Designation: B609/B609M – 12 (Reapproved 2016)

Standard Specification for Aluminum 1350 Round Wire, Annealed and Intermediate Tempers, for Electrical Purposes[1]

This standard is issued under the fixed designation B609/B609M; 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 aluminum 1350-O (annealed), 1350-H12 or -H22 (¼ hard), 1350-H14 or -H24 (½ hard), 1350-H16 or -H26 (¾ hard) and 1350-H142 or -H242 (½ hard), suitable for stranding into conductors or for solid single conductors, either bare or insulated (see Table 1 or Table 2).

1.2 The values stated in inch-pound units or SI units are to be regarded separately as standard. The values in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.2.1 For density, resistivity, and temperature, the values stated in SI units are to be regarded as standard.

NOTE 1—Prior to 1975, aluminum 1350 was designated as EC-aluminum.

NOTE 2—The aluminum and temper designations conform to ANSI H35.1. Aluminum 1350 corresponds to Unified Numbering System A91350 in accordance with Practice E527.

2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein.

2.2 *ASTM Standards:*[2]

B193 Test Method for Resistivity of Electrical Conductor Materials

B233 Specification for Aluminum 1350 Drawing Stock for Electrical Purposes

B354 Terminology Relating to Uninsulated Metallic Electrical Conductors

B557 Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products

B682 Specification for Metric Sizes of Electrical Conductors

B830 Specification for Uniform Test Methods and Frequency

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.3 *ANSI Standard:*[3]

ANSI H35.1 American National Standard for Alloy and Temper Designation Systems for Aluminum

ANSI H35.1[M] American National Standard for Alloy and Temper Designation Systems for Aluminum

2.4 *NIST Standards:*[4]

NBS Handbook 100 —Copper Wire Tables of the National Bureau of Standards

NBS Handbook 109 —Aluminum Wire Tables of the National Bureau of Standards

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *lot, n*—a group of production units, up to 30 000 lb of mass, of one type and size of wire, which was produced during the same time period, under similar production conditions, and is presented for acceptance at the same time (Explanatory Note 5).

3.1.2 *production unit, n*—a coil, reel, spool, or other package of wire that represents a single usable length.

3.1.3 *sample, n*—the production unit or units from which a test specimen or specimens has been removed, and which is considered to have properties representative of the lot.

3.1.4 *specimen, n*—a length of wire removed for test purposes.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Quantity of each size,

[1] This specification is under the jurisdiction of ASTM Committee B01 on Electrical Conductors and is the direct responsibility of Subcommittee B01.07 on Conductors of Light Metals.

Current edition approved Oct. 1, 2016. Published October 2016. Originally approved in 1977. Last previous edition approved in 2012 as B609/B609M – 12$^{\varepsilon 1}$. DOI: 10.1520/B0609_B0609M-12R16.

[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.

[4] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov.

TABLE 1 Standard Nominal Diameters, Cross-Sectional Areas, and Mass Per Unit Length of Solid Round Aluminum Wires and Conductors at 20°C AWG or cmil Sizes

NOTE 1—Metric values listed as follows represent a soft conversion and as such they may not be the same as those metric mass per unit length which are calculated from the basic metric density.
Conversion factors:

1 lb/1000 ft = 1.488 ft + 00 kg/km
1 in. = 25.4 mm

Size cmil or AWG	Diameter		Cross-Sectional Area			Mass Per Unit Length	
	mils	mm	cmil	in.^{2}	mm^2	lb/1000 ft	kg/km
500 000	707.1	17.960	500 000	0.3927	253.3	459.4	683.7
450 000	670.8	17.040	450 000	0.3534	228.0	413.5	615.3
400 000	632.5	16.070	400 000	0.3142	202.7	367.6	547.0
350 000	591.6	15.030	350 000	0.2749	177.3	321.6	478.6
300 000	547.7	13.910	300 000	0.2356	152.0	275.7	410.2
250 000	500.0	12.700	250 000	0.1963	126.7	229.7	341.8
0000	460.0	11.680	211 600	0.1662	107.2	194.4	289.3
000	409.6	10.4000	167 800	0.1318	85.01	154.2	229.4
00	364.8	9.2660	133 100	0.1045	67.43	122.3	182.0
0	324.9	8.2520	105 600	0.08291	53.49	97.00	144.3
1	289.3	7.3480	83 690	0.06573	42.41	76.91	114.4
2	257.6	6.5430	66 360	0.05212	33.62	60.98	90.73
3	229.4	5.8270	52 620	0.04133	26.67	48.36	71.96
4	204.3	5.1890	41 740	0.03278	21.15	38.35	57.07
5	181.9	4.6200	33 090	0.02599	16.77	30.40	45.24
6	162.0	4.1150	26 240	0.02061	13.30	24.12	35.88
7	144.3	3.6650	20 820	0.01635	10.55	19.13	28.47
8	128.5	3.2640	16 510	0.01297	8.67	15.17	22.58
9	114.4	2.9060	13 090	0.01028	6.631	12.03	17.89
10	101.9	2.5880	10 380	0.008455	5.261	9.542	14.20
11	90.7	2.3040	8 226	0.006461	4.168	7.559	11.25
12	80.8	2.0520	6 529	0.005128	3.308	5.999	8.927
13	72.0	1.8290	5 184	0.004072	2.627	4.764	7.088
14	64.1	1.6280	4 109	0.003227	2.082	3.776	5.618
15	57.1	1.4500	3 260	0.002561	1.652	2.996	4.458
16	50.8	1.2900	2 581	0.002027	1.308	2.371	3.529
17	45.3	1.1510	2 052	0.001612	1.040	1.886	2.806
18	40.3	1.0240	1 624	0.001276	0.8229	1.492	2.221
19	35.9	0.9119	1 289	0.001012	0.6531	1.184	1.762
20	32.0	0.8128	1 024	0.0008042	0.5189	0.9410	1.400
21	28.5	0.7239	812.2	0.0006379	0.4116	0.7464	1.111
22	25.3	0.6426	640.1	0.0005027	0.3243	0.5882	0.8752
23	22.6	0.5740	510.8	0.0004011	0.2588	0.4693	0.6984
24	20.1	0.5105	404.0	0.0003173	0.2047	0.3713	0.5542
25	17.9	0.4547	320.4	0.0002516	0.1624	0.2944	0.4381
26	15.9	0.4039	252.8	0.0001986	0.1281	0.2323	0.3457
27	14.2	0.3607	201.6	0.0001589	0.1022	0.1853	0.2757
28	12.6	0.3200	158.8	0.0001247	0.08045	0.1459	0.2171
29	11.3	0.2870	127.7	0.0001003	0.06470	0.1173	0.1746
30	10.0	0.2540	100.0	0.00007854	0.05067	0.09189	0.1367

4.1.2 Wire size; diameter in inches or millimetres (see 11.1),
4.1.3 Temper (Section 5),
4.1.4 Special tension test if required (see 7.2),
4.1.5 Special jointing procedures if permitted (see 12.2),
4.1.6 Place of inspection (see 15.2),
4.1.7 Package size and type (see 16.1), and
4.1.8 Special package marking, if required, (see 16.1).

5. Materials and Manufacture

5.1 The aluminum wire shall be made from drawing stock meeting the requirements of Specification B233.

5.2 Unless otherwise specified, the manufacturer shall have the option of producing the intermediate tempers by either strain-hardening only (H12, H14, H16, H142) or by strain-hardening and partial annealing (H22, H24, H26, H242) (Explanatory Note 1 and ANSI H35.1 or ANSI H35.1[M]).

5.2.1 When the manufacturer is to be given the option in 5.2, the intermediate tempers should be specified as H12 or H22, H14 or H24, H16 or H26, or H142 or H242.

5.2.2 When the manufacturer is not to be given the option in 5.2, the specific temper must be specified, for example, H12, H22, and so forth.

6. Workmanship, Finish, and Appearance

6.1 The wire shall be free of imperfections not consistent with good commercial practice.

TABLE 2 Standard Nominal Diameters, Cross-Sectional Areas, and Mass per Unit Length of Solid Round Aluminum Wires and Conductors at 20°C

NOTE 1—The data in Table 2 were extracted in part from Specification B682.

Diameter, mm	Cross-Sectional Area, mm^2	Mass per Unit Length, kg/km
18.0	255.0	702.0
16.0	201.0	555.0
14.0	154.0	425.0
12.5	123.0	339.0
11.2	98.5	272.0
10.0	78.5	217.0
9.00	63.6	176.0
8.00	50.3	139.0
7.10	39.6	109.0
6.30	31.2	86.0
5.60	24.6	68.0
5.00	19.6	54.2
4.50	15.9	43.9
4.00	12.6	34.7
3.55	9.90	27.3
3.15	7.79	21.5
2.80	6.16	17.0
2.50	4.91	13.5
2.24	3.94	10.9
2.00	3.14	8.67
1.80	2.55	7.02
1.60	2.01	5.55
1.40	1.54	4.25
1.25	1.23	3.39
1.12	0.985	2.72
1.00	0.785	2.17
0.900	0.636	1.76
0.800	0.503	1.39
0.710	0.396	1.09
0.630	0.312	0.860
0.560	0.246	0.680
0.500	0.196	0.542
0.450	0.159	0.439
0.400	0.126	0.347
0.355	0.0990	0.273
0.315	0.0779	0.215
0.280	0.0616	0.170
0.250	0.0491	0.135

TABLE 3 Tensile Property Limits

NOTE 1—For purposes of determining conformance with this specification, each calculated value of tensile strength shall be rounded to the nearest 0.1 ksi, in accordance with the rounding method of Practice E29.

Temper	Tensile Strength of Wires		Tensile Strength of Joints, min	
	ksi	MPa	ksi	MPa
1350-O	8.5 to 14.0	60 to 95	8.5	60
1350-H12 or -H22	12.0 to 17.0	85 to 120	11.0	75
1350-H14 or -H24	15.0 to 20.0	100 to 135	11.0	75
1350-H142 or -H242	15.0 to 22.0	100 to 150	11.0	75
1350-H16 or -H26	17.0 to 22.0	115 to 150	11.0	75

7. Tensile Properties

7.1 *Tensile Strength*—The wire shall conform to the tensile requirements prescribed in Table 3 (Explanatory Note 2).

7.2 When requested by the purchaser, tension tests of joints as permitted in 12.2 shall be made and the joints shall comply with the minimum tensile requirements shown in Table 3. Sampling shall be as agreed upon between the purchaser and the manufacturer.

8. Bending Properties

8.1 Annealed and intermediate tempers of aluminum wires are ductile due to the processing required. No bending tests are specified.

9. Resistivity

9.1 The electrical resistivity shall not exceed the following values in Table 4 (Explanatory Note 3):

10. Density

10.1 For the purpose of calculating mass, mass per unit length, cross sections, and so forth, the density of aluminum 1350 shall be taken as 2705/kg/m^3 (0.0975 lb/$in.^3$) at 20°C.

11. Diameter

11.1 The diameter of the wire shall be expressed in decimal fractions of an inch to the nearest 0.0001 in. (0.003 mm).

11.2 The actual wire diameter shall not vary from the specified diameter by more than the values shown in Table 5.

12. Joints

12.1 Joints may be made in drawing stock and in the wire prior to final drawing in accordance with good commercial practice.

12.2 If agreed upon between the manufacturer and the purchaser, joints may be made during final drawing or in the finished wire by electric-butt welding, by cold-pressure welding, or by electric-butt, cold-upset welding, with the following provisions:

12.2.1 For sizes 0.0100 to 0.0500 in. (0.254 to 1.270 mm), in diameter, not more than three such joints shall be present in any reel, spool, or coil of the nominal specified mass, and

12.2.2 For sizes larger than 0.0500 in. (1.270 mm) in diameter, not more than 10 % of the reels, coils, or spools shall contain such joints, and no such joint shall be closer than 50 ft (15 m) to another or to either end of the wire. In addition, there shall be no more than two such joints present in any reel, coil, or spool of the specified size and nominal mass.

13. Sampling

13.1 *Sampling*—Four test specimens shall be obtained. One from each of four production units (Explanatory Note 4) or in accordance with Specification B830.

14. Test Methods

14.1 *Tensile Strength*—Determine the tensile strength in accordance with Test Methods B557. Calculate the tensile strength by dividing the maximum load carried by the specimen during the tension test by the original cross-sectional area of the specimen (Explanatory Note 2).

14.1.1 If any part of the fracture takes place in the jaws of the tensile machine, or if an examination of the specimen indicates that there was external damage, the value obtained may not be representative of the material. In such cases discard the test and make a new test.

14.2 *Resistivity*—Determine the electrical resistivity of the wire in accordance with Test Method B193 (Explanatory Note 3 and Table 4).

TABLE 4 Equivalent Resistivity Requirements and Equivalent Copper Resistivity at 20°C[A]

Material	Volume Conductivity, % IACS	Resistivity Constants			
		Volume			
		Ω·cmil/ft	Ω·mm²/m	μΩ·in.	μΩ·cm
Copper Equivalent	100	10.371	0.017241	0.67879	1.7241
1350 Aluminum H_2 through H_6	61.0	17.002	0.028264	1.1128	2.8264
1350-O Temper Aluminum	61.8	16.782	0.027899	1.0984	2.7899

[A] The equivalent resistivity values for 100 % IACS (soft copper) were each computed from the fundamental IEC value (1/58Ω·mm²/m) using conversion factors each accurate to at least seven significant figures. Corresponding values for other conductivities (aluminum) were derived from these by multiplying by the reciprocal of the conductivity ratios accurate to at least seven significant figures.

TABLE 5 Diameter Tolerances

Specified Diameter, in. (mm)	Permissible Variations of Mean Diameter from Specified Diameter, plus and minus
0.0100 to under 0.0360 (0.254 to under 0.914)	0.0005 in. (0.013 mm)
0.0360 to under 0.1000 (0.914 to under 2.540)	0.0010 in. (0.025 mm)
0.1000 to 0.7071, incl (2.540 to 17.960, incl)	1 %

14.3 *Diameter Measurements*—Measure the diameter with a micrometer caliper graduated in 0.0001 in. (0.003 mm). Make measurements on each specimen selected for this test. Measure the diameter of the wire at two points, spaced approximately 90° apart, around the circumference of the specimen. Take the average of the two readings as the mean diameter of the specimen. Should the measured diameter of any specimen vary from the specified diameter by an amount greater than the tolerance permitted by Table 5, the lot shall be considered to not meet the diameter requirements.

14.4 *Finish*—Make a surface-finish inspection with the unaided eye (normal corrective lenses acceptable). The surface finish shall meet the requirements of 6.1. Should any specimen be found unacceptable, the lot shall be considered to not meet the surface finish requirements.

14.5 *Test Results*—A numerical average for the tensile strength, elongation, and resistivity of the four specimens shall be calculated and shall be considered the lot average.

14.6 *Conformance Criteria*—To be considered in conformance, the lot average test results shall meet the average for a lot requirements of Tables 3 and 4, and the test results of each specimen shall meet the individual tests requirements of Tables 3 and 4 unless otherwise specified.

14.6.1 If the lot average results are in conformance, and all of the individual specimen results are in conformance, the lot shall be considered in conformance.

14.6.2 If the lot average result for one or more of the tested properties is not in conformance and one or more of the individual specimen results is also not in conformance, the lot shall be considered not in conformance.

14.6.3 If the lot average results are in conformance, but one or more of the individual specimen results are not in conformance, the lot shall be considered in conformance except that the production unit or units represented by the non-conforming specimen or specimens shall be rejected.

14.6.4 If the lot average results for one or more of the tested properties is not in conformance, but all the individual specimen results are in conformance, then additional test specimens and tests shall be required as follows:

14.6.4.1 An additional six test specimens shall be obtained, one each from six production units other than the four originally sampled. Tests shall be run on the six additional specimens, and a numerical average of the ten tested specimens shall be calculated and considered the lot average.

14.6.4.2 If the ten specimen lot average results are in conformance, and all ten of the individual specimen results are in conformance, the lot shall be considered in conformance.

14.6.4.3 If the ten specimen lot average results for one or more of the tested properties are not in conformance, or if one or more of the ten individual specimen results are not in conformance, the lot shall be considered not in conformance.

14.6.5 In the event a lot is rejected in accordance with 14.6.2 or 14.6.4.3, production units making up that lot may be individually tested. Acceptance of individual production units from a rejected lot shall be dependent on the individual specimen test results meeting the average for a lot requirements of Tables 3 and 4.

15. Inspection

15.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for the performance of all inspection and test requirements specified.

15.2 All inspections and tests shall be made at the place of manufacture unless otherwise agreed to between the manufacturer and the purchaser at the time of the purchase.

15.3 The manufacturer shall afford the inspector representing the purchaser all reasonable manufacturer's facilities to satisfy him that the material is being furnished in accordance with this specification.

15.4 Unless otherwise agreed upon by the manufacturer and the purchaser, conformance of the wire to the requirements specified in Sections 6, 7, 9, and 11 shall be determined by sampling in accordance with Section 13 of each lot of wire presented for acceptance.

15.5 The manufacturer shall, if requested prior to inspection and testing, certify that the product as a whole was made under such uniform conditions that compliance with the requirements of this specification can be determined by the sampling, inspections, and tests performed in accordance with Section 13 (Explanatory Notes 2 and 5).

NOTE 3—Multiple lengths per package are allowable only when the bare conductor is intended for remanufacture, such as adding a covering or insulation. In such cases the position of each end of a length is to be clearly marked and the length of each portion shall be shown on the tag attached to the end of the conductor.

16. Packaging and Package Marking

16.1 Package sizes and types shall be agreed upon between the manufacturer and the purchaser at the time of placing the individual orders.

16.2 Unless otherwise specified, each coil, reel, or spool shall contain one continuous length of wire (Note 3).

16.3 The wire shall be protected against damage in ordinary handling and shipping.

16.4 Each coil, reel, spool, or other package shall bear a tag showing the manufacturer's name or trademark; the product identification as Aluminum 1350 wire; and the size, length, type (0 or temper designation), and net mass of the material. Additional information shall be as agreed upon between the manufacturer and the purchaser at the time of placing the individual orders.

17. Keywords

17.1 aluminum electrical conductors; aluminum 1350 round wire-annealed and intermediate tempers; aluminum 1350 wire; aluminum wire; electrical conductors; electrical conductors-aluminum

EXPLANATORY NOTES

NOTE 1—The H1X tempers (strain-hardened only) and the H2X tempers (strain-hardened and partially annealed) are considered equally suitable for most electrical purposes.

NOTE 2—In tension tests, the values obtained may be affected by testing speed. It is recommended that for conformance criteria the testing speed should not exceed 0.5 mm/mm of gage length or distance between grips per minute.

NOTE 3—Relationships that may be useful in connection with the values of electrical resistivity prescribed in this specification are shown in Table 4. Resistivity units are based on the International Annealed Copper Standard (IACS) adopted by IEC in 1913, which is $\frac{1}{58}$ $\Omega \cdot mm^2/m$ at 20°C for 100 % conductivity. The value of 0.017241 $\Omega \cdot mm^2/m$ at 20°C is the international equivalent of volume resistivity of annealed copper equal to 100 % conductivity. A complete discussion of this subject is contained in *NBS Handbook 100*. The use of five significant figures in expressing resistivity does not imply the need for greater accuracy of measurement than that specified in Test Method B193. The use of five significant figures is required for reasonably accurate reversible conversion from one set of resistivity units to another. The equivalent resistivity values in the tables were derived from the fundamental IEC value ($\frac{1}{58}$ $\Omega \cdot mm^2/m$) computed to seven significant figures and then rounded to five significant figures.

NOTE 4—Cumulative results secured on the product of a single manufacturer, indicating continued adherence to the sampling requirements, are necessary to ensure an overall product meeting the requirements of this specification. The sample sizes and requirements given for the various characteristics are applicable only to lots produced under these conditions.

NOTE 5—A lot should comprise material taken from a product regularly meeting the requirements of this specification. Inspection of individual lots of less than 5000 lb of wire cannot be justified economically. For small lots of 5000 lb or less the purchaser may agree to the manufacturer's regular inspection of the product as a whole as evidence of acceptability of such small loss.