Designation: B 1 – 01

Standard Specification for Hard-Drawn Copper Wire[1]

This standard is issued under the fixed designation B 1; 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 wire for electrical purposes.

1.2 The values stated in inch-pound or SI units are to be regarded separately as standard. Each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the specification. For conductor sizes designated by AWG or kcmil sizes, the requirements in SI units are numerically converted from the corresponding requirements in inch-pound units. For conductor sizes designation by AWG or kcmil, the requirements in SI units have been numerically converted from corresponding values stated or derived in inch-pound units. For conductor sizes designated by SI units only, the requirements are stated or derived in SI units.

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

2. Referenced Documents

2.1 *ASTM Standards:*

B 49 Specification for Copper Redraw Rod for Electrical Purposes[2]

B 193 Test Method for Resistivity of Electrical Conductor Materials[3]

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

2.2 *National Institute of Standards and Technology:*

NBS Handbook 100 —Copper Wire Tables[4]

3. Ordering Information

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

3.1.1 Quantity of each size,

3.1.2 Wire size: diameter in inches (5.4 and Table 1),

3.1.3 Type of copper, if special (Section 4),

3.1.4 Whether certification of resistivity of rod stock is acceptable instead of resistivity tests on the finished wire (6.2),

3.1.5 Package size (8.1),

3.1.6 Special package marking, if required, and

3.1.7 Place of inspection (7.1).

4. Materials and Manufacture

4.1 The material shall be copper of such quality and purity that the finished product shall have the properties and characteristics prescribed in this specification.

NOTE 1—Specification B 49 defines the materials suitable for use.

5. General Requirements (see Section 8)

5.1 *Tensile Strength and Elongation*—The wire shall conform to the requirements as to tensile strength and elongation prescribed in Table 1 (see Explanatory Note 1 and Note 2). For wire whose nominal diameter is more than 0.001 in. (1 mil) (0.025 mm) greater than a size listed in Table 1 and less than that of the next larger size, the requirements of the next larger size shall apply.

5.2 *Joints*—No joints shall be made in the completed wire (see Explanatory Note 3). Joints in the wire and rods made prior to final drawing shall be in accordance with the best commercial practice. Tests on a specimen containing a joint shall show at least 95% of the tensile strength given in Table 1. Elongation tests shall not be made on a specimen containing a joint.

5.3 *Resistivity*—The electrical resistivity at 20°C shall not exceed the following values:

Nominal Diameter, in.	Resistivity at 20°C, $\Omega \cdot lb/mile^2$
0.460 to 0.325, incl	900.77
Under 0.325 to 0.0403, incl	910.15

Nominal Diameter, in.	Resistivity at 20°C, $\Omega \cdot g/m^2$
11.68 to 8.25, incl	0.15775
Under 8.25 to 1.02, incl	0.15940

5.4 *Dimensions and Permissible Variations*—The wire sizes shall be expressed as the diameter of the wire in decimal fractions of an inch to the nearest 0.0001 in. (or 0.001 mm) (see Explanatory Note 4). Within the range of diameters given in

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[2] *Annual Book of ASTM Standards*, Vol 02.01.

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

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

TABLE 1 Tensile Properties

Diameter[A]			Area at 20°C		Nominal Tensile Strength[B] (see Explanatory Note 2)		Nominal Elongation,%[B]
in.	mm	cmil	$in.^2$	mm^2	psi	MPa	in 10 in. (250 mm)
0.4600	11.684	211 600	0.1662	107.0	49 000	340	3.8
0.4096	10.464	167 800	0.1318	85.0	51 000	350	3.3
0.3648	9.266	133 100	0.1045	67.4	52 800	365	2.8
0.3249	8.252	105 600	0.08291	53.5	54 500	375	2.4
0.2893	7.348	83 690	0.06573	42.4	56 100	385	2.2
0.2576	6.543	66 360	0.05213	33.6	57 600	395	2.0
0.2294	5.827	52 620	0.04133	26.7	59 000	405	1.8
0.2043	5.189	41 740	0.03278	21.2	60 100	415	1.7
0.1819	4.620	33 090	0.02599	16.8	61 200	420	1.6
0.1650*	4.191	27 220	0.02138	13.8	62 000	425	1.5
0.1620	4.115	26 240	0.02061	13.3	62 100	430	1.4
0.1443	3.665	20 820	0.01635	10.5	63 000	435	1.3
0.1340*	3.404	17 960	0.01410	9.10	63 400	435	1.3
0.1285	3.264	16 510	0.01297	8.37	63 700	440	1.3
0.1144	2.906	13 090	0.01028	6.63	64 300	445	1.2
0.1040*	2.642	10 820	0.008495	5.48	64 800	445	1.2
0.1019	2.588	10 380	0.008155	5.26	64 900	445	1.2
0.0920*	2.387	8 460	0.00665	4.29	65 400	450	1.1
0.0907	2.304	8 230	0.00646	4.17	65 400	450	1.1
0.0808	2.052	6 530	0.00513	3.31	65 700	455	1.1
0.0800*	2.032	6 400	0.00503	3.24	65 700	455	1.1
0.0720	1.829	5 180	0.00407	2.63	65 900	455	1.1
0.0650*	1.651	4 220	0.00332	2.14	66 200	455	1.0
0.0641	1.628	4 110	0.00323	2.08	66 200	455	1.0
0.0571	1.450	3 260	0.00256	1.65	66 400	460	1.0
0.0508	1.290	2 580	0.00203	1.31	66 600	460	1.0
0.0453	1.151	2 050	0.00161	1.04	66 800	460	1.0
0.0403	1.024	1 620	0.00128	0.823	67 000	460	1.0

[A] The diameters marked by asterisks (*) are often employed by purchasers for communication lines, but are not in the American Wire Gage (B & S Wire Gage) series, as are the other diameters listed (see Explanatory Note 4).

[B] These values are subject to the requirements of conformance criteria in Section 8 in determining acceptability of wire under this specification. They are intended to be used as the "minimum values" in design and in all dependent specifications.

Table 1, the wire shall not vary from the specified diameter by more than plus and minus 1 %, expressed to the nearest 0.0001 in. (or 0.001 mm).

5.5 *Finish*—The wire shall be free of all imperfections not consistent with the best commercial practice.

6. Test Methods

6.1 *Tensile Strength and Elongation*:

6.1.1 Obtain the tensile strength, expressed in pounds per square inch, by dividing the maximum load carried by the specimen during the tension test, by the original cross-sectional area of the specimen. Tensile strength and elongation may be determined simultaneously on the same specimen.

6.1.2 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 Explanatory Note 5).

6.1.3 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.

6.2 *Resistivity*—Determine the electrical resistivity of the material in accordance with Test Method B 193 (see Explanatory Note 6). The purchaser may accept certification that the wire was drawn from rod stock meeting the International Standard for Annealed Copper instead of resistivity tests on the finished wire.

6.3 *Dimensional Measurements*—Dimensional measurements shall be made with equipment capable of measuring to a graduation of 0.0001 in. (0.001 mm). Take measurements on at least three places on each unit selected for this test. If accessible, take one measurement on each end and one near the middle. The average of the three measurements shall determine compliance with the requirements.

6.4 *Surface Finish*—Make a surface-finish inspection with the unaided eye (normal spectacles accepted).

7. Inspection

7.1 *General (see* Explanatory Note 7)—Unless otherwise specified in the contract or purchaser order, the manufacturer shall be responsible for the performance of all inspection and test requirements specified.

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

7.1.2 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.

7.1.3 Unless otherwise agreed upon between the purchaser and the manufacturer, conformance of the wire to the various requirements listed in Section 5 shall be determined on samples taken from each lot of wire presented for acceptance.

7.1.4 The manufacturer shall, if requested prior to inspection, certify that all wire in the lot was made under such

conditions that the product as a whole conforms to the requirements of this specification as determined by regularly made and recorded tests.

7.2 *Inspection and Testing Terms*:

7.2.1 *Lot*—A lot is any amount of wire of one type and size presented for acceptance at one time, such amount, however, not to exceed 100 000 lb (45 000 kg) (see Explanatory Note 8).

7.2.2 *Sample*—A sample is a quantity of production units (coils, reels, etc.) selected at random from the lot for the purpose of determining conformance of the lot to the requirements of this specification.

7.2.3 *Specimen*—A specimen is a length of wire removed for test purposes from any individual production unit of the sample.

7.3 *Sample Size*—The number of production units in a sample (see Explanatory Note 7) shall be as follows:

7.3.1 For tension, elongation, and resistivity determinations, the sample shall consist of four production units. From each unit, one test specimen of sufficient length shall be removed for the performance of the required tests.

7.3.2 For dimensional measurements, the sample shall consist of a quantity of production units shown in Table 2 under the heading "First Sample."

7.3.3 For surface-finish inspection and for packaging inspection (when specified by the purchaser at the time of placing the order) the sample shall consist of a quantity of production units shown in Table 3.

TABLE 3 Sampling for Surface Finish and Packaging Inspection

Number of Units in Lot	Number of Units in Sample, *n*	Allowable Number of Defective Units, *c*
1 to 30, incl	all	0
31 to 50, incl	30	0
51 to 100, incl	37	0
101 to 200, incl	40	0
201 to 300, incl	70	1
301 to 500, incl	100	2
501 to 800, incl	130	3
Over 800	155	4

8. Packaging and Package Marking

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

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

9. Conformance Criteria (see Explanatory Note 7)

9.1 Any lot of wire, the samples of which comply with the conformance criteria of this section, shall be considered as complying with the requirements of Section 5. Individual production units that fail to meet one or more of the requirements shall be rejected. Failure of a sample group from a lot to meet one or more of the following criteria shall constitute cause for rejection of the lot. The conformance criteria for each of the prescribed properties given in Section 5 are as follows:

9.1.1 *Tensile Strength*—The lot shall be considered conforming if the average tensile strength of the four specimens is not less than the appropriate tensile strength of Table 1 minus 400 psi (3 MPa); however, any individual production unit, the specimen from which has a tensile strength less than the appropriate tensile strength value in Table 1 minus 1700 psi (12 MPa) shall be rejected.

9.1.1.1 The lot shall be considered to have failed to meet the tensile conformance criterion if the average of the four specimens is less than the tensile strength in Table 1 minus 400 psi (3 MPa) and the tensile strength of any of the individual specimens is less than the value in Table 1 minus 1700 psi (12 MPa).

9.1.1.2 If the average of the four specimens is less than the tensile strength in Table 1 minus 400 psi (3 MPa) and the tensile strength of each of the individual specimens is equal to or more than the value in Table 1 minus 1700 psi (12 MPa), six additional specimens from six production units other than the four originally sampled shall be tested. The lot shall be considered conforming if the tensile strength of each of the ten specimens is not less than the appropriate tensile strength value in Table 1 minus 1700 psi and the average of the ten specimens is not less than the value in Table 1 minus 400 psi. The lot shall be considered to have failed to meet the tensile strength requirement if the tensile strength of any of the individual specimens is less than the value in Table 1 minus 1700 psi or if the average of the ten specimens is less than the value in Table 1 minus 400 psi.

9.1.2 *Elongation*—The lot shall be considered conforming if the average elongation of the four specimens is not less than the appropriate elongation value in Table 1 minus 0.1 percentage points; however, any individual production unit, the specimen from which has an elongation less than the appropriate elongation value in Table 1 minus 0.2 percentage points shall be rejected.

9.1.2.1 The lot shall be considered to have failed to meet the

TABLE 2 Sampling for Dimensional Measurements

Number of Units in Lot	First Sample		Second Sample		
	Number of Units in Sample, n_1	Allowable Number of Defects in First Sample, c_1	Number of Units in Sample, n_2	n, plus n_2	Allowable Number of Defects in Both Samples, c_2
1 to 14, incl	all	0	...	...	...
15 to 50, incl	14	0	...	...	...
51 to 100, incl	19	0	23	42	1
101 to 200, incl	24	0	46	70	2
210 to 400, incl	29	0	76	105	3
401 to 800, incl	33	0	112	145	4
Over 800	34	0	116	150	4

elongation conformance criterion if the average of the four specimens is less than the appropriate elongation value in Table 1 minus 0.1 percentage points the elongation of any of the individual specimens is less than the elongation value in Table 1 minus 0.2 percentage points.

9.1.2.2 If the average of the four specimens is less than the appropriate elongation value in Table 1 minus 0.1 percentage points and the elongation of each of the individual specimens is equal to or more than the elongation value in Table 1 minus 0.2 percentage points, six additional specimens from six production units other than the four originally sampled shall be tested. The lot shall be considered conforming if the elongation of each of the ten specimens is not less than the appropriate elongation value in Table 1 minus 0.2 percentage points and the average of the ten specimens is not less than the value in Table 1 minus 0.1 percentage points. The lot shall be considered to have failed to meet the elongation requirement if any of the ten specimens is less than the appropriate elongation value in Table 1 minus 0.2 percentage points or if the average of the ten specimens is lessthan the elongation value in Table 1 minus 0.1 percentage points.

9.1.3 *Resistivity*—The electrical resistivity of each of the four specimens shall conform to the requirements of 5.3. Failure to meet this requirement shall constitute failure to meet the resistivity conformance criterion.

9.1.4 *Dimensions*—The dimensions of the first sample (Table 2) shall conform to the requirements of 5.4. If there are no failures, the lot conforms to this requirement. If there are failures but the number of these does not exceed the allowable defect number, c_2 (Table 2), for the respective number of units in the sample, a second sample equal to n_2 shall be taken and the total defects of the n_1 plus n_2 units shall not exceed the allowable defect number, c_2. Failure to meet this requirement shall constitute failure to meet the dimensional conformance criterion.

9.1.5 *Surface Finish*—The surface finish of the samples taken in accordance with Table 3 shall conform to the requirements of 5.5. The number of units in the sample showing surface defects not consistent with commercial practice shall not exceed the allowable defect number, *c*, in Table 3. Failure to meet this requirement shall constitute failure to meet the surface-finish conformance criterion.

9.1.6 *Packaging*—Conformance to the packaging requirements specified by the purchaser shall be determined in accordance with Table 3. The number of units in the sample showing nonconformance to the requirement shall not exceed the allowable defect number, *c*, in Table 3. Failure to meet this requirement shall constitute failure to meet the packaging conformance criterion.

10. Density

10.1 For the purpose of calculating mass per unit length, cross sections, etc., the density of the copper shall be taken as 8.89 g/cm^3(0.32117 lb/in.^{3}) at 20°C (see Explanatory Note 9).

11. Keywords

11.1 copper electrical conductor; copper wire; electrical conductor; electrical conductor—copper; hard-drawn copper wire.

EXPLANATORY NOTES

NOTE 1—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 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 2—The tensile strength values given in Table 1 cannot always be met if the wire is drawn into coils of less than 19 in. (48 mm) inside diameter or if the wire has been rewound. Lower tensile strength values, therefore, are permissible for smaller-diameter coils, or rewound wire, through mutual agreement between the manufacturer and the purchaser at the time the order is placed.

NOTE 3—Mechanical joints made during inspection at the request of the purchaser are permissible if agreed upon at the time of placing the order.

NOTE 4—The values of the wire diameters in Table 1 which correspond to gage numbers of the American Wire Gage (see Specification B 258) are given to the nearest 0.0001 in. (0.002 mm). The diameters preceded by asterisks are not in the American Wire Gage series. They correspond to certain of the numbers of the Birmingham Wire Gage or of the British Standard Wire Gage and are used for communication lines. The use of gage numbers to specify wire sizes is not recognized in this specification, because of the possibility of confusion. An excellent discussion of wire gages and related subjects is contained in *NBS Handbook 100*.[4]

NOTE 5—It is known that the rate of loading during tension testing of copper 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 wires. It is suggested that tests be made at speeds of moving head which, under no-load conditions, are not greater than 3 in. (75 mm)/min, but in no case at a speed greater than that at which correct readings can be made.

NOTE 6—Resistivity units are based on the International Annealed Copper Standard (IACS) adopted by IEC in 1913, which is 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 weight resistivity of annealed copper equal (to 5 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/cm of length of a copper bar 1 cm^2 in cross section. A complete discussion of this subject is contained in *NBS Handbook 100* of the National Bureau of Standards.[4] 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 Table 4 were derived from the fundamental IEC value (1/58 Ω·mm^2/m) computed to 7 significant

TABLE 4 Resistivity Relationships

Conductivity at 20°C %	100.00	97.16	96.16
Ω·lb/mile^2	875.20	900.77	910.15
Ω·g/m^2	0.15328	0.15775	0.15940
Ω·cmil/ft	10.371	10.674	10.785
Ω·mm^2/m	0.017241	0.017745	0.017930
μΩ·in.	0.67879	0.69863	0.70590
μΩ·cm	1.7241	1.7745	1.7930

figures and then rounded to 5 significant figures.

NOTE 7—Cumulative results secured on the product of a single manufacturer, indicating continued conformance to the criteria, are necessary to ensure an over-all product meeting the requirements of this specification. The sample sizes and conformance criteria given for the various characteristics are applicable only to lots produced under these conditions.

NOTE 8—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 (2270 kg) 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 lots.

NOTE 9—The value of density of copper is in accordance with the International Annealed Copper Standard. The corresponding value at 0°C is 8.90 g/cm^3(0.32150 lb/in.^{3}). As pointed out in the discussion of this subject in *NBS Handbook 100* of the National Bureau of Standards, there is no appreciable difference in values of density of hard-drawn and annealed copper wire.