Certification Specifications and Acceptable Means of Compliance for Engines (CS-E)

Amendment 7 — Change information

The European Union Aviation Safety Agency (EASA) issues amendments to the Certification Specifications and Acceptable Means of Compliance for Engines (CS-E) as consolidated documents. These documents are used for establishing the certification basis for applications submitted after the date of entry into force of the applicable amendment.

Consequently, except for a note, e.g. '[Amdt No: E/7]', under the amended certification specification (CS) or acceptable means of compliance (AMC), the consolidated CS-E (the Annex to ED Decision 2023/020/R) does not highlight the amendments introduced. To show these amendments, this change information document was created, using the following format:

— deleted text is ~~struck through~~;

— new or amended text is highlighted in blue;

— an ellipsis '[…]' indicates that the rest of the text is unchanged.

Note to the reader

In amended, and in particular in existing (that is, unchanged) text, 'Agency' *is used interchangeably with* 'EASA'*. The interchangeable use of these two terms is more apparent in the consolidated versions. Therefore, please note that both terms refer to the* 'European Union Aviation Safety Agency (EASA)'.

Item 1: Compressor and turbine blade failure

AMC E 510 is amended as follows:

AMC E 510 Safety A~~a~~nalysis

[…]

(3) Specific means.

[…]

(d) Hazardous Engine Effects

[…]

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

Uncontained debris covers 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.~~

As a general principle, if a Failure can result in debris being released with an energy and trajectory that cause an unsafe condition (refer to AMC1 21.A.3B(b)), such debris should be considered as uncontained high-energy debris causing a Hazardous Engine Effect.

Major Rotating Parts

Due to the extremely high energies involved, ~~T~~the Engine containment structures ~~is~~ are not ~~expected~~ required to contain major rotating parts should they fail ~~fracture~~. Unless containment has been demonstrated, the Failure of d~~D~~iscs, hubs, impellers, large rotating seals, and other similar large rotating components should therefore ~~always~~ be ~~considered to represent potential~~ assumed to result in uncontained high-energy debris, causing a Hazardous Engine Effect. For such parts, the Extremely Remote probability objective necessary for compliance with CS-E 510 (a)(3), can only be ensured through compliance with CS-E 515, supplemented by CS-E 840 and CS-E 850.

Blades

The Engine must be designed to ensure that debris resulting from the shedding of compressor or turbine blades, either singly or in likely combinations, will be radially contained (see CS-E 520(c)(1)).

Although blade Failures must be radially contained, it is possible that debris (typically lower-energy blade fragments) is released from the Engine, forward, rearward, or otherwise outside the Engine containment structure, as a result of the blade Failure. If this debris is released with an energy and trajectory that could cause an unsafe condition (refer to AMC1 21.A.3B(b)), such debris should be considered as uncontained high-energy debris causing a Hazardous Engine Effect. In order to demonstrate the Extremely Remote probability objective necessary for compliance with CS-E 510 (a)(3), the overall probability of occurrence of the unsafe condition should be assessed.

The integrity specifications of CS-E 515 provide some reliability benefits when applied to a blade (particularly when it forms a part of a blisk (also named integrally bladed rotor)). However, these specifications do not provide a valid basis to demonstrate an Extremely Remote blade failure probability. Blade reliability is affected by many factors. Whilst some of these are addressed by CS-E 515 (e.g. low- and high-cycle fatigue, manufacturing quality, service management), others are not (e.g. foreign object damage). Engineering judgement based on available test and service experience of comparable designs should therefore be used as the basis for a conservative estimate of blade reliability.

The likelihood of a blade failure resulting in an unsafe condition should be determined primarily based on debris energy and trajectories observed in testing and in service, along with an assessment of the trajectories which have the potential to impact the aircraft and cause an unsafe condition. Where possible, the threat to the safety of the aircraft should be assessed in coordination with the aircraft manufacturer, as this may allow some identified threats to be shown not to cause an unsafe condition when considering the particular installation. In any case, assumptions regarding the ability of the aircraft to withstand debris impact should be included in the Manuals required by CS-E 20(d).

Other Sources of Uncontained High-Energy Debris

The potential exists for other component(s) to be released from the Engine following Failure. For instance, ~~S~~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. Such Failures ~~Casings~~ may therefore need to be considered as ~~a~~ potentially causing the release of ~~for~~ high-energy debris.

In such cases, the probability that an unsafe condition results from the Failure should be assessed. An Extremely Remote probability must be demonstrated for compliance with CS-E 510 (a)(3).

[…]

CS-E 520 is amended as follows:

CS-E 520 Strength

[…]

(c) (1) The ~~strength~~ design of the Engine must be such that debris resulting from 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~~ be radially contained~~.~~ (~~S~~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~~.~~ (~~S~~see AMC E 520 (c)(2)).

[…]

AMC E 520(c)(2) is amended as follows:

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

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

— ~~F~~finite element model,

— ~~O~~out-of-balance,

— component F~~f~~ailure,

— 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 F~~f~~ailure~~.~~, and

— dynamic displacement of interface features between Engine and aircraft.

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

In addition, manufacturers should evaluate the effect of the most severe blade Failure which would not cause the Failure of the rotor structural support. The effect on the Engine and on the loads transmitted to the aircraft should be included in this evaluation.

(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, and any other differences between the test configuration and the aircraft installation (e.g. production inlet configuration replaced by test intake configuration). 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. Assumptions about the Engine installation configuration should be documented in the Manuals required by CS-E 20(d).

(4) Validation of the ~~e~~Engine model static structure is achieved by a combination of ~~e~~Engine and component tests, which include structural tests on major load path components, or by analysis, or both. The adequacy of the ~~e~~Engine model to predict rotor critical speeds and forced response behaviour is verified by measuring ~~e~~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 ~~e~~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 ~~e~~Engine test is a demonstration that the model accurately represents:

— initial blade release event loads,

— any rundown resonant response behaviour,

— frequencies,

— F~~f~~ailure sequences, and

— general ~~e~~Engine movements and displacements, including interface features between Engine and aircraft.

(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~~ aircraft and ~~e~~Engine manufacturers should mutually agree upon the definition of the model, based on test and experience.

CS-E 810 is amended as follows:

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 radially contained by the Engine after Failure and that the blade Failure will not lead to a ~~no~~ Hazardous Engine Effect ~~can arise~~ as a result of other ~~Engine~~ damage~~ likely to occur~~ before Engine ~~shut down~~ shutdown at a rate in excess of that defined as Extremely Remote. ~~following a blade Failure.~~

[…]

AMC E 810 is amended as follows:

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).

(c) In order to comply with CS-E 810(a), the threat represented by any blade Failure must be addressed. Therefore, the applicant should assess other possible blade Failure conditions (e.g. blade released at a different angular position, partial blade Failure, or release at speeds below the maximum to be approved) to ensure that the conditions of paragraphs (2)(c)(i) and (2)(c)(ii) below would be satisfied for any blade Failure. It is recognised that limitations on prediction capabilities exist, particularly in relation to the prediction of axially released debris. Engineering judgement based on available test and service experience may be used to evaluate these threats.

(d) When assessing the potential Hazardous Engine Effect resulting from other damage before Engine shutdown, the applicant should consider the long-term effects (e.g. unbalance loads) of blade Failures which would not be detected by the declared instrumentation, such as vibration detectors. If reliance is placed on Engine shutdown by the flight crew to prevent propagation to Hazardous Engine Effect, then appropriate means should be provided to ensure flight crew action and adequate instructions are required in the Engine manuals required by CS-E 20(d).

(2) Containment

[…]

(c) Condition after Tests. On completion of the tests, a complete Engine shutdown ~~power Failure~~ is acceptable, but there should be~~-~~:

(i) radial containment by the Engine and no ~~without causing~~ significant rupture or hazardous distortion of the Engine outer casing ~~or the expulsion of blades through the Engine casing or shield;~~, and

~~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~~ unsafe condition 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;~~.~~

(ii) no other Hazardous Engine Effect resulting from the blade Failure, including due to debris being released from the Engine, forward, rearward, or otherwise outside the containment structure, unless the Hazardous Engine Effect can be shown to occur at a rate not in excess of that defined as Extremely Remote (refer to AMC E 510).

Note (1): The approximate size and weight of debris released during the test, along with an estimate of the trajectory and velocity, should be recorded to determine whether the debris could result in a Hazardous Engine Effect. This data should be documented in the Manuals required by CS-E 20(d).

Note (2): The above assessment is required to demonstrate that the likelihood of a Hazardous Engine Effect due to blade Failure is low enough to be accepted for Engine certification (i.e. Extremely Remote). Additional considerations may be applied during aircraft certification to further mitigate the potential effects of blade Failures at the aircraft level.

Note (3): A Hazardous Engine Effect following a blade Failure may be found acceptable under CS-E 810(a), providing it can be shown that it occurs at a rate not in excess of that defined as Extremely Remote. However, the applicant must ensure that this Engine Effect is acceptable for compliance with other specifications of CS-E. For instance, if a blade Failure results in a shaft failure, this would be unacceptable under CS-E 850(a)(1) and/or CS-E 840(c), even though it is shown to occur at a rate not in excess of that defined as Extremely Remote.

(3) Running Following a Blade Failure

[…]

(c) *Condition after Tests*. On completion of the tests, the result should be such that there is no unsafe condition ~~hazard to the aircraft~~. A complete Engine shutdown ~~power Failure~~ is permitted.

Item 2: Assumptions — oil consumption

AMC E 30 is amended as follows:

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
[…]	[…]
Oil ~~S~~system CS-E 570	Oil(s) approved for use. Engine maximum allowable oil consumption, to enable the installer to show compliance with the aircraft certification specifications on oil systems. Note: when separate oil systems exist, the respective maximum allowable oil consumptions.
[…]	[…]

Item 3: Instrument provisions

AMC E 60 is amended as follows:

AMC E 60 Provision for I~~i~~nstruments

(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 which may be required for aircraft certification (for example, indication of engine ice protection system activation, rotor system unbalance, and fuel flow), 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.

[…]

Item 4: Piston engine failure analysis

AMC E 210 is amended as follows:

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., as applicable.

(2) Unless the effects can be shown to be adequately mitigated in the assumed installation, and appropriate assumptions are detailed in the Engine instructions for installation (as required under CS-E 30), the Failure effects considered to lead to unsafe Engine conditions beyond the normal control of the flight crew should include, but not necessarily be limited to, the following ones:

— non-containment of high-energy debris,

— uncontrolled fire,

— Failure of the Engine mount system leading to inadvertent Engine separation,

— release of the Propeller by the Engine,

— significant thrust in the opposite direction to that commanded by the pilot (e.g. unintended movement of the Propeller blades below the established minimum in-flight low-pitch position),

— complete inability to shut the Engine down.

(3) The analysis should take into account the effects of Failures of components that are part of the Engine type design on components that are not part of the Engine type design, and vice versa.

(~~2~~4) 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.

Item 5: Approval of engine use with a thrust reverser

CS-E 10 is amended as follows:

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~~ defined 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.

[…]

AMC E 10(b) is amended as follows:

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, where this is permitted, 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 500, 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.

(a) If a thrust reverser is declared as being part of the Engine type design under CS-E 20(a), it must comply with all appropriate CS-E specifications and therefore be certificated as part of the Engine.

(b) 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 must nevertheless be addressed for the approval of the use of the Engine with a thrust reverser. The thrust reverser definition must then be included in the Manuals required by CS-E 20(d). This may be a reference to the specific thrust reverser of the intended installation, or this may be limited to defining the key design characteristics that must be respected, including, but not limited to, mass, centre of gravity, aerodynamic flow lines and nozzle areas. In this case, the Engine data sheet would contain a note to the effect that the Engine may be used with the specified thrust reverser.

(c) If the engine is not intended to be used with a thrust reverser, then the Engine data sheet indicates that the use of a thrust reverser is prohibited.

(d) Whilst compliance with CS-E may rely solely on testing using a duct equivalent to a production thrust reverser, the compliance with applicable aircraft certification specifications (e.g. CS 25.934) typically requires testing of the actual Engine / thrust reverser combination.

Item 6: Fuel specifications for compression-ignition piston engines

AMC E 240 is created as follows:

AMC E 240 Ignition

The use of Special-Purpose Test Fuels for Aviation Compression-Ignition Engines per ASTM D8147 is recommended.

Item 7: Ice protection

AMC E 650 is amended as follows:

AMC E 650 Vibration Surveys

[…]

(5) Altitude, ~~and~~ Temperature and Environmental 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. These conditions should include icing (CS-E 780) and rain and hail (CS-E 790) under which sustained Engine operation is expected to occur and which may lead to high rotor imbalance, severe rotor-case interaction, higher vibratory amplitudes, or flutter. When showing compliance with CS-E 650, the applicant may take into account the tests performed to show compliance with CS-E 780 and CS-E 790 to characterise the Engine vibration behaviour.

Changes in operating conditions associated with ambient temperature, ~~and~~ altitude and environmental variations affect Engine performance ~~and~~, airflow characteristics and rotor imbalance. This can have a significant effect on aerodynamic and mechanical 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.

[…]

(9) Variations in Material Properties and Natural Frequencies

[…]

(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 (including the effects due to icing, rain and hail conditions, consistent with the corresponding certification test evidence) and other mitigating factors identified during the certification test.

[…]

(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 damping of the mount system; and

— rotor drive systems.

[…]

CS-E 780 is amended as follows:

CS-E 780 Icing Conditions

(See AMC E 780)

(a)(1) It must be established by tests, unless alternative appropriate evidence is available, that the Engine will function satisfactorily in flight and on the ground when operated throughout the applicable ~~conditions of~~ atmospheric icing conditions ~~(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~~i) ~~I~~immediate or ultimate reduction of Engine performance,

(~~2~~ii) ~~I~~increase of Engine operating temperatures,

(~~3~~iii) ~~D~~deterioration of Engine handling characteristics, and/or

(~~4~~iv) ~~M~~mechanical damage.

(2) The applicable atmospheric icing conditions must include the supercooled liquid water conditions defined in CS-Definitions Amendment 2 under 'Icing Atmospheric Conditions' for in-flight operation, freezing fog conditions for ground operation, and any additional conditions

(such as ice crystal icing conditions, supercooled large drop icing conditions, and snow conditions) applicable to the Engine air intake system in the ice protection specifications (CS 23.1093(b) of CS-23 until Amdt 4 or CS 23.2415 of CS-23 from Amdt 5, CS 25.1093(b), CS 27.1093(b), 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).

[…]

AMC E 780 is amended as follows:

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

[…]

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.

Unacceptable Mechanical Damage: Mechanical damage resulting from the testing of the Engine in icing conditions and that is in excess of the limited Engine damage defined below.

When assessing Engine damages, the applicant should fully account for cumulative damage from repeated icing conditions encounters. This should include the exposure to repeated induced vibration loads (at frequencies and magnitudes corresponding to the vibration spectrum predicted using available test evidence) and to repeated shed ice impacts.

Limited Engine damage should satisfy the following criteria:

(a) Continued In-Service Use. The applicant should evaluate any resultant Engine damage and demonstrate that it does not affect the Engine performance and operability for continued in-service use. This includes continued safe operation with no imminent failures expected, no significant power or thrust loss, and no significant aeromechanical effect.

(b) Sustained Power or Thrust Losses. The Engine should not experience any sustained power loss beyond 1.5 % (that is, the nominal accepted level considered to be within measurement capability).

(c) Temporary or Momentary Power Loss. Where possible, early coordination with the aircraft manufacturer is recommended to assess the acceptability of temporary or momentary power or thrust losses.

(d) Validation Basis. Analytical tools used to substantiate the criteria for determining acceptable damage should demonstrate an acceptable validation basis. For example, validation could utilise Engine tests or rig tests to substantiate the accuracy of results. An acceptable analytical tool validation basis includes test data which yields conservative results.

(e) Engine Damage. Damage to the Engine or Engine components as a result of icing compliance testing should not exceed the limits provided in the Instructions for Continued Airworthiness. Cumulative damage from repeated encounters should be considered a part of this assessment. Any damage findings should be brought to the attention of the Agency for approval.

(f) High Vibration. The applicant must ensure that high vibration that may occur during operation in icing conditions is assessed for the specific aircraft installation. The acceptability of high vibration with regard to its potential impact on the safety of the aircraft should be evaluated in cooperation with the aircraft manufacturer, where possible.

[…]

(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.~~

[…]

(1.6) Applicable Atmospheric Icing Conditions ~~Environments~~

Due to the potential for inadvertent icing condition encounters, t~~T~~he applicable atmospheric icing conditions ~~environments~~ always include the SLW conditions defined in CS-Definitions Amendment 2 under ‘Icing Atmospheric Conditions’, even for aircraft not approved for flight in icing conditions. The additional conditions to be addressed are dependent on the conditions applicable to the air intake system ~~are those applicable to~~ of 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~~ These conditions may include~~s atmospheric icing conditions (including freezing fog on ground)~~ ice crystal icing conditions, supercooled large drop icing conditions, 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.

[…]

(2) Supercooled Liquid Water (SLW) Icing Conditions

[…]

(2.2) Establishment of SLW 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 Amendment 2 ~~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)

[…]

(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 to simulate in-flight icing conditions, any differences in Engine operating conditions, LWC, ~~and~~ ice accretion, and shedding between the altitude condition to be simulated and the test conditions, which could affect ~~icing at the critical locations for accretion or shedding~~ the Engine behaviour in icing conditions, should be taken into account when establishing the test points to be carried out ~~conditions~~. This could involve the modification of Engine operating conditions and other test conditions of this paragraph in order to

~~generate equivalent ice accretion~~ adequately simulate all icing threats and effects which are relevant for the test conditions.

The icing threats which should be considered include but are not limited to:

— vibration;

— surge;

— flameout;

— core blockage; and

— ice impact energy and location following shedding.

For instance, if more ice would accrete at a critical location under altitude conditions, then the test conditions (e.g. LWC) may need to be adjusted. Similarly, if the rotor speed in flight would be higher, this should be considered to ensure that the Blade impact energy is at least as severe under test conditions. Furthermore, altitude effects on Engine performance, including surge and flameout margins, should be taken into account, either in the tested conditions, or through post-test assessment.

Because different Engine modules react differently to variations in altitude conditions (e.g. low pressure shaft speeds v high pressure shaft speeds), the various icing threats are also impacted differently by varying altitude conditions. Consequently, this may require running multiple test points to simulate all relevant/applicable icing threats associated with a single atmospheric condition.

In that context, a single atmospheric condition could either be:

— a single standard test point as listed in Table 1 above, or

— a single test point identified by a CPA (refer to AMC E 780 (2.1)).

Effects which should be considered and corrected for include but are not limited to:

— Engine shaft speeds;

— by-pass ratio;

— 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.~~

The effects of density, hardness, and adhesion strength of the ice as it sheds should be assessed in 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.

(2.3) Establishment of Test Points for Ground Operation

[…]

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 (Note 1)	-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 (Note 2) ~~(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.

Note 1: These conditions are provided as a guide, but they may need to be modified to address the requirements applicable to the intended installation. For instance, snow concentrations may need to be increased to address blowing snow. When applicable, the applicants should consider the material provided in AMC 25.1093(a) 1.6 (Falling and Blowing Snow).

Note 2: As per CS-E 780, those conditions only need to be considered if applicable to the Engine air intake system in the ice protection specifications of the Certification Specifications applicable to the aircraft on which the Engine is to be installed.

(2.4) Test results

Due to the repetitive nature of icing condition encounters during in-service operation, which may extend for longer duration than during the icing test campaign, the applicant should demonstrate that no unacceptable mechanical damage will occur as a result of prolonged operation with levels of high vibration due to repetitive icing encounters.

(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 accretion~~s~~.

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, such as frame leading edges especially if upstream vanes direct or concentrate impingement upon the frame leading edge;

(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), such as flow path concavity;

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

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

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

(vi~~i~~) variable geometry with stagnation points outside the flow path that could lead to accreted ice re-entering the flow path upon geometry movement ~~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.~~

(vii) airfoils with low tolerance to soft body damage immediately downstream of a potential ice accretion location;

(viii) Engine control sensors and measurement systems which may be affected by operation in ice crystal conditions and which may result in unacceptable control system response;

(ix) negative air temperature gradient along the gas path resulting in a potential accretion site downstream of melting; and

(x) surfaces with low temperatures downstream of or coincident with where melting could have occurred.

[…]

(6) ~~Inadvertent Entry into Icing Conditions or Delayed IPS Activation~~ Ice Protection Systems Activation and Deactivation

The ice ingestion demonstration of paragraph (4) of this AMC addresses the threat of ice released from ice-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), whether the activation is automatic or manual.

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

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

In lack of other evidence, a delay of ~~two~~ 2 minutes to switch on the IPS should be assumed. For thermal IPS, the time for the IPS to warm up should be added.

Consideration should also be given to the effects of delays in deactivating an ice protection system after leaving icing conditions, or to inadvertent operation of an ice protection system in the absence of icing conditions. These effects should not compromise the mechanical integrity of the Engine or the effectiveness of the ice protection system (e.g. due to overheating and damage of certain components).

[…]

(7) Instructions for installing and operating the Engine

The applicant should declare all identified limitations, and all Engine conditions observed during Engine certification icing tests, to the installer in the manuals required by CS-E 20(d) ~~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 with ~~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;

— any damage observed following the icing tests considered acceptable by the applicant and by the Agency;

— 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.

Item 8: Damage tolerance of critical parts

AMC E 515(3)(d)(v) is amended as follows:

AMC E 515 Engine Critical Parts

[…]

(3) *Means for defining an Engineering Plan*

[…]

(d) *Establishment of the Approved Life ~~-~~— Rotating parts*

[…]

The major elements of the analysis are:

[…]

(v) *Damage Tolerance ~~Assessment~~.*

1. General

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 builtin 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 a part of the design process and not a method for returning cracked parts to service whilst monitoring crack growth.

2. Anomaly types

Material anomalies.

Material anomalies include 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 or activated by the material heat treatment or 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. Activated anomalies include material anomalies which become more crack-like or are opened during heat treatment or when disturbed by metal removal methods.

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.

3. Elements of a Damage Tolerance Assessment.

The damage tolerance assessment should include the two following elements:

— The establishment of a minimum level of damage tolerance capability for each critical component using either a probabilistic approach or a deterministic approach. These should address the anomaly types described in paragraph 2. above,

— The establishment of a service damage monitoring process in order to gain assurance that service damage is consistent with serviceable and repairable limits and to initiate appropriate action if damage is found outside these established limits.

4. Establishment of a minimum level of damage tolerance capability.

a. Probabilistic approach.

Probabilistic damage tolerance approaches exist to address anomalies described in paragraph (3)(d)(v)(2) above. Hereafter are some examples:

— FAA Advisory Circular (AC) 33.70-2, Damage Tolerance of Hole Features in High Energy Turbine Rotors, includes an example of the probabilistic approach that applies to manufacturing anomalies in hole features.

— FAA Advisory Circular (AC) 33.70-3, Damage Tolerance for Material Anomalies in Titanium Life-Limited Turbine Engine Rotors, includes an example of the probabilistic approach that applies to hard alpha material anomalies in titanium alloy rotor components.

The Damage Tolerance Assessment ~~process~~ probabilistic approach 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 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.).

i. Risk Prediction and Allowable Risk.

The above elements of the Damage Tolerance Assessment are integrated in a probabilistic risk assessment which predicts the relative probability of Failure (POF) for each part. The predicted POF is compared to allowable design target risk (DTR) values. The allowable DTR values may be found in published FAA ACs which address specific materials and/or anomaly types (e.g. values provided in FAA AC 33.70-2 Damage Tolerance of Hole Features in High-Energy Turbine Engine Rotors). Designs that satisfy the allowable values will be considered to be in compliance with the 'appropriate damage tolerance assessment' required by CS-E 515(a). Manufacturers may use a variety of options to reduce the POF and achieve the level of relative risk allowed by the probabilistic risk assessment. These options include but are not limited to:

— component redesign,

— material change,

— material process improvements,

— manufacturing process improvements,

— manufacturing inspection improvements,

— enhanced in-service inspections, and

— life limit reduction.

When an applicant chooses to pursue a published industry or company-specific probabilistic damage tolerance approach, the applicant should provide and agree with the Agency such data that has an impact on the risk levels resulting from this approach. This data may include but is not limited to the following items as appropriate to the component:

— Anomaly size/frequency distribution

— Fleet utilisation

— Maintenance practices

— Production/Assembly processes

— Anomaly growth characteristics (crack initiation (incubation), crack propagation, or a combination of crack initiation and crack propagation)

— Inspection techniques and intervals

— Inspection Probability Of Detection (POD)

The process utilised to carry out the probabilistic approach needs to be agreed with the Agency.

The objectives in terms of probabilities of Failures of Critical Parts having Hazardous Engine Effects are defined in CS-E 510(a)(3).

Note: An individual Failure is considered to be a Failure occurring anywhere in the engine as a result of a damage mechanism intended to be addressed by the damage tolerance assessment and it is not related to the Failure of an individual component. Therefore, the individual Failure probability objective at the component level is a portion of the probability objective defined in CS-E 510 (a)(3) for an individual Failure occurring anywhere in the Engine as a result of a given cause.

The applicant should demonstrate that adequate processes are in place in order to validate the assumptions utilised in the analysis. These assumptions should be validated throughout the life of the certified product.

Any departure from the original assumptions will require the applicant to repeat the risk assessment, and communicate the results to the Agency.

If the revised risk assessment shows that the safety objectives of CS-E 510(a)(3) can no longer be met, then corrective action must be implemented in accordance with point 21.A.3 of Part 21.

~~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”~~

The Agency 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, fatigue testing of simulated damage, 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.~~

b. Deterministic approach applied to surface damage tolerance.

If the required input data (anomaly size and frequency distributions, etc.) is not available to fully implement the probabilistic approach for manufacturing- and service-induced anomaly types, the applicant may use the following deterministic approach, which ensures a minimum level of damage tolerance.

An analysis should be provided that demonstrates that the surface fracture mechanics life for all Critical Parts exceeds 3 000 representative flight cycles, or 50 % of the Approved Life of the part, whichever is less.

This analysis should take account of the following assumptions:

— Analyses performed using Linear Elastic Fracture Mechanics;

— Initial anomaly size is one of the following:

- 0.762 mm × 0.381 mm (0.030 inches × 0.015 inches) for an assumed (semi-circular) surface anomaly;

- 0.381 mm × 0.381 mm (0.015 inches × 0.015 inches) for an assumed (quarter-circular) corner anomaly;

— Any additional assumptions used in this analysis (i.e. material properties, reference engine cycle, operating environment and its effect on the stress cycle, use of compressive residual stresses, use of inelastic stresses, etc.);

— Anomalies should be treated as sharp propagating cracks from the first stress cycle, placed in the most unfavourable orientation and location.

5. Establishment of a Service Damage Monitoring Process.

The overall objective of service damage monitoring is to review data obtained from field operation of the Engine type design to determine whether there are anomalous conditions which require corrective action(s). Appropriate action(s) may include the assessment of the impact of damage observed on one part/location on other parts/locations.

Applicants should determine whether the damage that has been detected is consistent with the serviceable and repairable limits and determine whether additional actions are required to prevent Failure and rectify any potential unsafe condition which may be identified.

The establishment of a service damage monitoring process consists of the following:

a. Determine the serviceable and repairable damage limits using a process approved by the Agency and summarised within the service management plan. Damage size limits should be a function of part, part location, and damage type. Damage should include but may not be limited to nicks, dents, scratches and cracks. The serviceable and repairable limits must be published in the Instructions for Continued Airworthiness.

b. Establish a monitoring process to record damage that meets all of the following criteria:

— is inconsistent with or exceeds the repairable limits,

— is made available to the type certificate holder (TCH) or supplemental type certificate holder (STCH) through an appropriate reporting system.

The applicant should, as appropriate, consider the effectiveness of existing reporting systems as new product types/operations are introduced.

Document the monitoring process in the service management plan. This activity should record at a minimum the damage size, type and location observed during service inspections for each Critical Part.

c. Assess damage meeting the criteria defined in b. above. This assessment should consider:

— the impact of the observed damage on the life of the damaged part,

— the likelihood for recurrence of similar damage,

— whether the damage has been determined as having flown,

— whether the damage is likely to be undetected before the part is released to service,

— recommended corrective actions to identify/prevent/eliminate the source of the damage.

During the service life of the part, a summary of the damage information obtained by the service damage monitoring process, as well as the corrective actions implemented, should be made available to the Agency.

(e) Establishment of the Approved Life ~~-~~— Static, pressure loaded parts

[…]

Item 9: Engine critical parts — static pressure loaded parts

AMC E 515(e)(i) is amended as follows:

AMC E 515 Engine Critical Parts

[…]

(3) *Means for defining an Engineering Plan*

[…]

(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.

If the Approved Life of the part includes a portion of the residual crack growth life, the compliance with applicable certification specifications should be demonstrated assuming the presence of the maximum predicted size crack that can occur within the Approved Life of the part. In some cases, it may be necessary to limit the crack size allowed in service in order to demonstrate compliance with certification specifications other than CS-E 515, such as the blade containment requirement in CS-E 810.

[…]

Item 10: Various corrections

CS-E 10 is amended as follows:

CS-E 10 Applicability

[…]

(c) The specifications of ~~s~~Subparts A, B and C apply to Piston Engines. Any necessary variations of the specifications of ~~s~~Subparts B and C for Piston Engines intended for use in rotorcraft will be decided in accordance with ~~21.A.16~~ point 21.B.75 of Part 21.

[…]

CS-E 25 is amended as follows:

CS-E 25 Instructions for Continued Airworthiness

(See AMC E 25)

(a) ~~In accordance with 21.A.61(a),~~ M~~m~~anual(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.

[…]

CS-E 40 is amended as follows:

CS-E 40 Ratings

[…]

(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 point 21.A.41 of Part 21. 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.

[…]

CS-E 120 is amended as follows:

CS-E 120 Identification

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

[…]

CS-E 160 is amended as follows:

CS-E 160 Tests - History

(a) In order to enable compliance with point ~~21.A.21(c)(3)~~ 21.A.20(d)2 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.

[…]

CS-E 210 Failure Analysis

(a) […]

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

AMC E 650 is amended as follows:

AMC E 650 Vibration Surveys

[…]

(15) Inspection Specifications

[…]. Inspection of type design hardware in accordance with the requirements of point 21.A.33 of ~~Part-21~~ 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.