Certification Specifications and Acceptable Means of Compliance for Engines

(CS-E)

Amendment 6

24 June 2020[1]

[1] For the date of entry into force of this Amendment, kindly refer to Decision 2020/006/R in the Official Publication of the Agency.

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ED Decision 2020/006/R

Amendment 6

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AMC E 50	Amended (NPA2019-01)
AMC E-50(l)	Inserted (NPA 2019-01)

ED Decision 2018/014/R

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The following is a list of paragraphs affected by this amendment:

Editorial corrections made to the entire CS-E Amendment 5.	
Subpart A	
CS-E 20	Amended (Article 16 consultation with the ABs)
AMC E 25	Amended (Article 16 consultation with the ABs)
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CS-E 800	Amended (NPA 2017-16)
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CS-E 810	Amended (Article 16 consultation with the ABs)

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AMC E 840	Amended (Article 16 consultation with the ABs)
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ED Decision 2015/009/R

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The following is a list of paragraphs affected by this amendment:

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AMC E 1050	Created (NPA 2011-17)

ED Decision 2010/015/R

Amendment 3

The following is a list of paragraphs affected by this amendment:

Subpart F	
CS-E 1040	Created (NPA 2008-01)

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Amendment 2

The following is a list of paragraphs affected by this amendment:

Subpart A	
CS-E 15	Editorial change
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CS-E 520	Amended (NPA 2007-15)
AMC E 520(c)(2)	Created (NPA 2007-15)

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Amendment 1

The following is a list of paragraphs affected by this amendment:

Subpart A	
CS-E 10	Editorial change
AMC E 10(b)	Created by renaming AMC E 10(b)
AMC E 10(c)	Deleted and moved to AMC E 10(b)
CS-E 15	Amended (NPA 4/2005)
CS-E 20	Editorial change
AMC E 20	Editorial change
AMC E 20(f)	Editorial change
CS-E 25	Editorial change
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CS-E 40	Editorial change
AMC E 40	Editorial change
AMC E 40(b)(3)	Editorial change
AMC E 40(d)	Editorial change
CS-E 50	Amended (NPA 4/2005) plus editorial change
AMC E 50	Amended (NPA 3/2005)
AMC E 50(e)	Editorial change
AMC E 50(j)	Editorial change
CS-E 60	Editorial change
AMC E 60	Editorial change
AMC E 60(d)	Amended (NPA 3/2005)
CS-E 70	Editorial change
AMC E 70	Editorial change
CS-E 80	Editorial change
AMC E 80	Amended (NPA 3/2005)
CS-E 130	Amended (NPA 3/2005) plus editorial change
AMC E 130	Amended (NPA 3/2005)
CS-E 135	Created (NPA 3/2005)
AMC E 135	Created (NPA 3/2005)
CS-E 140	Editorial change
AMC E 140	Editorial change
CS-E 150	Editorial change
AMC E 150(a)	Editorial change
AMC E 150(f)	Deleted and moved to AMC E 740(h)(2)
CS-E 170	Editorial change
AMC E 170	Amended (NPA 3/2005)
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AMC E 740(g)(1)	Editorial change
AMC E 740(h)(2)	Created by renaming AMC E 150(f)
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CS-E 1000	Editorial change
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CS-E 1020	Editorial change
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CS-E 1030	Amended (NPA 3/2005)
AMC E 1030	Created (NPA 3/2005)

SUBPART A – GENERAL

AMC 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.

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 21.A.16.

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

[Amdt No: E/1]

AMC E 10(b) 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.

[Amdt No: E/1]

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.

Critical Attitude — means the maximum attitude at which, in standard atmosphere, it is possible to maintain, at a specified rotational speed without ram, a specified power or a specified manifold pressure. Unless otherwise stated, the critical altitude is the maximum altitude at which it is possible to maintain, without ram, at the maximum continuous rotational speed, one of the following:

a. The maximum continuous power, in the case of engines for which this power rating is the same at sea level and at the rated altitude.

b. The maximum continuous rated manifold pressure, in the case of engines the maximum continuous power of which is governed by a constant manifold pressure.

Manifold Pressure means the absolute static pressure measured at the appropriate point in the induction system.

Maximum Best Economy Cruising Power Conditions means the crankshaft rotational speed, Engine manifold pressure and any other parameters recommended in the Engine manuals as appropriate for use with economical-cruising mixture strength

Maximum Recommended Cruising Power Conditions means the crankshaft rotational speed, Engine manifold pressure and any other parameters recommended in the Engine manuals as appropriate for cruising operation.

(e) 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.

[Amdt No: E/1]
[Amdt No: E/2]

CS-E 20 Engine Configuration and Interfaces

(See AMC E 20)

(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 certification specification code which is assumed to be 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. Manuals must also include interface security requirements, when necessary

(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. (See AMC E 20(f))

[Amdt No: E/1]
[Amdt No: E/5]
[Amdt No: E/6]

AMC 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.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

CS-E 25 Instructions for Continued Airworthiness

(See AMC E 25)

(a) In accordance with 21.A.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 inservice 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 postflight 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 crossreferences 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.

(13) Instructions applicable to information system security protection as required by CS-E 50(l).

[Amdt No: E/1]
[Amdt No: E/6]

AMC 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 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.

(5) For an Engine with a 30-Minute Power rating, the usage of this rating should be considered in the establishment of instructions for continued airworthiness. Usage limitations, such as the cumulated time limit for the 30-Minute Power rating, should be specified in the appropriate section of the ICA. Instructions should also be included for when these limits are reached.

[Amdt No: E/1]
[Amdt No: E/5]

CS-E 30 Assumptions

(See AMC E 30)

(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.

[Amdt No: E/1]

AMC 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 on the usage recording system.
Strength CS-E 100 CS-E 520, CS-E 640	Ultimate and limit loads; – out-of-balance loads, – operating envelope.
Fire precautions CS-E 130	Reliance placed on the installation of fire-zone partitioning for any part of the mounting structure or Engine attachment points that are not Fireproof.
Electrical Bonding CS-E 135	Reliance placed on aircraft provisions for electrical bonding of the Engine.
Propeller Functioning Tests CS-E 180	Propeller system. Levels of the Propeller vibrations.
Failure Analysis CS-E 210, CS-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, CS-E 380, E 770	Minimum and maximum starting torque.
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.

Specifications/References	Assumptions
Continued Rotation CS-E 525	Aircraft conditions such as airspeed, flight duration and ambient conditions.
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 590	Reliance placed on aircraft provisions for any safety system that is outside the applicant's control.
Vibration Surveys 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 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.
Icing Conditions CS-E 780	Intake conditions and configuration. Aircraft speeds and appropriate Engine powers. Engine ingestion capabilities.
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.
Relighting in Flight CS-E 910	Flight relighting 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.

[Amdt No: E/1]
[Amdt No: E/4]
[Amdt No: E/5]

CS-E 40 Ratings

(See AMC E 40)

(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-engined aeroplanes:

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

(ii) Continuous OEI Power or Thrust;

(3) Turbine Engines for multi-engined rotorcraft (see AMC E 40(b)(3)):

(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;

(4) Turbine Engines for Rotorcraft:

(i) 30-Minute 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 (see AMC E 40(d)).

(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 21.A.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.

[Amdt No: E/1]
[Amdt No: E/5]

AMC 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.

[Amdt No: E/1]

AMC E 40(b)(3) and (b)(4) 30-Second OEI, 2-Minute OEI and 30-minute Power 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 they 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 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 that involves the possible use of these ratings three times in one flight (i.e., the event at take-off, baulked landing and final landing). While it was not initially intended, it is recognised that these 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 within 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 to be a derated 30-Second OEI Power rating. For the required mandatory maintenance actions, see CS-E 25(b)(2) and AMC E 25.

(6) The 30-Second and 2-Minute OEI Power ratings should account for any deterioration observed during the applicable portion of the 2-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 to establish the Engine characteristics throughout operating envelope of the Engine. In particular, the Power ratings for the 30-Second and 2-Minute OEI ratings should reflect the rated power deterioration that is observed during 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 it should be reflected in the data given to the aircraft manufacturer to define the performance characteristics of the aircraft system. In the event of a power deterioration that exceeds 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 any variability in the amount of deterioration.

(7) For Rotorcraft turbine Engines, 'Rated 30-Minute Power' is the approved brake horsepower, developed under static conditions at specified altitudes and temperatures within the operating limitations established for the Engine, and limited in use for periods of no more than 30 minutes.

The 30-Minute Power rating may be set at any level between the Maximum Continuous up to and including the take-off rating, and may be used for multiple periods of up to 30 minutes each, at any time between the take-off and landing phases in any flight.

[Amdt No: E/1]
[Amdt No: E/5]

AMC E 40(d) Operating Limitations

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

(1) General

(a) Environmental conditions. (Flight envelope)

(b) Maximum declared Engine conditions for Reversible 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.)

[Amdt No: E/1]

CS-E 50 Engine Control System

(See AMC E 50, AMC 20-1, AMC 20-3, AMC 20-115)

(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.* (See AMC E 50(e))

(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 Programmable 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. (See AMC E 50(j))

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

(l) *Information System Security Protection*.

Engine Control Systems, including networks, software and data, must be designed and installed so that they are protected from intentional unauthorised electronic interactions (IUEIs) that may result in adverse effects on the safety of the aircraft. The security risks and vulnerabilities must be identified, assessed, and mitigated as necessary. The applicant must make procedures and Instructions for Continued Airworthiness (ICA) available that ensure that the security protections of the Engine controls are maintained.

[Amdt No: E/1]
[Amdt No: E/5]
[Amdt No: E/6]

AMC 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 and AMC 20-3 provides additional and detailed interpretation of CS-E 50 with special consideration to interfaces with the aircraft, and the Propeller when applicable.

(3) Rotocraft Engines

For rotorcraft Engine Control Systems that have a power turbine speed governing mode, the specification of CS-E 50(a)(3) for modulation of Engine power should be interpreted as the ability to manage power as required to maintain power turbine speed within specified limits.

(4) 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.

(5) 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 and AMC 20-3 for relevant interpretation).

(6) 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.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

AMC 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 E 20(f).

[Amdt No: E/1]

AMC to CS-E 50(l) Information system security protection

For Engine Control Systems, AMC 20-42 provides acceptable means, guidance and methods to address CS-E 50(l), with special consideration given to any external interfaces of the Engine and the interfaces between the aircraft and the Engine, if applicable. In particular, specific cases of intentional unauthorised electronic interactions (IUEIs) that could potentially have similar effects on all the Engine Control Systems of an aircraft should be taken into account in the security risk assessment, and not just any interactions that could only have an adverse effect on a single Engine.

[Amdt No: E/6]

CS-E 60 Provision for Instruments

(See AMC E 60)

(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 (See AMC E 60(d)):

(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.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

AMC 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 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.

(5) An Engine can be approved with 30-Second/2-Minute OEI Power Ratings and any combination of Maximum Engine Over-torque, Maximum Engine Over-speed and Maximum Exhaust Gas Over-Temperature in compliance with CS-E 820, 830, and 870. In such a case, Engine operation above the Take-off Rating limits but within the limits established under CS-E 820, 830, and 870 need not be considered as usage of 30-Second/2-Minute OEI Power Ratings if the event was a true over-torque, over-speed or over-temperature event and it can be demonstrated that the recording system is able to distinguish between;

(i) an Engine over-speed, over-torque or over-temperature with all Engines operating, and

(ii) use of the 30 Second/2 Minute OEI Power Ratings with one Engine inoperative.

[Amdt No: E/1]

CS-E 70 Materials and Manufacturing Methods

(See AMC E 70)

(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.

[Amdt No: E/1]

AMC 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:

— *Class1* 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.

[Amdt No: E/1]

CS-E 80 Equipment

(See AMC E 80)

(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).

[Amdt No: E/1]

AMC 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, to cover more than one aircraft installation.

Consideration of general conditions, such as those of EUROCAE ED-14 / RTCA/DO-160, allows the 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), dependent 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

	ENVIRONMENTAL CONDITIONS	ACCEPTABLE TESTS/PROCEDURES
4	Contaminated Fluids	As a reminder. See relevant CS-E specifications for fuel/oil/air specifications or Mil-E-5007 paragraph 3.7.3.3.2 Table X (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, Sections 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 & CS-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/DO160 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/DO160 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 and AMC 20-3.

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 and AMC 20-3
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	AMC E 515(3)(e)
23	Fire	CS-E 130 (note: the Engine Control System should also comply with CS-E 130(e))

The related AMC E 130 and AMC 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 and AMC 20-3

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 and AMC 20-3. 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))

[Amdt No: E/1]
[Amdt No: E/5]

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 Enginemounting 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 21.A.801(a) and (b), and 21.A.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

(See AMC E 130)

(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) 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:

(1) This is not required for the particular aircraft installation, and in this case, this shall be declared in accordance with CS-E 30; or

(2) the Engine is a Piston Engine that fulfils the following conditions:

(i) The Engine mounting structure must be designed to be fail-safe so that in the case of a Failure of one load path, the remaining mounting structure is able to support the Engine under the loads and thermal conditions as specified under paragraph (ii) and (iii) below.

(ii) Those features of the Engine that form part of the mounting structure or Engine attachment points shall be at least Fire-resistant.

(A) The mounting structure and Engine attachment points shall be able to sustain the limit flight loads that are appropriate for a typical aircraft installation for which the Engine is intended, including Engine thrust and torque for Maximum Continuous Power, without Failure for 5 minutes under the fire test conditions of AMC E 130(4).

This ability shall be demonstrated by analysis or by tests for all mounting structures and attachment points.

If a test is selected, then the test shall be performed to demonstrate the ability of the most critical elements of the Engine mounting system or attachment points to retain the Engine under the loads specified above and in accordance with the fire test conditions of AMC E 130(4).

(B) At the end of the 5-minute period, it is assumed that the Engine will be shut down. Shutdown loads shall be evaluated.

Under the fire conditions as specified in paragraph (ii)(A) above, the mounting structure and the Engine attachment points shall be able to sustain flight loads of 0.5 g/1.5 g, superimposed with the evaluated shutdown loads, without Failure. This shall be demonstrated by analysis or test.

(iii) After 5 minutes of fire application according to paragraph (ii) above, and until the end of 15 minutes, the Engine is assumed to be shut down. Under the fire conditions of (ii)(A) above, the other remaining features of the Engine mounting structure shall have sufficient static strength to withstand the maximum loads expected during the remainder of the flight.

In the absence of a more rational analysis, a load factor of 70 per cent of manoeuvre loads and (separately) 40 per cent of gust loads may be applied.

(iv) If they are not specified, the loads referred to in paragraph (ii) and (iii) above shall be considered to be ultimate loads.

[Amdt No: E/1]
[Amdt No: E/5]

AMC 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-Definitions; 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 shutoff 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(e)(1)).

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) 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.

(6) 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

(7) 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.

(8) 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.

(9) 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.

[Amdt No: E/1]
[Amdt No: E/5]

CS-E 135 Electrical Bonding

(See AMC E 135)

Any components, modules, equipment and accessories that are susceptible to or are potential sources of static discharges or currents from electrical Faults, must be designed and constructed so as to be grounded to the main Engine earth, as necessary to minimise the accumulation of electro-static or electrical charge that would cause:

— Injury from electrical shock,

— Unintentional ignition in areas where flammable fluids or vapours could be present,

— Unacceptable interference with electrical or electronic equipment.

[Amdt No: E/1]

AMC E 135 Electrical Bonding

Electrical bonding is a means to protect against the effects of electro-static discharges and currents from electrical Faults. The overall intent of CS-E 135 is to ensure that:

(i) a main Engine earth is provided. This is generally achieved by showing that all the elements of the Engine carcass are electrically bonded together.

(ii) a current path for electrical bonding exists between certain components that are mounted externally to the Engine and the main Engine earth.

With respect to the accumulation of electro-static or electrical charge, the applicant should show that the modules, assemblies, components and accessories installed in or on the Engine are electrically bonded to the main Engine earth. This may be accomplished by examination of the type design drawings, electrical continuity checks, or actual inspection of a representative Engine.

[Amdt N.: E/1]

CS-E 140 Tests - Engine Configuration

(See AMC E 140)

(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.

[Amd. No: E/1]

AMC 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)(1) 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.

[Amd. No: E/1]
[Amdt No: E/2]

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. (See AMC E 150(a))

(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.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

CS-E 160 Tests - History

(a) In order to enable compliance with 21.A.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

(See AMC E 170)

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.

[Amdt No: E/1]

AMC 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:

1. 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.
2. 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.
3. 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.
4. When an Electronic Engine Control System has a mechanical back-up which is not normally used during the endurance test.
5. 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 E 80.

If, for compliance with CS-E 170, high intensity radiated fields (HIRF)/Lightning tests are carried out on anything other than a representative complete Engine, the test results may depend on the validity of the assumed electrical bonding between those elements of the Engine that are tested and the main Engine earth. In such cases, the applicant should demonstrate that these electrical bonding assumptions are valid. This may be accomplished by examination of the type design drawings, electrical continuity checks, or actual inspection of a representative Engine.

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 E 80 or in AMC 20-1 and AMC 20-3 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 E 80 for additional specific means.

[Amdt No: E/1]

CS-E 180 Propeller Functioning Tests

(See AMC E 180)

(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-E 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(f)(3)(i)) 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.

[Amdt No: E/1]

AMC 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).

[Amdt No: E/1]

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

(See AMC E 210)

(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.

[Amdt No: E/1]

AMC 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.

[Amd. No: E/1]

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

(a) All spark-ignition Engines shall comply with the following:

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

(i) a dual ignition system that has entirely independent magnetic and electrical circuits, including spark plugs; or

(ii) an ignition system which will function with at least the equivalent reliability.

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

(i) the maximum power reduction resulting from a loss of redundancy shall be declared in the appropriate manual(s);

ii) 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).

(b) All self-ignition Piston Engines shall comply with the following:

(1) The Engine design and operating procedure must provide a continued ignition capability under the intended operating conditions established in compliance with CS-E 40(d). This must be substantiated, considering the fuel with the limiting ignition delay time or cetane number, by conducting appropriate tests or by providing other evidence. The ignition delay time or the cetane number of the fuel considered for the demonstration will be recorded in the Engine type certificate data sheet.

(2) The Engine constructor must recommend an envelope of conditions for relighting in flight, and must substantiate it by conducting appropriate tests or by providing other evidence. The recommendation must state all of the conditions that are applicable, e.g. the altitude, airspeed, windmilling rotational speed, whether starter assistance is required, and the recommended drill. The possible effects of a low ambient temperature on the relight capability must be included in the development of the recommendation.

[Amdt No: E/5]

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.

(b) 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	± 3
Coolant outlet	Liquid-cooled Engines ± 3	± 3
Cylinder	Air-cooled Engines ± 5	± 5
Charge Cooler (when fitted)	All Engines ± 3	± 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. (See AMC E 300(f))

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

CS-E 320 Performance Correction

(See AMC E 320)

(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.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

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

(See AMC E 340)

(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.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

CS-E 350 Calibration Tests

(See AMC E 350)

(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

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

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 pressure and air temperature, most likely to cause detonation. An agreed method shall be used to determine the degree of detonation.

[Amdt No: E/1]

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

(see AMC E 380)

(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.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

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 Takeoff 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*. (See AMC E 440(b)(3)). 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.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

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

(See AMC E 470)

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.

[Amdt No: E/1]

AMC E 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.

[Amdt No: E/1]

SUBPART D – TURBINE ENGINES: DESIGN AND CONSTRUCTION

CS-E 500 Functioning

(See AMC E 500)

(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.

[Amdt No: E/1]

AMC 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 E 700 paragraph 3).

[Amdt No: E/1]

CS-E 510 Safety Analysis

(See AMC E 510)

(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-E 510(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.

[Amdt No: E/1]

AMC 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(a)(1)(i) requires the applicant to take account of aircraft-level devices in the Engine safety analysis. For example, the effects on the Engine failure of aircraft air ducts might be considered.

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 onboard 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)/EUROCAE, Document No. ARP4754A/EUROCAE ED-79A, Guidelines for Development of Civil Aircraft and 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.

[Amdt No: E/1]
[Amdt No: E/4]

CS-E 515 Engine Critical Parts

(See AMC E 515)

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.

[Amdt No: E/1]

AMC 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, and also 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.

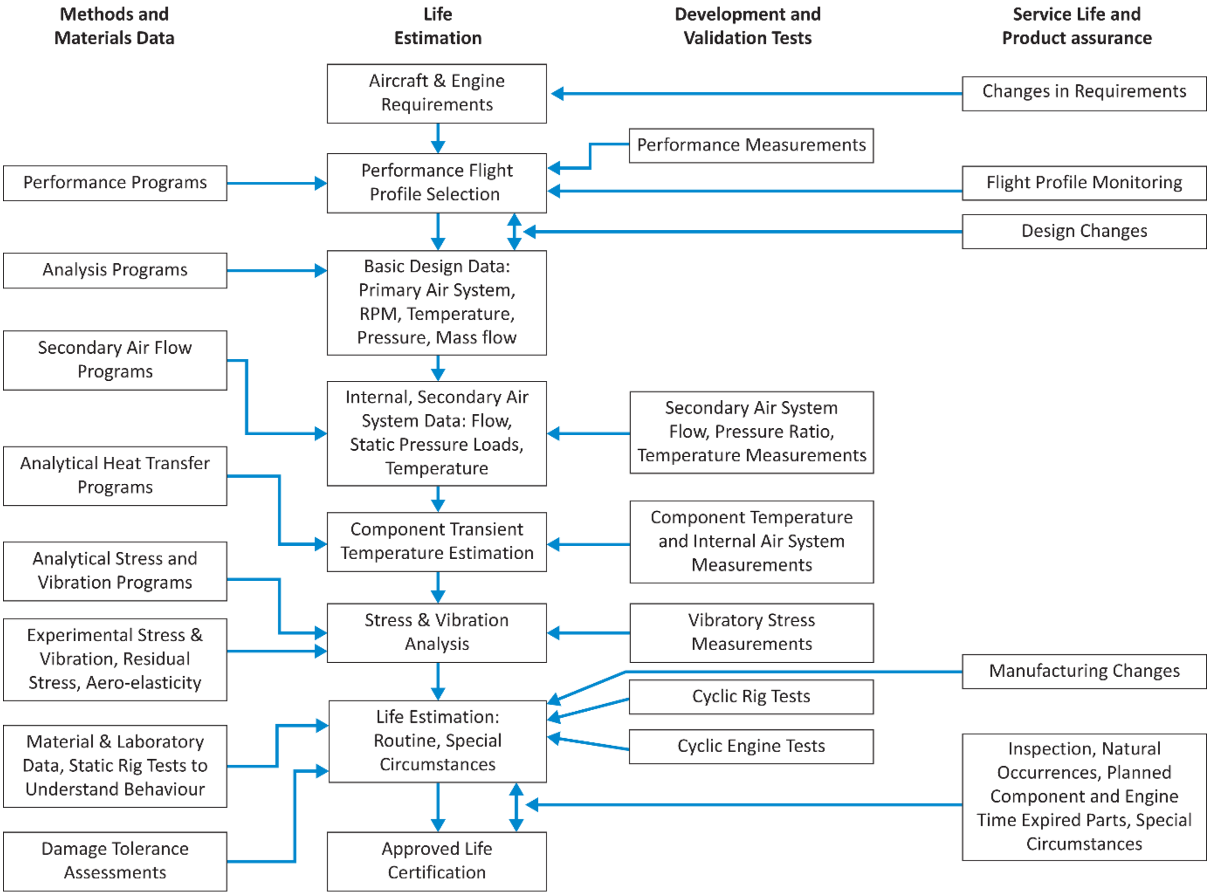
(c) *Establishment of the Approved Life – General*

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 to be 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 for the usage of the part to 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.). For Rotorcraft turbine Engines, the representative usage of the 30-minute Power rating should be considered in the Engine Flight Cycle when establishing the Approved Life of each Engine critical part. 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 take-off 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 dependent 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 is 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, subcomponent, 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 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 a number of anomalies 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 the 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 this data should be based upon the similarity of parameters such as:

— the size, shape, orientation, location, and chemical or metallurgical character of the anomaly;

— the condition of the surface condition and cleanliness of the parts;

— the material being inspected (such as its composition, grain size, conductivity, surface texture, etc.);

— variations in the inspection materials or equipment (such as the specific penetrant fluid and developer, equipment capability or condition, etc.);

— specific inspection process parameters such as the scan index;

— the inspector (such as their 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 the 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 the 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 the residual life used should consider the 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. If, as part of the Engineering Plan any dependence is placed upon crack detection to support the Approved Life, this 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 the 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 the 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 feedback 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 in-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 on 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 of a material that has 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 crossfunctional 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 crossfunctional 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.

[Amdt No: E/1]
[Amdt No: E/5]

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. (See AMC E 520(a))

(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. (See AMC E 520(c)(1))

(2) Validated data (from analysis or test or both) 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. If the Failure of a shaft, bearing or bearing support or bird strike event, as required under CS-E 800, result in higher forces being developed, such Failures must also be considered, except for bird strike in relation to continued out-of-balance running. (See AMC E 520 (c)(2))

(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.

[Amdt No: E/1]
[Amdt No: E/2]

AMC 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.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

AMC E 520(c)(2) Engine Model Validation

(1) Validated data specifically for blade loss analysis typically include:

- Finite element model
- Out-of-balance,
- component failure,
- rubs (blade-to-casing, and intershaft),
- resulting stiffness changes,
- aerodynamic effects, such as thrust loss and engine surge, and
- variations with time of the rotational speed(s) of the Engine's main rotating system(s) after failure.

(2) Manufacturers whose engines fail the rotor support structure by design during the blade loss event should also evaluate the effect of the loss of support on engine structural response.

(3) The model should be validated based on vibration tests and results of the blade loss test required for compliance with CS-E 810, giving due allowance for the effects of the test mount structure. The model should be capable of accurately predicting the transient loads from blade

release through run-down to steady state. In cases where compliance with CS-E 810 is granted by similarity instead of test, the model should be correlated to prior experience.

(4) Validation of the engine model static structure is achieved by a combination of engine and component tests, which include structural tests on major load path components, or by analysis, or both. The adequacy of the engine model to predict rotor critical speeds and forced response behaviour is verified by measuring engine vibratory response when imbalances are added to the fan and other rotors (See CS-E 650). Vibration data is routinely monitored on a number of engines during the engine development cycle, thereby providing a solid basis for model correlation.

(5) Correlation of the model against the CS-E 810 blade loss engine test is a demonstration that the model accurately represents:

— initial blade release event loads,

— any rundown resonant response behaviour,

— frequencies,

— failure sequences, and

— general engine movements and displacements.

(6) To enable this correlation to be performed, instrumentation of the blade loss engine test should be used (e.g., use of high-speed cinema and video cameras, accelerometers, strain gauges, continuity wires, and shaft speed tachometers). This instrumentation should be capable of measuring loads on the engine attachment structure.

(7) The airframe and engine manufacturers should mutually agree upon the definition of the model, based on test and experience.

[Amdt No: E/2]

AMC E 520(d) Strength – Local Failures

Local Failures of the Engine casing may include localised cracking. For any casing design that allows for residual crack growth:

(a) it should be demonstrated that the condition of the casing, including the maximum predicted crack size, will not lead to a Hazardous Engine Effect;

(b) if the Failure of the casing, for instance as the result of ultimate crack growth, could result in a Hazardous Engine Effect, then the part should be classified as a Critical Part in accordance with CS-E 510(a)(2) and be in compliance with the Integrity Specifications of CS-E 515.

[Amdt No: E/5]

CS-E 525 Continued Rotation

(see AMC E 525)

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.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

CS-E 540 Strike and Ingestion of Foreign Matter

(See AMC E 540)

(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.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

CS-E 560 Fuel System

(See AMC E 560)

(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.

[Amdt No: E/1]

AMC 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 compliance with CS-E 560(d) and (e), the applicant should consider the effect on Engine operability of the transient fuel icing conditions likely to be encountered in service. In the absence of a completed threat assessment by the aircraft manufacturer, the applicant should make an assessment of the potential threat, or declare that no capability has been demonstrated. The limitations on the demonstrated capability, any related assumptions, and potential effects on operability should be documented in the Engine installation manual, as required under CS-E 30(a) and CS-E 20(d). This should include but should not be limited to the quantity of ice, and the fuel temperature at the critical conditions for transient fuel icing. The compliance evidence should address the possibility of a blockage of Engine fuel system components, and the consequences of the resultant activation of any bypass features, under the minimum fuel heating conditions and with the worst-case Engine-to-Engine variability.

Note: A transient fuel icing condition is considered to be a short-duration exposure to high concentrations of (water) ice in the fuel delivered to the Engine that is caused by the accumulation and subsequent shedding of ice within the aircraft fuel system.

(5) 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 the 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.

(6) 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.

(7) 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.

(8) Any restriction in bypass operation condition should be specified in the appropriate manuals.

(9) CS-E 560(g) is intended to cover any likely changes in settings caused by vibrations, incorrect maintenance, mechanical interference when installed or during handling, etc. Examples of design precautions are: locking devices, sealing, inaccessible installation.

[Amdt No: E/1]
[Amdt No: E/5]

CS-E 570 Oil System

(See AMC E 570)

(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.

[Amdt No: E/1]

AMC 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 E 130.

[Amdt No. E/1]

CS-E 580 Air Systems

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.

[Amdt No: E/1]
[Amdt No: E/4]

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. (See AMC E 600(e)).

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

CS-E 620 Performance Correction

(See AMC E 620)

(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.

[Amdt No: E/1]

AMC 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

$$\mathrm{Pc} = \mathrm{Po} \times \frac{1013 \cdot 25}{\mathrm{B}}$$

Gas Temperatures

$$\mathrm{Tc} = \mathrm{To} \times \frac{288}{\theta}$$

Rotational Speed

$$\mathrm{Nc} = \mathrm{No} \times \sqrt{\frac{288}{\theta}}$$

Thrust

S.I. Units

$$\mathrm{Fc} = \mathrm{Fo} \times \frac{1013 \cdot 25}{\mathrm{B}}$$

Mass Air Flow

S.I. Units

$$\mathrm{Wc} = \mathrm{Wo} \times \frac{1013 \cdot 25}{\mathrm{B}} \times \sqrt{\frac{\theta}{288}}$$

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

$$\mathrm{Wc} = \mathrm{Wo} \times \frac{1013 \cdot 25}{\mathrm{B}} \times \sqrt{\frac{288}{\theta}}$$

Power

S.I. Units

$$\mathrm{Pc} = \mathrm{Po} \times \frac{1013 \cdot 25}{\mathrm{B}} \times \sqrt{\frac{288}{\theta}}$$

(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.

[Amdt No: E/1]

CS-E 640 Pressure Loads

(See AMC E 640)

(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.

[Amdt No: E/1]

AMC E 640 Pressure Loads

(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.

[Amdt No: E/1]

CS-E 650 Vibration Surveys

(See AMC E 650)

(a) It must be established by test or a combination of test and validated analysis that the vibration characteristics of all components that may be subject to mechanically or aerodynamically induced vibratory responses are acceptable throughout the declared flight envelope.

(b) The vibration surveys must cover the ranges of power or thrust and rotational speed for each rotor module, corresponding to operations throughout the range of ambient conditions in the declared flight envelope, from the minimum rotational speed up to at least the maximum of:

(1) 103 % of the maximum rotational speed permitted for rating periods of two minutes or longer;

(2) 100 % of the maximum rotational speed permitted for rating periods of less than two minutes;

(3) 100 % of any Maximum Engine Over-speeds declared under CS E 830.

(c) If there is any indication that a rising response amplitude may lead to peak vibratory stresses occurring at a speed above the maximum rotational speed established under CS-E 650(b), the surveys must be extended sufficiently to reveal the maximum amplitude, except that the extension need not cover more than a further 2 percentage points increase beyond this speed.

(d) The surveys must also cover the aerodynamic and aeromechanical factors which might induce or influence flutter in those systems susceptible to that form of vibration.

(e) Evaluations must be made of the effects on vibration characteristics of operating with scheduled changes (including allowance for tolerances) to variable vane angles, compressor bleeds, accessory loading, the most adverse inlet airflow distortion pattern declared by the applicant and the most adverse conditions in the exhaust duct(s).

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

(g) The effects on vibration characteristics of excitation forces caused by Fault conditions must be evaluated and shown not to result in a Hazardous Engine Effect.

(h) 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).

[Amdt No: E/1]
[Amdt No: E/4]

AMC E 650 Vibration Surveys

(1) Definitions. The following are defined for the purpose of this AMC:

Vibration Survey:	A vibration survey is a test or series of tests which, either alone or in conjunction with validated analysis, establishes the vibratory characteristics of Engine components.
Baseline Test:	A baseline test is one which was performed for the purpose of establishing experimentally the dynamic characteristics of Engine components using hardware, and/or under conditions, different from those for which approval is currently sought, and is an essential requirement for a complementary validated analysis.
Validated Analysis:	A validated analysis is one with demonstrated predictive capability within a specified domain of applicability that encompasses one or more complementary baseline tests.
Module:	A module is either a compressor or a turbine which may be single or multi-stage, or a gear box. If multi-stage, the rotating elements are mechanically joined and rotate at the same speed. The gas path entry and exit points are clearly defined and are frequently nodal points in a performance model. Note: A single stage or subset of stages isolated from a multi-stage compressor or turbine does not constitute a module.
Physical Rotational Speed (Nr):	The physical rotational speed of the rotating elements of a module is the raw uncorrected rotational speed. It is rotational speed as normally understood. The descriptor ‘physical’ is added in order to differentiate it clearly from corrected speed.
Minimum Rotational Speed (Min Nr):	The minimum rotational speed of the rotating elements of a module is the lowest steady state rotational speed which can be obtained within the limits imposed by the Engine Control System under Fault free conditions throughout the declared flight envelope.
Corrected Speed (Nc):	The corrected speed of the rotating elements of a module is the rotational speed normalised to a standard inlet temperature of 15°C in accordance with the formula:

	$$Nc = Nr/(T\ inlet/288)^e$$ where T inlet is the module gas path inlet temperature in Kelvin and the exponent e is determined empirically but has a typical value of 0.5. Corrected speed is a parameter widely used in performance modelling.
Declared Flight Envelope:	The declared flight envelope is the set of all airborne and ground conditions of operation to be approved, including start-up, shutdown and windmilling rotation in flight.
Resonance:	Resonance is a condition that occurs when an oscillatory force applied to a component has a frequency that coincides with one of the component's natural frequencies, resulting in an elevated vibratory response. A unique vibratory mode exists for each natural frequency.
Flutter:	Flutter is a self-excited vibration of a component in a gas flow, caused by a continuous interaction between the gas flow and the structure, in which energy from the flow is diverted to the structure such that the vibratory response is sustained or increased. In turbomachinery, it usually occurs at a natural frequency of the structure and in the associated mode shape.
Significant Response:	A significant response is one in which a vibratory stress exceeds the level that has been previously agreed by the Agency as providing acceptable margin under CS-E 70 and CS-E 100 for the type of feature concerned.
Endurance Limit:	The endurance limit of a component is the maximum value of alternating stress that, when repeated for an essentially infinite number of cycles, will not result in high cycle fatigue failure of the component. 10^7 cycles have generally been accepted as 'essentially infinite'. The endurance limit is a function of steady-state stress, temperature, geometry and material properties.

(2) Introduction

The intent of the rule is to ensure the acceptable dynamic behaviour of all components and assemblies in a gas turbine Engine. More specifically, the rule is aimed at the avoidance of damaging high cycle fatigue failures.

(3) Selection of Components

CS-E 650(a) requires that the survey covers all components that may be subject to mechanically or aerodynamically induced vibrations. Component selection for the survey should be based on an appropriate combination of experience, analysis, and component test. 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 module;

— all blade rows adjacent to variable incidence vanes;

— all fan, compressor and turbine discs and spacers;

— 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.

(4) Test Conditions

A test or series of tests is an essential element of the survey. Whether the tests are new or baseline, the following conditions apply:

(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 capable of being fitted or the range of inlet conditions that can be tested. Rig tests generally consist of testing full or part of Engine modules. If rig tests are employed, the applicant should demonstrate that all pertinent interface conditions and physical hardware closely replicate actual Engine conditions.

(b) Speed requirements

It should be the goal of the test programme to cover at least the ranges of conditions required under CS-E 650(b) and (c).

CS-E 650(b)(1) requires consideration of 103 % of the maximum rotational speed permitted for rating periods of two minutes or longer, but where it proves physically impracticable to achieve the appropriate extended test conditions, the Agency may accept an alternative that complies with the intent of the requirement. Historically, the 3 % margin has been imposed to account for transient overshoot. If it can be demonstrated that the characteristics of the Engine Control System are such that the maximum rated speed cannot be exceeded in fault-free operation, the required maximum tested speed may, with the agreement of the Agency, be adjusted downward, but may not be less than 100 %.

Where an extension to the range required by CS-E 650(b) is considered necessary for the identification of the effects of a rising vibratory stress peak, as required under CS-E 650(c), but it proves physically impracticable to achieve the appropriate extended test conditions, the Agency may accept an alternative that complies with the intent of the requirement. Historically, the requirement has been imposed to account for Engine-to-Engine variability. The Engine manufacturing and build tolerances can result in peak vibratory stresses occurring at slightly different rotor speeds for Engines and Engine parts (for example blades) of the same type design. If tested components are deliberately selected to cover an adverse range of manufacturing variability or any other effect normally captured by increasing the test maximum speed by a further 2 %, the required maximum tested speed may, with the agreement of the Agency, be adjusted downward, but may not be less than the maximum speed established for compliance with CS-E 650(b).

Any reduction in the speed range requirements of CS-E 650(b) and (c) proposed for the test programme should be justified by the applicant and agreed by the Agency. Normally, it would be expected that any test shortfall is covered by validated analysis.

Refer also to paragraph (5) 'Altitude and Temperature Effects' and (8) 'Flutter' for complementary guidance on affecting speeds.

(c) Instrumentation

To acquire the data required under CS-E 650 when conducting vibration surveys, the applicant should use suitable instrumentation, data acquisition, and analyser systems. Vibration-specific instrumentation may include dynamic strain gauges, accelerometers, dynamic pressure gauges and time-of-arrival sensors.

Vibratory stresses are most commonly calculated using dynamic strain gauges placed at predetermined locations and oriented to measure specific directional strains. These strain gauges should maintain their accuracy throughout the test conditions, particularly when repeatedly exposed to high temperatures for extended periods. The applicant should aim to take measurements at locations which are sensitive to the peak responses of interest but are also tolerant of a degree of mislocation/alignment variability. When these locations are not suitable or accessible for that purpose, stresses may be measured nearby provided that the relationships between the stresses at these locations and those at critical locations are known and predictable. To identify the accessible locations that best represent the critical stresses, knowledge of each natural mode and associated stress distributions is required, which may be gained from a combination of experience, analyses, or testing. This investigation is usually conducted before the certification test.

Time-of-arrival sensors, such as optical sensors or light probes, may prove convenient alternatives to strain gauges provided they are properly calibrated and their capabilities are clearly understood. The most common application for time-of-arrival sensors is to estimate blade tip displacements, which may then be converted to stresses at specific blade locations. Converting measured displacements or gauge strains to vibratory stresses requires a detailed knowledge of the blade normal mode frequencies, mode shapes, modal stress/strain distributions and associated tip displacements. This conversion should be shown to be sufficiently accurate or at least conservative. Time-of-arrival data for vibratory modes where measured displacements have low sensitivity in relation to stresses in critical areas should not be used in order to avoid excessive uncertainty in endurance limit calculations.

(d) 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, validated analysis would be expected to complete the substantiation. The loss of instrumentation should be minimal and the associated analysis should be primarily based on the surviving instrumentation data.

(e) Engine modifications

During testing, the Engine may be modified or adjusted in an effort to achieve the desired physical and corrected speeds, or any other test conditions. Any alterations made to the Engine for these purposes should be evaluated to show that their effects are not detrimental or do not compromise the intent of the test and the test results.

(5) Altitude and Temperature Effects

CS-E 650(a) requires that conditions throughout the declared flight envelope are evaluated when establishing that the dynamic behaviour of components and systems is acceptable.

Changes in operating conditions associated with ambient temperature and altitude variations affect Engine performance and airflow characteristics. This can have a significant effect on aerodynamic forcing and damping, which, in turn, affects the vibratory response and behaviour of certain components. Appropriate justification should be provided by the applicant that the worst operating conditions in the declared flight envelope have been fully explored.

Engine tests may be conducted by means of flight test or in altitude facilities or in other facilities such that the effects of altitude and temperature are properly represented and can be evaluated. Suitable test equipment and instrumentation should be used for each situation. The dependency of certain vibratory phenomena on temperature and altitude can be characterised as a dependency on corrected speed, which enables such phenomena to be investigated by means of sea-level testing, provided that the entire required corrected speed range can be achieved. In general, a high corrected speed implies that the airflow over the blading has a high

Mach number, which is associated with higher aerodynamic forcing and lower aerodynamic stability.

(6) Fault Conditions

A number of common Fault conditions can have the effect of introducing additional excitation sources or changes to those existing under Fault-free conditions. Any change in vibration response should be evaluated and shown not to result in a Hazardous Engine Effect.

CS-E 650(g) applies to those Fault conditions that would cause abnormal vibrations that are difficult to identify in a timely manner so that appropriate mitigating action can be taken. Notwithstanding the provisions of CS-E 60 and CS-E 510 with regard to instrumentation, certain low-level vibrations caused by Fault conditions may not be recognised as associated with an Engine Fault and may not prompt an immediate response. Subsequently, these Faults may escalate to Hazardous Engine Effects. For example, the loss of an airfoil tip would be likely to result in a change in vibration due to the increased out-of-balance. Even if indicated by the means required under CS-E 60 and CS-E 510, this vibration might not be immediately recognised as abnormal or may not prompt immediate action, and could cause further damage. Other Faults include incorrectly scheduled compressor variables, stator vanes blockages or enlargement, and blockages of fuel nozzles. These Faults could produce local airflow distortions and changes in the airflow or pressure distributions that in turn may affect component vibratory response and characteristics. To address these Fault conditions, the applicant may use prior experience with Faults that occurred on other similar Engines. Successful experience is such that, after exposure to a Fault condition, the Engine was able either to continue in safe operation or to be shut down without creating a Hazardous Engine Effect. Applicants may also use field experience or other means to show that certain Fault conditions are Extremely Remote because of specific Engine configurations, design features or operating conditions. The requirements of CS-E 650(g) apply to the same components that are considered under CS-E 650(a). When the effects of these Fault conditions extend to the rest of the Engine, they must be addressed under the requirements of CS-E 100 Strength and/or CS E 520 Strength (for example, the out-of-balance effects on the Engine structural components).

(7) Inlet Airflow Distortion

Fan and compressor vibration can be sensitive to inlet airflow distortion, and conditions consistent with the most adverse pattern declared by the applicant should be taken into account. Inlet airflow distortion may be associated with the air intake, crosswinds, or other operating and aircraft installation conditions. When an Engine test is performed, whether in a test cell or on a flight test bed, the inlet distortion may be achieved by various means, such as external crosswind devices, inlet distortion plates or suppression screens.

(8) Flutter

Testing required to demonstrate satisfactory vibratory clearance from flutter boundaries may be accomplished by rig and/or Engine sea-level or altitude test, subject to the following considerations:

(a) The presence of flutter may be acceptable in some circumstances, for example in a speed range encountered only briefly or infrequently, or where the flutter amplitude is limited to a safe level. However, the resulting vibration stresses must always satisfy the requirements of CS-E 650(f). A thorough investigation of the flutter response and its effects should be completed to show that the flutter does not result in a Hazardous Engine Effect. The investigation may include testing as required under paragraph (10) below for a significant response.

(b) In all 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.

(c) 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 also be given to possible variations between the nominal and extreme values of, for example, tip clearances, mechanical damping, operating lines and bleed flows. 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.

(d) If tests will be conducted at sea level only, the applicant should propose a procedure acceptable to the Agency to account for altitude effects. For certain Engine modules, especially fans and compressors, it is expected that this will be achieved by testing throughout the range of corrected speed that the module will encounter in service, in which case the requirements of CS-E 650(b) and (c) with regard to physical rotational speed should be considered to apply also to corrected speed. The provisions of paragraph (4)(b) of this AMC are also applicable.

(e) For some turbines, the propensity to flutter is not increased at maximum corrected speed, and other methods of demonstrating the absence of damaging flutter throughout the declared flight envelope may be more appropriate. It is important to ensure that the maximum stage inlet pressure at each physical speed is achieved, or compensation is provided. The strength of aerodynamic forcing on many turbine blades is predominantly driven by the total pressure levels, and the highest pressures are expected at the highest mechanical speed. Where turbines operate in aerodynamically choked conditions and the mass flow through the turbine is dictated by the fixed geometry of the blading, the corrected speed is essentially constant. Higher corrected speed (at an aerodynamic work level) will lower the blading Mach numbers (Mn) and, conversely, a lower corrected speed will increase blading Mn. This means that, in such cases, running up to 100 % of maximum mechanical speed will cover the worst case (highest forcing) condition.

(f) In general, 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 module;

(ii) the simultaneous occurrence of maximum fan or compressor inlet air total temperature and maximum corrected rotational speed (i.e. maximum reduced velocity);

(iii) the range of fan or compressor operating lines within the flight envelope;

(iv) the most adverse of other fan or compressor inlet air conditions encountered within the flight envelope (e.g. applicable combinations of total air pressure, density, temperature, and inlet distortion); and

(v) the hardware standard, the intake conditions and margins to account for Engine deterioration.

(9) Variations in Material Properties and Natural Frequencies

Allowance should be made as follows for the permitted variations in material properties, critical dimensions and resulting natural frequencies of production components when interpreting test results or making analytical predictions:

(a) Material allowable stresses

The material property that is important in relation to the requirements of CS-E 650(f) is the endurance limit associated with specific combinations of mean stress and alternating stress, usually represented on a Goodman diagram. The influence on the endurance limit of manufacturing processes, the local geometrical features, and temperatures should also be taken into account.

(b) Stress margins

Section CS-E 650(f) requires suitable stress margins for each part evaluated, usually represented by the stress margins at the critical or limiting locations. The stress margin is the difference between the material allowable at a particular location and the measured vibratory stress at that location. The criteria for stress margin suitability should account for the variability in design, operation and other mitigating factors identified during the certification test.

(c) Modal response

The total vibratory stress at any given location is the sum of the resonant stresses associated with all active and concurrent normal modes, plus any other vibratory stresses that occur at that particular rotational speed. Due to variability in properties (material and geometry) the frequencies and separation of the modes may be different from blade to blade (or other component). The applicant should consider the stress amplitudes that occur within permitted blade-to-blade variations of natural frequency. For example, if for a particular blade design the natural frequency (fn) range is fn ± 2.5 %, then the combined amplitudes within this range should be considered.

Where there is potential for more than one mode to be excited at the same time/speed, the overall amplitude will be a combination of contributions from each individual response. The combined stress is typically calculated by breaking down the vibratory stress of each mode into its stress components and then combining the modal contributions in proportion to the individual measured responses to obtain the overall principal or equivalent vibratory stresses.

(10) Dwell Testing

The applicant should determine all significant responses within the operating conditions prescribed in CS-E 650 and allow sufficient time for any associated resonant modes to respond. This is usually accomplished during slow acceleration and deceleration speed sweeps covering the range of required speeds.

If any significant response is found, then the relevant components should be subjected to sufficient cycles of vibration close to, and/or on, the response peak to demonstrate compliance with CS-E 650(f). This 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 dwell testing should subsequently also meet the strip inspection requirements of CS-E 740(h).

(11) Transient Response

Consideration should also be given to the speed range from zero to minimum rotational speed, especially in the case of supercritical shafts. Some predicted potentially damaging transient responses may require an aggressive control input to provoke a representative response.

(12) Instrumentation Incompatibility

If the dimensions of the components to be tested are incompatible with the necessary instrumentation, instrumented Engine tests to substantiate the vibration characteristics of these components 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 are sufficient to demonstrate that the vibration stress levels are acceptable.

(13) Installation Compatibility

The intent of CS-E 650(h) 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.

(14) Modelling and Analysis

Acceptable analytical methods are based on the complementary concepts of a baseline test and validated analysis. The general principle is that a baseline test in conjunction with validated analysis is equivalent to a new test.

(a) Baseline test

A baseline test is usually one of the following:

(i) An Engine or rig test run on the first model of an Engine type during the type certification programme. The validated analysis developed on the basis of this test may then be used for derivative models that are added to the same type certificate.

(ii) An Engine or rig test run on a previously certified Engine type. The validated analysis developed on the basis of this test may then be used for Engines whose design characteristics and operating conditions are shown to be sufficiently similar to those of the Engine in the baseline test.

(iii) An Engine or rig test specifically run to support the creation of the validated analysis.

The design characteristics and operating conditions run in the baseline test(s) should be shown to be sufficiently similar and inclusive of the domain of applicability for the Engine being certified, as defined in this AMC, paragraph (14)(b)(i), (ii) and (iii).

A test from which the results are used to calibrate an analysis is not in general eligible to be considered a baseline test in relation to the validation of that analysis. The same test results cannot be used both to calibrate and validate an analysis.

(b) Validated Analysis

(i) Development of the Validated Analysis.

The analytical model should be validated against one or more baseline tests.

For each baseline test on which the validation is based, it should be shown that the analysis consistently predicts the observed behaviour and vibratory responses of the components investigated to an acceptable precision and accuracy. Alternatively, it could be shown that predictions reliably overpredict the vibratory response.

The applicant should clearly define the domain of applicability of the analysis, comprising the ranges of design characteristics and operating conditions for which the analysis will be deemed to be validated. Typical design characteristics and operating conditions which may constitute a definition of the domain of applicability are as follows:

— Engine architecture:

  — general configuration, for example 2- or 3-shaft design, turboshaft, turbofan, open rotor, geared fan;

  — secondary air system;

  — number, location and type of bearings, including installation (inner/outer race grounded, inter-shaft, damped, etc.), and associated support structures.

— Module type, for example high or low pressure turbine, axial or radial compressor.

— Component geometry, for example shrouded or unshrouded blades, aerofoil aerodynamic shapes (‘2D’ or ‘3D’).

— Structural dynamic characteristics:

  — natural frequencies, which will influence the resonance speeds and aerodynamic stability (flutter);

  — mode shape similarity, for example a measure of accuracy that is often employed is the Modal Assurance Criterion (MAC). Typically, a MAC value greater than 0.9 indicates there is close agreement between measured and calculated mode shapes. Close matching of mode shapes implies that response to the same forcing will be similar;

  — mechanical damping levels; any difference will be directly reflected in the resonant response level or flutter suppression;

  — mistuning levels; the degree of scatter in frequency between blades will strongly influence the vibration amplitudes variability in a bladed disc and will have a stabilising influence on flutter.

— All structural dynamic characteristics affected by:

  — materials and construction technique, for example composites, anisotropic metals, joining methods

  — restraints, for example blade or vane attachment design, snubbers or dampers, flanges.

Similarity of the structural dynamic characteristics is frequently demonstrated by a combination of comparative analysis and modal testing in a laboratory.

— Aeroelastic characteristics:

  — The Strouhal number (k) or reduced frequency which characterises the variation of flow with time, where k = ω.c/U, ω = frequency, c = component length in flow direction and U = flow velocity, is relevant for flutter.

— Sources of vibratory excitations and forcing strength:

  — upstream or downstream rotors, stators or struts, for example numbers off, aerodynamic style, axial gapping;

  — gas stream characteristics, inlet or flow path asymmetry, main gas path and secondary flows;

  — power or thrust levels, air density, Mach number and Reynolds number that can affect both flutter and forced response amplitudes,

  — combustion system

  — mechanical sources, for example gearbox and rotor out-of-balance.

— Operating conditions:

  — rotational speeds, temperatures and gas pressures experienced by the subject components throughout the declared flight envelope.

The validated analysis and its domain of applicability should be acceptable to the Agency.

(ii) Use of the Validated Analysis

Similarity of the Engine, module or component(s) to be certified with previously tested and certified designs should be justified. For each new Engine certification programme, for which the use of validated analysis is proposed, the applicant should show that the design characteristics and operating conditions of the Engine fall within the domain of applicability of the analysis previously established and accepted by the Agency.

The demonstration of compliance will be considered to be the combination of the baseline test(s) used to create the validated analysis, and the analysis performed on the Engine for which approval is currently sought.

Examples where validated analysis may be used include but are not limited to the following:

— Where test speeds required by CS-E 650(b) and (c) are not achieved, by agreement with the Agency as described in paragraph (4)(b) of this AMC. The validated analysis would be expected to cover the speed range(s) or operating conditions not achieved during testing.

— Where instrumentation has been lost, for example due to the extreme test conditions. The validated analysis would be expected to cover the speed range(s) or operating conditions for which instrumentation was lost.

— Where stresses are not measured directly at critical locations. In that case, the peak stresses may be derived based on measurements taken at reference locations. This requires a detailed understanding of the modal composition of the response and the associated mode shapes to derive the relationship between each location.

— Where it proves necessary to justify the acceptability of any significant responses whether observed or predicted.

(iii) Update of the Validated Analysis

It is expected that the applicant may regularly update the validated analysis, for instance following new testing performed or service experience. The updated validated analysis and/or its domain of applicability should be reviewed and accepted by the Agency.

(15) 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 21.A.33 of Part-21 should be limited to only those pertinent Engine components and associated instrumentation that constitute the certification Engine test or the baseline tests supporting the validated analysis.

[Amdt No: E/1]
[Amdt No: E/4]

CS-E 660 Fuel Pressure and Temperature

(See AMC E 660)

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.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

CS-E 670 Contaminated Fuel

(See AMC E 670)

(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.

[Amdt No: E/1]

AMC 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 impending filter 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.

(3) Transient Fuel Icing Conditions

In compliance with CS-E 670(a), the applicant should consider the effect on Engine operability of the transient fuel icing conditions likely to be encountered in service in accordance with AMC E 560(4).

[Amdt No: E/1]
[Amdt No: E/5]

CS-E 680 Inclination and Gyroscopic Load Effects

(See AMC E 680)

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.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

CS-E 690 Engine Bleed

(See AMC E 690)

(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 maximu m 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.

[Amdt No: E/1]

AMC 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 strip examination specifications of CS-E 740(h)(2) is not enhanced. The analysis should include

1. The effect of the bleed air extraction to the Engine secondary air system which provides cooling air to various Engine components,
2. The thermodynamic cycle effects of bleed (e.g., gas generator speed to output shaft speed changes).

[Amdt No: E/1]

CS-E 700 Excess Operating Conditions

(See AMC E 700)

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.

[Amdt No: E/1]

AMC 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 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.

[Amdt No: E/1]

CS-E 710 Rotor Locking Tests

(See AMC E 710)

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.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

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. (See AMC E 720(a))

(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.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

CS-E 730 Engine Calibration Test

(See AMC E 730)

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.

[Amdt No.: E/1]

AMC 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-E 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.

[Amdt No: E/1]

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 690(a), CS-E 750 and 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 to 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 that are 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 6-hour stages, each stage comprising:

Part 1 1 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 or Thrust.

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

Part 3 1 hour and 30 minutes at Maximum Continuous Power or 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 or Thrust.

Part 5 30 minutes of accelerations and decelerations consisting of 6 cycles from Ground Idling to Take-off Power or Thrust, maintaining Take-off Power or 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 and/or 30-Minute Power (when appropriate).

25 6-hour stages, each stage comprising:

Part 1 1 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 or Thrust, run 2½ minutes at Take-off Power or Thrust followed by 2½ minutes at 2½-Minute OEI Power or Thrust.

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

Part 2

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

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

(D) Stages 16 to 20, each of 30 minutes duration at Take-off Power or 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 or Thrust.

Part 3

(A) For Engines for Aeroplanes:

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

(B) For Engines for Rotorcraft –

Either (for Engines to be approved with a Continuous OEI rating) 30 minutes at Maximum Continuous Power followed by 1 hour at Continuous OEI Power or (for Engines to be approved with a 30-Minute OEI Rating) 1 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.

For an Engine to be approved with the 30-Minute Power rating, the Engine must be run for continuous periods of 30 minutes at the power level and associated operating limitations of the 30-Minute Power rating. These periods must be alternated with periods at Maximum Continuous Power, or less. The accumulated total additional running time shall be 25 hours at the 30-Minute Power rating, and the time spent at 'standard' Take-off Power shall not be counted towards this total.

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 or Thrust, maintaining Take-off Power or 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 that is not required must be run at the power or thrust level appropriate to the next rating down the scale.

(iii) If 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. If 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 (See AMC E 740(c)(3)),

(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. (See AMC E 740(f)(1))

(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 30minute 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 vibration response is found to exist on relevant components in the course of establishing compliance with CS-E 650 at any condition within the operating range of the Engine (not prohibited under CS-E 650(f)), 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. (See AMC E 740(g)(1))

(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) *Inspection Checks*

(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). (See AMC E 740(h)(2))

(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.

[Amdt No: E/1]
[Amdt No: E/4]
[Amdt No: E/5]

AMC E 740(c)(2)(i) Endurance Tests – 30-Minute Power Rating

For Rotorcraft turbine Engines to be approved with a 30-Minute Power rating:

(a) An applicant may propose either to include the required additional 25 hours within the overall test normally required by CS-E 740, or to perform a complementary test on the same test article used for the test required by CS-E 740, or a combination of these methods. If the additional 25 hours are included within the overall test normally required by CS-E 740, the modified test periods should be uniformly distributed throughout the endurance testing.

(b) Credit may be sought for time accrued during testing at the 30-Minute OEI rating required by CS-E 740. This allowance excludes the time spent at 'standard' Take-off Power. It should then be shown that these sequences were run with operating limitations that are equal to or more stringent than the 30-Minute Power rating operating limitations.

(c) It is possible that the intended usage and performance characteristics of the Engine may be such that its power will be subject to mechanical limitations for a certain portion of its missions. In that case, it may be acceptable to run the Engine for a representative percentage of the time that is required at the 30-Minute Power rating at these mechanical limitations, but not to exceed 50 % of the required additional 25 hours (i.e. 12.5 hours). For the remaining percentage of the time, the Engine should be run at the higher thermal limits. The proposal must be substantiated and proposed to the Agency for acceptance. These assumptions will be recorded in the instructions for installing and operating the Engine, in accordance with CS-E 30(a).

(d) No specific maintenance action is normally expected following the use of the 30-minute Power rating. This will be justified by compliance with CS-E 740(h)(1).

[Amdt No: E/5]

AMC 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 740(h)(1).

The Engine is then reassembled using the same parts used for the 150-hour endurance test except as otherwise allowed by CS-E 740(h)(2)(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 740(h)(2)(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 740(h)(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)).

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

AMC 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 E 650 paragraph 10).

[Amdt No: E/1]
[Amdt No: E/4]

AMC E 740(h)(2) Endurance tests - Inspection checks

(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(b)). 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 740(h)(2)(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 strip examination. 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.

[Amdt No: E/1]

CS-E 745 Engine Acceleration

(See AMC E 745)

(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.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

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. (See AMC E 750(b))

(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.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

CS-E 770 Low Temperature Starting Tests

(See AMC E 770)

(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 takeoff in a time not greater than one second.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

CS-E 780 Icing Conditions

(See AMC E 780)

(a) It must be established by tests, unless alternative appropriate evidence is available, that the Engine will function satisfactorily when operated throughout the conditions of atmospheric icing (including freezing fog on ground) and falling and blowing snow defined in the turbine Engines air intake system ice protection specifications (CS-23.1093(b), CS-25.1093(b), CS-27.1093(b) or CS-29.1093(b)) of the Certification Specifications applicable to the aircraft on which the Engine is to be installed, as specified in CS-E 20(b), 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) In showing compliance with the specifications of CS-E 780(a), all Engine bleeds and mechanical power offtakes permitted during icing conditions must be set at the level assumed to be the most critical, or their effect must be simulated by other acceptable means. It must be established, however, that other likely use of bleed or mechanical power offtake will not lead to Engine malfunctioning.

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

(d) 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.

(e) Where an air 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.

(f) Ice ingestion

(1) Objective. To demonstrate that the Engine will function satisfactorily following the ingestion of defined quantities of ice, as part of compliance with CS-E 540. Ingestion of ice may result from ice released by the Engine air intake (including after delayed selection of the ice protection system) or from other aircraft surfaces. Compliance with the requirements of this sub-paragraph shall be demonstrated by an Engine ice slab ingestion test or by validated analysis showing equivalence to other means for demonstrating soft body damage tolerance.

(2) Following the ingestion of ice under the conditions of this paragraph, the Engine shall comply with CS-E 780(a).

(3) For an Engine that incorporates or requires the use of a protection device, compliance with this paragraph need not be demonstrated with respect to ice formed forward of the protection device if it is shown that:

(i) such ice is of a size that will not pass through the protection device;

(ii) the protection device will withstand the impact of the ice; and

(iii) the ice stopped by the protection device will not obstruct the flow of air into the Engine resulting in unacceptable effects under CS-E 780(a).

(4) In establishing the ice slab ingestion conditions, the assumed ice quantity and dimensions, the ingestion velocity and the Engine operating conditions must be determined. Those conditions shall be appropriate to the Engine installation on the aircraft. These assumptions must be included in the manuals containing instructions for installing and operating the Engine under CS-E 20(d).

[Amdt No: E/1]
[Amdt No: E/4]

AMC E 780 Icing Conditions

(1) Introduction

This AMC provides Guidance Material and Acceptable Means of Compliance for showing compliance with CS-E 780.

Test evidence is normally required for Supercooled Liquid Water (SLW) icing conditions. For other applicable icing conditions, compliance may be demonstrated by a combination of test, analysis and service experience.

(1.1) Definitions

Auto-Recovery Systems: Engine systems that ensure that Engines operate just before or immediately after an upset (that is, power loss or stall) without operator intervention. Auto-recovery systems include auto-relight systems, stall recovery systems, and other Engine systems intended to recover the operability of an Engine following a flameout, surge, stall, or a combination of these.

Freezing Fraction: The ratio of the mass of water that freezes at a point on a surface to the total mass of incoming water at that point.

Highlight Area: The area bounded by the leading edge of the nacelle inlet. This may be different for turboshaft installations where complex inlet schemes are utilised.

Ice Formations: Ice formations resulting from the impact of supercooled water droplets on propulsion system surfaces are classified as follows:

(a) Glaze Ice: This is a transparent or translucent ice formed by liquid water droplets that do not freeze immediately on impact and has horns. Droplets impacting the surface do not freeze immediately, but run back along the surface until freezing occurs. Glaze ice typically has a non-aerodynamic shape and is more susceptible to aerodynamic forces that result in shedding. Glaze ice typically has both a lower freezing fraction and lower adhesive properties than rime ice. Glaze ice is often a concern for static hardware while rime ice is often a concern for rotating hardware.

(b) Rime Ice: This is a milky and opaque ice formed by liquid cloud droplets that freeze immediately on impact. Rime ice typically forms in an aerodynamic shape, on both rotating and static Engine hardware. The freezing fraction is high for rime ice, typically approaching a value of 1.0. Rime ice typically has greater adhesion properties than glaze ice but often a lower density. Adhesion properties increase with lower temperature up to a test point where no additional adhesion is gained with additional lower temperature.

Ice Shed Cycle: The time period required to build up and then shed ice on a propulsion system surface for a given power and icing condition. A shed cycle can be identified visually (for example, with high-speed cameras), and with Engine instrumentation (such as vibration pickups, temperature probes, pressure probes, speed pickups, etc.). The ice shed cycle for rotating surfaces, such as fan blades, is strongly influenced by rotor speed and the adhesive strength of the ice to the surface. In general, ice adhesive strength increases as surface temperature decreases.

Icing Conditions: The presence of supercooled liquid water drops and temperature conducive to aircraft icing. These conditions are defined by the following parameters:

— Liquid Water Content (LWC): The total mass of water contained in liquid drops within a volume or mass unit of cloud or precipitation, usually given in units of grams of water per cubic meter or kilogram of dry air (g/m3, g/kg);

— Median Volumetric Diameter (MVD): The drop diameter which divides the total liquid water content present in the drop distribution in half, i.e., half the water volume will be in larger drops and half the volume in smaller drops. (Also sometimes called Median Volume Diameter). Note the MVD used in Appendices O and P to CS-25 is equivalent to the MED used in Appendix C to CS-25 and CS-29, CS-Definitions for an assumed Langmuir type droplet distribution);

— Mean Effective Diameter (MED): A term used with the rotating multicylinder method for measuring LWC in clouds. A droplet diameter which, when assigned to the midpoint of one of the Langmuir distributions, gives the best agreement between the computed and measured differential ice mass accumulations on a set of rotating multicylinders. The MED is approximately equal to the MVD;

— Total Air Temperature (TAT): The ambient air temperature plus the ram air temperature rise. For icing testing in test cells, the total Engine inlet temperature includes the static air temperature of the cloud from the applicable icing environment, plus the assumed flight airspeed; and

— Static Air Temperature (SAT): The local measured air temperature minus the air temperature rise from velocity effects.

Power/Thrust Loss Instabilities: Engine operating anomalies that cause Engine instabilities. These types of anomalies could include non-recoverable or repeating surge, stall, rollback, or flameout, which can result in Engine power or thrust cycling.

Scoop Factor (concentration factor): The ratio of nacelle inlet highlight area (AH) to the area of the captured air stream tube (AC) [scoop factor = AH/AC]. Scoop factor compares the liquid water available for ice formation in the Engine inlet to that available in the low-pressure compressor or Engine core, as a function of aircraft forward airspeed and Engine power condition. The scoop factor effect depends on the droplet diameter, the simulated airspeed and the Engine power level as well as the geometry and size of the Engine. This may be different for turboshaft installations where complex inlet schemes are utilised.

Sustained Power/Thrust Loss: This is a permanent loss in Engine power or thrust. Typically, sustained power loss is calculated at rated take-off power.

Water Impingement Rate: The rate of water collection on an Engine surface during a specific period of time. The units of the water impingement rate are g/m2/min.

Note: Additional definitions can be found in Reference 2. — SAE ARP 5624.

(1.2) References

1. Mixed-Phase Icing Condition: A review (DOT/FAA/AR-98/76), Dr. Riley, James T, Office of Aviation Research, Washington D.C. 20591, U.S. Department of Transportation, Federal Aviation Administration, December 1998.

2. SAE Aerospace Recommended Practice (ARP) 5624 — 'Aircraft Inflight Icing Terminology', issued on 3.3.2008, reaffirmed on 23.4.2013.

(1.3) Test Configuration — Engine

Because the Engine behaviour cannot easily be divorced from the effects of the Engine air intake and Propeller, where possible, it is recommended that the tests be conducted on an Engine complete with representative air intake, Propeller (or those parts of the Propeller which affect the Engine air intake), and Engine air data probes. Separate assessment and/or testing of the air intake, Propeller and air data probes are not excluded but in such circumstances, the details of the assumed Engine installation will be defined in the manuals containing instructions for installing and operating the Engine (under CS-E 20(d)). It would then finally be the responsibility of the aircraft manufacturer to show that the Engine tests would still be valid for the particular air intake and Propeller, taking into account:

— distortion of the airflow and partial blockage of the air intake as a result of, for example, incidence or ice formation on the air intake and Propeller;

— the shedding into the Engine of air intake and Propeller ice of a size greater than the Engine is able to ingest;

— the icing of any Engine sensing devices or other subsidiary air intakes or equipment contained within the Engine air intake; and

— the time required to bring the protective system into full operation.

Apart from tests carried out under paragraph (6) of this AMC, the icing tests should be carried out with all ice protection systems (IPS) operating. When dispatch is to be permitted with some ice protection systems inoperative, then the tests should address all configurations approved for aircraft dispatch.

CS-E 780(b) requires that Engine bleeds and mechanical power offtakes permitted during icing conditions be set at the level assumed to be the most critical, or their effect must be simulated by other acceptable means. If it is not possible to establish clearly which test configuration is most critical, the test should be repeated, if necessary, in order to ensure satisfactory operation in all permitted configurations.

(1.4) Test Configuration — Facility

The tests may be completed with adequately simulated icing conditions either in an altitude test facility capable of representing flight conditions, or in flight, or under non-altitude test conditions.

Where non-altitude testing is used to simulate altitude conditions, appropriate justification should be presented to demonstrate that the test conditions are not less severe for both ice accretion and shedding than the equivalent altitude test points. The effects of density, hardness, and adhesion strength of the ice as it sheds should be assessed to realistic flight conditions. For example, in realistic flight conditions, the ice shed cycle for rotating surfaces, such as fan blades, is strongly influenced by the rotor speed and the adhesive strength of the ice to the surface. The adhesive strength of ice generally increases with decreasing surface temperature. The ice thickness, ice properties and rotor speed at the time of the shed define the impact threat.

(1.5) Flight Testing

Flight testing is an acceptable method of demonstrating Engine operation in icing conditions. Under these conditions, two important flight testing considerations are the measurement of ambient meteorological data and the ability to correlate the measured Engine performance to the most critical icing point.

In practice, it may not be feasible to test the Engine in flight under natural icing conditions. However, testing in flight with simulated icing conditions could be possible and is not excluded. In this case, the applicant should define an acceptable means to establish and control the icing conditions.

(1.6) Applicable Icing Environments

The applicable icing environments are those applicable to the aircraft on which the Engine is to be installed, defined in CS 23.1093(b), CS 25.1093(b), CS 27.1093(b) and CS 29.1093(b), as appropriate. This includes atmospheric icing conditions (including freezing fog on ground) and falling and blowing snow conditions. Falling and blowing snow conditions are defined in AMC 25.1093(b).

The test altitude need not exceed any limitations proposed for aircraft approval, provided that a suitable altitude margin is demonstrated, and the altitude limitation is reflected in the manuals containing instructions for installing and operating the Engine.

(1.7) Compliance of Rotorcraft Engines with Icing Conditions

Specific provisions for rotorcraft Engines are currently not included in this AMC. Until guidance has been established, the necessary compliance method required for rotorcraft Engines should be agreed by the Agency.

(2) Supercooled Liquid Water (SLW) Icing Conditions

(2.1) Critical Points Analysis (CPA)

(a) General Principle

A Critical Points Analysis (CPA) is one analytical approach to determine suitable Engine test conditions in view of showing compliance of the Engine with Certification Specifications in Supercooled Liquid Water (SLW) icing conditions (including Supercooled Large Drops, if applicable).

Compliance evidence should include a description of the methodology and tools used as part of the CPA. The validation of tools should also be addressed.

Whilst the CPA is primarily intended to identify whether test points should be added to those defined in paragraph (2.2), the principles outlined below may also be used for justifying the testing necessary for approval of ground operation in SLW icing conditions.

Where a CPA test point is in a similar condition to a Table 1 test point, the more severe of the two should be demonstrated.

The applicant should consider pertinent service experience as well as the anticipated use of the aircraft when selecting critical icing test points.

Compliance with the requirements of CS-E 780 includes identifying, through analysis, the critical operating test points for icing within the declared operating envelope of the Engine. The CPA should relate icing conditions to the aircraft speed range and Engine powers/thrusts as defined by the applicant. It should also include prolonged flight operation in icing conditions (for example, in-flight hold pattern), or a repetition of icing encounters. These combined elements within the CPA should identify the most critical operational icing conditions:

(i) Applicants should ensure that their analysis is supported by test data. It should also include environmental and Engine operational effects on accumulation, accretion locations, and the most critical Engine operating conditions for ice shed and ingestion. The CPA may also be supplemented with development test data (for example wet and dry testing with thermocouple components).

(ii) The CPA should include ice accretion calculations that account for freezing fraction and aerodynamic effects of the ice as it moves into the air inlet. For example, water ingestion into fan module and core inlets, water impingement rates for critical surfaces, forward aircraft airspeed effects, Engine configuration effects such as inter-compressor bleed, and altitude effects such as by-pass ratio effects. The CPA should also include an energy balance of critical Engine surfaces (for example, latent heat and heat of fusion effects, metal-to-ice heat transfer effects, and ice-insulating effects).

(iii) For anti-iced parts, the CPA should identify a critical test point determined from energy balance calculations of required heat loads encompassing the range of possible combinations of icing conditions and Engine power/thrust. The effects of non-aerodynamic ice formations and their shedding as well as runback ice shedding should be assessed.

(iv) As part of the analysis, the CPA should also contain an assessment of the assumptions and any limitations of the models used as well as their validation.

(b) Elements of the CPA

The CPA should address, at a minimum, the following icing issues:

(i) Ice Shed Damage.

Shed ice can cause Engine damage if it impacts an Engine surface with sufficient mass and velocity. The following types of damage are common, and applicants should include them in their CPA with an assessment of each:

(A) Fan Module

Various parts of the fan module, both non-rotating and rotating, are susceptible to ice shed damage. For example, acoustic panels, fan rub strips, and fan blade tips are susceptible to ice shed from air intake probe(s), spinner, and fan blade roots.

In determining the critical conditions for fan module damage, the surface temperature, exposure time and rotor speed are important considerations as well as the atmospheric icing conditions and scoop factor. In particular, extended operation in a holding condition in very cold continuous maximum icing conditions will maximise the adhesion of ice on rotating fan components. This can result in large ice accretions and resulting sheds which can damage the Engine or cause power/thrust loss.

(B) Compressor Damage

When ice formations on static components shed, they often result in damage to the next downstream rotor stage. For instance, this type of damage has occurred on the first blade set in the high pressure compressor (intermediate pressure compressor for three spool Engines). Establishing the critical conditions for these ice accretions therefore requires careful consideration as the critical condition may occur at specific limited conditions of low freezing fractions over a range of local Mach numbers and air densities. The critical conditions may not occur during any of the power settings discussed in this AMC (for example, flight-idle, 50 %, 75 % or 100 % of maximum continuous power/thrust), and so the power/thrust setting at the critical condition should be evaluated. Applicants should evaluate any Engine compressor damage that results from ice testing against the possibility of multiple occurrences, since icing is a common environmental condition.

(ii) Engine Operability.

The applicant should consider Engine operability as part of their CPA. Engine accelerations and decelerations relative to operability challenges (for example, surge and stall) should also be considered. The most adverse Engine bleed settings for the condition being analysed should be assumed to minimise the operability margin. The establishment of CPA points should consider those conditions where the minimum operability margin is expected.

(iii) Core and Booster Ice Blockage.

Ice accretion on internal Engine vanes from glaze ice accretions may affect airflow capacity and rematch of the Engine cycle. This should be considered in the CPA. At Engine powers/thrusts that can sustain flight, ice accretion should be reconciled through a demonstration of several ice build/shed cycles to demonstrate no adverse operating effects of either the ice builds or sheds.

(2.2) Establishment of Test Points for In-Flight Operation

The test conditions outlined below are intended as a guide to establish the minimum testing necessary to comply with CS-E 780. These test points should be supplemented or, if applicable, replaced, by any test points identified by the CPA as applicable.

The conditions of horizontal and vertical extent and water concentration defined below are somewhat more severe than those implied by the SLW Icing Conditions in CS-Definitions, Appendix C to CS-25 and Appendix C to CS-29. Encounters with icing conditions more severe that those defined are considered possible, and it is, therefore, appropriate to ensure that a margin is maintained.

(a) Tests points to demonstrate icing capability at a power/thrust at or above that required for sustained flight

One test point should be run to simulate each of the conditions of Table 1 at the Engine minimum power/thrust to maintain sustained flight in the intended installation. For turbofan Engines, a second point should be run at a higher power/thrust condition, if it is predicted to result in a higher energy of ice shed from the fan blades. If an acceptable means to predict the critical fan speed is not available, tests at 50 %, 75 % and 100 % of maximum continuous power/thrust should be run.

The minimum duration of each test point should be determined by repetitions of either the cycle:

(i) 28 km horizontal extent in the LWC conditions of Table 1, Column (a), appropriate to the temperature, followed by 5 km in the LWC conditions of Table 1, Column (b), appropriate to the temperature, for a total duration of 45 minutes, or 30 minutes if clear evidence of repeat build/shed cycles has been observed;

or the cycle:

(ii) 6 km horizontal extent in the LWC conditions of Table 1, Column (a), appropriate to the temperature, followed by 5 km in the LWC conditions of Table 1, Column (b), appropriate to the temperature, for a total duration of 20 minutes, or 10 minutes if clear evidence of repeat build/shed cycles has been observed.

At the conclusion of each test point, the Engine should be run up to the maximum power/thrust corresponding to the test conditions, using a one second thrust/power lever movement, to demonstrate any effect of ice shedding. If repeat build/shed cycles have been established, the acceleration should be delayed to maximise the impact energy of the ice shed.

Table 1 — Standard test points

Ambient Air Temperature (°C)	Altitude		Liquid Water Content (LWC) (g/m3)		Mean Effective Droplet Diameter(µm)
	(ft)	(m)	(a) Continuous Max	(b) Intermittent Max	
-10	17 000	5 182	0.6	2.2	20
-20	20 000	6 096	0.3	1.7	20
-30	25 000	7 620	0.2	1.0	20

(b) Tests points at power/thrust below that required for sustained flight

An additional test at the minimum power/thrust associated with descent in icing conditions should be conducted at an ambient temperature of -10°C or lower if necessary to ensure splitter/core inlet icing, consisting of repetitions of the following cycle:

A 28 km horizontal extent in the LWC condition of Table 1, Column (a), appropriate to the temperature, followed by 5 km in the LWC condition of Table 1, Column (b), appropriate to the temperature, for a sufficient duration to cover an anticipated descent of 3 000 m.

If the temperature required to ensure core icing is below an ambient temperature of -10°C, the LWC should be determined by interpolating between the conditions defined in Table 1.

At the conclusion of the test, the Engine should be subjected to an 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 to ensure all ice is shed or, alternatively, it may be established by visual inspection that any remaining ice is insignificant.

Whenever a minimum power/thrust is required for safe operation of the Engine in icing conditions, the applicant should ensure that this minimum power/thrust will be selected when the aircraft is operating in icing conditions. If any action is required from the installer to fulfil this requirement, then the minimum power/thrust should be declared as a limitation in the manuals containing instructions for installing and operating the Engine.

(c) Test Installation Considerations

Altitude and ram effect have a significant impact on the Engine operating conditions, ice accretion and ice shedding. Therefore, the use of an altitude test cell is the most direct method of compliance because this approach enables the test to be carried out in the most representative way, requiring the minimum of correction to correlate Engine and icing test conditions with the real operating environment. It also allows accurate control of the icing conditions. However, it is recognised that such facilities are not always available, and alternative test methods are also considered acceptable, providing that evidence demonstrates that such testing is at least as severe.

When a non-altitude test is used, any differences in Engine operating conditions, LWC and ice accretion between the altitude condition to be simulated and the test conditions, which could affect icing at the critical locations for accretion or shedding, should be taken into account when establishing the test conditions. This could involve modification of other test conditions of this paragraph in order to generate equivalent ice accretion. Effects which should be considered and corrected for include but are not limited to:

— Engine shaft speeds;

— ice concentration and dilution effects at Engine and core inlet (i.e. scoop factor);

— mass flow (total and core Engine); and

— temperature effects.

Justification should be provided to demonstrate that altitude conditions for ice accretion and shedding are adequately replicated under test conditions at all critical Engine locations. If there is more than one critical location for any given test condition, and it is not possible to adequately simulate the icing conditions at both locations, separate test points may need to be run.

(2.3) Establishment of Test Points for Ground Operation

The Engine should demonstrate the ability to acceptably operate at minimum ground idle speed to be approved for use in icing conditions for a minimum of 30 minutes at each of the following icing conditions shown in Table 2, with the available air bleed for ice protection at its critical condition, without adverse effect. An acceleration to take-off power or thrust should be performed at the time when the maximum ice accretion is likely to have occurred. During the idle operation, the Engine may be run up periodically to a moderate power/thrust setting in a manner acceptable to the Agency.

Normally, the conditions established during the test in terms of time, temperature and run-up procedures will be deemed to be the limitations necessary for safe operation in the applicable environment provided that the acceptance criteria of CS-E 780(a) are met.

However, an analysis may be used to demonstrate that ambient temperatures below the tested temperature are less critical.

Moreover, the applicant may demonstrate unlimited time operation if complete ice shedding is shown to have occurred during the test, either through repeatable ice build/shed cycles or by using a run-up procedure.

In order to avoid any unsafe condition resulting from operation outside the demonstrated conditions, these limitations will be defined in the manuals containing instructions for installing and operating the Engine.

For rime and glaze ice conditions as defined in Table 2, approval for operation below -18°C may be substantiated by analysis. A reduced liquid water concentration may be acceptable subject to appropriate substantiation.

The applicant should demonstrate, taking into consideration expected airport elevations, the following:

Table 2 — Demonstration Methods for Specific Icing Conditions

Condition	Total Air Temperature	Liquid Water/Snow Concentrations (minimum)	Mean Effective Particle Diameter	Demonstration
1. Rime ice condition	-18 to -9 °C (0 to 15 °F)	Liquid — 0.3 g/m^3	15–25 µm	By Engine test
2. Glaze ice condition	-9 to -1 °C (15 to 30 °F)	Liquid — 0.3 g/m^3	15–25 µm	By Engine test
3. Snow condition	-3 to 0 °C (26 to 32 °F)	Snow — 0.9 g/m^3	100 µm (minimum)	By test, analysis (including comparative analysis) or combination of the two.
4. Large drop glaze ice condition (Turbojet, turbofan, and turboprop only)	-9 to -1 °C (15 to 30 °F)	Liquid — 0.3 g/m^3	100–3 000 µm	By test, analysis (including comparative analysis) or combination of the two.

(3) Mixed-phase/Ice Crystal Conditions

This paragraph is provided for certification of turbine Engines to be installed on aircraft which have mixed-phase and ice crystal icing conditions included in their Certification Specifications.

Until validated full-scale ground test facilities for mixed-phase and ice crystal icing conditions are available, compliance should be based on flight test and/or analysis (supported by Engine/component tests, as necessary).

(a) Design Precautions. The applicant should show that design precautions have been taken to minimise the susceptibility of the Engine to mixed-phase/ice crystal accretions.

The analysis should also identify remaining features or locations in which ice accretion could not be excluded. Design features which may increase the susceptibility include but are not limited to:

(i) stagnation points which could provide an increased accretion potential;

(ii) exposed core entrance (as opposed to hidden core);

(iii) high turning rates in the inlet, booster and core flow path (particularly compound turning elements);

(iv) protrusions into the core flow path (for example, bleed door edges and measurement probes);

(v) unheated surfaces on booster and front core stages;

(vi) narrow vane-to-vane circumferential stator spacing leading to a small stator passage hydraulic diameter;

(vii) variable stator vanes can accrete ice and shed it when rotated;

(viii) extraction capability of bleeds; and

(ix) runback ice formed downstream of internal Engine heated surfaces.

(b) Comparative Analysis. If service experience of comparable Engine design(s) is available, the applicant should perform a comparative analysis between previous designs and the new design in mixed phase/ice crystal icing conditions. The analysis should compare both design features and operational factors.

Where the analysis under paragraph (a) above identifies potential for ice accretion due to design features, the applicant should conduct an analysis to review the service experience of the comparable Engine design(s) in order to identify any evidence indicating susceptibility to ice crystal/mixed phase accretion.

The applicant may demonstrate that the identified potential susceptibility to ice accretion is acceptable based on the good service experience demonstrated on comparable Engine design. Good service experience means the absence of any event involving Engine malfunction or unacceptable damage caused by ice crystal or mixed-phase conditions. To validate the credit from the comparable Engine design, the applicant should demonstrate that the design feature on the new design is similar in all pertinent aspects.

When the comparable Engine design has experienced field events determined to have been caused by mixed-phase or ice crystal icing conditions, the analysis should show that measures have been taken on the new design to address these field events and result in acceptable Engine operation. Acceptable operation includes the absence of rollback, rundown, stall, flameout, and unacceptable compressor blade damage.

(c) Novel Design Features. Where the analysis under paragraph (a) above identifies potential for ice accretion due to novel design features for which a comparative analysis cannot be performed, additional tests should be made to establish satisfactory operation.

(4) Ice Ingestion

(a) Intent of Ice Slab Ingestion Test

The intent of the ice slab ingestion test required by CS-E 780(f) is to demonstrate tolerance to ice ingestion from ice shedding from nacelle surfaces. In addition, it also establishes limits for ice released from other aircraft surfaces in the frame of CS-23 or CS-25 certification.

The minimum ice slab dimensions for the ice slab ingestion test are provided in Table 3 below. The dimensions are related to Engine size (defined by inlet highlight area), based on service experience. The applicant should determine the ice slab dimensions by linear interpolation between the values of Table 3, based on the actual Engine's inlet highlight area.

Table 3 — Minimum ice slab dimensions based on Engine inlet size

Engine Inlet Highlight Area (inch^2/m^2)	Thickness (inch/mm)	Width (inch/cm)	Length (inch/cm)
0/0	0.25/6.35	0/0	3.6/9.144
80/0.0516128	0.25/6.35	6/15.24	3.6/9.144

300/0.193548	0.25/6.35	12/30.48	3.6/9.144
700/0.451612	0.25/6.35	12/30.48	4.8/12.192
2 800/1.806448	0.35/8.89	12/30.48	8.5/21.59
5 000/3.2258	0.43/10.922	12/30.48	11.0/27.94
7 000/4.51612	0.50/12.7	12/30.48	12.7/32.258
7 900/5.096764	0.50/12.7	12/30.48	13.4/34.036
9 500/6.12902	0.50/12.7	12/30.48	14.6/37.084
11 300/7.290308	0.50/12.7	12/30.48	15.9/40.386
13 300/8.580628	0.50/12.7	12/30.48	17.1/43.434
16 500/10.64514	0.50/12.7	12/30.48	18.9/48.006
20 000/12.9032	0.50/12.7	12/30.48	20.0/50.8

Note: Applicants should use a minimum ice slab density equivalent to a 0.9 specific gravity unless a different value is considered more appropriate.

The applicant should also include in its compliance plan an analysis of the potential installation effects of the Engine induction system.

The applicant and the installer should closely coordinate the ice slab sizing. This coordination ensures that potential airframe ice accumulation that can be ingested by the Engine are addressed under CS-E 780(f).

(b) Compliance Considerations

Compliance may be demonstrated through the standard Engine ice slab ingestion test or by means of a validated analysis procedure that uses an equivalent soft body testing.

The test demonstration should use ice slab trajectories aimed at critical Engine locations. Applicants should pick locations based on the ice accretion and shed characteristics of the induction system likely to be installed on the Engine. The most critical impact location should be tested.

Engine operation will be at the maximum cruise power or thrust unless lower power or thrust is shown to be more critical.

(c) Elements of a Validated Analysis

This analytical model may be used alone or in conjunction with the results of a certification medium bird ingestion test. A validated analysis should contain sufficient elements to show compliance. These elements may include:

— full fan (fan Engines) or first stage compressor (non-fan Engines) blade model using the latest techniques such as finite element analysis;

— blade material properties for yield or failure, or both, as appropriate;

— dynamic and time variant capability;

— thrust or power variance prediction if required to account for blade damage; and

— appropriate Engine or component testing, or both, with impact at the outer 1/3 of the first stage blade span location. The fan is the first stage blade row for turbofan Engines.

(i) The analysis of the ice slab impact on the fan should properly account for critical controlling parameters:

— relative kinetic energy normal to the leading edge chord,

— incidence angle — relative slab speed and blade speed,

— slab dimensions,

— sab orientation, and

— impact location.

(ii) Any predicted power/thrust loss or blade damage (distortion, cracking, tearing) should be assessed against the criteria of this AMC.

(iii) The relative kinetic energy of the ice slab should be determined from an assessment of the flight conditions that control Engine rotor speed versus ice slab velocity. Engine test results from previous ice slab testing may be used to support the predicted ice slab velocity. The applicant's analysis should assume the most critical orientation, unless it can be shown that an alternate ice slab orientation is more conservative for ice slab testing.

(iv) Ice Slab Break-Up. Typically, the ice slab breaks up into smaller pieces during an ice slab ingestion. The applicant's analysis should use the largest slab size consistent with a conservative assessment of a slab 'break-up' that can occur within the air stream ahead of the fan. Data derived from a number of tests shows that the largest ice piece is typically 1/3 to 1/2 of the original size. For analysis purposes, the applicant may assume 1/2 of the original slab greatest dimension unless evidence suggests that this is not conservative relative to the ice slab testing.

(d) Test Results

CS-E 780(f)(2) requires that, following ice ingestion, the Engine must comply with CS-E 780(a). The below elements should be considered:

(i) Engine Loss of Performance. Applicants should evaluate the impact of any first stage blade bending or damage on potential sustained Engine power/thrust loss. Sustained power/thrust loss associated with first stage damage from the slab should be less than 1.5 %. Ice and birds are 'soft body' objects in their impact behaviour, i.e. they are both highly deformable on impact and flow over the structure, spreading the impact load. They also have similar densities; thus they create similar strain footprints and, consequently, similar damage. As soft body fan damage is common from medium bird ingestion, applicants may use the medium bird ingestion test results to show compliance with this requirement. If the medium bird ingestion test results in less than 1.5 % permanent power/thrust loss, and no cracks, tears or blade piece breakout occur due to a bird ingested at the outer 33 % of the first stage blade span, then the CS-E 780(f)(2) requirement is met.

(A) If power/thrust loss exceeds 1.5 % when utilising the bird test, the applicant should provide a validated analysis that shows consistency with the bird test results. The applicant should also demonstrate that the standard ice slab would produce less than the 1.5 % power/thrust loss.

(B) Applicants should also demonstrate by test that any cracks, tears or blade piece breakout will not result in 'unacceptable sustained power or thrust loss' within 100 flight cycles (considered sufficient to allow Engine operation until the next scheduled 'A' check). Furthermore, any damage resulting from this test should be documented in the manuals containing instructions for installing and operating the Engine.

(ii) Engine Operability/Handling Characteristics. Ice slab ingestion should not cause surge, flameout, or prevent transient operation.

(iii) In-Service Capability. Engine damage resulting from ice slab ingestion should not result in a failure or a performance loss that would prevent continued safe operation for a conservative flight operations scenario (for example, within the time period for an "A" check or greater, if appropriate testing validates a continued period of in-service capability). The period of in-service capability to be demonstrated may vary with installation if the damage is not readily evident to the crew or visible on pre-flight inspection (for example, tail-mounted Engines).

(iv) Other Anomalies. Ice slab ingestion should not result in any other anomaly (for example, vibration) that may cause the Engine to exceed operating or structural limitations.

(v) Auto-Recovery Systems. If during ice slab ingestion testing, an Engine incurs a momentary flameout and auto-relight, then the acceptance of that test is predicated on including the auto-relight system as a required part of the Engine type design. However, additional dispatch criteria would also be required where the ignition system is fully operable before each dispatch. The reason for the additional dispatch criteria is to ensure that the ignition system's critical relight function is reliably available during the subsequent flight. The use of an auto-recovery system is allowed during ice slab ingestion certification testing, in order to account for ice accretion and shedding as a result of an inadvertent delay in actuating the ice protection system. This is considered as an abnormal operational result where operability effects, like momentary flameout and relight, may be accepted.

(e) Communication to the Installer. The manuals containing instructions for installing and operating the Engine should provide information on the Engine ingestion capability such as size, thickness and density of the ice slab ingested.

(5) Engine Air Data Probe Icing

In accordance with paragraph (1.3) of this AMC, the accretion and shedding of ice from the Engine air data probe(s) should be evaluated either as part of the Engine test, or by separate assessment and/or testing.

In addition, if data from an Engine air data probe is critical to ensure acceptable Engine operation, then the applicant should demonstrate that the Engine air data probe will operate normally without any malfunction under icing conditions. The icing conditions against which the Engine is tested may not cover the icing conditions that are critical for the Engine air data probe, in particular if high airflow conditions like Maximum Continuous Thrust/Power were not selected for the Engine tests in paragraph (2.2) above. The applicant should determine those critical probe icing conditions. In that respect, the guidance material of AMC 25.1324 of CS-25 should be used along with appropriate consideration of the installation effects and dependence on Engine airflow. In doing that, the substantiation may be limited to the icing environment applicable to the aircraft on which the Engine is to be installed.

In assessing whether data from an Engine air data probe is critical, the Engine system(s) response to erroneous in-range data and to data during transitions to/from icing conditions should be considered.

Note: If Engine air data probe signals are used by the aircraft system(s) on a CS-25 aeroplane, the aeroplane manufacturer will be responsible for showing that the involved Engine air data probe complies with CS 25.1324 (including rain conditions).

(6) Inadvertent Entry into Icing Conditions or Delayed IPS Activation

The ice ingestion demonstration of paragraph (4) of this AMC addresses the threat of ice released from protected airframe surfaces, including the Engine air intake, following a delay in the selection of the ice protection system such as might occur during inadvertent entry into icing conditions.

However, if satisfactory operation in any icing conditions relies on manual activation of Engine ice protection system(s), such as a raised idle function and/or an internal ice protection system, 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 Engine ice protection system(s).

In assessing the representative delay, the applicant should consider all factors that contribute to a delay in activation of the ice protection system(s).

This assessment should include the time for ice condition detection, pilot response time, time for the system to become operational, time for the system to become effective.

In lack of other evidence, a delay of two minutes to switch on the IPS should be assumed. For thermal IPS, the time for the IPS to warm up should be added.

(7) Instructions for installing and operating the Engine

The applicant should declare all identified limitations to the installer in the manuals containing instructions for installing and operating the Engine. These should include but are not limited to the following items (see background in the previous paragraphs of this AMC):

— the icing environment in which the engine has been certified;

— details of the assumed Engine installation, including protection device(s);

— operational altitude limitation;

— Engine ingestion capability such as size, thickness and density of the ice slab ingested;

— Engine ice ingestion protection device to be provided by the installer (when not part of the Engine configuration);

— effects that may be observed during or after the encounter of icing conditions, such as vibrations, temporary power/thrust loss, change in Engine power/thrust response;

— anomalous Engine behaviour that has been found acceptable following ice shed ingestion;

— minimum power/thrust required for safe operation of the Engine in icing conditions (if necessary); and

— for ground icing operation, the conditions established during the test in terms of time, temperature (if any limitation exists) and run-up procedures.

If the Engine is certified under the assumption that the protection device considered under CS-E 780(f)(3) is provided by the aircraft installation, and if (with respect to ice formed forward of the protection device) the compliance with CS-E 780(f)(1) to (f)(2) 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 780(f)(3)(i) to (iii) to the installation.

[Amdt No: E/1]
[Amdt No: E/4]

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 airspeed, for altitudes up to 4 500 metres, associated with a representative aircraft operating in rough air, with the Engine at Maximum Continuous Power or Thrust, must not cause unacceptable mechanical damage or unacceptable Power or Thrust loss after the ingestion, or require the Engine to be shut down.

Engine tests must be performed as follows, unless it is agreed that alternative evidence can be used, such as results from other Engine test(s), rig test(s), analysis, or an appropriate combination of these, provided by the applicant from their experience with Engines of comparable size, design, construction, performance and handling characteristics, obtained during development, certification or operation.

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. (See AMC E 790(a)(2)).

(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 4-percent. 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).

[Amdt No: E/1]
[Amdt No: E/5]

AMC 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 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 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 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.

[Amdt No: E/1]

AMC E 790(a)(1) Rain and Hail Ingestion Certification for Design Changes and Derivative Engines – Turbine Engine Power/Thrust Loss and Instability in Extreme Conditions of Rain and Hail

CS-E 790(a)(1) allows, as an alternative to conducting a full Engine test, the certification of design changes or derivative Engines based on alternative evidence provided by the applicant (such as other Engine test(s), rig test(s), analysis, or an appropriate combination of these); however, alternative evidence is not intended to be used for the certification of new Engines.

Any parametric analysis used to substantiate design changes or derivative Engines should fall within a 10 % variation in the critical impact parameter (CIP) that was used to substantiate the original base Engine. The CIP(s) is (are) often associated with the impact load at the point of contact between the hail and the rotor blade. This is generally a function of the impact speed, the rotor speed, and the blade twist angle. This 10 % variation in the CIP(s) should not be assumed to be a direct tolerance on the applicant's proposed changes to the Take-off Power or to the thrust ratings themselves.

[Amdt No: E/5]

AMC 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.

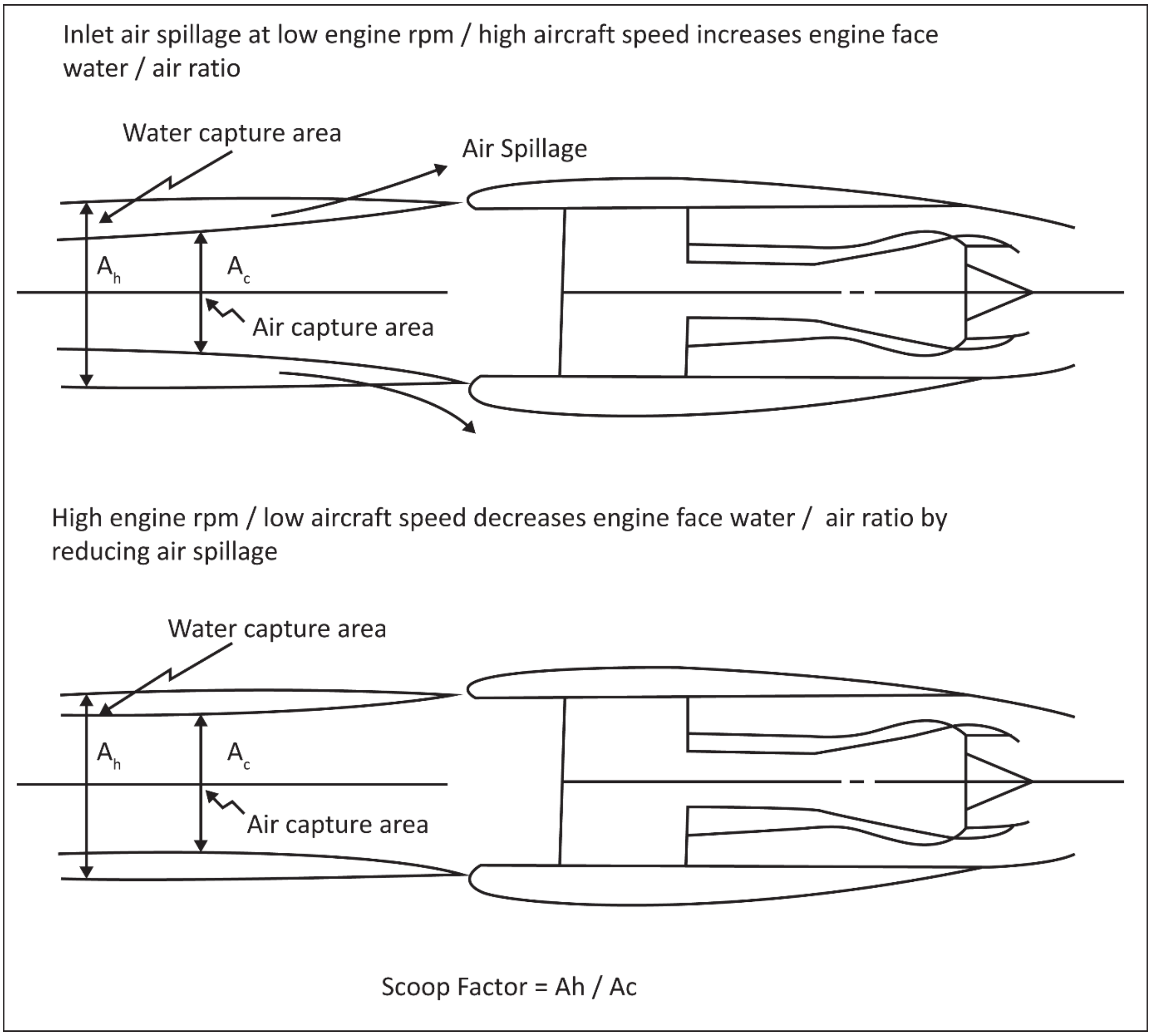


Figure 1 Scoop Factor

(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.

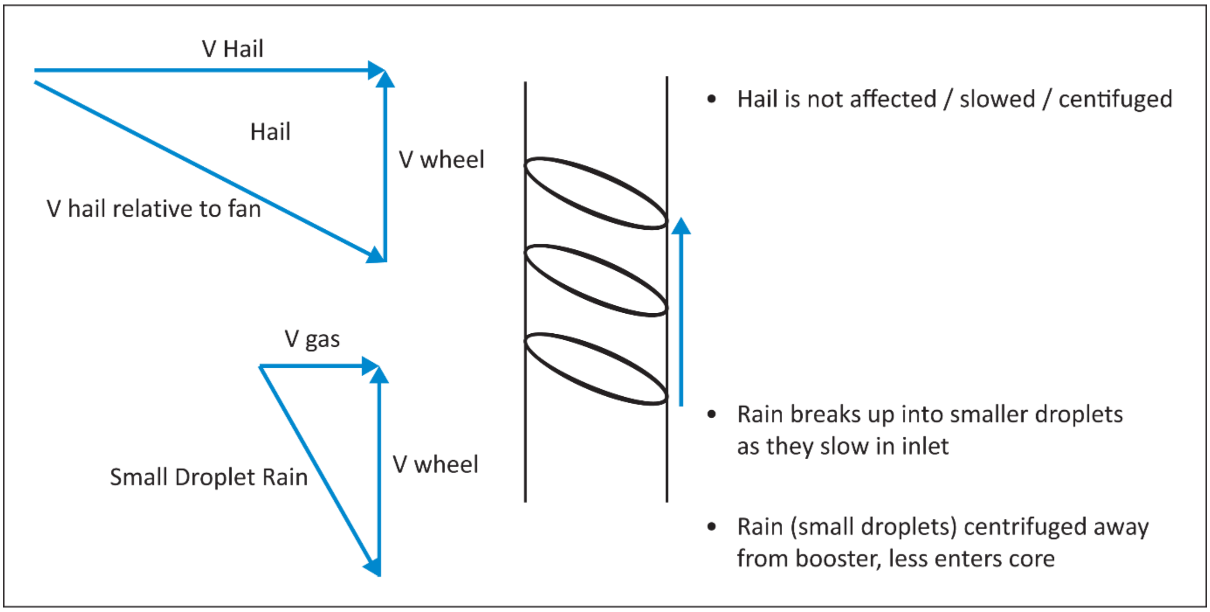


Figure 2 Velocity Vector Diagram

(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.

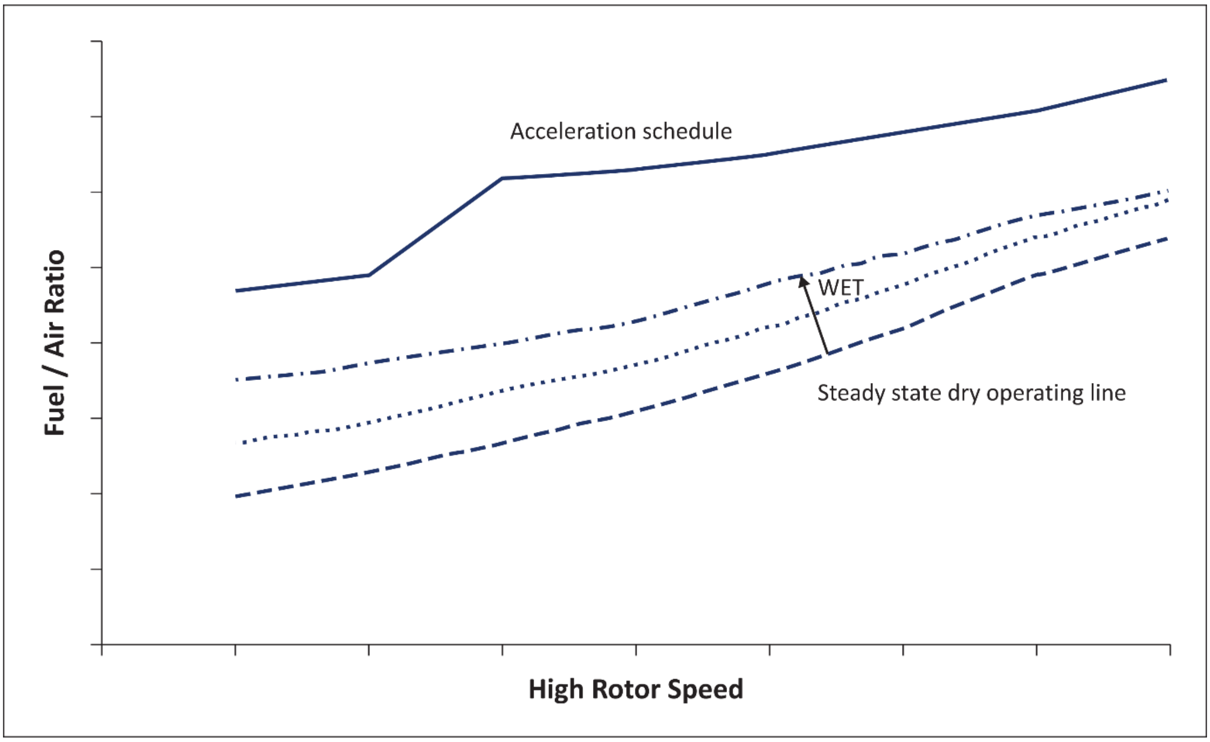


Figure 3 Typical Engine Control Characteristics

(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 and 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 rundown, 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 per cent 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 the 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 affect the 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 the 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(d) 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, and that plane should be 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 the rain and hail temperatures and concentrations, particle velocities and size distributions, and the 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 the continuous transient data recording prior to the initiation of rain or hail flow.

(D) Establish the altitude equivalent rain or hail flow at the proper inlet velocity and size distribution. The maximum rain and hail ingestion rates should occur within 10 seconds.

(E) Conduct operability critical point tests at the following steady-state conditions:

(a) 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.

(b) 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.

(c) Deliver a short burst of high-concentration hail of 13 g/m^3 hail water content (HWC) under conditions representative of a 15 000-ft altitude for a minimum of 5 seconds.

Note: Applicants can elect to integrate the test point required by paragraph (E)(c) within the 30-Second test point required by paragraph (E)(b), or consider it separately using test or analysis. Applicants may also propose justifiable alternatives to assess similar short-term, high-concentration threats.

(F) When testing low-power critical points (i.e. the minimum flameout and/or rundown margin), conduct tests with ingestion during the following transient operating conditions:

(α) accelerate the Engine with a 1-Second throttle movement to the rated Take-off Power or Thrust from the minimum rotor speed defined by the critical point analysis; and

(β) stabilise the Engine at 50% of the rated Take-off Power or Thrust with ingestion, then, with a 1-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 that 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. The 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 it was 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 autothrottle power excursions.

(vi) Acceptance criteria

Acceptable Engine operation precludes flameout, rundown, continued or non-recoverable surge or stall, or a 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 dependent upon the functioning of an automatic protection system, such as continuous ignition, auto-relight, surge recovery system, then the availability of this system is considered to be 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 per cent 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 in the Engine corrected thrust or power of up to 10 per cent 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.

Note: Due to the adjustment of the hail water content (HWC) to account for the higher air density at sea level compared with the altitude flight conditions required by paragraph (5)(c)(i)(A) of this AMC, it is possible that the pressure altitude density effect on the HWC may result in ice accretion within the Engine that would not occur in flight. The amount of ice accretion within the Engine compressor will depend on the absolute HWC level, rather than the water-to-air ratio within the Engine.

If an issue with ice accretion is revealed during the testing required by paragraph (5)(c)(iv) of this AMC with amplified HWC, the applicant may need to repeat the testing at the levels identified in Appendix A to CS-E to evaluate the true ice accretion threat.

Alternatively, the applicant may elect to run an initial test at those levels identified in Appendix A to CS-E to demonstrate the capability of the Engine with respect to ice accretion before performing the operability test with a higher HWC.

Irrespective of the effects of pressure altitude density, flight airspeed effects should still be applied to the Engine test simulation.

(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.

[Amdt No: E/1]
[Amdt No: E/5]

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.

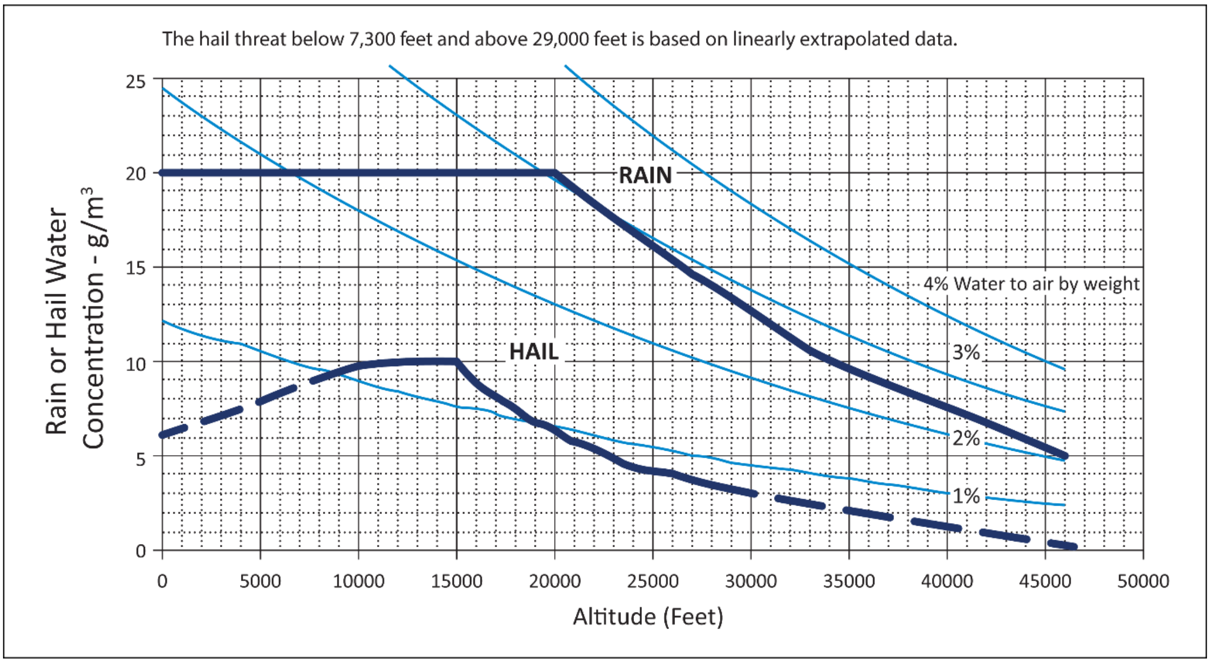


TABLE A1 – CERTIFICATION STANDARD ATMOSPHERIC RAIN CONCENTRATIONS

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	5.3

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
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

CS-E 800 Bird Strike and Ingestion

(See AMC E 800)

(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(g)(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(g)(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
$2.50 \le A < 3.50$	1.85
$3.50 \le A < 3.90$	2.10
$3.90 \le A$	2.50

(iv) The bird must be targeted on the first exposed rotating stage(s) at a blade aerofoil 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.

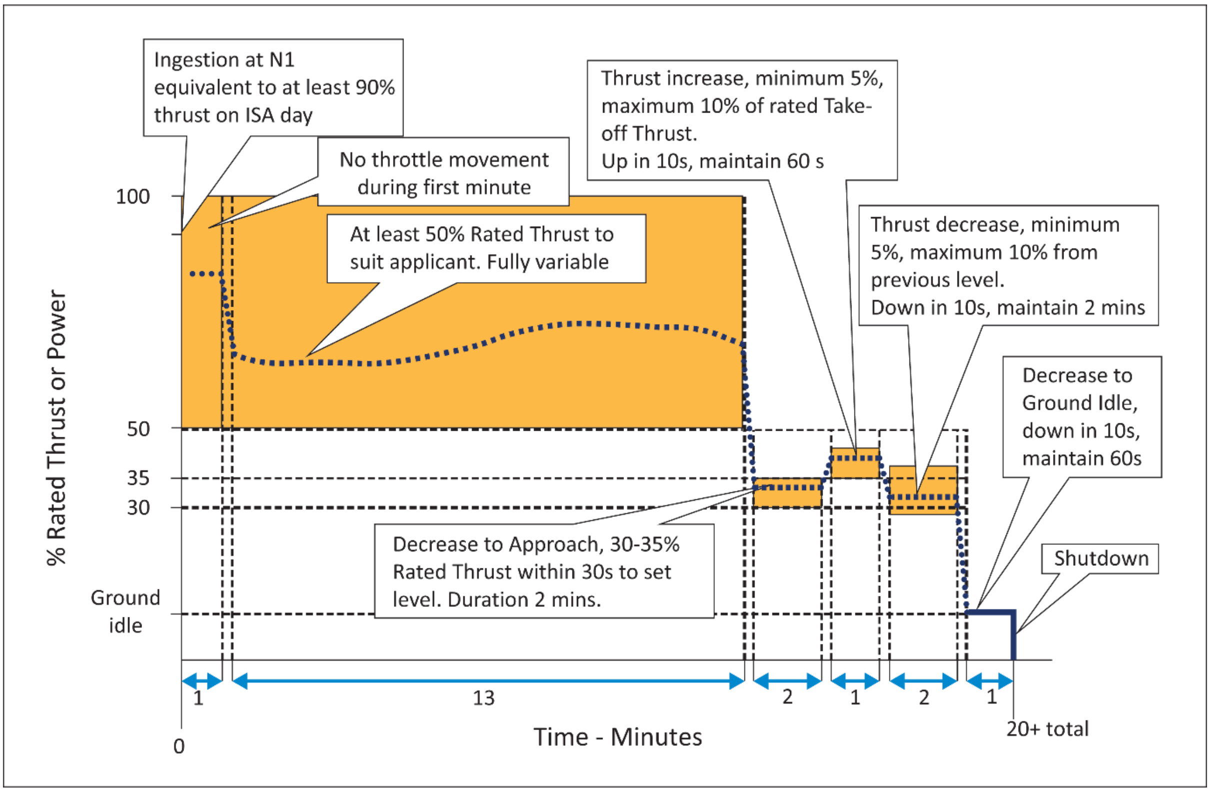
Step 4 - 1 minute at a thrust increased from that set in step 3 by between 5 and 10% of Rated Take-off Thrust.

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 shutdown.

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

Run-on For Large Flocking Bird Rule



(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 in 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(g)(1). The small-birds test will not be required if the prescribed number of medium-bird(s) 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 Takeoff Power or Thrust.

(ii) The critical ingestion parameters that affect 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 the bird speed, the critical target location and the 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 ft) above ground level, but not less than the V_1 minimum for Engines to be installed on aeroplanes.

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

— Perform an ingestion to simulate a flock encounter within 1 second;

— 2 minutes without any 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 the Engine at idle and then shut the 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:

— Perform an ingestion to simulate a flock encounter within 1 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 the Engine at idle and then shut the 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*. The masses and quantities of birds will be determined from the second column 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 of CS-E 800

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	1x 0.45	none
0.20 ≤ A < 0.40	2x 0.45	none
0.40 ≤ A < 0.60	2x 0.70	none
0.60 ≤ A < 1.00	3x 0.70	none
1.00 ≤ A < 1.35	4x 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	2x 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 the third Column 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) *Core Engine flocking bird ingestion test*. For turbofan Engines, an ingestion test shall be performed as follows:

(1) A core Engine flocking bird ingestion test shall be performed with one bird, using the heaviest bird specified in the second column of Table A above and ingested at a bird speed of 250 knots, unless it is shown by test or validated analysis that no bird material will be ingested into the core under the conditions of this subparagraph, in which case subparagraphs (e)(4), (5) and (6) should be applied. Prior to the ingestion, the Engine shall be stabilised at the mechanical rotor speed of the first exposed stage or stages that, on a standard day, would produce the lowest expected power or thrust required during a climb through 3 000 ft above ground level in revenue service. The bird must be targeted on the first exposed rotating stage or stages at the blade aerofoil height measured at the leading edge that would maximise the bird material that is ingested into the Engine core.

(2) Ingestion into the Engine core of a bird under the conditions prescribed in subparagraph (e)(1) shall not cause any of the following:

- (i) A sustained reduction in power or thrust to less than 50 % of the maximum rated Take-off Power or Thrust during the run-on specified under paragraph (e)(3)(iii) below, that cannot be restored only by movement of the power lever.
- (ii) A sustained reduction in power or thrust to less than flight idle power or thrust during the run-on segment specified under paragraph (e)(3) below.
- (iii) An Engine shutdown during the required run-on demonstration specified in paragraph (e)(3) below.
- (iv) The conditions specified in paragraph CS-E 800(b)(2).

(3) The following test schedule shall be used:

- (i) Ingestion followed by 1 minute without any power lever movement.
- (ii) Followed by power lever movement to increase the power or thrust to not less than 50 % of the maximum rated Take-off Power or Thrust, if the initial bird ingestion resulted in a reduction in power or thrust below that level.
- (iii) Followed by 13 minutes at not less than 50 % of the maximum rated Take-off Power or Thrust.
- (iv) Followed by 2 minutes at between 30 and 35 % of the maximum rated Take-off Power or Thrust.
- (v) Followed by 1 minute with the power or thrust increased by between 5 and 10 % of the maximum rated Take-off Power or Thrust from that set in subparagraph (e)(3)(iv) of this paragraph.
- (vi) Followed by 2 minutes with the power or thrust reduced by between 5 and 10 % of maximum rated Take-off Power or Thrust from that set in subparagraph (e)(3)(v) of this paragraph.
- (vii) Followed by a minimum of 1 minute at ground idle, then an Engine shutdown. The durations specified are the times at the defined conditions.

  The power lever movement between each condition shall be 10 seconds or less in duration, except power lever movements that are allowed within subparagraph (e)(3)(iii), that are not limited, and those for setting power under subparagraph (e)(3)(iv), which shall be 30 seconds or less in duration.

(4) If it is shown by test or analysis that no bird material will be ingested into the Engine core under the conditions of subparagraph (e)(1), then the core Engine ingestion test shall be

performed with one bird, using the heaviest bird specified in the second column of Table A, and ingested at a bird speed of 200 knots. Prior to the ingestion, the Engine must be stabilised at the mechanical rotor speed of the first exposed stage or stages that is consistent with a minimum approach idle setting, on a standard day, at 3 000 ft above ground level. The bird must be targeted on the first exposed rotating stage or stages at the blade aerofoil height measured at the leading edge that would maximise the bird material being ingested into the Engine core.

(5) Ingestion into the Engine core of a bird under the conditions prescribed in (e)(4) must not cause any of the following:

(i) an Engine shutdown during the required run-on demonstration specified in paragraph (e)(6) below;

(ii) the conditions specified in paragraph CS-E 800(b)(2).

(6) The following test schedule must be used:

(i) Ingestion followed by 1 minute without any power lever movement.

(ii) Followed by 2 minutes at between 30 and 35 % of the maximum rated Take-off Power or Thrust.

(iii) Followed by 1 minute with the power or thrust increased from that set in subparagraph (e)(6)(ii), by between 5 and 10 % of the maximum rated Take-off Power or Thrust.

(iv) Followed by 2 minutes with the power or thrust reduced from that set in subparagraph (e)(6)(iii), by between 5 and 10 % of maximum rated Take-off Power or Thrust.

(v) Followed by a minimum of 1 minute at ground idle, then an Engine shutdown. The durations specified are times at the defined conditions.

The power lever movement between each condition shall be 10 seconds or less in duration, except power lever movements that are allowed within subparagraph (e)(6)(iii), that are not limited, and those for setting power under subparagraph (e)(6)(iv), which shall be 30 seconds or less in duration.

(7) Applicants must show that no unsafe condition will result if any Engine operating limit is exceeded during the run-on demonstration.

(8) The core Engine flocking bird ingestion test of subparagraph (e) may be combined with the medium flocking bird test of subparagraph (d), if the climb fan rotor speed calculated in subparagraph (e)(1) is within 1 % of the first stage rotor speed required by subparagraph (d)(1).

(f) *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 ft) 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.

(g) *General*

(1) Engine tests must be performed as required under CS-E 800(b), (c), (d) and (e) unless it is agreed that alternative evidence such as from Engine tests, rig tests, analysis or an appropriate combination of these, may come from the spplicant's experience with 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 that are 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 stabilized; 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 exceedances may be permitted to occur during the tests of CS-E 800(c), (d) and (e). Any limit exceedance must be recorded and shown to be acceptable under CS-E 700.

(5) For an Engine that incorporates an inlet protection device, compliance with 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.

[Amdt No: E/1]
[Amdt No: E/5]

AMC 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 the excess torque that are likely to occur.

(ii) To comply with CS-E 800(b)(1)(ii)(A), rig tests may be used to determine whether a bird of a particular size will pass through the inlet.

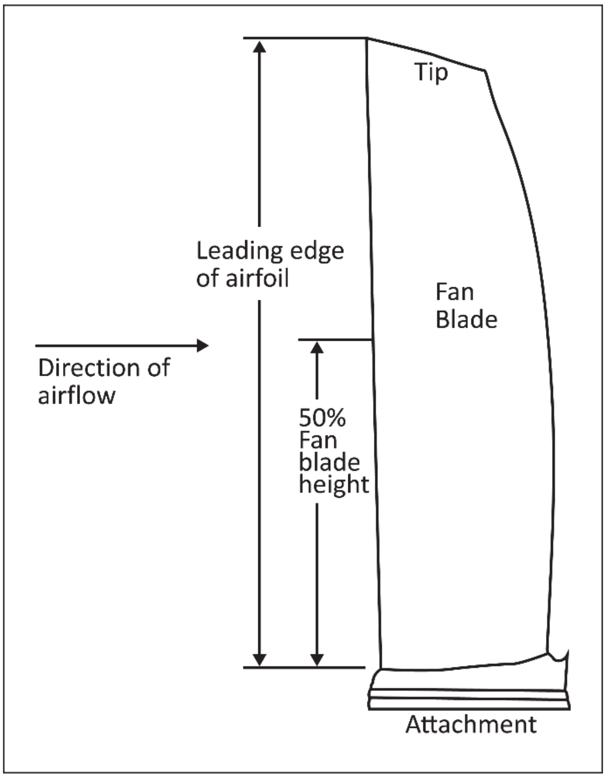
(iii) The complete loss of power or thrust is acceptable after the ingestion of the single large bird.

(b) Large flocking bird

The following advisory material applies to the test required by 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. The term '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. the fan) at a blade span height of 50%, or further outboard, as required by CS-E 800(c)(1)(iv) (see the 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 for which 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 exceedances and/or vibration, provided that at least 50% of the 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 specified thrust. 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(g)(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 subassembly 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(g)(3)(ii)(C) include, but are not limited to, surge and stall, flameout, limit exceedances, and any other considerations relative to the ability of the type-design Engine 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 maintaining acceptable handling characteristics during a 20-minute run-on simulating a return to the airport after the ingestion of medium or small flocking birds 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 the potential effects of the assumed aircraft installations. The spinner and the other parts of the front of the Engine may be evaluated separately under CS-E 800(f).

(iii) In the tests performed under paragraph CS-E 800(d), the Engine is required to produce at least 75% of the test conditions power or thrust after the ingestion of either small or 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) Exceedances 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 an exceedance 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 any power lever movement, it is permitted to control exceedances, if any. Any intervention to control exceedances should be recorded, and suitable instructions should be provided in the instructions for the 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.

(d) Core Engine flocking bird ingestion test

(i) Determining climb rotor speeds

The calculation of the core ingestion test Engine rotor speeds associated with the climb phase will depend on the aeroplane and the type of flight that is flown. For each Engine model and installation (where known), the Engine manufacturer should:

— determine the Engine rotor speeds that provide the thrust that is required, at an altitude of 3 000 ft (above ground level) to climb

— through that altitude, in International Standard Atmosphere (ISA) standard day conditions at 250 knots indicated airspeed (IAS);

— include the rotor speeds that were assumed in the instructions for installation as required by CS-E 20(d);

— establish the associated minimum mechanical fan rotor speed for this condition using Engine performance simulations;

— the fan speed chosen should be associated with the lowest rated thrust Engine model offered for that aircraft installation; if multiple climb settings are available for an intended aircraft, then the lowest climb setting should be used to determine the core ingestion rotor speed targets.

(ii) Climb rotor speed considerations

There is typically little or no difference between the take-off and climb rotor speeds for the smaller turbofan Engines that are installed on business jets. For this reason, the climb conditions for the core ingestion demonstration will often be very close to the conditions prescribed for the medium flocking bird (MFB) test of CS-E 800(d), in which the largest MFB is targeted at the core at the full-rated take-off condition.

The most significant difference between the MFB test and the core ingestion demonstration is expected to be the bird speed determined in CS-E 800(f) versus the 250-knot IAS core Engine test bird speed. An applicant who wants to demonstrate the recommended 250-knot IAS core bird within the existing MFB rated take-off test may do so if the applicant can show an equivalent level of test severity. Therefore, it is possible for the MFB core ingestion requirements to be satisfied by a single test at the rated Take-off Thrust in which the largest MFB that is aimed at the core is fired into the engine at the 250-knot IAS climb airspeed while the remaining bird velocities, targeting and run-on would follow the current MFB criteria. All the birds in the test would still have to be fired within the 1-second requirement of CS-E 800(d)(1)(iii). The objective is to show that the core ingestion is as rigorous at the current MFB fan speed condition as it would be at the aeroplane recommended climb fan speed condition.

(iii) Target selection and timing

— The bird should be targeted at the Engine in order to maximise the amount of bird material that enters the core for the given test condition. This will ensure that the core ingestion test properly challenges the core during an Engine demonstration.

— The optimum target location varies with the Engine design. The span-wise location will depend on the geometric features of the front of the Engine.

— The core bird target location should be determined so that it maximises the amount of core ingested bird material for the core ingestion test by:

  — analysis based on component testing;

  — dynamic simulation verified by test; or

  — experience with similar designs.

(iv) Engine operation

  — A momentary, 3 seconds maximum, power or thrust decrease below the required value of each segment, or when setting power between segments, is acceptable.

  — A power or thrust loss of greater than 3 seconds duration below the required value of each segment, or when setting power between segments, is considered to be a sustained power loss.

(v) Run-on sequence requirements

— The total test duration may exceed 20 minutes, due to the time used for accelerations and decelerations.

— If a percentage of the maximum rated Take-off Power or Thrust is specified, the rotor speed to attain the specified Power setting will vary with the test day conditions.

— The Power settings are a percentage of the maximum rated Take-off Power or Thrust, and not a percentage of the actual test day pre-ingestion Power or Thrust specified in CS-E 800(e)(1) or (4).

(vi) Core ingestion prediction analyses

— Some Engine configurations may include features that reject all bird material from the core intake at the take-off and climb conditions specified in CS-E 800(d) and (e)(1). Such Engines would be:

— exempt from the recommended climb ingestion criteria;

— subject only to the approach core ingestion test; and

— required to demonstrate 100 % bird rejection capability by analysis or similarity.

— Any analyses used to predict core ingestion will need to be validated using data that may be derived from:

— rig testing;

— Engine testing; or

— field experience.

— If the standard CS-E 800(d) MFB core demonstration results in any amount of bird material being found in the core, including a single feather or tissue fluorescence under ultraviolet light illumination, then:

— the prediction of zero core ingestion under the climb conditions of CS-E 800(e)(1) will be considered to be invalid; and

— the core ingestion capability in the climb condition should be demonstrated.

(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. the 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 (CIP) to variations in the controlling parameters.

The 'critical impact parameter (CIP)' is defined as a parameter that is 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 CIP is generally a function of such things as the 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 the fan blade leading edge stress, although other features or parameters may be more critical as a function of the operating conditions or the basic design. For turboprop and turbojet Engines, a core feature will most likely be the critical consideration. Regardless of the 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 their 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 the leading edge stress to the blade root stress. For fan blades with part span shrouds, it may be the blade deflection that produces shroud shingling and either a thrust loss or a blade fracture that could be the limiting event. 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 the controlling parameters of the test.

(b) The installation and especially the gun arrangement in some test facilities can induce air distortion in the Engine inlet, which can artificially reduce 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 a 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 the power level tolerance band to the desired level. This should be identified and approved prior to the test. Any exceedance 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 to determine how the Engine would respond in a representative installation, and to ensure 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, any 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 but is not limited to components such as a nose cone/spinner on the fan or compressor rotor, an Engine inlet guide vane assembly including the centrebody, any protection device, or inletmounted 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. For aft fan designs, blades on two different rotors (in the 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 that do not require 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 a 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 the power or thrust, turbine temperature and rotor speed(s).

(c) CS-E 800(g)(1) is intended to allow the 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 the 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(g)(1) should fall within a 10% variation in the CIP that was used to substantiate the original base Engine. The CIP(s) is (are) often associated with the 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 in the CIP should not be assumed to be a direct tolerance on the applicant's proposed changes to the take-off 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 that is based on representative tests and should have demonstrated its capability to predict Engine test results.

(e) When reference is made to an "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(g)(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.

[Amdt No: E/1]
[Amdt No: E/5]

CS-E 810 Compressor and Turbine Blade Failure

(See AMC E 810)

(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 Overspeed) and

(ii) Below the minimum rotor burst speed.

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

(c) In addition, for composite fan blades where the release of the fan blade is considered to be in the Engine flow path:

(1) it must be substantiated that, during the service life of the Engine, the total probability of the occurrence of a Hazardous Engine Effect defined in CS-E 510 due to an individual blade retention system Failure from all possible causes will be Extremely Improbable, with a calculated probability of Failure of less than 10^{-9} per Engine flight hour;

(2) it must be substantiated by test or analysis that a lightning strike to the composite fan blade structure will not prevent the continued safe operation of the affected Engine.

[Amdt No: E/1]
[Amdt No: E/5]

AMC 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 that substantiates the strength of the Engine either by blade Failure experience with 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, shutdown 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 tests 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 (i) and (ii).

NOTE: Where the Engine design is such that potentially Engine Critical Parts overlie the compressor or turbine casing (e.g. bypass 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 E 520(c)(1) paragraph (2).

(i) Number of blades to be detached. One blade should be released at the top of the retention member.

(A) For composite fan blades only, the fan blade may be released at the inner annulus flow path line, provided that:

(1) tests and analyses, or other methods that are acceptable to the Agency, substantiate that the minimum material properties of the fan disk and fan blade retention system can withstand, without Failure, a centrifugal load that is equal to two times the maximum load that the retention system could experience within the approved Engine operating limitations;

(2) a procedure that is approved by the Agency is used to establish an operating limitation that specifies the maximum allowable number of start-stop stress cycles for the fan blade retention system. The life evaluation should include the combined effects of high-cycle and low-cycle fatigue. If the operating limitation is less than 100 000 cycles, this limitation should be specified in the Airworthiness Limitation Section of the Instructions for Continued Airworthiness;

(3) the effects of in-service deterioration, manufacturing variations, minimum material properties, and environmental effects should be accounted for during the tests and/or analyses.

NOTE: The fan blade retention system includes the portion of the fan blade from the inner annulus flow path line inward to the blade dovetail, the blade retention components, and the fan disk and fan blade attachment features.

(ii) Engine Conditions at Release. The blade should be released at either -

(A) the maximum rotational speed to be approved (other than Maximum Engine Overspeed) and the associated maximum casing temperature, or

(B) any likely combination of the non-transient rotational speed, intake temperature and casing temperature that is considered to be more critical.

NOTE: Any deficiency in the required casing temperature may be compensated for by means of a suitable increase in the Engine speed.

(c) Condition after Tests. On completion of the tests, a 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: If debris is ejected from the Engine intake or exhaust, the approximate size and weight of the debris 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 they are contained within the external geometry of the Engine.

(3) Running Following a 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 subsequent 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 that is 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 that exist during the period prior to the Engine shutdown.

(i) The Engine should be run, with an out-of-balance that is 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. A complete power Failure is permitted.

[Amdt No: E/1]
[Amdt No: E/5]

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. (See AMC E 820(a)(2))

(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).

[Amdt No: E/1]

AMC E 820(a)(2) Over-torque Test

In order to comply with CS-E 820(a)(2), it should be shown that an over-torque event does not compromise the ability of the Engine to reach its Rated 30-Second/2-Minute OEI Power.

[Amdt No: E/1]

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. (See AMC E 830(c))

(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.

[Amdt No: E/1]

AMC E 830(c) Maximum Engine Over-speed

In order to comply with CS-E 830(c), it should be shown that an over-speed event does not compromise the ability of the Engine to reach its Rated 30-Second/2-Minute OEI Power.

[Amdt No: E/1]

CS-E 840 Rotor Integrity

(See AMC E 840)

(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.

[Amdt No: E/1]

AMC 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.

(2) General

(a) The demonstration of compliance with the safety objectives of CS-E 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 madeof 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) or (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) or (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) or (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.

[Amdt No: E/1]
[Amdt No: E/5]

CS-E 850 Compressor, Fan and Turbine Shafts

(See AMC E 850)

(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.

[Amdt No: E/1]

AMC E 850 Compressor, Fan and Turbine Shafts

(1) General

(a) A shaft is the system that transmits torque between the disc driving flange or the 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)(c) below). The exclusion of discs from this definition of a shaft does not preclude the specification that any Failure thereof should be Extremely Remote.

(b) Clarification of the 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 overspeed is by means of:

— disc rubbing;

— blade interference, spragging or shedding;

— Engine surge or stall;

— over-speed protection devices,

this may be substantiated by either test or validated analysis.

(b) If an applicant elects to demonstrate by test that the consequences of a shaft Failure are non-hazardous, then the test should be performed by initiating the shaft Failure under the worst-case operating conditions within the flight envelope, in any dispatchable configuration, that will maximise the rotor over-speed and the subsequent effects. If it is impractical to fully duplicate the worst-case conditions, an applicant may propose a test under suitably representative conditions to account for the worst case. Those test conditions would need to be submitted to the Agency for acceptance. In addition to the initial rotor speed, other aspects should also be taken into consideration, such as the shaft torque and the relevant Engine pressures and temperatures. Failures that are predicted to occur with a probability of Extremely Remote or less do not need to be taken into account if they meet all the requirements of CS-E 850(b)(2).

If compliance is not shown by a full Engine test, but instead by a system or component rig test(s), it should be shown that the test(s) is (are) sufficiently representative, in terms of the key characteristics of the shaft Failure and its consequences on all the relevant Engine parts and on the behaviour of subsystems, of the way the Failure would occur on a full Engine.

(c) If an applicant elects to demonstrate by validated analysis that the consequences of a shaft Failure are non-hazardous, it should be shown that all the likely Failure modes have been identified in the analysis (including the loss of loads caused by a 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 the loads on the surrounding structure of the Engine and determine whether the affected rotor components are retained substantially in their rotational plane. It should also demonstrate that the structural components, when the loads resulting from the Failure are applied, do not exceed their ultimate stress capability and not to lead to a Hazardous Engine Effect.

The analysis should be validated against an actual Engine, system or component rig test(s) and/or service events, and it should show a sufficient degree of similarity with the Engine model for which compliance is sought. This similarity should encompass all the relevant aspects of the Failure mechanism and its consequences, such as but not limited to aerodynamics, surge characteristics, engine control logic, rotor speeds and the associated acceleration characteristics, relevant rotor and stator design features, materials, clearances, etc., and should be submitted to the Agency for acceptance.

(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: a release of the complete fan or compressor moving forward and an over-speed of the turbine leading to disc burst.

Industry experience with 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 an 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;

— An oil fire around the shaft;

— Impingement of hot air on the shaft;

— A bearing Failure;

— An HCF Failure from a stress concentration feature;

— A loss of lubrication of a spline.

Further, features such as splines, oil feed holes, couplings, bearing tracks that are 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 the causes and probabilities of a 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 a bearing Failure and the desirability of provision (e.g. by maintenance techniques and/or flight instrumentation) for the detection of an 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.

[Amdt No: E/1]
[Amdt No: E/5]

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. (See AMC E 870(a)(3))

(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 maximum 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.

[Amdt No: E/1]

AMC E 870(a)(3) Exhaust Gas Over-temperature Test

In order to comply with CS-E 870(a)(3), it should be shown that an over-temperature event does not compromise the ability of the Engine to reach its Rated 30-Second/2-Minute OEI Power.

[Amdt No: E/1]

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 orthrust 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

(See AMC E 890)

(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.

[Amdt No: E/1]

AMC E 890 Thrust Reverser Tests

(1) Interpretation of CS-E 890(g):

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 the applicant's efforts to obtain it, it is acceptable that a suitably representative test reverser is fitted for the endurance test.

This addresses only the passive effects of the thrust reverser: cantilevered weight, the effect on vibrations and the 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.

[Amdt No: E/1]
[Amdt No: E/5]

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.

AMC E 910 Relighting In Flight

(1) AMC 25.903(e)(2) contains guidance that can be used to establish the objectives of the demonstration of compliance of the Engine with CS-E 910. Active coordination between the Engine type-certificate applicant and the aircraft type-certificate applicant is recommended.

(2) Either Engine altitude testing or Engine flight testing are considered to be acceptable means of demonstrating compliance. However, other appropriate tests or evidence can be proposed by the applicant.

(3) The following specific threats should be considered in the demonstration of compliance:

(a) Rapid relight after an in-flight Engine shutdown

If a functioning Engine is shut down for any reason and the pilot quickly initiates a restart command (after an initial delay of at least 5 seconds to simulate the pilot response time during an actual in-flight event), the Engine design, and in particular the Engine Control System, should not introduce any unnecessary delay in the Engine returning to the previous power or thrust setting.

(b) Rotor-lock

The potential for rotor-lock and its impact on the capability of the Engine to relight in flight should be determined. Any assessment should be based upon conservative assumptions that include but are not limited to clearances (taking into account tolerances), the initial conditions, flight effects, thermal effects and the dwell time. All the Engine rotors should be considered.

If a demonstration through flight test is proposed, it should represent a set of conservative operating assumptions for the Engine in terms of rotor-lock, or it should be supplemented by an analysis that satisfactorily addresses the conservative operating assumptions.

[Amdt No: E/5]

CS-E 920 Over-temperature Test

(See AMC E 920)

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.

[Amdt No: E/1]

AMC 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 overtemperature 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.

[Amdt No: E/1]

SUBPART F — TURBINE ENGINES - ENVIRONMENTAL AND OPERATIONAL DESIGN REQUIREMENTS

CS-E 1000 General

(See AMC E 1000)

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.

[Amdt No: E/1]

AMC 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.

[Amdt No: E/1]

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

(See AMC E 1020)

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.

[Amdt No: E/1]

AMC E 1020 Engine emissions

(1) The following format should be used for the note referred to in CS-E 1000.

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.

[Amdt No: E/1]

CS-E 1030 Time Limited Dispatch

(See AMC E 1030)

(a) If approval is sought for dispatch with Faults present in an Electronic Engine Control System (EECS), a time limited dispatch (TLD) analysis of the EECS must be carried out to determine the dispatch and maintenance intervals.

(b) For each dispatchable configuration it must be shown by test or analysis that:

(1) The Engine remains capable of meeting all CS-E specifications for:

(i) The operability aspects covered by CS-E 500(a), CS-E 750 and CS-E 745;

(ii) Re-light in flight covered by CS-E 910.

(2) The ability to control the Engine within limits is maintained;

(3) Protection is maintained against Hazardous Engine Effects, if provided solely by the EECS and shown to be necessary by the safety analyses required under CS-E 510 and CS-E 50;

(4) A means is maintained to provide necessary signals to identify EECS Faults;

(5) A further single Failure in the EECS will not produce a Hazardous Engine Effect;

(6) The Engine continues to meet its certification specifications for external threats;

(7) The proposed dispatch interval is justified.

(c) The time-weighted-average of the Full-up Configuration and all allowable dispatch configurations with Faults, must meet the Loss of Thrust Control / Loss of Power Control (LOTC/LOPC) rate for the intended application(s).

(d) The periods of time allowed prior to rectification of Faults must be documented in the appropriate manual(s).

(e) Provision must be made for any no-dispatch configuration to be indicated to the flight crew.

[Amdt No: E/1]

AMC E 1030 Time limited dispatch

(1) Guidance

This AMC provides guidance for obtaining type design approval of engines with EECS in a degraded condition with respect to redundancy when these systems are to be dispatched with

Faults present for limited time intervals before maintenance actions are required. This is commonly referred to as time limited dispatch (TLD).

The objective of TLD is to allow dispatch with certain EECS Faults present but without them compromising the prescribed fleet-wide average LOTC/LOPC rates and Hazardous Engine Effects rates.

TLD methodology is one way of managing dispatch with EECS Faults. Faults in systems or equipment other than EECS or EECS Faults other than loss of redundancy are typically addressed through the Master Minimum Equipment List (MMEL). Figure 2 illustrates the various ways of managing dispatch with engine faults.

TLD operations have been applied to EECS equipped engines used in multi-engine Aircraft applications, particularly those engines used in large transport Aeroplanes (certified under CS-25). The TLD requirements and limitations for those multi-engine Aircraft discussed in this advisory material should be acceptable in single engine Aircraft applications. However, the criteria used to establish acceptable TLD operations may need to be reviewed for those other applications. This assessment of control system reliability and availability requirements for single engine Aircraft applies to both piston and turbine engines.

(2) Definitions

Definitions may be found in CS-Definitions, CS-E 15 and AMC 20-3. For the purpose of this AMC E 1030 the following additional definitions apply:

“**Average fault exposure time**” means the average period of time between the Fault occurring and that Fault being repaired. It applies when the periodic inspection/repair maintenance approach is used. In this case the time of occurrence of the Fault may not be known. One-half of the periodic inspection interval will be used in the TLD analysis since the Fault could have occurred at any time during the interval. This assumes that the Fault rate of occurrence is constant throughout the interval. If the Fault rate is not constant throughout the interval, the average exposure time should be adjusted accordingly.

“**Dispatch interval**” means the maximum time interval approved for dispatch with Faults present in the system before corrective maintenance is required.

“**MEL maintenance approach**” means that the presence of a detected TLD approved fault in the EECS will be annunciated in the cockpit and that in the presence of the fault indication dispatch will be allowed by including the indication in the MMEL. The operator can then keep the indication listed within their approved MEL and disposition the indication as they do any other MEL items.

“**Inspection/Repair maintenance approach**” means that a periodic inspection and repair strategy has been approved to manage FADEC system faults. Within this approach, the presence of a detected TLD approved fault in the EECS need not be annunciated to the flight crew. The FADEC system must be interrogated by maintenance for the presence of faults during periodic inspections, and the faults found must be repaired within a specified time period or interval, so that the average exposure time of a fault in a particular category does not exceed the maximum average allowed exposure time for that category.

(3) Referenced Documents

ARP 5107 revB, Time-Limited-Dispatch (TLD) Analysis for Electronic Engine Control Systems, dated November 2006.

SAE World Headquarters, 400 Commonwealth Drive, Warrendale, PA 15096-0001, USA.

(4) Time Limited Dispatch Analysis

The factors and limitations used throughout this AMC, and in Tables 2 and 3 in particular, are examples and are used for illustrative purposes only. However, where supporting data and analysis are not available, the values quoted may be used as default values.

The TLD analysis should establish the dispatchable configurations. The TLD report should define the dispatchable configurations in terms of the Faults and their associated dispatch intervals. The TLD analysis, typically a Markov analysis or Fault tree analysis, should show that the fleet-wide average reliability or "average LOTC/LOPC rate," which includes full-up as well as degraded system dispatches (including those resulting from Uncovered Faults), meets the required LOTC/LOPC rate for the assumed installation (see also AMC 20-3).

The TLD analysis that substantiates compliance with the required LOTC/LOPC rate should be summarised in a graph. An example of such a graph is shown in Figure 1. The ordinates of the graph should be the estimate of fleet-wide average LOTC/LOPC rate of the EECS versus the dispatch interval(s) (in hours) for the EECS Faults.

If dispatchable EECS Faults have been grouped into two categories, a short-time dispatch (or repair) category and a long time dispatch (or repair) category (see paragraph (6) below), the ordinate of the graph should show a long time dispatch interval of at least twice the length of time of the dispatch interval being requested. When calculating the LOTC/LOPC rate as a function of the long time dispatch interval, the assumed short-time dispatch interval should be twice the requested short-time dispatch interval. This factor of two is used to cover uncertainties in the analysis itself.

In the TLD analysis, all Uncovered Faults should be assumed to lead to LOTC/LOPC unless it can be shown that they do not directly result in an LOTC/LOPC. The TLD analysis should provide the rationale and substantiation for the Failure rates used for Uncovered Faults.

(5) Certification specifications for all dispatchable configurations.

(a) CS-E 1030(b) and (c) prescribes the requirements for all dispatchable configurations.

(b) CS-E 1030(b)(3) is directed at protection systems within the EECS that provide the sole means of mitigation from Hazardous Engine Effects. There may be some cases that have a degree of protection from other sources. Such cases may best be addressed through the MMEL rather than the TLD.

(c) CS-E 1030(b)(5) stipulates that when dispatching with single or multiple Faults, there can be no further single Failure in the Engine Control System that would create a Hazardous Engine Effect. For example, it is necessary to ensure that the over-speed protection system function is operational at dispatch to guard against a Hazardous Engine Effect resulting from a single additional Fault driving fuel flow upwards.

(d) CS-E 1030(b)(6) requires that the applicant shows that the Engine, in all dispatchable configurations, continues to operate satisfactorily in the external threat levels for the system and remain compliant with the corresponding certification specifications. The Engine in each permitted TLD configuration should maintain the capability of operating through the external threats considered during Engine certification e.g. icing, rain, hail, birds, EMI, HIRF and lightning.

Relative to HIRF and lightning, compliance is typically, but not always, addressed by conducting the tests in the worst-case dispatchable configuration. This worst case is often represented by single channel operation. The other external threats are typically addressed by analysis.

(e) In showing compliance with CS-E 1030(b)(7), justification of the proposed dispatch intervals should be based on a reliability analysis. The reliability analysis is typically the result of a model of the EECS, like a Markov Model or a Fault Tree Analysis, and is based largely on electronic component databases for failure rates.

A Summary Report of the Engine Control System time-limited-dispatch analysis should be prepared and made available to the installer. This report should contain the list of the non-dispatchable and time limited dispatch configurations.

A means to monitor the in-service LOTC/LOPC rate should be established. This should compare service experience of component Failures with the modes, effects, rates, and exposure times predicted in the TLD analysis. The data collected by this means may be used to support applications for changing dispatch intervals and may be incorporated into the system required by Part 21A.3.

Entry level and mature level EECSs are differentiated to consider factors not included in a reliability analysis.

A mature level system is an EECS that has achieved a stable in-service LOTC/LOPC rate that meets the required LOTC/LOPC rate for the intended application and is consistent with the analysis on which TLD approval is based. For engines installed in large transport aeroplanes this might not be achieved until 250,000 Engine flight hours in-service operation have been accumulated.

An EECS is classified as an entry-level system if it is not a mature level system.

The applicant may request alleviation from entry level classification if it has sufficiently similar systems operating in the field that have accumulated enough flight hours to establish stable behaviour over time. Such applications will be reviewed on a case-by-case basis.

A reliability analysis is typically based on electronic component databases. These databases consider components to be mature and, hence, only random Failures are considered. Failures due to design, manufacturing, quality and operating environment of the EECS, as well as maintenance errors, are not included.

Since such failures due to design, manufacturing, quality and operating environment of the EECS, as well as maintenance errors, are not covered by the reliability analysis, and because these Faults tend to be exposed and corrected only as in-service time is accumulated, the EECS is classified as an entry-level system and appropriate limitations are applied as shown in Table 2. Thus, more conservative criteria for dispatch intervals for entry-level systems are applied compared to mature level systems, even though the reliability analysis may support dispatch for a longer dispatch interval for entry-level systems.

The TLD analysis report should include a tabulation of the various proposed dispatch configurations and provide: (1) the expected frequency of occurrence of the Faults leading to those dispatchable configurations; and (2) the LOTC/LOPC rate of the system when operating in those configurations.

The report should tabulate the chosen category described in paragraph (6) for each Fault covered in the analysis. The report should also show that the exposure time chosen for the short and long time Fault categories allows the EECS to continue to meet its reliability requirements.

(6) Dispatch Categories

The dispatch intervals determined in compliance with CS-E 1030(b)(7) and (c) are usually grouped into dispatch categories.

The following are typical dispatch categories:

(a) No Dispatch. Configurations that do not comply with CS-E 1030(b) and/or (c) or do not qualify for another category should be categorised as No Dispatch.

(b) Short Time Dispatch. Configurations that comply with CS-E 1030(b) and/or (c) and satisfy the following condition should be categorised as Short Time Dispatch: the computed LOTC/LOPC rate with the Fault(s) present is less than or equal to an upper limit that has been set at 10 times the fleet-wide average reliability criteria or “average LOTC/LOPC rate” for the installation. (The LOTC/LOPC rates for different installations may be found in AMC 20-3.)

However, even if the Long Time Dispatch LOTC/LOPC rate is met, configurations where the EECS has reverted to essentially single channel operation or has lost a significant degree of redundancy should be categorised as Short Time.

(c) Long Time Dispatch. Configurations that comply with CS-E 1030(b) and/or (c) and satisfy the following condition should be categorised as Long Time Dispatch: the computed LOTC/LOPC rate with the Fault(s) present is less than or equal to 75 percent of an upper limit that has been set at 10 times the fleet-wide average reliability criteria or “average LOTC/LOPC rate” for the installation. (The LOTC/LOPC rates for different installations may be found in AMC 20-3.)

(d) Applicant defined dispatch. This category is for Faults that do not have an impact on the LOTC/LOPC rate. These Faults do not have to be included in the LOTC/LOPC analysis. It should be substantiated that these Fault conditions do not have an impact on the LOTC/LOPC rate. These configurations should be included in the TLD summary report to enable an appropriate maintenance programme to be developed.

(7) TLD Operations Associated with the “MEL Maintenance Approach” and with the “Inspection/Repair Maintenance Approach.”

The dispatch intervals for Short Time and Long Time dispatch will also depend upon the approach used in the maintenance programme. Where a “MEL Maintenance Approach” is used, and hence the time of initial occurrence of the Fault is known, the dispatch interval starts from the point in time when the MEL procedures identify the presence of the fault. In the “Inspection/Repair maintenance approach”, the Fault is assumed to have occurred half-way through the inspection interval and the dispatch interval is therefore assumed to have started accordingly from this mid-point. In each case, the analysis should support the dispatch interval(s). Table 3 shows an example of operating times for TLD Operations Associated with the “MEL Maintenance Approach” and with the “Inspection/Repair Maintenance Approach.”

(8) Declaration of approved TLD operating limitations

The approved TLD operating limitations should be declared in the manuals specified in CS-E 20(d) and CS-E 25(a), whichever is appropriate, and provided to operators as required by Part 21A.61. The approved TLD operating limitations are the times allowed for rectification of Faults. An example of the typical operating limitations for TLD is provided in Table 1. The fact that the Engine has been approved for TLD operations should be recorded in the Engine TCDS (See CS-E 40(d)).

(9) Flight Crew Indication

CS-E 1030(e) requires provisions for indication to the flight crew for no-dispatch configurations. This does not mean that indication during flight is required. Indication on the ground only is an acceptable means of compliance.

Table 1. Typical Operating Limitations for TLD

This page gives the EASA-approved time limits to operate this engine (identify engine manufacturer and model) with control system Faults present. These limits are also defined in engine report (identify report number and date), the Engine Control System Time-Limited-Dispatch Summary Report.	
Fault Category	Operational Limitation
NO DISPATCH	DISPATCH NOT ALLOWED WITH THIS CONDITION PRESENT. Note 1: There must be a flight deck display of the presence of a no dispatch condition
SHORT TIME	DISPATCH IS ALLOWED WITH SHORT TIME FAULTS PRESENT. THE MAXIMUM (AVERAGE – IF APPLICABLE) EXPOSURE TIME OF THE SYSTEM TO THESE FAULTS MUST BE LIMITED TO (insert XXX) FLIGHT HOURS. Note 2: All Faults in this short time category must be corrected within a time period, such that (a) each Fault in the group does not have an exposure time greater than (insert XXX) hours, OR (b) the average exposure time for short time Faults does not exceed (insert XXX) hours. Also, it is noted that the time limitations contained herein with respect to short time EECS Faults may only be changed with approval of the agency. — If an MEL Maintenance Approach is used for this Fault category, there should be an appropriate generic flight deck display of the presence of a short time Fault condition(s). — If a Periodic Inspection/Repair Maintenance Approach is used, the system should be inspected for short time Faults at an interval, such that if Faults are found, they can be repaired so that the average length of time that a Fault is present in the system (average fault exposure time) does not exceed the specified (insert XXX) hour limitation. Reference SAE ARP5107 revB for a more complete understanding of these maintenance approaches.
LONG TIME	DISPATCH IS ALLOWED WITH LONG TIME FAULTS PRESENT. THE MAXIMUM (AVERAGE – IF APPLICABLE) EXPOSURE TIME OF THE SYSTEM TO THESE FAULTS MUST BE LIMITED TO (insert YYY) FLIGHT HOURS. Note 3: All Faults in this long time category must be corrected within a time period, such that (a) each Fault in the group does not have an exposure time greater than (insert YYY) hours, OR (b) the average exposure time for long time Faults does not exceed (insert YYY) hours. Also, it is noted that the time limitations contained herein with respect to long time Electronic Engine Control System Faults may only be changed with approval of the agency. — If an MEL Maintenance Approach is used for this Fault category, there should be an appropriate generic flight deck display of the presence of a long time Fault condition(s). — If a Periodic Inspection/Repair Maintenance Approach is used, the system should be inspected for long time Faults at an interval, such that if Faults are found, they can be repaired so that the average length of time that a Fault is present in the system (i.e., average fault exposure time) does not exceed the specified (insert YYY) hour limitation.

Table 2. An Example of Operating Times for TLD Operations associated with the MEL maintenance approach.

Limitations on Electronic Engine Control System Operations with Faults Present

Experience Level	No Dispatch Category	Short Time Faults Category - maximum operating time	Long Time Faults Category – maximum operating time	Electronic Engine Control System Faults Not Affecting the LOTC/LOPC Rate
Entry Level	No Flight Allowed	125 Engine flight hours.	250 Engine flight hours.	(2)
Mature Level	No Flight Allowed	(1)	(1)	(2)

Notes:

(1) Times vary depending upon the results of the TLD Analysis.

(2) The time to repair should be included in an appropriate document.

Table 3. Maximum Operating Times for TLD Operations Associated with the "MEL maintenance approach" and "Inspection/Repair maintenance approach."

Limitations on Electronic Engine Control System Short Time and Long Time Operations with Faults Present

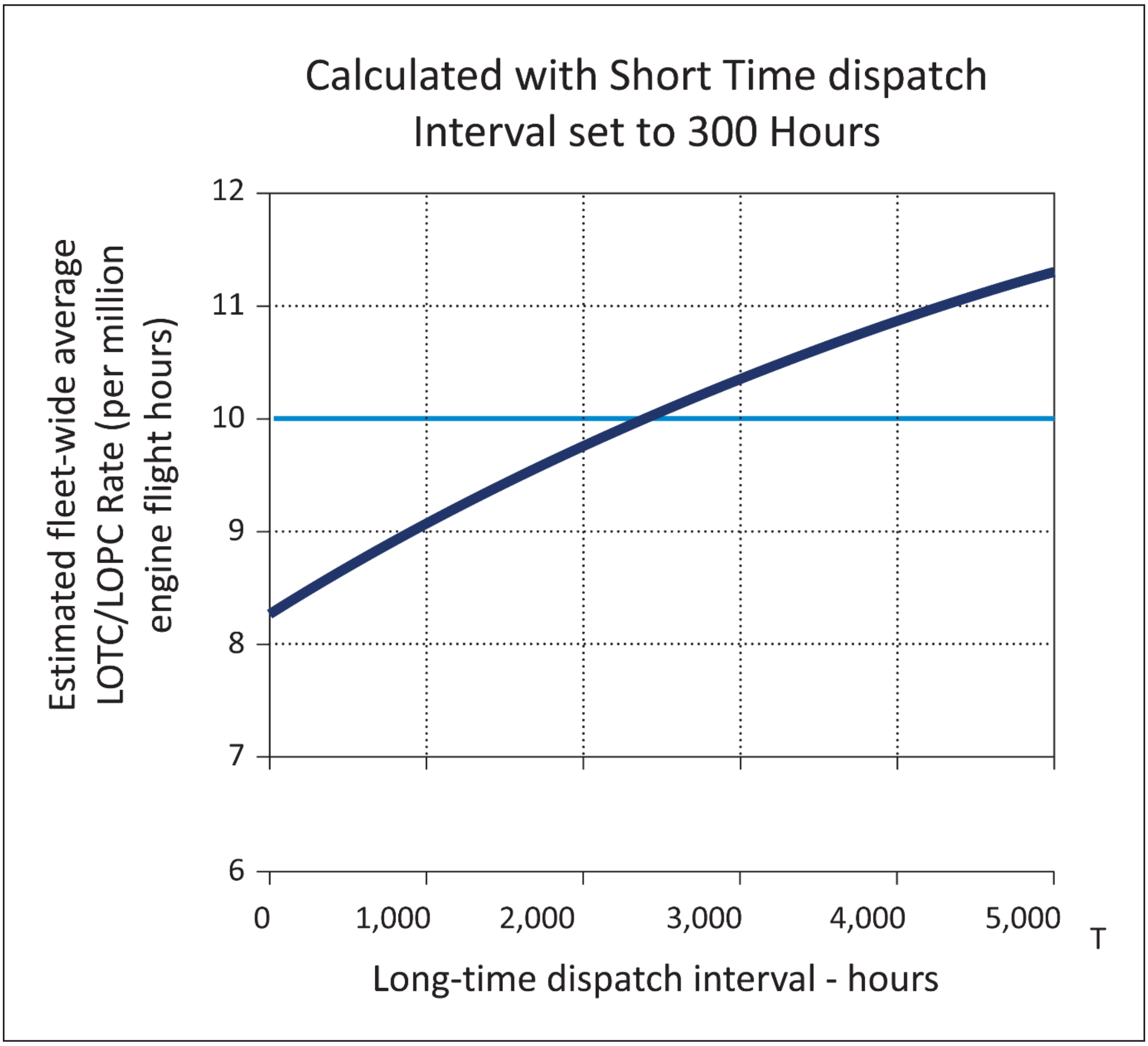
	Short Time Faults		Long Time Faults	
Experience Level	Time of Fault occurrence known and MEL maintenance approach used – max operating time with Fault(s) present	Time of Fault occurrence unknown and Periodic Inspection/ Repair maintenance approach used – max periodic inspection/repair interval	Time of Fault occurrence known and MEL maintenance approach used – max operating time with Fault(s) present	Time of Fault occurrence unknown and Periodic Inspection/ Repair maintenance approach used – max periodic inspection/repair interval
Entry Level	125 engine flight hours.	250 engine flight hours.	250 engine flight hours.	500 engine flight hours.
Mature Level	(1)	(2)	(1)	(2)

Notes:

(1) Times vary depending upon the results of the TLD Analysis.

(2) Should be equal to two times the value of note (1)

Figure 1. Example of the analysis results for a system with both Short Time Dispatch and Long Time Dispatch



In this example,

— The analysis was conducted with the Short Time dispatch interval set to 300 hours based on the assumption that the desired Short Time approval was 150 hours. This ratio is in accordance with paragraph (4)

— The target average LOTC / LOPC rate is 10 per million engine flight hours

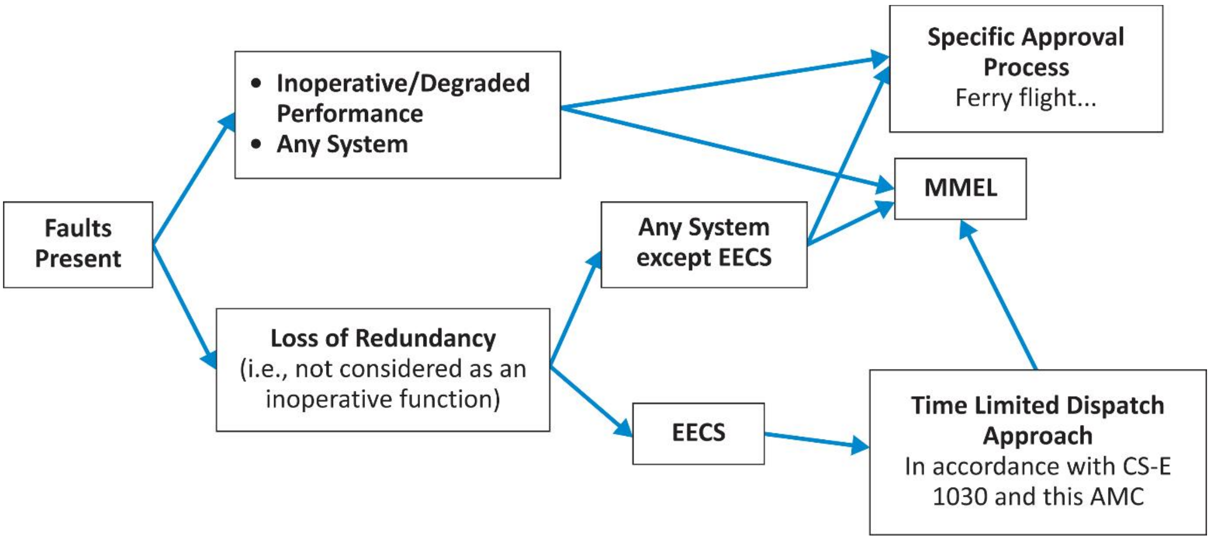
— The analysis shows that the target rate is not exceeded with a declared Short Time dispatch interval set to 150 (= 300/2) hours and the Long Time less than 2700 hours. However, the long-time interval would be limited to an operational time of 1,350 hours. Again this ratio is in accordance with paragraph (4).

— In the case of an entry level system the short-time Fault category would be limited to an operational time period of 125 hours, and Faults in the long-time interval would be limited to an operational time of 250 hours. This is in accordance with Table 2.

— If the long-time Faults were to be addressed using the periodic inspection/repair maintenance approach, the inspection/repair interval could not be longer than 500 hours for entry level system and 2,700 hours for a mature level system. This in accordance with Table 3.

— If the short-time Faults were to be addressed using the periodic inspection/repair maintenance approach, the inspection/repair interval could not be longer than 250 hours for entry level system and 300 hours for a mature level system. This in accordance with Table 3.

Figure 2: Different possible ways of managing Dispatch with Engine Faults



[Amdt No: E/1]

CS-E 1040 ETOPS

(See AMC 20-6)

In order to be approved for ETOPS capability, the engine shall achieve an IFSD rate that is compatible with the safety target associated to the maximum flight duration and the longest diversion time for which approval is being sought.

[Amdt No: E/3]

CS-E 1050 Exposure to volcanic cloud hazards

(See AMC E 1050)

(a) The susceptibility of turbine Engine features to the effects of volcanic cloud hazards must be established.

(b) Information necessary for safe operation must be provided in the relevant documentation.

[Amdt No: E/4]

AMC E 1050 Exposure to volcanic cloud hazards

Acceptable means of establishing the susceptibility of Engine features to the effects of volcanic clouds should include a combination of experience, studies, analysis, and/or testing of parts, sub-assemblies or Engines.

Information necessary for safe operation should be contained in the relevant documentation. This information may be used to assist operators in producing operational data and instructions for their flight crews when operating in, or avoiding, airspace contaminated with volcanic clouds. The information should be readily usable by operators in preparing a safety risk assessment as part of their overall management system.

A volcanic cloud comprises volcanic ash together with gases and other chemicals. Although the primary hazard is volcanic ash, other elements of the volcanic cloud may also be undesirable to operate through, and their effect on airworthiness should be assessed.

In determining the susceptibility of turbine Engine features to the effects of volcanic clouds and the necessary information to operators to allow safe Engine operation, the following points should be considered:

(1) Identify the features of the turbine Engine that are susceptible to airworthiness effects from volcanic clouds. These may include but are not limited to the following:

   a. erosion of compressor blades and other internal parts;

   b. glassy deposits on hot section parts, which can result in loss of surge margins, Engine stall, flame out, and inability to restart Engines;

   c. clogging of turbine blade cooling channels;

   d. corrosion of metallic parts;

   e. oil and fuel circuit contamination; and

   f. electrical, hydraulic and pneumatic systems.

(2) The nature and severity of effects.

(3) The related pre-flight, in-flight and post-flight precautions to be observed by the operator including any necessary amendments to Engine Manuals, Dispatch Deviation, or equivalents, required to support the operator.

(4) The recommended continued airworthiness inspections associated with operations in volcanic cloud contaminated airspace; these may take the form of Instructions for Continued Airworthiness or other advice.

[Amdt No: E/4]