No. 169 Guidelines on Approval of High Manganese Austenitic Steel for Cryogenic Service

(Sep 2021)

1. Application

1.1 This document provides guidance for manufacturing approval and batch release testing of high manganese austenitic steel as plate for cryogenic service.

1.2 This document is intended to provide guidance for steel plates with thickness between 6mm to 40mm. For greater thickness, special consideration should be given by each Classification Society.

1.3 High manganese austenitic steels differing in chemical composition, deoxidation practice, condition of supply and mechanical properties may be considered, subject to the special approval of the Classification Society.

2. Definitions

2.1 High manganese austenitic steel means the steel with a high amount of manganese in order to retain austenite as its primary phase at atmospheric and service temperature.

2.2 Piece means the rolled product from a single slab, billet or ingot if this is rolled directly into plates, sections or bars.

3. Approval

3.1 High manganese austenitic steel should be manufactured at steel works which have been approved by the Classification Society. The suitability of steel for forming and welding should be demonstrated during the initial approval test at the steelworks. Approval of the steelworks should follow a scheme given in the Appendix A.

3.2 It is the steelmaker’s responsibility to assure that effective quality, process and production controls during manufacturing are adhered to within the manufacturing specifications. The manufacturing specification should be submitted to the Classification Society at the time of initial approval.

3.3 Where non-conformities arise, the manufacturer should identify the cause and establish countermeasures to prevent its recurrence. The non-conformities and the countermeasures are to be documented and reported to the Classification Society

4. Method of Manufacture

4.1 Steel should be manufactured by the basic oxygen, electric furnace or open hearth processes or by other processes specially approved by the Classification Society.

4.2 The deoxidation practice should be fully killed for steel.

4.3 The steel should be fine grain treated and should have a fine grain structure. The fine grain practice should be as detailed in the manufacturing specification.

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5. Chemical composition

5.1 The chemical composition of samples taken from each ladle of each cast should be determined by the steelmaker in an adequately equipped and competently staffed laboratory and should comply with the appropriate requirements of Table 1.

5.2 The aim analysis should be in accordance with the manufacturing specification. All the elements listed in Table 1 should be reported.

Table 1 Chemical composition for high manganese austenitic steel

C	Si	Mn	P	S	Cr	B	N	Cu
0.35 ~0.55	0.10 ~0.50	22.50 ~25.50	≤0.030	≤0.010	3.00 ~4.00	≤0.005	≤0.050	0.30 ~0.70
The content of other elements used for alloying and fine grain treatment may be specified by steelmaker, as appropriate. Silicon(Si) may be less than 0.1%, provided total aluminium is 0.03% or higher, or provided acid soluble aluminium is 0.025% or higher.								

6. Condition of Supply

6.1 Condition of supply for all material is hot rolled and subsequent controlled cooling if necessary. Other conditions of supply are to be in accordance with each Classification Society's procedure.

6.2 The reduction ratio of slab to finished product thickness should be not less than 3:1.

7. Mechanical Properties

7.1 Material specifications for high manganese austenitic steel plates are defined in Table 2.

Table 2 Conditions of grade and mechanical properties for high manganese austenitic steel plates

Grade	Yield Strength (N/mm^2)	Tensile Strength (N/mm^2)	Elongation (%)min	Charpy Impact Energy, Average		
				Test Temp.(°C)	Transverse (J)	Longitudinal (J)
HMA400	≥400	800~970	≥22	-196	≥27	≥41

8. Surface Quality and Internal Soundness

8.1 The steel should be reasonably free from segregations and non-metallic inclusions.

8.2 The finished material should have a workmanlike finish and should be free from internal and surface defects prejudicial to the use of the material for the intended application.

8.3 Surface finish of steel should be in accordance with the relevant requirements in Unified Requirement W11.

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8.4 Verification of internal soundness is the responsibility of manufacturer. The acceptance by the Classification Society's Surveyor should not absolve the manufacturer of this responsibility.

9. Tolerances

9.1 Unless otherwise agreed or specially required, the thickness tolerances of high manganese austenitic steel plate should be in accordance with UR W13, irrespective of the applicability clause of W13.1.3 of UR W13.

10. Identification of Materials

10.1 The steelmaker should adopt a system for the identification of ingots, slabs and finished pieces which will enable the material to be traced to its original cast.

10.2 The surveyor should be given full facilities for so tracing the material when required.

11. Testing and Inspection

11.1 Facilities for inspection

Testing should be carried out under the witness of the surveyor, or an authorized deputy, in order to verify whether the test results meet the specified requirements.
The manufacturer should afford the surveyor all necessary facilities and access to all relevant parts of the steel works to enable him to verify the approved process is adhered to, for the selection of test materials, the witnessing of tests, and verifying the accuracy of the testing, calibration of inspection equipment.

11.2 Testing procedures

The tests and inspections may be carried out at the manufacturing place before dispatch. The test specimens and procedures are to be based on Unified Requirements W2 "Test Specimens and Mechanical Testing Procedures for Materials". All the test specimens are to be tested in his presence, unless otherwise agreed.

11.3 Ultrasonic examination

If required by the Classification Society, the manufacturer should perform ultrasonic examination in accordance with an approved standard.

11.4 Surface inspection and dimensions

Surface inspection and verification of dimensions are the responsibility of the steelmaker. The acceptance by the Classification Society's surveyor should not absolve the steelmaker of this responsibility in case defective material is found later.

12. Test Material

12.1 All material in a batch presented for acceptance tests should be of the same product form from the same cast and in the same condition of supply.

12.2 The test samples are to be fully representative of the material and, where appropriate, are not to be cut from the material until heat treatment has been completed.

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12.3 The test specimens are not to be heat treated separately from the test samples in any way.

12.4 Unless otherwise agreed, the test samples are to be taken from one end at a position approximately midway between the axis in the direction of the rolling and the edge of the rolled product(see Fig. 1).
Unless otherwise agreed, the tensile test specimens are to be prepared with their longitudinal axis transverse to the final direction of rolling.

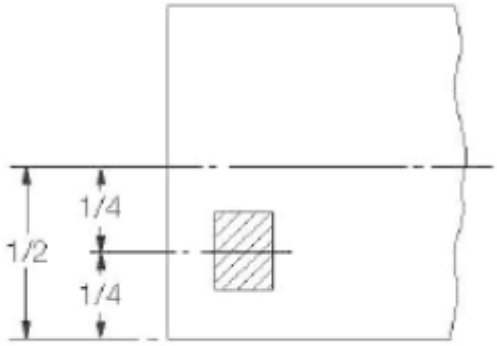

Fig. 1 The location of the test sample

13. Mechanical Test Specimens

13.1 Tensile Test Specimens. The dimensions of the tensile test specimens are to be in accordance with Unified Requirement, W2. Test specimens of full product thickness are to be used.

13.2 Impact Test Specimens. The impact test specimens are to be of the Charpy V-notch type cut with their longitudinal axis as near as practicable to a point midway between the surface and the centre of the thickness and with their longitudinal axis either parallel or transverse to the final direction of rolling of the material. The notch should be cut in a face of the test specimen which was originally perpendicular to the rolled surface. The position of the notch is not to be nearer than 25mm to a flame cut or sheared edge.

14. Number of Test Specimens

14.1 Number of Tensile Tests. One tensile test should be made from each piece.

14.2 Number of Impact Tests. At least one set of three Charpy V-notch test specimens should be made from each piece.

15. Retest Procedures

15.1 Retest procedures for tensile tests and Charpy impact tests are to be in accordance with UR W2.

15.2 If any test specimen fails because of faulty preparation, visible defects or (in the case of tensile test) because of fracturing outside the range permitted for the appropriate gauge length, the defective test piece may, at the surveyor’s discretion, be disregarded and replayed by an additional test piece of the same type.

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15.3 In the event of any material proving unsatisfactory during subsequent working or fabrication, such material may be rejected, notwithstanding any previous satisfactory testing and/or certification.

16. Marking

16.1 Each finished piece should be clearly marked by the manufacturer with the following particulars :

(a) Name or mark to identify the steel works
(b) Unified identification mark for the grade of steel
(c) Cast number/Heat number, plate number or equivalent identification mark
(d) Delivery condition
(e) Classification Society's brand mark

16.2 The marking particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products should be enriched with paint or otherwise marked so as to be easily recognizable.

17. Documentation

17.1 The surveyor should be supplied with the number of copies of the test certificates or shipping statements for all accepted materials. In addition to the description, dimensions, etc., of material, the following particulars should be included:

(a) Purchaser's order number and if known the hull number for which the material is intended
(b) Identification of the cast and piece including, where appropriate, the test specimen number
(c) Steelwork's identification
(d) Chemical analysis
(e) Condition of supply with heat treatment temperatures
(f) Mechanical properties test result, including traceable test identification
(g) Surface quality and inspection results
(h) UT result, where applicable
(i) Identification of the grade of steel

17.2 Before the test certificates or shipping statements are signed by the surveyor, the manufacturer is required to furnish him with a written declaration stating that the material has been made by an approved process and that it has been subjected to and has withstood satisfactory the required tests in the presence of the surveyor or his authorized deputy. The name of the Classification Society should appear on the test certificate. The following form of declaration will be accepted if stamped or printed on each test certificate or shipping statement with the name of the steelworks and initialled for the makers by an authorized official:

"We hereby certify that the material has been made by an approved process and has been satisfactorily tested in accordance with the Rules of the Classification Society"

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Appendix A. Manufacturing Approval Scheme of High Manganese Austenitic Steels

1. Scope of application

This appendix specifies the procedure for the approval of the manufacturing process of high manganese austenitic steels.

The manufacturing approval scheme is valid for verifying the manufacturer's capability to provide satisfactory products stably under effective process and production controls in which is required in this document 2.2.

2. Approval application

2.1 Documents to be submitted

The manufacturer has to submit to the Society, request of approval, proposed approval test program(see A3.1) and general information relevant to:

a) Outline of workshop details
- Name and site address of the manufacturer, location of the workshops, general indications relevant to the background, dimension of the works, estimated total annual production of finished products, as deemed useful.

b) Organization and quality
- Organization chart
- Number of staff employed
- Staff employed and organization of the quality control department
- Qualification of the personnel involved in activities related to the quality of the products
- Certification of compliance of the quality system with ISO 9001 or 9002, if any
- Approval certificates already granted by other Classification Societies, if any

c) Manufacturing process and facilities
- Flow chart of the manufacturing process including quality control process on each manufacturing stage
- Manufacturing facilities and equipment
- Origin and storage of raw materials
- Storage of finished products
- Equipment for systematic control during manufacturing

d) Inspection and quality control facilities
- Inspection and test procedure/standards
- Qualification of the personnel involved in activities related to the inspection and test
- Detail of system used for identification of materials at the different stages of manufacturing
- List and documents of equipment for mechanical tests, chemical analyses and metallography, non-destructive testing and relevant calibration procedures
- List of quality control procedures

e) Type of products, delivery condition, range of thickness and aim material properties as follows:
- Range of chemical composition, aim analyses and associated control limits, including grain refining, micro alloying and residual elements; if the range of chemical

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composition depends on thickness and delivery condition, the different ranges are to be specified, as appropriate.
- Production statistics of the chemical composition and mechanical properties(R_{eH}, R_m, A% and CVN). The statistics are intended to demonstrate the capability to manufacture the steel products in accordance with the requirements.

f) Steelmaking
- Steel making process and capacity of furnace/s or converter/s
- Raw material used
- Deoxidation, grain refining, and alloying practice
- Desulphurization, and vacuum degassing installations, if any
- Casting methods(ingot or continuous casting) : In the case of continuous casting, information relevant to type of casting machine, teeming practice, methods to prevent re-oxidation, inclusions and segregation control, presence of electromagnetic stirring, soft reduction, etc., should be provided as appropriate.
- Ingot or slab size and weight
- Ingot or slab treatment : scarfing and discarding procedures

g) Reheating and rolling
- Type of furnace and treatment parameters
- Rolling reduction ratio of slab to finished product thickness
- Descaling treatment during rolling
- Capacity of the rolling stands
- Description of the rolling process
- Control standard for typical rolling parameters used for the different thickness and steel(temperature and thickness at the beginning and at the end of the passes, interval between passes, reduction ratio, temperature range and cooling speed of accelerated cooling, if any) and relevant method of control
- Calibration of the control equipment

h) Heat treatment
- Description of the heat treatment applied
- Control standard of the heat treatment used for the different thickness and steel(including the temperature, holding time, cooling rate, etc) and the relevant method of cooling
- Type of furnaces, heat treatment parameters and their relevant record
- Accuracy and calibration of temperature control devices

i) Recommendations for working and welding in particular
- Cold and hot working recommendations if needed in addition to the normal practice used in the shipyards and workshops
- Minimum and maximum heat input and recommended pre-heat/interpass temperature

j) Where any part of the manufacturing process is assigned to other companies or other manufacturing plants, additional information required by the Society should be included.

k) Approval already granted by other Classification Societies and documentation of approval tests performed.

l) Technical documents demonstrating that the percent of the ductile fracture surface at -196°C is 100% by fractography(SEM).

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2.2 Documents to be submitted for changing the approval conditions

The manufacturer has to submit to the Society the documents required in 2.1 together with the request of changing the approval conditions, in the case of the following a) through e) as applicable:

a) Change of the manufacturing process(steel making, casting, rolling and heat treatment)
b) Change of the maximum thickness(dimension)
c) Change of the chemical composition, added element, etc.
d) Subcontracting the rolling, heat treatment, etc.
e) Use of the slabs manufactured by companies other than the ones verified in the approval tests.

3. Approval tests

3.1 Extent of the approval test

The extent of the test program is specified in 3.6 and 3.7; it may be modified based on the preliminary information submitted by the manufacturer.

In particular, a reduction of the indicated number of casts, steel plate thickness to be tested or complete suppression of the approval tests may be accepted by the Society taking into account:

a) Approval already granted by other Classification Societies and documentation of approval tests performed

b) Steel to be approved and where available the long term statistical results of chemical and mechanical properties

An increase of the number of casts and thickness to be tested may be required in the case of newly developed types of steels or manufacturing processes.

In case of multi-source slabs or changing of slab manufacturer, the rolled steel manufacturer is required to obtain the approval of the manufacturing process of rolled steels using the slabs from each slab manufacturer and to conduct approval tests in accordance with 3.6 and 3.7. A reduction or complete suppression of the approval tests may be considered by the Society taking into account previous approval as follows:

- The rolled steel manufacturer has already been approved for the rolling process and heat treatment using approved other semi-finished products characterized by the same thickness, steel grade, grain refining and micro-alloying elements, steel making and casting process;

- The semi-finished products have been approved for the complete manufacturing process with the same conditions(steelmaking, casting, rolling and heat treatment) for the same steel types.

3.2 Approval test program

Where the number of test differs from those shown in 3.6 and 3.7, the program should be confirmed by the Society before the tests are carried out.

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3.3 Approval survey

The approval tests may be carried out in the presence of the surveyor at the manufacturer's plant and the execution of the plant inspection in operation may be required by the surveyor during the visit for the approval.
If the testing facilities are not available at the works, the tests are to be carried out at recognized laboratories.

3.4 Selection of the test product

For each manufacturing process(e.g. steel making, casting, rolling and condition of supply), one test product with the maximum thickness to be approved is in general to be selected.

In addition, for initial approval, the Society requires selection of two test plate of average thickness.

3.5 Position of the test samples and specimens

The test samples are to be taken from the plate corresponding to the top of the ingot, unless otherwise agreed.

In the case of continuous castings, test samples are to be taken from the plates corresponding to the head and/or the end of the whole casting.

The location of the test sample in width of the product should be in compliance with 12.4.

The position of the samples to be taken in the length of the rolled product, "piece"(top and/or bottom of the piece) and the direction of the test specimens with respect to the final direction of rolling of the material are indicated in Table A1.

3.6 Tests on base material

3.6.1 Type of tests

The tests to be carried out are indicated in the following Table A1.

The Society may require the additional tests to verify the relevant characteristics of high manganese austenitic steels compared with those of the conventional materials applied to cryogenic service

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Table A1 Tests on base material

Type of Test	Position of the samples and direction of the test specimens	Remarks
1) Tensile Test	Top and bottom, L-direction & T-direction	Yield strength(R_{eH}), Tensile strength(R_m), Elongation(A_5), Reduction in area(R_A) are to be reported.
2) Impact tests on non-aged specimens	Top and bottom, 1/4t, L-direction & T-direction	At least testing temperature:-196°C
3) Impact test on strain aged specimens	Top, 1/4t, L-direction	At least testing temperature: -196°C
4) Drop weight test	Top	The test method should comply with ASTM E208:2019 or equivalent method.
5) Micro examination	Top	Grain size determination
6) Chemical analysis(ladle and product)	Top	Contents of C, Mn, Si, P, S, Ni, Cr, Mo, Al, N, Nb, V, Ti, B, Zr, Cu, As, Sn, Bi, Pb, Ca, Sb, O, H are to be reported.
7) CTOD test	Top, T-direction	Test method should comply with ISO 12135:2016, ASTM E1820:2020, BS7448-1:1991 or equivalent method.
8) S-N Fatigue test	Top, T-direction	Test method should comply with ASTM E466:2015 or equivalent method.
9) Fatigue crack growth rate test	Top, T-direction	Test method should comply with ASTM E647:2015 or equivalent method.
10) General corrosion test	Top	Test method should comply with ASTM G31-21 or equivalent method.
11) Elastic modulus test	Top	Test method should comply with ASTM E494:2015 or equivalent method.
12) Stress corrosion crack(SCC) test	Top	Test method should comply with ASTM G36:2018 and G123:2015 or equivalent method. Test specimen should comply with ASTM G30:2016 or equivalent.
13) Sulphur print	Top	
14) Intergranular corrosion test	Top	This method should comply with ASTM A262:2015 or equivalent method.

3.6.2 Test specimens and testing procedure

The test specimens and testing procedures are to be, as a rule, in accordance with UR W2. In particular the following applies:

(a) Tensile test
- Tensile test specimens are to be taken from one test sample.
- Tensile tests are to be carried out at room temperature and -165°C.
- Result of tensile tests at -165°C should be reported for reference.
- Tensile tests should be carried out with specimen of full thickness.

(b) Impact test on non-aged specimens
- One set of three Charpy V-notch impact specimens is required for each impact test.
- The Charpy V-notch impact test temperature should include -196°C at least.
- In addition to the determination of the energy value, the lateral expansion and the percentage crystallinity are also to be reported. The percentage of the ductile fracture surface at -196°C should be 100% by fractography(SEM).
- Additionally at each location, Charpy V-notch impact tests are to be carried out with appropriate temperature intervals(-196°C, -165°C, -100°C and -65°C) to verify the properties of toughness at each temperature for reference.

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(c) Impact test on strain aged specimens
- One set of three Charpy V notch impact specimens is required for each impact test.
- The test specimens which have been maintained for one hour at 250°C after strain of 5% have been applied, as a rule, to be used.
- The Charpy V-notch impact test temperature should include -196°C at least.
- The result should be reported for reference.

(d) Drop weight test
- Two specimens for drop weight test are to be taken from the surface of one test sample.
- The test temperature is -196°C.
- The test results should show no-break performance at -196°C.
- Photographs of the test specimens are to be taken and enclosed with the test report.

(e) Micro examination
- One test specimen for micrographic examination should be taken from one test sample.
- All micrographs are to be taken at ×100 magnification and where austenite grain size exceeds ASTM E112-2013 index 10 or equivalent, additionally at ×500 magnification.
- The austenite grain size should be measured and the non-metallic inclusions are to be examined.
- The micrographs are to be representative of the full thickness.
- The result should be reported for reference.

(f) Chemical analysis
- One test specimen for chemical analysis should be taken from one test sample.
- Both the ladle and product analysis are to be reported.
- The material for the product analysis should be taken from the tensile test specimen.

(g) CTOD test
- Test specimens for CTOD test are to be taken from one test sample
- One set of three CTOD specimens is required for each test.
- CTOD minimum value should be in accordance with design specification for testing at room and cryogenic temperatures as per design conditions. As a guidance, a minimum CTOD value of 0.2mm is often required.

(h) S-N fatigue test
- Sufficient number of test specimens to obtain S-N curve are to be taken from test samples.
- The test temperature is room temperature.
- The S-N curve should be established and the result should be equal or better than the FAT125-curve in International Institute of Welding(IIW) or C-curve in DNVGL-RP-C203-2020.
- At the discretion of the Society, S-N fatigue test may be waived.

(i) Fatigue crack growth rate test
- One test specimen for fatigue crack growth rate should be taken from one test sample.
- The test temperature is room temperature.
- The result should be reported for reference.
- At the discretion of the Society, fatigue crack growth rate test may be waived.

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(j) General corrosion test
- One test specimen for corrosion resistance should be taken from one test sample.
- The result should be reported for reference.

(k) Elastic modulus test
- One test specimen for elastic modulus should be taken from one test sample.
- The test temperature should include room temperature and -165°C at least.
- The result should be reported for reference.

(l) Stress corrosion crack(SCC) test
- One test specimen for stress corrosion crack should be taken from one test sample.
- The result should be reported for reference.

(m) Sulphur prints
- Sulphur prints are to be taken from plate edges which are perpendicular to the axis of the ingot or slab. These sulphur prints are to be approximately 600mm long taken from the centre of the edge selected, i.e. on the ingot centerline, and are to include the full product thickness.

(n) Intergranular corrosion test
- One test specimen for corrosion resistance should be taken from one test sample.
- The result should be reported for reference.

3.6.3 Other tests

Additional test such as large scale brittle fracture tests(Double tension test, ESSO test, Deep notch test, etc.) or other tests may be required in the case of newly developed type of steel, when deemed necessary by the Society.

3.7 Weldability Test

3.7.1 General

Weldability tests are required for plates and are to be carried out on samples of the thickest plate.

3.7.2 Preparation and welding of the test assemblies

In general, the following test assembles are to be prepared.

a) One butt weld test assembly welded with a heat input 15kJ/cm ±10%.

b) One butt weld test assembly welded with a heat input 30kJ/cm ±10%.

c) Where steel is required to be approved for heat input levels higher than 30kJ/cm, the maximum heat input to be approved should be used for the test assembly in agreement with the Society.

The butt weld test assemblies are to be prepared with the weld seam longitudinal to the plate rolling direction, so that impact specimens will result in the transverse direction.
The bevel preparation should be preferably 1/2V or K upon the test assembly thickness.
The welding procedure should be as far as possible in accordance with the normal welding practice used at the yards for the type of steel in question.

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The welding parameters including welding process, consumables designation and diameter, preheating temperature, interpass temperature, heat input, number of passes, etc. are to be reported.
The maximum approved heat input level may be specified on the approval certificate.

3.7.3 Type of tests

The tests to be carried out are indicated in the following Table A2.
The Society may require the additional tests to verify the relevant characteristics of high manganese austenitic steels compared with those of the conventional materials applied to cryogenic service.

Table A2 Tests on weld material

Type of Test	Position of the samples and direction of the test specimens	Remarks
1) Transverse tensile test	Top, T-direction(cross weld direction)	
2) Charpy impact test	Top, 1/4t, T-direction(cross weld direction)	Charpy impact test on center of WM, FL, FL+1, FL+3 and FL+5
3) Ductile fracture toughness test J_{1C}	Top	(a) Test method should comply with ASTM E1820:2020, ISO 15653:2018 or equivalent method. (b) This test may be omitted at the discretion of each Classification Society.
4) CTOD test	Top, T-direction(cross weld direction)	Test method should comply with ISO 15653:2018, ASTM E1820:2020, or equivalent method.
5) Hardness test	Top	
6) Stress corrosion crack(SCC) test	Top	Test method should comply with ASTM G36:2018 or equivalent method. Test specimen should comply with ASTM G58: 2015 or equivalent.
7) Micro and macro examination	Top	
8) Bending test	Top, L-direction	
9) S-N fatigue test	Top, T-direction(cross weld direction)	Test method should comply with ASTM E466:2015 or equivalent method.
10) Fatigue crack growth rate test	Top	Test method should comply with ASTM E647:2015 or equivalent method.
11) General corrosion test	Top	Test method should comply with ASTM G31-21 or equivalent method.
12) Intergranular corrosion test	Top	Test method should comply with ASTM A262:2015 or equivalent method.

Mechanical properties for butt weld tests are defined in Table A3.

Table A3 Mechanical properties for butt weld tests

Tensile Strength (N/mm^2)	Elongation % at $5.65\sqrt{S_0}$	Charpy Impact Energy, Average	
		Test Temp.(°C)	Average Energy(J)
≥660	≥22.0	-196	≥27

3.7.4 Test specimens and testing procedure

(a) Transverse tensile test
- Two tensile test specimens transverse to the weld are to be taken from one test assembly.
- Tensile tests are to be carried out at room temperature and -165°C.
- The result at tensile test at -165°C should be reported for reference.
- Tensile tests should be carried out with full thickness.

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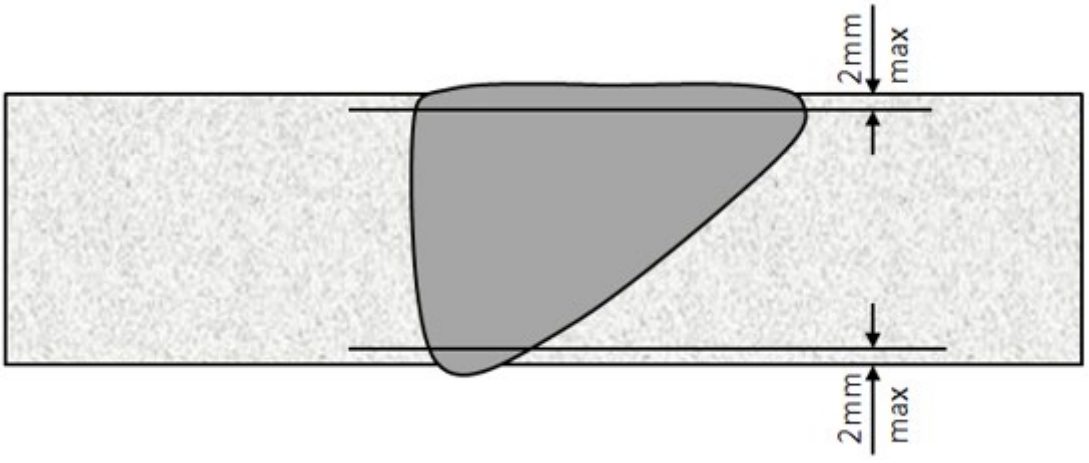
(b) Charpy impact test
- One set of three Charpy V-notch specimens transverse to the weld should be taken.
- The fusion boundary should be identified by etching the specimens with a suitable reagent.
- The impact test temperature should include -196°C at least.
- Additionally at each location, impact tests are to be carried out with appropriate temperature intervals(-196°C, -165°C, -100°C, 0°C) to verify the properties of toughness at each temperature for reference.

(c) Ductile fracture toughness test J1C
- One test specimen should be taken from the test sample.
- Test temperature should include cryogenic service temperature.
- The test results are to show the satisfactory resistance to the unstable ductile fracture.

(d) CTOD test
- CTOD test for three specimens transverse to the weld for each condition should be carried out at a position of coarse grained heat affected zone(CGHAZ). Additional set of CTOD tests with notch positions such as FL+1, FL+3, FL+5 may be required by the Classification Society.
- CTOD minimum value should be in accordance with design specification for testing at room and cryogenic temperatures as per design conditions.
- As a guidance, a minimum CTOD value of 0.2mm is often required.

(e) Hardness test
- Hardness tests HV10 across the weldment. The indentations are to be made along a transverse line which is 1~2mm beneath the plate surface on both the face side and the root side of the weld as follows:
- Fusion line
- HAZ : at each 0.7mm from fusion line into unaffected based material(6 to 7minimum measurements for each HAZ)
- A sketch of the weld joint depicting groove dimensions, number of passes, hardness indentations should be attached to the test report together with photomacrographs of the weld cross section.
- At least two rows of indentations are to be carried out in accordance with Fig A 1.
- The result should be reported for reference.



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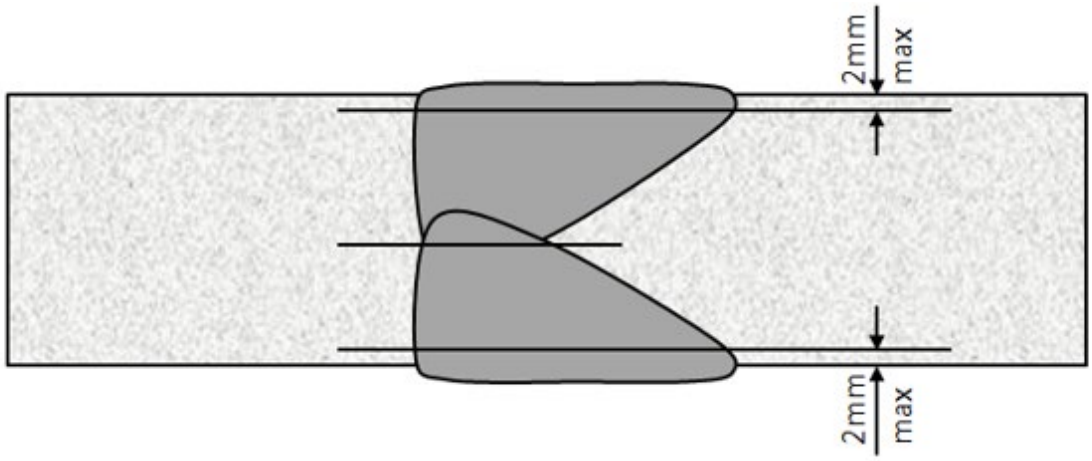

Fig. A 1 Examples of hardness test with rows of indentations in butt welds

(f) Stress corrosion cracking (SCC) test
- One test specimen transverse to the weld for stress corrosion crack should be taken from one test assembly.
- The result should be reported for reference.

(g) Micro and macro examination
- All micrographs are to be taken at ×100 magnification and where austenite grain size exceeds ASTM E112-2013 index 10 or equivalent, additionally at × 500 magnification.
- The austenite grain size should be measured and the non-metallic inclusions are to be examined.
- The micrographs are to be representative of the full thickness.
- Three examinations are to be made at surface, one quarter and mid-thickness of the product.
- The result including metallurgical phases should be reported for reference.
- One macroscopic photograph should be representative of transverse section of the welded joint and should show absence of cracks, lack of penetration, lack of fusion and other injurious defects.

(h) Bending test
- Longitudinal bend test should be carried out.
- No fracture should be acceptable after 180° bend over a former diameter four times the thickness of the test pieces.

(i) S-N fatigue test
- Sufficient number of test specimens to obtain S-N curve are to be taken from test samples.
- The test temperature is room temperature.
- The S-N curve should be established and the result should be equal or better than the FAT90-curve in IIW or D-curve in DNVGL-RP-C203:2020.
- At the discretion of the Society, S-N fatigue test may be waived.

(j) Fatigue crack growth rate test
- One test specimen for fatigue crack growth rate should be taken from one test sample.
- Notch in test specimen should be parallel with welding seam.
- The test temperature is room temperature.

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- The result should be reported for reference.
- As the discretion of the Society, the fatigue crack growth rate test may be waived.

(k) General corrosion test
- One test specimen for corrosion resistance should be taken from one test sample.
- The result should be reported for reference.

(l) Intergranular corrosion test
- One test specimen for corrosion resistance should be taken from one test sample.
- The result should be reported for reference.

4. Results

All the results, which are in any case to comply with the requirements, are evaluated for the approval.

The manufacturer should submit all the results of the test together with all the information required under Appendix 2.2 and manufacturing records relevant to steel making, casting, rolling and heat treatment of the test products.

5. Certification

5.1 Approval

Upon satisfactory completion of the survey, approval is granted by the Society.

5.2 List of approved manufacturers

The approved manufacturers are entered in a list containing the types of steel and the main conditions of approval.

6. Renewal of approval

The validity of the approval should be a maximum of five years.

Renewal can be carried out by an audit and assessment on the result of satisfactory survey during the period.

Where for operational reasons, the renewal audit falls outside the period of approval, the manufacturer will still be considered as approved if agreement to this audit date is made within the period of three months after expiry of the validity. In this instance if successful, the extension of approval will be back dated to the original renewal date.

Manufacturers who have not produced the approved products during the period between renewals may be required to either carry out approval tests or on the basis of results of production of similar products, at the discretion of the Society, be reapproved.

7. Suspension or withdrawal of the approval

During the period of validity, the approval may be withdrawn in the following cases:

a) Non-conformity of the material to the given requirement

b) In service failure, traceable to product quality

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c) Non-conformity of the product revealed during fabrication and construction

d) Discovered failure of the manufacturer's quality system

e) Changes brought by the manufacturer, without preliminary agreement of the Society, to the extent of invalidating the approval

f) Evidence of major non-conformities during testing of the products.

g) In case the manufacturer has failed to inform any changes which will affect the approved quality system.

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