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Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High- Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength¹

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1. Scope*

1.1 This specification covers hot-rolled, carbon, structural, high-strength low-alloy, high-strength low-alloy with improved formability, and ultra-high strength steel sheet and strip, in coils and cut lengths.

1.2 Hot rolled steel sheet and strip is available in the designations as listed in 4.1.

1.3 This specification is not applicable to the steel covered by Specification A635/A635M.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

2. Referenced Documents

2.1 *ASTM Standards*:²

A370 *Test Methods and Definitions for Mechanical Testing of Steel Products*

A568/A568M *Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for*

A569/A569M *Specification for Steel, Carbon (0.15 Maximum, Percent), Hot-Rolled Sheet and Strip Commercial*³

A622/A622M *Specification for Drawing Steel (DS), Sheet and Strip, Carbon, Hot-Rolled*³

A635/A635M *Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Hot-Rolled, Alloy, Carbon, Structural, High-Strength Low-Alloy, and High-Strength Low-Alloy with Improved Formability, General Requirements for*

A749/A749M *Specification for Steel, Strip, Carbon and High-Strength, Low-Alloy, Hot-Rolled, General Requirements for*

A941 *Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys*

E18 *Test Methods for Rockwell Hardness of Metallic Materials*

3. Terminology

3.1 *Definitions*—For definitions of other terms used in this specification refer to Terminology A941.

3.2 *Definitions of Terms Specific to This Standard*:

3.2.1 *aging*—loss of ductility with an increase in hardness, yield strength, and tensile strength that occurs when steel, which has been slightly cold worked (such as by temper rolling) is stored for some time.

3.2.1.1 *Discussion*—Aging also increases the tendency toward stretcher strains and fluting.

3.2.2 *inclusion control, n*—the process of reducing the volume fraction of inclusions or modifying the shape of inclusions to improve formability, weldability, and machinability.

3.2.2.1 *Discussion*—Inclusions, especially those elongated during the rolling process, create the conditions for initiating or propagating cracks when the material is stretched or bent during the manufacture of a part (or both). The adverse effects of inclusions are minimized by reducing the content of inclusions in the steel or by altering the shape of inclusions through the use of additions during the steelmaking process that change the elongated shape of the inclusions to less harmful small, well dispersed globular inclusions (or both).

3.2.3 *stabilization*—addition of one or more nitride or carbide forming elements, or both, such as titanium and columbium, to

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² 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.

³ Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

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

control the level of the interstitial elements carbon and nitrogen in the steel.

3.2.3.1 *Discussion*—Stabilization improves formability and increases resistance to aging.

3.2.4 *vacuum degassing*—process of refining liquid steel in which the liquid is exposed to a vacuum as part of a special technique for removing impurities or for decarburizing the steel.

4. Classification

4.1 Hot-rolled steel sheet and steel strip is available in the following designations:

4.1.1 Commercial Steel (CS Types A, B, C, and D),

4.1.2 Drawing Steel (DS Types A and B),

NOTE 1—CS Type B and DS Type B describe the most common product previously included, respectively, in Specifications A569/A569M and A622/A622M.

4.1.3 Structural Steel (SS grades 30[205], 33[230], 36[250] Types 1 and 2, 40[275], 45[310], 50[340], 55[380], 60[410], 70[480], and 80[550]),

4.1.4 High-Strength Low-Alloy Steel (HSLAS, classes 1 and 2, in grades 45[310], 50[340], 55[380], 60[410], 65[450], and 70[480]).

4.1.5 High-Strength Low-Alloy Steel with Improved Formability (HSLAS-F grades 50[340], 60[410], 70[480], and 80[550]).

4.1.5.1 HSLAS-F steel has improved formability when compared to HSLAS. The steel is fully deoxidized, made to a fine grain practice, and includes microalloying elements such as columbium, vanadium, and zirconium. The steel shall be treated to achieve inclusion control.

4.1.6 Ultra-High Strength (UHSS Types 1 and 2, in Grades 90 [620] and 100 [690]).

4.1.6.1 UHSS steel has increased strength compared with HSLAS-F. The steel is killed and made to a fine ferritic grain practice, and includes microalloying elements such as columbium (niobium), titanium, vanadium, molybdenum, and so forth. The steel shall be treated to achieve inclusion control. The material is intended for miscellaneous applications where higher strength, savings in weight, and weldability are important. Atmospheric corrosion resistance of these steels is equivalent to plain carbon steels. With copper specified, the atmospheric corrosion resistance is somewhat enhanced.

4.1.7 When required for HSLAS, HSLAS-F, and UHSS steels, limitations on the use of one or more of the microalloy elements shall be specified on the order.

5. Ordering Information

5.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to describe the required material. Examples of such information include, but are not limited to, the following:

5.1.1 ASTM specification number and year of issue,

5.1.2 Name of material and designation (hot-rolled steel sheet) (include grade, type and class, as appropriate, for CS, DS, SS, HSLAS, HSLAS-F, and UHSS) (see 4.1),

5.1.2.1 When a type is not specified for CS or DS, Type B will be furnished (see 4.1),

5.1.2.2 When a class is not specified for HSLAS, Class 1 will be furnished (see 4.1),

5.1.2.3 When a type is not specified for SS Grade 36, Type 1 will be furnished (see 4.1),

5.1.2.4 When a type is not specified for UHSS, Type 1 shall be furnished (see 4.1).

5.1.3 Finish (see 9.1)

5.1.4 Type of edge (see 9.3),

5.1.5 Oiled or not oiled, as required (see 9.2),

5.1.6 Dimensions (thickness, width, and whether cut lengths or coils),

NOTE 2—Not all producers are capable of meeting all the limitations of the thickness tolerance tables in Specifications A568/A568M and A749/A749M. The purchaser should contact the producer prior to placing an order.

5.1.7 Coil size (inside diameter, outside diameter, and maximum weight),

5.1.8 Copper bearing steel (if required),

5.1.9 Quantity,

5.1.10 Application (part identification and description),

5.1.11 A report of heat analysis will be supplied, if requested, for CS and DS. For materials with required mechanical properties, SS, HSLAS, HSLAS-F, and UHSS, a report is required of heat analysis and mechanical properties as determined by the tension test, and

5.1.12 Special requirements (if any).

5.1.12.1 When the purchaser requires thickness tolerances for $\frac{3}{8}$ in. [10 mm] minimum edge distance (see Supplementary Requirement in Specification A568/A568M), this requirement shall be specified in the purchase order or contract.

NOTE 3—A typical ordering description is as follows: ASTM A1011-XX, hot rolled steel sheet, CS Type A, pickled and oiled, cut edge, 0.075 by 36 by 96 in., 100 000 lb, for part no. 6310, for shelf bracket.

or:

ASTM A1011M-XX, hot rolled steel sheet, CS Type B, pickled and oiled, cut edge, 3.7 by 117 mm by coil, ID 600 mm, OD 1500 mm, max weight 10 000 kg, 50 000 kg, for upper control arm.

6. General Requirements for Delivery

6.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A568/A568M for sheets and Specification A749/A749M for strip, unless otherwise provided for herein.

7. Chemical Composition

7.1 The heat analysis of the steel shall conform to the chemical composition requirements of the appropriate designation shown in Table 1 for CS and DS and Table 2 for SS, HSLAS, HSLAS-F, and UHSS.

7.2 Each of the elements listed in Tables 1 and 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 %, report the analysis as <0.02 % or the actual determined value. When the amount of vanadium, columbium, or titanium is less than 0.008 %, report the analysis as <0.008 % or the actual determined value. When the amount of boron is less than 0.0005 %, report the analysis as <0.0005 % or the actual determined value.

7.3 Sheet steel grades defined by this specification are suitable for welding if appropriate welding conditions are selected. For certain welding processes, if more restrictive composition limits are desirable, they shall be specified at the time of inquiry and confirmed at the time of ordering.

8. Mechanical Properties

8.1 CS and DS:

8.1.1 Typical, nonmandatory mechanical properties for CS and DS are found in Table 3.

8.1.2 The material shall be capable of being bent at room temperature in any direction through 180° flat on itself without cracking on the outside of the bent portion (see the section on bend test in Test Methods and Definitions A370). The bend test is not a requirement of delivery. However, if testing is performed by the purchaser, material not conforming to the requirement shall be subject to rejection.

8.2 SS, HSLAS, HSLAS-F, and UHSS:

8.2.1 The available grades and corresponding mechanical properties for SS, HSLAS, HSLAS-F, and UHSS are shown in Table 4.

8.2.2 Tension Tests:

8.2.2.1 *Requirements*—Material as represented by the test specimen shall conform to the mechanical property requirements specified in Table 4. These requirements do not apply to the uncropped ends of unprocessed coils.

8.2.2.2 *Number of Tests*—Two tension tests shall be made from each heat or from each 50 tons [45 000 kg]. When the amount of finished material from a heat is less than 50 tons [45 000 kg], one tension test shall be made. When material rolled from one heat differs 0.050 in. [1.27 mm] or more in thickness, one tension test shall be made from the thickest and thinnest material regardless of the weight represented.

8.2.2.3 Tension test specimens shall be taken at a point immediately adjacent to the material to be qualified.

8.2.2.4 Tension test specimens shall be taken from the full thickness of the sheet as-rolled.

8.2.2.5 Tension test specimens shall be taken from a location approximately halfway between the center of sheet and the edge of the material as-rolled.

8.2.2.6 Tension test specimens shall be taken with the lengthwise axis of the test specimen parallel to the rolling direction (longitudinal test).

**TABLE 1 Chemical Composition^A
For Hot Rolled Steel Sheet and Strip Designations CS and DS**

| | Composition, % Heat Analysis | | | | | | | | | | | | | | | |
|------------------------------|--|------|-------|-------|----------|-----|-------------------|------|-----------------|------|-------|-------|-----------------|-----|-----|--|
| | Element maximum unless otherwise shown | | | | | | | | | | | | | | | |
| | C | Mn | P | S | Al | Si | Cu | Ni | Cr ^B | Mo | V | Cb | Ti ^C | N | B | |
| CS Type A ^{D,E,F,G} | 0.10 | 0.60 | 0.030 | 0.035 | ... | ... | 0.20 ^H | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.025 | ... | ... | |
| CS Type B ^F | 0.02 to 0.15 | 0.60 | 0.030 | 0.035 | ... | ... | 0.20 ^H | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.025 | ... | ... | |
| CS Type C ^{D,E,F,G} | 0.08 | 0.60 | 0.10 | 0.035 | ... | ... | 0.20 ^H | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.025 | ... | ... | |
| CS Type D ^F | 0.10 | 0.70 | 0.030 | 0.035 | ... | ... | 0.20 ^H | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.008 | ... | ... | |
| DS Type A ^{D,E,G} | 0.08 | 0.50 | 0.020 | 0.030 | 0.01 min | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.025 | ... | ... | |
| DS Type B | 0.02 to 0.08 | 0.50 | 0.020 | 0.030 | 0.01 min | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.025 | ... | ... | |

^A Where an ellipsis (...) appears in the table, there is no specified limit, but the analysis shall be reported.

^B Chromium is permitted, at the producer's option, to 0.25 % maximum when the carbon content is less than or equal to 0.05 %.

^C For steels containing 0.02 % carbon or more, titanium is permitted at the producer's option, to the lesser of 3.4N + 1.5S or 0.025 %.

^D Specify Type B to avoid carbon levels below 0.02 %.

^E For carbon levels less than or equal to 0.02 %, it is permissible to use vanadium, columbium, or titanium, or combinations thereof, as stabilizing elements at the producer's option. In such case, the limits for these elements are 0.10 % for vanadium or columbium and 0.15 % for titanium.

^F When an aluminum deoxidized steel is required, it is permissible to order a minimum of 0.01 % total aluminum.

^G It is permissible to furnish as a vacuum degassed or chemically stabilized steel, or both, at producer's option.

^H When copper steel is specified, the copper limit is a minimum requirement. When copper steel is not specified, the copper limit is a maximum requirement.



TABLE 2 Chemical Composition^A
For Hot Rolled Steel Sheet and Strip Designations SS, HSLAS, HSLAS-F, and UHSS

| Designation | % Heat Analysis, Element Maximum unless otherwise shown | | | | | | | | | | | | | |
|-------------------------------------|---|-----------|-------------|-------|------|------|-----------------|------|------|------|-------|-------|-------|-------------|
| | C | Mn | P | S | Al | Si | Cu ^B | Ni | Cr | Mo | V | Cb | Ti | N |
| SS: ^C | | | | | | | | | | | | | | |
| Grade 30 [205] | 0.25 | 0.90 | 0.035 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.025 | ... |
| Grade 33 [230] | 0.25 | 0.90 | 0.035 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.025 | ... |
| Grade 36 [250] Type 1 | 0.25 | 0.90 | 0.035 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.025 | ... |
| Grade 36 [250] Type 2 ^D | 0.25 | 1.35 | 0.035 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.025 | ... |
| Grade 40 [275] | 0.25 | 0.90 | 0.035 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.025 | ... |
| Grade 45 [310] ^D | 0.25 | 1.35 | 0.035 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.025 | ... |
| Grade 45 [310] Type 1 ^D | 0.25 | 1.35 | 0.035 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.025 | ... |
| Grade 45 [310] Type 2 | 0.02–0.08 | 0.30–1.00 | 0.030–0.070 | 0.025 | 0.02 | 0.60 | 0.20 | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.008 | 0.010–0.030 |
| Grade 50 [340] ^D | 0.25 | 1.35 | 0.035 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.025 | ... |
| Grade 55 [380] ^D | 0.25 | 1.35 | 0.035 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.025 | ... |
| Grade 60 [410] | 0.25 | 1.35 | 0.035 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.025 | ... |
| Grade 70 [480] | 0.25 | 1.35 | 0.035 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.025 | ... |
| Grade 80 [550] | 0.25 | 1.35 | 0.035 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.008 | 0.008 | 0.025 | ... |
| HSLAS: ^E | | | | | | | | | | | | | | |
| Grade 45 [310] Class 1 ^D | 0.22 | 1.35 | 0.04 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.005 | 0.005 | 0.005 | ... |
| Grade 45 [310] Class 2 | 0.15 | 1.35 | 0.04 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.005 | 0.005 | 0.005 | ... |
| Grade 50 [340] Class 1 ^D | 0.23 | 1.35 | 0.04 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.005 | 0.005 | 0.005 | ... |
| Grade 50 [340] Class 2 | 0.15 | 1.35 | 0.04 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.005 | 0.005 | 0.005 | ... |
| Grade 55 [380] Class 1 ^D | 0.25 | 1.35 | 0.04 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.005 | 0.005 | 0.005 | ... |
| Grade 55 [380] Class 2 | 0.15 | 1.35 | 0.04 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.005 | 0.005 | 0.005 | ... |
| Grade 60 [410] Class 1 | 0.26 | 1.50 | 0.04 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.005 | 0.005 | 0.005 | ... |
| Grade 60 [410] Class 2 | 0.15 | 1.50 | 0.04 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.005 | 0.005 | 0.005 | ... |
| Grade 65 [450] Class 1 | 0.26 | 1.50 | 0.04 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.005 | 0.005 | 0.005 | F |
| Grade 65 [450] Class 2 | 0.15 | 1.50 | 0.04 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.005 | 0.005 | 0.005 | F |
| Grade 70 [480] Class 1 | 0.26 | 1.65 | 0.04 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.16 | 0.005 | 0.005 | 0.005 | F |
| Grade 70 [480] Class 2 | 0.15 | 1.65 | 0.04 | 0.04 | ... | ... | 0.20 | 0.20 | 0.15 | 0.16 | 0.005 | 0.005 | 0.005 | F |
| HSLAS-F: ^E | | | | | | | | | | | | | | |
| Grade 50 [340] and 60 [410] | 0.15 | 1.65 | 0.020 | 0.025 | ... | ... | 0.20 | 0.20 | 0.15 | 0.06 | 0.005 | 0.005 | 0.005 | F |
| Grade 70 [480] and 80 [550] | 0.15 | 1.65 | 0.020 | 0.025 | ... | ... | 0.20 | 0.20 | 0.15 | 0.16 | 0.005 | 0.005 | 0.005 | F |
| UHSS: ^E | | | | | | | | | | | | | | |
| Grade 90 [620] and 100 [690] Type 1 | 0.15 | 2.00 | 0.020 | 0.025 | ... | ... | 0.20 | 0.20 | 0.15 | 0.40 | 0.005 | 0.005 | 0.005 | F |
| Grade 90 [620] and 100 [690] Type 2 | 0.15 | 2.00 | 0.020 | 0.025 | ... | ... | 0.60 | 0.50 | 0.30 | 0.40 | 0.005 | 0.005 | 0.005 | F |

^A Where an ellipsis (. . .) appears in the table, there is no requirement but the analysis shall be reported.

^B When copper is specified, a minimum of 0.20 % is required. When copper steel is not specified, the copper limit is a maximum requirement.

^C Titanium is permitted for SS designations, at the producer's option, to the lesser of 3.4N + 1.5S or 0.025 %. This does not apply to Grade 45 [310] Type 2.

^D For each reduction of 0.01 % below the specified carbon maximum, an increase of 0.06 % manganese above the specified maximum will be permitted up to a maximum of 1.50 %.

^E HSLAS, HSLAS-F, and UHSS steels contain the strengthening elements columbium (niobium), vanadium, titanium, and molybdenum added singly or in combination. The minimum requirements only apply to the microalloy elements selected for strengthening of the steel.

^F The purchaser has the option of restricting the nitrogen content. It should be noted that, depending on the microalloying scheme (for example, use of vanadium) of the producer, nitrogen may be a deliberate addition. Consideration should be made for the use of nitrogen binding elements (for example, vanadium, titanium).

8.2.2.7 *Test Method*—Yield strength shall be determined by either the 0.2 % offset method or the 0.5 % extension under load method unless otherwise specified.

8.2.3 Bending Properties:

8.2.3.1 The suggested minimum inside radii for cold bending are listed in Appendix X1 and is discussed in more detail in Specifications A568/A568M (6.6) and A749/A749M (7.6). Where a tighter bend radius is required, where curved or offset bends are involved, or where stretching or drawing are also a consideration, the producer shall be consulted.

9. Finish and Appearance

9.1 Surface Finish: