Designation: B2 – 13

Standard Specification for Medium-Hard-Drawn Copper Wire[1]

This standard is issued under the fixed designation B2; 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 medium-hard-drawn round copper wire for electrical purposes (see Explanatory Note 1).

1.2 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.

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

1.3 *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 The following documents of the issue in effect at the time of reference form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*[2]

B49 Specification for Copper Rod Drawing Stock for Electrical Purposes

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

2.3 *Other Documents:*

NBS Handbook 100 Copper Wire Tables of the National Bureau of Standards[3]

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 (see 5.3 and Table 1);

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

3.1.4 Package size (see 10.1);

3.1.5 Special package marking, if required; and

3.1.6 Place of inspection (Section 7).

4. Materials

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 B49 defines copper suitable for use.

4.2 Copper bars of special qualities, forms, or types, as may be agreed upon between the manufacturer and the purchaser, and which will conform to the requirements prescribed in this specification, may also be used.

5. General Requirements (see Section 8)

5.1 *Tensile Strength and Elongation*—The wire shall conform to the requirements as to tensile properties prescribed in Table 1 (Explanatory Note 3 and Note 4). For wire whose nominal diameter is more than 0.001 in. (0.025 mm) greater than a size listed in Table 1, but which is less than that of the next larger size, the requirements of the next larger size shall apply.

5.1.1 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.

5.2 *Resisitivity*—Electrical resistivity at 20°C shall not exceed the following values (see Explanatory Note 5):

Nominal Diameter, in.	Resistivity at 20°C, Ω·lb/mile [2]	Ω·g/m^2
0.460 to 0.325 (11.684 to 8.255 mm), incl	896.15	0.15694
Under 0.325 to 0.0403 (8.255 to 1.024 mm), incl	905.44	0.15857

5.3 *Dimensions and Permissible Variations*—Within the range of diameters included in Table 1 the wire shall not vary

[1] This specification is under the jurisdiction of ASTM Committee B01 on Electrical Conductors and is the direct responsibility of Subcommittee B01.04 on Conductors of Copper and Copper Alloys.

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

TABLE 1 Tensile Requirements

Diameter		Area at 20°C			Tensile Strength				Elongation, min, % in 10-in. (250 mm)
in.	mm	cmil	in.^{2}	mm^2	psi		MPa		
					Min	Max	Min	Max	
0.4600	11.684	211 600	0.1662	107.0	42 000	49 000	290	340	3.8
0.4096	10.404	167 800	0.1318	85.0	43 000	50 000	295	345	3.6
0.3648	9.266	133 100	0.1045	67.4	44 000	51 000	305	350	3.2
0.3249	8.252	105 600	0.08291	53.5	45 000	52 000	310	360	3.0
0.2893	7.348	83 690	0.06573	42.4	46 000	53 000	315	365	2.8
0.2576	6.543	66 360	0.05212	33.6	47 000	54 000	325	370	2.5
0.2294	5.827	52 620	0.04133	26.7	48 000	55 000	330	380	2.2
0.2043	5.189	41 740	0.03278	21.2	48 330	55 330	335	380	1.9
0.1819	4.620	33 090	0.02599	16.8	48 660	55 660	335	385	1.7
0.1620	4.115	26 240	0.02061	13.3	49 000	56 000	340	385	1.5
0.1443	3.665	20 820	0.01635	10.5	49 330	56 330	340	390	1.4
0.1285	3.264	16 510	0.01297	8.37	49 660	56 660	340	390	1.3
0.1144	2.906	13 090	0.01028	6.63	50 000	57 000	345	395	1.3
0.1019	2.588	10 380	0.00816	5.26	50 330	57 330	345	395	1.2
0.0907	2.304	8 230	0.00646	4.17	50 660	57 600	350	400	1.2
0.0808	2.052	6 530	0.00513	3.31	51 000	58 000	350	400	1.1
0.0720	1.829	5 180	0.00407	2.63	51 330	58 330	355	400	1.1
0.0641	1.628	4 110	0.00323	2.08	51 660	58 660	355	405	1.0
0.0571	1.450	3 260	0.00256	1.65	52 000	59 000	360	405	1.0
0.0508	1.290	2 580	0.00203	1.31	52 330	59 330	360	410	1.0
0.0453	1.151	2 050	0.00161	1.04	52 660	59 660	365	410	1.0
0.0403	1.024	1 620	0.00128	0.823	53 000	60 000	365	415	1.0

from the specified diameter by more than ±1 %, expressed to the nearest 0.0001 in. (0.001 mm) (see Explanatory Note 2).

5.4 *Joints*—No joints shall be made in the completed wire (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 5.1.

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 (see Explanatory Note 4).

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.

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 B193 (see Explanatory Note 5). 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 a micrometer caliper equipped with a vernier graduated in 0.0001 in. (0.0025 mm). Measurements shall be made on at least three places on each unit selected for this test. If accessible, one measurement shall be taken 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 (Explanatory Note 8 and Note 9)*—Unless otherwise specified in the contract or purchase 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 especially agreed upon between the manufacturer and the purchaser at the time of 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 *Definitions Applicable to Inspection:*

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_1 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
201 to 400, incl	29	0	76	105	3
401 to 800, incl	33	0	112	145	4
Over 800	34	0	116	150	4

7.2.1 *lot (Explanatory Note 9)*—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).

7.2.2 *unit(s)*—coil(s), reel(s), or other put-up method which makes up the lot from a production unit of one size of wire.

7.2.3 *sample*—a quantity of production units (coils, reels, and so forth) selected at random from the lot for the purpose of determining conformance of the lot to the requirements of this specification.

7.2.4 *specimen*—a length of wire removed for test purposes from any individual production unit of the sample.

7.3 *Sample Size (Explanatory Note 8)*—The number of production units in a sample shall be as follows:

7.3.1 For 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.

8. Conformance Criteria (see Explanatory Note 8)

8.1 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:

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

8.1.1 *Tensile and Elongation*—The lot shall be considered conforming if the tensile and elongation of each of the selected specimens is not less than the value in Table 1.

8.1.1.1 *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.

8.1.2 *Resistivity*—The electrical resistivity of each of the four specimens shall conform to the requirements of 5.2. Failure to meet these requirements shall constitute failure to meet the resistivity conformance criterion.

8.1.3 *Dimensions*—The dimensions of the first sample (Table 2) shall conform to the requirements of 5.3. 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.

8.1.4 *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.

8.1.5 *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.

9. Density

9.1 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 6).

10. Packaging and Package Marking

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

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

11. Keywords

11.1 copper wire; medium-hard copper wire; round copper electrical wire; round copper wire

EXPLANATORY NOTES

NOTE 1—Medium-hard drawn wire approaches hard-drawn wire in its characteristics, but from the very nature of the product, exact uniformity in tensile strength cannot be obtained. Hence it has been necessary to establish a range of tensile strengths within which standard medium-hard-drawn wire may be expected to be found.

NOTE 2—The values of the wire diameters in Table 1 are given to the nearest 0.0001 in. (0.001 mm) and correspond to the standard sizes given in Specification B258. 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.

NOTE 3—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 medium-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 medium-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 4—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 medium-hard-drawn wires. It is suggested that tests be made at speeds of moving head that, 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 5—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 volume and weight resistivity of annealed copper equal to (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 $\Omega \cdot lb/mile^2$, 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 Institute of Standards and Technology.[3] The use of 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 5 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 $\Omega \cdot mm^2/m$) computed to 7 significant figures and then rounded to 5 significant figures.

NOTE 6—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, there is no appreciable difference in values of density of medium-hard-drawn and annealed copper wire.

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.

NOTE 8—Cumulative results secured on the product of a single manufacturer, indicating continued conformance to the criteria, are necessary to ensure an overall 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 9—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 or 2270 kg of wire cannot be justified economically. For small lots of 5000 lb or less, or 2270 kg 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.

TABLE 4 Resistivity Relationships

Conductivity at 20°C, %	100.00	97.66	96.66
$\Omega \cdot lb/mile^2$	875.20	896.15	905.44
$\Omega \cdot g/m^2$	0.15328	0.15694	0.15857
Ω·cmil/ft	10.371	10.619	10.729
$\Omega \cdot mm^2/m$	0.017241	0.017654	0.017837
μΩ·in.	0.67879	0.69504	0.70224
μΩ·cm	1.7241	1.7654	1.7837