



Designation: A653/A653M – 11

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 A653/A653M; 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 [A924/A924M](#), 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 A653) or SI units (as A653M). 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 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.

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

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

[A90/A90M](#) Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings
[A370](#) Test Methods and Definitions for Mechanical Testing of Steel Products

[A568/A568M](#) Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for

[A902](#) Terminology Relating to Metallic Coated Steel Products

[A924/A924M](#) Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process

[D7396](#) Guide for Preparation of New, Continuous Zinc-Coated (Galvanized) Steel Surfaces for Painting

[E517](#) Test Method for Plastic Strain Ratio r for Sheet Metal

[E646](#) 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 [A902](#) 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

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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, <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 (TST)				Single-Spot Test (SST)
Inch-Pound Units				
Type	Coating Designation	TST Total Both Sides, oz/ft ²	TST One Side, oz/ft ²	SST 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	TST Total Both Sides, g/m ²	TST One Side, g/m ²	SST 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 A653/A653M 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.

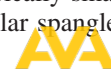
3.2.2.1 *Discussion*—The single side relationship of either specified “coating designation” is the same as shown in the note of Table 1 regarding uniformity of coating.

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

3.2.6.1 *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.

3.2.7 *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.

3.2.7.1 *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.

3.2.8 *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 D7396). 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 A653 for inch-pound units or A653M 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)).

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.)

5.2.16.3 When the purchaser requires thickness tolerances for $\frac{3}{8}$ -in. [10-mm] minimum edge distance (see Supplementary Requirement in Specification A924/A924M), this requirement shall be specified in the purchase order.





NOTE 1—Typical ordering descriptions are as follows: steel sheet, zinc-coated, commercial steel Type A, ASTM A653, Coating Designation G115, 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 A653M, 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 **A924/A924M** 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 **A924/A924M**.

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

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	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.

