



Designation: A 935/A 935M – 97a

## Standard Specification for Steel, Sheet and Strip, Heavy Thickness Coils, High Strength, Low-Alloy, Columbium or Vanadium, or Both, Hot- Rolled<sup>1</sup>

This standard is issued under the fixed designation A 935/A 935M; 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-rolled, heavy-thickness, high-strength, low-alloy columbium, or vanadium hot-rolled sheet and strip, or combinations thereof, in coils beyond the size limits of Specification A 607. This material is intended for miscellaneous applications where greater strength and savings in weight are important. The material is available as two classes. They are similar in strength level, except that Class 2 offers improved weldability and more formability than Class 1. Atmospheric corrosion resistance of these steels is equivalent to plain carbon steels. With copper specified, the atmospheric corrosion resistance is somewhat enhanced.

NOTE 1—For methods of establishing the atmospheric corrosion resistance of low-alloy steels see Guide G 101.

1.1.1 This material is available only in coils described as follows:

Size Limits, Coils Only

Product	Width, in. (mm)	Thickness, in. (mm)
Strip	Over 8 to 12 incl (Over 200 to 300)	0.230 to 1.000 incl (Over 6.0 to 25)
Sheet	Over 12 to 48 incl (Over 300 to 1200)	0.230 to 1.000 incl (Over 6.0 to 25)
	Over 48 (Over 1200)	0.180 to 1.000 incl (Over 4.5 to 25)

1.2 Sheet and strip in coils of sizes noted in 1.1 can be included in this specification only with the following:

1.2.1 The material is not to be converted into steel plates for structural or pressure vessel use unless tested in complete accordance with the appropriate section of Specifications A 6/A 6M (plates provided from coils) or A 20/A 20M (plates produced from coils).

1.2.2 This specification is not applicable to the steels covered by Specification A 635/A 635M.

1.2.3 The dimensional tolerances of Specification A 635/A 635M are applicable to material produced to this specification.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is under the direct responsibility of Subcommittee A01.19 on Steel Sheet and Strip.

Current edition approved March 10 and June 10, 1997. Published November 1997. Originally published as A 935/A 935M - 95. Last previous edition A 935/A 935M - 95.

1.2.4 The material is to be fed directly from coils into a blanking press, drawing or forming operation, tube mill, rolling mill, or sheared or slit into blanks for subsequent drawing or forming.

1.2.5 Not all strength levels are available in all thicknesses. The user should consult the producer for appropriate size limitations.

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 must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>2</sup>

A 607 Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Columbium or Vanadium, or Both, Hot-Rolled and Cold-Rolled<sup>2</sup>

A 635/A635M Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Carbon, Hot-Rolled<sup>2</sup>

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products<sup>2</sup>

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>3</sup>

G 101 Guide for Estimating the Atmospheric Corrosion on Resistance of Low-Alloy Steels<sup>4</sup>

### 3. Ordering Information

3.1 Orders for material under this specification shall include the following information, as required, to describe adequately the desired material:

3.1.1 ASTM specification number and year of issue, grade, type and class. When a type is not specified, choice of type will be made by the producer. When a class is not specified, Class 1 will be furnished.

<sup>2</sup> Annual Book of ASTM Standards, Vol 01.03.

<sup>3</sup> Annual Book of ASTM Standards, Vol 14.02.

<sup>4</sup> Annual Book of ASTM Standards, Vol 03.02.

3.1.2 Name of material (high-strength, low-alloy hot-rolled sheet coils or high-strength, low-alloy hot-rolled strip coils).

3.1.3 Copper-bearing (if required).

3.1.4 *Condition*—Material in accordance with this specification is furnished in the hot-rolled condition. Pickled (or blast-cleaned) must be specified if required. Material ordered as pickled (or blast-cleaned) will be oiled unless ordered dry.

3.1.5 Type of edge must be specified for hot-rolled sheet coils and strip coils, mill edge or cut edge (sheet), mill edge or slit edge (strip).

3.1.6 Dimensions (decimal thickness and width of material).

3.1.6.1 As agreed upon between the purchaser and the producer, material ordered to this specification will be supplied to meet the appropriate standard or restricted thickness tolerance table shown in Specification A 635/A 635M.

NOTE 2—Not all producers are capable of meeting all the limitations of the thickness tolerance tables in Specification A 635/A 635M. The purchaser should contact the producer regarding possible limitations prior to placing an order.

3.1.7 Coil size and weight requirements (must include inside diameter (ID), outside diameter (OD), and maximum weight).

3.1.8 Quantity (weight).

3.1.9 Application (part identification and description).

3.1.10 Special requirements (if required) or Supplementary Requirements S1.

3.1.11 Cast or heat analysis.

3.1.12 Test reports.

NOTE 3—A typical ordering description is as follows: (Inch-Pound) ASTM A 935/A 935M—XX: Grade 45, Type 2, Class 2, high-strength, low-alloy hot-rolled sheet coils, pickled and oiled, cut edge, 0.500 by 40 in. by coil; ID 24 in., OD 72 in., maximum; coil weight 40 000 lbs maximum; 200 000 lb for roll-forming shapes; (SI) ASTM A 935/A 935M—XX: Grade 310, Type 2, Class 2, high-strength, low-alloy hot-rolled sheet coils, pickled and oiled, cut edge, 10 mm by 900 mm by coil; ID 600 mm, OD 1800 mm, maximum; coil weight 18 000 kg maximum; 90 000 kg for roll-forming shapes.

## 4. Chemical Composition

4.1 The cast or heat analysis and product analysis of the

steel shall conform to the requirements in accordance with Table 1. Chemical analysis shall be conducted in accordance with Test Methods A 751.

4.1.1 Residual elements may be present. Limits on these elements shall be as stated in Table 2.

4.1.1.1 Each of the elements listed in Table 2 shall be included in the report of the heat analysis. When the amount of copper, nickel, chromium, or molybdenum is less than 0.02 %, these elements may be reported as <0.02 %.

4.2 When the steel is used in welded applications, welding procedure shall be suitable for the steel chemistry and the intended service.

4.3 When a class is not specified, Class 1 will be furnished.

4.4 The enhancement of corrosion resistance by copper additions may be based on a corrosion index calculated using the chemical composition of the steel in accordance with Guide G 101.

## 5. Mechanical Properties

5.1 Test specimen preparation and mechanical testing shall be in accordance with Test Methods A 370.

5.2 *Tensile Properties*—The material as represented by the test specimens shall conform to the requirements as to tensile properties in accordance with Table 3.

5.3 *Tension Test Specimen Location and Orientation*—The test shall be taken approximately midway between the center and edge of the material as rolled. The longitudinal axis of the tension test specimens shall be perpendicular to the direction of rolling (transverse test).

5.4 *Tension Tests*—Two tension tests shall be made from each heat or from each lot of 50 tons (45 Mg). When the amount of finished material from a heat or lot is less than 50 tons (45 Mg), only one tension test shall be made. When material rolled from one heat differs 0.050 in. (1.3 mm) or more in thickness, one tension test shall be made from both the thickest and the thinnest material rolled regardless of the weight represented.

5.5 To determine conformance with the product specification, a calculated value should be rounded to the nearest 1 Ksi (7 MPa) tensile strength and yield point, and to the nearest unit

**TABLE 1 Chemical Requirements<sup>A</sup>**  
**Composition, %**

NOTE 1—Class 2 requirements for manganese, phosphorus, sulfur, columbium, and vanadium are the same as shown for Class 1.

NOTE 2—An ellipsis (. . .) indicates that no limits have been set for that element.

Element	Grade 45		Grade 50		Grade 55		Grade 60		Grade 65		Grade 70	
	Heat or Cast Analysis	Product Analysis	Heat or Cast Analysis	Product Analysis	Heat or Cast Analysis	Product Analysis	Heat or Cast Analysis	Product Analysis	Heat or Cast Analysis	Product Analysis	Heat or Cast Analysis	Product Analysis
Class 1												
Carbon, max	0.22	0.26	0.23	0.27	0.25	0.29	0.26	0.30	0.26	0.30	0.26	0.30
Manganese, max	1.50	1.55	1.50	1.55	1.50	1.55	1.50	1.55	1.50	1.55	1.65	1.70
Phosphorus, max	0.04	0.05	0.04	0.05	0.04	0.05	0.04	0.05	0.04	0.05	0.04	0.05
Sulfur, max	0.04	0.06	0.04	0.06	0.04	0.06	0.04	0.06	0.04	0.06	0.04	0.06
Columbium or vanadium, min	Cb 0.005	0.004	Cb 0.005	0.004	Cb 0.005	0.004	Cb 0.005	0.004	Cb 0.005	0.004	Cb 0.005	0.004
Nitrogen, max	V 0.01	0.005	V 0.01	0.005	V 0.01	0.005	V 0.01	0.005	V 0.01	0.005	V 0.01	0.005
Class 2												
Carbon, max	0.15	0.18	0.15	0.18	0.15	0.18	0.15	0.18	0.15	0.18	0.15	0.18
Nitrogen, max	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024	0.020	0.024

<sup>A</sup> Copper, when specified, shall have a minimum content of 0.20 % by heat or cast analysis (0.18 % by product analysis).

**TABLE 2 Limits on Residual Elements (see 4.1.1)**

Copper, max % <sup>A</sup>	Heat analysis	0.20
	Product analysis	0.23
Nickel, max % <sup>A</sup>	Heat analysis	0.20
	Product analysis	0.23
Chromium, max % <sup>AB</sup>	Heat analysis	0.15
	Product analysis	0.19
Molybdenum, max % <sup>AB</sup>	Heat analysis	0.06
	Product analysis	0.07

<sup>A</sup> The sum of copper, nickel, chromium, and molybdenum shall not exceed 0.50 % on heat analysis. When one or more of these elements are specified, the sum does not apply; in which case, only the individual limits on the remaining residual elements will apply.

<sup>B</sup> The sum of chromium and molybdenum shall not exceed 0.16 % on heat analysis. When one or both of these elements are specified, the sum does not apply. In the case where only one of the two elements is specified, the individual limit on the remaining residual element will apply.

in the right hand place of figures used in expressing the limiting value for other values in accordance with the rounding off method given in Practice E 29.

5.6 Structural sheet steels commonly are fabricated by cold bending. There are many interrelated factors that affect the ability of a given steel to cold form over a given radius under shop conditions. These factors include thickness, strength level, degree of restraint, relationship to rolling direction, chemistry, and microstructure. The producer should be consulted as to recommended minimum inside radii and bending direction. Where possible, larger radii and “easy way” bending (bend axis perpendicular to rolling direction), or both, are recommended for improved performance.

5.7 Fabricators should be aware that cracks may initiate upon bending a sheared or burned edge. This is not considered to be a fault of the steel but is rather a function of the induced cold-work or heat-affected zone.

## 6. Workmanship, Finish, and Appearance

6.1 *Edges*—The normal edge condition in heavy thickness coils is mill edge. If cut edge is desired, it must be specified.

6.2 *Oiling*—Unless otherwise specified, hot-rolled as-rolled material shall be furnished dry, and hot-rolled pickled or blast-cleaned material shall be furnished oiled. When required, pickled or blast-cleaned material may be specified to be furnished dry, and as-rolled material may be specified to be furnished oiled.

6.3 *Surface Finish*—Unless otherwise specified, hot-rolled material shall have an as-rolled, not pickled surface finish. When required, material may be specified to be pickled or blast-cleaned.

## 7. General Requirements for Delivery

7.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 635/A 635M, unless otherwise provided herein.

## 8. Retests

8.1 If the results on an original tensile specimen are within 2000 psi (14 MPa) of the required tensile strength, within 1000 psi (7 MPa) of the required yield point, or within 2 % of the required elongation, a retest shall be permitted for which one random specimen from the heat or test lot shall be used. If the results on this retest specimen meet the specified mechanical requirements, the heat or lot will be accepted.

## 9. Certification

9.1 Material ordered in accordance with this specification is subject to mechanical properties and, as such, must be tested and such test results must be certified by the producer to the purchaser.

## 10. Keywords

10.1 alloy steel sheet; alloy steel strip; heavy thickness coils; high strength low-alloy steel; hot-rolled steel sheet; hotrolled steel strip; steel sheet; steel strip

**TABLE 3 Tensile Requirements<sup>A</sup>**

	Grade 45	Grade 50	Grade 55	Grade 60	Grade 65	Grade 70
Class 1						
Tensile strength, min, ksi (MPa)	60 (410)	65 (450)	70 (480)	75 (520)	80 (550)	85 (590)
Yield strength, min, ksi (MPa)	45 (310)	50 (340)	55 (380)	60 (410)	65 (450)	70 (480)
Elongation in 2 in. (50 mm), min, %, for thicknesses						
to 0.750 in. (19 mm) inclusive	22.0	20.0	18.0	16.0	14.0	12.0
Elongation in 8 in. (200 mm), min, %, for thicknesses 0.180 in. (4.5 mm) to 0.750 in. (19 mm) inclusive	17.0	16.0	15.0	14.0	12.0	10.0
Class 2						
Tensile strength, min, ksi (MPa)	55 (380)	60 (410)	65 (450)	70 (480)	75 (520)	80 (550)
Yield strength, min, ksi (MPa)	45 (310)	50 (340)	55 (380)	60 (410)	65 (450)	70 (480)
Elongation in 2 in. (50 mm), min, %, for thicknesses						
to 0.750 in. (19 mm) inclusive	22.0	20.0	18.0	16.0	14.0	12.0
Elongation in 8 in. (200 mm), min, %, for thicknesses 0.180 in. (4.5 mm) to 0.750 in. (19 mm) inclusive	17.0	16.0	15.0	14.0	12.0	10.0

<sup>A</sup> For coil products, testing by the producer is limited to the end of the coil. Results of such tests must comply with the specified values. Tensile properties throughout the balance of the coil must not be less than 90 % of the minimum values specified.

## SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply when specified in the order or contract:

### S1. Types

S1.1 When a purchaser prefers to designate the specific elements (columbium, vanadium, nitrogen, or combinations thereof), one of the types listed below shall be specified. The type, in addition to the grade, must be shown on the order (see 3.1.1).

Type 1—Columbium

Type 2—Vanadium

Type 3—Columbium and vanadium

Type 4—Vanadium and nitrogen

S1.2 The composition limits of Section 4 shall apply for any of these types.

*The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.*

*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

*This standard is copyrighted by ASTM, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org).*