



# Standard Specification for Structural Steel for Ships<sup>1</sup>

This standard is issued under the fixed designation A 131/A131M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

## 1. Scope

1.1 This specification covers structural steel shapes, plates, bars, and rivets intended primarily for use in ship construction.

1.2 Material under this specification is available in the following categories:

1.2.1 *Ordinary Strength*—Grades A, B, D, DS, CS, and E with a specified minimum yield point of 34 ksi [235 MPa], and

1.2.2 *Higher Strength*—Grades AH, DH, and EH with specified minimum yield points of either 46 ksi [315 MPa], 51 ksi [350 MPa], or 57 ksi [390 MPa].

1.3 Shapes and bars are normally available as Grades A, AH32, or AH36. Other grades may be furnished by agreement between the purchaser and the manufacturer.

1.4 When the steel is to be welded, it is presupposed that a welding procedure suitable for the grade of steel and intended use or service will be utilized. See Appendix X3 of Specification A 6/A 6M for information on weldability.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

## 2. Referenced Documents

### 2.1 *ASTM Standards:*

A 6/A6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling<sup>2</sup>

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>3</sup>

E 112 Test Methods for Determining the Average Grain Size<sup>4</sup>

## 3. Ordering Information

3.1 Inquiries, orders, contracts, etc., for material to this specification should include the following information to

describe adequately the desired material:

3.1.1 Quantity (weight or number of pieces),

3.1.2 Name of material (ordinary strength or higher strength, carbon steel shapes, plates, bars, or rivets),

3.1.3 ASTM specification designation, grade, and year of issue,

3.1.4 Cold flanging when applicable,

3.1.5 Dimensions,

3.1.6 Condition (hot rolled or hot rolled and normalized), and

3.1.7 Supplementary requirements, if any.

## 4. Manufacture

### 4.1 *Melting Process:*

4.1.1 The steel may be made by any of the following processes: open-hearth, basic-oxygen, electric-furnace, vacuum arc remelt (VAR), or electroslag remelt (ESR).

4.1.2 Except for Grade A steel up to and including ½ in. [12.5 mm] in thickness, rimming-type steels shall not be applied.

4.1.3 Grades AH32 and AH36 shapes through 426 lb/ft, and plates up to 0.5 in. [12.5 mm] in thickness may be semi-killed, in which case the 0.10 % minimum silicon does not apply.

4.1.4 Except as permitted in 4.1.4.1, Grades D, DS, CS, E, AH40, DH32, DH36, DH40, EH32, EH36, and EH40 shall be made using a fine grain practice. For ordinary strength grades, aluminum shall be used to obtain grain refinement. For high strength grades, aluminum, vanadium, or columbium (niobium) may be used for grain refinement.

4.1.4.1 Grade D material 1⅜ in. [35 mm] and under in thickness, at the option of the manufacturer, may be semi-killed and exempt from the fine austenitic grain size requirement of 7.1, but such material shall be subject to the toughness requirement of 8.2.1.

## 5. Heat Treatment

5.1 Plates in all thicknesses ordered to Grades CS and E shall be normalized. Plates over 1⅜ in. [35 mm] in thickness ordered to Grade D shall be normalized. When Grade D steel is furnished semi-killed, it shall be normalized over 1 in. [25 mm] in thickness. Upon agreement between the purchaser and the manufacturer, control rolling of Grade D steel may be substituted for normalizing, in which case impact tests are required for each 25 tons [25 Mg] of material in the heat.

5.2 Plates in all thicknesses ordered to Grades EH32 and

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.04.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 03.01.

EH36 shall be normalized. Plates in all thicknesses ordered to Grade EH40 shall be normalized or quenched and tempered. Grades AH32, AH36, AH40, DH32, DH36, and DH40 shall be normalized when so specified in Table 1. Upon agreement between the purchaser and the manufacturer, control rolling of Grade DH may be substituted for normalizing, in which case impact tests are required on each plate.

5.3 In the case of shapes, the thicknesses referred to are those of the flange.

**6. Chemical Requirements**

6.1 The heat analysis shall conform to the requirements for chemical composition prescribed in Table 2.

6.1.1 The steel shall conform on product analysis to the requirements prescribed in Table 2, subject to the product analysis tolerances in Specification A 6/A 6M, except as specified in 6.1.2.

6.1.2 Product analysis is not required for bar-size shapes or flat bars 1/2 in. [12.5 mm] and under in thickness.

6.1.3 When tension tests are waived in accordance with 8.1.1.2, chemistry consistent with the mechanical properties desired must be applied.

**7. Metallurgical Structure**

7.1 Fine grain practice for ordinary strength grades shall be met using aluminum. For higher strength grades, aluminum, vanadium, or columbium may be used as grain refining elements.

7.2 Except as modified by 7.2.1, grain size shall be determined on each heat by the McQuaid-Ehn test of Methods E 112. The grain size so determined shall be No. 5 or finer in 70 % of the area examined.

7.2.1 As an alternative to the McQuaid-Ehn test, a fine grain practice requirement may be met by a minimum acid-soluble aluminum content of 0.015 % or minimum total aluminum content of 0.020 % for each heat.

7.2.2 For Grades AH40, DH32, DH36, DH40, EH32, EH36, and EH40 the fine grain practice requirement may also be met as follows:

7.2.2.1 Minimum columbium (niobium) content of 0.020 % or minimum vanadium content of 0.050 % for each heat, or

7.2.2.2 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%.

**8. Mechanical Requirements**

8.1 *Tension Tests:*

8.1.1 Except as specified in the following paragraphs the material as represented by the test specimens shall conform to the tensile requirements prescribed in Table 3.

8.1.1.1 Unless a specific orientation is called for on the purchase order, tension test specimens may be taken parallel or transverse to the final direction of rolling at the option of the steel manufacturer.

8.1.1.2 Shapes less than 1 in.<sup>2</sup> [645 mm<sup>2</sup>] in cross section, and bars, other than flats, less than 1/2 in. [12.5 mm] in thickness or diameter need not be subjected to tension tests by the manufacturer.

8.1.1.3 The elongation requirement of Table 3 does not apply to material ordered as floor plates with a raised pattern. However, for floor plates over 1/2 in. [12.5 mm] in thickness, test specimens shall be bent cold with the raised pattern on the inside of the specimen through an angle of 180° without cracking when subjected to a bend test in which the inside diameter is three times plate thickness. Sampling for bend testing shall be as specified for the tension tests in 8.1.2.

8.1.2 One tension test shall be made from each of two different plates, shapes, or bars from each heat of structural steel and steel for cold flanging unless the finished material from a heat is less than 50 tons [45 Mg], when one tension test will be sufficient. If, however, material from one heat differs 3/8 in. [10 mm] or more in thickness or diameter, one tension test shall be made from both the thickest and the thinnest material rolled, regardless of the weight represented.

8.1.3 Two tension tests shall be made from each heat of rivet steel.

8.1.4 For Grade EH40, one tension test shall be made on each plate as quenched and tempered.

8.2 *Toughness Tests* (material 2 in. [50 mm] and less in thickness):

8.2.1 Except as permitted in 8.2.1.1, Charpy V-notch tests shall be made on Grade B material over 1 in. [25 mm] in thickness and on material of Grades D, E, AH32, AH36, DH32, DH36, DH40, EH32, EH36, and EH40. The test results shall conform to the requirements of Table 4.

8.2.1.1 Toughness tests are not required: (a) on Grade D normalized material made fully killed and having a fine austenitic grain size, (b) on Grades AH32 and AH36 when normalized, or when 0.5 in. [12.5 mm] or less in thickness when treated with vanadium or columbium (niobium) or 1 3/8 in. [35 mm] or less in thickness when treated with aluminum, and (c) on Grades DH32 and DH36 material when normalized.

8.2.2 For plate material, when required, one set of three impact specimens shall be made from the thickest material in each 50 tons [45 Mg] of each heat of Grades B, D, AH32, AH36, AH40, DH32, DH36, and DH40 steels and from each rolled product of Grades E, EH32, EH36, and EH40 steels. When heat testing is called for, a set of three specimens shall be tested for each 50 tons [45 Mg] of the same type of product produced on the same mill from each heat of steel. The set of impact specimens shall be taken from different as-rolled or

**TABLE 1 Heat Treatment Requirements for Higher Strength Grades (32, 36, and 40)<sup>A</sup>**

*Aluminum-treated steels:*

AH32 or AH36 Normalizing not required up to and including 2 in. [50 mm] in thickness

AH40 Normalizing required over 0.50 in. [12.5 mm]

DH32 or DH36 Normalizing required over 1.0 in. [25 mm]

DH40, EH32, or EH36 Normalized

EH40 Normalized or Quenched and Tempered

*Columbium (niobium) or vanadium-treated steels:*

AH32 or AH36 Normalizing not required up to and including 2 in. [50 mm] in thickness

AH40, DH32, or DH36 Normalizing required over 0.50 in. [12.5 mm]

DH40, EH32, or EH36 Normalized

EH40 Normalized or Quenched and Tempered

<sup>A</sup> When columbium (niobium) or vanadium is used in combination with aluminum, heat treatment requirements for columbium or vanadium apply.

TABLE 2 Chemical Requirements

NOTE 1— Where “. . .” appears in this table there is no requirement.

Element	Composition, %						
	Ordinary Strength Grades						Higher Strength Grades
	A	B	D	E	CS	DS	AH32, AH36, AH40, DH32, DH36, DH40, EH32, EH36, and EH40
Carbon, <sup>A</sup> max	0.23 <sup>B</sup>	0.21	0.21	0.18	0.16	0.16	0.18
Manganese <sup>A</sup>	<sup>C</sup>	0.80–1.10 <sup>D</sup>	0.70–1.35 <sup>D,E</sup>	0.70–1.35 <sup>D</sup>	1.00–1.35 <sup>D</sup>	1.00–1.35 <sup>D</sup>	0.90–1.60
Phosphorus, max	0.035	0.035	0.035	0.035	0.035	0.035	0.035
Sulfur, max	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Silicon	...	0.35 max	0.10–0.35 <sup>F</sup>	0.10–0.35	0.10–0.35	0.10–0.35	0.10–0.50 <sup>G</sup>
Nickel, max	...	...	...	...	...	...	0.40 <sup>G,H</sup>
Chromium, max	...	...	...	...	...	...	0.25 <sup>G,H</sup>
Molybdenum, max	...	...	...	...	...	...	0.08 <sup>G,H</sup>
Copper, max	...	...	...	...	...	...	0.35 <sup>G,H</sup>
Columbium (niobium), max	...	...	...	...	...	...	0.05 <sup>H,I</sup>
Vanadium, max	...	...	...	...	...	...	0.10 <sup>H,I</sup>
Aluminum	...	...	<sup>I</sup>	<sup>I</sup>	<sup>I</sup>	<sup>I</sup>	<sup>I</sup>

<sup>A</sup>For all ordinary strength grades, the carbon content plus 1/4 of the manganese content shall not exceed 0.40 %.

<sup>B</sup>A maximum carbon content of 0.26 % is acceptable for Grade A plates equal to or less than 1/2 in. [12.5 mm] and all thicknesses of Grade A shapes.

<sup>C</sup>Grade A plates over 1/2 in. [12.5 mm] in thickness shall have a minimum manganese content not less than 2.5 times the carbon content. Grade A shapes and bars are not subject to the manganese/carbon ratio of 2.5.

<sup>D</sup>For all ordinary strength grades, the upper limit of the manganese may be exceeded up to 1.65 % provided carbon content plus 1/4 of manganese content does not exceed 0.40 %. The lower limit of the manganese for Grade B may be reduced to 0.60 % when the silicon content is 0.10 % or more or when cold-flanging material is specified.

<sup>E</sup>For Grade D steel equal to or less than 1.00 in. [25 mm] in thickness, 0.60 % minimum manganese content is acceptable.

<sup>F</sup>Lower limit of silicon does not apply to semi-killed Grade D steel.

<sup>G</sup>See 5.1.3.

<sup>H</sup>These elements need not be reported on the mill sheet unless intentionally added.

<sup>I</sup>See Section 8.

TABLE 3 Tensile Requirements

	Ordinary Strength Grades (A, B, D, DS, CS, and E)						Higher Strength Grades			
	Structural Steel		Rivet Steel and Steel for Cold Flanging		AH32, DH32, and EH32		AH36, DH36, and EH36		AH40, DH40, and EH40	
	ksi	[MPa]	ksi	[MPa]	ksi	[MPa]	ksi	[MPa]	ksi	[MPa]
Tensile strength	58 to 71 <sup>A</sup>	[400 to 490]	55 to 65	[380 to 450]	68 to 85	[470 to 585]	71 to 90	[490 to 620]	74 to 94	[510 to 650]
Yield point, min	34 <sup>B</sup>	[235 <sup>B</sup> ]	30	[205]	46	[315]	51	[360]	57	[390]
Elongation in 8 in. [200 mm], min, % <sup>CDEF</sup>	21		23		19		19		19	
Elongation in 2 in. [50 mm], min, % <sup>DEF</sup>	24		26		22		22		22	

<sup>A</sup>A tensile strength range from 58 to 80 ksi [400 to 550 MPa] may be applied to Grade A shapes.

<sup>B</sup>For Grade A over 1 in. [25 mm] in thickness, the minimum yield point may be reduced to 32 ksi [220 MPa].

<sup>C</sup>For nominal thicknesses or diameters under 5/16 in. [8 mm], a deduction from the specified percentage of elongation in 8 in. [200 mm] shall be made for decreases of the nominal thickness or diameter below 5/16 in. [8 mm]. See elongation requirement adjustments under the Tension Tests section of Specification A 6/A 6M for deduction values.

<sup>D</sup>For nominal thicknesses or diameters over 3.5 in. [90 mm], a deduction from the specified percentage of elongation in 2 in. [50 mm] shall be made for increases of the nominal thickness or diameter above 3.5 in. [90 mm]. See elongation requirement adjustments under the Tension Tests section of Specification A 6/A 6M for deduction values.

<sup>E</sup>Elongation not required to be determined for floor plate.

<sup>F</sup>For plates wider than 24 in. [600 mm], the elongation requirement is reduced two percentage points.

heat-treated pieces of the heaviest gage produced. An as-rolled piece refers to the product rolled from a slab, billet, bloom, or directly from an ingot. For flats, rounds, and shapes, one set of three impact tests shall be taken from each 25 tons [25 Mg] of each heat for normalized Grade E, EH32, EH36, or EH40, and from each 15 tons [14 Mg] of each heat for quenched and tempered Grade EH40, and, when required, from each 50 tons [45 Mg] of each heat of Grade B, D, AH32, AH36, AH40, DH32, DH36, or DH40 material. Where the maximum thick-

ness or diameter of various sections differs by 3/8 in. [10 mm] or more, one set of impacts shall be made from both the thickest and the thinnest material rolled regardless of the weight represented.

8.2.3 The specimens for plates shall be taken from a corner of the material and the specimens from shapes shall be taken from the end of a shape at a point one third the distance from the outer edge of the flange or leg to the web or heel of the

**TABLE 4 Charpy V-Notch Requirements for Maximum Thickness of 2 in. [50 mm]**

Grade and Test Temperature	Longitudinal Specimens, min avg		Transverse Specimens, min avg	
	ft-lbf	[J]	ft-lbf	[J]
B <sup>A</sup> at 32°F [0°C]	20	[27]	14	[19]
D <sup>B</sup> at +14°F [-10°C]	20	[27]	14	[19]
E at -40°F [-40°C]	20	[27]	14	[19]
AH32 <sup>B</sup> at 32°F [0°C]	25	[34]	17	[23]
DH32 <sup>B</sup> at -4°F [-20°C]	25	[34]	17	[23]
EH32 at -40°F [-40°C]	25	[34]	17	[23]
AH36 <sup>B</sup> at 32°F [0°C]	25	[34]	17	[23]
DH36 <sup>B</sup> at -4°F [-20°C]	25	[34]	17	[23]
EH36 at -40°F [-40°C]	25	[34]	17	[23]
AH40 at 32°F [0°C]	30	[41]	20	[27]
DH40 at -4°F [-20°C]	30	[41]	20	[27]
EH40 at -40°F [-40°C]	30	[41]	20	[27]

<sup>A</sup>Impact tests are not required for Grade B 1 in. [25 mm] and under in thickness.  
<sup>B</sup>See 9.2.1.

shape. Specimens for bars shall be in accordance with Specification A 6/A 6M.

8.2.4 The center longitudinal axis of the specimens shall be located as near as practical mid-way between the surface and the center of the material and the length of the notch shall be perpendicular to the rolled surface.

8.2.5 Unless a specific orientation is called for on the purchase order, the longitudinal axis of the specimens may be parallel or transverse to the final direction of rolling of the material at the option of the steel manufacturer.

8.2.6 The impact test shall be made in accordance with the simple beam, Charpy V-notch type of test described in Sections S 23 and S 24 of Test Methods and Definitions A 370.

8.2.7 Each impact test shall constitute the average value of three specimens taken from a single test location. The average value shall meet the specified minimum with not more than one value below the specified minimum but in no case below two thirds of the specified minimum. If these requirements are not met, a retest of three additional specimens may be made as follows:

8.2.7.1 Retest three additional specimens, each of which must equal or exceed the minimum average energy value specified.

8.2.7.2 If the required energy values are not obtained upon retest, the material may at the option of the producer be heat treated in the case of as-rolled material or reheat treated in the case of heat-treated material.

8.2.7.3 After heat treatment or reheat treatment a set of three specimens shall be tested and evaluated in the same manner as for the original material.

8.2.7.4 If the impact test result fails to meet the requirement for the thickest product tested when heat testing, that material shall be rejected and the next thickest material may be tested to qualify the balance of the heat in accordance with 8.2.7. At the option of the producer retests may be made on each piece of the rejected material, in which case each piece shall stand on the results of its own test. It shall also be the option of the producer to heat treat the product prior to retesting if desired.

8.3 *Toughness Tests* (material over 2 in. [50 mm] thick):

8.3.1 Charpy V-notch tests are required for all grades of steel over 2 in. [50 mm] thick, except for Grade A that is

produced killed, using a fine grain practice and normalized.

8.3.2 For plate material one set of three impact specimens shall be made from the thickest material in each 50 tons [45 Mg] of each heat of Grades A, B, D, DS, AH32, AH36, DH32, and DH36, and from each rolled product of Grades CS, E, EH32, and EH36. For flats, rounds, and shapes, one set of three impact tests shall be taken from each 25 tons [25 Mg] of each heat for Grades CS, E, EH32, and EH36, and from each 50 tons [45 Mg] of each heat of Grades A, B, D, DS, AH32, AH36, DH32, and DH36 material. The test results shall conform to the requirements of Table 5.

8.3.3 Toughness test locations, orientations, specimen types, number of tests, and retests shall be in accordance with 8.2.3 through 8.2.7.

8.4 *Rivet Steel and Rivets:*

8.4.1 For rivet steel a sulfur print requirement shall be met when other than killed or semi-killed steel is applied, in order to confirm that its core is free of concentrations of sulfur segregates and other nonmetallic substances.

8.4.2 Test specimens for rivet bars that have been cold drawn shall be normalized before testing.

8.4.3 Finished rivets are to be selected as sample specimens from each diameter and tested hot and cold by bending and crushing as follows: The shank must stand being doubled together cold, and the head being flattened hot to a diameter 2½ times the diameter of the shank, both without fracture. Bend test requirements for rivets are given in Table 6.

**9. General Requirements for Delivery**

9.1 Material furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the ordered material, unless a conflict exists in which case this specification shall prevail.

**10. Plate Conditioning**

10.1 After removal of any imperfection preparatory to welding the thickness of the plate at any location must not be reduced by more than 20 % of the nominal thickness of the plate.

**11. Test Reports**

11.1 When test reports are required by the purchase order, the report shall show the results of each test required by

**TABLE 5 Charpy V-Notch Requirements for Thicknesses Over 2 in. [50 mm]**

Grade and Test Temperature	Longitudinal Specimens, min avg		Transverse Specimens, min avg	
	ft-lbf	[J]	ft-lbf	[J]
A <sup>A</sup> at +68°F [+20°C]	20	[27]	14	[19]
B at +32°F [0°C]	20	[27]	14	[19]
D at +14°F [-10°C]	20	[27]	14	[19]
DS at +14°F [-10°C]	20	[27]	14	[19]
CS at -40°F [-40°C]	20	[27]	14	[19]
E at -40°F [-40°C]	20	[27]	14	[19]
AH32 and AH36 at +32°F [0°C]	25	[34]	17	[23]
DH32 and DH36 at -4°F [-20°C]	25	[34]	17	[23]
EH32 and EH36 at -40°F [-40°C]	25	[34]	17	[23]

<sup>A</sup>See 9.3.1.

**TABLE 6 Bend Test Requirements for Rivet Steel**

Thickness of Material, in. [mm]	Ratio of Bend Diameter to Thickness of Specimen
3 / 4 [20] and under	flat on itself
Over 3 / 4 [20] to 1 1 / 4 [30], incl.	1
Over 1 1 / 4 [30]	2

Sections 7 and 8, except that the results of only one set of tests need be reported when the amount of material from a heat in a shipment is less than 10 tons [9 Mg] and when the thickness variations described in Section 8 are not exceeded.

11.2 The thickness of the product tested may not necessarily be the same as an individual ordered thickness since it is the

heat that is tested rather than each ordered item.

**12. Marking**

12.1 In addition to the marking specified in Specification A 6/A 6M, material ordered to cold flanging quality shall be additionally marked with the letter F. When Grades D, DH32, and DH36 are normalized, the material shall be marked DN, DHN32, or DHN36 as applicable. Material ordered to Grade E, EH32, or EH36 shall also be steel die stamped, marked, or stenciled with its slab number.

**13. Keywords**

13.1 bars; higher strength; ordinary strength; plates; rivets; shapes; ship construction; steel; structural steel

**SUPPLEMENTARY REQUIREMENTS**

The following supplementary requirements shall apply only when specified in the order:

**S85. Orientation of Tension Test Specimens**

S85.1 The orientation of the tension test specimens shall be as specifically stated on the order. (The purchaser shall state whether the tests are to be longitudinal or transverse.)

**S86. Orientation of Impact Test Specimens**

S86.1 The orientation of the impact test specimens shall be as specifically stated on the order. (The purchaser shall state whether the tests are to be longitudinal or transverse.)

**S87. Heat-Treatment of Grade DH**

S87.1 Grade DH aluminum-treated steel over 3/4 in. [19 mm]

in thickness shall be normalized.

**S88. Additional Tension Tests**

S88.1 At least one tension test shall be made from each 50 tons [45 Mg] or fraction thereof from each heat. If the material differs 0.375 in. [10 mm] or more in nominal thickness or diameter, one tension test shall be made from both the thickest and thinnest material in each 50 tons [45 Mg].

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