



Designation: ~~A646/A646M – 06 (Reapproved 2011)~~ A646/A646M – 06 (Reapproved 2016)

Standard Specification for Premium Quality Alloy Steel Blooms and Billets for Aircraft and Aerospace Forgings¹

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 cm²].

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~~ degassed.

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

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

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 Test Method 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](#)

[E127 Practice for Fabrication and Control of Aluminum Alloy Ultrasonic Standard Reference Blocks](#)

[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](#)

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:

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.

Current edition approved April 1, 2011; March 1, 2016. Published June 2011; April 2016. Originally approved in 1971. Last previous edition approved in 2006; 2011 as ~~A646/A646M – 06~~; ~~A646/A646M – 06 (2011)~~. DOI: ~~10.1520/A0646_A0646M-06R11~~; 10.1520/A0646_A0646M-06R16.

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 ~~15096-0001~~; 15096. <http://www.sae.org>.

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

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.

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 2**), grade designation (**Table 1**), 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 cm²] (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:

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.

TABLE 1 Maximum Permissible Discontinuities in Ultrasonic Examination

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

TABLE 2 Chemical and Hardness Requirements^A

Proprietary-Name or Grade	Grade No.	Composition, %										Maximum Annealed Brinell Hardness
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Vanadium	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 %.

5.2.2 Blooms having cross-sectional areas ranging from 16 to 225 in.² [100 to 1450 cm²] 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 cm²] 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 1** 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 1**.

6.1.2 When a standard grade is ordered, the analysis shall conform to the requirements as to chemical composition prescribed in **Table 1** 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 1** for standard grades, or to the requirements of the order.