Designation: A 646 – 95 (Reapproved 1999)

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

This standard is issued under the fixed designation A 646; 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.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

A 255 Test Method of End-Quench Test for Hardenability of Steel[2]

A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings[2]

A 604 Test Method for Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets[2]

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron and Wrought Iron[3]

E 45 Test Methods for Determining the Inclusion Content of Steel[4]

E 114 Practice for Ultrasonic Pulse-Echo Straight-Beam Testing by the Contact Method[5]

E 127 Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks[5]

E 214 Practice for Immersed Ultrasonic Examination by the Reflection Method Using Pulsed Longitudinal Waves[5]

E 350 Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron[3]

E 381 Method for Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings[4]

2.2 *AMS Standards:*[6]

AMS 2300 Premium Quality Steel Cleanliness, Magnetic Particle, and

AMS 2301 Aircraft Quality Steel Cleanliness.

2.3 *Government Standard:*[7]

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

3. Terminology

3.1 *Definitions:*

3.1.1 *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.

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

3.1.3 *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.

3.1.4 *heat*—for the purpose of this specification, if consumable electrode remelting is employed, all of the remelted ingots produced one parent arc- or induction-melted heat.

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[2] *Annual Book of ASTM Standards*, Vol 01.05.

[3] *Annual Book of ASTM Standards*, Vol 03.05.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

[5] *Annual Book of ASTM Standards*, Vol 03.03.

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

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

3.1.5 *vacuum induction melted steel*—metal that has been melted, refined, and poured from a furnace operating in vacuum.

4. Ordering Information

4.1 When this specification is to be applied to an inquiry, contract, or order, the purchaser shall so state, and shall also furnish the following information:

4.1.1 Class designation (see 1.3),

4.1.2 Quality level (Table 1), grade designation (Table 2), or detailed chemistry (Table 3) for nonstandard grades,

4.1.3 Desired billet or bloom size,

4.1.4 Weight or quantity and length,

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

4.1.6 Annealing, if required (see 5.3.2),

4.1.7 Macroetch standards of acceptance (see 7.1),

4.1.8 Microcleanliness standards of acceptance (see 7.2),

4.1.9 Ultrasonic quality level required (see 7.3.7.1),

4.1.9.1 Also any further restrictions on ultrasonic, such as transducer type and size, whether contact or immersion preferred, level of reportable discontinuities and any special surface finish requirements.

4.1.10 Hardenability standards of acceptance (see 8.1), and

4.1.11 Any supplementary requirements desired.

5. Manufacture

5.1 *Melting Practice*:

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

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

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} (103 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}, 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 untreated condition. In this condition some grades may not be soft enough for cold sawing.

TABLE 1 Maximum Permissible Discontinuities

NOTE 1—See 7.3.

Quality Level	Response, in. (mm)		Stringers, Length in. (mm)
	Single Discontinuities	Multiple Discontinuities	
AA	3/64 (1.2)	2/64 (0.8)	2/64 –1/2 (0.8–12.7)
A	5/64 (2.0)	3/64 (1.2)	3/64 –1 (1.2–25.4)
B	8/64 (3.2)	5/64 (2.0)	5/64 –1 (2.0–25.4)
C	12/64 (4.8)	8/64 (3.2)	8/64 –1 (3.2–25.4)

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 or of treatment before shipment shall be optional with the manufacturer, but he 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 any other specific treatment or conditioning of material is specified by the purchaser, the manufacturer shall be responsible only for carrying out those specific operations.

6. Chemical Requirements

6.1 *General Requirements*:

6.1.1 Table 2 lists 21 standard grades of alloy steel which 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 respective grades.

6.1.3 The steel when ordered to other than standard analysis shall conform to the requirements as to chemical ranges and limits prescribed in Table 3.

6.1.4 Small quantities of certain elements are present in alloy steels which are neither specified nor required. These elements are residual and 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 Each heat of steel shall be analyzed by the manufacturer to determine the percentage of elements prescribed in Table 2. This analysis shall be made on a sample taken during the pouring of the heat, except that in the event mechanical difficulties prevent obtaining samples from the ladle, that may be obtained from suitable portions of the ingots or product.

6.2.2 If consumable-electrode remelting is employed, the analysis of each resulting ingot shall conform to the requirements of Table 2. Samples for these analyses shall be removed from the top end of the ingot after adequate discard at any area midway between the center and surface of the ingot or bloom. One complete analysis from the master heat or from one remelt ingot plus carbon and manganese analysis from each remelt ingot are required.

6.3 *Product Analysis*:

6.3.1 Analysis may be made by the purchaser from material representing each heat or lot. The chemical composition thus determined shall not vary from the ranges or limits as specified in Table 2 or Table 3 by more than the amount specified in Table 4, unless otherwise agreed.

6.3.2 Samples for product analyses shall be taken from a location midway between center and surface of the bloom.

6.4 *Method of Analysis*—Test Methods E 30 and E 350 shall be used for referee purposes.

TABLE 2 Chemical and Hardness Requirements

AISI or Proprietary Name 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	0.025 max	0.025 max	0.20–0.35	3.25–3.75	1.40–1.75	. . .	. . .	. . .	262
9310	2	0.08–0.13	0.45–0.65	0.025 max	0.025 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	0.025 max	0.025 max	0.20–0.35	1.65–2.00	. . .	0.20–0.30	. . .	. . .	229
8620	4	0.18–0.23	0.70–0.90	0.025 max	0.025 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	0.025 max	0.025 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	0.025 max	0.025 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	0.025 max	0.025 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	0.025 max	0.025 max	0.20–0.35	. . .	0.80–1.10	0.15–0.25	. . .	. . .	229
4140	12	0.38–0.43	0.75–1.00	0.025 max	0.025 max	0.20–0.35	. . .	0.80–1.10	0.15–0.25	. . .	. . .	235
98BV40	13	0.40–0.46	0.75–1.00	0.025 max	0.025 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	0.025 max	0.025 max	0.20–0.35	. . .	0.80–1.10	. . .	0.15 min	. . .	235
52100	15	0.98–1.10	0.25–0.45	0.025 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 0.05–0.105; 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	0.025 max	0.025 max	0.20–0.40	. . .	1.40–1.80	0.30–0.40	. . .	Al 0.95–1.30	285

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 E 381 and Test Method A 604, as applicable. Standards of acceptance shall be by agreement.

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. The specimens shall be prepared and rated by the procedure described in Method A of Test Methods E 45. The polished face shall be longitudinal to the direction of maximum working. All specimens shall be prepared and rated in accordance with Test Methods E 45, using Method D (Modified JK Chart) for Class I steel and Method A (JK Chart) for Class II steel. Standards of acceptance shall be by agreement.

7.3 *Nondestructive Testing, Ultrasonic Inspection*:

7.3.1 *General*:

7.3.1.1 All material ordered to this specification shall be ultrasonic inspected unless otherwise specified. 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. (305 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 7.3.8.3.

7.3.2 *Apparatus*—An ultrasonic, pulsed, reflection type of instrument shall be used for this inspection. The system shall have a minimum capability for testing at frequencies of 1 to 5 MHz, and shall provide linear presentation, within ±5 % up to at least 75 % of full screen height.

7.3.2.1 *Voltage Regulation*—The response of equipment to line voltage variations shall be such that no change occurs in signal amplitude for normal line voltage variations.

7.3.3 *Immersion Inspection Procedure*— This method is recommended for material where the cross-sectional dimension to be inspected is less than approximately 8 in. (203 mm). Material inspected by the immersion method shall be performed in accordance with the procedure outlined in Practice E 214.