Additive Manufacturing - Guidelines for Certification of Product made using Wire Arc Additive Manufacturing (WAAM) Process

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Rule Note
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BUREAU VERITAS MARINE & OFFSHORE

GENERAL CONDITIONS

1. INDEPENDENCE OF THE SOCIETY AND APPLICABLE TERMS

1.1 The Society shall remain at all times an independent contractor and neither the Society nor any of its officers, employees, servants, agents or subcontractors shall be or act as an employee, servant or agent of any other party hereto in the performance of the Services.

1.2 The operations of the Society in providing its Services are exclusively conducted by way of random inspections and do not, in any circumstances, involve monitoring or exhaustive verification.

1.3 The Society acts as a services provider. This cannot be construed as an obligation bearing on the Society to obtain a result or as a warranty. The Society is not and may not be considered as an underwriter, broker in Unit's sale or chartering, expert in Unit's valuation, consulting engineer, controller, naval architect, designer, manufacturer, shipbuilder, repair or conversion yard, charterer or shipowner; none of them above listed being relieved of any of their expressed or implied obligations as a result of the interventions of the Society.

1.4 The Society only is qualified to apply and interpret its Rules.

1.5 The Client acknowledges the latest versions of the Conditions and of the applicable Rules applying to the Services' performance.

1.6 Unless an express written agreement is made between the Parties on the applicable Rules, the applicable Rules shall be the Rules applicable at the time of entering into the relevant contract for the performance of the Services.

1.7 The Services' performance is solely based on the Conditions. No other terms shall apply whether express or implied.

2. DEFINITIONS

2.1 **"Certificate(s)"** means classification or statutory certificates, attestations and reports following the Society's intervention.

2.2 **"Certification"** means the activity of certification in application of national and international regulations or standards, in particular by delegation from different governments that can result in the issuance of a Certificate.

2.3 **"Classification"** means the classification of a Unit that can result or not in the issuance of a classification Certificate with reference to the Rules. Classification is an appraisement given by the Society to the Client, at a certain date, following surveys by its surveyors on the level of compliance of the Unit to the Society's Rules or to the documents of reference for the Services provided. They cannot be construed as an implied or express warranty of safety, fitness for the purpose, seaworthiness of the Unit or of its value for sale, insurance or chartering.

2.4 **"Client"** means the Party and/or its representative requesting the Services.

2.5 **"Conditions"** means the terms and conditions set out in the present document.

2.6 **"Industry Practice"** means international maritime and/or offshore industry practices.

2.7 **"Intellectual Property"** means all patents, rights to inventions, utility models, copyright and related rights, trade marks, logos, service marks, trade dress, business and domain names, rights in trade dress or get-up, rights in goodwill or to sue for passing off, unfair competition rights, rights in designs, rights in computer software, database rights, topography rights, moral rights, rights in confidential information (including know-how and trade secrets), methods and protocols for Services, and any other intellectual property rights, in each case whether capable of registration, registered or unregistered and including all applications for and renewals, reversions or extensions of such rights, and all similar or equivalent rights or forms of protection in any part of the world.

2.8 **"Parties"** means the Society and Client together.

2.9 **"Party"** means the Society or the Client.

2.10 **"Register"** means the public electronic register of ships updated regularly by the Society.

2.11 **"Rules"** means the Society's classification rules and other documents. The Society's Rules take into account at the date of their preparation the state of currently available and proven technical minimum requirements but are not a standard or a code of construction neither a guide for maintenance, a safety handbook or a guide of professional practices, all of which are assumed to be known in detail and carefully followed at all times by the Client.

2.12 **"Services"** means the services set out in clauses 2.2 and 2.3 but also other services related to Classification and Certification such as, but not limited to: ship and company safety management certification, ship and port security certification, maritime labour certification, training activities, all activities and duties incidental thereto such as documentation on any supporting means, software, instrumentation, measurements, tests and trials on board. The Services are carried out by the Society according to the applicable referential and to the Bureau Veritas' Code of Ethics. The Society shall perform the Services according to the applicable national and international standards and Industry Practice and always on the assumption that the Client is aware of such standards and Industry Practice.

2.13 **"Society"** means the classification society **'Bureau Veritas Marine & Offshore SAS'**, a company organized and existing under the laws of France, registered in Nanterre under number 821 131 844, or any other legal entity of Bureau Veritas Group as may be specified in the relevant contract, and whose main activities are Classification and Certification of ships or offshore units.

2.14 **"Unit"** means any ship or vessel or offshore unit or structure of any type or part of it or system whether linked to shore, river bed or sea bed or not, whether operated or located at sea or in inland waters or partly on land, including submarines, hovercrafts, drilling rigs, offshore installations of any type and of any purpose, their related and ancillary equipment, subsea or not, such as well head and pipelines, mooring legs and mooring points or otherwise as decided by the Society.

3. SCOPE AND PERFORMANCE

3.1 Subject to the Services requested and always by reference to the Rules, the Society shall:

- review the construction arrangements of the Unit as shown on the documents provided by the Client;
- conduct the Unit surveys at the place of the Unit construction;
- class the Unit and enter the Unit's class in the Society's Register;
- survey the Unit periodically in service to note whether the requirements for the maintenance of class are met.

The Client shall inform the Society without delay of any circumstances which may cause any changes on the conducted surveys or Services.

3.2 The Society will not:

- declare the acceptance or commissioning of a Unit, nor its construction in conformity with its design, such activities remaining under the exclusive responsibility of the Unit's owner or builder;
- engage in any work relating to the design, construction, production or repair checks, neither in the operation of the Unit or the Unit's trade, neither in any advisory services, and cannot be held liable on those accounts.

4. RESERVATION CLAUSE

4.1 The Client shall always: (i) maintain the Unit in good condition after surveys; (ii) present the Unit for surveys; and (iii) inform the Society in due time of any circumstances that may affect the given appraisement of the Unit or cause to modify the scope of the Services.

4.2 Certificates are only valid if issued by the Society.

4.3 The Society has entire control over the Certificates issued and may at any time withdraw a Certificate at its entire discretion including, but not limited to, in the following situations: where the Client fails to comply in due time with instructions of the Society or where the Client fails to pay in accordance with clause 6.2 hereunder.

4.4 The Society may at times and at its sole discretion give an opinion on a design or any technical element that would 'in principle' be acceptable to the Society. This opinion shall not presume on the final issuance of any Certificate or on its content in the event of the actual issuance of a Certificate. This opinion shall only be an appraisal made by the Society which shall not be held liable for it.

5. ACCESS AND SAFETY

5.1 The Client shall give to the Society all access and information necessary for the efficient performance of the requested Services. The Client shall be the sole responsible for the conditions of presentation of the Unit for tests, trials and surveys and the conditions under which tests and trials are carried out. Any information, drawing, etc. required for the performance of the Services must be made available in due time.

5.2 The Client shall notify the Society of any relevant safety issue and shall take all necessary safety-related measures to ensure a safe work environment for the Society or any of its officers, employees, servants, agents or subcontractors and shall comply with all applicable safety regulations.

6. PAYMENT OF INVOICES

6.1 The provision of the Services by the Society, whether complete or not, involve, for the part carried out, the payment of fees thirty (30) days upon issuance of the invoice.

6.2 Without prejudice to any other rights hereunder, in case of Client's payment default, the Society shall be entitled to charge, in addition to the amount not properly paid, interests equal to twelve (12) months LIBOR plus two (2) per cent as of due date calculated on the number of days such payment is delinquent. The Society shall also have the right to withhold Certificates and other documents and/or to suspend or revoke the validity of Certificates.

6.3 In case of dispute on the invoice amount, the undisputed portion of the invoice shall be paid and an explanation on the dispute shall accompany payment so that action can be taken to solve the dispute.

7. LIABILITY

7.1 The Society bears no liability for consequential loss. For the purpose of this clause consequential loss shall include, without limitation:

- Indirect or consequential loss;
- Any loss and/or deferral of production, loss of product, loss of use, loss of bargain, loss of revenue, loss of profit or anticipated profit, loss of business and business interruption, in each case whether direct or indirect.

The Client shall defend, release, save, indemnify, defend and hold harmless the Society from the Client's own consequential loss regardless of cause.

7.2 Except in case of wilful misconduct of the Society, death or bodily injury caused by the Society's negligence and any other liability that could not be, by law, limited, the Society's maximum liability towards the Client is limited to one hundred and fifty per-cents (150%) of the price paid by the Client to the Society for the Services having caused the damage. This limit applies to any liability of whatsoever nature and howsoever arising, including fault by the Society, breach of contract, breach of warranty, tort, strict liability, breach of statute.

7.3 All claims shall be presented to the Society in writing within three (3) months of the completion of Services' performance or (if later) the date when the events which are relied on were first discovered by the Client. Any claim not so presented as defined above shall be deemed waived and absolutely time barred.

8. INDEMNITY CLAUSE

8.1 The Client shall defend, release, save, indemnify and hold harmless the Society from and against any and all claims, demands, lawsuits or actions for damages, including legal fees, for harm or loss to persons and/or property tangible, intangible or otherwise which may be brought against the Society, incidental to, arising out of or in connection with the performance of the Services (including for damages arising out of or in connection with opinions delivered according to clause 4.4 above) except for those claims caused solely and completely by the gross negligence of the Society, its officers, employees, servants, agents or subcontractors.

9. TERMINATION

9.1 The Parties shall have the right to terminate the Services (and the relevant contract) for convenience after giving the other Party thirty (30) days' written notice, and without prejudice to clause 6 above.

9.2 In such a case, the Classification granted to the concerned Unit and the previously issued Certificates shall remain valid until the date of effect of the termination notice issued, subject to compliance with clause 4.1 and 6 above.

9.3 In the event where, in the reasonable opinion of the Society, the Client is in breach, or is suspected to be in breach of clause 16 of the Conditions, the Society shall have the right to terminate the Services (and the relevant contracts associated) with immediate effect.

10. FORCE MAJEURE

10.1 Neither Party shall be responsible or liable for any failure to fulfil any term or provision of the Conditions if and to the extent that fulfilment has been delayed or temporarily prevented by a force majeure occurrence without the fault or negligence of the Party affected and which, by the exercise of reasonable diligence, the said Party is unable to provide against.

10.2 For the purpose of this clause, force majeure shall mean any circumstance not being within a Party's reasonable control including, but not limited to: acts of God, natural disasters, epidemics or pandemics, wars, terrorist attacks, riots, sabotages, impositions of sanctions, embargoes, nuclear, chemical or biological contaminations, laws or action taken by a government or public authority, quotas or prohibition, expropriations, destructions of the worksite, explosions, fires, accidents, any labour or trade disputes, strikes or lockouts.

11. CONFIDENTIALITY

11.1 The documents and data provided to or prepared by the Society in performing the Services, and the information made available to the Society, are treated as confidential except where the information:

- is properly and lawfully in the possession of the Society;
- is already in possession of the public or has entered the public domain, otherwise than through a breach of this obligation;
- is acquired or received independently from a third party that has the right to disseminate such information;
- is required to be disclosed under applicable law or by a governmental order, decree, regulation or rule or by a stock exchange authority (provided that the receiving Party shall make all reasonable efforts to give prompt written notice to the disclosing Party prior to such disclosure.

11.2 The Parties shall use the confidential information exclusively within the framework of their activity underlying these Conditions.

11.3 Confidential information shall only be provided to third parties with the prior written consent of the other Party. However, such prior consent shall not be required when the Society provides the confidential information to a subsidiary.

11.4 Without prejudice to sub-clause 11.1, the Society shall have the right to disclose the confidential information if required to do so under regulations of the International Association of Classifications Societies (IACS) or any statutory obligations.

12. INTELLECTUAL PROPERTY

12.1 Each Party exclusively owns all rights to its Intellectual Property created before or after the commencement date of the Conditions and whether or not associated with any contract between the Parties.

12.2 The Intellectual Property developed by the Society for the performance of the Services including, but not limited to drawings, calculations, and reports shall remain the exclusive property of the Society.

13. ASSIGNMENT

13.1 The contract resulting from to these Conditions cannot be assigned or transferred by any means by a Party to any third party without the prior written consent of the other Party.

13.2 The Society shall however have the right to assign or transfer by any means the said contract to a subsidiary of the Bureau Veritas Group.

14. SEVERABILITY

14.1 Invalidity of one or more provisions does not affect the remaining provisions.

14.2 Definitions herein take precedence over other definitions which may appear in other documents issued by the Society.

14.3 In case of doubt as to the interpretation of the Conditions, the English text shall prevail.

15. GOVERNING LAW AND DISPUTE RESOLUTION

15.1 These Conditions shall be construed and governed by the laws of England and Wales.

15.2 The Parties shall make every effort to settle any dispute amicably and in good faith by way of negotiation within thirty (30) days from the date of receipt by either one of the Parties of a written notice of such a dispute.

15.3 Failing that, the dispute shall finally be settled under the Rules of Arbitration of the Maritime Arbitration Chamber of Paris ("CAMP"), which rules are deemed to be incorporated by reference into this clause. The number of arbitrators shall be three (3). The place of arbitration shall be Paris (France). The Parties agree to keep the arbitration proceedings confidential.

16. PROFESSIONAL ETHICS

16.1 Each Party shall conduct all activities in compliance with all laws, statutes, rules, economic and trade sanctions (including but not limited to US sanctions and EU sanctions) and regulations applicable to such Party including but not limited to: child labour, forced labour, collective bargaining, discrimination, abuse, working hours and minimum wages, anti-bribery, anti-corruption, copyright and trademark protection, personal data protection (https://personaldataprotection.bureauveritas.com/privacypolicy).

Each of the Parties warrants that neither it, nor its affiliates, has made or will make, with respect to the matters provided for hereunder, any offer, payment, gift or authorization of the payment of any money directly or indirectly, to or for the use or benefit of any official or employee of the government, political party, official, or candidate.

16.2 In addition, the Client shall act consistently with the Bureau Veritas' Code of Ethics. https://group.bureauveritas.com/group/corporate-social-responsibility

GUIDANCE NOTE NI 662

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Section 1 General Guidelines

Section 2 Guidelines for Certification of Product made by WAAM Process

Section 3 Guidelines for Type Approval of Wire for WAAM Process

Section 4 Guidelines for Qualification of WAAM Process

Section 5 Guidelines for Recognition of Manufacturer for WAAM Process

SECTION 1 GENERAL GUIDELINES

1 Scope

1.1 General

1.1.1 This document gives guidelines describing the certification procedures for products made in metallic materials by Wire Arc Additive Manufacturing (WAAM) process when intended to be used on ships or offshore units classed by the Society.

Additive manufacturing which is also known as "3D printing" means a process where a machine manufactures a product layer by layer based on a 3D model data.

1.2 Classification Rules

1.2.1 Depending on the concerned ship or offshore unit, the applicable Society's classification Rules should be referred to.

1.2.2 This document is based on the principles or makes reference to the following Bureau Veritas Rules:

- NR216 Rules on Materials and Welding for the Classification of Marine Units
- NR320 Certification Scheme of Materials and Equipment for the Classification of Marine Units
- NR266 Requirements for Survey of Materials and Equipment for the Classification of Ships and Offshore Units
- NR467 Rules for the Classification of Steel Ships
- NR445 Rules for the Classification of Offshore Units.

2 Certification scheme

2.1 General

2.1.1 The certification scheme is described in Fig 1 for the products made by WAAM.

2.1.2 The certification procedures are given in the Sec 2 of this Guidance Note.

2.2 Type approval certification of raw materials

2.2.1 The raw materials (wire and gas combination) used should be certified by the Society as defined in the Sec 3 of this Guidance Note.

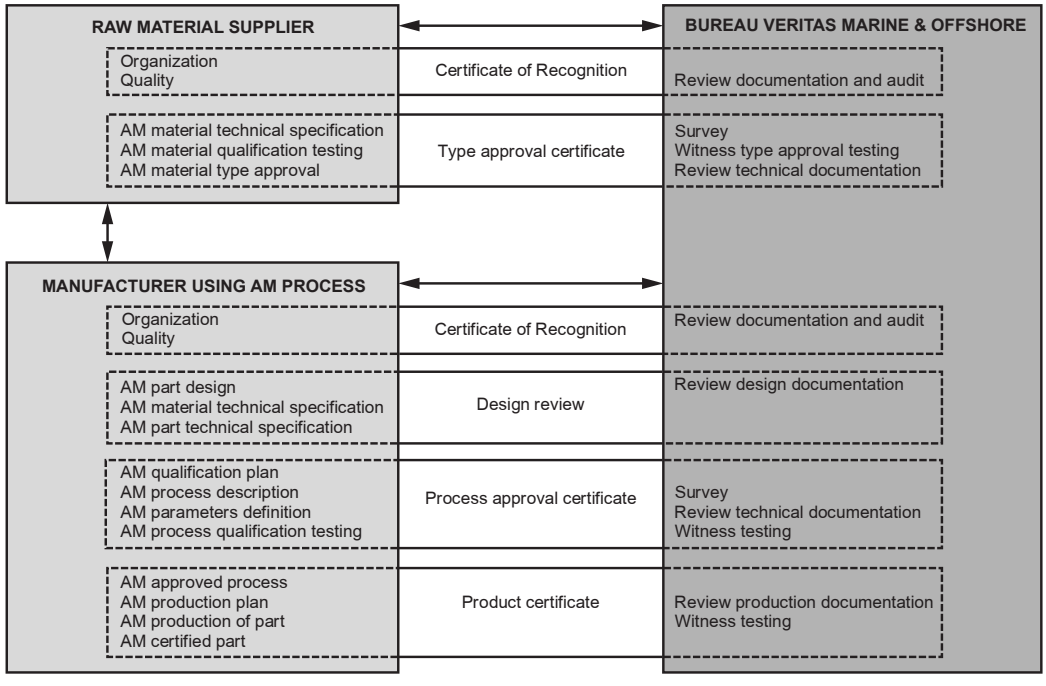
2.3 Qualification of manufacturing process

2.3.1 The additive manufacturing process should be subjected to a qualification process as defined in the Sec 4 of this Guidance Note.

2.4 Certification of products

2.4.1 The products should be certified individually or per batch according to the process described for product category IBV of the NR320 Certification Scheme of Materials and Equipment for the Classification of Marine Units.

Figure 1 : Certification scheme



3 Manufacturing, examination and testing

3.1 General

3.1.1 The plants, production and treatment procedures, testing machines, laboratories for analyses, internal control systems and personnel qualification should be suitable in the opinion of the Society.

3.2 Identification of products

3.2.1 In the course of manufacturing, inspection and testing, the identification of the various products in respect of their origin should be ensured.

To this end the surveyor should be given all facilities for tracing the products when required.

3.3 Delivery condition

3.3.1 The products should be supplied in the finished condition, including post-treatment as applicable.

Heat treatment should be carried out in suitable and efficient furnaces, fitted with appropriate means for temperature control and recording. Sufficient thermocouples should be connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace is verified at regular intervals. The manufacturer should maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature and time at temperature. The records should be presented to the surveyor on request.

The furnaces employed should have a size sufficient to allow a uniform increase in temperature up to the required value of the entire product to be heat treated.

3.4 Examinations and tests

3.4.1 The examinations and tests should be carried out at the manufacturer's works before delivery.

If the necessary facilities are not available at the manufacturer's works, testing may be carried out at testing facilities to be agreed with the Society.

3.4.2 Where the testing is agreed to be carried out or completed at works other than the manufacturer's it should be possible in any cases to trace back the products, samples or specimens to their documentation of origin.

3.4.3 The testing and measuring equipment should be adequate, maintained in proper condition and regularly calibrated, as required; the record of such checks should be kept up-to-date and made available to the surveyor.

3.4.4 Test methods and specimens used to verify material's mechanical properties should comply with the requirements of NR216, Chapter 1, Section 2 as far as practicable. Recognised standards acceptable to the Society may be used.

3.4.5 The type of mechanical tests, the type and number of test samples, the number and direction of the test specimens and the results of the tests should comply with the technical documents agreed at the qualification stage.

3.4.6 The test samples should be prepared, selected and marked for identification purposes in accordance with the technical documents agreed at the qualification stage.

3.4.7 The test samples have to be subjected to the same post treatment as the products they represent except when a different procedure is agreed with the Society.

3.5 Re-test procedures

3.5.1 General

Where the unsuccessful outcome of any test is attributable to defective machining of the test specimen and/or to improper test procedure, the negative result is disregarded and the test repeated, in correct conditions, on a substitute test specimen.

3.5.2 Rejection or reconsideration

The re-testing conditions, including possible reheat treatment, should be defined at the qualification stage.

In the absence of qualified conditions for re-testing, the unit or batch represented by the failed testing should be rejected.

3.6 Visual, dimensional and non-destructive examinations

3.6.1 General

The products should be subjected to:

- visual examination
- dimensional check
- non-destructive examination, when applicable.

These checks and examinations should be carried out on products in appropriate conditions under the responsibility of the manufacturer and should be witnessed or repeated in the presence of the surveyor when required.

When, following examinations and tests, there are grounds to presume that a product may be defective, the manufacturer is obliged, for the purpose of acceptance, to demonstrate its suitability using procedures deemed necessary.

3.6.2 Visual examination

Visual examination is to be carried out by the manufacturer. A general examination should be carried out by the surveyor at his discretion on each product tested individually and at random on products tested by batch.

3.6.3 Dimensional check

The dimensional checks and verification of compliance with approved drawings are the responsibility of the manufacturer. Some checks may be made in the presence of the surveyor, as deemed necessary.

3.6.4 Non-destructive examination

Non-destructive examination should be performed by skilled and qualified personnel, using calibrated equipment of suitable type and according to approved procedures, recognised standards and the requirements of the Society.

The manufacturer's laboratory or other organisation responsible for the non-destructive examination is required to issue, on its own responsibility, a certificate illustrating the results and, where requested, an opinion concerning the acceptability of the product; in the latter case, the certificate should be countersigned by the manufacturer.

The various steps of the examinations should be witnessed by the surveyor when required.

3.7 Repairs of defects

3.7.1 Small surface defects may be suitably removed by grinding or other appropriate means, provided that the dimensional tolerances are complied with.

The repaired zone should be found free from defects and to be acceptable in the opinion of the surveyor.

3.7.2 Other types of repair should be defined at the qualification stage according to a documented procedure.

3.8 Surveyor's interventions

3.8.1 Interested parties should apply for Society's intervention in adequate time.

Prior to the survey, the manufacturer should provide the surveyor with technical details of the orders, technical specifications and any special condition.

3.8.2 The surveyors should have free access to all departments involved in production, collection of test samples, internal control and, in general, all operations concerning the manufacturing, examination and testing.

They should be supplied with the information necessary to assess whether production and tests are performed according to the applicable documents.

3.8.3 The tests and checks should be carried out in the presence of the surveyors according to the applicable quality control plan agreed with the Society.

3.9 Responsibilities of the manufacturer

3.9.1 The manufacturer is fully responsible for the quality of the finished product and ensuring compliance with the specified requirements, as checked on the specimens subjected to the qualification tests.

The routine production shall be carried out according to the same procedures followed for the manufacture of specimens submitted to qualification tests.

The manufacturer shall give prior warning to the Society of any significant modifications to the manufacturing and control procedures. The Society may at its discretion, require further tests and surveys deemed necessary to extend the qualification to the new manufacturing conditions.

The manufacturer shall keep up-to-date records covering the manufacture and quality control of the products; the records shall contain details allowing the identification of the various raw materials, manufactured products, heat treatment and results of tests and examinations carried out. The Society's surveyor should have easy access to these records as deemed necessary.

3.9.2 Irrespective of the interventions of the Society, the manufacturer is entirely and solely responsible for compliance of the supplied products with the purchaser's specifications and the technical documents agreed with the Society.

The Society assumes no liability by its interventions in respect of the compliance of a tested product with the stipulated regulations and requirements.

Where, in the course of manufacture or after supply, a product is found not to be in compliance with the requirements or to present unacceptable defects, it will be rejected, irrespective of any previous satisfactory test results.

4 Identification and certification

4.1 Identification and marking

4.1.1 General

For the survey, a detailed record of the products to be certified should be submitted to the surveyor with indication of the necessary data, as applicable:

- name of purchaser and order number
- hull number or destination
- raw materials type, brand and identification
- number, size and mass of units or batches
- product reference number, details of manufacturing process and post treatment
- condition of supply.

4.1.2 Manufacturer's marking

Products, which have satisfactorily undergone the required examinations and tests should be appropriately marked by the manufacturer in at least one easily accessible location.

The marking should contain all necessary indications for the products, and should correspond to the content of the certification documentation.

The marks should be stamped, as a rule, by means of brands, except when products could be impaired by such a system. When paints or other reliable alternatives are adopted, adequate duration of marking should be ensured.

4.1.3 Marking with the Society's brand

The products found satisfactory should be marked with the Society's brand ⅋ in the presence of the surveyor unless otherwise agreed between manufacturer and Surveyor.

4.1.4 Society marking for incomplete inspection

Whenever a product is dispatched for delivery or should be marked without undergoing all the examinations and tests required by the agreed technical documents, the Society's brand ⅋ will be replaced by the Society's mark ⅋ for incomplete inspection.

The testing documents should contain clear indications of all outstanding inspections and tests and specify the reason why they have not been performed.

Upon satisfactory completion of all required tests, the product should be stamped with the Society's brand ⅋.

4.1.5 Invalidation of Society's brand

When during or subsequent to testing, a product already stamped is found not to be in compliance with the requirements and is therefore rejected, the Society's brand should be invalidated by punching them.

The surveyors may request to check the invalidation effected.

Any repairs after the product is tested are subject to the prior consent of the Society; failing this, the validity of the original testing will automatically expire and the original testing marks should be invalidated by the interested parties.

4.2 Documentation and certification

4.2.1 Society's product certificate

For products tested with satisfactory results, the Society issues a certificate signed by the surveyor stating that the products have been tested in accordance with stated referenced documents.

This Society's product certificate is identified by the letter C for ease of reference in the various relevant Society's Rules.

A document issued by the manufacturer should be attached to the Society's certificate and should include, as applicable, the following particulars:

- manufacturer's name
- purchaser's name, order number and hull number
- description of the product, dimensions and weight
- identification of specification or grade of material
- supply condition and details of heat treatment, including temperatures and holding times
- reference to the Society's approval for the qualification of the process
- results of all specified examinations and tests
- identification and testing marks stamped on the product.

SECTION 2 GUIDELINES FOR CERTIFICATION OF PRODUCT MADE BY WAAM PROCESS

1 General

1.1 Scope

1.1.1 This Section gives guidelines for the certification of products made by WAAM process.

1.1.2 A product is considered to be fully made by WAAM process when the finished product is fully made of metal deposited by the WAAM process. Finished product means the product obtained after all manufacturing operations, including final machining.

1.1.3 A product is considered to be partly made by WAAM process when the finished product is including the product used (like a plate, bar, pipe, casting or forging) to deposit the metal by the WAAM process (also called substrate).

2 Recognition of manufacturer

2.1 Scope

2.1.1 The manufacturer should be recognised according to the Sec 5 of this Guidance Note.

3 Design of product

3.1 Material data for design

3.1.1 The designer of the product has to define the material properties which are necessary to ensure that the design of the product is suitable with due consideration to the functions, applied loads, service environment and failure modes of the product, typically:

- tensile properties
- fracture properties (typically charpy V, CTOD, NDT Pellini)
- fatigue properties (typically S/N curves, crack propagation rates) including in specific environments as applicable
- corrosion resistance properties (general corrosion, specific types of corrosion like pitting, crevice and stress corrosion cracking), as applicable to the specific environments.

The design material data should be submitted to the Society with the justification of the choices made by the designer, with particular attention to the possible anisotropy of the material deposited by the WAAM process.

3.2 Design review

3.2.1 General

The design rules used for the concerned product should be described. Reference to the applicable Society's classification rules should be made with particular attention to the consistency of the material data taken as design hypothesis.

3.2.2 Documentation to be submitted

Reference is made to the relevant parts of the Society's Classification Rules which describe the documents to be submitted for design review (typically design drawings, material specification, calculation notes).

The non-destructive examination plan should be submitted to the Society for review. The plan should include magnetic particle or liquid penetrant testing, ultrasonics and/or radiographic testing. The plan should detail the extent of the testings and the associated acceptance criteria.

4 WAAM process qualification

4.1 Qualification

4.1.1 The WAAM process should be qualified according to the Sec 4 of this Guidance Note.

4.2 Validity of qualification

4.2.1 The manufacturer should submit documents justifying the validity of the WAAM process qualification conditions with regards to the design and manufacture of the product to be certified.

5 Wire-gas combination

5.1 General

5.1.1 The wire-gas combination intended to be used should be type approved in accordance with the requirements of the Sec 3 of this Guidance Note.

When non-approved wire-gas combination is used, the requirements relevant to the qualification and subsequent certification of products are agreed on a case-by-case basis.

6 WAAM Operators

6.1 General

6.1.1 The operators in charge of the setting-up and/or adjustment of the automatic WAAM equipment should be qualified.

The qualification testing and the conditions of approval should be agreed with the Society with reference to ISO 14732.

7 Manufacturing, examination and testing

7.1 Product fully made using WAAM

7.1.1 Manufacturing

The manufacturing of the product is to be carried out in accordance with the approved Additive Manufacturing Procedure Specification (AMPS).

The reference test sample is to be manufactured using the same equipment and the same AMPS under the same production conditions as defined during the qualification of the process.

In the case of a post-process heat treatment, the product and the reference test sample should be heat treated together in the same furnace charge according to the post-heat treatment parameters of the qualified AMPS.

The product used as substrate is to be fully removed from the final product as well as sufficient deposited metal in order to ensure the homogeneity of the final product (typically first 3 layers).

7.1.2 Production testing

The testing plan defined during the qualification for the reference test sample (type of tests, location and number of test specimens) should be carried out with satisfactory results in accordance with the reviewed material specification.

7.2 Product partly made using WAAM

7.2.1 Base product

The base product is the product on which the layers are deposited.

The base product should be certified by the Society in accordance with the appropriate requirements of NR216 Rules on Materials and Welding for the Classification of Marine Units.

7.2.2 Manufacturing

The base product should be prepared according to the approved Additive Manufacturing Procedure Specification. (AMPS)

The manufacturing of the product is to be carried out in accordance with the approved AMPS.

The reference test sample is to be manufactured using the same equipment and the same AMPS under the same production conditions as defined during the qualification of the process.

In the case of a post-process heat treatment, the product and the reference test sample should be heat treated together in the same furnace charge according to the post-heat treatment parameters of the qualified AMPS.

7.2.3 Production testing

The testing plan defined during the qualification for the reference test sample (type of tests, location and number of test specimens) should be carried out with satisfactory results in accordance with the reviewed material specification.

7.3 Visual and dimensional examination

7.3.1 Visual examination

The product is to be cleaned and adequately prepared for examination without using means which could obscure defects.

The visual examination is to be carried out by the manufacturer, including internal surfaces as applicable.

The product should be presented to the surveyor for visual examination.

7.3.2 Dimensional examination

The verification of dimensions and tolerances is the responsibility of the manufacturer at any stages of the production.

Checks of some dimensions for verification of compliance with the reviewed drawings might be done in the presence of the surveyor upon his request.

7.4 Non-destructive testing

7.4.1 General

Non-destructive examinations according to the plan reviewed by the Society should be carried out after any specified post heat treatment.

7.4.2 Magnetic particle or liquid penetrant testing

The magnetic particle or liquid penetrant testing, as applicable, should be carried out on the finished product in accordance with the plan reviewed by the Society.

The procedures for magnetic particle testing should take into account the deposition pattern in order to search for imperfections that may be transverse or longitudinal to the deposited runs.

The magnetic particle or liquid penetrant testing should be carried out in the presence of the surveyor according to the plan reviewed by the Society.

7.4.3 Radiographic testing

Radiographic testing, if any, should be carried out in accordance with the plan reviewed by the Society.

Radiographs and their examination results should be submitted to the surveyor for acceptance.

7.4.4 Ultrasonic testing

The ultrasonic testing procedure should be submitted to the Society for review.

The procedures for ultrasonic testing should take into account the deposition pattern in order to search for imperfections that may be transverse or longitudinal to the deposited runs.

Ultrasonic testing, if any, should be carried out in accordance with the plan reviewed by the Society. The surveyor may require to witness the testing.

7.5 Repair during printing

7.5.1 Defective parts of material may be removed by grinding or machining in order to obtain a surface which is compatible with a re-start of the printing process.

7.5.2 Complete elimination of the defective material should be verified by magnetic particle or liquid penetrant testing before re-starting the printing according to the AMPS.

7.5.3 If starts and stops locations which are not part of the initial pattern are to be kept in the finished product due to the repair conditions, their locations are to be recorded in order to take them into account in the same way as the scheduled starts and stops locations.

7.5.4 In case of repairs which are not carried out as part of the normal printing process, reference is made to [7.7].

7.6 Repair by grinding after printing

7.6.1 Defective parts of material may be removed by grinding, or by chipping and grinding or by arc-air gouging and grinding. When arc-air gouging is used, suitable preheating should be applied when necessary due to the chemical composition and/or the dimensions of the product.

All grooves should have a bottom radius of approximately three times the groove depth and should be smoothly blended to the surface area with a finish equal to that of the adjacent surface.

Shallow grooves or depressions resulting from the removal of defects should not to cause appreciable reduction in the strength of the product and may be accepted with the agreement of the Society.

Elimination of the defective part of material should be verified by a magnetic particle or liquid penetrant testing.

The manufacturer is to maintain records detailing the extent and location of repairs made to each product. The records should be presented to the surveyor and copies provided on request.

7.7 Repair by welding after printing

7.7.1 Before welding is started, full details of the extent and location of the repair, the proposed welding procedure specification, heat treatment and subsequent inspection procedures should be submitted to the Society for approval.

7.7.2 Depending on the type of repair to be done, the repair may be done using the qualified WAAM process used to manufacture the product. In other cases the welding procedure is to be qualified according to a program submitted to the Society taking the WAAM deposited metal as base metal.

7.7.3 The excavations should be suitably shaped to allow good access for welding. The resulting grooves should be subsequently ground smooth and complete elimination of the defective material should be verified by magnetic particle or liquid penetrant testing.

7.7.4 Depending on the grade of material to be repaired, suitable pre-heating is to be applied, in accordance with the welding procedure specification.

7.7.5 The welding consumables used should be of an appropriate composition, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent product.

7.7.6 Welding is to be done under cover in positions free from draughts and adverse weather conditions by qualified welders with adequate supervision, in accordance with the approved welding procedure specification. As far as possible, all welding is to be carried out in the downhand (flat) position.

7.7.7 After welding has been completed the products are to be heat treated, as required by the repair procedure.

7.7.8 On completion of heat treatment the weld repairs and adjacent material should be ground smooth and examined by magnetic particle or liquid penetrant testing. Supplementary examination by ultrasonics or radiography may also be required depending on the dimensions and nature of the original defect. Satisfactory results should be obtained from all forms of non-destructive testing used.

7.7.9 The manufacturer should maintain full records detailing the extent and location of repairs made to each product and details of weld procedures and heat treatment applied for repairs. These records should be available to the surveyor and copies provided on request.

7.8 Identification and marking

7.8.1 The manufacturer should adopt a system of identification which will enable all finished product to be traced to the wire drums used and treatments done.

Before acceptance, all products which have been tested and inspected with satisfactory results should be marked with the following details:

- manufacturer's name or trade mark
- identification mark for the grade of material
- identification number which will enable the history of the fabrication of the product to be traced
- Society's marks including Society's certificate number
- test pressure, where applicable.

Modified arrangements for identification and marking may be agreed with the Society in the case of small products manufactured in large numbers.

7.9 Documentation and certification

7.9.1 The testing documentation should include all the information, as appropriate.

Where applicable, the reports relevant to the non-destructive examination, weld repair and pressure test should be enclosed with the testing documentation.

7.9.2 Upon satisfactory results, the Society should issue a certificate to the manufacturer with relevant details.

SECTION 3 GUIDELINES FOR TYPE APPROVAL OF WIRE FOR WAAM PROCESS

1 General

1.1 Scope

1.1.1 This Section applies to the type approval and periodical control tests of wires used in WAAM process for normal and high strength steels, extra high strength steels, austenitic and austenitic-ferritic stainless steels, martensitic stainless steels, and aluminium bronze.

Other types of materials or grades may be considered by the Society.

1.2 Grading and designation

1.2.1 Grading

Wires are in general classified with a grade depending on the mechanical and chemical properties of the deposited metal.

Other grades of wires may be considered for specific applications or materials on a case-by-case basis.

1.2.2 Prefix or suffix

Acronyms are added as a prefix or suffix to the grade, as appropriate:

- prefix WAAM
- suffix PHT when mechanical properties on deposited metal have also been verified after a post-process heat treatment.

1.2.3 Shielding gases

The type of shielding gas used in combination with the wire should be reported.

The classification of the shielding gas should be in accordance with the standard ISO 14175.

2 Type approval procedure

2.1 General

2.1.1 Request for type approval

The request for type approval should be submitted to the Society by the manufacturer, together with the specific information indicated in the Articles relevant to the various wires.

2.1.2 Type approval tests

The type approval tests should be performed on samples of wires representative of the wires production.

Sampling procedures should be agreed with the surveyor.

The surveyor's interventions for the manufacturing of the test samples should be agreed with the Society. The inspection of the test samples and the mechanical tests should be carried out in the presence of the surveyor.

Unless otherwise specified, test specimens and procedures should be in accordance with the applicable Society's requirements or recognized standards accepted by the Society.

2.1.3 Type approval certification

Upon satisfactory completion of the approval tests, a certificate of approval is issued by the Society to the manufacturer. The certificate states the grade under which the wire has been approved and the terms of validity of the approval which is normally one year.

The approved wires and relevant grades are entered in the lists of consumables approved by the Society which is visible on the Society's web site.

2.1.4 Recognition of manufacturing plant

The manufacturer's plant should be recognized by the Society in accordance with NR320 and this Guidance Note.

The method of production and quality control of wires should be such as to ensure reasonable uniformity in manufacture.

The manufacturer should ascertain this uniformity by means of analysis and systematic testing on each production batch.

The wires should be supplied with a packaging sufficiently strong to resist the usual transportation and handling operations.

The manufacturer should stamp on each drum the markings which are necessary to trace back each production.

2.1.5 Annual inspections and tests

The workshops where type approved wires are manufactured are subject to annual inspections by the surveyor.

During the inspection, samples of the approved wires are selected by the surveyor and subjected to the tests detailed in the Articles relevant to the various products. These tests should be repeated annually so as to provide an average of at least one test per year.

At the Society's discretion, the wires to be used in the above tests may be obtained from users or dealers, instead of the manufacturer as stated above; the wires should be recently produced (in general less than 6 months).

Alternative procedures based on quality control and quality assurance systems may be considered and accepted subject to special approval by the Society, which will state the relevant acceptance conditions on a case-by-case basis.

2.1.6 Manufacturer's responsibilities

After the type approval has been obtained, and irrespective of the periodical tests carried out under witnessing of the Society, the manufacturer is fully responsible for the quality of the wires and compliance with the specified requirements, as verified in the type approval and periodical control tests.

The manufacturer should keep up-to-date records of the manufacture of the type approved wires, including details of the history of the single productions and results of associated tests. The Society should have free access to these records at all times.

The manufacturer is responsible for reporting to the Society any major modifications introduced in the wire production procedure subsequent to its type approval.

Full compliance on the part of the manufacturer with all the requirements stated by the Society in connection with the approval of wires is an essential condition for granting and renewing such approval.

2.1.7 Firms with several workshops or dealers

When wires of the same brand are manufactured in different workshops belonging to the same manufacturer, the complete series of tests is generally performed in one workshop only. In the other workshops, a reduced test program, at least equivalent to annual tests, is permitted if the manufacturer certifies that the material used and the fabrication process are identical to those used in the main works.

2.1.8 Different brand names

When a wire already approved at a manufacturer is transferred for sale under a different brand name to the manufacturer or to a dealer, the manufacturer and the dealer where applicable have to certify that the wire with the alternative brand name is strictly identical to the consumable already approved.

2.1.9 Changes in grading

Changes in grading of wires should be considered only at the manufacturer's request, in general at the time of annual testing. For upgrading, initial type approval tests are required.

Decision to downgrade or withdraw the type approval may be taken by the Society when the prescribed tests and re-tests fail to meet the requirements.

2.1.10 Additional tests

The Society may, in some specific cases, request additional tests or requirements as deemed necessary.

2.2 Documentation to be submitted

2.2.1 Wire specification

The technical specification of the wire should be submitted. The commercial name, type of wire, diameter range and chemical composition range should be included.

2.2.2 Shielding gas

The type of shielding gas or gas mixture, commercial name and manufacturer's name should be detailed.

2.2.3 Deposited metal

The grading under which the wire gas combination is to be approved and the limitations (like positions, type of current) should be specified.

The typical chemical composition of the deposited metal showing the content of alloying elements should be detailed.

2.2.4 Process recommendations

The manufacturer's recommendations for deposition patterns, process parameters and limitations should be included.

2.2.5 Testing plan and samples

The testing plan showing the type of tests and the number and location of test specimens should be submitted both for initial type approval testing and for periodical checks.

Drawings showing the dimensions of test samples should be submitted.

2.3 WAAM type test samples

2.3.1 Base material

For the preparation of type test samples, base material similar to the deposited material is normally used as basis for the deposits. When the chemical composition of deposited metal is substantially different from the base material, an overlay may be carried out, as deemed necessary. Three layers may be typically used in order to avoid dilution effects.

2.3.2 Wire diameter

The diameter tested should be the diameter type approved.

In case of a range of diameters, the minimum and maximum wire diameter to be type approved should be tested.

2.3.3 Depositing conditions

The depositing conditions used, such as amperage, voltage, travel speed, preheating temperature and temperature between layers should be within the range recommended by the manufacturer for WAAM practice.

The type test samples should be deposited using runs according to the defined pattern. The sequence of runs and the method to measure temperature between runs or between layers and the location of measurements, as applicable, should be described.

Records of parameters used during manufacturing of the type test sample should be kept by the manufacturer under appropriate format. Sample of records should be part of the technical documentation submitted to the Society.

2.3.4 Dimensions of type test samples

The dimensions of the type test sample(s) should be defined by the manufacturer in order to ensure that the properties are tested in the less favorable direction. The manufacturer should submit the limitations about minimum and maximum wall thicknesses which are considered represented by the type test sample(s).

For tensile properties, lower values are usually experienced in the Z direction which is perpendicular to the plane of the deposited layers.

The dimensions of the type test sample should be sufficient to allow to take the necessary specimens for testing. The volume made of the first three layers over the base material should not be used to sample test specimens in order to avoid dilution effects.

Typical dimensions of test sample could be a single wall of 12 mm width, 60 mm height and 500 mm length deposited on a suitable base material depending on the type of deposited metal.

2.3.5 Post-process heat treatment

Post-process heat treatment of the type test samples is not allowed unless the wire is to be approved for the PHT condition.

2.4 Reference test samples for periodic checks

2.4.1 Reference test samples identical to WAAM type test samples

The manufacturer may consider that the periodic checks should be made using the same geometry of samples as the one used for the initial type testing.

In such case, there are no additional samples to be prepared at the initial type approval stage.

2.4.2 Other reference test samples

The manufacturer may propose to use simplified reference test samples for periodic checks. The dimensions of the test samples and the testing plan showing the number and location of test specimens should be submitted by the manufacturer.

The reference test samples should be manufactured with a wire from the same batch as the one used to manufacture the WAAM type test samples.

The runs should be deposited using the parameters of the same procedure as the one used to make the WAAM type test sample.

In case of a post-process heat treatment, the reference test samples should be heat treated together with the type test samples.

The dimensions of the test samples should be sufficient in order to allow to take the specimens.

The test results from the simplified reference test samples should be consistent with the test results from the type test samples.

2.5 Non-destructive tests

2.5.1 General

The test samples should be subjected to non-destructive testing after post-process heat treatment, as applicable, and prior to the cutting of test specimens.

Non-destructive testing should consist of visual examination and liquid penetrant or magnetic particle test and radiography or ultrasonic test.

Imperfections should be assessed in accordance with ISO 5817 Class B for steel, as applicable.

2.6 Chemical composition

2.6.1 The checking of the chemical composition should be carried out on shavings taken from the test samples clear from the first three layers.

2.6.2 The chemical analysis of the deposited metal should be supplied by the manufacturer and should include the content of all significant alloying elements.

2.7 Mechanical tests

2.7.1 General

The test specimens for mechanical tests should be taken from the test samples according to the agreed plan.

The requirements relevant to the calibration of the equipment, test specimens and testing procedure should comply with NR216, Chapter 1, Section 2 as appropriate.

2.7.2 Tensile tests

Round test specimens for tensile tests should be taken from the test samples according to the agreed plan.

The yield stress, tensile strength and elongation should be determined and should comply with the requirements specified for the various wires. The reduction of area should be determined and reported for information.

2.7.3 Impact tests

Charpy V-notch impact test specimens should be taken from the test sample according to the agreed plan.

For each orientation tested, a set of three specimens should be prepared and tested. The average impact energy should comply with the values specified for grade tested and only one individual value may be lower than the average required, provided it is not lower than 70% of it.

2.8 Re-test procedures

2.8.1 General

When the non-destructive testing of the test sample gives unacceptable results which are due to the operating conditions, the test samples may be allowed to be repeated, in duplicate if deemed necessary, with the same procedure. In other cases, as well as when cracks are detected, the wire gas combination will not be approved.

The operating conditions for the re-test samples should be agreed with the surveyor, as deemed appropriate.

For the approval of the wire gas combination, or for the continuation of the testing program, the re-test samples should produce satisfactory results.

2.8.2 Tensile tests

Where the result of a tensile test does not comply with the requirements, duplicate test specimens of the same type should be prepared from the same sample and satisfactorily tested. Where original material is not available, a new test sample should be prepared using wire of the same batch. If the new test sample is made with the same procedure as the original test sample, only the duplicate re-test specimens need to be prepared and tested. Otherwise, all test specimens should be prepared for re-testing.

2.8.3 Charpy V-notch impact test

Reference is made to NR216, Ch 1, Sec 2, [4.4].

3 Wire-gas combinations for WAAM of normal and high strength steels

3.1 Grade

3.1.1 Wire gas combinations are divided, for the various strength levels, into grades as defined in Tab 1.

3.2 Type approval

3.2.1 Reference is made to procedure and testing described in Article [2].

The results of the tests should comply with the requirements of Tab 1.

3.3 Annual control tests

3.3.1 The annual tests should include at least the following:

- the agreed reference test samples should be welded with wires having minimum and maximum diameter, as applicable.
- the tests according to the agreed plan for periodical checks should be carried out.
- the chemical composition may be required to be checked under conditions corresponding to those of the type approval tests.

4 Wire-gas combinations for WAAM of extra high strength steels

4.1 Grade

4.1.1 Wire-gas combinations are divided, for the various strength levels, into grades as defined in Tab 2.

4.2 Type approval

4.2.1 Reference is made to procedure and testing described in Article [2].

The results of the tests should comply with the requirements of Tab 2.

4.3 Annual control tests

4.3.1 Reference is made to [3.3].

5 Wire-gas combination for WAAM of Cr-Ni austenitic and austenitic-ferritic stainless steels

5.1 Grade

5.1.1 Wires intended for additive manufacturing of austenitic steels are divided into the following grades designated by a symbol corresponding to the AWS designation of the deposited metal, as follows: 308, 308L, 316, 316L, 316LN, 317, 317L, 309, 309L, 309Mo, 310, 310Mo, 347.

The additional symbol BT is added when the requirements on impact test energy are satisfied at the temperature of –196°C.

Wires for austenitic-ferritic steels are designated by a symbol indicating the nominal percentage content of Cr and Ni in the deposited metal (e.g. 2205 means 22% Cr and 5% Ni).

The relevant prefix and/or suffix should be added to the grade.

5.2 Type approval

5.2.1 Reference is made to procedure and testing described in Article [2].

The results of the tests should comply with the requirements of Tab 3.

5.2.2 For wires to deposit austenitic-ferritic steels, the ratio ferrite/austenite is also to be determined in the all deposited material.

Table 1 : Mechanical properties - Normal and high strength steels

Grade	Tensile test			Charpy V-notch impact test	
	Yield stress R_{eH} (N/mm^2) min.	Tensile strength R_m (N/mm^2)	Elong. A_5 (%) min.	Test temp. (°C)	Minimum average energy (J)
1	305	400 - 560	22	+ 20	34
2				0	
3				– 20	
2Y	375	490 - 660	22	0	34
3Y				– 20	
4Y				– 40	
5Y				– 60	
2Y40	400	510 - 690	22	0	39
3Y40				– 20	
4Y40				– 40	
5Y40				– 60	

Table 2 : Mechanical properties - Extra high strength steels

Grade		Tensile test			Charpy V-notch impact test	
		Yield stress R_{eH} (N/mm^2) min.	Tensile strength R_m (N/mm^2)	Elong. A_5 (%) min.	Test temp. (°C)	Minimum average energy (J)
3	Y42	420	530 - 680	20	– 20	47
4					– 40	
5					– 60	
3	Y46	460	570 - 720	20	– 20	47
4					– 40	
5					– 60	
3	Y50	500	610 - 770	18	– 20	50
4					– 40	
5					– 60	
3	Y55	550	670 -830	18	– 20	55
4					– 40	
5					– 60	
3	Y62	620	720 -890	18	– 20	62
4					– 40	
5					– 60	
3	Y69	690	770 - 940	17	– 20	69
4					– 40	
5					– 60	

Table 3 : Mechanical properties - Cr-Ni austenitic and austenitic-ferritic stainless steels

Grade	Tensile test			Charpy V-notch impact test	
	Yield stress $R_{p0,2}$ (N/mm^2) min.	Tensile strength R_m (N/mm^2) min.	Elong. A_5 (%) min.	Test temp. (°C)	Minimum average energy (J)
Austenitic					
308	290	540	25	– 20 **(1)**	27
308L	275	490	25		
316	290	540	25		
316L	275	490	25		
316LN	290	540	25		
317	290	540	25		
317L	275	490	25		
309	290	540	22		
309L	275	490	22		
309Mo	290	540	22		
310	290	540	25		
310Mo	290	540	25		
347	290	540	25		
Austenitic-ferritic					
2205	480	680	25	– 20	27

(1) The impact test temperature is –20°C, except when the additional symbol BT is requested, in which case the test should be carried out at –196°C.

5.2.3 Corrosion tests according to ASTM A262 Practice E, ASTM G48 Method A or equivalent recognised standards may be requested, on a case-by-case basis, for austenitic and duplex stainless steel wires.

5.2.4 Unless special requests are made by the manufacturer, the samples are not to be post-process heat treated.

5.3 Annual control tests

5.3.1 Reference is made to [3.3].

6 Wire-gas combination for WAAM of martensitic stainless steel

6.1 Grade

6.1.1 Wires intended for additive manufacturing of martensitic stainless steels are graded according to their classification as per ISO 14343 (e.g. SS(410NiMo)).

6.2 Type approval

6.2.1 Reference is made to procedure and testing described in Article [2].

The manufacturer's specification for chemical composition, post-process heat treatment and mechanical properties should be submitted to the Society for approval.

The results of the tests should comply with the approved specification.

6.3 Annual control tests

6.3.1 Reference is made to [3.3].

7 Wire-gas combination for WAAM of aluminium bronze

7.1 Grade

7.1.1 Wires intended for additive manufacturing of aluminium bronze are graded according to their classification as per ISO standard 24373 (e.g. CuAl9Ni5Fe3Mn2).

7.2 Type approval

7.2.1 Reference is made to procedure and testing described in Article [2].

The manufacturer's specification for chemical composition, post-process heat treatment and mechanical properties should be submitted to the Society for approval.

The results of the tests should comply with the approved specification.

7.3 Annual control tests

7.3.1 Reference is made to [3.3].

SECTION 4 GUIDELINES FOR QUALIFICATION OF WAAM PROCESS

1 General

1.1 Scope

1.1.1 This Section gives guidelines for the qualification of WAAM process intended to be used for the manufacture of products.

1.1.2 This Section covers the case of products fully made by WAAM process or partly made by WAAM process.

2 Additive manufacturing procedure specification (AMPS)

2.1 Preliminary additive manufacturing procedure specification (pAMPS)

2.1.1 A preliminary additive manufacturing procedure specification (pAMPS) should be prepared by the manufacturer. This document should be submitted to the Society for review prior to the tests.

This pAMPS may be modified and amended during the procedure tests as deemed necessary however it shall define all relevant variables as described in [2.1.2].

In case of test pieces manufactured according to the pAMPS which show unacceptable results, the pAMPS shall be adjusted by the manufacturer. The new pAMPS shall be prepared and new test pieces should be manufactured in accordance with the new pAMPS.

2.1.2 Approval of the additive manufacturing procedure specification (AMPS)

The extent of the surveyor's interventions during the manufacturing of test samples should be agreed with the Society. Testing of test specimens should be witnessed by the surveyor unless otherwise agreed.

Upon satisfactory completion of the tests, the Society may approve the pAMPS as an AMPS.

In its final version, the additive manufacturing procedure specification (AMPS) should include all the parameters characterising the WAAM process; in particular, as applicable:

- type of process, maker and type of WAAM machine
- wire type and diameter
- type and grade of base product (substrate), or permanent base product as applicable, and its preparation
- shielding gas
- deposition pattern (runs direction and construction of layers)
- start and stop locations in deposition patterns and construction of layers
- deposition position(s)
- fusion process parameters ranges (Voltage, intensity, travel speed)
- wall thickness range
- minimum preheat temperature
- minimum and maximum interpass temperature or interlayer temperature as applicable. The location of measurements should be described in the procedure or in a separate document submitted to the Society
- post-process heat treatment parameters if applicable
- other information relevant to the fusion process as applicable.

The actual parameters used to manufacture the test pieces should be recorded. Manufacturer's process control sheets should be submitted and the results of the inspections and tests carried out should be recorded in the additive manufacturing procedure qualification record (AMPQR).

The AMPQR is generally prepared by the manufacturer and endorsed by the attending surveyor.

2.1.3 Responsibilities of the manufacturer

Irrespective of the interventions carried out by the surveyor, the manufacturer is responsible for the use of the AMPS, within the limits of the range qualified and the conditions stated at the time of the approval.

3 WAAM process qualification based on sacrificial piece

3.1 General

3.1.1 Qualification based on sacrificial piece should be preferred when complex and critical products are intended to be produced in series.

3.1.2 The objectives of the qualification are to assess the capacity of the process to manufacture a product having the expected properties and soundness and to verify the representativeness of the reference test sample(s) to be used for subsequent productions.

3.2 Sacrificial piece and reference test sample

3.2.1 Documentation to be submitted for product fully made by WAAM

The following documentation should be submitted to the Society taking into consideration this guidance note:

- the drawings of the sacrificial piece in finished condition and the material specifications
- the fabrication drawings showing the substrate and the separation line for its removal
- the drawings of the reference test sample(s), showing the starting base product
- the preliminary additive manufacturing specification
- the testing plan of the sacrificial piece detailing the type of tests, the location and number of test specimens. Depending on the type of products, other tests than material characterization tests may be needed (pressure tests, fatigue tests, performance tests)
- the testing plan of the reference test sample detailing the type of tests, the location and number of test specimens, to be taken sufficiently away from the substrate
- the non-destructive testing plan of the piece detailing the types of testing, the reference standards for testing or the specific procedures, the extent of testing and the acceptance criteria
- the procedures for non-destructive testing.

3.2.2 Documentation to be submitted for product partly made by WAAM

The following documentation should be submitted to the Society taking into consideration this guidance note:

- the drawings of the sacrificial piece in finished condition and the material specifications, showing the base product and the added material
- the drawings of the base product
- the drawings of the reference test sample(s) showing the base product
- the preliminary additive manufacturing specification
- the testing plan of the sacrificial piece detailing the type of tests, the location and number of test specimens. Depending on the type of products, other tests than material characterization tests may be needed (pressure tests, fatigue tests, performance tests)
- the testing plan of the reference test sample detailing the type of tests, the location and number of test specimens
- the non-destructive testing plan of the piece detailing the types of testing, the reference standards for testing or the specific procedures, the extent of testing and the acceptance criteria
- the procedures for non-destructive testing.

3.2.3 Manufacture of sacrificial piece

Preparation and manufacturing of the sacrificial piece should be made in accordance with the pAMPS and under the general condition of production which it represents.

Where starts and stops positions are intended to be kept within the finished product, the sacrificial piece should include the starts and stops positions.

Alternatively to the manufacture of the piece to its final shape, the Society may consider the manufacture of significant elements in size and geometry representing the product.

The piece should be subjected to post-process heat treatment where applicable.

Cutting, grinding, machining and similar operations should be performed in order to represent the finished product as far as practicable.

In the case of product fully made by WAAM, the substrate is to be fully removed as well as sufficient deposited metal in order to ensure the homogeneity of the final product (typically first 3 layers).

3.2.4 Reference test sample(s)

Reference test sample(s) is(are) to be designed in order to represent the thinner and thicker zones of the product in the most critical locations unless otherwise justified and agreed.

The objective of using a reference test sample should be adapted for production testing while being sufficiently representative of the product, as verified during the qualification.

In the case of process for product partly made by WAAM, the reference test sample(s) should be designed in order to test the interface between the base product and the deposited metal.

The reference test sample should include starts and stops positions as applicable for the envisaged production.

The reference test sample(s) is(are) to have sufficient dimensions in order to sample the test specimens according to the testing plan.

The reference test sample should be subjected to post-process heat treatment together with the sacrificial piece in the same furnace charge.

3.2.5 Non-destructive testing

Non-destructive testing plan should include visual examination, magnetic particle or liquid penetrant testing, radiographic and/or ultrasonics testing.

The procedures for non-destructive testing should take into account the deposition pattern as far as applicable to the detection of imperfections that may be transverse or longitudinal to the deposited runs.

In the case of complex shapes, it might be necessary to use mock-ups and/or numerical simulations to demonstrate the capacity of the method to detect imperfections.

Non-destructive testings according to the plan should be carried out after any specified post heat treatment and prior to the cutting of test specimens.

3.2.6 Macro examination

The testing plan should include macro examination in section(s) normal to the depositing direction at selected locations.

In the case of process for product partly made by WAAM, the testing plan should include additional macro examination at selected locations to reveal the base metal, the heat affected zone, the fusion line and the deposited metal.

3.2.7 Mechanical testing

The testing plan should be defined in order to include test specimens in the directions and at locations which are considered critical for the product like main stresses directions and highly stressed locations. The test plan should include typically:

- tensile tests
- hardness tests
- bending tests
- charpy V notch impact tests, as applicable.

In the case of process for product partly made by WAAM, the testing plan should include in addition:

- tensile tests transverse to the liaison
- hardness tests in the base metal, heat affected zone and deposited metal
- transverse or side bending tests, as practicable
- charpy V notch impact tests with the notch on the fusion line, in the HAZ 2mm from fusion and in the HAZ 5mm from fusion line, as applicable. The axis of the specimens should be perpendicular to the surface of the base part.

The testing parameters should correspond to the material specification and to the tests usually done for welding joints of similar type of material.

The test results should be in accordance with the material specification.

Additional test specimens may be needed depending on the type of product and type of material.

3.3 Results

3.3.1 Additive manufacturing procedure qualification record

The sampled process records and the testing results should be grouped in the additive manufacturing procedure qualification record and should be submitted to the Society.

3.3.2 Sacrificial piece and reference test sample

The test results from the sacrificial piece and reference test sample should be consistent in order to confirm the suitability of the reference test sample for the concerned product.

4 WAAM process qualification based on test sample(s)

4.1 General

4.1.1 Qualification based on test sample(s) may be envisaged for individual products of simple shape which may be subject to full scale testing in relation with their intended use.

4.2 Qualification test sample

4.2.1 Documentation to be submitted

The following documentation should be submitted to the Society taking into consideration this guidance note:

- the drawings of the product and the material specifications
- the drawings of the qualification test sample(s). In the case of process for product partly made by WAAM, the reference test sample should be designed in order to allow the testing of the interface between the base product and the deposited metal
- the technical explanations justifying the use of qualification test sample(s) instead of sacrificial piece; typically, documents like research & development reports, numerical simulations reports or other studies may be considered
- the preliminary Additive Manufacturing Specification (pAMPS),
- the testing plan of the qualification test sample(s) detailing the type of tests, the location and number of test specimens
- the non-destructive testing plan of the qualification test sample detailing the types of testing, the reference standards for testing or the specific procedures, the extent of testing and the acceptance criteria
- the procedures for non-destructive testing.

In the case of process for product partly made by WAAM, the following additional documentation should be submitted:

- the drawings of the base product and the material specification.

4.2.2 Manufacture of qualification test sample(s)

Preparation and manufacturing of the qualification test sample(s) should be made in accordance with the pAMPS and under the general condition of production which it represents.

The qualification test sample(s) is(are) to include starts and stops positions as applicable for the envisaged production.

The qualification test sample(s) is(are) to be subjected to post-process heat treatment where applicable.

Cutting, grinding, machining and similar operations should be performed in order to represent the finished product as far as practicable.

4.2.3 Reference test sample(s)

Where the qualification test samples are not planned to be repeated for production testing, the manufacturer should design reference test sample(s).

Reference test sample(s) should be designed in order to represent the thinner and thicker zones of the product in the most critical locations unless otherwise justified and agreed.

The objective of using a reference test sample should be adapted for production testing while being sufficiently representative of the product, as verified during the qualification.

The reference test sample(s) is(are) to be subjected to post-process heat treatment together with the qualification test sample(s) in the same furnace charge.

4.2.4 Non-destructive testing

Non-destructive testing plan should include visual examination, magnetic particle or liquid penetrant testing, radiographic and/or ultrasonics testing.

The procedures for non-destructive testing should take into account the deposition pattern as far as applicable to the detection of imperfections that may be transverse or longitudinal to the deposited runs.

In the case of complex shapes, it might be necessary to use mock-ups and/or numerical simulations to demonstrate the capacity of the method to detect imperfections.

Non-destructive testings according to the plan should be carried out after any specified post heat treatment and prior to the cutting of test specimens.

4.2.5 Macro examination

The testing plan should include macro examination in section(s) normal to the depositing direction at selected locations.

In the case of process for product partly made by WAAM, the testing plan should include additional macro examination at selected locations to reveal the base metal, the heat affected zone, the fusion line and the deposited metal.

4.2.6 Mechanical testing

The testing plan should be defined in order to take the test specimens in the directions and at locations which are considered critical for the functions of the product. The test plan should include typically:

- tensile tests
- hardness tests
- bending tests
- charpy V notch impact tests, as applicable.

In the case of process for product partly made by WAAM, the testing plan should include in addition:

- tensile tests transverse to the liaison
- hardness tests in the base metal, heat affected zone and deposited metal
- transverse or side bending tests, as practicable
- charpy V notch impact tests with the notch on the fusion line, in the HAZ 2 mm from fusion and in the HAZ 5 mm from fusion line, as applicable. The axis of the specimens should be perpendicular to the surface of the base part.

The testing parameters should correspond to the material specification and to the tests usually done for welding joints of similar type of material.

The test results should be in accordance with the material specification.

Additional test specimens may be necessary depending on the type of product and type of material.

4.3 Results

4.3.1 Additive manufacturing procedure qualification record

The sampled process records and the testing results should be grouped in the additive manufacturing procedure qualification record and should be submitted to the Society.

5 Range of qualification for WAAM process

5.1 General

5.1.1 The approval of a AMPS obtained by a manufacturer is valid for additive manufacturing in his workshops.

The additive manufacturing procedure specification should be used within the range of the parameters indicated below. Changes outside the range specified of one or more of these parameters require a new qualification program.

5.2 Range of parameters

5.2.1 Type of product

The qualification should be valid for the product defined by the qualification program. Extension to similar products in size and shape made with the same material may be considered by the Society based on justifications submitted by the manufacturer.

5.2.2 Manufacturing positions

The qualification should be restricted to the positions tested during the qualification program.

5.2.3 WAAM process

The qualification should be restricted to the WAAM process(es) used in the qualification tests.

5.2.4 Deposition pattern

The qualification should be restricted to the deposition pattern used in the qualification tests. A change of deposition pattern might be considered based on a reduced testing programme without repeating the full initial qualification programme.

5.2.5 Wire gas combination

The qualification is restricted to the type and trade name of wire used during the qualification testing.

Change in the type and trade name requires new qualification tests.

The qualification is restricted to the type of gas used during the qualification test. The type of gas means the type of gas composition as classified by a recognised standard (e.g. ISO 14175).

In case of a special gas composition not covered by a recognised standard, the qualification is restricted to the nominal composition of gas used during the qualification.

5.2.6 Parameters related to heat input

The parameters related to heat input (Voltage, intensity, travel speed) should be kept within the values corresponding to the qualification conditions.

5.2.7 Preheat and interpass temperature or interlayer temperature

The minimum preheat temperature is not to be less than that used in the qualification test.

The minimum interpass temperature or interlayer temperature, as applicable, is not to be less than the specified preheat temperature.

The maximum interpass temperature or interlayer temperature, as applicable, is not to be higher than that used in the qualification test.

5.2.8 Post-process heat treatment

The post-process heat treatment used in the qualification test should be applied in further production. Holding time may be adjusted as a function of thickness.

SECTION 5 GUIDELINES FOR RECOGNITION OF MANUFACTURER FOR WAAM PROCESS

1 General

1.1 Scope

1.1.1 This Section gives guidelines for the recognition of a manufacturer for WAAM process.

1.2 Recognition process

1.2.1 The recognition process is described in NR320 Certification Scheme of Materials and Equipment for the Classification of Marine Units.

1.3 Specific documentation for WAAM

1.3.1 Wire and gas

Document(s) describing the incoming controls, the storage and handling conditions and their monitoring for the wire(s) and the gas used for WAAM should be submitted.

1.3.2 WAAM Equipment

Document(s) describing the WAAM machine(s) including the wire feed system, the limitations, the controllable parameters and the associated recording systems should be submitted.

Document(s) describing the WAAM machine(s) maintenance plan should be submitted.

1.3.3 WAAM Operators

Document(s) describing the process for management of WAAM operators qualification should be submitted.

1.3.4 Data control

Document(s) describing the management of the files used to print products and to record manufacturing data should be submitted. The model of software(s) used to generate the 3D model, the 3D print file for the WAAM machine, and the WAAM machine parameter's records should be submitted.

1.3.5 WAAM process qualification

Documents describing the WAAM process qualification(s) granted to the manufacturer should be submitted.

1.3.6 Production control

Document(s) describing the generic examinations and tests conducted by the manufacturer before, during and after manufacture should be submitted.

1.3.7 Post treatment

Document(s) describing the post treatments other than machining, if any (typically heat treatment). In case of subcontracting, management of subcontracted operations should be described.

1.3.8 Testing facilities

Document(s) describing the in house testing facilities (including testing equipment calibration management) and the management of personnel qualification for non-destructive testing should be submitted.

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