CS-E AMENDMENT 5 — CHANGE INFORMATION

EASA publishes amendments to certification specifications as consolidated documents. These documents are used for establishing the certification basis for applications made after the date of entry into force of the amendment.

Consequently, except for a note [Amdt No: E/5] under the amended paragraph, the consolidated text of CS-E does not allow readers to see the detailed changes introduced by the new amendment. To allow readers to also see these detailed changes, this document has been created. The same format as for the publication of notices of proposed amendments has been used to show the changes:

— deleted text is ~~struck through~~;

— new or amended text is highlighted in grey;

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

CS-E BOOK 1 — CERTIFICATION SPECIFICATIONS

SUBPART A — GENERAL

CS-E 20 is amended as follows:

CS-E 20 Engine Configuration and Interfaces
(See AMC E 20)

[…]

(b) The aircraft ~~airworthiness~~ ~~code~~ certification specification which is assumed ~~as~~ to be~~ing~~ applicable to the intended installation of the Engine must be identified under CS-E 30.

[…]

CS-E 40 is amended as follows:

CS-E 40 Ratings
(See AMC E 40)

(a) Power ratings must be established for Take-off Power and/or Thrust and for Maximum Continuous Power and/or Thrust, for all Engines.

(b) Other ratings may also be established as:

(1) Piston Engines:

(i) Maximum Recommended Cruising Power,

(ii) Maximum Best Economy Cruising Power;

(2) Turbine Engines for ~~M~~multi-~~E~~engined Aeroplanes:

(i) ~~2 1/2~~2 ½-Minute OEI Power or Thrust,

(ii) Continuous OEI Power or Thrust;

(3) Turbine Engines for ~~M~~multi-~~E~~engined Rotorcraft (~~S~~see AMC E 40(b)(3)):

(i) 30-Second OEI Power,

(ii) 2-Minute OEI Power,

(iii) ~~2 1/2~~2 ½-Minute OEI Power,

(iv) 30-Minute OEI Power,

(v) Continuous OEI Power;

(4) Turbine Engines for Rotorcraft:

(i) 30-Minute Power.

(c) The Engine ~~t~~Thrust and/or ~~p~~Power ratings will be based on standard atmospheric conditions, with no air bleed for aircraft services and with only those accessories installed which are essential for Engine functioning, including controls, unless otherwise declared in the Engine ~~T~~type certificate data sheet.

(d) Operating limitations appropriate to the intended operating conditions for the Engine must be established~~.~~ (~~S~~see AMC E 40(d)).

(e) The Engine's rated Powers/Thrusts and any operating limitations established under ~~this~~ CS-E 40 which must be respected by the crew of an aircraft must be listed in the Engine ~~T~~type certificate data sheet specified in 21A.41. The Engine ~~T~~type certificate data sheet must also identify, or make reference to, all other information found necessary for the safe operation of the Engine.

(f) The ratings established under ~~this~~ CS-E 40 must be defined for the lowest ~~p~~Power/~~t~~Thrust that all Engines of the same type may be expected to produce under the conditions used to determine these ratings. The minimum testing must be defined, together with associated conditions, necessary for ensuring that the Engines will comply with this objective.

(g) In determining the Engine performance and operating limitations, the overall limits of accuracy of the Engine Control System and of the necessary instrumentation as defined in CS-E 60(b) must be taken into account.

(h) For Piston Engines, each declared rating must be defined in terms of the power produced at a given power setting and Engine rotational speed.

<u>CS-E 50 is amended as follows</u>:

CS-E 50 Engine Control System
(See AMC E 50, AMC 20-1, AMC 20-3, AMC 20-115)

(a) *Engine Control System Operation.* It must be substantiated by tests, analysis or a combination thereof that the Engine Control System performs the intended functions in a manner which:

[…]

<u>CS-E 130 is amended as follows</u>:

CS-E 130 Fire Protection
(See AMC E 130)

[…]

(g) Those features of the Engine which form part of the mounting structure or Engine attachment points must be Fireproof, either by construction or by protection, unless:

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

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

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

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

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

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

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

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

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

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

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

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

SUBPART B — PISTON ENGINES:~~,~~ DESIGN AND CONSTRUCTION

CS-E 240 is amended as follows:

CS-E 240 Ignition

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

(~~a~~1) The Engine shall be equipped either with:

(~~1~~i) ~~A~~a dual ignition system ~~having~~ that has entirely independent magnetic and electrical circuits, including spark plugs;~~,~~ or~~,~~

(~~2~~ii) ~~A~~an ignition system which will function with at least the equivalent reliability.

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

(~~1~~i) ~~T~~the maximum power reduction resulting from a loss of redundancy shall be declared in the appropriate manual(s);~~.~~

(~~2~~ii) ~~P~~provision shall be made to establish the serviceability of the ignition system;~~. T~~the associated procedures and required inspection intervals shall be specified in the appropriate manual(s).

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

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

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

SUBPART E — TURBINE ENGINES:~~;~~ TYPE SUBSTANTIATION

<u>CS-E 740 is amended as follows</u>:

CS-E 740 Endurance Tests

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

(b) (1) The test must be made in the order defined in the appropriate schedule and in suitable non-stop stages. An alternative schedule may be used if it is agreed ~~as~~ to be~~ing~~ at least as severe. In the event of a stop occurring during any stage, the stage must be repeated unless it is considered to be unnecessary. The complete test may need to be repeated if an excessive number of stops occur.

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

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

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

(5) The Engine must be subjected to an agreed extent of pre-assembly inspection, and a record must be made of the dimensions that are liable to change by reason of wear, distortion and creep. A record must also be made of the calibrations and

settings of separately functioning Engine components and equipment (e.g. the control system, pumps, actuators, valves).

(c) *Schedules*

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

25 ~~six~~6-hour stages, each stage comprising:

Part 1 1~~One~~ hour of alternate 5-minute periods at Take-off Power or Thrust and minimum ground idle, or, for rotorcraft Engines, minimum test bed idle.

Part 2 (A) Stages 1 to 15, each of 30 minutes duration, at Maximum Continuous Power~~/~~ or Thrust.

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

For Engines for Aeroplanes. Where Engine rotational speeds between Maximum Continuous and Take-off may be used in service, e.g. for reduced thrust take-off or due to variations ~~with~~ in the ambient temperature, and these speeds would not be adequately covered by other Parts of the endurance test, then the following Part 2 must be substituted:

(C) Stages 1 to 10, each of 30 minutes duration at Maximum Continuous Power~~/~~ or Thrust.

(D) Stages 11 to 15, each of 30 minutes duration at Take-off Power or Thrust.

(E) Stages 16 to 25, each of 30 minutes duration covering the range in 6 approximately equal speed increments between Maximum Continuous and Take-off Power~~/~~ or Thrust.

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

Part 4 2 hours and 30 minutes covering the range in 15 approximately equal speed increments from Ground Idling up to but not including Maximum Continuous Power~~/~~ or Thrust.

Part 5 30 minutes of accelerations and decelerations consisting of 6 cycles from Ground Idling to Take-off Power~~/~~ or Thrust, maintaining Take-off Power~~/~~ or Thrust for a period of 30 seconds, the remaining time being at Ground Idling.

(2) (i) *Schedule for Standard Ratings with 2 ½-Minute OEI and/or Continuous OEI Rating and/or 30-Minute OEI Rating and/or 30-Minute Power (when appropriate).*

25 ~~six~~6-hour stages, each stage comprising:

Part 1 1~~One~~ hour of alternate 5-minute periods at Take-off Power or Thrust and minimum ground idle, or, for rotorcraft Engines, minimum test bed idle, except that:

(A) In Stages 3 to 20, in place of two of the 5-minute periods at Take-off Power~~/~~ or Thrust, run 2 ½ minutes at Take-off Power~~/~~ or Thrust followed by 2 ½ minutes at 2 ½-Minute OEI Power~~/~~ or Thrust.

(B) In Stages 21 to 25, in place of three of the 5-minute periods at Take-off Power~~/ ~~or Thrust, run 1 minute at Take-off Power~~/~~or Thrust followed by 2 minutes at 2 ½-Minute OEI Power~~/~~ or Thrust and 2 minutes at Take-off Power~~/~~ or Thrust.

Part 2 (A) Stages 1 to 15, each of 30 minutes duration at Maximum Continuous Power~~/~~ or Thrust.

(B) Stages 16 to 25, each of 30 minutes duration at Take-off Power~~/~~ or Thrust, except that in one stage, a period of 5 minutes in the middle of a 30-minute period must be run at 2 ½-Minute OEI Power~~/~~ or Thrust.

For Engines for Aeroplanes. Where Engine rotational speeds between Maximum Continuous and Take-off may be used in service, e.g. for reduced thrust take-off or due to variations ~~with~~ in the ambient temperature, and these speeds would not be adequately covered by other Parts of the endurance test, then the following Part 2 must be substituted:

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

(D) Stages 16 to 20, each of 30 minutes duration at Take-off Power~~/~~ or Thrust except that in Stage 16 a period of 5 minutes in the middle of the 30-minute period must be run at 2 ½-Minute OEI Power~~/~~ or Thrust.

(E) Stages 21 to 25, each of 30 minutes duration covering the range in six approximately equal speed increments between Maximum Continuous and Take-off Power~~/~~ or Thrust.

Part 3 (A) For Engines for Aeroplanes:

30 minutes at Maximum Continuous Power~~/~~ or Thrust followed by 1~~one~~ hour at Continuous OEI Power~~/~~ or Thrust.

(B) For Engines for Rotorcraft:

Either (for Engines to be approved with a Continuous OEI rating) 30 minutes at Maximum Continuous Power followed by 1~~one~~ hour at Continuous OEI Power or (for Engines to be approved with a 30-Minute OEI Rating) 1~~one~~ hour at Maximum Continuous Power followed by 30 minutes at 30-Minute OEI Power. A Continuous OEI Rating and a 30-Minute OEI Rating at a higher power level can be cleared in the same test, if desired, by running 30 minutes at Maximum Continuous Power followed by 30 minutes at Continuous OEI Power and then 30 minutes at 30-Minute OEI Power.

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

Part 4 2 hours and 30 minutes covering the range in 15 approximately equal increments from Ground Idling, or, for rotorcraft Engines, minimum test bed idle, up to but not including Maximum Continuous Power.

Part 5 30 minutes of accelerations and decelerations consisting of 6 cycles from Ground Idling, or, for rotorcraft Engines, minimum test bed idle, to Take-off Power~~/~~ or Thrust, maintaining Take-off Power~~/~~ or Thrust for a period of 30 seconds, the remaining time being at Ground Idling, or, for rotorcraft Engines, minimum test bed idle.

(ii) If only one additional rating is required, then the periods at the rating that is not required must be run at the power~~/~~ or thrust level appropriate to the next rating down the scale.

(iii) ~~Where~~ If a constructor desires an en-route OEI ~~R~~rating for 30 minutes only, then the appropriate FAR 33.87 Schedule may be used in place of this Schedule. ~~Where~~ If this option is taken and a 2 ½-Minute OEI Power rating is also desired, then the appropriate Schedule of FAR 33.87 must be used.

[…]

CS-E 790 Ingestion of Rain and Hail
(See AMC E 790)

(a) *All Engines*.

(1) The ingestion of large hailstones (0·8 to 0·9 specific gravity) at the maximum true ~~air speed~~ airspeed, for altitudes up to 4 500 metres, associated with a representative aircraft operating in rough air, with the Engine at Maximum Continuous ~~p~~Power~~/~~ or ~~t~~Thrust, must not cause unacceptable mechanical damage or unacceptable ~~p~~Power or ~~t~~Thrust loss after the ingestion, or require the Engine to be shut down.

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

One-half the number of hailstones must be aimed randomly over the inlet face area and the other half aimed at the critical inlet face area. The hailstones must be ingested in a rapid sequence to simulate a hailstone encounter and the number and size of the hailstones must be determined as follows:

(i) ~~O~~one 25-millimetre~~s~~ diameter hailstone for Engines with inlet throat areas of not more than 0.0645 m^2;~~.~~

(ii) ~~O~~one 25-millimetre~~s~~ diameter and one 50-millimetre~~s~~ diameter hailstone for each 0.0968 m^2~~2~~ of inlet throat area, or fraction thereof, for Engines with inlet throat areas of more than 0.0645 m^2.

(2) In addition to complying with CS-E 790(a)(1) and except as provided in CS-E 790(b), it must be shown that each Engine is capable of acceptable operation throughout its specified operating envelope when subjected to sudden encounters with the certification standard concentrations of rain and hail as defined in Appendix A to CS-E. Acceptable Engine operation precludes, during any 3-M~~m~~inute continuous period in rain and during any 30-S~~s~~econd continuous period in hail, the occurrence

of flameout, rundown, continued or non-recoverable surge or stall, or loss of acceleration and deceleration capability. It must also be shown after the ingestion that there is no unacceptable mechanical damage, unacceptable power or thrust loss, or other adverse Engine anomalies~~.~~ (~~S~~see AMC E 790(a)(2)).

[…]

CS-E 800 is amended as follows:

CS-E 800 Bird Strike and Ingestion (See AMC E 800)

(a) *Objective*. To demonstrate that the Engine will respond in a safe manner following specified encounters with birds, as part of the compliance with CS-E 540.

The demonstration will address the ingestion of large, medium and small birds, and also the effect of the impact of such birds upon the front of the Engine.

(b) *Single large bird ingestion test*. An Engine ingestion test must be carried out using a large bird as specified below. Alternative evidence may be acceptable as provided under CS-E 800(~~f~~g)(1).

(1) *Test conditions.*

(i) The Engine operating conditions must be stabilised prior to ingestion at not less than 100 % of the Take-off Power or ~~t~~Thrust at the test day ambient conditions. In addition, the demonstration of compliance must account for Engine operation at sea level take-off conditions on the hottest day that a minimum Engine can achieve maximum rated Take-off Power or ~~t~~Thrust.

(ii) The bird to be used must be of a minimum mass of:

(A) 1·85 kg for Engine inlet throat areas of less than 1·35 m^2 unless a smaller bird is determined to be a more severe demonstration;~~,~~

(B) 2·75 kg for Engine inlet throat areas of less than 3·90 m^2 but equal to or greater than 1·35 m^2;~~,~~

(C) 3·65 kg for Engine inlet throat areas equal to or greater than 3·90 m^2.

(iii) The bird must be aimed at the most critical exposed location on the first stage rotor blades.

(iv) A bird speed of 200 knots for Engines to be installed on aeroplanes or the maximum airspeed for normal flight operations for Engines to be installed on ~~r~~Rotorcraft.

(v) Power lever movement is not permitted within 15 seconds following the ingestion.

(2) *Acceptance criteria*. Ingestion of this single large bird must not result in a Hazardous Engine Effect.

(c) *Large flocking bird.* An Engine test using a single bird must be carried out at the conditions specified below for Engines with an inlet throat area equal to or greater than 2.5 m^2. Alternative evidence may be acceptable as provided under CS-E 800(~~f~~g)(1).

(1) *Test conditions.*

(i) The Engine operating conditions must be stabilised prior to ingestion at not less than the mechanical rotor speed of the first exposed stage(s) that, on an ISA standard day, would produce 90 % of the sea level static Rated Take-off Thrust.

(ii) The bird speed must be 200 knots.

(iii) The bird mass must be at least as defined below:

Engine Inlet ~~t~~Throat Area (A) m^2	Mass of Bird ~~K~~kg
A < 2.50	Not applicable
2.50 ≤~~<~~ A < 3.50	1.85
3.50 ≤~~<~~ A < 3.90	2.10
3.90 ≤~~<~~ A	2.50

(iv) The bird must be targeted on the first exposed rotating stage(s) at a blade ~~airfoil~~ aerofoil height of not less than 50 %, measured at the leading edge.

(v) The following test schedule must be used:

Step 1 — Ingestion followed by 1 minute without power lever movement.

Step 2 — 13 minutes at not less than 50 % of Rated Take-off Thrust.

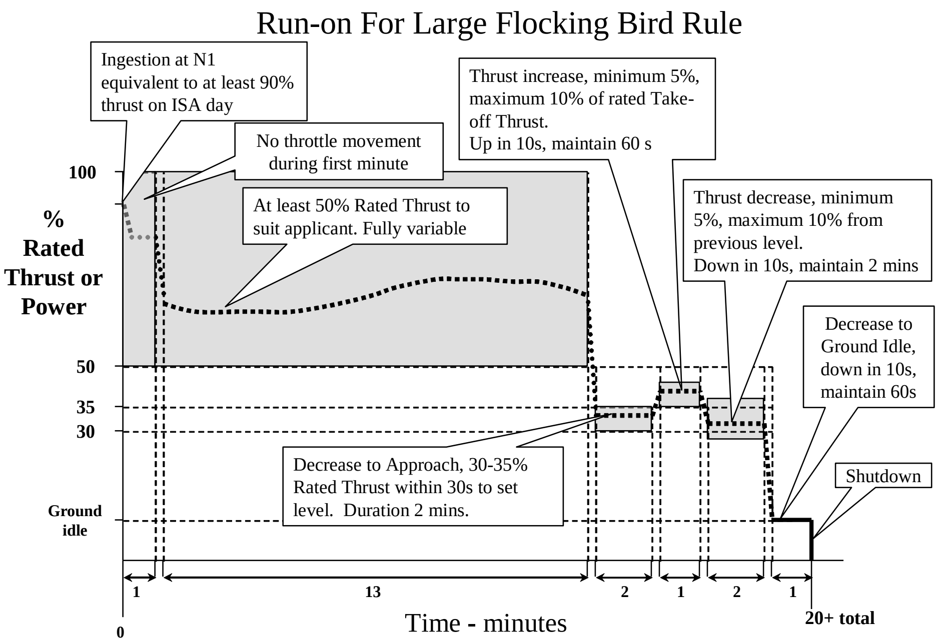
Step 3 — 2 minutes at a thrust set between 30 ~~%~~ and 35 % of Rated Take-off Thrust.

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

Step 5 — 2 minutes at a thrust decreased from that set in step 4 by between 5 ~~%~~ and 10 % of Rated Take-off Thrust.

Step 6 — At least 1 minute at ground idle followed by Engine ~~shut down~~ shutdown.

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



(2) *Acceptance criteria.*

The test of CS-E 800(c)(1)(v) must not cause:

— ~~T~~the Engine to be unable to complete the required test schedule;~~,~~

— ~~T~~the Engine to be shut down before the end of step 6;~~,~~

— ~~A~~a sustained reduction in ~~of~~ thrust to less than 50 % Rated Take-off Thrust during step 1;~~,~~

— ~~A~~a Hazardous Engine Effect.

(d) *Medium and small birds ingestion tests*. Engine ingestion tests and analysis with medium- and small-sized birds must be carried out as specified below. Alternative evidence may be acceptable as provided under CS-E 800(~~f~~g)(1). The small-birds test will not be required if the prescribed number of medium birds pass into the Engine rotor blades during the medium-bird(s) test.

(1) *Test conditions.*

(i) The Engine operating conditions must be stabilised prior to ingestion at not less than 100 % of the Take-off Power or ~~t~~Thrust at the test day ambient conditions. In addition, the demonstration of compliance must account for Engine operation at sea level take-off conditions on the hottest day at which a minimum Engine can achieve maximum rated Take-off Power or ~~t~~Thrust.

(ii) The critical ingestion parameters that affect~~ing~~ power loss and damage must be determined by analysis or component tests or both. They must include~~,~~ but are not limited to~~,~~ the effects of the bird speed, the critical target location and the first stage rotor speed. The critical bird ingestion speed must reflect the most critical condition within the range of airspeeds for normal flight operations up to 450 m (1 500 ft~~feet~~) above ground level, but not less than the V_1~~1~~ minimum for Engines to be installed on aeroplanes.

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

- Perform an ~~I~~ingestion to simulate a flock encounter within ~~one~~1 second;
- 2 minutes without any power lever movement;
- 3 minutes at 75 % of the test conditions of CS-E 800(d)(1)(i);
- 6 minutes at 60 % of the test conditions of CS-E 800(d)(1)(i);
- 6 minutes at 40 % of the test conditions of CS-E 800(d)(1)(i);
- 1 minute at ~~A~~approach ~~I~~idle;
- 2 minutes at 75 % of the test conditions of CS-E 800(d)(1)(i);
- Stabilise the Engine at idle and then shut the Engine down.

These durations are times at the defined conditions, the power lever being moved between each condition in less than 10 seconds.

(iv) For ~~r~~Rotorcraft Engines, the following test schedule must be used:

- Perform an ~~I~~ingestion to simulate a flock encounter within ~~one~~1 second;
- 3 minutes at 75 % of the test conditions of CS-E 800(d)(1)(i);
- 90 seconds at minimum test bed idle;
- 30 seconds at 75 % of the test conditions of CS-E 800(d)(1)(i);
- Stabilise the Engine at idle and then shut the Engine down.

These durations are times at the defined conditions, the power lever being moved between each condition in less than 10 seconds.

(A) *Medium birds*. The ~~M~~masses and quantities of birds will be determined from the second column ~~2~~ of Table A. When only one bird is specified, it must be aimed at the Engine core primary flow path; the other critical locations on the Engine face area must be addressed by appropriate tests or analysis or both.

When two or more birds are specified, the largest must be aimed at the Engine core primary flow path and a second bird must be aimed at the most critical exposed location on the first stage rotor blades. Any remaining birds must be evenly distributed over the Engine face area.

(B) *Small birds*. One 85-g bird for each 0·032 m^2 of the inlet throat area or fraction thereof with a maximum of 16 birds, distributed to take account of any critical exposed locations on the first stage rotor blades, but otherwise evenly distributed over the Engine face area.

TABLE A of CS-E 800

Medium (flocking) birds

	Engine test (CS-E 800(d)(1))	Additional integrity assessment (CS-E 800(d)(3))

Engine inlet throat area (A) m^2~~^{2}~~	Number of birds ×~~x~~ mass of birds ~~K~~kg	Number ×~~x~~ mass of birds kg
A < 0·05	none	none
0·05 ≤~~<~~ A < 0·10	1 ×~~x~~ 0·35	none
0·10 ≤~~<~~ A < 0·20	1 ×~~x~~ 0·45	none
0·20 ≤~~<~~ A < 0·40	2 ×~~x~~ 0·45	none
0·40 ≤~~<~~ A < 0·60	2 ×~~x~~ 0·70	none
0·60 ≤~~<~~ A < 1·00	3 ×~~x~~ 0·70	none
1·00 ≤~~<~~ A < 1·35	4 ×~~x~~ 0·70	none
1·35 ≤~~<~~ A < 1·70	1 ×~~x~~ 1·15 + 3 ×~~x~~ 0·70	1 ×~~x~~ 1·15
1·70 ≤~~<~~ A < 2·10	1 ×~~x~~ 1·15 + 4 ×~~x~~ 0·70	1 ×~~x~~ 1·15
2·10 ≤~~<~~ A < 2·50	1 ×~~x~~ 1·15 + 5 ×~~x~~ 0·70	1 ×~~x~~ 1·15
2·50 ≤~~<~~ A < 2·90	1 ×~~x~~ 1·15 + 6 ×~~x~~ 0·70	1 ×~~x~~ 1·15
2·90 ≤~~<~~ A < 3·90	1 ×~~x~~ 1·15 + 6 ×~~x~~ 0·70	2 ×~~x~~ 1·15
3·90 ≤~~<~~ A < 4·50	3 ×~~x~~ 1·15	1 ×~~x~~ 1·15 + 6 ×~~x~~ 0·70
4·50 ≤~~<~~ A	4 ×~~x~~ 1·15	1 ×~~x~~ 1·15 + 6 ×~~x~~ 0·70

(2) *Acceptance criteria*. The ingestion must not cause:

— ~~M~~more than a sustained 25 % power or thrust loss;

— ~~T~~the Engine to be shut down during the test.

(3) In addition, except for ~~r~~Rotorcraft Engines, it must be substantiated by appropriate tests or analysis or both that, when the full first stage rotor assembly is subjected to the quantity and mass of medium birds from the third ~~C~~column ~~3~~ of Table A fired at the most critical locations on the first stage rotor, the effects will not be such as to make the Engine incapable of complying with the acceptance criteria of CS-E 800(d)(2).

(e) *Core Engine flocking bird ingestion test*. For turbofan Engines, an ingestion test shall be performed as follows:

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

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

(i) A sustained reduction in power or thrust to less than 50 % of the maximum rated Take-off Power or Thrust during the run-on specified under paragraph (e)(3)(iii) below, that cannot be restored only by movement of the power lever.

(ii) A sustained reduction in power or thrust to less than flight idle power or thrust during the run-on segment specified under paragraph (e)(3) below.

(iii) An Engine shutdown during the required run-on demonstration specified in paragraph (e)(3) below.

(iv) The conditions specified in paragraph CS-E 800(b)(2).

(3) The following test schedule shall be used:

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

(ii) Followed by power lever movement to increase the power or thrust to not less than 50 % of the maximum rated Take-off Power or Thrust, if the initial bird ingestion resulted in a reduction in power or thrust below that level.

(iii) Followed by 13 minutes at not less than 50 % of the maximum rated Take-off Power or Thrust.

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

(v) Followed by 1 minute with the power or thrust increased by between 5 and 10 % of the maximum rated Take-off Power or Thrust from that set in subparagraph (e)(3)(iv) of this paragraph.

(vi) Followed by 2 minutes with the power or thrust reduced by between 5 and 10 % of maximum rated Take-off Power or Thrust from that set in subparagraph (e)(3)(v) of this paragraph.

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

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

(4) If it is shown by test or analysis that no bird material will be ingested into the Engine core under the conditions of subparagraph (e)(1), then the core Engine ingestion test shall be performed with one bird, using the heaviest bird specified in the second column of Table A, and ingested at a bird speed of 200 knots. Prior to the ingestion, the Engine must be stabilised at the mechanical rotor speed of the first exposed stage or stages that is consistent with a minimum approach idle setting, on a standard day, at 3 000 ft above ground level. The bird must be targeted on the first exposed rotating stage or stages at the blade aerofoil height measured at the leading edge that would maximise the bird material being ingested into the Engine core.

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

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

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

(6) The following test schedule must be used:

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

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

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

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

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

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

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

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

(~~e~~f) *Impact.* The impact against the front of the Engine of the largest medium bird required by CS-E 800(d)(1)(v)(A) and of the large bird required by CS-E 800(b)(1)(ii) must be evaluated for compliance with CS-E 540 under the Engine conditions specified for the ingestion tests. The bird speed must be the critical bird ingestion speed for the critical locations within the range of airspeeds for normal flight operations up to 450 m (1 500 ft~~feet~~) above ground level, but not less than the V_1~~1~~ minimum for Engines to be installed on aeroplanes or higher than the speeds for the ingestion tests.

The impact evaluation may be carried out separately from the ingestion evaluation; however, any damage resulting from the impact on the front of the Engine must be assessed in relation to consequential damage on the rotating blades.

(~~f~~g) *General*

(1) Engine tests must be performed as required under CS-E 800(b), (c), (d) and (~~d~~e) unless it is agreed that alternative evidence such as from Engine tests, rig tests, analysis or an

appropriate combination of these, may come from the ~~A~~applicant's experience with~~on~~ Engines of comparable size, design, construction, performance and handling characteristics, obtained during development, certification or operation.

(2) The Engine test described in CS-E 800(b)(1), with regard to the single large bird, may be waived if it can be shown by test or analysis that the specifications of CS-E 810(a) are more severe.

(3) Compliance with CS-E 800(c), in place of an Engine test, may be shown by:

(i) ~~I~~incorporating the run-on specifications of CS-E 800(c)(1)(v) into the Engine test demonstration specified in CS-E 800(b)(1); or

(ii) ~~U~~using a component test at the conditions of CS-E 800(b)(1) or (c)(1), subject to the following additional conditions:

(A) All components that are critical to achieving the run-on criteria of CS-E 800(c) are included in the component test; and

(B) The components tested under (A) above are subsequently installed in a representative Engine for a run-on demonstration in accordance with CS-E 800(c)(1)(v), except that steps 1 and 2 of CS-E 800(c)(1)(v) are replaced by a unique 14-minute~~s~~ step at a thrust not less than 50 % of Rated Take-off Thrust after the Engine is started and stabilised;~~,~~ and

(C) Dynamic effects that would have been experienced during a full Engine test can be shown to be negligible with respect to meeting the specifications of CS-E 800(c).

(4) Limit ~~exceedences~~ exceedances may be permitted to occur during the tests of CS-E 800(c), (d) and (~~d~~e). Any limit~~ exceedence~~ exceedance must be recorded and shown to be acceptable under CS-E 700.

(5) For an Engine that incorporates an inlet protection device, compliance with ~~this~~ CS-E 800 must be established with the device functioning and the Engine approval must be endorsed accordingly.

(6) If compliance with all of the specifications of CS-E 800 is not established, the Engine approval will be endorsed accordingly by restricting the Engine installations to those where birds cannot strike the Engine or be ingested by the Engine or adversely restrict the airflow into the Engine.

(7) An Engine to be installed in a multi-~~E~~engined ~~r~~Rotorcraft does not need to comply with the medium- or small-bird specifications of CS-E 800(d), but the Engine approval will be endorsed accordingly.

(8) The Engine inlet throat area, as used in CS-E 800 to determine the bird quantity and mass, must be established and identified as a limitation on the inlet throat area in the instructions for installation.

CS-E 810 is amended as follows:

CS-E 810 Compressor and Turbine Blade Failure
(See AMC E 810)

[…]

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

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

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

CS-E BOOK 2 — ACCEPTABLE MEANS OF COMPLIANCE

SUBPART A — GENERAL

AMC E 25 is amended as follows:

AMC E 25 Instructions for ~~c~~Continued ~~a~~Airworthiness

[…]

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

[…]

AMC E 30 is amended as follows:

AMC E 30 Assumptions

The details required by CS-E 30 concerning assumptions should normally include information on, at least, the items listed in Table 1.

TABLE 1

Specifications/References	Assumptions
All Engines	
Interfaces CS-E 20	Applicable aircraft specifications. Flight and ground loads. Aircraft components and equipment not included in the Engine definition. Attitudes. Negative g duration. Physical and functional interfaces with the aircraft. Mount flexibility.
Engine Control System CS-E 50	Type of aircraft installation. Conditions on the interfaces with the aircraft or the Propeller. Environmental conditions.
Instrumentation CS-E 60	Instrumentation required and statement of accuracy. For engines with 30-Second/2-Minute OEI ratings, conditions imposed on ~~to~~ the usage recording system.
Strength CS-E 100 CS-E 520, CS-E 640	Ultimate and limit loads: — ~~O~~out-of-balance loads, — ~~O~~operating envelope.
Fire precautions CS-E 130	Reliance placed on the installation of fire-zone partitioning for any part of the mounting structure or Engine attachment points that are not Fireproof.
Electrical ~~b~~Bonding CS-E 135	Reliance placed on aircraft provisions for electrical bonding of the Engine.
Propeller ~~f~~Functioning ~~t~~Tests CS-E 180	Propeller system. Levels of the Propeller vibrations.
Failure Analysis CS-E 210, CS-E 510	Installation aspects and the assumptions made with respect to any safety system that is required for the Engine and which is outside the applicant's control.
Low ~~t~~Temperature ~~s~~Starting ~~t~~Tests, CS-E 380, CS-E 770	Minimum and maximum starting torque.
Turbine Engines	

Freedom from surge CS-E 500	Operating envelope, i.e. altitude, temperature, aircraft speed. Permissible intake distortion.
Low-cycle fatigue CS-E 515	Engine Flight Cycle.
Continued ~~r~~Rotation CS-E 525	Aircraft conditions such as airspeed, flight duration and ambient conditions.
Fuel ~~s~~System CS-E 560	Fuel Specifications approved for use. Need for aircraft fuel anti-ice means or fuel with anti-ice additives. Assumptions made with respect to the maximum levels of contamination in the fuel supplied to the Engine.
Oil System CS-E 570	Oil(s) approved for use.
Starter ~~s~~Systems CS-E ~~570~~590	Reliance placed on aircraft provisions for any safety system that is outside the applicant’s control.
Vibration Surveys CS-E 650	Intake conditions, exhaust conditions. Propeller or thrust reverser effects.
Contaminated ~~f~~Fuel CS-E 670	Duration of flight with contaminated fuel following indication of impending filter blockage, and critical temperature for test of AMC E 670 ~~P~~paragraph 2.
Inclination and ~~g~~Gyroscopic ~~l~~Load~~s~~ ~~e~~Effects CS-E 680	Flight manoeuvres.
Excess ~~o~~Operating ~~c~~Conditions CS-E 700	Operating envelope.
Rotor ~~l~~Locking ~~t~~Tests CS-E 710	Maximum torque from continued flight.
Thrust or power response CS-E 745	Minimum ground idle. Minimum flight idle. Flight envelope.
Icing Conditions CS-E 780	Intake conditions and configuration. Aircraft speeds and appropriate Engine powers. Engine ingestion capabilities.
Ingestion of ~~r~~Rain and ~~h~~Hail	Aircraft speeds, Engine speeds and altitudes. Intake throat area — Intake configuration.

CS-E 790	
Bird strikes CS-E 800	Aircraft speeds, Engine speeds and altitudes. Intake throat area — Intake configuration.
~~Re-light~~Relighting in ~~f~~Flight CS-E 910	Flight ~~re-light~~relight envelope.
Piston Engines	
De-icing and anti-icing CS-E 230	Temperature rise provided.
Filters CS-E 260	Provision to be made in installation.
Vibration ~~t~~Tests CS-E 340	Propeller used.
Water Spray ~~t~~Tests CS-E 430	Installation details.

<u>AMC E 40(b)(3) is amended as follows</u>:

AMC E 40(b)(3) and (b)(4) 30-Second OEI, ~~and~~ 2-Minute OEI and 30-minute Power Ratings

(1) The 30-Second and 2-Minute OEI Power ratings are two separate ratings. However, they are associated in a combined structure of 2.5 minutes duration.

(2) The 30-Second and 2-Minute OEI ratings are optional ratings that may be specifically requested by the applicant, and they are intended for use only for continuation of the one-flight operation after the Failure of one Engine in multi-~~E~~engined ~~r~~Rotorcraft during take-off, climb or landing. The 30-Second OEI Power rating provides a short burst of power to complete the take-off or to effect a rejected take-off, should an Engine Failure occur at the critical decision point, so that the ~~r~~Rotorcraft can lift clear of any obstruction in the flight path and climb out or, alternatively, to reject the take-off. Similarly, this rating also provides adequate power for the ~~r~~Rotorcraft to execute a safe landing, or a baulked landing if an Engine fails at any point down to and including the landing decision point. The 2-Minute OEI Power rating provides a further period of increased power to enable the ~~r~~Rotorcraft to complete the climb out from take-off or baulked landing to safe altitude and airspeed.

(3) While the 30-Second and 2-Minute OEI ~~p~~Power ratings were originally conceived as high power ratings, using the available margins in the Engine design, and followed by a mandatory Engine overhaul, ~~the~~ experience has shown that the manufacturers provide engines with differing capabilities and different margins. Therefore, some flexibility is possible in defining the mandatory maintenance actions, provided they are appropriately validated during certification~~.~~ (~~S~~see also AMC E 25~~.~~).

(4) These ratings have been intended for one usage per flight in an emergency during the take-off or landing phases. Nevertheless, the certification specifications have been

defined around the worst-case scenario that involves~~ing~~ the possible use of these ratings three times in one flight (i.e.~~,~~ the event at take-off, baulked landing and final landing). While it was not initially intended, it is recognised that these ratings could also be inadvertently used in some unexpected, non-critical conditions like an Engine Failure in a ~~r~~Rotorcraft flying at a high-speed cruise. In all cases, the required mandatory maintenance actions apply after any use of the rating powers.

(5) In some circumstances, the highest power used during a 2.5-minute duration OEI event might be lower than the 30-S~~s~~econd OEI power band, but still ~~inside~~ within the certified power band of the 2-Minute OEI P~~p~~ower rating. In this case, it is permissible to extend the use of the 2-Minute OEI ~~p~~Power rating to a total duration of 2.5 minutes. However, that additional 30-S~~s~~econd~~s~~ period will be considered ~~as~~ to be a ~~de-~~derated 30-Second OEI ~~p~~Power rating. For the required mandatory maintenance actions, see CS-E 25(b)(2) and AMC E 25.

(6) The 30-Second and 2-Minute OEI ~~p~~Power ratings should account for any deterioration observed ~~from~~ during the applicable portion of the ~~two~~2-hour additional endurance test of CS-E 740(c)(3)(iii).

Any available information from tests of CS-E 740(c)(3)(iii) may be used ~~for~~ to establish~~ing~~ the Engine characteristics throughout the operating envelope of the Engine~~'s operating envelope~~. In particular, the ~~p~~Power ratings for the 30-Second and 2-Minute OEI ratings should reflect the rated power deterioration that is observed ~~from~~ during the pre-2-hour test calibration through and including the third application of 30-Second OEI rated power during the additional endurance test. The power deterioration through the third application is expected to be the best indicator of the worst-case power deterioration that could occur during actual usage of the rating, and thus it should be reflected in the data given to the aircraft manufacturer to define the performance characteristics of the aircraft system. In the event of a power deterioration that exceeds~~ing~~ 10 % at the 30-Second OEI rating over the course of the 2-hour test, the mode of deterioration should be evaluated to ensure that the availability of 30-Second OEI rated power in service will not be compromised by any variability in the amount of deterioration ~~variability~~.

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

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

AMC E 80 is amended as follows:

AMC E 80 Equipment

(1) The need for additional specifications in the equipment specifications should be determined when complying with CS-E 80 or be defined by the applicant on a general basis, for example, to~~for~~ cover~~ing~~ more than one aircraft installation.

Consideration of general conditions, such as those of EUROCAE ED-14/RTCA/DO-160, allows the certification of equipment in a consistent manner, independent from any installation consideration. However, additional testing may be required in order to comply with CS-E 80(b), depende~~a~~nt on the assumed installation conditions. All equipment, including all electronic units, sensors, harnesses, hydromechanical elements, and any other relevant elements or units, should be shown to operate properly in their declared environment.

(2) The manufacturer should consider the applicability of the items listed in the Tables 1 to 4 below, which are provided as a guide.

Documents that provide acceptable test procedures for each item are referenced in the same table. The manufacturer may define other acceptable appropriate test and analysis procedures. Compliance is normally demonstrated by test or analysis unless the equipment is shown to be sufficiently similar to and operates in an environment which is the same or less severe than previously certified equipment for which similarity is claimed.

The intent and applicability of each item of Tables 1 to 4 are also specified after each table.

The following list of applicable tests or procedures (or their equivalent) is acceptable for evaluating equipment airworthiness.

(a) General Environmental Conditions

The following environmental conditions should be considered for all ~~E~~equipment.

Table 1

	Environmental Conditions	ACCEPTABLE TESTS/PROCEDURES
1	High Temperature	EUROCAE ED-14 / RTCA/DO-160, ~~s~~Section 4 or Mil-E-5007 paragraph 4.6.2.2.5
2	Low Temperature	EUROCAE ED-14 / RTCA/DO-160, ~~s~~Section 4 or Mil-E-5007 paragraph 4.6.2.2.7
3	Room Temperature	EUROCAE ED-14 / RTCA/DO-160, ~~s~~Section 4 or Mil-E-5007 paragraph 4.6.2.2.6
4	Contaminated Fluids	As a reminder. See relevant CS-E specifications for fuel/oil/air specifications or Mil-E-5007 paragraph ~~4.6.2.2.6~~ 3.7.3.3.2 Table X (fuel test only)
5	Vibration	EUROCAE ED-14 / RTCA/DO-160, Section 8
6	Operational shock and crash safety	EUROCAE ED-14 / RTCA/DO-160, Sections 7.2 and 7.3.1

7	Sand and Dust	EUROCAE ED-14 / RTCA/DO-160, Section 12, Category D or MIL-STD-810
8	Fluid Susceptibility	EUROCAE ED-14 / RTCA/DO-160, Section 11, Category F
9	Salt Spray	EUROCAE ED-14 / RTCA/DO-160, Section 14, Category S or MIL-STD-810
10	Fuel System Icing	As a reminder. See CS-E 560(e)
11	Induction Icing	As a reminder. See CS-E 230 & CS-E 780
12	Fungus	EUROCAE ED-14 / RTCA/DO-160, Section 13, Category F
13	Temperature and altitude	EUROCAE ED-14 / RTCA/DO-160, Section 4

[…]

AMC E 130 is amended as follows:

AMC E 130 Fire ~~p~~Protection

[…]

(2) General

[…]

(c) Determination of level of fire protection

CS-E 130(b) requires that all flammable fluid conveying parts or components be at least ~~Fire Resistant~~Fire-resistant, whereas CS-E 130(c) requires flammable fluid tanks and associated shutoff means to be Fireproof. It should then be determined which level of fire protection should be shown for each component requiring a fire protection evaluation.

The 5-minute exposure which is associated with a 'Fire-r~~R~~esistant' status provides a reasonable time period for the flight crew to recognise a fire condition, shut down the appropriate Engine and close the appropriate fuel ~~shut off~~ shutoff valve(s). This cuts off the source of fuel.

Oil system components of turbine Engines, however, may continue to flow oil after the Engine has been shut down because of continued rotation. The supply of oil to the fire might exist for as long as the continued rotation effects are present or until the oil supply is depleted.

According to these assumptions, in general, components which convey flammable fluids can be evaluated to a ~~f~~Fire-resistant standard provided the normal supply of flammable fluid is stopped by a shutoff feature ~~[~~(also see CS-E 570 ~~(b)(7)(i)~~(e)(1)).

Oil system components may need to be evaluated from the standpoint of fire hazard (quantity, pressure, flow rate, etc.) to determine whether ~~f~~Fire-resistant or ~~f~~Fireproof standards should apply. It should be noted that, historically, most oil system components have been evaluated to a ~~f~~Fireproof standard.

Other flammable fluid conveying components (except flammable fluid tanks), such as hydraulic and thrust augmentation systems, should be evaluated in a similar manner. Flammable fluid tanks should be ~~f~~Fireproof as required by CS-E 130(c).

[…]

SUBPART D — TURBINE ENGINES:~~,~~ DESIGN AND CONSTRUCTION

<u>AMC E 515 is amended as follows</u>:

AMC E 515 Engine Critical Parts

[…]

(3) *Means for defining an Engineering Plan*

(a) *Introduction*

The Engineering Plan consists of comprehensive life assessment processes and technologies that ensure that each Engine Critical Part can be withdrawn from service at a life before Hazardous Engine Effects can occur. These processes and technologies address the design, test validation, and certification aspects, ~~as well as~~ and also define those manufacturing and service management processes that should be controlled in order to achieve the Engine Critical Part design intent.

(b) *Elements of the Engineering Plan*

The Engineering Plan should address the following subjects:

— Analytical and empirical engineering processes applied to determine the Approved Life.

— Structured component and ~~e~~Engine testing conducted to confirm ~~e~~Engine internal operating conditions and to enhance confidence in the Approved Life.

— Establishment of the ~~A~~attributes to be provided and maintained for the manufacture and service management of Engine Critical Parts.

— Development and certification testing, and service experience required to validate the adequacy of the design and Approved Life. Any in-service inspections identified as critical elements to the overall part integrity~~,~~ should be incorporated into the Service Management Plan.

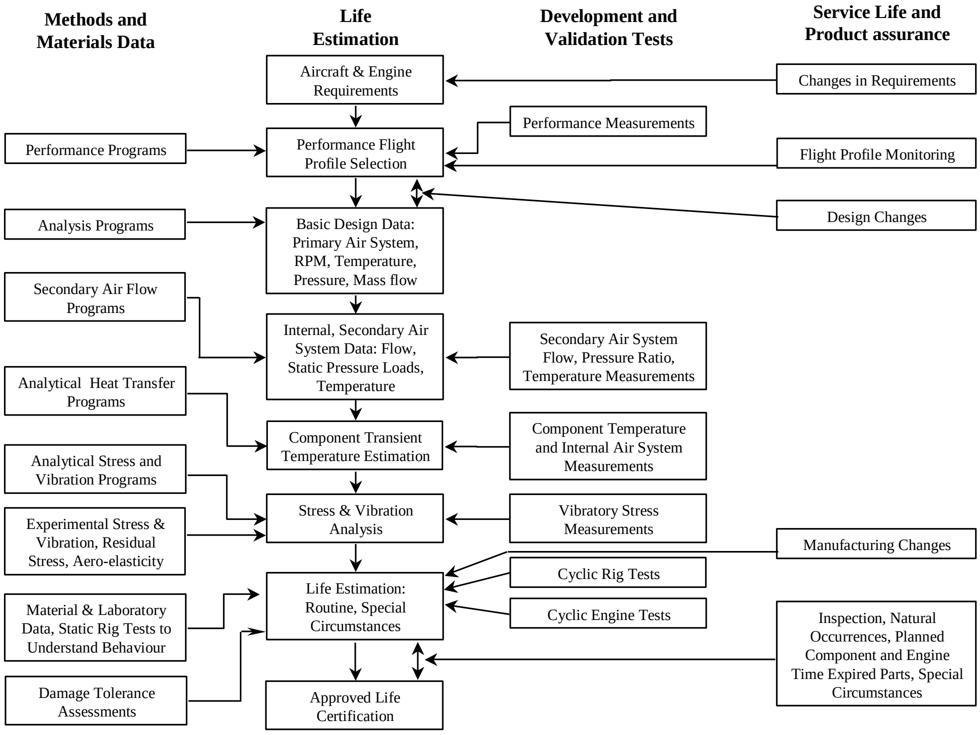
(c) *Establishment of the Approved Life — General*

Determining the life capability of an Engine Critical Part involves the consideration of many separate factors, each of which may have a significant influence on the final results.

It is possible that the final life calculated may be in excess of that considered to be likely for the associated airframe application. However, the life, in terms of cycles or hours, as appropriate, should still be recorded in the ~~a~~Airworthiness ~~l~~Limitations ~~s~~Section in order ~~that~~ for the usage of the part ~~may~~ to be properly tracked.

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

The following describes a typical process for establishing the Approved Life of rotating parts:



The major elements of the analysis are:

(i) *Operating conditions.*

For the purposes of certification, an appropriate flight profile or combination of profiles and the expected range of ambient conditions and operational variations will determine the predicted service environment. The Engine Flight Cycle should include the various flight segments such as start, idle, take-off, climb, cruise, approach, landing, reverse and shutdown. The assumed hold times at the various flight segments should correspond to the assumed limiting installation variables (aircraft weight, climb rates, etc.). For Rotorcraft turbine Engines, the representative usage of the 30-minute Power rating should be considered in the Engine Flight Cycle when establishing the Approved Life of each Engine critical part. A maximum severity cycle that is known to be conservative may be used as an alternative.

The corresponding rotor speeds, internal pressures, and temperatures during each flight segment should be adjusted to account for ~~e~~Engine performance variation due to production tolerances and installation trim procedures, as well as ~~e~~Engine deterioration that can be expected between heavy maintenance intervals. The range of ambient temperature and take-off altitude conditions encountered during the ~~e~~Engines' service life as well as the impact of cold and hot ~~e~~Engine starts should also be considered.

The appropriateness of the Engine Flight Cycle should be validated and maintained over the lifetime of the design. The extent of the validation is depende~~a~~nt upon the approach taken in the development of the Engine Flight Cycle. For example, a conservative flight cycle where all the variables are placed at the most life-damaging value would require minimum validation, whereas a flight cycle which more accurately represents some portion of the actual flight profile but is inherently less conservative, would require more extensive validation. Further refinements may be applied when significant field operation data is ~~are~~ gathered.

(ii) *Thermal analysis.*

Analytical and empirical engineering processes are applied to determine the ~~e~~Engine internal environment (temperatures, pressures, flows, etc.) from which the component steady-state and transient temperatures are determined for the Engine Flight Cycle. The ~~e~~Engine internal environment and the component temperatures should be correlated and verified experimentally during ~~e~~Engine development testing.

(iii) *Stress analysis.*

The stress determination is used to identify the limiting locations such as bores, holes, changes in section, welds or attachment slots, and the limiting loading conditions. Analytical and empirical engineering processes are applied to determine the stress distribution for each part. The analyses evaluate the effects on part stress of ~~e~~Engine speed, pressure, part temperature and thermal gradients at many discrete ~~e~~Engine cycle conditions. From this, the part's cyclic stress history is constructed. All methods of stress analysis should be validated by experimental measurements.

(iv) *Life analysis.*

The life analysis combines the stress, strain, temperature and material data to establish the life of the minimum property part. Plasticity- and creep-related effects should also be considered. Relevant service experience gained through a successful programme of parts retirement or precautionary sampling inspections, or both, may be included to adjust the life prediction system.

The fatigue life prediction system is based upon test data obtained from cyclic testing of representative laboratory, ~~sub-component~~ subcomponent, or specific component specimens and should account for the manufacturing processes that affect low-cycle fatigue (LCF) capability, including fabrication from production grade material. Sufficient testing should be performed to evaluate the effects of elevated temperatures and hold times, as well as interaction with other material Failure mechanisms such as high-cycle fatigue and creep. The fatigue life prediction system should also account for environmental effects, such as vibration and corrosion, and cumulative damage.

When the fatigue life is based on cyclic testing of specific parts, the test results should be corrected for inherent fatigue scatter. The factors used to account for scatter should be justified. In order to utilise this approach, the test should be designed to be representative of the critical ~~e~~Engine conditions in terms of ~~the~~ temperature and stress at the specific features, e.g. bore, rim or blade attachment details, of the part being tested. Appropriate analytical and empirical tools should be utilised such that the fatigue life can be adjusted for any differences between the ~~e~~Engine conditions and cyclic test. In the event the test is terminated by burst or complete Failure, crack initiation for this particular test may be defined using the appropriate crack growth calculations and/or fracture surface observations. It may also be possible to utilise the number of cycles at the last crack-free inspection to define the crack initiation point. This approach requires an inspection technique with a high level of detection capability consistent with that used by the ~~e~~Engine industry for rotating parts.

The test data should be reduced statistically in order to express the results in terms of minimum LCF capability (1/1000 or alternately ~~-~~–3 sigma). The fatigue life should be determined as a minimum life to initiation of a fatigue crack, defined typically as a crack length of 0.75mm.

An alternative way of using the data is to base the fatigue life on an agreed safety margin to burst of a minimum strength part. Typically a 2/3 factor has been applied to the minimum (1/1000 or alternatively –3 sigma) burst life; however, any factor used should be justified for a particular material.

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

Damage Tolerance ~~a~~Assessments should be performed to minimise the potential for Failure from material-, manufacturing- and service-induced anomalies within the Approved Life of the part. Service experience with gas turbine ~~e~~Engines has demonstrated that material-, manufacturing- and service-induced anomalies do occur which can potentially degrade the structural integrity of Engine Critical Parts. Historically, life management methodology has been founded on the assumption of the existence of nominal material variations and manufacturing conditions. Consequently, the methodology has not explicitly addressed the occurrence of such anomalies, although some level of tolerance to anomalies is implicitly built-in using design margins, factory and field inspections, etc. A Damage Tolerance ~~a~~Assessment explicitly addresses the anomalous condition(s) and complements the fatigue life prediction system. It should be noted that the 'Damage Tolerance Assessment' is part of the design process and not a method for returning cracked parts to service whilst monitoring crack growth.

The Damage Tolerance ~~a~~Assessment process typically includes the following primary elements:

Anomaly size and frequency distributions.

A key input in the ~~d~~Damage ~~t~~Tolerance ~~a~~Assessment is the size and rate of occurrence of the anomalies. This type of information may be statistical in nature and can be presented in a form that plots a number of anomalies that exceed a particular size in a specified amount of material. Anomalies should be treated as sharp propagating cracks from the first stress cycle unless there is sufficient data to indicate otherwise.

Crack growth ~~A~~analysis.

This determines the number of cycles for a given anomaly to grow to a critical size. This prediction should be based upon knowledge of the part stress, temperature, geometry, stress gradient, anomaly size and orientation, and material properties. The analysis approach should be validated against relevant test data.

Inspection techniques and intervals.

Manufacturing and in-service inspections are an option to address the fracture potential from inherent and induced anomalies. The intervals for each specified in-service inspection should be identified. Engine removal rates and module and piece part availability data could serve as the basis for establishing the inspection interval. The manufacturing inspections assumed in the ~~d~~Damage ~~t~~Tolerance ~~a~~Assessments should be incorporated into the Manufacturing Plan. Likewise, the assumed in-service inspection procedures and intervals should be integrated into the Service Management Plan and included, as appropriate, in the ~~a~~Airworthiness ~~l~~Limitations ~~s~~Section of the ~~i~~Instructions for ~~c~~Continued ~~a~~Airworthiness.

Inspection Probability of Detection (POD).

The Probability of Detection (POD) of the individual inspection processes, such as eddy-current, penetrant fluid or ultrasonic, used to detect potential anomalies, should be based upon the statistical review of sufficient quantities of relevant testing or experience. The relevance of ~~these~~ this data should be based upon the similarity of parameters such as:

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

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

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

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

— ~~S~~specific inspection process parameters such as the scan index;

— the ~~I~~inspector (such as their visual acuity, attention span, training, etc.).

In addition, the following should be noted with regard to the above:

— ~~A~~appropriate Damage Tolerance ~~a~~Assessments.

In the context of CS-E 515(a), ‘appropriate Damage Tolerance ~~a~~Assessments’ recognises that industry standards on suitable anomaly size and frequency distributions, and analysis techniques used in the ~~d~~Damage ~~t~~Tolerance ~~a~~Assessment process are not available in every case listed in the paragraphs below. In such cases, compliance with the rule should be based on such considerations as the design margins applied, application of damage tolerance design concepts, historical experience, crack-growth rate comparisons to successful experience, etc. Anomalies for which a common understanding has been reached within the Engine community and the Authorities should be considered in the analysis.

Material anomalies.

Material anomalies consist of abnormal discontinuities or non-homogeneities introduced during the production of the input material or melting of the material. Some examples of material anomalies that should be considered are hard alpha anomalies in titanium, oxide/carbide (slag) stringers in nickel alloys, and ceramic particulate anomalies in powder metallurgy materials unintentionally generated during powder manufacturing.

Manufacturing anomalies.

Manufacturing anomalies include anomalies produced in the conversion of the ingot-to-billet and billet-to-forging steps as well as anomalies generated by the metal removal and finishing processes used during manufacture and/or repair. Examples of conversion-related anomalies are forging laps and strain-induced porosity. Some examples of metal-removal-related anomalies are tears due to broaching, arc burns from various sources and disturbed microstructure due to localised overheating of the machined surface.

Service-induced anomalies.

Service-induced anomalies such as non-repaired nicks, dings and scratches, corrosion, etc., should be considered. Similarity of hardware design, installation, exposure and maintenance practice should be used to determine the relevance of the experience.

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

(i) *General Principles*

The general principles which are used to establish the Approved Life are similar to those used for rotating parts.

However, for static pressure loaded parts, the Approved Life may be based on the crack initiation life plus a portion of the residual crack growth life. The portion of the residual life used should consider the margin to burst. If the Approved Life includes reliance on the detection of cracks prior to reaching the Approved Life, the reliability of the crack detection should be considered. If, as part of the Engineering Plan, a~~A~~ny dependence is placed upon crack detection to support the Approved Life, this should result in mandatory inspections being included in the Service Management Plan and in the ~~a~~Airworthiness ~~l~~Limitations ~~s~~Section of the ~~i~~Instructions for ~~c~~Continued ~~a~~Airworthiness. Crack growth analysis techniques should be validated experimentally.

Some construction techniques, such as welding or casting, contain inherent anomalies. Such anomalies should be considered as part of the methodology to establish the Approved Life. Fracture mechanics is a common method for such assessments.

In determining the life of the part, the temperature of the part, any temperature gradients, any significant vibratory or other loads (for example, flight manoeuvre) should be taken into account in addition to the pressure loads.

Manufacturing and in-service inspections are an option to address the potential for fracture. The intervals for each specified in-service inspection should be identified. Engine removal rates and module and piece part availability data could serve as the basis for establishing the inspection interval. The manufacturing inspections should be incorporated into the Manufacturing Plan. Likewise, the assumed in-service inspection procedures and intervals should be integrated into the Service

Management Plan and included, as appropriate, in the ~~a~~Airworthiness ~~l~~Limitations ~~s~~Section of the ~~i~~Instructions for ~~c~~Continued ~~a~~Airworthiness.

(ii) *Tests*

When using testing as part of the substantiation of the life of the part, the basic load cycle should be from substantially zero differential pressure to a value that simulates the most critical operation stress condition and returning to substantially zero differential pressure.

When a test is performed, the test pressure level should be adjusted to include the effects of stress due to thermal gradients in actual operation. When this is impossible, due to over-stress of regions other than the critical location or stress reversal in the Engine Flight Cycle for example, the fatigue capability in operation should be established by an additional analysis.

If the part is subject to loads in addition to those resulting from differential pressure (e.g. flight manoeuvre loads, ~~e~~Engine mounting loads, etc.), an analysis should be made of these additional loads and their effect examined. If the effect of these loads is small, it may be possible to simulate them by an addition to the test pressure differential. However, if the loads are of significant magnitude or cannot adequately be represented by a pressure increment, the test should be carried out with such loads acting in addition to the pressure loads.

The part should be tested at the temperature associated with the most critical stress case or alternatively the test pressure differential may be increased to simulate the loss of relevant properties as a result of temperature.

Any fatigue scatter factors used should be justified.

During pressure testing, the methods of mounting and restraint by the test facility or test equipment of any critical section should be such as to simulate the actual conditions occurring on the ~~e~~Engine.

(iii) *Analytical Modelling Methods*

An analytical modelling method may be used to determine the adequate fatigue life, provided that the modelling method is validated by testing or successful field experience with parts of similar design.

(f) *Establishment of the Approved Life — Other Parts*

It is possible that the Safety Analysis required by CS-E 510 may identify Engine Critical Parts other than rotating parts or static pressure loaded parts. In such instances, a methodology for determining the Approved Life will need to be agreed with the Authority, using the general principles for rotating and static pressure loaded parts as a guideline.

(g) *Maintaining the Approved Life*

At certification, the Approved Life is based on predictions of the ~~e~~Engine operation, material behaviour, environment, etc., which all can be expected to influence the life at which the part should be withdrawn from service to avoid Hazardous Engine Effects.

After certification, it may be necessary to check the accuracy of such predictions, recognising that many aspects, for example, the usage of the ~~e~~Engine and its operating environment, may change during its operational life, especially with a change of ownership. It is important to use any service feedback to confirm that any assumptions made in the Engineering Plan remain valid, or are modified if required. The Engineering Plan should describe not only the basis of the Approved Life, but also those actions subsequent to certification, which will be necessary to ensure that the Approved Life is appropriate throughout the operational life of the ~~e~~Engine.

A regular review of the assumptions made when establishing the Approved Life may be required, depending on the conservative nature of the assumptions made when determining the Approved Life. The Engineering Plan should detail when such reviews should occur and what information will be required in order to complete the review.

Aspects which may be considered include~~,~~ but need not be limited to:

— ~~T~~the frequency of Approved Life reviews;

— ~~D~~detailed inspection of service run parts, including time-expired parts;

— ~~R~~review of flight plans;

— ~~F~~findings during maintenance;

— Engine development experience;

— ~~L~~lessons learned from other engine projects;

— ~~A~~any in-service events.

(h) *Influencing Parts*

Engine Critical Parts are part of a complex system and other parts of the ~~e~~Engine can have an impact on the Engine Critical Parts and their life capability. Therefore, the Engineering Plan needs to address these parts, and particularly changes to them. Examples of influencing parts include a turbine blade, a mating part, and a static part that impacts on the environment (temperatures, pressures, etc.) around the Engine Critical Part. Examples of changes to influencing parts include a blade with a different weight, centre of gravity, or root coating; a mating part made of~~from~~ a material that has~~ving~~ a different coefficient of thermal expansion; and a static part where changes in geometry or material modify the thermal and/or mechanical response of the component and could, as a result, affect the environment around the Engine Critical Part.

[…]

<u>AMC E 520(d) is created as follows</u>:

AMC E 520(d) Strength — Local Failures

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

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

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

<u>AMC E 560 is amended as follows</u>:

AMC E 560 Fuel ~~s~~System

(1) More than one type of fuel may be allowed: CS-E 560(a) applies to each type and covers additives in the fuel (for example, fuel system icing inhibitor).

Some ~~e~~Engines may use other fluids, such as water methanol: when appropriate, the word 'fuel' in CS-E 560 should be interpreted as covering these fluids as well.

If the Engine may be adversely affected by a parameter of the fuel specification, such as sulphur or gum content, this should be identified in the appropriate documentation.

When defining the fuel specifications under CS-E 560(a), CS-E 90 should also be considered for effects induced in the fuel system by the fuel itself, fuel additives or water in the fuel.

(2) To comply with CS-E 560(b)(1), contaminants likely to be present in the fuel delivered to the Engine from the aircraft should be considered, as well as contaminants resulting from wear of a part or component of the Engine fuel system (such as fuel pump bearing).

(3) In compliance with CS-E 560(e), any means provided for protection against icing in the fuel system may either be in operation continuously or commence operation automatically when required.

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

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

(~~4~~5) In complying with CS-E 110(d), because a fuel leakage is considered as a potential fire hazard, design precautions should be taken to minimise the possibilities of incorrect assembly of fuel system components, including pipes and fittings, especially if parts of the system have to be removed during the routine maintenance procedures.

(~~5~~6) For compliance with CS-E 130(a), in order to minimise the possibility of occurrence and spread of fire, each filter or strainer should be mounted so that its weight is not supported by the connecting lines or by the inlet or outlet connections of the filter or strainer, unless adequate strength margins under all loading conditions are provided in the lines and connections.

(~~6~~7) Each filter or strainer requiring regular servicing should:

— ~~B~~be accessible for draining and cleaning or replacement;~~,~~

— ~~I~~incorporate a screen or element that is easily removable;~~,~~ and

— ~~H~~have a sediment trap and drain except if the filter or strainer is easily removable for drain purposes.

(~~7~~8) Any restriction in ~~by-pass~~bypass operation condition should be specified in the appropriate manuals.

(~~8~~9) CS-E 560(g) is intended to cover any likely changes in settings caused by vibration~~s~~, incorrect maintenance, mechanical interference when installed or during handling, etc. Examples of design precautions are: locking devices, sealing, inaccessible installation.

SUBPART E — TURBINE ENGINES:~~;~~ TYPE SUBSTANTIATION

AMC E 670 is amended as follows:

AMC E 670 Contaminated Fuel Testing

[…]

(3) Transient Fuel Icing Conditions

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

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

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

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

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

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

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

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

AMC E 790(a)(1) is created as follows:

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

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

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

AMC E 790(a)(2) is amended as follows:

AMC E 790(a)(2) Rain and Hail Ingestion — Turbine Engine Power/Thrust Loss and Instability in Extreme Conditions of Rain and Hail

[…]

(5) Compliance Methods

(a) General

An Engine compliance test method consistent with the critical point analysis may include the use of a ground-level static facility with appropriate means of conducting Engine tests with the ingestion of simulated rain and hail at the increased concentrations that are necessary to produce in-flight effects on the concentrations of ingested rain and hail and to compensate for the differences between the critical point conditions and the ground-level test conditions. Other possibilities for demonstrating compliance include wind tunnel testing, direct core water-injection tests, component rig tests, scale model tests, and analyses.

(b) Test Point Selection

The critical hail point(s) and rain point(s) that yield the least operability margin should be demonstrated by Engine ingestion testing. Additional test points should be considered if any of the operability margins are determined to be minimal (i.e. compressor surge and stall, combustor blow-out, fuel control ~~run down~~ rundown, instrumentation sensing errors, etc.).

(c) Critical Point Testing At ~~Ground-Level~~ Ground Level

The applicant may test the Engine at ground-level conditions, provided the relevant Engine operational factors of the critical points are reproduced in a meaningful relationship.

(i) Test Compensation

The applicant should compensate for differences between the critical point conditions and the test facility conditions. These differences may include:

(A) Air ~~D~~density

The critical point percentage of rain and hail concentration by weight should be reproduced during the test. For example, 20 g/m^3~~3~~ of rain at 20 000 feet is approximately 3 ~~percent~~ per cent water by weight. At sea level, this percentage of water requires nearly 40 g/m^3~~3~~ to compensate for the higher air density (~~R~~refer to Figure A1 in Appendix A of CS-E).

(B) Atmospheric parameters

In respect of air temperature and other atmospheric parameters, the appropriate ISA data may be assumed when adjusting concentrations of rain and hail.

(C) Scoop factor

The appropriate rain and hail concentration amplification due to the scoop factor effect should be applied to further increase the quantities of rain and hail for the ground-level tests. This necessitates having knowledge of the inlet diffusing flow field throughout the Engine ~~p~~Power/~~t~~Thrust range and flight envelope.

(D) Engine rotational speeds

The low rotor speed for the ground-level test should be no greater than the altitude critical point condition. This is particularly important for turbofan Engines since the rotational speed determines the rain and hail centrifuging effects which prevent some of the rain and hail from reaching the Engine core. The rain and hail concentrations may be adjusted to compensate for any necessary deviation from critical point rotational speeds.

(E) Variable systems

All variable systems, such as Engine bleeds, whose position can ~~e~~affect the Engine operation in rain and hail, should be set in the position associated with the critical point.

(F) Engine power extraction

It should be shown by analysis or test that sufficient margin exists for the extraction of the representative electrical or shaft power loads and service air bleeds.

(G) Thermodynamic cycle differences

There may be thermodynamic cycle differences between the test point and the critical point which affect the operability of the Engine. There should be compensation for these cycle differences, or it should be shown that these differences provide additional conservatism.

(H) Enthalpy of water

Rain and hail concentrations may be adjusted to ensure that the heat extraction resulting from their ingestion is the same as the critical point. If the ingestion of liquid water droplets is accepted (see paragraph 5(d)~~.4~~ for compliance alternatives) for critical hail point testing, then the water concentration should at least be increased to compensate for the heat of fusion of ice.

(I) Rain droplet break-up

In the ground-level test environment, forces applied to accelerate the simulated rain droplets to flight speed, as well as shear forces between the droplets and the Engine airflow, are apt to break up the droplets. This break-up can result in reduced conservatism due to additional centrifuging by the fan or Propeller and spinner. The concentration of the rain may need to be increased to compensate for the added centrifuging resulting from ground-level testing.

(ii) Engine test facility

The Engine test facility should provide a uniform water droplet or hail spatial distribution within the critical area of a plane within the Engine intake, and that ~~such~~ plane should be~~ing~~ agreed to by the Agency. The facility should also provide proper droplet or particle sizes and proper velocity distributions, unless otherwise justified in accordance with Appendix A to CS-E.

(iii) Instrumentation

Instrumentation and data sampling rates should be sufficient to establish the rain and hail temperatures and concentrations, particle velocities and size distributions, and the Engine response. Primary exhaust water-to-air ratio measurements via gas sampling should be considered. Instrumentation accuracy and repeatability should be demonstrated by suitable means.

(iv) Test procedure

The test procedure should consider the following for operability critical point tests and for the thermal shock (rain only) critical point test:

(A) Stabilise the Engine at the critical point conditions.

(B) Take steady-state data readings before introducing rain or hail.

(C) Start the continuous transient data recording prior to the initiation of rain or hail flow.

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

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

(a) Deliver rain for a minimum of 3 minutes, at the altitude equivalent concentration defined in Figure A1 and Table A1 in Appendix A of CS-E.

(b) Deliver hail for a minimum of 30 seconds, at the altitude equivalent concentration defined in Figure A1 and Table A2 in Appendix A of CS-E.

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

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

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

(a) ~~A~~accelerate the Engine with a ~~one~~1-~~S~~second throttle movement to the rated ~~t~~Take-off ~~p~~Power~~/~~ or ~~t~~Thrust from the minimum rotor speed defined by the critical point analysis; and

(b) ~~S~~stabilise the Engine at 50 % of the rated ~~t~~Take-off ~~p~~Power~~/~~ or ~~t~~Thrust with ingestion, then, with a ~~one~~1-~~S~~second throttle movement, decelerate to the minimum rotor speed defined by the critical point analysis; or

(c) ~~I~~if test conditions or test facility limitations prevent transient testing as defined in (a) and (b) above, the applicant may propose alternative test criteria, provided that such alternative test criteria (and any complementary substantiation) validate~~s~~ that the Engine has sufficient operability margins to account for likely flight operations such as missed approaches (i.e.~~,~~ go-around) and likely throttle movements during descent.

(G) Conduct the thermal shock critical point test by delivering rain for 3 minutes at the critical ~~p~~Power/~~t~~Thrust condition following a normal stabilisation period without water ingestion. The ~~M~~maximum rain ingestion rate should occur within 10 seconds.

(v) Probable factors

It should be demonstrated by test or analysis~~,~~ that the Engine tested in accordance with paragraph (5)(c)(iv) of this AMC would have operated acceptably if it was exposed to other probable factors associated with a rain or hail encounter. These other probable factors would include~~,~~ but are not limited to~~,~~ typical Engine performance losses, installation effects, and typical ~~auto throttle~~autothrottle power excursions.

(vi) Acceptance criteria

Acceptable Engine operation precludes flameout, ~~run down~~rundown, continued or non-recoverable surge or stall, or a loss of acceleration and deceleration capability. A momentary flameout, surge or stall that arrests itself without operational intervention (e.g. without throttle manipulation) is acceptable. If, after test, it is found that damage has occurred, further running or other evidence may be required to show that subsequent Failures resulting from the damage are unlikely to occur before the damage is rectified. Engine performance should be measured before and after the rain and hail ingestion tests to assess steady-state performance changes. Data should be normalised according to the applicant’~~'~~s standard practices, and the evaluation of sustained loss or degradation of power or thrust should encompass the full range of Engine power or thrust.

If compliance with these criteria is depende~~a~~nt upon the functioning of an automatic protection system, such as continuous ignition, auto-relight, surge recovery system, then the availability of this system is considered ~~as~~ to be critical for dispatch.

(A) Sustained power or thrust loss

The sustained power or thrust loss as a result of a shift or error in measured thrust or power against the primary thrust or power set parameter(s) following the ingestion test~~,~~ should be limited to 3 per cent. Measured post-ingestion power or thrust losses greater than 3 ~~%~~ per cent at any value of the primary setting parameter~~,~~ can only be accepted when supported by appropriate assessments of aircraft performance.

(B) Power or thrust degradation

A change ~~of~~ in the Engine corrected thrust or power of up to 10 ~~percent~~ per cent from rated or pre-test levels when using the applicant’~~'~~s normal performance parameters (i.e.~~,~~ Exhaust Gas Temperature, High Rotor Speed, etc.), excluding the primary thrust or power setting parameter, is acceptable provided the criterion for sustained power or thrust loss is met.

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

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

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

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

(d) Other Compliance Alternatives

Analysis may be used in lieu of, or in combination with, Engine testing to demonstrate compliance with the specifications. The analytical methods used should have a sufficient validation basis to justify the accuracy of the predictions or be shown to yield conservative results. The amount of validation (i.e. Engine test, rig test, experimental test, etc.) should be proportional to the complexity of the analytical methods used and to the criticality of the particular calculation to the prediction of Engine operability.

<u>AMC E 800 is amended as follows:</u>

AMC E 800 Bird Strike and Ingestion

(1) Ingestion ~~T~~tests

(a) Single large ~~B~~bird

(i) The applicant is required to provide an analysis substantiating the definition of the ~~“~~‘most critical exposed location’~~”~~ (CS-E 800(b)(1)(iii)). Determination of this location should include evidence where necessary on:

— ~~T~~the effect of the bird strike on rotating components (excluding any spinner);~~.~~

— ~~T~~the compressor casing strength;~~.~~

— ~~T~~the possibility of multiple blade Failures;

— ~~T~~the strength of the Engine structure and main shafts relative to the unbalance and the excess torque that are likely to occur.

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

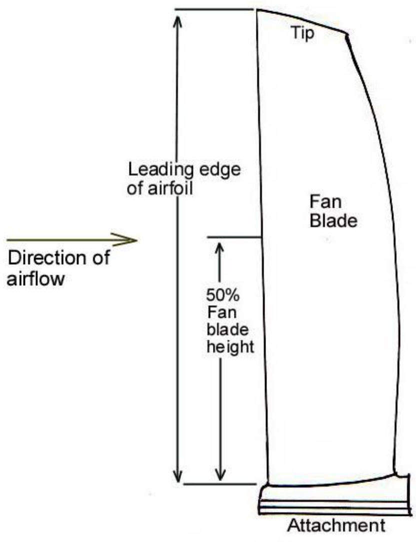
(iii) The complete loss of power or thrust is acceptable after the ingestion of the single large bird.

(b) Large ~~F~~flocking ~~B~~bird

The following advisory material applies to the test ~~of~~ required by CS-E 800(c):~~.~~

(i) The minimum first stage rotor rotational speed (N1) at which the Engine should be stabilised before ingestion should be determined from the Engine performance data. The term ‘Rated Take-Off Thrust’ means the maximum take-off thrust produced at sea-level static conditions on an ISA standard day.

(ii) The applicant should select a target on the first exposed rotating stage(s) of the Engine (e.g. the fan) at a blade span height of 50 %, or further outboard, as required by CS-E 800(c)(1)(iv) (see the figure below). The specified target location is at the discretion of the applicant.



The use of 'stage(s)' is intended to allow for alternative designs such as rear-mounted fans, for which ~~where~~ each exposed stage will be evaluated independently.

(iii) When setting the thrust between the steps of the 20-minute~~s~~ run-on period, momentary thrust drops below the specified values may be acceptable as long as the duration does not exceed 3 seconds.

(iv) The ~~e~~Engine is required to continue to run for 20 minutes and produce no less than 50 % of the Rated Take-off Thrust for the initial 14 minutes. During the first minute, the thrust lever is not to be manipulated. During step 2, the thrust lever may be manipulated at the discretion of the applicant to seek a power setting where the engine can continue to operate, for example to minimise ~~exceedences~~ exceedances and/or vibration, provided that at least 50 % of the Rated Take-off Thrust is maintained. However, a momentary thrust drop below this value may be acceptable as long as the duration does not exceed 3 seconds.

(v) Following the initial 14 minutes, the thrust is reduced, and a maximum of 30 seconds is allowed for the applicant to manipulate the thrust lever to find the specified thrust~~ specified~~. This is to allow for potential damage to the Engine, which might require careful throttle management.

(vi) The components referred to in CS-E 800~~(f)~~(g)(3)(ii)(A) include, for example, fan blades and their retention/spacer components, fan outlet guide vanes, spinners, fan disks and shafts, fan cases, frames, main bearings and bearing supports, including frangible bearing assemblies or devices. The intent is that a ~~sub-assembly~~ subassembly test should adequately represent the mechanical aspects of a type-design Engine during the large flocking bird ingestion.

(vii) The dynamic effects (and related operability concerns) referred to in CS-E 800~~(f)~~(g)(3)(ii)(C) include~~,~~ but are not limited to~~,~~ surge and stall, flameout, limit ~~exceedences~~ exceedances, and any other considerations relative to the ability of the type-design ~~engine's ability~~ Engine to comply with the specifications of CS-E 800(c).

(c) Medium and small flocking birds

(i) The Engine test of CS-E 800(d) will demonstrate that the Engine will produce the required power or thrust, while ~~keeping~~ maintaining acceptable handling characteristics during a 20-minute run-on simulating a return to the airport after the ingestion of medium or small flocking birds at take-off. This will consequently demonstrate compliance with CS-E 540(b).

(ii) The applicant will identify under CS-E 800(d)(1)(ii) all the critical locations and those which have to be used during the small or medium bird engine ingestion tests, and appropriately consider the potential effects of the assumed aircraft installations~~ in aircraft~~. The spinner and the other parts of the front of the ~~e~~Engine may be evaluated separately under CS-E 800~~(e)~~(f).

(iii) In the tests performed under paragraph CS-E 800(d), the Engine is required to produce at least 75 % of the test conditions power or thrust after the ingestion of either small ~~and~~ or medium birds. Nevertheless, a momentary power/thrust drop below this value is acceptable, but its duration should not exceed 3 seconds after the ingestion.

(iv) ~~Exceedences~~Exceedances of Engine operating limitations associated with Take-off conditions should not occur during the first 2 minutes following the ingestion of the birds in the 20-minute run-on test. If an ~~exceedence~~exceedance of limits occurs during these 2 minutes, except during the first 3 seconds of the test, this should be considered when complying with CS-E 700. After these initial 2 minutes without any power lever movement, it is permitted to control ~~exceedences~~exceedances, if any. Any intervention to~~for~~ control~~ling~~ ~~exceedences~~exceedances should be recorded, and suitable instructions should be provided in the instructions for the installation of the Engine. After any such power lever adjustment, the Engine should still produce the required power or thrust for the test. In CS-E 800(d)(1)(iii) and (iv), a movement of the power lever means an action on the means which provides a power or thrust setting for the Engine control. This can be a mechanical device in the test facility control room, or an electronic signal sent to the Engine Control System.

(d) Core Engine flocking bird ingestion test

(i) Determining climb rotor speeds

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

— determine the Engine rotor speeds that provide the thrust that is required, at an altitude of 3 000 ft (above ground level) to climb through that altitude, in International Standard Atmosphere (ISA) standard day conditions at 250 knots indicated airspeed (IAS);

- include the rotor speeds that were assumed in the instructions for installation as required by CS E 20(d);
- establish the associated minimum mechanical fan rotor speed for this condition using Engine performance simulations;
- the fan speed chosen should be associated with the lowest rated thrust Engine model offered for that aircraft installation; if multiple climb settings are available for an intended aircraft, then the lowest climb setting should be used to determine the core ingestion rotor speed targets.

(ii) Climb rotor speed considerations

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

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

(iii) Target selection and timing

- The bird should be targeted at the Engine in order to maximise the amount of bird material that enters the core for the given test condition. This will ensure that the core ingestion test properly challenges the core during an Engine demonstration.
- The optimum target location varies with the Engine design. The span-wise location will depend on the geometric features of the front of the Engine.
- The core bird target location should be determined so that it maximises the amount of core ingested bird material for the core ingestion test by:
  - analysis based on component testing;

- dynamic simulation verified by test; or
- experience with similar designs.

(iv) Engine operation

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

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

(v) Run-on sequence requirements

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

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

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

(vi) Core ingestion prediction analyses

— Some Engine configurations may include features that reject all bird material from the core intake at the take-off and climb conditions specified in CS-E 800(d) and (e)(1). Such Engines would be:
- exempt from the recommended climb ingestion criteria;
- subject only to the approach core ingestion test; and
- required to demonstrate 100 % bird rejection capability by analysis or similarity.

— Any analyses used to predict core ingestion will need to be validated using data that may be derived from:
- rig testing;
- Engine testing; or
- field experience.

— If the standard CS-E 800(d) MFB core demonstration results in any amount of bird material being found in the core, including a single feather or tissue fluorescence under ultraviolet light illumination, then:
- the prediction of zero core ingestion under the climb conditions of CS-E 800(e)(1) will be considered to be invalid; and
- the core ingestion capability in the climb condition should be demonstrated.

(2) Test facility related conditions

(a) The test facility should be appropriately calibrated to ensure that those controlling parameters defined by the analysis of the critical conditions which cannot be accurately controlled (e.g. the bird speed, aiming locations) are within an acceptable tolerance. This tolerance band should be derived from an analysis of the sensitivity of the critical impact parameter (CIP) to variations in the controlling parameters.

The ~~“~~‘critical impact parameter (CIP)’~~”~~ is defined as a parameter that is used to characterise the state of stress, strain, deflection, twist, or other condition which will result in the maximum impact damage to the Engine for the prescribed bird ingestion condition.

The CIP~~critical impact parameter~~ is generally a function of such things as the bird mass, bird velocity, fan/rotor speed, impact location, and fan/rotor blade geometry. The state of maximum impact damage to the Engine is relative to the ability to meet the criteria of CS-E 800. The CIP for most modern turbofan ~~e~~Engines is the fan blade leading edge stress, although other features or parameters may be more critical as a function of the operating conditions or the basic design. For turboprop and turbojet ~~e~~Engines, a core feature will most likely be the critical consideration. Regardless of the Engine design, the most limiting parameter should be identified and understood prior to any demonstration, as any unplanned variations in controlling test parameters will be evaluated for their effect on the CIP and CS-E 800 specifications.

For turbofan first stage fan blades, increasing the bird velocity or bird mass will increase the slice mass, and could shift the CIP from the leading edge stress to the blade root stress. For fan blades with part span shrouds, it may be the blade deflection that produces shroud shingling and either a thrust loss or a blade fracture that could be the limiting event. For unshrouded wide chord fan blades, it may be the twist of the blade in the dovetail that allows it to impact the trailing blade, resulting in trailing blade damage.

For certification tests, the CIP variation should not be greater than 10 % as a function of any deviation in the controlling parameters of the test ~~controlling parameters~~.

(b) The installation and especially the gun arrangement in some test facilities can induce air distortion in the Engine inlet, which can artificially reduce~~ing artificially~~ the stability margins of the Engine. This should be identified prior to the test.

(c) Power or thrust should be measured by a means which can be shown to be accurate throughout the test to enable the power or thrust to be set without undue delay and maintained to within ± 3 percentage points of the specified levels. For the test of CS-E 800(d), if, after the first 2 minutes, operation at the specified power or thrust levels would result in a sustained high vibratory condition, the power or thrust may be varied within the ± 3 % band. Alternative load devices of some test facilities may be unable to control the power level tolerance band to the desired level. This should be identified and approved prior to the test. Any ~~exceedence~~exceedance of this ± 3 % band should be justified in relation to the objectives of CS-E 540(b) or CS-E 800(d).

(d) If turboprop or turboshaft ~~e~~Engines are tested using an alternative load device which could induce different Engine response characteristics than when the

Engine is coupled with a propeller or installed in the aircraft, the interface with the test facility and aircraft or propeller systems should be monitored during the test and should be used ~~for~~ to determine~~ing~~ how the Engine would respond in a representative installation, and ~~for~~ to ensure~~ing~~ that the Engine would then comply with the specifications.

(e) Input and output data across the Engine interfaces with the aircraft systems should be provided by the Engine manufacturer in the instructions for installation regarding the expected interaction of the Engine with these systems during ingestion events. Of particular interest would be dynamic interactions such as auto surge recovery, and propeller autofeather.

(3) Impact

(a) The front of the Engine is defined as any part of the Engine which can be struck by a bird. This includes but is not limited to components such as~~, but not limited to,~~ a nose cone/spinner on the fan or compressor rotor, an Engine inlet guide vane assembly including the centrebody, any protection device, or inlet-mounted components.

(b) Ingestion is defined as the passage of a bird into the rotating blades.

(c) The term ~~"~~'first stage rotor blades'~~"~~ when used in CS-E 800 includes the first stage of any fan or compressor rotor which is susceptible to a bird strike or bird ingestion. These first stage rotor blades are considered to be part of the front of the Engine. This definition encompasses ducted, unducted and aft fan designs. ~~In this latter case~~ For aft fan designs, blades on two different rotors (in the primary and secondary flows) would probably need to be considered.

(4) General

(a) The Engine configuration for the test should comply with CS-E 140. The normal functioning of automatic systems that do not require~~ing~~ pilot intervention is acceptable provided that the dispatch criticality is addressed in the appropriate documentation. Systems which are not part of the Engine, such as a propeller autofeather system, should be disabled. Any OEI ratings do not have to be taken into account for compliance with CS-E 800(d).

(b) The minimum Engine referred to in CS-E 800(b)(1)(i) or (d)(1)(i) is defined as a new Engine that exhibits the type design's most limiting operating parameters with respect to the bird ingestion conditions prescribed by CS-E 800. These operating parameters include~~,~~ but are not limited to~~,~~ the power or thrust, turbine temperature and rotor speed(s).

(c) CS-E 800~~(f)~~(g)(1) is intended to allow the certification of design changes or derivative ~~e~~Engines without conducting a full ~~e~~Engine test. It is not intended, considering the present state of the art, to be used for the certification of new ~~e~~Engines. However, it offers the possibility of future advancement. Any parametric analysis used to substantiate derivative ~~e~~Engines as allowed under CS-E 800~~(f)~~(g)(1) should fall within a 10 % variation in the CIP ~~critical impact parameter~~ that was used to substantiate the original base ~~e~~Engine. The CIP~~critical~~

~~impact parameter~~(s) is (are) often associated with the impact load at the point of bird and rotor blade contact. This is generally a function of the bird speed, rotor speed, and blade twist angle. This 10 % variation ~~on~~ in the CIP~~critical impact parameter~~ should not be assumed to be a direct tolerance on the applicant's proposed changes to the take-off power or thrust ratings themselves.

(d) Any analytical means used in place of a test demonstration (where analysis is permitted) should be validated by evidence that is based on representative tests, and should have demonstrated its capability to predict ~~e~~Engine test results.

(e) When reference is made to an 'exposed location', this should be understood to be any part of the ~~e~~Engine which is not shielded.

(f) When the CS-E 810 test is proposed as an alternative to the single large bird test (see CS-E 800~~(f)~~(g)(2)), the demonstration should include consideration of unbalance, as well as effects of the axial loading from the bird strike on bearings or other structures.

(g) Artificial birds may be used in the tests if they are internationally standardised and are acceptable to the Agency.

AMC E 810 is amended as follows:

AMC E 810 Compressor and Turbine Blade Failure

(1) General

(a) Compliance with the specifications of CS-E 810(a) may be shown in accordance with either (i), (ii) or (iii):

(i) ~~B~~by compliance with the tests detailed in (2) and (3);~~,~~

(ii) ~~B~~by presentation of adequate evidence that substantiat~~ing~~es the strength of the Engine either by blade Failure experience with~~on~~ Engines agreed by the Agency to be of comparable size, design and construction, or by blade Failures which have occurred during the development of the Engine, provided that the conditions of Engine speed, ~~shut down~~ shutdown period, etc., are sufficiently representative;~~,~~

(iii) ~~B~~by other evidence acceptable to the Agency.

(b) Tests for containment are detailed in (2), and those for running following blade Failure are detailed in (3), but where the most critical blade from the point of view of blade containment is the same as that for the subsequent out-of-balance running, it is acceptable to combine the tests of (2) and (3).

(2) Containment

(a) General. Containment tests should be made, either:

(i) ~~O~~on the complete Engine;~~,~~ or

(ii) ~~O~~on the individual stage concerned with the adjacent stators, where:

(A) ~~T~~the actual strength of casing under the anticipated operation conditions (e.g. temperature and pressure) is taken into account;~~,~~ and

(B) ~~A~~adequate evidence is available such as to indicate that the aircraft would not be endangered by the effect of the blade Failure on subsequent blade rows.

(b) Test Conditions. Separate tests on each compressor and turbine stage adjudged to be most critical from the point of view of blade containment (account being taken of blade size, material, radius of rotation, Rotational Speed and the relative strength of the adjacent Engine casing under operating temperature and pressure conditions) should be carried out in accordance with the conditions of (i) and (ii).

NOTE: Where the Engine design is such that potentially Engine Critical Parts overlie the compressor or turbine casing (e.g. ~~by-pass~~bypass Engines, or reverse flow Engines where the combustion systems may be outside the rotors), consideration should also be given to possible hazardous internal damage caused by blades penetrating the rotor casings, even though they are contained within the external geometry of the Engine. Consideration should also be given to AMC E 520(c)(1) paragraph (2).

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

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

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

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

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

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

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

(A) ~~T~~the maximum rotational speed to be approved (other than Maximum Engine Over-speed) and the associated maximum casing temperature;~~,~~ or

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

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

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

(i) ~~C~~containment by the Engine without causing significant rupture or hazardous distortion of the Engine outer casing or the expulsion of blades through the Engine casing or shield;~~.~~

NOTE: ~~Should~~If debris ~~be~~ is ejected from the Engine intake or exhaust, the approximate size and weight of the debris should be reported with an estimate of its trajectory and velocity, so that the effect upon the aircraft can be assessed.

(ii) ~~N~~no hazard to the aircraft from possible internal damage to the Engine as a result of blades penetrating the rotor casings, even though they are contained within the external geometry of the Engine.

(3) Running Following a Blade Failure

(a) The tests should be conducted on a complete Engine, mounted in such a manner that the reactions induced by the out-of-balance on the Engine carcass and mounts will be representative of those which would occur in the installed condition. Alternatively, tests may be carried out on a rig but consideration should be given to the effects of shaft power input, further subsequent~~ial~~ damage, heavy out-of-balance forces on other parts of the Engine, possible shaft Failure, etc., when interpreting the test results as being indicative that no hazardous damage would occur in a complete Engine.

(b) Test Conditions. Separate tests should be carried out on each compressor and turbine stage that is adjudged to be most critical from the point of view of Engine damage subsequent to a blade Failure as a result of out-of-balance forces that exist~~ing~~ during the period prior to the Engine shutdown.

(i) The Engine should be run, with an out-of-balance that is representative of the loss of a blade from the top of the retention member, at the maximum rotational speed to be approved (other than the Maximum Engine Over-speed) until either the Engine stops of its own accord, or a period of at least 15 seconds has elapsed.

(ii) During the run, the power setting should not be altered.

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

<u>AMC E 840 is amended as follows:</u>

AMC E 840 Rotor ~~i~~Integrity

(1) Definitions

The following terms are defined for the purposes of interpreting CS-E 840 and this AMC.

Rotor:	Individual stage of a fan, compressor or turbine assembly (some assemblies may consist of only one stage).

Sample ~~R~~rotor: A test article or assembly including, where appropriate, cover plates, spacers, etc., that is representative of the standard to be certified and for which the material properties and dimensions are known.

Maximum permissible rotor speed associated with a rating: ~~t~~The maximum of all approved speeds, including transients, for the relevant rating. ~~When applicable, this includes the Maximum Engine Over-speed which is an approved 20-second transient.~~

[…]

AMC E 850 is amended as follows:

AMC E 850 Compressor, Fan and Turbine Shafts

(1) General

(a) A shaft is the system that transmits torque between the disc driving flange or the shaft attachment member of the system that produces power (e.g. turbine) and the system that uses this power (e.g. compressor/fan or driving flange), and for which the mechanical restraints are mainly torsional. This includes any Engine gearbox in that transmission system (for any aircraft gearbox, see paragraph (2)(~~b~~c) below). The exclusion of discs ~~in~~ from this definition of a shaft does not preclude the specification that any Failure thereof should be Extremely Remote.

(b) Clarification of the terms and probabilities used in CS-E 850 may be found in CS-E 510. The possible shedding of blades is also covered in CS-E 810(b).

(2) Non-Hazardous Shaft Failures

(a) Where it is claimed that Hazardous Engine Effects are avoided by ensuring that rotating components are retained substantially in their normal plane of rotation and the control of over-speed is by means of:

— ~~D~~disc rubbing;

— ~~B~~blade interference, spragging or shedding;

— Engine surge or stall;

— ~~O~~over-speed protection devices~~;~~,

this may be substantiated by either test or validated analysis. ~~This analysis should be based upon relevant service or test experience.~~

(b) If an applicant elects to demonstrate by test that the consequences of a shaft Failure are non-hazardous, then the test should be performed by initiating the shaft Failure under the worst-case operating conditions within the flight envelope, in any dispatchable configuration, that will maximise the rotor over-speed and the subsequent effects. If it is impractical to fully duplicate the worst-case conditions, an applicant may propose a test under suitably representative conditions to account for the worst case. Those test conditions would need to be submitted to the Agency for acceptance. In addition to the initial rotor speed, other aspects should also be taken into consideration, such as the shaft torque and the relevant

Engine pressures and temperatures. Failures that are predicted to occur with a probability of Extremely Remote or less do not need to be taken into account if they meet all the requirements of CS-E 850(b)(2).

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

(c) If an applicant elects to demonstrate by validated analysis that the consequences of a shaft Failure are non-hazardous ~~To substantiate compliance by analysis~~, it should be shown that all the likely Failure modes have been identified in the analysis (including the loss of loads caused by a Failure of any gearboxes supplied by the aircraft manufacturer). The Failure analysis should take into consideration the effect of Failures in terms of contact and the loads on the surrounding structure of the Engine, and determine whether the affected rotor components are retained substantially in their rotational plane. It ~~w~~should also demonstrate that the structural components, when the loads resulting from the Failure are applied, do not exceed their ultimate stress capability and do not lead to a Hazardous Engine Effect.

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

(3) Hazardous Shaft Failures

In general, experience has shown that Failures of shafts occur at a rate in excess of Extremely Remote. Consequently, shaft systems should be designed to fail safe as required by CS-E 850(a)(1). However, it is accepted under CS-E 850(a)(3) that, for conventional designs, this is not possible for all parts of a shaft system, but the use of this provision should be strictly limited.

Two possible hazardous effects of a shaft Failure should be particularly considered: a release of the complete fan or compressor moving forward and an over-speed of the turbine leading to disc burst.

Industry experience with~~of~~ shaft Failures should be considered under CS-E 850(b)(2)(v). In particular, the following Failure modes have all led to shaft Failures in service:

— Degradation of a bearing, leading to shaft orbiting and subsequent contact between the shaft and other rotating or static parts;

— Blade Failure, resulting in an imbalance and rubbing of the shaft on other parts;

— Corrosion inside the shaft;

— Fuel flow instability in the Engine Control System inducing a resonance in the shaft;

— An ~~O~~oil fire around the shaft;

— Impingement of hot air on the shaft;

— A ~~B~~bearing Failure;

— An HCF Failure from a stress concentration feature;

— A ~~L~~loss of lubrication of a spline.

Further, features such as splines, oil feed holes, couplings, bearing tracks that are integral with the shaft and sealing fins should be shown to be well understood and conducive to well-established and validated stressing techniques.

When the assessment for compliance with CS-E 850(b)(2)(iii) is that a shaft Failure due to the environment can be discounted, the ability to inspect the critical section of a shaft at the defined intervals and the appropriateness of the inspection method should be taken into account. For example, the Failure of a section of a shaft, which could cause Hazardous Engine Effects, in an area which would make inspection of the critical section in accordance with the manual difficult, may not be acceptable.

(4) Design Assessment

(a) The following aspects should be included when assessing the causes and probabilities of a shaft Failure:

(i) The potential for, and possible effects of, undetected material defects;

(ii) The effects of manufacturing tolerances allowed by the design;

(iii) Rubbing between any torque-loaded section of the shaft and adjacent surfaces (e.g. other shafts, oil seals, air seals) to the extent that significant over-heating or reduction in strength could occur;

(iv) The effect on the shaft of a bearing Failure and the desirability of provision (e.g. by maintenance techniques and/or flight instrumentation) for the detection of an incipient bearing Failure. The possibility of isolating the bearing from the shaft and thus increasing the damage tolerance of the system should be considered;

(v) The effect on the shaft of any likely Engine fire and the necessity for provision of an early warning of any internal fires that may occur;

(vi) The effect on the shaft of loads which could be transmitted by shock loading resulting from bird strikes, blade Failures, etc.;

(vii) The effect on the shaft of oscillatory loading, for example, resulting from fuel system oscillations.

(b) The shaft system should be subjected to the following investigations and/or testing to support the design assessment and the compliance with the objectives of CS-E 850(a):

(i) Strain gauge or other suitable means of investigation in order to satisfy the vibration survey specifications of CS-E 650 and to ensure that shaft whirling is not present to any significant degree at any likely Engine operating condition.

(ii) Fatigue evaluation of each shaft in torsional modes, in order to confirm its predicted safe life. An oscillatory torque of a magnitude equal to the maximum envisaged in a representative installation, but not less than ± 5 % of the normal maximum steady-state torque, should be superimposed on that steady-state torque. In addition, consideration should also be given to any high-frequency vibrations determined from paragraph (4)(b)(i) above and any possible shaft bending.

(iii) Where necessary, confirmation of stress assumptions by static strength tests.

(iv) Where necessary, substantiation by test of the design considerations detailed in paragraph (4)(a) above such as to demonstrate that shaft Failure is acceptably remote.

AMC E 890 is amended as follows:

AMC E 890 Thrust ~~r~~Reverser ~~t~~Tests

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

In cases where the Engine test of CS-E 740 cannot be run with the standard thrust reverser, for example because it is not available despite the applicant's efforts to obtain it, it is acceptable that a suitably representative test ~~"boiler plate~~ reverser~~"~~ is fitted for the endurance test.

This addresses only the passive effects of the thrust reverser: cantilevered weight, the effect on vibrations and the loading of the Engine carcass, etc. Other evidence will be necessary to address the effects of the thrust reverser when functioning.

It is also acceptable to use other Engine tests performed with a representative thrust reverser, such as cyclic tests performed for the ETOPS approval of the aircraft.

[…]

AMC E 910 is created as follows:

AMC E 910 Relighting In Flight

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

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

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

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

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

(b) Rotor-lock

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

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