Designation: A 831/A831M – 95 (Reapproved 2000)

Standard Specification for Austenitic and Martensitic Stainless Steel Bars, Billets, and Forgings for Liquid Metal Cooled Reactor Core Components[1]

This standard is issued under the fixed designation A 831/A831M; 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 hot- and cold-finished austenitic and martensitic stainless steel bars, billets, and forgings intended for use in manufacturing core components used at high temperatures in liquid metal cooled nuclear reactors.

1.2 The bars, billets, and forgings are intended for machining, welding, hot- and cold-forming operations.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, 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.

1.4 This specification and the applicable material specifications are expressed in both inch-pound and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished in inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 388/A388M Practice for Ultrasonic Examination of Heavy Steel Forgings[3]

A 484/A484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings[3]

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products[2]

E 3 Methods of Preparation of Metallographic Specimens[4]

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

E 112 Test Methods for Determining Average Grain Size[4]

E 407 Test Methods for Microetching Metals and Alloys[4]

2.2 *ANSI Standard:*

B 46.1 Surface Texture[5]

2.3 *ASNDT Standard:*

SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualifications and Certification[6]

2.4 *ASME Standard:*

NQA-1 Quality Assurance Program Requirements for Nuclear Facilities[7]

3. Ordering Information

3.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include but are not limited to the following:

3.1.1 Quantity (weight or number of pieces).

3.1.2 Condition (cold-worked, annealed, or tempered).

3.1.3 Finish.

3.1.4 Applicable dimensions, including size, thickness, width, and length (if forgings, include prints or sketches).

3.1.5 Form (bars, billets, etc.).

3.1.6 Grade designation.

3.1.7 ASTM designation and year of issue.

3.1.8 Marking requirements.

3.1.9 Other applicable documents (2.4).

3.1.10 Melting process (4.1).

3.1.11 Approval of procedures for conversion of ingots (4.2).

3.1.12 Cold working requirements for austenitic grades (4.4.3).

3.1.13 Identification requirements (4.6).

3.1.14 Chemistry requirements (5.1).

3.1.15 Product analysis tolerances (5.3).

3.1.16 Grain size limits for bar, billets, and forgings requiring rework (6.1).

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[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 A01.17 on Flat Stainless Steel Products.

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[2] *Annual Book of ASTM Standards,* Vol 01.03.

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

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

[5] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[6] Available from American Society for Nondestructive Testing, P.O. Box 5642, 3200 Riverside Dr., Columbus, OH 43228.

[7] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

3.1.17 Alternate inclusion limits (6.2).
3.1.18 Surface roughness limits (4.3.2).
3.1.19 Surface marring limits (4.3.3).
3.1.20 Ultrasonic test requirements (8.1).
3.1.21 Sampling levels (10.1).
3.1.22 Packaging requirements (12.1).

NOTE 1—A typical ordering description is as follows: 5000-lb [2000-kg] stainless steel, annealed and centerless ground, round bar 1½ in. [38 mm] in diameter, 10 to 12 ft. [3 to 4 m] Type 316, ASTM Specification A 831 – xx.

4. Manufacture

4.1 *Melting*—Unless an alternative melting process has been specified in Section 9, the process for austenitic grades shall consist of a vacuum induction melt followed by a consumable electrode vacuum-arc remelt. Additions of rare earths during melting are prohibited unless approved by the purchaser. The melting process for other grades shall be specified in the order.

4.2 *Ingot Processing*—A procedure for conversion of ingots shall be approved by the purchaser prior to use if specified in the order. The parameters for the conversion of austenitic grades shall be selected to minimize the formation of complex carbides and carbonitrides.

4.3 *Surface Requirements*:

4.3.1 *Surface Condition*—The finished bar shall be free of all scale, splits, laps, cracks, seams, and visible oxide.

4.3.2 *Surface Roughness*—The surface finish of finished bar shall meet the minimum requirements listed in Table 1. The surface finish of bar that will be machined subsequently shall be as specified in the order and shall be compatible with nondestructive examination requirements.

4.3.3 *Surface Marring*—The finished bar shall be free of scratches, dents, or mars as specified in the order.

4.4 *Heat Treatment*:

4.4.1 *Austenitic Grades*—Except for material ordered in the cold-worked condition, all austenitic grade material shall be furnished in the solution-annealed condition. Solution annealing shall consist of heating the material to a temperature of 1900°F [1038°C] minimum, for a time appropriate to ensure full carbide solution, followed by rapid cooling in air or water to prevent carbide precipitation at the grain boundaries.

4.4.2 *Martensitic Grades*—Unless otherwise specified by the purchaser, martensitic grade materials shall be supplied in the normalized and tempered condition. Tempered material shall be normalized at 1900°F [1038°C] minimum as a final heat treatment. Tempered martensitic materials shall be held at tempering temperature for at least 1 h/1in. [25 mm] of cross section as follows:

4.4.2.1 *Grade T91*—1350°F [732°C] minimum, 1485°F [807°C] maximum.

TABLE 1 Austenitic Stainless Steel Bar—Surface Finishes

Bar Diameter, in. (mm)	Surface Designation (ANSI B 46.1)
⅛ to ¼ [3.2 to 6.4] incl	32 µin. [0.8 µm] or finer
over ¼to 2 [6.4 to 50.8] incl	63 µin. [1.6 µm] or finer
over 2 to 10 [50.8 to 254.0] incl	125 µin. [3.2 µm] or finer

4.4.2.2 *S42100*—1365°F [740°C] minimum, 1470°F [799°C] maximum.

4.4.3 *Cold-Worked Austenitic Grades*—If required by the purchaser, austenitic grades shall be furnished in the cold-worked condition. Prior to any final cold working operations, solution annealing shall be performed in accordance with 4.4.1. Percentage of cold work shall be based upon reduction in area.

4.4.4 *Cleanliness During Manufacture*—All lubricants shall be removed prior to any heat treatment.

4.5 *Lotting*—Items of the same nominal dimension shall be lotted on the basis of material having the same metallurgical history, produced from the same melt heat, processed in one final tooling setup, annealed in the same annealing charge (or processed in one continuous run if annealed in a continuous furnace) and given the same cold work.

4.6 *Identification*—Material shall be identified and processed in a manner that will ensure traceability as specified in the order.

4.7 *Handling*—Special handling procedures shall be employed to maintain the identity of material from the final working operation through packaging for shipment. The handling procedure shall be submitted to the purchaser for review and approval prior to use.

5. Chemical Requirements

5.1 The material shall conform to the applicable chemistry requirements specified in Table 2 unless otherwise specified in the order.

5.2 An analysis of each heat of steel shall be made by the steel manufacturer in accordance with Test Methods, Practices, and Terminology A 751 to determine the percentages of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified in 5.1.

TABLE 2 Chemical Requirements

	Grade (UNS Designation)			
	316 (S31600)	. . . S 38660	. . . S 42100	T91 (. . .)
Carbon	0.040 to 0.060	0.030 to 0.050	0.17 to 0.23	0.08 to 0.12
Manganese	1.00 to 2.00	1.65 to 2.35	0.40 to 0.70	0.30 to 0.60
Phosphorus, max	0.040	0.040	0.040	0.020
Sulfur, max	0.010	0.010	0.010	0.010
Silicon	0.50 to 0.75	0.50 to 1.00	0.20 to 0.30	0.20 to 0.50
Nickel	13.0 to 14.0	14.5 to 16.5	0.30 to 0.80	0.40 max
Chromium	17.0 to 18.0	12.5 to 14.5	11.0 to 12.5	8.0 to 9.5
Molybdenum	2.00 to 3.00	1.50 to 2.50	0.80 to 1.20	0.85 to 1.05
Titanium	. . .	0.10 to 0.40[A]	. . .	. . .
Columbium	0.050 max	0.050 max	0.050 max	0.06 to 0.10
Tantalum, max	0.020	0.020	. . .	. . .
Tungsten	. . .	. . .	0.40 to 0.60	. . .
Nitrogen	0.010 max	0.005 max	. . .	0.03 to 0.07
Aluminum, max	0.050	0.050	0.050	0.04
Arsenic, max	0.030	0.030	. . .	. . .
Boron, max	0.0020	0.0020	. . .	. . .
Cobalt, max	0.050	0.050	. . .	. . .
Copper, max	0.04	0.04	. . .	. . .
Vanadium	0.05 max	0.05 max	0.25 to 0.35	0.18 to 0.25

[A] Aim for 0.25.

5.3 A product analysis shall be made by the manufacturer on a sample from one bar, billet, or forging in each lot as defined in 4.5. The analysis shall meet the requirements of Table 2 within appropriate product analysis tolerances as provided in Specification A 484/A 484M, unless otherwise specified in the order. In the event of failure, the lot represented shall be rejected except that, at the option of the manufacturer, each item in the lot may be tested for acceptance.

6. Metallurgical Requirements

6.1 *Grain Size*—The grain size of finished bars for austenitic grades shall meet the requirements specified in Table 3. Limits for bars, billets, and forgings that will be subsequently hot or cold worked shall be as specified in the order.

6.2 *Inclusions*—The inclusion content of the finished bars of austenitic grades shall not exceed the limits prescribed in Table 4 when determined as specified in Practice E 45, Microscope Method D, except, 35 % of the total fields rated may exhibit inclusion levels up to a rating of 1 for Types A, B, C, and D combined, and 3 % of the total fields rated may exhibit inclusion levels up to a rating of 1½ for Types A, B, C, and D combined. Other limits may be specified in the order. Complex carbides shall not be classified as inclusions.

6.3 *Carbide Precipitation*—Specimens from finished austenitic grade bars shall be mounted as transverse sections, polished, etched, and examined at 500 ×. Specimen preparation shall be as described in Methods E 3 using etching Procedure 13 prescribed in Table 2 of Test Methods E 407. Specimens shall exhibit no visible carbide precipitation at the grain boundaries.

7. Mechanical Properties Requirements

7.1 The material shall conform to the mechanical property requirements specified in Table 5 for the grade ordered. At least one room-temperature test shall be performed by the manufacturer on a sample from at least one bar, billet, or forging from each lot of material.

7.2 The yield strength shall be determined by the offset (0.2 %) method as prescribed in Test Methods and Definitions A 370.

7.3 Martensitic material supplied in the tempered condition shall meet the mechanical properties specified in Table 5 when heat treated in accordance with the requirements of 4.3.2. Hardness measurements shall be made at a location midway between the surface and the center of the cross section.

7.4 If in the course of preparation, a test specimen is made defective, for example by machining errors, the specimen may be replaced by another which shall be selected on the same basis as the one discarded. If, however, a specimen develops flaws upon testing or otherwise fails to meet test requirements, the material represented by the specimen shall be rejected except that, at the material manufacturer's option, the material may be reprocessed and retested, or each item may be tested individually for acceptance.

TABLE 3 Grain Size for Austenitic Grade Bar

Bar Diameter, in. (mm)	ASTM Grain Size (Test Methods E 112 Plate II)
⅛ to 2 incl [3 to 50]	5 or finer
Over 2 to 10 incl [50 to 254]	3 or finer

TABLE 4 Inclusion Content Limits for Austenitic Grades

Inclusion Type (Practice E 45)							
Sulfide Type (A)		Alumina Type (B)		Silicate Type (C)		Globular Oxides (D)	
Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick
½	0	0	0	0	0	½	½

8. Nondestructive Examination

8.1 *Ultrasonic Examination*—Each bar greater than 1 in. (25.4 mm) in the least dimension shall be examined using the examination and acceptance criteria specified in Section 9 and Practice A 388/A 388M. A bar 1 in. [25.4 mm] or less in the least dimension shall be examined as specified in the order.

8.2 *Testing Personnel*—All nondestructive testing personnel shall be qualified and perform in accordance with SNT-TC-1A.

9. General Requirements

9.1 Material supplied under this specification shall conform to the applicable requirements of Specification A 484/A 484M unless otherwise specified herein. Failure to comply with the general requirements of Specification A 484/A 484M constitutes nonconformance with this specification.

10. Sampling

10.1 *Lot Qualification*—Sampling levels shall be as specified in the order. Referenced test methods are the preferred methods. Actual methods used shall be equal to or better than the methods referenced and shall be approved by the purchaser prior to use.

11. Certification

11.1 The manufacturer shall certify that the material was manufactured, tested, and examined in accordance with this specification and any added requirements of the purchase order. A copy of the certification shall be furnished at the time of shipment, together with a report of the results of all required tests, examinations, and ASTM designation, year date and revision letter, if any. Certifications, test reports, and examination reports shall be positively traceable to the final product.

12. Packaging and Package Marking

12.1 *Packaging*—Packaging shall be in accordance with the requirements specified in the order.

12.2 *Marking*—Each lot shipment shall be legibly and conspicuously marked with the following data:

12.2.1 Purchase order number,
12.2.2 Name of supplier,
12.2.3 Alloy and heat numbers,
12.2.4 Lot number,
12.2.5 Number of pieces (or feet) in lot,
12.2.6 Gross and net weights,
12.2.7 Applicable drawing,
12.2.8 Size, and

TABLE 5 Mechanical Property Requirements

Alloy	Condition	Tensile Strength, min, psi (MPa)	Yield Strength[A], min, psi	Elongation in 2 in. [50 mm] or 4D, min %	Brinell Hardness, max
		Austenitic Types			
S31600, S 38660	annealed	75 000[B] [515]	30 000 [205]	30	. . .
S31600, S 38660	20 % cold-worked	95 000 [655]	75 000[C] [515]	30	302[D] (surface)
		Martensitic Types			
T91	tempered	85 000 [585]	60 000 [415]	20	250
S42100	tempered	100 000 [690]	71 000 [490]	10	229

[A] See Section 7.
[B] Tensile strength 70 000 psi (485 MPa) minimum permitted for extruded shapes.
[C] For bars greater than 2 in. (51 mm) in cross section, 65 000 psi (480 MPa) minimum.
[D] Minimum properties for all sizes in cold-worked condition.

12.2.9 Specification number.

13. Quality Assurance Requirement

13.1 *Requirements*—The materials manufacturer shall establish, maintain, and function in accordance with a quality verification program that will control quality of the product during manufacture, testing, examination, repair, and treatment of the material, including subcontracted services, to assure that all materials supplied by him conform to the requirements of this specification. ASME NQA-1 is an example of a program which meets the requirements of this section. The program shall be subject to audit and shall include the following:

13.1.1 *Organization*—The authority and responsibilities of personnel in charge of the quality assurance program shall be clearly established and be independent of the individual or group performing the specific manufacturing activity.

13.1.2 *Manufacturing Control*—The materials manufacturer shall operate under a controlled system using process sheets, shop procedures, check lists, travelers, or equivalent procedures.

13.1.3 *Calibration of Measuring and Test Equipment*—Procedures shall be in effect to ensure that tools, gages, instruments, and other measuring, testing, and examination equipment and devices used to verify compliance of material with the basic material specification and this specification are calibrated, controlled, adjusted, and maintained to assure accuracy within the specified limits. Calibration shall be against measurement standards that have a known valid relationship to those of the National Institute of Standards and Technology, where such standards exist. Corrective action is required when discrepancies, which significantly affect the measurement of material specification properties are found at calibration. Methods for resolution of these discrepancies shall be part of the quality system program.

13.1.4 *Control of Nondestructive Examination Procedures*—All nondestructive examinations required shall be performed in accordance with detailed written procedures that are capable of detecting and locating unacceptable discontinuities. Qualification of personnel performing or interpreting nondestructive examination, or both, shall be in accordance with SNT-TC-1A, supplements and appendixes, as applicable, for the technique and methods used. Written procedures and records shall be made available to the purchaser on request. At least one copy of the procedure shall be available to nondestructive examination personnel for reference on request.

13.1.5 *Procedure Control*—Procedural controls of heat treatment for all materials and material test coupons shall be maintained and implemented.

13.1.6 *Nonconforming Material*—Nonconforming material shall be identified and reviewed for acceptance, rejection, repair, or rework in accordance with documented procedures. The responsibility and authority for the disposition of nonconforming material shall be defined. Repaired and reworked material shall be re-examined in accordance with applicable procedures. Conditions adverse to final product quality (such as malfunctions, deficiencies, deviations, defective material and equipment and nonconformances) shall be identified promptly and reported to appropriate levels of the materials manufacturer's management. The identification, cause, and corrective action taken on nonconformances shall be documented.

13.1.7 *Audits*—Planned and periodic audits by personnel not having direct responsibility in the areas being audited shall be performed to assure compliance with the quality system program. Written procedures or checklists shall be used. Follow-up action including reaudit of deficient areas, shall be taken where indicated.

13.1.8 *Identification and Control of Materials*—Procedural controls for identification of materials including partially processed materials shall assure that identification is maintained either on the material or on records traceable to the material throughout manufacture.

13.2 *Records*—The manufacturer is responsible for the preparation of all quality assurance documentation specified in this specification and in the order. Records of all tests and examinations shall be kept complete and available to the purchaser. Quality verification records shall be furnished with the delivered product.

14. Keywords

14.1 austenitic stainless steel; high temperature core components; martensitic stainless steel; nuclear applications; stainless steel bars; stainless steel billets; stainless steel forgings