



Designation: A841/A841M – 17

Standard Specification for Steel Plates for Pressure Vessels, Produced by Thermo-Mechanical Control Process (TMCP)¹

This standard is issued under the fixed designation A841/A841M; 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 specification² covers steel plates produced by the thermo-mechanical control process (TMCP). The plates are intended primarily for use in welded pressure vessels. A description of the TMCP method is given in [Appendix X1](#).

1.2 Due to the inherent characteristics of the TMCP method, the plates cannot be formed at elevated temperatures without sustaining significant losses in strength and toughness. Except for Grade G, the plates may be formed and post-weld heat-treated at temperatures not exceeding 1200°F [650°C], providing the requirements of [6.1](#) are met. Grade G plates may be formed at temperatures not exceeding 985°F [530°C] provided the requirements of [6.1](#) are met.

1.3 The maximum permitted nominal thickness of plates furnished to this specification is 4 in. [100 mm] for Grades A, B, and C; 1.5 in. [40 mm] for Grades D,³ E, and F; and 2 in. [50 mm] for Grade G.

1.4 Grade G is susceptible to magnetization. Use of magnets in handling after heat treatment should be avoided if residual magnetism would be detrimental to subsequent fabrication or service.

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.

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² For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-841/SA-841M in Section II of that Code.

³ ExxonMobil Upstream Research Company has patents pending concerning the use of chemistry ranges in ASTM A841 Grade D, in combination with specific TMCP routes and/or specific microstructural features. Interested parties are invited to submit information regarding identification of alternatives to these patented items to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,¹ which you may attend.

1.6 *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:*⁴

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

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 Plates supplied to this product specification shall conform to Specification A20/A20M, which outlines the testing and retesting methods and procedures, permissible variations in dimensions, quality and repair of defects, marking, loading, etc.

3.2 Specification A20/A20M also establishes the rules for ordering information that should be complied with when purchasing plates to this specification.

3.2.1 If the plates are to be subjected to warm forming or post-weld heat treatment, the order must indicate the temperatures and times-at-temperature that will be utilized in such operations. (See [6.1](#) and Specification A20/A20M, Supplementary Requirement S3.)

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:

⁴ 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

- 3.3.1 Vacuum treatment,
- 3.3.2 Additional or special tension testing,
- 3.3.3 Additional or special 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 **A20/A20M**.

3.5 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**.

4.2 The plates shall be produced by the thermo-mechanical control process.

5. Chemical Composition

5.1 The chemical composition on heat analysis shall conform to the requirements given in **Table 1**, except as otherwise provided in Supplementary Requirement S17 of Specification **A20/A20M** when that requirement is involved.

5.2 If a product analysis is made on a sample taken from the standard location (see Specification **A20/A20M**), the results of the analysis shall not deviate from the limits for the heat analysis by more than the values given in **Table 2**.

6. Mechanical Requirements

6.1 If the plates are to be subjected to warm forming or post-weld heat treatment, the test coupons shall be subjected to heat treatment to simulate such fabrication operations. (See **3.2.1** and Specification **A20/A20M**, Supplementary Requirement S3.)

6.2 *Tension Test Requirements*—The plates as represented by the tension-test specimens shall conform to the requirements given in **Table 3**.

6.2.1 *Number and Location of Test Coupons*—Two tension tests shall be made from each plate-as-rolled. One test coupon shall be taken from a corner of the plate on each end.

6.3 Notch Toughness Test Requirements:

6.3.1 Except for Grade G, longitudinal Charpy V-notch tests shall be made in accordance with Specification **A20/A20M**.

6.3.2 For Grades A, B and C, unless the test temperature and absorbed energy requirements are specified in the purchase order, the tests shall be conducted at -40°F [-40°C] and the average absorbed energy for each set of three full size specimens shall be 15 ft-lb [20J] or more.

6.3.3 For Grade D, unless the test temperature and the lateral expansion requirements are specified in the purchase order, the tests shall be conducted at -40°F [-40°C] and the lateral expansion for each specimen shall be 0.015 in. [0.4 mm] or more.

6.3.4 For Grades E and F, unless the test temperature and absorbed energy requirements are specified in the purchase order, the tests shall be conducted at -40°F [-40°C] and the average absorbed energy for each set of three full size specimens shall be 20 ft-lb [27 J] or more.

6.3.5 For Grade G, transverse Charpy V-notch tests shall be made in accordance with Specification **A20/A20M**. Unless the test temperature is specified in the purchase order, the tests shall be conducted at -320°F [-195°C]. Each specimen shall have a lateral expansion opposite the notch of not less than 0.015 in. [0.38 mm], up to a plate thickness of 1.25 in. [31.75 mm] inclusive; and 0.019 in. [0.48 mm] at a plate thickness of 2.0 in. [50 mm]. Values of lateral expansion for plate thicknesses between 1.25 in. [31.75 mm] and 2.0 in. [50 mm] shall be determined by linear interpolation.

7. Marking

7.1 In addition to the marking required in Specification **A20/A20M**, each plate shall be legibly stamped with the letters “TMC” following the stamped specification designation.

8. Keywords

8.1 pressure containing parts; pressure vessel steel; steel plates; steel plates for pressure vessel applications



TABLE 1 Chemical Requirements^A

Element	Composition, %						
	Grade A	Grade B	Grade C	Grade D	Grade E	Grade F	Grade G
Carbon	0.20	0.15	0.10	0.09	0.07	0.10 ^B	0.13
Manganese	0.70–1.35 ^C	0.70–1.35 ^C	0.70–1.60	1.00–2.00	0.70–1.60	1.10–1.70 ^B	0.60–1.20
t ≤ 1.5 in. [40 mm]	1.00–1.60	1.00–1.60	1.00–1.60	0.010	0.015	0.020	0.60–1.20
t > 1.5 in. [40 mm]	0.030	0.030	0.030	0.005	0.005	0.008	0.015
Phosphorus	0.030	0.025	0.015	0.05–0.25	0.05–0.30	0.10–0.45	0.015
Sulfur	0.15–0.50	0.15–0.50	0.15–0.50	0.50	0.35	0.40	0.04–0.15 ^F
Silicon	0.35	0.35	0.35	1.0–5.0	0.60	0.85	...
Copper	0.25	0.60	0.25	0.30	0.30	0.30	6.0–7.5
Nickel	0.25	0.25	0.25	0.40	0.30	0.50	0.30–1.00
Chromium	0.08	0.30	0.08	0.05	0.08	0.10	0.30
Molybdenum	0.03	0.03	0.06	0.02	0.06	0.09	...
Coluumbium (Niobium) ^F	0.06	0.06	0.06	0.006–0.03	0.06	0.09	...
Vanadium	0.06	0.06	0.06	0.0005–0.002	0.0007	0.020 total or	...
Titanium	...	...	...	...	0.015 acid	0.015 acid	...
Boron	0.020 total or	0.020 total or	0.020 total or	0.020 total or	0.015 acid	0.020 total or	0.008 acid soluble
Aluminum, min	0.015 acid	0.015 acid	0.015 acid	0.015 acid	0.015 acid	0.015 acid	0.015 acid
	soluble ^G	soluble ^G	soluble ^G	soluble ^G	soluble ^G	soluble ^H	soluble ^H

^A Values are maximums unless a minimum or a range is indicated. Where ellipses appear in this table, there is no requirement.

^B For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage points above the specified maximum for manganese is permitted, up to a maximum of 1.85 %.

^C Manganese may exceed 1.35 % on heat analysis, up to a maximum of 1.60 %, provided that the carbon equivalent on heat analysis does not exceed 0.47 %, or the value specified in Supplementary Requirement S77 when that requirement is invoked, when based on the following formula:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15\%$$

When this option is exercised, the manganese content on product analysis shall not exceed the heat analysis content by more than 0.12 percentage points.

^D Not applicable.

^E Silicon may be less than 0.04 %, provided that total aluminum is 0.030 % or over, or provided acid soluble aluminum is 0.025 % or over.

^F Coluumbium and niobium are interchangeable names for the same element and both names are acceptable in A01 specifications.

^G By agreement, the steel may be produced with titanium, in which case the minimum aluminum content shall not apply. When this option is exercised, the titanium content, by heat analysis, shall be 0.006 % to 0.02 %, and the actual titanium content shall be reported on the test report.

^H By agreement, the steel may be produced with titanium, in which case the minimum aluminum content shall not apply. When this option is exercised, the titanium content, by heat analysis, shall be 0.006 % to 0.03 %, and the actual titanium content shall be reported on the test report.



TABLE 2 Product Analysis Tolerances

Element	Specified Limit, %	Tolerances, %	
		Under Minimum Limit	Over Maximum Limit
Carbon	to 0.15, incl	0.02	0.03
	over 0.15	0.03	0.04
Manganese	to 0.60, incl	0.05	0.06
	over 0.60 to 0.90, incl	0.06	0.08
	over 0.90 to 1.20, incl	0.08	0.10
	over 1.20 to 1.35, incl	0.09	0.11
	over 1.35 to 1.65, incl	0.09	0.12
Phosphorus	over 1.65	0.11	0.14
	to 0.020, incl	...	0.005
Sulfur	over 0.020	...	0.010
	to 0.020, incl	...	0.005
Silicon	over 0.020	...	0.010
	to 0.30, incl	0.02	0.03
Nickel	over 0.30 to 0.40, incl	0.05	0.05
	over 0.40	0.06	0.06
	to 1.00, incl	0.03	0.03
Chromium	over 1.0 to 2.0, incl	0.05	0.05
	over 2.0 to 3.8, incl	0.07	0.07
	over 3.8	0.08	0.08
Molybdenum	to 0.90, incl	0.04	0.04
Copper	to 0.20, incl	0.01	0.01
	over 0.20	0.03	0.03
Vanadium	to 1.00, incl	0.03	0.03
Columbium (Niobium) ^A	to 0.10, incl	0.01	0.01
	to 0.15, incl	0.005	0.01
Titanium	to 0.010, incl	0.002	0.01
	over 0.010	0.01	0.01
Boron	any	^B	^B

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

^B Product analysis is not applicable for this element.

Document Preview

[ASTM A841/A841M-17](https://standards.iteh.ai/catalog/standards/sist/91126050-0ca2-4ed4-95b1-b951562c4d6b/astm-a841-a841m-17)

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TABLE 3 Tensile Requirements

	Grades A, B, and C			Grade E			Grade F			Grade G		
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10		
Yield strength, min, ksi [MPa] to 1.5 in. [40 mm] incl over 1.5 in. [40 mm] to 2.0 in. [50 mm]	50 [345] A	60 [415] A	100 [690] A	70 [485] A	75 [515] A	70 [485] A	75 [515] A	80 [550] A	85 [585] A	90 [620] A		
over 1.5 in. [40 mm] to 2.5 in. [to 65 mm]	50 [345] 45 [310]	60 [415] 55 [380]	A A	A A	A A	A A	A A	A A	A A	A A		
Tensile strength, ksi [MPa] to 1.5 in. [40 mm] incl over 1.5 in. [40 mm] to 2.0 in. [50 mm]	70-90 [485-620]	80-100 [550-690]	145-170 [1000-1170]	84-104 [580-715]	88-108 [605-745]	82-102 [565-705]	86-106 [590-730]	90-110 [620-760]	100-120 [690-825]	109-129 [750-885]		
over 1.5 in. [40 mm] to 2.5 in. [to 65 mm]	70-90 [485-620] 65-85 [450-585]	80-100 [550-690] 75-95 [515-655]	A A	A A	A A	A A	A A	A A	A A	A A		
Elongation in 2 in. [50 mm], min, % ^B	22	22	13	20	19	20	19	18	20	20		
to 1.5 in. [40 mm] incl over 1.5 in. [40 mm] to 2.0 in. [50 mm]	A	A	A	A	A	A	A	A	A	A		
over 1.5 in. [40 mm] to 2.5 in. [to 65 mm]	22	22	A	A	A	A	A	A	A	A		
Elongation in 8 in. [200 mm], min, % ^B	18	...	...	16	15	16	15	14	A	A
to 1.5 in. [40 mm] incl over 1.5 in. [40 mm] to 2.5 in. [to 65 mm]	18	...	A	A	A	A	A	A	A	A		
over 2.5 in. [over 65 mm]	18	...	A	A	A	A	A	A	A	A		

^A Not applicable.

^B See Specification A20/A20M for elongation requirement adjustments.

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 that are 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.

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| <ul style="list-style-type: none"> S1. Vacuum Treatment, S2. Product Analysis, S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons, 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, | <ul style="list-style-type: none"> S9. Magnetic Particle Examination, S10. Charpy V-Notch Test Curve, S11. Ultrasonic Examination in accordance with Specification A577/A577M, S12. Ultrasonic Examination in accordance with Specification A578/A578M, S13. NDT Temperature Determination, S17. Vacuum Carbon-Deoxidized Steel, S18. Unspecified Elements, and S19. Restricted Chemical Requirements. |
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ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed are additional supplementary requirements suitable for use with this specification.

S55. Longitudinal Charpy Impact Energy Absorption Requirement

S55.1 Longitudinal Charpy V-notch tests shall be made in accordance with Specification **A20/A20M**. Unless the test temperature is specified in the purchase order, the tests shall be conducted at -320°F [-195°C] and the average absorbed energy for each set of three full size specimens shall be 25 ft-lb [34 J] or more, and the individual test value of not more than one specimen may be below 25 ft-lb [34 J], but in no case below 20 ft-lb [27 J].

S56. Transverse Charpy Impact Energy Absorption Requirement

S56.1 Transverse Charpy V-notch tests shall be made in accordance with Specification **A20/A20M**. Unless the test temperature is specified in the purchase order, the tests shall be conducted at -320°F [-195°C] and the average absorbed energy for each set of three full size specimens shall be 20 ft-lb [27 J] or more, and the individual test value of not more than one specimen may be below 20 ft-lb [27 J], but in no case below 15 ft-lb [20 J].

S64. Heat Treatment Parameters for Grad G

S64.1 Except for the TMR-I-T process, the plates shall be cooled directly after rolling without being allowed to cool below 1025°F [550°C]. Quenching hardening shall be initiated from a temperature within the range from 1025 to 1490°F [550 to 810°C].

S64.2 Subsequent to quenching, the plates shall be tempered within the range from 1030 to 1155°F [555 to 625°C], holding at that temperature for a minimum of 30 min/in. [1.2

min/mm] of thickness but for not less than 15 min, and then cooling at a rate of not less than 300°F/h [165°C/h], either in air or by quenching in water, to ambient temperature.

S64.3 Prior to the tempering treatment, the plates may be subjected to an intermediate heat treatment (**Note S64.1**) consisting of heating to a temperature in the range from 1185 to 1310°F [640 to 710°C], holding at that temperature for a minimum of 1 hr/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and then water-quenching to below 300°F [150°C] in the case of plate thicknesses of more than $\frac{5}{8}$ in. [16 mm]; or cooling in air or water-quenching in the case of plate thickness of $\frac{5}{8}$ in. [16 mm] and under.

NOTE S64.1—The intermediate heat treatment is for the purpose of enhancing elongation and notch-toughness and for reducing susceptibility to strain-aging embrittlement and temper embrittlement. It may be performed at the option of the material manufacturer or may be specified by the purchaser.

S64.4 Heat treatment temperatures and times shall be reported in accordance with Section 19 of Specification **A20/A20M**.

S77. Carbon Equivalent Limit

S77.1 The carbon equivalent, on heat analysis, shall not exceed the limits listed in this section when based on the following equation:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Cu + Ni)/15 \%$$

[Grade A]	
t = 2 in. [50 mm] and under in thickness	0.40 %
t > 2 in. [50 mm] in thickness	0.45 %
[Grade B]	
t = 2 in. [50 mm] and under in thickness	0.45 %
t > 2 in. [50 mm] in thickness	0.50 %