— heat-treating, or

— additive manufacturing methods.

Fabrication method process specifications should include all critical inspection steps and/or process controlled steps, and should be substantiated (they may require re-evaluation and new substantiation, if modified later). All the inherent part characteristics that result from the fabrication method and affect the material strength and other properties should be closely correlated with non-destructive inspection (NDI) and/or process control variables. Furthermore, the applicant should show that the equipment used to support the process-critical manufacturing steps (particularly those steps that are not directly supported and controlled through inspection) is under appropriate process control, to ensure the consistent production of safe parts.

Note 1: 'safe parts' must comply with CS 25.603 and CS 25.605 to ensure safety by maintaining the appropriate 'material strength and other properties' that are assumed in the design data. Therefore, applicants are reminded that, beyond the consideration of airframe strength, these CSs are also applicable to other applications for which safety relies on strength or stiffness, e.g. system structures. Furthermore, the reference to 'other properties' is intended to ensure that safety is also maintained for applications for which safety relies on 'other properties' (for example, safe interior cabin parts that rely upon suitable flammability properties).

Note 2: approved fabrication process specifications and approved material specifications can be, for example, industry or military specifications, or European Technical Standard Orders (ETSOs).

[Amdt No: 25/27]

AMC 25.605(b) New fabrication methods — Test programme

ED Decision 2021/015/R

The test programme should initially consider the material strength and other properties resulting from each new fabrication method ('new' means new to the industry, an applicant, or an application configuration). The scope of the test programme should include considering the potential for anisotropic properties unless the applicant has already established an understanding of these properties.

The test programme that is required for the certification of new fabrication methods should be used to evaluate the critical process variables. Based on that evaluation, the applicant should establish in the fabrication specifications the relevant parameters that govern the final material strength and other properties of the part at the time of its production and throughout its operational life. Furthermore, the applicant should evaluate the sensitivity of the material strength and other properties to the critical process variables to ensure that the established parameters are both robust and practical.

Note: the test programme may also be used to help applicants understand the defect types and damage modes to be considered when showing compliance with other specifications, e.g. CS 25.571. Understanding the potential defects and damage modes is particularly important for sensitive fabrication processes, e.g. those used for structural bonding.

[Amdt No: 25/27]

CS 25.607 Fasteners

ED Decision 2003/2/RM

(See AMC 25.607)

(a) Each removable bolt, screw, nut, pin or other removable fastener must incorporate two separate locking devices if –

(1) Its loss could preclude continued flight and landing within the design limitations of the aeroplane using normal pilot skill and strength; or

(2) Its loss could result in reduction in pitch, roll or yaw control capability or response below that required by Subpart B of this CS-25.

(b) The fasteners specified in sub-paragraph (a) of this paragraph and their locking devices may not be adversely affected by the environmental conditions associated with the particular installation.

(c) No self-locking nut may be used on any bolt subject to rotation in operation unless a non-friction locking device is used in addition to the self-locking device.

AMC 25.607 Fasteners

ED Decision 2003/2/RM

FAA Advisory Circular AC 20-71 Dual Locking Devices on Fasteners, date 12-8-70, is accepted by the Agency as providing acceptable means of compliance with CS 25.607.

CS 25.609 Protection of structure

ED Decision 2016/010/R

(See AMC 25.609)

Each part of the structure must-

(a) Be suitably protected against deterioration or loss of strength in service due to any cause, including –

(1) Weathering;

(2) Corrosion; and

(3) Abrasion; and

(b) Have provisions for ventilation and drainage where necessary for protection.

[Amdt 25/18]

AMC 25.609 Protection of structure

ED Decision 2003/2/RM

The comprehensive and detailed material standards accepted in the member states will be accepted as satisfying the requirement of CS 25.609.

CS 25.611 Accessibility provisions

ED Decision 2008/006/R

(a) Means must be provided to allow inspection (including inspection of principal structural elements and control systems), replacement of parts normally requiring replacement,

adjustment, and lubrication as necessary for continued airworthiness. The inspection means for each item must be practicable for the inspection interval for the item. Non-destructive inspection aids may be used to inspect structural elements where it is impracticable to provide means for direct visual inspection if it is shown that the inspection is effective and the inspection procedures are specified in the maintenance manual required by CS 25.1529.

(b) Electrical wiring interconnection systems must meet the accessibility requirements of CS 25.1719.

[Amdt 25/5]

CS 25.613 Material strength properties and Material Design Values

ED Decision 2005/006/R

(See AMC 25.613)

(a) Material strength properties must be based on enough tests of material meeting approved specifications to establish design values on a statistical basis.

(b) Material design values must be chosen to minimise the probability of structural failures due to material variability. Except as provided in sub-paragraphs (e) and (f) of this paragraph, compliance must be shown by selecting material design values which assure material strength with the following probability:

(1) Where applied loads are eventually distributed through a single member within an assembly, the failure of which would result in loss of structural integrity of the component, 99% probability with 95% confidence.

(2) For redundant structure, in which the failure of individual elements would result in applied loads being safely distributed to other load carrying members, 90% probability with 95% confidence.

(c) The effects of environmental conditions, such as temperature and moisture, on material design values used in an essential component or structure must be considered where these effects are significant within the aeroplane operating envelope.

(d) *Reserved*

(e) Greater material design values may be used if a “premium selection” of the material is made in which a specimen of each individual item is tested before use to determine that the actual strength properties of that particular item will equal or exceed those used in design.

(f) Other material design values may be used if approved by the Agency.

[Amdt 25/1]

AMC 25.613 Material strength properties and material design values

ED Decision 2021/015/R

1. *Purpose.* This AMC sets forth an acceptable means, but not the only means, of demonstrating compliance with the provisions of CS-25 related to material strength properties and material design values.

2. *Related Certification Specifications.*

CS 25.571 “Damage-tolerance and fatigue evaluation of structure”

CS 25.603 “Materials”

CS 25.613 "Material strength properties and material design values”

3. *General*. CS 25.613 contains the requirements for material strength properties and material design values. Material properties used for fatigue and damage tolerance analysis are addressed by CS 25.571 and AMC 25.571(a).

When developing the material strength properties and material design values, the applicant should also consider potential anisotropies and establish all properties and design values relevant to the application of the material.

4. *Material Strength Properties and Material Design Values.*

4.1. *Definitions.*

Material strength properties. Material properties that define the strength related characteristics of any given material. Typical examples of material strength properties are: ultimate and yield values for compression, tension, bearing, shear, etc.

Material design values. Material strength properties that have been established based on the requirements of CS 25.613(b) or other means as defined in this AMC. These values are generally statistically determined based on enough data that when used for design, the probability of structural failure due to material variability will be minimised. Typical values for moduli can be used.

Aeroplane operating envelope. The operating limitations defined for the product under Subpart G of CS-25.

4.2. *Statistically Based Design Values*. Design values required by CS 25.613(b) must be based on sufficient testing to assure a high degree of confidence in the values. In all cases, a statistical analysis of the test data must be performed.

The ‘A’ and ‘B’ properties published in the SAE ‘Metallic Materials Properties Development and Standardization (MMPDS) Handbook’ or ESDU 00932 are acceptable, as are the statistical methods specified in the applicable chapters/sections of these handbooks. Other methods of developing material design values may be acceptable to EASA.

The test specimens used for material property certification testing should be made from material produced using production processes. Test specimen design, test methods, and testing should:

(i) conform to universally accepted standards such as those of the American Society for Testing Materials (ASTM), European Aerospace Series Standards (EN),

International Standard Organisation (ISO), or other national standards acceptable to the Agency, or:

(ii) conform to those detailed in the applicable chapters/sections of the SAE MMPDS Handbook, Composite Materials Handbook 17 (CMH-17), ESDU 00932 or other accepted equivalent material data handbooks, or:

(iii) be accomplished in accordance with an approved test plan which includes definition of test specimens and test methods. This provision would be used, for example, when the material design values are to be based on tests that include effects of specific geometry and design features as well as material.

EASA may approve the use of other material test data after review of test specimen design, test methods, and test procedures that were used to generate the data.

The use of some materials and processes may allow the applicant to design parts for which the material strength and other properties are produced during production or repair. Consequently, the use of simple material test coupons (as typically produced, independent of the part) at the base of a typical test pyramid (e.g. as defined in AMC 20-29 for 'composite structures') may not be representative of the material strength and other properties of the final part. When a higher test pyramid is required, then the applicant may need to reduce (for practical reasons) the number of specimens below what is normally expected for generating statistically significant values, e.g. as those associated with A and B basis data (as defined in the MMPDS Handbook). Therefore, other mitigating measures are likely necessary (e.g. coupon testing of prolongations, testing of coupons from sections of production parts, other sampling strategies, more intensive non-destructive inspection (NDIs), etc.). Until industry establishes standards for such situations, the applicant should agree with EASA whether and how to use test articles of a higher test pyramid, as well as associated small datasets, to generate material and design data. In that agreement, EASA may give credit to the applicant for applicable established practices.

4.3. *Consideration of Environmental Conditions*. The material strength properties of a number of materials, such as non-metallic composites and adhesives, can be significantly affected by temperature as well as moisture absorption. For these materials, the effects of temperature and moisture should be accounted for in the determination and use of material design values. This determination should include the extremes of conditions encountered within the aeroplane operating envelope. For example, the maximum temperature of a control surface may include effects of direct and reflected solar radiation, convection and radiation from a black runway surface and the maximum ambient temperature. Environmental conditions other than those mentioned may also have significant effects on material design values for some materials and should be considered.

4.4. *Use of Higher Design Values Based on Premium Selection*. Design values greater than those determined under CS 25.613(b) may be used if a premium selection process is employed in accordance with CS 25.613(e). In that process, individual specimens are tested to determine the actual strength properties of each part to be installed on the aircraft to assure that the strength will not be less than that used for design.

The applicant should have data available to understand if a material is anisotropic and should account for this condition during testing.

If premium selection is to be used, the test procedures and acceptance criteria must be specified on the design drawing.

4.5. *Other Material Design Values*. Previously used material design values, with consideration of the source, service experience and application, may be approved by the Agency on a case by case basis (e.g. "S" values of "The Metallic Materials Properties Development and Standardization (MMPDS) handbook" or ESDU 00932).

4.6. Material Specifications and Processes. Materials should be produced using production specifications and processes accepted by the Agency.]

[Amdt 25/1]
[Amdt 25/27]

CS 25.619 Special factors

ED Decision 2003/2/RM

The factor of safety prescribed in CS 25.303 must be multiplied by the highest pertinent special factor of safety prescribed in CS 25.621 through CS 25.625 for each part of the structure whose strength is –

(a) Uncertain.

(b) Likely to deteriorate in service before normal replacement; or

(c) Subject to appreciable variability because of uncertainties in manufacturing processes or inspection methods.

Where the Agency is not satisfied in a specific case that a special factor is the correct approach to ensuring the necessary integrity of the parts of the structure under service conditions, other appropriate measures must be taken.

CS 25.621 Casting factors

ED Decision 2005/006/R

(see AMC 25.621.)

(a) General. For castings used in structural applications, the factors, tests, and inspections specified in sub-paragraphs (b) through (d) of this paragraph must be applied in addition to those necessary to establish foundry quality control. The inspections must meet accepted specifications. Sub-paragraphs (c) and (d) of this paragraph apply to any structural castings except castings that are pressure tested as parts of hydraulic or other fluid systems and do not support structural loads.

(b) Bearing stresses and surfaces. The casting factors specified in sub-paragraphs (c) and (d) of this paragraph:

(1) Need not exceed 1.25 with respect to bearing stresses regardless of the method of inspection used; and

(2) Need not be used with respect to the bearing surfaces of a part whose bearing factor is larger than the applicable casting factor.

(c) Critical castings. (See AMC 25.621(c)) Each casting whose failure could preclude continued safe flight and landing of the aeroplane or could result in serious injury to occupants is considered a critical casting. Each critical casting must have a factor associated with it for showing compliance with strength and deformation requirements, and must comply with the following criteria associated with that factor:

(1) A casting factor of 1.0 or greater may be used, provided that:

(i) It is demonstrated, in the form of process qualification, proof of product, and process monitoring that, for each casting design and part number, the castings produced by each foundry and process combination have coefficients of variation of the material properties that are equivalent to those of wrought alloy products of similar composition. Process monitoring must include testing of coupons cut from the prolongations of each casting (or each set of castings, if produced from a single pour into a single mould in a runner system) and, on a sampling basis, coupons cut from critical areas of production castings. The acceptance criteria for the process monitoring inspections and tests must be established and included in the process specifications to ensure the properties of the production castings are controlled to within levels used in design.

(ii) Each casting receives:

(A) Inspection of 100 percent of its surface, using visual and liquid penetrant, or equivalent, inspection methods; and

(B) Inspection of structurally significant internal areas and areas where defects are likely to occur, using radiographic, or equivalent, inspection methods.

(iii) One casting undergoes a static test and is shown to meet the strength and deformation requirements of CS 25.305(a) and (b).

(see AMC 25.621(c)(1).)

(2) A casting factor of 1.25 or greater may be used, provided that:

(i) Each casting receives:

(A) Inspection of 100 percent of its surface, using visual and liquid penetrant, or equivalent inspection methods; and

(B) Inspection of structurally significant internal areas and areas where defects are likely to occur, using radiographic, or equivalent, inspection methods.

(ii) Three castings undergo static tests and are shown to meet:

(A) The strength requirements of CS 25.305(b) at an ultimate load corresponding to a casting factor of 1.25; and

(B) The deformation requirements of CS 25.305(a) at a load of 1.15 times the limit load.

(3) A casting factor of 1.50 or greater may be used, provided that:

(i) Each casting receives:

(A) Inspection of 100 percent of its surface, using visual and liquid penetrant, or equivalent, inspection methods; and

(B) Inspection of structurally significant internal areas and areas where defects are likely to occur, using radiographic, or equivalent, inspection methods.

(ii) One casting undergoes a static test and is shown to meet:

(A) The strength requirements of CS 25.305(b) at an ultimate load corresponding to a casting factor of 1.50; and

(B) The deformation requirements of CS 25.305(a) at a load of 1.15 times the limit load.

(d) Non-critical castings. For each casting other than critical castings, as specified in sub-paragraph (c) of this paragraph, the following apply:

(1) A casting factor of 1.0 or greater may be used, provided that compliance is shown with sub-paragraph (c)(1) of this paragraph, or with the following three conditions:

(i) Castings are manufactured to accepted specifications that specify the minimum mechanical properties of the material in the casting and provides for demonstration of these properties by testing of coupons cut from the castings on a sampling basis.

(ii) Each casting receives:

(A) Inspection of 100 percent of its surface, using visual and liquid penetrant, or equivalent, inspection methods; and

(B) Inspection of structurally significant internal areas and areas where defects are likely to occur, using radiographic, or equivalent, inspection methods.

(iii) Three sample castings undergo static tests and are shown to meet the strength and deformation requirements of CS 25.305(a) and (b).

(2) A casting factor of 1.25 or greater may be used, provided that each casting receives:

(i) Inspection of 100 percent of its surface, using visual and liquid penetrant, or equivalent, inspection methods; and

(ii) Inspection of structurally significant internal areas and areas where defects are likely to occur, using radiographic, or equivalent, inspection methods.

(3) A casting factor of 1.5 or greater may be used, provided that each casting receives inspection of 100 percent of its surface using visual and liquid penetrant, or equivalent, inspection methods.

(4) A casting factor of 2.0 or greater may be used, provided that each casting receives inspection of 100 percent of its surface using visual inspection methods.

(5) The number of castings per production batch to be inspected by non-visual methods in accordance with sub-paragraphs (d)(2) and (d)(3) of this paragraph may be reduced from 100% when an accepted quality control procedure is established.

[Amdt 25/1]

AMC 25.621 Casting Factors

ED Decision 2005/006/R

1. *Purpose.*

CS 25.621 is an additional rule/requirement for structural substantiation of cast parts and components. It is used in combination with a number of other paragraphs, and does not replace or negate compliance with any other paragraph of CS-25. The intent of this AMC is to provide general guidance on the use and background of "Casting Factors" as required by CS 25.621.

2. *General Guidance For Use Of Casting Factors.*

2.1 For the analysis or testing required by CS 25.307, the ultimate load level must include limit load multiplied by the required factor required by CS 25.619. The testing required in accordance with CS 25.621 may be used in showing compliance with CS 25.305 and CS 25.307. These factors need not be considered in the fatigue and damage tolerance evaluations required by CS 25.571.

2.2 The inspection methods prescribed by CS 25.621(c) and (d) for all production castings must be such that 100% of the castings are inspected by visual and liquid penetrant techniques, with total coverage of the surface of the casting. With regard to the required radiographic inspection, each production casting must be inspected by this technique or equivalent inspection methods; the inspection may be limited to the structurally significant internal areas and areas where defects are likely to occur.

2.3 With the establishment of consistent production, it is possible to reduce the inspection frequency of the non-visual inspections required by the rule for non-critical castings, with the acceptance of the Agency. This is usually accomplished by an accepted quality control procedure incorporating a sampling plan. (Refer to CS 25.621(d)(5).)

2.4 The static test specimen(s) should be selected on the basis of the foundry quality control inspections, in conjunction with those inspections prescribed in CS 25.621(c) and (d). An attempt should be made to select the worst casting(s) from the first batch produced to the production standard.

2.5 If applicable, the effects on material properties due to weld rework should be addressed. The extent and scope of weld rework should be detailed in the manufacturing specifications as well as on the design drawings.

3. *Background.*

3.1 Regulatory Background. CS 25.621 (“Casting factors”) requires classification of structural castings as either “critical” or “non-critical.” Depending on classification, the requirement specifies the accomplishment of certain inspections and tests, and the application of special factors of safety for ultimate strength and deformation.

3.2 Application of Special Factors of Safety. The application of factors of safety applied to castings is based on the fact that the casting process can be inconsistent. Casting is a method of forming an object by pouring molten metal into a mould, allowing the material to solidify inside the mould, and removing it when solidification is complete. Castings are subject to variability in mechanical properties due to this casting process, which can result in imperfections, such as voids, within the cast part. Using certain inspection techniques, for example radiographic (X-ray), it is possible to detect such imperfections above a minimum detectable size, but accurate detection depends on the dimensions of the part, the inspection equipment used, and the skill of the inspector.

3.2.1 CS 25.619 (“Special factors”) includes a requirement to apply a special factor to the factor of safety prescribed in CS 25.303 for each part of the aeroplane structure whose strength is subject to appreciable variability because of uncertainties in the manufacturing processes or inspection methods. Since the mechanical properties of a casting depend on the casting design, the design values established under CS 25.613 (“Material strength properties and material design values”) for one casting might not be applicable to another casting made to the same specification. Thus, casting factors have been necessary for castings produced by normal

techniques and methodologies to ensure the structural integrity of castings in light of these uncertainties.

3.2.2 Another approach is to reduce the uncertainties in the casting manufacturing process by use of a "premium casting process" (discussed in AMC 25.621(c)(1)), which provides a means of using a casting factor of 1.0. CS 25.621 ("Casting factors") does permit the use of a casting factor of 1.0 for critical castings, provided that:

— the manufacturer has established tight controls for the casting process, inspection, and testing; and

— the material strength properties of the casting have no more variability than equivalent wrought alloys.

[Amdt 25/1]

AMC 25.621(c) Critical Castings

ED Decision 2005/006/R

Examples of castings that may be critical are: structural attachment fittings; parts of flight control systems; control surface hinges and balance weight attachments; seat, berth, safety belt and fuel and oil tank supports and attachments; pressurised doors; and cabin pressure valves.

[Amdt 25/1]

AMC 25.621(c)(1) Premium Castings

ED Decision 2005/006/R

1. *Purpose.*

This AMC details an acceptable means, but not the only means, for compliance with CS 25.621 for using a casting factor of 1.0 or greater for "critical" castings used in structural applications. A premium casting process is capable of producing castings with predictable properties, thus allowing a casting factor of 1.0 to be used for these components. Three major steps, required by CS 25.621(c)(1)(i), are essential in characterising a premium casting process:

— qualification of the process,

— proof of the product, and

— monitoring of the process.

2. *Definitions.* For the purposes of this AMC, the following definitions apply:

2.1 Premium Casting Process: a casting process that produces castings characterised by a high quality and reliability

2.2 Prolongation: an integrally cast test bar or test coupon.

2.3 Test Casting: a casting produced specifically for the purpose of qualifying the casting process.