Designation: B 338 – 01

Standard Specification for Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers[1]

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This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers the requirements for 20 grades of titanium and titanium alloy tubing intended for surface condensers, evaporators, and heat exchangers, as follows:[2]

1.1.1 *Grade 1*—Unalloyed titanium,

1.1.2 *Grade 2*—Unalloyed titanium,

1.1.3 *Grade 3*—Unalloyed titanium,

1.1.4 *Grade 7*—Unalloyed titanium plus 0.12 to 0.25 % palladium,

1.1.5 *Grade 9*—Titanium alloy (3 % aluminum, 2.5 % vanadium),

1.1.6 *Grade 11*—Unalloyed titanium plus 0.12 to 0.25 % palladium,

1.1.7 *Grade 12*—Titanium alloy (0.3 % molybdenum, 0.8 % nickel),

1.1.8 *Grade 13*—Titanium alloy (0.5 % nickel, 0.05 % ruthenium),

1.1.9 *Grade 14*—Titanium alloy (0.5 % nickel, 0.05 % ruthenium),

1.1.10 *Grade 15*—Titanium alloy (0.5 % nickel, 0.05 % ruthenium),

1.1.11 *Grade 16*—Unalloyed titanium plus 0.04 to 0.08 % palladium,

1.1.12 *Grade 17*—Unalloyed titanium plus 0.04 to 0.08 % palladium,

1.1.13 *Grade 18*—Titanium alloy (3 % aluminum, 2.5 % vanadium) plus 0.04 to 0.08 % palladium,

1.1.14 *Grade 26*—Unalloyed titanium plus 0.08 to 0.14 % ruthenium,

1.1.15 *Grade 27*—Unalloyed titanium plus 0.08 to 0.14 % ruthenium,

1.1.16 *Grade 28*—Titanium alloy (3 % aluminum, 2.5 % vanadium) plus 0.08 to 0.14 % ruthenium,

1.1.17 *Grade 30*—Titanium alloy (0.3 % cobalt, 0.05 % palladium),

1.1.18 *Grade 31*—Titanium alloy (0.3 % cobalt, 0.05 % palladium),

1.1.19 *Grade 33*—Titanium alloy (0.4% nickel, 0.015% palladium, 0.025% ruthenium, 0.15% chromium), and

1.1.20 *Grade 34*—Titanium alloy (0.4% nickel, 0.015% palladium, 0.025% ruthenium, 0.15% chromium).

1.2 Tubing covered by this specification shall be heat treated by at least a stress relief as defined in 5.3.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

E 8 Test Methods for Tension Testing of Metallic Materials[4]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[5]

E 120 Test Methods for Chemical Analysis of Titanium and Titanium Alloys[6]

E 1409 Test Method for Determination of Oxygen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique[7]

E 1447 Test Method for Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity Method[7]

3. Terminology

3.1 *Lot Definitions:*

3.1.1 *Castings*—A lot shall consist of all castings produced from the same pour.

3.1.2 *Ingot*—No definition required.

3.1.3 *Rounds, Flats, Tubes and Wrought Powder Metallurgical Products*—(Single definition, common to nuclear and non-nuclear Standards.) A lot shall consist of a material of the same size, shape, condition, and finish produced from the same ingot or powder blend by the same reduction schedule and the

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[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SB-338 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] *Annual Book of ASTM Standards*, Vol 03.05.

[7] *Annual Book of ASTM Standards*, Vol 03.06.

same heat treatment praameters. Unless otherwise agreed between manufacturer and purchaser, a lot shall be limited to the product of an 8 h period for final continuous anneal, or to a single furnace load for final batch anneal.

3.1.4 *Sponge*—A lot shall consist of a single blend produced at one time.

3.1.5 *Weld Fittings*—Definition is to be mutually agreed upon between manufacturer and the purchaser.

TABLE 1 Chemical Requirements[A]

Element	Composition, %									
	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 9	Grade 11	Grade 12
Nitrogen, max	0.03	0.03	0.05	0.05	0.05	0.03	0.03	0.03	0.03	0.03
Carbon, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Hydrogen,[B,C] max	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Iron, max	0.20	0.30	0.30	0.50	0.40	0.50	0.30	0.25	0.20	0.30
Oxygen, max	0.18	0.25	0.35	0.40	0.20	0.20	0.25	0.15	0.18	0.25
Aluminum	...	...	...	...	5.5–6.75	4.0–6.0	...	2.5–3.5	...	...
Vanadium	...	...	...	...	3.5–4.5	...	...	2.0–3.0	...	...
Tin	...	...	...	...	...	2.0–3.0	...	...	...	...
Ruthenium	...	...	...	...	...	...	...	...	...	...
Palladium	...	...	...	...	...	...	0.12–0.25	...	0.12–0.25	...
Cobalt	...	...	...	...	...	...	...	...	...	...
Molybdenum	...	...	...	...	...	...	...	...	...	0.2–0.4
Chromium	...	...	...	...	...	...	...	...	...	...
Nickel	...	...	...	...	...	...	...	...	...	0.6–0.9
Niobium	...	...	...	...	...	...	...	...	...	...
Zirconium	...	...	...	...	...	...	...	...	...	...
Silicon	...	...	...	...	...	...	...	...	...	...
Residuals,[D,E,F] max each	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Residuals,[D,E,F] max total	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Titanium[G]	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance

Element	Composition, %									
	Grade 13	Grade 14	Grade 15	Grade 16	Grade 17	Grade 18	Grade 19	Grade 20	Grade 21	Grade 23
Nitrogen, max	0.03	0.03	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Carbon, max	0.08	0.08	0.08	0.08	0.08	0.08	0.05	0.05	0.05	0.08
Hydrogen,[B,C] max	0.015	0.015	0.015	0.015	0.015	0.015	0.02	0.02	0.015	0.0125
Iron, max	0.20	0.30	0.30	0.30	0.20	0.25	0.30	0.30	0.40	0.25
Oxygen, max	0.10	0.15	0.25	0.25	0.18	0.15	0.12	0.12	0.17	0.13
Aluminum	...	...	...	...	...	2.5–3.5	3.0–4.0	3.0–4.0	2.5–3.5	5.5–6.5
Vanadium	...	...	...	...	...	2.0–3.0	7.5–8.5	7.5–8.5	...	3.5–4.5
Tin	...	...	...	...	...	...	...	...	...	...
Ruthenium	0.04–0.06	0.04–0.06	0.04–0.06	...	...	...	...	...	...	...
Palladium	...	...	...	0.04–0.08	0.04–0.08	0.04–0.08	...	0.04–0.08	...	...
Cobalt	...	...	...	...	...	...	...	...	...	...
Molybdenum	...	...	...	...	...	...	3.5–4.5	3.5–4.5	14.0–16.0	...
Chromium	...	...	...	...	...	...	5.5–6.5	5.5–6.5	...	...
Nickel	0.04–0.06	0.04–0.06	0.04–0.06	...	...	...	...	...	...	...
Niobium	...	...	...	...	...	...	...	...	2.2–3.2	...
Zirconium	...	...	...	...	...	...	3.5–4.5	3.5–4.5	...	...
Silicon	...	...	...	...	...	...	...	...	0.15–0.25	...
Residuals,[D,E,F] max each	0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.15	0.1	0.1
Residuals,[D,E,F] max total	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Titanium[G]	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance

TABLE 1 *Continued*

Element	Composition, %										
	Grade 24	Grade 25	Grade 26	Grade 27	Grade 28	Grade 29	Grade 30	Grade 31	Grade 32	Grade 33	Grade 34
Nitrogen, max	0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.05	0.03	0.03	0.05
Carbon, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Hydrogen,[B,C] max	0.015	0.0125	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Iron, max	0.40	0.40	0.30	0.20	0.25	0.25	0.30	0.30	0.25	0.30	0.30
Oxygen, max	0.20	0.20	0.25	0.18	0.15	0.13	0.25	0.35	0.11	0.25	0.35
Aluminum	5.5–6.75	5.5–6.75	...	...	2.5–3.5	5.5–6.5	...	...	4.5–5.5	...	...
Vanadium	3.5–4.5	3.5–4.5	...	...	2.0–3.0	3.5–4.5	...	...	0.6–1.4	...	...
Tin	...	...	...	...	...	...	...	...	0.6–1.4	...	...
Ruthenium	...	...	0.08–0.14	0.08–0.14	0.08–0.14	0.08–0.14	...	...	...	0.02-0.04	0.02-0.04
Palladium	0.04–0.08	0.04–0.08	...	...	...	...	0.04–0.08	0.04–0.08	...	0.01-0.02	0.01-0.02
Cobalt	...	...	...	...	...	...	0.20–0.80	0.20–0.80	...	...	...
Molybdenum	...	...	...	...	...	...	...	...	0.6–1.2	...	...
Chromium	...	...	...	...	...	...	...	...	...	0.1-0.2	0.1-0.2
Nickel	...	0.3–0.8	...	...	...	...	...	...	...	0.35-0.55	0.35-0.55
Niobium	...	...	...	...	...	...	...	...	...	...	...
Zirconium	...	...	...	...	...	...	...	...	0.6–1.4	...	...
Silicon	...	...	...	...	...	...	...	...	0.06–0.14	...	...
Residuals,[D,E,F] max each	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Residuals,[D,E,F] max total	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Titanium[G]	balance	balance	balance	balance	balance	balance	balance	balance	balance	Remainder	Remainder

[A] Analysis shall be completed for all elements listed in this table for each grade. The analysis results for the elements not quantified in the table need not be reported unless the concentration level is greater than 0.1 % each or 0.4 % total.
[B] Lower hydrogen may be obtained by negotiation with the manufacturer.
[C] Final product analysis.
[D] Need not be reported.
[E] A residual is an element present in a metal or an alloy in small quantities and is inherent to the manufacturing process but not added intentionally. In titanium these elements include aluminum, vanadium, tin, chromium, molybdenum, niobium, zirconium, hafnium, bismuth, ruthenium, palladium, yttrium, copper, silicon, cobalt, tantalum, nickel, boron, manganese, and tungsten.
[F] The purchaser may, in his written purchase order, request analysis for specific residual elements not listed in this specification.
[G] The percentage of titanium is determined by difference.

4. Ordering Information

4.1 Orders for material to this specification shall include the following information, as required:

4.1.1 Quantity,
4.1.2 Grade number (Section 1),
4.1.3 Diameter and wall thickness (Section 12) (Note 1),
4.1.4 Length (Section 12),
4.1.5 Method of manufacture and finish (Sections 5 and 13),
4.1.6 Restrictive chemistry, if desired (Section 6 and Table 1),
4.1.7 Product analysis, if desired (Section 7 and Table 2),
4.1.8 Special mechanical properties, if desired (Section 8 and Table 3),
4.1.9 Nondestructive tests (Section 11),
4.1.10 Packaging (Section 23),
4.1.11 Inspection (Section 17), and
4.1.12 Certification (Section 21).

NOTE 1—Tube is available to specified outside diameter and wall thickness (state minimum or average wall).

TABLE 2 Permissible Variations in Product Analysis

Element	%	
	Maximum or Specified Range	Permissible Variation in Product Analysis
Nitrogen	0.05	+ 0.02
Carbon	0.10	+ 0.02
Hydrogen	0.015	+ 0.002
Iron	0.35	+ 0.15
Oxygen	0.30	+ 0.03
	0.31 to 0.40	±0.04
Palladium	0.01 to 0.02	±0.002
Palladium	0.04 to 0.25	±0.02
Ruthenium	0.02 to 0.04	±0.005
Ruthenium	0.04 to 0.06	±0.005
Aluminum	2.5 to 3.5	±0.40
Vanadium	2.0 to 3.0	±0.15
Molybdenum	0.2 to 0.4	±0.03
Chromium	0.1 to 0.2	±0.02
Nickel	0.3 to 0.9	±0.05
Residuals[A] (each)	0.1	+ 0.02
Cobalt	0.2 to 0.8	±0.05
Ruthenium	0.08 to 0.14	±0.01

[A] A residual is an element present in a metal or an alloy in small quantities inherent to the manufacturing process but not added intentionally. In titanium these elements include aluminum, vanadium, tin, iron, chromium, molybdenum, niobium, zirconium, hafnium, bismuth, ruthenium, palladium, yttrium, copper, silicon, cobalt, tantalum, nickel, boron, manganese, and tungsten.

5. Materials and Manufacture

5.1 Seamless tube shall be made from hollow billet by any cold reducing or cold drawing process that will yield a product meeting the requirements of this specification. Seamless tube is produced with a continuous periphery in all stages of manufacturing operations.

5.2 Welded tube shall be made from flat-rolled product by an automatic arc-welding process or other method of welding that will yield a product meeting the requirements of this specification. Use of a filler material is not permitted.

5.3 Welded/cold worked tube (WCS) shall be made from welded tube manufactured as specified in 5.2. The welded tube shall be sufficiently cold worked to final size in order to transform the cast weld microstructure into a typical equiaxed