SAE International™

SURFACE VEHICLE RECOMMENDED PRACTICE

SAE J2745

ISSUED JUL2007

Issued 2007-07

Categorization and Properties of Advanced High Strength Automotive Sheet Steels

RATIONALE

This is a global, advanced high strength sheet steel specification, which incorporates and commonizes the most widely accepted grades and respective strength levels presently available in the world market. It incorporates both minimum tensile and minimum yield strength callouts in the grade nomenclature.

FOREWORD

The grades described in this specification are distinguished by their higher yield strengths, tensile strengths, and formability than those of conventional low-carbon sheet steel, which are described in SAE J2329. Dual Phase and Martensitic grades along with TRIP grades are being incorporated in this specification. Higher strength steels are desirable for dent resistance, increased load bearing capability, better crash energy management, better intrusion control performance, or part mass reduction through a decrease in sheet metal thickness.

An increase in strength generally leads to reduced ductility or formability. Care must be taken in designing parts, tooling, and fabrication processes to obtain the greatest benefit from the higher strength sheet steels. Consultation in grade selection between user and steel producer is recommended to insure compatibility of the strength, forming, and joining characteristics.

Strength in these steels is achieved through chemical composition (alloying) and thermo-mechanical processing. Thermo-mechanical processing includes mechanical rolling techniques, temperature control in hot rolling, and time/temperature control in annealing of cold-reduced steel. Steel users should be aware that further thermal treatment may modify the as-produced mechanical properties.

1. SCOPE

This SAE Recommended Practice defines various grades of continuously cast high-strength sheet steels and establishes mechanical property ranges. These sheet steels can be formed, welded, assembled and painted in automotive manufacturing processes. They can be specified as hot-rolled or cold-rolled sheet. Furthermore, they can be coated (hot-dipped galvanized, hot-dipped galvannealed, and electrogalvanized) or uncoated. Not all combinations of strength, dimensions and coatings may be commercially available; consult your steel supplier for details.

2. REFERENCES

2.1 Applicable Publications

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE and ASTM publications shall apply.

2.1.1 SAE Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J1562 Selection of Zinc and Zinc-Alloy (Hot Dipped and Electrodeposited) Coated Steel Sheet

SAE J2329 Categorization and Properties of Low Carbon Automotive Sheet Steels

SAE J2340 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, Tel: (610) 832-9585, www.astm.org.

ASTM A 370 Standard Test Methods and Definitions for Mechanical Testing of Steel Products

ASTM A 980 Standard Specification for Steel Sheet, Carbon, Ultra High Strength Cold Rolled

ASTM E 8/E 8M Standard Test Methods of Tension of Metallic Materials

ASTM E 517 Standard Test Method for Plastic Strain Ratio r for Sheet Metal

ASTM E 646 Standard Test Method for Tensile Strain-Hardening Exponents (n value) of Metallic Sheet Materials

ASTM A 568/A 568M General Requirements Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled

ASTM A 635/A 635M Standard Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Hot-Rolled Carbon, Structural, High Strength Low-Alloy with Improved Formability

ASTM A 924/A 924M General Requirements for Steel Sheet Metallic Coated by the Hot Dip Process

2.1.3 ISO Publications

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO 377-1 Selection of preparation of samples and test pieces of wrought steel

ISO 6892 Metallic materials—Tensile testing at ambient temperature

ISO 7438 Metallic materials—Bend test

ISO 7500 Metallic materials—Verification of static uniaxial testing machines

ISO 9513 Metallic materials—Calibration of extensometers used in uniaxial testing

ISO 10113 Metallic materials—Sheet and strip—Determination of plastic strain ratio

ISO 10275 Metallic materials—Sheet and strip—Determination of tensile strain hardening exponent

ISO TS 16630 Hole expansion testing

2.1.4 JIS Publications

Available from Japanese Standards Association, 4-1-24, Akasaka Minato-ku, Tokyo 107-8440, Japan; Phone: +81-3-3583-8005, Fax: +81-3-3586-2014, www.jsa.or.jp/.

JIS Z 2201 Test Pieces for Tensile Test for Metallic Materials

JIS Z 2204 Bend Test Pieces for Metallic Materials

2.1.5 EN Publications

Available from CEN Management Centre, 36 rue de Stassart, B-1050 Brussels, Belgium, Tel: +32-2-550-08-11, www.cenorm.be.

EN 10 051 Hot Rolled Flat Strips and Sheets without Coating Unalloyed and Alloyed

EN 10 131 Cold Rolled Flat Strips without Coating with Low and Higher YS

EN 10 143 Continuously Hot Dipped Coated Steel Sheet and Strip—Tolerances on Dimensions and Shape

2.1.6 ANSI/AWS/SAE Publications

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ANSI/AWS/SAE D8.7M-05 Recommended Practices for Automotive Weld Quality—Resistance Spot Welding

ANSI/AWS/SAE D8.8-97 A Specification for Automotive and Light Truck Component Weld Quality—Arc Welding

2.1.7 Other Publication

Available from Auto/Steel Partnership (A/SP), 2000 Town Center, Suite 320, Southfield, MI 48075, www.A-SP.org.

AZ-017-02-295 1.0C RI Weld Quality Test Method Manual; Standardized Welding Test Method Task Force, Auto/Steel Partnership (A/SP)

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 SAE Publication

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J810 Classifications of Common Imperfections in Sheet Steel

2.2.2 ASTM Publications

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, Tel: (610) 832-9585, www.astm.org.

ASTM A 463 Standard Specification for Cold Rolled Aluminum Coated Type 1 & Type 2 Steel Sheet

ASTM A 653 Steel Sheet, Zinc Coated (Galvanized) or Zinc-Iron Alloy Coated (Galvanneal) by the Hot-Dip Process

ASTM A 751 Standard Test Methods for Determining Chemical Composition of Steel Products

ASTM A 924/A 924M General Requirements for Steel Sheet Metallic Coated by the Hot Dip Process

ASTM A 635/A 635M Standard Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Hot-Rolled Carbon, Structural, High Strength Low-Alloy with Improved Formability

ASTM A 879/A 879M Standard Specification for Steel Sheet, Zinc Coated by the Electrolytic Process for Applications Requiring Designations of the Coating Mass on Each Surface

2.2.3 ISO Publication

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO 13887 Cold reduced steel sheet of higher strength with improved formability

2.2.4 Other Publication

Steel Products Manual, Sheet Steel; Iron and Steel Society Publication, latest revision

3. GENERAL INFORMATION

This document defines various grades of advanced higher strength steel based on material type. These strength grades with cold-rolled substrate are shown in Table 1 and with hot-rolled substrate are shown in Table 2. Collectively, DP, TRIP, HHE, and MS grades are referred to as “Advanced High Strength Steels” (AHSS) to reflect their enhanced properties over what has traditionally been used for automotive applications. The chemical composition in this specification is not mandated but is for reference only, with the exception of the elements listed below.

TABLE 1 - ADVANCED HIGH STRENGTH STEEL GRADES - COLD ROLLED

Steel Description	Grade Designator	Available Strength Levels - MPa (min. Tensile Strength/min. Yield Strength)
Dual Phase	DP	440T/250Y, 490T/290Y, 590T/340Y, 690T/550Y, 780T/420Y, 980T/550Y
Transformation Induced Plasticity	TRIP	590T/380Y, 690T/400Y, 780T/420Y
Ultra High Strength Low Carbon Martensitic	MS	900T/700Y, 1100T/860Y, 1300T/1030Y, 1500T/1200Y

TABLE 2 - ADVANCED HIGH STRENGTH STEEL GRADES - HOT ROLLED

Steel Description	Grade Designator	Available Strength Grade - Mpa (min. Tensile Strength/min. Yield Strength)
Dual Phase	DP	590T/300Y, 780T/380Y
High Hole Expansion	HHE	440T/310Y, 590T/440Y, 780T/600Y
Transformation Induced Plasticity	TRIP	590T/400Y, 780T/450Y

TABLE 3 - CHEMICAL LIMITS

Element	Maximum Weight Percent Allowed
S	0.015
Cu	0.20

4. GRADE DESCRIPTIONS

4.1 Dual Phase (DP) Grades

The microstructure of these steels typically consists of martensite in a ferritic matrix, with the volume fraction of martensite influencing the strength level. The C and Mn content are generally higher than in HSLA steels (e.g. 0.15%C, 2%Mn). Additions of Mo, Cr, B or other elements may be made, their levels depending on the subsequent processing. Nb, Ti and V additions may be made for precipitation strengthening.

DP steels exhibit excellent energy-absorption behavior. Accordingly, they are advantageously used in "crash sensitive" structural applications.

4.2 High Hole-Expansion (HHE) Grades

The microstructure of these steels typically consists of a high proportion of bainite.

Excellent edge stretching behavior is typically achieved in these grades through a combination of special chemistry and/or thermo-mechanical processing. The edge stretching behavior is quantified by a hole-expansion test described in ISO TS 16630.

4.3 Transformation-Induced Plasticity (TRIP) Grades

The microstructure of these steels typically consists of bainite and retained austenite in a ferritic matrix. During deformation (forming), the retained austenite transforms to martensite, resulting in excellent formability. Achieving this microstructure may require the addition of Si (e.g. 1.5%Si) and/or Al (e.g. 1.7%Al), along with an addition of Mn (e.g. 1.5%Mn). The carbon levels may be higher than in the dual phase grades (e.g. 0.25%C).

Compared to DP steels, TRIP steels exhibit superior formability and similar energy-absorption behavior.

4.4 Martensitic (MS) Grades

Ultra-high strengths are achieved typically with a fully martensitic microstructure. The carbon content (e.g. 0.25% C) and manganese content (e.g. 1.25% Mn) influence the strength level.

Martensitic steel grades exhibit extremely high yield and tensile strengths and are typically used for anti-intrusion and/or load bearing applications.

5. COLD-ROLLED, UNCOATED OR COATED, STEEL GRADES

Cold-Rolled steel grades, and their required tensile properties, are listed in Table 4. Both uncoated and coated (electrogalvanized, hot-dip galvanized or galvannealed) steels are included. Applications can be exposed or unexposed.

TABLE 4 - ADVANCED HIGH STRENGTH, COLD ROLLED (COATED AND UNCOATED) SHEET STEELS MECHANICAL PROPERTY REQUIREMENTS*

Grade	Yield Strength (MPa) Min	Yield Strength (MPa) Max	Tensile Strength (MPa) Min	Total Elongation, Min 50mm (ISO I or ASTM A 370)	Total Elongation, Min 50mm (JIS #5)	Total Elongation, Min 80mm (ISO II)	n value (10-20%) Min.	n value (4-6%) Min.	BHI_2 (MPa) Min.	Applicable Notes
DP 440T/250Y	250	330	440	28	30	27	0.16		30	1, 2, 3, 4, 5, 6
DP 490T/290Y	290	390	490	25	27	24	0.15	0.19	30	1, 2, 3, 4, 5, 6
DP 590T/340Y	340	440	590	21	22	20	0.14	0.18	30	1, 2, 3, 4, 5, 6
DP 690T/550Y	550	660	690	13	15	12	0.06	0.08	30	1, 2, 3, 4, 5, 6, 7
DP 780T/420Y	420	550	780	15	17	14	0.11	0.15	30	1, 2, 3, 4, 5, 6, 7
DP 980T/550Y	550	730	980	8	10	7	n/a	0.08	30	1, 2, 3, 4, 5, 6, 7
TRIP 590T/380Y	380	480	590	27	29	26	0.19		30	1, 2, 3, 4, 6, 8
TRIP 690T/400Y	400	520	690	25	27	24	0.19		30	1, 2, 3, 4, 6, 8
TRIP 780T/420Y	420	560	780	21	23	20	0.15		30	1, 2, 3, 4, 6, 7, 8
MS 900T/700Y	700	1000	900	3	3	2				1, 2, 6
MS 1100T/860Y	860	1100	1100	3	3	2				1, 2, 6
MS 1300T/1030Y	1030	1300	1300	2	3	2				1, 2, 6
MS 1500T/1200Y	1200	1500	1500	2	3	2				1, 2, 6

NOTE 1: Test direction shall be either longitudinal or transverse, but not both, as agreed upon between customer and supplier. In the absence of an agreement, the longitudinal direction shall be used.
NOTE 2: The yield stress values shall be measured as the 0.2% proof stress, Rp 0.2. If yield point elongation is present, the lower yield stress, Rel, shall be used.
NOTE 3: If maximum uniform elongation is less than 20%, then n-value shall be measured from 10% to end of uniform elongation.
NOTE 4: When the specified nominal thickness is less than 0.7 mm and greater than 0.5 mm the minimum value for elongation is reduced by 2 units. For thickness less than or equal to 0.5 mm the minimum value is reduced by 4 units.
NOTE 5: For ZnNi and Galvanneal coated steels, elongation shall be reduced by 1 unit and n-value shall be reduced by 0.01.
NOTE 6: Test using one of the following methods, as agreed upon between user and supplier: ISO I, ISO II, ASTM A 370, or JIS method.
NOTE 7: If maximum uniform elongation is less than 10%, then n-value shall be measured from 6% to end of uniform elongation.
NOTE 8: For Galvanneal coated TRIP steels, elongation and n-value shall be reduced by an amount agreed upon between the customer and supplier.

6. HOT-ROLLED, UNCOATED OR COATED, STEEL GRADES

Hot-Rolled Steel grades, and their required tensile properties, are listed in Table 5. Both uncoated and coated (hot-dip galvanized or galvannealed) steels are included.

TABLE 5 - ADVANCED HIGH STRENGTH, HOT ROLLED (COATED AND UNCOATED), SHEET STEELS MECHANICAL PROPERTY REQUIREMENTS*

	Yield Strength (MPa)		Tensile Strength (MPa)	Total Elongation, Min							
Grade	Min	Max	Min	50mm (ISO I or ASTM A 370)	50mm (JIS #5)	80mm (ISO II)	n value (10-20%) Min.	n value (4-6%) Min.	BHI_2 (MPa) Min	Hole Expansion Ratio (%)	Applicable Notes
DP 590T/300Y	300	450	590	21	22	19	0.12	0.16	30		1, 2, 3, 5, 6, 8
DP 780T/380Y	380	610	780	15	16	14	0.11	0.14	30		1, 2, 3, 4, 5, 6, 8
HHE 440T/310Y	310	400	440	26	28	25	0.09			85	1, 2, 3, 7, 8
HHE 590T/440Y	440	620	590	15	17	14	0.08			75	1, 2, 3, 7, 8
HHE 780T/600Y	600	800	780	13	15	12	0.07			55	1, 2, 3, 7, 8
TRIP 590T/400Y	400	550	590	24	26	23	0.18		30		1, 2, 6, 8
TRIP 780T/450Y	450	700	780	20	21	19	0.16		30		1, 2, 6, 8

NOTE 1: Test direction shall be either longitudinal or transverse, but not both, as agreed upon between customer and supplier. In the absence of an agreement, the longitudinal direction shall be used.
NOTE 2: The yield stress values shall be measured as the 0.2% proof stress, Rp 0.2. If yield point elongation is present, the lower yield stress, R_{el}, shall be used.
NOTE 3: If maximum uniform elongation is less than 20%, then n-value shall be measured from 10% to end of uniform elongation.
NOTE 4: n-value tested from 6% to end of uniform elongation, instead of 10 to 20%.
NOTE 5: When the specified nominal thickness is less than 2.5 mm the elongation is reduced by 2 units and n-value shall be reduced by 0.01.
NOTE 6: Elongation shall be reduced by 1 unit and n-value shall be reduced by 0.01 for hot dipped coated steels.
NOTE 7: Hole Expansion testing shall be performed per ISO TS 16630.
NOTE 8: Test using one of the following methods, as agreed upon between user and supplier: ISO I, ISO II, ASTM A 370, or JIS method.

7. SURFACE CONDITION

Several surface conditions of hot-rolled and cold-reduced uncoated and coated sheet steels are used by the automotive stamping and assembly operations. The conditions of sheet steel are referred to by letter code that follows the class designation.

7.1 Cold-Reduced Uncoated and Metallic Coated Sheet Steel

Three conditions of sheet steel surface characteristics are defined. See SAE J1562 for full explanation. Acceptability of surface characteristics or discontinuities shall be negotiated between customer and supplier.

7.1.1 An unexposed (U) quality steel surface is intended for unexposed applications and may also have special use where improved ductility over a temper rolled product is desired. Unexposed can be produced without temper rolling; this surface condition of sheet steel may be susceptible to exhibit coil breaks, fluting, and stretcher straining. Standard tolerances for flatness and surface texture are not applicable. In addition, surface imperfections can be more prevalent and severe than with exposed.

7.1.2 A Semi Exposed (Z) quality steel surface is intended for non-critical exposed applications.

7.1.3 An exposed (E) quality steel surface is intended for the most critical exposed applications where painted surface appearance is of primary importance. This surface condition of sheet steel will meet requirements for controlled surface texture, surface quality, and flatness. Exposed quality product may be temper rolled to improve surface appearance, but temper rolling usually reduces formability.

8. WELDABILITY

When high strength steel is used in welded applications, welding procedures shall be suitable for the steel chemistry and intended service. The user may specify additional chemistry requirements based on their processes and applications (see Appendix B).

9. NOMENCLATURE AND SUGGESTED ORDERING PRACTICE

The coding system shall use a nomenclature consisting of the material designation, steel product type, minimum tensile/minimum yield strength, and surface quality or coating designation. The minimum tensile strength and minimum yield strengths are specified in megapascals (MPa) by a numerical designation.

The Surface Quality is designated as either E for exposed, Z for semi-exposed, or U for unexposed applications.

9.1 Specifying sheet steel on the engineering drawing under this document should include the following information to adequately describe the desired material:

a. Name of material being specified; such as hot-dip galvannealed dual phase steel.

b. SAE Recommended Practice number (SAE J2745).

c. Base metal type; hot rolled (HR) or cold reduced (CR).

d. Grade (sheet steel product type, minimum tensile strength and minimum yield strength).

e. Coating type and coating weight, if any. Indicate hot-dip or electro-galvanized zinc coating and coating weight. See SAE J1562 for detailed nomenclature.

f. Surface condition. Indicate unexposed (U) semi exposed (Z) or exposed (E).

g. Exceptions to this specification as agreed upon in writing between the user and supplier.

9.2 Suggested ordering practice should include the specification from the engineering drawing plus the following additional information.

a. Application (show part identification and description).

b. Dimensions (thickness, tolerance, width, and length for cut lengths).

c. Condition (specify pickled if required, specify oiled or not oiled as required, specify chemical treatment for coated product if required).

d. Edges (must be specified for hot-rolled sheet and strip, that is, mill edge or cut edge).

e. Coil size and weight requirements (must include inside diameter, outside diameter, and maximum weight).

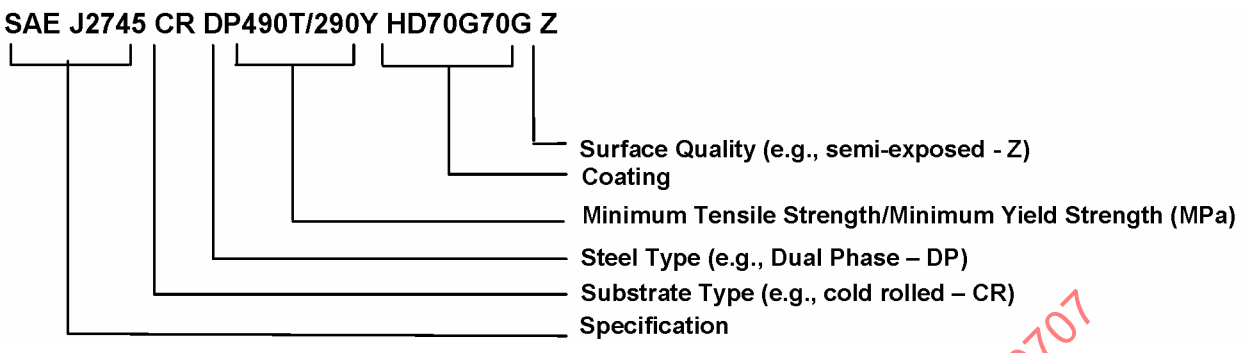
f. Cut length weight restrictions, that is, maximum weight of individual bundle.

g. Heat or cast analysis and mechanical property report (if required).

h. Restrictions to this specification as agreed upon in writing between the user and supplier.

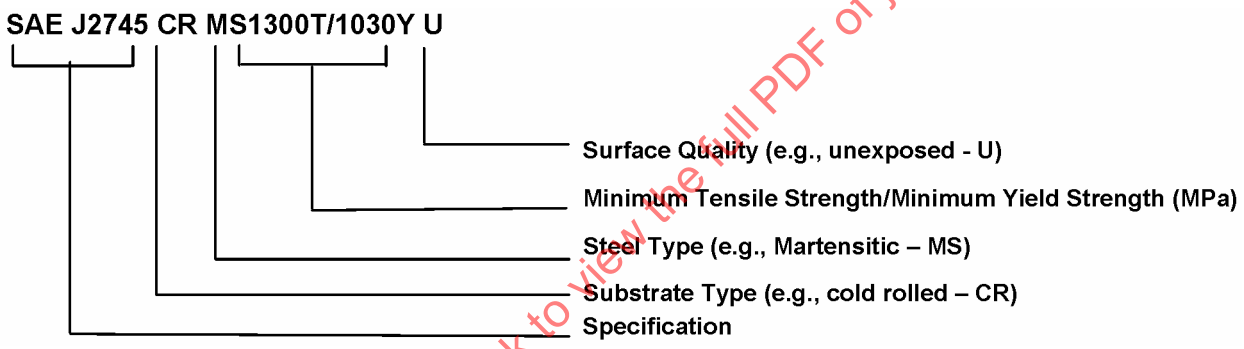
9.3 Typical specification are as follows:

a.



Advanced high strength cold-rolled hot-dip galvanized dual phase steel per SAE J2745 CR DP490T/290Y HD70G70GZ. Cold-reduced hot-dip galvanized dual phase steel with min. tensile strength of 490 MPa and min. yield strength of 290 MPa, for a semi-exposed application.

b.



Advanced high strength cold-rolled sheet steel per SAE J2745 CR MS 1300T/1050Y, 1.20 mm min. ± thick. Cold-reduced ultra high strength sheet Martensitic steel with min. tensile strength of 1300 MPa and min. yield strength of 1030 MPa.

10. DIMENSIONAL TOLERANCES

Tolerances for dimensions shall be as agreed upon between customer and supplier following applicable ASTM, EN, JIS or other specifications.