European Union Aviation Safety Agency

Notice of Proposed Amendment 2023-06

in accordance with Article 6 of MB Decision 01-2022

Turbine-engine endurance and initial maintenance programme testing, and substantiation of piston-engine time between overhauls or replacements

RMT.0180

EXECUTIVE SUMMARY

This Notice of Proposed Amendment (NPA) proposes to amend CS-E to modernise the applicable engine certification test requirements as follows:

— update the turbine-engine endurance test specifications taking into account modern turbofan-engine design characteristics;

— improve the level of confidence in the robustness of turbine-engine designs prior to entry into service by requiring a test to demonstrate the engine's initial maintenance programme (IMP);

— ensure that EASA oversees IMP tests and benefits from the corresponding knowledge gained that can help understand the potential required corrective actions when turbine-engine continuing airworthiness issues are discovered;

— ensure a robust and harmonised substantiation of piston-engine time between overhauls (TBO) / time between replacements (TBR) intervals and the related maintenance programme;

— ensure as much as possible harmonisation with the corresponding FAA regulations and certification policies.

The proposed regulatory material is expected to improve safety and have a positive economic impact.

REGULATION(S) TO BE AMENDED/ISSUED	**ED DECISIONS TO BE AMENDED/ISSUED**
n/a	ED Decision 2003/009/RM on certification specifications, including airworthiness codes and acceptable means of compliance, for engines (CS-E)

AFFECTED STAKEHOLDERS: Engine (turbine and piston engines) design organisations

WORKING METHOD(S)		
Development	**Impact assessment(s)**	**Consultation**
By EASA	Detailed	NPA — Public

Related documents / information
ToR RMT.0180 issued on 7.5.2021

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

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1. About this NPA

1.1. How this regulatory material was developed

The European Union Aviation Safety Agency (EASA) identified the need to modernise the engine certification test requirements, and after having assessed the impacts of the possible intervention actions and having consulted those with the EASA Advisory Bodies, identified rulemaking as the appropriate intervention action.

This rulemaking activity is included in Volume II of the European Plan for Aviation Safety (EPAS) for 2023–2025[1] under Rulemaking Task (RMT).0180.

EASA developed the regulatory material in question in line with Regulation (EU) 2018/1139[2] (the Basic Regulation) and the Rulemaking Procedure[3], as well as in accordance with the objectives and working methods described in the Terms of Reference (ToR) for this RMT[4].

1.2. How to comment on this NPA

Please submit your comments using solely the dedicated **Comment-Response Tool (CRT)** available at http://hub.easa.europa.eu/crt/[5].

To facilitate the collection and technically support the subsequent review of comments by EASA in an efficient, controlled, and structured manner, stakeholders are kindly requested to submit their comments to the respective predefined segments of the NPA within the CRT, and refrain from submitting specific comments or all their comments to the 'General Comments' segment.

Further, once all comments are placed to the respective predefined segments, there is no need to submit them (as a pdf attachment) to the 'General Comments' segment.

The deadline for the submission of comments is **21 September 2023**.

1.3. The next steps

Following the consultation of the draft regulatory material, EASA will review all the comments received and will duly consider them in the subsequent phases of this rulemaking activity.

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1 European Plan for Aviation Safety (EPAS) 2023-2025 | EASA (europa.eu)

2 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).

3 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).

4 ToR RMT.0180 - Turbine engine endurance and initial maintenance inspection testing, and piston engine time between overhauls substantiation | EASA (europa.eu)

5 In case of technical problems, please send an email with a short description at crt@easa.europa.eu.

Considering the above, EASA may issue a Decision amending the certification specifications (CSs) and acceptable means of compliance (AMC) for engines (CS-E).

When issuing the Decision, EASA will also provide feedback to the commentators and information to the public on who engaged in the process and/or provided comments during the consultation of the draft regulatory material, which comments were received, how such engagement and/or consultation was used in rulemaking, and how the comments were considered.

2. In summary — why and what

2.1. Why we need to act — issue/rationale

EASA and industry have identified the need to modernise the turbine- and piston-engine certification test requirements in order to address the three issues described in Section 2.2.

2.2. Description of the issues

Issue 1: Turbofan-engine endurance test

The engine endurance test required under CS-E 740 is an accelerated severity test intended to demonstrate a minimum level of engine operability and durability within, and including, the approved engine ratings and operating limitations. The test originated 60 years ago in the days of reciprocating engines and single-shaft turbine engines, and was suitable for the operational characteristics of those engines. The fundamental approach, i.e. the demonstration of concurrent redline speed and temperatures, has been retained because these conditions are undeniably conservative and thus desirable from a safety demonstration perspective.

The issues with the requirement arise due to the test running conditions becoming harder to achieve as engine designs and operations have evolved to meet the performance demands of the modern air transport market. To achieve concurrent redline speed and temperatures, applicants often need to modify the configuration of the test engine and the required test sequence.

The current test practice and accepted methods of compliance do allow modifications to the test engine configuration and test sequence, provided certain conditions are met. Specifically, that the engine, as modified, is substantiated as being representative of the intended type design in terms of durability and operating characteristics. However, experience with more recent engine certification projects has highlighted the complexity of such substantiations, considering the modifications required (such as adapted cooling circuits, ground blade tips, and introduction of thermal barrier coating to turbine blades). This introduced possible doubts about the representativeness of the demonstration.

In 2013, a joint study was performed by the Aerospace, Security and Defence Industries Association of Europe (ASD) and the USA-based Aerospace Industries Association (AIA) on this issue. The scope of the study was focused on multiple shaft, high bypass aeroplane turbine engines. While this study might also be of interest to high technology turboshaft and turboprop engines, there was insufficient industry interest at that time to assess whether the proposal being developed might be directly applicable or modified for application to these engines. In the end, the study recommended an alternate endurance test. In response to the AIA–ASD proposal, the FAA, EASA and TCCA recognised that the current endurance test does not adequately address the technological advances found in modern engines, but did not feel that the proposal sufficiently fulfilled the regulatory intent.

Consequently, in January 2014, the FAA assigned the Aviation Rulemaking Advisory Committee (ARAC) a new task to review the existing engine endurance test requirement per 14 CFR § 33.87, assess its suitability for all turbine engines, and consider an alternate endurance test and associated methods of compliance. The task was assigned to the Engine Harmonization Working Group (EHWG) (that included an EASA member), which produced a report in January 2017[6]. After the publication of this report, the FAA requested in March 2020 some clarifications related to the recommendations contained in the report. The FAA found that certain ambiguities in this report could lead to disparate approaches when developing an alternate endurance test. More specifically, the FAA requested clarifications in the following areas:

(a) Severity equivalence process and its intended purpose.

(b) Severity equivalence process for other than creep failure modes, including failure modes not currently addressed by § 33.87 regulation.

(c) Constraints for implementing the recommended hybrid performance-based and prescriptive solutions.

(d) Role of the engine critical point analysis (CPA).

(e) Simplify the possible approaches by removing the turbine component metal temperature (T_{metal}) option.

(f) Various acceptable outcomes for an alternate endurance test.

The EHWG has, therefore, been reconvened and the related clarifications were provided in Revision A of the report dated 31 March 2021[7].

The proposed alternate test recommended by the EHWG combines elements of the currently defined test with new prescriptive requirements and performance-based aspects, making it a hybrid prescriptive / performance-based test. The proposed test is an alternate, not a superseding replacement, for the test currently defined in 14 CFR § 33.87 for turbofan engines.

Note: The EHWG report states that follow-on work needs to be performed to develop an alternate test for turboshaft and turboprop engines, including the case where a one-engine-inoperative (OEI) rating may be desired.

EASA should, therefore, consider the ARAC alternate endurance test proposal to ensure the representativeness of the endurance test for turbofan engines.

Issue 2: Turbine-engine initial maintenance programme (IMP) test

An initial maintenance inspection (IMI) test has been a requirement of the FAA's Part 33 (refer to 14 CFR § 33.90) for many years while not included in European (JAA and EASA) specifications.

FAA Advisory Circular (AC) 33.90-1A (Initial Maintenance Inspection (IMI), 14 CFR § 33.90, Test for Turbine Engines) provides guidance to demonstrate compliance with 14 CFR § 33.90.

There is, therefore, a lack of harmonisation between EASA and the FAA on this subject.

Furthermore, this test is considered an important element of the engine certification as it can reveal some design-related issues that may not be evidenced by the other certification tests required by CS-E. During this test, the engine is run under representative service conditions and also unbalance

6 https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/EHWG%20Final%20Report%202017-01-31.pdf

7 https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/ARAC%20EHWG%20Revised%20Recommendation%20Report;%20June%202021.pdf

vibrations. The test supports the establishment of the engine initial maintenance programme based on a demonstrated initial level of reliability.

Although an IMI test is required by the FAA, if an applicant applies for EASA CS-E certification only, this test is not required.

Issue 3: Substantiation of piston-engine TBO/TBR

CS-E does not contain certification specifications and acceptable means of compliance that can be used by applicants to demonstrate a time between overhaul (TBO) or a time between replacements (TBR) interval and the corresponding maintenance programme. Therefore, it is left at the discretion of the applicant to apply for a TBO/TBR approval by EASA.

Meanwhile, CS-E 25 'Instructions for Continued Airworthiness' paragraph (c)(5) states:

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

[…]

(5) Scheduling information for each part of the Engine that provides the recommended periods at which it should be cleaned, inspected, adjusted, tested and lubricated, and the degree of inspection, the applicable serviceability limits, and work recommended at these periods. Necessary cross references to the Airworthiness Limitations Section must also be included. In addition, if appropriate, an inspection programme must be included that states the frequency of the inspections necessary to provide for the continued airworthiness of the Engine.'

However, CS-E 25(c)(5) and the corresponding AMC do not specify any means to substantiate a TBO/TBR.

Applicants may substantiate a TBO/TBR based on the outcome of the 150-hour engine endurance test carried out in accordance with CS-E 440. However, this test may only reveal a limited amount of design deficiencies on the engine. Therefore, a limited initial TBO/TBR is accepted by EASA based on this test only. As mentioned under Issue 2 (Turbine-engine initial maintenance programme (IMP) test) above, this situation contrasts with the fact that an IMI test is required for turbine engines under FAA 14 CFR § 33.90 in addition to the endurance test.

In order to accept TBO values higher than the commonly accepted initial TBO/TBR, EASA and some applicants agreed on the means to provide adequate evidence to support a TBO/TBR using a project-specific certification review item (CRI) means of compliance (MoC). Such MoC refers to CS-E 25(c) and provides a substantiation based on an engine cyclic endurance test run on an engine representative of a given type design and using a cycle profile that is based on estimated aircraft flight profiles. This test is similar to an IMI test. The engine cyclic test is developed by the applicant and agreed with EASA. The maintenance programme associated with the intended TBO/TBR is performed and validated during the engine cyclic test.

Although the above-mentioned CRI process is well established within EASA, a project-specific CRI is not publicly available. This process may well be known by established applicants, but new potential applicants may not be aware of the expectations from EASA.

Finally, a safety recommendation was addressed to EASA in 2009, related to the accident to a Diamond DA42 registration OE-FCL, on 20 July 2007, close to St. Pantaleon, Austria, triggered by the failure in-flight of the right position engine, and followed by a loss of control during an attempt to perform an emergency landing. Safety Recommendation (SR) AUST-2009-011 was issued by VESRA (the Austrian Safety Investigation Authority):

'Amend the certification requirements for piston engines, CS-E:

After the certification of the DA 40 and DA 42 with TAE engine Centurion 1.7 and 2.0 a number of serious incidents and loss of engine power have occurred.

The certification regulations should be amended in such way that before the first delivery to customers, the overall system is proven to be fully functioning over a given time period, within TBO (Time Between Overhaul), without experiencing loss of power, or major mechanical failures.'

2.3. Assessment of the issues

Issue 1: Turbofan-engine endurance test

Some turbofan engines have faced unexpected failures shortly after entry into service. Such issues required urgent corrective actions (mandated by airworthiness directives) to control the associated safety risk posed by multiple engine shutdown occurrences.

The root cause of such failures may have been identified during the engine endurance test if the test conditions and the engine configuration had been more representative.

Although no fatal or serious injuries have been directly attributed to these safety issues, EASA and the industry identified the need to ensure a more representative test and thereby increase the probability of detecting such issues before entry into service of the engine.

Issue 2: Turbine-engine initial maintenance programme (IMP) test

Although an IMI test is required by the FAA, if an applicant applies for EASA CS-E certification only, no such test is required to demonstrate the IMP of the engine. In this case, the certification tests may not reveal some design-related issues that may be discovered while running an IMP test, due to the use of representative service conditions and also unbalance vibration.

This is a safety concern to EASA as potential unsafe conditions may develop once the engine enters into service.

Issue 3: Substantiation of engine TBO/TBR

The absence of specifications and acceptable means of compliance in CS-E regarding the substantiation of TBO/TBR does not guarantee a rigorous and harmonised demonstration among the different applicants. The approved TBO/TBR may, therefore, not be commensurate with the level of testing performed, and some engines may be more prone to develop design-related failures, including loss of power, after entry into service and before reaching the certified TBO/TBR interval. A safety recommendation (see above) has been issued to EASA after the investigation of an accident involving the failure of an engine in flight, to improve the specifications related to the substantiation of the engine TBO/TBR.

2.4. Who is affected by the issue

Engine (turbine and piston engines) design organisations.

2.5. How could the issue evolve

If no action is taken, unsafe conditions may develop because of design deficiencies that have not been discovered during engine certification testing. In addition, a lack of harmonisation as regards Issue 2 (Turbine-engine initial maintenance programme (IMP) test) with other authorities will remain, which increases the workload for support to the validation of European products by foreign authorities.

2.6. What we want to achieve — objectives

The overall objectives of the EASA system are defined in Article 1 of the Basic Regulation. The regulatory material presented here is expected to contribute to achieving these overall objectives by addressing the issues described in Section 2.1.

More specifically, with the regulatory material presented here, EASA intends to modernise the applicable engine certification test requirements as follows:

— update the turbine-engine endurance test specifications taking into account modern turbofan-engine design characteristics;

— improve the level of confidence in the robustness of turbine-engine designs prior to entry into service by requiring a test to demonstrate the engine's initial maintenance programme (IMP);

— ensure that EASA oversees IMP tests and benefits from the corresponding knowledge gained that can help understand the potential required corrective actions when turbine-engine continuing airworthiness issues are discovered;

— ensure a robust and harmonised substantiation of piston-engine TBO/TBR intervals and the related maintenance programme;

— ensure as much as possible harmonisation with the corresponding FAA regulations and certification policies.

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

Issue 1: Turbofan-engine endurance test

It is proposed to amend CS-E 740 (Endurance Tests). The proposal takes into account the recommendations contained in the report issued by the Engine Harmonization Working Group (EHWG), entitled 'Alternate Test to 14CFR33.87 Endurance Test', Revision A, dated 31 March 2021. An alternate test for turbofan engines would be available to the applicant as an optional alternative to the current endurance test, as provided for in new subparagraph (4) of CS-E 740(c). The alternate test demonstration would be achieved by evaluating (via a critical point analysis (CPA) of the product's design and intended use (operating envelope)) and defining a hybrid prescriptive / performance-based severity test for the engine. This would test the engine type design to its limiting speeds and temperatures (redlines) for type-certificate limits. Furthermore, the proposed test would evaluate the engine's capability to successfully run in close proximity to minimum speed and temperature margins (close to redlines) as expected while in service still operating at a severity level consistent with the intent of today's CS-E 740 (or FAA 14 CFR § 33.87) prescriptive test.

The proposed test would run more hours and cycles than today's prescribed test schedule, utilising a simulated flight cycle. Therefore, it would provide results that are more representative of responses to threats characteristic of revenue service, while also providing a test of the engine's capability at least as severe as intended by the current test.

A new AMC E 740(c)(4) is proposed to support demonstration of compliance with CS-E 740(c)(4). The proposed AMC provides a description of the alternate endurance test concept and of the CPA that is expected to be conducted. It also deals with the methods to be used to demonstrate the severity equivalence between the alternate and the classic endurance tests. Some alternate endurance test examples are provided to illustrate the comparative severity methodology.

In addition, the following amendments are proposed to ensure consistency of other CS-E parts with the new specifications and acceptable means of compliance for alternate endurance testing:

— CS-E 690 (Engine Bleed) would be amended to mention the alternate endurance test and account for the fact that this test does not prescribe testing stages.

— AMC E 650 (Vibration Surveys), AMC E 690 (Engine Bleed), AMC E 740(c)(2)(i) (Endurance Tests — 30-Minute Power Rating), AMC E 740(c)(3) (Endurance Tests), AMC E 740(h)(2) (Endurance Tests — Inspection Checks), CS-E 890 (Thrust Reverser Tests) would be amended to update a reference to a CS-E 740 subparagraph that has been renumbered.

— CS-E 730 (Engine Calibration Test) would be amended to add a statement clarifying the purpose of the calibration test.

— In CS-E 740, several paragraphs would be amended to refer to the alternate endurance test option. CS-E 740(h) is proposed to be amended so that it now addresses the engine-rated performance demonstration (harmonised with FAA CFR33.87(a)(3)); as a consequence, the content of the current CS-E 740(h) is moved to new CS-E 740(i).

— In CS-E 740(f)(4)(iv), it is proposed to include the possibility to obtain an approval for a transient gas temperature limit up to 30 seconds, in addition to the current '2-minutes' option, as included in the EHWG report. This would reflect what has been performed on some certification projects using special conditions (SCs) and would also harmonise with the related content of FAA AC 33.87-1.

— CS-E 870 (Exhaust Gas Over-temperature Test) would be amended to account for the alternate endurance test, i.e. provide the possibility to run a 5-minute period as a substitution of the 15-minute period test.

Issue 2: Turbine-engine initial maintenance programme (IMP) test

It is proposed to create new CS-E specifications (i.e. CS-E 930), considering the requirements under FAA 14 CFR § 33.90, but adapted to allow the applicant to demonstrate an IMP (instructions for continued airworthiness (ICAs) submitted under CS-E 25) in a performance-based way. The IMI approach would be one method that the applicant may use. Other methods would be allowed, in particular, on-condition based maintenance programming. The applicant would have to complete one of the following tests with an engine that substantially conforms to the type design to substantiate the IMP:

— An approved engine test that simulates the conditions in which the engine is expected to operate in service, including typical start–stop cycles.

— An approved engine test performed in accordance with the early ETOPS test requirements (i.e. in accordance with the current AMC 20-6 Revision 2 requirements).

A new corresponding AMC E 930 is also proposed to support applicants when demonstrating compliance with the new CS-E 930 specifications. This AMC is based on the FAA AC 33.90-1A (Initial

Maintenance Inspection (IMI), 14 CFR § 33.90, Test for Turbine Engines) that has been adapted to the CS-E 930 performance-based concept.

Issue 3: Substantiation of piston-engine TBO/TBR

It is proposed to create a new paragraph in AMC E 25 (Instructions for continued airworthiness) to indicate how applicants may substantiate a TBO/TBR interval and maintenance programme. Limited credit could be taken from the CS-E 440 endurance test alone. In order to go beyond this limitation, the substantiation would require running an engine cyclic endurance test on an engine representative of the type design using a cycle profile that is based on estimated aircraft flight profiles. The number of cycles should be representative of the TBO/TBR intended to be declared and should represent a level of engine deterioration at least equivalent to that of an engine at the end of the intended TBO/TBR.

Targeted applicability of the regulatory material [CS-E amendment]: the Decision shall enter into force and apply on the day following that of its publication in the Official Publication of EASA.

2.8. What are the stakeholders' views

During the consultation of the ToR with the EASA Advisory Bodies, some comments were provided by the DM.TEC members. The comments were supportive to the proposed rulemaking. In particular, the introduction of an alternate endurance test in CS-E has been asked by engine manufacturers for years and this was materialised by their contribution to the work done under the ARAC EHWG. The harmonisation with FAR § 33.90 IMI has also been welcomed. Some detailed technical recommendations were made that EASA took into account during the drafting of this NPA.

3. What are the expected benefits and drawbacks of the regulatory material

The expected benefits and drawbacks of the proposal are summarised below. For the full impact assessment of the alternative options, please refer to Appendix 1 (Impact assessment).

For turbine engines:

— It would improve the robustness and the representativeness of turbofan-engine endurance testing, thereby reducing the number of continuing airworthiness issues, including less potentially hazardous or catastrophic failure conditions at aircraft level. It would also ease the EASA continued airworthiness oversight of turbine engines thanks to a better involvement in the IMP testing activities. This would result in an improvement of safety with a reduction in the number of design-related issues, and a more efficient management of the corrective actions when such issues appear.

— The overall economic impact would be positive for applicants and EASA using the alternate endurance test when the classic test is not adapted, and from the IMP new specification (ease of validations). A negative economic impact could be created for applicants intending to get only EASA TCs without voluntarily running an IMP test (which is considered improbable).

For piston engines:

— It would implement in CS-E the content of the most recent MoC CRIs approved by EASA (equivalent to the corresponding FAA policy statement) to improve the robustness of the TBO/TBR substantiation. It is expected that this would improve safety by reducing the number of design-related failures occurring before the engine overhaul.

— The economic impact would be neutral as the proposal would not universally mandate additional tests. Applicants would be able to base the TBO on the endurance test only, but with a limit applied to the TBO/TBR that they can substantiate. This is already what is done according to the last MoC CRI.

No other impacts have been identified.

4. Proposed regulatory material

The amendments are arranged as follows to show deleted, new and unchanged text:

— deleted text is ~~struck through~~;

— new text is highlighted in blue;

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

Draft certification specifications and acceptable means of compliance (draft EASA decision on Amendment XX to CS-E)

Issue 1: Turbofan-engine endurance test

AMC E 650(10) is amended as follows:

AMC E 650 Vibration Surveys

[…]

(10) Dwell Testing

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

If any significant response is found, then the relevant components should be subjected to sufficient cycles of vibration close to, and/or on, the response peak to demonstrate compliance with CS-E 650(f). This dwell testing would normally be incorporated into the incremental periods of the CS-E 740 Endurance Test as required by CS-E 740(g)(1). Components subjected to such dwell testing should subsequently also meet the strip inspection requirements of CS-E 740(i~~h~~).

[…]

CS-E 690 is amended as follows:

CS-E 690 Engine Bleed

(See AMC E 690)

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

(1) *General*

(i) Exercise the bleed controls at the end of each stage of the endurance test as per CS-E 740(c)(1), (2) or (3). If the applicant uses an alternate endurance test as per CS-E 740(c)(4), which does not have a prescribed number of test stages, the bleed controls must be exercised to an equivalent level.

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

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

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

(3) *Endurance Test.*

(i) If the applicant uses an endurance test as per CS-E 740(c)(1), (2) or (3), ~~R~~run Stages 3, 7, 13, 17 and 23 with the bleed(s) in operation during all the conditions of running for which they are intended to be approved for use. If the applicant uses an alternate endurance test as per CS-E 740(c)(4), which does not have prescribed test stages, the bleed(s) must be exercised in an equivalent way.

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

(b) […]

AMC E 690 is amended as follows:

AMC E 690 Engine bleed

For reducing test complexity, and for improved flexibility needed to attain the key parameters (speed, temperature and torque) during the 2-hour test of CS-E 740(c)(3)(iii), maximum air bleed for Engine and aircraft services need not be used if the applicant can show by test or analysis based on test that the Engine’~~'~~s ability to meet the strip examination specifications of CS-E 740(i~~h~~)(2) is not enhanced.

The analysis should include:

1. ~~T~~the effect of the bleed air extraction to the Engine’s secondary air system which provides cooling air to various Engine components;~~,~~

2. ~~T~~the thermodynamic cycle effects of bleed (e.g.~~,~~ gas generator speed to output shaft speed changes).

CS-E 730 is amended as follows:

CS-E 730 Engine Calibration Test

(See AMC E 730)

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

CS-E 740 is amended as follows:

CS-E 740 Endurance Tests

(a) The specifications of ~~this~~ CS-E 740 must be varied and supplemented as necessary to comply with CS-E 690(a), CS-E 750 and CS-E 890.

(b) (1) The test must be performed~~made~~ in the order defined in the appropriate schedule (either as prescribed in paragraphs (c)(1), (2) and (3) below, or as defined by the applicant in a test plan and agreed with EASA when paragraph (c)(4) below is used), and in suitable non-stop stages. An alternative schedule may be used if it is agreed to be at least as severe. In the event of a stop occurring during any stage, the stage must be repeated unless it is considered to be unnecessary. The complete test may need to be repeated if an excessive number of stops occur.

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

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

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

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

(c) *Schedules*

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

[…]

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

[…]

(3) For Engines with 30-Second and 2-Minute OEI Power ratings (See AMC E 740(c)(3)),

[…]

(4) *Alternate Endurance Testing — Turbofan Engine*

The following alternate endurance testing may be used by the applicant for the purpose of testing turbofan Engines instead of the above-mentioned test schedules. In particular, this may be suitable when running of the above-mentioned schedules would require substantial modifications of the Engine such that it would deviate excessively from the type-design definition. The alternate endurance test must, however, provide a severity at least equivalent to the intent of the classic endurance test prescribed by CS-E 740(c)(1).

A test plan addressing the proposed test schedule and full assessment of the elements identified below must be agreed with EASA in advance of test commencement.

(i) *Alternate Test Definition*

The definition of the test may be divided into seven separate elements as follows:

(A) Test Vehicle Definition,

(B) Critical Point Analysis (CPA),

(C) Engine Redline Limit Demonstration (TCDS physical speeds and temperatures),

(D) Test Severity Demonstration over extended operating periods,

(E) Additional Severity Testing,

(F) Incremental Cruise Power and Thrust,

(G) Ancillary TCDS Limits Demonstration.

(ii) *Test Vehicle Definition*

The test should be performed using a test vehicle that substantially conforms to the Engine type design.

Exceptions could include external test equipment, controls systems settings, and other modifications required to achieve the test conditions detailed below; however, Engine hardware modifications should be minimised to preserve the Engine type design hardware configuration and engine cycle match. Hardware modifications may be temporarily applied to achieve specific test conditions (e.g. for the limiting redline physical core speed test segment).

(iii) *Critical Point Analysis (CPA)*

Using a thermodynamic engine model representative of a production engine (accounting for new and deteriorated engine conditions) in conjunction with the aeroplane flight envelope, the applicant will identify the critical points (rotor physical speeds, temperatures, altitude, etc.) representing the most severe operation and the extent of exposure to those levels.

For the purpose of redline demonstrations, the CPA must establish the extent of exposure to the redline levels and close proximity to the redline levels. The CPA must also establish maximum levels of corresponding rotor speed for a redline temperature case, and maximum levels of temperature for a redline speed case. If it is found that redline conditions could at any point be coincident, then this would need to be reflected in the demonstration.

The applicant will then conduct analyses to identify the areas in the declared flight envelope where endurance test critical components are exposed to the most damaging conditions. Critical components are components within the Engine which are most limiting in terms of useful (serviceable) life under the endurance test conditions.

If the maximum critical component temperature method is used (as described in CS E-740(c)(4)(v) 'Test Severity Demonstration' below), then the applicant's CPA will identify the maximum critical component temperature (this would normally, but not necessarily, be a redline engine condition on a fully deteriorated engine), the capability must also be demonstrated to establish engine condition settings to achieve the same critical component temperatures during the test severity demonstration.

Failure modes of endurance test critical components must also be identified in the CPA process for assessment and possible demonstration within the alternate endurance test to support the severity equivalence demonstration (further demonstration may also be necessary in compliance with CS-E 170).

(iv) *Engine Redline Demonstrations (TCDS physical speeds and temperatures)*

Type certification data sheet (TCDS) physical speed and temperature limiting conditions (redlines) must be demonstrated as detailed in this paragraph.

Declared shaft redline values will be demonstrated in the Engine redline demonstration sections of the test and established in accordance with CS-E 740(f).

Concurrent redline demonstration of speed and temperature for a particular shaft is required unless the CPA indicates it is not possible to occur in service within the declared operating envelope. The corresponding speed or temperature identified in the CPA must be met or exceeded on average during the demonstrations below.

(1) *Core Speed Redline Demonstration*

The greater of maximum take-off (MTO) and maximum continuous (MCT) physical core speed redline in conjunction with at least the level of the corresponding temperature, as identified in the CPA, must be demonstrated for a minimum of 10 minutes. However, if the CPA for a new engine design shows that more than 10 minutes could occur in service, or that physical core speed redlines could be encountered regularly in service, then the core speed redline test time will be extended accordingly. Where the CPA shows a longer period is required for MCT, the testing would be extended at MCT conditions to cover that period.

When demonstrated in conjunction with meeting the minimum severity requirements of CS-E 740(c)(4)(v), this demonstration comprises the appropriate period of the test for establishing the TCDS MTO- and MCT-declared core speed limits in accordance with CS-E 740(f).

(2) *Fan Speed Redline Demonstration*

The MTO fan physical speed redline must be demonstrated for a minimum of 30 minutes. The MCT fan physical speed redline must be demonstrated for a minimum of 90 minutes. Both cases must be demonstrated in conjunction with at least the level of corresponding temperature, as identified in the CPA.

If MTO and MCT have the same declared fan speed redline, then 120 minutes must be demonstrated.

Additional time may be necessary if the applicant’s CPA indicates that additional time at MTO or MCT physical fan speed redline could occur in service within the declared operating envelope. In conjunction with meeting minimum severity requirements, this demonstration comprises the appropriate period of the test for establishing the TCDS MTO- and MCT-declared fan speed limits in accordance with CS-E 740(f).

(3) *Turbine Exhaust Gas Temperature (EGT) Redline Demonstration*

MTO EGT redline must be continuously demonstrated for 10 minutes in conjunction with at least the level of corresponding rotor speeds as identified in the CPA. Three snap/burst accelerations (1 second or shorter) from idle to the MTO EGT redline (hold redline for a duration of 90 seconds each) must also be demonstrated. MCT EGT redline must be continuously demonstrated for 90 minutes in conjunction with at least the level of corresponding rotor speeds as identified in the CPA.

Additional time at any or all these conditions may be necessary if the applicant's CPA indicates that additional time at the EGT redline may occur in service.

EGT redline demonstration for alternate endurance testing also requires the equivalent severity to the intent of the specifications in CS-E 740(a), (b) and (c)(1) to be demonstrated by running significant time and cycles at or above the maximum critical component temperature as identified in the CPA as per CS-E 740(c)(4)(iii) and must be performed when showing compliance with CS-E 740(c)(4)(v).

Additional testing required to show compliance with CS-E 740(c)(4)(v), to justify unlimited operation up to the EGT redline, must be addressed when showing compliance with CS-E 740(c)(4)(vi).

The TCDS-declared EGT redline temperatures for MTO and MCT will be determined by analysis upon completion of the test and are established as the lower of the following values:

(A) values no greater than the EGT values derived in accordance with CS-E 740(f) where EGTs demonstrated in this turbine gas temperature redline demonstration comprises the 'appropriate periods of the endurance test';

(B) derived values for MTO and MCT for which the severity demonstration for the entire test can be shown to have cumulative severity, for the critical component, greater than or equal to the reference severity.

(v) *Test Severity Demonstration over extended operating periods*

Limiting temperature must be demonstrated for extended periods to achieve the equivalent cumulative creep severity for the critical component as would be achieved by the 18.75 hours at MTO and 45 hours at MCT conditions prescribed in CS-E 740(c)(1) (also referred to as the reference severity).

The limiting temperature is either the turbine gas path temperature redline or the gas path temperature that corresponds to the maximum critical component temperature where this has been established for both a production engine and the test engine, as defined by the applicant's CPA (refer to AMC E 740(c)(4) for further considerations of severity assessment). The applicant should, therefore, decide which limiting temperature method will be used during the test.

The duration and the split between MTO and MCT operation are to be determined and justified by the applicant.

The applicant must determine the mix of cycles and cycle durations that best represent the Engine design and operation. A methodology showing how creep damage, and other damage, to critical components accumulates is necessary for a comparative severity assessment to the intent of the test schedule specified in CS-E 740(c)(1).

During this testing phase, rotor physical speeds must be maintained at the highest levels feasible with a test vehicle that meets type design as per the specifications in CS-E 740(c)(4)(ii), and on average should be held within +/– 3 % of the limiting speeds.

(vi) _Additional severity testing_

The need for additional severity testing must be determined and agreed with EASA at completion of the scheduled Test Severity Demonstration of CS-E 740(c)(4)(v). The additional testing must be completed to the same target EGT conditions (necessary if the conditions did not meet those that were assumed in the original analysis that was used to establish the test schedule), in order to compensate the missed cumulative severity equivalence. Additional cyclic content may also be included, if necessary, to address other damage mechanism demonstration identified in the CPA, for which target conditions should be justified.

(vii) _Incremental Cruise Power and Thrust_

The following incremental acceleration must be completed 25 times: 2 hours and 30 minutes covering the range in 15 approximately equal speed increments from ground idle up to but not including MCT power or thrust.

(viii) _Ancillary TCDS Limits Demonstration_

The alternate test must comply with CS-E 690(a)(3), CS-E 140(d)(1) and (2), CS-E 170, CS-E 740(e) and (f), and CS-E 750. This includes testing at bleed, power extraction, oil temperature, fuel minimum and maximum pressure, transient, and start limits. Minor facilitating modifications may need to be made to run the conditions as required. The applicant must propose test sequence intervals equivalent to the stages specified in CS-E 690(a)(3) and CS-E 740(e) that are acceptable to EASA.

(d) _Accelerations and Decelerations_

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

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

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

(2) _Observations_

(i) _Turbine Engines for Aeroplanes._

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

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

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

(ii) _Turbine Engines for Rotorcraft_.

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

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

(1) Stage 22 of the test schedule specified in CS-E 740(c)(1), (2) and (3), or an equivalent demonstration in the alternate endurance test specified in CS-E 740(c)(4), if applicable, must be run with the pressure set to give that declared as the minimum for completion of the flight, at ~~maximum continuous~~ MCT conditions; ~~,~~ and

(2) One other stage, or an equivalent demonstration in the alternate endurance test specified in CS-E 740(c)(4), if applicable, must be run with the pressure set to give that declared as the maximum normal, at ~~maximum continuous~~ MCT conditions. During this stage, the oil temperature need not be held at its maximum value. Alternatively, this test may be omitted from the endurance test if appropriate evidence is available from other testing.

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

The turbine entry temperature limitations may be derived from an analysis when the applicant uses the alternate test specified in CS-E 740(c)(4).

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

(1) The characteristics of multi-spool Engines may be such that it is not possible to obtain the maximum rotational speed of each spool simultaneously at sea-level test bed conditions, without making the Engine unacceptably non-standard, or running it in a non-representative manner. In such circumstances, the endurance test must be run at the turbine entry temperatures for which approval is sought, and evidence from supplementary endurance testing, to a schedule acceptable to the Agency, must be provided to substantiate the approval of any higher rotational speed limitations desired. (See AMC E 740(f)(1))

(2) If Stages 3, 7, 13, 17 and 23, or an equivalent demonstration in the alternate endurance test specified in CS-E 740(c)(4), if applicable, with bleed(s) in operation, require the use of a rotational speed less than the maximum without bleed (as permitted by CS-E 690(a)(1)(iii)), these Stages, or the equivalent demonstration, need not be included in the assessment of the mean rotational speed value, subject to agreement by the Agency.

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

(4) _Temperatures_.

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

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

(iii) In the case of the alternate test specified in CS-E 740(c)(4), MTO EGT redline must be continuously demonstrated for at least 10 minutes. MCT EGT redline must be continuously demonstrated for at least 90 minutes. In addition, the showing of equivalence for EGT redline demonstration to the intent of the classic endurance test is achieved by running significant time and cycles to component metal temperatures.

The TCDS MTO- and MCT-declared EGT redline will be determined by analysis upon completion of the test and established as the lower of the following values:

(A) values no greater than the average temperatures demonstrated in the EGT redline demonstration.

(B) values for MTO and MCT for which the severity demonstration for the entire test can be shown to have damage greater than or equal to the reference severity.

(~~iii~~iv) Engines for Aeroplanes. Where the Engine characteristics are such that an acceleration from cold produces a transient over-temperature in excess of that for steady state running, a maximum EGT ~~turbine gas temperature~~ limit for acceleration with a time limitation of either up to 30 seconds or up to 2 minutes may be approved.

Transient EGT limits up to 30 seconds may be approved by running at the required temperature for the first 30 seconds of 50 % of the prescribed periods at Take-off Power or Thrust conditions.

Transient EGT limits up to 2 minutes may be approved by running at the required temperature for the first 2 minutes of each prescribed period at Take-off Power or Thrust conditions for 5 minutes or ~~more~~ longer, and for the whole of all the 30-second periods at Take-off Power or Thrust.

Approval for short-period transient conditions at 2½-Minute OEI Power or Thrust will not be considered and any temperature clearance required must be demonstrated normally during the 2½-Minute OEI periods of the endurance test.

In the case of the alternate test specified in CS-E 740(c)(4), transient EGT limits may be approved as follows:

(A) transient EGT limits up to 30 seconds must be demonstrated on at least 155 of the accelerations to MTO;

(B) transient EGT limits up to 2 minutes must be demonstrated on at least 310 of the accelerations to MTO.

(~~i~~v) Engines for Rotorcraft.

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

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

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

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

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

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

(g) *Incremental Periods.*

(1) If a significant vibration response is found to exist on relevant components in the course of establishing compliance with CS-E 650 at any condition within the operating range of the Engine (not prohibited under CS-E 650(f)), not less than 10 hours, but not exceeding 50%, of the incremental periods of Part 4 in CS-E 740(c)(1), (2) or (3) of the endurance test, or CS-E 740(c)(4)(vii) of the alternate endurance test, if applicable, must be run with the rotational speed varied continuously over the range for which vibrations of the largest amplitude were disclosed by the vibration survey; if there are other ranges of rotational speed within the operational range of the Engine where approximately the same

amplitude exists, a further 10 hours must be run in the same way for each such range. The speed variation must be effected by automatic means using a method acceptable to the Agency. (See AMC E 740(g)(1))

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

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

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

(h) *Engine-rated Performance Demonstration.*

Power or thrust of the Engine must be at least 100 % of the value associated with the particular Engine operation being tested.

(~~h~~i) *Inspection Checks*

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

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

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

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

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

AMC E 740(c)(2)(i) is amended as follows:

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

[…]

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

AMC E 740(c)(3) is amended as follows:

AMC E 740(c)(3) Endurance tests

(1) Two procedures for running the tests required under CS-E 740(c)(3) are acceptable:

(a) After the basic 150-hour endurance test, the Engine may be subjected to a strip inspection in accordance with CS-E 740(i~~h~~)(1).

The Engine is then reassembled using the same parts used for the 150-hour endurance test except as otherwise allowed by CS-E 740(i~~h~~)(2)(ii) and the additional 2-hour endurance test is run to CS-E 740(c)(3)(iii).

Completion of the additional 2-hour endurance test would be followed by compliance with the strip inspection specifications of CS-E 740(i~~h~~)(2)(iii);

or

(b) The 2-hour additional endurance test of CS-E 740(c)(3)(iii) may be run immediately after the basic 150-hour endurance test without Engine disassembly.

The strip inspection standards that will be applied after completion of the additional 2-hour endurance test will be those prescribed in CS-E 740(i~~h~~)(2).

[…]

The following AMC E 740(c)(4) is added:

AMC E 740(c)(4) Alternate endurance testing — Turbofan Engine

(1) Alternate Endurance Test Concept

The alternate endurance test is intended to address a problem faced by turbofan-engine designs disadvantaged by the classic endurance test (as per CS-E 740(c)(1)) where speed and temperature limiting conditions must be demonstrated concurrently. These engines, for which this demonstration is not representative of the in-service operation, can be subjected to excessively severe conditions (normally due to reduced effectiveness of secondary air-cooling systems) during the test. The alternate endurance test allows more representative conditions to be tested, provided that those conditions are established by a validated critical point analysis (CPA), and provided that the overall severity of the test is at least equivalent to the intent of the classic endurance test prescribed by CS-E 740(c)(1) by an extended test duration. This, in turn, allows to test a more representative hardware configuration (avoiding modifications otherwise necessary to be able to complete the classic endurance test, also called 'enabling' modifications).

(2) Critical Point Analysis (CPA)

The CPA is the process in which the actual/anticipated in-service running conditions of a production engine are assessed (taking into account new to fully deteriorated engine condition, and the whole engine operating envelope). This assessment should then be considered further in the severity assessment for creep and other relevant damage mechanisms.

The applicant should assess the engine operating envelope using thermodynamic models for new and fully deteriorated engines to identify conditions at the most critical point(s), including any coincident maxima. These conditions will likely be associated with limit temperature cases (for a secondary air system operating at design conditions, it is reasonable to assume that the highest exhaust gas temperatures (EGTs) are coincident with the highest metal temperatures (T_{metal}), even if T_{metal} is not directly scalable with the EGT).

The CPA is expected to provide the following two types of data outputs:

- CPA data for production engine in-service redlines (RL) study: necessary to establish conditions for the speed and temperature RL demonstrations (refer to CS-E 740(c)(4)(iv)).

  Output data:

  Cumulative exposure time of concurrent shaft speeds RL (individually in the case of multiple shafts) and EGT RL.

  Note: A tendency to concurrent RL levels at the end of the service interval would suggest that the alternate endurance test is inappropriate for the given Engine type.

  Cumulative exposure time at, and in close proximity to, shaft speeds RL and associated EGTs (EGT below EGT RL).

  Note: To be compared with mandatory demonstration times required by CS-E 740(c)(4)(iv).

  Cumulative exposure time at, and in close proximity to, EGT RL and associated maximum rotor speeds.

- CPA data for severity comparison purposes: necessary to establish conditions for the test severity demonstration (refer to CS-E 740(c)(4)(v)).

  Output data:

  Identification of the critical component(s) and associated damage mechanism(s).

  Maximum damage conditions for the critical components at EGT RL.

  Note: For consideration of metal creep damage, and other temperature-related damage, the maximum component temperature T_{metal} should be established, to be used in the assessment of reference severity as part of the severity analysis of the classic endurance test, and in assessing the required power settings and eventual severity value of the physical alternate test.

(3) Severity Equivalence between the Alternate and the Classic Endurance Tests

The key input parameters to characterise the severity of a test are the time on condition, the number of cycles run to critical component temperatures, and the physical engine speeds reached while operating at rated thrust.

This classic endurance test provides a number of challenges to the engine design. The primary intent is to perform an accelerated severity test of the creep capability, i.e. the durability at sustained high turbine temperature and physical speed, and of the effects of deterioration on operability driven by the prescribed operating conditions (not inclusive of all flight environment deterioration effects).

Therefore, the severity equivalence of the alternate endurance test should be assessed on the basis of accelerated creep life usage as compared to the intent of the classic test.

In addition, the alternate endurance test should demonstrate equal or more damage accumulation in the other damage mechanisms.

(4) Elements to be Used in a Severity Comparison

To demonstrate that the proposed alternate test is adequately severe, i.e. commensurate with the intent of the classic endurance test, a method of severity comparison to the classic test intent is required. In addition to creep as the primary damage mechanism, other damage mechanisms should be assessed at the operating conditions determined by the CPA. The following elements should be considered in a severity comparison:

(a) declared operating limits,

(b) temperature- and physical-speed-related damage mechanisms (creep, sustained peak low cycle fatigue (SPLCF), thermomechanical fatigue (TMF), etc.),

(c) cyclic content,

(d) transients,

(e) oil system demonstrations,

(f) fuel system demonstrations,

(g) start/stop.

This list is not exhaustive, and the applicant should evaluate its proposed type design for all significant elements and damage mechanisms.

(5) Application of a Severity Comparison

The comparative methodology and damage mechanism(s) are dependent on the applicant's CPA, and on the details of the Engine application.

(a) Comparative Severity Analysis

The primary approach, as per CS-E 740(c)(4)(v), is to use creep damage to critical gas-path components as a comparative arbiter to the original intent of the classic test. Stress-rupture and creep damage were the prevalent failure mechanisms when the classic test was originally adapted for turbine engines.

An approach based on creep damage as a comparative means to assess severity for an alternate test does not mean that the alternate test must be defined only to identify creep issues, or that it will not adequately assess other potential failure mechanisms. Rather, it is only a means of comparing any alternate test's severity to that of the original intent of the classic test for the creep mechanism. It is expected that within the applicant's severity assessment and comparison, any other relevant damage mechanisms will be identified and an Engine-specific comparison of the classic to the alternate test will be provided to demonstrate that the proposed test will adequately expose the Engine to the relevant failure and/or deterioration mechanisms to meet the test intent. Paragraph (8) of this AMC provides additional guidance for severity assessment.

(b) Reference Severity

The reference severity is a theoretically determined value based on the material temperatures of the critical component(s) identified using the CPA and on the time at elevated temperature and rotor speed to which the component(s) would be subjected when the Engine is tested in accordance with CS-E 740(c)(1). The rotor speeds assumed for this determination will include the redline levels (for the appropriate test sections) which are intended to be claimed at the conclusion of the test. Therefore, the severity representing the intent of the classic test as per CS-E 740(c)(1) is the damage that would be accrued at these assumed conditions, which may not in reality be concurrently achievable, for those durations, and this is referred to as the 'reference severity', and can be normalised to 1 for comparison to the severity of a physical alternate endurance test.

(c) Comparative Severity

With both a reference severity representing the intent of CS-E 740(c)(1) (with a type-design engine) and a method for performing an alternate test in place, the next aspect required is a methodology for determining the severity of the alternate test proposal. The proposed methodology is dependent on the limiting component, the failure mechanism for that component, the operating duration at the CPA conditions, and the engine systems that affect and are affected by the failure mechanism.

To create a comparison metric, the damage on the critical components can be characterised per hour of operation for all potential thrust/power-setting conditions and then used to calculate the actual damage accrued for the proposed cyclic conditions and time durations in the alternate endurance test. This will provide the ability to accumulate damage consumed for cycles of varying number, duration, and thrust/power setting. Examples of damage include creep, SPLCF, TMF, etc.

Methods such as spreadsheet tools may be developed to facilitate implementation of the severity comparison during the applicant's test-planning phase. This will aid in defining the aspects of the alternate test that best suits the particular design and intended operation of the engine, while ensuring the test is adequately severe. The proposed test consists of a mix of cycles run at various power-settings for varying durations as derived from the CPA to accumulate the expected damage for each test segment.

(d) When severity equivalence is not achieved by testing

Unanticipated factors occurring during testing may lead to a situation where the intended severity equivalence is not achieved. As indicated in CS-E 740(c)(4)(iv)(3), the implication of this is that the demonstrated EGT will be reduced to the level at which the revised reference severity, based on a reduced EGT, meets the achieved severity. This exercise, therefore, involves a back-calculation, via the reference severity process, of the critical component temperatures that have been demonstrated for this test level of severity, and thus also the demonstrated EGT.

The severity deficit may also be compensated by additional testing in compliance with CS-E 740(c)(4)(vi).

(6) Number of cycles to reach equivalent severity

It is expected that a cyclic accumulation of approximately 500–750 cycles is needed for the equivalent severity demonstration in order to also expose any potential incipient LCF, SPLCF, and TMF type damage to aerofoil components. A cycle is defined as a rapid acceleration (throttle move in 1 second or shorter) from ground idle to at least maximum rated thrust and a rapid deceleration back to ground idle.

(7) Alternate endurance test examples

The following examples illustrate an approach, but not the only approach, to create an alternate endurance test that uses the comparative severity methodology presented in paragraph (5) of this AMC.

In these examples, comparative severity to the original intent of the classic endurance test is based on the creep failure mode as explained in paragraphs (4) and (5) of this AMC. Damage factors relating to this failure mode are calculated for 1 hour of operation at each of the intended limiting power-settings and input into a spreadsheet accounting tool (see below).

Severity / Hr. for Critical Components

Test Segment	Component #1	Component #2	Component #3
MTO NL Redline	0.00324		
MTO NH Redline	0.01354		
MTO EGT Redline	0.00726		
MCT NL Redline	0.00284		
MCT NH Redline	0.00933		
MCT EGT Redline	0.00448		
MTO EGT Limiting	0.00551		
MCT EGT Limiting	0.00273		
MTO Rated Thrust	0.00156		
MCT Rated Thrust	0.00142		

Damage Factors for Each Condition Normalized to 1 Hour at That Condition.

Figure 7.1 — Severity Factors (Life Usage Rate) for Critical Components

The specifications of CS-E 740(c)(4)(iv) 'Engine Redline Demonstration' are illustrated below, along with the damage factors associated with Engine operation at each power-setting condition for each prescribed duration. These test specifications represent minimum durations in a prescribed portion of the test. Additional testing at these conditions may be required based on the results of the applicant's CPA.

Engine Redline Demonstrations -- Rated thrust must be met or exceeded.:

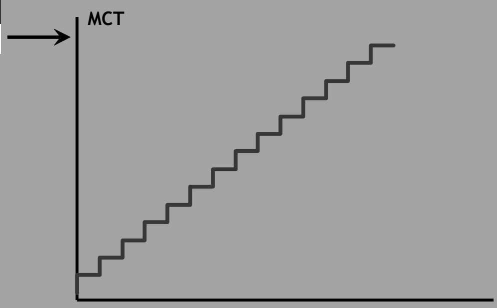
		Accumulated Damage
30	minute minimum demonstration for N1	0.00112
10	minute minimum demonstration for N2	0.00225
10	minute minimum demonstration for N3	N/A
10	minute minimum continuous demonstration for MTO Temp.	0.00103
4.5	minute minimum demonstration for MTO Temp. Completed as three 90 second cycles.	0.00047
90	minute minimum continuous demonstration for MCT Temp.	0.00135

Damage Accumulated for Each Condition and Duration at That Condition.

Figure 7.2 — Severity Usage for Engine Redline Demonstrations

Compliance with the specifications of CS-E 740(c)(4)(vii) consists of testing at 15 equally spaced power-settings between idle and MCT. A duration of 10 minutes is prescribed at each power-setting. 25 total cycles are also prescribed. The accumulated damage at the MCT power-setting is accounted for. The damage accumulated at the lower power-settings is minor, and not accounted for in the overall comparison.

Powerset	Cycles	MCT Duration (min.)	Total MCT Time (hr.)
MCT	25	10	4.2



Accumulated Damage
0.00592

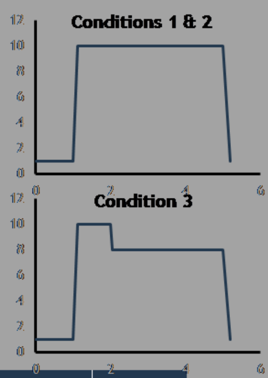
Figure 7.3 — Severity Usage for Stair Step Cycles per Part 4 of CS-E 740(c)(1)

Engine limiting temperature (EGT) demonstration testing (refer to CS-E 740(c)(4)(v)) is a performance-based aspect of the alternate endurance test. It requires analysis from the applicant to support the limiting temperature, and methodologies for how to perform the test to represent the limiting temperature, and for demonstrating its severity. A mix of cycles is illustrated here that defines durations related to operation (e.g. 5 or 10 minutes at MTO, 30 or 90 minutes at MCT), and includes some cyclic content that contributes to the minimum cycle count defined in CS-E 740(c)(4)(viii) 'Ancillary TCDS Limits Definition'.

Engine Limiting Temperature Demonstration -- Rotor speeds must be held at or above the speeds predicted for the CPA condition. Rated thrust must be met or exceeded:

Condition No.	Powerset	Cycles	MTO Duration (min.)	Idle Duration (min.)	Total MTO Time (hr.)	Accumulated Damage
1a	MTO	20	10	5	3.3	0.01837
1b	MTO	60	5	5	5.0	0.02755
1c	MTO				0.0	0.00000

Condition No.	Powerset	Cycles	MCT Duration (min.)	Idle Duration (min.)	Total MCT Time (hr.)	Accumulated Damage
2a	MCT	10	90	5	15.0	0.04095
2b	MCT	20	30	5	10.0	0.02730
2c	MCT				0.0	0.00000



Condition No.	Powerset	Cycles	MTO Duration (min.)	MCT Duration (min.)	Idle Duration (min.)	Total MTO Time (hr.)	Total MCT Time (hr.)	Accumulated Damage
3a	MTO/MCT	20	5	30.0	5	1.7	10.0	0.03648
3b	MTO/MCT					0.0	0.0	0.00000
3c	MTO/MCT					0.0	0.0	0.00000

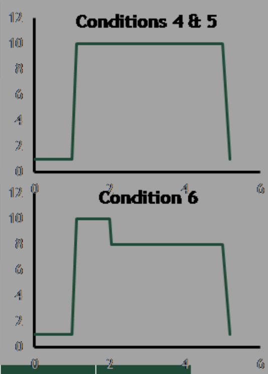
Figure 7.4 — Severity Usage for Extended Operating Periods

Engine-rated performance demonstration is also a performance-based element of the alternate endurance test, and is also supported by analysis that assesses the accumulated damage to critical components as part of the overall test severity assessed. A similar mix of various cycles and durations has also been used in this illustration, along with the respective accumulated damage. In this example, much of the cyclic content is conducted during this test segment.

Engine Rated Performance demonstration -- Rated thrust must be met or exceeded:

Condition No.	Powerset	Cycles	MTO Duration (min.)	Idle Duration (min.)	Total MTO Time (hr.)	Accumulated Damage
4a	MTO	50	0.5	5	0.4	0.00065
4b	MTO	200	5	5	16.7	0.02600
4c	MTO				0.0	0.00000

Condition No.	Powerset	Cycles	MCT Duration (min.)	Idle Duration (min.)	Total MCT Time (hr.)	Accumulated Damage
5a	MCT	20	90	5	30.0	0.04260
5b	MCT	20	30	5	10.0	0.01420
5c	MCT				0.0	0.00000



Condition No.	Powerset	Cycles	MTO Duration (min.)	MCT Duration (min.)	Idle Duration (min.)	Total MTO Time (hr.)	Total MCT Time (hr.)	Accumulated Damage
6a	MTO/MCT	30	5	20.0	5	2.5	10.0	0.01810
6b	MTO/MCT					0.0	0.0	0.00000
6c	MTO/MCT					0.0	0.0	0.00000

Figure 7.5 — Severity Usage for Additional Extended Conditions

Finally, in this example, a summary of the test times and accumulated damage is compiled. This accumulated damage can be normalised by the reference severity, which, for this example, was the creep damage caused by 18.75 hours of operation at MTO limits and 45 hours of operation at MCT limits, the total accumulated times at these conditions in the classic endurance test.

Endurance Test Dashboard

Power-Setting	Test Time (hrs.)
MTO	30.7
MCT	70.7
Idle	50.0
Part Power Thrust	54.2
Total Time	205.5

Cycles	No.
MTO	380
MCT	70
Total Cycles	450

Power-Setting	Accumulated Damage	Reference Damage	Normalized Damage
MTO	0.09128	0.16000	0.57051
MCT	0.17327	0.06000	2.88783
Total Damage	0.26455	0.22000	1.20251

Accumulated damage normalized by the reference severity

Figure 7.6 — Cumulative Severity Usage for Whole Test — first example

In this example, the total test time is more than 35 % longer than the classic endurance test, with the portions performed at or above the MTO and MCT ratings approximately 50 % longer. This example alternate endurance test also includes 30 % more cyclic content than the classic endurance test. The comparative severity of this example alternate endurance test indicates that it is 20 % more severe with regard to creep damage than the original intent of the classic endurance test.

A different mix of cycles more weighted to MCT operation illustrates that more time at lower temperatures can yield the same comparative severity. The second example below uses a ratio between MTO and MCT power-settings that better reflects how a modern large aeroplane is operated. In this example, the total test time is nearly 60 % longer than that of the classic endurance test, but the comparative severity to the original intent of the classic endurance test is the same as in the previous example.

Endurance Test Dashboard

Power-Setting	Test Time (hrs.)
MTO	17.9
MCT	130.7
Idle	31.7
Part Power Thrust	54.2
Total Time	234.4

Cycles	No.
MTO	240
MCT	240
Total Cycles	480

Power-Setting	Accumulated Damage	Reference Damage	Normalized Damage
MTO	0.04111	0.16000	0.25692
MCT	0.22462	0.06000	3.74367
Total Damage	**0.26573**	**0.22000**	**1.20785**

Figure 7.7 — Cumulative Severity Usage for Whole Test — second example

(8) Severity Equivalence Assessment for T_{metal} and EGT methods

(a) Introduction

This paragraph provides a breakdown of the steps involved in establishing the alternate endurance test severity equivalence, and hence EGT RL, for the alternate test. The process visualisation provided by the following flow charts intends to provide a better understanding of two optional alternate endurance test approaches: the T_{metal} method and the simpler EGT RL method.

(b) Discussion on the methods

The establishment of the test severity equivalence, required to substantiate the cleared EGT RL, demonstrated during the alternate endurance test, is a complex aspect of this compliance method. This is illustrated by comparing the process for each type of endurance test against the classic test as per CS-E 740(c)(1):

(i) *Method 1:* For the classic test as per CS-E 740(c)(1): the EGT recorded for the test is simply accepted as the RL (complying with CS-E 740(f)(4)); no test severity equivalence is required.

(ii) *Method 2:* For the alternate test (by T_{metal} method): the EGT RL is derived from the metal temperatures demonstrated during the test. This derivation requires that the applicant is able to establish the metal temperatures (using performance/thermal modelling of the test engine), and to establish the EGT values corresponding to this metal temperature, which will be claimed as EGT RL, for the case of a deteriorated version of the Engine, by similar modelling, but of a deteriorated Engine. The metal temperatures are also used to assess the accumulated severity of the alternate test and to ensure equivalence to the target severity which comes from a simulation of the classic test (which assumes the metal temperature for the case of a deteriorated version of the Engine). Validated analytical methods would be necessary for these steps (see *Figure 8.1* overview chart below).

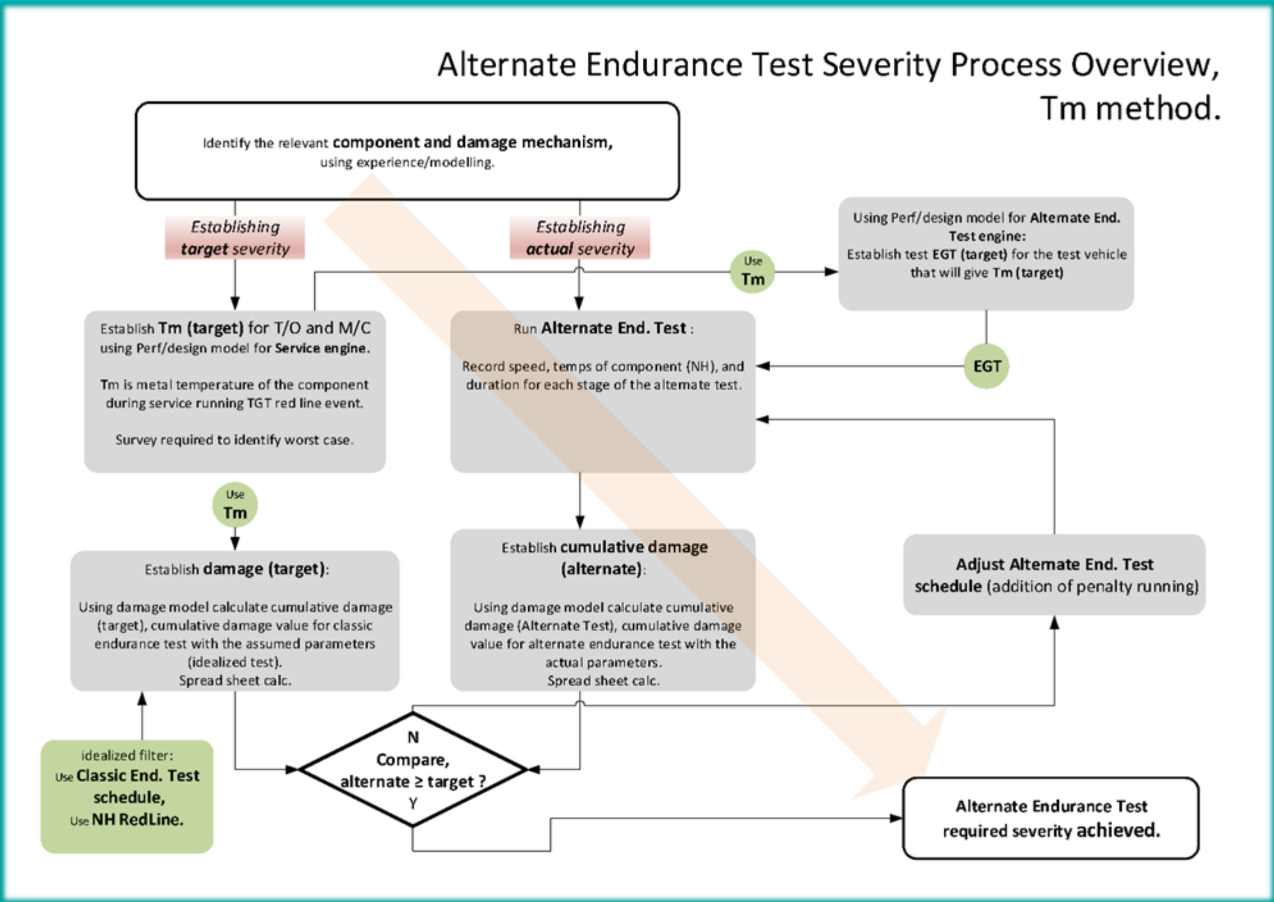


Figure 8.1 — T_{metal} Method 2 overview

Abbreviations

$T_m = T_{metal}$:	metal temperature
T/O:	take-off thrust
M/C:	maximum continuous thrust
NH:	core rotor speed
End.:	endurance

(iii) *Method 3:* For the alternate test (by EGT RL method), a compromise alternate test, avoiding the complications of the metal temperature methods above, the EGT recorded for the test is accepted as the RL (complying with CS-E 740(f)(4)), contingent upon substantiation of the severity equivalence to the target severity (see *Figure 8.2* overview chart below).

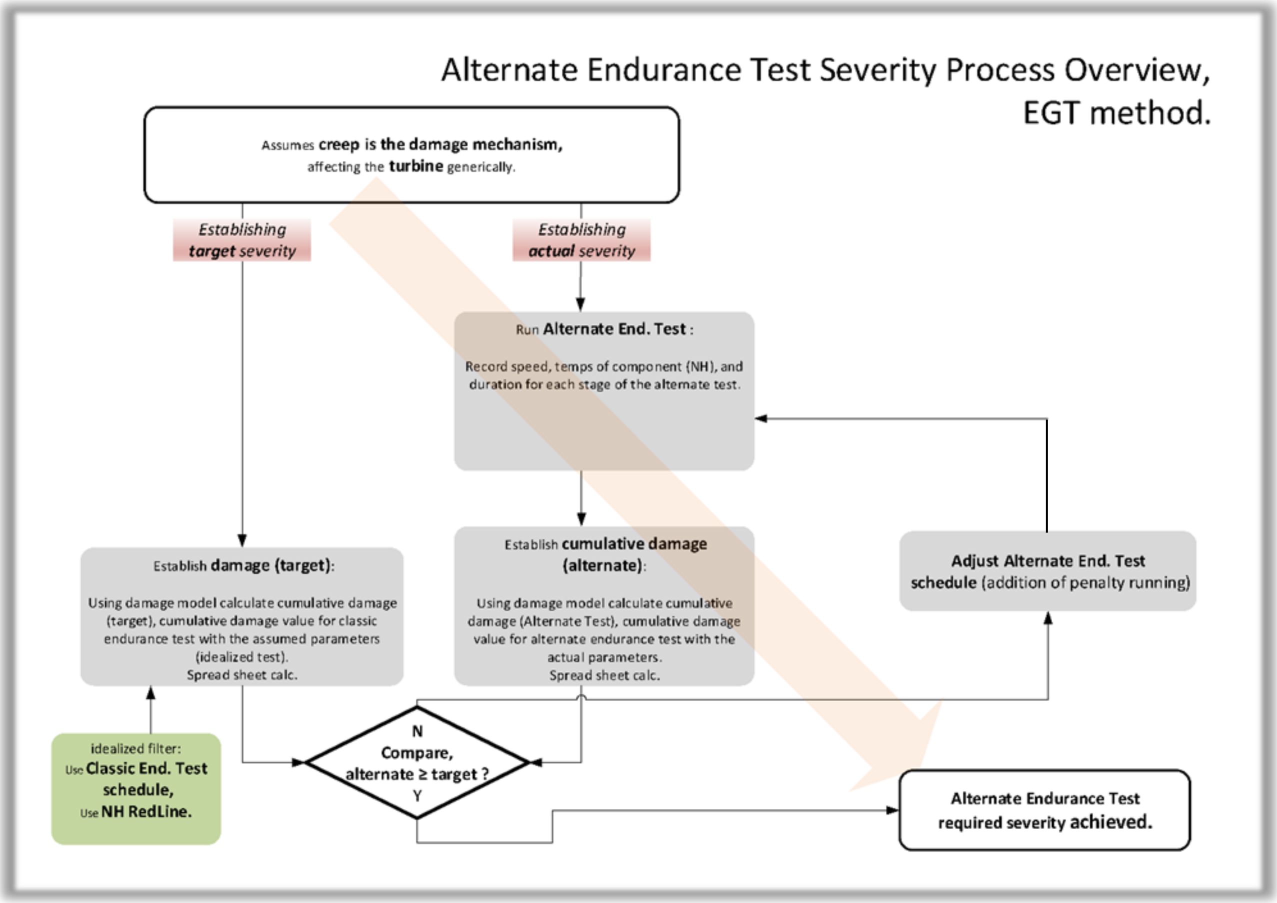


Figure 8.2 — EGT Method 3 overview

(c) Explanation of the detailed flow charts (below)

The flowcharts represent the process used to calculate a severity level for a particular cumulative damage mechanism affecting a particular Engine part/component during an endurance test.

The severity calculation process will be performed for the alternate test, using the recorded test data, to give the 'actual severity' level achieved (*Figure 8.5*). The severity calculation process will also be performed for a theoretical test of the same component but completed to the classic test requirements, using a combination of data taken from a production Engine simulation and assumed RL speeds, to give the target levels required: the 'idealised severity' (*Figure 8.3*). While the processes appear similar, the inputs are actually different; therefore, separate flow charts are provided for each. Also included is a 'plan severity' flow chart which would be used prior to commencement of an Engine test to establish an accurate test plan (*Figure 8.4*). Thus, three separate calculation processes are envisaged, each represented by a separate flow chart: the calculation of the Engine *target/idealised test severity level*, the *planned test severity level* and the *actual test severity level*.

The main flow charts (*Figures 8.3, 8.4, 8.5, 8.9, 8.10 and 8.11*) are divided into two parts:

— The left column is the main loop that will be repeated for each fixed condition of the test, for each of which a particular damage-per-hour (DPH) value will be derived to calculate increments of accumulated damage, to give the overall sum for the process.

— On the right side is the sequence required to calculate the DPH, which utilises three separate models. The modelling sequence starts with a performance model that simulates the particular Engine fixed (power) conditions (Z_m) and derives the local conditions (Y_m) for the particular part being assessed. A design model of the part would then be used to simulate the part under those local conditions to give the local input parameters (X_m) for the damage mechanism. A damage model would then simulate those material conditions to provide the DPH.

Some secondary charts are also included to provide further insight into the concept for each model.

(d) Mathematical Background / Basis

Ⓐ Severity is the sum of accumulated damage

$$Severity = \sum_{k=1}^{k_n} Damage_k$$

Ⓑ Damage is the accumulated damage per cycle (k)

$$Damage = \int Dph\, dt \cong Dph * t$$

For the ease of calculation (and introducing only a small error), we neglected the small amount of damage accumulated in the ramp up to and down from the stabilised points.

$$Dph = Dph(x_1, x_2, x_3, x_4, .., x_n)$$

Ⓒ Damage per hour (DPH) is calculated based on the damage mode specific inputs (x_m). Typical local inputs include local stress (σ_{metal}), local temperature (T_{metal}), etc.

$$x_m = x_m(y_1, y_2, y_3, y_4, .., y_n, z_1, z_2, z_3, z_4, .., z_n)$$

Ⓓ Each of these local inputs into the damage model is in turn calculated from other parameters (y_m and z_m). Other typical parameters include both instrumented Engine conditions (z_m) and derived Engine conditions (y_m). Typical instrumented Engine conditions (z_m) include N1, N2, EGT, EPR, etc. Typical derived Engine conditions (y_m) include $\dot{m}_{bleed}, T_{bleed}, P_{bleed}, P_{upstream}, P_{downstream}, T_{upstream}, T_{bulk}$, etc.

Ⓔ The derived Engine conditions are calculated by performance analyses, CFD, FEA, etc. Ultimately, each of the derived Engine conditions are functions of the instrumented Engine conditions.

$$y_m = y_m(z_1, z_2, z_3, z_4, .., z_n)$$

Therefore, while very complicated and including potentially multiple modelling calculations, each of the local inputs can ultimately be written as a function of the instrumented Engine conditions:

$$x_m = x_m(z_1, z_2, z_3, z_4, .., z_n)$$

(e) Main T_{metal} method flow charts

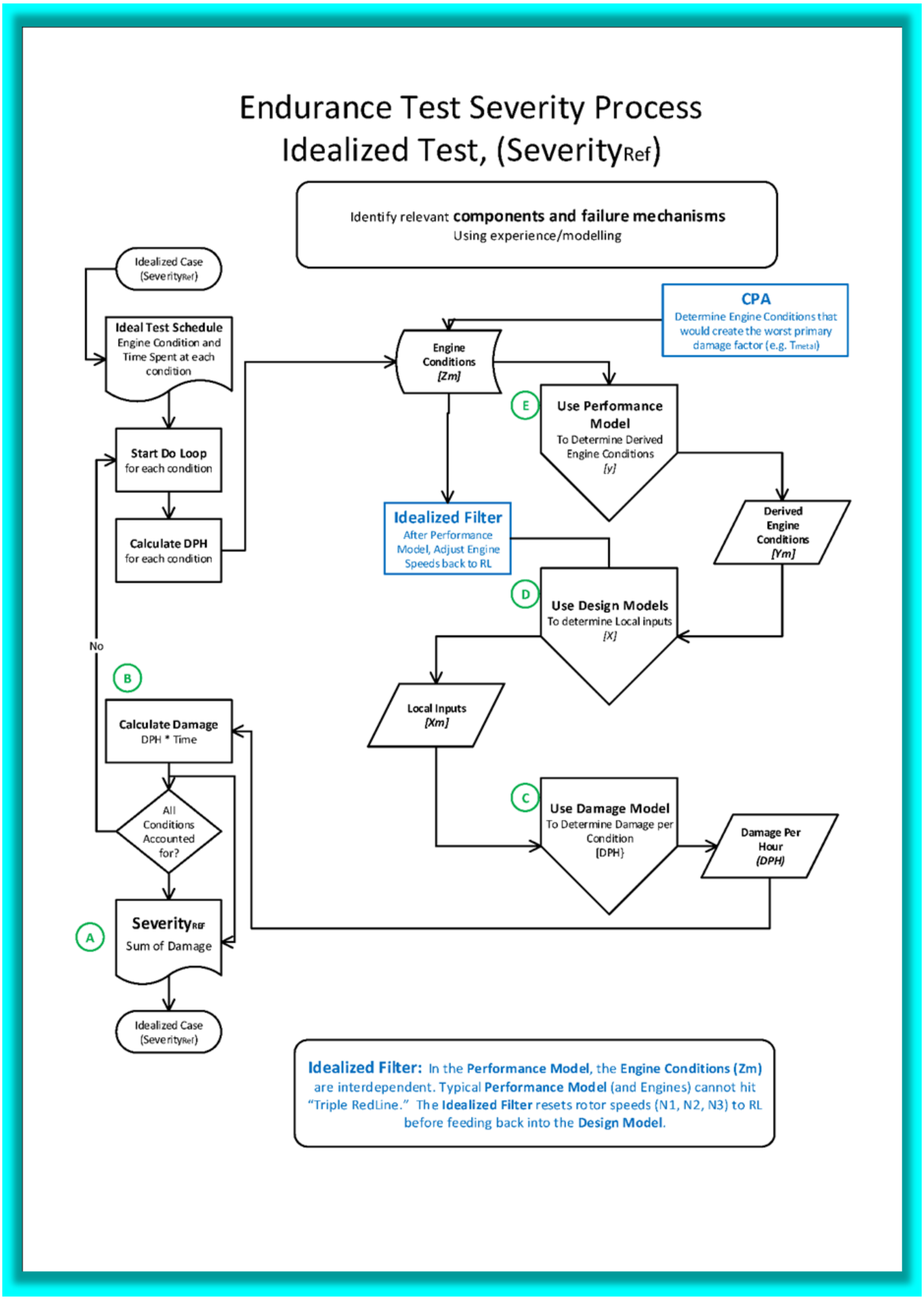


Figure 8.3 — Endurance Test Severity Process — Idealised Test ($\text{Severity}_{\text{Ref}}$)

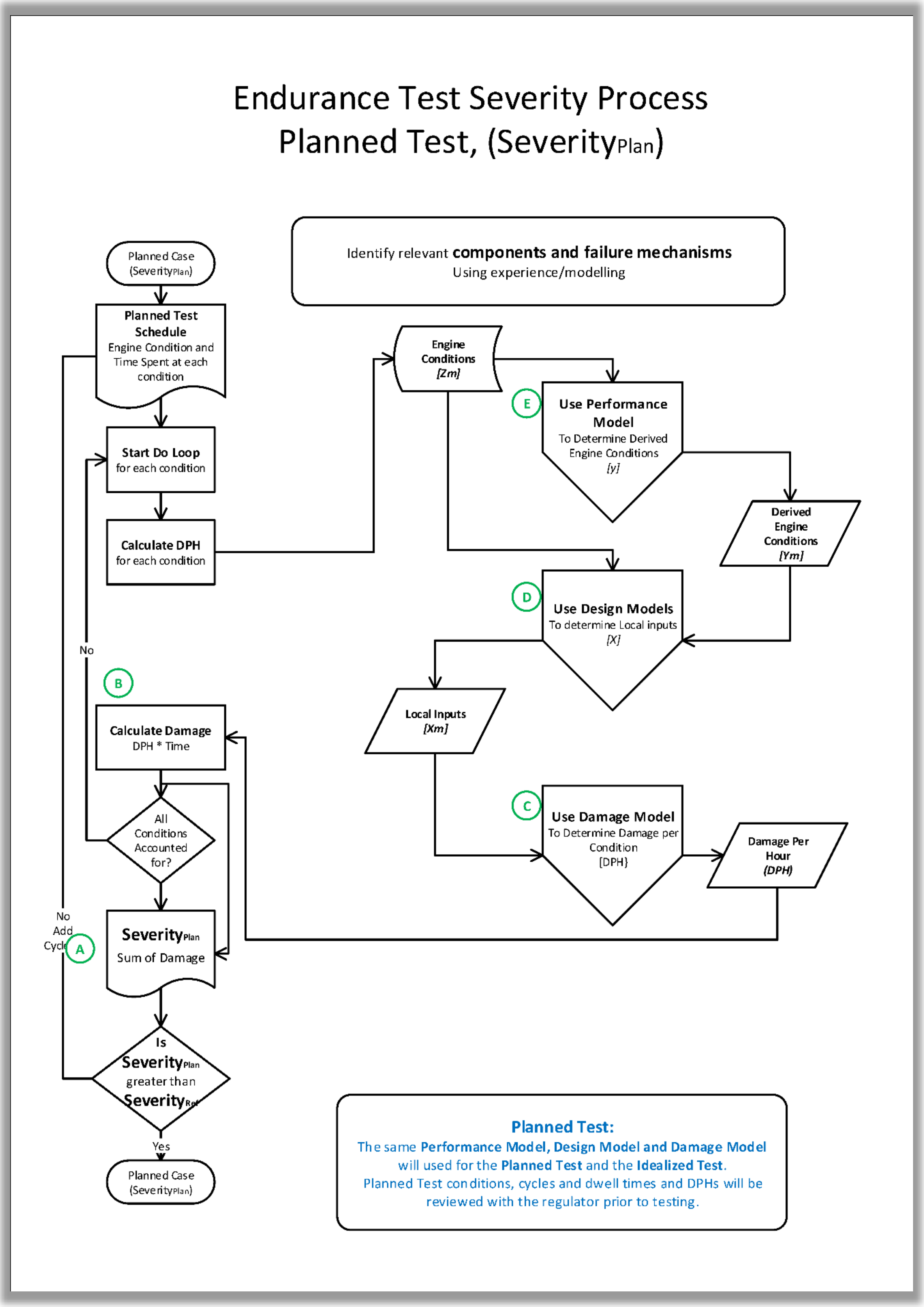


Figure 8.4 — Endurance Test Severity Process — Planned Test (SeverityPlan)

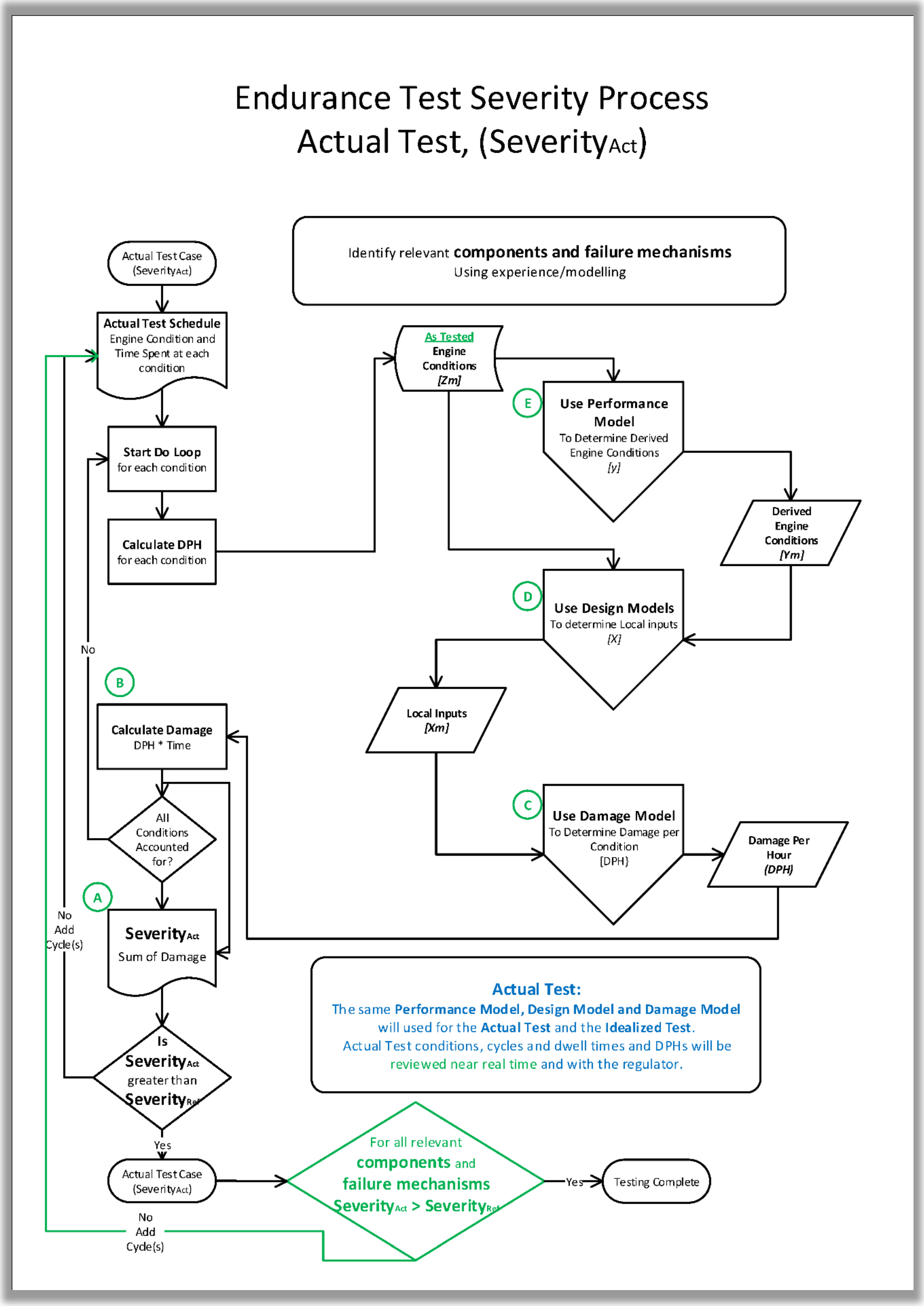


Figure 8.5 — Endurance Test Severity Process — Actual Test (SeverityAct)

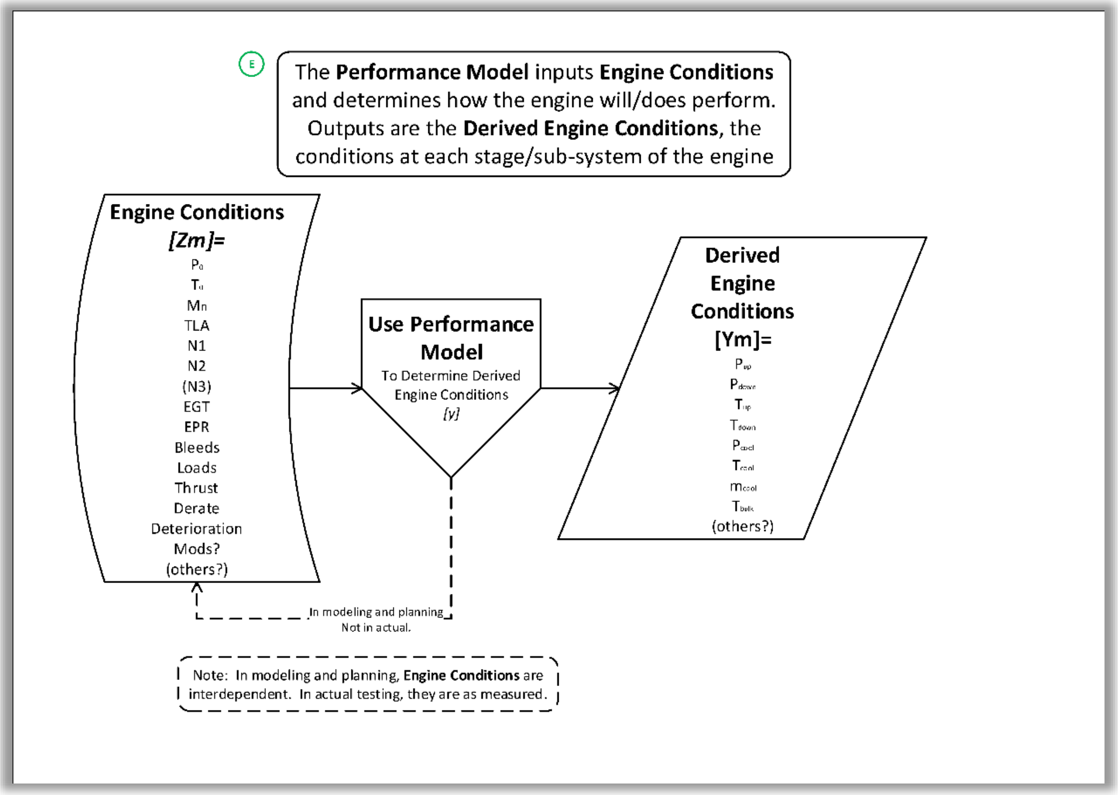


Figure 8.6 — Performance Model

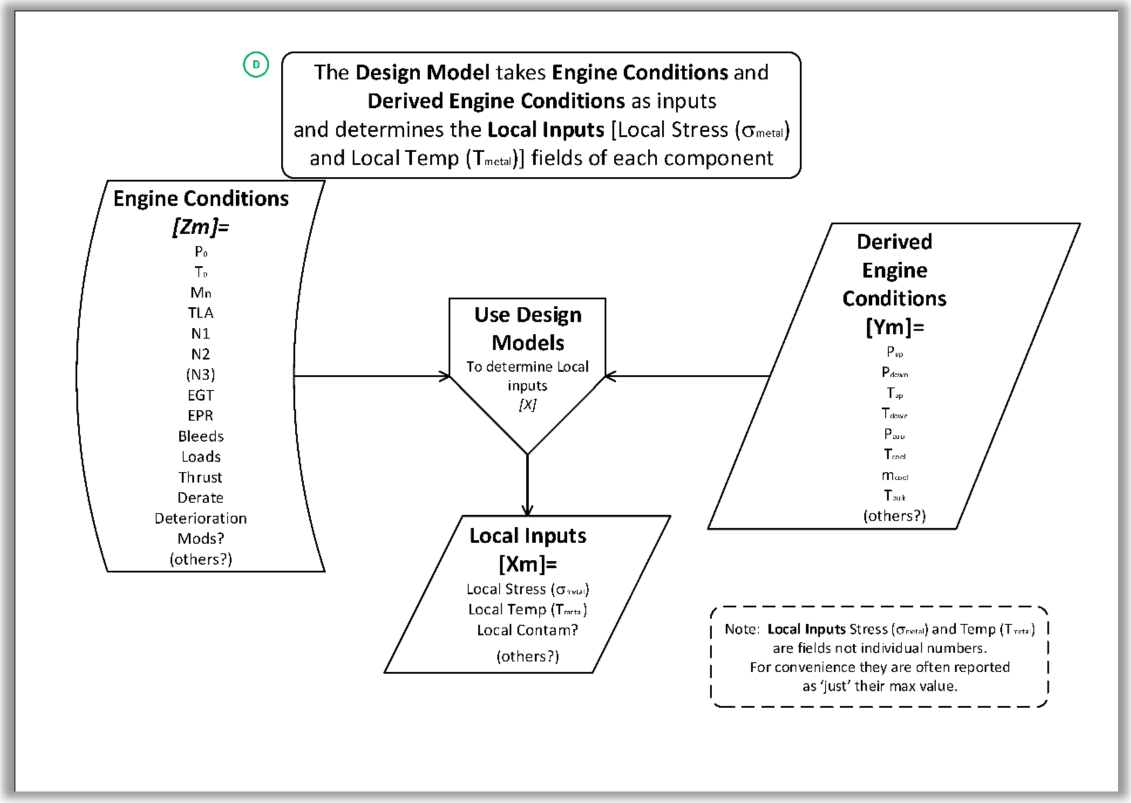


Figure 8.7 — Design Model

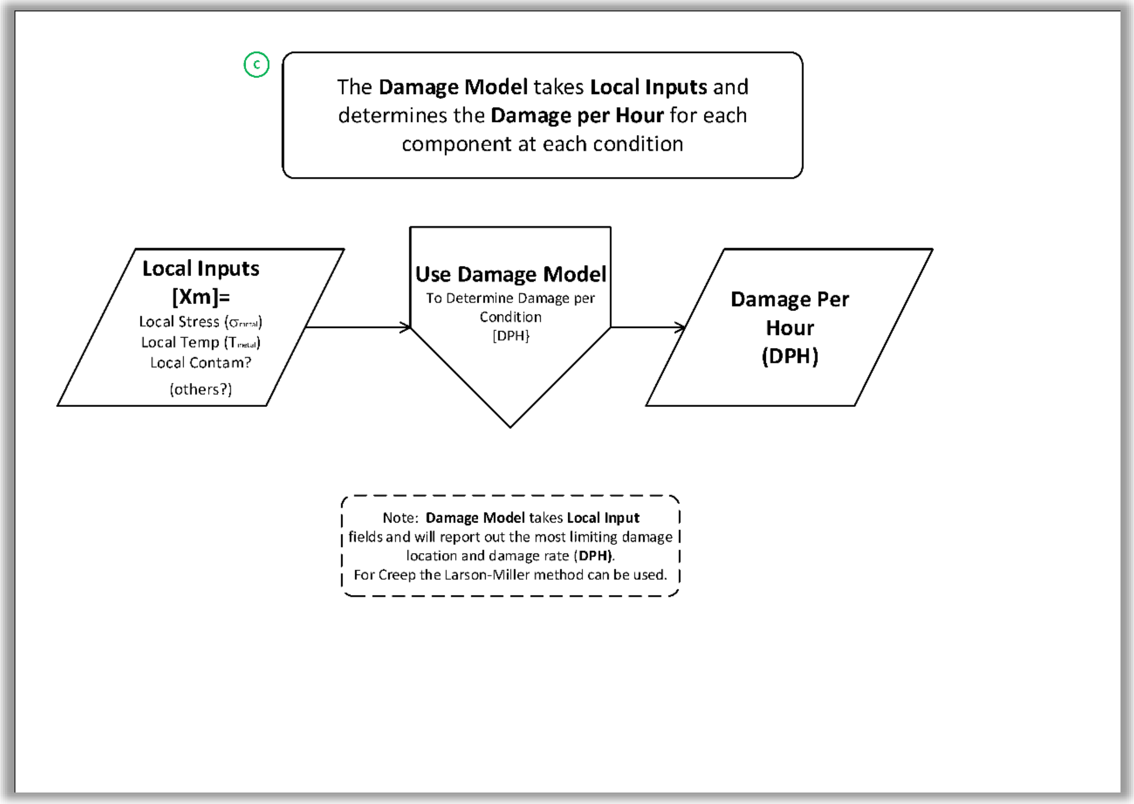


Figure 8.8 — Damage Model

(d) EGT as a proxy for T_{metal}

A significant simplification to the T_{metal} approach is to run the test using EGT as a proxy for T_{metal}. The immediate benefit of this approach is that the EGT recorded for the test is accepted as the approved operating limitation, contingent upon substantiation of the severity equivalence to the target severity. The drawback of the approach is that metal temperatures of some turbine components may be different (normally assumed to be higher, but theoretically lower is also possible, in which case the T_{metal} method is more appropriate) compared to a T_{metal} method when substantiating the same EGT RL value. The test will be similar to the classic test with the exception that the target speed RL is not met during all Take-off and MCT settings, hence the need for the severity equivalence assessment to establish the additional penalty running required. The applicant wanting to use the EGT method would need to justify that it would be conservative on T_{metal} relative to CPA conditions.

With regard to the process for this approach, the following flow charts (*Figures 8.9–8.12*) illustrate the steps and provide a comparison to the T_{metal} process. As it can be seen, the modelling sequence is significantly simplified.

Note that the flow charts indicate that the damage mechanism assumed by the EGT approach, as for the classic test, is creep. The assumption is taken because the process in this case, as for the classic test, does not demand that a specific component be identified. This does not rule out that an EGT-based test could be assessed for severity of damage mechanisms other than creep.

(e) Main EGT method flow charts

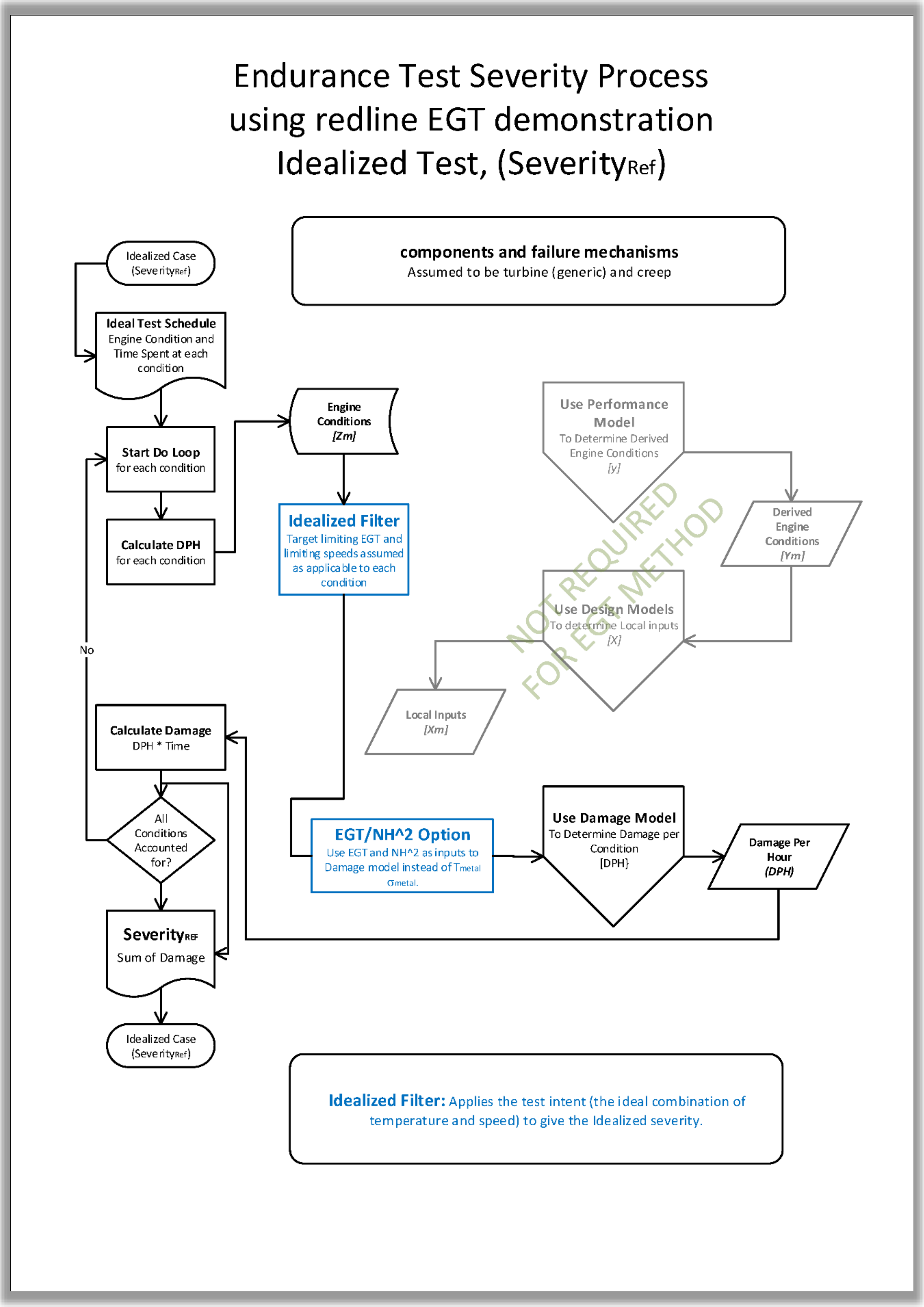


Figure 8.9 — Endurance Test Severity Process using RL EGT Demonstration — Idealised Test ($Severity_{Ref}$)

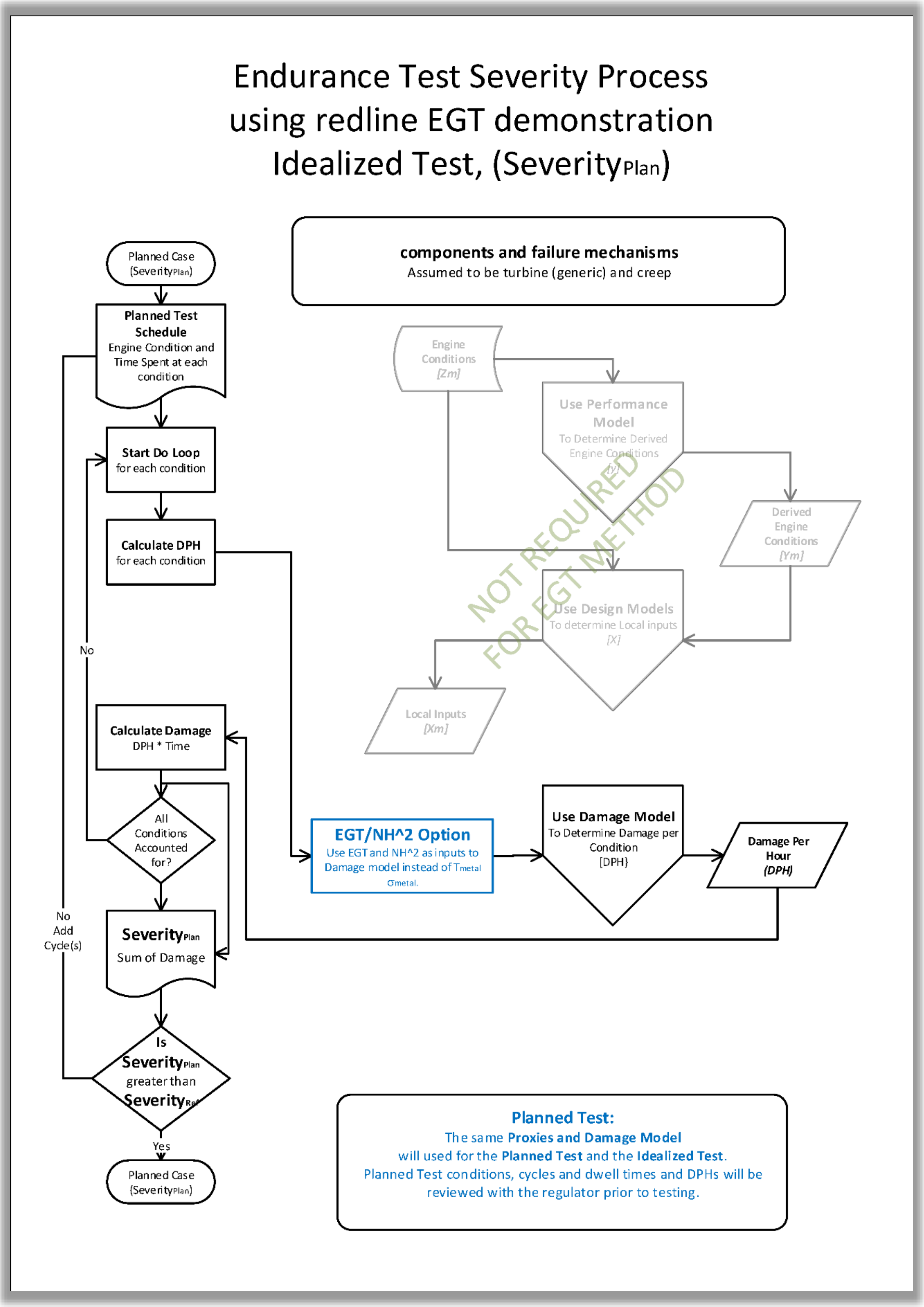


Figure 8.10 — Endurance Test Severity Process using RL EGT Demonstration — Idealised Test ($Severity_{Plan}$)

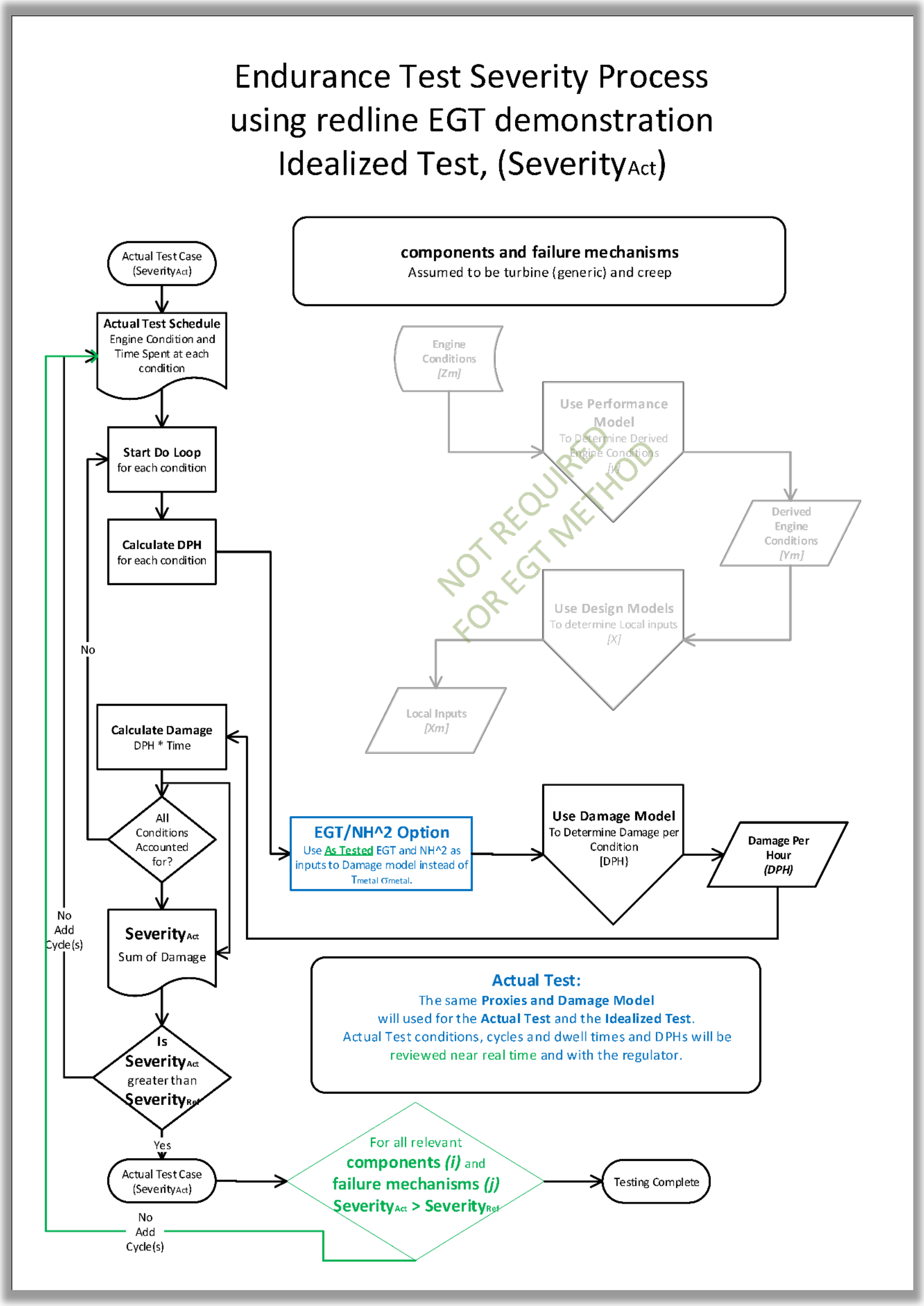


Figure 8.11 — Endurance Test Severity Process using RL EGT Demonstration — Idealised Test (Severity$_{Act}$)

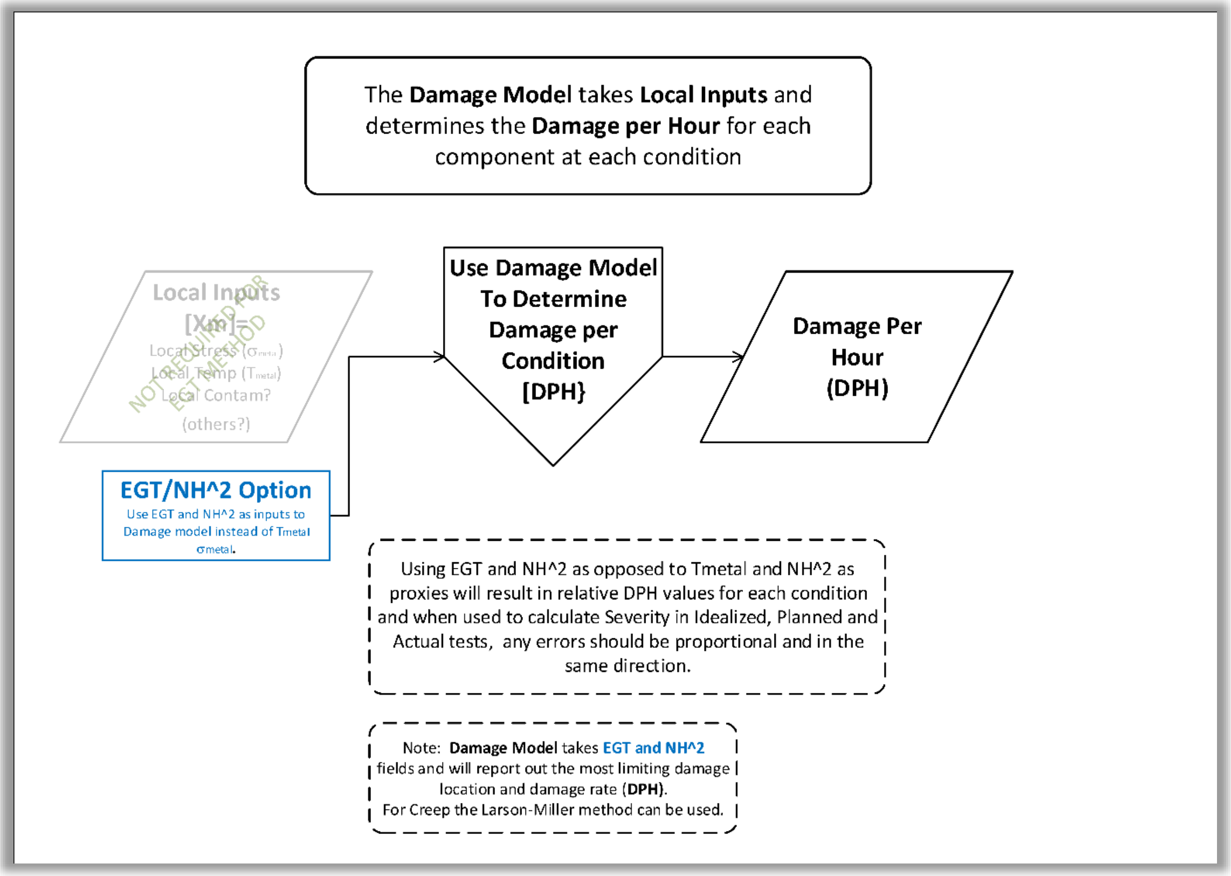


Figure 8.12 — EGT Method Damage Model

(f) Conclusion

For the 150-hour endurance test, either method (Method 1 *Classic endurance test*, Method 2 *Alternate test (T_{metal} method)*, or Method 3 *Alternate test (EGT method)*) could be used. Each method has its benefits and drawbacks; however, following each of the methodologies will result in an adequately severe test. The applicant will be required to discuss with EASA which method it plans to use before the start of the test.

Important for both Methods 2 and 3 is that the performance and damage calculation methodology MUST be consistent between the $Severity_{Ref}$ and $Severity_{Act}$ calculations. If during the testing there is test data that requires an update to one of the modelling methodologies, then $Severity_{Ref}$ would need to be recalculated with the new methodology as well.

AMC E 740(h)(2) is amended as follows:

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

(1) […]

(2) For complying with the structural integrity specification of CS-E 740(i~~h~~)(2)(iii), the applicant should show that no Failure of any significant Engine component occurs during test or during shutdown, or becomes evident during the subsequent strip examination. In the event that any Failure becomes evident, this should be analysed and corrective actions taken, or certain

limitations imposed on the Engine as appropriate. For the purpose of this specification, the Engine parts deemed significant are those that can affect the structural integrity, including but not limited to mountings, casings, bearing supports, shafts and rotors.

[…]

CS-E 870 is amended as follows:

CS-E 870 Exhaust Gas Over-temperature Test

(a) *General*

[…]

(b) *Test Conditions*

(1) A 15-minute period at Maximum Exhaust Gas Over-temperature must be run with each spool of the Engine which could be significant to the test, at the maximum speed to be approved (excluding the Maximum Engine Over-speed (20 Seconds)). If run as part of an alternate endurance test in accordance with CS-E 740(c)(4), then a 5-minute period at Maximum Exhaust Gas Over-temperature may be substituted for the 15-minute period.

(2) […]

CS-E 890 is amended as follows:

CS-E 890 Thrust Reverser Tests

[…]

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

[…]

Issue 2: Turbine-engine initial maintenance programme (IMP) test

The following CS-E 930 is added:

CS-E 930 Initial Maintenance Programme Test

(See AMC E 930)

One of the following tests must be performed with an Engine that substantially conforms to the type design to substantiate the initial maintenance programme (IMP) that will be included in the instructions for continued airworthiness (ICAs) in order to ensure sufficient Engine reliability under in-service conditions:

(a) an Engine test that simulates the conditions in which the Engine is expected to operate in service, including typical start–stop cycles; or

(b) an Engine test performed in accordance with AMC 20-6 Revision 2 (Extended Range Operation with Two-Engine Aeroplanes ETOPS Certification and Operation), Appendix 1 Section 2.b.

If the applicant applies for a change through amendment of an existing type certificate or through supplemental type certification, it is not required to complete the above test.

The following AMC E 930 is added:

AMC E 930 Initial Maintenance Programme Test

(a) Definitions

For the purposes of this AMC, the following definitions apply:

(1) 'Engine flight cycle': predicted average flight profile of the Engine parameters and conditions representative of the way the Engine is expected to operate in service.

(2) 'Initial maintenance programme (IMP)': instructions for continued airworthiness (ICAs) submitted under CS-E 25 that are considered necessary to ensure sufficient Engine reliability. These instructions may be required by the type certificate (TC) holder in the ICAs' Airworthiness Limitations Section or may be recommended at certain intervals.

(3) 'Initial maintenance inspection (IMI) intervals': an IMP approach for maintenance tasks based on hard time policy, maximum hours or cycles, that an Engine or Engine module should be operated before a maintenance task is performed.

(4) 'Overhaul': the process to disassemble, clean, inspect, repair or replace (as necessary), reassemble, and test for return-to-service approval within the manufacturer's overhaul data specifications. This process relates to the periodic disassembly of the entire Engine rather than maintenance of individual parts or assemblies.

(b) Purpose of the IMP test

The primary purpose of the IMP test run is to demonstrate sufficient Engine reliability and support the establishment of the entry-into-service (EIS) initial maintenance programme (IMP) for that type design. Therefore, this AMC provides guidance and acceptable means of compliance on:

(1) test methods and procedures,

(2) test pass/fail criteria,

(3) EIS IMP requirements, or recommendations.

(c) IMP test

(1) IMP test cycle assessment

(i) General

The applicant should provide an assessment of expected service operating conditions as part of the test plan. In this assessment, the applicant should show that the proposed test cycle represents the expected in-service Engine flight cycles, including the following:

— established power/thrust ratings,

— reverse thrust use,

— component stress and temperature,

— exhaust gas temperature (EGT),

— vibration,

— cycle/operating time cumulative damage,

— other critical factors.

For multiple aircraft applications, the applicant should show that the test cycle adequately represents all identified or anticipated installations and Engine flight cycles.

Test cycles that have been used in the past include:

— full cycle (paragraph (c)(1)(ii)),

— accelerated severity cycle (paragraph (c)(1)(iii)),

— combinations of the above test cycle types.

If the test plan combines the IMP test with the AMC 20-6 Revision 2 Appendix 1 Section 2.b early ETOPS test, the applicant must successfully complete the early ETOPS test prior to EIS. See paragraph (c)(7).

(ii) Full Cycle Test

The full cycle test requires that the Engine is run through the exact thrust or power setting sequences for the time periods identified in the Engine flight cycle. Thus, one complete cycle of a full cycle test should include:

— a typical Engine flight cycle,

— the exact number of operating hours, from Engine start through complete shutdown.

(iii) Accelerated Severity Cycle Test

The accelerated severity cycle test provides a rigorous test of those Engines (or Engine parts) for which durability is primarily affected by cyclic operation. This type of test allows to vary from the Engine flight cycle the following conditions:

— time at various thrust or power settings,

— sequence of thrust or power selections.

To determine the relationship between the accelerated severity cycle test and the full flight cycle as required above, a detailed analysis should be performed of:

— the stress,

— the temperature, and

— the resulting life of each affected part of the Engine.

The accelerated severity cycle test may include the equivalent of several flight cycles during a given portion of the overall Engine test. This can result in a small number of Engine hours in comparison to the number of Engine flight cycles demonstrated.

The accelerated severity cycle test is generally not considered ideal for Engine parts for which durability is primarily affected by hours of operation rather than by cycles. For those cases, the IMP substantiation may require other test or in-service experience data (including, if available, comparison of relevant past IMP demonstrations to subsequent successful entry-into-service (EIS) Engine experience).

The accelerated severity cycle test should include Engine start and shutdown.

(2) IMP Test Engine Configuration

(i) General

CS-E 930 requires the test to be performed with an Engine that substantially conforms to its final type design. Therefore, no significant Engine modification should be required to complete the IMP test.

(ii) Consideration of Hardware Items Not Part of the Engine Type Design

The applicant should include in the IMP test other hardware items, or representative hardware items, that are not normally part of the Engine type design (for example, thrust reverser, air starter, Engine build-up hardware) and that have an impact on the reliability of the Engine.

(iii) Engine Test Configuration

The applicant should perform the IMP test when the Engine is installed in a typical configuration, to the maximum extent possible.

For example, the applicant should:

— connect and operate, in a way representative of the intended service, the airframe accessories and the interfaces that load the Engine;

— schedule, throughout the test, typical accessory loads and bleed air extraction that would be experienced during the Engine flight cycle.

(iv) Turbopropeller Applications

For turbopropeller Engine applications, the test should be run with an installation-eligible propeller installed. The applicant should incorporate into the test cycle applicable design features, such as:

— propeller braking,

— auxiliary power unit (APU)-mode operation(s).

(v) Turboshaft Applications

For turboshaft applications, the applicant should load the test Engine output shaft to simulate the appropriate rotor drive system characteristics of the intended installation. Potential rotor drive system characteristics include but are not limited to inertial and torsional vibration.

(3) Test Parameters

The conditions achieved during the test should effectively represent the conditions expected during an Engine flight cycle, including:

— power/thrust,

— stress,

— component temperature,

— EGT,

— unbalance vibration.

(4) Test Duration

The total number of test cycles and the test duration should be sufficient to demonstrate the effectiveness of the IMP for the new Engine model in a typical installation.

Note: CS-E 930 does not require a fixed number of cycles (i.e. the IMP test is not a 1 000-cycle test). However, the applicant should correlate the number of cycles proposed for the test to the planned Engine IMP. Please refer to paragraph (c)(6).

(5) Pass/Fail Criteria

(i) General

The Engine type design will comply with CS-E 930 when the post-test hardware condition demonstrates that the Engine will remain airworthy when applying the proposed IMP. The Engine should comply with paragraphs (c)(5)(ii), (iii) and (iv) of this AMC.

(ii) Test.

Over the test duration, and when the applicant follows normal ICA maintenance practices, the Engine should:

— meet all proposed thrust or power ratings without exceeding any operating limitations;

— be free of significant anomalies (for example, surge, stall) when operated as per the operating instructions provided in compliance with CS-E 20(d).

(iii) Post-Teardown Inspection

A post-test teardown inspection should demonstrate that each Engine part:

— conforms to the type design;

— is eligible for continued operation in service.

Hardware may be considered serviceable if the applicant includes, within the ICAs, appropriate inspections or limitations.

(iv) Certification Documentation

The certification documentation should identify those parts of the Engine that will have specific ICA requirements or recommendations that result from the IMP test. The final ICAs should include these specific requirements and/or recommendations, in compliance with CS-E 25, including:

— life limits,

— inspections,

— intervals,

— accept/reject criteria.

(6) Determination of the IMP

(i) Full Cycle Test

For a successful full cycle test, the applicant may take credit from the full number of cycles and the full number of hours demonstrated during the test when proposing an IMP.

(ii) Accelerated Severity Cycle Test

For a successful accelerated severity cycle test, the applicant may take credit from the full number of cycles for those Engine parts for which the test cycle was shown to be equal to or more severe than the assumed Engine flight cycle.

(iii) High Thrust Settings during Selected Test Cycle

The test cycle used (for example, accelerated severity cycle) may involve high thrust setting operation for durations that significantly exceed those of the Engine flight cycle. If so, EASA may accept that the applicant takes credit from interval(s) longer than the IMP test length.

This approach requires caution because:

— some Engine parts will wear as a function of time at load, rather than from low-cycle fatigue;

— life extrapolation based on material property data alone is imprecise.

Under these circumstances, the applicant may need to draw supporting evidence from other:

— Engine tests,

— component tests,

— subassembly tests.

(7) Using the early ETOPS test of AMC 20-6 Revision 2.

(i) General

CS-E 930 allows the use of an approved test performed as per AMC 20-6 Revision 2 Appendix 1 Section 2.b, in lieu of a separate IMP test. The use of the early ETOPS test allows to demonstrate compliance with both CS-E 930 and CS-E 1040 through a single test on one Engine.

If the applicant uses this method, the following conditions apply:

(A) After completing the full number of test cycles required for an IMP test performed as per CS-E 930(a), the AMC 20-6 Revision 2 test should be interrupted to conduct a complete on-wing (or other) inspection.

Please note the following:

(a) The inspection should be acceptable to EASA in order to demonstrate compliance with CS-E 930.

(b) An acceptable on-wing inspection should include but is not limited to the inspections and tests listed in paragraph (c)(7)(ii) of this AMC.

(B) Prior to EIS, the AMC 20-6 Revision 2 test must be completed in its entirety. This will provide further evidence that no undiscovered Engine fault exists during the IMP portion of the test.

(C) If the IMP inspection is completed and the type certificate is issued, the applicant must complete the remaining portion of the AMC 20-6 Revision 2 test in order to comply with CS-E 930(b).

(D) The application of the general pass/fail criteria defined in paragraph (c)(5) of this AMC should demonstrate that the Engine is fully serviceable as per the ICAs, unless otherwise accepted by EASA.

(ii) On-Wing Inspection

(A) Borescope Inspection

The applicant should fully borescope-inspect all accessible gas path stages or areas of the fan, compressor, combustor, and turbine modules, to the serviceable limits of the ICAs.

(B) System Fault and Status Message Interrogation

The applicant should evaluate all system fault and status messages for electronic-control-equipped Engines. The applicant should include both current and previously recorded messages to the serviceable limits of the ICAs.

(C) Oil System Chip Detector and Filter Inspection

The applicant should inspect all oil system chip detectors and filters for contaminants.

(D) Fuel System Filter Inspection

The applicant should inspect all fuel system filters for contaminants.

(E) Main Engine Oil Sample Test

The applicant should test the Engine oil (for example, spectrographic analysis) for contaminants that might indicate impending internal failure.

(F) Visual Inspection

The applicant should perform a complete visual inspection of the inlet, exhaust and externals to the serviceable limits of the ICAs. The Engine should be serviceable.

(G) Power Calibration

The applicant should demonstrate that the Engine can produce rated power or thrust at a sea-level, hot-day corner point condition within approved limits.

(d) Fixed Engine Overhaul Period.

The applicant may recommend a fixed overhaul period as the equivalent of an IMP, if the applicant does not intend to cover the Engine with a structured inspection programme. If this approach is selected, the applicant should:

— perform the Engine test of CS-E 930 in a similar manner to that described in paragraph (c) of this AMC;

— determine whether the test results support the desired fixed overhaul period.

Issue 3: Substantiation of piston-engine TBO/TBR

Point (6) is added in AMC E 25 as follows:

AMC E 25 Instructions for continued airworthiness

[…]

(6) The applicant for the certification of a piston Engine may substantiate a time between overhauls (TBO) or a time between replacements (TBR) as follows:

(a) The applicant may use the 150-hour endurance test required by CS-E 440 for the substantiation of the TBO/TBR. The applicant may then propose a TBO/TBR ranging between 600 flight hours (e.g. for fully new designs) and 1 000 flight hours (e.g. for derivative designs). The TBO/TBR value should be agreed by EASA.

(b) If the applicant wishes to propose a TBO/TBR higher than what the CS-E 440 test allows to substantiate, then the following method may be used:

(i) An additional Engine cyclic endurance test should be run on an Engine representative of the type design.

(ii) The cycle profile should be based on estimated aircraft flight profiles.

(iii) The number of cycles should be representative of the TBO/TBR intended to be declared and should represent a level of Engine deterioration at least equivalent to that of an Engine at the end of the intended TBO/TBR.

(iv) The maintenance programme associated with the intended TBO/TBR should be performed and validated during the Engine cyclic test.

(v) Complementary analysis and/or testing should be provided to support any aspects not adequately demonstrated throughout the Engine cyclic test.

(vi) If it is proposed to subject the tested Engine to any kind of strip examination during the test in order to validate an interim TBO/TBR, it should then be shown that cleaning or replacement of any seal or component (such as bolts) during reassembly of the Engine will not favourably influence the outcome of the test.

(vii) Past experience with Engines of similar design and/or in-service operation, where applicable, may also be used as alternative evidence to support or complement the proposed TBO/TBR.

The credit taken from the duration of such cyclic endurance test should use a factor of 1, unless the applicant can justify, and EASA accepts, a higher value.

(c) The TBO/TBR should be declared, and the necessary corresponding instructions (for example, an Engine overhaul manual when using a TBO) should be provided, as required by CS-E 25(a).

5. Monitoring and evaluation

EASA will assess the implementation of the amended CS-E through the following:

— the experience gathered during CS-E certification projects carried out following the issue of the subject CS-E amendment;

— the monitoring ensured in the frame of the normal continuing airworthiness process that is followed by EASA and type-certificate holders (TCHs); and

— the investigation of occurrences (incidents and accidents) and the analysis of safety recommendations from designated safety investigation authorities.

6. Proposed actions to support implementation

No specific action is proposed.

7. References

— Engine Harmonization Working Group (EHWG) report, dated 31 January 2017[8]

— Engine Harmonization Working Group (EHWG) report Revision A, dated 31 March 2021[9]

[8] https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/EHWG%20Final%20Report%202017-01-31.pdf

[9] https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/ARAC%20EHWG%20Revised%20Recommendation%20Report;%20June%202021.pdf

Appendix 1 — Impact assessment

1. Introduction

An impact assessment was developed to support the decision to amend CS-E in order to address the issues identified in Section 2.1.

2. What are the possible options

Table 1: Selected policy options

Option No	*Short title*	*Description*
0	No change	No policy change (rules remain unchanged and risks as outlined in the issue analysis).
1	Amend CS-E	Amend CS-E as follows: — introduce in the endurance test specifications (CS-E 740) for turbofan engines the possibility to use an alternate test, and provide a corresponding AMC; — create IMP test specifications (CS-E 930) for turbine engines, along with a corresponding AMC. Indicate in the AMC to CS-E 25 on Instructions for Continued Airworthiness how applicants may substantiate a TBO/TBR interval and maintenance programme.

Option 0 ('no policy change') would leave the identified issues unchanged.

Option 1 would consist of amending CS-E such as to reach the objectives presented in Section 2.2:

— **Turbofan-engine endurance test:** The amendment of CS-E 740 would be based on the recommendations from the Engine Harmonization Working Group (EHWG). The EHWG recommended introducing an alternate test that would be an optional alternative to the current test. The alternate test demonstration would be achieved by evaluating (via a critical point analysis (CPA) of the product's design and intended use (operating envelope)) and defining a hybrid prescriptive and performance-based severity test for the engine. This would test the engine type design to its limiting speeds and temperatures (redlines) for type certificate limits. Further, the proposed test would evaluate the engine's capability to successfully complete running in close proximity to minimum speed and temperature margins (close to redlines) as expected while in service still operating at a severity level consistent with the intent of today's CS-E 740 or FAA 14 CFR § 33.87 prescriptive test.

The proposed test would run more hours and cycles than today's prescribed test schedule, utilising a simulated flight cycle. Therefore, it would provide results that are more representative of responses to threats characteristic of revenue service, while also providing a test of the engine's capability at least as severe as intended by the current test.

— **Turbine-engine IMP test:** CS-E specifications would be created, considering the requirements under FAA 14 CFR § 33.90, but adapted to allow the applicant to demonstrate an initial maintenance programme (IMP) (instructions for continued airworthiness (ICAs) submitted under CS-E 25) in a performance-based way. The initial maintenance inspection (IMI) approach would be one method that the applicant may use. Other methods would be allowed, in particular on-condition based maintenance programming. The applicant would have to complete one of the following tests with an engine that substantially conforms to the type design to substantiate the IMP:

  — An approved engine test that simulates the conditions in which the engine is expected to operate in service, including typical start–stop cycles.

  — An approved engine test performed in accordance with the early ETOPS test requirements (in accordance with the current AMC 20-6 Revision 2 provisions).

— **Substantiation of piston-engine TBO/TBR:** AMC E 25 on ICAs would be amended to indicate how applicants should substantiate the TBO/TBR interval and maintenance programme. Limited credit could be taken from the CS-E 440 endurance test alone. In order to go beyond this limitation, the substantiation would require running an engine cyclic endurance test on an engine representative of the type design using a cycle profile that is based on estimated aircraft flight profiles. The number of cycles should be representative of the TBO/TBR intended to be declared and should represent a level of engine deterioration at least equivalent to that of an engine at the end of the intended TBO/TBR.

3. What are the impacts

a. Safety impact

Option 1, compared to the baseline scenario (Option 0), would improve the safety of aircraft equipped with new engines as follows:

Issue 1: Turbofan-engine endurance test

The proposal aims to ensure that a more representative test is performed. Compared to the current test requirements, the alternate endurance test will improve the detection of design weaknesses before entry into service of the engine. This will translate into less continued airworthiness issues, including less potentially hazardous or catastrophic failure conditions. Such issues may include various mechanical parts failures resulting in in-flight shutdown (IFSD). The risk is most acute during the time right after entry into service where the dual IFSD rate may be very high. The quality of the endurance test is a key element of the certification programme to mitigate this risk.

Issue 2: Turbine-engine IMP test

The proposal aims to ensure that turbine engines, certified under CS-E only, will be subjected to an IMP test in a similar way like it is required by FAA 14 CFR Part 33.

With this proposal, the reliability of such engine will be equivalent to the reliability of engines certified against FAA 14 CFR Part 33 and, therefore, the same safety level will be achieved for aircraft equipped with such engines. Otherwise, these engines may face more failures and in-flight shutdown occurrences before maintenance action is due.

In addition, the proposal would allow EASA to be involved in the follow-up and approval of IMP tests also when a FAR33 certification is requested by the applicant, instead of relying on the FAA. This would allow EASA to acquire knowledge on how the test was handled, and on the behaviour of the engine during the test. This would then ease the EASA continued airworthiness oversight and the identification of corrective actions with the engine TC holder, in case of issues found after entry into service, which also benefits safety in the end.

Issue 3: Substantiation of piston-engine TBO/TBR

The proposal would ensure a robust and harmonised substantiation of TBO/TBR intervals and maintenance programmes. This would ensure that the approved TBO/TBR is commensurate with the level of testing performed. The number of engine failures and in-flight shutdowns caused by design weaknesses, before reaching the TBO/TBR threshold, should therefore decrease on newly certified designs.

b. Environmental impact

No impact identified.

c. Social impact

No impact identified.

d. Economic impact

Issue 1: Turbofan-engine endurance test

The proposal is to provide an alternate test, which is therefore not mandatory.

Applicants that can justify that the original endurance test is compatible with the design of their engine may elect to use the original endurance test. For these applicants, there is no economic impact.

Regarding applicants that will use the alternate test, the EHWG assessed that using this test will have a positive economic impact on both the applicant and the approving authority:

'The critical point analysis (CPA) evaluations required to define the test condition are extracts from engineering analyses already undertaken as part of an engine's design process, thus require minimum additional effort. There are however, substantial cost savings in not having to design test enabling and survivability modifications and manufacture custom parts in order to conduct the current test as prescribed. Additionally these test enabling and survivability changes need to be reconciled by the applicant and accepted by the authorities. The effect of running the proposed alternate test also requires a substantially shorter lead-time to prepare an engine for test as it significantly reduces engineering effort by the Applicant and Agency. Consequently adaptation of the proposed alternate test will have a positive financial impact on the Applicant and the approving Agency.'

The alternate test may induce an increase of the fuel burn compared to the original endurance test; however, the EHWG estimated the following: 'The effect of running the proposed alternate test requires substantially less engineering effort by the Applicant and Agency, which more than offsets the increased fuel burn required to run the alternate test.'

Issue 2: Turbine-engine IMP test

There is no economic impact for applicants that used to apply for both EASA and FAA certification (or certification by another authority also requiring an IMP test or equivalent, such as TCCA, ANAC Brazil, FATA Russia).

There is a potential significant economic impact (additional costs to run an IMI test) for applicants that:

— would apply either for EASA certification only, or for EASA certification in addition to the certification by their primary certification authority that had not required an IMP test or equivalent; and

— would not elect themselves to run an IMP test or equivalent.

The IMP test cost for a modern turbofan engine is estimated to be between EUR 3 and 4 million (comprising test preparation, test running and post-test inspections).

In practice, applicants have been using IMP tests or equivalent (e.g. IMI test) to substantiate their maintenance programme. Therefore, the proposed new IMP test specifications in CS-E should bring no, or negligible, additional costs.

As regards EU applicants, the certification of their IMPs by EASA should be more efficient than by non-EU certification authorities. The reason is that, as the primary EU certification authority, EASA has a better knowledge of the engine being certified and, therefore, the IMP test programme development and approval will require less time investment by the certification team. The validation of their products by certification authorities that already require an IMP test or equivalent will be streamlined because of the harmonisation of CS-E with foreign regulators (the FAA and others). This will result in an economic benefit for the applicants.

On the EASA side, the new IMP test specifications will require more workload for CS-E certification (around 20 hours), but they will decrease the workload for support to the validation of European products by foreign authorities (also around 20 hours). In the end, the impact is deemed to be neutral.

Issue 3: Substantiation of piston-engine TBO/TBR

There is no economic impact for applicants because the proposal will provide them with the option to either use the endurance test or add a cyclic test (in order to increase the TBO/TBR intervals).

The new test specifications will reflect the current EASA certification practices.

They will also improve harmonisation with the FAA certification policies dealing with TBO/TBR substantiation.

ICAO and third-country references relevant to this RMT

— FAA 14 CFR Part 33

— ICAO Annex 8

Issue 1: Turbofan-engine endurance test

FAR 14 CFR Part 33: CS-E 740 on endurance testing is currently broadly harmonised with the equivalent FAR § 33.87 rule. The proposal of this NPA will create a difference as long as FAR § 33.87 is not concurrently amended, as it introduces the possibility to perform an alternate test. The FAA has not yet announced a rulemaking project to amend FAR § 33.87, but it is expected that this will be done in the near future, and this should ensure harmonisation with CS-E 740.

ICAO Annex 8: Part VI, Chapter 3 Tests, requires performing an endurance test as follows:

'Tests of sufficient duration shall be conducted at such powers, thrust, speeds, temperatures and other operating conditions as are necessary to demonstrate reliability and durability of the engine. They shall also include operation under conditions in excess of the declared limits to the extent that such limitations might be exceeded in actual service.'

Current CS-E 740 and the proposed alternate test specifications fulfil the objective of this requirement. Therefore, no difference exists, and no difference will be introduced.

Issue 2: Turbine-engine IMP test

FAR Part 33: There is currently in CS-E no equivalent specification to FAR § 33.90. Therefore, a difference exists. The proposal of this NPA (creation of CS-E 930) will bring about harmonisation with the FAA rule, although it will be more performance based. The same applies to the creation of AMC E 930, which will bring about harmonisation with FAA AC 33.90-1A.

ICAO Annex 8: There is currently no difference with CS-E. The NPA proposal will introduce a test requirement that is not present in Annex 8 (in particular, Part VI).

Issue 3: Substantiation of piston-engine TBO/TBR

FAR Part 33: No difference exists with CS-E on this matter, and the NPA proposal will not change this situation.

ICAO Annex 8: No difference exists with CS-E on this matter, and the NPA proposal will not change this situation.

e. General Aviation and proportionality issues

No issue identified

4. Conclusion

a. Comparison of the options

Table 2: Comparison of the options

Impact criteria	*Option 0 'No change'*	*Option 1 'Amend CS-E'*
Safety impact	0	+ Improve robustness and reliability of turbine engines before entry into service. Improve robustness and harmonisation of piston-engine TBO substantiation.
Economic impact	0	+/– Positive for applicants and EASA by using alternate endurance tests when classic tests are not adapted, and by using the new IMP specifications (ease of validations). Negative for applicants intending to obtain only EASA TCs without voluntarily running IMP tests (improbable). Neutral impact of the new TBO/TBR substantiation for piston engines (no new constraints).
Total	0	+

Question to stakeholders:

Stakeholders are invited to provide any other quantitative information they find necessary to bring to the attention of EASA.
As a result, the relevant parts of the IA may be adjusted on a case-by-case basis.

Appendix 2 — Quality of the NPA

To continuously improve the quality of its documents, EASA welcomes your feedback on the quality of this document with regard to the following aspects:

Please provide your feedback on the quality of this document as part of the other comments you have on this NPA. We invite you to also provide a brief justification, especially when you disagree or strongly disagree, so that we consider this for improvement. Your comments will be considered for internal quality assurance and management purposes only and will not be published (e.g. as part of the CRD).

a. The regulatory proposal is of technically good/high quality

Please choose one of the options
Fully agree / Agree / Neutral / Disagree / Strongly disagree

b. The text is clear, readable and understandable

Please choose one of the options
Fully agree / Agree / Neutral / Disagree / Strongly disagree

c. The regulatory proposal is well substantiated

Please choose one of the options
Fully agree / Agree / Neutral / Disagree / Strongly disagree

d. The regulatory proposal is fit for purpose (achieving the objectives set)

Please choose one of the options
Fully agree / Agree / Neutral / Disagree / Strongly disagree

e. The regulatory proposal is proportionate to the size of the issue

Please choose one of the options
Fully agree / Agree / Neutral / Disagree / Strongly disagree

f. The regulatory proposal applies the 'better regulation' principles[1]

Please choose one of the options
Fully agree / Agree / Neutral / Disagree / Strongly disagree

g. Any other comments on the quality of this document (please specify)

[1] For information and guidance, see:
- https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how_en
- https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how/better-regulation-guidelines-and-toolbox_en
- https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how/better-regulation-guidelines-and-toolbox/better-regulation-toolbox_en