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Standard Specification for Structural Steel for Ships[1]

This standard is issued under the fixed designation A131/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 reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers structural steel plates, shapes, 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, and E with a specified minimum yield point of 34 ksi [235 MPa], and

1.2.2 *Higher Strength*—Grades AH, DH, EH, and FH with a specified minimum yield point of 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, and AH36. Other grades may be furnished by agreement between the purchaser and the manufacturer.

1.4 The maximum thickness of products furnished under this specification is 4 in. [100 mm] for plates and 2 in. [50 mm] for shapes and bars.

1.5 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 A6/A6M for information on weldability.

1.6 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:*[2]

A6/A6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

E112 Test Methods for Determining Average Grain Size

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *control rolling, n*—a steel treatment that consists of final rolling within the range used for normalizing heat treatments so that the austenite completely recrystallizes.

3.1.2 *thermo-mechanical controlled processing, n*—a steel treatment that consists of strict control of the steel temperature and the rolling reduction. A high proportion of the rolling reduction is to be carried out close to or below the Ar_3 transformation temperature and may involve rolling towards the lower end of the temperature range of the intercritical dual-phase region, thus permitting little if any recrystallization of the austenite. The process may involve accelerated cooling on completion of rolling.

4. Ordering Information

4.1 Specification A6/A6M establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock and Ships.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

4.2 Additional ordering considerations specific to this specification are:
4.2.1 Condition (control rolled or thermo-mechanical control processed, if applicable).

5. Materials and Manufacture

5.1 ~~Rimmed steels~~The steel shall ~~not~~ be ~~applied.~~killed.

~~5.2 Except for Grades A and B steel, semi-killed steels shall not be applied.~~

5.2 Grades D, E, AH32, AH36, AH40, DH32, DH36, DH40, EH32, EH36, EH40, FH32, FH36, and FH40 shall be made using a fine grain practice. For ordinary-strength grades, aluminum shall be used to obtain grain refinement. For higher-strength grades, aluminum, vanadium, or columbium (niobium) may be used for grain refinement.

5.3 Plates in all thicknesses ordered to Grade E shall be normalized, or thermo-mechanical control processed. Plates over 1⅜ in. [35 mm] in thickness ordered to Grade D shall be normalized, control rolled, or thermo-mechanical control processed. See Table 1.

5.4 Plates in all thicknesses ordered to Grades EH32 and EH36 shall be normalized, or thermo-mechanical control processed. Plates in all thicknesses ordered to Grade EH40, FH32, FH36, and FH40 shall be normalized, thermo-mechanical control processed, or quenched and tempered. Plates ordered to Grades AH32, AH36, AH40, DH32, DH36, and DH40 shall be normalized, control rolled, thermo-mechanical control processed, or quenched and tempered when so specified. See Table 2.

5.5 In the case of shapes, the thicknesses referred to are those of the flange. Heat treatment and rolling requirements for shapes and bars are given in Table 1 and Table 2.

6. Chemical Requirements

6.1 The heat analysis shall conform to the requirements for chemical composition given in Table 3 and Table 4.
6.1.1 When specified, the steel shall conform on product analysis to the requirements given in Table 3 and Table 4, subject to the product analysis tolerances in Specification A6/A6M.

6.2 For thermo-mechanical control process steel, the carbon equivalent shall be determined from the heat analysis and shall conform to the requirements given in Table 5.

7. Metallurgical Structure

7.1 The steel grades indicated in ~~5.3~~5.2 shall be made to fine grain practice, and the requirements for fine austenitic grain size in Specification A6/A6M shall be met.

7.2 Where the use of fine grain practice using columbium, vanadium, or combinations is permitted in ~~5.3~~5.2, one or more of the following shall be met:

TABLE 1 Condition of Supply and Frequency of Impact Tests for Ordinary-Strength Structural Steel

Grade	Deoxidation	Product[A]	Condition of Supply[B] (Frequency of Impact Test[C]) Thickness (t), in. [mm]			
			t >0.25 [6.4] t ≤1.0 [25]	t >1.0 [25] t ≤1.375 [35]	t >1.375 [35] t ≤2.0 [50]	t >2.0 [50] t ≤4.0 [100]
~~A~~	~~Semi-Killed~~	~~All~~	~~A (–)~~	~~A (–)~~		~~NA[D]~~
	A	Killed				N (–)[E], TM (–), CR (50 [45]), AR (50 [45])
	~~Killed~~	~~P~~				~~N (–)[E], TM (–), CR (50 [45]), AR (50 [45])~~
		S				NA[D]
~~B~~	~~Semi-Killed~~	~~All~~	~~A (–)~~	~~A (50 [45])~~		~~NA[D]~~
	B	Killed		A (50 [45])		N (50 [45]), TM (50 [45]), CR (25 [23]), AR (25 [23])
	~~Killed~~	~~P~~				~~N (50 [45]), TM (50 [45]), CR (25 [23]), AR (25 [23])~~
		S				NA[D]
~~D~~	~~Killed, Fine Grain Practice~~	~~P~~	~~A (50 [45]), N (50 [45])~~		~~N (50 [45]), TM (50 [45]), CR (50 [45])~~	~~N (50 [45]), TM (50 [45]), CR (25 [23])~~
		~~P~~				~~N (50 [45]), TM (50 [45]), CR (25 [23])~~
		~~D~~	~~A (50 [45]), N (50 [45])~~			~~NA[D]~~
		~~S~~				
E	Killed, Fine Grain Practice	P	N (P), TM (P)			N (P), TM (P)
		S	N (25 [23]), TM (25 [23]), CR (15 [14])			NA[D]

[A] Product: P = plate; S = shapes and bars
[B] Condition of Supply: A = any condition; AR = as-rolled; N = normalized; CR = control rolled; TM = thermo-mechanical controlled processing
[C] Frequency of Impact Test: (impact test lot size in tons [Mg] from each heat); (–) = no impact test required; (P) = each plate-as-rolled
[D] Condition of supply is not applicable
[E] Impact tests for Grade A are not required if material is produced using a fine grain practice and normalized

TABLE 2 Condition of Supply and Frequency of Impact Tests for Higher-Strength Structural Steel

Grade	Deoxidation	Grain Refining Element	Product[A]		Condition of Supply[B] (Frequency of Impact Test[C]) Thickness (t), in. [mm]					
					t >0.25 [6.4] t ≤0.5 [12.5]	t >0.5 [12.5] t ≤0.80 [20]	t >0.80 [20] t ≤1.0 [25]	t >1.0 [25] t ≤1.375 [35]	t >1.375 [35] t ≤2.0 [50]	t
AH32 AH36		Killed, Fine Grain Practice	Cb V	P S	A (50 [45])	N (50 [45]), TM (50 [45]), CR (50 [45])				N (50 [45]), TM
			Al	P	A (50 [45])		AR (25 [23]), N (50 [45]) , TM (50 [45]), CR (50 [45])	N (50 [45]), TM (50 [45]), CR (50 [45])		N (50 [45],) TM
			Al + Ti	S	A (50 [45])		AR (25 [23]), N (50 [45]), TM (50 [45]), CR (50 [45])	N (50 [45]), TM (50 [45]), CR (50 [45]), AR (25 [23])		
DH32 DH36			Cb V	P S	A (50 [45])	N (50 [45]), TM (50 [45]), CR (50 [45])				N (50 [45]), TM
			Al	P	A (50 [45])		AR (25 [23]), N (50 [45]), TM (50 [45]), CR (50 [45])	N (50 [45]), TM (50 [45]), CR (50 [45])		N (50 [45]), TM
			Al + Ti	S	A (50 [45])		AR (25 [23]), N (50 [45]), TM (50 [45]), CR (50 [45])	N (50 [45]), TM (50 [45]), CR (50 [45])		
EH32 EH36			Any	P S	N (P), TM (P) N (25 [23]), TM (25 [23]), CR (15 [14])					N
FH32 FH36			Any	P S	N (P), TM (P), QT (P) N (25 [23]), TM (25 [23]), QT (25 [23])					N (P
~~AH40~~	~~S~~		~~Any~~	~~P~~	~~A (50 [45])~~	~~N (50 [45]), TM (50 [45]), CR (50 [45])~~				~~N (50 [45]),~~
AH40			Any	P	A (50 [45])	N (50 [45]), TM (50 [45]), CR (50 [45])				N (50 [45]),
				A (50 [45])	N (50 [45]), TM (50 [45]), CR (50 [45])					
~~DH40~~			~~Any~~	~~P~~	~~N (50 [45]), TM (50 [45]), CR (50 [45])~~					~~N (50 [45]),~~
DH40	~~S~~		Any	P	N (50 [45]), TM (50 [45]), CR (50 [45])					N (50 [45]),
					N (50 [45]), TM (50 [45]), CR (50 [45])					
~~EH40~~			~~Any~~	~~P~~	~~N (P), TM (P), QT (P)~~					~~N~~
EH40			Any	P	N (P), TM (P), QT (P)					N
				~~S~~	~~N (25 [23]), TM (25 [23]), CR (25 [23])~~					
				S	N (25 [23]), TM (25 [23]), CR (25 [23])					
FH40			Any	P	N (P), TM (P), QQT (P)					N
				S	N (25 [23]), TM (25), CR (25 [23])					

[A] Product: P = plate; S = shapes and bars
[B] Condition of Supply: A = any condition; AR = as-rolled; TM = thermo-mechanical controlled processing; CR = control rolled; QT = quenched and tempered; N = normalized
[C] Frequency of Impact Test: (impact test lot size in tons [Mg] from each heat); (P) = each plate-as-rolled
[D] Condition of supply is not applicable

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

7.2.2 When vanadium and aluminum are used in combi-nation, minimum vanadium content of 0.030 % and minimum acid-soluble aluminum content of 0.010 %, or minimum total aluminum content of 0.015 %.

7.2.3 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 %.

7.2.4 A McQuaid-Ehn austenitic grain size of 5 or finer in accordance with Test Methods E112 for each ladle of each heat.

8. Mechanical Requirements

8.1 *Tension Test:*

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 6.

8.1.1.1 Shapes less than 1 in.^{2} [645 mm^2] in cross section, and bars, other than flats, less than ½ in. [12.5 mm] in thickness or diameter need not be subjected to tension tests by the manufacturer, but chemistry consistent with the required tensile properties must be applied.

8.1.1.2 The elongation requirement of Table 6 does not apply to floor plates with a raised pattern. However, for floor plates over ½ 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.

TABLE 3 Chemical Requirements for Ordinary-Strength Structural Steel

Element	Chemical Composition (heat analysis), % max unless otherwise specified[A]			
	Grade A	Grade B	Grade D	Grade E
	Deoxidation and Thickness (*t*), in. [mm]			
	Killed or Semi-Killed *t* ≤2.0 in. [50 mm] Killed *t* >2.0 in. [50 mm]	Killed or Semi-Killed *t* ≤2.0 in. [50 mm] Killed *t* >2.0 in. [50 mm]	Killed, Fine Grain Practice[B]	Killed, Fine Grain Practice[B]
C	0.21[C]	0.21	0.21	0.18
Mn, min	2.5 × C	0.60	0.60	0.70
Si	0.50	0.35	0.10–0.35[D]	0.10–0.35[D]
P	0.035	0.035	0.035	0.035
S	0.035	0.035	0.035	0.035
Ni	[E]	[E]	[E]	[E]
Cr	[E]	[E]	[E]	[E]
Mo	[E]	[E]	[E]	[E]
Cu	[E]	[E]	[E]	[E]
C + Mn/6	0.40	0.40	0.40	0.40

[A] Intentionally added elements are to be determined and reported.
[B] Grade D steel over 1.0 in. [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 Section 7).
[C] A maximum carbon content of 0.23 % is acceptable for Grade A shapes and bars.
[D] Where the content of acid soluble aluminum is not less than 0.015 %, the minimum required silicon content does not apply.
[E] 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 %.

TABLE 4 Chemical Requirements for Higher-Strength Structural Steel

Element	Chemical Composition[A] (heat analysis), % max unless otherwise specified	
	Grades AH/DH/EH32, AH/DH/EH36, and AH/DH/EH40	Grades FH32/36/40
	Deoxidation	
	Killed, Fine Grain Practice[B]	Killed, Fine Grain Practice[B]
C	0.18	0.16
Mn	0.90–1.60[C]	0.90–1.60
Si	0.10–0.50[D]	0.10–0.50[D]
P	0.035	0.025
S	0.035	0.025
Al (acid soluble), min[E,F]	0.015	0.015
Cb[F]	0.02–0.05	0.02–0.05
V[F]	0.05–0.10	0.05–0.10
Ti	0.02	0.02
Cu	0.35	0.35
Cr	0.20	0.20
Ni	0.40	0.40
Mo	0.08	0.08
N	...	0.009[G]

[A] The contents of any other element intentionally added is to be determined and reported.
[B] The steel is to contain at least one of the grain refining elements in sufficient amount to meet the fine grain practice requirement (see Section 7).
[C] Grade AH 0.5 in. [12.5 mm] and under in thickness may have a minimum manganese content of 0.70 %.
[D] If the content of soluble aluminum is not less than 0.015 %, the minimum required silicon content does not apply.
[E] The total aluminum content may be used instead of acid soluble content, in accordance with 7.1.
[F] The indicated amount of aluminum, columbium, and vanadium applies if any such element is used singly. If used in combination, the minimum content in 7.2.2 and 7.2.3, as appropriate, will apply.
[G] 0.012 if aluminum is present.

TABLE 5 Carbon Equivalent for Higher-Strength Structural Steel Produced by TMCP

Grade	Carbon Equivalent[A], max, %	
	Thickness (*t*), in. [mm]	
	t ≤2.0 in. [50 mm]	*t* >2.0 in. [50 mm] *t* ≤4.0 in. [100 mm]
AH32, DH32, EH32, FH32	0.36	0.38
AH36, DH36, EH36, FH36	0.38	0.40
AH40, DH40, EH40, FH40	0.40	0.42

[A] The following carbon equivalent formula shall be used to calculate the carbon equivalent, C_{eq}:

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