Designation: B105 – 05 (Reapproved 2012)

Standard Specification for Hard-Drawn Copper Alloy Wires for Electric Conductors[1]

This standard is issued under the fixed designation B105; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This specification covers hard-drawn round copper alloy wires for electric conductors.

1.2 The copper alloy wires shall be made in any one of ten distinct alloys designated 8.5 to 85 in accordance with their increasing conductivities or designated by assigned UNS numbers (see Explanatory Note 1) as follows:

	Copper Alloy UNS No.		Copper Alloy UNS No.
Alloy 8.5	C65100	Alloy 40	
Alloy 13	C51000	Alloy 55	C16500
Alloy 15		Alloy 74	C19600
Alloy 20		Alloy 80	C16200
Alloy 30	C50700	Alloy 85	C16200

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3.1 *Exception*—The SI values of density and resistivity are to be regarded as standard.

2. Referenced Documents

2.1 The following documents of the issue in effect on the 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

B258 Specification for Nominal Diameters and Cross-Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical Conductors

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

2.3 *Other Document:*

NBS Handbook 100—Copper Wire Tables[3]

3. Ordering Information

3.1 Orders for material under this specification should include the following information:

3.1.1 Quantity of each size and grade,

3.1.2 Wire size: diameter in inches or millimetres (see 9.1 and Table 1),

3.1.3 Alloy (see 1.2 and Table 1),

3.1.4 Special composition limits, if required (see 5.2),

3.1.5 Package size (see 14.1),

3.1.6 Special package marking, if required, and

3.1.7 Place of inspection (see 13.1).

4. Materials and Manufacture

4.1 The material used shall be copper alloys of such nature and composition as to secure by proper treatment the properties prescribed in this specification for the finished wire.

5. Chemical Composition

5.1 The chemical composition of copper alloy wires shall conform to the requirements of Table 2. The values prescribed in Table 2 cover limits of composition of the different alloys which may be supplied (see Note 2).

5.2 The maximum percentage of the various alloying elements to be found in any one of the alloys is prescribed in Table 2. If the purchaser elects to check the composition of any material supplied to conform to the performance requirements of any one of the alloys, the composition limits should be made the subject of a definite agreement between the manufacturer and the purchaser in the placing of individual orders.

6. Chemical Analysis

6.1 An analysis may be made on each lot of 5000 lb (2300 kg) or fraction thereof. Millings or clippings shall be made from at least ten separate coils. Equal quantities shall be taken

[1] This specification is under the jurisdiction of the ASTM Committee B05 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.02 on Rod, Bar, Wire, Shapes and Forgings.

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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 National Technical Information Service (NTIS), 5301 Shawnee Rd., Alexandria, VA 22312, http://www.ntis.gov.

TABLE 1 Tensile Requirements[A]

NOTE 1—Conversion factors are presented for ready adaptation to computer readout and electronic data transmission. The factors are written as a number greater than one and less than ten with six or less decimal places. This number is followed by the letter E (for exponent), a plus or minus symbol, and two digits which indicate the power of 10 by which the number must be multiplied to obtain the correct value. For example: 2.54 E + 01 = 2.54 × 10^1 = 25.4.

Diameter		Area			Elongation, min, % in 10 in. (250 mm)	Tensile Strength, min																	
						Alloy 8.5		Alloy 13		Alloy 15 and 20		Alloy 30		Alloy 40		Alloy 55		Alloy 74		Alloy 80		Alloy 85	
in.	mm	cmil	in.^{2}	mm^2		ksi	Mpa	ksi	Mpa	ksi	Mpa	ksi	Mpa	ksi	Mpa	ksi	Mpa	ksi	Mpa	ksi	Mpa	ksi	Mpa
0.2893	7.348	83694	0.06573	42.41	2.2	97.5	672.2	102.5	706.7	109.5	755.0	74.0	510.2	73.4	508.1	76.0	524.0	74.0	510.2	72.0	496.4	68.5	472.3
0.2576	6.543	66358	0.05212	33.62	2.0	103.8	715.7	108.8	750.2	114.5	789.5	80.0	551.6	74.9	516.4	77.8	536.4	75.5	520.6	73.5	506.8	69.9	481.9
0.2294	5.827	52624	0.04133	26.67	1.8	107.5	741.2	112.5	775.7	118.5	817.0	85.0	586.1	76.3	526.1	79.3	546.8	77.5	534.3	75.0	517.1	71.2	490.9
0.2043	5.189	41738	0.03278	21.15	1.6	110.2	759.8	115.2	794.3	121.3	836.3	89.0	613.6	77.7	535.7	80.9	557.8	79.0	544.7	76.4	526.8	72.5	499.9
0.1819	4.620	33088	0.02599	16.77	1.5	112.2	773.6	117.2	808.1	123.3	850.1	92.5	637.8	79.0	544.7	82.4	568.1	80.0	551.6	77.5	534.3	73.6	507.5
0.1620	4.115	26244	0.02061	13.30	1.4	114.0	786.0	119.0	820.5	125.0	861.9	94.8	653.6	80.4	554.3	84.0	579.2	81.0	558.5	78.6	541.9	74.7	515.0
0.1443	3.665	20822	0.01635	10.55	1.3	115.3	795.0	120.3	829.4	126.5	872.2	96.5	665.3	81.8	564.0	85.5	589.5	82.4	568.1	79.8	550.2	75.8	522.6
0.1285	3.264	16512	0.01297	8.367	1.3	116.6	803.9	121.6	838.4	127.9	881.8	97.9	675.0	83.2	573.6	87.0	599.8	83.5	575.7	81.0	558.5	77.0	530.9
0.1144	2.906	13087	0.01028	6.632	1.2	117.8	812.2	122.8	846.7	129.2	890.8	99.0	682.6	84.6	583.3	88.5	610.2	84.6	583.3	82.2	566.8	78.1	538.5
0.1019	2.588	10384	0.008155	5.262	1.2	118.9	819.8	123.9	854.3	130.3	898.4	100.1	690.2	86.0	593.0	90.0	620.5	85.5	589.5	83.4	575.0	79.2	546.1
0.0907	2.304	8226.5	0.006461	4.1684	1.2	119.8	826.0	124.8	860.5	131.2	904.6	101.2	697.8	87.1	600.5	91.3	629.5	86.6	597.1	84.6	583.3	80.3	553.7
0.0808	2.052	6528.6	0.005128	3.308	1.1	120.6	831.5	125.6	866.0	132.0	910.1	102.2	704.6	88.2	608.1	92.6	638.5	87.7	604.7	85.7	590.9	81.4	561.2
0.0720	1.829	5184.0	0.004072	2.627	1.1	121.2	835.6	126.2	870.1	132.6	914.3	103.0	710.2	89.6	617.8	93.8	646.7	88.8	612.3	86.8	598.5	82.5	568.8
0.0641	1.628	4108.8	0.003227	2.082	1.1	121.7	839.1	126.7	873.6	133.2	918.4	103.7	715.0	90.4	623.3	95.0	655.0	89.8	619.2	87.8	605.4	83.4	575.0
0.0571	1.450	3260.4	0.002561	1.652	1.0	122.2	842.5	127.2	877.0	133.6	921.1	104.4	719.8	91.4	630.2	96.0	661.9	90.6	624.7	88.7	611.6	84.2	580.5
0.0508	1.290	2580.6	0.002027	1.308	1.0	122.5	844.6	127.5	879.1	134.0	923.9	105.2	725.3	92.1	635.0	97.0	668.8	92.0	634.3	89.5	617.1	85.0	586.1
0.0453	1.151	2052.1	0.001612	1.040	1.0	122.8	846.7	127.8	881.2	134.2	925.3	105.9	730.2	93.1	641.9	98.0	675.7	92.8	639.8	90.3	622.6	85.7	590.9
0.0403	1.024	1624.1	0.001276	0.8229	0.9	123.0	848.1	128.0	882.5	134.5	927.4	106.6	735.0	94.0	648.1	98.6	679.8	93.5	644.7	91.0	627.4	86.4	595.7
0.0359	0.912	1288.8	0.001012	0.6530	0.9	123.2	849.4	128.2	883.9	134.8	929.4	107.3	739.8	94.5	651.6	99.0	682.6	94.0	648.1	91.6	631.6	87.0	599.8
0.0320	0.813	1024.0	0.0008043	0.5189	0.9	123.5	851.5	128.5	886.0	135.0	930.8	108.0	744.8	95.0	655.0	99.5	686.0	94.5	651.6	92.2	635.7	87.6	604.0

[A] Conversion factors: 1 in. = 2.54 E + 01 mm, 1 kcmil = 5.067 E – 01 mm^2. 1 in.^{2} = 6.452 E + 02 mm^2, 1 ksi = 6.895 E + 00 MPa.

TABLE 2 Chemical Requirements

Element	Composition, %
Phosphorus, max	0.35
Manganese, max	0.75
Iron, max	1.20
Cadmium, max	1.50
Silicon, max	3.00
Aluminum, max	3.50
Tin, max	5.00
Zinc, max	10.50
Copper, min	89.00
Sum of the above elements, min	99.50

from each coil and shall be thoroughly mixed together. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the manufacturer, one for the purchaser, and one for a referee, if necessary.

7. Tensile Properties

7.1 The wire of a designated alloy shall be drawn to conform to the tensile requirements prescribed in Table 1 (see Explanatory Note 3 and Explanatory Note 4).

7.2 Tests on a specimen containing a joint shall show at least 95 % of the minimum tensile strength given in Table 1. Elongation tests shall not be made on a specimen containing a joint.

7.3 Nominal wire diameters between those listed in Table 1, shall conform to the requirements of the next larger size if (*1*) the nominal diameter is greater than 0.003 in. (3 mils) (0.076 mm) larger than a listed size whose diameter is 0.100 in. (2.5 mm) or greater, or (*2*) the nominal diameter is greater than 0.002 in. (2 mils) (0.051 mm) larger than a listed size whose diameter is less than 0.100 in. (2.5 mm) diameter.

7.4 Tension tests shall be made on representative samples. The elongation of the wire shall be determined by measuring the permanent increase in length, due to the breaking of the wire in tension, between gauge marks placed originally 10 in. (250 mm) apart upon the test specimen (see Explanatory Note 5).

7.5 If any part of the fracture takes place outside the gage marks or in the jaws of the testing machine, or if an examination of the specimen indicates a flaw, the value obtained may not be representative of the material. In such cases the test may be discarded and a new test made.

7.6 *Retests*—If upon testing a sample from any coil or spool of wire, the results do not conform to the requirements prescribed in Table 1, two additional samples shall be tested, and the average of the three tests shall determine the acceptance or rejection of the coil or spool.

8. Resistivity

8.1 Electrical resistivity shall be determined on representative samples by resistance measurements (see Explanatory Note 6). At a temperature of 20°C the resistivity shall not exceed the values shown in Table 3 for the designated alloy.

8.2 The electrical resistivity of the material shall be determined in accordance with Test Method B193.

TABLE 3 Electrical Resistivity

Alloy	Maximum Resistivity at 20°C		
	Ω·mm ^{2}/m.	Ω·lb/mile^2	Ω·cmil/ft
8.5	0.202 84	10 169	122.01
13	0.132 63	6 649.0	79.779
15	0.114 94	5 605 0	69.141
20	0.086 207	4 376.0	51.856
30	0.057 471	2 917.3	34.571
40	0.043 103	2 188.0	25.929
55	0.031 348	1 591.3	18.857
74	0.023 299	1 182.7	14.015
80	0.021 552	1 094.0	12.964
85	0.020 284	1 029.7	12.201

9. Diameter and Permissible Variations

9.1 The wire sizes shall be expressed as the diameter of the wire in decimal fractions of an inch or a millimetre to the nearest 0.0001 in. (0.001 mm) (see Explanatory Note 3).

9.2 The wire shall not vary from the specified diameter by more than the amounts shown in Table 4.

9.3 Ten percent, but not less than five coils or spools (or all if the lot is less than five) from any lot of wire shall be gaged at three places. If accessible, one gaging shall be taken near each end and one near the middle. If any of the selected coils or spools fails to conform to the requirements prescribed in 9.2, all coils or spools shall be gaged in the manner specified.

10. Density

10.1 For the purpose of calculating mass per unit length, cross sections, etc., the density of the various alloys shall be taken as shown in Table 5, based on a temperature of 20°C.

11. Joints

11.1 No joints shall be made in the completed wire (see Explanatory Note 7). Joints in wire and rods, prior to final drawing, shall be made in accordance with the best commercial practice and shall conform to the requirements prescribed in 7.2.

12. Finish

12.1 The wire shall be free from all imperfections not consistent with the best commercial practice.

13. Inspection

13.1 All tests and inspection shall be made at the place of manufacture unless otherwise especially agreed upon between the manufacturer and the purchaser at the time of purchase. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification.

TABLE 4 Permissable Variations in Diameter

Nominal Diameter		Permissable Variations in Diameter			
		in.		mm	
in.	mm	plus	minus	plus	minus
Under 0.0571	Under 1.45	0.001	0.001	0.025	0.025
0.0571 and over	1.45 and over	3 %	1 %	3 %	1 %

TABLE 5 Densities

Alloy	Density	
	kg/m^{3A}	lb/in.^{3}
8.5 and 13	8.78 E + 03	0.31720
15	8.54 E + 03	0.30853
20, 30, 40, 55, 74, 80, and 85	8.89 E + 03	0.32117

[A] See Note of Table 1.

14. Packaging and Shipping

14.1 Package sizes shall be agreed upon by the manufacturer and the purchaser in the placing of individual orders.

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

15. Keywords

15.1 copper alloy wires for electric conductors; hard-drawn round copper alloy; round copper alloy wires

EXPLANATORY NOTES

NOTE 1—The UNS system for copper and copper alloys (see Practice E527) is a simple expansion of the former standard designation system accomplished by the addition of a prefix "C" and a suffix "00." The suffix can be used to accommodate composition variations of the base alloy.

NOTE 2—It is the intention of this specification to permit under each of the alloys listed in 1.2 any alloy coming within the total range of analysis specified in Section 5, provided the product conforms to the other requirements of this specification. For purposes of information only, the types of alloy now commonly used for each of the several alloys are listed below. Certain alloys that have a "commercial standing" may have been assigned a UNS designation (see 1.2). The chemical composition of any of the materials shall be within the total range specified in Section 5, but in no case shall the alloy contain the allowed maximum of more than one constitutent other than copper.

Alloy	Alloy Type
8.5	Copper, Silicon, Iron
	Copper, Silicon, Manganese
	Copper, Silicon, Zinc
	Copper, Silicon, Tin, Iron
	Copper, Silicon, Tin, Zinc
13	Copper, Aluminum, Tin
	Copper, Aluminum, Silicon, Tin
	Copper, Silicon, Tin
15	Copper, Aluminum, Silicon
	Copper, Aluminum, Tin
	Copper, Aluminum, Silicon, Tin
	Copper, Silicon, Tin
20	Copper, Tin
30	Copper, Tin
	Copper, Zinc, Tin
40	Copper, Tin
	Copper, Tin, Cadmium
55	Copper, Tin, Cadmium
74	Copper, Iron, Phosphorus
80	Copper, Cadmium
85	Copper, Cadmium

NOTE 3—The values of the wire diameters in Table 1 are given to the nearest 0.0001 in. or 0.0001 mm and correspond to the standard sizes given in Specification B258. The use of gage numbers to specify wire size is not recognized in these specifications because of the possibility of confusion. An excellent discussion of wire gages and related subjects is contained in *NBS Handbook 100*.

NOTE 4—Other tests than those provided in this specification have been considered at various times, such as twist tests, wrap tests, tests for elastic limit, etc. It is the opinion of the committee that twist and wrap tests on hard-drawn alloy wire do not serve a useful purpose and should be regarded as undesirable, as well as inconclusive as to results and significance. Tests for values of elastic limit are likewise indefinite as to results. Tests to determine elastic properties of hard-drawn wire from which wire stringing and sagging data may be compiled are considered to be outside the scope of the acceptance tests contemplated in this specification.

NOTE 5—It is known that the rate of loading during tension testing of copper and copper alloys affects the performance of the sample to a greater or lesser extent, depending upon many factors. In general, tested values of tensile strength are increased and tested values of elongation are reduced with increase of speed of the moving head of the testing machine. These effects are pronounced when the speed of the moving head is excessive in the testing of hard-drawn and medium-hard-drawn copper and copper-alloy wires. It is suggested that tests be made at speeds of moving head which, under no-load conditions, are not greater than 3 in./min (75 mm/min), but in no case at a speed greater than that at which correct readings can be made.

NOTE 6—Relationships that may be useful in connection with the values of electrical resistivity prescribed in this specification are shown in Table 3. Resistivity units are based on the International Annealed Copper Standard (IACS) adopted by IEC in 1913, which is $\frac{1}{58}$ Ω· mm^2/m at 20°C for 100 % conductivity. The value of 0.017241 Ω·mm^2/m and the value of 0.15328 Ω·g/m^2 at 20°C are respectively the international equivalent of volume and mass resistivity of annealed copper equal (to five significant figures) to 100 % conductivity. The latter term means that a copper wire 1 m in length and weighing 1 g would have a resistance of 0.15328 Ω. This is equivalent to a resistivity value of 875.20 Ω·lb/mile^2, which signifies the resistance of a copper wire 1 mile in length weighing 1 lb. It is also equivalent, for example, to 1.7241 μΩ per centimetre of length of a copper bar 1 cm^2 in cross section. 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 table were derived from the fundamental IEC value ($\frac{1}{58}$ Ω·mm^2/m) computed to seven significant figures and then rounded to five significant figures.

NOTE 7—Mechanical joints made during inspection at the request of the purchaser are permissible if agreed upon at the time of placing the order.