



Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process¹

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](#) and in [Table S2.1](#).

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*

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, Structural, 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 7396](#) Guide for Preparation of New, Continuous 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:³

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

[ISO 4998](#) Continuous Hot-Dip Zinc-Coated Carbon Steel of Structural Quality

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

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.

Current edition approved May 1, 2009. Published June 2009. Originally approved in 1994. Last previous edition approved in 2008 as A 653/A 653M - 08.

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, <http://www.ansi.org>.

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

NOTE 1— Use the information provided in 8.1.3 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, oz/ft ²	Total Both Sides, oz/ft ²
Zinc	G01	no minimum	no minimum	no minimum
	G30	0.30	0.10	0.25
	G40	0.40	0.12	0.30
	G60	0.60	0.20	0.50
	G90	0.90	0.32	0.80
	G100	1.00	0.36	0.90
	G115	1.15	0.40	1.00
	G140	1.40	0.48	1.20
	G165	1.65	0.56	1.40
	G185	1.85	0.64	1.60
	G210	2.10	0.72	1.80
	G235	2.35	0.80	2.00
	G300	3.00	1.04	2.60
	G360	3.60	1.28	3.20
Zinc-iron alloy	A01	no minimum	no minimum	no minimum
	A25	0.25	0.08	0.20
	A40	0.40	0.12	0.30
	A60	0.60	0.20	0.50
	SI Units			
Type	Coating Designation	Total Both Sides, g/m ²	One Side, g/m ²	Total Both Sides, g/m ²
Zinc	Z001	no minimum	no minimum	no minimum
	Z90	90	30	75
	Z120	120	36	90
	Z180	180	60	150
	Z275	275	94	235
	Z305	305	110	275
	Z350	350	120	300
	Z450	450	154	385
	Z500	500	170	425
	Z550	550	190	475
	Z600	600	204	510
	Z700	700	238	595
	Z900	900	316	790
	Z1100	1100	390	975
Zinc-iron alloy	ZF001	no minimum	no minimum	no minimum
	ZF75	75	24	60
	ZF120	120	36	90
	ZF180	180	60	150

^AThe coating designation is the term by which the minimum triple spot, total both sides coating weight [mass] 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.

^BAs 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.

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

^DNo minimum means that there are no established minimum requirements for triple- and single-spot tests.

heat treatment, such as that used for paint baking, follows straining or cold working.

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), vana-

dium, 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 7396](#)). 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 three 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 in [Table S2.1](#), 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 $\frac{3}{8}$ -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.)

5.2.16.2 If required, the product may be ordered to a specified single spot/single side coating mass (see Supplementary Requirement S2.)

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. When the amount of boron is less than 0.0005 %, report as <0.0005 % 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).

TABLE 2 Chemical Requirements^A

Designation	Composition, %—Heat Analysis Element, max (unless otherwise shown)													
	Carbon	Manganese	Phosphorus	Sulfur	Aluminum, min	Cu	Ni	Cr	Mo	V	Cb	Ti ^B	N	B
CS Type A ^{C,D,E}	0.10	0.60	0.030	0.035	...	0.25	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	...	0.25	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	...	0.25	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	...	0.25	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	...	0.25	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	0.25	0.20	0.15	0.06	0.008	0.008	0.025	...	...
DDS Type C ^{D,E}	0.02	0.50	0.020 to 0.100	0.025	0.01	0.25	0.20	0.15	0.06	0.10	0.10	0.15	...	...
EDDS ^H	0.02	0.40	0.020	0.020	0.01	0.25	0.20	0.15	0.06	0.10	0.10	0.15	...	...

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

^BFor 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 %.

^CWhen 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.

^DSteel is permitted to be furnished as a vacuum degassed or chemically stabilized steel, or both, at the producer’s option.

^EFor 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.

^FFor CS and FS, specify Type B to avoid carbon levels below 0.02 %.

^GShall not be furnished as a stabilized steel.

^HShall 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 ^{B,C,D}	N
SS														
33 [230]	0.20	1.35	0.10	0.04			0.25	0.20	0.15	0.06	0.008	0.008	0.025	...
37 [255]	0.20	1.35	0.10	0.04			0.25	0.20	0.15	0.06	0.008	0.008	0.025	...
40 [275]	0.25	1.35	0.10	0.04			0.25	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			0.25	0.20	0.15	0.06	0.008	0.008	0.025	...
50 [340] Class 3	0.25	1.35	0.04	0.04			0.25	0.20	0.15	0.06	0.008	0.008	0.025	...
55 [380]	0.25	1.35	0.04	0.04			0.25	0.20	0.15	0.06	0.008	0.008	0.025	...
60 [410]	0.25	1.35	0.04	0.04			0.25	0.20	0.15	0.06	0.008	0.008	0.025	...

TABLE 3 Continued

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 ^{B,C,D}	N
70 [480]	0.25	1.35	0.04	0.04			0.25	0.20	0.15	0.06	0.008	0.008	0.025	...
80 [550] Class 1	0.20	1.35	0.04	0.04			0.25	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			0.25	0.20	0.15	0.06	0.10	0.10	0.15	...
80 [550] Class 3	0.20	1.35	0.04	0.04			0.25	0.20	0.15	0.06	0.008	0.015	0.025	...
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	...
55 [380] Class 1	0.25	1.35	...	0.035			0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
55 [380] Class 2	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]	0.20	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	...
55 [380] Class 1	0.20	1.35	...	0.035			0.20	0.20	0.15	0.16	0.01 min	0.005 min	0.01 min	...
55 [380] Class 2	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 ^D	0.12	1.50	0.12	0.030	...	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...
BHS ^D	0.12	1.50	0.12	0.030	...	...	0.20	0.20	0.15	0.06	0.008	0.008	0.025	...

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

^BFor 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.

^CTitanium is permitted for SS steels at the producer's option, to the lesser of 3.4N + 1.5S or 0.025 %.

^DFor steels containing more than 0.02 % carbon, titanium is permitted to the lesser of 3.4N + 1.5S or 0.025 %.

^EShall be furnished as a stabilized steel.

^FHSLAS 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.

^GHSLAS-F steel shall be treated to achieve inclusion control.

TABLE 4 Mechanical Requirements, Base Metal (Longitudinal)

Designation	Grade	Inch-Pound Units			Bake Hardening Index, min, ksi Upper Yield/Lower Yield ^A
		Yield Strength, min, ksi	Tensile Strength, min, ksi ^A	Elongation in 2 in., min, % ^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	...
	55	55	70	11	...
	60	60	70	10 ^B	...
	70	70	80	9 ^B	...
	80 Class 1 ^C	80 ^D	82	...	...
	80 Class 2 ^{C,E}	80 ^D	82	...	...
	80 Class 3	80 ^D	82	3 ^F	...
	HSLAS	40	40	50 ^G	22
50		50	60 ^G	20	...
55 Class 1		55	70 ^G	16	...
	55 Class 2	55	65 ^G	18	...

TABLE 4 *Continued*

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	
HSLAS-F	60	60	70 ^G	16	...	
	70	70	80 ^G	12	...	
	80	80	90 ^G	10	...	
	40	40	50 ^G	24	...	
	50	50	60 ^G	22	...	
	55 Class 1	55	70 ^G	18	...	
	55 Class 2	55	65 ^G	20	...	
	60	60	70 ^G	18	...	
	70	70	80 ^G	14	...	
SHS	80	80	90 ^G	12	...	
	26	26	43	32	...	
	31	31	46	30	...	
	35	35	50	26	...	
	41	41	53	24	...	
BHS	44	44	57	22	...	
	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	...	
	380	380	480	11	...	
	410	410	480	10 ^B	...	
	480	480	550	9 ^B	...	
	550 Class 1 ^C	550 ^D	570	...	...
	550 Class 2 ^{C,E}	550 ^D	570	...	...
	550 Class 3	550 ^D	570	3 ^F	...	
	HSLAS	275	275	340 ^G	22	...
		340	340	410 ^G	20	...
380 Class 1		380	480 ^G	16	...	
380 Class 2		380	450 ^G	18	...	
410		410	480 ^G	16	...	
480		480	550 ^G	12	...	
550		550	620 ^G	10	...	
HSLAS-F		275	275	340 ^G	24	...
	340	340	410 ^G	22	...	
	380 Class 1	380	480 ^G	18	...	
	380 Class 2	380	450 ^G	20	...	
	410	410	480 ^G	18	...	
	480	480	550 ^G	14	...	
	550	550	620 ^G	12	...	
SHS	180	180	300	32	...	
	210	210	320	30	...	
	240	240	340	26	...	
	280	280	370	24	...	
BHS	300	300	390	22	...	
	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	

^AWhere an ellipsis (...) appears in this table there is no requirement.

^BFor sheet thickness of 0.028 in. [0.71 mm] or thinner, the elongation requirement is reduced two percentage points for SS Grades 60 [410] and 70 [480].

^CFor 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.

^DAs 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.

^ESS Grade 80 [550] Class 2 may exhibit different forming characteristics than Class 1, due to difference in chemistry.

^FThe purchaser should consult with the producer when ordering SS Grade 80 [550] Class 3 material in sheet thicknesses 0.028 in. [0.71 mm] or thinner regarding elongation and tension test requirements.

^GIf a higher tensile strength is required, the user should consult the producer.

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, or

8.1.2 If required, the coating mass shall conform to the requirements as shown in **Table S2.1** for the specific single spot/single side coating mass designation (single spot/single side designations are available only in SI units).

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

8.1.3.1 1 oz/ft² coating weight = 1.7 mils coating thickness, and

8.1.3.2 7.14 g/m² coating mass = 1 μm coating thickness.

8.1.4 Use the following relationship to convert coating weight to coating mass:

8.1.4.1 1 oz/ft² coating weight = 305.15 g/m² coating mass.

8.2 Coating Weight [Mass] Tests:

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 the Discussion following **3.2.8**, coating bend tests are not applicable.

9. Retests and Disposition of Non-Conforming Material

9.1 Retests, conducted in accordance with the requirements of the section on Retests and Disposition of Non-Conforming Material of Specification **A 924/A 924M**, are permitted when an unsatisfactory test result is suspected to be the consequence of the test method procedure.

9.2 Disposition of non-conforming material shall be subject to the requirements of 13.2 of Specification **A 924/A 924M**.

10. Dimensions and Permissible Variations

10.1 All dimensions and permissible variations shall comply with the requirements of Specification **A 924/A 924M**.

11. Keywords

11.1 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 5 Typical Ranges of Mechanical Properties^{A,B} (Nonmandatory)

Designation	(Longitudinal Direction)		Elongation in 2 in. [50 mm], %	<i>r_m</i> Value ^C	<i>n</i> Value ^D
	Yield Strength				
	ksi	[MPa]			
CS Type A	25/55	[170/380]	≥20	<i>E</i>	<i>E</i>
CS Type B	30/55	[205/380]	≥20	<i>E</i>	<i>E</i>
CS Type C	25/60	[170/410]	≥15	<i>E</i>	<i>E</i>
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

^AThe 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.

^BThese 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**.

^ENo typical mechanical properties have been established.

^FEDDS Sheet will be free from changes in mechanical properties over time, that is, nonaging.

TABLE 6 Coating Bend Test Requirements

Inch-Pound Units									
Ratio of the Inside Bend Diameter to Thickness of the Specimen (Any Direction) CS, FS, DDS, EDDS, SHS, BHS									
Coating Designation ^B	Sheet Thickness			SS, Grade ^A					
	Through 0.039 in.	Over 0.039 through 0.079 in.	Over 0.079 in.	33	37	40			
	G01	0	0	0	1½	2	2½		
G30	0	0	0	1½	2	2½			
G40	0	0	0	1½	2	2½			
G60	0	0	0	1½	2	2½			
G90	0	0	1	1½	2	2½			
G100	0	0	1	1½	2	2½			
G115	0	0	1	1½	2	2½			
G140	1	1	2	2	2	2½			
G165	2	2	2	2	2	2½			
G185	2	2	2	2	2	2½			
G210	2	2	2	2	2	2½			
G235	2	2	3	3	3	3			
HSLAS^A									
HSLAS-F									
	40	50	60	40	50	60	70	80	
G01	1½	1½	3	1	1	1	1½	1½	
G30	1½	1½	3	1	1	1	1½	1½	
G40	1½	1½	3	1	1	1	1½	1½	
G60	1½	1½	3	1	1	1	1½	1½	
G90	1½	1½	3	1	1	1	1½	1½	
G100	1½	1½	3	1	1	1	1½	1½	
G115	1½	1½	3	1	1	1	1½	1½	

SI Units									
Ratio of the Inside Bend Diameter to Thickness of the Specimen (Any Direction) CS, FS, DDS, EDDS, SHS, BHS									
Coating Designation ^B	Sheet Thickness			SS, Grade ^C					
	Through 1.0 mm	Over 1.0 mm through 2.0 m	Over 2.0 mm	230	255	275			
	Z001	0	0	0	1½	2	2½		
Z90	0	0	0	1½	2	2½			
Z120	0	0	0	1½	2	2½			
Z180	0	0	0	1½	2	2½			
Z275	0	0	0	1½	2	2½			
Z305	0	0	1	1½	2	2½			
Z350	0	0	1	1½	2	2½			
Z450	1	1	2	2	2	2½			
Z500	2	2	2	2	2	2½			
Z550	2	2	2	2	2	2½			
Z600	2	2	2	2	2	2½			
Z700	2	3	3	3	3	3			
HSLAS^C									
HSLAS-F									
	275	340	410	275	340	410	480	550	
Z001	1½	1½	3	1	1	1	1½	1½	
Z90	1½	1½	3	1	1	1	1½	1½	
Z120	1½	1½	3	1	1	1	1½	1½	
Z180	1½	1½	3	1	1	1	1½	1½	
Z275	1½	1½	3	1	1	1	1½	1½	
Z305	1½	1½	3	1	1	1	1½	1½	
Z350	1½	1½	3	1	1	1	1½	1½	

^ASS Grades 50, 60, 70, and 80, HSLAS, and HSLAS-F Grades 70 and 80 are not subject to bend test requirements.

^BIf other coatings are required, the user should consult the producer for availability and suitable bend test requirements.

^CSS Grades 340, 410, 480, and 550, HSLAS, and HSLAS-F Grades 480 and 550 are not subject to bend test requirements.

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**.

S2. Single Spot/Single Side Coating Mass

S2.1 The coating designation shown on the order indicates the coating mass to be applied to a single side. The order shall specify a coating mass designation from **Table S2.1** for each surface. No inch pound designations are available, although for each SI coating mass designation in **Table S2.1**, corresponding inch-pound values are shown for information purposes

S2.2 The format for specifying the coating for each surface on the order shall be, for instance, 60G60G. In the case of differential coating masses, the thicker (heavier) coating mass side shall be specified first, for instance 90G45G.

TABLE S2.1 Mass of Coating Requirements—Single Spot/Single Side^{A,B,C}

NOTE 1—Use the information provided in 8.1.3 to obtain the approximate coating thickness per side from the coating mass.

NOTE 2—As stated in 1.5, values in SI and inch-pound units are not necessarily equivalent.

Single Spot/Single Side Coating Mass					
Type	Coating Designation	SI Units		Inch-Pound Units (information only)	
		Minimum, g/m ²	Maximum, g/m ²	Minimum, oz/ft ²	Maximum, oz/ft ²
Zinc	20G	20	70	0.07	0.23
	30G	30	80	0.10	0.26
	40G	40	90	0.12	0.29
	45G	45	95	0.15	0.31
	50G	50	100	0.16	0.33
	55G	55	105	0.18	0.34
	60G	60	110	0.20	0.36
	70G	70	120	0.23	0.40
	90G	90	160	0.30	0.62
	100G ^D	100	200	0.32	0.65
Zinc-Iron Alloy	40A	40	70	0.13	0.23
	45A	45	75	0.15	0.25
	50A	50	80	0.16	0.26

^AThe coating designation is the term by which the minimum single spot/single side coating mass is specified for each side.

^BAs 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 (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.

^COrdering to single spot/single side spot coating weight designations allows for the possibility of receiving product with a higher average total coating mass on both surfaces than what might be expected on assumed equivalent product coated to the total both sides requirement of **Table 1**. The user should be aware that this may result in issues during forming and spot welding.

^DIt is permissible to order Coating Designation 100G as 98G. Historically, the conversion from 0.32 oz/ft² to g/m² resulted in a value of 98 g/m² which was subsequently rounded to 100 g/m². Both SI designations have the same limits.

ANNEX

(Mandatory Information)

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:

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

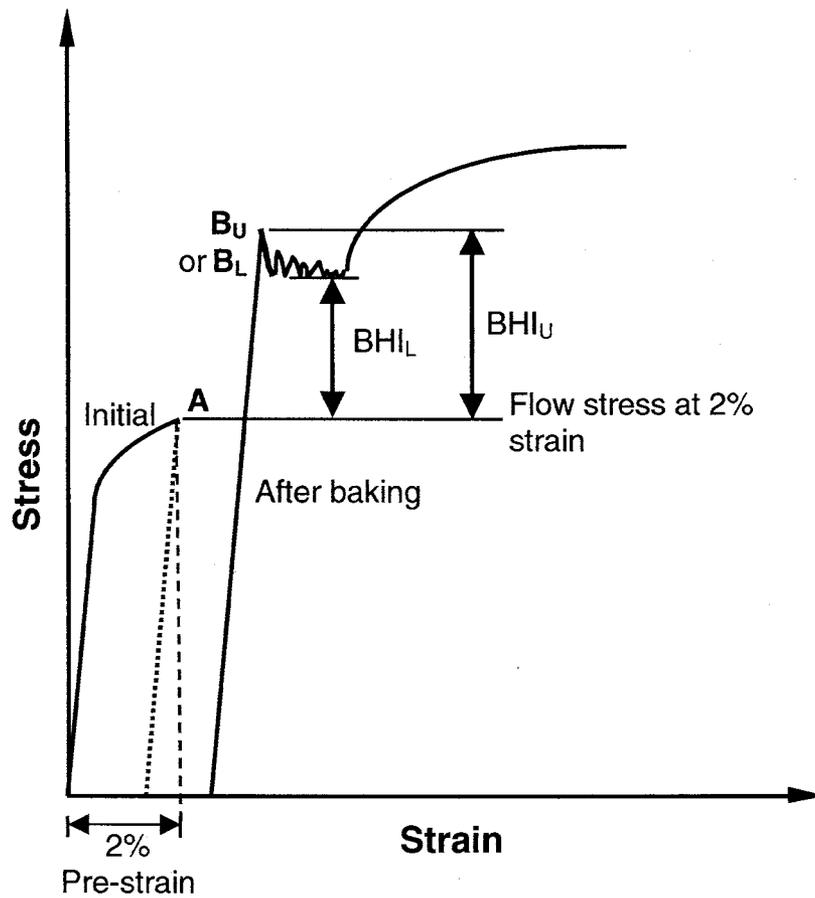


FIG. A1.1 Representation of Bake Hardening Index

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 <i>t</i>
	37 [255]	2 <i>t</i>
	40 [275]	2 <i>t</i>
	50 [340] Class 1	not applicable
	50 [340] Class 2	not applicable
	50 [340] Class 3	not applicable
	50 [340] Class 4	not applicable
	55 [380]	not applicable
	60 [410]	not applicable
	70 [480]	not applicable
	80 [550] Class 1	not applicable
	80 [550] Class 2	not applicable
	80 [550] Class 3	not applicable
	HSLAS	40 [275]	2t
50 [340]		2½ <i>t</i>
55 [380] Class 1		3 <i>t</i>
55 [380] Class 2		3 <i>t</i>
60 [410]		3 <i>t</i>
70 [480]		4 <i>t</i>
80 [550]		4½ <i>t</i>
HSLAS-F		40 [275]	1½ t
	50 [340]	2 <i>t</i>
	55 [380] Class 1	2 <i>t</i>
	55 [380] Class 2	2 <i>t</i>
	60 [410]	2 <i>t</i>
	70 [480]	3 <i>t</i>
SHS	80 [550]	3 <i>t</i>
	26 [180]	½ <i>t</i>
	31 [210]	1 <i>t</i>
	35 [240]	1½ <i>t</i>
	41 [280]	2 <i>t</i>
	44 [300]	2 <i>t</i>
BHS	26 [180]	½ <i>t</i>
	31 [210]	1 <i>t</i>
	35 [240]	1½ <i>t</i>
	41 [280]	2 <i>t</i>
	44 [300]	2 <i>t</i>

^AMaterial 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.

^BBending 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 main-

tained 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 RATES⁴ 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:*

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

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

SUMMARY OF CHANGES

Committee A05 has identified the location of selected changes to this standard since the last issue (A 653/A 653M - 08) that may impact the use of this standard. (May 1, 2009)

- (1) Added new Grade 80 Class 3 requirements to Tables 3, 4, and X1.1.
- (2) Added new SS Grade 60 [410] and 70 [480] requirements to Tables 3, 4, 6, and X1.1.
- (3) Changed reference from D 2092 to D 7396 in 2.1 and 3.2.8.1.

- (4) Changed the order of the coating weight [mass] designations in Table 6 from descending to ascending.
- (5) Added 20G coating designation to Table S2.1

Committee A05 has identified the location of selected changes to this standard since the last issue (A 653/A 653M - 07) that may impact the use of this standard. (July 15, 2008)

- (1) Changed the order of the coating weight [mass] designations in **Table 1** from descending to ascending, and changed Footnote A.
- (2) Added Supplementary Requirement S2 that allows a purchaser to order product to single spot/single side coating designations. In support of this, revisions were made in **1.2**, **4.3**, and **8.1.1**; and added **5.2.16.2** and **8.1.2**, with previous 8.1.2 renumbered as **8.1.3**.
- (3) Added **8.1.4** added showing the formula for converting coating weight to coating mass.
- (4) Replaced footnote H with footnotes D and E on DDS Type C in Table 2.
- (5) In **Table 3**, revised SS GRD 33 to increase P level.
- (6) Revised **10.1**.
- (7) Deleted Flatness Tables: 7 and 8.

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