2026

Guidance for Approval of Additive Manufacturing(3D Printing)

GC-45-E

KR

APPLICATION OF

"Guidance for Approval of Additive Manufacturing(3D Printing)"

1. Unless expressly specified otherwise, the requirements in this Guidance apply to products(materials, parts, components) for approval on or after 1 January 2026.

CONTENTS

CHAPTER 1 GENERAL

Section 1 General

101. Application

1. This Guidance provides procedures and methods that can be applied to type approval of feedstock, approval of manufacturing process, product inspection, AM repair, etc. for metal equipment on marine and offshore manufactured by additive manufacturing (3D printing) technology to be applied as an alternative to the traditional materials manufacturing process, such as rolling, casting, forging, welding in construction.
   (1) The scope of this Guidance is the additive manufacturing using Powder Bed Fusion(PBF) process, Directed Energy Deposition(DED) process and Binder Jetting(BJT) process.
   (2) The feedstock type are limited to wire, powder and binder.
   (3) In case other additive manufacturing method and feedstock of (1) and (2) are to be used, it is to be agreed with the Society.
2. This Guidance does not apply to hull structural members as defined in **Pt 3, Ch 1, Sec 4 of the Rules**. The approval of any proposal to apply metallic additive manufacturing (AM) processes for hull structure members is subject to the Society
3. For parts subject to classification, the manufacturer is to follow this Guidance. With the agreement of the Society, recognized international or national standards may be accepted instead of this Guidance for certified parts.
4. For metallic parts damaged in-service, an AM process could be selected for repair, which is similar to a welding repair for damaged metallic parts. The repair procedure or repair facility should be qualified and approved.
5. For the situations and projects involving reverse engineering, any such arrangements should be formally agreed to by the designer/original equipment manufacturers (OEMs), part manufacturer and end user.
6. The matters not specified in this Guidance are subject to the respective requirements of the **Rules and Guidance for the Classification of Steel Ships** and **the Guidance for Approval of Manufacturing Process and Type Approval, Etc.**.
7. In addition, the matters not provided for in **the Rules and Guidance for the Classification of Steel Ships** and of **the Guidance for Approval of Manufacturing Process and Type Approval** are to be approved by the Society and may comply with the relevant National or International standards.
8. If it is impracticable to apply the requirements specified in this Guidance, alternative methods are to be discussed by the Society.

102. Definition of Terms

1. The definitions of terms used in this Guidance are as follows. The definitions of terms are to be in accordance with the Rules and Guidance for Steel Ships unless otherwise specified in this Guidance.
   (1) 3D printer : a machine used for 3D printing
   (2) 3D printing : the fabrication of objects through the deposition of a material using a print head, nozzle, or other printer technologies
   (3) Additive Manufacturing(AM) : a process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methods and forming manufacturing
   (4) Additive Manufacturing system(AM system) : software and machinery for Additive Manufacturing
   (5) Additive Manufacturing machine(AM machine) : the hardware, machine control software, setup software, and peripherals required to complete the manufacturing cycle as part of the additive manufacturing system
   (6) Feedstock : bulk raw material supplied to the AM process; generally supplied in various forms such as liquid, powder, suspension, wire, filament, sheet, etc. This Guidance mainly deals with feedstock of powder type and wire type.

(7) Post processing : one or more process steps taken after the completion of an additive manufacturing build cycle in order to achieve the desired properties in the final product
(8) Powder batch : as a feedstock, reusable and unusable powder or a mixture of both powder. The powder batch can be used in one or more production using different process parameters.
(9) Powder bed : the manufacturing zone within the additive manufacturing system where the powder feedstock is melted or selectively fused by thermal energy to produce an output
(10) Process parameters : set of operating parameters and system settings used during a build cycle
(11) AM file format : file format for communicating AM model data including a description of the 3D surface geometry with native support for color, materials, lattices, textures, constellations and metadata
(12) Directed Energy Deposition, DED : additive manufacturing process in which focused energy is used to fuse materials by melting as they are being deposited. The focused thermal energy means a focused energy source (eg laser, electron beam or plasma arc) that melts the material to be deposited.
(13) Powder Bed Fusion, PBF : an AM process that uses energy source to sinter or melt powder particles in the powder bed for making the desired shape
(14) Wire Arc Additive Manufacturing, WAAM : an AM process that manufactures 3D structure by melting wire using arc source similar to the conventional welding process
(15) Binder Jetting, BJT : Additive manufacturing process in which a liquid bonding agent is selectively deposited to join powder materials
(16) AM facility : Equivalent to AM manufacturer, which is considered as an entity with the capability of making an AM final part/component/material following a qualified process to meet the requirements by the client or purchaser
(17) Green part : A green part is a body that is made of powdered material that has been compressed and is held together with a binding material
(18) Brown part : A brown part is a green part which has been heated and/or chemically treated to remove the binding material. It is a body ready to be sintered/infiltrated to become a final part.
(19) Component : A part or member of some equipment or a system
(20) Conformity : Where a design, product, process or service demonstrates compliance with defined specific requirements
(21) Design analysis : Investigative methodology selectively used to assess the design
(22) Design review and approval : Part of the appraisal process to evaluate specific aspects of the design including drawing or solid model review and approval supported by the final material specification
(23) Equivalent : An acceptable, no less effective alternative to the specified criteria
(24) Essential Parameters : Any parameter is considered to be essential when any aspect falling outside the qualified range affects the mechanical properties or final part quality. Essential parameters are to be defined in the specification and are required to be reviewed and surveyed. Any change of essential parameters outside the qualified range requires requalification.
(25) Infiltration : A process of filling the pores of an un-sintered or sintered object with a metal or alloy of lower melting point than that of the object
(26) Installation : The assembling and final placement of components, equipment and subsystems to permit operation of the system
(27) Modification : A limited change that does not affect the current approval
(28) Part, sepcific : A specific part or component with the same geometric requirements, material requirements and function requirements.
(29) Part, family : A family of parts (or similar parts) with the same function requirements, material requirements and same design features or shape but different size or section thickness.
(30) Part, similar : A similar part with similar function requirements, the same material requirements and similar design features including different shape, size, thickness.
(31) Performance test : A technical operation where a specific performance characteristic is determined
(32) Prototype test : Investigations on the first or one of the first new parts for optimization, fine tuning of equipment/system parameters and verification of the expected running behavior
(33) Reverse Engineering : A process to disassemble and examine or analyze in detail (a product or device) to discover the concepts involved in manufacture, usually to produce something similar (a product or device). i.e. AM building a new product by scanning an existing product. Consideration of intellectual property (IP) issues should be addressed on a case-by-case basis.
(34) Sintering : A thermal treatment of a powder or compact, at a temperature below the melting

point of the main constituent, for the purpose of increasing its strength by the metallurgical bonding of its particles

2. The classification of additive manufacturing techniques covered in this Guidance is shown in **103.** and the principle of each additive manufacturing techniques is shown in **Figures** of **103.**.

103. Metallic AM Process

1. This Guidance covers the following metallic AM processes for marine and offshore applications, which can be further subcategorized as **Table 1.1**.

Table 1.1 Metallic AM Process

Powder Bed Fusion (PBF) Process	Directed Energy Deposition (DED) Process(1)	Binder Jetting (BJT)(2)(3)
• PBF-LB: Powder Bed Fusion-Laser Beam • PBF-EB: Powder Bed Fusion-Electron Beam	• DED-LB: Directed Energy Deposition-Laser Beam • DED-EB: Directed Energy Deposition-Electron Beam • DED-PA: Directed Energy Deposition-Plasma Arc • DED-GTA: Directed Energy Deposition-Gas Tungsten Arc • Directed Energy Deposition-Gas Metal Arc	• BJT

(Notes)
(1) Directed Energy Deposition (DED) Process including Powder DED and Wire DED (also, named Wire Arc Additive Manufacturing, WAAM)
(2) Binder Jetting (BJT) or equivalent processes including post build sintering or an infiltration process to achieve the required material properties.
(3) Due to the process characteristics of BJT or equivalent processes, the final part, after de-binder and sintering/infiltration, may contain more and larger porosities than those parts built through the PBF and DED processes. Additionally, it is important to be aware of dimensional changes due to shrinkage of the final part during the sintering process. Metallic parts through BJT or equivalent processes should be limited to non-cyclic loading applications until more successful service experiences are obtained.

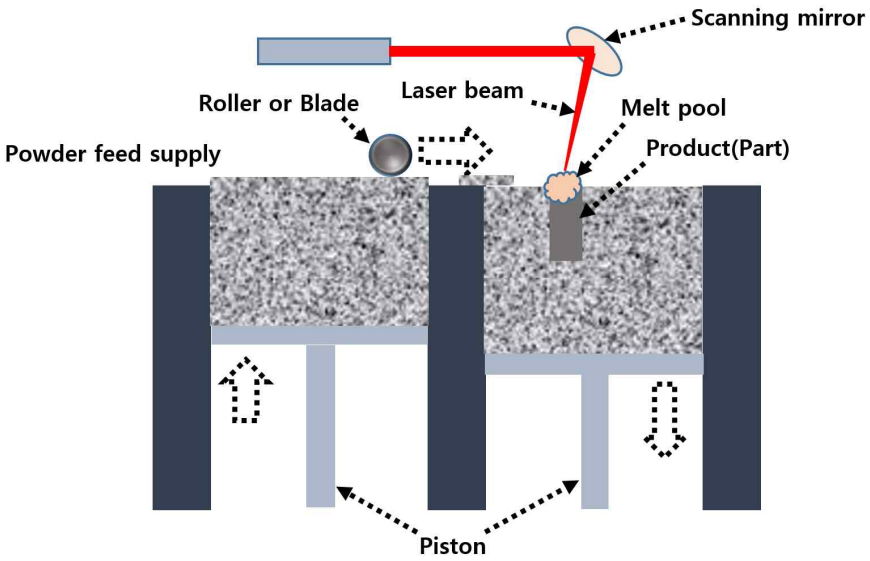

Fig 1.1 Schematic for PBF-LB Process

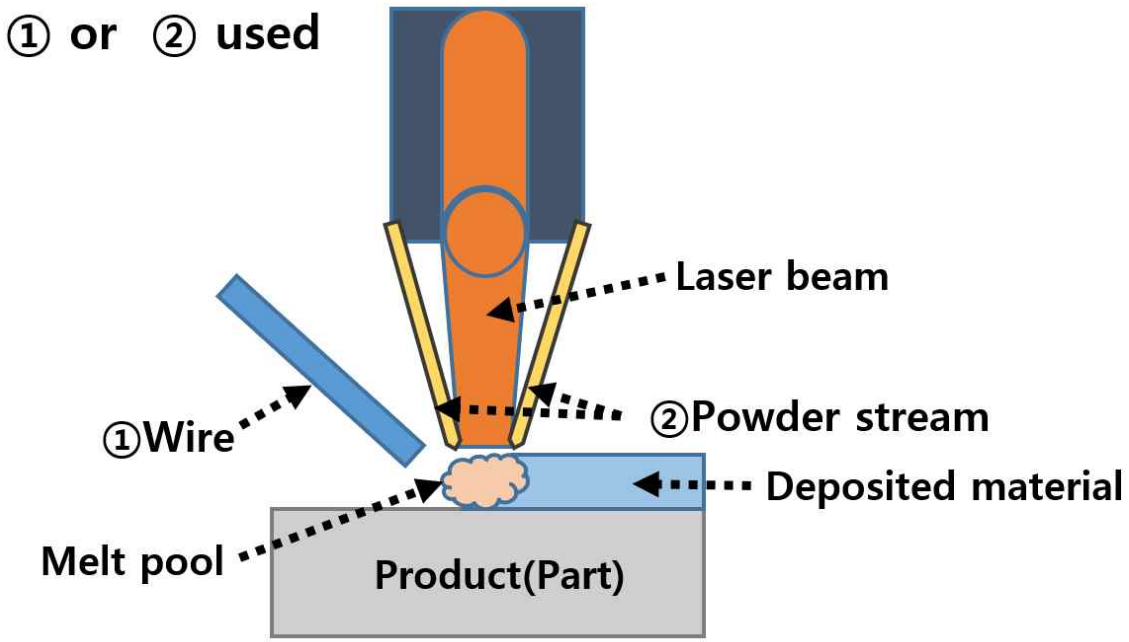

Fig 1.2 Schematic for DED-LB Process

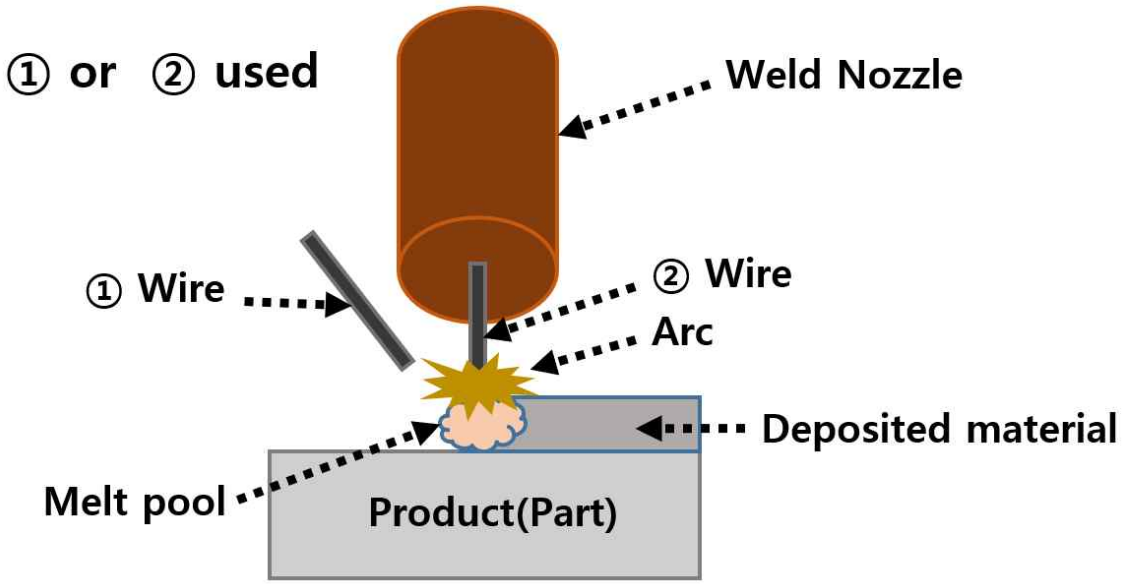

Fig 1.3 Schematic for WAAM Process

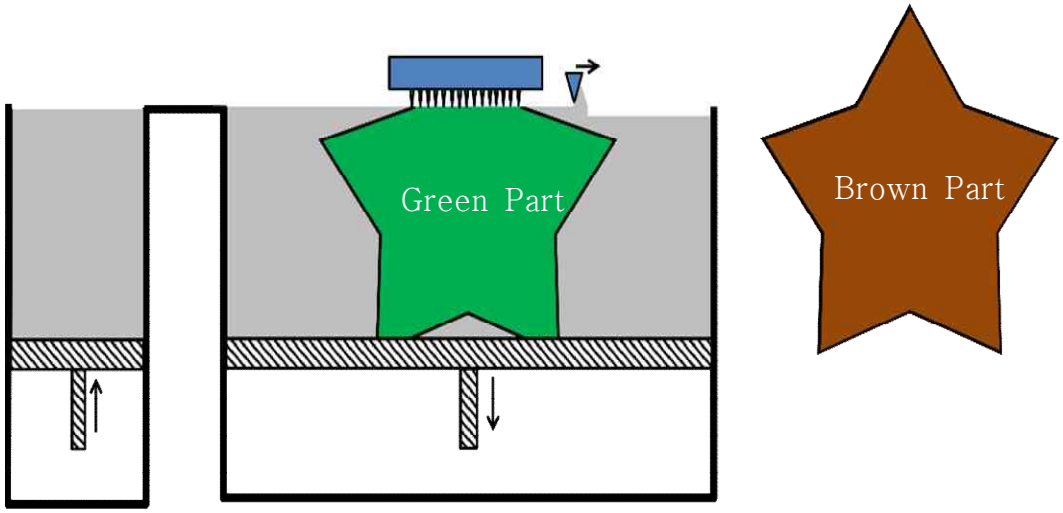

Fig 1.4 Schematic for Binder Jetting Process

104. Parts Categories

1. Parts Categories

(1) Part is technically defined as the combination of geometric requirements by CAD model or drawing(OEM/designer), material requirements by material specification(OEM/designer) and function requirements for the system(Purchaser). The part fabricated by the additive manufacturer should include the pre-build layout as specified in **Ch 4, 202.** and a certificate of conformity which details the results of materials testing, inspection and non-destructive testing.

(2) Parts are categorized into "class items" and "certified items".

(3) For class items, AM metallic parts should meet the existing requirements in accordance with the applicable **Rules and Guidance for the Classification of Steel Ships** of the Society.

(4) For certified items, AM metallic parts should meet applicable specifications in accordance with industry standards, designer or OEM requirements.

2. Criticality Levels

(1) The criticality level of the AM metallic part can be determined from the service environment, a risk analysis and the potential consequence of part failure. For certified items, criticality levels should be determined by the part designer/manufacturer and agreed with the purchaser. Class items should be in accordance with Class Rules, unless otherwise agreed by the part designer/manufacturer and the Society. Criticality levels are determined as follows.

(A) Non-critical application, refer to services for habitability in **Pt 6, Ch 1, 101. 4.** (14) **of the Rules** for machinery.

(B) Critical application, refer to primary essential services in **Pt 6, Ch.1, 101. 4.** (13) (A) **of the Rules** and secondary essential services in **Pt 6, Ch 1, 101. 4.** (13) (B) **of the Rules** for machinery or structural members other than hull structural members.

3. Test Levels

(1) For qualification/approval and quality control during production, test levels can be referred to the additive manufacturing level (AM Level).

(A) AM Level 1 for certified items for non-critical applications other than class items

(B) AM Level 2 for certified items for critical applications other than class items

(C) AM Level 3 for items subject to classification (hereinafter referred to as class items)

(2) The agreed AM Level should be retained in the additive manufacturer's qualification/approval and production records.

Section 2 Approval and Certification Process

201. Approval and certification process

1. The general process for approval and certification requirements is to be in accordance with **Fig 1.5** as follows.

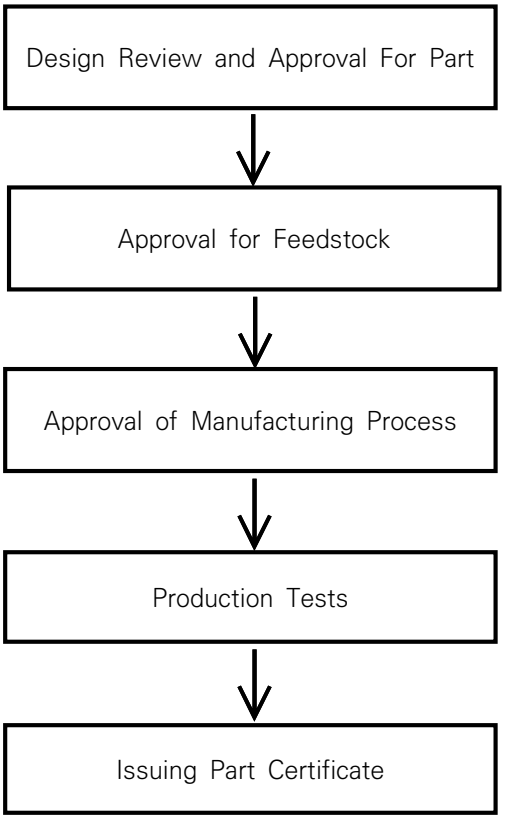

Fig 1.5 General Process for Approval and Certification

202. Details of Process

1. The details of requirements for AM feedstock, procedures, part and final material for approval are shown in **Table 1.1** and listed as follows.

(1) Approval should be requested by the client, along with the submitted information and a detailed inspection and test plan (ITP) (refer to, **Ch 3** for AM Feedstock Approval, **Ch 4** for AM Part Qualification and Approval and **Ch 5** for Additively Manufactured – Final Materials Approval, and **Ch 7** for AM Repair Facility Approval).

(2) The ITP should be agreed and should include Part Design, AM Procedure Specification (AMPS), Post Process, Non-destructive Testing (NDT), Materials Testing, Functional Testing, Part Qualification and Certification Plan, Repair Methodology Plan.

(3) The part design should be reviewed for geometry modification or a different material grade from the original design.

(4) The CAD model or drawing for AM Level 3 should be reviewed and approved in accordance with classification Rules. The CAD model or drawing for AM Level 2 and Level 1 could be reviewed and type approval could be issued in accordance with industry standards.

(5) The feedstock should be qualified according to international standards/specifications defined by the purchase specification for certified items, such as **ISO 17296-2:2015**, **ISO/ASTM 52907:2019**. The feedstock should be approved for class items by the Society. The approval of feedstock materials should be in accordance with **Ch 3**. The qualified/approved feedstock material should be linked to the feedstock supplier by a contractual agreement.

(6) For certified items, the purchaser should specify via a purchase order the requirements for manufacturer qualification. For this purpose, they can specify international standards/specifications,

such as **ISO/ASTM 52920:2023**. For class items, the AM manufacturer should be approved by the Society in accordance with **Ch 4** and **Ch 5**. The range of approval should be determined by the Society and approved materials should be included in the approval of manufacturing process.

(7) If applicable, additive manufacturing repair procedures should be qualified according to international standards/specifications defined by purchase specification for certified items. Additive manufacturing repair procedures and facilities should be approved for class items by the Society in accordance with **Ch 7**.

(8) The Society should witness testing, review test results, complete the facility survey and issue an approval letter or certificate.

(9) During production, witness by the Society for final part acceptance is required prior to the issue of approval or certificates for class items in accordance with applicable Rules and in accordance with applicable industry standards for certified critical items. For non-critical items, witness by the Society is subject to agreement between the manufacturer and purchaser.

2. The initial survey should be conducted in accordance with the relevant steps in **this Section** and **Table 1.2**. The approval tests should be witnessed by the attending surveyor. The annual survey should include a plan to demonstrate the essential parameters in **Table 1.2** which should be followed during production. Approval and certificate for an AM part can be issued by the Society with documented qualification/production stages in accordance with **Table 1.2**.

Table 1.2 Approval and Certification Requirements

Qualification or Production Stages	Section or Subsection Number in **this Guidance**	Certified Items		Class Items
		AM Level 1	AM Level 2	AM Level 3
		Non-Critical	Critical	
		Requirements		
Part Design Review and Approval	**Ch 2**	MQ	MQ	CS
Powder Feedstock	**Ch 3, 201. and 202.**	MQ	MQ	CS
Wire Feedstock	**Ch 3, 201. and 203.**	MQ	MQ	CS
AM Procedure Specification	**Ch 4, Sec 2**	MQ	CS	CS
Post Processing	**Ch 4, 204.**	MQ	CS	CS
Inspection and Testing	**Ch 6, 202.**	MQ	CS	CS
Prototype Part Qualification	**Ch 4**	MQ	MQ	CS
Functional Testing	**Ch 4, 402.**	MQ	MQ	CS
Range of Approval	**Ch 4, 502.**	MQ	CS	CS
Part Certification during Production	**Ch 6, 205.**	MQ	CS	CS
Approval for AM Feedstock	**Ch 3**	MQ	MQ	CS
Approval of Manufacturing Process for AM Final Material	**Ch 5**	MQ	CS	CS
Approval for AM Repair Facility	**Ch 7**	MQ	CS	CS

(Notes)
(1) "MQ" in the table indicates manufacturer qualified requirements determined by the manufacturer, designer and purchaser, which may optionally include the Rules of the Society and recognized standard requirements.
(2) "CS" in the table indicates approved requirements by the Society.

3. The AM process and documentation steps for an AM Part are shown in **Table 1.3**.

Table 1.3 Process and Documentation Steps

Step 1: Purchaser Specification
• Purchaser's Details • Part Design Requirement • Acceptance Criteria • Decision on appropriate AM Level 1, 2, 3 • Additional Requirements by Specification or by Application
Step 2: Qualification Records
• Qualified and Documented Procedure with support of Qualified Specific Part and Final AM Material Grade
Step 3: Risk Assessment or Justification
• AM Level 3 may require qualification for each specific part • AM Level 2 may accept a part family qualification • AM Level 1 may recognize a qualification of a similar part with the same design feature family
Step 4: Production
• Apply Qualified Procedure and Specification • Production • Production Testing • Inspection of Part • Materials Tests for Required Properties by Design • Verify Test Results against Acceptance Criteria
Step 5: Documentation
• Accepted with Compliance Record • Engineering Justification for non-conformance, specifically agreed by Purchaser and the Society
(Notes) (1) If a part is planned to be repaired, the evaluation plan and acceptance criteria should be agreed with the Society for Level 2 and 3 items.

CHAPTER 2 DESIGN REVIEW AND APPROVAL

Section 1 General

101. General

1. The quality and performance of the AM part should be considered for part design requirements and the material requirements, with appropriate control of essential parameters during the manufacturing process including pre-build, build and post-build.

2. The additive manufacturer should prepare a product design package, refer to **Table 2.1**, including additive manufacturing procedures, specifications in accordance with the purchase specification, the purchase order including all the requirements for the fabrication of all built parts, etc.

Table 2.1 Product Design Package

No.	Item
1	Design Code, Rules, Standards, or Manufacturer/OEM's Specifications
2	AM Level (1, 2 or 3)
3	Revision controlled drawing, CAD model or digital build file including test coupons (for reference)
4	The applicable material specification with acceptance criteria for each intended part/application
5	Design analysis report, if applicable
6	Powder/wire/binder specification
7	AM pre-build, build and post-build specification/procedure
8	Inspection and Testing Plan
9	Any other specifications, requirements or procedures identified as necessary by the additive manufacturer or purchaser.

3. Part solid model/drawing and materials specifications should be qualified in accordance with **Ch 4, Sec 4** and included in the qualification records in accordance with the applicable **Sec 2** and **Sec 3**.

4. The qualified specifications and procedures for the AM part should be followed and retained in the additive manufacturer's production records.

Section 2 Design Requirements

201. Drawing or Solid Model

1. Part design includes the creation of the part drawing or solid model for end-use and should consider the achievable material properties defined in the final material specification.
2. The CAD model or drawing for the final AM part should include requirements for final geometry, dimensions, and tolerances in accordance with an internationally recognized industry standard, e.g.: **ASME Y14.46:2018**, **Y14.41:2019**, **Y14.5:2018**.
3. If the CAD model or drawing for the final AM part is redesigned, optimized by topology, or generated by design algorithms, the CAD model for the final AM part should be calculated or simulated using engineering software to verify design compliance and integrity for service. The design analysis report including the applicable procedure and results should be submitted for review by the Society for Level 3.
4. The optimized design requirements for the final AM part should demonstrate at least an equivalent level of functionality and integrity, such as the capability to withstand the applied loads or the applied environmental conditions to traditionally manufactured parts, which the Society should accept and approve for Level 3, and could accept and approve for Levels 1 and 2.
5. The revision number of the solid model, drawing or digital build file should be included in the AM part approval and included in manufacturer's production records.

Section 3 Materials Requirements

301. Material Specification

1. Refer to **Table 2.2**, the material specification should include all material properties, including the specified AM process, for the final delivered condition and the acceptance criteria for the AM part or material. The selected material specification/grade with the heat treatment condition should be identified in the final AM material specification.
2. Depending on the intended application, the acceptable material properties should provide equivalency to traditional manufactured materials in accordance with applicable Rules of the Society or alternatively with internationally recognized industry standards or the designer's specifications.
3. Due to the inherent morphology of the AM process, consideration may be given to use an AM material with alternative chemistry and enhanced mechanical/corrosion properties, which are equivalent to or exceed the material properties typically required in the service condition, such as impact, fatigue, wear, or corrosion resistance. The selected final AM material should be appropriate for the loading condition, the functionality, the environment, and should be approved by the Society as an alternative new manufacturing method for the specified part/application.
4. The following items in **Table 2.2** should be specified in the AM material specification for the final delivered condition. In the case of AM materials for AM Level 3, the material specification, including the following items in **Table 2.2**, should be submitted to the Society for approval.

Table 2.2 Final Material Specification

No.	Item
1	Material type and grade
2	Manufacturing process, including the AM process and any post-build heat treatment process
3	Chemical composition
4	Microstructure, such as grain size, and metallographic analysis
5	Fusion density, applicable to powder processes and not required for wire DED
6	Tensile properties
7	Charpy impact properties and test temperature, if required, according to the design temperature and material grade
8	Hardness tests, if required
9	Other special properties such as fatigue, fracture mechanics properties, corrosion, erosion, or wear resistance, if required for the intended application
10	Non-destructive testing methods, test level, quality level, and acceptance criteria
(Notes) (1) Microstructure, fusion density and special properties are required during qualification/approval but are optional for production.	

CHAPTER 3 TYPE APPROVAL OF FEEDSTOCK

Section 1 General

101. General

1. This requirements of this Chapter apply to approval procedure and tests for Type Approval of feedstock.

2. This Guidance can also be used for feedstock qualified by the AM manufacturer for an AM manufacturer approval and applied under a commercial agreement between the two parties, the AM manufacturer and the feedstock supplier.

3. If the traditionally manufactured parts are class items, feedstock materials should be approved by the Society. For certified items, the approval for feedstock materials could be agreed by purchase specification.

4. Approval for feedstock materials involves a documentation review, an audit of the facility and the witness of approval tests. Unless otherwise agreed, the Class approval is valid subject to Periodical(annual) inspection and/or endorsement by the attending Surveyor. An additional audit may be requested at Periodical(annual) inspection.

102. Approval application

1. The applicant

The applicant is, in principle, to be the manufacturer of the Parts. However, the applicant, where deemed appropriate by the Society, need not always be the manufacturer of the Parts.

2. The manufacturer wishing to obtain a type approval is to submit a copy of the application of type approval (refer to **Annex 6** of **the Guidance for Approval of Manufacturing Process and Type Approval, Etc.**) of the Society, together with three copies of the required data for approval and two copies of the required data for reference, to the Society.

3. Data to be submitted

(1) Data for approval

The following items of **Table 3.1** are to be submitted to the Society. Where test methods and procedure are specified into this **Guidance**, **KS**, **ISO** standard, etc., the relevant standards may be indicated and replaced.

Table 3.1 Approval Application for Additive Manufacturing Feedstock

No.	Item
1	An outline of the organization including the quality management system, a facility description, details of organization and quality control responsibilities
2	Manufacturing process description or flow charts indicating all process steps
3	A list of documented manufacturer's procedures, specifications, documentation, reports and product certificates
4	Documented procedures for feedstock identification and traceability using lot control and batch control
5	Documented historical data for parts built using the feedstock, if available
6	Inspection and testing plan (ITP)

(2) Data for reference
In addition to the **Ch 3, Sec 1, 102.** of **the Guidance for Approval of Manufacturing Process and Type Approval, Etc.**, the following data is to be submitted.
(A) Performance used for purposes other than additive manufacturing (welding, etc.)
(B) Performance approved or applied by industries other than ship and offshore

Section 2 Feedstock Specification Approval

201. General

1. An additive manufacturing feedstock specification should be prepared for each material grade for which approval is requested. Prior to conducting approval tests, the feedstock specification and ITP should be submitted and approved by the Society/AM manufacturer.

2. The feedstock supplier should maintain a quality management system, which should, at least, meet the minimum requirements in accordance with internationally recognized quality standards such as **ISO 9001:2015**.

3. Feedstock material should be qualified using feedstock materials approval tests in accordance with **Sec.3**.

4. If approval is already granted by other Classification Societies, evidence of the approval together with documentation of performed approval tests should be submitted. The indicated approval tests in **this Chapter** could be reduced with the agreement of the Society.

5. The feedstock specification should be submitted to the Society/AM manufacturer for review and approval. A description and specification of the feedstock should be prepared in accordance with **202.** for a powder feedstock specification together with the followings and with **203.** for a wire feedstock specification.
(1) **ISO 3954:2007** or **ASTM B215:2020** can be referred to for powder sampling. The material grade may be a trade name, common name, or typical material designation.
(2) The chemical composition is to be tested and determined by a suitable testing procedure such as wet chemical process, atomic absorption spectrometry, flame emission spectroscopy, X-ray fluorescence analysis, or other recognized methods. Industry standards may be referenced to determine the content of interstitial elements such as carbon, nitrogen, hydrogen, sulphur, and oxygen.
(3) Powder size and distribution are to be tested in accordance with **ASTM E2651:2019** or other equivalent standards, such as sieving in accordance with **ASTM B214:2022** for DED powder, static or dynamic image analysis, light scattering, laser diffraction in accordance with **ASTM B822:2020** or other recognized methods. The powder size distribution (PSD) may be described by D10, D50 and D90. D10 is the first decile (e.g.,1/10 of the statistical population is below this value). D50 is the median value (e.g., 50% of the statistical population is below this value). D90 is the last decile (e.g., 90% of the statistical population is below this value). Other powder size distribution methods may also be specified by the powder manufacturer. For a powder DED process, the maximum powder size may be specified depending upon the powder feeding system.
(4) Morphology can be affected by the powder manufacturing process. The preferred inspection method is by scanning electronic microscopy (SEM), secondary electron imaging, or other recognized methods.
(5) Flowability can be affected by multiple factors such as powder size and distribution, cohesive strength by moisture, inter-particles friction, powder sphericality, etc. Industry standards, such as **ASTM B213:2020**, may be referenced to test flowability through piping, nozzle, funnel, etc.

202. Powder Feedstock

1. Powder Feedstock Specification

(1) For powder feedstock material specification, documentation, handling, and storage, internationally recognized industry standards, such as **ISO 17296-2:2015**, **ISO/ASTM 52907:2019**, can be referred to by the manufacturer.
(2) Refer to **Table 3.2**, the powder specification should be defined with the applicable powder manu-

facturing process and the range of essential parameters. Refer to **Table 3.3**, the non-essential parameters should be indicated for information.

(3) Unless otherwise agreed the powder specification could be qualified for certified items by the manufacturer and should be approved for class items by the Society, to a range of parameters, refer to **Sec 3** and **Sec 4**. Any change of essential parameters outside the qualified range requires requalification. The essential parameters for powder feedstock include the following items in **Table 3.2**.

Table 3.2 Essential Parameters for Powder Feedstock

No.	Essential parameters for powder feedstock
1	Material grade
2	Powder manufacturing process, including the melting and atomization process, type of gas used, environmental conditions.
3	Post-atomization process, such as sieving.
4	Chemical composition
5	Powder size range
6	Particle size distribution
7	Powder morphology and internal microstructure
8	Flowability
9	The applicable additive manufacturing process (e.g., powder for PBF-LB, powder for PBF-EB, powder for DED, or powder for BJT)

(4) Non-essential parameters for powder feedstock include the following items in **Table 3.3**.

Table 3.3 Non-essential Parameters for Powder Feedstock

No.	Non-essential parameters for powder feedstock
1	Density, such as apparent density, tap density, skeletal density, and fusion density
2	Thermal properties, such as solidus, liquidus temperature for reference
3	Oxygen content
4	Moisture content, etc.

(5) The manufacturer should ensure that feedstock materials comply with all local and national regulations for environment, handling and safety.

2. Powder Feedstock Documentation

(1) The powder supplier should issue a statement of conformity in accordance with the additive manufacturer's powder feedstock specification. For each powder lot and/or batch supplied, the powder supplier shall document, for raw material control and traceability, the information given in **Table 3.4**.

Table 3.4 Documentation for Powder Feedstock

No.	Item
1	Procurement information (Powder should be sourced from a feedstock supplier approved by the Society for class items.)
2	Powder supplier's contact information
3	Lot and Batch Number
4	Powder description
5	Powder manufacturing process, including the melting and atomization process, type of gas used, environmental conditions
6	Post-atomization process, such as sieving
7	Sampling methods such as chute splitting, blending or spin riffling
8	Testing method, standard, and results required by the powder material specification
9	Packing date, quantity, handling requirements, shelf life and storage instructions
10	SDS

(Notes)

(1) The control of powder feedstock is by Lot Number and Batch Number. Powder from the single Lot Number and single Batch Number indicates that quantity of feedstock produced under traceable and controlled conditions from a single manufacturing process cycle. The size of the feedstock lot is determined by the feedstock supplier. A single powder lot is used as feedstock in build cycles. Powder from the single Lot Number and multiple Batch Number indicates that quantity of feedstock produced under traceable and controlled conditions from a single manufacturing process cycle. The remaining feedstock of insufficient quantity to complete the build cycle that has been used in multiple AM machines is combined, blended and used to finish the powder lot. Powder from multiple Lot Numbers indicates that more than one powder lot is used as feedstock in build cycles. Multiple lots are usually blended before being loaded into the feed region.

(2) Samples taken for testing should be representative of the powder lot, ensuring homogeneity when split. **ASTM B215** can be referred to for sampling of metallic powders subject to a prior customer/supplier agreement. The sampling method(s) should be reported. For sampling metal powder, the preferred method is to use a dynamic sampling technique like chute splitting or spin riffling to ensure a representative sample is collected by dividing the powder stream while it is flowing, minimizing segregation issues that can occur with static sampling methods.

3. Powder Recycling

(1) Powder should be protected against damage, contamination, and deterioration during handling, storage, and recycling.
(2) For the DED powder process, only powder which has not exited the DED nozzle may be recycled.
(3) For the PBF or applicable BJT processes, powder recycling with mixed lots is not allowed. Powder recycling for the same lot may be allowed in accordance with procedures agreed by the Society. Procedures for powder recycling may consider the following factors in **Table 3.5**.

Table 3.5 Factors for Powder Recycling

No.	Factors
1	The documented methods for tracking the progression of powder recycling
2	Limitation for powder recycling times
3	Performance of the final delivered material property by the recycled powder
4	The documented control procedures, such as sieving, blending, testing oxygen, moisture, or other practices
5	Test results of the essential parameters should be within the specified range of virgin powder, if applied
6	Implementation of procedures for prevention of cross contamination on multi-materials use by one machine. Alternatively, linking one machine for one type of material

203. Wire Feedstock

1. Wire Feedstock Specification

(1) For wire feedstock, internationally recognized industry standards such as **AWS A5.01:2019**, **AWS A5.32:2021**, **ASME BPVC. II. C:2023** or other equivalent standards such as **ISO 14175:2008** can be referred to by the manufacturer.
(2) The wire specification should be defined including the manufacturing process and the acceptable range for the essential parameters in **Table 3.6**. Any non-essential parameters should be indicated for information in the procedure qualification record specified in **Ch 4, 205.**.
(3) Unless otherwise agreed, the wire specification should be qualified for certified items by the manufacturer or approved for class items by the Society. Qualification should include the acceptable range for the parameters. Any change of the following essential parameters outside the qualified range requires requalification.

Table 3.6 Essential Parameters for Wire Feedstock

No.	Essential parameters
1	Material grade
2	Mechanical properties
3	Chemical composition
4	Wire size
5	Tolerance and surface condition(Ra) throughout the length
6	The applicable additive manufacturing process for which the wire feedstock can be used

2. Wire Feedstock Documentation

(1) The wire material supplier should issue a statement of conformity and document the following information in **Table 3.7** for raw material control and traceability per lot per batch.

Table 3.7 Documentation for Wire Feedstock

No.	Information
1	Wire should be sourced from a feedstock supplier approved by the Society for class items.
2	Wire supplier's contact information
3	Lot and Batch Number
4	Wire description such as wire size, material grade, AWS designation, F No., A No. if applicable
5	Wire manufacturing process
6	Associated shielding gas
7	Testing method and results as required by the wire specification
8	Packing date, quantity, and instructions for handling, storage, incoming control
9	As-built properties and Post Weld Heat Treatment (PWHT) properties, if applicable
10	SDS

204. Binder Feedstock

1. If required, the binder feedstock specification should be qualified by the AM facility. The following factors in **Table 3.8** should be specified or considered by the manufacturer.

Table 3.8 Factors for Binder Feedstock

No.	Factors
1	Material grade
2	Chemical composition
3	Viscosity
4	Surface tension
5	Thermogravimetric analysis
6	Flash point
7	Evaporation temperature
8	Curing temperature
9	Storage, handling, and expiration date, if applicable

(Notes)
(1) Additional factors which should be considered during binder selection include: deposition method, compatibility with building process, interaction between binder and powder, effects on the strength of the as-built part, stability, and burnout characteristics.

2. The binder feedstock is a secondary material, which is a liquid bonding agent or glue that binds the metal/ceramic particles together. The binder feedstock can affect the binder jetting and sintering/infiltration process but should not affect the quality of the final part. The final material properties and part dimensions should be achieved by the post-build sintering/infiltration process. The qualification of binder materials should be documented by the AM facility and submitted to the Society, if deemed necessary.

Section 3 Type Test

301. Type test

1. General

(1) The properties of feedstock (mechanical properties, material types, etc.) are to be met the requirements of additive manufacturing machines and end users.
(2) Additives, such as intentionally added pigments, can affect the properties of feedstock, so retesting is required if changed.
(3) The type test can be conducted by feedstock manufacturer or by an organization designated by the manufacturer / the Society, and inspected by the Surveyor.
(4) Type tests are required for each feedstocks and material type. In addition, type tests are required for each additive position.
(5) Additional tests may be required by the Surveyor as deemed necessary.

2. Specimen

(1) The manufacturer selects the shape (cylindrical, rectangular, etc.) of the samples(test coupons) so that the required test specimens can be sufficiently collected, and manufactures two samples(test coupons) with different shapes. The additive directions are to be recorded.
(2) Unless otherwise specified, the specimen is taken at 1/4 of the sample(test coupon)'s thickness.
(3) Only the heat treatment recommended by the feedstock manufacturer or required by the additive manufacturing manufacturer can be applied to the samples(test coupons). After all hest treatment, the specimen can be taken.
(4) An appropriate non-destructive test is to be carried out on the samples(test coupons) before the specimen is taken.
(5) The shape of the specimen is in accordance with **Part 2** of the Rules.

3. Approval test and acceptance criteria

Unless otherwise agreed, the following approval tests in **Table 3.9** should be carried out and test results should be reported using AM built test coupons in accordance with **Ch 6, Sec 2** for inspection and testing. The results should be included in qualification records. Test coupons should represent the performance of the feedstock.

Table 3.9 Approval Tests and Test Results for Additive Manufacturing Feedstock

No.	Test Items
1	Visual inspection: Sample ID and results
2	Dimension inspection: Sample ID and results
3	Surface flaw inspection: Sample ID and results
4	If specified, embedded flaw inspection: Sample ID and results
5	3 tension tests: Sample ID, sample orientation, sample size and test results including yield strength, tension strength, failure type and location
6	If required, 1 set of Charpy impact tests, applicable to materials with ductile-to-brittle transition: Sample ID, sample orientation, sample size and test results
7	If applicable, bend tests: 2 bend tests in the Z and 2 bend tests in X or Y direction for wire arc DED processes and test results
8	Hardness test for the interface cross-section and heat affected zone (HAZ) in the substrate for an integrated build: Sample ID, hardness values or hardness profile from AM build material to HAZ
9	Microstructure examination: Sample ID, part thickness at the section plane, section plane angle relative to build platform, magnification, and results
10	Chemical analysis: Sample ID and results
11	Density test: Sample ID and results
12	Other tests: other tests may be performed if the manufacturer assesses them to be useful for qualification of the feedstock or if they are specified by the powder purchaser.

302. Marking

The marks of feedstock that accepted the test is as follows.

(1) Additive manufacturing techniques used for each type of feedstock and material grades are added together.

(2) It is followed examples as below.

(A) AMF(Additive Manufacturing Feedstock)-P(Powder)-PBF-LB(Powder Bed Fusion-Laser Beam)
-16Cr5Ni(Stainless steel casting for propeller) : AMF-P-PBF-LB-16Cr5Ni

(B) AMF(Additive Manufacturing Feedstock)-W(Wire)-DED-LB(Directed Energy Deposition- Laser Beam)
-16Cr5Ni(Stainless steel casting for propeller) : AMF-W-DED-LB-16Cr5Ni

Section 4 Survey & Range of Approval

401. Survey

1. Initial Survey

The manufacturer should be audited by the attending Surveyor. The initial survey of feedstock production facilities should include witness of the feedstock manufacturing process, survey of manufacturing control for repeatability of the AM feedstock quality, evaluation of the quality management system, document control for the manufacturing procedure and specification, and quality control for sampling, testing, reporting etc.

2. Witness of Approval Tests

The approval tests should be witnessed by the attending Surveyor.

3. Periodical Inspection(Annual Survey)

It is in accordance with **Ch 3, Sec 2, 204.** of **Guidance for Approval of Manufacturing Process and Type Approval, etc.**. The periodical inspection(annual survey) should be carried out by the attending Surveyor. The periodical inspection(annual survey) should include a plan to demonstrate the essential parameters are followed during production. During the periodical inspection(annual survey), full or partial approval tests could be requested based on the performance of the annual production record.

402. Information to be Submitted for Approval by the Society

For class parts, the following items in **Table 3.10** should be submitted to the Society:

Table 3.10 Information to be Submitted for Additive Manufacturing Feedstock Approval

No.	Item
1	Operator qualifications record
2	Feedstock material specification and documentation
3	Recommend AM build parameters for the feedstock material
4	Types of approval tests, test standards and test results in accordance with **301.**
5	Witness of the qualification approval tests
6	Qualification records with a certifying statement acknowledging the validity of the data and certifying the qualification tests and test results
7	Agreed plan for quality control during feedstock production

403. Range of Approval

Upon satisfactory completion of the feedstock specification review and survey, approval will be granted by the Society. The following information is to be stated in the approval certificate issued by the Society:

1. Feedstock supplier
2. Feedstock Mark
3. Qualified feedstock material specification in accordance with **202.** for powder feedstock and **203.** for wire feedstock and **204.** for binder feedstock ⚓

CHAPTER 4 APPROVAL OF MANUFACTURING PROCESS – PRODUCT(PART)

Section 1 General

101. General

1. Application

The requirements of this Chapter apply to approval procedures and tests for the approval of manufacturing process of manufacturers who manufacture products(parts) using additive manufacturing technology.

102. Approval application

1. The manufacturer wishing to obtain the approval of manufacturing process is to submit a copy of the application of approval for manufacturing process (refer to **Annex 6** of **the Guidance for Approval of Manufacturing Process and Type Approval, Etc.**) of the Society together with three copies of the required data for the approval and two copies of the required data for reference to the Society.
2. When applying for approval, the manufacturer should consider the product's approval range.
3. **Data to be submitted**

(1) Data for approval
The following documents in **Table 4.1** should be submitted for AM part approval, for review and survey by the Society. The Society may request additional documents.

Table 4.1 Information to be Submitted for Additively Manufactured Part Final Approval and Certification

No.	Item
1	Documentation identifying the part as either a class part or certified part
2	AM Level 1, 2, or 3
3	If applicable, CAD model or drawing for the final AM part and supporting engineering calculations or simulations for the model
4	If applicable, a digital build model of the part and test coupons for building, including orientation, support structures, etc., for reference
5	Evidence of approval for the AM manufacturer for class items or evidence of certification of the AM manufacturer by an appropriate inspection body for certified items
6	Final material specification including material grade, composition, properties requirements, and the NDT test standard and acceptance criteria
7	Evidence of approval of the feedstock material for class items or evidence of certification of the feedstock material by an appropriate inspection body for certified items
8	The AM procedure specification
9	The post-build procedure specification
10	Qualification records for the part approval, including inspection and testing results with traceability of applied parameters
11	Functionality testing procedures and results
12	Agreed plan for installation, operation, and survey
13	Inspection and test plan for the part certification during production, refer to **Ch.6**.
(Notes) (1) The results of tests and inspections are submitted after the tests and inspections are completed.	

(2) Data for reference

In addition to the **Ch 2, Sec 1, 102.** of **the Guidance for Approval of Manufacturing Process and Type Approval, Etc.**, the following data is to be submitted.

(A) Manufacturer's feasibility verification data

(B) Data for design

(a) Design Requirements (Legal and Regulatory Requirements)

(b) Design concept

(c) Component complexity

(d) Design optimization

(ⅰ) Prepared 3D Model Information

(ⅱ) Procedures for reviewing the quality of the 3D model and suitability for AM (e.g. inner surfaces, overhanging features)

(ⅲ) Details about scaling, slicing, sub-division, hatch strategies, simulation models, and boundary conditions

(ⅳ) Information on how to place a product that is fabricated in the optimal direction by adding fixtures, supports or other required shapes (see **ISO/ASTM 52921** for build orientation)

(ⅴ) Information for integration of topology optimization with design for additive tools, lattice structures, geometric compensation approaches, optimization of input file, slicing and build orientation for achieving part tolerances (minimizing and optimal removal of support structures)

(ⅵ) Model calculation of distorted geometry result performed in advance

(e) Final design

(C) Data relating to facilities

(a) Facility descriptions, ambient conditions(and control) and other related information

(b) Specifications, functions and limitations of additive manufacturing systems (e.g. model number, software and firmware version)

(c) Parameter setting of AM machine and variable parameters that operator can control

(d) Details of accreditation of AM machine

(e) Operator qualification

(f) Details of data sensing and logging procedures to input file version verification, trace file revisions and machine logging

(g) Identification ensuring full traceability

(h) Generating reports on control data

(i) AM machine preparation and raw material verification

(j) Loading and retrieval of build data

(k) Optimal process variables (laser power, scan speed, height and gap of layer, respectively height and width, overlap rate building direction, printing strategy including number and spacing of parts, etc.) and their control range

(l) Scan and deposition strategies and monitoring methods

(m) Sieving type and mesh size

(n) Details of gases used during the process, flow rate

(o) Preheating of feedstock

(D) Data relating to software

(a) Details of STL/AMF files and preprocessing software used

(b) Procedures for quality check of STL/AMF files (e.g. magic software)

(c) Details of the software version and IP rights for the design to be printed

(d) Methods for data encryption, compression, and other cyber security issues

(E) Data relating to manufacturing process

(a) Standard for operating procedures

(b) Work instructions for each part/component

(c) Risk assessment

(d) Test procedures on site

(e) Instructions for Installation, operation and maintenance

(f) Pre-maintenance items

(g) Performance test items

(h) Calibration data

(i) Manufacturing parameters

(F) The following data are to be additionally submitted depending on the type of techniques.

(a) Laser Powder Bed Fusion

(ⅰ) Laser (e.g. power, spot dimensions, exposure time, focus position)
(ⅱ) Scanning strategy (e.g. scan speed, layer thickness)
(ⅲ) Point distance (distance between successive laser spots)
(ⅳ) Hatch distances and conditions (shift between tracks in the plane of the beam scanning and track distance)
(ⅴ) Laser absorptivity or reflectance (e.g. substrate material may require shot blasting to reduce reflectance)
(ⅵ) Build environmental controls (e.g. inert gas, build platform preheating temperature, build space temperature and pressure, recoater blades);
(ⅶ) External environmental controls (e.g. temperature, humidity)
(ⅷ) Powder feedstock (e.g. particle size range and distribution, morphology)
(ⅸ) Baseplate control (e.g. selected baseplate material for build, cleanliness of the baseplate)

(b) Laser Metal Deposition
(ⅰ) Laser (e.g. power, spot dimensions)
(ⅱ) Nozzles (coaxial, three-beam or side feeder)
(ⅲ) Travel speed
(ⅳ) Standoff distance (distance between nozzle tip and surface)
(ⅴ) Shielding gas (e.g. Ar or He, gas flow rate and direction)
(ⅵ) Heat input and cooling characteristics
(ⅶ) External environmental controls (e.g. temperature, humidity)
(ⅷ) Powder feedstock (particle size range and distribution, morphology, feed rate, flow rate, deposition rate)
(ⅸ) Laser absorption/reflectance (e.g. substrate material may require shot blasting to reduce reflectance)
(ⅹ) Baseplate control (e.g. selected baseplate material for build, cleanliness of the baseplate)

(c) Wire Arc Additive Manufacturing
(ⅰ) Consumables manufacturing information
(ⅱ) WAAM procedures and positions
(ⅲ) Technical details (e.g. weaving, multi-wire)
(ⅳ) Consumables, including flux and shielding gas
(ⅴ) Consumables control (e.g. drying conditions)
(ⅵ) Chemical composition of the deposit
(ⅶ) Process parameters
(ⅷ) Preheating and Interpass Temperature
(ⅸ) Cleaning between layers and inspection during production
(ⅹ) Baseplate control (e.g. selected baseplate material for build, cleanliness of the baseplate)
(ⅺ) Post heat treatment

(d) Post processing
(ⅰ) Waiting time for the object on the machine platform after finishing the additive work
(ⅱ) Machining or other surface finishing work
(ⅲ) Methods for taking out the object from the machine's platform
(ⅳ) Removal of powder particles from the inner hollow part
(ⅴ) Object cleaning
(ⅵ) Methods for removal of support from the product
(ⅶ) Details of post heat treatment
(ⅷ) Machining or other surface finishing work, such as treatment with abrasive media or shot peening, and related requirements
(ⅸ) Density achieved, as well as methods how this is verified
(ⅹ) Process for cleaning the AM machine after printing
(ⅺ) Heat treatment method for stress relief

103. Data review

The Society examines the approval test program for approval of manufacturing process submitted in accordance with the requirements in **102. 3** and where deemed appropriate, the test program is approved and returned to the manufacturer.

104. Type approval of feedstock

1. The AM manufacturer apply to AM process based on various parameters used in type approval of feedstock.
2. When the Society agrees, the approval of manufacturing process can be carried out by submitting the feedstock specification and the statement of conformity in **Ch 3** even without type approval of feedstock.

105. Feedstock control

1. **Storage of feedstock**
   (1) Feedstock is to be stored by separating and labelling for each type, and humidity is to be controlled in designated storage areas.
   (2) Powder feedstock is not to be mixed with different types or batches during transportation or storage.
   (3) A system is to be settled to clearly manage the distinction between used and reused feedstock.
2. **Reuse of powder**
   (1) When reusing feedstock, obstructions are not to be mixed and to be filtered out by proper facilities.
   (2) The manufacturer should identify how many times the feedstock is reused. For identifying, the manufacturer should test whether the reused feedstock has a quality equivalent that of the unreused feedstock and submit the result. The number of reuses identified in the type approval of feedstock can be accepted.

Section 2 Additive Manufacturing Process Specification(AMPS)

201. General

1. The AMPS should be documented by the additive manufacturer for controlling and monitoring both the essential parameters and non-essential parameters that may affect the final part quality.
2. The AMPS should be qualified using a range of parameters in association with the approval tests by the Society. Any change of essential parameters beyond the range should be requalified. Test witnessing is required for class items and certified critical items.
3. The applicable essential and non-essential parameters should be documented by the AM facilities/manufacturers. Any parameter that influences heat source/input and heat deposition/history should be considered as an essential parameter.
4. The additive manufacturing procedure should be included in the additive manufacturer's production records.

202. Pre-Build Procedure

1. The following pre-build process characteristics in **Table 4.2** should be defined and identified, which may be supported by slicing software for the preparation of the manufacturing procedure.

Table 4.2 Pre-build Process Characteristics

No.	Pre-build process characteristics
1	Part location and orientation
2	Test coupon location and orientation
3	Machining allowance for part and test coupon, if applicable
4	Build location and nesting, if applicable
5	Build surface, direction, and gravity direction, if applicable
6	Support/infill structure, if applicable
7	Appropriate cleaning procedure for build platform

(Notes)
(1) Part orientation should be identified relative to a specified build surface, such as the build platform or incorporated substrate. If applicable or required, the build location should be identified using X, Y, Z directions in accordance with internationally recognized industry standards, such as **ISO 17295:2023**.
(2) For PBF or applicable BJT processes, the part may be oriented and optimized using pre-build software, to reduce the build time or thermal residual stress. For PBF processes, the location of a single part may be specified within a build envelope. Multiple build locations may be necessary when multiple parts are built simultaneously within the same building envelope.
(3) For DED processes, parts may be oriented vertically, horizontally or to other angles determined by machine flexibility to manipulate the substrate.
(4) Test coupons should be identified in the build layout with a unique label. If the build layout and build surface are depicted, the build location, orientation, and related tolerance for test coupons are also to be indicated in accordance with internationally recognized industry standards such as **ISO 17295:2023**. Digital build models of parts and test coupons should be submitted for reference as part of the submission.
(5) For PBF or applicable BJT processes, test coupons may be built as near-net-shape test samples or test samples could be retrieved from the sufficient test blocks.
(6) For DED processes, test coupons may be taken from a prolongated part/artifact, or a separate test block that represents the part features or part section thickness, which can be specially considered and agreed to by the Society.
(7) For PBF or applicable BJT processes, overhangs and sacrificial support structures may be applied for support during fabrication, if required. Alternatively, the part may be re-orientated during the building process to avoid overhang if this is possible. If specified, a bounded surface or volume region may be used to define locations to limit or require support/infill structure. If not specified, a default support/infill structure may be applied depending upon the machine and software.

2. Internationally recognized industry standards, such as **ISO/ASTM 52950:2021**, may be referred to for an overview of data processing. Digital files may include derivatives from the original CAD model (e.g., STL, AMF, STEP or 3MF).

3. Digital build files should be accurately exported, especially for the critical features, documented and submitted for information, if deemed necessary by the Society. During exporting digital building files, the conversion of digital building file from solid model to machine recognized model/code should be verified and any errors should be fixed automatically by available software or manually by the operator.

203. Build Procedure

1. General

(1) Building parameters related to heat source/input, refer to **2.** for PBF processes and **3.** for DED processes, and heat deposition/history, refer to **2.** for PBF processes and **3.** for DED processes, are considered as essential parameters and should be specified in the procedure specification, controlled, and qualified within the range.

(2) Non-essential operating parameters identified by experience or fixed parameters imposed by the machine system should be documented and controlled as much as possible, including the build platform, build environment, and any other related parameters.
(3) If process characteristics are required for in-process monitoring during building, those requirements should be monitored for conformance, such as machine building errors, failures, or defect inspection.

2. Powder Bed Fusion (PBF)

(1) For powder processes, internationally recognized industry standards, such as **ISO/ASTM 52904:2019**, can be referred to by the manufacturer for inclusion in the procedure specification.
(2) PBF-EB has similar capabilities as PBF-LB but demonstrates differences due to different beam sources. Compared with PBF-LB, the beam energy transferred by the electron beam is higher. The process may operate at higher temperatures, with faster build rates and relatively lower resolutions. Additionally, the powder bed is preheated to slightly below melting temperature, which results in less thermally induced stress.
(3) The parameters in **Table 4.3** should be defined in the PBF-LB or PBF-EB procedure specification.

Table 4.3 Additive Manufacturing Procedure Specification for PBF Process

No.	Item
1	Heat Source: a. Beam type, such as laser or electron beam b. Beam power c. Beam size d. Beam frequency or waveform control e. Beam splitting f. Beam focus setting
2	Deposition: a. Layer thickness b. Scan pattern/strategy c. Travel speed d. Hatch overlap, distance/spacing e. Specific settings control for edges or surfaces
3	Build Environment for PBF-LB: a. Build platform material specification/designation, thickness, surface finish, dimension, parallelism, and tolerance b. Build platform preheat temperature c. Shielding gas composition and flow rate d. Supplemental gas shielding e. Build chamber gas composition f. Environmental enclosure hardware and configuration
4	Build Environment for PBF-EB: a. Build platform material specification/designation and thickness b. Build platform preheat temperature c. Vacuum pressure d. Build Environment
5	Other Parameters: a. Re-coater blade type, material, or roller wear b. Powder dosing rate c. Ambient environmental conditions d. Feedstock condition, such as powder lot, batch number, virgin or recycled

3. Directed Energy Deposition (DED)

For DED processes, internationally recognized industry standards, such as **ASTM F3187:2016**, can be referred to by the manufacturer for inclusion in the procedure specification. The parameters in **Table 4.4** should be defined in the DED procedure specification.

Table 4.4 Additive Manufacturing Procedure Specification for DED Process

No.	Item
1	Heat Source: a. Type of beam/arc b. Beam/arc power c. Beam/arc size d. Heat pulse frequency or waveform control e. Preheating by beam splitting (not applicable to DED-PA, DED-GTA, and DED-GMA) f. Use of energized (pre-heated) wire (not applicable to Powder DED) g. Beam/arc focus setting (not applicable to DED-PA, DED-GTA, and DED-GMA)
2	Deposition: a. Programmed layer thickness (applicable to laser powder DED, not applicable to other DED processes) b. Scan pattern/toolpath c. Travel speed d. Hatch overlap, distance/spacing (applicable to laser powder DED, not applicable to other DED processes) e. Feed rate f. Start working distance/nozzle standoff distance (not applicable to DED-PA, DED-GTA, and DED-GMA) g. Specific settings that may affect edge and surface build condition h. Wire delivery parameters such as incidence angle, offset distance or path orientation (not applicable to powder DED) i. The applied techniques such as weaving, multi-wires or pulse for wire DED, if applicable j. Start and stop point
3	Build Environment: a. Build platform material specification/designation, thickness, surface finish, dimension, and tolerance b. Build platform preheat temperature c. Inter-pass temperature and inter-pass cleaning, if applicable d. Shielding gas composition and flow rate (not applicable to DED-EB) e. Powder carrier gas flow rate (applicable to powder DED) f. Supplemental gas shielding (not applicable to DED-EB) g. Supply gas composition (not applicable to DED-EB) h. Build chamber gas composition, if applicable i. Vacuum pressure (applicable to DED-EB only) j. Environmental enclosure hardware and configuration
4	Other parameters: a. Orientation of heat source impingement b. Ambient environment conditions, such as temperature, moisture, etc. c. Feedstock type, such as powder or wire
(Notes) (1) If the substrate is integrated within the final part, the mechanical and metallurgical properties at the bonding interface, together with any inspection requirements, should be included in the qualification tests. The substrate for qualification should be representative of the substrate for production.	

4. Binder Jetting (BJT)

The main parameters in **Table 4.5** should be defined in the BJT or equivalent procedure specification. These factors are the AM build parameters, which should be controlled for the dimensions of the green part. The final dimensions and quality are determined by the sintering/infiltration process of the brown part.

Table 4.5 Main Parameters for BJT Process

No.	Main parameters for BJT
1	Layer thickness
2	Powder spread, if applicable
3	Build speed
4	Binder saturation, if applicable
5	Drying time and heater powder ratio, if applicable
6	Build orientation
7	Travel strategy

5. In-Process Monitoring or Controlling

(1) Some AM systems may have subsystems using one or more real-time sensors to monitor or control various performance and status indications during building, such as melt pool temperature, size, lack of fusion, spattering, and other parameters.

(2) If subsystems can change or can control any qualified essential parameters, subsystems should be included in the AMPS and are required in qualification records, including details of the monitoring or controlling type and method, monitoring or controlling system settings and the qualified essential parameters. Subsystems are not required in AMPS and qualification records, if they do not change or do not control any qualified essential parameters.

204. Post-Build Procedure

1. General

(1) The post-build process required to meet the quality and properties of the final delivered part should be provided in documented procedures or specifications.

(2) The parameters such as temperature, soak time, and cooling media should be specified and controlled by the heat treatment facility. Reference should be made to industry standards depending upon materials.

(3) If specified, allowances for machining could be referred to internationally recognized industry standards or manufacturer's practices.

(4) The same post-build heat treatment processes should be applied to the test coupons and the sacrificial/actual parts if the post-build process affects the final delivered material properties or is defined as an essential parameter.

2. Powder Removal

The manufacturer's procedure should include a process for removal of loose powder from parts manufactured by PBF or BJT processes. The residual powder in the part may cause health and safety issues for personnel while working during the post processing steps, especially for reactive materials such as titanium-based or aluminum-based powder. Any health and safety risks should be identified and either designed out or minimized.

3. Heat Treatment

Heat treatment, where specified, should be in accordance with Class Rules, internationally recognized industry standards, or best practice suited to the materials, refer to the same traditionally manufactured material grade. To avoid distortion, the part should be adequately supported during heat treatment as appropriate for the component shape/complexity.

4. Part Removal

(1) Procedures should be prepared by the manufacturer for part removal or support structure removal. The following information in **Table 4.6** should be documented.

Table 4.6 Procedure for Part Removal

No.	Item
1	Suitable build platform temperature when the part is planned to be removed from build chamber
2	If applicable, powder removal needs to be verified before heat treatment
3	Applicable methods and tools, such as band saw, slow speed saw, manual tools, machining, grinding etc.
4	Step-by-step instructions

(2) Generally, to reduce residual stress, stress relief heat treatment should be carried out before the part is removed. However, this might not be applicable for large parts due to the furnace capacity. Therefore, there are some cases where parts may be removed before stress relief heat-treatment. Depending upon materials, special attention to avoid cracking may be required and this should be specially considered and agreed to by the Society.

(3) The removal of support structures should be done in a manner to avoid detrimental impact on the part. This can be proactively considered during design for the ease of removal of the interface between the support structure and the part.

5. Surface Finish or Machining

Surface finishing is important for fatigue, non-destructive testing, maintaining tolerance, surface texture and appearance. Surface finish should be in accordance with the manufacturer's procedure. Surface finishing or additional machining operations should be performed after the applicable heat treatment processing due to potential deformation and discoloring/oxidization during heat treatment.

205. Additive Manufacturing Procedure Specification Qualification

1. Refer to **Table 4.7**, the purpose of procedure qualification is to demonstrate the capabilities of an AM procedure to produce a specific AM build component, AM feedstock, AM final material, or repair part by an AM process to meet the requirements.

2. The AM procedure specification (AMPS) should document the required variables to ensure the repeatability of the AM process. Procedure qualification records should document the data recorded during qualification testing, including the applied parameters and corresponding test results.

3. Qualification records for AMPS should be established and documented for review and survey when approval is requested for an AM part, AM feedstock, AM manufacturers for final material, AM repair facilities, refer to **Table 4.7**.

4. The qualification procedure of an AM repair facility, as described in **Ch 7**, requires both a procedure specification and documented qualification records. See also **Ch 6, 203.** (4) for Repair of an AM Part.

Table 4.7 Additive Manufacturing Procedure Specification Qualification

Qualification records for AMPS	
Item	Detail
AM Part	The qualification procedure for an AM part, as described in **Ch 4, Sec 2**, requires the procedure specification and the documented qualification records for the delivered part and should meet all the design requirements in **Ch 2**.
AM Feedstock	The qualification procedure for AM feedstock, as described in **Ch 3**, requires the procedure specification and documented qualification records to meet the requirements for the final delivered feedstock material in **Ch 3, Sec 3**.
AM Materials	The qualification procedure for an AM manufacturer for final material, as described in **Ch 5**, requires the procedure specification and documented qualification records for the final delivered material and should meet the acceptance criteria in **Ch 5, Sec 2**.
AM Repair	The qualification procedure for an AM repair facility, as described in **Ch 7**, is applicable when using an AM process for repair of in-service damaged parts. The part(s) will require a procedure specification and documented qualification records.

Section 3 Plant Audit

301. Plant audit

1. Purpose

The Society will, where deemed appropriate upon review of documents and data submitted, carry out the plant audit in the presence of the Surveyor to verify that the manufacturer has a technical capability to continuously produce the proposed products of equal level in quality under the stable workmanship to the satisfaction of the Society.

2. Items to be audited

The plant audit is to apply to the following items for each manufacturing plant and each product.

(1) Quality system in general
  (A) Establishment and implementation of quality system
  (B) Observance and establishment of procedure for handling of customer complaints
  (C) Education and training of employees

(2) Control of process and quality
  (A) Observance of work instruction
  (B) Observance and confirmation of Q.C flow charts
  (C) Control of nonconforming product and corrective action
  (D) Feedstock management

(3) Control of manufacturing and inspection equipment
  (A) Observance and establishment of maintenance procedure for manufacturing equipment and software
  (B) Calibration and control of inspection equipment

(4) Others
  (A) Updating of documents such as applicable standards, etc.
  (B) Comprehension of related requirements for class surveys

(5) Audit methods and acceptance criteria are to be as deemed appropriate by the Society.

3. Time for audit

The time of the audit is to correspond, in principle, to either the time when the proposed product is manufactured or the time when the approval test is carried out. In this case, the manufacturer is to provide the necessary information related to this audit.

4. Exemption of audit

When the manufacturer submits the application of newly produced product with the same manufacturing facilities and similar method of manufacture for products which have been approved by the Society, the audit items may be exempted wholly or partly according to the review result of the documents.

Section 4 Approval Test

401. Approval test

1. General

(1) Test method and acceptance criteria are to be submitted before approval test.
(2) The number, direction, and location of the specimens are to be discussed in advance with Surveyor.
(3) A generic procedure qualification for prototype parts is required in accordance with **205.**. Refer to **Table 4.8**, AMPS and qualification records for part approval should be documented with revision control. Evidence should be provided that the technical/design requirements are achievable for the required application.

Table 4.8 Additively Manufactured Prototype Part Qualification

AMPS and qualification records for part approval	
No.	Detail
1	Test coupons and a prototype AM part should be built in the same build batch using the established digital build volume model including part location and orientation, support structure, machining stock, and the test sample's location and direction to meet the same specifications as for production.
2	Test coupons should represent the actual part or the worst-case scenario, such as edge of build platform in the Z direction for laser-based process.
3	As applicable, the height/length of each separately built tensile specimen in the Z direction should be at least the maximum height of the intended part for the PBF or applicable BJT process. If not applicable for a large part/component, the standardized tensile sample with 50 mm (2 in.) gauge length should be tested or multiple tensile samples should be tested in the Z direction to cover the height/length of the large part/component.
4	As applicable, for DED processes the samples should be retrieved from the prolongation of the intended part to replace the sacrificial part tests, considering that prolongation has similar dimensions (e.g., section thickness of the part). For separate coupons, the test samples should represent the intended part and features. For PBF process, the samples can be built separately from the intended part and at least one sample should be built for each laser zone, if applicable.
5	The relationship between controlled/specified process parameters as inputs and test results as output, in accordance with the part model and the materials specification, should be established by qualification records for the specific combination of parameters.
6	The relationships of dimensions and material properties between test coupons and the intended AM part should be established. The test coupons are used to assist quality control continuity during fabrication or production.
7	The test coupons and the specific part are to achieve the required properties by approval tests in accordance with applicable Class Rules, industry standards, or designer/OEM specification.

2. Test coupons(Samples)

(1) The test coupon(sample) is to be represented the approval range considering follows.
- Material type or grade
- Manufacturing process
- Type and manufacturer of feedstock
- Types and brand of facilities
- Product type or shape
- Maximum size or weight
- Heat treatment or post processing

(2) One test coupon(sample) with the maximum size and one with the average size are to be manufactured separately. If only products of the same size are produced, two products are to be manufactured for test coupon(sample).
(3) Selection of test samples and approval tests, in principle, are to be carried out in the presence of the Surveyor. However density, micro structure, corrosion resistance, fatigue, residual stress or in case the Society deems the test unnecessary may be omitted.

(4) When the sample (product) has a shape and dimensions that are difficult to be taken all of the required specimens, it can be added layers to the insufficient direction (x, y, z).
(5) The specimens are to be taken after the final conditions including heat treatment and surface treatment of the product are completed.

402. Approval Tests for Prototype Part

1. The prototype part qualification for approval includes materials tests such as mechanical tests, metallurgical tests, non-destructive tests and functional tests. If the prototype part is built by an approved additive manufacturer in accordance with **Ch 5**, a reduced scope for mechanical and metallurgical testing could be agreed by the Society.
2. Unless otherwise agreed, the test samples, methods, and test quantity denoted in **Table 4.9** for PBF processes, **Table 4.10** for DED processes and **Table 4.11** for BJT or equivalent processes should be followed.
3. Charpy impact testing may be specially considered and agreed to by the Society, depending upon materials, design temperature, and build process.
4. Depending upon the intended parts and applications, supplementary tests may be required, such as for fatigue, fracture mechanics, corrosion, wear, erosion, weldability, and residual stress measurements.
5. Depending on the application, function tests could be proof load tested for a load bearing part, pressure/leak tested for a pressure bearing part or balance tested for a rotary machinery part etc.
6. Alternative approval test samples, methods, and quantities may be accepted by the Society provided that the AM manufacturer submits explanations showing that they are technically similar.

Table 4.9 Approval Tests for Powder Bed Fusion Process

Sampling	Types of Tests	AM Level 1	AM Level 2	AM Level 3 for Class
		Certified and Non-Critical	Certified and Critical	
Test Specimen	Visual Inspection	Yes	Yes	Yes
	Surface Flaw Inspection	Yes	Yes	Yes
	Embedded Flaw Inspection	By Agreement	By Agreement	By Agreement
	Chemistry	Feedstock certif icate	AM built coupon	AM built coupon
	Tensile	1	3	5
		1 in Z at one corner	3 in Z (diagonal 2 corners and 1 center)	5 in Z (4 corners and 1 center)
	Impact, if applicable	By Agreement	1 set	3 sets
			1 set in Z, at corner	1 set in Z, 1 set in X and 1 Set in Y, at corner
	Hardness	By Agreement	3	6
			1 at 1/8 below surface, 1 at 1/4 thickness, 1 at center	2 at 1/8 below surface, 2 at 1/4 thickness, 2 at center
	Microstruc ture	By Agreement	2	4
			1 in Z and 1 in X/Y	2 in Z and 2 in X/Y
	Density	Optional - to be agreed	3	3
Component Tests	Visual Inspection	Yes	Yes	Yes
	Surface Flaw Inspection	Yes	Yes	Yes
	Embedded Flaw Inspection	By Agreement	Yes	Yes
	Hardness Tests	If Applicable	If Applicable	If Applicable
	Function Tests	Yes	Yes	Yes

(Notes)
(1) For PBF-EB processes, tensile and Charpy test directions and quantities could be specially considered and agreed to by the Society.
(2) X, Y, Z is the direction of the build, refer to internationally recognized industry standards. Number count refers to the number of test specimens to be taken in each location, e.g. tensile '1 in Z at one corner' equates to "1 tensile test in the Z direction taken from one corner".

Table 4.10 Approval Tests for Directed Energy Deposition Process

Sampling	Types of Tests	AM Level 1	AM Level 2	AM Level 3 for Class
		Certified and Non-Critical	Certified and Critical	
Test Specimen	Visual Inspection	Yes	Yes	Yes
	Surface Flaw Inspection	Yes	Yes	Yes
	Embedded Flaw Inspection	By Agreement	By Agreement	By Agreement
	Chemistry	Feedstock certificate	AM built coupon	AM built coupon
	Tensile	1	3	6
		1 in Z	3 in Z	3 in Z, 3 in X or Y
	Impact, if applicable	By Agreement	1 set	3 sets
			1 set in Z	1 set in Z, 1 set in X and 1 set in Y
	Hardness	By Agreement	3	6
			1 at 1/8 below Surface, 1 at 1/4 Thickness, 1 at Center	2 at 1/8 below Surface, 2 at 1/4 Thickness, 2 at Center
	Microstructure	By Agreement	2	4
			1 in Z and 1 in X/Y	2 in Z and 2 in X/Y
	Density, if powder DED	By Agreement	3	3
	Bend, if wire DED	By Agreement	4	4
			2 in Z and 2 in X/Y	2 in Z and 2 in X/Y
Component Tests	Visual Inspection	Yes	Yes	Yes
	Surface Flaw Inspection	Yes	Yes	Yes
	Embedded Flaw Inspection	By Agreement	Yes	Yes
	Hardness Tests	If Applicable	If Applicable	If Applicable
	Function Tests	Yes	Yes	Yes

(Notes)

(1) For part approval by DED processes, reference or sacrificial parts are applicable for approval tests in lieu of test coupons.

(2) If the DED procedure is qualified for an integrated build platform, the AM part or material should not be removed from the build platform for the final delivered condition. As a minimum, six tensile samples should be retrieved and tested for each integrated build platform material. Three tensile samples should represent the interface and heat affected zone (HAZ). The other three samples should represent the AM build materials in the gauge length. Charpy tests for integrated build qualification could be specially considered and agreed to by the Society. The interface and HAZ should be characterized and documented, with reference to traditional welding procedure qualification. Two bend tests in the Z and two bend tests in the X or Y direction for wire arc DED processes should be included for the integrated build component for AM Level 2 and AM Level 3 during the qualification stage.

(3) Number count refers to the number of test specimens to be taken in each location, e.g. tensile '1 in Z' equates to "1 tensile test in the Z direction".

Table 4.11 Approval Tests for Binder Jetting or Equivalent Process

Sampling	Types of Tests	AM Level 1	AM Level 2	AM Level 3 for Class
		Certified and Non-Critical	Certified and Critical	
Test Specimen	Visual Inspection	Yes	Yes	Yes
	Surface Flaw Inspection	Yes	Yes	Yes
	Embedded Flaw Inspection	By Agreement	By Agreement	By Agreement
	Chemistry	Feedstock certificate	AM built coupon	AM built coupon
	Tensile	1	2	3
		1 in any direction	1 in Z and 1 in X/Y	Agreed direction
	Impact, if applicable	By Agreement	1 set	2 sets
			1 set in Z, any location	1 set in Z, 1 set in X/Y, any location
	Hardness	By Agreement	3	3
	Microstructure	By Agreement	1	1
	Density	By Agreement	3	3
Tests Component	Visual Inspection	Yes	Yes	Yes
	Surface Flaw Inspection	Yes	Yes	Yes
	Embedded Flaw Inspection	By Agreement	Yes	Yes
	Hardness Tests	If Applicable	If Applicable	If Applicable
	Function Tests	Yes	Yes	Yes

(Notes)
(1) Number count refers to the number of test specimens to be taken in each location, e.g. tensile '1 in any direction' equates to "1 tensile test taken in the X, Y, or Z direction".

403. Marking

For AM products which have satisfactorily complied with the required tests, "***-AM***" is to be suffixed to the product marking.

Section 5 Survey & Range of Approval

501. Survey

1. Initial Survey

The manufacturer should be audited by the attending Surveyor. The initial survey of additive manufacturing fa cilities for production should include follows.

(1) Witness of the additive manufacturing process
(2) Survey of manufacturing control for repeatability
(3) Evaluation of the quality management system
(4) Document control for the manufacturing procedure, specification and quality control for sampling, testing, reporting
(5) Incoming control for feedstock materials
(6) Outgoing control for the AM build final parts or materials etc.

2. Witness of Approval Tests

The approval tests should be witnessed by the attending Surveyor.

3. Annual Survey

The annual survey should be carried out by the attending Surveyor. The annual survey should include a plan to demonstrate the essential parameters are followed. During the annual survey, full or partial approval tests could be requested based on the performance of the annual production record.

502. Range of Approval

1. Refer to **Table 4.12**, the range of approval should consider the combination of the qualified model and procedures/specifications.

Table 4.12 Range of Approval for AM Part

No.	Item
1	Documentation identifying the part as either a class or a certified part
2	AM Level (1, 2, or 3)
3	CAD model or drawing with revision number
4	Materials specification of final delivered condition
5	AM machine model
6	Feedstock material linked to feedstock supplier
7	AM procedure specification including pre-build, build and post-build
8	The intended application of the finished part (e.g., the equipment/system in which the part is to be installed)

2. The approval range for the size of each product is in accordance with the relevant **Classification Technical Rules**.

3. Approval of AM Level 3 parts, such parts may be qualified and approved with the support of the qualification record of a specific part.

4. Approval of AM Level 2 parts, a family of parts may be qualified and approved with the support of a risk analysis for the part family and/or with simulation model results, both of which should be specially considered and agreed to by the Society.

5. Approval of AM Level 1 parts, a similar part may be qualified and approved with the support of a risk analysis for the design feature family and/or with simulation model results, both of which could be specially considered and agreed by the Society.

6. Change in the range of approval

(1) Requalification should be carried out if there are any quality concerns for the delivered part or if there are any changes as defined in **Ch 6**.

(2) Supplementary tests can be carried out and recorded to expand the range of approval. To extend the range of approval from AM Level 1 to AM Level 2, the manufacturer should complete the additional tests specified for AM Level 2.

(3) To extend the range of approval from AM Level 1 to AM Level 3 or AM Level 2 to AM Level 3, the manufacturer should complete the additional tests specified for AM Level 3.

(4) Additional testing for expanding the range of approval may also include the supplementary tests specified in **Ch 4, Sec 4.** ⚓

CHAPTER 5 APPROVAL OF MANUFACTURING PROCESS - ADDITIVELY MANUFACTURED METALLIC MATERIALS

Section 1 General

101. General

1. For class items, the manufacturer should be approved in accordance with this Chapter. For certified items, the approval of the manufacturer should be agreed by a purchase specification.

2. Manufacturers should comply with the applicable requirements in their quality management system. The machine, procedure and personnel should be qualified and documented. The procedure should be followed during production by the manufacturer.

3. The manufacturer should prepare the manufacturing specifications/procedures, qualified using approved tests of qualification build block or coupons. The manufacturing specifications/procedures should be approved with repeatedly and consistently achievable AM final materials properties.

4. Manufacturers should be evaluated with reference to both quality management system and AM capability. In addition, the sub suppliers or outsourcing of any services or production should be reviewed by using a specification/procedure. The sub suppliers or outsourcing may include a feedstock supplier, a post-build heat treatment shop, a machine shop, a laboratory for testing, NDT facilities, or service supplier.

5. Class approval involves a documentation review, an audit of the facility/manufacturer and witness of the approval tests. Unless otherwise agreed, the approval is valid for a maximum of 5 years subject to annual verification and/or endorsement by the attending Surveyor. Renewal approval should be requested and issued with the effective date being the 5 years anniversary date from the previous approval. An additional audit may be requested if there is any quality concern.

102. Approval application

1. The manufacturer wishing to obtain the approval of manufacturing process is to submit a copy of the application of approval for manufacturing process (refer to **Annex 6** of **the Guidance for Approval of Manufacturing Process and Type Approval, Etc.**) of the Society together with three copies of the required data for the approval and two copies of the required data for reference to the Society.

2. When applying for approval, the manufacturer should consider the product's approval range.

3. Data to be submitted

(1) Data for approval

Approval should be requested by the AM manufacturer, and submitted with the information listed in **Table 5.1** and a detailed inspection and test plan (ITP). The Society may request additional documents.

Table 5.1 Approval Application for Manufacturer – Additively Manufactured Metallic Materials

No.	Submitted documents
1	An outline description of the manufacturer including their quality management system (see (A) (a)), a facility description (see (A) (b)), and details of the manufacturer's organization and quality control (see (A) (c))
2	Additive manufacturing capability (see (B))
3	Documentation for manufacturing equipment (see (C))
4	Documentation for operators (see (D))
5	A list of documented manufacturing procedure specifications, supporting documentation and test reports and the/any AM product/part/material certificates
6	Inspection and testing plan for qualification and production
7	Documented procedures for incoming feedstock materials identification and traceability using batch control
8	Documented historical data for previously built AM final parts or materials

(A) Description of Manufacturer

(a) Quality Management System (QMS)

The review and survey of the AM manufacturer by the Society should cover the facility description, organization, quality, and AM capability and should include any historical data for the AM manufacturer approval, to the satisfaction of the Society. A formal QMS in accordance with an internationally recognized standard is not mandatory, however, the AM manufacturer is to have a QMS in place which is documented, controlled, auditable, and embedded in the organizational structures.

(b) Facility Description

General information for the facility should include the following items in **Table 5.2**.

Table 5.2 Description for the Facility

No.	General information for the facility
1	Name and address of AM facility
2	General relevant information and background
3	Estimated annual production of finished parts for AM products, and a brief description of intended applications

(c) Organization and Quality

High level organization should provide the following items in **Table 5.2**.

Table 5.3 Organization and Quality

No.	Item
1	Organizational chart
2	Organization of the quality control department and the staff employed
3	Qualification of the operators involved in activities related to the quality of the part/material
4	Certification of compliance with the quality system with internationally recognized industry standards, where applicable
5	A management system of engineering specifications, procedures with revision control, and documentation for part/sample labelling and traceability
(Notes) (1) If recognized certification is not available, then adequate controls should be demonstrated through a review of the manufacturer's QMS.	

(B) Additive Manufacturing Capability

The following items in **Table 5.4** should be provided for AM capability.

Table 5.4 Additive Manufacturing Capability

No.	Item
1	Approval certificates/documentation already granted by the Society, if any
2	List of machines and materials/parts for approval
3	Manufacturing flow chart for the AM Process
4	Feedstock handling and storage procedure
5	Final delivered part/material handling and storage procedure
6	Details of the various equipment used or outsourcing facilities, including pre-build, AM build, and post-build activities (e.g., furnace, condition and recording method of heat treatment)
7	Non-destructive and destructive testing facilities or service suppliers intended to be used, if out-sourced
8	Information about the different types of material grades the facility intends to manufacture, with frequency of manufacturing, and any previous examples
9	Information about the different types of AM processes the facility intends to use to fabricate parts with the manufacturing frequency and any previous examples
10	Previous examples of the different types of test coupons/manufactured parts at the facility
11	Information about maximum weights, dimensions, section thickness the facility is capable of han-dling
(Notes) (1) The manufacturers should take responsibility for feedstock quality, storage, handling and re-use, if applicable.	

(C) Documentation for Manufacturing Equipment

(a) The manufacturer should establish and document evidence to demonstrate the following items in **Table 5.5**(refer to internationally recognized industry standards depending upon the AM process).

Table 5.5 Documentation for Manufacturing Equipment

No.	Item
1	Documentation to confirm that process equipment and ancillary systems can operate within the established/specified limits and tolerances.
2	Documentation that test coupons throughout the build envelope can achieve the re-quired properties by approval tests for a standard qualification build.

(b) The written quality procedures and machine qualification records should be documented for equipment calibration, maintenance, monitoring, and control by the manufacturer in their quality management system and submitted to the Society if deemed necessary.

(c) Documentation of a machine should include the following information in **Table 5.6**.

Table 5.6 Documentation for AM Machine Qualification

No.	Documentation items
1	Machine manufacturer
2	Machine model
3	Serial number
4	Any additional components which impact build parameters
5	Software version
(Notes) (1) Any changes to the above items should be documented as a change of machine. Any change should be linked to a machine model number. A serial number for the same machine model number is not considered as a change of machine. If multiple machines with different serial numbers are used, they should be separately documented.	

(D) Documentation for Operators

(a) Operators should be competent with documented practical experience and knowledge tests (such as written exams, internal training, external training, certification by the third party, or a combination of these factors).

(b) The operator should have the appropriate competence of understanding of the qualified additive manufacturing procedure specification (AMPS) and operating practices in accordance with the approved procedures for the part or material qualification builds.

(c) For practical skills, the operator should demonstrate the necessary process steps on the machine and demonstrate the necessary capabilities to follow a preliminary/qualified AM procedure specification.

(d) For the procedure, part and material qualification or production, the operator should be assessed based on the practical qualification/approval tests in accordance with the requirements of the procedure for material approval and/or part approval tests and as specified in the manufacturer's operating procedures.

(e) The range of documentation for the operator should include the combination of process, feedstock material and machine, refer to **Table 5.7**.

Table 5.7 Documentation for AM Machine Operators Qualification

Item	Detail
Metal AM process	Change of process should be requalified.
Feedstock material group	Change of material group should be requalified.
Machine	Change of machine should be requalified.

(f) The written quality procedures and operator performance/qualification records should be documented and managed by the manufacturer in their quality management system and available to the Society, as requested.

Section 2 Approval Test

201. General

1. A procedure should be qualified to produce AM final material/part. General requirements in **Ch 4, 205.** are applicable to the AM facility/manufacturer/materials qualification. Additional procedure qualification requirements for the approval of additive manufacturers are included in this Chapter with AM final materials properties in accordance with **Ch 2, Sec 3** for final material specification.
2. AMPS and qualification records should be established by specification and documentation control to demonstrate that the material requirements meet the technical/design requirements in accordance with Class Rules, industry standards, or the designer/OEM specification.

202. Approval test

1. Sufficient test coupons for the final delivered condition should be prepared for all qualification tests. Repeatability should be demonstrated and agreed to by the Society, refer to **Table 5.8**.

Table 5.8 Approval Tests for Additive Manufacturer

No.	Test coupons
1	Test coupons with or without a sacrificial/actual part should be built using standard qualification builds and should achieve the required material properties confirmed by approval tests.
2	For PBF or applicable BJT processes, test samples for approval tests should be evenly distributed on the overall build platform and represent a worst-case scenario for samples during production.
3	For DED processes, test samples should represent the intended section thickness such as thin and thick test blocks.
4	Test samples should represent the intended AM part and applications or worst-case scenario, such as edge of the build platform with fast cooling rate.
5	The relationship between input variables and output results should be established for the specific combination of parameters by qualification records for manufacturer approval.
6	Test quantities could be specially considered and agreed by the Society, if the AM facility/manufacturer can provide historical test results for the technically same combination of machine, feedstock, procedure, and final material of the final delivered condition.

2. If part approval and facility approval are carried out concurrently, the procedure qualification for part approval and facility approval should be combined in one build batch. The test methods, quantities, and acceptance criteria for approval tests should meet the requirements, whichever is more stringent.
3. Approval tests, test methods, and acceptance criteria should be related to the material specification of the final delivered condition and agreed to before testing samples are prepared. Test coupons should represent the performance of the overall build envelope. Alternative tests may be specially considered and agreed to by the Society.
4. Unless otherwise agreed, the following approval tests should be carried out and test results should be reported using the AM built test coupons in accordance with **Ch 6, Sec 2** for inspection and testing and included in the qualification records, refer to **Table 5.9**.

Table 5.9 Documentation for Approval Tests and Test Results

Types of tests	Recorded items in test results
Visual inspection	Sample ID and results
Dimension inspection	Sample ID and results
Surface flaw inspection	Sample ID and results
Embedded flaw inspection	Sample ID and results
Tensile tests	3 in Z (refer to **ASME PTB-13:2021**) and 3 in X/Y including sample ID, sample orientation, sample size and test results including yield strength, tension strength, failure type and location
Charpy tests for materials with ductile-to-brittle transition (if applicable)	3 sets of Charpy impact test including sample ID, sample orientation, sample size and test results
Bend tests for wire arc DED processes (if applicable)	2 in the Z and 2 in X/Y direction
Microstructure examination	Sample ID, part thickness at the section plane, section plane angle relative to build platform, magnification, and results
Chemical analysis	Sample ID and results
3 fusion density tests for powder feedstock	Sample ID and results
Residual stress measurement (if applicable and required)	Sample ID and results
Other tests	Other tests may be performed depending on material grade or intended application, such as fatigue test, corrosion test or weldability test.
(Notes) (1) Additional Charpy tests may be requested by the purchase specification at a different test temperature, such as 20 ℃ below the specified temperature, at the specified temperature, or 20 ℃ above the specified temperature. (2) Test direction for tensile, Charpy and bend tests could refer to **Annex C of AWS D20.1**	

203. Marking

For AM products which have satisfactorily complied with the required tests, "***-AM***" is to be suffixed to the product marking.

Section 3 Survey & Range of Approval

301. Survey

1. Initial Survey

The manufacturer should be audited by the attending Surveyor. The initial survey of additive manufacturing facilities for production should include follows.

(1) Witness of the additive manufacturing process
(2) Survey of manufacturing control for repeatability
(3) Evaluation of the quality management system
(4) Document control for the manufacturing procedure, specification and quality control for sampling, testing, reporting
(5) Incoming control for feedstock materials
(6) Outgoing control for the AM build final parts or materials etc.

2. Witness of Approval Tests

The approval tests should be witnessed by the attending Surveyor.

3. Annual Survey

The annual survey should be carried out by the attending Surveyor. The annual survey should include a plan to demonstrate the essential parameters are followed. During the annual survey, full or partial approval tests could be requested based on the performance of the annual production record.

302. Information to be Submitted for Approval by the Society

The following documents in **Table 5.10** should be submitted for AM facility approval, for review and survey by the Society.

Table 5.10 Information to be Submitted for Additive Manufacturer Approval

No.	Documentation items
1	Quality management system
2	Additive manufacturing capability
3	Machine and operator qualification record, if requested by the Society
4	Build volume model or test plan for standard qualification build
5	Feedstock procurement specification and data sheet with testing results
6	AM procedure specification including pre-build, build, and post-build
7	Procedure specification qualification records linked to the material grade
8	Destructive and non-destructive testing standard and testing report
9	Material specification for final delivered condition

303. Range of Approval

1. The range of approval for the AM facility/manufacturer should be the combination of the following qualified specifications including any revisions.

(1) Machine
(2) Feedstock material approved or qualified in accordance with **Ch 3**
(3) AM procedure specification including pre-build, build, and post-build
(4) Materials specification of final delivered condition
(5) Supplementary tests can be carried out and recorded to expand the range of approval. Requalification should be carried out if there is any quality concern for the delivered AM part or material.

2. Notes

(1) For AM Level 1, 2 and 3, all test results should meet the minimum design requirements.

(2) Unless otherwise agreed, powder and wire feedstock should be type approved in accordance with **Ch 3**. The manufacturer can procure approved feedstock from different approved suppliers/brands. The approved feedstock type and grade should be documented for each specific supplier.

(3) Unless otherwise agreed, the approval tests in this Chapter should be carried out for Approval of Manufacturing Process.

(4) For AM Level 2 and 3, each material grade should be qualified and approved. For AM Level 1, a family of materials may be qualified and approved with the support of a risk analysis and/or physics simulation, which could be specially considered and agreed to by the Society. The material group could be categorized to.
   (A) A: Unalloyed, low-alloyed steels and high alloyed ferritic steels
   (B) B: Austenitic, martensitic and precipitation hardening steels
   (C) C: Titanium and Titanium alloys, Niobium, Zirconium and other reactive materials
   (D) D: Aluminum alloys
   (E) E: Magnesium alloys
   (F) F: Nickel alloys, Cobalt alloys
   (G) G: Other than above, such as Copper alloys, Ceramic

(5) The post-build heat treatment condition should be recorded during the qualification and the same heat treatment condition should be followed during production. Typical heat treatment conditions for AM final parts/materials include follows.
   (A) A: As build
   (B) SR: Stress Relief
   (C) SA: Solution Annealed
   (D) HIP: Hot Isostatic Pressed
   (E) Other: Other Delivery Conditions ⚓

CHAPTER 6 APPROVAL FOR PRODUCT(PART)

Section 1 General

101. General

1. The provisions of this Chapter apply to approval procedures and tests for inspection of products using additive manufacturing techniques.
2. During production, the approved, certified, classed parts should follow the qualified AMPS requirements for feedstock, pre-build, build and post-build. The inspection and testing reports should be documented by batch control and included in the additive manufacturer's production records to provide evidence that part design requirements have been achieved during the manufacturing process.
3. The production batch is to be randomly selected and tested to represent all parts/components with the same batch feedstock, the same equipment, the same operator, the same process parameters, and the same post-processing.
4. Qualified Additive Manufacturing Process Specifications

   Production for approved or certified parts with batch control should be completed following the steps in **Table 6.1**.

Table 6.1 Qualified Additive Manufacturing Process Specifications for Production

Step No.	Item	
1	Items/functions to be Qualified	CAD model or drawing or digital build model with revision number
2	Qualified	Feedstock material specification linked to feedstock supplier by contractual agreement
3	Qualified	AM procedure specification
4	Qualified	Post-build heat treatment procedure/specification, if applicable
5	Items/functions to be verified by manufacturer and customer as agreed	Machine maintenance, qualification, and calibration, operator knowledge - practices and qualification, the applicable essential and non-essential parameters, pre-build check of the digital file, test coupons, machine hardware and software, sufficient raw materials for the build cycle, planned or un-planned interruption etc.
6	Inspection and testing plan (ITP) to be agreed	The test scope for production control should be included in the ITP agreed by the purchaser and manufacturer. As a minimum, the test scope for AM Level 1 should be included in the ITP. Other applicable tests in **Ch 4, Sec 4** could be added based on design requirements and the intended service environment. The test scope for AM Level 2 and Level 3 should be appropriately adjusted to a higher test frequency, quantity or extent above the test scope defined for Level 1. This should be defined in the purchase specification, and specifically considered and agreed to by the Society.

Section 2 Test and Inspection

201. General

1. The test procedure and acceptance criteria for individual products are in accordance with the **Classification Technical Rules** or equivalent International/National Standards relevant to the products, and the approval test is carried out in the presence of the Surveyor.
2. The manufacturer should inform to the Surveyor about the Specifications with the customer that can affect the mechanical properties and quality of the product, and discuss the inspection method and acceptance criteria before test.
3. The Surveyor may require additional tests because AM is new technique.

202. Test method

1. General

(1) The inspection and testing should verify that the technical design requirements and function requirements are met repeatedly, accurately, and consistently using representative parts and/or testing coupons through non-destructive or destructive testing methods.
(2) The inspection and testing of representative parts and/or test coupons should be performed after all post-build processes. Material testing should be carried out after heat treatment and may exclude machining and surface finishing. NDT should be carried out with appropriate machining and surface finishing.
(3) Testing should be in accordance with applicable Class Rules, industry standards, or designer/OEM specifications for quality control during production. The frequency of production testing should follow the agreed ITP, referred to **Table 6.1** Step 6.

2. Test and inspection plan

(1) The test and inspection plan based on the approval of manufacturing process are to be submitted to the Surveyor.
(2) The test and inspection plan are to be described for identifying the different parts with the approval of manufacturing process.
(3) **Classification Technical Rules** or equivalent International/National standards relevant to the test methods and acceptance are to be provided.
(4) The manufacturer may propose items not specified in the **Classification Technical Rules** or international / national standards considered equivalent.
(5) Test and inspection can be carried out after the submitted test and inspection plan have been satisfied by the Surveyor.

3. Samples

(1) The number of samples are to be in accordance with the **Classification Technical Rules** or equivalent International/National standards relevant to products. The samples(product) are to be represented the shape of the products and have the maximum and average size of the products.
(2) If it is determined that the product is special, additional sample may be produced for test.
(3) Considering the quantity of products produced, the number of samples may be increased/decreased appropriately after approval by the Society.
(4) When the samples(product) has a shape and dimensions that are difficult to take all specimens, it can be laminated to the product by adding it in the required direction(x, y, z).
(5) The specimens are to be taken from samples after the final conditions including heat treatment and surface treatment of the samples have been completed.

4. Test method

(1) Chemical Composition
The chemical composition should be analyzed in accordance with internationally recognized industry standards such as **ASTM A751**, and the results should be documented including all elements. The chemical composition should meet the requirements of the materials specification of the final delivered condition, see **Ch 2, Sec 3**.
(2) Microstructure
Samples should be prepared in accordance with internationally recognized industry standards. The microstructure after the final heat treatment should be examined using optical microscopy or

scanning electron microscopy(SEM). The following information in **Table 6.2** should be documented for qualification and production if required.

Table 6.2 Documentation for Material Microstructure

No.	Information
1	Sample ID
2	Part thickness at sectioning plane
3	Sectioning plane angle relative to build platform
4	Pictures at a quarter and half thickness with different magnifications, such as 5X, 100X, 500X or in line with the facility's procedures
5	Reported description of microstructure with grain size or other observation
6	Characterization of flaws or defects, such as morphology, type, size, location, frequency, if applicable

(3) Tensile Properties

Tensile properties should be tested in accordance with internationally recognized industry standards such as Class Rules, **ASTM E8:2022**. Subsize samples are acceptable for PBF or applicable BJT processes with a minimum gauge diameter of 6.25 mm (0.25 in.) according to **ASTM E8:2022**. Other alternative sample sizes may be specially considered and agreed to by the Society. At least one tensile test, preferably in the Z orientation, should be carried out and the test results should be reported in accordance with **ASTM F2971-13:2021** and documented for qualification and production including, as a minimum, the items in **Table 6.3**.

Table 6.3 Documentation for Tensile Properties

No.	Item
1	Tensile sample information such as identification, gauge length, diameter for round samples or width and thickness for flat samples, and the sample orientation
2	Test temperature should be stated if it is not room temperature
3	Test results such as yield strength, ultimate tensile strength, elongation, reduction of area, and tensile failure type and location
(Notes) (1) At elevated temperatures different tensile properties to those at room temperature may be specified as additional requirements by the materials specification. If specified, tensile properties should be carried out in accordance with internationally recognized industry standards, such as Class Rules or **ASTM E8:2022**. (2) If required by the design, tensile properties may be tested at a defined temperature above the design temperature for the intended part application. (3) If required, the acceptance criteria for elevated temperature tensile properties should be defined in material specification for the final delivered condition.	

(4) Impact Properties

If required by material specification, at least one set of Charpy V-Notch impact tests should be carried out in accordance with Class Rules. Test results should be documented and include the following items in **Table 6.4**.

Table 6.4 Documentation for Impact Properties

No.	Item
1	Charpy sample information such as identification, sample size, and notch orientation
2	Test temperature
3	Test results for qualification and production such as absorbed energy, crystallinity percentage, and lateral expansion
4	Ductile to brittle transition temperatures if required during qualification

(5) Hardness

Three hardness tests can be applied for quality control in accordance with the manufacturer's procedure. These could be the Brinell Hardness test, the Rockwell Hardness test, the Vickers hardness test or other applicable hardness testing methods in accordance with internationally recognized industry standards. Hardness can also be a finished product design requirement.

(6) Bend Test

If required, two bend tests should be carried out. Bend test sample size and bending mandrel can refer to the bend tests required for welding procedure qualification, or other internationally recognized industry standards.

(7) Special Properties

(A) Other special properties may need testing during qualification depending upon the material specification and intended application, which may include fusion density, fatigue properties, corrosion properties, wear, erosion, fracture toughness, high or low temperature properties, etc.

(B) The inspection and testing plan and testing procedures should be submitted to the Society for review. Test results should be documented for qualification. The sampling of special properties for production control, including frequency and quantity, should be in accordance with the approved or agreed test plan.

(C) Weldability testing may need to be performed depending on the fabrication, installation, and build process, etc. If welding is planned, specific testing will be considered and agreed to by the Society.

(8) Non-destructive Testing

(A) General

(a) The final delivered part should be non-destructively tested by NDT personnel certified to the appropriate level of a nationally recognized scheme for the applied techniques, such as those schemes specified in **Guidance for Approval of Service Suppliers**. A surveyor witness is required for NDT processes for classification and certification. The NDT timing (delayed time between NDT starting and completion of fabrication) should be considered, refer to **Pt2, Annex 2-7** and **Annex 2-12 of the Guidance**, which may be material dependent.

(b) The extent of NDT should be in accordance with the agreed NDT plan.

(c) For class items, NDT should be carried out in accordance with **Pt 2, Annex 2-7 of the Guidance**(conventional NDT techniques) and **Pt 2, Annex 2-12 of the Guidance**(advanced NDT techniques) and meet the corresponding product standards, e.g., Class Rules or other standards acceptable to the Society. The requirements for NDT suppliers, including certified operator and supervisor levels, should follow **Guidance for Approval of Service Suppliers**.

(d) For certified items, NDT should be carried out in accordance with recognized national/international standards and meet the design specification.

(B) Visual Examination

100% visual examination is required. The acceptance criteria should follow internationally recognized industry standards and the purchaser's specification, and should include surface finish, tolerance, and dimensions.

(C) Surface Flaw Examination

Surface examination should follow the applicable NDT techniques in **Pt 2, Annex 2-7** or **Annex 2-12 of the Guidance**. The as-built surface of AM part may give false indications, so, where surface NDT is required, the surface should be made suitable for the NDT method applied.

(D) Embedded Flaw Examination

Conventional ultrasonic or radiographic inspection should refer to **Pt 2, Annex 2-7 of the Guidance**. Further guidance on NDT is given in **Pt 2, Ch 1 of the Rules**, for products corresponding to equivalent forged or cast components. Advanced NDT should refer to **Pt 2, Annex 2-12 of the Guidance**. Computerized Tomography (CT) scan may be applied where defined in the project specifications.

(E) In-Situ Process Monitoring

(a) In-situ process monitoring can be a viable method for qualification/production control, which can partially/fully replace surface or embedded flaw inspection, depending on the level and the agreed ITP.

(b) Before adoption in production, the in-situ process monitoring technology should be verified and validated, by suitable NDT techniques, with supporting data, in conjunction with agreed inspection quality levels, test levels and acceptance criteria. The acceptance of in-situ process monitoring for inspection could be qualified and agreed by the Society.

(i) The in-situ process monitoring model-based approach should apply the in-situ sensor data to monitor the AM build process. Methods and algorithms such as machine learning models may be utilized to calibrate and map layer-wise images to laser scan vectors. Images/Spectral/Data are stacked and exported to standardized 3D data formats to enable easy inspection and comparison to post-build a 3D CT or UT/RT surface or embedded flaw. Procedures are to be in place to address discrepancies between in-situ indications as identified during process monitoring and subsequent NDT results, including additional diagnostic scanning or other verification measures.

(ii) The in-situ process monitoring model can be validated using the data captured by high-resolution CT scans as verified data (actual flaw location and size).

(iii) NDT indications or defects, e.g. gas porosity, keyhole pores, lack of fusion, is classified or categorized by outputs/resultant data of the machine learning model, if applicable.

(iv) Unless otherwise agreed, the probability of detection for in-situ process monitoring should meet the 90%/95% reliability of flaw detection. e.g. 100 layers were selected for analysis and detection of flaws in 90 layers can meet the lower bound of 95% confidence interval for the defined flaw size in accordance with the acceptance criteria of the applicable requirements of **Pt2, Annex 2-7** and **Annex 2-12 of the Guidance**, **ISO 5817:2023**, **ISO 10675-1:2021**, **ISO 10675-2:2021** or equivalent standards, which may depend on the section thickness of the part. In-situ flaw detection procedures should be documented, and capability should be supported by procedure verification and validation results.

(v) When in-situ process monitoring is adopted during initial qualification and production, repeatability and data detection should be verified, and results should be analyzed, with at least 10% of the cross-validated data verified by the traditional or advanced NDT techniques. (e.g. 10 parts use an in-situ process for flaw detection, at least 1 part should be inspected using traditional or advanced NDT techniques). To accept in-situ process monitoring for small-batch or one-off critical parts, the Society may require a higher percentage of cross-checking, commensurate with the criticality of the component and the agreed ITP.

203. Identification, Retesting and Surveys

1. Identification

The manufacturer should adopt a system for the identification of AM parts e.g. build batch number control, which will enable the parts to be traceable to the applied AM process and test report, and the Surveyor should be given full facility access for tracing the material when required.

2. Retesting

Material retesting for parts subject to classification requirements should follow Class Rules. For certified parts, material retesting may be specifically agreed. Test results for the original test and retest should be reported for class and certified parts.

3. Surveys

(1) Surveyor witness for functional testing, such as pressure or proof load tests, is required for class

and certified critical parts during the prototype part qualification stage and may be required for class parts during production. Functional testing could be carried out at a workshop or on-board, subject to a factory acceptance test and/or a site acceptance test as specified in the approved ITP or contract agreement. Surveyor witness after installation should be agreed in accordance with the applicable Society requirements.

(2) A surveyor witness for material testing is required for class and certified parts during the prototype qualification stage. During the production stage, surveyor witness for material testing is required for a class part but is optional for a certified part.

- Notes: AM parts may need additional survey when in service, when compared to traditionally manufactured parts. This may be required because AM parts do not yet have sufficient marine service history. This should be identified early on as part of the design and build philosophy.

4. Repair for AM Part

(1) Unless otherwise agreed, repair of an AM class part is prohibited without approval by the purchaser and the Society.

(2) If repair of the AM part during production is needed, repair procedures and the method for repair should be suitably established and agreed to by the Society prior to repair.

204. Repair of AM Part Damaged In-service

1. If repair of an AM class part in service is needed, repair procedures and the method for repair should be suitably established and agreed to by the original additive manufacturer or AM repair facility and the Society prior to repair, refer to **Ch 7**.

2. For the repair of non-class AM parts damaged in service, the repair procedure and the method of repair should be according to the applicable specifications per industry standards, designer/OEM requirements, refer to **Ch 7**.

205. Part Certificate

A part certificate should be issued by the Society for class. Certificates for certified items should be issued by the manufacturer and should be supported by the manufacturer's documents in accordance with **Ch 6, Sec 1** and **Sec 2** as applicable. Unless otherwise agreed, certification should be furnished for the final delivered part by the additive manufacturer indicating.

(1) Material grade
(2) Chemical composition
(3) Reference to the Additive Manufacturing Procedure Qualification Record
(4) Tensile test results
(5) Charpy test results, if applicable
(6) Hardness, if applicable
(7) Nondestructive test results
(8) Any additional specialized test results
(9) Function test results, if applicable
(10) Other intermediate processes such as heat treatment, surface finish, machining conditions

206. Marking

For AM products which have satisfactorily complied with the required tests, "***-AM***" is to be suffixed to the product marking.

Section 3 Non-Conformance and Documentation

301. Non-Conformance

1. If parts do not conform to the specified requirements, non-conformance reports should be generated, documented, and maintained by the additive manufacturer. Parts may be accepted or rejected with or without reworking based on engineering justification, which should be agreed to by the Society and purchaser.
2. The manufacturer should keep a record of all non-conformities, where warranted, and should carry out root-cause investigations, if systematic errors are identified within any part of the process or components.

302. Documentation

The following items in **Table 6.5** should be documented by the manufacturer in accordance with the quality management system/program and provided as production records with full traceability.

Table 6.5 Documentation for Production Records

No.	Item
1	AMPS with revision control including the feedstock specification, the final material specification, and the procedure (pre-build, build and post-build) specification
2	Drawing, solid model, software or digital build file with revision control
3	Type Approval Number or Feedstock test report
4	Additive manufacturing procedure qualification report
5	Part certificate
6	Any other part/application specific tests including test results and acceptance criteria
7	Any non-conformance reports

CHAPTER 7 APPROVAL FOR ADDITIVE MANUFACTURING REPAIR FACILITY

Section 1 General

101. General

1. This Chapter is to apply the additive manufacturing process to repair damaged parts back to the approved design.

2. This Chapter may also apply when applying the additive manufacturing process to repair products manufactured using conventional (non-additive) methods. However, additional verification may be required at the interface between the additively manufactured and conventionally manufactured areas, and this will be determined in agreement with the Society.

3. If the parts are class items, the repair facility or repair process should be approved by the Society. If the parts are not class items, the repair process should be qualified by the repair facility and the repair facility may be recognized by the purchaser or approved by the Society.

4. Approval for a repair facility involves a documentation review, an audit of the facility and the witness of approval tests. Unless otherwise agreed, the approval is valid for a maximum of 5 years subject to annual verification and/or endorsement by the attending Surveyor. An additional audit may be requested.

102. Approval application

Approval should be requested by the client, along with supporting information and a detailed inspection and test plan (ITP), refer to **Table 7.1**.

Table 7.1 Approval Application for Additive Manufacturing Repair Facility

No.	Item
1	An outline description of the repair facility including the quality management system, a facility description, details of the organization and quality control responsibilities
2	Additive manufacturing repair capability
3	Programme of inspection and evaluation of damaged parts prior to repair
4	A list of documented repair facility's repair procedures, specifications, documentation and reports and any historical repair certificates or data

Section 2 Repair Procedure Specification and Approval

201. General

The additive manufacturing procedure specification for repair should be prepared for each material and each part. Prior to conducting the repair procedure qualification tests, the repair procedure should be submitted and approved by the Society.

202. Repair Procedure Specification Approval

The repair procedure specification should be submitted to the Society for review and approval. A general description of the procedure should be prepared in accordance with **Ch 4, 203.** and **205.**.

203. Approval Test

1. Test coupons should represent the shape of the intended parts such as flat or cylinder test coupons, and the specific form of repair as allowed by the application standard for the intended use.v
2. Refer to **Table 7.2**, test coupons should be sufficient to complete the required approval tests. Based on the design requirements, the repair facility should select the applicable tests in **Table 7.3**. Test methods and test results should be in accordance with **Table 7.4**.
3. Unless otherwise agreed, the following approval tests in **Table 7.2** should be carried out and test results should be reported in accordance with **Ch 6, Sec 2** for inspection and testing and included in the qualification records.

Table 7.2 Documentation for Approval Tests and Test Results

Types of tests	Recorded items in test results
Visual inspection	Sample ID and results
Dimension inspection	Sample ID and results
Surface flaw inspection	Sample ID and results
Embedded flaw inspection (if required)	Sample ID and results
3 tensile tests for interface cross-section (if required and applicable to the damage)	Sample ID, sample orientation, sample size and test results including yield strength, tension strength, failure type and location
1 set of Charpy impact test for interface cross-section, applicable to materials with ductile-to-brittle transition (if required and applicable to the damage)	Sample ID, sample orientation, sample size and test results
Bend tests for wire arc DED processes (if applicable)	2 in the Z and 2 in X/Y direction
Hardness test for interface cross-section and heat affected zone (HAZ) in substrate	Sample ID, hardness values or hardness profile from AM build material to HAZ
Microstructure and macrostructure examination (if required)	Sample ID, part thickness at the section plane, section plane angle relative to build platform, magnification, and results
Chemical analysis	Sample ID, and results

Table 7.3 Approval Tests for Additive Manufacturing Repair Process

Material	Test items (as listed in **Table 7.4**)
Structural Steels	(1) (2) (3) (4) (5)
Nonferrous Metals for Structural Use	(1) (2) (3) (4) (5)
Corrosion Resistant Layer	(2) (4) (6) (7)
Wear-resisting Layer	(1) (3) (4) (5) (7)
Other material or other application	According to the technical design requirements, such as (6) or (9)

Table 7.4 Test Methods

Test Type		Sampling and Test Process	Acceptance Criteria for Test Results
(1)	Tensile Test (Room and High Temperature)	Refer to Class Rules or relevant internationally or nationally recognized standards and this Chapter	The minimum tensile strength should meet the design technical requirements and not to be lower than the base metal value
(2)	Bending Test		The bent surface of the specimen is not to reveal any crack exceeding 3 mm
(3)	Impact Test		Meet the base metal requirements, or design technical requirements
(4)	Hardness Test		The repair layer is to meet the design technical requirements, and the heat affected zone and base metal are to meet the recognized standards
(5)	Macro Section Test		Well fused, no defect
(6)	Corrosion Test, if required		Meet the design technical requirements
(7)	Chemical Composition		Meet the design technical requirements
(8)	Microstructure		Meet the design technical requirements
(9)	Fatigue Test, if required		Meet the design technical requirements

Section 3 Survey & Range of Approval

301. Survey

1. Initial Survey

The manufacturer should be audited by the attending Surveyor. The initial survey of additive manufacturing repair facilities should include follows.

(1) Witness of the additive manufacturing repair process
(2) Survey of repair control for agreed repeatability
(3) Evaluation of the quality management system, document control for repair procedure, specification and quality control for sampling, testing, reporting
(4) Incoming control for feedstock
(5) Inspection and testing procedure of damaged traditionally manufactured parts
(6) Outgoing inspection and testing procedure for the final repair parts through AM process etc.

2. Witness of Approval Tests

The approval tests should be witnessed by the attending Surveyor.

3. Annual Survey

The annual survey should be carried out by the attending Surveyor. The annual survey should include a plan to demonstrate the essential parameters are followed by production of a test coupon. During the annual survey, full or partial approval tests could be requested based on the performance of the annual production/repair record.

302. Information to be Submitted for Approval by the Society

The following items in **Table 7.5** should be submitted to the Society.

Table 7.5 Information to be Submitted for Additive Manufacturing Repair Facility Approval

No.	Documentation items
1	Documentation of the damaged part including the original dimensions and material grade for substrate, allowed wastage, method of defect excavation and verification of defect removal.
2	Audit report for the repair facility by the Society
3	Operator qualifications record
4	AM build material specification and documentation
5	AM repair procedure specification
6	Types of approval tests, test standards and test results in **Sec 2**
7	Surveyor's report of the witness of the repair procedure qualification approval tests
8	Qualification records with a certifying statement acknowledging the validity of the data and certifying the qualification tests and test results
9	Agreed plan for nondestructive testing during production
10	Agreed plan for in-service survey

303. Range of Approval

1. For repair of a damaged metallic part, a repair procedure specific approval letter should be issued to the repair facility by the Society, refer to **Table 7.6**.

Table 7.6 Range of Approval for Additive Manufacturing Repair Facility

No.	Items to be included in approval letter
1	Qualified feedstock linked to feedstock supplier
2	Qualified procedure(s) for repair
3	Compatible substrate material grade(s)
4	Applicable range of part size or section thickness

2. In addition, the approved AM repair procedure may be applied to other application scopes provided supplementary tests are carried out to expand the range of approval. ⚓

GUIDANCE FOR APPROVAL OF ADDITIVE MANUFACTURING (3D PRINTING)

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