SAE The Engineering Society For Advancing Mobility Land Sea Air and Space® INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE RECOMMENDED PRACTICE

Submitted for recognition as an American National Standard

SAE J1392

REV. FEB2001

Issued 1982-05
Revised 2001-02

Superseding J1392 JUN1984

(R) Steel, High Strength, Hot Rolled Sheet and Strip, Cold Rolled Sheet, and Coated Sheet[1]

NOTE 1—This document shall not be used on new designs—Superseded by SAE J2340.

NOTE 2—NOTE—High-strength, low-alloy Sheet and Strip products formerly were included in SAE J410c (Cancelled), but are now detailed in this separate SAE Recommended Practice.

1. ***Scope—***This SAE Recommended Practice covers seven levels of high strength carbon and low-alloy hot rolled sheet and strip, cold rolled sheet, and coated sheet steels. The strength is achieved through chemical composition and special processing.

2. *References*

2.1 Applicable Publications—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated, the latest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J410c (Cancelled)—High Strength, Low Alloy Steel
SAEJ2340—Categorization and Properties of Dent Resistant, High Strength, and Ultra High Strength Automotive Sheet Steel

2.1.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM A 308—Specification for Steel, Sheet, Cold-Rolled, Long Terne Coated
ASTM A 370—Test Methods and Definitions for Mechanical Testing of Steel Products
ASTM A 463—Specification for Steel Sheet, Cold-Rolled, Aluminum-Coated Type I and Type II
ASTMA568—Specification for General Requirements for Steel, Carbon and High-Strength Low-Alloy Hot-Rolled Sheet and Cold-Rolled Sheet
ASTMA568M—Specification for General Requirements for Steel, Carbon, and High-Strength Low-Alloy Hot-Rolled Sheet and Cold-Rolled Sheet (Metric)
ASTM A 591—Specification for Steel Sheet, Electrolytic Zinc-Coated, for Light Coating Mass Applications
ASTMA924—Standard Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip-Process

1. The values stated in U.S. customary units are to be regarded as the standard recommended practice.

3. ***Introduction***—High strength steel discussed in this document involves hot rolled sheet and strip and cold rolled sheet as dimensionally described in ASTM A 568 (A 568M) latest revision (Steel, Carbon and High-Strength Low-Alloy Hot-Rolled Sheet, Hot-Rolled Strip and Cold-Rolled Sheet, General Requirements). It also includes coated sheet, that is, sheet coated by hot dipping, electroplating, or vapor deposition of zinc, terne, aluminum, and organic compounds normally applied by coil coating. Public specifications related to these coated products are the latest revisions of ASTM A 924 (Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, General Requirements), A 591 (Steel Sheet, Cold Rolled, Electrolytic Zinc-Coated), A 463 (Steel Sheet, Cold-Rolled, Aluminum-Coated Type 1), and A 308 (Steel, Sheet, Cold-Rolled, Long Terne Coated).

The strength is achieved through chemical composition and special processing. Special processing includes mechanical rolling techniques, and temperature control in hot rolling and subsequent heat treatments. The primary use of high strength steel is based on the increased yield and tensile properties which are higher than those of conventional sheet and strip for which minimum mechanical properties are not normally specified.

The seven strength levels are 240 (35), 280 (40), 310 (45), 340 (50), 410 (60), 480 (70), and 550 (80) MPa (ksi) minimum yield strength. Different chemical compositions are normally used to achieve the specified mechanical properties. These compositions are significantly different at the same strength level depending on additional material requirements, that is, weldability, formability, toughness, fatigue life, atmospheric corrosion resistance, and economics. The correct type of high strength sheet or strip should be specified to establish compatibility of the producers' chemical composition with the fabrication and application requirements.

Because high strength steel is characterized by special mechanical properties, consultation of producer and user in grade selection is recommended to insure compatibility of the strength and forming requirements. Care must be taken in designing parts, tooling, and fabrication processes to obtain the greatest benefit from the high strength sheet and strip steels. It is advisable that the purchaser furnish information to the producer relating the individual requirements of an identified part; this may be accomplished by visual examination of the part, by prints, through a description, or a combination of these. Also, it is highly desirable for the producer to observe the fabricating practices, or at least be provided with a detailed description of the operations.

The steels discussed in this document are characterized by their special mechanical properties achieved through chemical composition and special processing. They normally are not intended for any heat treatment by the purchaser. Subjecting these steels to such heat treatments will modify the original mechanical properties. For certain applications these steels may be annealed, normalized, or stress relieved with some effect on the mechanical properties. It is recommended that prior to such heat treatments the producer and purchaser consult to determine the need for a heat treatment and its effect on mechanical properties.

All grades and chemical compositions in this practice are weldable despite the differences in carbon, manganese, and alloying additions. However, as variations in composition from one producer to another do exist, it is advisable to discuss with the producers the features of their chemical composition relative to specific types of welding and any special considerations for each application.

These steels, because of their strength-to-weight ratio, may be adapted for use in mobile equipment and other structures where substantial weight savings are generally desirable.

4. General Information—The specific grades are identified by a six character code that describes the strength level, general chemical composition, general carbon level, and deoxidation/sulfide inclusion control system, as follows:

4.1 First, Second and Third Characters—Minimum yield strength expressed in megapascals (MPa 240, 280, 310, 340, 410, 480, and 550 or as kips per square inch (ksi): 35, 40, 45, 50, 60, 70, and 80, expressed as 035, 040, 045, 050, 060, 070, and 080 respectively.

4.2 Fourth Character—General chemical composition:

A—C and Mn only
B—C, Mn, N
C—C, Mn, P
S—C, Mn, (N and/or P added at producer option)
W—Weathering composition (Si, P, Cu, Ni, and Cr in various combinations)
X—High Strength Low Alloy (HSLA), that is, Cb, Cr, Cu, Mo, Ni, Si, Ti, V, Zr either singly or in combination, with a 70 MPa (10 ksi) spread between the specified minima of the yield and tensile strengths. N and P may be used in combination with any of the aforementioned elements.
Y—Same as X with a 100 MPa (15 ksi) spread between the specified minima of the yield and tensile strengths.
Z—Same as X with a 140 MPa (20 ksi) spread between the specified minima of the yield and tensile strengths.

4.3 Fifth Character—General carbon level:

H—Maximum carbon as shown in Table 3 and Table 4
L—0.13% carbon max except as indicated in Table 4

4.4 Sixth Character—Deoxidation/sulfide inclusion control practices:

K—Killed, made to a fine grain practice
F—Sulfide inclusion controlled, killed, made to a fine grain practice
O—Other than K and F

4.5 A material grade corresponding to every combination of numbers and letters is not available. Therefore, it is recommended that the purchaser consult with the producers to determine that the desired grade is available before releasing engineering approved prints and specifications, and before purchase orders are placed.

These steels are generally produced as semi-killed or killed steel, although rimmed and capped practices may be used in certain situations. When selecting a deoxidation practice, the following items should be considered. Rimmed and capped steels are less homogeneous than killed steels. Therefore, the producer must plan his processing to compensate for variations in chemical composition and maintain mechanical strength properties specified. With the greater range in chemical composition of rimmed and capped steels, variations in fabrication, such as maintaining part dimensions, springback, and breakage, on complex parts can result. If these material variations are not compatible with specific part designs and tooling, a deoxidation practice resulting in a more homogeneous steel should be considered.

5. Mechanical Properties—The mechanical properties of these high strength sheet and strip steels are shown in Table 1 (hot rolled) and Table 2 (cold rolled and coated). Current steel industry practice is to determine the yield point of these materials by the drop of the beam, halt of pointer, dividers, 0.2% offset, or 0.5% extension under load method. In cases involving dispute between two or more parties, the yield strength shall be determined by the 0.2% offset method as described in ASTM A 370, Paragraph 13.2.1, which describes yield strength.

TABLE 1—MECHANICAL PROPERTIES—HOT ROLLED

Grade	Yield Strength, MPa (ksi) min.	Tensile Strength, MPa (ksi) min.	% Elongation[1] (50 mm or 2 in) min
035 A, B, C, S	240 (35)	(2)	21
035 X, Y, Z	240 (35)	(2)	28
040 A, B, C, S	280 (40)	(2)	20
040 X, Y, Z	280 (40)	(2)	27
045 A, B, C, S	310 (45)	(2)	18
045 W	310 (45)	450 (65)	25
045 X	310 (45)	380 (55)	25
045 Y	310 (45)	410 (60)	25
045 Z	310 (45)	450 (65)	25
050 A, B, C, S	340 (50)	(2)	16
050 W	340 (50)	480 (70)	22
050 X	340 (50)	410 (60)	22
050 Y	340 (50)	450 (65)	22
050 Z	340 (50)	480 (70)	22
060 X	410 (60)	480 (70)	20
060 Y	410 (60)	520 (75)	20
070 X	480 (70)	550 (80)	17
070 Y	480 (70)	590 (85)	17
080 X	550 (80)	620 (90)	14
080 Y	550 (80)	650 (95)	14

1. Elongation values are dependent upon specimen geometry (cross-sectional area). Thicker and wider specimens normally result in higher percentages.
2. Minimum tensile strength normally does not apply.

TABLE 2—MECHANICAL PROPERTIES—COLD ROLLED AND COATED

Grade	Yield Strength, MPa (ksi) min.	Tensile Strength, MPa (ksi) min.	% Elongation[1] (50 mm or 2 in) min
035 A, B, C, S	240 (35)	(2)	22
035 X, Y, Z	240 (35)	(2)	27
040 A, B, C, S	280 (40)	(2)	20
040 X, Y, Z	280 (40)	(2)	25
045 A, B, C, S	310 (45)	(2)	18
045 W	310 (45)	450 (65)	22
045 X	310 (45)	380 (55)	22
045 Y	310 (45)	410 (60)	22
045 Z	310 (45)	450 (65)	22
050 A, B, C, S	340 (50)	(2)	16
050 X	340 (50)	410 (60)	20
050 Y	340 (50)	450 (65)	20
050 Z	340 (50)	480 (70)	20

1. Elongation values are dependent upon specimen geometry (cross-sectional area). Thicker and wider specimens normally result in higher percentages.
2. Minimum tensile strength normally does not apply.

Because of the different rates of heat transfer in the various parts of a coil of hot rolled sheet steel, and to a lesser degree, the variation in chemical composition, especially when deoxidation practices other than killed are employed, mechanical properties will vary in a coil or cut lengths which are sheared from a coil. Because of the faster cooling rates that may occur on the outside and inside (eye) wraps of a coil, the leading and trailing ends of a coil tend to be harder and higher in yield and tensile strength than the material from the interior of the coil. Cooling is generally faster as the thickness decreases, thus the strength tends to increase as the thickness decreases. For a specified grade and thickness, both coils and cut lengths will be produced to the same mill practices. Testing within the body of the coil cannot be performed by the producer, thus producer testing is limited practically to coil ends and random pieces sheared from coils for cut length orders. Considering this practical limitation on testing, the producer has specific knowledge of material properties only at the test location. Therefore, the mechanical properties in the body of a coil may vary from those at the ends.

Based on the data developed from above, each producer establishes testing procedures and frequency to ensure that the processes designed to produce the specified mechanical properties are under control. These procedures also provide knowledge of the product properties and guidance in evaluating the product for the intended application. Since the local manufacturing conditions vary from one producer location to another, and the characteristics of the grades within the scope of this report vary, there is no one testing frequency plan. If the purchaser requires any special testing program it should be discussed with the producer at the time of evaluating the steel grades for the intended application.

6. ***Chemical Composition—***The chemical composition of the steels in this document may vary from one producing facility to another for the same strength level. Therefore, it is not practical to list all the combinations for each strength level and general chemical compositions. While all producers comply with the carbon and manganese content shown in Tables 3 and 4, a more precise value or range is dependent on the alloys, if used, and their specific amounts, the thickness of the steel being produced on a given unit, and the special characteristics of the producing unit. Chemical composition is important for achieving the specified minimum mechanical properties. Chemical composition also affects other properties such as weldability, formability, toughness, and fatigue. When these are critical, the fabricator should discuss the details with the producer so that the material selected will be compatible with the fabrication and application requirements.

The following provides a brief description and comparison of the eight compositional systems.

6.1 A—Carbon/Manganese—Only carbon and manganese are used to meet the minimum strength requirements. No other elements that significantly add to strength and hardness are intentionally added. As the carbon and/or manganese are increased, the strength and hardness are increased, but ductility and weldability are decreased. Carbon has a greater effect on these properties than manganese.

6.2 B—Nitrogenized—Nitrogen is used to increase strength and hardness. Producers of this system generally lower the carbon and/or manganese of the A system. Nitrogen is inherently present in all steels. When added intentionally, so that the content is higher than that normally exhibited in SAE 1006/1008/1010 type steels, the resulting product not only increases in strength and hardness, but, by additional processing, provides the potential to increase in strength beyond as-rolled strength. The additional processing usually involves straining in part fabrication followed by a thermal treatment, such as a paint bake cycle. The nitrogen encountered in this chemical composition is responsible for the accelerated aging phenomenon. This also reduces ductility, and with this consideration, nitrogenized steel may be specified when higher strength is desired beyond that achieved by simply forming the intended part. Toughness may be reduced with the addition of nitrogen in heavier thicknesses.

6.3 C—Phosphorized—As in previous case B, this system utilizes another strengthener, phosphorus, in combination with carbon and manganese. The carbon and/or manganese of this system is usually lower than that found in carbon/manganese steel (A). Phosphorus increases strength and hardness, but generally reduces ductility and toughness. Phosphorized steel may be specified when nitrogenized steel (B) is not suitable. Phosphorus is intentionally added so that the content is higher than that normally exhibited in SAE 1006/1008/1010 steel.

TABLE 3—CHEMICAL COMPOSITION (HEAT OR CAST ANALYSIS) HOT ROLLED (ALL MAXIMUMS UNLESS OTHERWISE NOTED)

Grade	Carbon(1) H	Carbon(1) L	Manganese	Additional
035 A	0.25	0.13	0.60	None
035 B	0.25	0.13	0.60	Nitrogen
035 C	0.25	0.13	0.60	Phosphorus
035 S	0.25	0.13	0.60	Producer option, i.e., A or B or C
035 X, Y, Z	—	0.13	0.60	Microalloy(2)
040 A, B, C, S	0.25	0.13	0.90	Same as 035 A, B, C, S above
040 X, Y, Z	—	0.13	0.60	Microalloy(2)
045 A, B, C, S	0.25	0.13	0.90	Same as 035 A, B, C, S above
045 W	0.22	—	1.25	Various combinations of Si, P, Cu, Ni, Cr
045 X	—	0.13	1.35	Microalloy(2)
045 Y, Z	0.22	—	1.35	Microalloy(2)
050 A, B, C, S	0.25	—	1.35	Same as 035 A, B, C, S above
050 W	0.22	—	1.25	Various combinations of Si, P, Cu, Ni, Cr
050 X	—	0.13	0.90	Microalloy(2)
050 Y, Z	0.23	—	1.35	Microalloy(2)
060 X	—	0.13	0.90	Microalloy(2)
060 Y, Z	0.26	—	1.50	Microalloy(2)
070 X	—	0.13	1.65	Microalloy(2)
070 Y, Z	0.26	—	1.65	Microalloy(2)
080 X	—	0.13	1.65	Microalloy(2)
080 Y	0.18	—	1.65	Microalloy(2)

1. Lower levels are available upon inquiry.
2. Cb, V, and Ti are commonly used singly or in combination. Combinations of the following elements are sometimes used with or without Cb, V, and Ti: Cr, Cu, Mo, Ni, Si, and Zr. P and/or N may be added to any of the foregoing.

TABLE 4—CHEMICAL COMPOSITION (HEAT OR CAST ANALYSIS) COLD ROLLED AND COATED (ALL MAXIMUMS UNLESS OTHERWISE NOTED)

Grade	Carbon(1) H	Carbon(1) L	Manganese	Additional
035 A	0.20	0.13	0.60	None
035 B	0.20	0.13	0.60	Nitrogen
035 C	0.20	0.13	0.60	Phosphorus
035 S	0.20	0.13	0.60	Producer option, i.e., A or B or C
035 X, Y, Z	0.18	0.13	0.60	Microalloy(2)
040 A, B, C, S	0.24	0.15	0.90	Same as 035 A, B, C, S
040 X, Y, Z	0.20	0.13	0.90	Microalloy(2)
045 A, B, C, S	0.25	0.17	1.20	Same as 035 A, B, C, S
045 W	0.22	—	1.35	Various combinations of Si, P, Cu, Cr, Ni
045 X, Y, Z	0.22	0.15	1.20	Microalloy(2)
050 A, B, C, S	0.25	0.20	1.35	Same as 035 A, B, C, S
050 X, Y, Z	0.23	0.17	1.35	Microalloy(2)

1. Lower levels are available upon inquiry.
2. Cb, V, and Ti are commonly used singly or in combination. Combinations of the following elements are sometimes used with or without Cb, V, and Ti: Cr, Cu, Mo, Ni, Si, and Zr. P and/or N may be added to any of the foregoing.

6.4 S—Optional (A or B or C)—This system may be specified when the carbon/manganese steel (A), nitrogenized steel (B), and phosphorized steel (C) chemical compositions are satisfactory for the intended application. The advantage of using this system is that it provides more options.

6.5 W—Weathering—This system utilizes two or more elements to produce a weathering steel. The elements most commonly used are silicon, phosphorus, nickel, copper, and chromium. The "atmospheric" corrosion resistance is improved at least fourfold compared to plain carbon steel with less than 0.02% copper. As "vehicle" corrosion is not limited to "atmospheric" corrosive environments, weathering steel will not provide adequate protection.

6.6 X, Y, and Z—High Strength Low Alloy (HSLA)—From a chemical composition standpoint, these systems can be grouped together. They are alloyed systems in which the alloying is a major source of strength. The elements most commonly used are columbium (niobium), titanium, vanadium, and zirconium. Other elements such as chromium, copper, molybdenum, nickel and silicon may be used. The elements may be used singularly or in combination to achieve the specified minimum mechanical properties. Nitrogen and/or phosphorus may be used in combination with any of the aforementioned elements. The use of these elements enables the producer to reduce the carbon and/or manganese content. The major difference in these systems is the spread between the specified minima of the yield and tensile strengths. This spread is mainly dependent on the carbon content, although other factors such as hot and cold rolling practices, and associated thermal practices have some influence. Thus, steels in the X system usually contain less carbon than the Y and Z systems, and steels in the Y system usually contain less carbon than the Z system. These HSLA steels provide better formability, weldability, and toughness at a given strength level than the steels produced by the A, B, and C systems.

7. Cold Bending—High strength steels are frequently fabricated by cold bending. There are a multiplicity of inter-related factors which affect the ability of a given piece of steel to form over any given radius in shop practice. These factors include thickness, strength level, degree of restraint in bending, relationship to rolling direction, chemical composition, and microstructure. The table of Suggested Minimum Inside Radii for Cold Bending, for Hot Rolled Sheet and Strip, Table 5, lists those ratios which should be used as minimums for 90degree bends in actual shop practice. It recognizes that "hard way" bending (bend axis parallel to rolling direction) is common in production and presupposes that reasonably good forming practices will be employed. Where design permits, users are encouraged to employ larger radii than shown in Table 5 for improved performance. Where the bend axis can be designed across the width ("easy way") of the sheet or strip, or bends less than 90 degrees, slightly tighter radii can be employed. As the cold forming becomes progressively more difficult, that is from a straight bend to a curved or offset bend to stretching or drawing, it is advisable that the producer and user consult to determine the special material, design, and tooling requirements of the application. The fabricator should be aware that steel may crack to some degree when bent on a sheared or burned edge. This is not considered to be the fault of the steel, but rather a function of the induced cold work or heat affected zone (HAZ).

8. Suggested Ordering Practice—Orders for material under this document should include the following information to adequately describe the desired material:

(1) SAE Recommended Practice number (J1392).
(2) Name of material (hot rolled or cold rolled or coated sheet, or hot rolled strip; in the case of coated sheet, the specific coating should be described, such as electrozinc coated, hot dip zinc coated (galvanized), aluminum coated, etc.)
(3) Grade (six character identification including minimum yield strength, chemical composition system, general carbon level, deoxidation/sulfide inclusion control practice).
(4) Condition (specify pickled if required, specify oiled or not oiled as required, specify chemical treatment for coated product if required).
(5) Copper bearing steel (when required).
(6a) Surface condition—Cold Rolled (indicate exposed, E, or unexposed, U; matte, or dull finish will be supplied unless otherwise specified).

(6b) Surface condition—Coated (indicate regular spangle or minimized spangle or minimized spangle extra smooth, and coating weight for hot dip zinc coated (galvanized) sheet).
(7) Edges (must be specified for hot rolled sheet and strip, that is, mill edge or cut edge).
(8) Dimensions (thickness, width, and length for cut lengths).
(9) Coil size and weight requirements (must include inside diameter, outside diameter, and maximum weight).
(10) Cut length weight restrictions, that is, maximum weight of individual bundle.
(11) Application (show part identification and description).
(12) Heat or cast analysis and mechanical property report (if required).

TABLE 5—SUGGESTED MINIMUM INSIDE RADII FOR COLD BENDING[1][2][3][4] FOR HOT ROLLED SHEET AND STRIP

	H[5] Up to 4.55 mm (0.179 in) O	H[5] Up to 4.55 mm (0.179 in) K	H[5] Up to 4.55 mm (0.179 in) F	L[5] Up to 4.55 mm (0.179 in) Q	L[5] Up to 4.55 mm (0.179 in) K	L[5] Up to 4.55 mm (0.179 in) F
035 A, B, C, S	1-1/2	—	—	1	—	—
035 X, Y, Z	—	—	—	—	1/2	—
040 A, B, C, S	1-1/2	—	—	1	—	—
045 A, B, C, S	2	—	—	1-1/2	1	—
045 W	—	2	1	—	—	—
045 X	—	—	—	1-1/2	1	1/2
045 Y, Z	1-1/2	1	—	—	—	—
050 A, B, C, S	2-1/2	—	—	—	—	—
050 W	—	2-1/2	1-1/2	—	2	1
050 X	—	—	—	1-1/2	1	1/2
050 Y, Z	2	1-1/2	1	—	—	—
060 X	—	—	—	—	2	1
060 Y, Z	2-1/2	2	1-1/2	—	—	—
070 X	—	—	—	—	3	1
070 Y, Z	—	3-1/2	1-1/2	—	—	—
080 X	—	—	—	—	—	1
080 Y, Z	—	—	1-1/2	—	—	—

1. Ratio of bend radius to thickness.
2. Refer to the paragraph headed "Cold Bending" for a more detailed explanation of the use of this table.
3. The suggested minimum bending radius is based on the nominal rolled thickness, not the minimum ordered thickness.
4. For thicknesses over 4.55 mm (0.180 in) to 5.85 mm (0.230 in) inclusive, add 1/2t to the radii shown in the table above.
5. H–maximum carbon as shown in Tables 3 and 4; L–0.13% maximum carbon except as noted in Table 4.

8.1 Typical ordering descriptions are as follows:

A—SAE J1392, Grade 050YLO, Hot Rolled Sheet, High Strength Low Alloy, pickled and oiled, cut edge, 0.095 in min. x 46.50 in x coil for front lower control arm (the metric grade equivalent is 340YLO)

B—SAE J1392, Grade 040CHO, Hot Dipped Zinc Coated (Galvanized) Sheet, High Strength Carbon, Regular Spangle, G90 coating weight, oiled, 0.035 in min. x 41.25 in x 94 in for member front side front upper (the metric grade equivalent is 280CHO)

C—SAE J1392, Grade 050XLF, Cold Rolled Sheet, High Strength Low Alloy, oiled, U finish, 0.031 in min. x 39.37 in x coil for frame back window upper (the metric grade equivalent is 340XLF)

D—SAE J1392, Grade 410XLK, Hot Dipped Zinc Coated (Galvanized) Sheet, High Strength Low Alloy, Regular Spangle, G60 coating weight, chemically treated not oiled, 1.30 mm min. x 1220 mm x coil for railmotor side inner.