Designation: A646/A646M – 17 (Reapproved 2022)

Standard Specification for Premium Quality Alloy Steel Blooms and Billets for Aircraft and Aerospace Forgings[1]

This standard is issued under the fixed designation A646/A646M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers premium quality alloy steel semifinished rolled or forged blooms and billets for reforging into critical parts such as aircraft landing-gear forgings.

1.2 Blooms and billets, hereinafter referred to as blooms, are semifinished steel products, hot rolled or forged to approximate cross-sectional dimensions. Blooms may be square, round, hexagonal, octagonal, or rectangular in section. For the purposes of this specification, minimum bloom section size will be 16 in.^{2} [103 cm^2].

1.3 This specification covers two basic classifications of steel:

1.3.1 *Class I*—Vacuum-induction melted or consumable-electrode vacuum melted, or other suitable processes which will satisfy the quality requirements of this specification.

1.3.2 *Class II*—Air-melted vacuum degassed.

1.3.3 *Class III*—Air melted electric furnace ladle refined and vacuum degassed.

1.4 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as standard. Within the text and tables, the SI units are shown in brackets. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.5 Unless the order specifies the applicable "M" specification the material shall be furnished to the inch-pound units.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A255 Test Methods for Determining Hardenability of Steel

A388/A388M Practice for Ultrasonic Examination of Steel Forgings

A788/A788M Specification for Steel Forgings, General Requirements

A604/A604M Practice for Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets

E45 Test Methods for Determining the Inclusion Content of Steel

E114 Practice for Ultrasonic Pulse-Echo Straight-Beam Contact Testing

E214 Practice for Immersed Ultrasonic Testing by the Reflection Method Using Pulsed Longitudinal Waves (Withdrawn 2007)[3]

E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E428 Practice for Fabrication and Control of Metal, Other than Aluminum, Reference Blocks Used in Ultrasonic Testing (Withdrawn 2019)[3]

2.2 *AMS Standards:* [4]

AMS 2300 Steel Cleanliness, Premium-Quality

AMS 2301 Steel Cleanliness, Aircraft-Quality

AMS 2304 Steel Cleanliness, Special Aircraft-Quality

3. Terminology

3.1 In addition to the terminology requirements of Specification A788/A788M, the following terms that are specific to this specification apply:

3.2 *Definitions:*

3.2.1 *air-melted vacuum-degassed steel*—arc- or induction-furnace-melted steel that is vacuum treated immediately prior to or during the operation of pouring the ingot.

[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 A01.06 on Steel Forgings and Billets.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

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

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

3.2.2 *consumable-electrode vacuum-remelted steel*—metal that has been remelted into a crucible in vacuum from single or multiple electrodes.

3.2.3 *electroslag-melted steel*—metal that has been remelted into a crucible from single or multiple electrodes utilizing an electrical discharge through molten slag as a source of heat.

3.2.3.1 *Discussion*—For the purposes of this specification the parent heat from which any electrode for remelting by the electroslag process has been produced shall have been either melted under vacuum or vacuum degassed immediately prior to or during pouring of the heat.

3.2.4 *vacuum induction melted steel*—metal that has been melted, refined, and poured from an induction furnace operating under vacuum.

4. Ordering Information and General Requirements

4.1 Material supplied to this specification shall conform to the requirements of Specification A788/A788M, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

4.1.1 If the requirements of this specification are in conflict with the requirements of Specification A788/A788M, the requirements of this specification shall prevail.

4.2 In addition to the ordering requirements of Specification A788/A788M, the following information should be supplied by the purchaser:

4.2.1 Class designation (see 1.3),

4.2.2 Quality level (Table 1), grade designation (Table 2), or detailed chemistry for nonstandard grades,

4.2.3 Desired billet or bloom size,

4.2.4 Weight or quantity and length,

4.2.5 Minimum forging reduction required if ordered size exceeds 225 in.^{2} [1450 cm^2] (see 5.2.2),

4.2.6 Annealing, if required (see 5.3.2),

4.2.7 Macroetch standards of acceptance (see 7.1),

4.2.8 Microcleanliness standards of acceptance (see 7.2),

4.2.9 Specific ultrasonic examination requirements, such as transducer type and size, whether contact or immersion preferred, level of reportable discontinuities and any special surface finish requirements.

4.2.10 Hardenability standards of acceptance (see 8.1), and

4.2.11 Any supplementary requirements desired.

5. Manufacture

5.1 *Melting Practice:*

TABLE 1 Maximum Permissible Discontinuities in Ultrasonic Examination

Quality Level	Response, in. [mm]		Stringers, Length in. [mm]
	Single Discontinuities	Multiple Discontinuities	
AA	3/64 [1.0]	2/64 [0.8]	2/64 –1/2 [1.0–12.0]
A	5/64 [2.0]	3/64 [1.0]	3/64 –1 [1.0–25]
B	8/64 [3.0]	5/64 [2.0]	5/64 –1 [2.0–25]
C	12/64 [5.0]	8/64 [3.0]	8/64 –1 [3.0–25]

5.1.1 The steel making provisions of Specification A788/A788M shall apply, except for the following modifications;

5.1.1.1 Class I material shall be manufactured by the vacuum-induction-melting process or by the consumable-electrode vacuum-melting (VAR) process. By agreement other processes such as electroslag or electron-beam melting may be considered acceptable.

5.1.1.2 Class II material shall be manufactured by an electric-furnace vacuum-degassed process.

5.1.1.3 Class III material shall be manufactured by the electric furnace process with ladle refining and vacuum degassing.

5.2 *Hot-Working Procedure:*

5.2.1 Blooms may be either hot rolled or forged.

5.2.2 Blooms having cross-sectional areas ranging from 16 in.^{2} to 225 in.^{2} [100 cm^2 to 1450 cm^2] when made from air-melt ingots shall have at least 2 to 1 reduction of area from ingot to bloom. On blooms exceeding 225 in.^{2} [1450 cm^2] forging reduction requirements shall be by agreement. Ingot-to-final forging reduction is not included in this requirement.

5.3 *Heat Treatment:*

5.3.1 Unless otherwise specified all material purchased to this specification will be furnished in the as forged or rolled (untreated) condition. In this condition some grades may not be soft enough for cold sawing, and may be prone to cracking.

5.3.2 When specified, the material may be ordered annealed or normalized and tempered to a maximum Brinell Hardness, as specified in Table 2 or by agreement.

5.3.3 Material shall be furnished in condition to withstand, for an indefinite time, exposure to all climatic conditions without developing any external or internal cracks. The method of cooling after hot working or of heat treatment before shipment shall be optional with the manufacturer, who shall be responsible (in the same manner as for discontinuities disclosed after delivery) for cracks which may develop before material is subjected to reheating. When a specific heat treatment or conditioning of material is specified by the purchaser, the manufacturer shall be responsible only for carrying out those specific operations and not for any cracking that may subsequently develop.

6. Chemical Requirements

6.1 *General Requirements:*

6.1.1 Table 2 lists standard grades of alloy steel that are currently produced in premium quality; however, it is not the intent of this specification to restrict application only to the materials listed in Table 2.

6.1.2 When a standard grade is ordered, the analysis shall conform to the requirements as to chemical composition prescribed in Table 2 for the ordered grade.

6.1.3 The steel, when ordered to other than a standard analysis, shall conform to the requirements of the order.

6.2 *Heat Analysis:*

6.2.1 The heat analysis obtained from sampling in accordance with Specification A788/A788M shall comply with Table 2 for standard grades, or to the requirements of the order.

TABLE 2 Chemical and Hardness Requirements[A]

Proprietary Name or Grade	Grade No.	Composition, %										Maximum Annealed Brinell Hardness
		Carbon	Manga-nese	Phos-phorus	Sulfur	Silicon	Nickel	Chro-mium	Molyb-denum	Vana-dium	Others	
3310	1	0.08–0.13	0.45–0.60	0.015max	0.012 max	0.20–0.35	3.25–3.75	1.40–1.75	. . .	. . .	. . .	262
9310	2	0.08–0.13	0.45–0.65	0.015 max	0.012 max	0.20–0.35	3.00–3.50	1.00–1.40	0.08–0.15	. . .	. . .	262
4620	3	0.17–0.22	0.45–0.65	0.015 max	0.012 max	0.20–0.35	1.65–2.00	. . .	0.20–0.30	. . .	. . .	229
8620	4	0.18–0.23	0.70–0.90	0.015max	0.012 max	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	. . .	. . .	229
4330 Mod.	5	0.28–0.33	0.75–1.00	0.015 max	0.012 max	0.20–0.35	1.65–2.00	0.70–0.95	0.35–0.50	0.05–0.10	. . .	285
4335 Mod.	6	0.33–0.38	0.60–0.90	0.015 max	0.012 max	0.40–0.60	1.65–2.00	0.65–0.90	0.30–0.40	0.17–0.23	. . .	285
4340	7	0.38–0.43	0.65–0.85	0.015 max	0.012 max	0.20–0.35	1.65–2.00	0.70–0.90	0.20–0.30	. . .	. . .	285
300 M	8	0.38–0.43	0.65–0.90	0.012 max	0.012 max	1.45–1.80	1.65–2.00	0.70–0.95	0.35–0.45	0.05–0.10	. . .	285
D6AC	9	0.45–0.50	0.60–0.90	0.010 max	0.010 max	0.15–0.30	0.40–0.70	0.90–1.20	0.90–1.10	0.08–0.15	. . .	285
H-11	10	0.38–0.43	0.20–0.40	0.015 max	0.015 max	0.80–1.00	. . .	4.75–5.25	1.20–1.40	0.40–0.60	. . .	235
4130	11	0.28–0.33	0.40–0.60	0.015 max	0.012 max	0.20–0.35	. . .	0.80–1.10	0.15–0.25	. . .	. . .	229
4140	12	0.38–0.43	0.75–1.00	0.015 max	0.012 max	0.20–0.35	. . .	0.80–1.10	0.15–0.25	. . .	. . .	235
98BV40	13	0.40–0.46	0.75–1.00	0.015 max	0.012 max	0.50–0.80	0.60–0.90	0.80–1.05	0.45–0.60	0.01–0.06	0.0005 min, Boron	285
6150	14	0.48–0.53	0.70–0.90	0.015 max	0.012 max	0.20–0.35	. . .	0.80–1.10	. . .	0.15 min	. . .	235
52100	15	0.98–1.10	0.25–0.45	0.015 max	0.010 max	0.20–0.35	. . .	1.30–1.60	. . .	. . .	. . .	302
HP 9-4-20	16	0.17–0.23	0.20–0.40	0.010 max	0.010 max	0.10 max	8.5–9.5	0.65–0.85	0.90–1.10	0.06–0.12	Co 4.25–4.75	341
HP 9-4-30	17	0.29–0.34	0.10–0.35	0.010 max	0.010 max	0.10 max	7.0–8.0	0.90–1.10	0.90–1.10	0.06–0.12	Co 4.25–4.75	341
Marage 200	18	0.03 max	0.10 max	0.010 max	0.010 max	0.10 max	17.0–19.0	. . .	3.0–3.50	. . .	Co 8.0–9.0 Ti 0.10–0.25 Al 0.05–0.15 B, Zr, Ca added	321
Marage 250	19	0.03 max	0.10 max	0.010 max	0.010 max	0.10 max	17.0–19.0	. . .	4.6–5.2	. . .	Co 7.0–8.5 Ti 0.30–0.50 Al 0.05–0.15 B, Zr, Ca added	321
Marage 300	20	0.03 max	0.10 max	0.010 max	0.010 max	0.10 max	18.0–19.0	. . .	4.7–5.2	. . .	Co 8.5–9.5 Ti 0.50–0.80 Al 0.05–0.15 B, Zr, Ca added	321
Nit. 135	21	0.38–0.43	0.50–0.70	0.015 max	0.012 max	0.20–0.40	. . .	1.40–1.80	0.30–0.40	. . .	Al 0.95–1.30	285

[A] If any of the following elements are not specified, the following maximum limits shall apply: Nickel 0.35 %; Chromium 0.20 %; Molybdenum 0.06 %; Copper 0.35 %.

6.3 *Product Analysis:*

6.3.1 The purchaser may use the product analysis provision of Specification A788/A788M to obtain a product analysis from a billet or bloom representing each heat or multiple heat.

7. Quality Evaluation Tests

7.1 *Macroetch*—Macroetch inspection shall be required for all material furnished to this specification. Samples representing the top and bottom of each ingot shall be examined. Macroetching shall be performed in accordance with Method E381 and Practice A604/A604M, as applicable. Standards of acceptance shall be specified by the purchaser in the order.

7.2 *Microcleanliness*—All material furnished to this specification shall be inspected for microcleanliness. At least one sample shall be removed from a location midway between the center and outside surface representing the top and bottom of the first and last ingots of each heat or from an ingot from each plate for bottom poured ingots. For blooms produced from continually cast material the samples shall represent the beginning and end of each strand produced from the heat. The specimens shall be prepared and rated by the procedure described in Method A of Test Methods E45. The polished face shall be longitudinal to the direction of maximum hot working. All specimens shall be prepared and rated in accordance with Test Methods E45, using Method D (Modified JK Chart) for Class I steel and Method A (JK Chart) for Classes II and III steel. Standards of acceptance shall be specified by the purchaser in the order.

7.3 *Nondestructive Testing, Ultrasonic Inspection:*

7.3.1 *General:*

7.3.1.1 All material ordered to this specification shall be subjected to ultrasonic examination. Inspection may be performed by either the immersion or the contact method providing that the manufacturer can ensure adequate resolution of the applicable reference standards with the chosen method.

7.3.1.2 The usage of reference blocks containing flat-bottomed holes for calibration is the preferred method for evaluation of discontinuity size up to billet cross-sectional dimensions of approximately 12 in. [300 mm]. With larger sizes, it is recognized that reference block fabrication becomes difficult and in general a back reflection method of calibration can be used as an alternative as referenced in 7.3.6.3.

7.3.2 *Immersion Examination Procedure*—This method is recommended for material where the cross-sectional dimension to be inspected is less than approximately 8 in. [200 mm]. Material inspected by the immersion method shall be performed in accordance with the procedure outlined in Practice E214.