



Designation: **A703/A703M—20 A703/A703M – 20a**

Standard Specification for Steel Castings, General Requirements, for Pressure-Containing Parts¹

This standard is issued under the fixed designation A703/A703M; 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 a group of common requirements that, unless otherwise specified in an individual specification, shall apply to steel castings for pressure-containing parts under each of the following ASTM specifications:

| Title of Specification | ASTM Designation |
|---|------------------|
| Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service | A216/A216M |
| Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service | A217/A217M |
| Castings, Austenitic, for Pressure-Containing Parts | A351/A351M |
| Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service | A352/A352M |
| Steel Castings, Alloy, Specially Heat-Treated, for Pressure-Containing Parts, Suitable for High-Temperature Service | A389/A389M |
| Steel Castings Suitable for Pressure Service | A487/A487M |
| Castings, Iron-Nickel-Chromium and Nickel Alloys, Specially Controlled for Pressure-Retaining Parts for Corrosive Service | A990/A990M |
| Castings, Austenitic-Ferritic (Duplex) Stainless Steel, for Pressure-Containing Parts | A995/A995M |

1.2 This specification also covers a group of supplementary requirements which may be applied to the above specifications as indicated therein. These are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.3 In case of conflict between the requirements of the individual specification and this general specification, the former shall prevail.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each

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.

Current edition approved July 1, 2020 Nov. 1, 2020. Published August 2020 November 2020. Originally approved in 1974. Last previous edition approved in 2018 2020 as A703/A703M—18a. A703/A703M – 20. DOI: 10.1520/A0703_A0703M-20.10.1520/A0703_A0703M-20A.

² For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-703/SA-703M in Section II of that Code.

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

system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.5 *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:³

- A216/A216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service
 - A217/A217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service
 - A351/A351M Specification for Castings, Austenitic, for Pressure-Containing Parts
 - A352/A352M Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service
 - A370 Test Methods and Definitions for Mechanical Testing of Steel Products
 - A380/A380M Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
 - A389/A389M Specification for Steel Castings, Alloy, Specially Heat Treated, for Pressure-Containing Parts, Suitable for High-Temperature Service
 - A487/A487M Specification for Steel Castings Suitable for Pressure Service
 - A488/A488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel
 - A609/A609M Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof
 - A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
 - A800/A800M Practice for Estimating Ferrite Content of Stainless Steel Castings Containing Both Ferrite and Austenite
 - A802/A802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination
 - A903/A903M Specification for Steel Castings, Surface Acceptance Standards, Magnetic Particle and Liquid Penetrant Inspection
 - A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
 - A967/A967M Specification for Chemical Passivation Treatments for Stainless Steel Parts
 - A990/A990M Specification for Castings, Iron-Nickel-Chromium and Nickel Alloys, Specially Controlled for Pressure-Retaining Parts for Corrosive Service
 - A991/A991M Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products
 - A995/A995M Specification for Castings, Austenitic-Ferritic (Duplex) Stainless Steel, for Pressure-Containing Parts
 - A1058 Test Methods for Mechanical Testing of Steel Products—Metric
 - A1067/A1067M Specification for Test Coupons for Steel Castings
 - A1080/A1080M Practice for Hot Isostatic Pressing of Steel, Stainless Steel, and Related Alloy Castings
 - E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
 - E94/E94M Guide for Radiographic Examination Using Industrial Radiographic Film
 - E125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings
 - E165/E165M Practice for Liquid Penetrant Testing for General Industry
 - E186 Reference Radiographs for Heavy-Walled (2 to 4½ in. (50.8 to 114 mm)) Steel Castings
 - E208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels
 - E280 Reference Radiographs for Heavy-Walled (4½ to 12 in. (114 to 305 mm)) Steel Castings
 - E340 Practice for Macroetching Metals and Alloys
 - E353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys
 - E354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys
 - E446 Reference Radiographs for Steel Castings Up to 2 in. (50.8 mm) in Thickness
 - E709 Guide for Magnetic Particle Testing
- ### 2.2 ANSI Standard:⁴
- B16.5 Pipe Flanges and Flanged Fittings

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 National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

2.3 Standards of the Manufacturers Standardization Society of the Valve and Fitting Industry:⁵

MSS SP 53 Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components (Magnetic Particle Exam Method)

MSS SP 54 Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components (Radiographic Examination Method)

2.4 SAE Standard:⁶

AMS 2750 Pyrometry

3. Terminology

3.1 Definitions:

3.1.1 The definitions in Test Methods and Definitions A370, Terminology A941, and Test Methods A1058 are applicable to this specification and to those listed in 1.1.

3.1.2 *chaplet, n*—a chaplet is a metallic support placed in a mold cavity to maintain the spacing between a core and the mold.

3.1.3 *electronic data interchange (EDI), n*—the computer-to-computer exchange of business information in a standard format such as ANSI ASC X12.

3.1.4 *heat, n*—all the molten metal poured from a single furnace or all the molten metal from two or more furnaces poured into a single ladle or casting prior to the replenishing of the furnace(s).

3.1.5 *internal chill, n*—an internal chill is a metallic device placed in a mold cavity to increase the rate of heat removal at that location.

3.1.6 *test coupon, n*—the part from which the test specimen will be extracted.

3.1.7 *test specimen, n*—the part that will be acted upon in a mechanical test.

4. Materials and Manufacture

4.1 *Melting Process*—The steel shall be made by open-hearth or electric-furnace process, with or without separate refining such as argon-oxygen-decarburization (AOD), unless otherwise designated by the individual specification.

4.2 Heat Treatment:

4.2.1 Ferritic and martensitic steel shall be cooled after pouring to provide substantially complete transformation of austenite prior to heat treatment to enhance mechanical properties.

4.2.2 Castings shall be heat treated in the working zone of a furnace that has been surveyed in accordance with Test Method A991/A991M or AMS 2750.

4.2.2.1 When using furnaces surveyed in accordance with Test Method A991/A991M, the following requirements apply for heat treatments above 2000 °F [1100 °C]. When castings are heat treated at temperatures above 2000 °F [1100 °C], then the working zone shall have been established by a survey performed at not more than 25 °F [15 °C] below nor more than 200 °F [110 °C] above the minimum heat treatment temperature specified for the grade. If a minimum heat treatment temperature is not specified for the grade, then the survey temperature shall be not more than 50 °F [30 °C] below nor more than 175 °F [100 °C] above the furnace set point used.

4.2.2.2 When using furnaces surveyed in accordance with AMS 2750, there are no additional requirements beyond those stated in AMS 2750.

4.2.2.3 The maximum variation in measured temperature as determined by the difference between the highest temperature and the

⁵ Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602, <http://www.mss-hq.org>.

⁶ Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, <http://www.sae.org>.

lowest temperature shall be as agreed between the purchaser and producer, except that during production heat treatment no portion of the furnace shall be below the minimum specified temperature nor above the maximum specified temperature for the grade being processed.

5. Chemical Composition

5.1 *Chemical Analysis*—Chemical analysis of materials covered by this specification shall be in accordance with Test Methods [A751](#).

5.2 *Heat Analysis*—An analysis of each heat shall be made by the manufacturer to determine the percentages of the elements specified. The analysis shall be made from a test sample preferably taken during the pouring of the heat. When drillings are used, they shall be taken not less than ¼ in. [6.4 mm] beneath the surface. The chemical composition thus determined shall be reported to the purchaser, or their representative, and shall conform to the requirements in the individual specification for the grade being poured.

5.3 *Product Analysis*—A product analysis may be made by the purchaser from material representing each heat, lot, or casting. The analysis shall be made on representative material. Due to the possibility of decarburization, samples for carbon analysis shall be taken no closer than ¼ in. [6.4 mm] to a cast surface, except that castings too thin for this shall be analyzed on representative material. The chemical composition thus determined shall meet the requirements specified in the applicable specification for the grade involved, or shall be subject to rejection by the purchaser, except that the chemical composition determined for carbon and low-alloy steel and stainless steel, stainless steel, and nickel and cobalt castings may vary from the specified limits by the amounts shown in [Table 1](#) and [Table 2](#), and [Table 3](#), respectively. The product analysis tolerances of [Tables 1 and 1-23](#) are not applicable as acceptance criteria for heat analysis by the casting manufacturer. When comparing product and heat analysis for other than carbon and low-alloy steels and stainless steels, the reproducibility data R_2 , in Test Methods [E353](#) or [E354](#), as applicable, shall be taken into consideration.

5.4 *Unspecified Elements*—When chemical analysis for elements not specified for the grade ordered is desired, Supplementary Requirement S1 may be specified.

5.5 *Grade Substitution*—Grade substitution is not permitted. Grade substitution occurs when the material being supplied contains one or more elements that are not specified for the supplied material such that the material conforms to the requirements of a different grade.

5.6 Where more than one ladle is poured into a single casting, the molten metal in each ladle must conform to the specified chemical requirements.

6. Mechanical Test Methods

6.1 All mechanical tests shall be conducted in accordance with Test Methods and Definitions [A370](#). When material is ordered to an M-suffix (SI units) standard, then in accordance with Test Methods [A1058](#).

6.2 Choice of testing track from the options listed in Test Methods [A1058](#) when material is ordered to an M-suffix (SI units) product standard should be identified by the purchaser in the ordering information. If the choice of test track is not specified in the order, then the default ASTM track shall be used as noted in Test Methods [A1058](#).

7. Tensile Requirements

7.1 One tension test shall be made from each heat, and shall conform to the tensile requirements specified. Test coupons shall be cast from the same heat as the castings represented, except that for investment castings, the test coupons shall be cast in the same type of mold as the castings.⁷

7.2 The coupon from which the test specimen is taken shall be heat treated in production furnaces to the same procedure as the castings it represents.

⁷ Information on the relationship of mechanical properties determined on test coupons obtained as specified in [7.1](#) and [7.4](#) with those obtained from the casting may be found in *The Steel Castings Handbook*, Fifth Edition, Steel Founders' Society of America, 1980, pp. 15–35 through 15–43.

TABLE 1 Product Analysis Tolerances – Carbon and Low-Alloy Steels

| Element | Range ^A | Tolerances ^{B,C} over max or under min, Limit, % |
|-----------------|-----------------------|---|
| Carbon (C) | up to 0.65 % | $0.03 \times \% C_L + 0.02$ |
| | above 0.65 % | 0.04 % |
| Manganese (Mn) | up to 1 % | $0.08 \times \% Mn_L + 0.01$ |
| | above 1 % | 0.09 |
| Silicon (Si) | up to 0.60 % | $0.22 \times \% Si_L - 0.01$ |
| | above 0.60 % | 0.15 % |
| Phosphorus (P) | all | $0.13 \times \% P_L + 0.005$ |
| Sulfur (S) | all | $0.36 \times \% S_L + 0.001$ |
| Nickel (Ni) | up to 2 % | $0.10 \times \% Ni_L + 0.03$ |
| | above 2 % | 0.25 % |
| Chromium (Cr) | up to 2 % | $0.07 \times \% Cr_L + 0.04$ |
| | above 2 % | 0.18 % |
| Molybdenum (Mo) | up to 0.6 % | $0.04 \times \% Mo_L + 0.03$ |
| | above 0.6 % | 0.06 % |
| Vanadium (V) | up to 0.25 % | $0.23 \times \% V_L + 0.004$ |
| | above 0.25 % | 0.06 % |
| Tungsten (W) | up to 0.10 % | $0.08 \times \% W_L + 0.02$ |
| | above 0.10 % | 0.02 % |
| Copper (Cu) | up to 0.15 % | $0.18 \times \% Cu_L + 0.02$ |
| | above 0.15 % | 0.05 % |
| Aluminum (Al) | up to 0.03 % | 0.01 % |
| | 0.03 to 0.10 %, incl. | $0.08 \times \% Al + 0.02$ |
| | above 0.10 % | 0.03 % |

^A The range denotes the composition limits up to which the tolerances are computed by the equation, and above which the tolerances are given by a constant.

^B The subscript_L for the elements in each equation indicates that the limits of the element specified by the applicable specification are to be inserted into the equation to calculate the tolerance for the upper limit and the lower limit, if applicable, respectively. Examples of computing tolerances are presented in the footnote C.

^C To compute the tolerances, consider the manganese limits 0.50 to 80 % of Grade WC4 of Specification **A217/A217M**. In accordance with **Table 1**, the maximum permissible deviation of a product analysis below the lower limit 0.50 is $0.05 \% = (0.08 \times 0.50 + 0.01)$. The lowest acceptable product analysis of Grade WC4, therefore, is 0.45 %. Similarly, the maximum permissible deviation above the upper limit of 0.80 % is $0.074 \% = (0.08 \times 0.80 + 0.01)$. The highest acceptable product analysis of Grade WC4, therefore, is 0.874. For Grade WCC of Specification **A216/A216M**, the maximum manganese content is 1.40 % if the carbon content is 0.20 %. In this case, the highest acceptable product analysis is $1.49 \% = (1.40 + 0.09)$.

<https://standards.iteh.ai/catalog/standards/sist/22f88f23-9737-47fe-b581-0456225c844f/astm-a703-a703m-20a>

7.3 Test specimens may be cut from heat-treated castings, at the producer's option, instead of from test coupons.

7.4 *Investment Castings*—For investment castings, the coupons may be cast to shape or machined from coupons to dimensions in accordance with Test Methods and Definitions **A370** or the ICI coupon shown in Specification **A1067/A1067M**, Fig. 1.

7.5 *Other Castings*—Unless otherwise specified by the purchaser, test coupons may be cast integrally with the castings or separately in accordance with Specification **A1067/A1067M**, Fig. 1 and Table 1, with Fig. 2, or with Fig. Figure 1, Figure 2, or Figure 4, except when Supplementary Requirement S26 is specified. The test coupon in Specification **A1067/A1067M**, Fig. Figure 4 shall be employed only for austenitic alloy castings with cross sections less than 2½ in. [63.5 mm]. Tension test specimens shall be prepared in accordance with Test Methods and Definitions **A370** or Test Methods **A1058** as applicable.

7.6 To determine conformance with the tension test requirements, an observed value or calculated value shall be rounded off in accordance with Practice **E29** to the nearest 500 psi [5 MPa] for yield and tensile strength and to the nearest 1 % for elongation and reduction of area.

8. Repair by Welding

8.1 Repair by welding shall be in accordance with the requirements of individual specification using procedures and welders qualified in accordance with Practice **A488/A488M**.

TABLE 2 Product Analysis Tolerances – Stainless Steels

| Elements | Limit or Maximum of Specified Range, % | Tolerance Over the Maximum Limit or Under the Minimum Limit | Elements | Limit or Maximum of Specified Range, % | Tolerance Over the Maximum Limit or Under the Minimum Limit | |
|------------|--|---|-------------------------|--|---|--|
| Carbon | to 0.010, incl | 0.002 | Titanium | to 1.00, incl | 0.05 | |
| | over 0.010 to 0.030, incl | 0.005 | | over 1.00 to 3.00, incl | 0.07 | |
| | over 0.030 to 0.20, incl | 0.01 | Cobalt | over 0.05 to 0.50, incl | 0.01 ^A | |
| | over 0.20 to 0.60, incl | 0.02 | | over 0.50 to 2.00, incl | 0.02 | |
| | over 0.60 to 1.20, incl | 0.03 | | over 2.00 to 5.00, incl | 0.05 | |
| Manganese | to 1.00, incl | 0.03 | Columbium plus tantalum | to 1.50, incl | 0.05 | |
| | over 1.00 to 3.00, incl | 0.04 | | | | |
| | over 3.00 to 6.00, incl | 0.05 | | | | |
| | over 6.00 to 10.00, incl | 0.06 | | | | |
| | over 10.00 to 15.00, incl | 0.10 | | | | |
| | over 15.00 to 20.00, incl | 0.15 | Tantalum | to 0.10, incl | 0.02 | |
| Phosphorus | to 0.040, incl | 0.005 | Copper | to 0.50, incl | 0.03 | |
| | over 0.040 to 0.20, incl | 0.010 | | over 0.50 to 1.00, incl | 0.05 | |
| | | | | over 1.00 to 3.00, incl | 0.10 | |
| Sulfur | to 0.040, incl | 0.005 | | over 3.00 to 5.00, incl | 0.15 | |
| | over 0.040 to 0.20, incl | 0.010 | | over 5.00 to 10.00, incl | 0.20 | |
| | over 0.20 to 0.50, incl | 0.020 | | | | |
| Silicon | to 1.00, incl | 0.05 | Aluminum | to 0.15, incl | –0.005, +0.01 | |
| | over 1.00 to 3.00, incl | 0.10 | | over 0.15 to 0.50, incl | 0.05 | |
| | over 3.00 to 6.00, incl | 0.15 | | over 0.50 to 2.00, incl | 0.10 | |
| Chromium | over 4.00 to 10.00, incl | 0.10 | Nitrogen | to 0.02, incl | 0.005 | |
| | over 10.00 to 15.00, incl | 0.15 | | over 0.02 to 0.19, incl | 0.01 | |
| | over 15.00 to 20.00, incl | 0.20 | | over 0.19 to 0.25, incl | 0.02 | |
| | over 20.00 to 30.00, incl | 0.25 | | over 0.25 to 0.35, incl | 0.03 | |
| Nickel | to 1.00, incl | 0.03 | Tungsten | over 0.35 to 0.45, incl | 0.04 | |
| | over 1.00 to 5.00, incl | 0.07 | | over 0.45 to 0.55, incl | 0.05 | |
| | over 5.00 to 10.00, incl | 0.10 | | to 1.00, incl | 0.03 | |
| | over 10.00 to 20.00, incl | 0.15 | | over 1.00 to 2.00, incl | 0.05 | |
| | over 20.00 to 30.00, incl | 0.20 | | | | |
| Molybdenum | over 0.20 to 0.60, incl | 0.03 | Vanadium | to 0.50, incl | 0.03 | |
| | over 0.60 to 2.00, incl | 0.05 | | over 0.50 to 1.50, incl | 0.05 | |
| | over 2.00 to 8.00, incl | 0.10 | | | | |
| | | | Selenium | all | 0.03 | |

^A Product analysis limits for cobalt under 0.05 % have not been established, and the manufacturer should be consulted for those limits.

9. Flanges

9.1 When a flange from a flanged casting is removed to make a weld end casting, discontinuities may be observed that would not have been detrimental in a flanged casting. The disposition of the casting shall be subject to agreement between the purchaser and manufacturer.

10. Quality

10.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Practice A802/A802M 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.

10.2 The castings shall not be peened, plugged, or impregnated to stop leaks or disguise rejectable indications.

10.3 Internal chills and chaplets may be used in the manufacture of castings. However, the chills, chaplets, and affected cast material must be completely removed.

11. Hydrostatic Tests

11.1 Each casting shall be tested after machining to the hydrostatic shell test pressures prescribed in ANSI B16.5 for the applicable

TABLE 3 Product Analysis Tolerances – Nickel and Cobalt Base Alloys

| Element | Limit or Maximum of Specified Element, % | Variation Under Min or Over Max | Element | Limit or Maximum of Specified Element, % | Variation Under Min or Over Max | | |
|--------------------------------------|---|--|---------------------------|---|--|---------------------------|------|
| Carbon | up to 0.02, incl | 0.005 | Aluminum | up to 0.10, incl | 0.02 | | |
| | over 0.02 to 0.20, incl | 0.01 | | over 0.10 to 0.50, incl | 0.05 | | |
| | over 0.20 to 0.60, incl | 0.02 | | over 0.50 to 2.00, incl | 0.10 | | |
| | over 0.60 to 1.00, incl | 0.03 | | over 2.00 to 5.00, incl | 0.20 | | |
| Manganese | up to 1.00, incl | 0.03 | Boron | over 5.00 to 10.00, incl | 0.25 | | |
| | over 1.00 to 3.00, incl | 0.04 | | over 10.00 to 15.00, incl | 0.30 | | |
| | over 3.00 to 6.00, incl | 0.07 | | Iron | up to 0.01, incl | 0.002 | |
| | over 6.00 to 10.00, incl | 0.10 | | | over 0.01 to 0.05, incl | 0.005 | |
| Silicon | up to 0.05, incl | 0.02 | over 0.05 to 0.15, incl | | 0.010 | | |
| | over 0.05 to 0.25, incl | 0.03 | Copper | | up to 0.20, incl | 0.02 | |
| | over 0.25 to 0.50, incl | 0.04 | | over 0.20 to 0.75, incl | 0.03 | | |
| | over 0.50 to 1.00, incl | 0.05 | | over 0.75 to 2.50, incl | 0.05 | | |
| over 1.00 to 4.50, incl | 0.10 | over 2.50 to 5.00, incl | | 0.07 | | | |
| Phosphorus | all | 0.005 | over 5.00 to 10.00, incl | 0.10 | | | |
| Sulfur | up to 0.02, incl | 0.003 | over 10.00 to 15.00, incl | 0.15 | | | |
| | over 0.02 to 0.06, incl | 0.005 | over 15.00 to 30.00, incl | 0.30 | | | |
| Chromium | up to 5.00, incl over 5.00 to 15.00, incl over 15.00 to 25.00, incl over 25.00 to 35.00, incl over 35.00 to 45.00, incl over 45.00 to 50.00, incl | 0.10 0.15 0.25 0.30 0.40 0.50 | over 30.00 to 50.00, incl | 0.45 | | | |
| | | | up to 0.20, incl | 0.02 | | | |
| | | | over 0.20 to 0.50, incl | 0.03 | | | |
| | | | over 0.50 to 5.00, incl | 0.04 | | | |
| | | | over 5.00 to 10.00, incl | 0.05 | | | |
| | | | over 10.00 to 20.00, incl | 0.10 | | | |
| Nickel | up to 1.00, incl over 1.00 to 5.00, incl over 5.00 to 10.00, incl over 10.00 to 20.00, incl over 20.00 to 30.00, incl over 30.00 to 40.00, incl over 40.00 to 60.00, incl over 60.00 to 80.00, incl over 80.00 to 99.00, incl | 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.45 0.60 | over 20.00 to 30.00, incl | 0.15 | | | |
| | | | over 30.00 to 40.00, incl | 0.20 | | | |
| | | | over 40.00 to 60.00, incl | 0.30 | | | |
| | | | over 60.00 to 80.00, incl | 0.45 | | | |
| | | | over 80.00 to 99.00, incl | 0.60 | | | |
| | | | Cobalt | up to 0.10, incl over 0.10 to 0.20, incl over 0.20 to 1.00, incl over 1.00 to 5.00, incl over 5.00 to 10.00, incl over 10.00 to 15.00, incl over 15.00 to 20.00, incl over 20.00 to 25.00, incl over 25.00 to 30.00, incl over 30.00 to 35.00, incl over 35.00 to 50.00, incl | 0.01 0.02 0.03 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.50 | over 30.00 to 40.00, incl | 0.20 |
| over 40.00 to 50.00, incl | 0.25 | | | | | | |
| over 50.00 to 60.00, incl | 0.30 | | | | | | |
| over 60.00 to 70.00, incl | 0.35 | | | | | | |
| over 70.00 to 80.00, incl | 0.45 | | | | | | |
| over 80.00 to 99.00, incl | 0.60 | | | | | | |
| Molybdenum | up to 1.00, incl over 1.00 to 3.00, incl over 3.00 to 5.00, incl over 5.00 to 20.00, incl over 20.00 to 30.00, incl over 30.00 to 40.00, incl | 0.03 0.05 0.10 0.15 0.25 0.35 | over 10.00 to 20.00, incl | 0.20 | | | |
| | | | over 20.00 to 30.00, incl | 0.25 | | | |
| | | | over 30.00 to 40.00, incl | 0.35 | | | |
| | | | Tungsten | up to 1.00, incl over 1.00 to 3.00, incl over 3.00 to 5.00, incl over 5.00 to 10.00, incl over 10.00 to 20.00, incl | 0.04 0.10 0.15 0.20 0.25 | over 10.00 to 20.00, incl | 0.20 |
| | | | | | | over 20.00 to 30.00, incl | 0.25 |
| | | | | | | over 30.00 to 40.00, incl | 0.35 |
| Niobium ^A and/or Tantalum | up to 1.50, incl over 1.50 to 3.00, incl over 3.00 to 5.00, incl over 5.00 to 7.00, incl over 7.00 to 10.00, incl over 10.00 to 13.00, incl | 0.05 0.10 0.15 0.20 0.25 0.30 | | | | over 10.00 to 20.00, incl | 0.20 |
| | | | | | | over 20.00 to 30.00, incl | 0.25 |
| | | | | | | over 30.00 to 40.00, incl | 0.35 |
| | | | Vanadium | up to 0.50, incl over 0.50 to 1.50, incl | 0.04 0.05 | over 10.00 to 20.00, incl | 0.20 |
| | | | | | | over 20.00 to 30.00, incl | 0.25 |
| | | | | | | over 30.00 to 40.00, incl | 0.30 |
| over 40.00 to 50.00, incl | 0.35 | | | | | | |
| over 50.00 to 60.00, incl | 0.45 | | | | | | |
| over 60.00 to 70.00, incl | 0.60 | | | | | | |
| Yttrium | up to 0.050, incl over 0.050 to 0.10, incl over 0.10 to 0.20, incl | 0.005 0.010 0.015 | over 10.00 to 20.00, incl | 0.20 | | | |
| | | | over 20.00 to 30.00, incl | 0.25 | | | |
| | | | over 30.00 to 40.00, incl | 0.30 | | | |
| | | | over 40.00 to 50.00, incl | 0.35 | | | |
| | | | over 50.00 to 60.00, incl | 0.45 | | | |
| | | | over 60.00 to 70.00, incl | 0.60 | | | |
| Zirconium | up to 0.10, incl over 0.10 to 0.20, incl | 0.01 0.02 | over 10.00 to 20.00, incl | 0.20 | | | |
| | | | over 20.00 to 30.00, incl | 0.25 | | | |
| | | | over 30.00 to 40.00, incl | 0.30 | | | |
| | | | over 40.00 to 50.00, incl | 0.35 | | | |
| | | | over 50.00 to 60.00, incl | 0.45 | | | |
| | | | over 60.00 to 70.00, incl | 0.60 | | | |
| Lanthanum | up to 0.20, incl | 0.01 | over 10.00 to 20.00, incl | 0.20 | | | |
| | | | over 20.00 to 30.00, incl | 0.25 | | | |
| | | | over 30.00 to 40.00, incl | 0.30 | | | |
| | | | over 40.00 to 50.00, incl | 0.35 | | | |
| | | | over 50.00 to 60.00, incl | 0.45 | | | |
| | | | over 60.00 to 70.00, incl | 0.60 | | | |
| Cerium | up to 0.050, incl over 0.050 to 0.10, incl over 0.10 to 0.20, incl | 0.005 0.010 0.015 | over 10.00 to 20.00, incl | 0.20 | | | |
| | | | over 20.00 to 30.00, incl | 0.25 | | | |
| | | | over 30.00 to 40.00, incl | 0.30 | | | |
| | | | over 40.00 to 50.00, incl | 0.35 | | | |
| | | | over 50.00 to 60.00, incl | 0.45 | | | |
| | | | over 60.00 to 70.00, incl | 0.60 | | | |
| Hafnium | up to 1.50, incl over 1.50 to 3.00, incl | 0.05 0.10 | over 10.00 to 20.00, incl | 0.20 | | | |
| | | | over 20.00 to 30.00, incl | 0.25 | | | |
| | | | over 30.00 to 40.00, incl | 0.30 | | | |
| | | | over 40.00 to 50.00, incl | 0.35 | | | |
| | | | over 50.00 to 60.00, incl | 0.45 | | | |
| | | | over 60.00 to 70.00, incl | 0.60 | | | |
| Rhenium | up to 1.50, incl over 1.50 to 3.00, incl over 3.00 to 5.00, incl over 5.00 to 7.00, incl | 0.05 0.10 0.15 0.20 | over 10.00 to 20.00, incl | 0.20 | | | |
| | | | over 20.00 to 30.00, incl | 0.25 | | | |
| | | | over 30.00 to 40.00, incl | 0.30 | | | |
| | | | over 40.00 to 50.00, incl | 0.35 | | | |
| | | | over 50.00 to 60.00, incl | 0.45 | | | |
| | | | over 60.00 to 70.00, incl | 0.60 | | | |
| Platinum | up to 0.50, incl | 0.03 | over 10.00 to 20.00, incl | 0.20 | | | |
| | | | over 20.00 to 30.00, incl | 0.25 | | | |
| | | | over 30.00 to 40.00, incl | 0.30 | | | |
| | | | over 40.00 to 50.00, incl | 0.35 | | | |
| | | | over 50.00 to 60.00, incl | 0.45 | | | |
| | | | over 60.00 to 70.00, incl | 0.60 | | | |
| Oxygen | up to 0.010, incl | 0.005 | over 10.00 to 20.00, incl | 0.20 | | | |
| | | | over 20.00 to 30.00, incl | 0.25 | | | |
| | | | over 30.00 to 40.00, incl | 0.30 | | | |
| | | | over 40.00 to 50.00, incl | 0.35 | | | |
| | | | over 50.00 to 60.00, incl | 0.45 | | | |
| | | | over 60.00 to 70.00, incl | 0.60 | | | |
| Nitrogen | up to 0.02, incl over 0.02 to 0.19, incl over 0.19 to 0.25, incl over 0.25 to 0.35, incl over 0.35 to 0.45, incl over 0.45 to 0.60, incl | 0.005 0.01 0.02 0.03 0.04 0.05 | over 10.00 to 20.00, incl | 0.20 | | | |
| | | | over 20.00 to 30.00, incl | 0.25 | | | |
| | | | over 30.00 to 40.00, incl | 0.30 | | | |
| | | | over 40.00 to 50.00, incl | 0.35 | | | |
| | | | over 50.00 to 60.00, incl | 0.45 | | | |
| | | | over 60.00 to 70.00, incl | 0.60 | | | |
| Magnesium | up to 0.10, incl | 0.01 | over 10.00 to 20.00, incl | 0.20 | | | |
| | | | over 20.00 to 30.00, incl | 0.25 | | | |
| | | | over 30.00 to 40.00, incl | 0.30 | | | |
| | | | over 40.00 to 50.00, incl | 0.35 | | | |
| | | | over 50.00 to 60.00, incl | 0.45 | | | |
| | | | over 60.00 to 70.00, incl | 0.60 | | | |
| Lead | up to 0.01, incl | 0.002 | over 10.00 to 20.00, incl | 0.20 | | | |
| | | | over 20.00 to 30.00, incl | 0.25 | | | |
| | | | over 30.00 to 40.00, incl | 0.30 | | | |
| | | | over 40.00 to 50.00, incl | 0.35 | | | |
| | | | over 50.00 to 60.00, incl | 0.45 | | | |
| | | | over 60.00 to 70.00, incl | 0.60 | | | |
| Tin | up to 0.01, incl over 0.01 to 0.05, incl | 0.002 0.005 | over 10.00 to 20.00, incl | 0.20 | | | |
| | | | over 20.00 to 30.00, incl | 0.25 | | | |
| | | | over 30.00 to 40.00, incl | 0.30 | | | |
| | | | over 40.00 to 50.00, incl | 0.35 | | | |
| | | | over 50.00 to 60.00, incl | 0.45 | | | |
| | | | over 60.00 to 70.00, incl | 0.60 | | | |
| Zinc | up to 0.01, incl over 0.01 to 0.05, incl | 0.002 0.005 | over 10.00 to 20.00, incl | 0.20 | | | |
| | | | over 20.00 to 30.00, incl | 0.25 | | | |
| | | | over 30.00 to 40.00, incl | 0.30 | | | |
| | | | over 40.00 to 50.00, incl | 0.35 | | | |
| | | | over 50.00 to 60.00, incl | 0.45 | | | |
| | | | over 60.00 to 70.00, incl | 0.60 | | | |