accumulated on test beds or in flight, under representative conditions, prior to certification is sufficient to demonstrate that the vibration stress levels are acceptable.

(9) Installation Compatibility.

The intent of CS-E 650 (f) is to ensure vibratory compatibility between the Engine and each intended installation configuration when the Engine is installed and operated in accordance with the manufacturer's approved instructions. The applicant will normally be expected to provide sufficient information in the Engine instructions for installation to enable the aircraft manufacturer(s) to establish that the installation does not unacceptably affect the Engine's vibration characteristics. In establishing vibratory compatibility between the Engine and the installation, consideration should be given to the need to declare operating limitations and procedures. Where appropriate, at least the following aspects and installation features should be considered:

- Each Propeller approved for use on the Engine.
- Each thrust reverser approved for use on the Engine.
- Installation influences on inlet and exhaust conditions.
- Mount stiffness; and
- Rotor drive systems.

(10) Inspection Specifications.

The pre-certification activity necessary for determining which Engine components require verification by Engine test and also for determining the proper location of Engine test instrumentation will typically include substantive tests and analyses for determining component (or system) natural frequencies, mode shapes, steady state mean stress and vibratory stress distributions. These development activities will generate engineering data essential to supporting the certification test and should be exempt from formal Agency approval of test plans and reports. Inspection of type design hardware in accordance with the requirements of 21A.33 of Part 21 should be limited to only those pertinent Engine components and associated instrumentation that constitute the certification Engine test.

AMC to CS-E 660
Fuel Pump Tests (Turbine Engines for Aeroplanes)

When testing equipment susceptible to cavitation erosion (e.g. Engine fuel pumps) the possibility of such erosion being relieved by dissolved air in the test fluid should be considered and, if appropriate, some testing should be carried out with fuel at the most critical temperature and pressure with regard to cavitation erosion and having the minimum amount of air in solution that is likely to occur during normal operating conditions.

AMC to CS-E 670
Contaminated Fuel Testing

(1) Solid Contaminants

(a) A contaminant with the characteristics detailed in the following table is acceptable.

CONTAMINANT	PARTICLE SIZE	QUANTITY
FERROSO – FERRIC Iron oxide (Fe_30_4) Magnetite (Black) FERRIC iron oxide (Fe_20_3) Hematite FERRIC iron oxide (Fe_20_3) Hematite	0 - 5 microns 0 -5 microns 5 -10 microns	0.40 g/1000 litre 7.13 g/1000 litre 0.40 g/1000 litre
Crushed quartz Crushed quartz Crushed quartz Crushed quartz	1000 – 1500 microns 420 – 1000 microns 300 – 420 microns 150 – 300 microns	0.07 g/1000 litre 0.46 g/1000 litre 0.26 g/1000 litre 0.26 g/1000 litre
Prepared dirt conforming to ISO 12103-1 A4 (Arizona test dust – coarse)	Mixture as follows: 0 - 5 microns (9.25%) 5 - 10 microns (10.25%) 10 - 20 microns (14.5%) 20 - 40 microns (25%) 40 - 80 microns (29.5%) 80 - 200 microns (11.5%)	2.11 g/1000 litre
Cotton linters	Below 7 staple (US Dept of Agriculture Grading Standards SRA-AMS 180 and 251)	0.03 g/1000 litre

Crude Napthenic Acid		0.03 percent by volume
Salt water prepared by dissolving salt in distilled water or other water containing not more than 200 parts per million of total solids	4 parts by weight of NaC1 96 parts by weight of H_2 0	0.01 percent by volume

Additionally, for engines to be fitted to Aircraft with Carbon Fibre Composite Material Fuel Tanks:

Carbon fibre rods of tensile strength 5.59 GPa nominal.	5 microns nominal diameter 0 to 2000 microns in length Population distribution: 0 - 25 microns (43% ± 5%) 25 - 50 microns (25% ± 5%) 50 - 75 microns (13% ± 5%) 75 - 125 microns (12% ± 5%) >125 microns (7% ± 5%) Maximum fibre length 2000 microns	0.54 g/1000 litre

(b) A test on the complete fuel system should be carried out either on a running Engine, or on a rig, using fuel continuously contaminated at a rate of 4·5 g of contaminant per 4 500 litres.

(c) The point at which blockage will be indicated to the flight crew should also be established and the fuel system should be shown to be capable of continuing to operate without causing Engine malfunction for a further period equal to at least half the maximum flight duration of the aircraft in which it is likely to be installed. Once this has been established, it is permissible to clean or replace filter(s) as frequently as necessary for the remainder of the test. If blockage has not occurred by the time the total quantity of contaminant has reached the level specified in paragraph (d) below, the objective of this paragraph (c) may be considered to have been met.

(d) The test should then be continued at typical running conditions with respect to Rotational Speeds, pressures, fuel flow, etc., for a sufficient time to ensure that the total weight of contaminant passing into the system would be equivalent to 500 hours of normal operation with fuel contaminated to a level of 0·5 g per 4 500 litres. At the conclusion of the test, the fuel system should be functioning satisfactorily.

(2) Water Contaminant

A test on the fuel system should be carried out, using the fuel contaminated with water, either on a running Engine or on a rig.

The contaminated fuel should consist of fuel initially saturated with water at a fuel/water temperature of 27°C into which a further 0·2 ml of free water per litre of fuel has been evenly dispersed.

The test should be conducted with the contaminated mixture cooled to the most critical condition for icing likely to be encountered in operation.

AMC to CS-E 680

Inclination and Gyroscopic Load Effects

Normally inclination and gyroscopic load effects will be proved during flight testing but in certain cases some supplementary running or rig testing, to an agreed schedule, may be required before flight tests can be permitted.

AMC to CS-E 690
Engine bleed

For reducing test complexity, and for improved flexibility needed to attain the key parameters (speed, temperature and torque) during the 2-hour test of CS-E 740 (c)(3)(iii), maximum air bleed for Engine and aircraft services need not be used if the applicant can show by test or analysis based on test that the Engine's ability to meet the tear-down inspection specifications of CS-E 150 (f)(3)(iii) is not enhanced. The analysis should include

- The effect of the bleed air extraction to the Engine secondary air system which provides cooling air to various Engine components,
- The thermodynamic cycle effects of bleed (e.g., gas generator speed to output shaft speed changes).

AMC to CS-E 700
Excess Operating Conditions (Turbine Engines for Aeroplanes)

(1) Case at VMO* (* For light aeroplanes the speed VNE is normally used)

The Engine should be run at the excess pressures and thrusts which would result from operation at VMO under the most critical ambient pressure and temperature conditions, with Maximum Continuous Power and/or Thrust selected.

The duration of the test should be related to the likelihood of the conditions occurring and the frequency of the occurrence in respect of a representative type of aeroplane. If limitations are declared and provision made for the necessary instrumentation, the test conditions may be modified accordingly.

On conclusion of the test, the Engine should be subjected to a strip examination and should not reveal features that could lead to a significant increase in the risk of Engine Failure.

(2) Case at VD.

The Engine should be run for 5 minutes (comprising five 1 minute runs or fewer longer runs of equal total duration) at the excess pressures and thrusts, which would result from operation at VD under the most critical ambient pressure and temperature conditions, with Maximum Continuous Power and/or Thrust selected, followed by the demonstration of ability of the Engine to complete a flight in which such circumstances have occurred. This latter demonstration may consist of running the Engine at typical cruising conditions for a period equal to the maximum likely flight time following such an incident on a representative type of aeroplane. The value should be established in consultation with the Agency.

(3) Case of 'Throttle Slam'.

The Engine should be rapidly accelerated from minimum flight idle conditions in simulation of throttle slam (i.e. opening the throttle as rapidly as is physically possible) and then run for two minutes to cover the excess conditions (e.g. rpm, pressure, thrust, temperature), which result from operating the Engine with the power control lever in the maximum forward position under the most critical ambient conditions likely to exist within the range of aerodrome altitudes for which performance is scheduled. If desired, the 2 minutes test may be made up of separate tests, each of not less than one-minute duration. At the end of the test the condition of the Engine should be such as to enable it to complete a flight in which such circumstances have occurred. This may be shown by demonstrating that the Engine will run satisfactorily at typical cruising conditions for a continuous period of 30 minutes (see also AMC to CS-E 500 paragraph 3).

(4) When exceedence of an Engine operating limitation has occurred during the bird tests of CS-E 800 (c) or (d), it should be demonstrated in compliance with CS-E 700 that the value of the exceeded parameter which was reached during the testing has been adequately validated by other tests of CS-E or by specific additional test if needed. The maintenance actions associated with such exceedences for a similar in-service event should also be adequately validated and documented in the appropriate manuals. Compliance with CS-E 700 might include consideration either of a change in the finally certified limit so that the value achieved during the test would no longer be an exceedence, or of an approval of a transient under CS-E 820, CS-E 830 or CS-E 870 as appropriate.

AMC to CS-E 710
Rotor locking tests

(1) The applicant has the option to incorporate a rotor-locking device into the type design of the Engine in order not to have to comply with CS-E 525. Activation of the device will stop and prevent subsequent continued rotation of the Engine rotor(s) during flight when the Engine is not operating. The device is part of the Engine type design and is subject to the same test criteria as other components on the Engine. In addition, the rotor-locking device should satisfy the operational and endurance test specifications identified in CS-E 710 while the Engine is subjected to the environmental conditions that result in the maximum rotational torque. The assessment of the maximum rotational torque should consider both damaged and undamaged Engine rotors.

(2) An Engine that is shut down and that has a rotor locking device but continues to rotate due to Failure of the rotor locking device might not satisfy the safety objectives of CS-E 525. Therefore the design of the rotor-locking device should be assessed for all possible Failure modes under CS-E 510. The effects of an uncommanded or inadvertent activation of the rotor-locking device in flight should be considered.

(3) Due to the expected infrequency of using the rotor locking device, it should be designed such that under normal Engine operating conditions it will not deteriorate beyond serviceable limits to the extent that it fails to perform its intended function when activated during an Engine shut down (see also CS-E 510 (e)).

(4) The rotor-locking device should be designed in such a manner that it is possible for the flight crew to unlock the Engine rotor(s) in order to initiate Engine restart attempts. In the event these attempts are unsuccessful, the flight crew should be able to re-lock the Engine rotor(s).

(5) The effects of the temperature of the induction air and external surfaces of the Engine should be considered where relevant to the design.

AMC to CS-E 720 (a)
Continuous Ignition

The necessity for a continuously-operated system may arise, for example, in consideration of water or slush ingestion at take-off, ice ingestion, or for compliance with the icing specifications.

AMC to CS-E 730
Calibration Tests

(1) The parameters used for the calibration curves are those appropriate to, and compatible with, the Engine's design. Thrust, Power, Torque, Rotational Speed, EPR (Engine Pressure Ratio), EGT (Exhaust Gas Temperature), are typical parameters of known Engine designs.

(2) The Calibration Test should be run to cover the maximum possible rotational speed range, but at least to cover the range from minimum idle to the normal maximum compatible with the ambient external atmospheric condition of the test day.

(3) The pre and post test calibration curves required by CS-E 730 should be established up to the highest rating to be approved for a duration of more than 2 minutes prior to the additional endurance test of CS-740 (c)(3)(iii). Because the Engine operation at the 30-Second and 2-Minute OEI Power ratings could significantly affect Engine hardware conditions, these Engine ratings are therefore not required to comply with the calibration specifications of CS-E 730.

AMC to CS-E 740 (c)(3)
Endurance tests

(1) Two procedures for running the tests required under CS-E 740 (c)(3) are acceptable :

(a) After the basic 150-hour endurance test the Engine may be subject to a strip inspection in accordance with CS-E 150 (f)(2).

The Engine is then reassembled using the same parts used for the 150-hour endurance test except as otherwise allowed by CS-E 150 (f)(3)(ii) and the additional 2-hour endurance test is run to CS-E 740 (c)(3)(iii).

Completion of the additional 2-hour endurance test would be followed by compliance with the strip inspection specifications of CS-E 150 (f)(3)(iii); or

(b) The 2-hour additional endurance test of CS-E 740 (c)(3)(iii) may be run immediately after the basic 150-hour endurance test without Engine disassembly.

The strip inspection standards that will be applied after completion of the additional 2-hour endurance test will be those prescribed in CS-E 150 (f)(2).

(2) Per CS-E 50 (f), the Engine control should prevent exceedence of the speed limitation associated with the 30-Second OEI Power rating. Nevertheless, for ensuring the shortest time of establishment of the corresponding power, it might be necessary to design the Engine control in such a manner that a short overshoot of the speed will occur at the beginning of the 30 seconds period. This is acceptable if this is validated throughout the CS-E 740 (c)(3)(iii) test.

(3) In the event of a stop occurring during the four test sequences of CS-E 740 (c)(3)(iii), the interrupted sequence needs to be repeated in full or can be re-started from the interrupt point if there is a technical justification acceptable to the Agency. If it is determined that the sequence need not be repeated in its entirety, the test should be restarted from a point where the Engine thermal condition would be the same as at the time of interruption. (See CS-E 740 (b)(1)).

AMC to CS-E 740 (f)(1)

Multi-spool Engines

Where an Endurance Test is conducted in accordance with CS-E 740 (f)(1) supplementary evidence is required to substantiate any rotational speed limitations higher than those covered in that test. This AMC indicates an acceptable basis for conducting such supplementary tests.

(1) The Engine on which the supplementary tests are conducted may be the same Engine as that which completed the Endurance Test, or an Engine of a standard similar in all those aspects which could be affected by the increased rotational speed.

(2) Where increased rotational speed limitations are desired in respect of both Take-off and Maximum Continuous Power/Thrust conditions, the supplementary testing should provide for running at the increased rotational speed of equal duration to, and in all other relevant respects as severe as, the conditions prescribed in the type endurance test schedule for running at Take-off and Maximum Continuous Power/Thrust conditions.

(3) Where increased rotational speed limitations are desired in respect of either Take-off or Maximum Continuous Power/Thrust conditions only, the supplementary testing should provide for –

(a) *Where the test is conducted on parts which have already completed the Endurance Test (or its equivalent)*. Running at the increased rotational speed of equal duration to, and in all other relevant respects as severe as, the conditions of the Endurance Test schedule for running at the Take-off or Maximum Continuous Power/Thrust conditions as appropriate.

(b) *Where the test is conducted on parts which have not completed an Endurance Test (or its equivalent).* Running of equal duration to, and in all other relevant respects as severe as, the conditions of the Endurance Test schedule for running at the Take-off and Maximum Continuous Power/Thrust conditions, but with only that period of running for which higher limitations are desired, conducted at the increased rotational speed.

AMC to CS-E 740 (g)(1)
Endurance Tests – Incremental Periods

As an alternative to revising the incremental running as indicated in CS-E 740 (g)(1), separate Engine running of appropriate severity may be completed (see also AMC to CS-E 650 paragraph 8).

AMC to CS-E 745
Engine Acceleration

(1) Compliance with CS-E 745 may be demonstrated during tests performed to meet other sections of CS-E.

(2) In complying with CS-E 745 (a)(1) and (a)(2) for evaluation of a potential ‘over-temperature’, the appropriate adverse combination is probably ‘maximum bleed air and maximum power extraction’. For evaluation of ‘surge’ and ‘stall’, the combination should probably be ‘no bleed air and maximum power extraction’. An ‘over-temperature’ event is considered as being any exceedence of the steady state and transient values which are substantiated under CS-E 740.

(3) The ‘minimum test bed idle’ which is referenced for rotorcraft Engines in CS-E 745 (a) or other CS-E paragraphs is the minimum practically possible power extraction from the Engine in the test facility while the output shaft is at the governed speed.

(4) If, when complying with CS-E 745 (a)(3), an acceleration time longer than 5 seconds is experienced, the justification should address operational aspects as well as aircraft certification specifications for the

intended installation. For example, this would be considered for the very large engines which could have a difficulty in meeting exactly the 5 seconds because of the inertia of their rotors or other reasons.

AMC to CS-E 750 (b)
Starting tests

The « declared drainage period » after a false start referred to in CS-E 750 (b) is the minimum period necessary to allow surplus fuel to drain from the Engine prior to making a further attempt to start the Engine. The period is measured from the time at which the starter is switched off and/or the Engine fuel cock is closed during a false start.

AMC to CS-E 770
Low Temperature Starting Tests

It is normally acceptable in each of the tests of CS-E 770 (b) and (c) to allow the Engine to inspire uncooled intake air.

The Constructor may declare a Minimum oil temperature which, with any associated conditions, may be used for the purpose of opening up from ground idle for warming up or taxying.

AMC to CS-E 780
Tests in Ice-Forming Conditions (Engines for Aeroplanes)

Non-altitude testing is permissible where appropriate justification can be presented, but this could involve modification of other test conditions of this paragraph.

(1) Because Engine behaviour cannot easily be divorced from the effects of the intake and Propeller, where appropriate, it is recommended that the tests be conducted on an Engine complete with representative intake and Propeller (or those parts of the Propeller which affect the Engine air intake). Separate assessment and/or testing of the intake and Propeller are not excluded, but in such circumstances the details of the actual intake and Propeller used in the Engine tests will be defined in the Engine approval documents. It would then finally be the responsibility of the aeroplane constructor to show that the Engine tests would still be valid for his particular installation, taking into account –

- Intake distortion as a result of, for example, incidence or ice formation on the intake and Propeller,

- The shedding of ice from the intake and Propeller into the Engine, or

- The icing of any Engine sensing devices, other subsidiary intakes or equipment contained in the intake.

See also, in CS-25, AMC to CS-25.1093 (b) and/or CS-25.929 (a).

(2) The tests may be completed either in an altitude test facility capable of representing flight conditions, or in flight with adequately simulated icing conditions. The altitudes for the tests in an altitude test facility should be as indicated in Table 1 or, for flight tests, those appropriate to the desired temperature, except that the test altitude need not exceed any limitations proposed for approval. The conditions of horizontal and vertical extent, and water concentration required by tests described below are somewhat more severe than those implied by the icing conditions of CS-Definitions so as to provide a margin.

(3) A separate test should be conducted at each temperature condition of Table 1 the test being made up of repetitions of either the cycle –

(a) 28 km horizontal extent in the liquid water content conditions of Table 1 Column (a) appropriate to the temperature, followed by 5 km in the liquid water content conditions of Table 1 Column (b) appropriate to the temperature, for a total duration of 30 minutes.

or the cycle –

(b) 6 km horizontal extent in the liquid water content conditions of Table 1 Column (a) appropriate to the temperature, followed by 5 km in the liquid water content conditions of Table 1 Column (b) appropriate to the temperature, for a total duration of 10 minutes.

TABLE 1

Ambient air temperature	Altitude		Liquid water content (g/m^3)		Mean effective droplet diameter
(°C)	(ft)	(m)	(a)	(b)	(µm)
–10	17 000	5 200	0·6	2·2	
–20	20 000	6 100	0·3	1·7	20
–30	25 000	7 600	0·2	1·0	

(4) Either as separate tests, or in combination with those of 3, it should be demonstrated that the Engine characteristics are not unacceptably affected by the introduction of a representative delay in the initiation of operation of the ice-protection systems, such as might occur during inadvertent entry into the conditions. In the absence of better evidence the representative delay should normally be two minutes in the liquid water content conditions of Table 1 Column (a), which may, if desired, be introduced at the beginning of a test to 3(a) or prior to the commencement of the first 5 km cycle in 3(b).

(5) At the conclusion of each test of 3, the Engine should be run up to the maximum power/thrust conditions corresponding to the test altitude to demonstrate any effects of ice shedding.

(6) Each test of 3 should be run at the minimum power/thrust for which satisfactory operation in icing conditions is claimed, or at the minimum power/thrust appropriate to the aeroplane in which it is intended to install the Engine.

(7) An additional test at the –30°C condition of 3 should be carried out at the highest Engine speed (up to Maximum Continuous Power/Thrust) at which appreciable ice could, when shed, enter the Engine combustion chamber.

(8) Where the minimum power/thrust necessary to provide adequate protection (as established in complying with 6) is greater than that required for descent, an additional test at the minimum power/thrust associated with descent should be conducted by means of either –

(a) A run at the –10°C liquid water content condition of Table 1 Column (a), for sufficient duration to cover an anticipated descent of 3 000 m, or

(b) A run simulating an actual descent, in the liquid water content conditions of Table 1 Column (a), covering an altitude change of not the less than 3000 m, the highest total temperature reached being not greater than 0°C.

(9) At the conclusion of the test of 8, the Engine should be set to flight idling power and then subjected to a timed acceleration, using a one second power/thrust control lever movement, to maximum power/thrust conditions, so as to simulate a balked landing. The maximum power/thrust conditions should then be maintained for a sufficient period during which the air temperature should be raised above 0°C to ensure all ice is shed, or altematively, it may be established by visual inspection that any remaining ice is insignificant.

(10) A test should be conducted for a duration of 30 minutes, with the Engine set to the minimum ground idle conditions approved for use in icing, in an atmosphere of –2°C and a liquid water concentration of 0·3 g/m^3. The mean effective droplet size for the test should be 20 µm. At the end of the period, the Engine should be accelerated to Take-off Power/Thrust (in a manner approved for inclusion in the operating instructions) without suffering unacceptable damage or power/thrust loss.

(11) Ice Crystal Conditions.

CS-E 780 (d) requires consideration of Engine vulnerability to ice crystal conditions. An assessment of the need for tests should be made in conjunction with the Agency when the main layout of the Engine design is sufficiently defined. Engines with 'pitot' type intakes have not proved to be susceptible to ice crystal difficulties, and the Agency will not normally require tests on Engines with such layout. However, Engines designed with reverse flow intakes, or with intakes involving considerable changes of airflow direction may be susceptible. Also subsidiary intakes, control sensors, instrumentation probes, etc. should be considered individually. Where any doubt exists as to safe operation in ice crystal conditions, appropriate tests should be conducted to establish the proper functioning of the whole Engine, or as appropriate, the local areas. Table 2 gives provisional details of the conditions likely to be encountered in service.

TABLE 2

Air Temperature (°C)	Altitude Range		Max. Ice Crystal Content	Horizontal Extent		Mean Particle Diameter
	(ft)	(m)	(g/m^3)	(km)	(n miles)	(mm)
0 to –20	10 000 to 30 000	3 000 to 9 000	5·0 2·0 1·0	5 100 500	3 50 300	1·0
–20 to –40	15 000 to 40 000	4 500 to 12 000	5·0 2·0 1·0 0·5	5 20 100 500	3 10 50 300	

NOTES:

- The source of information is SAE Tech. Note Mech. Eng. 283, dated May 1959.

- In the temperature range 0 to –10°C the ice crystals are likely to be mixed with water droplets (with a maximum diameter of 2 mm) up to a content of 1 g/m^3 or half the total content whichever is the lesser, the total content remaining numerically the same.

AMC to CS-E 790
Rain and Hail Ingestion

(1) For the purposes of interpreting the words ‘unacceptable mechanical damage’ and ‘unacceptable power or thrust loss' in CS-E 790 (a)(1), (a)(2), (b) and (c), see paragraphs (5)(c)(vi), (5)(c)(vi)(A) and (B) in AMC to CS-E 790 (a)(2).

(2) For the purposes of interpreting the words ‘flameout, rundown, continued or non-recoverable surge or stall’ in CS-E 790 (a)(2) and (b), see paragraphs (1) and (5)(c)(vi) in AMC to CS-E 790 (a)(2).

(3) For the purposes of interpreting the words ‘sudden encounter’ in CS-E 790 (a)(2) and the words ‘suddenly commencing’ in CS-E 790 (b), see paragraphs (5)(c)(iv)(D) and (G) in AMC to CS-E 790 (a)(2).

(4) For the purposes of interpreting the words ‘rapid acceleration’ and ‘rapid deceleration’ in CS-E 790 (b)(2) and (b)(4) should be interpreted as meaning a throttle movement in not more than one second.

(5) If the Engine is certified under the assumption that the protection device considered under CS-E 790 (d) is provided by the aircraft installation and if the compliance with CS-E 790 (a) to (c) is waived, then the Engine approval would be endorsed accordingly and the Engine instructions for installation would need to impose the conditions of CS-E 790 (d)(1) to (3) to the installation.

AMC to CS-E 790 (a)(2)
Rain and Hail Ingestion – Turbine Engine Power/Thrust Loss and Instability in Extreme Conditions of Rain and Hail

(1) Definitions

The following terms are defined for the purpose of this AMC :

Critical point(s)	Operating conditions within the Engine flight envelope at which an Engine's operability margin is reduced to a minimum level. Operability margin includes compressor surge and stall margin, fuel control rundown margin, combustor flameout margin and instrumentation sensing errors.
Flameout	The total extinction of flame within the combustor, resulting in a rundown and, ultimately, a shutdown of the Engine.
Hail	Water in a solid granular state, either in its naturally occurring form or in a fabricated form, for the purpose of testing Engines.
Hail water content (HWC)	The concentration, in the air, of water in the form of hail, expressed in grams of hail per cubic metre of air.
Rain	Water in liquid droplet state, either in its naturally occurring form, or created artificially by discharging water from spray nozzles, for the purpose of testing Engines.

Rain water content (RWC)	The concentration, in the air, of water in the form of rain, expressed in grams of rain per cubic metre of air.
Rundown	The uncommanded reduction of Engine rotor speed that will result from the fuel control steady state operating line coinciding with the fuel control acceleration schedule.
Scoop factor	The ratio of nacelle inlet highlight area (A_h) to the area of the captured air stream tube (A_c) (Scoop factor = A_h/A_c).
Stall	An airflow breakdown at one or more compressor aerofoil stages.
Surge	The response of an entire Engine that is characterised by a significant airflow stoppage or reversal in the compression system.
Sustained power or thrust loss	A permanent reduction in power or thrust at the Engine's primary power/thrust set parameter (e.g., rotor speed, Engine pressure ratio, torque, shaft power).

(2) Power-Loss and Instability Phenomena

(a) General

There have been multiple Engine power-loss and instability events, forced landings, and accidents attributed to turbine Engine malfunction in extreme conditions of rain or hail. Investigations have revealed that ambient concentrations of rain and hail can be amplified significantly through the Engine core at certain combinations of flight speed and Engine power/thrust condition. In some instances, the resulting increased amounts of ingested rain and hail have been sufficient to produce Engine anomalies such as surging, power loss and Engine flameout.

(b) Meteorological Data

Appendix A to CS-E defines the atmospheric conditions of rain and hail for the purpose of establishing certification test standards. Note that the water concentrations defined for rain and hail in Appendix A represent ambient conditions, not test conditions at the Engine inlet.

(c) Rain and Hail Concentration Amplification and Attenuation Effects

During in-flight encounters with rain and hail, changes in Engine power/thrust and flight speed can alter the rain or hail concentration within the Engine for any given atmospheric rain or hail content.

(i) Scoop Factor Effect (Refer to Figure 1)

The inlet capture stream tube for airflow varies widely across the spectrum of Engine power/thrust and flight speed. At low Engine power/thrust and high flight speed, the air intake specifications are minimal in comparison to the available ram air. Consequently, a significant portion of the air in front of the inlet spills outside the inlet lip (see Figure 1). Due to their mass, large rain droplets and hail are relatively unaffected by this spillage and will be captured by the inlet. The amount of rain or hail captured through the inlet will be established by the inlet highlight area. The amount of this amplification effect is equal to the ratio of the nacelle inlet highlight area (A_h) to the captured air stream tube area (A_c). This ratio is the scoop factor and it increases with decreasing Engine speed and increasing aircraft speed, due to the increase in inlet airflow spillage resulting from a smaller captured air stream tube. Further, by-pass turbofan engines may have an additional internal scoop factor effect due to the divergence of the Engine core stream tube from the nacelle inlet to the core inlet at low Engine power and high flight speed. Therefore although the scoop factor effect generally results in concentration amplification, the amplification is greatest when high flight speed is combined with low power / thrust.

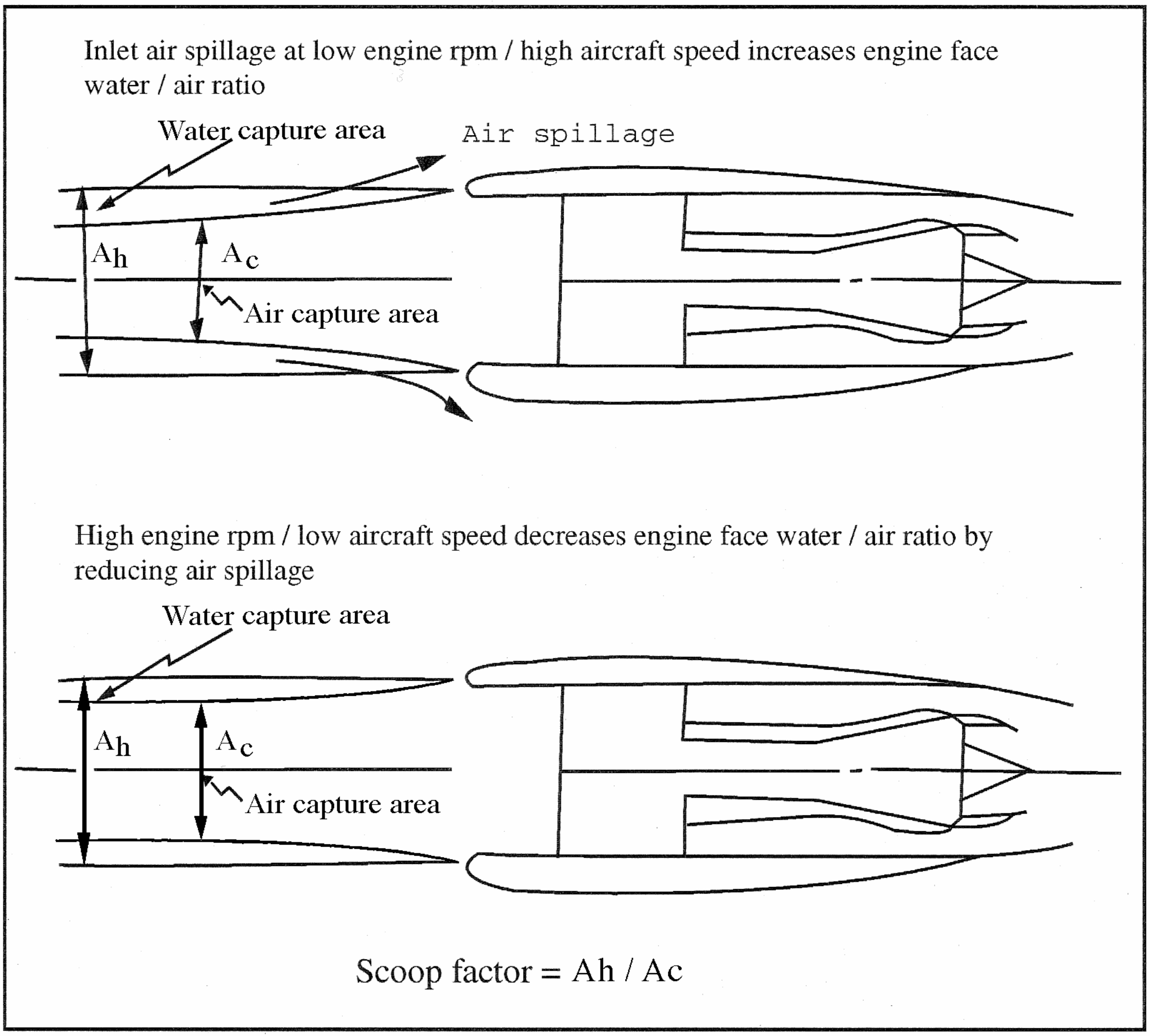


Figure 1 Scoop Factor

(ii) Relative velocity centrifuging effects

Some of the rain and hail will be centrifuged away from the Engine core by a fan and, to a lesser extent, away from the Engine by a Propeller. This beneficial effect is dependent upon the fan or Propeller geometry and rotational speed, inlet design and location, Engine design, aircraft velocity and on the sizes of the rain droplets and hailstones.

(A) Turbofan and turbojet aeroplane Engines (Refer to Figure 2)

- *Rain*

The inlet diffusing flow field pressure gradients act to shear large droplets into small droplets that decelerate and enter the fan at velocities close to the inlet air velocity. As depicted in Figure 2, the majority of droplets that enter the Engine at gas path speeds will strike the fan and be centrifuged away from the Engine core.

The forces acting upon the rain droplets in flight will vary with aeroplane velocity and altitude. A portion of the rain droplets entering the Engine may have sufficient mass such that deceleration to gas path velocity is not possible. At low Engine rotational speeds and high flight speeds, the velocity of the large rain droplets, relative to the fan, may allow that portion of the rain droplets to pass through the fan without impact (refer to hail velocity vector diagram in Figure 2) and could possibly result in higher water concentrations in the Engine core.

- Hail

Hail particles will maintain their size and will not be significantly affected by the Engine inlet flow field. Consequently, the hail particles will enter the Engine at close to aeroplane speed. At low Engine rotational speeds, a significant portion of the hail particles, like large rain droplets, may pass through the fan without impact (see Figure 2) and could possibly result in higher hail concentrations in the Engine core.

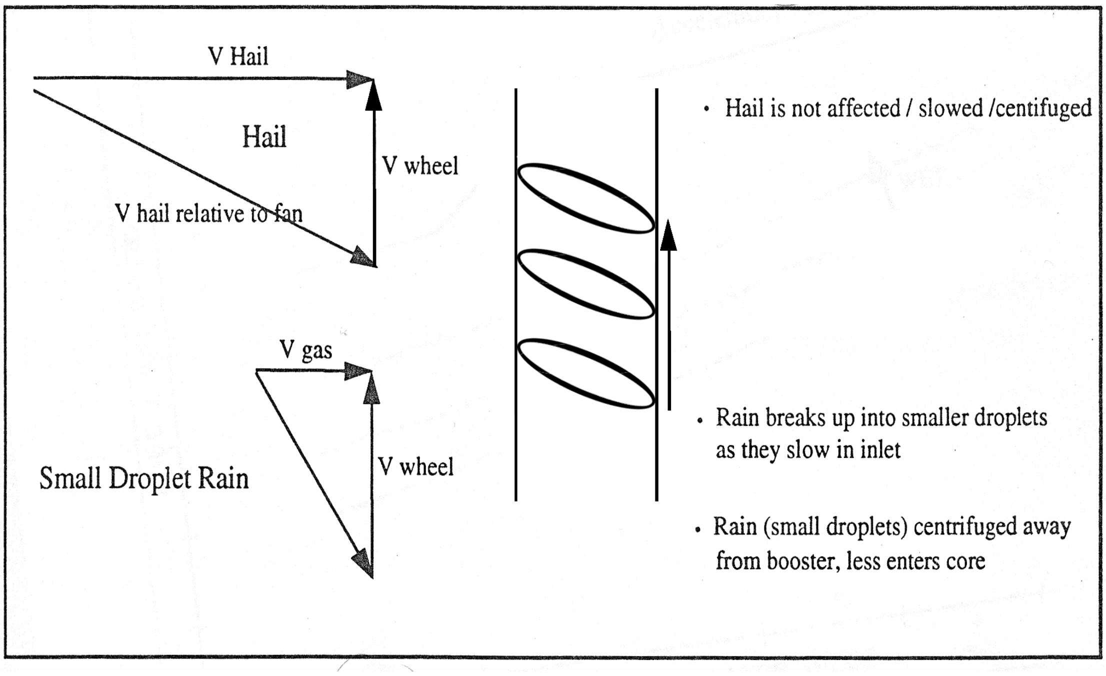


Figure 2 Velocity Vector Diagram

(B) Turboprop Aeroplane Engines

- Rain

When compared to a turbofan Engine, the inlet flow field effect of the Propeller on droplet size and the relative velocity centrifugal effects are reduced because of the lower solidity of the Propeller. Conducting this type of test without the Propeller, either by using some other load-absorbing device or running the gas generator alone, normally results in an added degree of conservatism.

Unlike turbofan Engines, the Propeller rotational speed does not vary significantly in flight, regardless of power setting. Thus, any beneficial effect of the Propeller will remain reasonably independent of altitude and power setting. Where an inlet particle separation system is incorporated, credit may be taken for its characteristics.

- Hail

As with rain, the effects of the Propeller on hail ingestion are generally considered beneficial by reducing the effective core concentrations so that conducting a hail test without a Propeller should result in an added degree of conservatism.

Another consideration is the effect of the Propeller spinner. In a continuous hail encounter, the spinner may redirect hail into the general area of the Engine intake. The trajectory of this material will influence the effective inlet concentration and should be included in any supportive analysis for other than full-scale powerplant tests.

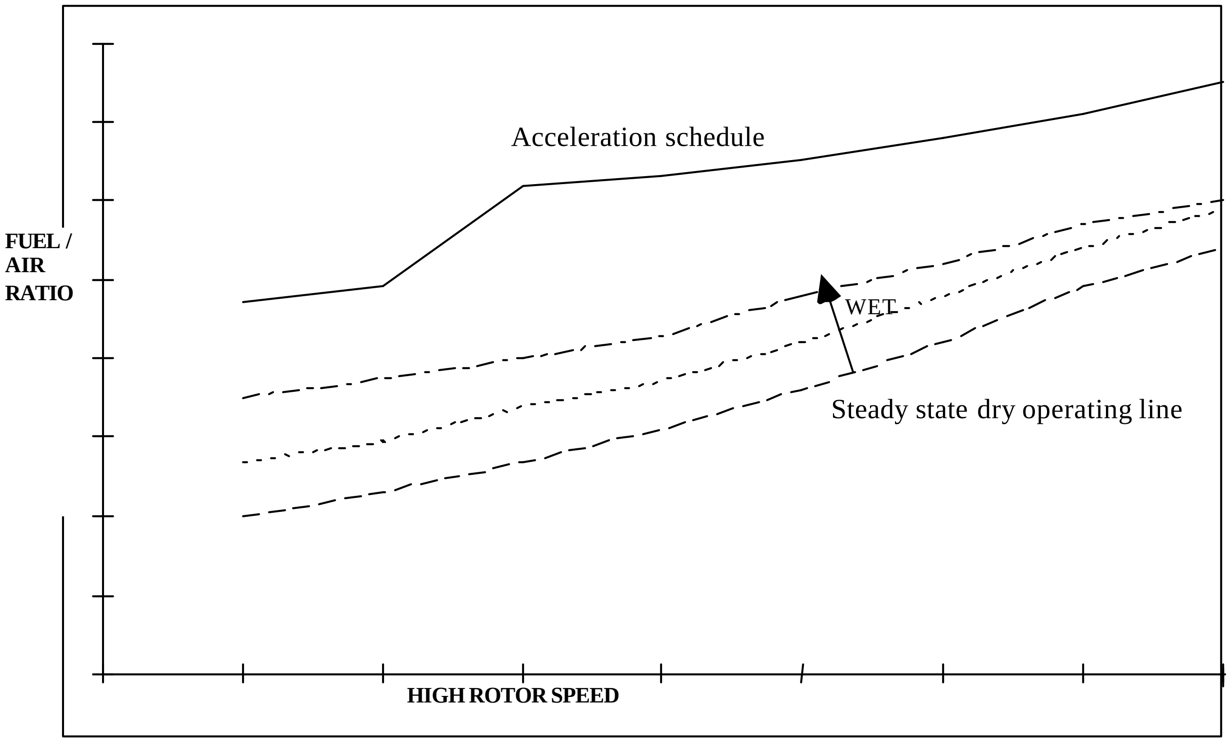


Figure 3 Typical Engine Control Characteristics

(d) Rotorcraft Turbine Engines

For rotorcraft applications, testing to the specifications of CS-E 790 (a)(2) may be replaced by the static rain ingestion test specified in CS-E 790 (b). While it may be possible to define in-flight rain and hail concentration amplification and attenuation effects for rotorcraft installations similar to aeroplane installations, these effects are typically small. When compared to aeroplanes, the proportionately higher Engine power during descent and the lower flight speeds of rotorcraft result in a small scoop factor effect. Rotorcraft turbine engines might not have rotating components that centrifuge rain or hail away from the Engine. While differences in centrifuging capability between static test conditions and flight operation is an important consideration for turbofan engines, it typically has no applicability to rotorcraft turbine engines. Increasing the ambient rain concentration from Appendix A values to 4 percent water droplet flow to airflow, by weight, will usually compensate for any flight effects.

(e) Turbine Engine Operability Effects

As stated previously, rain and hail ingested into a turbine Engine can be at greater than ambient concentrations in the Engine at certain combinations of flight speed and Engine power/thrust condition. Ingestion of rain or hail through the Engine core can produce a number of Engine operational anomalies including compressor surge, power/thrust loss and flameout. These operational anomalies are partly a result of the changes in the thermodynamic cycle of the turbine Engine because of the presence of water as a result of ingesting rain or hail.

(i) Compressor rematch

The presence of rain or hail particles or water from melted hail in the gas path causes the compressor to assume new operating conditions. The net overall effect may result in an increase in compressor operating line, with a corresponding decrease in compressor surge and stall margins.

(ii) Engine control response (Refer to Figure 3)

The fuel control steady state operating line will move upward toward the acceleration schedule as the amount of ingested rain or hail increases (see Figure 3). A higher operating line means that more fuel is required to sustain steady-state operation. When the operating line coincides with the acceleration schedule, the fuel control may be unable to deliver additional fuel to accommodate the increasing rain or hail ingestion. Under this condition, the Engine may rundown and could result in sub-idle Engine operation, a loss of throttle response, or flameout.

(iii) Combustor response

The evaporation, in the combustor, of the liquid water resulting from the ingestion of rain or hail will cause a reduction in combustor flame temperature and will adversely affect combustor performance. The reduced temperature will result in slowing of the chemical reaction rate and inhibit complete combustion. This results in reductions in combustor efficiency and stability. Typically, the combustor is most susceptible to flameout when it is required to operate at a sub-idle operating condition. Therefore, a flameout condition may be preceded by Engine rundown as discussed previously in paragraph (2)(e)(ii) of this AMC.

(f) Case Contraction

As rain or hail is ingested into any turbine Engine, the temperature of the compressor case may decrease at a faster rate than the compressor rotor. This would result in a reduction in compressor blade tip clearances and may result in blade tip rubs. Turbine Engine types, such as turbojets, that have a significant scoop factor effect but lack design features to direct rain or hail away from the Engine core (e.g. fan blades, bypass splitter, etc.) may be more susceptible to damage resulting from case contraction.

(3) Design Factors

(a) General

The response of a turbine Engine to a rain or hail encounter depends on a number of design and operational factors. The manufacturer can greatly improve the operability of the Engine during an extreme rain or hail encounter by incorporating certain design features. However, there may be a trade-off with some of these design features. For instance, a spinner designed to maximise hail rebound and rain droplet centrifuging may also result in a spinner which is more susceptible to large ice accretions.

(b) Design Features

With knowledge of the power-loss and instability phenomena, the applicant can incorporate design features that increase the Engine's tolerance to rain and hail ingestion.

(i) Fan blade or Propeller design and operating speeds.

The fan blade or Propeller, under the right conditions, can effectively centrifuge small droplets of rain away from the Engine core. Hail particles and large droplets of rain can also be moved away from the Engine core by the fan blade or Propeller, but with considerably less effectiveness. The applicant should consider the relative velocity effects at the critical points when establishing fan blade or Propeller geometry and operating speeds.

(ii) Spinner or nose cone

A spinner or nose cone can effectively deflect rain and hail away from the Engine core. Designing the spinner or nose cone to maximise hail deflection requires knowledge of the post impact trajectory characteristics of hail particles.

(iii) Bypass splitter

In the case of turbofan Engines, increasing the gap between the fan blades' trailing edges and the bypass splitter will normally tend to enhance the benefits, to the Engine core, of the centrifugal effects of the fan blades.

(iv) Engine air bleeds

Engine air bleeds ports provide a direct means of redirecting or extracting rain and hail away from the Engine core and a direct means of improving compressor surge and stall margins. The effectiveness of the bleed port in extracting liquid water or hail particles out of the Engine core will depend on the radial distribution of the water or hail particles, the location and the entrance geometry of the bleed port and the bleed control logic. Also, in the case of hail, the bleed port should be designed to minimise the likelihood of clogging and blockage.

(v) Engine and aircraft accessory loads

Accessory loads will tend to move the fuel control operating line closer to the acceleration schedule and, therefore, should be minimised, where possible, while in rain and hail conditions.

(vi) Fuel control

Fuel controls that schedule fuel using a rate change of compressor speed should provide consistent acceleration and deceleration thrust response during rain or hail ingestion.

(vii) Variable stator vane

The schedule of the compressor variable stator vanes directly affects the compressor performance, operability and stability characteristics. Weather-related sensing or scheduling errors may cause a loss of surge or stall margin.

(c) Operational Factors

With knowledge of the power-loss and instability phenomena, the applicant can establish an operating envelope which minimises the power-loss and instability threats.

(i) Increased power/thrust levels

Increasing Engine power/thrust will increase rotor speeds and air intake specifications. This is beneficial because an increase in rotor speed will tend to improve centrifuging, while an increase in airflow will tend to decrease the adverse scoop factor effect. Combustor stability margin will also be improved with increased power / thrust.

(ii) Avoidance of Engine transients

Avoidance of Engine transients improves the stall and surge tolerance of the Engine and reduces the likelihood of rundown. However, avoidance of throttle transients should not be used by the applicant to show compliance with the rain and hail ingestion specifications.

(iii) Decreased flight speeds

Reduced aircraft speed, like increased power levels, is beneficial because it improves centrifuging while decreasing the adverse scoop factor effect.

(4) Critical Point Analysis

(a) General

Compliance with the specifications of CS-E 790 (a)(2) is a two-step procedure. The first step is to identify, through analysis, the critical operating points for rain and hail ingestion. The second step is to test the Engine at selected critical points to validate the Engine's capability to adequately withstand extreme rain and hail encounters. The applicant should develop a critical point analysis and submit the analysis to the Agency for concurrence, prior to the rain and hail ingestion testing.

(b) Critical Point Analysis Elements

The purpose of the critical point analysis is to identify operating points within the Engine flight envelope where operability margins are minimised due to the ingestion of rain or hail. The analysis should encompass the full range of all pertinent variables. These variable include, but are not limited to:

(i) Atmospheric conditions

The rain and hail threats identified in Figure A1 and Tables A1 to A4 in Appendix A of CS-E should be used for this purpose. The critical point analysis should consider the effects of nominal, as well as extreme, levels of rain or hail on the function of all relevant Engine components and systems.

(ii) Rain and hail concentration amplification and attenuation effects

The critical point analysis should quantify the amount of rain and, separately, the amount of hail ingested into the Engine core. Therefore, amplification and attenuation effects, such as the scoop factor effect and the relative velocity effect, should be quantified. This may necessitate assessing a representative installation aerodynamic flow field and probable flight profiles. In the case of rain ingestion, droplet break-up characteristics need to be established or conservatively assessed. In the case of hail ingestion, the trajectories of hail particles after impacting nose cones, spinners, inlet surfaces, blades and vanes, etc. need to be established or conservatively assessed for determining critical points.

(iii) Engine power level

The entire envelope of power/thrust conditions should be analysed. While rundown and flameout are predominantly low power/thrust anomalies, compressor stability problems could occur at high power/thrust.

(iv) Engine parasitics

The variability of Engine parasitics, such as air bleeds and accessory loads, should be analysed for their effect on the critical points.

(c) Critical Point Analysis Procedure

The critical point analysis is an assessment of the Engine's capability throughout its operating envelope, given the range of event variables described above and any Engine operability condition which is affected by ingested rain or hail. Typical operability conditions to consider include surge and stall margin, fuel control rundown margin, combustor flameout margin and instrumentation sensing errors. The critical point analysis should also address case contraction.

(5) Compliance Methods

(a) General

An Engine compliance test method consistent with the critical point analysis may include the use of a ground-level static facility with appropriate means of conducting Engine tests with the ingestion of simulated rain and hail at the increased concentrations that are necessary to produce in-flight effects on the concentrations of ingested rain hail and to compensate for the differences between the critical point conditions and the ground-level test conditions. Other possibilities for demonstrating compliance include wind tunnel testing, direct core water-injection tests, component rig tests, scale model tests, and analyses.

(b) Test Point Selection

The critical hail point(s) and rain point(s) that yield the least operability margin should be demonstrated by Engine ingestion testing. Additional test points should be considered if any of the operability margins are determined to be minimal (i.e. compressor surge and stall, combustor blow-out, fuel control run down, instrumentation sensing errors, etc.).

(c) Critical Point Testing At Ground-Level

The applicant may test the Engine at ground-level conditions, provided the relevant Engine operational factors of the critical points are reproduced in a meaningful relationship.

(i) Test Compensation

The applicant should compensate for differences between the critical point conditions and the test facility conditions. These differences may include:

(A) Air Density

The critical point percentage of rain and hail concentration by weight should be reproduced during the test. For example, 20 g/m^3 of rain at 20 000 feet is approximately 3 percent water by weight. At sea level this percentage of water requires nearly 40 g/m^3 to compensate for the higher air density (Refer to Figure A1 in Appendix A of CS-E).

(B) Atmospheric parameters

In respect of air temperature and other atmospheric parameters, the appropriate ISA data may be assumed when adjusting concentrations of rain and hail.

(C) Scoop factor

The appropriate rain and hail concentration amplification due to the scoop factor effect should be applied to further increase the quantities of rain and hail for the ground-level tests. This necessitates having knowledge of the inlet diffusing flow field throughout the Engine power/thrust range and flight envelope.

(D) Engine rotational speeds

The low rotor speed for the ground-level test should be no greater than the altitude critical point condition. This is particularly important for turbofan Engines since rotational speed determines the rain and hail centrifuging effects which prevent some of the rain and hail from reaching the Engine core. The rain and hail concentrations may be adjusted to compensate for any necessary deviation from critical point rotational speeds.

(E) Variable systems

All variable systems, such as Engine bleeds, whose position can effect Engine operation in rain and hail, should be set in the position associated with the critical point.

(F) Engine power extraction

It should be shown by analysis or test that sufficient margin exists for extraction of the representative electrical or shaft power loads and service air bleeds.

(G) Thermodynamic cycle differences

There may be thermodynamic cycle differences between the test point and the critical point which affect the operability of the Engine. There should be compensation for these cycle differences, or it should be shown that these differences provide additional conservatism.

(H) Enthalpy of water

Rain and hail concentrations may be adjusted to ensure that the heat extraction resulting from their ingestion is the same as the critical point. If the ingestion of liquid water droplets is accepted (see paragraph 5.4 for compliance alternatives) for critical hail point testing, then the water concentration should at least be increased to compensate for the heat of fusion of ice.

(I) Rain droplet break-up

In the ground-level test environment, forces applied to accelerate the simulated rain droplets to flight speed, as well as shear forces between the droplets and the Engine airflow, are apt to break up the droplets. This break-up can result in reduced conservatism due to additional centrifuging by the fan or Propeller and spinner. The concentration of the rain may need to be increased to compensate for the added centrifuging resulting from ground level testing.

(ii) Engine test facility

The Engine test facility should provide a uniform water droplet or hail spatial distribution within the critical area of a plane within the Engine intake, such plane being agreed to by the Agency. The facility should also provide proper droplet or particle sizes and proper velocity distributions, unless otherwise justified in accordance with Appendix A to CS-E.

(iii) Instrumentation

Instrumentation and data sampling rates should be sufficient to establish rain and hail temperature and concentrations, particle velocities and size distributions, and Engine response. Primary exhaust water-to-air ratio measurements via gas sampling should be considered. Instrumentation accuracy and repeatability should be demonstrated by suitable means.

(iv) Test procedure

The test procedure should consider the following for operability critical point tests and for the thermal shock (rain only) critical point test:

(A) Stabilise the Engine at the critical point conditions.

(B) Take steady-state data readings before introducing rain or hail.

(C) Start continuous transient data recording prior to initiation of rain or hail flow.

(D) Establish altitude equivalent rain or hail flow at proper inlet velocity and size distribution. Maximum rain and hail ingestion rates should occur within 10 seconds.

(E) Conduct operability critical point tests at the following steady-state conditions:

- Deliver rain for a minimum of 3 minutes, at the altitude equivalent concentration defined in Figure A1 and Table A1 in Appendix A of CS-E.
- Deliver hail for a minimum of 30 seconds, at the altitude equivalent concentration defined in Figure A1 and Table A2 in Appendix A of CS-E.

(F) When testing low power critical points (i.e. minimum flameout and/or rundown margin), conduct tests with ingestion during the following transient operating conditions:

(α) Accelerate the Engine with a one-second throttle movement to rated takeoff power/thrust from the minimum rotor speed defined by the critical point analysis; and

(β) Stabilise the Engine at 50% rated take-off power/thrust with ingestion, then, with a one-second throttle movement, decelerate to the minimum rotor speed defined by the critical point analysis; or

(γ) If test conditions or test facility limitations prevent transient testing as defined in (α) and (β) above, the applicant may propose alternative test criteria, provided such alternative test criteria (and any complementary substantiation) validates that the Engine has sufficient operability margins to account for likely flight operations such as missed approaches (i.e., go-around) and likely throttle movements during descent.

(G) Conduct the thermal shock critical point test by delivering rain for 3 minutes at the critical power / thrust condition following a normal stabilisation period without water ingestion. Maximum rain ingestion rate should occur within 10 seconds.

(v) Probable factors

It should be demonstrated by test or analysis, that the Engine tested in accordance with paragraph (5)(c)(iv) of this AMC would have operated acceptably if exposed to other probable factors associated with a rain or hail encounter. These other probable factors would include, but are not limited to, typical Engine performance losses, installation effects, and typical auto throttle power excursions.

(vi) Acceptance criteria

Acceptable Engine operation precludes flameout, run down, continued or non- recoverable surge or stall, or loss of acceleration and deceleration capability. A momentary flameout, surge or stall that arrests itself without operational intervention (e.g. without throttle manipulation) is acceptable. If, after test, it is found that damage has occurred, further running or other evidence may be required to show that subsequent Failures resulting from the damage are unlikely to occur before the damage is rectified. Engine performance should be measured before and after the rain and hail ingestion tests to assess steady-state performance changes. Data should be normalised according to the applicant's standard practices and the evaluation of sustained loss or degradation of power or thrust should encompass the full range of Engine power or thrust.

If compliance with these criteria is dependant upon the functioning of an automatic protection system, such as continuous ignition, auto-relight, surge recovery system, then availability of this system is considered as critical for dispatch.

(A) Sustained power or thrust loss

The sustained power or thrust loss as a result of a shift or error in measured thrust or power against the primary thrust or power set parameter(s) following the ingestion test, should be limited to 3 percent. Measured post-ingestion power or thrust losses greater than 3% at any value of the primary setting parameter, can only be accepted when supported by appropriate assessments of aircraft performance.

(B) Power or thrust degradation

A change of Engine corrected thrust or power of up to 10 percent from rated or pre-test levels when using the applicant's normal performance parameters (i.e., Exhaust Gas Temperature, High Rotor Speed etc.), excluding the primary thrust or power setting parameter, is acceptable provided the criterion for sustained power or thrust loss is met.

(d) Other Compliance Alternatives

Analysis may be used in lieu of, or in combination with, Engine testing to demonstrate compliance with the specifications. The analytical methods used should have a sufficient validation basis to justify the accuracy of the predictions or be shown to yield conservative results. The amount of validation (i.e. Engine test, rig test, experimental test, etc.) should be proportional to the complexity of the analytical methods used and to the criticality of the particular calculation to the prediction of Engine operability.

AMC to CS-E 800
Bird Strike and Ingestion

(1) Ingestion Tests

(a) Single large Bird

(i) The applicant is required to provide an analysis substantiating the definition of the “most critical exposed location” (CS-E 800 (b)(1)(iii)). Determination of this location should include evidence where necessary on:

- The effect of the bird strike on rotating components (excluding any spinner).
- The compressor casing strength.
- The possibility of multiple blade Failures
- The strength of the Engine structure and main shafts relative to the unbalance and excess torque likely to occur.

(ii) For complying with CS-E 800 (b)(1)(ii)(A), rig tests may be used to determine if a particular bird size will pass through the inlet.

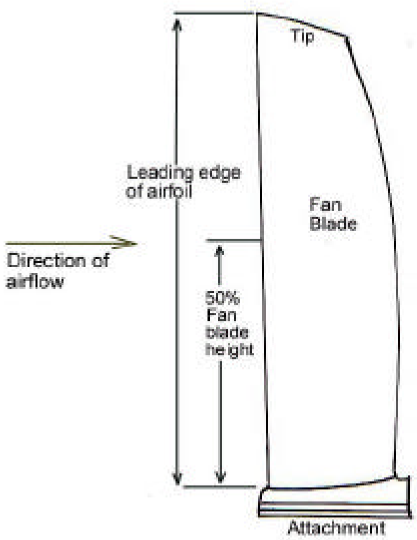
(iii) The complete loss of power or thrust is acceptable after ingestion of the single large bird.

(b) Large Flocking Bird

The following advisory material applies to the test of CS-E 800 (c).

(i) The minimum first stage rotor rotational speed (N1) at which the Engine should be stabilised before ingestion should be determined from the Engine performance data. Rated Take Off Thrust means the maximum take off thrust produced at sea level static conditions on an ISA standard day.

(ii) The applicant should select a target on the first exposed rotating stage(s) of the Engine (e.g. fan) at a blade span height of 50%, or further outboard, as required by CS-E 800 (c)(1)(iv) (see figure below). The specified target location is at the discretion of the applicant.



The use of ‘stage(s)’ is intended to allow for alternative designs such as rear mounted fans where each exposed stage will be evaluated independently.

(iii) When setting the thrust between the steps of the 20-minutes run-on period, momentary thrust drops below the specified values may be acceptable as long as the duration does not exceed 3 seconds.

(iv) The engine is required to continue to run for 20 minutes and produce no less than 50% of the Rated Take-off Thrust for the initial 14 minutes. During the first minute, the thrust lever is not to be manipulated. During step 2, the thrust lever may be manipulated at the discretion of the applicant to seek a power setting where the engine can continue to operate, for example to minimise exceedences and/or vibration, provided that at least 50% of Rated Take-off

Thrust is maintained. However, a momentary thrust drop below this value may be acceptable as long as the duration does not exceed 3 seconds.

(v) Following the initial 14 minutes, the thrust is reduced and a maximum of 30 seconds is allowed for the applicant to manipulate the thrust lever to find the thrust specified. This is to allow for potential damage to the Engine which might require careful throttle management.

(vi) The components referred to in CS-E 800 (f)(3)(ii)(A) include, for example, fan blades and their retention / spacer components, fan outlet guide vanes, spinners, fan disks and shafts, fan cases, frames, main bearings and bearing supports including frangible bearing assemblies or devices. The intent is that a sub-assembly test should adequately represent the mechanical aspects of a type design Engine during the large flocking bird ingestion.

(vii) The dynamic effects (and related operability concerns) referred to in CS-E 800 (f)(3)(ii)(C) include, but are not limited to, surge and stall, flameout, limit exceedences, and any other considerations relative to the type design engine's ability to comply with the specifications of CS-E 800 (c).

(c) Medium and small flocking birds

(i) The Engine test of CS-E 800 (d) will demonstrate that the Engine will produce the required power or thrust, while keeping acceptable handling characteristics during a 20-minute run-on simulating return to the airport after bird ingestion at take-off. This will consequently demonstrate compliance with CS-E 540 (b).

(ii) The applicant will identify under CS-E 800 (d)(1)(ii) all the critical locations and those which have to be used during the small or medium bird engine ingestion tests and appropriately consider potential effects of assumed installations in aircraft. The spinner and other parts of the front of the engine may be evaluated separately under CS-E 800 (e).

(iii) In the tests performed under paragraph CS-E 800 (d), the Engine is required to produce at least 75% of test conditions power or thrust after ingestion of small and medium birds. Nevertheless, a momentary power/ thrust drop below this value is acceptable but its duration should not exceed 3 seconds after the ingestion.

(iv) Exceedences of Engine operating limitations associated with Take-off conditions should not occur during the first 2 minutes following the ingestion of the birds in the 20-minute run-on test. If exceedence of limits occurs during these 2 minutes, except during the first 3 seconds of the test, this should be considered when complying with CS-E 700. After these initial 2 minutes without power lever movement, it is permitted to control exceedences, if any. Any intervention for controlling exceedences should be recorded and suitable instructions provided in the instructions for installation of the Engine. After any such power lever adjustment, the Engine should still produce the required power or thrust for the test. In CS-E 800 (d)(1)(iii) and (iv), a movement of the power lever means an action on the means which provides a power or thrust setting for the Engine control. This can be a mechanical device in the test facility control room or an electronic signal sent to the Engine Control System.

(2) Test facility related conditions

(a) The test facility should be appropriately calibrated to ensure that those controlling parameters defined by the analysis of the critical conditions which cannot be accurately controlled (e.g. bird speed, aiming locations) are within an acceptable tolerance. This tolerance band should be derived from an analysis of the sensitivity of the critical impact parameter to variation in the controlling parameters.

The " critical impact parameter (CIP) " is defined as a parameter used to characterise the state of stress, strain, deflection, twist, or other condition which will result in the maximum impact damage to the Engine for the prescribed bird ingestion condition.

The critical impact parameter is generally a function of such things as bird mass, bird velocity, fan/rotor speed, impact location, and fan/rotor blade geometry. The state of maximum impact damage to the Engine is relative to the ability to meet the criteria of CS-E 800. The CIP for most modern turbofan engines is fan blade leading edge stress, although other features or parameters may be more critical as a function of operating conditions or basic design. For turboprop and turbojet engines, a core feature will most likely be the critical consideration. Regardless of Engine design, the most limiting parameter should be identified and understood prior to any demonstration, as any unplanned variations in controlling test parameters will be evaluated for the effect on the CIP and CS-E 800 specifications.

For turbofan first stage fan blades, increasing the bird velocity or bird mass will increase the slice mass, and could shift the CIP from leading edge stress to blade root stress. For fan blades with part span shrouds, it may be blade deflection that produces shroud shingling and either thrust loss or a blade fracture that could be limiting. For unshrouded wide chord fan blades it may be the twist of the blade in the dovetail that allows it to impact the trailing blade resulting in trailing blade damage.

For certification tests, the CIP variation should not be greater than 10% as a function of any deviation in test controlling parameters.

(b) The installation and especially the gun arrangement in some test facilities can induce air distortion in the Engine inlet, reducing artificially the stability margins of the Engine. This should be identified prior to the test.

(c) Power or thrust should be measured by a means which can be shown to be accurate throughout the test to enable the power or thrust to be set without undue delay and maintained to within ± 3 percentage points of the specified levels. For the test of CS-E 800 (d), if, after the first 2 minutes, operation at the specified power or thrust levels would result in sustained high vibratory condition, the power or thrust may be varied within the ± 3% band. Alternative load devices of some test facilities may be unable to control power level tolerance band to the desired level. This should be identified and approved prior to the test. Any exceedence of this ± 3% band should be justified in relation to the objectives of CS-E 540 (b) or CS-E 800 (d).

(d) If turboprop or turboshaft engines are tested using an alternative load device which could induce different Engine response characteristics than when the Engine is coupled with a propeller or installed in the aircraft, the interface with the test facility and aircraft or propeller systems should be monitored during the test and should be used for determining how the Engine would respond in a representative installation and for ensuring that the Engine would then comply with the specifications.

(e) Input and output data across the Engine interfaces with the aircraft systems should be provided by the Engine manufacturer in the instructions for installation regarding the expected interaction of the Engine with these systems during ingestion events. Of particular interest would be dynamic interactions such as auto surge recovery, propeller autofeather.

(3) Impact

(a) The front of the Engine is defined as any part of the Engine which can be struck by a bird. This includes components such as, but not limited to, nose cone/spinner on the fan or compressor rotor, an Engine inlet guide vane assembly including centrebody, any protection device, or inlet-mounted components.

(b) Ingestion is defined as the passage of a bird into the rotating blades.

(c) The term “first stage rotor blades” when used in CS-E 800 includes the first stage of any fan or compressor rotor which is susceptible to a bird strike or bird ingestion. These first stage rotor blades are considered to be part of the front of the Engine. This definition encompasses ducted, unducted and aft fan designs. In this latter case, blades on two different rotors (in primary and secondary flows) would probably need to be considered.

(4) General

(a) The Engine configuration for the test should comply with CS-E 140. The normal functioning of automatic systems not requiring pilot intervention is acceptable provided that the dispatch criticality is addressed in the appropriate documentation. Systems which are not part of the Engine, such as propeller autofeather system, should be disabled. Any OEI ratings do not have to be taken into account for compliance with CS-E 800 (d).

(b) The minimum Engine referred to in CS-E 800 (b)(1)(i) or (d)(1)(i) is defined as a new Engine that exhibits the type design's most limiting operating parameters with respect to the bird ingestion conditions prescribed by CS-E 800. These operating parameters include, but are not limited to, power or thrust, turbine temperature and rotor speed(s).

(c) CS-E 800 (f)(1) is intended to allow certification of design changes or derivative engines without conducting a full engine test. It is not intended, considering the present state of the art, to be used for certification of new engines. However, it offers the possibility of future advancement. Any parametric analysis used to substantiate derivative engines as allowed under CS-E 800 (f)(1) should fall within a 10% variation in the critical impact parameter used to substantiate the original base engine. The critical impact parameter(s) is often associated with impact load at the point of bird and rotor blade contact. This is generally a function of bird speed, rotor speed, and blade twist angle. This 10% variation on the critical impact parameter should not be assumed to be a direct tolerance on the applicants proposed changes to takeoff power or thrust ratings themselves.

(d) Any analytical means used in place of a test demonstration (where analysis is permitted) should be validated by evidence based on representative tests and should have demonstrated its capability to predict engine test results.

(e) When reference is made to "exposed location" this should be understood to be any part of the engine which is not shielded.

(f) When the CS-E 810 test is proposed as an alternative to the single large bird test (see CS-E 800 (f)(2)), the demonstration should include consideration of unbalance as well as effects of the axial loading from the bird strike on bearings or other structures.

(g) Artificial birds may be used in the tests if they are internationally standardised and are acceptable to the Agency.

AMC to CS-E 810
Compressor and Turbine Blade Failure

(1) General

(a) Compliance with the specifications of CS-E 810 (a) may be shown in accordance with either (i), (ii) or (iii) –

(i) By compliance with the tests detailed in 2 and 3,

(ii) By presentation of adequate evidence substantiating the strength of the Engine either by blade Failure experience on Engines agreed by the Agency to be of comparable size, design and construction, or by blade Failures which have occurred during the development of the Engine, provided that the conditions of Engine speed, shut down period, etc., are sufficiently representative,

(iii) By other evidence acceptable to the Agency.

(b) Tests for containment are detailed in 2 and those for running following blade Failure are detailed in 3, but where the most critical blade from the point of view of blade containment is the same as that for the subsequent out-of-balance running, it is acceptable to combine the test of 2 and 3.

(2) Containment

(a) General. Containment tests should be made, either –

(i) On the complete Engine, or

(ii) On the individual stage concerned with the adjacent stators, where –

(A) The actual strength of casing under the anticipated operation conditions (e.g. temperature and pressure) is taken into account, and

(B) Adequate evidence is available such as to indicate that the aircraft would not be endangered by the effect of the blade Failure on subsequent blade rows.

(b) Test Conditions. Separate tests on each compressor and turbine stage adjudged to be most critical from the point of view of blade containment (account being taken of blade size, material, radius of rotation, Rotational Speed and the relative strength of the adjacent Engine casing under operating temperature and pressure conditions) should be carried out in accordance with the conditions of (a) and (b).

NOTE: Where the Engine design is such that potentially Engine Critical Parts overlie the compressor or turbine casing (e.g. by-pass Engines, or reverse flow Engines where the combustion systems may be outside the rotors) consideration should also be given to possible hazardous internal damage caused by blades penetrating the rotor casings, even though they are contained within the external geometry of the Engine. Consideration should also be given to AMC to CS-E 520 (c)(2).

(i) Number of blades to be detached. One blade should be released at the top of the retention member.

(ii) Engine Conditions at Release. The blade should be released at either –

(A) The maximum rotational speed to be approved (other than Maximum Engine Over-speed) and the associated maximum casing temperature, or

(B) Any likely combination of non-transient rotational speed, intake temperature and casing temperature considered to be more critical.

NOTE: Any deficiency in the required casing temperature may be compensated for by means of a suitable increase of the Engine speed.

(c) Condition after Tests. On completion of the tests, complete power Failure is acceptable, but there should be –

(i) Containment by the Engine without causing significant rupture or hazardous distortion of the Engine outer casing or the expulsion of blades through the Engine casing or shield.

NOTE: Should debris be ejected from the Engine intake or exhaust, the approximate size and weight should be reported with an estimate of its trajectory and velocity, so that the effect upon the aircraft can be assessed.

(ii) No hazard to the aircraft from possible internal damage to the Engine as a result of blades penetrating the rotor casings even though contained within the external geometry of the Engine.

(3) Running Following Blade Failure

(a) The tests should be conducted on a complete Engine, mounted in such a manner that the reactions induced by the out-of-balance on the Engine carcass and mounts will be representative of those which would occur in the installed condition. Alternatively, tests may be carried out on a rig but consideration should be given to the effects of shaft power input, further subsequential damage, heavy out-of-balance forces on other parts of the Engine, possible shaft Failure etc., when interpreting the test results as being indicative that no hazardous damage would occur in a complete Engine.

(b) Test Conditions. Separate tests should be carried out on each compressor and turbine stage adjudged to be most critical from the point of view of Engine damage subsequent to blade Failure as a result of out-of-balance forces existing during the period prior to Engine shutdown.

(i) The Engine should be run, with an out-of-balance representative of the loss of a blade from the top of the retention member, at the maximum rotational speed to be approved (other than the Maximum Engine Over-speed) until either the Engine stops of its own accord, or a period of at least 15 seconds has elapsed.

(ii) During the run the power setting should not be altered.

(c) *Condition after Tests.* On completion of the tests the result should be such that there is no hazard to the aircraft. Complete power Failure is permitted.

AMC to CS-E 840
Rotor integrity

(1) Definitions

The following terms are defined for the purposes of interpreting CS-E 840 and this AMC.

Rotor:	Individual stage of a fan, compressor or turbine assembly (some assemblies may consist of only one stage).
Sample Rotor:	A test article or assembly including, where appropriate, cover plates, spacers, etc. that is representative of the standard to be certified and for which the material properties and dimensions are known.
Maximum permissible rotor speed associated with a rating	the maximum of all approved speeds, including transients, for the relevant rating. When applicable, this includes the Maximum Engine Over-speed which is an approved 20-second transient.

(2) General

(a) The demonstration of compliance with the safety objectives of CSE 840 (a) and (d) may be made separately or be combined, as described in this advisory material.

(b) CS-E 840 (a) and (d) allow various means of compliance ("tests, analysis or combination thereof) in order to meet the objective identified therein. It is the applicant's responsibility to propose the appropriate means of compliance, in accordance with the guidelines defined in this AMC.

(c) Any analysis approach allowed under CS-E 840 should be defined and validated before usage.

(d) The applicant should submit to the Agency the appropriate analysis to determine which of the conditions in CS-E 840 b)(1) through (b)(4) is the most critical for each individual rotor stage with respect to the specifications of CS-E 840 (a). A similar analysis should be submitted with respect to the specifications of CS-E 840 (d).

Where the peak over-speed is limited by deliberate blade shedding :

(i) The factors of CS-E 840 (b)(3) and (b)(4) nevertheless apply to a fully bladed rotor at the shedding speed, and

(ii) The analysis to determine the most critical speed with respect to rotor integrity should consider blade shedding throughout the flight envelope. Consideration should be given to the blade Failure speed taking into account the effects of tolerances, temperature and material property variations of the blades together with the most adverse combination of the effects of tolerances and material properties on the integrity of the rotor. Consequently the most critical speed with respect to rotor integrity might not be coincident with the highest achievable blade shedding speed.

(e) While considering the most adverse combination of dimensional tolerances and material properties, as required in CS-E 840 (a) and (d), the applicant should also consider the tolerances and material properties of blades, over-speed limiter etc. adversely influencing stress levels in the rotor. The material properties assumptions, including material anomalies, used for lifing calculations should also be considered for the purposes of this specification.

(f) Failure conditions which are of a sudden transient nature (reference CS-E 840 (a) & (d)) are typified by loss of load Failures, i.e. characterised by high rates of acceleration and deceleration with no dwell period at the highest over-speed attained.

The applicant should also examine all possible Failure conditions to determine if any case exists which would result in a dwell period at speeds close to that of the transient short duration Failure condition. If such a case exists, the applicant should determine which condition is the most critical with respect to rotor integrity.

(g) The appropriate percentage speed factor of CS-E 840 (b) should be applied after making the necessary speed adjustments for temperatures, material properties, tolerance effects, etc. The necessary speed adjustments for temperature and material properties will normally be established on the basis of appropriate ratios of material properties.

(h) The consequences of rotor growth sufficient to cause significant contact or displacement between Engine components should be assessed to determine that the specifications of CS-E 840 (d)(1) can be met.

(i) When determining compliance with the specifications of CS-E 840 (d)(2) the applicant should consider whether or not the rotor would exhibit any condition that would be likely to prevent the safe operation of the Engine for a period of time that could occur in service following any Failure or combination of Failures considered under CS-E 840 (b)(3) or (b)(4). This period of time might be equal to that required to recognise the event and shut the Engine down, or to that required for continued safe flight and landing. The length of time might also depend upon the operational instructions for an over-speed event.

(j) Where a number of rotors are of similar design, are made of materials to the same specification and are subjected to similar stress conditions, temperature levels and gradients, it is permissible for compliance with CS-E 840 (a) to test only the most critical rotor, with respect to burst. This would require determination of the burst speed for each rotor in order to select the most critical which is assumed to have the smaller margin to burst above the speeds specified in CS-E 840 (b).

The most adverse combination of temperatures and temperature gradients which is possible throughout the entire operating envelope may vary for individual rotors in an assembly.

The most critical rotor with respect to burst might not be the most critical with respect to growth. Consideration should be given to the components surrounding each rotor in order to determine the most critical rotor with respect to growth for compliance with CS-E 840 (d).

(k) Appropriate tests or analysis based on tests should establish the burst speed of each fan, compressor, and turbine rotor design in relation to the most critical condition prescribed in CS-E 840 (b) and this should be reported in the certification documentation. These burst speeds should be based on the most adverse combination of dimensional tolerances and material properties.

(l) For a multi stage rotor in which the rotors do not meet the conditions of similarity as described in paragraph (2)(j) above, the compliance of each rotor stage with CS-E 840 should be substantiated using representative test data.

(3) Acceptable means of compliance may include

(a) Testing a sample rotor on a rig or Engine at the conditions necessary to demonstrate that a minimum strength rotor would meet the specifications of CS-E 840.

(b) Where the conditions of CS-E 840 (b)(1) or (b)(2) are the most critical, testing a sample rotor for the required period of time in an Engine at not less than 96% of the speed necessary to demonstrate that a minimum strength rotor would meet the specifications of CS-E 840 provided that this resultant reduced test condition is not less severe than that required to demonstrate compliance with CS-E 840 (b)(3) and (b)(4) and, it is shown from a validated method of burst prediction that burst would not have occurred at the conditions of CS-E 840 (b)(1) or (b)(2).

(c) An analytical modelling method based on representative test data may be acceptable provided that :

(i) The model has been validated by comparison with results from specimen and rotor tests and

(ii) Its use is limited to rotors with material, geometry, stress, and temperature conditions encompassed by those used to construct the model and

(iii) The predictions show that the certification standard rotor is not more critical, with respect to burst and growth, than any similar rotor for which substantiation has been demonstrated both by rotor test and model prediction.

(d) Any test may be continued to rotor burst after the required time duration by increasing the speed until the rotor bursts. If the applicant chooses this method, then it should be shown that :

(i) The sample rotor was initially run at conditions not less severe than those required for compliance with CS-E 840 (a), and

(ii) CS-E 840 (d) can be complied with using an approved analytical modelling method.

(4) Factors To Be Considered When Determining Test Conditions

(a) Temperature

The rotor temperatures required by CS-E 840 (b) are:

(i) For CS-E 840 (b)(1) and (b)(2) the material temperatures and temperature gradients equal to the most adverse which could be achieved when operating in the Engine at the required rating condition.

(ii) For CS-E 840 (b)(3) and (b)(4) the material temperatures and temperature gradients equal to the most adverse which could be achieved when operating in the Engine at the required rating condition immediately prior to the Failure(s).

These temperatures and temperature gradients should be established by temperature surveys on an Engine, or derived by a validated analysis. Adjustments of test speed or blade mass or both should be applied to compensate for any deviation from the required temperatures and temperature gradients.

(b) Sample Rotor Material Properties

Material properties of the sample rotor may be determined from attached test rings/bars when the correlation of their properties has been established by a validated method using coupons obtained from forgings/castings of the type to be approved.

When attached test rings/bars are not available to determine the material properties of the sample rotor, a value for the material properties may be established by assuming that the sample rotor possesses material properties equal to known average properties of similar rotors from the same manufacturing process lot if it can be shown that the assumption is valid within acceptable confidence limits.

(c) Dimensional tolerances

Analysis of dimensional tolerances should be made to identify the most adverse combination with respect to the integrity of the rotors.

(5) Failure Cases

In order to determine the highest over-speed resulting from a loss of load to be considered under CS-E 840 (c), it will be necessary to consider, for possible Failure locations, such factors as system inertia, available gas energy, whether the rotor is held in plane, over-speed protection devices, etc.

AMC to CS-E 850
Compressor, Fan and Turbine Shafts

(1) General

(a) A shaft is the system that transmits torque between the disc driving flange or shaft attachment member of the system that produces power (e.g. turbine) and the system that uses this power (e.g. compressor/fan or driving flange) and for which the mechanical restraints are mainly torsional. This includes any Engine gearbox in that transmission system (for any aircraft gearbox see paragraph (2)(b) below). The exclusion of discs in this definition of a shaft does not preclude the specification that any Failure thereof should be Extremely Remote.

(b) Clarification of terms and probabilities used in CS-E 850 may be found in CS-E 510. The possible shedding of blades is also covered in CS-E 810 (b).

(2) Non Hazardous Shaft Failures

(a) Where it is claimed that Hazardous Engine Effects are avoided by ensuring that rotating components are retained substantially in their normal plane of rotation and the control of over-speed is by means of :

- Disc rubbing;
- Blade interference, spragging or shedding;
- Engine surge or stall;
- Over-speed protection devices;

this may be substantiated by analysis. This analysis should be based upon relevant service or test experience.

(b) To substantiate compliance by analysis, it should be shown that all likely Failure modes have been identified in the analysis (including loss of loads caused by Failure of any gearboxes supplied by the aircraft manufacturer). The Failure analysis should take into consideration the effect of Failures in terms of contact and loads on the surrounding structure of the Engine and determine whether the affected rotor components are retained substantially in their rotational plane. It would also demonstrate that the structural components, when the loads resulting from the Failure are applied, do not exceed their ultimate stress capability and lead to a Hazardous Engine Effect.

(3) Hazardous Shaft Failures

In general, experience has shown that Failures of shafts occur at a rate in excess of Extremely Remote. Consequently shaft systems should be designed to fail safe as required by CS-E 850 (a)(1). However, it is accepted under CS-E 850 (a)(3) that, for conventional designs, this is not possible for all parts of a shaft system, but the use of this provision should be strictly limited.

Two possible hazardous effects of shaft Failure should be particularly considered : release of the complete fan or compressor moving forward and an over-speed of the turbine leading to disc burst.

Industry experience of shaft Failures should be considered under CS-E 850 (b)(2)(v). In particular, the following Failure modes have all led to shaft Failures in service :

- Degradation of a bearing leading to shaft orbiting and subsequent contact between the shaft and other rotating or static parts

- Blade Failure resulting in imbalance and rubbing of the shaft on other parts

- Corrosion inside the shaft

- Fuel flow instability in the Engine Control System inducing a resonance in the shaft

- Oil fire around the shaft

- Impingement of hot air on the shaft

- Bearing Failure

- HCF Failure from a stress concentration feature

- Loss of lubrication of a spline

Further, features such as splines, oil feed holes, couplings, bearing tracks integral with the shaft and sealing fins should be shown to be well understood and conducive to well established and validated stressing techniques.

When the assessment for compliance with CS-E 850 (b)(2)(iii) is that a shaft Failure due to the environment can be discounted, the ability to inspect the critical section of a shaft at the defined intervals and the appropriateness of the inspection method should be taken into account. For example, the Failure of a section of a shaft, which could cause Hazardous Engine Effects, in an area which would make inspection of the critical section in accordance with the manual difficult, may not be acceptable.

(4) Design Assessment

(a) The following aspects should be included when assessing causes and probabilities of shaft Failure-

(i) The potential for, and possible effects of, undetected material defects;

(ii) The effects of manufacturing tolerances allowed by the design;

(iii) Rubbing between any torque-loaded section of the shaft and adjacent surfaces (e.g. other shafts, oil seals, air seals) to the extent that significant over-heating or reduction in strength could occur;

(iv) The effect on the shaft of bearing Failure and the desirability of provision (e.g. by maintenance techniques and/or flight instrumentation) for the detection of incipient bearing Failure. The possibility of isolating the bearing from the shaft and thus increasing the damage tolerance of the system should be considered;

(v) The effect on the shaft of any likely Engine fire and the necessity for provision of an early warning of any internal fires that may occur;

(vi) The effect on the shaft of loads which could be transmitted by shock loading resulting from bird strikes, blade Failures, etc.

(vii) The effect on the shaft of oscillatory loading for example resulting from fuel system oscillations.

(b) The shaft system should be subjected to the following investigations and/or testing to support the design assessment and the compliance with the objectives of CS-E 850 (a).

(i) Strain gauge or other suitable means of investigation in order to satisfy the vibration survey specifications of CS-E 650 and to ensure that shaft whirling is not present to any significant degree at any likely Engine operating condition.

(ii) Fatigue evaluation of each shaft in torsional modes, in order to confirm its predicted safe life. An oscillatory torque of a magnitude equal to the maximum envisaged in a representative installation, but not less than ±5% of the normal maximum steady state torque should be superimposed on that steady state torque. In addition consideration should also be given to any high frequency vibrations determined from paragraph (4)(b)(i) above and any possible shaft bending.

(iii) Where necessary, confirmation of stress assumptions by static strength tests.

(iv) Where necessary, substantiation by test of the design considerations detailed in paragraph (4)(a) above such as to demonstrate that shaft Failure is acceptably remote.

AMC to CS-E 890
Thrust reverser tests

(1) Interpretation of CS-E 890 (f) :

In cases where the Engine test of CS-E 740 cannot be run with the standard thrust reverser, for example because it is not available despite applicant's efforts to obtain it, it is acceptable that a ''boiler plate reverser'' is fitted for the endurance test.

This addresses only the passive effects of the thrust reverser: cantilevered weight, effect on vibrations and loading of the Engine carcass, etc. Other evidence will be necessary to address the effects of the thrust reverser when functioning.

It is also acceptable to use other Engine tests performed with a representative thrust reverser, such as cyclic tests performed for the ETOPS approval of the aircraft.

(2) Representative control system.

It is not necessary that the whole control system (i.e. up to throttle levers) be representative of that of standard production thrust reverser. The necessary components of the control system are those situated on the powerplant assembly (nacelle) and which are subject to functioning when the reverser deployment is requested. This includes magnetic, hydraulic, electric, actuated controls but not necessarily the supply upstream, depending on the installation. The automatic throttle retarder system and forward thrust restrictor should be representative of the standard reverser system, but the control from pylon to flight deck need not be. Provision for instrumentation in the nacelle area are necessary for test follow up.

(3) Duration of use.

Thrust reverser intended for ground use only addressed in CS-E 890 (c), as opposed to in-flight use addressed in CS-E 890 (d), means a thrust reverser for which there is a means to prevent the reverser from deploying in flight.

The cycles prescribed in CS-E 890 (c)((1) refer to a duration of use for which approval is sought. When no particular use is intended other than the braking during post-landing and taxiing, it is commonly assumed that the duration should be taken as 30 seconds.

For in-flight use, in CS-E 890 (d), when no particular value is foreseen for duration use, the duration should be taken equal to one minute.

During the tests prescribed under CS-E 890 (c) and (d), the cycles to be run up to the «declared maximum reverse thrust conditions » should be such as to explore the Engine/reverser combination up to conditions likely to be encountered inside the declared envelope for use of the thrust reverser, in terms of temperatures (EGT) and pressures.

The required reverser operation cycles conducted should average no less than 100 percent of the specified maximum thrust conditions for maximum forward and maximum reverse. While some reverser operating cycles are acceptable with operation below the specified thrust values, to be credited the gas temperature should be maintained at least to the specified 100 percent value.

(4) Combination of tests.

The tests of CS-E 890 may be combined with parts of the Endurance Test of CS-E 740 by suitable arrangement in agreement with the Agency. For example, test of CS-E 890 (c)((1) may be combined with idling periods of Part 1 and 5 of the Endurance Test provided the idling period with forward thrust is not reduced to less than 3 ½ minutes per cycles.

AMC to CS-E 920
Over-temperature test

For the purpose of the test of CS-E 920, "Maximum power-on rpm" is normally the steady state rotor speed associated with the 30-Second OEI Power rating. However, this speed should be substituted by the transient rotor speed if the Engine characteristic transient speed stabilisation exceeds 3 seconds during the transition to the 30-Second OEI power.

In order to demonstrate that the Engine maintains the integrity of the turbine assembly after the over-temperature test, the applicant should show that no burst, no blade Failure or no other significant Failure of any Engine component would occur or become evident during the test, during shutdown or during the subsequent strip examination.

In the event that any Failure becomes evident, this should be analysed and it should be established by analysis or test that the cause is not such that in service the OEI rating structure would not be satisfactorily achieved.

SUBPART F – TURBINE ENGINES - ENVIRONMENTAL AND OPERATIONAL DESIGN SPECIFICATIONS

AMC to CS-E 1000
Environmental and Operational Design Specifications - General

CS-E subpart F defines specifications for the design of an engine to determine a configuration which would be required as part of the approval for particular aircraft operations such as ETOPS or Time Limited Dispatch.

It also defines the specifications necessary at the engine level for compliance with CS-34.

AMC to CS-E 1020
Engine emissions

(1) The following format should be used for the note referred to in CS-E 1000 (c).

Note x : Engine emissions
Engine (type/model) complies with CS-34 amendment (number).

(2) It should be noted that only the type design at time of engine certification will be assessed against CS-34 and that the applicable emissions standard for a production engine is dependent on its date of manufacture. Any further change to the type design should assess the effect on its engine emissions characteristics and its compliance with the specifications of CS-34, to enable demonstration of compliance for each individual engine when required.