



Designation: **A29/A29M – 12<sup>ε1</sup> A29/A29M – 15**

# Standard Specification for General Requirements for Steel Bars, Carbon and Alloy, Hot-Wrought<sup>1</sup>

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 ( $\epsilon$ ) 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.*

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<sup>ε1</sup> NOTE—Title was editorially revised in December 2013.

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## 1. Scope\*

1.1 This specification<sup>2</sup> 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 <sup>4</sup>
Title of Specification	ASTM Designation <sup>4</sup>
<i>Hot-Rolled Carbon Steel Bars:</i>	
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
Steel Bars for Springs, Carbon and Alloy	A689
<i>Cold-Finished Carbon Steel Bars:</i>	
Steel Bars, Carbon and Alloy, Cold-Finished	A108
Cold-Drawn Stress-Relieved Carbon Steel Bars Subject to Mechanical Property Requirements	A311/A311M
<i>Hot-Rolled Alloy Steel Bars:</i>	
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
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
<i>Cold-Finished Alloy Steel Bars:</i>	
Steel Bars, Alloy, Hot-Rolled or Cold-Finished, Quenched and Tempered	A434
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

<sup>4</sup> 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.

<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 A01.15 on Bars.

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

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

<sup>△</sup>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 inch-pound units or SI units are to be regarded as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

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

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>3</sup>

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

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

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)<sup>4</sup>

A322 Specification for Steel Bars, Alloy, Standard Grades

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

~~A434~~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, Practices, and Terminology 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 ~~A29/A29M-15~~

### 2.2 Federal Standards:<sup>5</sup>

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

### 2.3 Military Standard:<sup>5</sup>

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

### 2.4 Other Standards:<sup>6</sup>

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,

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For Annual Book of ASTM Standards volume information, refer to the standard’s Document Summary page on the ASTM website.

<sup>4</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

<sup>5</sup> 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 the Standardization Documents Order Desk, Bldg. 4 Section D, DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS: <http://quicksearch.dla.mil>.

<sup>6</sup> Available from Automotive Industry Action Group, North Park Plaza, Ste. 830, 17117 W. Nine Mile Rd., Southfield, MI 48075: Group (AIAG), 26200 Lahser Rd., Suite 200, Southfield, MI 48033-7156, <http://www.aiag.org>.

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

3.1.1.4 *flats*— $\frac{1}{8}$  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*—*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*—*rounds*— $\frac{7}{32}$  to 10.0 in. [5.5 to 250 mm], inclusive,

3.1.2.2 *Squares*—*squares*— $\frac{7}{32}$  to 6.0 in. [6 to 160 mm], inclusive,

3.1.2.3 *Round-Cornered Squares*—*round-cornered squares*— $\frac{7}{32}$  to 8.0 in. [6 to 200 mm], inclusive,

3.1.2.4 *Flats*—*flats*— $\frac{1}{4}$  to 8 in. inclusive, in width:  $\frac{13}{64}$  in. in minimum thickness up to 6 in. in width; and 0.230 in. in minimum thickness for over 6 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]-[mm],

3.1.2.5 *Hexagons**hexagons* and *Octagons*—*octagons*— $\frac{1}{4}$  to  $4\frac{1}{16}$  in. [6 to 103 mm], inclusive, between parallel surfaces,

3.1.2.6 *Bar Size Shapes*—*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*—*special bar sections*—Half-rounds, ovals, half-ovals, other special bar size sections.

3.1.2 *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:

3.1.2.1 *Rounds*—9 in. [230 mm] and under in diameter,

3.1.2.2 *Squares*—6 in. [150 mm] and under between parallel surfaces,

3.1.2.3 *Hexagons*—4 in. [100 mm] and under between parallel surfaces,

3.1.2.4 *Flats*— $\frac{1}{8}$  in. [3 mm] and over in thickness and not over 12 in. [300 mm] in width, and

3.1.2.5 *Special Bar Sections*.—

3.1.3 *Lot*—*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.

<https://standards.iteh.ai/catalog/standards/sist/56b5dda6-825a-4b94-b21c-b59b93831b84/astm-a29-a29m-15>

## 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 **Tables 1 and 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, Practices, and Terminology **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, Practices, and Terminology **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

**TABLE 1 Grade Designations and Chemical Compositions of Carbon Steel Bars**

Grade Designation	Heat Chemical Ranges and Limits, %				
	Carbon	Manganese	Phosphorus, max	Sulfur, max <sup>A</sup>	
<b>Nonresulfurized Carbon Steels<sup>B,C, D,E,F</sup></b>					
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	
<b>Resulfurized Carbon Steels<sup>B,D,F</sup></b>					
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	
<b>Rephosphorized and Resulfurized Carbon Steels<sup>D,F</sup></b>					
Grade Designation	Carbon	Manganese	Phosphorus	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	...

**TABLE 1** *Continued*

Rephosphorized and Resulfurized Carbon Steels <sup>D,F</sup>					
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 <sup>B,C,D,E,F</sup>					
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 <sup>G</sup>	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	

<sup>A</sup> Maximum unless otherwise indicated.

<sup>B</sup> 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 %.

<sup>C</sup> Copper can be specified when required as 0.20 % minimum.

<sup>D</sup> 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.

<sup>E</sup> 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.

<sup>F</sup> The elements bismuth, calcium, selenium, or tellurium may be added as agreed upon between purchaser and supplier.

<sup>G</sup> 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 %.

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.<sup>2</sup> [500 mm<sup>2</sup>] 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.<sup>2</sup> 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.

**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 0.15–0.35 %. 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 <sup>A</sup>	Nickel	Chromium	Molybdenum
<del>1330</del>	<del>0.28–0.33</del>	<del>1.60–1.90</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>...</del>	<del>...</del>
1330	0.28–0.33	1.60–1.90	0.035	0.040	0.15–0.35	...	...	...
<del>1335</del>	<del>0.33–0.38</del>	<del>1.60–1.90</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>...</del>	<del>...</del>
1335	0.33–0.38	1.60–1.90	0.035	0.040	0.15–0.35	...	...	...
<del>1340</del>	<del>0.38–0.43</del>	<del>1.60–1.90</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>...</del>	<del>...</del>
1340	0.38–0.43	1.60–1.90	0.035	0.040	0.15–0.35	...	...	...
<del>1345</del>	<del>0.43–0.48</del>	<del>1.60–1.90</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>...</del>	<del>...</del>
1345	0.43–0.48	1.60–1.90	0.035	0.040	0.15–0.35	...	...	...
<del>4012</del>	<del>0.09–0.14</del>	<del>0.75–1.00</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>...</del>	<del>0.15–0.25–</del>
4012	0.09–0.14	0.75–1.00	0.035	0.040	0.15–0.35	...	...	0.15–0.25
<del>4023</del>	<del>0.20–0.25</del>	<del>0.70–0.90</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>...</del>	<del>0.20–0.30–</del>
4023	0.20–0.25	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.20–0.30
<del>4024</del>	<del>0.20–0.25</del>	<del>0.70–0.90</del>	<del>0.035</del>	<del>0.035–0.050</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>...</del>	<del>0.20–0.30–</del>
4024	0.20–0.25	0.70–0.90	0.035	0.035–0.050	0.15–0.35	...	...	0.20–0.30
<del>4027</del>	<del>0.25–0.30</del>	<del>0.70–0.90</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>...</del>	<del>0.20–0.30–</del>
4027	0.25–0.30	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.20–0.30
<del>4028</del>	<del>0.25–0.30</del>	<del>0.70–0.90</del>	<del>0.035</del>	<del>0.035–0.050</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>...</del>	<del>0.20–0.30–</del>
4028	0.25–0.30	0.70–0.90	0.035	0.035–0.050	0.15–0.35	...	...	0.20–0.30
<del>4032</del>	<del>0.30–0.35</del>	<del>0.70–0.90</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>...</del>	<del>0.20–0.30–</del>
4032	0.30–0.35	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.20–0.30
<del>4037</del>	<del>0.35–0.40</del>	<del>0.70–0.90</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>...</del>	<del>0.20–0.30–</del>
4037	0.35–0.40	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.20–0.30
<del>4042</del>	<del>0.40–0.45</del>	<del>0.70–0.90</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>...</del>	<del>0.20–0.30–</del>
4042	0.40–0.45	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.20–0.30
<del>4047</del>	<del>0.45–0.50</del>	<del>0.70–0.90</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>...</del>	<del>0.20–0.30–</del>
4047	0.45–0.50	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.20–0.30
<del>4118</del>	<del>0.18–0.23</del>	<del>0.70–0.90</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>0.40–0.60</del>	<del>0.08–0.15–</del>
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
<del>4120</del>	<del>0.18–0.23</del>	<del>0.90–1.20</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>0.40–0.60</del>	<del>0.13–0.20–</del>
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
<del>4121</del>	<del>0.18–0.23</del>	<del>0.75–1.00</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>0.45–0.65</del>	<del>0.20–0.30–</del>
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
<del>4130</del>	<del>0.28–0.33</del>	<del>0.40–0.60</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>0.80–1.10</del>	<del>0.15–0.25–</del>
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
<del>4135</del>	<del>0.33–0.38</del>	<del>0.70–0.90</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>0.80–1.10</del>	<del>0.15–0.25–</del>
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
<del>4137</del>	<del>0.35–0.40</del>	<del>0.70–0.90</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>0.80–1.10</del>	<del>0.15–0.25–</del>
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
<del>4140</del>	<del>0.38–0.43</del>	<del>0.75–1.00</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>0.80–1.10</del>	<del>0.15–0.25–</del>
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
<del>4142</del>	<del>0.40–0.45</del>	<del>0.75–1.00</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>0.80–1.10</del>	<del>0.15–0.25–</del>
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
<del>4145</del>	<del>0.43–0.48</del>	<del>0.75–1.00</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>0.80–1.10</del>	<del>0.15–0.25–</del>
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
<del>4147</del>	<del>0.45–0.50</del>	<del>0.75–1.00</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>0.80–1.10</del>	<del>0.15–0.25–</del>
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
<del>4150</del>	<del>0.48–0.53</del>	<del>0.75–1.00</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>0.80–1.10</del>	<del>0.15–0.25–</del>
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
<del>4161</del>	<del>0.56–0.64</del>	<del>0.75–1.00</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>0.70–0.90</del>	<del>0.25–0.35–</del>
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
<del>4320</del>	<del>0.17–0.22</del>	<del>0.45–0.65</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>1.65–2.00</del>	<del>0.40–0.60</del>	<del>0.20–0.30–</del>
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
<del>4340</del>	<del>0.38–0.43</del>	<del>0.60–0.80</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>1.65–2.00</del>	<del>0.70–0.90</del>	<del>0.20–0.30–</del>
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
<del>E4340</del>	<del>0.38–0.43</del>	<del>0.65–0.85</del>	<del>0.025</del>	<del>0.025</del>	<del>0.15 to 0.35</del>	<del>1.65–2.00</del>	<del>0.70–0.90</del>	<del>0.20–0.30–</del>
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
<del>4419</del>	<del>0.18–0.23</del>	<del>0.45–0.65</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>...</del>	<del>0.45–0.60–</del>
4419	0.18–0.23	0.45–0.65	0.035	0.040	0.15–0.35	...	...	0.45–0.60
<del>4422</del>	<del>0.20–0.25</del>	<del>0.70–0.90</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>...</del>	<del>0.35–0.45–</del>
4422	0.20–0.25	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.35–0.45
<del>4427</del>	<del>0.24–0.29</del>	<del>0.70–0.90</del>	<del>0.035</del>	<del>0.040</del>	<del>0.15 to 0.35</del>	<del>...</del>	<del>...</del>	<del>0.35–0.45–</del>
4427	0.24–0.29	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.35–0.45



**TABLE 2** *Continued*

Grade Designation	Heat Chemical Ranges and Limits, %							
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon <sup>A</sup>	Nickel	Chromium	Molybdenum
4615	0.13-0.18	0.45-0.65	0.035	0.040	0.15 to 0.35	1.65-2.00	...	0.20-0.30
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 to 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
4624	0.18-0.23	0.70-0.90	0.035	0.040	0.15 to 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 to 0.35	0.70-1.00	...	0.15-0.25
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 to 0.35	0.70-1.00	0.45-0.65	0.45-0.60
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 to 0.35	0.90-1.20	0.35-0.55	0.30-0.40
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 to 0.35	0.90-1.20	0.35-0.55	0.15-0.25
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
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 to 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 to 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 to 0.35	...	0.30-0.50	...
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 to 0.35	...	0.20-0.35	...
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 to 0.35	...	0.70-0.90	...
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 to 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 to 0.35	...	0.80-1.10	...
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 to 0.35	...	0.75-1.00	...
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 to 0.35	...	0.80-1.05	...
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 to 0.35	...	0.70-0.90	...
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 to 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 to 0.35	...	0.85-1.15	...
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 to 0.35	...	0.70-0.90	...
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 to 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 to 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	...
E50100	0.98-1.10	0.25-0.45	0.025	0.025	0.15 to 0.35	...	0.40-0.60	...
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 to 0.35	...	0.90-1.15	...
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 to 0.35	...	1.30-1.60	...
E52100	0.98-1.10	0.25-0.45	0.025	0.025	0.15-0.35	...	1.30-1.60	...
52100 <sup>B</sup>	0.93-1.05	0.25-0.45	0.025	0.015	0.15 to 0.35	...	1.35-1.60	...
52100 <sup>B</sup>	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 to 0.35	...	0.50-0.70	(0.10-0.15 V)
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 V)
6150	0.48-0.53	0.70-0.90	0.035	0.040	0.15 to 0.35	...	0.80-1.10	(0.15 min V)
6150	0.48-0.53	0.70-0.90	0.035	0.040	0.15-0.35	...	0.80-1.10	(0.15 min V)
8115	0.13-0.18	0.70-0.90	0.035	0.040	0.15 to 0.35	0.20-0.40	0.30-0.50	0.08-0.15
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 to 0.35	0.40-0.70	0.40-0.60	0.15-0.25
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 to 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 to 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 to 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 to 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 to 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

**TABLE 2** *Continued*

Grade Designation	Heat Chemical Ranges and Limits, %							
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon <sup>a</sup>	Nickel	Chromium	Molybdenum
8630	0.28–0.33	0.70–0.90	0.035	0.040	0.15 to 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 to 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
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 to 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
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 to 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 to 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 to 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 to 0.35	0.40–0.7	0.40–0.60	0.20–0.30
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 to 0.35	0.40–0.70	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 to 0.35	0.40–0.70	0.40–0.60	0.30–0.40
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	...
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 to 0.30	3.00–3.50	1.00–1.40	0.08–0.15
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 <sup>c</sup>								
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

<sup>a</sup> Silicon may be specified by the purchaser as 0.10 % maximum. The need for 0.10% maximum generally relates to severe cold-formed parts.  
<sup>b</sup> The purchaser may also require the following maximums: copper 0.30 %; aluminum 0.050 %; oxygen 0.0015 %.  
<sup>c</sup> 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.

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. <sup>2</sup> (cm <sup>2</sup> ) 16 [100] or less Over 16 [100]	Approximate Drill Diameter, in. (mm) ½ [12.5] 1 [25.0]
Area of Sample Cross Section, in. <sup>2</sup> [cm <sup>2</sup> ] 16 [100] or less Over 16 [100]	Approximate Drill Diameter, in. [mm] ½ [12.5] 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:

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



**TABLE 3 Heat Analysis Chemical Ranges and Limits of Carbon Steel Bars**

Element	Chemical Ranges and Limits, %		
	When Maximum of Specified Elements is:	Range	Lowest Maximum
Carbon <sup>A</sup>	...	...	0.06
	to 0.12, incl	...	...
	over 0.12 to 0.25, incl	0.05	...
	over 0.25 to 0.40, incl	0.06	...
	over 0.40 to 0.55, incl	0.07	...
	over 0.55 to 0.80, incl	0.10	...
Manganese	over 0.80	0.13	...
	...	...	0.35
	to 0.40, incl	0.15	...
Phosphorus	over 0.40 to 0.50, incl	0.20	...
	over 0.50 to 1.65, incl	0.30	...
	to 0.040, incl	...	0.040 <sup>B</sup>
Sulfur	over 0.040 to 0.08, incl	0.03	...
	over 0.08 to 0.13, incl	0.05	...
	to 0.050, incl	...	0.050 <sup>B</sup>
Silicon <sup>C</sup>	over 0.050 to 0.09, incl	0.03	...
	over 0.09 to 0.15, incl	0.05	...
	over 0.15 to 0.23, incl	0.07	...
	over 0.23 to 0.50, incl	0.09	...
	...	...	0.10
Copper	to 0.10, incl	...	...
	over 0.10 to 0.15, incl	0.08	...
Lead <sup>D</sup>	over 0.15 to 0.20, incl	0.10	...
	over 0.20 to 0.30, incl	0.15	...
Bismuth <sup>E</sup>	over 0.30 to 0.60, incl	0.20	...
	When copper is required	0.20	...
Calcium <sup>E</sup>	min is generally used	...	...
	When lead is required, a range	of 0.15 to 0.35 is specified	...
Selenium <sup>E</sup>			
Tellurium <sup>E</sup>			

<sup>A</sup> The carbon ranges shown in the column headed "Range" apply when the specified maximum limit for manganese does not exceed 1.10 %. When the maximum manganese limit exceeds 1.10 %, add 0.01 to the carbon ranges shown above.

<sup>B</sup> For steels produced in merchant quality the phosphorus maximum is 0.04 % and the sulfur maximum is 0.05 %.

<sup>C</sup> It is not common practice to produce a rephosphorized and resulfurized carbon steel to specified limits for silicon because of its adverse effect on machinability.

<sup>D</sup> A cast or heat analysis is not determinable when lead is added to the ladle stream.

<sup>E</sup> Element specification range as agreed upon between purchaser and supplier.

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, Practices, and 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.

**TABLE 4 Heat Analysis Chemical Ranges and Limits of Alloy Steel Bars**

NOTE 1—Boron steels can be expected to have 0.0005 % minimum boron content.

NOTE 2—Alloy steels can be produced with a lead range of 0.15–0.35 %. A cast or heat analysis is not determinable when lead is added to the ladle stream.

Element	Chemical Ranges and Limits, %			
	When Maximum of Specified Element is:	Open-Hearth or Basic-Oxygen Steel	Electric Furnace Steel	Maximum Limit, % <sup>A</sup>
Carbon	To 0.55, incl	0.05	0.05	
	Over 0.55–0.70, incl	0.08	0.07	
	Over 0.70 to 0.80, incl	0.10	0.09	
	Over 0.80–0.95, incl	0.12	0.11	
	Over 0.95–1.35, incl	0.13	0.12	
Manganese	To 0.60, incl	0.20	0.15	
	Over 0.60–0.90, incl	0.20	0.20	
	Over 0.90–1.05, incl	0.25	0.25	
	Over 1.05–1.90, incl	0.30	0.30	
	Over 1.90–2.10, incl	0.40	0.35	
Phosphorus	Basic open-hearth or basic-oxygen steel			0.035
	Acid open-hearth steel			0.050
	Basic electric-furnace steel			0.025
	Acid electric-furnace steel			0.050
Sulfur	To 0.050, incl	–0.015	–0.015	
Sulfur	To 0.050, incl	0.015	0.015	
	Over 0.050–0.07, incl	0.02	0.02	
	Over 0.07–0.10, incl	0.04	0.04	
	Over 0.10–0.14, incl	0.05	0.05	
	Basic open-hearth or basic-oxygen steel			0.040
	Acid open-hearth steel			0.050
	Basic electric-furnace steel			0.025
Acid electric-furnace steel			0.050	
Silicon	To 0.20, incl	0.08	0.08	
	Over 0.20–0.30, incl	0.15	0.15	
	Over 0.30–0.60, incl	0.20	0.20	
	Over 0.60–1.00, incl	0.30	0.30	
	Over 1.00–2.20, incl	0.40	0.35	
	Acid steels <sup>B</sup>			
Nickel	To 0.50, incl	0.20	0.20	
	Over 0.50–1.50, incl	0.30	0.30	
	Over 1.50–2.00, incl	0.35	0.35	
	Over 2.00–3.00, incl	0.40	0.40	
	Over 3.00–5.30, incl	0.50	0.50	
	Over 5.30–10.00, incl	1.00	1.00	
Chromium	To 0.40, incl	0.15	0.15	
	Over 0.40–0.90, incl	0.20	0.20	
	Over 0.90–1.05, incl	0.25	0.25	
	Over 1.05–1.60, incl	0.30	0.30	
	Over 1.60–1.75, incl	<sup>C</sup>	0.35	
	Over 1.75–2.10, incl	<sup>C</sup>	0.40	
	Over 2.10–3.99, incl	<sup>C</sup>	0.50	
Molybdenum	To 0.10, incl	0.05	0.05	
	Over 0.10–0.20, incl	0.07	0.07	
	Over 0.20–0.50, incl	0.10	0.10	
	Over 0.50–0.80, incl	0.15	0.15	
	Over 0.80–1.15, incl	0.20	0.20	
Tungsten	To 0.50, incl	0.20	0.20	
	Over 0.50–1.00, incl	0.30	0.30	
	Over 1.00–2.00, incl	0.50	0.50	
	Over 2.00–4.00, incl	0.60	0.60	
Vanadium	To 0.25, incl	0.05	0.05	
	Over 0.25–0.50, incl	0.10	0.10	
Aluminum	Up to 0.10, incl	0.05	0.05	
	Over 0.10–0.20, incl	0.10	0.10	
	Over 0.20–0.30, incl	0.15	0.15	
	Over 0.30–0.80, incl	0.25	0.25	
	Over 0.80–1.30, incl	0.35	0.35	
	Over 1.30–1.80, incl	0.45	0.45	
Copper	To 0.60, incl	0.20	0.20	
	Over 0.60–1.50, incl	0.30	0.30	
	Over 1.50–2.00, incl	0.35	0.35	

<sup>A</sup> Applies to only nonrephosphorized and nonresulfurized steels.

<sup>B</sup> Minimum silicon limit for acid open-hearth or acid electric-furnace alloy steels is 0.15 %.

<sup>C</sup> Not normally produced in open-hearth.