

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:

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

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:

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

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
O	± ⁽³⁾	±
6L	± ⁽⁴⁾	± ⁽⁴⁾
P	0.035	0.025
S	0.035	0.025
Al (acid Soluble) min ^(5, 6)	0.015	0.015
Nb ^(6, 7)	±	±
V ^(6, 7)	±	±
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
1	≥	LL \$CSUHWQW
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 ≤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 (1996)

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

3. For CRMA, HYDRXVP DMLA grades, A, D, E and F.

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

Grade	Temp	Average Absorbed Energy ⁽¹⁾ J (kgf-m, ft-lbf)					
		50 mm (2.0 in.)		50 mm (2.0 in.) < 70 mm (2.8 in.)		70 mm (2.8 in.) < 100 mm (4.0 in.)	
	°C (°F)	/ RO ₁₀ ⁽²⁾	Transv ⁽²⁾	/ RO ₁₀ ⁽²⁾	Transv ⁽²⁾	/ RO ₁₀ ⁽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.

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.)					
AH 32 AH 36		Nb V	P S	exceeding: 12.5	20	25	35	50	50
				not exceeding: 20	25	35	50	100	100
DH 32 DH 36		Al Al + Ti	P S	A 50	AR 25	N 50*	TM 50	CR 50	AR 25
				A 50	N 50*	TM 50	CR 50	AR 25	N 50*
EH 32 EH 36		Nb V	P S	A 50	N 50*	TM 50	CR 50	AR 25	N 50
				A 50	N 50	TM 50	CR 50	AR 25	N 50
FH 32 FH 36	Killed, Fine Grain Practice	Al Al + Ti	P S	A 50	AR 25	N 50	TM 50	CR 50	AR 25
				A 50	AR 25	N 50	TM 50	CR 50	N 50
AH 40		Any	P S	N	TM				N
				N 25	TM 25	CR 15			N
DH 40		Any	P S	N	TM	OT			N
				N 25	TM 25	OT 25			N 50
EH 40		Any	P S	A 50	N 50	TM 50	CR 50		N 50
				A 50	N 50	TM 50	CR 50		N 50
FH 40		Any	P S	N 50	TM 50	CR 50			N 50
				N 50	TM 50	CR 50			N 50

Notes

- Products: P = plate
- Conditions of Supply: A = Any Condition
AR = As Rolled
CR = Control Rolled
- Frequency of Impact Test: Impact Test Lot Size in Tons): (-) = no impact test required
(*) = upon application and approval, the impact frequency may be reduced

S = sections
 N = normalized
 TM = thermo mechanically controlled processing
 OT = quenched and tempered
 = 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⁾	
	$t \leq 50 \text{ mm (2.0 in.)}$	$50 \text{ mm (2.0 in.)} < t \leq 100 \text{ mm (4.0 in.)}$
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.