



Designation: B381 – 13 (Reapproved 2019)

Standard Specification for Titanium and Titanium Alloy Forgings¹

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1. Scope

1.1 This specification² covers 39 grades of annealed titanium and titanium alloy forgings as follows:

- 1.1.1 *Grade F-1*—UNS R50250. Unalloyed titanium,
- 1.1.2 *Grade F-2*—UNS R50400. Unalloyed titanium,
 - 1.1.2.1 *Grade F-2H*—UNS R50400. Unalloyed titanium (Grade 2 with 58 ksi (400 MPa) minimum UTS),
- 1.1.3 *Grade F-3*—UNS R50550. Unalloyed titanium,
- 1.1.4 *Grade F-4*—UNS R50700. Unalloyed titanium,
- 1.1.5 *Grade F-5*—UNS R56400. Titanium alloy (6 % aluminum, 4 % vanadium),
- 1.1.6 *Grade F-6*—UNS R54520. Titanium alloy (5 % aluminum, 2.5 % tin),
- 1.1.7 *Grade F-7*—UNS R52400. Unalloyed titanium plus 0.12 to 0.25 % palladium,
 - 1.1.7.1 *Grade F-7H*—UNS R52400. Unalloyed titanium plus 0.12 to 0.25 % palladium (Grade 7 with 58 ksi (400 MPa) minimum UTS),
- 1.1.8 *Grade F-9*—UNS R56320. Titanium alloy (3 % aluminum, 2.5 % vanadium),
- 1.1.9 *Grade F-11*—UNS R52250. Unalloyed titanium plus 0.12 to 0.25 % palladium,
- 1.1.10 *Grade F-12*—UNS R53400. Titanium alloy (0.3 % molybdenum, 0.8 % nickel),
- 1.1.11 *Grade F-13*—UNS R53413. Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
- 1.1.12 *Grade F-14*—UNS R53414. Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
- 1.1.13 *Grade F-15*—UNS R53415. Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
- 1.1.14 *Grade F-16*—UNS R52402. Unalloyed titanium plus 0.04 to 0.08 % palladium,
 - 1.1.14.1 *Grade F-16H*—UNS R52402. Unalloyed titanium plus 0.04 to 0.08 % palladium (Grade 16 with 58 ksi (400 MPa) minimum UTS),

1.1.15 *Grade F-17*—UNS R52252. Unalloyed titanium plus 0.04 to 0.08 % palladium,

1.1.16 *Grade F-18*—UNS R56322. Titanium alloy (3 % aluminum, 2.5 % vanadium) plus 0.04 % to 0.08 % palladium,

1.1.17 *Grade F-19*—UNS R58640. Titanium alloy (3 % aluminum, 8 % vanadium, 6 % chromium, 4 % zirconium, 4 % molybdenum),

1.1.18 *Grade F-20*—UNS R58645. Titanium alloy (3 % aluminum, 8 % vanadium, 6 % chromium, 4 % zirconium, 4 % molybdenum) plus 0.04 to 0.08 % palladium,

1.1.19 *Grade F-21*—UNS R58210. Titanium alloy (3 % aluminum, 2.7 % niobium, 15 % molybdenum, 0.25 % silicon),

1.1.20 *Grade F-23*—UNS R56407. Titanium alloy (6 % aluminum, 4 % vanadium, extra low interstitials, ELI),

1.1.21 *Grade F-24*—UNS R56405. Titanium alloy (6 % aluminum, 4 % vanadium) plus 0.04 to 0.08 % palladium,

1.1.22 *Grade F-25*—UNS R56403. Titanium alloy (6 % aluminum, 4 % vanadium) plus 0.3 to 0.8 % nickel and 0.04 to 0.08 % palladium,

1.1.23 *Grade F-26*—UNS R52404. Unalloyed titanium plus 0.08 to 0.14 % ruthenium,

1.1.23.1 *Grade F-26H*—UNS R52404. Unalloyed titanium plus 0.08 to 0.14 % ruthenium (Grade 26 with 58 ksi (400 MPa) minimum UTS),

1.1.24 *Grade F-27*—UNS R52254. Unalloyed titanium plus 0.08 to 0.14 % ruthenium,

1.1.25 *Grade F-28*—UNS R56323. Titanium alloy (3 % aluminum, 2.5 % vanadium plus 0.08 to 0.14 % ruthenium),

1.1.26 *Grade F-29*—UNS R56404. Titanium alloy (6 % aluminum, 4 % vanadium, extra low interstitial, ELI plus 0.08 to 0.14 % ruthenium),

1.1.27 *Grade F-30*—UNS R53530. Titanium alloy (0.3 % cobalt, 0.05 % palladium),

1.1.28 *Grade F-31*—UNS R53532. Titanium alloy (0.3 % cobalt, 0.05 % palladium),

1.1.29 *Grade F-32*—UNS R55111. Titanium alloy (5 % aluminum, 1 % vanadium, 1 % tin, 1 % zirconium, 0.8 % molybdenum),

1.1.30 *Grade F-33*—UNS R53442. Titanium alloy (0.4 % nickel, 0.015 % palladium, 0.025 % ruthenium, 0.15 % chromium),

¹ This specification is under the jurisdiction of ASTM Committee B10 on Reactive and Refractory Metals and Alloys and is the direct responsibility of Subcommittee B10.01 on Titanium.

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² For ASME Boiler and Pressure Vessel Code applications, see related Specification SB-381 in Section II of that Code.



1.1.31 *Grade F-34*—UNS R53445. Titanium alloy (0.4 % nickel, 0.015 % palladium, 0.025 % ruthenium, 0.15 % chromium),

1.1.32 *Grade F-35*—UNS R56340. Titanium alloy (4.5 % aluminum, 2 % molybdenum, 1.6 % vanadium, 0.5 % iron, 0.3 % silicon),

1.1.33 *Grade F-36*—UNS R58450. Titanium alloy (45 % niobium),

1.1.34 *Grade F-37*—UNS R52815. Titanium alloy (1.5 % aluminum), and

1.1.35 *Grade F-38*—UNS R54250. Titanium alloy (4 % aluminum, 2.5 % vanadium, 1.5 % iron).

NOTE 1—H grade material is identical to the corresponding numeric grade (that is, Grade 2H = Grade 2) except for the higher guaranteed minimum UTS, and may always be certified as meeting the requirements of its corresponding numeric grade. Grades 2H, 7H, 16H, and 26H are intended primarily for pressure vessel use.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *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

B348 Specification for Titanium and Titanium Alloy Bars and Billets

E8 Test Methods for Tension Testing of Metallic Materials [Metric] E0008_E0008M

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E539 Test Method for Analysis of Titanium Alloys by Wavelength Dispersive X-Ray Fluorescence Spectrometry

E1409 Test Method for Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by Inert Gas Fusion

E1447 Test Method for Determination of Hydrogen in Titanium and Titanium Alloys by Inert Gas Fusion Thermal Conductivity/Infrared Detection Method

E1941 Test Method for Determination of Carbon in Refractory and Reactive Metals and Their Alloys by Combustion Analysis

E2371 Test Method for Analysis of Titanium and Titanium Alloys by Direct Current Plasma and Inductively Coupled Plasma Atomic Emission Spectrometry (Performance-Based Test Methodology)

E2626 Guide for Spectrometric Analysis of Reactive and Refractory Metals (Withdrawn 2017)⁴

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 The last approved version of this historical standard is referenced on www.astm.org.

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *bar, n*—a hot rolled, forged or cold worked semifinished solid section product whose cross sectional area is less than 16 in.² (10 323 mm²).

3.1.2 *billet, n*—a solid semifinished section, hot rolled or forged from an ingot, with a cross sectional area greater than 16 in.² (10 323 mm²).

3.1.3 *forging, n*—any product of work on metal formed to a desired shape by impact or pressure in hammers, forging machines, upsetters presses or related forming equipment.

4. Ordering Information

4.1 Orders for forgings under this specification shall include the following information, as applicable:

4.1.1 Grade number (Section 1),

4.1.2 Tensile properties (Table 1),

4.1.3 Dimensions and tolerances (Section 10),

4.1.4 Sampling, mechanical properties (Section 8),

4.1.5 Methods for chemical analysis (Section 6),

4.1.6 Marking (Section 17),

4.1.7 Packaging (Section 17),

4.1.8 Certification (Section 16),

4.1.9 Disposition of rejected material (Section 14), and

4.1.10 Supplementary requirements (S1).

5. Materials and Manufacture

5.1 Material conforming to the latest revision of Specification **B348** shall be used when producing forgings to this specification.

6. Chemical Composition

6.1 The grades of titanium and titanium alloy metal covered by this specification shall conform to the requirements as to chemical composition prescribed in Table 2.

6.1.1 The elements listed in Table 2 are intentional alloy additions or elements which are inherent to the manufacturer of titanium sponge, ingot or mill product.

6.1.1.1 Elements other than those listed in Table 2 are deemed to be capable of occurring in the grades listed in Table 2 by and only by way of unregulated or unanalyzed scrap additions to the ingot melt. Therefore, product analysis for elements not listed in Table 2 shall not be required unless specified and shall be considered to be in excess of the intent of this specification.

6.1.2 Elements intentionally added to the melt must be identified, analyzed, and reported in the chemical analysis.

6.2 When agreed upon by the producer and purchaser and requested by the purchaser in his written purchase order, chemical analysis shall be completed for specific residual elements not listed in this specification.

6.3 *Product Analysis*—Product analysis tolerances do not broaden the specified heat analysis requirements, but cover variations between laboratories in the measurement of chemical content. The manufacturer shall not ship material which is outside the limits specified in Table 2 for the applicable grade. Product analysis limits shall be as specified in Table 3.

TABLE 1 Tensile Requirements^A

Grade	Tensile Strength, min		Yield Strength (0.2 % Offset), min or Range		Elongation in 4D, min, %	Reduction of Area, min, %
	ksi	(MPa)	ksi	(MPa)		
F-1	35	(240)	20	(138)	24	30
F-2	50	(345)	40	(275)	20	30
F-2H ^{B,C}	58	(400)	40	(275)	20	30
F-3	65	(450)	55	(380)	18	30
F-4	80	(550)	70	(483)	15	25
F-5	130	(895)	120	(828)	10	25
F-6	120	(828)	115	(795)	10	25
F-7	50	(345)	40	(275)	20	30
F-7H ^{B,C}	58	(400)	40	(275)	20	30
F-9	120	(828)	110	(759)	10	25
F-9 ^D	90	(620)	70	(483)	15	25
F-11	35	(240)	20	(138)	24	30
F-12	70	(483)	50	(345)	18	25
F-13	40	(275)	25	(170)	24	30
F-14	60	(410)	40	(275)	20	30
F-15	70	(483)	55	(380)	18	25
F-16	50	(345)	40	(275)	20	30
F-16H ^{B,C}	58	(400)	40	(275)	20	30
F-17	35	(240)	20	(138)	24	30
F-18	90	(620)	70	(483)	15	25
F-18 ^D	90	(620)	70	(483)	12	20
F-19 ^E	115	(793)	110	(759)	15	25
F-19 ^F	135	(930)	130 to 159	(897) to (1096)	10	20
F-19 ^G	165	(1138)	160 to 185	(1104) to (1276)	5	20
F-20 ^E	115	(793)	110	(759)	15	25
F-20 ^F	135	(930)	130 to 159	(897) to (1096)	10	20
F-20 ^G	165	(1138)	160 to 185	(1104) to (1276)	5	20
F-21 ^E	115	(793)	110	(759)	15	35
F-21 ^F	140	(966)	130 to 159	(897) to (1096)	10	30
F-21 ^G	170	(1172)	160 to 185	(1104) to (1276)	8	20
F-23	120	(828)	110	(759)	10	25
F-23 ^D	120	(828)	110	(759)	7.5 ^H , 6.0 ^I	25
F-24	130	(895)	120	(828)	10	25
F-25	130	(895)	120	(828)	10	25
F-26	50	(345)	40	(275)	20	30
F-26H ^{B,C}	58	(400)	40	(275)	20	30
F-27	35	(240)	20	(138)	24	30
F-28	90	(620)	70	(483)	15	25
F-28 ^D	90	(620)	70	(483)	12	20
F-29	120	(828)	110	(759)	10	25
F-29 ^D	120	(828)	110	(759)	7.5 ^H , 6.0 ^I	15
F-30	50	(345)	40	(275)	20	30
F-31	65	(450)	55	(380)	18	30
F-32	100	(689)	85	(586)	10	25
F-33	50	(345)	40	(275)	20	30
F-34	65	(450)	55	(380)	18	30
F-35	130	(895)	120	(828)	5	20
F-36	65	(450)	60 to 95	(410 to 655)	10	...
F-37	50	(345)	31	(215)	20	30
F-38	130	(895)	115	(794)	10	25

^A These properties apply to forgings having a cross section no greater than 3 in.² (1935 mm²). Mechanical properties of forgings having greater cross sections shall be negotiated between the manufacturer and the purchaser.

^B Material is identical to the corresponding numeric grade (that is, Grade F-2H = Grade F-2) except for the higher guaranteed minimum UTS, and may be dual certified with its corresponding numeric grade. Grade F-2H, F-7H, F-16H, and F-26H are intended primarily for pressure vessel use.

^C The H grades were added in response to a user association request based on its study of over 5200 commercial Grade 2, 7, 16, and 26 test reports where over 99 % met the 58 ksi minimum UTS.

^D Properties for material in transformed-beta condition.

^E Properties for material in the solution treated condition.

^F Properties for solution treated and aged condition-Moderate strength (determined by aging temperature).

^G Properties for solution treated and aged condition-High Strength (determined by aging temperature).

^H For product section or wall thickness values <1.0 in.

^I For product section or wall thickness values ≥1.0 in.

6.4 *Sampling*—Samples for chemical analysis shall be representative of material being tested. Except for hydrogen and unless otherwise specified, chemical analysis of ingot or billet shall be reported. Samples for hydrogen determination shall be

obtained from the forgings on a test basis and a frequency as agreed upon between the forger and the purchaser. The utmost care must be used in sampling titanium for chemical analysis because of its great affinity for elements such as oxygen,



TABLE 2 Chemical Requirements

Composition, Weight Percent ^{A,B,C,D,E}																													
Grade	UNS Number	Carbon, max.	Oxygen, range or max.	Nitrogen, max.	Hydrogen, max.	Iron, range or max.	Aluminum	Vanadium	Palladium	Ruthenium	Nickel	Molybdenum	Chromium	Cobalt	Zirconium	Niobium	Tin	Silicon	Other Elements, max. each		Other Elements, max. total								
F-1	R50250	0.08	0.18	0.03	0.015	0.20	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4								
F-2/ F-2H	R50400	0.08	0.25	0.03	0.015	0.30	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4								
F-3	R50550	0.08	0.35	0.05	0.015	0.30	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4								
F-4	R50700	0.08	0.40	0.05	0.015	0.50	--	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4								
F-5	R56400	0.08	0.20	0.05	0.015	0.40	5.5-6.75	3.5-4.5	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4								
F-6	R54520	0.08	0.20	0.03	0.015	0.50	4.0-6.0	--	--	--	--	--	--	--	--	--	--	2.0-3.0	--	0.1	0.4								
F-7/ F-7H	R52400	0.08	0.25	0.03	0.015	0.30	--	--	0.12-0.25	--	--	--	--	--	--	--	--	--	--	0.1	0.4								
F-9	R56320	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4								
F-11	R52250	0.08	0.18	0.03	0.015	0.20	--	--	0.12-0.25	--	--	--	--	--	--	--	--	--	--	0.1	0.4								
F-12	R53400	0.08	0.25	0.03	0.015	0.30	--	--	--	--	0.6-0.9	0.2-0.4	--	--	--	--	--	--	--	0.1	0.4								
F-13	R53413	0.08	0.10	0.03	0.015	0.20	--	--	--	0.04-0.06	0.6	--	--	--	--	--	--	--	--	0.1	0.4								
F-14	R53414	0.08	0.15	0.03	0.015	0.30	--	--	--	0.04-0.06	0.6	--	--	--	--	--	--	--	--	0.1	0.4								
F-15	R53415	0.08	0.25	0.05	0.015	0.30	--	--	--	0.04-0.06	0.6	--	--	--	--	--	--	--	--	0.1	0.4								
F-16/ F-16H	R52402	0.08	0.25	0.03	0.015	0.30	--	--	0.04-0.08	--	--	--	--	--	--	--	--	--	--	0.1	0.4								
F-17	R52252	0.08	0.18	0.03	0.015	0.20	--	--	0.04-0.08	--	--	--	--	--	--	--	--	--	--	0.1	0.4								
F-18	R56322	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	0.04-0.08	--	--	--	--	--	--	--	--	--	--	0.1	0.4								
F-19	R58640	0.05	0.12	0.03	0.02	0.30	3.0-4.0	7.5-8.5	--	--	--	3.5-4.5	5.5-6.5	--	3.5-4.5	--	--	--	--	0.15	0.4								
F-20	R58645	0.05	0.12	0.03	0.02	0.30	3.0-4.0	7.5-8.5	0.04-0.08	--	--	3.5-4.5	5.5-6.5	--	3.5-4.5	--	--	--	--	0.15	0.4								
F-21	R58210	0.05	0.17	0.03	0.015	0.40	2.5-3.5	--	--	--	--	14.0-16.0	--	--	--	2.2-3.2	--	0.15-0.25	--	0.1	0.4								
F-23	R56407	0.08	0.13	0.03	0.0125	0.25	5.5-6.5	3.5-4.5	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4								
F-24	R56405	0.08	0.20	0.05	0.015	0.40	5.5-6.75	3.5-4.5	0.04-0.08	--	--	--	--	--	--	--	--	--	--	0.1	0.4								
F-25	R56403	0.08	0.20	0.05	0.015	0.40	5.5-6.75	3.5-4.5	0.04-0.08	--	0.3-0.8	--	--	--	--	--	--	--	--	0.1	0.4								
F-26/ F-16H	R52404	0.08	0.25	0.03	0.015	0.30	--	--	--	0.08-0.14	--	--	--	--	--	--	--	--	--	0.1	0.4								
F-27	R52254	0.08	0.18	0.03	0.015	0.20	--	--	--	0.08-0.14	--	--	--	--	--	--	--	--	--	0.1	0.4								
F-28	R56323	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	--	0.08-0.14	--	--	--	--	--	--	--	--	--	0.1	0.4								
F-29	R56404	0.08	0.13	0.03	0.0125	0.25	5.5-6.5	3.5-4.5	--	0.08-0.14	--	--	--	--	--	--	--	--	--	0.1	0.4								
F-30	R53530	0.08	0.25	0.03	0.015	0.30	--	--	0.04-0.08	--	--	--	--	0.20-0.80	--	--	--	--	--	0.1	0.4								
F-31	R53532	0.08	0.35	0.05	0.015	0.30	--	--	0.04-0.08	--	--	--	--	0.20-0.80	--	--	--	--	--	0.1	0.4								



TABLE 2 Continued

Composition, Weight Percent ^{A,B,C,D,E}																				
Grade	UNS Number	Oxygen		Nitrogen, max.	Hydrogen, max.	Iron range or max.	Composition, Weight Percent ^{A,B,C,D,E}							Other Elements, max. each		Other max. total				
		Carbon, max.	range				Aluminum	Vanadium	Palladium	Ruthenium	Nickel	Molybdenum	Chromium	Cobalt	Zirconium		Niobium	Tin	Silicon	
F-32	R55111	0.08	0.11	0.03	0.015	0.25	4.5-5.5	0.6-1.4	--	--	--	0.6-1.4	--	--	--	0.6-1.4	0.06-0.14	0.1	0.4	
F-33	R53442	0.08	0.25	0.03	0.015	0.30	--	--	0.01-0.02	0.02-0.04	0.35-0.55	--	0.1-0.2	--	--	--	--	0.1	0.4	
F-34	R53445	0.08	0.35	0.05	0.015	0.30	--	--	0.01-0.02	0.02-0.04	0.35-0.55	--	0.1-0.2	--	--	--	--	0.1	0.4	
F-35	R56340	0.08	0.25	0.05	0.015	0.20-0.80	4.0-5.0	1.1-2.1	--	--	--	1.5-2.5	--	--	--	--	0.20-0.40	0.1	0.4	
F-36	R58450	0.04	0.16	0.03	0.015	0.03	--	--	--	--	--	--	--	--	42.0-47.0	--	--	0.1	0.4	
F-37	R52815	0.08	0.25	0.03	0.015	0.30	1.0-2.0	--	--	--	--	--	--	--	--	--	--	0.1	0.4	
F-38	R54250	0.08	0.20-0.30	0.03	0.015	1.2-1.8	3.5-4.5	2.0-3.0	--	--	--	--	--	--	--	--	--	0.1	0.4	

^A At minimum, the analysis of samples from the top and bottom of the ingot shall be completed and reported for all elements listed for the respective grade in this table.

^B Final product hydrogen shall be reported. Ingot hydrogen need not be reported. Lower hydrogen may be obtained by negotiation with the manufacturer.

^C Single values are maximum. The percentage of titanium is determined by difference.

^D Other elements need not be reported unless the concentration level is greater than 0.1 % each, or 0.4 % total. Other elements may be present in titanium or titanium alloys in small quantities and are inherent to the manufacturing process. In titanium these elements typically include aluminum, vanadium, tin, chromium, molybdenum, niobium, zirconium, hafnium, bismuth, ruthenium, palladium, yttrium, copper, silicon, cobalt, tantalum, nickel, boron, manganese, and tungsten.

^E The purchaser may, in the written purchase order, request analysis for specific residual elements not listed in this specification.



TABLE 3 Permissible Variations in Product Analysis

Element	Product Analysis Limits, max or Range, %	Permissible Variation in Product Analysis
Aluminum	0.5 to 2.5	±0.20
Aluminum	2.5 to 6.75	±0.40
Carbon	0.10	+0.02
Chromium	0.1 to 0.2	±0.02
Chromium	5.5 to 6.5	±0.30
Cobalt	0.2 to 0.8	±0.05
Hydrogen	0.02	+0.002
Iron	0.80	+0.15
Iron	1.2 to 1.8	±0.20
Molybdenum	0.2 to 0.4	±0.03
Molybdenum	0.6 to 1.2	±0.15
Molybdenum	1.5 to 4.5	±0.20
Molybdenum	14.0 to 16.0	±0.50
Nickel	0.3 to 0.9	±0.05
Niobium	2.2 to 3.2	±0.15
Niobium	>30	±0.50
Nitrogen	0.05	+0.02
Oxygen	0.30	+0.03
Oxygen	0.31 to 0.40	±0.04
Palladium	0.01 to 0.02	±0.002
Palladium	0.04 to 0.08	±0.005
Palladium	0.12 to 0.25	±0.02
Ruthenium	0.02 to 0.04	±0.005
Ruthenium	0.04 to 0.06	±0.005
Ruthenium	0.08 to 0.14	±0.01
Silicon	0.06 to 0.40	±0.02
Tin	0.6 to 3.0	±0.15
Vanadium	0.6 to 4.5	±0.15
Vanadium	7.5 to 8.5	±0.40
Zirconium	0.6 to 1.4	±0.15
Zirconium	3.5 to 4.5	±0.20
Residuals ^A (each)	0.15	+0.02

^A 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, iron, chromium, molybdenum, niobium, zirconium, hafnium, bismuth, ruthenium, palladium, yttrium, copper, silicon, cobalt, tantalum, nickel, boron, manganese, and tungsten.

nitrogen, and hydrogen. Therefore, the cutting and handling of samples should include practices that will prevent contamination. Samples shall be collected from clean metal.

6.5 At least two samples for chemical analysis shall be tested to determine chemical composition. Samples shall be taken from opposite extremes of the product to be analyzed.

7. Methods of Chemical Analysis

7.1 The chemical analysis shall normally be conducted using the ASTM standard test methods referenced in 2.1. Other industry standard methods may be used where the ASTM test methods in 2.1 do not adequately cover the elements in the material or by agreement between the producer and purchaser. Alternate techniques are discussed in Guide E2626.

8. Mechanical Properties

8.1 Forgings supplied under this specification shall conform to the requirements as to mechanical properties specified in Table 1, as applicable.

8.2 Specimens for tension tests shall be machined and tested in accordance with Test Methods E8. Tensile properties shall be determined using a strain rate of 0.003 to 0.007 in./in.·min through the specified yield strength. After the specified yield strength has been reached, the crosshead speed shall be

increased to a rate sufficient to produce fracture in approximately one additional minute.

8.3 *Sampling*—Tension test specimens shall be machined from material as agreed upon by the manufacturer and the purchaser.

9. Nondestructive Tests

9.1 Nondestructive test requirements such as ultrasonic test, X ray, or surface inspection shall be specified by the purchaser, if required. The standard for acceptance or rejection shall be agreed upon between the forger and the purchaser.

10. Dimensions and Permissible Variations

10.1 Dimensions and tolerances of titanium and titanium alloy forgings covered by this specification shall be as shown on the applicable forging drawing or otherwise agreed upon by the manufacturer and the purchaser.

11. Workmanship, Finish, and Appearance

11.1 Titanium alloy forgings shall be free of injurious external and internal imperfections of a nature that will interfere with the purpose for which they are intended. Annealed forgings may be furnished as descaled, sandblasted, or ground. The manufacturer shall be permitted to remove minor surface imperfections by spot grinding if such grinding does not reduce the thickness of the forging below the minimum permitted by the tolerance for the forging at the applicable location.

12. Retests

12.1 If the results of any chemical or mechanical property test lot are not in conformance with the requirements of this specification, the lot may be retested at the option of the manufacturer. The frequency of the retest will double the initial number of tests. If the results of the retest conform to the specification, then the retest values will become the test values for certification. Only original conforming test results or the conforming retest results shall be reported to the purchaser. If the results for the retest fail to conform to the specification, the material will be rejected in accordance with Section 14.

13. Rounding-Off Procedure

13.1 For purposes of determining conformance with this specification, an observed or a calculated value shall be rounded off to the nearest “unit” in the last right-hand significant digit used in expressing the limiting value. This is in accordance with the round-off method of Practice E29.

14. Rejection

14.1 Forgings not conforming to this specification or to authorized modifications shall be subject to rejection. Unless otherwise specified, rejected forgings may be returned to the manufacturer at the manufacturer’s expense, unless the purchaser receives, within three weeks of notice of rejection, other instructions for disposition.

15. Referee Test and Analysis

15.1 In the event of disagreement between the manufacturer and the purchaser on the conformance of the material to the



requirements of this specification, a mutually acceptable referee shall perform the tests in question using the ASTM standard methods in 2.1. The referee's testing shall be used in determining conformance of the material to this specification.

16. Certification

16.1 The manufacturer shall supply at least one copy of the report certifying that the material supplied has been manufactured, inspected, sampled, and tested in accordance with the requirements of this specification and that the results of chemical analysis, tensile, and other tests meet the requirements of the specification for the grade specified. The report

shall include results of all chemical analysis, tensile tests, and all other tests required by the specification.

17. Packaging and Package Marking

17.1 *Packaging*—Unless otherwise specified, forgings purchased under this specification shall be packaged in accordance with the manufacturer's standard practice.

17.2 *Marking*—Forgings shall be marked for identification as agreed upon by the manufacturer and the purchaser.

18. Keywords

18.1 forgings; titanium; titanium alloys

SUPPLEMENTARY REQUIREMENTS

SUPPLEMENTARY REQUIREMENTS COVERING GRADE F3 TITANIUM FORGINGS

The following supplementary requirements are primarily intended for U.S. military applications and shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. U.S. Military Requirements

S1.1 Referenced Documents section follows.

S1.2 Unless otherwise specified in the contract or purchase order, the seller is responsible for the performance of all inspection and test requirements in this specification, and the seller may use his or other suitable facilities for the performance of the inspection and testing.

S1.3 Grade F-3 composition shall be modified as follows:

Hydrogen	0.0125 max
Iron	0.20 max
Oxygen	0.26 max

S1.4 Two tensile specimens shall be taken from each lot of forgings up to and 125 pounds, and two tensile specimens shall be taken from each forging greater than 125 pounds for verification of compliance with Grade F-3 mechanical properties of Table 3. A lot shall constitute all forgings from the same heat, of the same design and size and heat treated in the same heat treat furnace load. The test specimens shall be taken from integral prolongations or extra forgings may be provided by the forger. Forgings under 3½ in. (90 mm) in cross section may use separately forged test bars provided the wall thickness and amount of working are equivalent to the forgings being supplied. Extra forgings may be provided for samples when forgings are over 3½ in. (90 mm) in cross section provided samples cannot be taken from prolongations or by trepanning. Samples shall be taken from the section of forging having the largest cross section. The longitudinal axis of the tensile specimens shall be parallel to the major direction of metal flow in the forging.

S1.5 Repair welding is not permitted.

S1.6 Each forging shall be ultrasonically inspected in accordance with MIL-STD-2154 throughout 100 % of their volume. Inspection shall be performed after heat treating when the forging is machined to the configuration for ultrasonic

inspection as shown on the forging sketch or drawing. Inspection shall be performed prior to drilling holes, cutting keyways, tapers, grooves, or machining section to final contour. Forgings shall be scanned using a straight beam technique such that all major planes are covered. Disc type forgings shall be scanned using a straight beam from at least one flat face and radially from the circumference when possible. Cylindrical, ring, and hollow forgings shall be scanned from the entire external surface using the straight beam technique, and in the axial direction to the maximum extent possible. Acceptance criteria shall be to class A of MIL-STD-2154.

S1.7 All surfaces of each forging shall be liquid penetrant inspected in accordance with NAVSEA T9074-AS-GIB-010/271. Acceptance criteria shall be in accordance with NAVSEA S9074-AR-GIB-010/278 as specified in the order.

S1.8 Forgings shall be free of foreign material and contaminants such as sulfur, lead, marking paints or machining or forming lubricants. Forgings shall be cleaned prior to any heat treatment operations. Forgings shall be free of any oxygen rich layer, such as alpha case.

S1.9 The first forging of each type and design submitted for inspection shall be the first article sample. Mechanical properties for first article inspections shall be determined throughout the forging as specified in the order (which should also include specific instructions regarding arrangements for examinations, approval of test results, and disposition of the first article samples), and the number and location of the test specimens and the acceptance criteria shall be as specified or as agreed upon between the contracting activity and the manufacturer. In addition, A full cross-section shall be macroetched in accordance with ASTM E340 and examined at 10× magnification for uniformity, soundness, grain size and grain flow. The macro etch cross section shall evidence uniformity of quality, soundness and freedom from cracks and porosity. A



fully wrought structure shall be evident and variation in grain size shall be such that it will not interfere with ultrasonic examination.

The manufacturer shall maintain a record of production practices used for the first article forging. In the event of change in the production practice in the same or subsequent order, the manufacturer shall notify the contracting activity and obtain approval of the changes. The manufacturer may be required to perform specific first article tests and examinations to verify that the change will not or has not degraded forging quality.

S1.10 The material shall be electron beam and/or plasma melted or shall be multiple melted with at least one of the melting cycles under vacuum.

S2. Referenced Documents

S2.1 ASTM Standard:

E340 Test Method for Macroetching Metals and Alloys

S2.2 Military Standards:

T9074–AS-GIB-010/271 Requirements for Nondestructive Testing Methods

S9074–AR-GIB-010/278 Requirements for Fabrication Welding and Inspection, and Casting Inspection and Repair for Machinery, Piping, and Pressure Vessels

MIL-STD-2154 Inspection, Ultrasonic, Wrought Metals, Processing for

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Standard Specification for General Requirements for Carbon and Low Alloy Steel Tubes¹

This standard is issued under the fixed designation A450/A450M; 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 requirements which, with the exceptions of 6.3 and Sections 7, 8, 19, 20, 21, 22, 23, 24, and 25, are mandatory requirements to the following ASTM tubular product specifications:³

Title of Specification	ASTM Designation ⁴
Electric-Resistance-Welded Carbon Steel and Carbon Manganese Steel Boiler Tubes	A178/A178M
Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes	A179/A179M
Seamless Carbon Steel Boiler Tubes for High-Pressure Service	A192/A192M
Seamless Medium-Carbon Steel Boiler and Superheater Tubes	A210/A210M
Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes	A214/A214M
Seamless and Electric-Welded Low-Alloy Steel Tubes Specification for Seamless and Welded Carbon Steel Heat-Exchanger Tubes with Integral Fins	A423/A423M A498
Seamless Cold-Drawn Carbon Steel Feedwater Heater Tubes	A556/A556M
Seamless, Cold-Drawn Carbon Steel Tubing for Hydraulic System Service	A822/A822M

⁴ These designations refer to the latest issue of the respective specifications.

1.2 One or more of Sections 6.3, 7, 8, 19, 20, 21, 22, 22.1, 24, and 25 apply when the product specification or purchase order has a requirement for the test or analysis described by these sections.

1.3 In case of conflict between a requirement of the product specification and a requirement of this general requirement specification only the requirement of the product specification need be satisfied.

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

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 A01.09 on Carbon Steel Tubular Products.

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² For ASME Boiler and Pressure Vessel Code applications see related Specification SA-450 in Section II of that Code.

³ *Annual Book of ASTM Standards*, Vols 01.01 and 01.04.

SI units are shown in brackets. 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 non-conformance with the standard. The inch-pound units shall apply unless the “M” designation (SI) of the product specification is specified in the order.

2. Referenced Documents

2.1 ASTM Standards:⁴

A178/A178M Specification for Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler and Superheater Tubes
A179/A179M Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes
A192/A192M Specification for Seamless Carbon Steel Boiler Tubes for High-Pressure Service
A210/A210M Specification for Seamless Medium-Carbon Steel Boiler and Superheater Tubes
A214/A214M Specification for Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes
A370 Test Methods and Definitions for Mechanical Testing of Steel Products
A423/A423M Specification for Seamless and Electric-Welded Low-Alloy Steel Tubes
A498 Specification for Seamless and Welded Carbon Steel Heat-Exchanger Tubes with Integral Fins
A530/A530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
A556/A556M Specification for Seamless Cold-Drawn Carbon Steel Feedwater Heater Tubes
A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment
A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A822/A822M Specification for Seamless Cold-Drawn Carbon Steel Tubing for Hydraulic System Service

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

A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A1047/A1047M Test Method for Pneumatic Leak Testing of Tubing

A1058 Test Methods for Mechanical Testing of Steel Products—Metric

D3951 Practice for Commercial Packaging

E92 Test Method for Vickers Hardness of Metallic Materials (Withdrawn 2010)⁵

E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing

E273 Practice for Ultrasonic Testing of the Weld Zone of Welded Pipe and Tubing

E309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

E426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Titanium, Austenitic Stainless Steel and Similar Alloys

E570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 Federal Standard:

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products⁶

2.3 Military Standards:

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage⁶

MIL-STD-271 Nondestructive Testing Requirements for Metals⁶

MIL-STD-792 Identification Marking Requirements for Special Purpose Equipment⁶

2.4 ASME Boiler and Pressure Vessel Code:

Section IX⁷

2.5 Steel Structures Painting Council:

SSPC-SP 6 Surface Preparation Specification No. 6 Commercial Blast Cleaning⁸

2.6 Other Document:

SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification.

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *remelted heat*—in secondary melting, all of the ingots remelted from a single primary heat.

3.1.2 *thin-wall tube*—a tube meeting the specified outside diameter and specified wall thickness set forth as follows:

Specified Outside Diameter	Specified Wall Thickness
2 in. [50.8 mm] or less	2 % or less of specified outside diameter
Greater than 2 in. [50.8 mm]	3 % or less of specified outside diameter
Any	0.020 in. [0.5 mm] or less

3.2 *Other defined terms*—The definitions in Test Methods and Definitions **A370**, Test Methods, Practices, and Terminology **A751**, and Terminology **A941** are applicable to this specification and to those listed in **1.1**.

4. Ordering Information

4.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include, but are not limited to, the following:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Specification number with grade or class, or both, as applicable and year date,

4.1.3 Manufacture (hot-finished or cold-finished),

4.1.4 Size (outside diameter and minimum wall thickness),

4.1.5 Length (specific or random),

4.1.6 Test report required (see Section **27**),

4.1.7 Choice of testing track from the options listed in Test Methods **A1058** when material is ordered to an M suffix (SI units) product standard. If the choice of test track is not specified in the order, then the default ASTM test track shall be used as noted in Test Methods **A1058**.

4.1.8 Supplementary Requirements, and

4.1.9 Additional requirements.

5. Process

5.1 The steel may be made by any process.

5.2 If a specific type of melting is required by the purchaser, it shall be as stated on the purchase order.

5.3 The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, such as electroslag remelting or vacuum-arc remelting.

5.4 Steel may be cast in ingots or may be strand cast. When steel of different grades is sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by an established procedure that positively separates the grades.

6. Chemical Composition

6.1 Samples for chemical analysis, and method of analysis shall be in accordance with Test Methods, Practices, and Terminology **A751**.

6.2 *Heat Analysis*—If the heat analysis reported by the steel producer is not sufficiently complete for conformance with the heat analysis requirements of the applicable product specification to be fully assessed, the manufacturer may complete the assessment of conformance with such heat analysis requirements by using a product analysis for the specified elements that were not reported by the steel producer, provided that product analysis tolerances are not applied and the heat analysis is not altered.

⁵ The last approved version of this historical standard is referenced on www.astm.org.

⁶ Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098.

⁷ Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, <http://www.asme.org>.

⁸ Available from Society for Protective Coatings (SSPC), 40 24th St., 6th Floor, Pittsburgh, PA 15222-4656, <http://www.sspc.org>.



6.3 *Product Analysis*—Product analysis requirements and options, if any, are contained in the product specification.

7. Tensile Properties

7.1 The material shall conform to the requirements as to tensile properties prescribed in the individual specification.

7.2 The yield strength corresponding to a permanent offset of 0.2 % of the gage length or to a total extension of 0.5 % of the gage length under load shall be determined.

7.3 If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than $\frac{3}{4}$ in. [19.0 mm] from the center of the gage length, as indicated by scribe marks on the specimen before testing, a retest shall be allowed.

8. Standard Weights

8.1 The calculated weight per unit length, based upon a specified minimum wall thickness, shall be determined by the following equation:

$$W = C(D - t)t \quad (1)$$

where:

C = 10.69 [0.0246615],
 W = weight, lb/ft [kg/m],
 D = specified outside diameter, in. [mm], and
 t = specified minimum wall thickness, in. [mm]

8.2 The permissible variations from the calculated weight per foot [kilogram per metre] shall be as prescribed in **Table 1**.

9. Permissible Variations in Wall Thickness

9.1 Variations from the specified minimum wall thickness shall not exceed the amounts prescribed in **Table 2**.

9.2 For tubes 2 in. [50.8 mm] and over in outside diameter and 0.220 in. [5.6 mm] and over in thickness, the variation in wall thickness in any one cross section of any one tube shall not exceed the following percentage of the actual mean wall at the section. The actual mean wall is defined as the average of the thickest and thinnest wall in that section.

Seamless tubes ± 10 %

Welded tubes ± 5 %

9.3 When cold-finished tubes as ordered require wall thicknesses $\frac{3}{4}$ in. [19.1 mm] or over, or an inside diameter 60 % or less of the outside diameter, the permissible variations in wall thickness for hot-finished tubes shall apply.

TABLE 1 Permissible Variations in Weight Per Unit Length^A

Method of Manufacture	Permissible Variation in Weight per Unit Length, %	
	Over	Under
Seamless, hot-finished	16	0
Seamless, cold-finished:		
$\frac{1}{2}$ in. [38.1 mm] and under OD	12	0
Over $\frac{1}{2}$ in. [38.1 mm] OD	13	0
Welded	10	0

^A These permissible variations in weight apply to lots of 50 tubes or more in sizes 4 in. [101.6 mm] and under in outside diameter, and to lots of 20 tubes or more in sizes over 4 in. [101.6 mm] in outside diameter.

TABLE 2 Permissible Variations in Wall Thickness^A

Outside Diameter, in. [mm]	Wall Thickness, %							
	0.095 [2.4] and Under		Over 0.095 to 0.150 [2.4 to 3.8], incl		Over 0.150 to 0.180 [3.8 to 4.6], incl		Over 0.180, [4.6]	
	Over	Under	Over	Under	Over	Under	Over	Under
Seamless, Hot-Finished Tubes								
4 [101.6] and under	40	0	35	0	33	0	28	0
Over 4 [101.6]	...	...	35	0	33	0	28	0
Seamless, Cold-Finished Tubes								
			Over		Under			
1½ [38.1] and under			20		0			
Over 1½ [38.1]			22		0			
Welded Tubes								
All sizes			18		0			

^A These permissible variations in wall thickness apply only to tubes, except internal-upset tubes, as rolled or cold-finished, and before swaging, expanding, bending, polishing, or other fabricating operations.

10. Permissible Variations in Outside Diameter

10.1 Except as provided in **10.2**, variations from the specified outside diameter shall not exceed the amounts prescribed in **Table 3**.

10.2 Thin-wall tubes usually develop significant ovality (out of roundness) during final annealing, or straightening, or both. The diameter tolerances of **Table 3** are not sufficient to provide for additional ovality expected in thin-wall tubes, and, for such tubes, are applicable only to the *mean* of the extreme (maximum and minimum) outside diameter readings in any one cross section. However, for thin wall tubes the *difference* in extreme outside diameter readings (ovality) in any one cross section shall not exceed the following ovality allowances:

Outside Diameter	Ovality Allowance
1 in. [25.4 mm] and under	0.020 in. [0.5 mm]
Over 1 in. [25.4 mm]	2.0 % of specified outside diameter

TABLE 3 Permissible Variations in Outside Diameter^A

Outside Diameter, in. [mm]	Permissible Variations, in. [mm]	
	Over	Under
Hot-Finished Seamless Tubes		
4 [101.6] and under	$\frac{1}{64}$ [0.4]	$\frac{1}{32}$ [0.8]
Over 4 to $7\frac{1}{2}$ [101.6 to 190.5], incl	$\frac{1}{64}$ [0.4]	$\frac{3}{64}$ [1.2]
Over $7\frac{1}{2}$ to 9 [190.5 to 228.6], incl	$\frac{1}{64}$ [0.4]	$\frac{1}{16}$ [1.6]
Welded Tubes and Cold-Finished Seamless Tubes		
Under 1 [25.4]	0.004 [0.1]	0.004 [0.1]
1 to $1\frac{1}{2}$ [25.4 to 38.1], incl	0.006 [0.15]	0.006 [0.15]
Over $1\frac{1}{2}$ to 2 [38.1 to 50.8], excl	0.008 [0.2]	0.008 [0.2]
2 to $2\frac{1}{2}$ [50.8 to 63.5], excl	0.010 [0.25]	0.010 [0.25]
$2\frac{1}{2}$ to 3 [63.5 to 76.2], excl	0.012 [0.3]	0.012 [0.3]
3 to 4 [76.2 to 101.6], incl	0.015 [0.38]	0.015 [0.38]
Over 4 to $7\frac{1}{2}$ [101.6 to 190.5], incl	0.015 [0.38]	0.025 [0.64]
Over $7\frac{1}{2}$ to 9 [190.5 to 228.6], incl	0.015 [0.38]	0.045 [1.14]

^A Except as provided in **10.2**, these permissible variations include out-of-roundness. These permissible variations in outside diameter apply to hot-finished seamless, welded and cold-finished seamless tubes before other fabricating operations such as upsetting, swaging, expanding, bending, or polishing.



11. Permissible Variations in Length

11.1 Variations from the specified length shall not exceed the amounts prescribed in **Table 4**.

12. Permissible Variations in Height of Flash on Electric-Resistance-Welded Tubes

12.1 For tubes over 2 in. [50.8 mm] in outside diameter, or over 0.135 in. [3.44 mm] in wall thickness, the flash on the inside of the tubes shall be mechanically removed by cutting to a maximum height of 0.010 in. [0.25 mm] at any point on the tube.

12.2 For tubes 2 in. [50.8 mm] and under in outside diameter and 0.135 in. [3.4 mm] and under in wall thickness, the flash on the inside of the tube shall be mechanically removed by cutting to a maximum height of 0.006 in. [0.15 mm] at any point on the tube.

13. Straightness and Finish

13.1 Finished tubes shall be reasonably straight and have smooth ends free of burrs. They shall have a workmanlike finish. Surface imperfections (see **Note 1**) may be removed by grinding, provided that a smooth curved surface is maintained, and the wall thickness is not decreased to less than that permitted by this or the product specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

NOTE 1—An imperfection is any discontinuity or irregularity found in the tube.

14. Repair by Welding

14.1 Repair welding of base metal defects in tubing is permissible only with the approval of the purchaser and with the further understanding that the tube shall be marked “WR” and the composition of the deposited filler metal shall be suitable for the composition being welded. Defects shall be thoroughly chipped or ground out before welding and each repaired length shall be reheat treated or stress relieved as required by the applicable specification. Each length of repaired tube shall be tested hydrostatically as required by the product specification.

14.2 Repair welding shall be performed using procedures and welders or welding operators that have been qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX.

TABLE 4 Permissible Variations in Length^A

Method of Manufacture	Outside Diameter, in. [mm]	Cut Length, in. [mm]	
		Over	Under
Seamless, hot-finished	All sizes	3/16 [5]	0 [0]
Seamless, cold-finished	Under 2 [50.8]	1/8 [3]	0 [0]
	2 [50.8] and over	3/16 [5]	0 [0]
Welded	Under 2 [50.8]	1/8 [3]	0 [0]
	2 [50.8] and over	3/16 [5]	0 [0]

^A These permissible variations in length apply to tubes before bending. They apply to cut lengths up to and including 24 ft [7.3 m]. For lengths greater than 24 ft [7.3 m], the above over-tolerances shall be increased by 1/8 in. [3 mm] for each 10 ft [3 m] or fraction thereof over 24 ft or 1/2 in. [13 mm], whichever is the lesser.

15. Retests

15.1 If the results of the mechanical tests of any group or lot do not conform to the requirements specified in the individual specification, retests may be made on additional tubes of double the original number from the same group or lot, each of which shall conform to the requirements specified.

16. Retreatment

16.1 If the individual tubes or the tubes selected to represent any group or lot fail to conform to the test requirements, the individual tubes or the group or lot represented may be retreated and resubmitted for test. Not more than two reheat treatments shall be permitted.

17. Test Specimens

17.1 Test specimens shall be taken from the ends of finished tubes prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They shall be smooth on the ends and free of burrs and flaws.

17.2 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

18. Method of Mechanical Testing

18.1 The specimens and mechanical tests required shall be made in accordance with Annex A2 of Test Methods and Definitions **A370** if inch-pound units are specified or to the requirements described in the applicable track of Test Methods **A1058** if SI units are specified.

18.2 Specimens shall be tested at room temperature.

18.3 Small or subsize specimens as described in Test Methods and Definitions **A370** or Test Methods **A1058** may be used only when there is insufficient material to prepare one of the standard specimens. When using small or subsize specimens, the largest one possible shall be used.

19. Flattening Test

19.1 A section of tube not less than 2 1/2 in. [63 mm] in length for seamless and not less than 4 in. [100 mm] in length for welded shall be flattened cold between parallel plates in two steps. For welded tubes, the weld shall be placed 90° from the direction of the applied force (at a point of maximum bending). During the first step, which is a test for ductility, no cracks or breaks, except as provided for in **19.4**, on the inside, outside, or end surfaces shall occur in seamless tubes, or on the inside or outside surfaces of welded tubes, until the distance between the plates is less than the value of H calculated by the following equation:

$$H = \frac{(1 + e)t}{e + t/D} \quad (2)$$

where:

H = distance between flattening plates, in. [mm],

t = specified wall thickness of the tube, in. [mm],

D = specified outside diameter of the tube, in. [mm], and



e = deformation per unit length (constant for a given grade of steel: 0.07 for medium-carbon steel (maximum specified carbon 0.19 % or greater), 0.08 for low alloy steel, and 0.09 for low-carbon steel (maximum specified carbon 0.18 % or less)).

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the tube meet. Evidence of laminated or unsound material, or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

19.2 Surface imperfections in the test specimens before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements.

19.3 Superficial ruptures resulting from surface imperfections shall not be cause for rejection.

19.4 When low D -to- t ratio tubular products are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the D to t ratio is less than 10.

20. Reverse Flattening Test

20.1 A 5 in. [100 mm] in length of finished welded tubing in sizes down to and including ½ in. [12.7 mm] in outside diameter shall be split longitudinally 90° on each side of the weld and the sample opened and flattened with the weld at the point of maximum bend. There shall be no evidence of cracks or lack of penetration or overlaps resulting from flash removal in the weld.

21. Flaring Test

21.1 A section of tube approximately 4 in. [100 mm] in length shall stand being flared with a tool having a 60° included angle until the tube at the mouth of the flare has been expanded to the percentages specified in Table 5 without cracking or showing imperfections rejectable under the provisions of the product specification.

22. Flange Test

22.1 A section of tube shall be capable of having a flange turned over at a right angle to the body of the tube without cracking or showing imperfections rejectable under the provisions of the product specification.

TABLE 5 Flaring Test Requirements

Ratio of Inside Diameter to Outside Diameter ^A	Minimum Expansion of Inside Diameter, %	
	Carbon Steels	Low Alloy Steels
0.9	21	15
0.8	22	17
0.7	25	19
0.6	30	23
0.5	39	28
0.4	51	38
0.3	68	50

^A In determining the ratio of inside diameter to specified outside diameter, the inside diameter shall be defined as the actual mean inside diameter of the material tested.

sions of the product specification. The width of the flange for carbon and alloy steels shall be not less than the percentages specified in Table 6.

23. Hardness Test

23.1 For tubes 0.200 in. [5.1 mm] and over in wall thickness, either the Brinell or Rockwell hardness test shall be used. When Brinell hardness testing is used, a 10-mm ball with 3000, 1500, or 500-kg load, or a 5-mm ball with 750-kg load may be used, at the option of the manufacturer.

23.2 For tubes less than 0.200 in. [5.1 mm] to and including 0.065 in. [1.7 mm] in wall thickness, the Rockwell hardness test shall be used.

23.3 For tubes less than 0.065 in. [1.7 mm] in wall thickness, the hardness test shall not be required.

23.4 The Brinell hardness test may be made on the outside of the tube near the end, on the outside of a specimen cut from the tube, or on the wall cross section of a specimen cut from the tube at the option of the manufacturer. This test shall be made so that the distance from the center of the impression to the edge of the specimen is at least 2.5 times the diameter of the impression.

23.5 The Rockwell hardness test may be made on the inside surface, on the wall cross section, or on a flat on the outside surface at the option of the manufacturer.

23.6 For tubes furnished with upset, swaged, or otherwise formed ends, the hardness test shall be made as prescribed in 23.1 and 23.2 on the outside of the tube near the end after the forming operation and heat treatment.

23.7 For welded or brazed tubes, the hardness test shall be made away from the joints.

23.8 When the product specification provides for Vickers hardness, such testing shall be in accordance with Test Method E92.

24. Hydrostatic Test

24.1 Except as provided in 24.2 and 24.3, each tube shall be tested by the manufacturer to a minimum hydrostatic test pressure determined by the following equation:

$$\text{Inch - Pound Units: } P = 32000 t/D \quad (3)$$

$$\text{SI Units: } P = 220.6t/D$$

where:

P = hydrostatic test pressure, psi or MPa,

t = specified wall thickness, in. or mm, and

D = specified outside diameter, in. or mm.

TABLE 6 Flange Requirements

Outside Diameter of Tube, in. [mm]	Width of Flange
To 2½ [63.5], incl	15 % of OD
Over 2½ to 3¾ [63.5 to 95.2], incl	12½ % of OD
Over 3¾ to 8 [95.2 to 203.2], incl	10 % of OD

24.1.1 The hydrostatic test pressure determined by Eq 3 shall be rounded to the nearest 50 psi [0.5 MPa] for pressure below 1000 psi [7 MPa], and to the nearest 100 psi [1 MPa] for pressures 1000 psi [7 MPa] and above. The hydrostatic test may be performed prior to cutting to final length, or prior to upsetting, swaging, expanding, bending or other forming operations, or both.

24.2 Regardless of the determination made by Eq 3, the minimum hydrostatic test pressure required to satisfy these requirements need not exceed the values given in Table 7. This does not prohibit testing at higher pressures at manufacturer's option or as provided in 24.3.

24.3 With concurrence of the manufacturer, a minimum hydrostatic test pressure in excess of the requirements of 24.2 or 24.1, or both, may be stated on the order. The tube wall stress shall be determined by the following equation:

$$S = PD/2t \quad (4)$$

where:

S = tube wall stress, psi or MPa, and all other symbols as defined in 24.1.1.

24.4 The test pressure shall be held for a minimum of 5 s.

24.5 If any tube shows leaks during the hydrostatic test, it shall be rejected.

24.6 The hydrostatic test may not be capable of testing the end portion of the pipe. The lengths of pipe that cannot be tested shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

25. Air Pressure Test

25.1 *Air Underwater Test*—When this test is employed, each tube, with internal surface clean and dry, shall be internally pressurized to 150 psi [1000 kPa] minimum with clean and dry compressed air while being submerged in clear water. The tube shall be well-lighted, preferably by underwater illumination. Any evidence of air leakage of the pneumatic couplings shall be corrected prior to testing. Inspection shall be made of the entire external surface of the tube after holding the pressure for not less than 5 s after the surface of the water has become calm. If any tube shows leakage during the air underwater test, it shall be rejected. Any leaking areas may be cut out and the tube retested.

25.2 *Pneumatic Leak Test*—When this test is employed, each tube shall be subjected to a pneumatic leak test in accordance with Specification A1047/A1047M.

Acceptance criteria shall be as follows:

TABLE 7 Hydrostatic Test Pressures

Outside Diameter of Tube, in. [mm]	Hydrostatic Test Pressure, psi [MPa]
Under 1 [25.4]	1000 [7]
1 to 1½ [25.4 to 38.1], excl	1500 [10]
1½ to 2 [38.1 to 50.8], excl	2000 [14]
2 to 3 [50.8 to 76.2], excl	2500 [17]
3 to 5 [76.2 to 127], excl	3500 [24]
5 [127] and over	4500 [31]

Tube O.D. in [mm]	Calibration Hole, max. in [mm]
≤1.5 [≤40]	0.003 [0.076]
>1.5≤2.0 [>40≤50]	0.004 [0.162]
>2.0≤2.5 [>50≤65]	0.005 [0.127]
>2.5≤3.0 [>65≤75]	0.006 [0.152]
>3.0 [>75]	by agreement

26. Nondestructive Examination

26.1 When nondestructive examination is specified by the purchaser or the product specification, each tube shall be examined by a nondestructive examination method in accordance with Practice E213, Practice E309 (for ferromagnetic materials), Practice E426 (for non-magnetic materials), or Practice E570. Upon agreement, Practice E273 shall be employed in addition to one of the full periphery tests. The range of tube sizes that may be examined by each method shall be subject to the limitations in the scope of that practice. In case of conflict between these methods and practices and this specification, the requirements of this specification shall prevail.

26.2 The following information is for the benefit of the user of this specification.

26.2.1 Calibration standards for the nondestructive electric test are convenient standards for calibration of nondestructive testing equipment only. For several reasons, including shape, orientation, width, etc., the correlation between the signal produced in the electric test from an imperfection and from calibration standards is only approximate. A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

26.2.2 The ultrasonic examination referred to in this specification is intended to detect longitudinal discontinuities having a reflective area similar to or larger than the calibration reference notches specified in 26.4. The examination may not detect circumferentially oriented imperfections or short, deep defects.

26.2.3 The eddy current examination referenced in this specification has the capability of detecting significant discontinuities, especially of the short abrupt type. Practices E309 and E426 contain additional information regarding the capabilities and limitations of eddy-current examination.

26.2.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. The provisions of this specification only provide for longitudinal calibration for flux leakage. It should be recognized that different techniques should be employed to detect differently oriented imperfections.

26.2.5 The hydrostatic test referred to in Section 23 is a test method provided for in many product specifications. This test has the capability of finding defects of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. This test may not detect very tight, through-the-wall defects or defects that extend an appreciable distance into the wall without complete penetration.

26.2.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can



be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular products.

26.3 Time of Examination—Nondestructive examination for specification acceptance shall be performed after all deformation processing, heat treating, welding, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

26.4 Surface Condition:

26.4.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

26.4.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

26.5 Extent of Examination:

26.5.1 The relative motion of the tube and the transducer(s), coil(s), or sensor(s) shall be such that the entire tube surface is scanned, except for end effects as noted in **26.5.2**.

26.5.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

26.6 Operator Qualifications:

26.6.1 The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent documented standard agreeable to both purchaser and manufacturer.

26.7 Test Conditions:

26.7.1 For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.0 MHz, and the maximum transducer size shall be 1.5 in. [38 mm].

26.7.2 For eddy current testing, the excitation coil frequency shall be chosen to ensure adequate penetration, yet provide good signal-to-noise ratio.

26.7.2.1 The maximum coil frequency shall be:

Specified Wall Thickness	Maximum Frequency
<0.050 in.	100 KHz
0.050 to 0.150	50
>0.150	10

26.8 Reference Standards:

26.8.1 Reference standards of convenient length shall be prepared from a length of tube of the same grade, specified size (outside diameter and wall thickness), surface finish and heat treatment condition as the tubing to be examined.

26.8.2 For eddy current testing, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

26.8.2.1 Drilled Hole—The reference standard shall contain three or more holes, equally spaced circumferentially around the tube and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the tube wall, with care being taken to avoid distortion of the tube while drilling. The holes shall not be larger than 0.031 in. [0.8 mm] in diameter. As an alternative, the producer may choose to drill

one hole and run the calibration standard through the test coil three times, rotating the tube approximately 120° each time. More passes with smaller angular increments may be used, provided testing of the full 360° of the coil is obtained. For welded tubing, if the weld is visible, one of the multiple holes or the single hole shall be drilled in the weld.

26.8.2.2 Transverse Tangential Notch—Using a round tool or file with a ¼ in. [6.4 mm] diameter, a notch shall be milled or filed tangential to the surface and transverse to the longitudinal axis of the tube. Said notch shall have a depth not exceeding 12½ % of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater.

26.8.2.3 Longitudinal Notch—A notch 0.031 in. [0.8 mm] or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to have a depth not exceeding 12½ % of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater. The length of the notch shall be compatible with the testing method.

26.8.3 For ultrasonic testing, the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E213, at the option of the manufacturer. The depth of the notches shall not exceed 12½ % of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater. The width of the notch shall not exceed two times the depth. For welded tubing, the notches shall be placed in the weld, if the weld is visible.

26.8.4 For flux leakage testing, the longitudinal reference notches shall be straight-sided notches machined in a radial plane parallel to the tube axis on the inside and outside surfaces of the tube. Notch depth shall not exceed 12½ % of the specified wall thickness or 0.004 in. [0.1 mm], whichever is greater. Notch length shall not exceed 1 in. [25.4 mm], and the width shall not exceed the depth. Outside and inside notches shall have sufficient separation to allow distinct identification of the signal from each notch.

26.8.5 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

26.9 Standardization Procedure:

26.9.1 The test apparatus shall be standardized at the beginning and end of each series of tubes of the same specified size (diameter and wall thickness), grade and heat treatment condition, and at intervals not exceeding 4 h during the examination of such tubing. More frequent standardizations may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

26.9.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss or shutdown.

26.9.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the tube to be tested, except that, at the manufacturer's discretion, the tubes may be tested at a higher sensitivity.

26.9.4 The signal-to-noise ratio for the reference standard shall be 2.5:1 or greater, and the reference signal amplitude for each discontinuity shall be at least 50 % of full scale of the display. In establishing the noise level, extraneous signals from



identifiable surface imperfections on the reference standard may be ignored. When reject filtering is used during UT testing, linearity must be demonstrated.

26.9.5 If, upon any standardization, the reference signal amplitude has decreased by 29 % (3.0 dB), the test apparatus shall be considered out of standardization. The test system settings may be changed, or the transducer(s), coil(s), or sensor(s) adjusted, and the unit restandardized, but all tubes tested since the last acceptable standardization must be retested.

26.10 *Evaluation of Imperfections:*

26.10.1 Tubing producing a test signal to or greater than the lowest signal produced by the reference standard shall be designated suspect, shall be clearly marked or identified, and shall be separated from the acceptable tubing.

26.10.2 Such suspect tubing shall be subject to one of the following three dispositions:

26.10.2.1 The tubes may be rejected without further examination, at the discretion of the manufacturer.

26.10.2.2 If the test signal was produced by imperfections such as scratches, surface roughness, dings, straightener marks, loose ID bead and cutting chips, steel die stamps, stop marks, tube reducer ripple, or chattered flash trim, the tubing may be accepted or rejected depending on visual observation of the severity of the imperfection, the type of signal it produces on the testing equipment used, or both.

26.10.2.3 If the test signal was produced by imperfections which cannot be identified, or was produced by cracks or crack-like imperfections, the tubing shall be rejected.

26.10.3 Any tubes with imperfections of the types in **26.10.2.2** and **26.10.2.3**, exceeding 0.004 in. [0.1 mm] or 12½ % of the specified minimum wall thickness (whichever is greater) in depth shall be rejected.

26.10.4 Rejected tubes may be reconditioned and retested providing the wall thickness is not decreased to less than that required by this or the product specification. If grinding is performed, the outside diameter in the area of grinding may be reduced by the amount so removed. To be accepted, reconditioned tubes must pass the nondestructive examination by which they were originally rejected.

27. Test Report

27.1 When specified in the purchase order or contract, the producer or supplier shall furnish a test report stating that the material was manufactured, sampled, tested and inspected in accordance with the specification, including year date, the supplementary requirements, and any other requirements designated in the purchase order or contract, and that the results met the requirements of that specification, the supplementary requirements and the other requirements. A signature or notarization is not required on the test report, but the document shall be dated and shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature or notarization, the organization submitting the report is responsible for the contents of the report.

27.2 In addition, the test report shall include the following information and test results, when applicable:

27.2.1 Heat Number,

27.2.2 Heat Analysis,

27.2.3 Product Analysis, when specified,

27.2.4 Tensile Properties,

27.2.5 Width of the gage length, when longitudinal strip tension test specimens are used,

27.2.6 Flattening Test acceptable,

27.2.7 Reverse Flattening Test acceptable,

27.2.8 Flaring Test acceptable,

27.2.9 Flange Test acceptable,

27.2.10 Hardness Test values,

27.2.11 Hydrostatic Test pressure,

27.2.12 Non-destructive Electric Test method,

27.2.13 Impact Test results, and

27.2.14 Other test results or information required to be reported by the product specification.

27.3 Test results or information required to be reported by supplementary requirements, or other requirements designated in the purchase order or contract shall be reported, but may be reported in a separate document.

27.4 The test report shall include a statement of explanation for the letter added to the specification number marked on the tubes (see **30.2**), when all of the requirements of the specification have not been completed. The purchaser must certify that all requirements of the specification have been completed before removal of the letter (that is, X, Y, or Z).

27.5 A test report, certificate of compliance, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document shall meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

28. Inspection

28.1 The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All required tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

29. Rejection

29.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.



29.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside and the manufacturer shall be notified for mutual evaluation of the material's suitability. Disposition of such material shall be a matter for agreement.

30. Product Marking

30.1 Each length of tube shall be legibly stenciled with the manufacturers's name or brand, the specification number, and grade. The marking need not include the year date of the specification. For tubes less than 1 1/4 in. [31.8 mm] in diameter and tubes under 3 ft. [1 m] in length, the required information may be marked on a tag securely attached to the bundle or box in which the tubes are shipped.

30.2 When it is specified that certain requirements of a specification adopted by the ASME Boiler and Pressure Vessel Committee are to be completed by the purchaser upon receipt of the material, the manufacturer shall indicate that all requirements of the specification have not been completed by a letter such as X, Y, or Z, immediately following the specification number. This letter may be removed after completion of all requirements in accordance with the specification. An explanation of specification requirements to be completed is provided in Section 27.

30.3 *Bar Coding*—In addition to the requirements in 30.1 and 30.2, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

31. Packaging, Marking, and Loading

31.1 When specified on the purchase order, packaging, marking, and loading for shipment shall be in accordance with the procedures of Practices A700.

32. Government Procurement

32.1 Scale Free Pipe:

32.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry contract or order, for agencies of the U.S. Government where scale free tube is required. These requirements shall take precedence if there is a conflict between these requirements and the product specification.

32.1.2 Tube shall be ordered to outside diameter (OD) and wall thickness.

32.1.3 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility for ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept the material. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other

suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth when such inspections and tests are deemed necessary to ensure that the material conforms to the prescribed requirements.

32.1.4 *Sampling for Flattening and Flaring Test and for Visual and Dimensional Examination*—Minimum sampling for flattening and flaring tests and visual and dimensional examination shall be as follows:

Lot Size (pieces per lot)	Sample Size
2 to 8	Entire lot
9 to 90	8
91 to 150	12
151 to 280	19
281 to 500	21
501 to 1200	27
1201 to 3200	35
3201 to 10 000	38
10 001 to 35 000	46

In all cases, the acceptance number is zero and the rejection number is one. Rejected lots may be screened and resubmitted for visual and dimensional examination. All defective items shall be replaced with acceptable items prior to lot acceptance.

32.1.5 *Sampling for Chemical Analysis*—One sample for chemical analysis shall be selected from each of two tubes chosen from each lot. A lot shall be all material poured from one heat.

32.1.6 *Sampling for Tension and Bend Test*—One sample shall be taken from each lot. A lot shall consist of all tube of the same outside diameter and wall thickness manufactured during an 8-h shift from the same heat of steel, and heat treated under the same conditions of temperature and time in a single charge in a batch type furnace, or heat treated under the same condition in a continuous furnace, and presented for inspection at the same time.

32.1.7 *Hydrostatic and Ultrasonic Tests*—Each tube shall be tested by the ultrasonic (when specified) and hydrostatic tests.

32.1.8 Tube shall be free from heavy oxide or scale. The internal surface of hot finished ferritic steel tube shall be pickled or blast cleaned to a free of scale condition equivalent to the CSA2 visual standard listed in SSPC-SP6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

32.1.9 In addition to the marking in Specification A530/A530M, each length of tube 1/4 in. outside diameter and larger shall be marked with the following listed information. Marking shall be in accordance with Fed. Std. No. 183 and MIL-STD-792. (a) Outside diameter, wall thickness, and length (b) Heat or lot identification number.

32.1.10 Tube shall be straight to within the tolerances specified in Table 8:

32.1.11 When specified, each tube shall be ultrasonically examined in accordance with MIL-STD-271, except that the notch depth in the calibration standard shall be 5 % of the wall thickness or 0.005 in., whichever is greater. Any tube which produces an indication equal to or greater than 100 % of the indication from the calibration standard shall be rejected.



TABLE 8 Straightness Tolerances

Specified OD (in.)	Specified Wall Thickness (in.)	Maximum Curvature in Any 3 ft (in.)	Maximum Curvature in Total Length (in.)
Up to 5.0, incl	Over 3 % OD to 0.5, incl	0.030	0.010 × length, ft
Over 5.0 to 8.0, incl	Over 4 % OD to 0.75, incl	0.045	0.015 × length, ft
Over 8.0 to 12.75, incl	Over 4 % OD to 1.0, incl	0.060	0.020 × length, ft

32.1.12 The tube shall be free from repair welds, welded joints, laps, laminations, seams, visible cracks, tears, grooves, slivers, pits, and other imperfections detrimental to the tube as determined by visual and ultrasonic examination, or alternate tests, as specified.

32.1.13 Tube shall be uniform in quality and condition and have a finish conforming to the best practice for standard

quality tubing. Surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale pattern will not be considered injurious if the imperfections are removable within the tolerances specified for wall thickness or 0.005 in., whichever is greater. The bottom of imperfections shall be visible and the profile shall be rounded and faired-in.

32.1.14 No weld repair by the manufacturer is permitted.

32.1.15 Preservation shall be level A or commercial, and packing shall be level A, B, or commercial, as specified. Level A preservation and level A or B packing shall be in accordance with MIL-STD-163 and commercial preservation and packing shall be in accordance with Practices A700 or Practice D3951.

33. Keywords

33.1 alloy steel tube; austenitic stainless steel; carbon steel tube; general delivery; stainless steel tube; steel tube

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A450/A450M–10, which may impact the use of this specification. (Approved May 1, 2015)

- (1) Incorporated Test Methods A1058 throughout.
- (2) Added Section 4.
- (3) Added metric equivalent of foot in 8.1 and Table 1.
- (4) Deleted the word “certified” from the term “certified test report” in Section 27.

- (5) Deleted Note 2 of 27.5 and moved its requirements to the text of 27.5.

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