RULES FOR

MATERIALS AND WELDING
2008

PART 2

American Bureau of Shipping
Incorporated by Act of Legislature of
the State of New York 1862

Rule Change Notice *(2008)*

The effective date of each technical change since 1993 is shown in parenthesis at the end of the subsection/paragraph titles within the text of each Part. This date is based on the date of purchase order of the materials. Unless a particular date and month are shown, the years in parentheses refer to the following effective dates:

(2000) and after	1 January 2000 (and subsequent years)	*(1996)*	9 May 1996
(1999)	12 May 1999	*(1995)*	15 May 1995
(1998)	13 May 1998	*(1994)*	9 May 1994
(1997)	19 May 1997	*(1993)*	11 May 1993

Listing by Effective Dates of Changes from the 2007 Rules

EFFECTIVE DATE 1 January 2008 – shown as *(2008)*
(based on the date of purchase order of the materials)

Part/Para. No.	*Title/Subject*	*Status/Remarks*
2-1-1/Figure 2 (Note)	Standard Round Tension Test Specimen with 50 mm (2 in.) Gauge Length	To clarify the determination of elongation numbers.
2-1-2/15.1	Surface Examination	To reflect materials survey practice.
2-1-2/Table 2 (Note 4)	Tensile Properties of Ordinary Strength Hull Structural Steel 100 mm (4.0 in.) and Under	To clarify the determination of elongation numbers.
2-1-2/Table 4	Impact Properties of Ordinary Strength Hull Structural Steel 100 mm (4.0 in.) and Under	To remove reference to Note 3 from "Temperature" column, as it can be interpreted that CVN tests are required for Grade A steel at $t \leq 50$ mm.
2-1-3/Table 2 (Note 3)	Tensile Properties of Higher-strength Hull Structural Steel 100 mm (4.0 in.) and Under	To clarify the determination of elongation numbers.
2-1-5/13.1	General	To reflect materials survey practice.
2-1-6/1.7	Chemical Composition	To align the requirements with IACS UR W7.
2-1-6/7	Tensile Properties	To clarify the determination of elongation numbers.
2-1-6/11.7	Examination	To reflect materials survey practice.
2-2-1/Figure 3	Stockless Anchor	To reflect materials survey practice.
2-2-3/Table 1	Rolled Bars for Chain – Chemical Composition and Intended Chain Condition	To clarify that the heat treatment description refers to the condition of the chain, not the bars. To add other heat treatment options in accordance with 2-2-2/15.3.
2-3-1/Figure 2 (Note)	Standard Round Tension Test Specimen with 50 mm (2 in.) Gauge Length	To clarify the determination of elongation numbers.
2-3-2/1.1.1	Examination at Mills	To reflect materials survey practice.
2-3-2/1.13.2	For Heat-treated Material	To reflect materials survey practice.
2-3-5/37	Finish	To reflect materials survey practice.
2-3-6/1	Process of Manufacture	To reflect materials survey practice.
2-3-7/1.1.2	Chemical Composition	To align the requirements with IACS UR W7.
2-3-7/1.13	Examination	To reflect materials survey practice.
2-3-7/3.5.6	Stress Relieving	To require that stress relief be carried after machining, in accordance with ASTM A291.

Part/Para. No.	*Title/Subject*	*Status/Remarks*
2-3-7/3.11	Examination	To reflect materials survey practice.
2-3-7/5.11	Examination	To reflect materials survey practice.
2-3-7/7.13	Examination	To reflect materials survey practice.
2-3-7/Table 1	Chemical Composition Requirements for Carbon Steel Machinery Forgings, in percent	To align the requirements with IACS UR W7.
2-3-7/Table 2	Tensile Property Requirements for Carbon-steel Machinery Forgings	To clarify the determination of elongation numbers.
2-3-7/Table 4	Tensile Property Requirements For Alloy Steel Gear Assemble Forgings	To clarify the determination of elongation numbers.
2-3-7/Table 6	Tensile Property Requirements for Alloy Steel Shaft and Stock Forgings	To clarify the determination of elongation numbers.
2-3-7/Table 8	Tensile Property Requirements for General Shipboard Alloy Steel Forgings	To clarify the determination of elongation numbers.
2-3-9/7	Tensile Properties	To clarify the determination of elongation numbers.
2-3-9/15.1	General	To reflect materials survey practice.
2-3-10/3.1	<No Title>	To clarify “important castings” and to remove the requirement for approval testing.
2-3-11/3.1	<No Title>	To remove the requirement for approval testing.
2-3-12/35.1	Group I Piping	To reflect materials survey practice.
2-3-14/3.9	Tensile Properties	To clarify the determination of elongation numbers.
2-3-14/3.11	Test Specimens	To modify the dimension of the test specimen, in accordance with IACS UR W2
2-3-16/5	Process of Manufacture	To reflect materials survey practice.
2-3-17/5	Process of Manufacture	To reflect materials survey practice.
2-3-18/5	Process of Manufacture	To reflect materials survey practice.
2-4-1/7.9	Special Welding Processes and Techniques	To clarify that special welding techniques such as friction stir welding and laser beam welding are to be specially considered.
2-A2-2/7.5	Test Specimens	To align the requirements with IACS UR W17F4.2.
2-A2-2/13.3	Upgrading and Uprating	To require testing of the filler metal at all positions originally tested.
2-A2-3/15.3	Upgrading and Uprating	To align the requirements with IACS UR W17/5.4.2.1.
2-A2-3/Figure 2	Butt-Weld Test Assembly for Submerged Arc Welding – Multi-run Technique	To align the requirements with IACS UR W17/5.2.3.1.
2-A2-4/3	Chemical Analysis and Shielding Gas Composition	To align the requirements with IACS UR W17/6.1.3.2.
2-A2-4/Table (New)	Compositional Limits of Designated Groups of Gas Types and Mixtures	To align the requirements with IACS UR W17/6.1.3.2.
2-A2-4/5.5	Automatic Test Assembly	To align the requirements with IACS UR W17/6.3.2 and 5.2.2.1.
2-A2-4/15.3	Upgrading and Uprating	To require testing of the filler metal at all positions originally tested. To align the requirements with 2-A2-2/13.3.
Appendix 2-A3	Application of Filler Metals to ABS Steels	To align the requirements with IACS UR W17 Table 1.

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PART

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Foreword

For the 1996 edition, the "*Rules for Building and Classing Steel Vessels – Part 2: Materials and Welding*" was re-titled "*Rule Requirements for Materials and Welding (Part 2)*." The purpose of this generic title was to emphasize the common applicability of the material and welding requirements in "Part 2" to ABS-classed vessels, other marine structures and their associated machinery, and thereby make "Part 2" more readily a common "Part" of the various ABS Rules and Guides, as appropriate.

Accordingly, the subject booklet, *Rules for Materials and Welding (Part 2)*, is to be considered, for example, as being applicable and comprising a "Part" of the following ABS Rules and Guides:

- *Rules for Building and Classing Steel Vessels*
- *Rules for Building and Classing Steel Vessels Under 90 Meters (295 Feet) in Length*
- *Rules for Building and Classing Steel Vessels for Service on Rivers and Intracoastal Waterways*
- *Rules for Building and Classing Mobile Offshore Drilling Units*
- *Rules for Building and Classing Steel Barges*
- *Guide for Building and Classing High Speed Craft*
- *Guide for Building and Classing High Speed Naval Craft*
- *Guide for Building and Classing Liftboats*
- *Guide for Building and Classing Floating Production Installations*

In the 2002 edition, Section 4, "Piping" was added to Part 2, Chapter 4, "Welding and Fabrication". This Section is applicable only to piping to be installed on vessels to be built in accordance with the ABS *Rules for Building and Classing Steel Vessels*.

In the 2004 edition, Part 2 was reorganized to incorporate the new divisions "Rules for Testing and Certification of Materials," comprised of Chapters 1, 2 and 3 and Appendices 1, 4, 5, 6 and 7, and "Rules for Welding and Fabrication," comprised of Chapter 4 and Appendices 2 and 3. This reorganization was purely an editorial change intended to clarify the requirements for the materials themselves and for construction, respectively, and does not contain any technical changes.

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PART

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Rule Requirements for Materials and Welding

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PART

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Rules for Testing and Certification of Materials

CHAPTER 1 Materials for Hull Construction

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PART

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CHAPTER 1 Materials for Hull Construction

SECTION 1 General Requirements

1 Testing and Inspection

1.1 General

All materials subject to test and inspection, intended for use in the construction of hulls and equipment of vessels classed or proposed for classification, are to be to the satisfaction of the Surveyor and in accordance with the following requirements or their equivalent. Materials, test specimens and mechanical testing procedures having characteristics differing from those prescribed herein may be approved upon application, due regard being given to established practices in the country in which the material is produced and the purpose for which the material is intended, such as the parts for which it is to be used, the type of vessel and intended service, and the nature of the construction of the vessel.

1.2 Manufacturer Approval *(2003)*

1.2.1 *(2005)*

All rolled products for hull construction are to be manufactured at steel works approved by the Bureau for the type and grade of steel contemplated. The suitability of the products for welding and assumed forming is to be demonstrated during the initial approval test at the steel works. Approval of the steel works is to be in accordance with Part 2, Appendix 4.

1.2.2 *(2006)*

It is the manufacturer's responsibility to assure that effective procedures and production controls are implemented during the production, and that the manufacturing specifications are adhered to. Should any deviation from the procedures and controls occur that could produce an inferior product, the manufacturer is to carry out a thorough investigation to determine the cause of the mishap and establish countermeasures to prevent its recurrence. The complete investigation report is to be submitted to the Surveyor. The Bureau reserves the right to request a closer survey until the cause is resolved to the satisfaction of the Surveyor. Each affected piece is to be tested to the satisfaction of the attending Surveyor prior to distribution from the steel works. In addition, the frequency of testing for subsequent products may be increased to gain confidence in the quality.

1.2.3

Where the steel is not produced at the rolling mill, the procedures in 2-1-1/7.3 are to be followed.

1.3 Test and Test Data

1.3.1 Witnessed Tests

The designation (W) indicates that a Surveyor is to witness the testing unless the plant is enrolled and product is manufactured under the Bureau's Quality Assurance Program.

1.3.2 Manufacturer's Data

The designation (M) indicates that test data is to be provided by the manufacturer without verification by a Surveyor of the procedures used or the results obtained.

1.3.3 Other Tests

The designation (A) indicates those tests for which test data is to be provided by the supplier and audited by the Surveyor to verify that the procedures used and random tests witnessed are in compliance with Rule requirements.

See Part 2, Appendix 1 for a complete listing of indicated designations for the various tests called out by Part 2, Chapter 1 and Part 2, Chapter 2 of this Part.

1.5 Certification on the Basis of the ABS Quality Assurance Program for Rolled Products

Upon application, consideration will be given to the acceptance of plates, shapes and bars without witnessing of mechanical tests by the Surveyor, on the basis of compliance with the Bureau's Quality Assurance Program.

1.7 Rejection of Previously Accepted Material

In the event of any material proving unsatisfactory in the process of being worked, it is to be rejected, notwithstanding any previous certificate of satisfactory testing.

1.9 Calibrated Testing Machines *(2005)*

The Surveyor is to be satisfied that the testing machines are maintained in a satisfactory and accurate condition. Additionally, the Surveyor is to keep a record of the dates and by whom the machines were rechecked or calibrated. All tests are to be carried out to a recognized national or international Standard by competent personnel.

1.11 Structural Pipe

Pipes intended for structural use are to be tested to the physical requirements of Section 2-3-12.

1.13 ASTM References *(1998)*

Frequent references will be found within Part 2, Chapter 1 through Part 2, Chapter 3 to various American Society for Testing and Materials (ASTM) specification designations without year notations. Unless otherwise noted, the current issue of the ASTM specification is to be used.

3 Defects

All materials are to be free from cracks, injurious surface flaws, injurious laminations and similar defects. Except as indicated for specific materials, welding or dressing for the purpose of remedying defects is not permitted unless sanctioned by the Surveyor. In such cases where sanction is required for materials to be so treated, the Surveyor may prescribe further probing and necessary heat treatment; then, if found satisfactory, the part treated is to be stamped with the Surveyor's identification mark and surrounded by a ring of paint.

5 Identification of Materials

The manufacturer is to adopt a system for the identification of ingots, slabs, finished plates, shapes, castings and forgings which will enable the material to be traced to its original heat and the Surveyor is to be given every facility for so tracing the material.

7 Manufacturer's Certificates

7.1 Form of Certificate

Unless requested otherwise, four copies of the certified mill test reports and shipping information (may be separate or combined documents) of all accepted material indicating the grade of material, heat identification numbers, test results and weight shipped are to be furnished to the Surveyor. One copy of the mill test report is to be endorsed by the Surveyor and forwarded to the Purchaser, and three are to be retained for the use of the Bureau. Before the certified mill tests reports and shipping information are distributed to the local Bureau office, the manufacturer is to furnish the Surveyor with a certificate stating that the material has been made by an approved process and that it has satisfactorily withstood the prescribed tests. The following form of certificate will be accepted if printed on each certified mill test report with the name of the firm and initialed by the authorized representative of the manufacturer:

''We hereby certify that the material described herein has been made to the applicable specification by the _____ process (state process) and tested in accordance with the requirements of _____ (the American Bureau of Shipping Rules or state other specification) with satisfactory results.''

At the request of manufacturers, consideration may be given to modifications in the form of the certificate, provided it correspondingly indicates compliance with the requirements of the Rules to no less degree than indicated in the foregoing statement.

7.3 Other Certificates

Where steel is not produced in the works at which it is rolled or forged, a certificate is to be supplied to the Surveyor stating the process by which it was manufactured, the name of the manufacturer who supplied it, the number of the heat from which it was made and the ladle analysis. The number of the heat is to be marked on each ingot, bloom, slab or billet for the purpose of identification.

9 Marking and Retests

9.1 Identification of Specimens

Where test specimens are required to be selected by the Surveyor, they are not to be detached until stamped with his identification mark, nor are they to be detached until the material has received its final treatment.

9.3 Defects in Specimens

If any test specimen shows defective machining or develops defects, it may be discarded and another specimen substituted, except that for forgings a retest is not allowed if a defect develops during testing which is caused by rupture, cracks or flakes in the steel.

9.5 Retests

If the percentage of elongation of any tension test specimen is less than that specified and any part of the fracture is more than 19 mm (0.75 in.) from the center of the gauge length of a 50 mm (2 in.) specimen, or is outside the middle half of the gauge length of a 200 mm (8 in.) specimen, as indicated by scribe scratches marked on the specimen before testing, a retest is to be allowed.

9.7 Rejected Material

In the event that any set of test specimens fails to meet the requirements, the material from which such specimens have been taken is to be rejected and the required markings withheld or obliterated.

11 Standard Test Specimens

11.1 General *(2005)*

The tension test specimens are to be of the full thickness or section of material as rolled, except as otherwise specified. The specimens are to receive no other preparation than that prescribed and are to receive similarly and simultaneously all of the treatment given the material from which they are cut. Straightening of specimens distorted by shearing is to be carried out while the piece is cold. The accuracy of the tensile test machines is to be within ±1% of the load.

11.3 Test Specimens Orientation

Tension test specimens are to be taken longitudinal to the final direction of rolling for plates equal to or less than 600 mm (24 in.) in width and transverse to the final direction of rolling for plates wider than 600 mm (24 in.), except for shapes and bars which are to be taken longitudinal to the final direction of rolling.

11.5 Tension Test Specimens, Plates and Shapes *(1996)*

11.5.1 Flat Specimens

Tension test specimens for rolled plates, shapes and flats are to be cut from the finished material and machined to the form and dimensions referred to in 2-1-1/Figure 1 or tension test specimens of dimensions other than described may be approved at the request of the manufacturer.

11.5.2 Round Specimens

For material over 19 mm (0.75 in.) in thickness or diameter, tension test specimens may be machined to dimensions referred to in 2-1-1/Figure 1. The axis of each round specimen is to be located as near as practicable midway between the center and the surface of the material. Tension test specimens of dimensions other than described above may be approved at the request of the manufacturer.

11.7 Tension Test Specimens for Castings (other than Gray Cast Iron) and Forgings *(2006)*

Tension test specimens for castings and forgings are to be machined to the form and dimensions shown in for the round specimen alternative C in 2-1-1/Figure 1 or in accordance with 2-1-1/Figure 2.

11.9 Bend Test Specimens, Castings and Forgings *(2005)*

When required, bend test specimens for castings and forgings may be machined to 25 mm × 20 mm (1 in. × 0.790 in.) in section. The length is unimportant, provided that it is enough to perform the bending operation. The edges on the tensile side of the bend test specimens may have the corners rounded to a radius of 1–2 mm (0.040–0.080 in.).

11.11 Impact Test Specimens *(2006)*

An impact test is to consist of three specimens taken from a single test coupon or test location. Impact test specimens are to be machined to the form, dimensions and tolerances shown in 2-1-1/Figure 3. Full size standard specimens are to be used unless the section thickness of the product is less than 12 mm (0.5”). For plates, flats and bars, the specimens are to be located with their edges within 2 mm (0.08 in.) from the surface, except that where the thickness exceeds 40 mm (1.57 in.), the longitudinal axis of the specimen is to be located at a point midway between the surface and the center of the thickness. These test specimens are to be cut with their longitudinal axes either longitudinal or transverse to the final direction of rolling of the material at the option of the steel manufacturer, unless a specific orientation is specified. The length of the notch is to be perpendicular to the original rolled surface. Also see 2-1-2/11.1 and 2-1-4/5.1, as applicable.

11.13 Tolerances *(1998)*

The tolerances of the tension test specimen dimensions are to be in accordance with a recognized national standard.

13 Definition and Determination of Yield Point and Yield Strength

13.1 Yield Point *(2005)*

The yield point is the first stress in a material, less than the maximum obtainable stress, at which an increase in strain occurs without an increase in stress. The value of stress is measured at the commencement of plastic deformation at yield, or the value of stress measured at the first peak obtained during yielding even when that peak is equal to or less than any subsequent peaks observed during plastic deformation at yield. Yield point may be determined by the halt of the pointer, or autographic diagram. The 0.5% total extension under load method will also be considered acceptable.

The test is to be carried out with an elastic stress within the following limits:

Modulus of Elasticity of the Material (E), N/mm^2	*Rate of Stressing, N/mm^2-s^{-1}*	
	Min.	*Max.*
< 150,000	2	20
≥ 150,000	6	60

13.3 Yield Strength *(2005)*

The yield strength is the stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain. When no well-defined yield phenomenon exists, yield strength is to be determined by the 0.2% (*Rp 0.2*) offset method. Alternatively, for material whose stress-strain characteristics are well known from previous tests in which stress-strain diagrams were plotted, the 0.5% extension under load method may be used. When agreed upon between the supplier and purchaser for austenitic and duplex stainless steel products, the 1% proof stress (*Rp 1*) may be determined in addition to *Rp 0.2*.

The rate of loading is to be as stated in the limits above.

13.5 Tensile Strength *(2005)*

After reaching the yield or proof load, for ductile material, the machine speed during the tensile test is not to exceed that corresponding to a strain rate of 0.008 s^{-1}. For brittle materials, such as gray cast iron, the elastic stress rate is not to exceed 10 N/mm^2 per second.

14 Elongation *(2005)*

The elongation value is, in principle, valid only if the distance between the fracture and the nearest gauge mark is not less than one-third of the original gauge length. However, the result is valid irrespective of the location of the fracture if the percentage elongation after fracture is equal to or greater than the required value.

Generally, the elongation, A_5, is determined on a proportional gauge length, $5.65\sqrt{S_0} = 5d$, but may also be given for other specified gauge lengths.

If the material is a ferritic steel of low or medium strength and not cold worked, and the elongation is measured on a non-proportional gauge length, the required elongation, A_0, on that gauge length, L_0, may after agreement be calculated from the following formula:

$$A_0 = 2A_5\left(\frac{\sqrt{S_0}}{L_0}\right)^{0.40}$$

15 Permissible Variations in Dimensions *(1994)*

15.1 Scope *(2002)*

The under tolerance specified below represents the minimum material certification requirements and is to be considered as the lower limit of the usual range of variations (plus/minus) from the specified dimension.

The responsibility for meeting the tolerances rests with the manufacturer who is to maintain a procedure acceptable to the Surveyor. Where any tolerance (including over thickness tolerance) to be used is more stringent than the normal commercial tolerance, the Bureau is to be advised before the steel is presented for acceptance to assure that the thickness measuring procedure is appropriate.

In all cases, the thickness of the steel is to comply with the under tolerance specified below. The steel mill is to consider the effect of mill scale on the resulting measurement.

For classification purposes, including the assessment of deterioration at future thickness gaugings, the thickness indicated on the approved plan is to be used.

15.3 Plates *(1996)*

The maximum permissible under thickness tolerance for hull steel plates and wide flats of 5 mm (0.20 in.) or more in thickness is 0.3 mm (0.012 in.).

The thickness is to be measured at a distance of 10 mm (0.375 in.) or more from the edge.

The under thickness tolerance for plates and wide flats less than 5 mm (0.2 in.) in thickness will be specially considered.

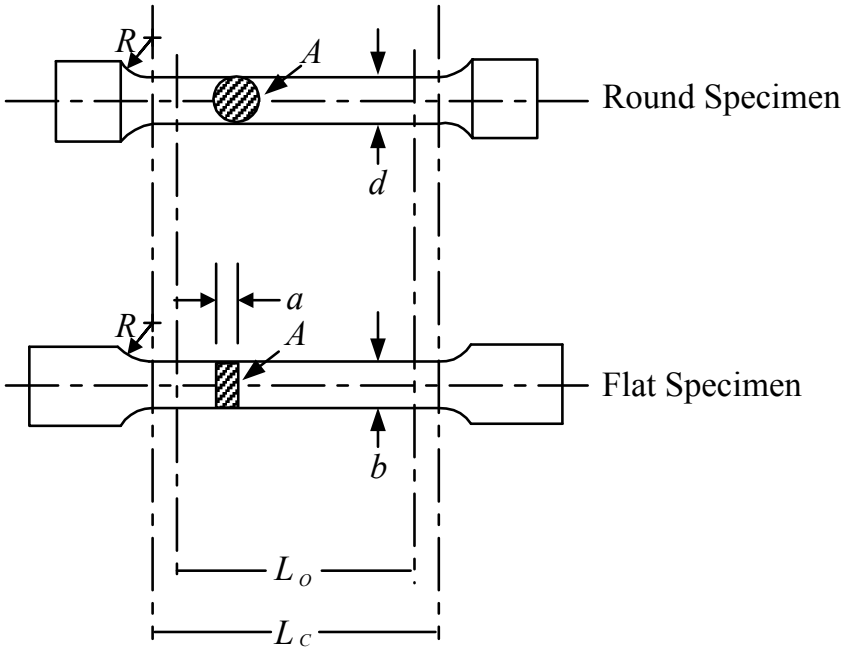
15.5 Shapes and Bars

The under tolerance of cross sectional dimensions for shapes and bars are based on the ordered dimensions and are to conform to those given in ASTM A6 or other recognized standards as may be specified in the purchase order.

16 Rolled Plates over 100 mm (4 in.) Thick *(2006)*

Where rolled plates over 100 mm (4 in.) thick are manufactured at the request of purchaser, chemical analysis, tensile, and impact properties of the material are to be submitted for review and approval together with the application of the material.

FIGURE 1
Standard Tension Test Specimen (1) *(1995)*



d = diameter in mm
a = thickness in mm
b = width in mm
L_o = *(2005)* original gauge length in mm
L_c = *(2005)* parallel length in mm
A = *(2005)* original cross sectional area in mm^2
R = transition radius in mm

	d	a	b	L_o	L_c	R
Flat specimen Alternative A	–	t (2)	25	$5.65\sqrt{A}$	$L_o + 2\sqrt{A}$	25
Flat specimen Alternative B	–	t (2)	25	200	225	25
Round specimen Alternative C	14	–	–	70	85	10

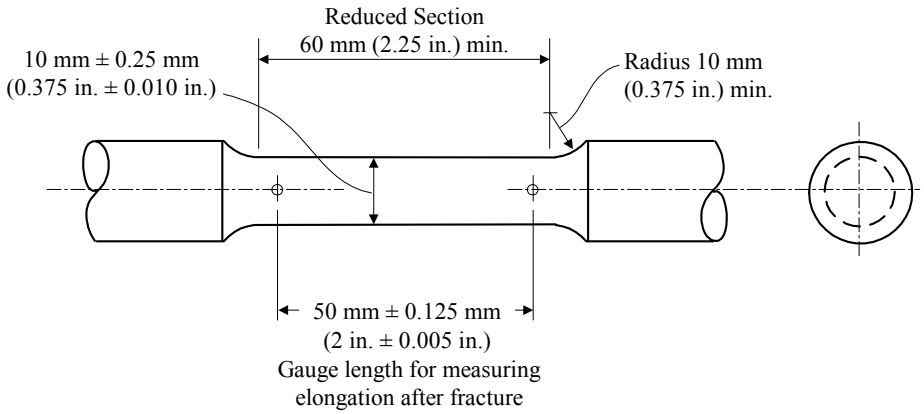
Notes:

1 Standard specimen in accordance with ASTM E8/E8M or A370 will also be acceptable in conjunction with the corresponding elongation requirements in 2-1-2/Table 2 or 2-1-3/Table 2.

2 t is the full thickness of the material as produced. If the capacity of the testing machine does not allow full thickness specimens to be broken, the thickness may be reduced by machining one surface only.

3 *(2005)* L_o, the proportional gauge length, is to be greater than 20 mm.

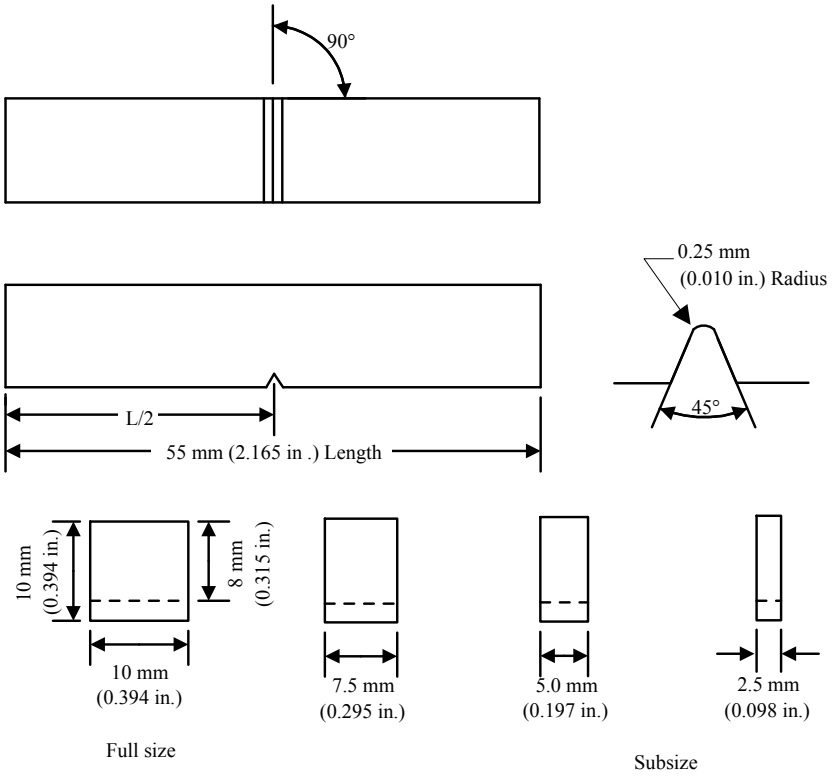
FIGURE 2
Standard Round Tension Test Specimen with 50 mm (2 in.) Gauge Length *(2008)*



Note:

(2008) The gauge length and fillets are to be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load is to be axial. The reduced section may have a gradual taper from the ends towards the center, with the ends not more than 0.13 mm (0.005 in.) larger in diameter than the center.

FIGURE 3
Charpy V-notch Impact Test Specimens



Notes (2005)

Adjacent Sides are to be at 90 Deg ± 10 min.

Width:

Standard Specimen	10 mm ± 0.11mm (0.004 in.)
Subsize Specimen	7.5 mm ± 0.11 mm (0.004 in.)
Subsize Specimen	5 mm ± 0.06 mm (0.0024 in.)
Subsize Specimen	2.5 mm ± 0.06 mm (0.0024 in.)

Angle between plane of symmetry of notch and longitudinal axis of test specimen is to be at 90 Deg. ± 2 Deg.

Length of specimen ± 0.60 mm (0.024 in.)

Surface Finish Requirements on:

Notched surface and opposite face	2 µm (63 µin.)
Other surfaces	4 µm (125 µin.)

Centering of notch ± 1 mm (0.039 in.)

Thickness ± 0.06 mm (0.0024 in.)

Angle of Notch ± 2 Degs.

Radius of Notch ± 0.025 mm (0.001 in.)

Dimension to Bottom of Notch ± 0.06 mm (0.0024 in.)

All impact tests are to be carried out on Charpy machines complying with the requirements of ISO 148 or other national and international recognized Standards, and having a striking energy of not less than 150 J.

Where the test temperature is other than ambient, the temperature of the test specimen at the moment of breaking shall be the specified temperature within ± 1°C (± 2°F).

17 Steel Plates and Wide Flats with Specified Minimum Through Thickness Properties ("Z" Quality) *(2007)*

"Z" quality steel is employed in those structural details subject to strains in the through thickness direction in order to minimize the possibility of lamellar tearing during fabrication.

These requirements are intended for material with a thickness greater than or equal to 15 mm (0.60 in.) where a specified minimum ductility in the through thickness or "Z" direction is specified. Products with a thickness less than 15 mm (0.60 in.) may also be included.

Two "Z" quality steels are specified:

Z25 for normal ship applications

Z35 for more severe applications.

Through thickness properties are characterized by specified values for reduction of area in a through thickness tension test.

The steel works are to be approved by the Bureau for the manufacture of "Z" quality steels, in accordance with Part 2, Appendix 4. In addition, the maximum sulfur content is to be 0.008%, determined by ladle analysis.

When steels with improved through thickness properties are specified, special steel-making processes are to be used. The following processes used either singly or in combination would be considered to meet this requirement.

i) Low sulfur practices

ii) Addition of elements known to control the shape of nonmetallic inclusions.

iii) Electroslag or vacuum arc remelting.

iv) Control of centerline segregation during continuous casting

The following requirements apply to plates and wide flats with thickness not less than 15 mm (0.60 in.). Recognized standards such as ASTM A770 may be specified for use in lieu of 2-1-1/17.1 through 2-1-1/17.5 and 2-1-1/17.9.

17.1 Sampling

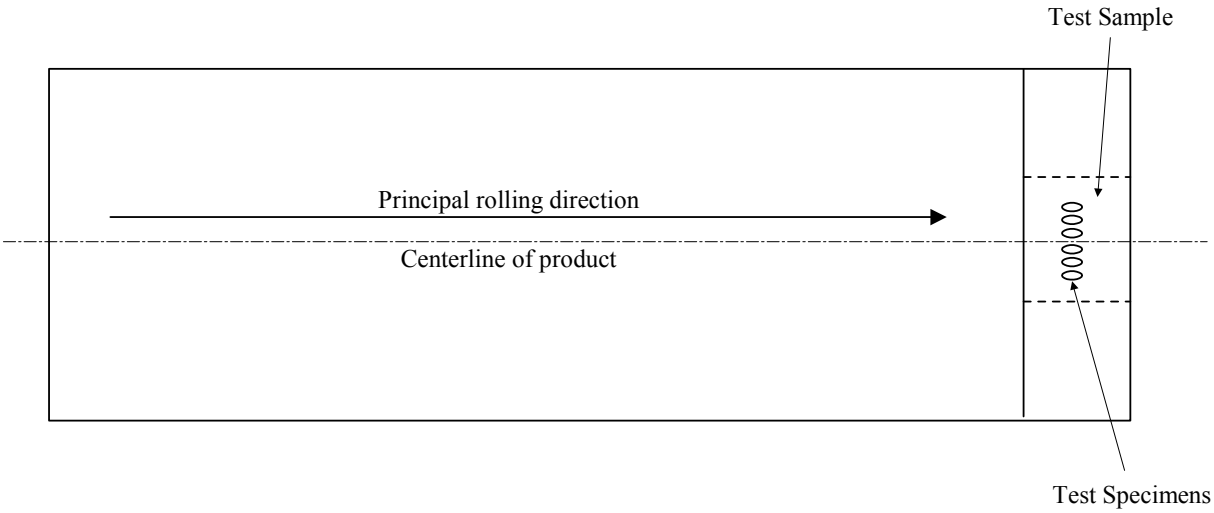
The samples for preparing test specimens for plates and wide flats are to be taken as follows:

One test sample is to be taken close to the longitudinal centerline of one end of each rolled piece representing the batch. See 2-1-1/Table 1 and 2-1-1/Figure 4.

TABLE 1
Batch Size Depending Upon Product and Sulfur Content *(2005)*

Product	*Sulfur > 0.005%*	*Sulfur ≤ 0.005%*
Plates	Each piece (parent plate)	Maximum 50 t of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness ≤ 25 mm (1.0 in.)	Maximum 10 t of products of the same cast, thickness and heat treatment	Maximum 50 t of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness > 25 mm (1.0 in.)	Maximum 20 t of products of the same cast, thickness and heat treatment	Maximum 50 t of products of the same cast, thickness and heat treatment

FIGURE 4
Plate and Wide Flat Sampling Position *(2005)*



17.3 Number of Tensile Test Specimens

The test sample must be large enough to accommodate the preparation of six (6) specimens. Three (3) test specimens are to be prepared while the remaining samples are set aside for possible retest.

17.5 Tensile Test Specimen Dimensions

Round test specimens, including built-up type by welding, are to be prepared in accordance with a recognized national standard.

17.7 Tensile Test Results

The minimum average value for the reduction of area of at least three (3) tensile test specimens taken in the through thickness direction must be that shown for the appropriate grade given in 2-1-1/Table 2. Only one individual value may be below the minimum average but not less than minimum individual value shown for the appropriate grade. See 2-1-1/Figure 5.

A value less than the minimum individual value is a cause for rejection

The test is considered invalid and a further replacement test is required if the fracture occurs in the weld or heat-affected zone.

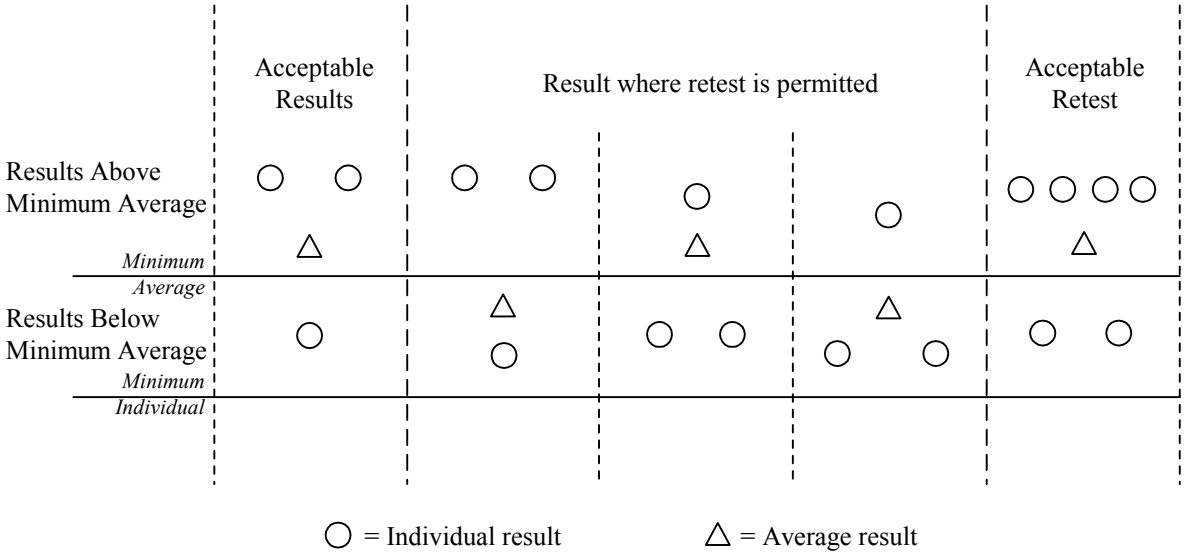
TABLE 2
Reduction of Area Acceptance Values *(2005)*

Grade	*Z25*	*Z35*
Minimum Average	25%	35%
Minimum Individual	15%	25%

17.9 Retests

2-1-1/Figure 5 shows the three cases where retest is permitted. In these instances, three more tensile tests are to be taken from the remaining test sample. The average of all six (6) tensile tests is to be greater than the required minimum average with no greater than two results below the minimum average. In the case of failure after retest, either the batch represented by the piece is rejected or each piece within the batch is required to be tested.

FIGURE 5
Diagram Showing Acceptance/Rejection and Retest Criteria *(2005)*



17.11 Ultrasonic Inspection *(2007)*

Ultrasonic testing is required and is to be performed in accordance with either EN 10160 Level S1/E1 or ASTM A 578 Level C.

Ultrasonic testing should be carried out on each piece in the final supply condition and with a probe frequency of 2.0 or 2.25 MHz. When carrying out UT on material less than 20 mm ($^3/_4$") thick, frequency up to 5 MHz may be considered acceptable if satisfactorily documented and qualified.

17.13 Marking

Products complying with these requirements are to be marked in accordance with the appropriate steel requirement and, in addition, with the notation Z25 or Z35 added to the material grade designation, (e.g., EH36Z25 or EH36Z3).

17.15 Certification

The following information is required to be included on the certificate:

i) Through thickness reduction in area (%)

ii) Steel grade with Z25 or Z35 notation.

19 Formed Materials

When material is hot or cold formed, confirmatory mechanical tests are to be conducted when required by 2-4-1/3.13.

21 Ultrasonic Examination of Plate Material

In order to be specially marked in accordance with paragraph 2-1-2/13.13, ABS steels are to be ultrasonically examined in accordance with a recognized specification such as ASTM A435 or equivalent.

23 Fracture Toughness Testing *(2006)*

When specified, fracture toughness testing of materials and weldments is to be carried out. Fracture toughness testing may involve tests for properties such as plane strain fracture toughness parameter, K_{IC}; elastic-plastic fracture toughness parameter, J_{IC}; or critical crack-tip opening displacement (CTOD) parameter, for mode-I type of deformation. Tests are to be carried out as per BS 7448 Parts 1 & 2/ASTM E1820 specification or any other recognized standard. The test is deemed to be valid and acceptable provided post-test data analyses meets all validity criteria of BS 7448 Parts 1 & 2/ASTM E1820 or any other recognized standard, and the fracture toughness value determined is equal to or greater than the minimum specified value in the Bureau approved specification. Specific aspects that are to be taken into considerations before testing is initiated are listed below:

23.1

Specimen geometry, notch orientation and load type (bend or tension) are to be selected as per the specification and are to be in conformity with BS 7448 Parts 1 & 2/ASTM E 1823 or any other recognized standard.

23.3

Cut samples for machining test specimens are to be extracted from test coupons or locations with proper orientation identified as specified in the material specification for plates, and for welds, as given in the manufacturing procedure specification. Orientation mark, heat number, plate number, etc., based on the manufacturer's evolved traceability system are to be transferred onto the samples using a template and paint, local chemical etching or appropriate mechanical means. No plastic deformation or distortions are permitted during this process. This process is to be repeated on the finished, inspected and accepted specimens before the testing program is initiated. A mix-up of specimens without proper identification will call for rejection of the test results.

23.5

If straightening of the samples is needed, then it is to be carried out between the platens of a suitable press (mechanical or hydraulic) under the slowest possible loading rate, and the compressive load applied is not to exceed the compressive yield stress of the material. It is the responsibility of the manufacturer during this operation to ensure complete safety to personnel and the witnessing Surveyor.

23.7

Dimensions, machined notch root radius, side grooving and other fine details (such as specimen surface finish, centerline offset of loading pins, etc.) in the test specimens are to be as per the approved specimen drawing and in conformity with ASTM E1820 or to any other recognized standard.

23.9

Calibration certificates for servo-mechanical/hydraulic universal testing machines, load cells, transducers, and recording equipment used in testing are to be provided to the Surveyor by the testing lab for verification and record. Selection of the loading roller diameter and its alignment with the crack plane of the specimen in the case of bend specimen testing and proper alignment of the clevis for compact tension testing are to be ensured by the Surveyor prior to the beginning of a test.

23.11

Crack opening displacement (COD) gauges are to be calibrated once per batch of testing in the presence of the Surveyor.

23.13

Fatigue pre-cracking loads and cyclic loading rates (applied stress intensity level/time) are to be as per BS7448/ASTM E1820 or any other recognized standards, and the Surveyor is to witness at least one specimen in a batch of specimens being tested. For the rest, the test lab has to provide the loading history and certify that these were done in accordance with BS 7448/ASTM E1820 or any other recognized standard requirements.

23.15

Crack length measurement can be made by compliance or electrical potential technique and may be supplemented by optical means of measurements. The calibration method employed is to be verified by the Surveyor and is to be validated by nine (9) point measurements made on the broken specimen after the test as per BS 7448/ASTM E1820 or to any other recognized standard. Heat tinting/etching or any other suitable method(s) used to reveal the crack front to estimate the final crack length in post-test analysis shall be to the satisfaction of the Surveyor. Photo-macrographs of the broken samples are to be captured and documented along with the valid test report for each specimen tested.

23.17

The following acceptance criteria for CTOD tests are to be applied whenever CTOD tests are specified and performed. If the scatter in CTOD (δ_c, δ_u or δ_m) data from a set of three tests is such that the minimum value is greater than or equal to 70% of the average value of the set, then the minimum value of the three specimens is to be taken as the characteristic CTOD value for a specified location (base metal, weld metal, or HAZ) and is to be equal to or higher than the specified minimum CTOD value for the material at the location. If the minimum value is less than 70% of the average value of the set, or if the minimum value of the three specimens fails to meet the specified minimum CTOD value, then three additional specimens are to be machined and tested from the same previously tested plate, product, or weldment. The second lowest of all six values is to be reported as the characteristic CTOD value and this has to be equal to or greater than the specified minimum CTOD value as stipulated in the Bureau-approved material and fabrication specifications for the specified location.

PART

2

CHAPTER 1 Materials for Hull Construction

SECTION 2 Ordinary-strength Hull Structural Steel

1 Ordinary-strength Hull Structural Steel *(1996)*

The requirements in this subsection are intended for products of the following thicknesses.

Plates and Wide Flats	up to and including 100 mm (4.0 in.)
Sections and Bars	up to and including 50 mm (2.0 in.)

3 Process of Manufacture

The steel is to be made by one or more of the following processes: open-hearth, basic-oxygen, electric-furnace, vacuum-arc remelt, electro-slag remelt, or such other process as may be specially approved. The steel may be cast in ingots or may be strand (continuous) cast. The ratio of reduction of thickness from a strand (continuous) cast slab to finished plate is to be a minimum of 3 to 1 unless specially approved. Data in support of mechanical properties, weldability and compliance with the Rules in all respects are to be submitted by the steel manufacturer for review and approval when new or special steels or production methods are proposed or when new steel mills begin production.

3.1 Plates Produced from Coils

For coiled plate, the manufacturer or processor is to submit supporting data for review and approval to indicate that the manufacturing, processing, and testing will provide material which is in compliance with the Rules.

5 Chemical Composition

5.1 Ladle Analysis

The chemical composition is to be determined by the steel manufacturer on samples taken from each ladle of each heat and is to conform to the applicable chemical requirements of the grades of steel listed in 2-1-2/Table 1.

5.3 Product Analysis

When product (check) analysis is required, the chemical tolerances of ASTM A6 or of other nationally recognized standards are to be applied.

5.5 Special Compositions

Material differing in chemical composition, deoxidation practice, mechanical properties or heat treatment from that shown in 2-1-2/Table 1 will be subject to special approval.

5.7 Fine Grain Practice

Where steel is required to be made using fine grain practice, the requirement is to be met by adding aluminum, unless some other method is specially approved. The fine grain requirement may be determined by one of the following methods.

5.7.1

A McQuaid-Ehn austenite grain size of 5 or finer in accordance with ASTM E112 for each ladle of each heat, or

5.7.2

Minimum Acid-soluble Aluminum content of 0.015% or minimum total Aluminum content of 0.020% for each ladle of each heat.

7 Condition of Supply *(2005)*

The conditions of supply are to be in accordance with the requirements in 2-1-2/Table 5 and the following:

Controlled manufacturing processes require approval for each plant and combination of grade and thickness limit.

The applicable rolling procedures are defined as follows.

7.1 As Rolled – AR *(2005)*

This procedure involves the rolling of steel at high temperature followed by air cooling. The rolling and finishing temperatures are typically in the austenite recrystallization region and above the normalizing temperature. The strength and toughness properties of steel produced by this process are generally less than steel heat treated after rolling or than steel produced by advanced processes.

7.3 Heat Treatment *(1995)*

7.3.1 Normalizing Heat Treatment *(2005)*

A normalizing heat treatment is to consist of heating plates, wide flats, bars or shapes from an appropriate temperature below the transformation range to the proper temperature above the transformation range, holding for a sufficient time to effect the desired transformation and then individually cooling the material in air. The process improves the mechanical properties of as-rolled steel by refining the austenitic grain size, provided that the steel is produced to fine austenitic grain size practice. Normalizing heat treatments are usually conducted at the steel manufacturer's plant. Such heat treatment may be carried out at a shipyard or fabricator's plant, provided the Surveyor is satisfied with the heat-treating facilities and procedures. In such cases, the shipyard or fabricator is to indicate on the purchase order that the mill tests are to be made on normalized coupons. Otherwise, tests on the normalized material will be required at the shipyard or fabricator's plant.

7.3.2 Special Heat Treatment

Other types of heat treatment are to be specially approved.

7.5 Controlled Manufacturing Process *(1995)*

7.5.1 Controlled Rolling – CR (Normalized Rolling – NR) *(2005)*

Controlled rolling is a procedure in which the final rolling temperature is generally controlled within the range used for normalizing heat treatments so that the austenite completely recrystallizes, resulting in a material condition generally equivalent to that obtained by normalizing.

7.5.2 Thermo-mechanical Rolling – TM (Thermo-mechanical Controlled Processing – TMCP) *(2005)*

Thermo-mechanical controlled processing involves the strict control of the steel temperature and the rolling reduction. Generally, a high proportion of the rolling reduction is carried out close to or below the Ar_3 transformation temperature and may involve rolling toward the lower end of the temperature range of the intercritical duplex phase region, thus permitting little if any recrystallization of the austenite. Unlike controlled rolling, the properties produced by TM (TMCP) cannot be reproduced by subsequent normalizing or other heat treatment.

The use of accelerated cooling on completion of rolling may also be accepted, subject to the special approval of the Bureau.

Accelerated cooling (AcC) is a process which aims to improve mechanical properties by controlled cooling with rates higher than air cooling immediately after the final TM (TMCP) operation. Direct quenching is excluded from accelerated cooling.

Where CR and TM with/without AcC are applied, the programmed rolling schedules are to be verified by the Bureau at the time of the steel works approval, and are to be made available when required by the attending Surveyor. On the manufacturer's responsibility, the programmed rolling schedules are to be adhered to during the rolling operation. Refer to 2-1-1/1.2.2. To this effect, the actual rolling records are to be reviewed by the manufacturer and occasionally by the Surveyor.

When deviation from the programmed rolling schedules or normalizing or quenching and tempering procedures occurs, the manufacturer shall take the further measures required in 2-1-1/1.2.2 to the Surveyor's satisfaction.

7.7 Quenching and Tempering – QT *(2005)*

Quenching involves a heat treatment process in which steel is heated to an appropriate temperature above the Ac_3 and then cooled with an appropriate coolant for the purpose of hardening the microstructure. Tempering subsequent to quenching is a process in which the steel is reheated to an appropriate temperature not higher than the Ac_1 to restore toughness properties by improving the microstructure.

9 Tensile Properties

9.1 Required Tensile Properties

The material, except as specified in 2-1-2/9.5, is to conform to the requirements of 2-1-2/Table 2 as to tensile properties.

9.3 Tension Test Specimens

One tension test is to be made on two different plates, shapes or bars from each heat of steel, unless the finished material from a heat is less than 50 tons, when one tension test will be sufficient. If, however, material from one heat differs 9.5 mm (0.375 in.) or more in thickness or diameter, one tension test is to be made from both the thickest and the thinnest material rolled, regardless of the weight represented. One tension test is to be made on each plate as quenched and tempered. For plates from coils, tension tests are to be made from not less than two coils from each heat, except where a single coil is to be certified in which case tension test specimens from that coil only need be tested. Two tension tests are to be made from each coil tested. One tension test specimen is to be obtained from a location immediately prior to the first plate produced and a second test specimen obtained from the approximate center lap. When the coiled material from one heat differs by 1.6 mm ($^1/_{16}$ in.) or more in thickness, test specimens are to be obtained from both the thinnest and the thickest material rolled.

9.5 Exceptions

Shapes less than 645 mm^2 (1 in^2) in cross section and bars, other than flats, less than 12.5 mm ($^1/_2$ in.) in thickness or diameter need not be subject to tension test, but chemistry consistent with the required tensile properties is to be applied.

9.7 *<No Text>* *(2007)*

9.9 Omission of Elongation Requirements

For raised-pattern floor plates not exceeding 12.5 mm (0.50 in.) in thickness, the requirement for elongation is waived.

9.11 Retests *(1996)*

Where the results of the tension test do not comply with the requirements, two further tests may be carried out on specimens taken from the same sample. For elongation retest, 2-1-1/9.5 is to be complied with. For plates from coils, the retest specimens are to be taken adjacent to the original specimen.

If the results of both additional tests meet the requirements, the material tested or represented by the test may be accepted.

When the results of one or both additional tests do not meet the requirements, the sample is to be rejected unless the manufacturer elects to resubmit it after heat treatment or reheat treatment, or as another grade. The rest of the material represented by the test may be treated under 2-1-2/9.13.

9.13 Unsatisfactory Tests *(1996)*

Where the tests under 2-1-2/9.3 and 2-1-2/9.13 fail, the remaining material from the same heat may be accepted, provided satisfactory results are obtained on both of two additional plates, shapes or bars selected in accordance with 2-1-2/9.3.

When the results of one or both samples do not meet the requirements, all materials represented by the tests are to be rejected unless the manufacturer elects to submit each piece individually, or to resubmit the lot after heat treatment or reheat treatment or as another grade.

11 Impact Properties

11.1 Impact Tests *(1996)*

Charpy V-notch impact tests are to be carried out in accordance with 2-1-2/Table 4. These same requirements apply for flats, rounds and shapes when specially ordered in these grades unless agreed otherwise. For rolled sections, impact tests specimens are to be taken from the flanges of beams, channels and tees, and from the legs of angles and bulb angles. One set of three impact specimens is to be obtained from the thickest material rolled, except when the maximum thickness or diameter of the material represented by the test differs by 9.5 mm (0.375 in.) or more, in which case, one set of impacts is to be made from both the thickest and the thinnest material represented, regardless of their weight. See 2-1-1/11.11.

For plates produced from coils, impact test coupons are to be obtained adjacent to both tension test coupons and a third impact test coupon is to be obtained immediately after the last plate produced to the qualifying grade or specification; in no case, however, is the frequency of impact testing to be less than that given above for plates, and where additional testing is required, three sets of specimens are to be obtained from each coil tested.

11.3 Impact Test Frequency

The frequency of impact testing is to be in accordance with 2-1-2/Table 5.

11.5 Initial Test Requirements

The average value of three specimens is to comply with the required average value in the Tables. Only one individual value may be below the required average and it is not to be less than 70% of the required average.

Where the subsize specimens in 2-1-1/Figure 2 are to be used, the modified energy values will apply, as follows:

Subsize Specimen Impact Requirements

Specimen Size	10 × 7.5 mm (0.394 × 0.295 in.)	10 × 5.0 mm (0.394 × 0.197 in.)	10 × 2.5 mm (0.394 × 0.098 in.)
Required Energy	5*E*/6	2*E*/3	*E*/2

E = energy required for 10 × 10 mm (0.394 × 0.394 in.) specimen

11.7 Retests

When the results fail to meet the above requirements but conditions ii) and iii) below are complied with, three additional specimens may be taken from the location as close to the initial specimens as possible and their test results added to those previously obtained to form a new average. The material represented may be accepted if for the six specimens all of the following conditions are met:

i) The average is not less than the required average.

ii) No more than two individual values are below the required average.

iii) No more than one individual value is below 70% of the required average.

If the results of tests do not meet the above requirements, the material tested is to be rejected unless the manufacturer elects to resubmit it after heat treatment or reheat treatment, or to resubmit as another grade.

11.9 Unsatisfactory Tests

The remaining material from the heat may be accepted, provided satisfactory impact results are obtained on both of two further plates of the same thickness as the rejected plate in the heat. Alternatively, the manufacturer may qualify material of the same thickness by impact testing each plate. Plates of a lesser thickness in the same heat may be accepted, provided that satisfactory results are obtained on impact specimens taken from the next lower thickness than the rejected plate.

11.11 Thin Plates *(1996)*

Generally, impact tests are not required for plates less than 6 mm (0.24 in.) in thickness.

13 Marking

13.1 Stamped or Stenciled Material

The Bureau markings **AB** and the applicable grades listed in 2-1-2/Table 1 indicating satisfactory compliance with the Rules are to be clearly steel-die-stamped or stenciled by the manufacturer on each finished plate, shape and bar to signify that the material has satisfactorily complied with the tests prescribed and that certificates for the material will be furnished to the Surveyor in accordance with 2-1-1/7. Coiled steel which is certified for chemical analysis only, is to be marked **AB** without the grade designation.

13.3 Coils, Lifts and Bundles

In special cases, upon application, coils intended for light plate and secured lifts or bundles of light plates, shapes or bars of comparatively small size may be steel-die stamped, stenciled, or labeled on only the top piece or at another approved location, or the markings may be shown on a tag attached to each coil, lift or bundle.

13.5 Flanging-quality Identification

All material intended for cold flanging, when specially approved in accordance with 3-1-2/1.1, is to be additionally marked **F** to signify that it is of such quality.

13.7 Special Stamping and Marking

Material, other than those grades listed in 2-1-2/Table 1, is to be marked with both the initials **AB/S** and with either the applicable specification number, or such other markings as may be required for ready identification, to signify that the material has been produced and satisfactorily tested in accordance with the specification. When a specification does not specifically require normalizing but the material is so ordered and so produced, then the plates are also to be marked with the initial **N** to indicate that the material has been normalized. A shipyard or fabricator who carries out a normalizing heat treatment in accordance with 2-1-2/7 is to also mark such material with the initial **N**.

13.9 Special Impact Testing

When steel is impact tested at temperatures other than those specified in 2-1-2/Table 4, the grade marking is to be followed by the test temperature in degrees Celsius. A prefix “0” to the test temperature is to indicate a temperature colder than zero degrees Celsius.

13.11 Steel with Improved Through Thickness Properties

Steel plates meeting the requirements of 2-1-1/17 are to have the letter **Z** marked after the grade designation.

13.13 Steel with Ultrasonic Examination

Steels meeting the requirements of 2-1-1/21 are to have the letter **U** marked after the grade designation as a final letter.

13.15 Shipping Procedure

No material bearing these markings is to be forwarded from the steel works until the prescribed tests have been satisfactorily carried out in accordance with the Rules.

13.17 Steel at Secondary Sources

Secondary sources for ABS Grade Steel are required to assure traceability of steel intended for Bureau certification. To retain proper identification, steel may be marked with the information indicated by the manufacturer's markings to the satisfaction of the Surveyor.

15 Surface Finish

15.1 Surface Examination *(2008)*

The material surfaces will be examined by the Surveyor when specially requested by the purchaser. It is to be free from defects and have a workmanlike finish subject to the conditions given in the following subparagraphs.

15.3 Treatment of Surface Defects – Plates

Plates may be conditioned by the manufacturer for the removal of surface defects on either surface by grinding, provided each ground area is well faired and the grinding does not reduce the thickness of the plate

i) More than 7% under the nominal thickness and in no case more than 3.2 mm (0.125 in.) when ordered to weight or;

ii) Below the minimum thickness permissible under 2-1-1/15.3 when ordered to thickness.

Plates may have surface defects removed by chipping, grinding or gouging and then depositing weld metal, subject to the following limiting conditions.

15.3.1 Extent of Weld Repaired Area

The total weld repaired area of each surface of a plate is not to exceed 2% of the area of that surface.

15.3.2 Minimum Thickness Before Weld Repairs

After removal of any defect preparatory to welding, the thickness of the plate is not to be reduced by more than 20% of the nominal thickness.

15.3.3 Inspection Before Weld Repairs

An experienced mill inspector is to examine the work to see that the defects have been removed completely and that the foregoing limitations have not been exceeded. The Surveyor is to be given full opportunity to make this same inspection. To assure removal of defects, magnetic particle or liquid penetrant examination may be required.

15.3.4 Repair-welding Quality

All welding is to be performed by qualified operators, using an approved welding procedure and low hydrogen filler metal/practice. The welding is to be sound, thoroughly fused, and without undercutting or overlap. Weld metal is to have at least 1.6 mm (0.063 in.) reinforcement, which is to be removed by grinding or chipping and grinding flush with the rolled surface, and is to present a workmanlike finish.

15.5 Treatment of Surface Defects – Shapes

Shapes may be conditioned by the manufacturer for the removal of surface defects by grinding or by chipping to sound metal and depositing weld metal, in accordance with the following limitations.

15.5.1 Chipping and Grinding Material Under 9.5 mm (0.375 in.) in Thickness

For material less than 9.5 mm (0.375 in.) thickness, in which the defects are not more than 0.8 mm (0.031 in.) in depth, the defects may be removed by grinding or chipping and grinding with the edges well faired.

15.5.2 Chipping and Grinding Material 9.5 mm (0.375 in.) and Over in Thickness

For material 9.5 mm (0.375 in.) and over in thickness, in which the defects are not more than 1.6 mm (0.063 in.) in depth, the defects may be removed by grinding or chipping and grinding with the edges well faired.

15.5.3 Welding Repairs

Surface defects which are greater in depth than the limits shown above may be removed by chipping or grinding and then depositing weld metal, subject to the following limiting conditions.

15.5.3(a) The total area of the chipped or ground surface of any piece is not to exceed 2% of the total surface area of that piece.

15.5.3(b) After removal of any defect preparatory to welding, the thickness of the shape is not to be reduced by more than 30% of the nominal thickness, nor is the depth of depression prior to welding to exceed 12.5 mm (0.50 in.) in any case.

15.5.3(c) The toes of angles, beams, channels and zees and the stems and toes of tees may be conditioned by grinding or chipping and welding. Prior to welding, the depth of depression, measured from the toe inward, is to be limited to the thickness of the material at the base of the depression, with a maximum depth limit of 12.5 mm (0.50 in.).

15.5.3(d) An experienced mill inspector is to inspect and the welding is to be done in accordance with the requirements of 2-1-2/15.3.3 and 2-1-2/15.3.4.

15.7 Bar-stock Repairs

Bars may be conditioned by the manufacturer for the removal of surface defects by grinding, chipping or some other means, provided the conditioned area is well faired and the depth of depression does not extend below the nominal thickness or diameter by more than 1.5%.

15.9 Rivet Steel and Rivets *(1996)*

Material test requirements for rivet steel are to comply with the requirements of Section 25 of the 1969 *Rules for Building and Classing Steel Vessels*.

TABLE 1
Chemical Properties of Ordinary Strength Hull Structural Steel 100 mm (4.0 in.) and Under *(1996)*

Grade	*A*	*B*	*D*	*E*
Deoxidation	*Killed or semi-killed* [1] *(t ≤ 50 mm (2.0 in.)) Killed (t > 50 mm (2.0 in.))*	*Killed or semi-killed (t ≤ 50 mm (2.0 in.)) Killed (t > 50 mm (2.0 in.))*	*Killed (t ≤ 25 mm (1.0 in.)) Killed and fine grain (t > 25 mm (1.0 in.))* [2]	*Killed and fine grain* [2]
Chemical Composition (Ladle Analysis), % max. unless specified otherwise.[8]				
C	0.21 [3]	0.21	0.21	0.18
$Mn_{min.}$	2.5 × C	0.80 [4]	0.60	0.70
Si	0.50	0.35	0.10–0.35 [5]	0.10–0.35 [5]
P	0.035	0.035	0.035	0.035
S	0.035	0.035	0.035	0.035
Ni	See Note 6	See Note 6	See Note 6	See Note 6
Cr	See Note 6	See Note 6	See Note 6	See Note 6
Mo	See Note 6	See Note 6	See Note 6	See Note 6
Cu	See Note 6	See Note 6	See Note 6	See Note 6
C + Mn/6	0.40	0.40	0.40	0.40
Marking	AB/A	AB/B	AB/D [7]	AB/E

Notes:

1 For Grade A, rimmed steel sections may be accepted up to and including 12.5 mm (0.5 in).

2 Grade D steel over 25 mm and Grade E steel are to contain at least one of the grain refining elements in sufficient amount to meet the fine grain practice requirements. (See 2-1-2/5.7.)

3 A maximum carbon content of 0.23% is acceptable for Grade A sections.

4 For Grade B steel of cold flanging quality or where fully killed, the lower limit of manganese may be reduced to 0.60%.

5 Where the content of soluble aluminum is not less than 0.015%, the minimum required silicon content does not apply.

6 The contents of nickel, chromium, molybdenum and copper are to be determined and reported. When the amount does not exceed 0.02%, these elements may be reported as ≤0.02%.

7 Grade D hull steel which is normalized, thermo-mechanical control processed or control rolled is to be marked AB/DN.

8 Intentionally added elements are to be determined and reported.

TABLE 2
Tensile Properties of Ordinary Strength Hull Structural Steel 100 mm (4.0 in.) and Under *(2008)*

Grade	*Tensile Strength* N/mm^2 *(kgf/mm², ksi)*	*Yield Point min.* N/mm^2 *(kgf/mm², ksi)*	*Elongation* [1, 3, 4] *min. %*
A, B, D, E	400-520 [2] (41-53, 58-75)	235 (24, 34)	22

Notes:

1 Based on alternative A flat test specimen or alternative C round specimen in 2-1-1/Figure 1.

2 For Grade A sections, the upper limit of tensile strength may be 550 N/mm^2 (56 kgf/mm^2, 80 ksi).

3 Minimum elongation for alternative B flat specimen in 2-1-1/Figure 1 is to be in accordance with 2-1-2/Table 3.

4 *(2008)* Minimum elongation for ASTM E8M/E8 or A370 specimen is 2-1-2/Table 3 for 200 mm (8 in.) specimen and 22% for 50 mm (2 in.) specimen.

5 Steel ordered to cold flanging quality may have tensile strength range of 380-450N/mm^2 (39-46 kgf/mm^2, 55-65 ksi) and a yield point of 205N/mm^2 (21 kgf/mm^2, 30 ksi) minimum. See also 2-1-2/13.5 and 3-1-2/1.1.

TABLE 3
Elongation Requirements for Alternative B Specimen *(1995)*

	Thickness in mm (in.)							
exceeding		5 (0.20)	10 (0.40)	15 (.60)	20 (.80)	25 (1.0)	30 (1.2)	40 (1.6)
not exceeding	5 (0.20)	10 (0.40)	15 (.60)	20 (.80)	25 (1.0)	30 (1.2)	40 (1.6)	50 (2.0)
elongation (min. %)	14	16	17	18	19	20	21	22

TABLE 4
Impact Properties of Ordinary-Strength Hull Structural Steel 100 mm (4.0 in.) and Under *(2008)*

Average Absorbed Energy [1] *J (kgf-m, ft-lbf)*							
		t ≤ 50 mm (2.0 in.)		50 mm (2.0 in) < *t* ≤ 70 mm (2.8 in.)		70 mm (2.8 in.) < *t* ≤ 100 mm (4.0 in)	
Grade	*Temperature °C (°F)*	*Long'l* [2]	*Transv* [2]	*Long'l* [2]	*Transv* [2]	*Long'l* [2]	*Transv* [2]
A	20 (68)	—	—	34 (3.5, 25) [3]	24 (2.4, 17) [3]	41 (4.2, 30) [3]	27 (2.8, 20) [3]
B [4]	0 (32)	27 (2.8, 20)	20 (2.0, 14)	34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)
D	-20 (-4)	27 (2.8, 20)	20 (2.0, 14)	34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)
E	-40 (-40)	27 (2.8, 20)	20 (2.0, 14)	34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)

Notes:

1 The energy shown is minimum for full size specimen. See 2-1-2/ 11.5 for subsize specimen requirements.

2 Either direction is acceptable.

3 Impact tests for Grade A are not required when the material is produced using a fine grain practice and normalized.

4 CVN test requirements for Grade B apply where such test is required by 2-1-2/Table 5.

TABLE 5
Condition of Supply and Frequency of Impact Tests
Ordinary Strength Hull Structural Steel *(2005)*

Grade	*Deoxidation*	*Products*	*Condition of Supply (Impact Test Lot Size in Tons)*					
			Thickness in mm (in.)					
			exceeding: □ *not exceeding:* ➔	*12.5 (0.5)*	*12.5 (0.5)* *25 (1.0)*	*25 (1.0)* *35 (1.375)*	*35 (1.375)* *50 (2.0)*	*50 (2.0)* *100 (4.0)*
A	Rimmed	All		A (-)				
	Semi-Killed	All		A (-)				
	Killed	P		A (-)				N (-) [4] TM (-) CR (50) AR (50)
		S		A (-)				
B	Semi-Killed	All		A (-)		A (50)		
	Killed	P		A (-)		A (50)		N (50) TM (50) CR (25) AR (25)
		S		A (-)		A (50)		
D	Killed & Fine Grain	P		A (50) N (50)			N (50) TM (50) CR (50)	N (50) TM (50) CR (25)
		S		A (50) N (50)			N (50) TM (50) CR (50)	
E	Killed & Fine Grain	P		N (P) TM (P)				N (P) TM (P)
		S		N (25) TM (25) CR (15)				

Notes

1 Products: P = plate S = sections

2 Conditions of Supply: A = Any Condition N = normalized
AR = As Rolled TM = thermomechanical controlled processing
CR= Control Rolled

3 Frequency of Impact Test (Impact Test Lot Size in Tons):
(-) = no impact test required
(P) = each piece

4 Impact tests for Grade A are not required when material is produced using a fine grain practice and normalized.

PART

2

CHAPTER 1 Materials for Hull Construction

SECTION 3 Higher-strength Hull Structural Steel

1 Higher-strength Hull Structural Steel *(2005)*

The requirements in this subsection are intended for products for the following thicknesses:

Plates and Wide Flats

AH32, DH32, EH32, AH36, DH36 and EH36 steels:	up to and including 100 mm (4 in.)
AH40, DH40, EH40, FH32, FH36 and FH40 steels:	up to and including 100 mm (4 in.)
Sections and Bars	up to and including 50 mm (2 in.)

3 General *(1996)*

The requirements in 2-1-2/3 through 2-1-2/15 are also applicable to higher-strength hull structural steels with the following paragraphs and Tables replaced by the higher-strength requirements as indicated.

2-1-2/Table 1	replaced by 2-1-3/Table 1
2-1-2/Table 2	replaced by 2-1-3/Table 2
2-1-2/Table 3	replaced by 2-1-3/Table 3
2-1-2/Table 4	replaced by 2-1-3/Table 4
2-1-2/Table 5	replaced by 2-1-3/Table 5
2-1-2/5.7	replaced by 2-1-3/5

5 Fine Grain Practice *(1996)*

Where steel is required to be made using fine grain practice, the requirement may be met by one of the following conditions.

i) A McQuaid-Ehn austenite grain size of 5 or finer in accordance with ASTM E112 for each ladle of each heat, or

ii) Minimum Acid-soluble Aluminum content of 0.015% or minimum total Aluminum content of 0.020% for each ladle of each heat, or

iii) Minimum Columbium (Niobium) content of 0.020% or minimum Vanadium content of 0.050% for each ladle of each heat, or

iv) When Vanadium and Aluminum are used in combination, minimum Vanadium content of 0.030% and minimum acid-soluble Aluminum content of 0.010% or minimum total Aluminum content of 0.015%.

v) When Columbium (Niobium) and Aluminum are used in combination, minimum Columbium (Niobium) content of 0.010% and minimum acid-soluble Aluminum content of 0.010% or minimum total Aluminum content of 0.015%.

7 Additional Requirements of TMCP Steel *(1996)*

7.1 Carbon Equivalent

The carbon equivalent C_{eq} as determined from the ladle analysis in accordance with the following equation is to meet the requirements in 2-1-3/Table 6:

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

7.3 Cold Cracking Susceptibility

Unless otherwise specified by the purchaser, the cold cracking susceptibility, P_{cm}, may be calculated in accordance with the following equation:

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

Selection of the maximum value for P_{cm} is a matter to be agreed between the fabricator and the steel mill when the steel is ordered.

TABLE 1
Chemical Properties of Higher-strength Hull Structural Steel 100 mm (4.0 in.) and Under *(1996)*

Grades	*AH/DH/EH 32, AH/DH/EH 36 and AH/DH/EH 40*	*FH 32/36/40*
Deoxidation	*Killed, Fine Grain Practice* [1]	
Chemical Composition [2]	*(Ladle Analysis), % max. unless specified in range*	
C	0.18	0.16
Mn	0.90–1.60 [3]	0.90–1.60
Si	0.10–0.50 [4]	0.10–0.50 [4]
P	0.035	0.025
S	0.035	0.025
Al (acid Soluble) min [5, 6].	0.015	0.015
Nb [6, 7]	0.02–0.05	0.02–0.05
V [6, 7]	0.05–0.10	0.05–0.10
Ti	0.02	0.02
Cu [8]	0.35	0.35
Cr [8]	0.20	0.20
Ni [8]	0.40	0.80
Mo [8]	0.08	0.08
N	—	0.009 (0.012 if Al present)
Marking [9]	AB/XHYY (X = A, D, E or F YY = 32, 36 or 40)	

Notes:

1 The steel is to contain at least one of the grain refining elements in sufficient amount to meet the fine grain practice requirement (See 2-1-3/5).

2 The contents of any other element intentionally added is to be determined and reported.

3 AH steel 12.5 mm (0.50 in.) and under in thickness may have a minimum manganese content of 0.70%.

4 Where the content of soluble aluminum is not less than 0.015%, the minimum required silicon content does not apply.

5 The total aluminum content may be used in lieu of acid soluble content, in accordance with 2-1-3/5.

6 The indicated amount of aluminum, niobium and vanadium applies when any such element is used singly. When used in combination, the minimum content in 2-1-3/5 will apply.

7 These elements need not be reported on the mill sheet unless intentionally added.

8 These elements may be reported as $\leq$0.02% where the amount present does not exceed 0.02%.

9 The marking AB/DHYYN is to be used to denote Grade DHYY plates which have either been normalized, thermo-mechanically control rolled or control rolled in accordance with an approved procedure.

10 See 2-1-3/7 for carbon equivalent and cold cracking susceptibility requirements for thermo-mechanically controlled steel.

11 For other steels, the carbon equivalent (Ceq) may be calculated from the ladle analysis in accordance with the equation in 2-1-3/7.1. Selection of the maximum value of carbon equivalent for these steels is a matter to be agreed between the fabricator and steel mill when the steel is ordered.

TABLE 2
Tensile Properties of Higher-strength Hull Structural Steel 100 mm (4.0 in.) and Under *(2008)*

Grade	*Tensile Strength N/mm^2 (kgf/mm^2, ksi)*	*Yield Point min. N/mm^2 (kgf/mm^2, ksi)*	*Elongation [1, 2, 3] min. %*
AH 32 DH 32 EH 32 FH 32	440-590 (45-60, 64-85)	315 (32, 46)	22
AH 36 DH 36 EH 36 FH 36	490-620 (50-63, 71-90)	355 (36, 51)	21
AH 40 DH 40 EH 40 FH 40	510-650 (52-66, 74-94)	390 (40, 57)	20

Notes:

1 Based on alternative A flat test specimen or alternative C round specimen in 2-1-1/Figure 1.

2 Minimum elongation for alternative B flat specimen in 2-1-1/Figure 1 is to be in accordance with 2-1-3/Table 3.

3 *(2008)* Minimum elongation for ASTM E8M/E8 or A370 specimen is 2-1-3/Table 3 for 200 mm (8 in.) specimen and 20% for 50 mm (2 in.) specimen.

TABLE 3
Elongation Requirements for Alternative B Specimen *(1996)*

	Thickness in mm (in.)							
exceeding:		*5 (.20)*	*10 (.40)*	*15 (.60)*	*20 (.80)*	*25 (1.00)*	*30 (1.20)*	*40 (1.60)*
not exceeding:	*5 (.20)*	*10 (.40)*	*15 (.60)*	*20 (.80)*	*25 (1.00)*	*30 (1.20)*	*40 (1.60)*	*50 (2.00)*
GradeSteel	elongation (%)							
XH 32	14	16	17	18	19	20	21	22
XH 36	13	15	16	17	18	19	20	21
XH 40	12	14	15	16	17	18	19	20

Note:

"X" denotes the various material grades, A, D, E and F.

TABLE 4
Impact Properties of Higher-strength Steel
100 mm (4.0 in.) and Under *(2005)*

		Average Absorbed Energy [1] J (kgf-m, ft-lbf)					
	Temp	*t ≤ 50 mm (2.0 in.)*		*50 mm (2.0 in.) < t ≤ 70 mm (2.8 in.)*		*70 mm (2.8 in.) < t ≤ 100 mm (4.0 in.)*	
Grade	*°C (°F)*	*Long'l [2]*	*Transv [2]*	*Long'l [2]*	*Transv [2]*	*Long'l [2]*	*Transv [2]*
AH 32	0 (32)	31 (3.2, 23)	22 (2.3, 16)	38 (3.9, 28)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)
AH 36		34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)	50 (5.1, 37)	34 (3.5, 25)
AH 40		39 (4.0, 29)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)	55 (5.6, 41)	37 (3.8, 27)
DH 32	-20 (-4)	31 (3.2, 23)	22 (2.3, 16)	38 (3.9, 28)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)
DH 36		34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)	50 (5.1, 37)	34 (3.5, 25)
DH 40		39 (4.0, 29)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)	55 (5.6, 41)	37 (3.8, 27)
EH 32	-40 (-40)	31 (3.2, 23)	22 (2.3, 16)	38 (3.9, 28)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)
EH 36		34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)	50 (5.1, 37)	34 (3.5, 25)
EH 40		39 (4.0, 29)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)	55 (5.6, 41)	37 (3.8, 27)
FH 32	-60 (-76)	31 (3.2, 23)	22 (2.3, 16)	38 (3.9, 28)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)
FH 36		34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)	50 (5.1, 37)	34 (3.5, 25)
FH 40		39 (4.0, 29)	26 (2.7, 19)	46 (4.7, 34)	31 (3.2, 23)	55 (5.6, 41)	37 (3.8, 27)

Notes:

1 The energy shown is minimum for full size specimen. See 2-1-2/11.5 for sub size specimen requirement.

2 Either direction is acceptable.

TABLE 5
Condition of Supply and Frequency of Impact Tests – Higher-strength Hull Structural Steel *(2005)*

Grade	*Deoxidation*	*Grain Refining Element*	*Products*	*Condition of Supply impact Test lot Size in Tons*						
				Thickness in mm (in.)						
				exceeding: ➔	*12.5 (0.5)*	*12.5 (0.5)*	*20 (9.80)*	*25 (1.0)*	*35 (1.375)*	*50 (2.0)*
				not exceeding: ➔	*12.5 (0.5)*	*20 (0.80)*	*25 (1.0)*	*35 (1.375)*	*50 (2.0)*	*100 (4.0)*
AH 32 AH 36	Killed, Fine Grain Practice	Nb	P		A (50)	N (50*) TM (50) CR (50)				N (50) TM (50) CR (25)
		V	S		A (50)	N (50*) TM (50) CR (50) AR (25)				N/A
		Al	P		A (50)		AR (25) N (50*) TM (50) CR (50)		N (50*) TM (50) CR (50)	N (50) TM (50) CR (25)
		Al + Ti	S		A (50)		N (50*) TM (50) CR (50) AR (25)			N/A
DH 32 DH 36		Nb	P		A (50)	N (50) TM (50) CR (50)				N (50) TM (50) CR (25)
		V	S		A (50)	N (50) TM (50) CR (50)				N/A
		Al Al + Ti	P		A (50)		AR (25) N (50) TM (50) CR (50)		N (50) TM (50) CR (50)	N (50) TM (50) CR (25
			S		A (50)		AR (25) N (50) TM (50) CR (50)		N (50) TM (50) CR (50)	N/A
EH 32 EH 36		Any	P		N (P) TM (P)					N (P) TM (P)
			S		N (25) TM (25) CR (15)					N/A
FH 32 FH 36		Any	P		N (P) TM (P) QT (P)					N (P) TM (P)
			S		N (25) TM (25) QT (25)					N/A
AH 40		Any	P		A (50)	N (50) TM (50) CR (50)				N (50) TM (50) QT (P)
			S		A (50)	N (50) TM (50) CR (50)				N/A
DH 40		Any	P		N (50) TM (50) CR (50)					N (50) TM (50) QT (P)
			S		N (50) TM (50) CR (50)					N/A
EH 40		Any	P		N (P) TM (P) CR (P)					N (P) TM (P) QT (P)
			S		N (25) TM (25) CR (25)					N/A
FH 40		Any	P		N (P) TM (P) QT (P)					N (P) TM (P) QT (P)
			S		N (25) TM (25) CR (25)					N/A

Notes

1 Products: P = plate; S = sections

2 Conditions of Supply: A = Any Condition; N = normalized; AR = As Rolled; TM = thermo-mechanically controlled processing; CR = Control Rolled; QT = quenched and tempered

3 Frequency of Impact Test (Impact Test Lot Size in Tons): (-) = no impact test required; (*) = upon application and approval, the impact frequency may be reduced; (P) = each piece

TABLE 6
Carbon Equivalent for Higher-strength Hull Structural Steel 100 mm (4.0 in.) and Under Produced by TMCP *(2005)*

Grade	*Carbon Equivalent, Max. (%)* [1]	
	t ≤ 50 mm (2.0 in.)	*50 mm (2.0 mm (2.0 in.) < t ≤ 100 mm (4.0 in.)*
AH 32, DH 32, EH 32, FH 32	0.36	0.38
AH 36, DH 36, EH 36, FH 36	0.38	0.40
AH 40, DH 40, EH 40, FH 40	0.40	0.42

Note:

1 It is a matter for the manufacturer and shipbuilder to mutually agree in individual cases as to whether they wish to specify a more stringent carbon equivalent.

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