



# Standard Specification for Stainless Steel Bars for Compressor and Turbine Airfoils<sup>1</sup>

This standard is issued under the fixed designation A 1028; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers stainless steel bars for compressor and turbine bucket, blade, and airfoil applications.

1.2 The values stated in inch-pound units are to be considered the standard.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings<sup>2</sup>

A 484/A 484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings<sup>3</sup>

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment<sup>2</sup>

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys<sup>4</sup>

E 112 Test Methods for Determining Average Grain Size<sup>5</sup>

E 292 Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials<sup>5</sup>

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings<sup>5</sup>

E 562 Test Method for Determining Volume Fraction by Systematic Manual Point Count<sup>5</sup>

## 3. Terminology

3.1 Refer to Terminology A 941 for definitions of terms used in this standard.

## 4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for product under this specification. Such requirements to be considered may include but are not limited to the following:

4.1.1 Quantity (weight or number of pieces).

4.1.2 Grade and Class (Table 3).

4.1.3 Applicable dimensions including size, thickness, width, and length.

4.1.4 Whether bars are to be rolled as bars or cut from plate.

4.1.5 Supplementary Requirements.

## 5. General Requirements

5.1 Product furnished to this specification shall conform to the requirements of Specification A 484/A 484M including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 484/A 484M constitutes nonconformance with this specification.

5.2 In case of conflict between the requirements of this specification and Specification A 484/A 484M, this specification shall prevail.

## 6. Manufacture

6.1 *Melting Process*—The steel shall be made using the Basic Electric Furnace Process with Argon-Oxygen-Decarburization (AOD) refining or by Vacuum Ladle Degasing. Use of Electro-Slag Remelting is permitted unless otherwise specified by the purchaser (see Supplemental Requirement S1).

6.2 *Heat Treatment*—Heat treating of all bars is required in accordance with Table 1 to develop the required mechanical properties.

6.2.1 *Number of Heat Treatments*—Two complete heat treatments, consisting of an austenitize, quench and temper, are permitted. Purchaser approval is required prior to any additional heat treatments.

6.2.2 *Temperature Variation*—Heat treating temperatures shall be controlled in the range of  $\pm 25^\circ\text{F}$ .

6.3 *Stress Relief*—When heat treatment for mechanical properties is followed by straightening, a stress relieving heat treatment is required in accordance with Table 1.

6.3.1 *Quenching after Stress Relief*—Water or oil quenching of stress-relieved bars is prohibited.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.17 on Flat-Rolled and Wrought Stainless Steel.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.05.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 01.01.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 03.01.

**TABLE 1 Heat Treatment, °F**

	Grade A	Grade B	Grade C		Grade D	Grade E		Grade F
	Classes 1 and 2	Class 1	Class 1	Class 2	Classes 1 and 2	Class 1	Class 2	Class 1
Austenitizing	1725-1775	1600-1750	1825 to 1875	1725 to 1875	1875 to 1925	2075 to 2125	1725 to 1775	1875 to 1925
Quenching	Air or liquid	Air or liquid	Air or liquid	Air or liquid	Air or liquid	Air or liquid	Air or liquid	Air or liquid
First temper	1100 min	1100 min	1050 min	1000 min	1150 min	1250 min	1100 min	...
Second temper	...	...	1025 min	1000 min	...	...	...	...
Aging	...	...	...	...	...	...	...	1135 to 1165
Stress Relieving	1065 min	1065 min	1000 min	1000 min	1100 min	1200 min	1050 min	1100 min

**TABLE 2 Chemical Requirements**

UNS Designation	Composition %					
	Grade A	Grade B	Grade C	Grade D	Grade E	Grade F
	S41000	S41005	S41428	S42225	S41041	S17400
Carbon	0.15 max	0.10 to 0.15	0.10 to 0.17	0.20 to 0.25	0.13 to 0.18	0.07 max
Manganese	1.0 max	0.25 to 0.80	0.65 to 1.05	0.5 to 1.0	0.4 to 0.6	1.0 max
Phosphorus, max	0.018	0.018	0.020	0.020	0.030	0.040
Sulfur, max	0.015	0.015	0.015	0.010	0.030	0.030
Silicon	0.5 max	0.5 max	0.10 to 0.35	0.20 to 0.50	0.5 max	1.0 max
Nickel	0.75 max	0.75 max	2.25 to 3.25	0.5 to 1.0	0.5 max	3.0 to 5.0
Chromium	11.5 to 13.0	11.5 to 13.0	11.25 to 12.75	11.0 to 12.5	11.5 to 13.0	15.0 to 17.5
Molybdenum	0.5 max	0.5 max	1.5 to 2.0	0.9 to 1.25	0.20 max	...
Vanadium	...	Report only	0.25 to 0.40	0.20 to 0.30	...	...
Tungsten	...	0.10 max	0.10 max	0.9 to 1.25	...	...
Nitrogen	...	0.08 max	0.020 to 0.045	Report only	...	...
Aluminum	...	0.025 max	0.025 max	0.025 max	0.05 max	...
Columbium	...	0.20 max	...	0.05 max	0.15 to 0.45	0.15 to 0.45
Cobalt	...	...	...	0.20 max	...	...
Titanium	...	0.05 max	0.05 max	0.025 max	...	...
Copper	...	0.50 max	0.50 max	0.15 max	...	3.0 to 5.0
Tin	...	0.05 max	0.05 max	0.02 max	...	...

**TABLE 3 Tensile, Impact, and Hardness Requirements**

	Grade A		Grade B		Grade C		Grade D		Grade E		Grade F
	Class 1	Class 2	Class 1	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2	Class 1	
Tensile strength, min, ksi	100	110	110	145	160	140	140	115	110	135	
Yield strength, min, ksi, 0.2 % offset	70	80	90	115	120	90	100	75	80	105	
Elongation in 2 in., min, %	20	18	18	15	16	13	13	15	18	16	
Reduction of area, min, %	60	50	50	30	50	30	35	50	55	50	
Impact strength, min, av., Cv, Rt, ft-lb	30	25	30	30	40	8	10	20	25	41	
Hardness, Brinell, max	255	269	269	352	375	331	331	277	262	341	

## 7. Chemical Composition

7.1 The steel shall conform to the requirements for chemical composition prescribed in Table 2.

## 8. Mechanical Properties

8.1 *Lot Size*—A lot shall consist of all bars of the same size from one electric furnace heat of steel and heat treated, either in the same charge in either a batch furnace or a continuous type furnace.

8.2 *Hardness Tests*—All testing shall be performed after heat treatment and stress relief, as applicable. The test specimens shall meet the requirements of Table 3.

8.2.1 *Number of Tests*—A minimum of four bars or 10 % of the lot, whichever is less, shall be tested on each end.

8.3 *Tensile and Impact Tests*—One room temperature tensile test and two room temperature Charpy V-Notch Impact tests shall be taken from the softest and hardest Bar in each lot of material. Impact tests are only required on bars or shapes 1/2 in. or larger in minor dimension.

8.3.1 *Test Specimen Location*—The axis of the specimen shall be located at the center of the bars up to and including 1 1/2 in. width. For bars over 1 1/2 in. width, the axes of the specimen shall be located midway between the center and the edge (corner) of the bar.

## 9. Workmanship and Nondestructive Examination

9.1 *General Requirements*—All bars shall be free of cracks, fissures, seams, laps, bursts, shrinkage, and similar discontinuities.

9.2 *Nondestructive Tests*—Nondestructive testing and corresponding acceptance criteria shall be as specified by the purchaser.

## 10. Dimensions, Tolerances, and Finish

10.1 Hot-rolled or cold-finished bar, or both, shall be furnished to the tolerances (permissible variations) in Specification A 484/A 484M, with the following additional requirements:

10.1.1 All tolerances except straightness and length shall be plus (+) (over) with no minus (–) (under) tolerance allowed. The total spread in tolerance for any specific size shall be equal to the total spread allowed in Specification A 484/A 484M.

10.2 Flat bar with ordered sizes greater than rolling mill capabilities may be produced by a forging or blooming mill process, or combination thereof. Such material shall conform to the following tolerances:

10.2.1 Material produced by the blooming mill process shall have a normal thickness tolerance with a special allowable width tolerance of plus (+) 0.250 in. with no minus (–) (under) tolerance.

10.2.2 Material produced by the forging process shall have special tolerances as agreed upon by the Purchaser and the Supplier.

## 11. Certification

11.1 All tests required by this specification shall be made by the manufacturer and reported on a certificate of test to the purchaser. Each test certificate shall include the following items:

11.1.1 Purchase order number.

11.1.2 Specification number and year date of issue, grade, and class.

11.1.3 Heat number.

11.1.4 Lot number and size.

11.1.5 Mechanical properties including tension, impact, and hardness.

11.1.6 Heat treatment and stress relief temperatures and times.

11.1.7 Results of any specified supplementary requirements.

11.1.8 Statement that the bars were manufactured, sampled, tested, and inspected in accordance with this specification and that the results satisfied the requirements.

## 12. Product Marking

12.1 The packing, marking, and loading methods described in Practices A 700 shall be used.

## 13. Keywords

13.1 compressor airfoils; martensitic stainless steel; stainless steel bar; turbine airfoils

## SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order. Details of these supplementary requirements shall be agreed upon by the manufacturer and purchaser.

### S1. Secondary Melting and Refining

S1.1 ESR or VAR is required. Use of either is permitted unless otherwise specified.

### S2. Ingot Chemical Analysis

S2.1 If consumable electrode remelting is used, then chemical analyses of each remelted ingot shall meet the chemical composition requirements listed and shall be reported.

### S3. Macrostructure

S3.1 Samples shall be taken from the top and bottom of the first and last ingot of each heat. The structure of the starting billets shall meet the criteria of Method E 381, S-3, R-2, C-3  $\leq$  36 in.<sup>2</sup>, and S-3, R-3, C-3  $>$  36 in.<sup>2</sup>

### S4. Heat Treatment of Cold-Finished Shapes

S4.1 Cold-finished shapes shall be re-austenitized in a vacuum or inert atmosphere at the temperatures listed in Table 1, accelerated gas cooled, tempered, and uniformly cooled below the martensite finish temperature. Oxidation of the surface resulting in decarburization or scale formation is not permitted.

### S5. Magnetic Particle Inspection

S5.1 Each bar shall be magnetic particle inspected in accordance with Test Method A 275/ A 275M. The maximum acceptable indication size shall be  $\frac{1}{8}$  in. unless otherwise specified by the purchaser.

### S6. Nondestructive Examination—Grade D

S6.1 *Method*—Each bar shall be subjected to NDE. The method used shall be Eddy Current (ET), Magnetic Particle (MPI wet or dry), Liquid Penetrant (LPI), or Ultrasonic (UT), at the option of the vendor unless otherwise indicated in the purchase order.

S6.2 *Acceptance Criteria*—For LPI or MPI, linear indications (those indications longer than  $\frac{1}{16}$  in. with a length greater than three times their width) are unacceptable. For UT or ET, reject levels for linear indications shall be based on the alarm response from a 0.012-in. maximum deep surface notch in a calibration bar.

### S7. Microstructure

S7.1 The microstructure shall be uniformly fine grain tempered martensite with no more than 1 % delta ferrite as etched with “Vilella’s” etchant.

S7.2 Metallographic inspection shall be performed at 100 $\times$  magnification to determine the metallurgical structure, grain size, decarburization, and delta ferrite content. Visual estimation for the volume fraction of delta ferrite of various representative areas of examination is acceptable. When the visual estimation method indicates the delta ferrite content is greater than the allowed limit, the manufacturer may employ Test Method E 562 for determining the acceptability of a lot.

S7.3 Grades A, B, and Grade E Class 2 shall have an average grain size of ASTM 5 or finer as determined in accordance with Test Methods E 112. The maximum size of individual grains, distributed at random, shall be ASTM 3.

S7.4 Grades C and D shall have an average grain size of ASTM 4 or finer as determined in accordance with Test Methods E 112. The maximum size of individual grains, distributed at random, shall be ASTM 3.

**S8. Decarburization**

S8.1 Surface decarburization of bars shall not exceed 0.06 in. [1.5 mm].

**S9. Minimum Hardness Requirements**

S9.1 When agreed upon by the purchaser and producer, a minimum hardness value is required.

**S10. Stress Rupture Testing—Grade D**

S10.1 Stress rupture testing shall be conducted at 1200°F and 26 000 psi using a combination test bar in accordance with Test Methods E 292. Rupture must occur in the smooth section of each test specimen. The test may be discontinued after 25 h,

provided the certification so notes. Stress rupture testing is not required on bars less than 1/2 in. in diameter or thickness.

S10.2 One test shall be made for each heat treat lot.

**S11. Squareness**

S11.1 Out of square is defined as the difference between the two diagonal measurements of a square or flat bar. Material less than 5 in. in width that has been hot rolled shall meet the following criteria:

Specified Thickness, in.	Maximum Out of Square, in.
0.25 to 0.32	0.014
Over 0.32 to 0.44	0.015
Over 0.44 to 0.63	0.017
Over 0.63 to 0.88	0.018
Over 0.88 to 1.00	0.018
Over 1.00 to 1.12	0.021
Over 1.12 to 1.25	0.023
Over 1.25 to 1.37	0.025
Over 1.37 to 1.50	0.030
Over 1.50 to 2.00	0.034
Over 2.00 to 2.50	0.038

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