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

Amendment 8 — Change information

The European Union Aviation Safety Agency (EASA) issues amendments to certification specifications (CSs) as consolidated documents. These documents are used for establishing the certification basis for applications submitted after the date of entry into force of the applicable amendment.

Consequently, except for a note '[Amdt No: E/8]' under the amended rule, the consolidated text of CS-E (the Annex to ED Decision 2025/003/R) does not allow readers to see the amendments that have been introduced compared to the previous amendment. To show the changes, this change information document was created, using the following format:

— deleted text is ~~struck through~~;

— new text is highlighted in blue;

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

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 25 times in evenly distributed intervals.

(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 in operation for one fifth of the test during all the conditions of running for which they are intended to be approved for use.

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

(b) […]

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 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).

(6) The thrust or power of the Engine achieved throughout the endurance test must be at least 100 % of the value associated with the particular Engine rating being tested, in order to substantiate the thrust or power ratings established under CS-E 40.

(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 abovementioned test schedule as per CS-E 740(c)(1). In particular, this may be suitable when running this schedule 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 endurance test prescribed by CS-E 740(c)(1) (here designated as the 'classic' endurance test).

(i) *Alternate Test Definition*

The test must be defined considering the following elements:

(A) Test Vehicle Definition;

(B) Critical Point Analysis (CPA);

(C) Engine Operating Limits Demonstration (type certification data sheet (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.

The compliance document(s) addressing the proposed test schedule and full assessment of the above elements must be agreed with EASA in advance of test commencement.

(ii) *Test Vehicle Definition*

The test must be performed using a test vehicle that adequately 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 physical core speed operating limits 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 operating limits demonstrations, the CPA must establish the extent of exposure to the operating limits levels and close proximity to those levels. The CPA must also establish maximum levels of corresponding rotor speed for an operating limit temperature case, and maximum levels of temperature for an operating limit speed case. If it is found that operating limits conditions could at any point be coincident, then this will 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 the components within the Engine that are most limiting in terms of useful (serviceable) life under the endurance test conditions.

If the maximum critical component temperature method is used (see (v) Test Severity Demonstration Over Extended Operating Periods), then the applicant's CPA will identify the maximum critical component temperature (this would normally, but not necessarily, be an operating limit 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 Operating Limits Demonstrations (TCDS Physical Rotor Speeds and Turbine Gas Temperatures)*

TCDS physical rotor speed and turbine gas temperature limiting conditions must be demonstrated as detailed in this paragraph.

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

Concurrent operating limits demonstration of speed and turbine gas temperature for a particular rotor 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 Operating Limits Demonstration*

The greater of maximum take-off (MTO) and maximum continuous (MCT) physical core speed operating limits 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 operating limits could be encountered regularly in service, then the core speed operating limit test time will be extended accordingly. Where the CPA shows a longer period is required for MCT, the testing will 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 Operating Limits Demonstration*

The MTO fan physical speed operating limit must be demonstrated for a minimum of 30 minutes. The MCT fan physical speed operating limit 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 operating limit, 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 operating limit 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) Operating Limits Demonstration*

The conditions necessary to demonstrate the MTO exhaust gas temperature (EGT) operating limit must be continuously run for 10 minutes in conjunction with at least the level of corresponding rotor speeds as identified in the CPA. Three snap/burst accelerations (throttle move in 1 second or shorter) from idle to the MTO EGT operating limit (hold operating limit for a duration of 90 seconds each) must also be run. The conditions necessary to demonstrate the MCT EGT operating limit must be continuously run 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 operating limit may occur in service.

EGT operating limits 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) must be addressed in accordance with CS-E 740(c)(4)(vi).

(v) *Test Severity Demonstration Over Extended Operating Periods*

Limiting temperature for MTO and MCT must be demonstrated for extended periods to achieve the equivalent cumulative damage for the critical component as would be achieved by the conditions prescribed in CS-E 740(c)(1) (also referred to as the 'reference severity'; see also AMC E 740(c)(4), Section 5(b)).

The limiting temperature is either the turbine gas path temperature operating limit 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 on 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 for 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 thrust or power.

(viii) *Ancillary Type Certification Data Sheet Limits Demonstration*

The alternate test must take into account specifications CS-E 690(a)(3), CS-E 740(e) and (f), and CS-E 750. 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 or power 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, EGT~~turbine entry temperature~~, bleed, 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 EGT limitations may be derived from an analysis when the applicant uses the alternate test specified in CS-E 740(c)(4) (see CS-E 740(f)(4)(ii) below).

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 the case of the alternate test specified in CS-E 740(c)(4), the TCDS-declared EGT operating limits 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 demonstrated in the EGT operating limits demonstration as per CS-E 740(c)(4)(iv)(3);

(B) Derived EGT 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.

Depending on the option chosen in CS-E 740(c)(4)(v), EGT values used in this analysis will be either the turbine gas path temperature established during the test or the gas path temperature that corresponds to the maximum critical component temperature.

(iii) 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 EGTs~~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~~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~~operating limit for acceleration with a time limitation of either up to 30 seconds or up to 2 minutes may be approved.

(A) In the case of the classic endurance test, transient EGT operating limits may be approved as follows.

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

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

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

- Transient EGT operating limits up to 30 seconds may be approved by running the Engine at the required temperature for 30 seconds as part of at least 155 periods at Take-off Thrust or Power conditions following an acceleration.
- Transient EGT operating limits up to 2 minutes may be approved by running the Engine at the required temperature for 30 seconds as part of at least 310 periods at Take-off Thrust or Power conditions following an acceleration.

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

(~~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~~ operating 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 Performance Target after Test Completion.*

After completion of the endurance test, the Engine must be able to provide the rated thrust or power levels without exceeding operating limitations.

(~~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~~i)(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 T~~t~~ests

(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 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, and provided that the overall severity of the test is at least equivalent to the intent of the classic endurance test by an extended test duration. This, in turn, makes it possible 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/expected 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 probably 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 operating limits (OL) study. Necessary to establish conditions for the speed and temperature OL demonstrations (see CS-E 740(c)(4)(iv)).

  Output data.

  Cumulative exposure time of concurrent rotor speeds OL (individually in the case of multiple rotors) and EGT OL.

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

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

  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 OL 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 OL.

  Note: For consideration of metal creep damage, and other temperature-related damage, the highest 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 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 with the intent of the classic endurance 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 with the classic endurance 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-related 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 is to use creep damage to critical gas path components as a comparative arbiter to the original intent of the classic endurance test. Stress rupture and creep damage were the prevalent failure mechanisms when the classic endurance 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 a means of comparing any alternate test's severity to that of the original intent of the classic endurance test for the creep mechanism. Within the applicant's severity assessment and comparison, it is expected that any other relevant damage mechanisms will be identified and an Engine-specific comparison of the classic with the alternate endurance 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) will 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 operating limits levels (for the appropriate test sections) that are intended to be claimed at the conclusion of the test. Therefore, the severity representing the intent of the classic endurance test 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 with 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 and TMF.

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 suit the particular design and intended operation of the Engine, while ensuring that the test is adequately severe. The proposed test consists of a mix of cycles run at various thrust /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

Unexpected 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).

When a damage mechanism is identified in the CPA (other than creep) that cannot be substantiated by the endurance test without unreasonable modifications to test schedules, further substantiation may be provided under CS-E 170.

(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 one 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 one hour of operation at each of the intended limiting power settings and input into a spreadsheet accounting tool (see Figure 7.1).

Severity / Hr for Critical Components			
Test Segment	Component #1	Component #2	Component #3
MTO NL OL	0.00324		
MTO NH OL	0.01354		
MTO EGT OL	0.00726		
MCT NL OL	0.00284		
MCT NH OL	0.00933		
MCT EGT OL	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 normalised to one 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 Operating Limits Demonstration' are illustrated in Figure 7.2, 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.

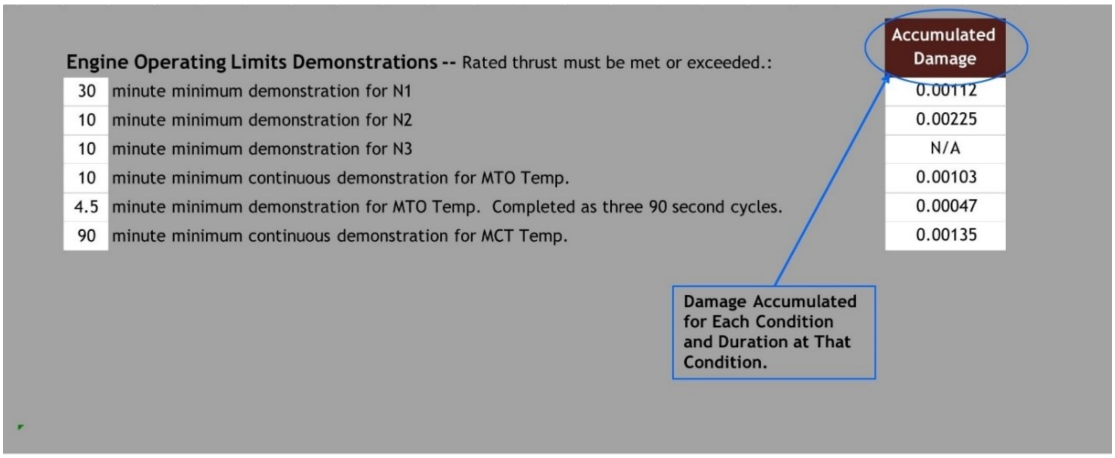


Figure 7.2. Severity Usage for Engine Operating Limit Demonstrations

Compliance with the specifications of CS-E 740(c)(4)(vii) consists of testing at 15 equally spaced thrust/power settings between idle and MCT. A duration of 10 minutes is prescribed at each thrust/power setting. Twenty-five 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.

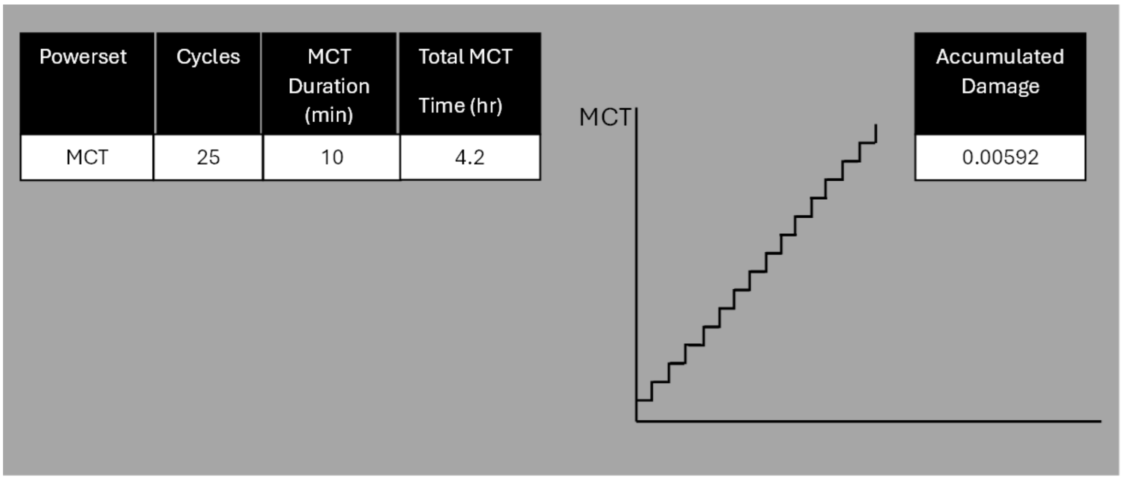


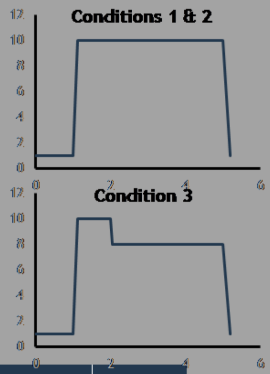
Figure 7.3. Severity Usage for Stair Step Cycles as per Part 4 of CS-E 740(c)(1)

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. Figure 7.4 illustrates a mix of cycles at 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

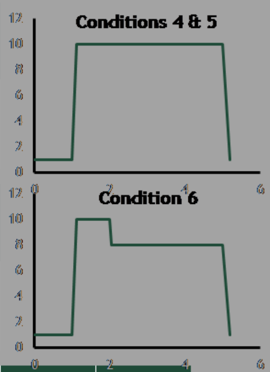
Figure 7.4. Severity Usage for Extended Operating Periods

Engine-rated performance demonstration is also a performance-based element of the alternate endurance test and 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 (Figure 7.5), 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 Figure 7.6, 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 (Figure 7.7) 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 OL, 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 OL method.

(b) Description of the methods

(i) *T_{metal} method*. For the alternate test, using the T_{metal} method, the EGT OL 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 the EGT values corresponding to this metal temperature, which will be claimed as EGT OL, for the case of a deteriorated version of the Engine by similar modelling. 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 endurance 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).

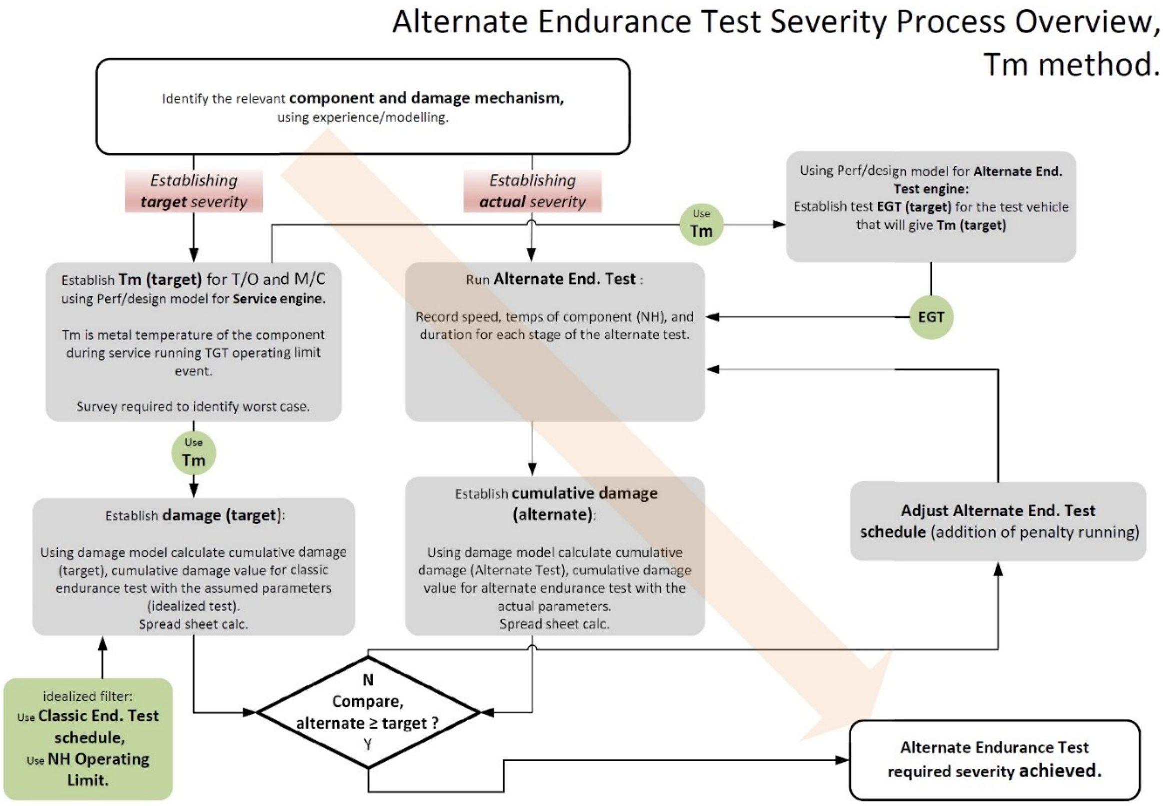


Figure 8.1. T_{metal} method overview.

Abbreviations

Calc.	calculation
End.:	endurance
M/C:	maximum continuous thrust
NH:	core rotor speed

Perf: performance
T/O: take-off thrust
$T_m = T_{metal}$: metal temperature

(ii) *EGT OL method.* For the alternate test, using the EGT OL method, a compromise alternate test, avoiding the complications of the T_{metal} temperature method above, the EGT recorded for the test is accepted as the OL (complying with CS-E 740(f)(4)), contingent upon substantiation of the severity equivalence to the target severity (see Figure 8.2).

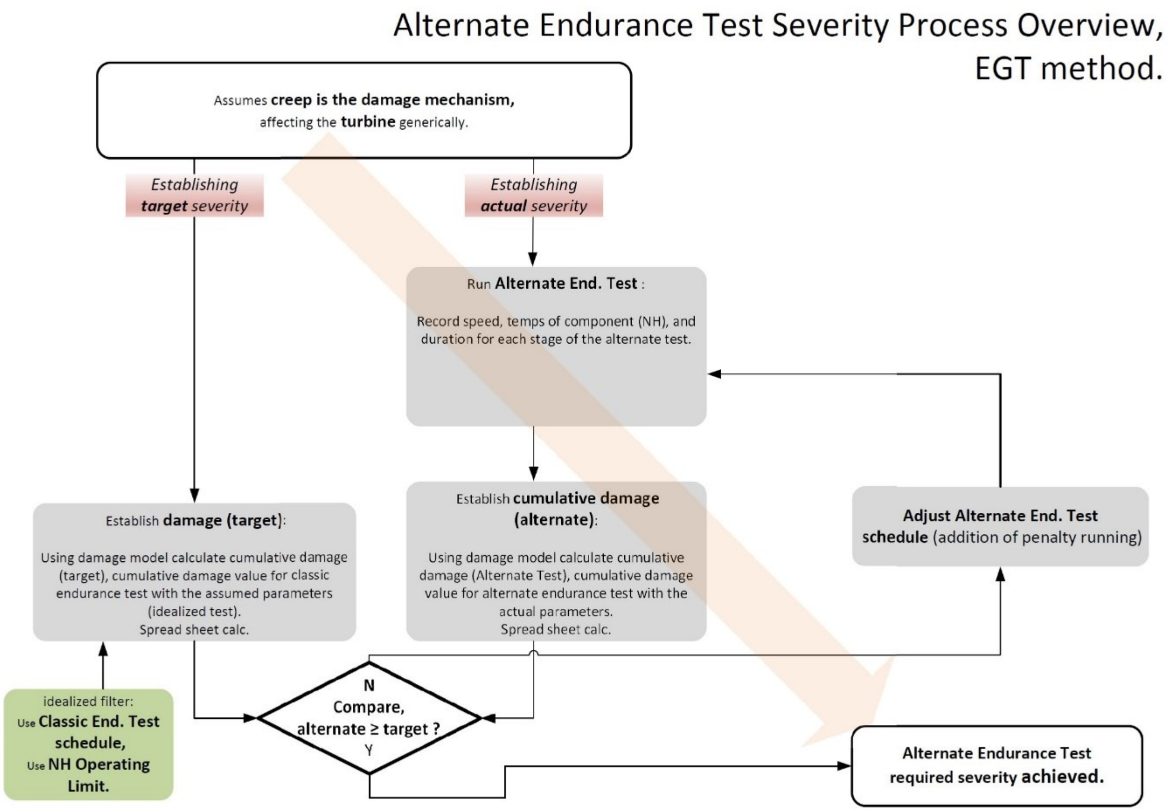


Figure 8.2. EGT method overview.

Abbreviations
Calc. calculation
End.: endurance
NH: core rotor speed

(c) Explanation of the detailed flow charts

The flow charts 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 endurance test requirements, using a combination of data taken from a production Engine simulation and assumed OL speeds, to give the target levels required: the 'idealised severity' (Figure 8.3). While the processes appear similar, the inputs are actually different, and 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 calculation of the planned test severity level and the calculation of the actual test severity level.

The main flow charts (Figures 8.3–8.5 and 8.9–8.11) are divided into two parts.

— The left-hand side is the main loop that will be repeated for each fixed condition of the test, and 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-hand 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.

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

Ⓒ 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 is a function 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

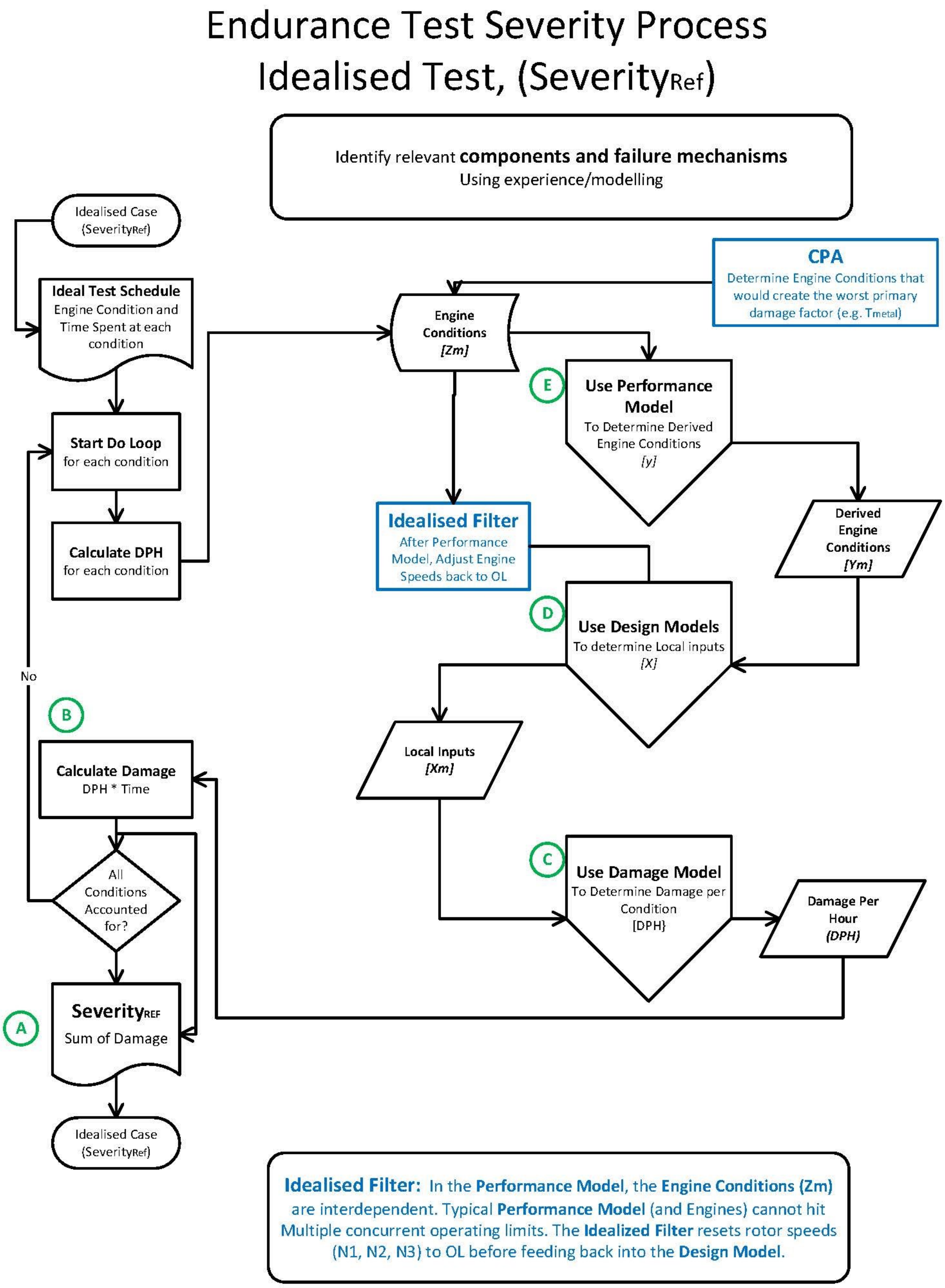


Figure 8.3. Endurance Test Severity Process – Idealised Test ($Severity_{Ref}$)

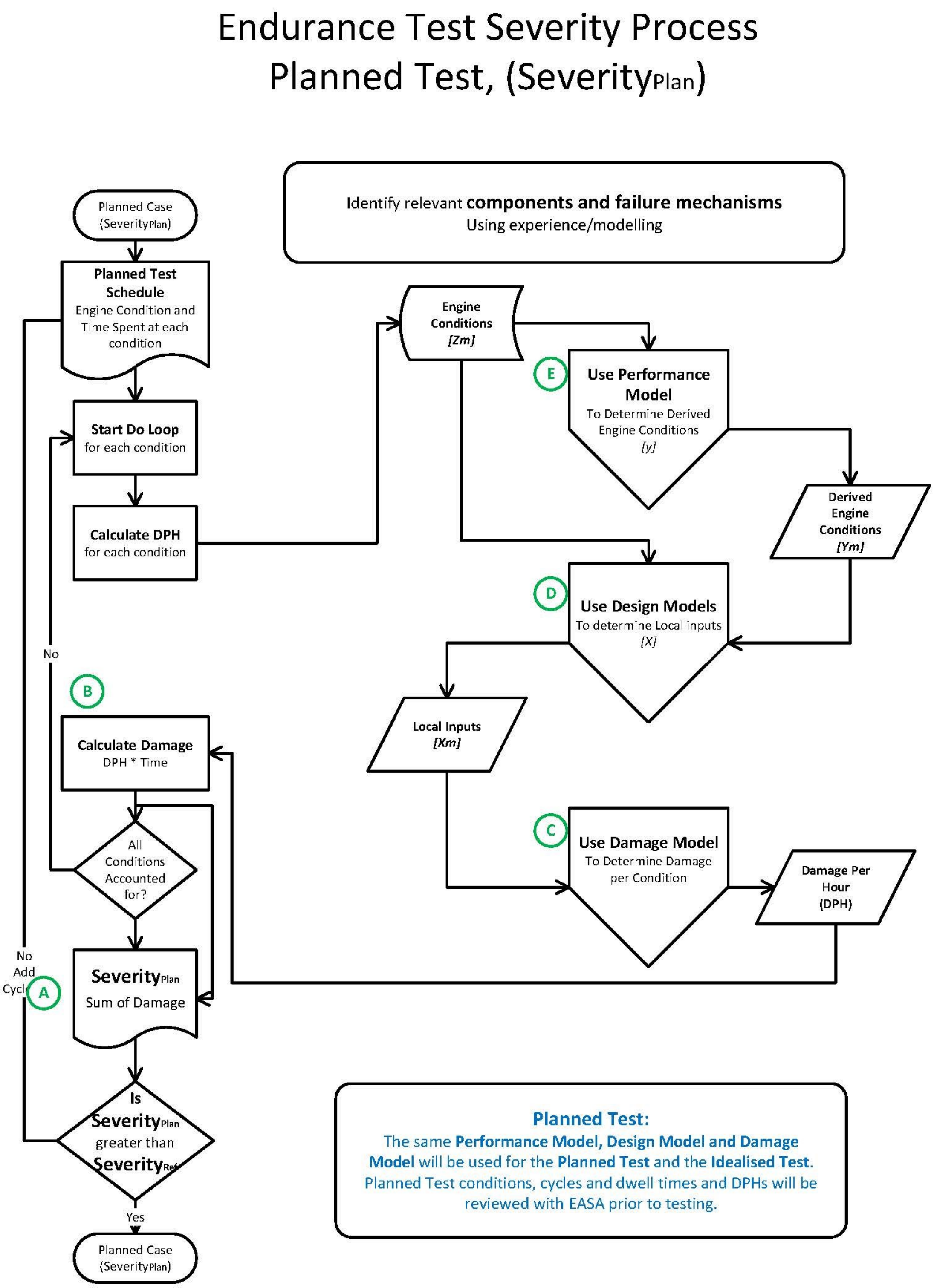


Figure 8.4. Endurance Test Severity Process – Planned Test (Severity$_{Plan}$)

Endurance Test Severity Process
Actual Test, ($Severity_{Act}$)

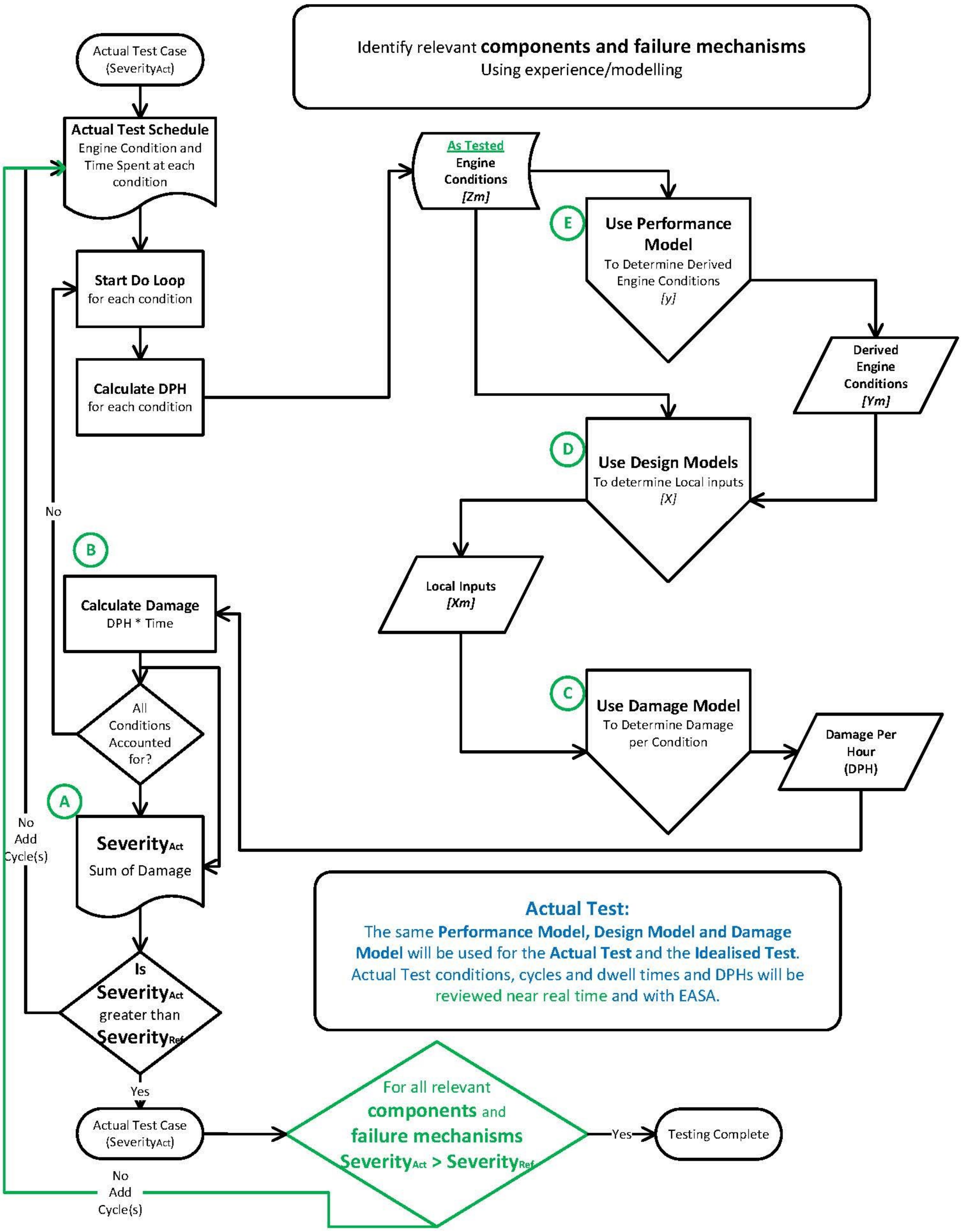


Figure 8.5. Endurance Test Severity Process – Actual Test ($Severity_{Act}$)

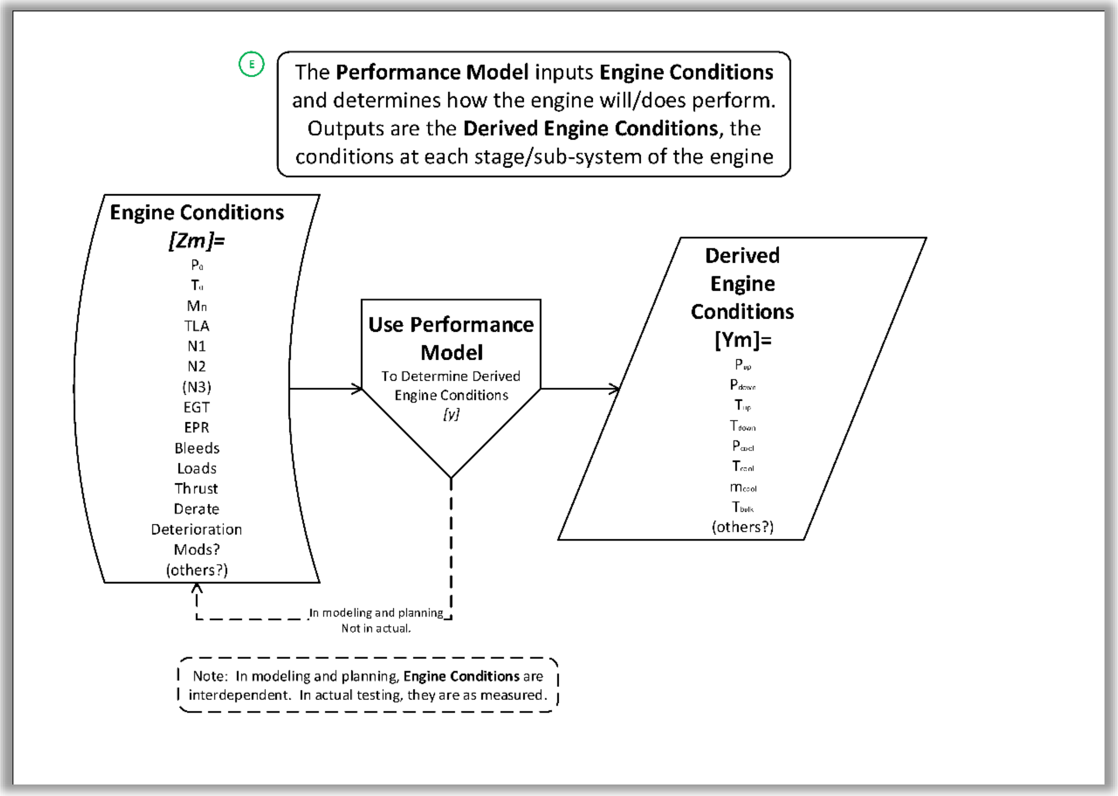


Figure 8.6. Performance Model

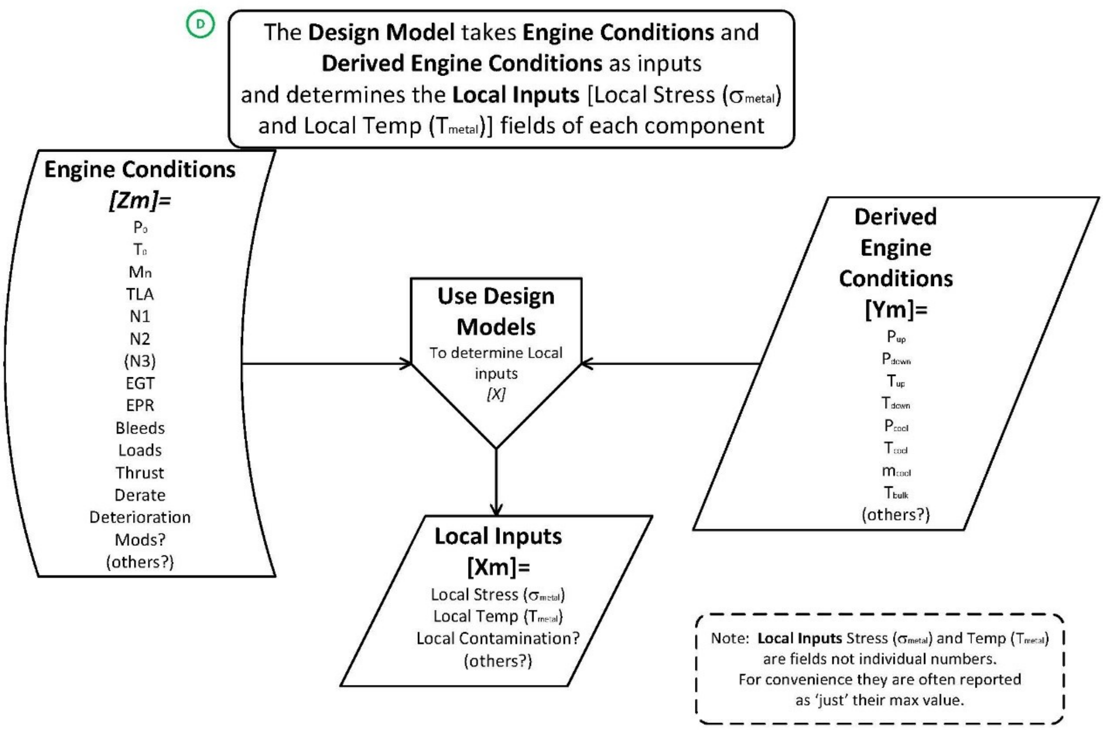


Figure 8.7. Design Model

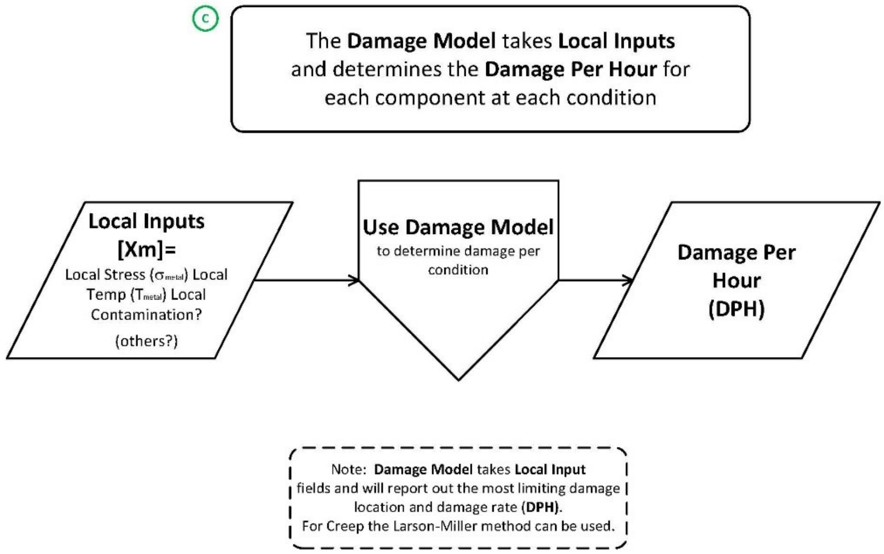


Figure 8.8. Damage Model

(f) 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 with a T_{metal} method when substantiating the same EGT OL value. The test will be similar to the classic endurance test with the exception that the target speed OL 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 show that it would be conservative on T_{metal} relative to CPA conditions.

With regard to the process for this approach, Figures 8.9–8.12 illustrate the steps and provide a comparison with the T_{metal} process. As 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 endurance test, is creep. The assumption is taken because the process in this case, as for the classic endurance 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.

(g) Main EGT method flow charts

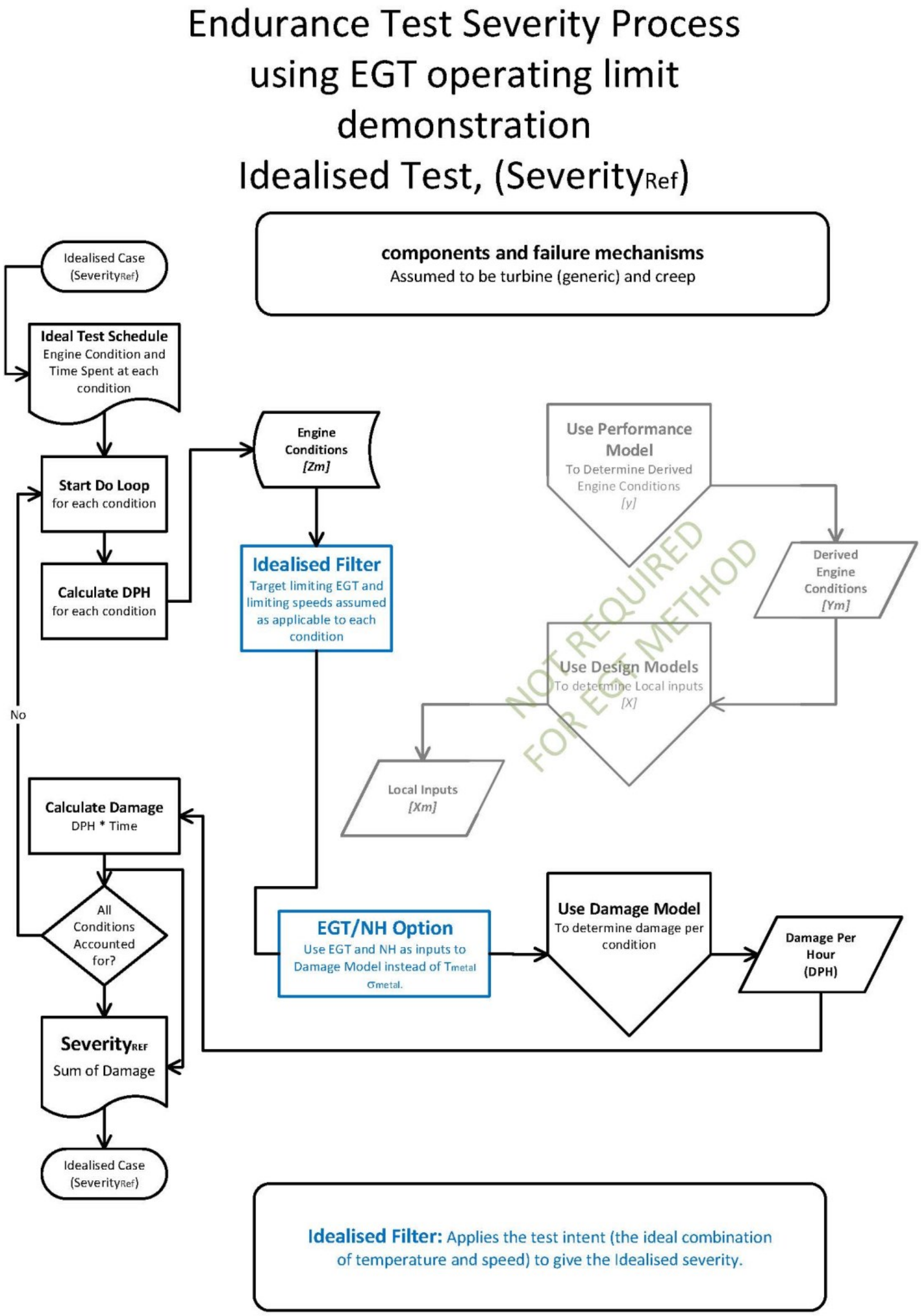


Figure 8.9. Endurance Test Severity Process using EGT OL Demonstration – Idealised Test ($Severity_{Ref}$)

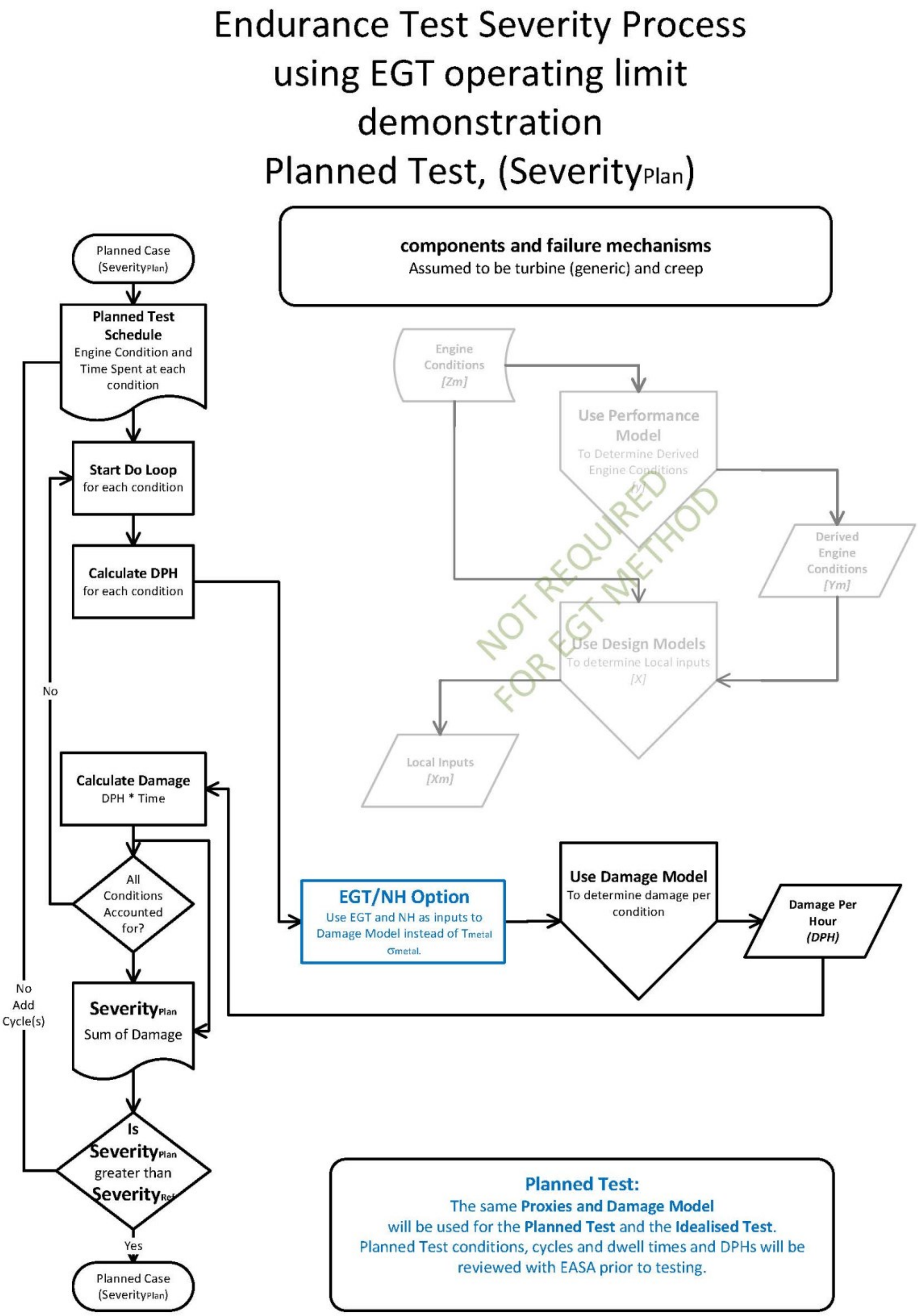


Figure 8.10. Endurance Test Severity Process using EGT OL Demonstration – Idealised Test ($Severity_{Plan}$)

Endurance Test Severity Process using EGT operating limit demonstration Actual Test, (Severity$_{Act}$)

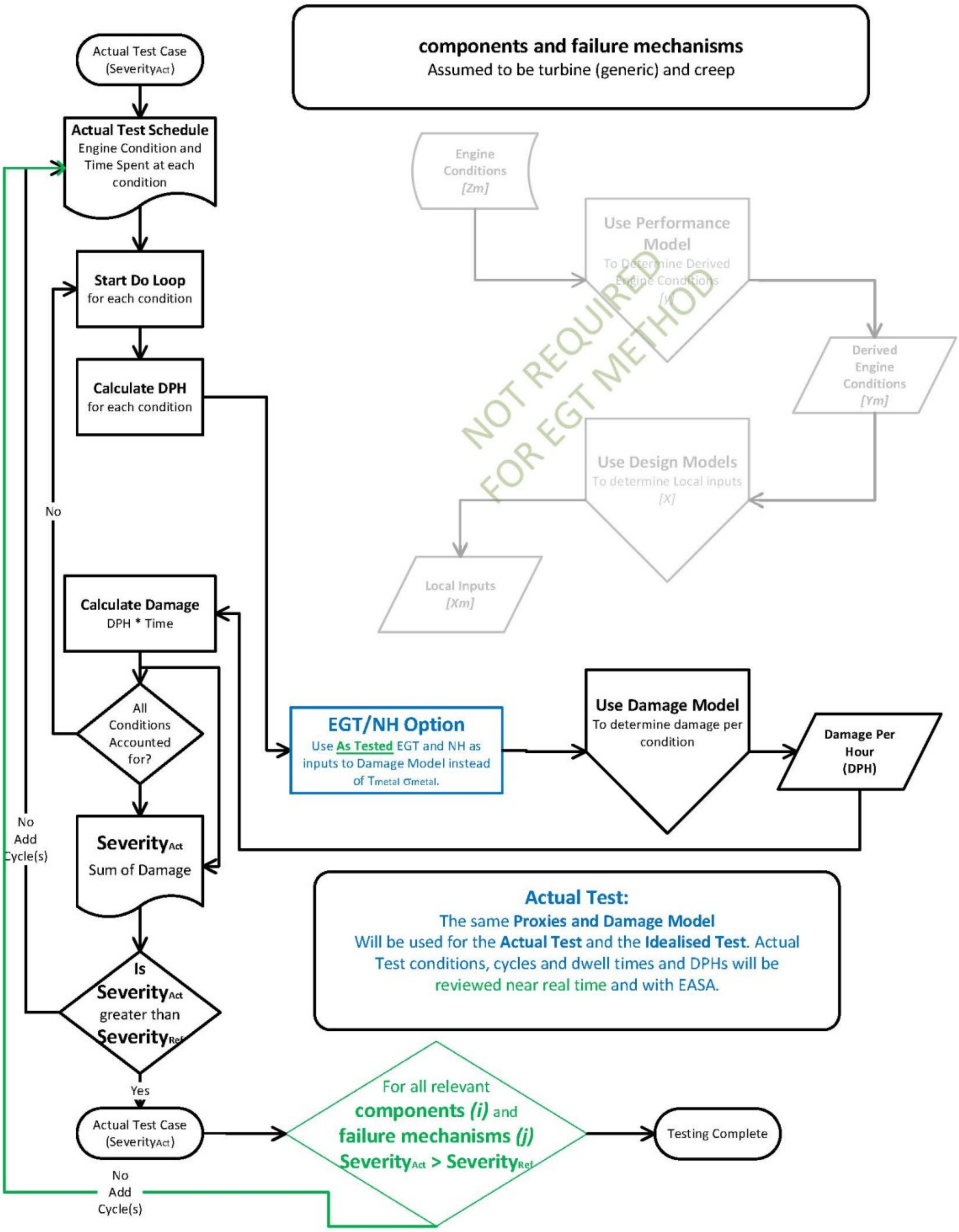


Figure 8.11. Endurance Test Severity Process using EGT OL Demonstration – Idealised Test (Severity$_{Act}$)

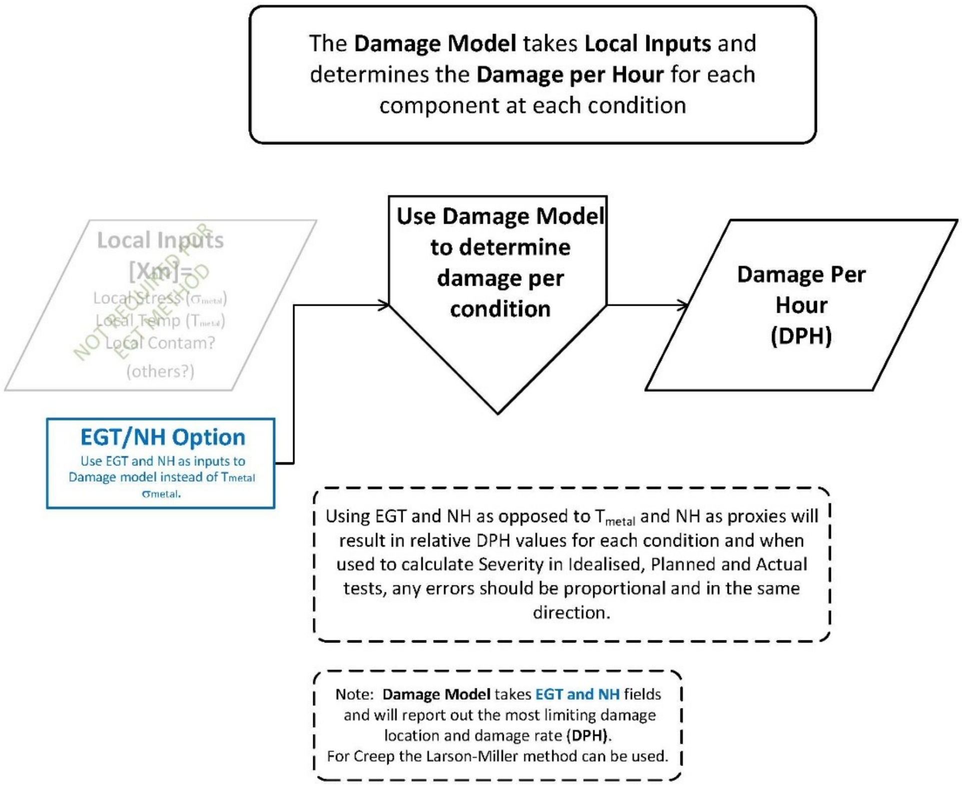


Figure 8.12. EGT Method Damage Model

(h) Conclusion

For the alternate endurance test, either 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.

For both methods, it is important that the performance and damage calculation methodology be consistent between the Severity_{Ref} and Severity_{Act} calculations. If during the testing there are test data that require an update to one of the modelling methodologies, then Severity_{Ref} will need to be recalculated with the new methodology as well.

AMC E 740(h)(2) is renamed as AMC E 740(i)(2) and its content is amended as follows:

AMC E 740(i)(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 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~~).

[…]

CS-E 920 is amended as follows:

CS-E 920 Over-temperature Test

(See AMC E 920)

(a) Each Engine must run for 5 minutes at maximum permissible rotational speed (rpm) with the turbine entry gas temperature at least 42 °C (75 °F) higher than the maximum rating's steady-state operating limit, excluding maximum values of rpm and gas temperature associated with the 30-second OEI and 2-minute OEI ratings. Following this run, the turbine assembly must be within serviceable limits.

(b) In addition to the test requirements in paragraph (a), ~~F~~for Engines with 30-Second and 2-Minute OEI Power ratings, the Engine must be run for a period of 4 minutes at the maximum power-on rotor speed with the turbine entry gas temperature at least 19 °C (35 °F) higher than the 30-Second OEI Power rating operating temperature limit. Following this test, the turbine assembly may exhibit distress beyond the limits for an over-temperature condition provided the Engine is shown by analysis or test or both to maintain the integrity of the turbine assembly.

AMC E 920 is amended as follows:

AMC E 920 Over-temperature test

(1) To establish a datum turbine entry gas temperature, when this may vary at a fixed gas temperature operating limit dependent upon the deterioration condition of the engine, it is considered reasonable to assume an Engine condition in which the gas temperature operating limit is likely to be achieved when at the maximum power setting. This would normally suggest that a deteriorated engine condition may be assumed.

(2) For the purpose of the test of CS-E 920(b), "Maximum power-on rotor speed~~rpm~~" is normally the steady state rotor speed associated with the 30-Second OEI Power rating. However, this speed should

be substituted by the transient rotor speed if the Engine characteristic transient speed stabilisation exceeds 3 seconds during the transition to the 30-Second OEI power.

In order to demonstrate that the Engine maintains the integrity of the turbine assembly after the over-temperature test, the applicant should show that no burst, no blade Failure or no other significant Failure of any Engine component would occur or become evident during the test, during shutdown or during the subsequent strip examination.

In the event that any Failure becomes evident, this should be analysed and it should be established by analysis or test that the cause is not such that in service the OEI rating structure would not be satisfactorily achieved.

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)

A test must be performed with an Engine that adequately conforms to the type design to substantiate the initial maintenance programme (IMP) that will be included in the instructions for continued airworthiness (ICA) in order to ensure sufficient Engine reliability under in-service conditions. The test must simulate the conditions in which the Engine is expected to operate in service, including typical start–stop cycles.

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 (ICA) submitted under CS-E 25 that are considered necessary to ensure sufficient Engine reliability. The ICA may be required by the type certificate holder in the 'Airworthiness Limitations' section of the ICA or may be recommended at certain intervals. The IMP may use hard time-based maintenance programming or on-condition-based maintenance programming, or a combination of both.

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

(4) 'Engine 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, or modules when applicable, 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) 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) Applicability to changes to type certificate

Following the initial demonstration of compliance with CS-E 930, Minor design changes do not require a new demonstration of compliance with CS-E 930.

For Major design changes (following the initial demonstration of compliance with CS-E 930), the applicant should assess the impact on the validity of the previously established IMP. The applicant should either substantiate the previous IMP or propose means to substantiate a change to the IMP. Such means may include analysis, testing or a combination of both. A full test to redemonstrate compliance with CS-E 930 may not be required.

When assessing the IMP's validity, the applicant should evaluate the impact of the change on the Engine design factors and Engine system dynamics.

Engine design factors include, but are not limited to: mechanical size and stiffness, static structure, dynamics of Engine, bearing arrangement, number of structural frames, arrangement of mounting to aircraft, number of compression and turbine stages, size and diameter of the fan, changes to Engine control system architecture (e.g. supervisory to full authority type, or analogue to digital), changes to installation (e.g. service bleed and power extraction) and new technology (e.g. design, materials or manufacturing processes), to the extent that these factors contribute to the system dynamics of the Engine.

System dynamics of the Engine are the vibratory response signature (system critical frequencies and amplitudes). These can be a function of Engine mass and stiffness, rotor speeds, and Engine or aircraft mount and strut mass and stiffness.

(d) 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:

— established power/thrust ratings,

— reverse thrust use,

— component stress and temperature,

— exhaust gas temperature (EGT),

— Engine vibration,

— cycle / operating time cumulative damage,

— other critical factors.

If the Engine includes OEI power ratings, representation of cumulative usage of those OEI power ratings before maintenance should be included in the Engine flight cycles of the IMP test.

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 (d)(1)(ii)),

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

— combinations of the above test cycle types.

The applicant may combine the IMP test with the AMC 20-6B early ETOPS test (refer to Appendix 1, Section 2.b). In this case, the applicant must successfully complete the early ETOPS test prior to EIS. See paragraph (d)(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 makes it possible to vary the following aspects of the Engine flight cycle:

— 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 with the number of Engine flight cycles demonstrated.

The accelerated severity cycle test is generally not considered ideal for Engine parts whose 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 with 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 adequately conforms to its final type design. Therefore, no significant Engine modification should be required to complete the IMP test.

Engine parts that are included in the Engine type design but not installed on the Engine may be substantiated by taking credit for validated analyses and/or other tests. Equipment qualification performed under CS-E 80(b) may be considered an appropriate means of compliance in this case.

(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 (e.g. 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.

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 (d)(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 (d)(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 (e.g. surge, stall) when operated as per the operating instructions provided in compliance with CS-E 20(d).

(iii) Post-Test Teardown Inspection

A post-test teardown inspection should demonstrate that:

- each engine part conforms to the type design; or

— damage is evaluated and the part is considered acceptable for safe continued operation; or

— damage is evaluated and the part is considered not acceptable for safe continued operation, but there is no imminent failure identified at the end of test.

Engine parts may be considered acceptable for safe continued operation if the applicant includes, within the ICA, appropriate inspections and/or limitations.

For those parts damaged beyond criteria ensuring safe continued operation, the applicant should substantiate the finding that there is no imminent failure and should provide in the ICA an appropriate fixed Engine overhaul period.

For Engines having 30-second OEI and 2-minute OEI power ratings, the IMP test results may be used when showing compliance with CS-E 25(b)(2) for OEI power availability demonstration at the end of the fixed Engine overhaul period.

(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 ICA 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 for 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 for 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 (e.g. accelerated severity cycle) may involve a 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 for 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,

— sub-assembly tests.

(7) Using the early ETOPS test of AMC 20-6B

(i) General

The applicant may use a test performed as per AMC 20-6B (Appendix 1, Section 2.b), in lieu of a separate IMP test. The use of the early ETOPS test allows the applicant 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, the AMC 20-6B 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 (d)(7)(ii) of this AMC.

(B) The AMC 20-6B test should be completed in its entirety. This will provide further evidence that no undiscovered Engine fault exists during the IMP portion of the test.

(C) The application of the general pass/fail criteria defined in paragraph (d)(5) of this AMC should demonstrate that the Engine is fully serviceable as per the ICA, 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 ICA.

(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 ICA.

(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 (e.g. 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 ICA. The Engine should be serviceable.

(G) Power Calibration

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

(e) Fixed Engine Overhaul Period

A simplified IMP may consist of a fixed Engine overhaul period. If this approach is selected, the applicant should:

— perform the Engine test of CS-E 930 described in paragraph (d) of this AMC;

— substantiate the fixed Engine overhaul period from the test results as per paragraph (d)(5)(iii).

AMC E 25 Instructions for continued airworthiness

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

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).

TBO is a recommended number of running hours or calendar time before the Engine requires overhaul.

TBR is a recommended number of running hours or calendar time before the Engine requires replacement (instead of overhaul).

The substantiation of the recommended TBO/TBR running hours should be performed 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 it to substantiate (see paragraph (6)(a) above), then the following method may be used.

(i) An additional Engine cyclic durability 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 instructions for continued airworthiness 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 durability 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 (e.g. 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 for the duration of such cyclic durability test should use a factor of 1, unless the applicant can justify, and EASA accepts, a higher value.

(c) The applicant may also include a calendar time in the recommended TBO/TBR that takes into account Engine components degradation that are time dependent, such as ageing of some material, corrosion, etc.

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

Editorial corrections

AMC E 20(f) is amended as follows:

AMC E 20(f) Power A~~a~~ssurance D~~d~~ata for E~~e~~ngines with O~~o~~ne or more OEI P~~p~~ower R~~r~~atings

[…]

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

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

AMC E 740(c)(3) Endurance T~~t~~ests

[…]

(2) Per CS-E 50(j~~f~~), the Engine control should prevent exceedance ~~exceedence~~ of the speed limitation associated with the 30-Second OEI Power rating. […]

[…]

AMC E 130 is amended as follows:

AMC E 130 Fire Protection

[…]

(4) Specific interpretations

[…]

(d) Electrical Systems components

For compliance with CS-E 130(e~~c~~), the effects of fire on components of the electrical system should be evaluated. Electrical cables, connectors, terminals and equipment, installed in or on the Engine, in designated fire zones should be at least fire resistant.

[…]

AMC E 320 is amended as follows:

AMC E 320 Performance C~~c~~orrection

(1) An acceptable method for calculating performance corrections is defined in ISO 1585:~~1992~~2020, Road vehicles - Engine test code - Net power.

[…]