W16 High Strength Steels for Welded Structures

(1984) (Rev.1 1994) (Rev.2 May 2004) (Rev.3 Mar 2016 Complete Revision)

1. Scope

1.1 These requirements apply to hot-rolled, fine-grain, weldable high strength structural steels, intended for use in marine and offshore structural applications. These requirements do not apply to steels intended for hull structure of commercial ships whose requirements are specified in Unified Requirement W11.

1.2 Steels covered by the scope of these requirements are specified in yield strength levels of 420, 460, 500, 550, 620, 690, 890 and 960 N/mm^2. For each yield strength level grades A, D, E and F are specified, based on the impact test temperature, except for yield strength level of 890 and 960 N/mm^2 for which grade F is not applicable.

The full list of grades are:

AH420	DH420	EH420	FH420
AH460	DH460	EH460	FH460
AH500	DH500	EH500	FH500
AH550	DH550	EH550	FH550
AH620	DH620	EH620	FH620
AH690	DH690	EH690	FH690
AH890	DH890	EH890	
AH960	DH960	EH960	

1.3 Steels covered by the scope may be delivered in Normalized (N)/Normalised rolled (NR); Thermo-mechanical controlled rolled (TM) or Quenched and Tempered (QT) condition.

Note:
TM is a generic delivery condition that may or may not include accelerated cooling, and may or may not include direct quenching followed by tempering after TM-rolling.

1.4 Product forms include plates, wide flats, sections, bars and seamless tubulars.

Note:

1. This UR is to be uniformly implemented by IACS Societies in marine and offshore structures contracted for construction on or after 1 July 2017, or when the application for certification of steel products submitted by an approved manufacturer is dated on or after 1 July 2017, or the application for certification of manufacturer approval is dated on or after 1 July 2017.

2. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.

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1.5 Steels with a thickness beyond the maximum thicknesses as given in Table 3 of section 5.3 may be approved at the discretion of the Classification Society.

1.6 Steels differing in chemical composition, deoxidation practice, delivery condition and mechanical properties may be accepted, subject to the special approval of the Classification Society. Such steels are to be given a special designation.

2. Approval

2.1 For applications subjected to Classification, all steels are to be manufactured at steel works which have been approved by the Classification Society for the type and grade of steel which is being supplied. The procedure for approval is shown in Appendix A.

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

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

2.4 When the semi-finished products were not manufactured by the approved manufacturer of the finish rolled and heat treated products, the manufacturer of the semi-finished product shall also be subject to approval by Classification Society.

Note 1:
The attention of the users must be drawn to the fact that when fatigue loading is present, the effective fatigue strength of a welded joint of high strength steel may not be greater than that of a welded joint in normal strength steels.

Note 2:
Before subjecting steels produced by both thermo-mechanical rolling or quenched and tempered after rolling to further heating for forming or stress relieving, or using high heat-input welding, special consideration must be given to the possibility of a consequent reduction in mechanical properties.

3. Method of Manufacture

3.1 Steel making process

3.1.1 The steel is to be manufactured, by the basic oxygen, basic electric arc furnace or by processes specially approved by the Classification Society.

3.1.2 Vacuum degassing shall be used for any of the following:

a) All steels with enhanced through-thickness properties, and

b) All steels of grade H690, H890 and H960.

3.2 Deoxidation

3.2.1 The steel is to be fully killed.

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3.3 Grain size

3.3.1 The steel is to be fine grain treated, and is to have a fine grain structure. The fine grain practice is to be as detailed in the manufacturing specification.

Note:
A fine grain structure has an equivalent index ≥ 6 determined by micrographic examination in accordance with ISO 643 or alternative test method.

3.4 Nitrogen control

3.4.1 The steels shall contain nitrogen binding elements as detailed in the manufacturing specification. Also see note 4 in Table 1.

4. Chemical Composition

4.1 The chemical composition is to be determined by the steelmaker in an adequately equipped and competently staffed laboratory. The method of sampling is to follow that carried out for the initial approval tests, either from the ladle, the tundish or the mould in the case of continuous casting. The aim analysis is to be in accordance with the manufacturing specification. All the elements listed in Table 1 are to be reported.

4.2 Elements used for alloying, nitrogen binding, and fine grain treatment, and as well as the residual elements are to be as detailed in the manufacturing specification, e.g. when boron is deliberately added for enhancement of hardenability of the steels, the maximum content of the boron content shall not be higher than 0.005%; and the analysis result shall be reported.

4.3 The carbon equivalent value is to be calculated from the ladle analysis. Maximum values are specified in Table 2.

a) For all steel grades the following formula of IIW may be used:

$$Ceq = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}\ (\%)$$

b) For steel grades H460 and higher, *CET* may be used instead of *Ceq* at the discretion of the manufacturer, and is to be calculated according to the following formula:

$$CET = C + \frac{(Mn + Mo)}{10} + \frac{(Cr + Cu)}{20} + \frac{Ni}{40}\ (\%)$$

Note:
The *CET* is included in the standard EN 1011-2:2001 used as one of the parameters for pre-heating temperature determination which is necessary for avoiding cold cracking.

c) For TM and QT steels with carbon content not more than 0.12%, the cold cracking susceptibility *P*cm for evaluating weldability may be used instead of carbon equivalent of *Ceq* or *CET* at manufacturer's discretion and is to be calculated using the following formula:

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$$Pcm = C + \frac{Si}{30} + \frac{Mn}{20} + \frac{Cu}{20} + \frac{Ni}{60} + \frac{Cr}{20} + \frac{Mo}{15} + \frac{V}{10} + 5B\ (\%)$$

Table 1 Chemical Composition

Delivery condition[1)]	N/NR		TM		QT	
Steel grade / Chemical Composition[2)]	AH420 DH420 AH460 DH460	EH420 EH460	AH420 DH420 AH460 DH460 AH500 DH500 AH550 DH550 AH620 DH620 AH690 DH690 AH890	EH420 FH420 EH460 FH460 EH500 FH500 EH550 FH550 EH620 FH620 EH690 FH690 DH890 EH890	AH420 DH420 AH460 DH460 AH500 DH500 AH550 DH550 AH620 DH620 AH690 DH690 AH890 AH960	EH420 FH420 EH460 FH460 EH500 FH500 EH550 FH550 EH620 FH620 EH690 FH690 DH890 EH890 DH960 EH960
Carbon % max	0.20	0.18	0.16	0.14	0.18	
Manganese %	1.0~1.70		1.0~1.70		1.70	
Silicon % max	0.60		0.60		0.80	
Phosphorus % max[3)]	0.030	0.025	0.025	0.020	0.025	0.020
Sulphur % max[3)]	0.025	0.020	0.015	0.010	0.015	0.010
$Aluminium_{total}$ % min[4)]	0.02		0.02		0.018	
Niobium % max[5)]	0.05		0.05		0.06	
Vanadium % max[5)]	0.20		0.12		0.12	
Titanium % max[5)]	0.05		0.05		0.05	
Nickel % max[6)]	0.80		2.00[6)]		2.00[6)]	
Copper % max	0.55		0.55		0.50	
Chromium % max[5)]	0.30		0.50		1.50	
Molybdenum % max[5)]	0.10		0.50		0.70	
Nitrogen % max	0.025		0.025		0.015	
Oxygen ppm max[7)]	Not applicable		Not applicable	50	Not applicable	30

Note 1 See section 5.1 for definition of delivery conditions.

Note 2 The chemical composition is to be determined by ladle analysis and shall meet the approved manufacturing specification at the time of approval.

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Note 3 For sections the P and S content can be 0.005% higher than the value specified in the table.

Note 4 The total aluminium to nitrogen ratio shall be a minimum of 2:1. When other nitrogen binding elements are used, the minimum Al value and Al/N ratio do not apply.

Note 5 Total Nb+V+Ti ≤ 0.26% and Mo+Cr ≤ 0.65%, not applicable for QT steels.

Note 6 Higher Ni content may be approved at the discretion of the Classification Society.

Note 7 The requirement on maximum Oxygen content is only applicable to DH890; EH890; DH960 and EH960.

Table 2 Maximum *Ceq*, *CET* and *P*cm values

Steel grade and delivery condition	Carbon Equivalent (%)							
	Ceq						*CET*	*P*cm
	Plates			Sections	Bars	Tubulars	all	all
	t ≤ 50 (mm)	50 < t ≤ 100 (mm)	100 < t ≤ 250 (mm)	t ≤ 50 (mm)	t ≤ 250 or d ≤ 250 (mm)	t ≤ 65 (mm)	all	all
H420N/NR	0.46	0.48	0.52	0.47	0.53	0.47	N.A	N.A
H420TM	0.43	0.45	0.47	0.44	N.A	N.A	N.A	N.A
H420QT	0.45	0.47	0.49	N.A	N.A	0.46	N.A	N.A
H460N/NR	0.50	0.52	0.54	0.51	0.55	0.51	0.25	N.A
H460TM	0.45	0.47	0.48	0.46	N.A	N.A	0.30	0.23
H460QT	0.47	0.48	0.50	N.A	N.A	0.48	0.32	0.24
H500TM	0.46	0.48	0.50	N.A	N.A	N.A	0.32	0.24
H500QT	0.48	0.50	0.54	N.A	N.A	0.50	0.34	0.25
H550TM	0.48	0.50	0.54	N.A	N.A	N.A	0.34	0.25
H550QT	0.56	0.60	0.64	N.A	N.A	0.56	0.36	0.28
H620TM	0.50	0.52	N.A	N.A	N.A	N.A	0.34	0.26
H620QT	0.56	0.60	0.64	N.A	N.A	0.58	0.38	0.30
H690TM	0.56	N.A	N.A	N.A	N.A	N.A	0.36	0.30
H690QT	0.64	0.66	0.70	N.A	N.A	0.68	0.40	0.33
H890TM	0.60	N.A	N.A	N.A	N.A	N.A	0.38	0.28
H890QT	0.68	0.75	N.A	N.A	N.A	N.A	0.40	N.A
H960QT	0.75	N.A	N.A	N.A	N.A	N.A	0.40	N.A

Note N.A = Not applicable

5. Delivery Condition - Rolling Process and Heat Treatment

5.1 Steel is to be delivered in accordance with the processes approved by the Classification Society. These processes include:

- Normalized (N)/Normalized rolled (NR)
- Thermo-mechanical controlled rolled (TM)/with Accelerated cooling (TM+AcC)/with direct quenching followed by tempering (TM+DQ), or

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- Quenched and Tempered condition (QT)

The definition of these delivery conditions are defined in UR W11.

Note:
Direct quenching after hot-rolling followed by tempering is considered equivalent to conventional quenching and tempering.

5.2 Rolling reduction ratio

5.2.1 The rolling reduction ratio of slab, billet, bloom or ingot should not be less than 3:1 unless agreed at the time of approval.

5.3 Thickness limits for approval

5.3.1 The maximum thickness of slab, billet or bloom from the continuous casting process shall be at the manufacturer's discretion.

5.3.2 Maximum thickness of plates, sections, bars and tubulars over which a specific delivery condition is applicable are shown in Table 3.

Table 3 Maximum thickness limits

Delivery condition	Maximum thickness (mm)			
	Plates	Sections	Bars	Tubulars
N	250[2)]	50	250	65
NR	150	[1)]		
TM	150	50	Not applicable	Not applicable
QT	150[2)]	50	Not applicable	50

Note 1 The maximum thickness limits of sections, bars and tubulars produced by NR process route are less than those manufactured by N route, and shall be at the discretion of Classification Society.

Note 2 Approval for N steels with thickness larger than 250 mm and QT steels with thickness larger than 150 mm is subject to the special consideration of the Classification Society.

6. Mechanical Properties

Test specimens and test procedures for mechanical properties are in accordance with UR W2 and UR W11.

6.1 Tensile test

6.1.1 Test specimens are to be cut with their longitudinal axes transverse to the final direction of rolling, except in the case of sections, bars, tubulars and rolled flats with a finished width of 600 mm or less, where the tensile specimens may be taken in the longitudinal direction.

6.1.2 Full thickness flat tensile specimens are to be prepared. The specimens are to be prepared in such a manner as to maintain the rolling scale at least at one side. When the capacity of the test machine is exceeded by the use of a full thickness specimen, sub-sized flat tensile specimens representing either the full thickness or half of the product thickness retaining one rolled surface are to be used. Alternatively, machined round test specimens

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may be used. The specimens are to be located at a position lying at a distance of t/4 from the surface and additionally at t/2 for thickness above 100 mm or as near as possible to these positions.

6.1.3 The results of the tests are to comply with the appropriate requirements of Table 4. In the case of product forms other than plates and wide flats where longitudinal tests are agreed, the elongation values are to be 2 percentage units above those transverse requirements as listed in Table 4.

Table 4 Tensile properties at ambient temperature for all steel grades

Mechanical properties / Steel grade and delivery condition		Minimum yield strength R_{eH} [1] (N/mm²)			Ultimate tensile strength R_m (N/mm²)		Minimum percentage elongation after fracture (%) $L_0=5.65\sqrt{S_0}$ [2]		Charpy V-notch impact test		
		Nominal thickness (mm)[4]			Nominal thickness (mm)[4]				Test temp (°C)	Minimum (Joules)	
		≥ 3 ≤ 50	> 50 ≤ 100	> 100 ≤ 250	≥ 3 ≤ 100	> 100 ≤ 250	T	L[3]		T	L
H420N/NR H420TM H420QT	A D E F	420	390	365	520~680	470~650	19	21	0 -20 -40 -60	28	42
H460N/NR H460TM H460QT	A D E F	460	430	390	540~720	500~710	17	19	0 -20 -40 -60	31	46
H500TM H500QT	A D E F	500	480	440	590~770	540~720	17	19	0 -20 -40 -60	33	50
H550TM H550QT	A D E F	550	530	490	640~820	590~770	16	18	0 -20 -40 -60	37	55
H620TM H620QT	A D E F	620	580	560	700~890	650~830	15	17	0 -20 -40 -60	41	62
H690TM H690QT	A D E F	690	650	630	770~940	710~900	14	16	0 -20 -40 -60	46	69
H890TM H890QT	A D E	890	830	Not applicable	940~1100	Not applicable	11	13	0 -20 -40	46	69
H960QT	A D E	960	Not applicable	Not applicable	980~1150	Not applicable	10	12	0 -20 -40	46	69

Note 1 For tensile test either the upper yield stress (R_{eH}) or where R_{eH} cannot be determined, the 0,2 percent proof stress (Rp0.2) is to be determined and the material is considered to comply with the requirement if either value meets or exceeds the specified minimum value of yield strength.

Note 2 For full thickness flat test specimens with a width of 25 mm and a gauge length of 200 mm the elongation is to comply with the minimum values shown in Table 5.

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Note 3 In the case that the tensile specimen is parallel to the final rolling direction, the test result shall comply with the requirement of elongation for longitudinal (L) direction.

Note 4 For plates and sections for applications, such as racks in offshore platforms etc, where the design requires that tensile properties are maintained through the thickness, a decrease in the minimum specified tensile properties is not permitted with an increase in the thickness.

Table 5 Elongation Minimum Values for a Width of 25 mm and a 200 mm Gauge Length[1)]

Strength level	Thickness (mm)						
	≤ 10	> 10 ≤ 15	> 15 ≤ 20	> 20 ≤ 25	> 25 ≤ 40	> 40 ≤ 50	> 50 ≤ 70
H420	11	13	14	15	16	17	18
H460	11	12	13	14	15	16	17
H500	10	11	12	13	14	15	16
H550	10	11	12	13	14	15	16
H620	9	11	12	12	13	14	15
H690	9[2)]	10[2)]	11[2)]	11	12	13	14

Note 1 The tabulated elongation minimum values are the requirements for testing specimen in transverse direction. H890 and 960 specimens and specimens which are not included in this table shall be proportional specimens with a gauge length of $L_0=5.65\sqrt{S_0}$.

Note 2 For H690 plates with thickness ≤ 20 mm, round specimen in accordance with Unified Requirement W2 may be used instead of the flat tensile specimen. The minimum elongation for testing specimen in transverse direction is 14%.

6.2 Impact test

6.2.1 The Charpy V-notch impact test specimens for plates and wide flats over 600 mm in width are to be taken with their axes transverse to the final rolling direction and the results should comply with the appropriate requirements for transverse direction of Table 4. For other product forms, the impact tests are to be in the longitudinal direction, the results of the tests are to comply with the appropriate requirements for longitudinal direction of Table 4.

6.2.2 Sub-surface test specimens will be taken in such a way that one side is not further away than 2 mm from a rolled surface, however, for material with a thickness in excess of 50 mm, impact tests shall be taken at the quarter thickness (t/4) location and mid-thickness (t/2).

6.2.3 Impact test for a nominal thickness less than 6 mm are normally not required.

6.3 Test frequency

6.3.1 Tensile test sample is to be randomly selected from each batch, as defined in IACS UR W11, that is to be less than or equal to 25 tonnes, and to be from the same cast, in the same delivery condition and of the same thickness.

6.3.2 Impact test

a) For steels plates in N/NR or TM condition test sample is to be taken from each piece.

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b) For steels in QT condition test sample is to be taken from each individually heat treated part thereof.

c) For sections, bars and tubulars, test sample is to be taken from each batch of 25 tonnes or fraction thereof.

Note 1:
If the mass of the finished material is greater than 25 tonnes, one set of tests from each 25 tonnes and/or fraction thereof is required. (e.g. for consignment of 60 tonnes would require 3 plates to be tested).

Note 2:
For continuous heat treated product special consideration may be given to the number and location of test specimens required by the manufacturer to be agreed by the Classification Society.

6.4 Traceability

Traceability of test material, specimen sampling and test procedures including test equipment with respect to mechanical properties testing, is to be in accordance with UR W11.

6.5 Re-test procedures

Re-test procedures for tensile tests and Charpy impact tests are to be in accordance with UR W2.

6.6 Through thickness tensile test

6.6.1 For steels designated with improved through thickness properties, through thickness tensile tests are to be performed in accordance with Unified Requirement W14, “Steel plates and wide flats with specified minimum through thickness properties (“Z” quality)”.

6.6.2 Subject to the discretion of Classification Society, through thickness tensile strength may be required to be not less than 80% of the specified minimum tensile strength.

7. Tolerances

Unless otherwise agreed or specially required, the thickness tolerances in Unified Requirement W13, “Allowable under thickness tolerances of steel plates and wide flats” are applicable.

8. Surface Quality

8.1 All materials are to be free from cracks, injurious surface flaws, injurious laminations and similar defects.

8.2 The surface quality inspection method shall be in accordance with recognised national or international standards agreed between purchaser and manufacturer.

a) Welding repair procedures and the method for reporting repairs are to be approved by the individual Classification Societies.

b) Where repair by grinding is carried out then the remaining plate thickness below the ground area must be within the allowable under thickness tolerance.

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8.3 Surface finish requirement shall be in accordance with the relevant requirements in Unified Requirement W11.

8.4 Surface inspection is the responsibility of the manufacturer. The acceptance by the Classification Society's Surveyor of material later found to be defective shall not absolve the manufacturer of this responsibility.

9. Internal Soundness

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

9.2 Ultrasonic examination

9.2.1 If required by the Classification Society, ultrasonic examination should be carried out in accordance with UR W11 for the requirement of internal soundness, and is to be performed in accordance with an approved standard.

10. Stress relieving heat treatment and other heat treatments

10.1 Steels approved by the procedures given in Appendix A with respect to Heat Treatment are suitable for stress relieving heat treatment such as post-weld heat treatment and stress relieving heat treatment after cold forming for the purpose of reducing the risk of brittle fracture, increasing the fatigue lifetime and dimensional stability for machining.

Note:
Products can be susceptible to deterioration in mechanical strength and toughness if they are subjected to incorrect post-weld heat treatment procedures or other processes involving heating such as flame straightening, rerolling, etc. where the heating temperature and the holding time exceed the limits given by the manufacturer.

11. Facilities for Inspection

11.1 Testing is to be carried out under the witness of the Surveyor, or an authorised deputy, in order to verify whether the test results meet the specified requirements.

11.2 The manufacturer is to 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, and the witnessing of tests, as required by this UR. Also for verifying the accuracy of the testing, calibration of inspection equipment and traceability of materials.

12. Identification of Materials

12.1 The manufacturer is to adopt a system for the identification of ingots, slabs, billet or bloom and finished products, which will enable the material to be traced to its original cast. The Surveyor is to be given full facilities for so tracing the material when required.

13. Branding

13.1 Each finished piece is to be clearly marked by the manufacturer with the following particulars:

a) Classification Society's brand mark

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b) Unified identification mark for the grade of steel (e.g. EH620)

c) Name or initials to identify the steelworks

d) Cast number/Heat number, plate number or equivalent identification mark

e) Delivery condition (N/NR, TM/TM+AcC/TM+DQ or Q&T)

The entire markings are to be encircled with paint or otherwise marked so as to be easily recognised. Steels which have been specially approved by the Classification Society and which differ from these requirements (see W16.1.6) are to have the letter “S” after the identification mark (e.g. EH620S)

14. Documentation of Inspection Tests

14.1 The Surveyor is to be supplied with two copies, of the test certificates or shipping statements for all accepted materials. In addition to the description, dimensions, etc., of the material, the following particulars are to be included:

a) Purchaser's order number

b) Identification of the cast and piece

c) Manufacturer’s identification

d) Identification of the grade of steel

e) Chemical analysis, *Ceq*, *CET* or *P*cm value

f) Delivery condition with heat treatment temperatures

g) Mechanical properties test results, including traceable test identification

h) Surface quality and inspection results

i) UT result, where applicable

14.2 Before the test certificates are signed by the Surveyor, the steelmaker is required to provide a written declaration stating that the material has been made by an approved process, and that it has been subjected to and has withstood satisfactorily the required tests in the presence of the Surveyor, or an authorised deputy. The following form of declaration will be accepted if stamped or printed on each test certificate with the name of the steelworks and signed by an authorised representative of the manufacturer:

“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 Strength Steels for Welded Structures

1. Scope of application

This appendix specifies the procedure for the approval of the manufacturing process of high strength steels for welded structures.

All materials are to be manufactured at works which have been approved by the Classification Society for the type, delivery condition, grade and thickness of steel which is being supplied. The suitability of each grade of steel for forming and welding is to be demonstrated during the initial approval tests at the steelworks.

The manufacturing approval scheme is valid for verifying the manufacturer's capability to provide satisfactory products stably under effective process and production controls in operation including programmed rolling, which is required in W16.2.2.

2. Approval application

2.1 Documents to be submitted

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

a) 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) Organisation and quality

- organisational chart
- number of staff employed
- staff employed and organisation 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 IS0 9001 or 9002, if any
- approval certificates already granted by other Classification Societies, if any

c) Manufacturing facilities

- flow chart of the manufacturing process
- origin and storage of raw materials
- storage of finished products
- equipment for systematic control during manufacturing

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d) Details of inspections and quality control facilities

- details of system used for identification of materials at the different stages of manufacturing
- equipment for mechanical tests, chemical analyses and metallography and relevant calibration procedures
- equipment for non-destructive examinations (NDE)
- list of quality control procedures

2.2 Manufacturing specification

a) Material to be approved, including type of products (plates, sections, bars and tubular), delivery condition, grades of steel, range of thickness and aim material properties as follows:

- range of chemical composition, aim analyses and associated control limits, including grain refining, nitrogen binding, micro alloying and residual elements, for the various grades of steel; if the range of chemical composition depends on thickness and delivery condition, the different ranges are to be specified, as appropriate.
- in addition, where zirconium, calcium and rare earth metals have been used during steelmaking for grain refinement and, or inclusion modification, the contents of these elements shall be specified in the manufacturing specification.
- aim carbon equivalent *Ceq* according to IIW formula or *CET* formula and/or aim *P*cm content and associated control limits.
- 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.

b) Steelmaking (if applicable)

- steel making process and capacity of furnace/s or converter/s
- raw material used
- deoxidation, grain refining, nitrogen binding and alloying practice
- desulphurisation, dehydrogenation, sulphide treatment, ladle refining 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., is to be provided as appropriate
- casting/solidification cooling rate control
- ingot or slab size and weight
- ingot or slab treatment: scarfing and discarding procedures

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c) Reheating and rolling

- type of furnace and treatment parameters
- rolling: reduction ratio of ingot/slab/bloom/billet to finished product, rolling and finishing temperatures for each grade/thickness combination
- descaling treatment during rolling
- capacity of the rolling stands

d) Heat treatment

- type of furnaces, heat treatment parameters for products to be approved
- accuracy and calibration of temperature control devices
- the methods used to determine austenitizing temperature, re-crystallization temperature and Ar3 temperature
- description of quenching and tempering process, if applicable

e) Programmed rolling

For products delivered in the Normalised rolling (NR) or thermo-mechanical rolling (TM) condition, the following additional information on the programmed rolling schedules is to be given:

- description of the rolling process
- the methods used to determine austenitizing temperature, re-crystallization temperature and Ar3 temperature
- control standards for typical rolling parameters used for the different thickness and grades of 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

f) Recommendations for fabrication and welding in particular for products delivered in the NR or TM condition:

- 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

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

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

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2.3 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 ingots, slabs, blooms and billets manufactured by companies other than the ones verified in the approval tests.

However, where the documents are duplicated by the ones at the previous approval for the same type of product, part or all of the documents may be omitted except the approval test program (see 3.1).

3. Approval tests

3.1 Extent of the approval tests

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

In particular a reduction of the indicated number of casts, steel plate thicknesses and grades 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) Grades of 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 thicknesses to be tested may be required in the case of newly developed types of steel 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 range, steel grade, grain refining and micro-alloying elements, steel making(deoxidation) 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.

W16 (cont)

3.2 Approval test program

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

3.3 Approval survey

The approval tests are to be witnessed by 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 accredited laboratories.

3.4 Selection of the test product

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

In addition, for initial approval, the Society will require selection of one test product of representative thickness.

The selection of the casts for the test product is to be based on the typical chemical composition, with particular regard to the aimed *Ceq*, *CET* or *P*cm values and grain refining micro-alloying additions.

3.5 Position of the test samples and specimens

The test samples are to be taken, unless otherwise agreed, from the product (plate, flat, section, bar and tubular) corresponding to the top and bottom of the ingot as indicated in Table A1, or, in the case of continuous casting, a random sample.

The position of the samples to be taken in the length of the rolled product, "piece" defined in W11, (top and bottom of the piece) and the direction of the test specimens with respect to the final rolling direction of the material are indicated in Table A1.

The position of the samples in the width of the product is to be in accordance with W11.

The position of the tensile and Charpy impact test samples with respect to the plate thickness is to be in accordance with Appendix 2 section 3.6.2 of W11.

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.

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(cont)

Table A1 Tests on base material

Type of Test		Position and direction of test specimens	Remarks			
1	Chemical analysis (ladle and product[1)])	Top	a) 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. b) Carbon equivalent calculation, and/or c) *P*cm calculation, as applicable.			
2	Segregation examination	Top	Sulphur prints[2)] 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 600 mm long taken from the centre of the edge selected, i.e. on the ingot centreline, and are to include the full plate thickness.			
3	Micrographic examination[3)]	Top	a) Grain size determination. Ferrite and/or prior austenite grain size should be determined. b) All photomicrographs are to be taken at x 100 and 500 magnification. c) Non-metallic inclusion contents/Cleanliness The level of non-metallic inclusions and impurities in term of amount, size, shape and distribution shall be controlled by the manufacturer. The standards of the micrographic examination methods ISO 4967 or equivalent standards are applicable. Alternative methods for demonstrating the non-metallic inclusions and impurities may be used by the manufacturer.			
4	Tensile test	Top and bottom - longitudinal and transverse direction	Yield strength (R_{eH}), Tensile strength (R_m), Elongation (A5), Reduction in Area (RA) and Y/T ratio are to be reported.			
5a	Charpy Impact tests on unstrained specimens for grades[4)]	Top and bottom	Testing temperature (°C)			
	AH	Longitudinal and transverse direction	+20	0	-20	
	DH		0	-20	-40	
	EH		0	-20	-40	-60
	FH		-20	-40	-60	-80

W16
(cont)

Type of Test		Position and direction of test specimens	Remarks			
5b	Charpy Impact tests on strain aged specimens for grades[4)5)]	Top	Deformation of 5% + 1 hour at 250°C			
	AH	Either longitudinal or transverse	+20	0	-20	
	DH		0	-20	-40	
	EH		0	-20	-40	-60
	FH		-20	-40	-60	-80
6	Drop weight test	Top	The test is to be performed only on plates in accordance with ASTM E208. The NDTT is to be determined and photographs of the tested specimens are to be taken and enclosed with the test report.			
7	Through thickness tensile tests	Top and bottom	Optional for grades with improved through thickness properties, testing in accordance with UR W14.			
8	Weldability test[6)]					
a)	Butt Weld Assembly as-welded	Top	Cross weld tensile, Charpy impact test on WM, FL, FL+2, FL+5, FL+20 Macro examination and hardness survey, CTOD at -10°C on Grain-coarsened HAZ.			
b)	Butt Weld Assembly (PWHT), if applicable	Top	Cross weld tensile, Charpy impact test on WM, FL, FL+2, FL+5, FL+20 Macro examination and hardness survey, CTOD at -10°C on Grain-coarsened HAZ.			
c)	Y-shape weld crack test (Hydrogen crack test)	Top				

Note 1 The product analyses should be taken from the tensile specimen. The deviation of the product analysis from the ladle analysis shall be permissible in accordance with the limits given in the manufacturing specification.

Note 2 Other tests than Sulphur prints for segregation examination may be applied and subject to acceptance by the Classification Society.

Note 3 The micrographs are to be representative of the full thickness. For thick products in general at least three examinations are to be made at surface, 1/4t and 1/2t of the product.

Note 4 In addition to the determination of the absorbed energy value, also the lateral expansion and the percentage crystallinity are to be reported.

Note 5 Strain ageing test is to be carried out on the thickest plate.

Note 6 Weldability test is to be carried out on the thickest plate.

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3.6.2 Test specimens and testing procedure

The test specimens and testing procedures are to be in accordance with W2, where applicable.

3.6.3 Other tests

Additional tests such as CTOD test on parent plate, 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, outside the scope of W16, or when deemed necessary by the Society.

3.7 Weldability tests - Butt weld test

3.7.1 For H420 to H500 grade steels: Weldability tests are to be carried out on samples of the thickest plate. Testing on higher grades can cover the lower strength and toughness grades.

a) 1x butt weld test assembly welded with a heat input 15±2 kJ/cm is to be tested as-welded.

b) 1x butt weld test assembly welded with a heat input 50±5 kJ/cm for N/NR and TM and 35±3.5 kJ/cm for QT steels is to be tested as-welded.

c) 1x butt weld test assembly welded with the same heat input as given in b) is to be post-weld heat treated (PWHT) prior to testing.

Option: Steels intended to be designated as steels for high heat input welding are to be tested with 1x butt weld test assembly in the as-welded condition and 1x test assembly in the PWHT condition, both welded with the maximum heat input being approved.

3.7.2 For H550 to H960 grade steels:

In general, the thickest plate with the highest toughness grade for each strength grade is to be tested. Provided the chemical composition of the higher grade is representative to the lower grade, testing requirements on the lower grades may be reduced at the discretion of the Classification Society.

a) 1x butt weld test assembly welded with a heat input 10±2 kJ/cm is to be tested as-welded.

b) 1x butt weld test assembly welded with a maximum heat input as proposed by the manufacturer is to be tested as-welded. The approved maximum heat input shall be stated on the manufacturer approval certificate.

Option: If the manufacturer requests to include the approval for Post Weld Heat Treated (PWHT) condition, 1x additional butt weld test assembly welded with a maximum heat input proposed by the manufacturer for the approval same as test assembly b) is to be post-weld heat treated (PWHT) prior to testing.

3.7.3 Butt weld test assembly

The butt weld test assemblies of N/NR plates are to be prepared with the weld seam transverse to the final plate rolling direction.

The butt weld test assemblies of TM/TM+AcC/TM+DQ and QT plates are to be prepared with the weld seam parallel to the final plate rolling direction. The butt weld test assemblies of long

W16 (cont)

products, sections and seamless tubular in any delivery condition are to be prepared with the weld seam transverse to the rolling direction.

3.7.4 Bevel preparation

The bevel preparation should be preferably 1/2V or K related to thickness.

The welding procedure should be as far as possible in accordance with the normal welding practice used for the type of steel in question.

The welding procedure and welding record are to be submitted to the Classification Society for review.

3.7.5 Post-weld heat treatment procedure

a) Steels delivered in N/NR or TM/TM+AcC/TM+DQ condition shall be heat treated for a minimum time of 1 hour per 25 mm thickness (but not less than 30 minutes and needs not be more than 150 minutes) at a maximum holding temperature of 580°C, unless otherwise approved at the time of approval.

b) Steels delivered in QT condition shall be heat treated for a minimum time of 1 hour per 25 mm thickness (but not less than 30 minutes and needs not be more than 150 minutes) at a maximum holding temperature of 550°C with the maximum holding temperature of at least 30°C below the previous tempering temperature, unless otherwise approved at the time of approval.

c) Heating and cooling above 300°C shall be carried out in a controlled manner in order to heat/cool the material uniformly. The cooling rate from the max. holding temperature to 300°C shall not be slower than 55°C/hr.

3.7.6 Type of tests

From the test assemblies the following test specimens are to be taken:

a) 1 cross weld tensile test - 1 full thickness test sample or sub-sized samples cover the full thickness cross section.

b) 1 set of 3 Charpy V-notch impact specimens transverse to the weld seam and 1-2 mm below the surface with the notch located at the fusion line and at a distance 2, 5 and 20 mm from the straight fusion line. An additional set of 3 Charpy test specimens at root is required for each aforementioned position for plate thickness $t \geq 50$ mm. The fusion boundary is to be identified by etching the specimens with a suitable reagent. The test temperature is to be the one prescribed for the testing of the steel grade.

c) Hardness tests HV10 across the weldment. The indentations are to be made along a 1-2 mm transverse line beneath the plate surface on both the face side and the root side of the weld as follows:

- fusion line
- HAZ: at each 0.7 mm from fusion line into unaffected base material (6 to 7 minimum measurements for each HAZ)

W16 (cont)

The maximum hardness value should not be higher than 350HV for grade steels H420 to H460; not be higher than 420HV for H500 to H690; and not be higher than 450HV for H890 and H960.

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.

d) CTOD test

CTOD test specimens are to be taken from butt weld test assembly specified in 3.7.1 b) or 3.7.2 b) in Appendix A of this UR. CTOD test is to be carried out in accordance with EN ISO 15653 or equivalent.

- the specimen geometry (B = W) is permitted for plate thickness up to 50 mm. For plate thicker than 50 mm, subsidiary specimen geometry (50x50 mm) is permitted, which is to be taken 50 mm in depth through thickness from the subsurface and 50 mm in width. See Figure A1 a) and b) for more details

- the specimens shall be notched in through thickness direction

- grain-coarsened HAZ (GCHAZ) shall be targeted for the sampling position of the crack tip

- the test specimens shall be in as-welded and post-weld heat treated, if applicable

- three tests shall be performed at -10°C on each butt weld test assembly

For grades H690 and above, dehydrogenation of as-welded test pieces may be carried out by a low temperature heat treatment, prior to CTOD testing. Heat treatment conditions of 200°C for 4 h are recommended, and the exact parameters shall be notified with the CTOD test results.

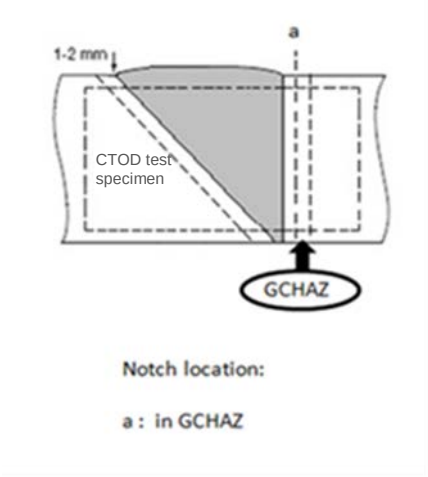

Figure A1 a) - For plate thickness t ≤ 50 mm, CTOD test specimen is to be sampled in full thickness

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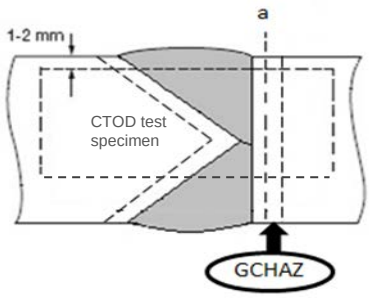
(cont)



Notch location:

a : in GCHAZ

Figure A1 b) - For plate thickness t > 50 mm, subsidiary test specimen with a thickness of maximum 50 mm in subsurface area is to be sampled

3.7.7 Crack susceptibility weld test (Hydrogen crack test)

Testing in accordance with national and international recognised standards such as GB/T4675.1 and JIS Z 3158 for Y-groove weld crack test. Minimum preheat temperature is to be determined and the relationship of minimum preheat temperature with thickness is to be derived.

3.7.8 Other tests

Additional tests may be required in the case of newly developed types of steel, outside the scope of W16, or when deemed necessary by the Society.

4. Results

All the results are to comply with the requirements of the scheme of initial approval.

The subject manufacturer shall submit all the test results together with the manufacturing specification containing all the information required under Appendix A, Section 2, and manufacturing records relevant to steel making, casting, rolling and heat treatment, applicable to the product submitted to the tests.

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.

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6. Renewal of approval

The validity of the approval is to be a maximum of five years.

Renewal can be granted by a periodic inspection and evaluation of the result of the inspection to the surveyor's satisfaction 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 original period of approval, 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 grades and products during the period between renewals may be required to either carry out approval tests or, on the basis of the statistical data of results of production of similar grades of products, at the discretion of the Society, be reapproved.

7. Removal of the approval

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

a) In service failures, traceable to product quality.

b) Non conformity of the product revealed during fabrication and construction.

c) Discovered failure of the Manufacturer's quality system.

d) Changes brought by the Manufacturer, without preliminary agreement of the Society, to the extent of invalidating the approval.

e) Evidence of major non conformities during testing of the products.

* The provision for renewal of approval is also to be applied to all grades and products which were approved by the Society prior to an implementation of revision 3 of this UR W16 regardless of the validity of certificate in existing approvals. Such renewal is to be completed within five years after the revision 3 becomes effective.

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