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Titanium and titanium alloy forgings

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Foreword

This standard is identical with ASTM B 381-2006a, *Standard Specification for Titanium and Titanium Alloy Forgings* (English edition).

This standard is a translation of ASTM B 381-2006a. For ease of use, the following editorial modifications have been made:

— the title of this standard is changed to *Titanium and titanium alloy forgings*;

— the word “specification” is changed to “standard”;

— Subclause 1.2 is modified to: “Values are stated in SI units; inch-pound values given in parentheses are for information only.”

— Clause 17 (Keywords) is deleted;

— Appendix B (cross-reference of titanium grades) has been added.

Appendixes A and B are informative.

This standard was proposed by and is under the jurisdiction of SAC/TC 74 (National Technical Committee on Forging Standardization).

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Titanium and titanium alloy forgings

1 Scope

1.1 This specification is covered for the following 39 grades of annealed titanium and titanium alloy forgings:

1) F-1 commercially unalloyed titanium;

2) F-2 commercially unalloyed titanium;

3) F-2H commercially unalloyed titanium [minimum tensile strength 400 MPa (58 ksi) of F-2];

4) F-3 commercially unalloyed titanium;

5) F-4 commercially unalloyed titanium;

6) F-5 titanium alloy (6 % Al, 4 % V);

7) F-6 titanium alloy (5 % Al, 2.5 % Sn);

8) F-7 commercially unalloyed titanium + 0.12 %–0.25 % Pd;

9) F-7H commercially unalloyed titanium + 0.12 %–0.25 % Pd [minimum tensile strength 400 MPa (58 ksi) of F-7];

10) F-9 titanium alloy (3 % Al, 2.5 % V);

11) F-11 commercially unalloyed titanium + 0.12 %–0.25 % Pd;

12) F-12 titanium alloy (0.3 % Mo, 0.8 % Ni);

13) F-13 titanium alloy (0.5 % Ni, 0.05 % Ru);

14) F-14 titanium alloy (0.5 % Ni, 0.05 % Ru);

15) F-15 titanium alloy (0.5 % Ni, 0.05 % Ru);

16) F-16 commercially unalloyed titanium + 0.04 %–0.08 % Pd;

17) F-16H commercially unalloyed titanium + 0.04 %–0.08 % Pd [minimum tensile strength 400 MPa (58 ksi) of F-16];

18) F-17 commercially unalloyed titanium + 0.04 %–0.08 % Pd;

19) F-18 titanium alloy (3 % Al, 2.5 % V) + 0.04 %–0.08 % Pd;

20) F-19 titanium alloy (3 % Al, 8 % V, 6 % Cr, 4 % Zr, 4 % Mo);

21) F-20 titanium alloy (3 % Al, 8 % V, 6 % Cr, 4 % Zr, 4 % Mo) + 0.04 %–0.08 % Pd;

22) F-21 titanium alloy (3 % Al, 2.7 % Nb, 15 % Mo, 0.25 % Si);

23) F-23 titanium alloy (6 % Al, 4 % V), extra low interstitial (ELI);

24) F-24 titanium alloy (6 % Al, 4 % V) + 0.04 %–0.08 % Pd;

25) F-25 titanium alloy (6 % Al, 4 % V) + 0.3 %–0.8 % Ni + 0.04 %–0.08 % Pd;

26) F-26 commercially unalloyed titanium + 0.08 %–0.14 % Ru;

27) F-26H commercially unalloyed titanium + 0.08 %–0.14 % Ru [minimum tensile strength 400 MPa (58 ksi) of F-26];

28) F-27 commercially unalloyed titanium + 0.08 %–0.14 % Ru;

29) F-28 titanium alloy (3 % Al, 2.5 % V) + 0.08 %–0.14 % Ru;

30) F-29 titanium alloy (6 % Al, 4 % V), extra low interstitial (ELI) + 0.08 %–0.14 % Ru;

31) F-30 titanium alloy (0.3 % Co, 0.05 % Pd);

32) F-31 titanium alloy (0.3 % Co, 0.05 % Pd);

33) F-32 titanium alloy (5 % Al, 1 % V, 1 % Sn, 1 % Zr, 0.8 % Mo);

34) F-33 titanium alloy (0.4 % Ni, 0.015 % Pd, 0.025 % Ru, 0.15 % Cr);

35) F-34 titanium alloy (0.4 % Ni, 0.015 % Pd, 0.025 % Ru, 0.15 % Cr);

36) F-35 titanium alloy (4.5 % Al, 2 % Mo, 1.6 % V, 0.5 % Fe, 0.3 % Si);

37) F-36 titanium alloy (45 % Nb);

38) F-37 titanium alloy (1.5 % Al);

39) F-38 titanium alloy (4 % Al, 2.5 % V, 1.5 % Fe).

1.2 Values are stated in SI units; inch-pound values given in parentheses are for information only.

2 Normative references

The following documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ASTM B 348 Standard Specification for Titanium and Titanium Alloy Bars and Billets

ASTM E 8 Test Methods for Tension Testing of Metallic Materials

ASTM E 29 Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

ASTM E 120 Test Methods for Chemical Analysis of Titanium and Titanium Alloys

ASTM E 1409 Test Method for Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique

ASTM E 1447 Test Methods for Hydrogen Determination in Titanium and Titanium Alloys by Inert Gas Fusion Thermal Conductivity/Infrared Detection

3 Terms and definitions

3.1 bar, n—semifinished solid product of rectangular cross-section whose area is less than 10 323 mm^2 (16 in^2), produced by hot rolling, hot forging, or cold working.

3.2 billet, n—semifinished solid product of rectangular cross-section whose area is 10 323 mm^2 (16 in^2) or greater, produced by hot rolling or hot forging from an ingot.

3.3 forging, n—product of a predetermined shape produced by hammering, pressing, upsetting, or similar forming equipment.

4 Purchase information

Orders for material under this specification shall include the following, as applicable:

a) alloy grade (see Clause 1);

b) tensile properties (see Table 1);

c) dimensions and permissible tolerances (see Clause 9);

d) sampling and mechanical properties (see Clause 7);

e) chemical composition (see Clause 6);

f) marking (see Clause 16);

g) packaging (see Clause 16);

h) certification (see Clause 15);

i) disposition of rejected material (see Clause 13);

j) special requirements (see Appendix A).

Table 1 Tensile requirements

Grade	Tensile strength, min		Yield strength, min or range		Elongation, % 4d, min	Reduction of area, % min
	MPa	(ksi)	MPa	(ksi)		
F-1	240	(35)	138	(20)	24	30
F-2	345	(50)	275	(40)	20	30
F-2H	400	(58)	275	(40)	20	30
F-3	450	(65)	380	(55)	18	30
F-4	550	(80)	483	(70)	15	25
F-5	895	(130)	828	(120)	10	25
F-6	828	(120)	795	(115)	10	25
F-7	345	(50)	275	(40)	20	30
F-7H	400	(58)	275	(40)	20	30
F-9	828	(120)	759	(110)	10	25
F-9 d	620	(90)	483	(70)	15	25
F-11	240	(35)	138	(20)	24	30
F-12	483	(70)	345	(50)	18	25
F-13	275	(40)	170	(25)	24	30
F-14	410	(60)	275	(40)	20	30
F-15	483	(70)	380	(55)	18	25
F-16	345	(50)	275	(40)	20	30
F-16H	400	(58)	275	(40)	20	30
F-17	240	(35)	138	(20)	24	30
F-18	620	(90)	483	(70)	15	25
F-18 d	620	(90)	483	(70)	12	20
F-19 e	793	(115)	759	(110)	15	25
F-19 f	930	(135)	897–1 096	(130–159)	10	20
F-19 g	1 138	(165)	1 104–1 276	(160–185)	5	20
F-20 e	793	(115)	759	(110)	15	25
F-20 f	930	(135)	897–1 096	(130–159)	10	20
F-20 g	1 138	(165)	1 104–1 276	(160–185)	5	20
F-21 e	793	(115)	759	(110)	15	35
F-21 f	966	(140)	897–1 096	(130–159)	10	30
F-21 g	1 172	(170)	1 104–1 276	(160–185)	8	20
F-23 e	828	(120)	759	(110)	10	25
F-23 d	828	(120)	759	(110)	7.5 h, 6.0 i	25
F-24	895	(130)	828	(120)	10	25
F-25	895	(130)	828	(120)	10	25
F-26	345	(50)	275	(40)	20	30
F-26H	400	(58)	275	(40)	20	30
F-27	240	(35)	138	(20)	24	30
F-28	620	(90)	483	(70)	15	25
F-28 d	620	(90)	483	(70)	12	20

Grade	Tensile strength, min		Yield strength, min or range		Elongation, % 4d, min	Reduction of area, % min
	MPa	(ksi)	MPa	(ksi)		
F-29	828	(120)	759	(110)	10	25
F-29 d	828	(120)	759	(110)	7.5 h, 6.0 i	15
F-30	345	(50)	275	(40)	20	30
F-31	450	(65)	380	(55)	18	30
F-32	689	(100)	586	(85)	10	25
F-33	345	(50)	275	(40)	20	30
F-34	450	(65)	380	(55)	18	30
F-35	895	(130)	828	(120)	5	20
F-36	450	(65)	410–655	(60–95)	10	—
F-37	345	(50)	215	(31)	20	30
F-38	895	(130)	794	(115)	10	25

NOTE a These values apply to forgings having a cross-sectional area not greater than 1 935 mm² (3 in.²); for forgings over this area, the values shall be agreed upon between the manufacturer and the purchaser.
b These materials differ from the corresponding regular grades only in having a higher minimum tensile strength requirement. Grades F-2H, F-7H, F-16H and F-26H are intended principally for pressure-vessel service.
c The H grades have been added to meet the requirements of the Pressure Vessel Research Council. That Council evaluated reports on 5 200 commercial heats for Grades 2, 7, 16 and 26; over 99 % had a minimum tensile strength greater than 400 MPa (58 ksi).
d Beta-annealed product.
e Solution-treated product.
f Solution-treated plus aged product — intermediate strength (depending on aging temperature).
g Solution-treated plus aged product — high strength (depending on aging temperature).
h Applies to product having a section or wall thickness less than 25.4 mm (1.0 in.).
i Applies to product having a section or wall thickness not greater than 25.4 mm (1.0 in.).
***** Tensile strengths for Grades F-3 and F-4 have been revised.

5 Raw materials and manufacture

Raw material shall be forged from material conforming to the latest revision of Specification B 348.

6 Chemical composition

6.1 The chemical composition for the titanium and titanium alloy grades listed in this standard shall conform to the requirements prescribed in Table 2.

6.1.1 The elements listed in Table 2 are those intentionally added as alloying elements, or those normally present in sponge titanium, ingot, and mill products. Other elements may be present in the corresponding grade designation but need not be analyzed or reported. Elements not listed in Table 2 need not be analyzed unless otherwise specified and considered outside the scope of this standard.

6.1.2 Elements intentionally added shall be identified, analyzed, and reported.

6.2 When a special analysis is specified in the purchase order, the elements not listed in this standard shall be analyzed.

6.3 Product analysis tolerances shall not extend beyond the specified heat analysis limits; they shall cover only the normal variations found between laboratories. Material whose composition falls outside the limits specified in Table 2 shall not be shipped. Product analysis tolerances are given in Table 3.

6.4 Samples for chemical analysis shall represent the material tested. Results shall be furnished except for hydrogen, unless otherwise specified, for ingots and billets. Hydrogen specimens shall be taken from forgings based on test requirements, and the frequency shall be agreed upon between the manufacturer and the purchaser. Because titanium has a strong affinity for oxygen, nitrogen, and hydrogen, the most stringent precautions shall be taken during sampling and processing. Samples shall be taken from clean metal.

6.5 The test methods used shall be, as far as possible, in agreement with those prescribed in Test Methods E 120, E 1409, and E 1447, unless otherwise agreed upon between the manufacturer and the purchaser.

6.6 Chemical analysis shall be made on at least two samples; two samples shall be taken from each end of the product under test.

Table 2 Chemical composition requirements, %

Element	F-1	F-2	F-2H	F-3	F-4	F-5	F-6	F-7	F-7H	F-9	F-11	F-12
N, max	0.03	0.03	0.03	0.05	0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.03
C, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
H b,c, max	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Fe, max	0.20	0.30	0.30	0.30	0.50	0.40	0.50	0.30	0.30	0.25	0.20	0.30
O, max	0.18	0.25	0.25	0.35	0.40	0.20	0.20	0.25	0.25	0.15	0.18	0.25
Al	—	—	—	—	—	5.5–6.75	4.0–6.0	—	—	2.5–3.5	—	—
V	—	—	—	—	—	3.5–4.5	—	—	—	2.0–3.0	—	—
Sn	—	—	—	—	—	—	2.0–3.0	—	—	—	—	—
Ru	—	—	—	—	—	—	—	—	—	—	—	—
Pd	—	—	—	—	—	—	—	0.12–0.25	0.12–0.25	—	0.12–0.25	—
Co	—	—	—	—	—	—	—	—	—	—	—	—
Mo	—	—	—	—	—	—	—	—	—	—	—	0.2–0.4
Cr	—	—	—	—	—	—	—	—	—	—	—	—
Ni	—	—	—	—	—	—	—	—	—	—	—	0.6–0.9
Nb	—	—	—	—	—	—	—	—	—	—	—	—
Resid. each d,e,f, max	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Resid. total d,e,f, max	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Ti g	remainder	remainder	remainder	remainder	remainder	remainder	remainder	remainder	remainder	remainder	remainder	remainder

Element	F-13	F-14	F-15	F-16	F-16H	F-17	F-18	F-19	F-20	F-21	F-23
N, max	0.03	0.03	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

Element	F-13	F-14	F-15	F-16	F-16H	F-17	F-18	F-19	F-20	F-21	F-23
C, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.05	0.05	0.05	0.08
H b,c, max	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.02	0.02	0.015	0.0125
Fe, max	0.20	0.30	0.30	0.30	0.30	0.20	0.25	0.30	0.30	0.40	0.25
O, max	0.10	0.15	0.25	0.25	0.25	0.18	0.15	0.12	0.12	0.17	0.13
Al	—	—	—	—	—	—	—	2.5–3.5	3.0–4.0	4.0–5.0	2.5–3.5
V	—	—	—	—	—	—	—	7.5–8.5	7.5–8.5	—	3.5–4.5
Sn	—	—	—	—	—	—	—	—	—	2.5–3.5	—
Ru	0.04–0.06	0.04–0.06	0.04–0.06	—	—	—	—	—	—	—	—
Pd	—	—	—	0.04–0.08	0.04–0.08	0.04–0.08	0.04–0.08	—	0.04–0.08	—	—
Co	—	—	—	—	—	—	—	—	—	14.0–16.0	—
Mo	—	—	—	—	—	—	—	3.5–4.5	3.5–4.5	—	—
Cr	—	—	—	—	—	—	—	5.5–6.5	5.5–6.5	—	—
Ni	0.4–0.6	0.4–0.6	0.4–0.6	—	—	—	—	—	—	—	—
Nb	—	—	—	—	—	—	—	—	—	2.2–3.2	—
Zr	—	—	—	—	—	—	—	3.5–4.5	3.5–4.5	—	—
Si	—	—	—	—	—	—	—	—	—	0.15–0.25	—
Resid. each d,e,f, max	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.15	0.1	0.1
Resid. total d,e,f, max	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Ti g	remainder	remainder	remainder	remainder	remainder	remainder	remainder	remainder	remainder	remainder	remainder

ement	F-24	F-25	F-26	F-26H	F-27	F-28	F-29	F-30	F-31	F-32	F-33	F-34	F-35	F-36	F-37	
max	0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.05	0.03	0.03	0.05	0.05	0.03	0.03	
max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.04	0.08	0.08	
,c, max	0.015	0.0125	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.0035	0.015	0.015	
, max	0.40	0.40	0.30	0.30	0.20	0.25	0.25	0.30	0.30	0.25	0.30	0.30	0.20–0.80	0.03	0.30	
, max	0.20	0.20	0.25	0.25	0.18	0.15	0.13	0.25	0.35	0.11	0.25	0.35	0.25	0.16	0.25	0
Al	5.5–6.75	5.5–6.75	—	—	—	2.5–3.5	5.5–6.5	—	—	4.5–5.5	—	—	4.0–5.0	—	1.0–2.0	
V	3.5–4.5	3.5–4.5	—	—	—	2.0–3.0	3.5–4.5	—	—	0.6–1.4	—	—	1.1–2.1	—	2.0–3.0	
Sn	—	—	—	—	—	—	—	—	—	0.6–1.4	—	—	—	—	—	
Ru	—	—	0.08–0.14	0.08–0.14	0.08–0.14	0.08–0.14	0.08–0.14	—	—	—	0.02–0.04	0.02–0.04	—	—	—	
Pd	0.04–0.08	0.04–0.08	—	—	—	—	—	0.04–0.08	0.04–0.08	—	0.01–0.02	0.01–0.02	—	—	—	
Co	—	—	—	—	—	—	—	0.20–0.80	0.20–0.80	—	—	—	—	—	—	
Mo	—	0.3–0.8	—	—	—	—	—	—	—	0.6–1.2	—	—	1.5–2.5	—	—	
Cr	—	—	—	—	—	—	—	—	—	—	0.1–0.2	0.1–0.2	—	—	—	
Ni	—	0.3–0.8	—	—	—	—	—	—	—	—	—	0.35–0.55	0.35–0.55	—	—	
Nb	—	—	—	—	—	—	—	—	—	—	—	—	—	42.0–47.0	—	
Zr	—	—	—	—	—	—	—	—	—	0.6–1.4	—	—	—	—	—	
Si	—	—	—	—	—	—	—	—	—	0.06–0.14	—	—	0.20–0.40	—	—	
ch d,e,f, max	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
tal d,e,f, max	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	
Ti g	remainder	remainder	remainder	remainder	remainder	remainder	remainder	remainder	remainder	remainder	remainder	remainder	remainder	remainder	remainder	re

a For each grade listed above, the content of all elements shall be analyzed. Elements for which no content is indicated need not be reported, provided the content of each element does not exceed 0.1 % or the total exceeds 0.4 %.
b With the agreement of the supplier, the hydrogen content may be reduced.
c Product analysis on the finished product.
d Need not be reported.
e Residuals are minor elements present in the metal or alloy; they are inherent in the production of the material rather than being added. Residual elements in unalloyed titanium include Al, V, Sn, Cr, Mo, Nb, Zr, Fe, Ni, Cu, Si, Co.

f If the purchaser requires analysis of residual elements other than those listed in this standard, it shall be stated in the written purchase order.
g The proportion of titanium may be determined by difference.

Table 3 Product analysis tolerances

Element	Product analysis limit, % (max or range)	Product analysis tolerance
Al	0.5–2.5	±0.20
Al	2.5–6.75	±0.40
C	0.10	+0.02
Cr	0.1–0.2	±0.02
Cr	5.5–6.5	±0.30
Co	0.2–0.8	±0.05
H	0.02	+0.002
Fe	0.80	+0.15
Fe	1.2–1.8	±0.20
Mo	0.2–0.4	±0.03
Mo	0.6–1.2	±0.15
Mo	1.5–4.5	±0.20
Mo	14.0–16.0	±0.50
Ni	0.3–0.9	±0.05
Nb	2.2–3.2	±0.15
Nb	≥30	±0.50
N	0.05	+0.02
O	0.30	+0.03
O	0.31–0.40	±0.04
Pd	0.01–0.02	±0.002
Pd	0.04–0.08	±0.005
Pd	0.12–0.25	±0.02
Ru	0.02–0.04	±0.005
Ru	0.04–0.06	±0.005
Ru	0.08–0.14	±0.01
Si	0.06–0.40	±0.02
Sn	0.6–3.0	±0.15
V	0.6–4.5	±0.15
V	7.5–8.5	±0.40
Zr	0.6–1.4	±0.15
Zr	3.5–4.5	±0.20
Residual* (each)	0.15	+0.02

***** Residuals are minor elements present in the metal or alloy; they are inherent in the production of the material rather than being added. Residual elements in unalloyed titanium include Al, V, Sn, Cr, Mo, Nb, Zr, Fe, Ni, Cu, Si, Co.

7 Mechanical properties

7.1 When the forgings are supplied as specified in this standard, their mechanical properties shall conform to the requirements of Table 1.

7.2 Tension-test specimens shall be prepared and tested in accordance with Test Methods E 8. The rate of stressing prior to reaching the yield strength shall be 0.000 05 mm/mm·s to 0.000 12 mm/mm·s (0.003 in./in./min to 0.007 in./in./min); after yielding, the strain rate shall be increased so that the specimen fractures in approximately 60 s.

7.3 Tension specimens shall be taken from material agreed upon between the manufacturer and the purchaser.

8 Nondestructive testing

Nondestructive inspection, such as ultrasonic, radiographic, or surface inspection, shall be at the purchaser's option; the acceptance criteria shall be agreed upon between the manufacturer and the purchaser.

9 Dimensions and permissible tolerances

Dimensions and tolerances for the titanium and titanium alloy forgings specified in this standard shall conform to the forging drawing requirements, or shall be as agreed upon between the manufacturer and the purchaser.

10 Surface quality

Titanium and titanium alloy forgings shall be free of harmful internal and external defects that would impair the intended use. Annealed forgings shall be descaled and, when specified, sandblasted or ground. The manufacturer may, at the manufacturer's option, remove minor surface defects by local grinding, provided the minimum forging thickness tolerance is not exceeded.

11 Retest

If the chemical composition or mechanical property test results from a lot of forgings do not conform to the requirements of this standard, the manufacturer may retest the lot. Two specimens shall be tested; if the retest results conform, the lot shall be accepted, and the results of both the initial and retest tests shall be reported to the purchaser. If the retest results still do not conform to the requirements of this standard, the lot shall be rejected in accordance with Clause 13.

12 Rounding method

To determine conformance with this standard, observed or calculated values shall be rounded off to the nearest unit in the last right-hand digit used in expressing the specification limit. Rounding shall be in accordance with Practice E 29.

13 Rejection

Forgings failing to conform to this standard or to other approved revision requirements shall be rejected. Unless otherwise agreed, rejected forgings shall be returned to the manufacturer at the purchaser's expense.

14 Arbitration test and analysis

In case of dispute between the manufacturer and the purchaser as to whether the test results conform to the requirements of this standard, testing shall be conducted by an mutually agreed arbitration agency; the test results shall serve as the basis for determining conformance.

15 Certification

When specified in the purchase order, the manufacturer shall furnish at least one copy of a test report certifying that the forgings have been tested and examined in accordance with this standard, and that the chemical composition and mechanical property test results conform to the requirements for the applicable grade.

16 Packaging and marking

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

16.2 Marking—Forgings shall be marked as agreed upon between the manufacturer and the purchaser.

Appendix A
(Informative)
Additional requirements for F-3 titanium alloy forgings

The following additional requirements are primarily U.S. military requirements and apply only when specified in the purchaser's contract or order.

A.1 U.S. military requirements

A.1.1 Referenced documents are listed as attachments.

A.1.2 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for performing all inspection and testing required by this standard. Inspection and testing may be performed on the manufacturer's own equipment or on other suitable equipment.

A.1.3 Chemical composition for grade F-3 shall be adjusted as follows:

Hydrogen ≤ 0.012 5

Iron ≤ 0.20

Oxygen ≤ 0.26

A.1.4 For forgings weighing 56.70 kg (125 lb) or less, two tension specimens shall be taken from each lot; for forgings over 56.70 kg (125 lb), two tension specimens shall be taken from each forging to verify conformance with the mechanical property requirements of Table 1. Forgings of the same heat lot, design, and size produced in the same heat-treat furnace shall constitute one lot. Specimens shall be taken from a continuous extended length or from an oversize forging supplied by the forging producer. Forgings with a section less than 90 mm (3.5 in.) may be sampled on a separate forging test bar of equivalent thickness and same forging process; for forgings over 90 mm (3.5 in.), an oversize forging shall be provided as a sample, taken not from a continuous extended length nor from piercing discard, but from the largest cross-section of the forging. The longitudinal axis of the tension specimen shall be parallel to the principal direction of metal flow.

A.1.5 Repair welding is not permitted.

A.1.6 Each forging shall be subjected to full-volume ultrasonic inspection in accordance with MIL-STD-2154. The forging shall be machined to the ultrasonic-inspection configuration specified on the forging drawing, and ultrasonic inspection shall also be performed after drilling, keyway cutting, taper machining, and recess machining, and before machining to the final contour. Straight-beam inspection shall be used to ensure that all major planes are scanned. Disc forgings shall be scanned with a straight beam from at least one plane and, if possible, also in the radial direction. Round, ring, and hollow forgings shall be scanned with a straight beam from all external surfaces, and the axial scan shall be performed at the maximum allowable beam intensity. The corresponding basis for rejection shall be Class A of MIL-STD-2154.

A.1.7 All surfaces of each forging shall be subjected to penetrant inspection in accordance with NAVSEA T9074-AS-GIB-010/271, and the corresponding basis shall be the NAVSEA S9074-AR-GIB-010/278 requirements specified in the order.

A.1.8 Forgings shall be free of foreign matter and of surface contamination such as sulfur, lead, identification paint, cutting fluid, or forming lubricant. Forgings shall be cleaned prior to heat treatment. The forging surface shall be free of alpha case.

A.1.9 The mechanical properties of each submitted lot shall be represented by first-article forgings that also conform to the order requirements (including the test arrangement, acceptance of test results, and disposition of first-article samples). The number of test specimens, their sampling locations, and the corresponding acceptance basis shall be agreed upon and clearly specified by the manufacturer and the purchaser. In addition, the entire cross-section shall be subjected to low-magnification etching in accordance with ASTM E 340 and examined at 10× magnification for uniformity, soundness, grain size, and flow lines. The macro-etched transverse section shall be selected from a relatively uniform, sound area, and shall be free of cracks and porosity. The forging structure shall be clearly defined, and variations in grain size shall not affect the ultrasonic inspection.

The manufacturer shall retain the production process records for the first-article forgings. For the same or follow-on orders, when a change occurs in the production process, the manufacturer shall notify the purchaser and obtain purchaser approval of the change. The manufacturer shall perform first-article inspection and testing to demonstrate that the process change has not resulted in degradation of forging quality.

A.1.10 Raw material shall be by electron-beam and/or plasma melting, or by multiple remelts, at least one of which shall be performed in a vacuum.

A.2 Referenced standards

A.2.1 ASTM standards

E340 Macroetch Testing for Metals and Alloys

A.2.2 Military standards

T9074-AS-GIB-010/271 Nondestructive Test Method Requirements

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

MIL-STD-2154 Ultrasonic Inspection Method for Wrought Metals

Appendix B
(Informative)
Cross-reference of titanium grades

In the application of this standard, the grades and chemical composition in Table 2 may be cross-referenced with the material grades in GB/T 3620.1—2007, *Titanium and Titanium Alloy Grades and Chemical Composition*.

Table B.1 Cross-reference between this standard and GB/T 3620.1—2007

Grade in this standard	GB/T 3620.1—2007 grade	Grade in this standard	GB/T 3620.1—2007 grade
F-1	TA1	F-16	TA8
F-2	TA2	F-16H	TA8
F-2H	TA2	F-17	TA8-1
F-3	TA3	F-18	TA25
F-4	TA4	F-24	TC22
F-5	TC4	F-26	TA27
F-7	TA9	F-26H	TA27
F-7H	TA9	F-27	TA27-1
F-11	TA9-1	F-28	TA26
F-12	TA10		

Note The residual Fe of grade F-5 in this standard is ≤0.40 %, while the residual Fe of grade TC4 in GB/T 3620.1—2007 is ≤0.30 %; all other chemical compositions are identical.