Designation: ~~A985/A985M – 20~~ A985/A985M – 21

Standard Specification for Steel Investment Castings General Requirements, for Pressure-Containing Parts[1]

This standard is issued under the fixed designation A985/A985M; 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 covers a group of common requirements that are mandatory for steel castings produced by the investment casting process 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 requirements 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 When investment casting is ordered, the requirements of this specification shall take precedence over the individual material specification requirements.

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 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.

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

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

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:*[2]

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 and Practices for Chemical Analysis of Steel Products
A800/A800M Practice for Estimating Ferrite Content of Stainless Steel Castings Containing Both Ferrite and Austenite
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
E192 Reference Radiographs of Investment Steel Castings for Aerospace Applications
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
E2660 Digital Reference Images for Investment Steel Castings for Aerospace Applications

2.2 *ANSI Standard:*[3]

B16.5 Pipe Flanges and Flanged Fittings

[2] 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.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

2.3 *ASME Standard:*[4]
ASME Boiler and Pressure Vessel Code, Section III, NB-2546

2.4 *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)

2.5 *SAE Standards:*[6]
AMS 2750 Pyrometry
ARP 1341 Determining Decarburization and Carburization in Finished Parts of Carbon and Low-Alloy Steels

3. Terminology

3.1 *Definitions*—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.

3.2 *Definitions of Terms Specific to This Standard:*

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

3.2.2 *investment casting, n*—a metal casting that is produced in a mold obtained by investing (surrounding) an expendable pattern with a ceramic slurry, which is allowed to solidify. The expendable pattern may consist of wax, plastic, or other material, and is removed prior to filling the mold with liquid metal.

3.2.3 *master heat, n*—a single furnace charge of alloy that may be either poured directly into castings or into remelt alloy for individual melts.

3.2.4 *sub-heat, n*—a portion of master heat remelted with only minor additions for deoxidation for pouring into castings. Synonyms—*melt*,*production heat*.

4. Materials and Manufacture

4.1 When the purchaser imposes the requirements of this specification, the manufacturer is responsible for compliance with the specification requirements during the production and processing of the casting by themselves and any of their subcontractors.

4.2 *Melting Process*—Master heats shall be made by the electric furnace process, with or without separate refining such as argon-oxygen-decarburization (AOD), vacuum-oxygen-degassing (VOD), vacuum-induction-melting (VIM), and so forth, unless otherwise specified in the individual specification or agreed upon between the customer and producer. Master heats may be used directly for producing castings or converted into ingot, bar, shot, or other suitable form, not including gates and risers from casting production, for later remelting as a sub-heat.

4.3 *Re-Melting Process*—Sub-heats shall be produced from master heat metal in suitable batch sizes by electric induction furnace, with or without atmosphere protection such as vacuum or inert gas, unless otherwise agreed upon between the customer and producer. Revert (gates, sprues, risers, and rejected castings) shall not be remelted except in master heats.

4.4 *Heat Treatment:*

4.4.1 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] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[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.com.

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

4.4.2 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.

4.4.2.1 When using furnaces surveyed in accordance with Test Method A991/A991M, the following requirements apply for heat treatments above 2000 °F [1100 °F]. 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.

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

4.4.2.3 The maximum variation in measured temperature, as determined by the difference between the highest temperature and the 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.

4.5 *Sampling:*

4.5.1 If castings are poured directly from one or more master heats, then the samples for chemical and other required testing also shall be poured directly from each of the master heats.

4.5.2 If castings are poured from a sub-heat, then the samples for chemical and other required testing also shall be poured from a sub-heat of that same master heat, but not necessarily from the same sub-heat as the castings. The sub-heat used for the test samples shall be produced using the same melting practices and additions as used to produce the castings.

4.5.3 Test specimens may be taken from castings or from coupons cast either integrally with the castings, in the same molds as the castings, or in separate molds.

4.5.4 Separately cast coupons for other than chemical analysis shall be cast in molds of the same material as those used for the castings, as shown in Specification A1067/A1067M, Figs. 1–4, except when Supplementary Requirement S26 is specified. The test coupon in Specification A1067/A1067M, Fig. 4 shall be employed only for austenitic alloy castings with cross sections less than 2½ in. [65 mm].[7]

4.5.5 Coupons for chemical analysis may be chill cast.

5. Chemical Composition

5.1 *Chemical Analysis*—Chemical analysis of materials covered by this specification shall be in accordance with Test Methods, Practices, and Terminology A751.

5.2 *Heat Analysis*—An analysis of samples obtained in accordance with 4.5 or Supplementary Requirement S29, as appropriate, shall be made by the manufacturer to determine the percentages of the elements specified for the grade being poured. When drillings are used, they shall be taken not less than 1⁄16 in. [1.6 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 master heat, sub-heat, lot, or casting. The analysis shall be made on representative material. Samples for carbon analysis shall be taken no closer than 1⁄16 in. [1.6 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~~

[7] Information on the relationship of mechanical properties determined on test coupons obtained as specified in 4.5.4 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 for 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 × % C_L + 0.02
	above 0.65 %	0.04 %
Manganese (Mn)	up to 1 %	0.08 × % Mn_L + 0.01
	above 1 %	0.09
Silicon (Si)	up to 0.60 %	0.22 × % Si_L - 0.01
	above 0.60 %	0.15 %
Phosphorus (P)	all	0.13 × % P_L + 0.005
Sulfur (S)	all	0.36 × % S_L + 0.001
Nickel (Ni)	up to 2 %	0.10 × % Ni_L + 0.003
	above 2 %	0.25 %
Chromium (Cr)	up to 2 %	0.07 × % Cr_L + 0.04
	above 2 %	0.18 %
Molybdenum (Mo)	up to 0.6 %	0.04 × % Mo_L + 0.03
	above 0.6 %	0.06 %
Vanadium (V)	up to 0.25 %	0.23 × % V_L + 0.004
	above 0.25 %	0.06 %
Tungsten (W)	up to 0.10 %	0.08 × % W_L + 0.02
	above 0.10 %	0.02 %
Copper (Cu)	up to 0.15 %	0.18 × % Cu_L + 0.02
	above 0.15 %	0.05 %
Aluminum (Al)	up to 0.10 %	0.08 × % Al_L + 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 footnote C.

[C] To compute the tolerances, consider the manganese limits 0.50 to 80 % of Grade WC4 of Specification A217/A217M. According to Table 1, the maximum permissible deviation of a product analysis below the lower limit 0.50 is 0.05 % = (0.08 × 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 × 0.08 + 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).

~~stainless steel~~ steel, stainless steel, and nickel and cobalt based 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-~~2~~3 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, the reproducibility data R2 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.

NOTE 1—All commercial metals contain small amounts of various elements in addition to those which are specified. It is neither practical nor necessary to specify limits for every unspecified element that might be present, despite the fact that the presence of many of these elements often is determined routinely by the producer.

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.

6. Mechanical Test Methods

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

7. Tensile Requirements

7.1 Sampling for tension testing shall be in accordance with 4.5 or with Supplementary Requirement S30, as appropriate.

TABLE 2 Product Analysis Tolerances for Stainless Steels

Element	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit	Element	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	to 0.010, incl	0.002	Copper	to 0.50, incl	0.03
	over 0.010 to 0.030, incl	0.005		over 0.50 to 1.00, incl	0.05
	over 0.030 to 0.20, incl	0.01		over 1.00 to 3.00, incl	0.10
	over 0.20 to 0.60, incl	0.02			
	over 0.60 to 1.20, incl	0.03			
Manganese	to 1.00, incl	0.03	Niobium 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			
Phosphorus	to 0.040, incl	0.005	Titanium	to 1.00, incl	0.05
	over 0.040 to 0.20, incl	0.010		over 1.00 to 3.00, incl	0.07
Sulfur	to 0.040, incl	0.005	Vanadium	to 0.50 incl	0.03
	over 0.040 to 0.20, incl	0.010		over 0.50 to 1.50, incl	0.05
	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	Tantalum	to 0.10, incl	0.02
	over 10.00 to 15.00, incl	0.15			
	over 15.00 to 20.00, incl	0.20			
	over 20.00 to 30.00, incl	0.25			
Nickel	to 1.00, incl	0.03	Cobalt	over 0.05 to 0.50, incl	0.01[A]
	over 1.00 to 5.00, incl	0.07		over 0.50 to 2.00, incl	0.02
	over 5.00 to 10.00, incl	0.10		over 2.00 to 5.00, incl	0.05
	over 10.000 to 20.00, incl	0.15			
	over 20.00 to 30.00, incl	0.20			
Molybdenum	over 0.20 to 0.60, incl	0.03	Selenium	all	0.03
	over 0.60 to 2.00, incl	0.05			
	over 2.00 to 8.00, incl	0.10			
Nitrogen	to 0.02, incl	0.005	Tungsten	to 1.00, incl	0.03
	over 0.02 to 0.19, incl	0.01		over 1.00 to 2.00, incl	0.05
	over 0.19 to 0.25, incl	0.02			
	over 0.25 to 0.35, incl	0.03			
	over 0.35 to 0.45, incl	0.04			
	over 0.45 to 0.55, incl	0.05			

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

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.

7.3 To determine accordance with the tension test requirements, an observed value or calculated value shall be rounded off in accordance with Practice E29 to the nearest 0.5 ksi [5 MPa] for yield and tensile strength and to the nearest 1 % for elongation and reduction of area. In the special case of rounding the number "5" when no additional numbers other than "0" follow the "5," rounding shall be done in the direction of the specification limits if following Practice E29 would cause rejection of material.

8. Repair by Welding

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

TABLE 3 Product Analysis Tolerances – Nickel and Cobalt Base Alloys

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