Designation: A 387/A 387M – 03

Standard Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum[1]

This standard is issued under the fixed designation A 387/A 387M; 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.

1. Scope*

1.1 This specification[2] covers chromium-molybdenum alloy steel plates intended primarily for welded boilers and pressure vessels designed for elevated temperature service.

1.2 Plates are available under this specification in several grades having different alloy contents as follows:

Grade	Nominal Chromium Content, %	Nominal Molybdenum Content, %
2	0.50	0.50
12	1.00	0.50
11	1.25	0.50
22, 22L	2.25	1.00
21, 21L	3.00	1.00
5	5.00	0.50
9	9.00	1.00
91	9.00	1.00
911	9.00	1.00

1.3 Each grade except Grades 21L, 22L, 91 and 911 is available in two classes of tensile strength levels as defined in the Tensile Requirements tables, depending on heat treatment. In the annealed condition all grades are available only as Class 1. Grades 21L and 22L are available only as Class 1. Grade 91 and 911 are available only as Class 2.

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

1.5 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 weight, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information that 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 listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M. If the requirements of this

[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-387/SA-387M 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.

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

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.

5. Heat Treatment

5.1 Except for Grades 91 and 911, all plates shall be thermally treated either by annealing, normalizing- and -tempering, or, when permitted by the purchaser, accelerated cooling from the austenitizing temperature by air blasting or liquid quenching, followed by tempering. Minimum tempering temperatures shall be as follows:

Grade	Temperature, °F [°C]
2, 12, and 11	1150 [620]
22, 22L, 21, 21L, and 9	1250 [675]
5	1300 [705]

5.1.1 Grades 91 and 911 plates shall be normalized at 1900 to 2000°F [1040 to 1095°C] and shall be tempered at not less than 1350°F [730°C].

5.2 Grade 5, 9, 21, 21L, 22, 22L, 91 and 911 plates ordered without the heat treatment required by 5.1 shall be furnished in either the stress-relieved or the annealed condition.

5.3 For plates ordered without the heat treatment required by 5.1, heat treatment of the plates to conform to 5.1 and to Table 2 or Table 3, as applicable, shall be the responsibility of the purchaser.

6. Chemical Requirements

6.1 The steel shall conform to the requirements as to chemical composition shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M for grades other than Grade 11.

7. Metallurgical Structure

7.1 *Austenitic Grain Size*—Grade 2 material shall have a coarse austenitic grain size.

8. Mechanical Requirements

8.1 *Tension Test Requirements*:

8.1.1 The material as represented by the tension test specimens shall conform to the applicable requirements of Table 2 or Table 3, as specified on the order.

8.1.2 Adjustment of the percentage elongation requirements is permitted in accordance with Specification A 20/A 20M for plates up to ¾ in. [20 mm] inclusive, in thickness when an 8-in. [200-mm] gage length is used.

9. Marking

9.1 In addition to the marking required in Specification A 20/A 20M, each plate shall be legibly stamped or stenciled, depending upon the ordered thickness, with the letter *A* for annealed, *N* for normalized and tempered, and *Q* for accelerated cooled and tempered, as applicable.

TABLE 2 Tensile Requirements for Class 1 Plates

	Grades 2 and 12	Grade 11	Grades 22, 21, 5, 9, 21L, 22L
Tensile strength, ksi [MPa]	55 to 80 [380 to 550]	60 to 85 [415 to 585]	60 to 85 [415 to 585]
Yield strength, min, ksi [MPa]	33 [230]	35 [240]	30 [205]
Elongation in 8 in. [200 mm], min, %[A]	18	19	...
Elongation in 2 in. [50 mm], min, %[A]	22	22	18
Reduction of area, min, %	...	...	45[B] 40[C]

[A] See Specification A 20/A 20M, elongation adjustments.
[B] Measured on round test specimens.
[C] Measured on flat specimen.

TABLE 3 Tensile Requirements for Class 2 Plates[A]

	Grade 2	Grade 11	Grade 12	Grades 22, 21, 5, 9	Grade 91	Grade 911
Tensile strength, ksi [MPa]	70 to 90 [485 to 620]	75 to 100 [515 to 690]	65 to 85 [450 to 585]	75 to 100 [515 to 690]	85 to 110 [585 to 760]	90 to 120 [620 to 840]
Yield strength, min, ksi [MPa]/(0.2 % offset)	45 [310]	45 [310]	40 [275]	45 [310]	60 [415]	64 [440]
Elongation in 8 in. [200 mm], min, %[B]	18	18	19	...	...	...
Elongation in 2 in. [50 mm], min, %[B]	22	22	22	18	18	18
Reduction of area, min, %	...	...	...	45[C] 40[D]	...	...

[A] Not applicable to annealed material.
[B] See Specification A 20/A 20M, elongation adjustments.
[C] Measured on round test specimens.
[D] Measured on flat specimen.

TABLE 1 Chemical Requirements

Element	Composition, %										
	Grade 2	Grade 12	Grade 11	Grade 22	Grade 22L	Grade 21	Grade 21L	Grade 5	Grade 9	Grade 91	Grade 911
Carbon:											
Heat analysis	0.05–0.21	0.05–0.17	0.05–0.17	0.05–0.15[A]	0.10 max	0.05–0.15[A]	0.10 max	0.15 max	0.15 max	0.08–0.12	0.09–0.13
Product analysis	0.04–0.21	0.04–0.17	0.04–0.17	0.04–0.15[A]	0.12 max	0.04–0.15[A]	0.12 max	0.15 max	0.15 max	0.06–0.15	0.08–0.14
Manganese:											
Heat analysis	0.55–0.80	0.40–0.65	0.40–0.65	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60
Product analysis	0.50–0.88	0.35–0.73	0.35–0.73	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66
Phosphorus, max:											
Heat analysis	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.030	0.020	0.020
Product analysis	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.030	0.025	0.025
Sulfur, max:											
Heat analysis	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.030	0.030	0.010	0.010
Product analysis	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.030	0.030	0.012	0.012
Silicon:											
Heat analysis	0.15–0.40	0.15–0.40	0.50–0.80	0.50 max	0.50 max	0.50 max	0.50 max	0.50 max	1.00 max	0.20–0.50	0.10–0.50
Product analysis	0.13–0.45	0.13–0.45	0.44–0.86	0.50 max	0.50 max	0.50 max	0.50 max	0.55 max	1.05 max	0.18–0.56	0.08–0.56
Chromium:											
Heat analysis	0.50–0.80	0.80–1.15	1.00–1.50	2.00–2.50	2.00–2.50	2.75–3.25	2.75–3.25	4.00–6.00	8.00–10.00	8.00–9.50	8.50–10.50
Product analysis	0.46–0.85	0.74–1.21	0.94–1.56	1.88–2.62	1.88–2.62	2.63–3.37	2.63–3.37	3.90–6.10	7.90–10.10	7.90–9.60	8.40–10.70
Molybdenum:											
Heat analysis	0.45–0.60	0.45–0.60	0.45–0.65	0.90–1.10	0.90–1.10	0.90–1.10	0.90–1.10	0.45–0.65	0.90–1.10	0.85–1.05	0.90–1.10
Product analysis	0.40–0.65	0.40–0.65	0.40–0.70	0.85–1.15	0.85–1.15	0.85–1.15	0.85–1.15	0.40–0.70	0.85–1.15	0.80–1.10	0.85–1.15
Nickel, max:											
Heat analysis	...	...	...	...	...	...	...	...	...	0.40	0.40
Product analysis	...	...	...	...	...	...	...	...	...	0.43	0.43
Vanadium:											
Heat analysis	...	...	...	...	...	...	...	...	...	0.18–0.25	0.18–0.25
Product analysis	...	...	...	...	...	...	...	...	...	0.16–0.27	0.16–0.27
Columbium:											
Heat analysis	...	...	...	...	...	...	...	...	...	0.06–0.10	0.060–0.10
Product analysis	...	...	...	...	...	...	...	...	...	0.05–0.11	0.05–0.11
Boron:											
Heat analysis	...	...	...	...	...	...	...	...	...	...	0.0003–0.006
Product analysis	...	...	...	...	...	...	...	...	...	...	0.0002–0.007
Nitrogen:											
Heat analysis	...	...	...	...	...	...	...	...	...	0.030–0.070	0.04–0.09
Product analysis	...	...	...	...	...	...	...	...	...	0.025–0.080	0.035–0.095
Aluminum, max:											
Heat analysis	...	...	...	...	...	...	...	...	...	0.04	0.04
Product analysis	...	...	...	...	...	...	...	...	...	0.05	0.05
Tungsten:											
Heat analysis	...	...	...	...	...	...	...	...	...	...	0.90–1.10
Product analysis	...	...	...	...	...	...	...	...	...	...	0.85–1.15

[A] The carbon content for plates over 5 in. [125 mm] in thickness is 0.17 max on product analysis.

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 is included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed below 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,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

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,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

In addition, the following supplementary requirements are suitable for this application. S62 and S63 are applicable for Grades 22 and 21 only.

S60. Restricted Carbon

S60.1 The maximum carbon content of Grade 5 shall be 0.10 %.

S62. Temper Embrittlement Factor

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

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

$$Cu \leq 0.20\%$$

$$Ni \leq 0.30\%$$

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:

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

$$Cu \leq 0.20\%$$

$$Ni \leq 0.30\%$$

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.

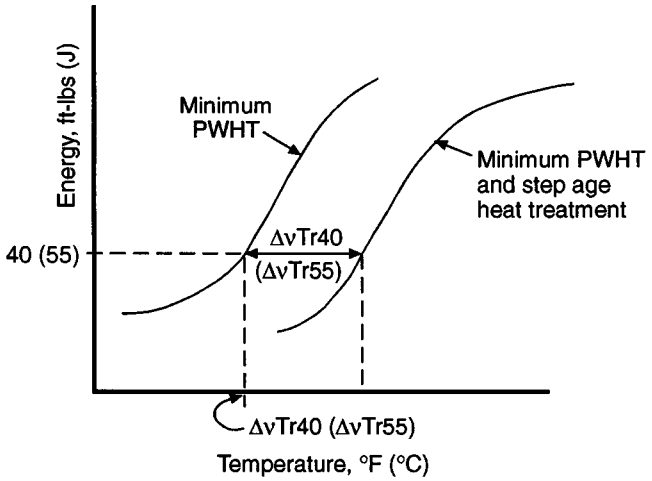

FIG. S1.1 Transition Temperature Curves Before and After Step Cool Heat Treatment

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.

$$vTr40 + 2.5\Delta vTr40 \leq 50°F$$

$$vTr55 + 2.5\Delta vTr55 \leq 10°C$$

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.

SUMMARY OF CHANGES

Committee A01 has identified the location of the following changes to this standard since A 387/A 387M-99$^{\epsilon 1}$ that may impact the use of this standard.

(1) Added SI units [MPA] to the yield strength values in Table 2.