This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: A29/A29M – 23

Standard Specification for General Requirements for Steel Bars, Carbon and Alloy, Hot-Wrought[1]

This standard is issued under the fixed designation A29/A29M; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This specification[2] covers a group of common requirements which, unless otherwise specified in the purchase order or in an individual specification, shall apply to carbon and alloy steel bars under each of the following ASTM specifications (or under any other ASTM specification which invokes this specification or portions thereof):

Title of Specification	ASTM Designation[A]
Hot-Rolled Carbon Steel Bars:	
Steel Bars, Carbon, Quenched and Tempered	A321
Steel Bars and Shapes, Carbon Rolled from "T" Rails	A499
Steel Bars, Carbon, Merchant Quality, M-Grades	A575
Steel Bars, Carbon, Hot-Wrought, Special Quality	A576
Steel Bars, Carbon, Merchant Quality, Mechanical Properties	A663/A663M
Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties	A675/A675M
Carbon and Alloy Steel Bars for Springs	A689
Cold-Finished Carbon Steel Bars:	
Steel Bar, Carbon and Alloy, Cold-Finished	A108
Cold-Drawn Stress-Relieved Carbon Steel Bars Subject to Mechanical Property Requirements	A311/A311M
Hot-Rolled Alloy Steel Bars:	
Steel Bars, Alloy, Standard Grades	A322
Carbon and Alloy Steel Bars Subject to End-Quench Hardenability Requirements	A304
Steel Bars, Alloy, Hot-Wrought or Cold-Finished, Quenched and Tempered	A434/A434M
Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both	A739
Cold-Finished Alloy Steel Bars:	
Steel Bars, Alloy, Hot-Rolled or Cold-Finished, Quenched and Tempered	A434/A434M
Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality, for Pressure Piping Components	A696

[A] These designations refer to the latest issue of the respective specifications, which appear either in the *Annual Book of ASTM Standards*, Vol 01.05, or as reprints obtainable from ASTM.

1.2 In case of any conflict in requirements, the requirements of the purchase order, the individual material specification, and this general specification shall prevail in the sequence named.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall used independently of the other, and values from the two systems shall not be combined.

1.4 For purposes of determining conformance to this specification and the various material specifications referenced in 1.1, dimensional values shall be rounded to the nearest unit in the right-hand place of figures used in expressing the limiting values in accordance with the rounding method of Practice E29.

NOTE 1—Specification A29/A29M previously listed dimensional tolerances for cold-finished bars; these are now found in Specification A108.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

A108 Specification for Steel Bar, Carbon and Alloy, Cold-Finished

A304 Specification for Carbon and Alloy Steel Bars Subject to End-Quench Hardenability Requirements

[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 A01.15 on Bars.

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[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-29/SA-29M in Section II of that Code.

[3] 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.

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

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A311/A311M Specification for Cold-Drawn, Stress-Relieved Carbon Steel Bars Subject to Mechanical Property Requirements
A321 Specification for Steel Bars, Carbon, Quenched and Tempered (Withdrawn 2007)[4]
A322 Specification for Steel Bars, Alloy, Standard Grades
A370 Test Methods and Definitions for Mechanical Testing of Steel Products
A434/A434M Specification for Steel Bars, Alloy, Hot-Wrought or Cold-Finished, Quenched and Tempered
A499 Specification for Steel Bars and Shapes, Carbon Rolled from "T" Rails
A575 Specification for Steel Bars, Carbon, Merchant Quality, M-Grades
A576 Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality
A663/A663M Specification for Steel Bars, Carbon, Merchant Quality, Mechanical Properties
A675/A675M Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties
A689 Specification for Carbon and Alloy Steel Bars for Springs
A696 Specification for Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality, for Pressure Piping Components
A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment
A739 Specification for Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both
A751 Test Methods and Practices for Chemical Analysis of Steel Products
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E112 Test Methods for Determining Average Grain Size

2.2 *ASME Code:*[5]

ASME Boiler and Pressure Vessel Code

2.3 *Federal Standards:*[6]

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)
Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

2.4 *Military Standard:*[6]

MIL-STD-163 Steel Mill Products—Preparation for Shipment and Storage

2.5 *Other Standards:*[7]

AIAG B-1 Bar Code Symbology Standard for 3-of-9 Bar Codes
AIAG B-5 02.00 Primary Metals Tag Application Standard

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *cold-finished steel bars*—steel bars produced by cold finishing previously hot-wrought bars by means of cold drawing, cold forming, turning, grinding, or polishing (singly or in combination) to yield straight lengths or coils in sections that are uniform throughout their length and in the following sections and sizes:

3.1.1.1 *rounds*—9 in. [230 mm] and under in diameter,

3.1.1.2 *squares*—6 in. [150 mm] and under between parallel surfaces,

3.1.1.3 *hexagons*—4 in. [100 mm] and under between parallel surfaces,

3.1.1.4 *flats*—⅛ in. [3 mm] and over in thickness and not over 12 in. [300 mm] in width, and

3.1.1.5 *special bar sections.*

3.1.2 *hot-wrought steel bars*—steel bars produced by hot forming ingots, blooms, billets, or other semifinished forms to yield straight lengths (or coils, depending upon size, section, and mill equipment) in sections that are uniform throughout their length, and in the following sections and sizes:

3.1.2.1 *rounds*—7/32 in. to 10.0 in. [5.5 mm to 250 mm], inclusive;

3.1.2.2 *squares*—7/32 in. to 6.0 in. [6 mm to 160 mm], inclusive;

3.1.2.3 *round-cornered squares*—7/32 in. to 8.0 in. [6 mm to 200 mm], inclusive;

3.1.2.4 *flats*—¼ in. to 8 in. inclusive, in width: 13/64 in. in minimum thickness up to 6 in. in width; and 0.230 in. in minimum thickness for over 6 in. to 8 in. in width, inclusive [over 5 mm in thickness up to 150 mm in width; and over 6 mm in thickness for over 150 mm through 200 mm in width]. Maximum thickness for all widths is 4 in. [100 mm];

3.1.2.5 *hexagons and octagons*—¼ in. to 4 1/16 in. [6 mm to 103 mm], inclusive, between parallel surfaces;

3.1.2.6 *bar size shapes*—angles, channels, tees, zees, when their greatest cross-sectional dimension is under 3 in. [75 mm]; and

3.1.2.7 *special bar sections*—half-rounds, ovals, half-ovals, other special bar size sections.

3.1.3 *lot*—unless otherwise specified in the contract or order, a lot shall consist of all bars submitted for inspection at the same time of the same heat, condition, finish, size, or shape. For bars specified in the quenched and tempered condition, when heat treated in batch-type furnaces, a lot shall consist of all bars from the same heat, of the same prior condition, the same size, and subjected to the same heat treatment in one tempering charge. For bars specified in the quenched and tempered condition, when heat treated without interruption in a continuous-type furnace, a lot shall consist of all bars from the same heat, of the same prior condition, of the same size, and subjected to the same heat treatment.

[4] The last approved version of this historical standard is referenced on www.astm.org.

[5] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[6] Copies of military specifications, military standards, and federal standards required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer, or from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, http://quicksearch.dla.mil.

[7] Available from Automotive Industry Action Group (AIAG), 4400 Town Center, Southfield, MI 48075-1104, http://www.aiag.org.

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4. Chemical Composition

4.1 *Limits:*

4.1.1 The chemical composition shall conform to the requirements specified in the purchase order or the individual product specifications. For convenience, the grades commonly specified for carbon steel bars are shown in Table 1 and for alloy steel bars in Table 2. Bars may be ordered to these grade designations and when so ordered shall conform to the specified limits by heat analysis.

4.1.2 When compositions other than those shown in Tables 1 and 2 are required, the composition limits shall be prepared using the ranges and limits shown in Table 3 for carbon steel and Table 4 for alloy steel.

4.2 *Heat or Cast Analysis:*

4.2.1 The chemical composition of each heat or cast shall be determined by the manufacturer in accordance with Test Methods and Practices A751.

4.2.2 The heat or cast analysis shall conform to the requirements specified in the product specification or purchase order. These can be the heat chemical range and limit for a grade designated in Tables 1 and 2, or another range and limit in accordance with 4.1.2, or with requirements of the product specification.

NOTE 2—Heat analysis for lead is not determinable since lead is added to the ladle stream while each ingot is poured. When specified as an added element to a standard steel, the percentage of lead is reported as 0.15 to 0.35 incl, which is the range commonly specified for this element.

4.2.3 If requested or required, the heat analysis shall be reported to the purchaser or his representative.

4.2.4 Reporting of significant figures and rounding shall be in accordance with Test Methods and Practices A751.

4.3 *Product Analysis:*

4.3.1 Merchant quality carbon bar steel is not subject to rejection for product analysis unless misapplication of a heat is clearly indicated.

4.3.2 Analyses may be made by the purchaser from finished bars other than merchant quality representing each heat of open-hearth, basic-oxygen, or electric-furnace steel. The chemical composition thus determined shall not vary from the limits specified in the applicable specification by more than the amounts prescribed in Table 5 and Table 6, but the several determinations of any element, excluding lead, in a heat may not vary both above and below the specified range. Rimmed or capped steel is characterized by a lack of homogeneity in its composition, especially for the elements carbon, phosphorus, and sulfur; therefore, when rimmed or capped steel is specified or required, the limitations for these elements shall not be applicable. Because of the degree to which phosphorus and sulfur segregate, the limitations for these elements shall not be applicable to rephosphorized or resulfurized steels.

4.3.3 Samples for product analysis shall be taken by one of the following methods:

4.3.3.1 Applicable to small sections whose cross-sectional area does not exceed 0.75 in.^{2} [500 mm^2] such as rounds, squares, hexagons, and the like. Chips are taken by milling or machining the full cross section of the piece. Drilling is not a feasible method for sampling sizes 0.75 in.^{2} and smaller.

4.3.3.2 Applicable to products where the width of the cross section greatly exceeds the thickness, such as bar size shapes and light flat bars. Chips are taken by drilling entirely through the steel at a point midway between the edge and the middle of the section, or by milling or machining the entire cross section.

4.3.3.3 Applicable to large rounds, squares semifinished, etc. Chips are taken at any point midway between the outside and the center of the piece by drilling parallel to the axis or by milling or machining the full cross section. In cases where these methods are not practicable, the piece may be drilled on the side, but chips are not taken until they represent the portion midway between the outside and the center.

4.3.3.4 When the steel is subject to tension test requirements, the tension test specimen can also be used for product analysis. In that case, chips for product analysis can be taken by drilling entirely through the tension test specimens or by the method described in 4.3.3.1.

4.3.4 When chips are taken by drilling, the diameter of the drill used shall conform to the following:

Area of Sample Cross Section, in.^{2} [cm^2]	Approximate Drill Diameter, in. [mm]
16 [100] or less	½ [12.5]
Over 16 [100]	1 [25.0]

4.3.5 The minimum number of samples to be taken from material representing the same heat or lot before rejection by the purchaser shall be as follows:

	Minimum Number of Samples
15 tons [15 Mg] and under	4
Over 15 tons [15 Mg]	6

4.3.6 In case the number of pieces in a heat is less than the number of samples required, one sample from each piece shall be considered sufficient.

4.3.7 In the event that product analysis determinations are outside the permissible limits as prescribed in 4.3.2, additional samples shall be analyzed and the acceptability of the heat negotiated between the purchaser and the producer.

4.4 *Referee Analysis*—In case a referee analysis is required and agreed upon to resolve a dispute concerning the results of a chemical analysis, the referee analysis shall be performed in accordance with the latest issue of Test Methods and Practices Terminology A751, unless otherwise agreed upon between the manufacturer and the purchaser.

5. Grain Size Requirement

5.1 *Austenitic Grain Size*—All requirements for austenitic grain size control in Section 5 refer to the size of the austenite grain which forms during a subsequent bar reheating operation at or above the recrystallization temperature. These requirements do not apply to, nor do they in any way control, the prior austenite grain size or the ferrite grain size of the bar in the as-rolled condition.

5.1.1 When a coarse austenitic grain size is specified, the steel shall have a grain size number of 1 to 5 exclusive as determined in accordance with Test Methods E112. Conformance to this grain size of 70 % of the grains in the area examined shall constitute the basis of acceptance. One test per heat shall be made.

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TABLE 1 Grade Designations and Chemical Compositions of Carbon Steel Bars

Grade Designation	Heat Chemical Ranges and Limits, %			
	Carbon	Manganese	Phosphorus, max	Sulfur, max[A]
Nonresulfurized Carbon Steels[B, C, D, E, F]				
1005	0.06 max	0.35 max	0.040	0.050
1006	0.08 max	0.25–0.40	0.040	0.050
1008	0.10 max	0.30–0.50	0.040	0.050
1010	0.08–0.13	0.30–0.60	0.040	0.050
1011	0.08–0.13	0.60–0.90	0.040	0.050
1012	0.10–0.15	0.30–0.60	0.040	0.050
1013	0.11–0.16	0.50–0.80	0.040	0.050
1015	0.13–0.18	0.30–0.60	0.040	0.050
1016	0.13–0.18	0.60–0.90	0.040	0.050
1017	0.15–0.20	0.30–0.60	0.040	0.050
1018	0.15–0.20	0.60–0.90	0.040	0.050
1019	0.15–0.20	0.70–1.00	0.040	0.050
1020	0.18–0.23	0.30–0.60	0.040	0.050
1021	0.18–0.23	0.60–0.90	0.040	0.050
1022	0.18–0.23	0.70–1.00	0.040	0.050
1023	0.20–0.25	0.30–0.60	0.040	0.050
1025	0.22–0.28	0.30–0.60	0.040	0.050
1026	0.22–0.28	0.60–0.90	0.040	0.050
1029	0.25–0.31	0.60–0.90	0.040	0.050
1030	0.28–0.34	0.60–0.90	0.040	0.050
1034	0.32–0.38	0.50–0.80	0.040	0.050
1035	0.32–0.38	0.60–0.90	0.040	0.050
1037	0.32–0.38	0.70–1.00	0.040	0.050
1038	0.35–0.42	0.60–0.90	0.040	0.050
1039	0.37–0.44	0.70–1.00	0.040	0.050
1040	0.37–0.44	0.60–0.90	0.040	0.050
1042	0.40–0.47	0.60–0.90	0.040	0.050
1043	0.40–0.47	0.70–1.00	0.040	0.050
1044	0.43–0.50	0.30–0.60	0.040	0.050
1045	0.43–0.50	0.60–0.90	0.040	0.050
1046	0.43–0.50	0.70–1.00	0.040	0.050
1049	0.46–0.53	0.60–0.90	0.040	0.050
1050	0.48–0.55	0.60–0.90	0.040	0.050
1053	0.48–0.55	0.70–1.00	0.040	0.050
1055	0.50–0.60	0.60–0.90	0.040	0.050
1059	0.55–0.65	0.50–0.80	0.040	0.050
1060	0.55–0.65	0.60–0.90	0.040	0.050
1064	0.60–0.70	0.50–0.80	0.040	0.050
1065	0.60–0.70	0.60–0.90	0.040	0.050
1069	0.65–0.75	0.40–0.70	0.040	0.050
1070	0.65–0.75	0.60–0.90	0.040	0.050
1071	0.65–0.70	0.75–1.05	0.040	0.050
1074	0.70–0.80	0.50–0.80	0.040	0.050
1075	0.70–0.80	0.40–0.70	0.040	0.050
1078	0.72–0.85	0.30–0.60	0.040	0.050
1080	0.75–0.88	0.60–0.90	0.040	0.050
1084	0.80–0.93	0.60–0.90	0.040	0.050
1086	0.80–0.93	0.30–0.50	0.040	0.050
1090	0.85–0.98	0.60–0.90	0.040	0.050
1095	0.90–1.03	0.30–0.50	0.040	0.050
Resulfurized Carbon Steels[B,D,F]				
1108	0.08–0.13	0.60–0.80	0.040	0.08–0.13
1109	0.08–0.13	0.60–0.90	0.040	0.08–0.13
1110	0.08–0.13	0.30–0.60	0.040	0.08–0.13
1116	0.14–0.20	1.10–1.40	0.040	0.16–0.23
1117	0.14–0.20	1.00–1.30	0.040	0.08–0.13
1118	0.14–0.20	1.30–1.60	0.040	0.08–0.13
1119	0.14–0.20	1.00–1.30	0.040	0.24–0.33
1132	0.27–0.34	1.35–1.65	0.040	0.08–0.13
1137	0.32–0.39	1.35–1.65	0.040	0.08–0.13
1139	0.35–0.43	1.35–1.65	0.040	0.13–0.20
1140	0.37–0.44	0.70–1.00	0.040	0.08–0.13
1141	0.37–0.45	1.35–1.65	0.040	0.08–0.13
1144	0.40–0.48	1.35–1.65	0.040	0.24–0.33
1145	0.42–0.49	0.70–1.00	0.040	0.04–0.07
1146	0.42–0.49	0.70–1.00	0.040	0.08–0.13
1151	0.48–0.55	0.70–1.00	0.040	0.08–0.13

Rephosphorized and Resulfurized Carbon Steels[D,F]					
Grade Designation	Carbon	Manganese	Phosphorous	Sulfur	Lead
1211	0.13 max	0.60–0.90	0.07–0.12	0.10–0.15	...
1212	0.13 max	0.70–1.00	0.07–0.12	0.16–0.23	...

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TABLE 1 *Continued*

Rephosphorized and Resulfurized Carbon Steels[D,F]					
Grade Designation	Carbon	Manganese	Phosphorous	Sulfur	Lead
1213	0.13 max	0.70–1.00	0.07–0.12	0.24–0.33	...
1215	0.09 max	0.75–1.05	0.04–0.09	0.26–0.35	...
12L13	0.13 max	0.70–1.00	0.07–0.12	0.24–0.33	0.15–0.35
12L14	0.15 max	0.85–1.15	0.04–0.09	0.26–0.35	0.15–0.35
12L15	0.09 max	0.75–1.05	0.04–0.09	0.26–0.35	0.15–0.35

High-Manganese Carbon Steels[B,C,D,E,F]					
Grade Designation	Former Designation	Carbon	Manganese	Phosphorous, max	Sulfur, max
1513	...	0.10–0.16	1.10–1.40	0.040	0.050
1518	...	0.15–0.21	1.10–1.40	0.040	0.050
1522	...	0.18–0.24	1.10–1.40	0.040	0.050
1524	1024	0.19–0.25	1.35–1.65	0.040	0.050
1525	...	0.23–0.29	0.80–1.10	0.040	0.050
1526	...	0.22–0.29	1.10–1.40	0.040	0.050
1527	1027	0.22–0.29	1.20–1.50	0.040	0.050
1536	1036	0.30–0.37	1.20–1.50	0.040	0.050
1541	1041	0.36–0.44	1.35–1.65	0.040	0.050
1547	...	0.43–0.51	1.35–1.65	0.040	0.050
1548	1048	0.44–0.52	1.10–1.40	0.040	0.050
1551	1051	0.45–0.56	0.85–1.15	0.040	0.050
1552	1052	0.47–0.55	1.20–1.50	0.040	0.050
1561	1061	0.55–0.65	0.75–1.05	0.040	0.050
1566	1066	0.60–0.71	0.85–1.15	0.040	0.050
1572	1072	0.65–0.76	1.00–1.30	0.040	0.050

Heat Chemical Ranges and Limits, percent				
Merchant Quality M Series Carbon Steel Bars				
Grade Designation	Carbon	Manganese[G]	Phosphorous, max	Sulfur, max
M 1008	0.10 max	0.25–0.60	0.04	0.05
M 1010	0.07–0.14	0.25–0.60	0.04	0.05
M 1012	0.09–0.16	0.25–0.60	0.04	0.05
M 1015	0.12–0.19	0.25–0.60	0.04	0.05
M 1017	0.14–0.21	0.25–0.60	0.04	0.05
M 1020	0.17–0.24	0.25–0.60	0.04	0.05
M 1023	0.19–0.27	0.25–0.60	0.04	0.05
M 1025	0.20–0.30	0.25–0.60	0.04	0.05
M 1031	0.26–0.36	0.25–0.60	0.04	0.05
M 1044	0.40–0.50	0.25–0.60	0.04	0.05

[A] Maximum unless otherwise indicated.
[B] When silicon is required, the following ranges and limits are commonly specified: 0.10 %, max, 0.10 % to 0.20 %, 0.15 % to 0.35 %, 0.20 % to 0.40 %, or 0.30 % to 0.60 %.
[C] Copper can be specified when required as 0.20 % minimum.
[D] When lead is required as an added element to a standard steel, a range of 0.15 % to 0.35 % inclusive is specified. Such a steel is identified by inserting the letter "L" between the second and third numerals of the grade designation, for example, 10 L 45. A cast or heat analysis is not determinable when lead is added to the ladle stream.
[E] When boron treatment for killed steels is specified, the steels can be expected to contain 0.0005 % to 0.003 % boron. If the usual titanium additive is not permitted, the steels can be expected to contain up to 0.005 % boron.
[F] The elements bismuth, calcium, selenium, or tellurium may be added as agreed upon between purchaser and supplier.
[G] Unless prohibited by the purchaser, the manganese content may exceed 0.60 % on heat analysis to a maximum of 0.75 %, provided the carbon range on heat analysis has the minimum and maximum reduced by 0.01 % for each 0.05 % manganese over 0.60 %.

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5.1.2 When a fine austenitic grain size is specified, the steel shall have a grain size number of 5 or higher as determined in accordance with Test Methods E112. Conformance to this grain size of 70 % of the area examined shall constitute the basis of acceptance. One test per heat shall be made unless the provisions of 5.1.2.1 or 5.1.2.2 are exercised.

5.1.2.1 When aluminum is used as the grain refining element, the fine austenitic grain size requirement shall be deemed to be fulfilled if, on heat analysis, the aluminum content is not less than 0.020 % total aluminum or, alternately, 0.015 % acid soluble aluminum. The aluminum content shall be reported. The grain size test specified in 5.1.2 shall be the referee test.

5.1.2.2 By agreement between purchaser and supplier, columbium[8] or vanadium, or both, may be used for grain refining instead of or with aluminum. When columbium or vanadium is used as a grain refining element, the fine austenitic grain size requirement shall be deemed to be fulfilled if, on heat analysis, the columbium or vanadium content is as follows (the content of the elements shall be reported with the heat analysis):

[8] Columbium (Cb) and Niobium (Nb) are alternate names for element 41 in the Periodic Table of the Elements.

TABLE 2 Grade Designations and Chemical Compositions of Alloy Steel Bars

NOTE 1—Small quantities of certain elements are present in alloy steels, which are not specified or required. These elements are considered as incidental and may be present to the following maximum amounts: copper, 0.35 %; nickel, 0.25 %; chromium, 0.20 % and molybdenum, 0.06 %.

NOTE 2—Where minimum and maximum sulfur content is shown it is indicative of resulfurized steel.

NOTE 3—The chemical ranges and limits shown in Table 2 are produced to product analysis tolerances shown in Table 6.

NOTE 4—Standard alloy steels can be produced with a lead range of 0.15 % to 0.35 %. Such steels are identified by inserting the letter "L" between the second and third numerals of the AISI number, for example, 41 L 40. A cast or heat analysis is not determinable when lead is added to the ladle stream.

Grade Designation	Heat Chemical Ranges and Limits, %								
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon[A]	Nickel	Chromium	Molybdenum	Vanadium
1330	0.28–0.33	1.60–1.90	0.035	0.040	0.15–0.35	...	...	...	...
1335	0.33–0.38	1.60–1.90	0.035	0.040	0.15–0.35	...	...	...	...
1340	0.38–0.43	1.60–1.90	0.035	0.040	0.15–0.35	...	...	...	...
1345	0.43–0.48	1.60–1.90	0.035	0.040	0.15–0.35				...
4012	0.09–0.14	0.75–1.00	0.035	0.040	0.15–0.35	...	...	0.15–0.25	...
4023	0.20–0.25	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.20–0.30	...
4024	0.20–0.25	0.70–0.90	0.035	0.035–0.050	0.15–0.35	...	...	0.20–0.30	...
4027	0.25–0.30	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.20–0.30	...
4028	0.25–0.30	0.70–0.90	0.035	0.035–0.050	0.15–0.35	...	...	0.20–0.30	...
4032	0.30–0.35	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.20–0.30	...
4037	0.35–0.40	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.20–0.30	...
4042	0.40–0.45	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.20–0.30	...
4047	0.45–0.50	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.20–0.30	...
4118	0.18–0.23	0.70–0.90	0.035	0.040	0.15–0.35	...	0.40–0.60	0.08–0.15	...
4120	0.18–0.23	0.90–1.20	0.035	0.040	0.15–0.35	...	0.40–0.60	0.13–0.20	...
4121	0.18–0.23	0.75–1.00	0.035	0.040	0.15–0.35	...	0.45–0.65	0.20–0.30	...
4130	0.28–0.33	0.40–0.60	0.035	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25	...
4135	0.33–0.38	0.70–0.90	0.035	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25	...
4137	0.35–0.40	0.70–0.90	0.035	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25	...
4140	0.38–0.43	0.75–1.00	0.035	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25	...
4142	0.40–0.45	0.75–1.00	0.035	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25	...
4145	0.43–0.48	0.75–1.00	0.035	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25	...
4147	0.45–0.50	0.75–1.00	0.035	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25	...
4150	0.48–0.53	0.75–1.00	0.035	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25	...
4161	0.56–0.64	0.75–1.00	0.035	0.040	0.15–0.35	...	0.70–0.90	0.25–0.35	...
4320	0.17–0.22	0.45–0.65	0.035	0.040	0.15–0.35	1.65–2.00	0.40–0.60	0.20–0.30	...
4340	0.38–0.43	0.60–0.80	0.035	0.040	0.15–0.35	1.65–2.00	0.70–0.90	0.20–0.30	...
E4340	0.38–0.43	0.65–0.85	0.025	0.025	0.15–0.35	1.65–2.00	0.70–0.90	0.20–0.30	...
4419	0.18–0.23	0.45–0.65	0.035	0.040	0.15–0.35	...	...	0.45–0.60	...
4422	0.20–0.25	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.35–0.45	...
4427	0.24–0.29	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.35–0.45	...
4615	0.13–0.18	0.45–0.65	0.035	0.040	0.15–0.35	1.65–2.00	...	0.20–0.30	...
4620	0.17–0.22	0.45–0.65	0.035	0.040	0.15–0.35	1.65–2.00	...	0.20–0.30	...
4621	0.18–0.23	0.70–0.90	0.035	0.040	0.15–0.35	1.65–2.00	...	0.20–0.30	...
4626	0.24–0.29	0.45–0.65	0.035	0.040	0.15–0.35	0.70–1.00	...	0.15–0.25	...
4715	0.13–0.18	0.70–0.90	0.035	0.040	0.15–0.35	0.70–1.00	0.45–0.65	0.45–0.60	...
4718	0.16–0.21	0.70–0.90	0.035	0.040	0.15–0.35	0.90–1.20	0.35–0.55	0.30–0.40	...
4720	0.17–0.22	0.50–0.70	0.035	0.040	0.15–0.35	0.90–1.20	0.35–0.55	0.15–0.25	...
4815	0.13–0.18	0.40–0.60	0.035	0.040	0.15–0.35	3.25–3.75	...	0.20–0.30	...
4817	0.15–0.20	0.40–0.60	0.035	0.040	0.15–0.35	3.25–3.75	...	0.20–0.30	...
4820	0.18–0.23	0.50–0.70	0.035	0.040	0.15–0.35	3.25–3.75	...	0.20–0.30	...
5015	0.12–0.17	0.30–0.50	0.035	0.040	0.15–0.35	...	0.30–0.50	...	...
5046	0.43–0.48	0.75–1.00	0.035	0.040	0.15–0.35	...	0.20–0.35	...	...
5115	0.13–0.18	0.70–0.90	0.035	0.040	0.15–0.35	...	0.70–0.90	...	...
5120	0.17–0.22	0.70–0.90	0.035	0.040	0.15–0.35	...	0.70–0.90	...	...
5130	0.28–0.33	0.70–0.90	0.035	0.040	0.15–0.35	...	0.80–1.10	...	...
5132	0.30–0.35	0.60–0.80	0.035	0.040	0.15–0.35	...	0.75–1.00	...	...
5135	0.33–0.38	0.60–0.80	0.035	0.040	0.15–0.35	...	0.80–1.05	...	...
5140	0.38–0.43	0.70–0.90	0.035	0.040	0.15–0.35	...	0.70–0.90	...	...
5145	0.43–0.48	0.70–0.90	0.035	0.040	0.15–0.35	...	0.70–0.90	...	...
5147	0.46–0.51	0.70–0.95	0.035	0.040	0.15–0.35	...	0.85–1.15	...	...
5150	0.48–0.53	0.70–0.90	0.035	0.040	0.15–0.35	...	0.70–0.90	...	...
5155	0.51–0.59	0.70–0.90	0.035	0.040	0.15–0.35	...	0.70–0.90	...	...
5160	0.56–0.64	0.75–1.00	0.035	0.040	0.15–0.35	...	0.70–0.90	...	...

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TABLE 2 *Continued*

Grade Designation	Heat Chemical Ranges and Limits, %								
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon[A]	Nickel	Chromium	Molybdenum	Vanadium
E50100	0.98–1.10	0.25–0.45	0.025	0.025	0.15–0.35	...	0.40–0.60	...	...
E51100	0.98–1.10	0.25–0.45	0.025	0.025	0.15–0.35	...	0.90–1.15	...	...
E52100	0.98–1.10	0.25–0.45	0.025	0.025	0.15–0.35	...	1.30–1.60	...	...
52100[B]	0.93–1.05	0.25–0.45	0.025	0.015	0.15–0.35	...	1.35–1.60	...	...
6118	0.16–0.21	0.50–0.70	0.035	0.040	0.15–0.35	...	0.50–0.70	...	0.10–0.15
6150	0.48–0.53	0.70–0.90	0.035	0.040	0.15–0.35	...	0.80–1.10	...	0.15 min
8115	0.13–0.18	0.70–0.90	0.035	0.040	0.15–0.35	0.20–0.40	0.30–0.50	0.08–0.15	...
8615	0.13–0.18	0.70–0.90	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25	...
8617	0.15–0.20	0.70–0.90	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25	...
8620	0.18–0.23	0.70–0.90	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25	...
8622	0.20–0.25	0.70–0.90	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25	...
8625	0.23–0.28	0.70–0.90	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25	...
8627	0.25–0.30	0.70–0.90	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25	...
8630	0.28–0.33	0.70–0.90	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25	...
8637	0.35–0.40	0.75–1.00	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25	...
8640	0.38–0.43	0.75–1.00	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25	...
8642	0.40–0.45	0.75–1.00	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25	...
8645	0.43–0.48	0.75–1.00	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25	...
8650	0.48–0.53	0.75–1.00	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25	...
8655	0.51–0.59	0.75–1.00	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25	...
8660	0.56–0.64	0.75–1.00	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25	...
8720	0.18–0.23	0.70–0.90	0.035	0.040	0.15–0.35	0.40–0.7	0.40–0.60	0.20–0.30	...
8740	0.38–0.43	0.75–1.00	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.20–0.30	...
8822	0.20–0.25	0.75–1.00	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.30–0.40	...
9254	0.51–0.59	0.60–0.80	0.035	0.040	1.20–1.60	...	0.60–0.80	...	...
9255	0.51–0.59	0.70–0.95	0.035	0.040	1.80–2.20	...	...	...	...
9259	0.56–0.64	0.75–1.00	0.035	0.040	0.70–1.10	...	0.45–0.65	...	...
9260	0.56–0.64	0.75–1.00	0.035	0.040	1.80–2.20	...	...	...	...
E9310	0.08–0.13	0.45–0.65	0.025	0.025	0.15–0.30	3.00–3.50	1.00–1.40	0.08–0.15	...
Standard Boron Steels[C]									
50B44	0.43–0.48	0.75–1.00	0.035	0.040	0.15–0.35	. . .	0.20–0.60	. . .	...
50B46	0.44–0.49	0.75–1.00	0.035	0.040	0.15–0.35	. . .	0.20–0.35	. . .	...
50B50	0.48–0.53	0.75–1.00	0.035	0.040	0.15–0.35	. . .	0.40–0.60	. . .	...
50B60	0.56–0.64	0.75–1.00	0.035	0.040	0.15–0.35	. . .	0.40–0.60	. . .	...
51B60	0.56–0.64	0.75–1.00	0.035	0.040	0.15–0.35	. . .	0.70–0.90	. . .	...
81B45	0.43–0.48	0.75–1.00	0.035	0.040	0.15–0.35	0.20–0.40	0.35–0.55	0.08–0.15	...
94B17	0.15–0.20	0.75–1.00	0.035	0.040	0.15–0.35	0.30–0.60	0.30–0.50	0.08–0.15	...
94B30	0.28–0.33	0.75–1.00	0.035	0.040	0.15–0.35	0.30–0.60	0.30–0.50	0.08–0.15	...

[A] Silicon may be specified by the purchaser as 0.10 % maximum. The need for 0.10 % maximum generally relates to severe cold-formed parts.
[B] The purchaser may also require the following maximums: copper 0.30 %; aluminum 0.050 %; oxygen 0.0015 %.
[C] These steels can be expected to contain 0.0005 % to 0.003 % boron. If the usual titanium additive is not permitted, the steels can be expected to contain up to 0.005 % boron.

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Steels having 0.25 % carbon or less:

Cb	0.025 min
V	0.05 min

Steels having over 0.25 % carbon:

Cb	0.015 min
V	0.02 min

5.1.2.3 When provisions of 5.1.2.1 or 5.1.2.2 are exercised, a grain size test is not required unless specified by the purchaser. Unless otherwise specified, fine austenitic grain size shall be certified using the analysis of grain refining element(s).

5.1.2.4 *Referee Test*—In the event that the chemical analysis of columbium[8] or vanadium does not meet the requirements of 5.1.2.2, the grain size test shown in 5.1.2 shall be the referee test unless an alternative test method is agreed upon between the manufacturer and the purchaser.