Designation: A 352/A 352M – 06

Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service[1]

This standard is issued under the fixed designation A 352/A 352M; 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 Department of Defense.

1. Scope*

1.1 This specification[2] covers steel castings for valves, flanges, fittings, and other pressure-containing parts intended primarily for low-temperature service.

1.2 Several grades of ferritic steels and one grade of martensitic steel are covered. Selection of analysis will depend on design and service conditions (Note). The temperature shown is the lowest temperature at which the material ordinarily is required to meet the impact requirements of this specification (see Supplementary Requirement S22, Impact Test Temperatures). Users should note that hardenability of some of the grades mentioned may restrict the maximum size at which the required mechanical properties are obtainable (see Appendix X1).

Grade	Usual Minimum Testing Temperatures, °F [°C]
LCA	−25 [−32]
LCB	−50 [−46]
LCC	−50 [−46]
LC1	−75 [−59]
LC2	−100 [−73]
LC2–1	−100 [−73]
LC3	−150 [−101]
LC4	−175 [−115]
LC9	−320 [−196]
CA6NM	−100 [−73]

NOTE 1—This specification covers the low-temperature requirements particularly pertinent for ferritic and martensitic steels. Certain of the grades of austenitic steel castings furnished in accordance with Specification A 351/A 351M have been found suitable for low-temperature service down to −300°F [−184°C] and others down to −425°F [−254°C]. These grades may be used when impact tested in accordance with Specification A 352/A 352M with energy levels and temperatures of test mutually agreed upon between the purchaser and the manufacturer. As a guide to the selection of energy levels and testing temperatures, Appendix X1 should be consulted.

1.3 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 the specification. Inch-pound units are applicable for material ordered to Specification A 352 and SI units for material ordered to Specification A 352M.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 351/A 351M Specification for Castings, Austenitic, for Pressure-Containing Parts

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

A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts

E 165 Test Method for Liquid Penetrant Examination

E 709 Guide for Magnetic Particle Examination

2.2 *Manufacturers' Standardization Society of the Valve and Fittings Industry Standard:*

SP-55 Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components (Visual Method)[4]

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 703/A 703M including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

[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 A01.18 on Castings.

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[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-352, 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.

[4] Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602.

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

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4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 The supplementary requirements desired, including the standards of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment proper to their design and chemical composition. It should be recognized that liquid quenching of the ferritic grades is normally required to meet the mechanical properties of heavier sections and will greatly enhance the low-temperature properties of thinner sections.

5.2 Ferritic castings shall be furnished in the normalized and tempered or liquid-quenched and tempered condition, except for Grade LC9, which shall be liquid-quenched and tempered. Castings shall be tempered at a minimum of 1100°F [590°C], except Grade LC4, which shall be 1050°F [565°C], and Grade LC9, which shall be tempered in the range of 1050 to 1175°F [565 to 635°C], followed by cooling in air or liquid.

5.3 CA6NM castings shall be heat-treated by heating to 1850°F [1010°C] minimum, and air cooling to 200°F [95°C] maximum before any optional intermediate temper, but shall cool to 100°F [40°C] maximum before the final temper, which shall be between 1050 and 1150°F [565 and 620°C].

5.4 Castings shall be allowed to cool below the transformation range directly after pouring and solidification before they are reheated for normalizing or liquid quenching.

5.5 *Temperature Control*—Furnace temperature for heat treating shall be controlled by use of pyrometers.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition for the grade ordered as specified in Table 1.

7. Mechanical Requirements

7.1 *Tension Test*:

7.1.1 Tensile properties of steel used for the castings shall conform to the requirements specified in Table 1.

7.2 *Impact Test*:

7.2.1 The notched bar impact properties of the material shall be determined by testing a set of three Charpy V-notch impact specimens for each heat at one of the standard test temperatures shown in Table 1, depending on the intended service temperature (see Appendix X1). The average energy value of the three specimens shall not be less than specified, with not more than one value permitted below the average minimum specified and no value permitted below the minimum specified for a single specimen.

7.2.2 The notched bar impact test shall be made in accordance with Test Methods and Definitions A 370.

7.2.3 Impact test specimens shall be machined to the form and dimensions shown in Test Methods and Definitions A 370, Fig. 11.

8. Quality

8.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities. When methods involving high temperature are used in the removal of discontinuities, castings shall be preheated to at least the minimum temperatures in Table 2.

8.2 When additional inspection is desired, Supplementary Requirements S4, S5, and S10, may be ordered.

8.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

9. Repair by Welding

9.1 Repairs shall be made using procedures and welders in accordance with Practice A 488/A 488M.

9.2 Welding of Grade LC9 shall be accomplished using nonmagnetic filler material of AWS classification ENiCrFe-2, and shall require liquid penetrant inspection of the weld (Supplementary Requirement S6) when magnetic particle inspection (Supplementary Requirement S4) is specified for the casting.

9.3 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S4 specified, weld repairs shall be inspected by magnetic particle examination to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic tests, or on castings in which the depth of any cavity prepared for repair welding exceeds 20 % of the wall thickness or 1 in. [25 mm] whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.^{2}[65 cm^{2}shall be radiographed to the same standards that are used to inspect the castings.

9.4 Castings containing any repair weld that exceeds 20 % of the wall thickness, or 1 in. [25 mm], whichever is smaller, or that exceeds approximately 10 in.^{2}[65 cm^2] in area, or that was made to correct hydrostatic test defects shall be stress relieved or heat treated after welding. This mandatory stress relief or heat treatment shall be in accordance with the procedure qualification used. When stress relief is required for Grade LC9, cooling shall be in still air.

10. Product Marking

10.1 All marking shall be on a raised pad using low-stress stamps.

10.2 In addition to the marking required by Specification A 703/A 703M, castings that have been liquid quenched and tempered shall be marked with the letters “QT”.

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TABLE 1 Chemical, Tensile, and Impact Requirements

Type	Carbon Steel	Carbon Steel	Carbon-Manganese Steel	Carbon-Molybdenum Steel	2½ % Nickel Steel	Nickel-Chromium-Molybdenum Steel	3½ % Nickel Steel	4½ % Nickel Steel	9 % Nickel Steel	12½ % Chromium, Nickel-Molybdenum Steel
Grade	LCA	LCB[A]	LCC	LC1	LC2	LC2-1	LC3	LC4	LC9	CA6NM
UNS Number	J02504	J03003	J02505	J12522	J22500	J42215	J31550	J41500	J31300	J91540
Element, % (max, except where range is given)										
Carbon	0.25[A]	0.30	0.25[A]	0.25	0.25	0.22	0.15	0.15	0.13	0.06
Silicon	0.60	0.60	0.60	0.60	0.60	0.50	0.60	0.60	0.45	1.00
Manganese	0.70[A]	1.00	1.20[A]	0.50-0.80	0.50-0.80	0.55-0.75	0.50-0.80	0.50-0.80	0.90	1.00
Phosphorus	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.03
Nickel	0.50[B]	0.50[B]	0.50[B]	. . .	2.00-3.00	2.50-3.50	3.00-4.00	4.00-5.00	8.50-10.0	3.5-4.5
Chromium	0.50[B]	0.50[B]	0.50[B]	. . .	. . .	1.35-1.85	. . .	. . .	0.50	11.5-14.0
Molybdenum	0.20	0.20[B]	0.20[B]	0.45-0.65	. . .	0.30-0.60	. . .	. . .	0.20	0. 4-1.0
Copper	0.30	0.30[B]	0.30[B]	. . .	. . .	. . .	. . .	. . .	0.30	. . .
Vanadium	0.03[B]	0.03[B]	0.03[B]	. . .	. . .	. . .	. . .	. . .	0.03	. . .
Tensile Requirements:[C]										
Tensile strength, ksi [MPa]	60.0-85.0 [415-585]	65.0-90.0 [450-620]	70.0-95.0 [485-655]	65.0-90.0 [450-620]	70.0-95.0 [485-655]	105.0-130.0 [725-895]	70.0-95.0 [485-655]	70.0-95.0 [485-655]	85.0 [585]	110.0-135.0 [760-930]
Yield strength,[D] min, ksi [MPa]	30.0 [205]	35.0 [240]	40.0 [275]	35.0 [240]	40.0 [275]	80.0 [550]	40.0 [275]	40.0 [275]	75.0 [515]	80.0 [550]
Elongation in 2 in. or 50 mm, min, %[E]	24	24	22	24	24	18	24	24	20	15
Reduction of area, min, %	35	35	35	35	35	30	35	35	30	35
Impact Requirements Charpy V-Notch[C,F]										
Energy value, ft·lbf [J], min value for two specimens and min avg of three specimens	13 [18]	13 [18]	15 [20]	13 [18]	15 [20]	30 [41]	15 [20]	15 [20]	20 [27]	20 [27]
Energy value, ft·lbf [J], min for single specimen	10 [14]	10 [14]	12 [16]	10 [14]	12 [16]	25 [34]	12 [16]	12 [16]	15 [20]	15 [20]
Testing temperature, °F [°C]	–25 [–32]	–50 [–46]	–50 [–46]	–75 [–59]	–100 [–73]	–100 [–73]	–150 [–101]	–175 [–115]	–320 [–196]	–100 [–73]

[A] For each reduction of 0.01 % below the specified maximum carbon content, an increase of 0.04 % manganese above the specified maximum will be permitted up to a maximum of 1.10 % for LCA, 1.28 % for LCB, and 1.40 % for LCC.
[B] Specified Residual Elements—The total content of these elements is 1.00 % maximum.
[C] See1.2.
[D] Determine by either 0.2 % offset method or 0.5 % extension-under-load method.
[E] When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.
[F] See Appendix X1.

TABLE 2 Minimum Preheat Temperatures

Grade	Thickness, in. [mm]	Minimum Preheat Temperature, °F [°C]
LCA	all	50 [10]
LCB	all	50 [10]
LCC	all	50 [10]
LC1	over ⅝ [15.9]	250 [120]
	⅝ and under	50 [10]
LC2	all	300 [150]
LC2-1	all	300 [150]
LC3	all	300 [150]
LC4	all	300 [150]
CA6NM	all	50 [10]

11. Keywords

11.1 alloy steel; carbon steel; ferritic steel; low temperature applications; martensitic stainless steel; pressure containing parts; stainless steel; steel castings

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SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below together with additional supplementary requirements that are applicable only to this specification. Other supplementary requirements enumerated in A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements
S2. Destruction Tests
S4. Magnetic Particle Inspection
S5. Radiographic Inspection
S9. Drop Weight Tests
S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E 709 or Practice E 165.

S21. Heat Treatment

S21.1 Castings shall be liquid quenched and tempered.

S22. Impact Test Temperatures

S22.1 When an impact test temperature other than that listed in Table 1 is used, the lowest test temperature at which the material met the impact test requirements shall be stamped with low-stress stamps on a raised pad located immediately ahead of the material symbol; for example, 25 LCB for +25°F [–4°C] and 025 LCB for –25°F [–32°C].

S22.2 Lateral expansion of V-notch specimens shall be measured in accordance with 23.2.3.1 of Test Methods and Definitions A 370, and reported for information.

S23. Carbon Equivalent

S23.1 When specified on the order the maximum carbon equivalent shall be:

Grade	Carbon Equivalent, max
LCA	0.50
LCB	0.50
LCC	0.55

S23.2 Determine carbon equivalent, *CE*, as follows:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

APPENDIX

(Nonmandatory Information)

X1. EXPLANATION OF THE USE OF NOTCHED BAR IMPACT TESTS IN DETERMINING THE ACCEPTABILITY OF STEELS FOR LOW-TEMPERATURE SERVICE

X1.1 Years of experience and test work have shown that some materials, particularly ferritic steels, change from tough to brittle behavior with a decrease in temperature. The transition temperatures and the levels of notch toughness vary with different materials, depending on many factors. When materials are used under conditions where brittle behavior may occur, there is danger that flaws, which would be considered nonhazardous if the material were tough, may propagate to disastrous failure of the equipment.

X1.2 Accordingly, many varieties of tests have been developed in an effort to evaluate the toughness of materials and the conditions under which they will transform from tough to brittle behavior. There are many opinions and shadings of opinion as to which test is most suitable for evaluating the suitability of materials for service at low temperatures; however, as yet, only the Charpy impact test has received sufficient general acceptance and has been used as a basis for purchasing for sufficient time to be included in ASTM standards. Furthermore, this test is required for low-temperature service vessels and piping constructed in accordance with ASME Code for Unfired Pressure Vessels and the American National Standard Code for Pressure Piping (ANSI B 31), respectively. These ASTM specifications for materials for low-temperature service are primarily used in piping and pressure vessel construction that are subjected to temperatures lower than ambient; consequently, the notched bar impact test requirements are written to provide material that in quality and by its testing can be validated for use under the construction codes.

X1.3 No assurance is offered that compliance with these requirements will provide a material that will resist brittle failure under all possible conditions of service to as low as the specified impact test temperature. It may eventually be possible that other types of tests will provide greater assurance of material suitability for low-temperature services, but at this time there is insufficient knowledge for agreement and general acceptance of some test other than the Charpy impact test.

X1.4 Attention is directed to the following subjects which have a bearing on the value of Charpy impact tests:

X1.4.1 Much of the original work in the field of notch toughness was done on wrought materials that had definite

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directional grain flow parallel to the axis of the bar, and the specimens were taken with the longitudinal axis of the specimen parallel to the axis of the bar. It has been well established that the results from impact testing of the same piece of steel may vary considerably, depending upon the orientation of the specimen to the direction of grain flow. Although it is known that specimens taken with their axis transverse to the direction of grain flow will have lower values depending on the amount of cross rolling or forging the material has received, there were insufficient test data to permit specific mandatory requirements on the impact properties of wrought materials determined in any direction other than parallel to the direction of grain flow. Except in special cases this limitation still exists.

X1.4.2 It is acknowledged that notched bar impact tests are of a qualitative rather than a quantitative nature. As yet, except possibly for ship steel, no satisfactory correlation has been possible between tests on small standardization specimens and the behavior of a structural part under any given conditions of loading in service. The required values as determined by the Charpy V-notch impact test are arbitrary values which can be met by carbon and low-alloy constructional steels when tested at temperatures above that where their behavior changes from tough to brittle as judged by this test. The acceptability of this dividing line seems to be justified by service experience on carbon and certain low-alloy steels.

X1.4.3 The literature shows that notched bar impact strengths in constructional steels differ widely in accordance with many variables. Consequently, there is bound to be some discrepancy between an individual test bar and the entire part that it represents. No system of test bar selection can guarantee that every sample would meet minimum requirements. Test bar selection must be a compromise to generally represent the product.

X1.4.4 The committees responsible for these material specifications have had as an objective the selection of test specimens that will represent the properties of the materials, in the form in which they will be used. However, accomplishment of this objective has only partially been realized. At this time it is impossible to select samples for testing that will represent all parts and sizes of the product involved. Particularly in ferritic steels, it is impractical to remove the test bars from heavy sections over about 4 in. [100 mm] and expect them to show results as high as tests from light sections of the same material. The practical commercial limits on the amount of testing possible, as well as limits to knowledge of what results may be expected from testing in non-standard locations, have been considered in drafting these specifications. With time and increased knowledge, it may be possible to require more representative testing.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 352/A 352M-03) that may impact the use of this standard.

(*1*) Deleted reference to Type A Charpy specimen in 7.2.3.

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