3. *General.* The objective of a premium casting process is to consistently produce castings with high quality and reliability. To this end, the casting process is one that is capable of consistently producing castings that include the following characteristics:

— Good dimensional tolerance

— Minimal distortion

— Good surface finish

— No cracks

— No cold shuts

— No laps

— Minimal shrinkage cavities

— No harmful entrapped oxide films

— Minimal porosity

— A high level of metallurgical cleanness

— Good microstructural characteristics

— Minimal residual internal stress

— Consistent mechanical properties

The majority of these characteristics can be detected, evaluated, and quantified by standard non-destructive testing methods, or from destructive methods on prolongation or casting cut-up tests. However, a number of them cannot. Thus, to ensure an acceptable quality of product, the significant and critical process variables must be identified and adequately controlled.

4. *A Means of Qualification of Casting Process.*

4.1 To prove a premium casting process, it should be submitted to a qualification program that is specific to a foundry/material combination. The qualification program should establish the following:

(a) The capability of the casting process of producing a consistent quality of product for the specific material grade selected for the intended production component.

(b) The mechanical properties for the material produced by the process have population coefficients of variation equivalent to that of wrought products of similar composition (i.e., plate, extrusions, and bar). Usage of the population coefficient of variation from forged products does not apply. In most cases, the coefficients of variation for tensile ultimate strength and tensile yield strength less than or equal to 3.5% and 4.0% respectively is adequate to demonstrate this equivalency of mechanical properties.

(c) The casting process is capable of producing a casting with uniform properties throughout the casting or, if not uniform, with a distribution of material properties that can be predicted to an acceptable level of accuracy.

(d) The (initial) material design data for the specified material are established.

(e) The material and process specifications are clearly defined.

4.2 For each material specification, a series of test castings from a number of melts, using the appropriate production procedures of the foundry, should be manufactured. The test casting produced should undergo a standardised inspection or investigation of non-destructive inspection and cut-up testing, to determine the consistency of the casting process.

4.3 The test casting should be representative of the intended cast product(s) with regard to section thicknesses and complexity, and should expose any limitations of the casting process. In addition, the test casting should be large enough to provide mechanical test specimens from various areas, for tensile and, if applicable, compression, shear, bearing, fatigue, fracture toughness, and crack propagation tests. If the production component complies with these requirements, it may be used to qualify the process. The number of melts sampled should be statistically significant. Typically, at least 10 melts are sampled, with no more than 10 castings produced from each melt. If the material specification requires the components to be heat-treated, this should be done in no fewer than 10 heat treatment batches consisting of castings from more than one melt. Reduction of qualification tests may be considered if the casting process and the casting alloy is already well known for aerospace applications and the relevant data are available.

4.4 Each test casting should receive a non-destructive inspection program which should include as a minimum:

— inspection of 100% of its surface, using visual and liquid penetrant, or equivalent, inspection methods; and

— inspection of structurally significant internal areas and areas where defects are likely to occur, using radiographic methods or equivalent inspection methods. The specific radiographic standard to be employed is to be determined, and the margin by which the test castings exceed the minimum required standard should be recorded.

4.4.1 The program of inspection is intended to:

(a) confirm that the casting process is capable of producing a consistent quality of product, and

(b) verify compliance with the stated objectives of a premium casting process with regard to surface finish, cracks, cold shuts, laps, shrinkage cavities, and porosity, (see paragraph 3), and

(c) ensure that the areas from which the mechanical property test samples were taken were typical of the casting as a whole with respect to porosity and cleanness.

4.4.2 Guidance on non-destructive inspection techniques and methods can be obtained from national and international standards. The standard listing below is not a comprehensive list but is given as an initial reference guide.

ASTM A802 Standard practice for steel castings, surface acceptance standards, visual examination.

ASTM A903 Standard specification for steel castings, surface acceptance standards, magnetic particle and liquid penetrant inspection.

ASTM E155 Standard Reference Radiographs for Inspection of Aluminum and Magnesium Castings.

ASTM E192 Standard Reference Radiographs for Investment Steel Castings of Aerospace Applications.

ASTM E433 Standard reference photographs for liquid penetrant inspection.

ASTM E1030 Standard test method for radiographic examination of metallic castings.

ASTM E1320 Standard Reference Radiographs for Titanium Castings.

ISO 4986 Steel castings - Magnetic particle inspection

ISO 4987 Steel castings - Penetrant inspection

ISO 4993 Steel castings - Radiographic inspection

ISO 9915 Aluminium alloy castings - Radiography testing

ISO 9916 Aluminium alloy and magnesium alloy castings - Liquid penetrant inspection

ISO 10049 Aluminium alloy castings - Visual method for assessing the porosity

ISO 11971 Visual examination of surface quality of steel castings

The test castings must show that the Foundry/Process combination is capable of producing product free of cracks, laps, and cold shuts. Ideally the test castings should be free of detectable shrinkage cavities and porosity. With regard to dimensional tolerance, distortion, and surface finish guidance for acceptance criteria can be gained from the standards cited above. Consideration that these standards are for general quality castings must be given when they are used.

4.5 All test castings should be cut up to a standardised methodology to produce the mechanical test specimens as detailed by paragraph 4.3 above. Principally, the tests are to establish the variability within the cast component, as well as to determine the variability between components from the same melt and from melt to melt. The data gathered also may be used during latter phases to identify deviations from the limits established in the process qualification and product proving programs.

4.6 All the fracture surfaces generated during the qualification program should be inspected at least visually for detrimental defects. Evidence of inclusions, oxide films, porosity or shrinkage cavities would indicate inadequate control of the casting process.

4.7 As part of the cut-up investigation, it is usually necessary to take metallographic samples for cleanness determination and microstructural characterisation.

4.8 When the process has been qualified, it should not be altered without completing comparability studies and necessary testing of differences.

5. *Proof of Product*

5.1 Subsequent to the qualification of the process, the production castings should be subjected to a production-proving program. Such castings should have at least one prolongation; however, large and/or complex castings may require more than one. If a number of castings are produced from a single mould with a single runner system, they may be treated as one single casting. The production-proving program should establish the following:

(a) The design values developed during the process qualification program are valid (e.g., same statistical distribution) for the production casting.

(b) The production castings have the same or less than the level of internal defects as the test castings produced during qualification.

(c) The cast components have a predictable distribution of tensile properties.

(d) The prolongation(s) is representative of the critical area(s) of the casting.

(e) The prolongation(s) consistently reflects the quality process, and material properties of the casting.

5.2 A number of (i.e., at least two) pre-production castings of each part number to be produced should be selected for testing and inspection. All of the selected castings should be non-destructively inspected in accordance with the qualification program.

(a) One of these castings should be used as a dimensional tolerance test article. The other selected casting(s) should be cut up for mechanical property testing and metallographic inspection.

(b) The casting(s) should be cut up to a standardised program to yield a number of tensile test specimens and metallographic samples. There should be sufficient cut-up tensile specimens to cover all critical ("critical" with respect to both the casting process and service loading) areas of the casting.

(c) All prolongations should be machined to give tensile specimens, and subsequently tested.

(d) The production castings should be produced to production procedures identical to those used for these pre-production castings.

5.3 On initial production, a number of castings should undergo a cut-up for mechanical property testing and metallographic inspection, similar to that performed for the pre-production casting(s). The cut-up procedure used should be standardised, although it may differ from that used for the pre-production casting(s). Tensile specimens should be obtained from the most critical areas.

(a) For the first 30 castings produced, at least 1 casting in 10 should undergo this testing program.

(b) The results from the mechanical property tests should be compared with the results obtained from the prolongations to further substantiate the correlation between prolongation(s) and the critical area(s) of the casting.

(c) In addition, if the distribution of mechanical properties derived from these tests is acceptable, when compared to the property values determined in the qualification program, the frequency of testing may be reduced. However, if the comparison is found not to be acceptable, the test program may require extension.

5.4 At no point in the production should the castings contain shrinkage cavities, cracks, cold shuts, laps, porosity, or entrapped oxide film, or have a poor surface finish, exceeding the acceptance level defined in the technical specifications.

6. *Monitoring the Process.*

6.1 For the product quality techniques should be employed to establish the significant/critical foundry process variables that have an impact on the quality of the product. For the product it should be shown that these variables are controlled with positive corrective action throughout production.

6.2 During production, every casting should be non-destructively inspected using the techniques and the acceptance standards employed during the qualification program.

(a) Rejections should be investigated and process corrections made as necessary.

(b) Alternative techniques may be employed if the equivalence in the acceptance levels can be demonstrated.

(c) In addition, tensile tests should be taken from the prolongations on every component produced, and the results should comply with limits developed in the process qualification and product proving programs.

(d) Additionally, as previously mentioned, a periodic casting cut-up inspection should be undertaken, with the inspection schedule as agreed upon during the proof of product program.

(e) Deviations from the limits established in the process qualification and product proving programs should be investigated and corrective action taken.

7. *Modifications to the Casting Design, Material, and Process.*

7.1 Additional testing may be required when alterations are made to the casting geometry, material, significant/critical process variables, process, or production foundry to verify that the alterations have not significantly changed the castings' properties. The verification testing recommended is detailed in Table 1, below:

Modifications					Verification Testing		
Case	Geometry	Material	Process	Foundry	Qualification of Process	Proof of Product	Tests per CS 25.621(c)(1)
1	**yes**	none	none	none	not necessary	yes	yes (b)
2	none	**yes**	none	none	yes (a)	yes	yes (b)
3	**yes**	yes	none	none	yes	yes	yes
4	none	none	**yes**	None	yes (a)	yes	yes (b)
5	none	none	none	**yes**	yes (a)	yes	yes (b)

(a) The program described in paragraph 4. of this AMC to qualify a new material, process, and foundry combination may not be necessary if the following 3 conditions exist for the new combination:

(1) Sufficient data from relevant castings to show that the process is capable of producing a consistent quality of product, and that the quality is comparable to or better than the old combination.

(2) Sufficient data from relevant castings to establish that the mechanical properties of the castings produced from the new combination have a similar or better statistical distribution than the old combination.

(3) Clearly defined material and process specifications.

(b) The casting may be re-qualified by testing partial static test samples (with larger castings, re-qualification could be undertaken by a static test of the casting's critical region only).

[Amdt 25/1]

CS 25.623 Bearing factors

ED Decision 2003/2/RM

(a) Except as provided in sub-paragraph (b) of this paragraph, each part that has clearance (free fit), and that is subject to pounding or vibration, must have a bearing factor large enough to provide for the effects of normal relative motion.

(b) No bearing factor need be used for a part for which any larger special factor is prescribed.

CS 25.625 Fitting factors

ED Decision 2003/2/RM

For each fitting (a part or terminal used to join one structural member to another), the following apply:

(a) For each fitting whose strength is not proven by limit and ultimate load tests in which actual stress conditions are simulated in the fitting and surrounding structures, a fitting factor of at least 1·15 must be applied to each part of –

(1) The fitting;

(2) The means of attachment; and

(3) The bearing on the joined members.

(b) No fitting factor need be used –

(1) For joints made under approved practices and based on comprehensive test data (such as continuous joints in metal plating, welded joints, and scarf joints in wood); or

(2) With respect to any bearing surface for which a larger special factor is used.

(c) For each integral fitting, the part must be treated as a fitting up to the point at which the section properties become typical of the member.

(d) For each seat, berth, safety belt, and harness, the fitting factor specified in CS 25.785(f)(3) applies.

CS 25.629 Aeroelastic stability requirements

ED Decision 2020/001/R

(See AMC 25.629)

(a) *General*. The aeroelastic stability evaluations required under this paragraph include flutter, divergence, control reversal and any undue loss of stability and control as a result of structural deformation. The aeroelastic evaluation must include whirl modes associated with any propeller or rotating device that contributes significant dynamic forces. Compliance with this paragraph must be shown by analyses, tests, or some combination thereof as found necessary by the Agency.

(b) *Aeroelastic stability envelopes*. The aeroplane must be designed to be free from aeroelastic instability for all configurations and design conditions within the aeroelastic stability envelopes as follows:

(1) For normal conditions without failures, malfunctions, or adverse conditions, all combinations of altitudes and speeds encompassed by the V_D/M_D versus altitude envelope enlarged at all points by an increase of 15 percent in equivalent airspeed at constant Mach number and constant altitude. In addition, a proper margin of stability must exist at all speeds up to V_D/M_D and, there must be no large and rapid reduction in

stability as V_D/M_D is approached. The enlarged envelope may be limited to Mach 1.0 when M_D is less than 1.0 at all design altitudes; and

(2) For the conditions described in CS 25.629(d) below, for all approved altitudes, any airspeed up to the greater airspeed defined by:

(i) The V_D/M_D envelope determined by CS 25.335(b); or,

(ii) An altitude-airspeed envelope defined by a 15 percent increase in equivalent airspeed above V_C at constant altitude, from sea level to the altitude of the intersection of 1.15 V_C with the extension of the constant cruise Mach number line, M_C, then a linear variation in equivalent airspeed to M_C +.05 at the altitude of the lowest V_C/M_C intersection; then, at higher altitudes, up to the maximum flight altitude, the boundary defined by a .05 Mach increase in M_C at constant altitude; and

(iii) Failure conditions of certain systems must be treated in accordance with CS 25.302.

(3) For failure conditions in those systems covered by CS 25.302, the margins defined in Appendix K of CS-25 apply.

(c) *Balance weights*. If balance weights are used, their effectiveness and strength, including supporting structure, must be substantiated.

(d) *Failures, malfunctions, and adverse conditions*. The failures, malfunctions, and adverse conditions which must be considered in showing compliance with this paragraph are:

(1) Any critical fuel loading conditions, not shown to be extremely improbable, which may result from mismanagement of fuel.

(2) Any single failure in any flutter damper or flutter control system.

(3) For aeroplanes not approved for operation in icing conditions, the maximum likely ice accumulation expected as a result of an inadvertent encounter.

(4) Failure of any single element of the structure supporting any engine, independently mounted propeller shaft, large auxiliary power unit, or large externally mounted aerodynamic body (such as an external fuel tank).

(5) For aeroplanes with engines that have propellers or large rotating devices capable of significant dynamic forces, any single failure of the engine structure that would reduce the rigidity of the rotational axis.

(6) The absence of aerodynamic or gyroscopic forces resulting from the most adverse combination of feathered propellers or other rotating devices capable of significant dynamic forces. In addition, the effect of a single feathered propeller or rotating device must be coupled with the failures of sub-paragraphs (d)(4) and (d)(5) of this paragraph.

(7) Any single propeller or rotating device capable of significant dynamic forces rotating at the highest likely overspeed.

(8) Any damage or failure condition, required or selected for investigation by CS 25.571. The single structural failures described in sub-paragraphs (d)(4) and(d)(5) of this paragraph need not be considered in showing compliance with this paragraph if;

(i) The structural element could not fail due to discrete source damage resulting from the conditions described in CS 25.571(e) and CS 25.903(d); and

(ii) A damage tolerance investigation in accordance with CS 25.571(b) shows that the maximum extent of damage assumed for the purpose of residual strength evaluation does not involve complete failure of the structural element.

(9) The following flight control system failure combinations where aeroelastic stability relies on flight control system stiffness and/or damping:

(i) any dual hydraulic system failure;

(ii) any dual electrical system failure; and

(iii) any single failure in combination with any probable hydraulic system or electrical system failure.

(10) Any damage, failure or malfunction, considered under CS 25.631, CS 25.671, CS 25.672, and CS 25.1309.

(11) Any other combination of failures, malfunctions, or adverse conditions not shown to be extremely improbable.

(e) *Flight flutter testing*. Full scale flight flutter tests at speeds up to V_{DF}/M_{DF} must be conducted for new type designs and for modifications to a type design unless the modifications have been shown to have an insignificant effect on the aeroelastic stability. These tests must demonstrate that the aeroplane has a proper margin of damping at all speeds up to V_{DF}/M_{DF}, and that there is no large and rapid reduction in damping as V_{DF}/M_{DF} is approached. If a failure, malfunction, or adverse condition is simulated during flight test in showing compliance with sub-paragraph (d) of' this paragraph, the maximum speed investigated need not exceed V_{FC}/M_{FC} if it is shown, by correlation of the flight test data with other test data or analyses, that the aeroplane is free from any aeroelastic instability at all speeds within the altitude-airspeed envelope described in sub-paragraph (b)(2) of this paragraph.

[Amdt No: 25/1]
[Amdt No: 25/18]
[Amdt No: 25/24]

AMC 25.629 Aeroelastic stability requirements

ED Decision 2020/001/R

1. *General*.

The general requirement for demonstrating freedom from aeroelastic instability is contained in CS 25.629, which also sets forth specific requirements for the investigation of these aeroelastic phenomena for various aeroplane configurations and flight conditions. Additionally, there are other conditions defined by the CS-25 paragraphs listed below to be investigated for aeroelastic stability to assure safe flight. Many of the conditions contained in this AMC pertain only to the current amendment of CS-25. Type design changes to aeroplanes certified to an earlier CS-25 amendment must meet the certification basis established for the modified aeroplane.

Related CS-25 paragraphs:

CS 25.251 - Vibration and buffeting

CS 25.305 - Strength and deformation

CS 25.335 - Design airspeeds

CS 25.343 - Design fuel and oil loads

CS 25.571 - Damage-tolerance and fatigue evaluation of structure

CS 25.629 - Aeroelastic stability requirements

CS 25.631 - Bird strike damage

CS 25.671 - General (Control systems)

CS 25.672 - Stability augmentation and automatic and power operated systems

CS 25.1309 - Equipment, systems and installations

CS 25.1329 - Flight Guidance system

CS 25.1419 - Ice protection

CS 25.1420 – Supercooled large drop icing conditions

2. *Aeroelastic Stability Envelope*

2.1. For nominal conditions without failures, malfunctions, or adverse conditions, freedom from aeroelastic instability is required to be shown for all combinations of airspeed and altitude encompassed by the design dive speed (V_D) and design dive Mach number (M_D) versus altitude envelope enlarged at all points by an increase of 15 percent in equivalent airspeed at both constant Mach number and constant altitude. Figure 1A represents a typical design envelope expanded to the required aeroelastic stability envelope. Note that some required Mach number and airspeed combinations correspond to altitudes below standard sea level.

2.2. The aeroelastic stability envelope may be limited to a maximum Mach number of 1.0 when M_D is less than 1.0 and there is no large and rapid reduction in damping as MD is approached.

2.3. Some configurations and conditions that are required to be investigated by CS 25.629 and other CS-25 regulations consist of failures, malfunctions or adverse conditions. Aeroelastic stability investigations of these conditions need to be carried out only within the design airspeed versus altitude envelope defined by:

(i) the V_D/M_D envelope determined by CS 25.335(b); or,

(ii) an altitude-airspeed envelope defined by a 15 percent increase in equivalent airspeed above V_C at constant altitude, from sea level up to the altitude of the intersection of 1.15 V_C with the extension of the constant cruise Mach number line, M_C, then a linear variation in equivalent airspeed to M_C + 0.05 at the altitude of the lowest V_C/M_C intersection; then at higher altitudes, up to the maximum flight altitude, the boundary defined by a 0.05 Mach increase in M_C at constant altitude.

Figure 1B shows the minimum aeroelastic stability envelope for fail-safe conditions, which is a composite of the highest speed at each altitude from either the V_D envelope or the constructed altitude-airspeed envelope based on the defined V_C and M_C.

Fail-safe design speeds, other than the ones defined above, may be used for certain system failure conditions when specifically authorised by other rules or special conditions prescribed in the certification basis of the aeroplane.

FIGURE 1A. MINIMUM REQUIRED AEROELASTIC STABILITY MARGIN

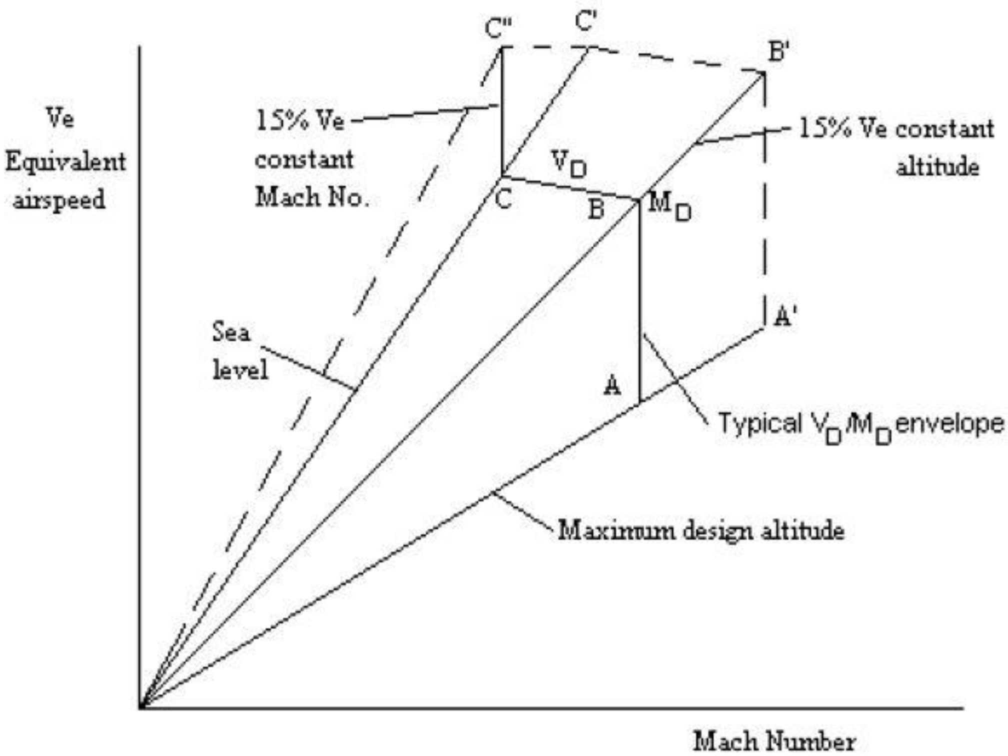

FIGURE 1B MINIMUM FAIL-SAFE CLEARANCE ENVELOPE