European Union Aviation Safety Agency

Explanatory Note to ED Decision 2023/020/R

in accordance with Article 4(2) of MB Decision 01-2022

Regular update of CS-E

'CS-E — Amendment 7'

RMT.0184

EXECUTIVE SUMMARY

This Decision amends CS-E to improve the certification of turbine engines to better assess and mitigate the potential hazards from blade failures, especially by better integrating the analysis and identification of the potential threats to the aircraft on which the engine is to be installed. The objective is to ensure a more robust certification process and decrease the risk of substantial aircraft damage and fatalities.

In addition, CS-E is amended to reflect the state of the art of engine certification, improve the harmonisation of CS-E with the Federal Aviation Administration (FAA) regulations and make some editorial corrections. To that end, amendments are made in the following areas: assumptions — oil consumption, instrument provisions, piston engine failure analysis, approval of engine use with a thrust reverser, fuel specifications for compression-ignition piston engines, ice protection, damage tolerance of critical parts, and engine critical parts — static pressure loaded parts.

The regulatory material is expected to improve safety, cause no social or environmental impacts, and provide economic benefits by streamlining the certification process.

REGULATION(S) TO BE AMENDED/ISSUED	**ED DECISION TO BE AMENDED**
N/A	ED Decision 2003/009/RM

AFFECTED STAKEHOLDERS
Engine manufacturers

WORKING METHODS

Development	**Impact assessment(s)**	**Consultation**
By EASA	Light	Public – NPA

RELATED DOCUMENTS/INFORMATION

— ToR RMT.0184, issued on 27 July 2015
— NPA 2021-13
— CRD 2021-13

PLANNING MILESTONES: Refer to the latest edition of the EPAS Volume II.

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1. About this Decision

1.1. How this regulatory material was developed

The European Union Aviation Safety Agency (EASA) identified the need to mitigate some safety risks and reflect the state of the art of engine certification in CS-E and, after having assessed the impacts of the possible intervention actions, identified rulemaking as the necessary intervention action.

This rulemaking activity is included in Volume II of the European Plan for Aviation Safety (EPAS) for 2023-2025 under Rulemaking Task RMT.0184.

EASA developed this Decision in line with Regulation (EU) 2018/1139[1] (the 'Basic Regulation') and the Rulemaking Procedure[2], as well as in accordance with the objectives and working methods described in the Terms of Reference (ToR) for this RMT[3].

The draft regulatory material was consulted in accordance with the ToR for this RMT with Notice of Proposed Amendment (NPA) 2021-13.

EASA reviewed the comments received and duly considered them for the preparation of the regulatory material presented here.

1 Regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency, and amending Regulations (EC) No 2111/2005, (EC) No 1008/2008, (EU) No 996/2010, (EU) No 376/2014 and Directives 2014/30/EU and 2014/53/EU of the European Parliament and of the Council, and repealing Regulations (EC) No 552/2004 and (EC) No 216/2008 of the European Parliament and of the Council and Council Regulation (EEC) No 3922/91 (OJ L 212, 22.8.2018, p. 1) (https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1535612134845&uri=CELEX:32018R1139).

2 EASA is bound to follow a structured rulemaking process as required by Article 115(1) of Regulation (EU) 2018/1139. Such a process has been adopted by the EASA Management Board (MB) and is referred to as the 'Rulemaking Procedure'. See MB Decision No 01-2022 of 2 May 2022 on the procedure to be applied by EASA for the issuing of opinions, certification specifications and other detailed specifications, acceptable means of compliance and guidance material ('Rulemaking Procedure'), and repealing Management Board Decision No 18-2015 (https://www.easa.europa.eu/the-agency/management-board/decisions/easa-mb-decision-01-2022-rulemaking-procedure-repealing-mb).

3 ToR RMT.0184

2. In summary — why and what

2.1. Why we need to act

CSs and AMC need to be updated regularly to ensure that they are fit for purpose, cost-effective and can be implemented in practice.

Regular updates are issued when relevant data is available following an update of industry standards, feedback from certification activities or minor issues raised by the stakeholders.

Lessons learnt from accident and incident investigations may also be addressed in regular updates when the topic is not complex and not controversial.

Item 1: Compressor and turbine blade failure

The analysis and lessons learnt from occurrences involving the failure of fan blades indicates that the certification of turbofan engines could be improved to better assess and mitigate the potential hazards from such blade failures, especially by better integrating the analysis and identification of the potential threats to the aircraft on which the engine is to be installed.

On 17 April 2018, Southwest Airlines flight 1380, a Boeing 737-7H4, experienced a left engine failure while climbing through flight level 320 en-route to the flight's assigned cruise altitude. The flight had departed from LaGuardia Airport, New York, about 30 minutes earlier. As a result of the engine failure, the flight crew conducted an emergency descent and diverted to the Philadelphia International Airport (PHL), Pennsylvania. Portions of the left engine inlet and fan cowl separated from the aeroplane, and fragments from the inlet and fan cowl struck the left wing, the left-side fuselage and the left horizontal stabiliser. One fan cowl fragment impacted the left-side fuselage near a cabin window, and the window departed from the aeroplane, which resulted in a rapid depressurisation. The aeroplane landed safely at PHL about 17 minutes after the engine failure occurred. Of the 144 passengers and 5 crew members aboard the aeroplane, 1 passenger received fatal injuries and 8 passengers received minor injuries. The aeroplane was substantially damaged.

The National Transportation Safety Board (NTSB) determined that the probable cause of this accident was a low-cycle fatigue crack in the dovetail of fan blade No 13, which resulted in the fan blade separating in flight and impacting the engine fan case at a location that was critical to the structural integrity and performance of the fan cowl structure. This impact led to the in-flight separation of fan cowl components, including the inboard fan cowl aft latch keeper, which struck the fuselage near a cabin window and caused the window to depart from the aeroplane, the cabin to rapidly depressurise and the passenger fatality.

The NTSB issued the following safety recommendation (UNST-2019-007) to EASA (an equivalent recommendation was also issued to the FAA):

'Expand your certification requirements for transport-category airplanes and aircraft engines to mandate that airplane and engine manufacturers work collaboratively to:

(1) analyze all critical fan blade impact locations for all engine operating conditions, the resulting fan blade fragmentation, and the effects of the fan-blade-out-generated loads on the nacelle structure; and

(2) develop a method to ensure that the analysis findings are fully accounted for in the design of the nacelle structure and its components.'

EASA analysed the existing certification specifications and acceptable means of compliance applicable to turbine engines in CS-E and identified the following issues.

(a) The potential release of uncontained debris in the engine forward and rearward directions is not sufficiently addressed. It is limited to a provision in AMC E 810 ('Compressor and Turbine Blade Failure') relating to the blade containment test, requiring the reporting of the estimated size, weight, trajectory and velocity of any debris ejected from the intake or exhaust during the test.

(b) CS-E 520(c)(2) requires that validated data (from analysis or test or both) be established and provided to enable the aircraft manufacturer to ascertain the forces that could be imposed on the aircraft structure and systems as a consequence of the 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 ('Compressor and Turbine Blade Failure'). AMC E 520(c)(2) provides some guidance and acceptable means of compliance regarding the engine model validation. However, it appears that the displacements and loads transmitted to the engine nacelle structure (certified at the aircraft level) have not been sufficiently addressed during the certification of some engines and aircraft.

Item 2: Assumptions — oil consumption

AMC E 30 provides in its Table 1 the assumptions which should normally be provided in the engine instructions for installation, as required under CS-E 30.

Regarding the oil system, Table 1 indicates the 'oil(s) approved for use'.

However, the oil consumption and the flight duration are also important assumptions that should be listed in Table 1.

Item 3: Instrument provisions

CS-E 60 requires that provision be made for the installation of instrumentation necessary to ensure operation in compliance with the engine operating limitations.

According to AMC E 60, 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.

Such instrumentation typically includes the indication of the ice protection system activation, rotor system unbalance and fuel flow. This is not mentioned in AMC E 60, and EASA has identified the need to clarify this point.

Item 4: Piston engine failure analysis

CS-E 210(a) requires a failure analysis of the engine, including its control system, in order to demonstrate 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.

CS-E 210(b) specifies that this failure analysis may depend on assumed installation conditions and requires that such assumptions are stated in the analysis.

AMC E 210 specifies that 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.'

However, there is currently no AMC provision explaining how to interpret the CS-E 210(a) specification 'unsafe Engine conditions beyond the normal control of the flight crew'.

Therefore, during certification projects, a generic means of compliance (MoC) has been agreed with applicants via certification review items (CRIs) (entitled 'CS-E 210 Failure Analysis'), in order to define the kinds of failure conditions to be taken into account. This MoC is considered mature enough to be introduced in AMC E 210.

Item 5: Approval of engine use with a thrust reverser

On many aeroplanes, the turbine engines are equipped with a thrust reverser. This thrust reverser is usually not part of the engine type design but is certificated with the aeroplane.

In many cases, the engine type certificate applicant does not plan to test the engine with the aeroplane thrust reverser during engine certification. Instead, an equivalent duct is used that simulates the mechanical and aerodynamic characteristics of a representative production thrust reverser. This duct generally cannot simulate all the thrust reverser functions.

EASA published Certification Memorandum CM-PIFS-002 Issue 1, dated 8 March 2012, entitled 'Approval of Engine Use with a Thrust Reverser'. This Certification Memorandum (CM) describes how it can be allowed that a turbine engine is equipped and used with a thrust reverser, even when this thrust reverser is not part of the engine type design.

EASA considers that the content of this CM is sufficiently mature to be reflected in CS-E.

Item 6: Fuel specifications for compression-ignition piston engines

EASA recommends that applicants for certification of compression-ignition piston engines use test fuels that comply with ASTM standard D8147 Standard Specification for Special-Purpose Test Fuels for Aviation Compression-Ignition Engines.

This is however not indicated in CS-E.

Item 7: Ice protection

Icing ground tests. These tests are performed at lower bypass ratio conditions than actual altitude conditions, which is not representative for operability and surges. According to AMC E 780 paragraph (1.4), applicants should justify that non-altitude conditions are not less severe for both ice accretion and shedding than the equivalent altitude test points, but it does not address the engine operability.

Icing conditions. EASA has identified the need to bring clarifications on the range of icing conditions that are applicable under AMC E 780.

Icing-induced vibrations. EASA has identified the need to clarify the effects to be taken into account when showing compliance with CS E 100(c) for turbine engines. This includes, among other items, the effect of ice accretion and ingestion.

Use of ice protection systems. EASA has identified the need to clarify the needs to be addressed as a consequence of delayed activation or deactivation of ice protection systems in AMC E 780 (Section 6).

Item 8: Damage tolerance of critical parts

EASA had previously identified the need for clarification for compliance demonstration based on both deterministic and probabilistic surface damage tolerance, and this topic has been addressed under EASA CM-PIFS-007 Issue 1, dated 22 February 2013, entitled 'Engine Critical Parts – Damage Tolerance Assessment – Manufacturing and Surface Induced Anomalies'.

The content of this CM can now be introduced in CS-E.

Item 9: Engine critical parts — static pressure loaded parts

AMC E 515 ('Engine Critical Parts') paragraph (3) deals with the definition of an engineering plan, which is one of the three elements required by CS-E 515 to ensure the integrity of engine critical parts.

Sub-paragraph (e) of this paragraph addresses the establishment of the approved life for static pressure loaded parts.

Unlike FAA Advisory Circular (AC) 33.70-1 ('Guidance material for aircraft engine life-limited parts requirements'), AMC E 515(3)(e) does not indicate that the CS-E certification specifications applicable to static pressure loaded parts should be complied with assuming the presence of the maximum predicted size crack that can occur within the approved life of the part, and that it may be necessary to limit the crack size allowed in service to comply with certification specifications other than CS-E 515.

EASA agrees with the AC 33.70-1 guidance material on this topic (provided in Section 8(e)), which is also accepted by the industry. There is therefore an opportunity to harmonise AMC E 515 with FAA AC 33.70-1 to improve the efficiency of the EASA certification process.

Item 10: Various corrections

— **Reference to Part 21 in CS-E 10.** CS-E 10(c) refers to point 21.A.16 of Part 21, which has been deleted and replaced by the new point 21.B.75 through Regulation (EU) 2019/897[4].

— **Reference to Part 21 in CS-E 25.** CS-E 25(a) refers to point 21.A.61(a) of Part 21, which has been deleted and replaced by the new point 21.A.7 through Regulation (EU) 2021/699[5].

4 Commission Delegated Regulation (EU) 2019/897 of 12 March 2019 amending Regulation (EU) No 748/2012 as regards the inclusion of risk-based compliance verification in Annex I and the implementation of requirements for environmental protection (OJ L 144, 3.6.2019, p. 1) (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX %3A32019R0897&qid=1634744922897).

5 Commission Delegated Regulation (EU) 2021/699 of 21 December 2020 amending and correcting Regulation (EU) No 748/2012 as regards the instructions for continued airworthiness, the production of parts to be used during maintenance and the consideration of ageing aircraft aspects during certification (OJ L 145, 28.4.2021, p. 1) (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX %3A32021R0699&qid=1634745081017).

— **Reference to Part 21 in CS-E 160.** CS-E 160(a) refers to point 21.A.21(c)(3) of Part 21. Point 21.A.21 has been amended through Regulation (EU) 2019/897 and the content of point 21.A.21(c)(3) has been relocated in point 21.A.20(d)2.

2.2. What we want to achieve — objectives

The overall objectives of the EASA system are defined in Article 1 of the Basic Regulation. This NPA will contribute to the achievement of the overall objectives by addressing the issues outlined in Section 2.1.

The specific objective of this proposal is to amend CS-E based on the above selection of non-complex, non-controversial and mature subjects, with the ultimate goal of increasing safety.

2.3. How we want to achieve it — overview of the amendments

Item 1: Compressor and turbine blade failure

(a) CS-E 520 (‘Strength’), paragraph (c)(1) is amended to require that compressor and turbine blades are ‘radially’ contained after their failure, instead of the current requirement to demonstrate no hazardous engine effect. This better reflects the actual design and certification practices regarding engine casing strength. The effects of secondary effects associated with the blade failure are addressed by CS-E 810 (‘Compressor and Turbine Blade Failure’).

(b) AMC E 520(c)(2) (‘Engine Model Validation’) is amended to:

(1) add provisions clarifying that the engine model validated data (to be provided to the aircraft manufacturer) includes the dynamic displacement of interface features between engine and aircraft;

(2) clarify, regarding engines designed for the failure of the rotor support structure following a blade failure, that engine manufacturers should also evaluate the effect of the most severe blade failure which would not cause the failure of the rotor structural support, and that the effect on the engine and on the loads transmitted to the aircraft should be included in this evaluation; and

(3) specify that the engine model validation should consider any differences between the test configuration and the aircraft installation.

(c) AMC E 510 (‘Safety Analysis’), paragraph (3)(d)(iii) on ‘Hazardous Engine Effects – Non-containment of high-energy debris’ is amended to specify:

(1) when debris, released after a failure, should be considered as uncontained high-energy debris causing a hazardous engine effect, i.e. when this can cause an unsafe condition;

(2) how applicants should address the threat posed by major rotating parts (which are not required to be contained);

(3) how applicants should address the threat posed by blade failure debris. A link is made with CS-E 520(c)(1) regarding the requirement for debris radial containment. In addition, the case where blade failure debris is released forward, rearward or otherwise outside the engine containment structure is addressed. The need to assess the hazard at the aircraft level is included and this assessment should be performed as far as possible in coordination with the aircraft manufacturer;

(4) how applicants should address other sources of uncontained high-energy debris, such as high-pressure casing failures.

(d) CS-E 810 ('Compressor and Turbine Blade Failure') is amended to align with CS-E 520(c)(1) regarding the 'radial' containment requirement and clarify that hazardous engine effects that may be triggered by the blade failure must not occur at a rate greater than that defined as extremely remote. The current wording, which requires demonstrating that no hazardous engine effect can happen, is not considered as adequate, as some debris may be released outside the radial containment area and this must be addressed and mitigated.

(e) AMC E 810 ('Compressor and Turbine Blade Failure'), paragraph (2)(c), relating to the conditions after the containment test, is amended to:

(1) reflect the amendments made to CS-E 810 and AMC E 510;

(2) specify that applicants should assess the threats represented by blade failure conditions other than the test conditions;

(3) specify that the assessment of potential hazardous engine effect resulting from other damage before engine shutdown should consider the long-term effects (e.g. unbalance loads) of blade failures which would not be detected by the declared instrumentation;

(4) specify that the assessment of potential hazardous engine effect resulting from the blade failure should consider debris being released from the engine, forward, rearward or otherwise outside the containment structure, thereby also referring to AMC E 510;

(5) remind the applicability of other CS-E specifications according to which some failures that could be triggered after a blade failure are not acceptable.

Item 2: Assumptions — oil consumption

Table 1 of AMC E 30 is amended to add the engine maximum allowable oil consumption for the oil system.

Item 3: Instrument provisions

AMC E 60 is amended to mention some examples of instrumentation required for aircraft certification (indication of engine ice protection system activation, rotor system unbalance, and fuel flow).

Item 4: Piston engine failure analysis

AMC E 210 is amended to reflect the content of the above-mentioned generic MoC CRI (see Section 2.1). The amendment provides a (non-exhaustive) list of failure effects that, unless demonstrated differently by the applicant, are considered to lead to unsafe engine conditions beyond the normal control of the flight crew. In addition, this amendment specifies that the failure 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.

Item 5: Approval of engine use with a thrust reverser

CS-E 10(b) and AMC E 10(b) are amended to better specify how the approval for the use of an engine thrust reverser has to be handled and introduce the guidance provided in CM-PIFS-002 Issue 1. The amendment addresses the cases where the thrust reverser is part of the engine type design and where it is not.

Item 6: Fuel specifications for compression-ignition piston engines

AMC E 240 is created to recommend the use of test fuels complying with ASTM D8147.

Item 7: Ice protection

AMC E 650 (Vibration surveys) is amended to add provisions regarding the assessment of the effects on turbine engines caused by operation into icing, rain and hail conditions.

CS-E 780 and AMC E 780 are amended to clarify the applicable atmospheric icing conditions.

AMC E 780 is amended to:

(a) add provisions supporting applicants with the assessment of unacceptable mechanical damage;

(b) expand and clarify the existing provisions dealing with the use of a non-altitude test to simulate in-flight supercooled liquid water (SLW) icing conditions;

(c) add two notes supporting the understanding of the use of Table 2 in the establishment of test points for ground operation (SLW icing conditions);

(d) specify that the analysis of test results should take into account the repetitive nature of icing condition encounters (SLW icing conditions);

(e) regarding mixed phase/ice crystal icing conditions, amend the list of design features which may increase the susceptibility to ice accretion;

(f) regarding the engine ice protection system, in the section dealing with the analysis of the effects of delayed activation and deactivation of this system, clarify that both automatic and manual activation modes should be considered, and that applicants should also analyse the effects of deactivation delays after having left icing conditions;

(g) add an item in the list of limitations to be provided to the installer, regarding damage observed following the icing tests considered acceptable by the applicant and by EASA.

Item 8: Damage tolerance of critical parts

AMC E 515 Section 3(d)(v) (now entitled 'Damage Tolerance') is amended to introduce the content of CM-PIFS-007:

(a) some anomaly types are defined in a new section;

(b) elements of a damage tolerance assessment are defined;

(c) guidance is provided for the establishment of a minimum level of damage tolerance capability, considering probabilistic and deterministic approaches;

(d) a new section specifies how to establish a service damage monitoring process.

Item 9: Engine critical parts — static pressure loaded parts

A sub-paragraph is added to AMC E 515(3)(e)(i) ('General Principles') to clarify that the allowance of residual crack growth life within the approved life can only be accepted on the condition that compliance with other applicable CS-E certification specifications is unaffected.

The amendment allows to harmonise with the FAA AC 33.70-1 guidance material on this topic (provided in Section 8(e)).

Item 10: Editorial corrections

CS-E 10(c) is amended to replace the reference to point 21.A.16 by a reference to point 21.B.75 of Part 21.

CS-E 25(a) is amended to delete the reference to point 21.A.61(a).

CS-E 160(a) is amended to replace the reference to point 21.A.21(c)(3) by point 21.A.20(d)2 of Part 21.

Other existing references to points of Part 21 are updated in order to ensure editorial consistency of the references.

2.4. What are the stakeholders' views

During the consultation of the draft regulatory material, EASA received 168 comments from industry (engine and aircraft manufacturers), national aviation authorities and one individual.

Globally, stakeholders agreed with the need for the proposed amendments. However, some substantial comments were received on the proposals made under Item 1 (Compressor and turbine blade failure), Item 7 (Ice protection) and Item 8 (Damage tolerance of critical parts). On some aspects, this included some disagreements and requirements to improve or modify the proposals.

EASA carefully analysed these comments and made various changes to the proposals, in particular on the three above-mentioned items.

Please refer to CRD 2021-13, which provides:

— the list of commentators;

— the distribution of comments per NPA segment;

— a summary of the comments received, highlighting the most substantial ones, together with the EASA positions and responses;

— the list of individual comments received, together with the EASA positions and responses.

3. Expected benefits and drawbacks of the regulatory material

The amendments are expected to contribute to reflecting the state of the art of engine certification in CS-E and improve the harmonisation of CS-E with the FAA regulations.

The amendments also take into account the lessons learnt from turbine engine occurrences involving a compressor or turbine blade failure, in order to improve the identification and mitigation of the hazards associated with such a failure. In particular, the threat represented by uncontained axial debris and the loads transmitted to aircraft structural elements will be better analysed and mitigated during certification of the engine. Also, cooperation between the engine and aircraft manufacturers should be enhanced, to take into account the failure consequences at the aircraft level. The amendments do not mandate design changes relative to the current industry practice, but will ensure a more robust certification process and will decrease the risk of substantial aircraft damage and fatalities. A reasonable cost impact for the turbine engine manufacturers and EASA is anticipated, due to the additional efforts expected during certification of the engine. However, this impact will be compensated for by the economic and safety benefits gained from the decrease of the severity of blade failure occurrences.

Overall, the amendments are expected to improve safety, cause no social or environmental impacts and provide economic benefits by streamlining the certification process.

4. Monitoring and evaluation

EASA will assess the implementation of this CS-E amendment through:

— the experience gathered during CS-E certification projects carried out after this amendment;

— the monitoring of the rules under the normal continuing airworthiness process that is followed by EASA and type certificate holders; and

— the investigation of occurrences and the analysis of safety recommendations issued to EASA by designated safety investigation authorities.

5. Proposed actions to support implementation

No action is planned.

6. References

— National Transportation Safety Board (NTSB) investigation of accident to Southwest Airlines (SWA) flight 1380, a Boeing 737-7H4, on 17 April 2018 (https://www.ntsb.gov/investigations/Pages/DCA18MA142.aspx)

— EASA Certification Memorandum CM-PIFS-002 Issue 1, dated 8 March 2012, entitled 'Approval of Engine Use with a Thrust Reverser'

— EASA Certification Memorandum CM-PIFS-007 Issue 1, dated 22 February 2013, entitled 'Engine Critical Parts – Damage Tolerance Assessment – Manufacturing and Surface Induced Anomalies'

— ASTM standard D8147 Standard Specification for Special-Purpose Test Fuels for Aviation Compression-Ignition Engines

— FAA Advisory Circular (AC) 33.70-1 ('Guidance material for aircraft engine life-limited parts requirements')