Designation: A 653/A 653M – 05

Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process[1]

This standard is issued under the fixed designation A 653/A 653M; 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 steel sheet, zinc-coated (galvanized) or zinc-iron alloy-coated (galvannealed) by the hot-dip process in coils and cut lengths.

1.2 The product is produced in various zinc or zinc-iron alloy-coating weights [masses] or coating designations as shown in Table 1.

1.3 Product furnished under this specification shall conform to the applicable requirements of the latest issue of Specification A 924/A 924M, unless otherwise provided herein.

1.4 The product is available in a number of designations, grades and classes in four general categories that are designed to be compatible with different application requirements.

1.4.1 Steels with mandatory chemical requirements and typical mechanical properties.

1.4.2 Steels with mandatory chemical requirements and mandatory mechanical properties.

1.4.3 Steels with mandatory chemical requirements and mandatory mechanical properties that are achieved through solid-solution or bake hardening.

1.5 This specification is applicable to orders in either inch-pound units (as A 653) or SI units (as A 653M). Values in inch-pound and SI units are not necessarily equivalent. Within the text, SI units are shown in brackets. Each system shall be used independently of the other.

1.6 Unless the order specifies the "M" designation (SI units), the product shall be furnished to inch-pound units.

1.7 The text of this specification references notes and footnotes that provide explanatory material. These notes and footnotes, excluding those in tables and figures, shall not be considered as requirements of this specification.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings

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

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

A 902 Terminology Relating to Metallic Coated Steel Products

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

D 2092 Guide for Treatment of Zinc-Coated (Galvanized) Steel Surfaces for Painting

E 517 Test Method for Plastic Strain Ratio *r* for Sheet Metal

E 646 Test Method for Tensile Strain-Hardening Exponents (*n* values) of Metallic Sheet Materials

2.2 *ISO Standard:*

ISO 3575 Continuous Hot-Dip Zinc-Coated Carbon Steel of Commercial and Drawing Qualities[3]

ISO 4998 Continuous Hot-Dip Zinc-Coated Carbon Steel of Structural Quality[3]

3. Terminology

3.1 *Definitions*—See Terminology A 902 for definitions of general terminology relating to metallic-coated hot-dip products.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bake hardenable steel*, *n*—steel sheet in which a significant increase in yield strength is realized when moderate heat treatment, such as that used for paint baking, follows straining or cold working.

[1] This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.

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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] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

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

TABLE 1 Weight [Mass] of Coating Requirements[A,B,C]

NOTE 1— Use the information provided in 8.1.2 to obtain the approximate coating thickness from the coating weight [mass].

		Minimum Requirement[D]		
		Triple-Spot Test		Single-Spot Test
Inch-Pound Units				
Type	Coating Designation	Total Both Sides, oz/ft^2	One Side	Total Both Sides, oz/ft^2
Zinc	G360	3.60	1.28	3.20
	G300	3.00	1.04	2.60
	G235	2.35	0.80	2.00
	G210	2.10	0.72	1.80
	G185	1.85	0.64	1.60
	G165	1.65	0.56	1.40
	G140	1.40	0.48	1.20
	G115	1.15	0.40	1.00
	G90	0.90	0.32	0.80
	G60	0.60	0.20	0.50
	G40	0.40	0.12	0.30
	G30	0.30	0.10	0.25
	G01	no minimum	no minimum	no minimum
Zinc-iron alloy	A60	0.60	0.20	0.50
	A40	0.40	0.12	0.30
	A25	0.25	0.08	0.20
	A01	no minimum	no minimum	no minimum
SI Units				
Type	Coating Designation	Total Both Sides, g/m^2	One Side	Total Both Sides, g/m^2
Zinc	Z1100	1100	390	975
	Z900	900	316	790
	Z700	700	238	595
	Z600	600	204	510
	Z550	550	190	475
	Z500	500	170	425
	Z450	450	154	385
	Z350	350	120	300
	Z275	275	94	235
	Z180	180	60	150
	Z120	120	36	90
	Z90	90	30	75
	Z001	no minimum	no minimum	no minimum
Zinc-iron alloy	ZF180	180	60	150
	ZF120	120	36	90
	ZF75	75	24	60
	ZF001	no minimum	no minimum	no minimum

[A]The coating designation number is the term by which this product is specified. Because of the many variables and changing conditions that are characteristic of continuous hot-dip coating lines, the zinc or zinc-iron alloy coating is not always evenly divided between the two surfaces of a coated sheet; nor is it always evenly distributed from edge to edge. However, the minimum triple-spot average coating weight (mass) on any one side shall not be less than 40 % of the single-spot requirement.

[B]As it is an established fact that the atmospheric corrosion resistance of zinc or zinc-iron alloy-coated sheet products is a direct function of coating thickness (weight (mass)), the selection of thinner (lighter) coating designations will result in almost linearly reduced corrosion performance of the coating. For example, heavier galvanized coatings perform adequately in bold atmospheric exposure whereas the lighter coatings are often further coated with paint or a similar barrier coating for increased corrosion resistance. Because of this relationship, products carrying the statement "meets ASTM A 653/A 653M requirements" should also specify the particular coating designation.

[C]International Standard, ISO 3575, continuous hot-dip zinc-coated carbon steel sheet contains Z100 and Z200 designations and does not specify a ZF75 coating.

[D]No minimum means that there are no established minimum requirements for triple- and single-spot tests.

3.2.2 *differentially coated*, *n*—galvanized steel sheet having a specified "coating designation" on one surface and a significantly lighter specified "coating designation" on the other surface.

3.2.2.1 *Discussion*—The single side relationship of either specified "coating designation" is the same as shown in the note of Table 1 regarding uniformity of coating.

3.2.3 *high strength low alloy steel*, *n*—a specific group of sheet steels whose strength is achieved through the use of microalloying elements such as columbium (niobium), vanadium, titanium, and molybdenum resulting in improved formability and weldability than is obtained from conventional carbon-manganese steels.

3.2.3.1 *Discussion*—Producers use one or a combination of microalloying elements to achieve the desired properties. The product is available in two designations, HSLAS and HSLAS-F. Both products are strengthened with microalloys, but HSLAS-F is further treated to achieve inclusion control.

3.2.4 *minimized spangle*, *n*—the finish produced on hot-dip zinc-coated steel sheet in which the grain pattern is visible to the unaided eye, and is typically smaller and less distinct than the pattern visible on regular spangle.

3.2.4.1 *Discussion*—This finish is produced by one of two methods: either *(1)* the zinc crystal growth has been started but arrested by special production practices during solidification of the zinc, or *(2)* the zinc crystal growth is inhibited by a combination of coating-bath chemistry plus cooling during solidification of the zinc. Minimized spangle is normally produced in coating designations G90 [Z275] and lighter.

3.2.5 *regular spangle*, *n*—the finish produced on hot-dip zinc-coated steel sheet in which there is a visible multifaceted zinc crystal structure.

3.2.5.1 *Discussion*—Solidification of the zinc coating is typically uncontrolled, which produces the variable grain size associated with this finish.

3.2.6 *spangle-free*, *n*—the uniform finish produced on hot-dip zinc-coated steel sheet in which the visual spangle pattern, especially the surface irregularities created by spangle formation, is not visible to the unaided eye.

3.2.6.1 *Discussion*—This finish is produced when the zinc crystal growth is inhibited by a combination of coating-bath chemistry, or cooling, or both during solidification of the zinc.

3.2.7 *solid-solution hardened steel or solution hardened steel*, *n*—steel sheet strengthened through additions of substitutional alloying elements such as Mn, P, or Si.

3.2.7.1 *Discussion*—Substitutional alloying elements such as Mn, P, and Si can occupy the same sites as iron atoms within the crystalline structure of steels. Strengthening arises as a result of the mismatch between the atomic sizes of these elements and that of iron.

3.2.8 *zinc-iron alloy*, *n*—a dull grey coating with no spangle pattern that is produced on hot-dip zinc-coated steel sheet.

3.2.8.1 *Discussion*—Zinc-iron alloy coating is composed entirely of inter-metallic alloys. It is typically produced by subjecting the hot-dip zinc-coated steel sheet to a thermal treatment after it emerges from the molten zinc bath. This type of coating is suitable for immediate painting without further treatment except normal cleaning (refer to Guide D 2092). The lack of ductility of the alloy coating presents a potential for powdering, etc.

4. Classification

4.1 The material is available in several designations as follows:

4.1.1 Commercial steel (CS Types A, B, and C),

4.1.2 Forming steel (FS Types A and B),

4.1.3 Deep drawing steel (DDS Types A and C),

4.1.4 Extra deep drawing steel (EDDS),

4.1.5 Structural steel (SS),

4.1.6 High strength low alloy steel (HSLAS),

4.1.7 High strength low alloy steel with improved formability (HSLAS-F),

4.1.8 Solution hardened steel (SHS), and

4.1.9 Bake hardenable steel (BHS).

4.2 Structural steel, high strength low alloy steel, solution hardened steel, and bake hardenable steel are available in several grades based on mechanical properties. Structural Steel Grade 50 [340] is available in four classes based on tensile strength. Structural Steel Grade 80 [550] is available in two classes, based on chemistry.

4.3 The material is available as either zinc-coated or zinc-iron alloy-coated in several coating weights [masses] or coating designations as shown in Table 1, and

4.3.1 The material is available with the same or different coating designations on each surface.

5. Ordering Information

5.1 Zinc-coated or zinc-iron alloy-coated sheet in coils and cut lengths is produced to thickness requirements expressed to 0.001 in. [0.01 mm]. The thickness of the sheet includes both the base metal and the coating.

5.2 Orders for product to this specification shall include the following information, as necessary, to adequately describe the desired product:

5.2.1 Name of product (steel sheet, zinc-coated (galvanized) or zinc-iron alloy-coated (galvannealed)),

5.2.2 Designation of sheet [CS (Types A, B, and C), FS (Types A and B), DDS (Types A and C), EDDS, SS, HSLAS, HSLAS-F, SHS, or BHS].

5.2.2.1 When a CS type is not specified, CS Type B will be furnished. When a FS type is not specified, FS Type B will be furnished. When a DDS type is not specified, DDS Type A will be furnished.

5.2.3 When a SS, HSLAS, HSLAS-F, SHS, or BHS designation is specified, state the grade, or class, or combination thereof.

5.2.4 ASTM designation number and year of issue, as A 653 for inch-pound units or A 653M for SI units.

5.2.5 Coating designation,

5.2.6 Chemically treated or not chemically treated,

5.2.7 Oiled or not oiled,

5.2.8 Minimized spangle (if required),

5.2.9 Extra smooth (if required),

5.2.10 Phosphatized (if required),

5.2.11 Dimensions (show thickness, minimum or nominal, width, flatness requirements, and length, if cut lengths). The purchaser shall specify the appropriate table of thickness tolerances in Specification A 924/A 924M that applies to the order, that is, the table of thickness tolerances for ⅜-in. [10-mm] edge distance, or the table of thickness tolerances for 1-in. [25-mm] edge distance.

5.2.12 Coil size requirements (specify maximum outside diameter (OD), acceptable inside diameter (ID), and maximum weight [mass]),

5.2.13 Packaging,

5.2.14 Certification, if required, heat analysis and mechanical property report,

5.2.15 Application (part identification and description), and

5.2.16 Special requirements (if any).

5.2.16.1 If required, the product may be ordered to a specified base metal thickness (see Supplementary Requirement S1.)

NOTE 1—Typical ordering descriptions are as follows: steel sheet, zinc-coated, commercial steel Type A, ASTM A 653, Coating Designation G 115, chemically treated, oiled, minimum 0.040 by 34 by 117 in., for stock tanks, or steel sheet, zinc-coated, high strength low alloy steel Grade 340, ASTM A 653M, Coating Designation Z275, minimized spangle, not chemically treated, oiled, minimum 1.00 by 920 mm by coil, 1520-mm maximum OD, 600-mm ID, 10 000-kg maximum, for tractor inner fender.

NOTE 2—The purchaser should be aware that there are variations in manufacturing practices among the producers and therefore is advised to establish the producer's standard (or default) procedures for thickness tolerances.

6. Chemical Composition

6.1 *Base Metal*:

6.1.1 The heat analysis of the base metal shall conform to the requirements shown in Table 2 for CS (Types A, B, and C), FS (Types A and B), DDS (Types A and C), and EDDS, and Table 3 for SS, HSLAS, HSLAS-F, SHS, and BHS.

6.1.2 Each of the elements listed in Tables 2 and 3 shall be included in the report of heat analysis. When the amount of copper, nickel, chromium, or molybdenum is less than 0.02 %, report the analysis as either <0.02 % or the actual determined value. When the amount of vanadium, titanium, or columbium is less than 0.008 %, report the analysis as either <0.008 % or the actual determined value.

6.1.3 See Specification A 924/A 924M for chemical analysis procedures and product analysis tolerances.

6.2 *Zinc Bath Analysis*—The bath metal used in continuous hot-dip galvanizing shall contain not less than 99 % zinc.

NOTE 3—To control alloy formation and promote adhesion of the zinc coating with the steel base metal, the molten coating metal composition normally contains a percentage of aluminum usually in the range from 0.05 to 0.25. This aluminum is purposely supplied to the molten coating bath, either as a specified ingredient in the zinc spelter or by the addition of a master alloy containing aluminum.

7. Mechanical Properties

7.1 Structural steel, high-strength low-alloy steel, high strength low alloy steel with improved formability, solution hardened steel, and bake hardenable steel shall conform to the mechanical property requirements in Table 4 for the grade, or class, or both.

7.1.1 Bake hardenable steel shall conform to bake hardening index requirements included in Table 4 for the grade specified. The method for measuring the bake hardening index is described in the Annex. Bake hardenable steel shall exhibit a minimum increase in yield strength of 4 ksi [25 MPa] as based on the upper yield point or of 3 ksi [20 MPa] as based on the lower yield stress, after a prestrained specimen has been exposed to a standard bake cycle (340°F [170°C] for 20 minutes).

7.2 The typical mechanical properties for CS (Types A, B, and C), FS (Types A and B), DDS (Types A and C), and EDDS sheet designations are listed in Table 5. These mechanical property values are nonmandatory. They are intended solely to provide the purchaser with as much information as possible to make an informed decision on the steel to be specified. Values outside of these ranges are to be expected.

7.3 When base metal mechanical properties are required, all tests shall be conducted in accordance with the methods specified in Specification A 924/A 924M.

7.4 *Bending Properties Minimum Cold Bending Radii*—Structural steel and high-strength low-alloy steel are commonly fabricated by cold bending. There are many interrelated factors that affect the ability of a 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 base metal microstructure. The table in Appendix X1 lists the suggested minimum inside radius for 90° cold bending for structural steel and high-strength low-alloy steel. They presuppose "hard way" bending (bend axis parallel to rolling direction) and reasonably good shop forming practices. Where possible, the use of larger radii or "easy way" bends are recommended for improved performance.

8. Coating Properties

8.1 *Coating Weight [Mass]*:

8.1.1 Coating weight [mass] shall conform to the requirements as shown in Table 1 for the specific coating designation.

8.1.2 Use the following relationships to estimate the coating thickness from the coating weight [mass]:

8.1.2.1 1 oz/ft^2 coating weight = 1.7 mils coating thickness, and

8.1.2.2 7.14 g/m^2 coating mass = 1 µm coating thickness.

8.2 *Coating Weight [Mass] Tests*:

TABLE 2 Chemical Requirements[A]

	Composition, %—Heat Analysis Element, max (unless otherwise shown)												
Designation	Carbon	Manganese	Phosphorus	Sulfur	Aluminum, min	Cu	Ni	Cr	Mo	V	Cb	Ti[B]	N
CS Type A[C,D,E]	0.10	0.60	0.030	0.035	. . .	0.20	0.20	0.15	0.06	0.008	0.008	0.025	. . .
CS Type B[F,C]	0.02 to 0.15	0.60	0.030	0.035	. . .	0.20	0.20	0.15	0.06	0.008	0.008	0.025	. . .
CS Type C[C,D,E]	0.08	0.60	0.100	0.035	. . .	0.20	0.20	0.15	0.06	0.008	0.008	0.025	. . .
FS Type A[C,G]	0.10	0.50	0.020	0.035	. . .	0.20	0.20	0.15	0.06	0.008	0.008	0.025	. . .
FS Type B[F,C]	0.02 to 0.10	0.50	0.020	0.030	. . .	0.20	0.20	0.15	0.06	0.008	0.008	0.025	. . .
DDS Type A[D,E]	0.06	0.50	0.020	0.025	0.01	0.20	0.20	0.15	0.06	0.008	0.008	0.025	. . .
DDS Type C[H]	0.02	0.50	0.020 to 0.100	0.025	0.01	0.20	0.20	0.15	0.06	0.10	0.10	0.15	. . .
EDDS[H]	0.02	0.40	0.020	0.020	0.01	0.20	0.20	0.15	0.06	0.10	0.10	0.15	. . .

[A] Where an ellipsis (. . .) appears in this table, there is no requirement, but the analysis shall be reported.
[B]For steels containing more than 0.02% carbon, titanium is permitted to 0.025% provided the ratio of % titanium to % nitrogen does not exceed 3.4.
[C]When a deoxidized steel is required for the application, the purchaser has the option to order CS and FS to a minimum of 0.01 % total aluminum.
[D]Steel is permitted to be furnished as a vacuum degassed or chemically stabilized steel, or both, at the producer's option.
[E]For carbon levels less than or equal to 0.02%, vanadium, columbium, or titanium, or combinations thereof are permitted to be used as stabilizing elements at the producer's option. In such cases, the applicable limit for vanadium and columbium shall be 0.10 % max and the limit for titanium shall be 0.15% max.
[F]For CS and FS, specify Type B to avoid carbon levels below 0.02 %.
[G]Shall not be furnished as a stabilized steel.
[H]Shall be furnished as a stabilized steel.

TABLE 3 Chemical Requirements[A]

Designation	Composition, %—Heat Analysis Element, max (unless otherwise shown)													
	Carbon	Manganese	Phosphorus	Sulfur	Si	Al, min.	Cu	Ni	Cr	Mo	V[B]	Cb[B]	Ti[C,B,D]	N
SS														
33 [230]	0.20	1.35	0.04	0.04			0.20	0.20	0.15	0.06	0.008	0.008	0.025	. . .
37 [255]	0.20	1.35	0.10	0.04			0.20	0.20	0.15	0.06	0.008	0.008	0.025	. . .
40 [275]	0.25	1.35	0.10	0.04			0.20	0.20	0.15	0.06	0.008	0.008	0.025	. . .
50 [340] Class 1, 2, and 4	0.25	1.35	0.20	0.04			0.20	0.20	0.15	0.06	0.008	0.008	0.025	. . .
50 [340] Class 3	0.25	1.35	0.04	0.04			0.20	0.20	0.15	0.06	0.008	0.008	0.025	. . .
80 [550] Class 1	0.20	1.35	0.04	0.04			0.20	0.20	0.15	0.06	0.008	0.015	0.025	. . .
80 [550] Class 2[E]	0.02	1.35	0.05	0.02			0.20	0.20	0.15	0.06	0.10	0.10	0.15	. . .
HSLAS[F]														
40 [275]	0.20	1.20	. . .	0.035			. . .	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	. . .
50 [340]	0.20	1.20	. . .	0.035			0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	. . .
60 [410]	0.20	1.35	. . .	0.035			0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	. . .
70 [480]	0.20	1.65	. . .	0.035			0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	. . .
80 [550]	0.20	1.65	. . .	0.035			0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	. . .
HSLAS-F[F,G]														
40 [275]	0.15	1.20	. . .	0.035			. . .	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	. . .
50 [340]	0.15	1.20	. . .	0.035			0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	. . .
60 [410]	0.15	1.20	. . .	0.035			0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	. . .
70 [480]	0.15	1.65	. . .	0.035			0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	. . .
80 [550]	0.15	1.65	. . .	0.035			0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	. . .
SHS	0.12	1.50	0.12	0.030	...	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
BHS	0.12	1.50	0.12	0.030	...	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...

[A] Where an ellipsis (. . .) appears in this table there is no requirement, but the analysis shall be reported.
[B] For carbon levels less than or equal to 0.02%, vanadium, columbium, or titanium, or combinations thereof, are permitted to be used as stabilizing elements at the producer's option. In such cases, the applicable limit for vanadium and columbium shall be 0.10% max., and the limit for titanium shall be 0.15% max.
[C] Titanium is permitted for SS steels to 0.025% provided the ratio of % titanium to % nitrogen does not exceed 3.4.
[D] For steels containing more than 0.02% carbon, titanium is permitted to 0.025%, provided the ratio of % titanium to % nitrogen does not exceed 3.4.
[E] Shall be furnished as a stabilized steel.
[F] HSLAS and HSLAS-F steels commonly contain the strengthening elements columbium, vanadium, and titanium added singly or in combination. The minimum requirements only apply to the microalloy elements selected for strengthening of the steel.
[G] HSLAS-F steel shall be treated to achieve inclusion control.

8.2.1 Coating weight [mass] tests shall be performed in accordance with the requirements of Specification A 924/A 924M.

8.2.2 The referee method to be used shall be Test Method A 90/A 90M.

8.3 *Coating Bend Test*:

8.3.1 The bend test specimens of coated sheet designated by prefix "G" ["Z"] shall be capable of being bent through 180° in any direction without flaking of the coating on the outside of the bend only. The coating bend test inside diameter shall have a relation to the thickness of the specimen as shown in Table 6. Flaking of the coating within 0.25 in. [6 mm] of the edge of the bend specimen shall not be cause for rejection.

8.3.2 Because of the characteristics of zinc-iron alloy coatings designated by prefix "A" ["ZF"] as explained in 3.2.3, coating bend tests are not applicable.

9. Dimensions and Permissible Variations

9.1 All dimensions and permissible variations shall comply with the requirements of Specification A 924/A 924M, except for flatness of SS, HSLAS, and HSLAS-F, which is specified in Table 7 for SS and Table 8 for HSLAS and HSLAS-F.

10. Keywords

10.1 alloyed coating; bake hardenable steel; high strength low alloy; minimized spangle coating; sheet steel; solution hardened steel; spangle; steel; steel sheet; structural steel; zinc; zinc coated (galvanized); zinc iron-alloy; zinc iron-alloy coated

TABLE 4 Mechanical Requirements, Base Metal (Longitudinal)

Inch-Pound Units

Designation	Grade	Yield Strength, min, ksi	Tensile Strength, min, ksi[A]	Elongation in 2 in., min, %[A]	Bake Hardening Index, min, ksi Upper Yield/Lower Yield[A]
SS	33	33	45	20	. . .
	37	37	52	18	. . .
	40	40	55	16	. . .
	50 Class 1	50	65	12	. . .
	50 Class 2	50	. . .	12	. . .
	50 Class 3	50	70	12	. . .
	50 Class 4	50	60	12	. . .
	80 Class 1[B]	80[C]	82	. . .	. . .
	80 Class 2[B,D]	80[C]	82	. . .	. . .
HSLAS	40	40	50[E]	22	. . .
	50	50	60[E]	20	. . .
	60	60	70[E]	16	. . .
	70	70	80[E]	12	. . .
	80	80	90[E]	10	. . .
HSLAS-F	40	40	50[E]	24	. . .
	50	50	60[E]	22	. . .
	60	60	70[E]	18	. . .
	70	70	80[E]	14	. . .
	80	80	90[E]	12	. . .
SHS	26	26	43	32	. . .
	31	31	46	30	. . .
	35	35	50	26	. . .
	41	41	53	24	. . .
	44	44	57	22	. . .
BHS	26	26	43	30	4 / 3
	31	31	46	28	4 / 3
	35	35	50	24	4 / 3
	41	41	53	22	4 / 3
	44	44	57	20	4 / 3

SI Units

Designation	Grade	Yield Strength, min, MPa	Tensile Strength, min, MPa[A]	Elongation in 50 mm, min, %[A]	Bake Hardening Index, min, MPa Upper Yield/Lower Yield[A]
SS	230	230	310	20	. . .
	255	255	360	18	. . .
	275	275	380	16	. . .
	340 Class 1	340	450	12	. . .
	340 Class 2	340	. . .	12	. . .
	340 Class 3	340	480	12	. . .
	340 Class 4	340	410	12	. . .
	550 Class 1[B]	550[C]	570	. . .	. . .
	550 Class 2[B,D]	550[C]	570	. . .	. . .
HSLAS	275	275	340[E]	22	. . .
	340	340	410[E]	20	. . .
	410	410	480[E]	16	. . .
	480	480	550[E]	12	. . .
	550	550	620[E]	10	. . .
HSLAS-F	275	275	340[E]	24	. . .
	340	340	410[E]	22	. . .
	410	410	480[E]	18	. . .
	480	480	550[E]	14	. . .
	550	550	620[E]	12	. . .
SHS	180	180	300	32	. . .
	210	210	320	30	. . .
	240	240	340	26	. . .
	280	280	370	24	. . .
	300	300	390	22	. . .
BHS	180	180	300	30	25 / 20
	210	210	320	28	25 / 20
	240	240	340	24	25 / 20
	280	280	370	22	25 / 20
	300	300	390	20	25 / 20

[A]Where an ellipsis (. . .) appears in this table there is no requirement.
[B]For sheet thickness of 0.028 in. [0.71 mm] or thinner, no tension test is required if the hardness result in Rockwell B 85 or higher.
[C]As there is no discontinuous yield curve, the yield strength should be taken as the stress at 0.5 % elongation under load or 0.2 % offset.
[D]SS Grade 80 [550] Class 2 may exhibit different forming characteristics than Class 1, due to difference in chemistry.
[E]If a higher tensile strength is required, the user should consult the producer.

TABLE 5 Typical Ranges of Mechanical Properties[A,B] (Nonmandatory)

Designation	(Longitudinal Direction)			r_m Value[C]	n Value[D]
	Yield Strength		Elongation in 2 in. [50 mm], %		
	ksi	[MPa]			
CS Type A	25/55	[170/380]	≥20	[E]	[E]
CS Type B	30/55	[205/380]	≥20	[E]	[E]
CS Type C	25/60	[170/410]	≥15	[E]	[E]
FS Types A and B	25/45	[170/310]	≥26	1.0/1.4	0.17/0.21
DDS Type A	20/35	[140/240]	≥32	1.4/1.8	0.19/0.24
DDS Type C	25/40	[170/280]	≥32	1.2/1.8	0.17/0.24
EDDS[F]	15/25	[105/170]	≥40	1.6/2.1	0.22/0.27

[A]The typical mechanical property values presented here are nonmandatory. They are intended solely to provide the purchaser with as much information as possible to make an informed decision on the steel to be specified. Values outside of these ranges are to be expected. The purchaser may negotiate with the supplier if a specific range or a more restrictive range is required for the application.

[B]These typical mechanical properties apply to the full range of steel sheet thicknesses. The yield strength tends to increase and some of the formability values tend to decrease as the sheet thickness decreases.

[C]r_m Value—Average plastic strain ratio as determined by Test Method E 517.

[D]n Value—Strain-hardening exponent as determined by Test Method E 646.

[E]No typical mechanical properties have been established.

[F]EDDS Sheet will be free from changes in mechanical properties over time, that is, nonaging.

TABLE 6 Coating Bend Test Requirements

Inch-Pound Units

Coating Designation[B]	Ratio of the Inside Bend Diameter to Thickness of the Specimen (Any Direction) CS, FS, DDS, EDDS, SHS, BHS — Sheet Thickness: Through 0.039 in.	Over 0.039 through 0.079 in.	Over 0.079 in.	SS, Grade[A] 33	37	40
G235	2	3	3	3	3	3
G210	2	2	2	2	2	2½
G185	2	2	2	2	2	2½
G165	2	2	2	2	2	2½
G140	1	1	2	2	2	2½
G115	0	0	1	1½	2	2½
G90	0	0	1	1½	2	2½
G60	0	0	0	1½	2	2½
G40	0	0	0	1½	2	2½
G30	0	0	0	1½	2	2½
G01	0	0	0	1½	2	2½

	HSLAS[A] 40	50	60	HSLAS-F 40	50	60	70	80
G115	1½	1½	3	1	1	1	1½	1½
G90	1½	1½	3	1	1	1	1½	1½
G60	1½	1½	3	1	1	1	1½	1½
G40	1½	1½	3	1	1	1	1½	1½
G30	1½	1½	3	1	1	1	1½	1½
G01	1½	1½	3	1	1	1	1½	1½

SI Units

Coating Designation[B]	Ratio of the Inside Bend Diameter to Thickness of the Specimen (Any Direction) CS, FS, DDS, EDDS, SHS, BHS — Sheet Thickness: Through 1.0 mm	Over 1.0 mm through 2.0 m	Over 2.0 mm	SS, Grade[C] 230	255	275
Z700	2	3	3	3	3	3
Z600	2	2	2	2	2	2½
Z550	2	2	2	2	2	2½
Z500	2	2	2	2	2	2½
Z450	1	1	2	2	2	2½
Z350	0	0	1	1½	2	2½
Z275	0	0	1	1½	2	2½
Z180	0	0	0	1½	2	2½
Z120	0	0	0	1½	2	2½
Z90	0	0	0	1½	2	2½
Z001	0	0	0	1½	2	2½

	HSLAS[C] 275	340	410	HSLAS-F 275	340	410	480	550
Z350	1½	1½	3	1	1	1	1½	1½
Z275	1½	1½	3	1	1	1	1½	1½
Z180	1½	1½	3	1	1	1	1½	1½
Z120	1½	1½	3	1	1	1	1½	1½
Z90	1½	1½	3	1	1	1	1½	1½
Z001	1½	1½	3	1	1	1	1½	1½

[A] SS Grades 50 and 80, HSLAS, and HSLAS-F Grades 70 and 80 are not subject to bend test requirements.
[B] If other coatings are required, the user should consult the producer for availability and suitable bend test requirements.
[C] SS Grades 340 and 550, HSLAS, and HSLAS-F Grades 480 and 550 are not subject to bend test requirements.

TABLE 7 Structural Steel—Flatness Tolerances (Cut Lengths Only)

NOTE 1—This table also applies to sheets cut to length from coils by the consumer when adequate flattening measures are performed.

NOTE 2— For Grade 50 [340] (Classes 1, 2, 3, and 4) use 1½ times the values given in this table.

NOTE 3—For Grade 80 [550], there are no defined flatness standards.

Specified Thickness, in. [mm]	Specified Width, in. [mm]	Flatness Tolerance (Maximum Deviation from a Horizontal Flat Surface), in. [mm]
Over 0.060 [1.5]	to 60 [1500], inclusive	½ [12]
	over 60 [1500] to 72 [1800], inclusive	¾ [20]
0.060 [1.5] and thinner	to 36 [900], inclusive	½ [12]
	over 36 [900] to 60 [1500], inclusive	¾ [20]
	over 60 [1500] to 72 [1800], inclusive	1 [25]

TABLE 8 High-Strength Low-Alloy Steel and High-Strength Low-Alloy Steel with Improved Formability—Flatness Tolerances (Cut Lengths Only)

NOTE 1—This table also applies to sheets cut to length from coils by the consumer when adequate flattening measures are performed.

Inch-Pound Units						
Specified Thickness, in.	Specified Width, in.	Flatness Tolerances (Maximum Deviation from a Horizontal Flat Surface), in.				
		Grade				
		40	50	60	70	80
Over 0.060	to 60, inclusive	⅝	¾	⅞	1	1⅛
	over 60	1	1⅛	1¼	1⅜	1½
0.060 and thinner	to 36, inclusive	⅝	¾	⅞	1	1⅛
	over 36 to 60, inclusive	1	1⅛	1¼	1⅜	1½
	over 60	1⅜	1½	1⅝	1¾	1⅞
SI Units						
Specified Thickness, mm	Specified Width, mm	Flatness Tolerances (Maximum Deviation from a Horizontal Flat Surface), mm				
		Grade				
		275	340	410	480	550
Over 1.5	to 1500, inclusive	15	20	22	25	30
	over 1500	25	30	32	35	38
1.5 and thinner	to 900, inclusive	15	20	22	25	30
	over 900 to 1500, inclusive	25	30	32	35	33
	over 1500	35	38	40	45	48

SUPPLEMENTARY REQUIREMENTS

The following standardized supplementary requirements are for use when desired by the purchaser. These additional requirements shall apply only when specified on the order.

S1. Base Metal Thickness

S1.1 The specified minimum thickness shall apply to the base metal only.

S1.2 The coating designation shown on the order indicates the coating to be applied to the specified minimum base metal thickness.

S1.3 The applicable tolerances for base metal thickness are shown in Tables 16 and Tables 17, Thickness Tolerance of Cold-Rolled Sheet (Carbon and High-Strength, Low-Alloy Steel), of Specification A 568/A 568M.

ANNEX

A1. BAKE HARDENABLE STEELS

A1.1 Determination of Bake Hardening Index

A1.1.1 The bake hardening index (BHI) is determined by a two-step procedure using a standard longitudinal (rolling direction) tensile-test specimen, prepared in accordance with Test Methods A 370. The test specimen is first strained in tension. The magnitude of this tensile "pre-strain" shall be 2 % (extension under load). The test specimen is then removed from the test machine and baked at a temperature of 340°F [170°C] for a period of 20 minutes. Referring to Fig. A1.1, the bake hardening index (BHI) of the material is calculated as follows:

$$BHI = B - A \tag{A1.1}$$

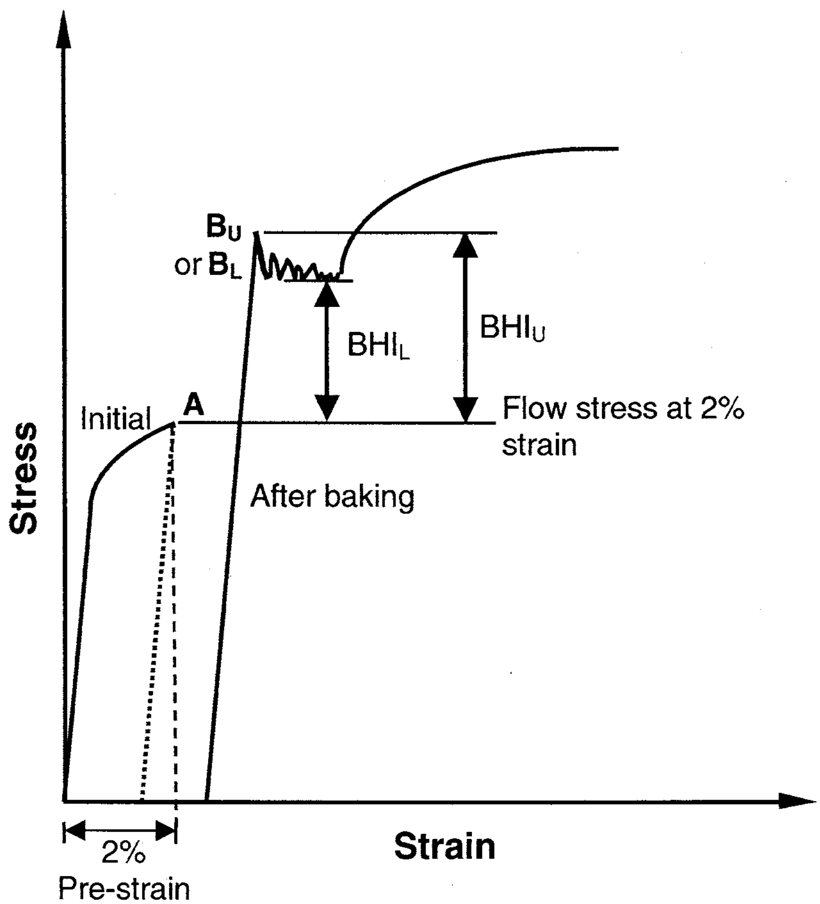

FIG. A1.1 Representation of Bake Hardening Index where:

A = flow stress at 2 % extension under load

B = yield strength [upper yield strength (B_U) or lower yield stress (B_L)] after baking at 340°F [170°C] for 20 minutes.

A1.1.2 The original test specimen cross section (width and thickness) is used in the calculation of all engineering strengths in this test.

A1.1.3 The pre-straining of 2 % in tension is intended to simulate a modest degree of forming strain, while the subsequent baking is intended to simulate a paint-curing or similar treatment. In the production of actual parts, forming strains and baking treatments can differ from those employed here and, as a result, final properties can differ from the values obtained under these controlled conditions.

APPENDIXES

(Nonmandatory Information)

X1. BENDING PROPERTIES

X1.1 Table X1.1 lists suggested minimum inside radii for cold bending.

TABLE X1.1 Suggested Minimum Inside Radii for Cold Bending[A]

NOTE 1— (t) equals a radius equivalent to the steel thickness.

NOTE 2—The suggested radii should be used as minimums for 90° bends in actual shop practice.

Designation	Grade	Minimum Inside Radius for Cold Bending[B]
SS	33 [230]	1½ *t*
	37 [255]	2*t*
	40 [275]	2*t*
	50 [340] Class 1	not applicable
	50 [340] Class 2	not applicable
	50 [340] Class 3	not applicable
	50 [340] Class 4	not applicable
	80 [550] Class 1	not applicable
	80 [550] Class 2	not applicable
HSLAS	40 [275]	2*t*
	50 [340]	2½ *t*
	60 [410]	3*t*
	70 [480]	4*t*
	80 [550]	4½ *t*
HSLAS-F	40 [275]	1½ *t*
	50 [340]	2*t*
	60 [410]	2*t*
	70 [480]	3*t*
	80 [550]	3*t*
SHS	26 [180]	½ *t*
	31 [210]	1*t*
	35 [240]	1½ *t*
	41 [280]	2*t*
	44 [300]	2*t*
BHS	26 [180]	½ *t*
	31 [210]	1*t*
	35 [240]	1½ *t*
	41 [280]	2*t*
	44 [300]	2*t*

[A]Material that does not perform satisfactorily, when fabricated in accordance with the requirements in Table X1.1, may be subject to rejection pending negotiation with the steel supplier.

[B]Bending capability may be limited by coating designation.

X2. RATIONALE FOR CHANGES IN PRODUCT DESIGNATIONS

X2.1 Subcommittee A05.11 has revised the designations used to classify the various products available in each hot-dip coated specification. The previous "quality" designations have been replaced with designations and descriptions more closely related with product characteristics. Many of the former "quality" specifications described the steel only in terms of limited chemical composition, which in some cases was identical for two or more qualities. The former designations also did not reflect the availability of new steels which are the result of the use of new technologies such as vacuum degassing and steel ladle treatments.

X2.2 The former "quality" designators, defined in very broad qualitative terms, did not provide the user with all the information needed to select the appropriate steel for an application. The new designations are defined with technical information such as specific chemical composition limits and typical nonmandatory mechanical properties. These steel characteristics are important to users concerned with the weldability and formability of the coated steel products. The typical mechanical properties included in the new designation system are those indicated by the tension test. These properties are more predictive of steel formability than other tests such as the hardness test which may not compensate adequately for product variables such as substrate thickness and coating weight.

X2.3 The new designations also provide the user with the flexibility to restrict the steels applied on any order. For example, a user can restrict the application of ultra low carbon steels on an application through the selection of an appropriate "type" designator.

X2.4 There is a limited relationship between the former and current systems of designation. Some of the reasons for this limited relationship are: addition of steels not previously described in ASTM specifications, restrictions placed on ranges of chemical composition, the addition of typical mechanical properties, and the enhanced capability of steel producers to combine chemical composition and processing methods to achieve properties tailored to specific applications.

X2.5 The changes in designation are significant which may create transition issues that will have to be resolved. Continued dialogue between users and producers will have to be maintained to assist with the transition to the new system of designations. A user with concerns about the appropriate coated steel to order for a specific application should consult with a steel supplier or producer.

X3. RELATIONSHIP BETWEEN SPECIFICATIONS THAT DESCRIBE REQUIREMENTS FOR A COMMON PRODUCT

X3.1 ISO 3575 and ISO 4998 may be reviewed for comparison with this standard. The relationship between the standards may only be approximate; therefore, the respective documents should be consulted for actual requirements. Those who use these documents must determine which specifications address their needs.

X4. COATING MASS SELECTION BASED ON ATMOSPHERIC CORROSION RATES[4] FOR ZINC-COATED STEEL SHEET

X4.1 The proper selection of coating mass to meet a user's needs for zinc-coated steel sheet requires some knowledge about the relative corrosiveness of the environment in which the product will be used. The corrosion rate of the zinc coating varies widely depending upon many factors of the environment. For example, the time of wetness is an important issue that affects the corrosion rate. The presence of impurities such as chlorides, nitrates, and sulfates can also dramatically affect the rate of corrosion. Other issues such as the presence or absence of oxygen and the temperature of the environment are important determinants for predicting the "life of the product."

X4.2 The final performance requirements can also impact the minimum coating mass needed for a given application. For example, is the application an aesthetic one that requires no red rust. In this case, the time to failure is thus defined as the time for the onset of red rust (the time for the zinc coating to be consumed in a large enough area for rusting of the steel to be observed). Or, is the application one in which the time to failure is defined as the time when perforation of the steel sheet is observed? In this case, the thickness of the steel sheet as well as the thickness of the zinc coating impact the time to failure.

X4.3 No matter how one defines the "product life," there are data in the published literature to assist users once the environment and desired product life are determined.

X4.4 Although the corrosion rate can vary considerably depending on the environmental factors, it is well known that, in most instances, the life of the zinc coating is a linear function of coating mass for any specific environment. That means, to achieve twice the life for any specific application, the user should order twice the coating mass.

X4.4.1 *Examples*:

[4] Atmospheric corrosion rates do not apply to zinc-iron alloy coatings.

X4.4.1.1 A G60 coating mass will exhibit approximately twice the life of a G30 coating mass.

X4.4.1.2 A G90 coating mass will exhibit about 50 % longer life than a G60 coating mass.

X4.5 The following two reference books are excellent sources for additional and more detailed information on the corrosion behavior of zinc-coated steel sheet products:

X4.5.1 *Corrosion and Electrochemistry of Zinc*, X. Gregory Zhang, published by Plenum Press, 1996.

X4.5.2 *Corrosion Resistance of Zinc and Zinc Alloys*, Frank C. Porter, Published by Marcel Dekker, Inc., 1994

SUMMARY OF CHANGES

Committee A05 has identified the location of selected changes to this standard since the last issue, A 653/A 653M - 04a, that may impact the use of this standard. (June 1, 2005)

(*1*) Added a second type of DDS, Type C. Renamed original DDS, Type A. Changes were made in 4.1.3, 5.2.2, 5.2.2.1, 6.1.1, 7.2, Table 2, and Table 5.
(*2*) Revised the definition of "high strength low alloy steel."
(*3*) Removed the "Type" classifications of HSLAS.
(*4*) Revised 4.2.
(*5*) Renamed existing Grade 80 [550] to Grade 80 [550] Class 1 in Table 3, Table 4, and Table X1.1.
(*6*) Added Grade 80 [550] Class 2 to Table 3, Table 4, and Table X1.1.
(*7*) Added Mn limit to Table 3.

Committee A05 has identified the location of selected changes to this standard since the last issue, A 653/A 653M - 04, that may impact the use of this standard. (May 1, 2004)

(*1*) Table 4 was revised to include tensile strength requirements for SHS and BHS designations.

Committee A05 has identified the location of selected changes to this standard since the last issue, A 653/ A653M - 03, that may impact the use of this standard. (February 1, 2004)

(*1*) Added new Class of Structural Steel, SS Grade 50 Class 4.