



Standard Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum¹

This standard is issued under the fixed designation A387/A387M; 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 U.S. Department of Defense.

1. Scope*

1.1 This specification² 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

1.3 Each grade except Grades 21L, 22L, and 91 is available in two classes of tensile strength levels as defined in the Tensile Requirements tables. Grades 21L and 22L are available only as Class 1. Grade 91 is available only as Class 2.

NOTE 1—Grade 911, previously covered by this specification, is now covered by Specification [A1017/A1017M](#).

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.

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.

Current edition approved April 1, 2011. Published April 2011. Originally approved in 1955. Last previous edition approved in 2010 as [A387/A387M – 10](#). DOI: 10.1520/A0387_A0387M-11.

² For ASME Boiler and Pressure Vessel Code applications, see related Specification [SA-387/SA-387M](#) in Section II of that Code.

2. Referenced Documents

2.1 ASTM Standards:³

[A20/A20M](#) Specification for General Requirements for Steel Plates for Pressure Vessels

[A370](#) Test Methods and Definitions for Mechanical Testing of Steel Products

[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

[A1017/A1017M](#) Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Tungsten

2.2 AWS Specifications:⁴

[A5.5/A5.5M](#) Low-Alloy Steel Electrodes for Shielded Metal Arc Welding

[A5.23/A5.23M](#) Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding

[A5.28/A5.28M](#) Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding

[A5.29/A5.29M](#) Low-Alloy Steel Electrodes for Flux Cored Arc Welding

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, permissible variations in dimensions and weight, 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 when additional control, testing, or examination is required to

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.

⁴ Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, <http://www.aws.org>.

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

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.

5. Heat Treatment

5.1 Except for Grade 91, 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 Grade 91 plates shall be thermally treated, either by normalizing-and-tempering or by accelerated cooling from the austenitizing temperature by air blasting or liquid quenching, followed by tempering. Grade 91 plates shall be austenitized at 1900 to 1975°F [1040 to 1080°C] and shall be tempered at 1350 to 1470°F [730 to 800°C].

5.2 Grade 5, 9, 21, 21L, 22, 22L, and 91 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 **A20/A20M** 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 **A20/A20M** for plates up to ¾ in. [20 mm] inclusive, in thickness when an 8-in. [200-mm] gage length is used.

9. Repair Welding

9.1 Repair welding shall be permitted only with the approval of the purchaser. Repair welds shall meet the requirements of the construction code specified by the purchaser.

9.2 All repair welds in Grade 91 shall be made with one of the following welding processes and consumables: SMAW, A5.5/A5.5M E90XX-B9; SAW, A5.23/A5.23M EB9 + neutral flux; GTAW, A5.28/A5.28M ER90S-B9; and FCAW A5.29/A5.29M E91T1-B9. In addition, the sum of the Ni+Mn content of all welding consumables used to weld repair Grade 91 plate shall not exceed 1.0 %.

10. Marking

10.1 In addition to the marking required in Specification **A20/A20M**, 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.

11. Keywords

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



TABLE 1 Chemical Requirements

NOTE 1—Where “...” appears, there is no requirement.

Element	Composition, %									
	Grade 2 S50460	Grade 12 K11757	Grade 11 K11789	Grade 22 K21590	Grade 22L K21590	Grade 21 K31545	Grade 21L K31545	Grade 5 S50200	Grade 9 K90941	Grade 91 K90901
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
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
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
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
Phosphorus, max:										
Heat analysis	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.020
Product analysis	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Sulfur, max:										
Heat analysis	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.010
Product analysis	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	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
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
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
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
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
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
Nickel, max:										
Heat analysis	...	...	...	...	...	...	...	...	...	0.40
Product analysis	...	...	...	...	...	...	...	...	...	0.43
Vanadium:										
Heat analysis	...	...	...	...	...	...	...	...	0.04 max	0.18–0.25
Product analysis	...	...	...	...	...	...	...	...	0.05 max	0.16–0.27
Columbium:										
Heat analysis	...	...	...	...	...	...	...	...	...	0.06–0.10
Product analysis	...	...	...	...	...	...	...	...	...	0.05–0.11
Boron:										
Heat analysis	...	...	...	...	...	...	...	...	...	...
Product analysis	...	...	...	...	...	...	...	...	...	...
Nitrogen:										
Heat analysis	...	...	...	...	...	...	...	...	...	0.030–0.070
Product analysis	...	...	...	...	...	...	...	...	...	0.025–0.080
Aluminum, max:										
Heat analysis	...	...	...	...	...	...	...	...	...	0.02
Product analysis	...	...	...	...	...	...	...	...	...	0.02
Titanium, max:										
Heat analysis	...	...	...	...	...	...	...	...	...	0.01
Product analysis	...	...	...	...	...	...	...	...	...	0.01
Zirconium, max:										
Heat analysis	...	...	...	...	...	...	...	...	...	0.01
Product analysis	...	...	...	...	...	...	...	...	...	0.01

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

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 **A20/A20M**, 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
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]
Yield strength, min, ksi [MPa]/(0.2 % offset)	45 [310]	45 [310]	40 [275]	45 [310]	60 [415]
Elongation in 8 in. [200 mm], min, % ^B	18	18	19	...	...
Elongation in 2 in. [50 mm], min, % ^B	22	22	22	18	18
Reduction of area, min, %	...	...	...	45 ^C 40 ^D	...

^A Not applicable to annealed material.
^B See Specification **A20/A20M**, elongation adjustments.
^C Measured on round test specimens.
^D Measured on flat specimen.

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 **A20/A20M**. 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 (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**, and
- S17. Vacuum Carbon-Deoxidized Steel.

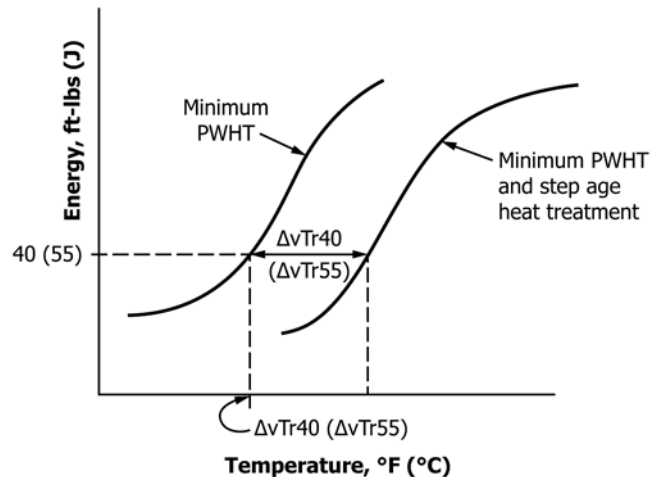


FIG. S1.1 Transition Temperature Curves Before and After Step Cool Heat Treatment

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

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

S53. Alternative Location for Mechanical Testing

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.

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:

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

$$Cu \leq 0.20\%$$

$$Ni \leq 0.30\%$$

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:

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

$$Cu \leq 0.20\%$$

$$Ni \leq 0.30\%$$

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 **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.

$$vTr40 + 2.5\Delta vTr40 \leq 50^\circ F$$

$$vTr55 + 2.5\Delta vTr55 \leq 10^\circ C$$

where:

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

$\Delta vTr40$ ($\Delta vTr55$) = 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 selected changes to this standard since the last issue (A387/A387M – 10) that may impact the use of this standard. (Approved April 1, 2011.)

- (1) Added 2.2 and 9.
- (2) Revised 5.1.1 and Table 1.
- (3) Editorially corrected 2.1.

Committee A01 has identified the location of selected changes to this standard since the last issue (A387/A387M – 06a) that may impact the use of this standard. (Approved Oct. 1, 2010.)

- (1) Revised Section 3.
- (2) Revised Table 1.
- (3) Revised Supplementary Requirements S53 and S63.3.

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org). Permission rights to photocopy the standard may also be secured from the ASTM website (www.astm.org/COPYRIGHT).