



Designation: A 646/A 646M – 04

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

This standard is issued under the fixed designation A 646/A 646M; 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

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 must be used independent 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

A 255 Test Method of End-Quench Test for Hardenability of Steel

A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings

A 788 Specification for Steel Forgings, General Requirements

A 604 Test Method for Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets

E 45 Test Methods for Determining the Inclusion Content of Steel

E 114 Practice for Ultrasonic Pulse-Echo Straight-Beam Testing by the Contact Method

E 214 Practice for Immersed Ultrasonic Examination by the Reflection Method Using Pulsed Longitudinal Waves

E 381 Method for Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings

2.2 *AMS Standards*:³

AMS 2300 Steel Cleanliness, Premium-Quality

AMS 2301 Steel Cleanliness, Aircraft-Quality

AMS 2304 Steel Cleanliness, Special Aircraft-Quality

2.3 *Government Standard*:⁴

MIL-STD-430A Macrograph Standards for Steel Bars, Billets, and Blooms

3. Terminology

3.1 In addition to the terminology requirements of Specification **A 788**, 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.

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

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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 Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

⁴ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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

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 **A 788**, 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 **A 788**, the requirements of this specification shall prevail.

4.2 In addition to the ordering requirements of Specification **A 788**, 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 **A 788** 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 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 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.

6.1.4 Small quantities of certain elements are present in alloy steels which are neither specified nor required. These elements may be present up to the following amounts: copper, 0.35 %; nickel, 0.25 %; chromium, 0.20 %; and molybdenum, 0.06 %.

6.2 *Heat Analysis:*

6.2.1 The heat analysis obtained from sampling in accordance with specification **A 788** shall comply with **Table 1** for standard grades, or to the requirements of the order.

6.3 *Product Analysis:*

6.3.1 The purchaser may use the product analysis provision of Specification **A 788** to obtain a product analysis from a billet or bloom representing each heat or multiple heat.

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]	3/64 -1/2 [1.0-12.0]
A	5/64 [2.0]	3/64 [1.0]	3/64 -1 [1.0-25]
B	5/64 [3.0]	5/64 [2.0]	5/64 -1 [2.0-25]
C	12/64 [5.0]	5/64 [3.0]	5/64 -1 [3.0-25]