Designation: B 105 – 00

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

This standard is issued under the fixed designation B 105; 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 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 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

NOTE 1—The UNS system for copper and copper alloys (see Practice E 527) 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.

1.3 The SI values of density and resistivity are to be regarded as standard. For all other properties the inch-pound values are to regarded as standard, and the SI values may be approximate.

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:*

B 193 Test Method for Resistivity of Electrical Conductor Materials[2]

B 258 Specification for Standard Nominal Diameters and Cross-Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical Conductors[2]

E 527 Practice for Numbering Metals and Alloys (UNS)[3]

2.3 *Other Document:*

NBS Handbook 100—Copper Wire Tables[4]

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

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

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[2] *Annual Book of ASTM Standards*, Vol 02.03.

[3] *Annual Book of ASTM Standards*, Vol 01.01.

[4] Available from the National Technical Information Service, 5285 Port Royal Rd, Springfield, VA 22161.

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 at 20°C			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	7.3482	83694.49	0.065733	42.4086	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	6.5430	66357.76	0.052117	33.6240	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	5.8268	52624.36	0.041331	26.6652	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	5.1892	41738.49	0.032781	21.1492	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	4.6203	33087.61	0.025987	16.7657	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	4.1148	26244.00	0.020612	13.2980	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	3.6652	20822.49	0.016354	10.5509	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	3.2639	16512.25	0.012969	8.3669	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	2.9058	13087.36	0.01027879	6.6315	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	2.5883	10383.61	0.00815527	5.2615	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	2.3038	8226.49	0.00646107	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	2.0523	6528.64	0.00512758	3.3081	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	1.8288	5184.00	0.00407150	2.6268	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	1.6281	4108.81	0.00322705	2.0820	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	1.4503	3260.41	0.00256072	1.6521	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	1.2903	2580.64	0.00202683	1.3076	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	1.1506	2052.09	0.00161171	1.0398	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	1.0236	1624.09	0.00127556	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	0.9119	1288.81	0.00101223	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	0.8128	1024.00	0.00080425	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

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

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 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 so drawn that it conforms to the requirements as to tensile properties prescribed in Table 1 (see Note 3 and Note 4).

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 B 258. 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.

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 Wire, the nominal diameter of which is between sizes listed in Table 1, shall conform to the requirements of the next larger size if the nominal diameter is more than 0.003 in. (3 mils) (0.076 mm) larger than a listed size whose diameter is 0.100 in. (2.5 mm) or over, and likewise if the nominal diameter is more than 0.002 in. (2 mils) (0.051 mm) larger than a listed size whose diameter is less than 0.100 in.

7.4 Tension tests shall be made on representative samples. Determine the elongation of the wire as the permanent increase in length, due to the breaking of the wire in tension, measured between gage marks placed originally 10 in. (250 mm) apart upon the test specimen (see Note 5).

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.

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 Note 6). At a temperature of 20°C the resistivity shall not exceed the values shown in Table 3 for the designated alloy.

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 $1/58$ $\Omega \cdot mm^2/m$ at 20°C for 100 % conductivity. The value of 0.017241 $\Omega \cdot mm^2/m$ and the value of 0.15328 $\Omega \cdot g/m^2$ at 20°C are respectively the international equivalent of

TABLE 3 Electrical Resistivity

Alloy	Maximum Resistivity at 20°C		
	Ω·mm²/m.	Ω·lb/mile²	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

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 B 193. 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 (1⁄58 Ω·mm^2/m) computed to seven significant figures and then rounded to five significant figures.

8.2 The electrical resistivity of the material shall be determined in accordance with Test Method B 193.

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 0.1 mil (0.0001 in. or 0.0001 mm) (see 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 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.

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.

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.

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

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/m³ [A]	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.