Designation: A 542/A 542M – 99 (Reapproved 2004)ε1

Standard Specification for Pressure Vessel Plates, Alloy Steel, Quenched-and-Tempered, Chromium-Molybdenum, and Chromium-Molybdenum-Vanadium[1]

This standard is issued under the fixed designation A 542/A 542M; 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.

ε[1] NOTE—Supplementary Requirement S14, Bend Test, was editorially removed in September 2004.

1. Scope

1.1 This specification[2] covers two types of 2¼ Cr-1 Mo and three types of Cr-Mo-V alloy steel plates for use in the quenched-and-tempered condition, intended for the fabrication of welded pressure vessels and components.

1.2 Material under this specification is available in five types, designated "A," "B," "C," "D," and "E." Type B is identical to Type A except for restrictive limits for carbon, phosphorus, sulfur, and nickel. The material is also available in five classes having the following strength levels. Type E is available only as Class 4 and 4a.

Class	Minimum Tensile Strength, ksi [MPa]
1	105 [725]
2	115 [795]
3	95 [655]
4 and 4a	85 [585]

1.3 The maximum thickness of plates is limited only by the capacity of the chemical composition to meet the specified mechanical property requirements.

1.4 The minimum thickness of plates is limited to 3⁄16 in. [5 mm].

1.5 The material is intended to be suitable for fusion welding. Welding technique is of fundamental importance and it is presupposed that welding procedures will be in accordance with approved methods.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as 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:* [3]

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information which should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the supplementary requirements listed in this specification and to the detailed requirements in Specification A 20/A 20M.

[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 A01.11 on Steel Plates for Boilers and Pressure Vessels.

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[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-542 in Section II of that Code.

[3] 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.

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3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 All plates shall be heat treated by heating to a suitable austenitizing temperature, holding for a sufficient period of time to attain uniform temperature throughout the thickness, and quenching in a suitable liquid medium by spraying or immersion. For Type D material, the minimum austenitizing temperature shall be 1650°F [900°C]. For Type E material, the minimum austenitizing temperature shall be 1850°F [1010°C].

5.2 After quenching, the plates shall be tempered to produce the specified tensile requirements by heating to a suitable temperature and holding for a period of time of not less that 30 min/in. [1.2 min/mm] of thickness but not less than ½ h. The minimum tempering temperature shall be as follows:

Type	Class	Temperature, °F [°C]
A, B, C	1, 2, 3	1050 [565]
A, B, C	4	1200 [650]
A, B, C, D	4a	1250 [675]

5.3 Plates over 4 in. [100 mm] in thickness shall receive a prior heat treatment of normalizing at, or water quenching from, a temperature within the range from 1650 to 1850°F [900 to 1010°C] for Types A, B, C, and D and 1850 to 2050°F [1010 to 1120°C] for Type E before the heat treatment specified in 5.1.

5.4 When the purchaser elects to perform the heat treatment required above, the material manufacturer shall temper the plates prior to shipment at a temperature not lower than 1050°F [565°C] for Types A, B, C, and D and not lower than 1200°F [650°C] for Type E.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements shown in Table 1.

7. Mechanical Properties

7.1 *Tension Test Requirements*:

7.1.1 The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

7.1.2 For nominal plate thicknesses of ¾ in. [20 mm] and under, the 1½-in. [40-mm] wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2-in. [50-mm] gage length that includes the fracture and that shows the greatest elongation.

7.2 *Notch Toughness Requirements—Classes 4 and 4a*:

7.2.1 A transverse Charpy V-notch test from each plate-as-heat-treated shall have a minimum energy absorption value of 40 ft·lbf [54 J] average of three specimens and 35 ft·lbf [48 J] for one specimen only in the set.

7.2.2 For Class 4, the impact test temperature shall be as specified on the order.

7.2.3 For Class 4a, the impact test temperature shall be 0°F [−18°C].

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TABLE 1 Chemical Requirements

Element	Composition, %				
	Type A	Type B	Type C	Type D	Type E
Carbon:					
Heat analysis	0.15 max	0.11–0.15	0.10–0.15	0.11–0.15	0.10–0.15
Product analysis	0.18 max[A]	0.09–0.18	0.08–0.18	0.09–0.18	0.08–0.18
Manganese:					
Heat analysis	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60
Product analysis	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66
Phosphorus, max	0.025[B]	0.015[B]	0.025[B]	. . .	0.025
Heat analysis	. . .	. . .	. . .	0.015	. . .
Product analysis	. . .	. . .	. . .	0.020	. . .
Sulfur, max	0.025[B]	0.015[B]	0.025[B]	. . .	0.010
Heat analysis	. . .	. . .	. . .	0.010	. . .
Product analysis	. . .	. . .	. . .	0.015	. . .
Silicon, max	0.50[B]	0.50[B]	0.13[B]	. . .	0.15
Heat analysis	. . .	. . .	. . .	0.10	. . .
Product analysis	. . .	. . .	. . .	0.13	. . .
Chromium:					
Heat analysis	2.00–2.50	2.00–2.50	2.75–3.25	2.00–2.50	2.75–3.25
Product analysis	1.88–2.62	1.88–2.62	2.63–3.37	1.88–2.62	2.63–3.37
Molybdenum:					
Heat analysis	0.90–1.10	0.90–1.10	0.90–1.10	0.90–1.10	0.90–1.10
Product analysis	0.85–1.15	0.85–1.15	0.85–1.15	0.85–1.15	0.85–1.15
Copper, max:					
Heat analysis	0.40	0.25	0.25	0.20	0.25
Product analysis	0.43	0.28	0.28	0.23	0.28
Nickel, max:					
Heat analysis	0.40	0.25	0.25	0.25	0.25
Product analysis	0.43	0.28	0.28	0.28	0.28
Vanadium:					
Heat analysis	0.03 max	0.02 max	0.20–0.30	0.25–0.35	0.20–0.30
Product analysis	0.04 max	0.03 max	0.18–0.33	0.23–0.37	0.18–0.33
Titanium:					
Heat analysis	. . .	. . .	0.015–0.035	0.030 max	. . .
Product analysis	. . .	. . .	0.005–0.045	0.035 max	. . .
Boron:					
Heat analysis	. . .	. . .	0.001–0.003	0.0020 max	. . .
Product analysis	. . .	. . .	NA[C]	NA[C]	. . .
Columbium:					
Heat analysis	. . .	. . .	. . .	0.07 max	0.015–0.070
Product analysis	. . .	. . .	. . .	0.08 max	0.010–0.075
Calcium:[D]					
Heat analysis	. . .	. . .	. . .	0.015 max	0.0005–0.0150
Product analysis	. . .	. . .	. . .	0.020 max	NA[C]

[A] In A 542/A 542M – 82 and earlier editions, for plates 5 in. [125 mm] and under in thickness, the carbon was limited to 0.15 % maximum.
[B] Applies to both heat analysis and product analysis.
[C] NA = Product analysis is *not applicable*.
[D] Rare earth metals (REM) may be added in place of calcium, subject to agreement between the producer and the purchaser. In that case, the total amount of REM shall be determined and reported.

TABLE 2 Tensile Requirements

	Class 1	Class 2	Class 3	Class 4	Class 4a
Tensile strength, ksi [MPa]	105–125 [725–860]	115–135 [795–930]	95–115 [655–795]	85–110 [585–760]	85–110 [585–760]
Yield strength, min, ksi [MPa]	85 [585]	100 [690]	75 [515]	55 [380]	60 [415]
Elongation in 2 in. [50 mm], min, %[A]	14	13	20	20	18

[A] See Specification A 20/A 20M for elongation adjustment.

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SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed in this section by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.2 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

In addition, the following supplementary requirements are suitable for this application.

S62. Temper Embrittlement Factor

S62.1 The composition of the steel, based on heat analysis, shall be restricted in accordance with the following equations:

$$J = (\text{Si} + \text{Mn}) \times (P + Sn) \times 10^4 \leq 150 \qquad \text{(Si, Mn, P and Sn in wt \%)}$$

$$Cu \leq 0.20\ \%$$

$$\text{Ni} \leq 0.30\ \%$$

S62.1.1 Lower values of J, Cu and Ni can be specified by agreement between purchaser and the supplier.

S62.1.2 When so specified by the purchaser, the maximum value of J shall not exceed 100.

S62.1.3 The values of J shall be reported.

S62.1.4 If the plates are repaired by welding, the composition of the weld deposit shall be restricted in accordance with the following equations:

$$X = (10P + 5Sb + 4Sn + As)/100 \leq 15 \qquad (P, \text{Sb, Sn and As in ppm})$$

$$Cu \leq 0.20\ \%$$

$$Ni \leq 0.30\ \%$$

S62.1.5 The values of X shall be reported.

S63. Impact Properties After Step Cooling

S63.1 The Charpy V-notch impact properties shall be determined as follows:

S63.1.1 A sufficient amount of Charpy V-notch test specimens shall be taken from the same location from a plate from each heat of steel to construct two transition temperature curves.

S63.1.2 The test specimens for one transition temperature curve shall be given the minimum post-weld heat treatment (PWHT) cycle specified by the purchaser.

S63.2 The test specimens for the other transition temperature curve shall be given the PWHT cycle specified in S63.1.2 plus the following step cooling heat treatment:

Hold at 1100°F (593°C) for 1 h, then cool at 10°F (5.6°C)/h to 1000°F (538°C).

Hold at 1000°F (538°C) for 15 h, then cool at 10°F (5.6°C)/h to 975°F (524°C).

Hold at 975°F (524°C) for 24 h, then cool at 10°F (5.6°C)/h to 925°F (496°C).

Hold at 925°F (496°C) for 60 h, then cool at 5°F (2.8°C)/h to 875°F (468°C).

Hold at 875°F (468°C) for 100 h, then cool at 50°F (27.8°C)/h to 600°F (315°C).

Cool in still air.

S63.3 Test the Charpy V-notch test specimens in accordance with Test Methods and Definitions A 370 to determine the 40 ft-lbs (55 J) transition temperature from each transition temperature curve using a set of three test specimens at each test temperature. The test temperatures shall include tests on the upper and lower shelves and a minimum of four intermediate temperatures.

S63.4 The following requirements shall be met.

$$\text{vTr40} + 2.5\Delta\text{vTr40} \leq 50°\text{F}$$

$$\text{vTr55} + 2.5\Delta\text{vTr55} \leq 10°C$$

where:

vTr40 (vTr55) = the 40 ft-lbs (55 J) transition temperature of the material subjected to the minimum PWHT specified by the purchaser.

ΔvTr40 (ΔvTr55) = the shift of the 40 ft-lbs (55 J) transition temperature the of the step cooled material. (The 40 ft-lbs (55 J) transition temperature the of the step cooled material minus that of the material subjected to the minimum PWHT only).

S63.5 The 40 ft-lbs (55 J) transition temperatures for the two material conditions shall be reported.

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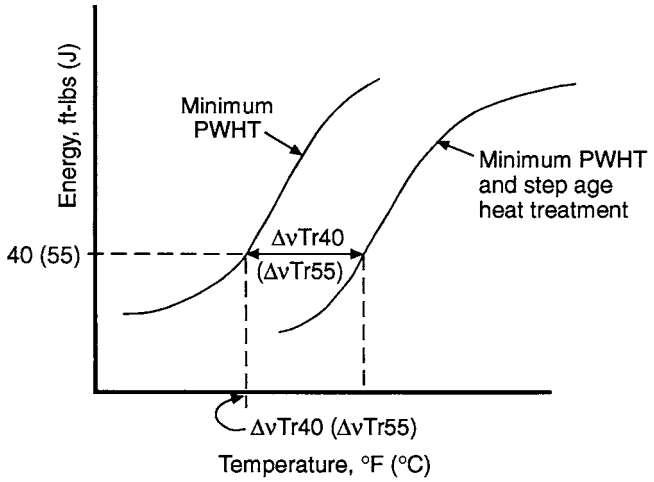

FIG. S1.1 Transition Temperature Curves Before and After Step Cool Heat Treatment

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