SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, QUENCHED-AND-TEMPERED, CHROMIUM-MOLYBDENUM, AND CHROMIUM-MOLYBDENUM-VANADIUM

SA-542/SA-542M (23)

(Identical with ASTM Specification A542/A542M-19.)

Specification for Pressure Vessel Plates, Alloy Steel, Quenched-and-Tempered, Chromium-Molybdenum, and Chromium-Molybdenum-Vanadium

1. Scope

1.1 This specification 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 These alloy steel plates in the as-rolled condition are sensitive to cracking during flame cutting, transit, and handling. They should be shipped in the as-rolled condition only with the mutual agreement of the manufacturer and the purchaser or fabricator.

1.7 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.

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A387/A387M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available

TABLE 1 Chemical Requirements

NOTE 1—Where "..." appears there is no requirement. Values are maximum unless minimum or a range is indicated.

Element	Composition, %				
	Type A	Type B	Type C	Type D	Type E
Carbon:					
Heat analysis	0.15	0.11–0.15	0.10–0.15	0.11–0.15	0.10–0.15
Product analysis	0.18	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:					
Heat analysis	0.025	0.015	0.025	0.015	0.025
Product analysis	0.025	0.015	0.025	0.020	0.025
Sulfur:					
Heat analysis	0.025	0.015	0.025	0.010	0.010
Product analysis	0.025	0.015	0.025	0.015	0.010
Silicon:					
Heat analysis	0.50	0.50	0.13	0.10	0.15
Product analysis	0.50	0.50	0.13	0.13	0.15
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:					
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:					
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	0.02	0.20–0.30	0.25–0.35	0.20–0.30
Product analysis	0.04	0.03	0.18–0.33	0.23–0.37	0.18–0.33
Titanium:					
Heat analysis	...	...	0.015–0.035	0.030	...
Product analysis	...	...	0.005–0.045	0.035	...
Boron:					
Heat analysis	...	...	0.001–0.003	0.0020	...
Product analysis	...	...	...	...	...
Columbium (niobium):[A]					
Heat analysis	...	...	...	0.07	0.015–0.070
Product analysis	...	...	...	0.08	0.010–0.075

[A] Columbium and niobium are interchangeable names for the same element and both names are acceptable for use in A01 specifications.

when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, 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 A20/A20M.

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 Plates ordered without the heat treatment required by 5.1 – 5.3 shall be furnished in either the stress-relieved or the

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 A20/A20M for elongation adjustment.

annealed condition. Minimum stress relieving temperature shall be 1050°F [565°C] except for Type E which shall be 1200°F [650°C].

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].

8. Keywords

8.1 alloy steel; alloy steel plate; pressure containing parts; pressure vessel steels; steel plates for pressure vessels

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 A20/A20M. 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 A435/A435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A577/A577M,

S12. Ultrasonic Examination in accordance with Specification A578/A578M,

S17. Vacuum Carbon-Deoxidized Steel.

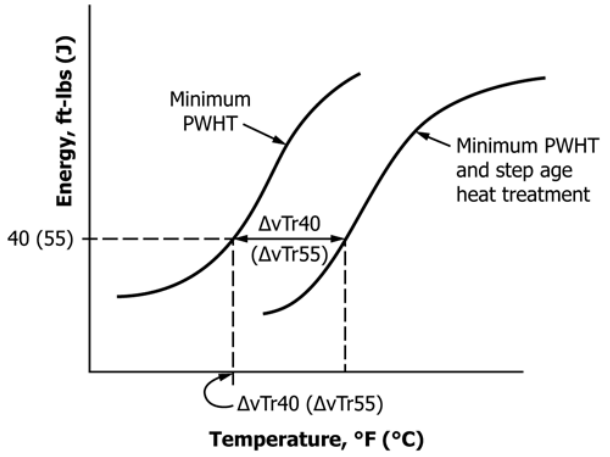

FIG. S1.1 Transition Temperature Curves Before and After Step Cool Heat Treatment

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

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

S53. Alternative Location for Mechanical Testing

S53.1 When specified by the purchaser, the axis of the tensile and impact test specimens shall come from the mid-thickness of each plate tested, in lieu of midway between the center thickness and the top or bottom surface of the plate.

S62. Temper Embrittlement Factor

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

$$J = (Si + Mn) \times (P + Sn) \times 10^4 \le 150 \quad (Si, Mn, P, \text{ and } Sn \text{ in wt\%})$$
$$Cu \le 0.20\%$$
$$Ni \le 0.30\%$$

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:

$$X = (10P + 5Sb + 4Sn + As)/100 \le 15 \quad (P, Sb, Sn, \text{ and } As \text{ in ppm})$$
$$Cu \le 0.20\%$$
$$Ni \le 0.30\%$$

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 A370 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.

$$vTr40 + 2.5\Delta vTr40 \le 50°F$$
$$vTr55 + 2.5\Delta vTr55 \le 10°C$$

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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