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# Standard Specification for Tinned Hard-Drawn and Medium-Hard-Drawn Copper Wire for Electrical Purposes[1]

This standard is issued under the fixed designation B 246; 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 tinned hard-drawn and medium-hard-drawn round copper wire for electrical purposes.

1.2 The SI values of resistance and density are to be regarded as standard. For all other properties, values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

1.3 The following *safety hazards caveat* pertains only to the test method described in this specification. *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.* For hazard statement, see Sections 10 and 13.

## 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 5 Specification for High Conductivity Tough-Pitch Copper Refinery Shapes[2]

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

B 170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes[2]

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

2.3 *National Bureau of Standards:*

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 (see 5.1 and Table 1),

3.1.3 Type of copper, if special (see 4.2),

3.1.4 Temper (see 7.1 and Table 1),

3.1.5 Package size (see 18.1),

3.1.6 Special package marking, if required, and

3.1.7 Place of inspection (Section 16).

## 4. Materials and Manufacture

4.1 The tinned wire shall be made by coating hard-drawn and medium-hard-drawn copper wire with commercially pure tin (see Note 1). For purposes of this specification, the tin shall be considered“ commercially pure” if the total of other elements, exclusive of copper, does not exceed 1 %. Notwithstanding the previous sentence, chemical analysis of the tin coating or of the tin used for coating shall not be required under this specification. Adequacy of the tin coating is ensured by the continuity of coating and adherence of coating requirements (Sections 9 and 13, respectively).

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

NOTE 1—Specifications B 5, B 49, and B 170 define the materials suitable for use.

4.3 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. Dimensions, Mass, and Permissible Variations

5.1 The wire sizes shall be expressed as the diameter of the coated wire in decimal fractions of an inch to the nearest 0.0001 in. (0.1 mil) (Explanatory Note 4).

5.2 The coated wire shall not vary from the specified diameter by more than plus 3 % or minus 1 %.

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

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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.

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**TABLE 1 Tensile Requirements**

| Diameter | | Area at 20°C | | | Tinned Hard-Drawn Wire | | | Tinned Medium-Hard-Drawn Wire | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Tensile Strenth, min. | | Elongation in 10 in. (250mm), % min | Tensile Strength, min. | | | | |
| | | | | | | | | psi | | Mpa | | Elongation in 10 in. (250mm), % min |
| in. | mm | cmil | in.$^2$ | mm$^2$ | psi | Mpa | | min. | max. | min. | max. | |
| 0.2043 | 5.1892 | 41738.49 | 0.032781 | 21.1492 | 54100 | 370.6 | 1.7 | 42400 | 55300 | 290.4 | 378.8 | 1.9 |
| 0.1819 | 4.6203 | 33087.61 | 0.025987 | 16.7657 | 55100 | 377.4 | 1.6 | 43300 | 55700 | 296.6 | 381.5 | 1.7 |
| 0.1620 | 4.1148 | 26244.00 | 0.020612 | 13.2980 | 55900 | 382.9 | 1.4 | 44100 | 56000 | 302.1 | 383.6 | 1.5 |
| 0.1443 | 3.6652 | 20822.49 | 0.016354 | 10.5509 | 56700 | 388.4 | 1.3 | 44900 | 56300 | 307.6 | 385.6 | 1.4 |
| 0.1285 | 3.2639 | 16512.25 | 0.012969 | 8.3669 | 57300 | 392.5 | 1.3 | 45500 | 56700 | 311.7 | 388.4 | 1.3 |
| 0.1144 | 2.9058 | 13087.36 | 0.01027879 | 6.6315 | 57900 | 396.6 | 1.2 | 46000 | 57000 | 315.1 | 390.4 | 1.3 |
| 0.1019 | 2.5883 | 10383.61 | 0.00815527 | 5.2615 | 58400 | 400.0 | 1.2 | 46500 | 57300 | 318.5 | 392.5 | 1.2 |
| 0.0907 | 2.3038 | 8226.49 | 0.00646107 | 4.1684 | 58900 | 403.5 | 1.1 | 46900 | 57700 | 321.3 | 395.2 | 1.2 |
| 0.0808 | 2.0523 | 6528.64 | 0.00512758 | 3.3081 | 59100 | 404.8 | 1.1 | 47200 | 58000 | 323.3 | 397.3 | 1.1 |
| 0.0720 | 1.8288 | 5184.00 | 0.00407150 | 2.6268 | 59300 | 406.2 | 1.1 | 47300 | 58300 | 324.0 | 399.3 | 1.1 |
| 0.0641 | 1.6281 | 4108.81 | 0.00322705 | 2.0820 | 59600 | 408.2 | 1.0 | 47600 | 58700 | 326.1 | 402.1 | 1.0 |
| 0.0571 | 1.4503 | 3260.41 | 0.00256072 | 1.6521 | 59800 | 409.6 | 1.0 | 47800 | 59000 | 327.4 | 404.1 | 1.0 |
| 0.0508 | 1.2903 | 2580.64 | 0.00202683 | 1.3076 | 59900 | 410.3 | 1.0 | 47900 | 59300 | 328.1 | 406.2 | 1.0 |

5.3 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 taken near each end and one near the middle. If any of these selected coils or spools fails to conform to the requirements prescribed in 5.2, all coils or spools shall be gaged in the manner specified.

## 6. Workmanship, Finish, and Appearance

6.1 The tin coating shall consist of a smooth continuous layer, firmly adhering to the surface of the copper.

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

## 7. Tensile Properties

7.1 The tinned wire shall conform to the requirements as to tensile properties prescribed in Table 1 (Explanatory Note 1).

7.2 For wire the nominal diameter of which is more than 0.001 in. (1 mil) or 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.

7.3 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 (Explanatory Note 1).

7.4 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.

7.5 *Retests*—If upon testing a specimen from any coil or spool of wire, the results do not conform to the requirements prescribed in Table 1, two additional specimens 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 specimens by resistance measurements (Explanatory Note 2) made in accordance with Test Method B 193. At a temperature of 20°C the resistivity of coated wire shall not exceed the values prescribed in Table 2 (Explanatory Note 3).

## 9. Continuity of Coating

9.1 The continuity of coating on the wire shall be determined on representative samples taken before stranding or insulating (Explanatory Note 3).

9.2 The continuity of the tin coating shall be determined by the sodium polysulfide test, which shall be applied as specified in Sections 10-12.

## 10. Specimens for Coating Tests

10.1 *Length of Specimens*—Test specimens shall each have a length of about 6 in. They shall be tagged or marked to correspond with the coil, spool, or reel from which they were cut.

10.2 *Treatment of Specimens*—The specimens shall be thoroughly cleaned by immersion in a suitable solvent for the appropriate time required to remove oil or grease from surface; then removed and wiped dry with a clean soft cloth

**TABLE 2 Electrical Resistivity Requirements**

| Nominal Diameter | | Resistivity at 20°C | | | |
|---|---|---|---|---|---|
| | | lb/mile$^2$ | | g/m$^2$ | |
| in. | mm | Hard | Medium-Hard | Hard | Medium-Hard |
| 0.2043 to 0.103, incl | 5.2 to 2.6, incl | 943.92 | 938.85 | 0.1653 | 0.1644 |
| Under 0.103 to 0.0508, incl | Under 2.6 to 1.3, incl | 910.15 | 946.06 | 0.1594 | 0.1657 |

(**Caution**—see Explanatory Note 5). The specimens thus cleaned shall be kept wrapped in a clean, dry cloth until tested. That part of the specimen to be immersed in the test solution shall not be handled. Care shall be taken to avoid abrasion by the cut ends.

## 11. Special Solutions Required

11.1 *Hydrochloric Acid Solution* (sp gr 1.088)—Commercial HCl (sp gr 1.12) shall be diluted with distilled water to a specific gravity of 1.088 measured at 15.6°C. A portion of HCl solution having a volume of 180 mL shall be considered to be exhausted when the number of test specimens prescribed in Table 3 of a size as indicated in Section 12 have been immersed in it for two cycles.

11.2 *Sodium Polysulfide Solution* (sp gr 1.142)—A concentrated solution shall be made by dissolving sodium sulfide cp crystals in distilled water until the solution is saturated at about 21°C, and adding sufficient flowers of sulfur (in excess of 250 g/L of solution) to provide complete saturation as evidenced by the presence in the solution of an excess of sulfur after the solution has been allowed to stand for at least 24 h. The test solution shall be made by diluting a portion of the concentrated solution with distilled water to a specific gravity of 1.142 at 15.6°C. The sodium polysulfide test solution shall have sufficient strength to blacken thoroughly a piece of clean untinned copper wire in 5 s. A portion of the test solution used for testing samples shall not be considered to be exhausted until it fails to blacken a piece of clean copper as described here (Explanatory Note 6).

## 12. Procedure for Coating Continuity Test

12.1 *Immersion of Specimens*—Immerse a length of at least 4½in. from each of the clean specimens, in accordance with the following cycles, in test solutions maintained at a temperature between 15.6 and 21°C:

12.1.1 Immerse the specimen for 1 min in the HCl solution described in 11.1, wash, and wipe dry.

12.1.2 Immerse the specimen for 30 s in the sodium polysulfide solution described in 11.2, wash, and wipe dry.

12.1.3 Immerse the specimen for 1 min in HCl solution described in 11.1, wash, and wipe dry.

12.1.4 Immerse the specimen for 30 s in the sodium polysulfide solution described in 11.2, wash, and wipe dry.

12.2 *Washing Specimens*—After each immersion, immediately wash thoroughly the specimens in clean water and wipe dry with a clean, soft cloth.

12.3 *Examination of Specimens*—After the operations described in 12.1 and 12.2, examine the specimens to ascertain if copper exposed through openings in the tin coating has been blackened by action of the sodium polysulfide. The specimens shall be considered to have failed if by such blackening exposed copper is revealed. Pay no attention to blackening within 0.5 in. of the cut end.

## 13. Mechanical Test for Adhesion of Coating

13.1 *Length of Specimens*—Test specimens shall be approximately 12 in. in length and shall be tagged or marked to correspond with the coil, spool, or reel from which they are cut.

13.2 *Preparation of Specimen*—Thoroughly clean the specimens, if required, by immersion in a suitable solvent for the appropriate time required to remove oil and grease from surface, then remove and dry (**Caution**—Explanatory Note 5). Store the specimens thus cleaned wrapped in a clean, dry cloth until tested. Do not handle that part of the specimens to be immersed in the test solution. Use care to avoid abrasion of the surface to be subjected to test.

13.3 *Wrapping Procedure*—Slowly wrap the test specimen in a suitable manner in an open helix around a polished mandrel having rounded ends and a diameter equal to four times the diameter of the specimens. Use care not to stretch the specimen during the wrapping operation. Make the spacing of the consecutive turns approximately equal to the diameter of the wire. Do not use more than three turns for the test.

13.4 *Immersion Test*— Remove the helically wrapped portion of the test specimen from the mandrel and completely immerse in the sodium polysulfide solution (see 11.2) for 30 s at the temperature in accordance with 12.1. On removal from the sodium polysulfide solution, rinse the specimen immediately in clean water and remove the excess by shaking.

13.5 *Examination of Specimen*—Examine visually the outer peripheral surface of the helically wrapped portion of the specimen. Any cracking or parting of the coating in this area shown by blackening of the copper shall be cause for rejection. A grayish appearance of the coating after immersion shall not constitute failure.

13.6 *Retest*—In the event of failure, two additional specimens shall be tested. If either of these specimen fails, the coil, reel, or spool shall be rejected.

## 14. Joints

14.1 Joints shall not be made in the wire after it has been drawn to size or coated. Joints in the wire or rods prior to final drawing shall be made in accordance with the best commercial practice (Explanatory Note 7).

## 15. Density

15.1 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$^3$ or 0.32117 lb/in.$^3$ at 20°C (Explanatory Note 8).

**TABLE 3 Limiting Number of Test Specimens for Coating Tests**

| Nominal Diameter | | Maximum Number of Specimens to Be Tested for Two Cycles in 180 mL of Acid Solution |
|---|---|---|
| in. | mm | |
| 0.2043 to 0.141, incl | 5.2 to 3.6, incl | 2 |
| Under 0.141 to 0.0851, incl | Under 3.6 to 2.2, incl | 4 |
| Under 0.0851 to 0.0508, incl | Under 2.2 to 1.3, incl | 6 |

## 16. Inspection

16.1 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.

## 17. Rejection

17.1 Wire that shows exposed copper by blackening after testing in the sodium polysulfide solution in accordance with Sections 11 and 12, or that fails to conform to the other requirements of this specification, shall be rejected.

## 18. Packaging and Package Marking

18.1 Package sizes shall be agreed upon between the manufacturer and the purchaser in the placing of individual orders (Explanatory Note 9).

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

## 19. Keywords

19.1 tinned copper wire; tinned hard-drawn copper wire; tinned medium-hard-drawn copper; tinned round copper wire for electrical purposes

## 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—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./min or 75 mm/min, but in no case at a speed greater than that at which correct readings can be made.

NOTE 3—"Resistivity" is used in place of" conductivity." The value of 0.15328 $\Omega \cdot g/m^2$ at 20°C (68°F) is the international standard for the resistivity of annealed copper, equal to 100 % conductivity. This term means that a wire 1 m in length and weighing 1 g would have a resistance of 0.15328Ω . This is equivalent to a resistivity value of 875.20$\Omega \cdot$ lb/$mile^2$ which signifies the resistance of a wire 1 mile in length weighing 1 lb. It is also equivalent, for example, to 1.7241 μΩ/cm of length of a bar, 1 $cm^3$ in cross section. A complete discussion of resistivity is contained in *NBS Handbook 100*. Because the specific resistance of tin is greater than copper and because the relative amount of tin is greater on fine wire than on wire of larger diameter, the resistivity of tin-coated copper wire varies inversely with the diameter. Relationships that may be useful in connection with the values of resistivity prescribed in this specification are as given in Table 4, each column containing equivalent expressions, at 20°C.

NOTE 4—The coating of tin on copper wire is for the purpose of protecting the copper against the action of the insulation. It is, therefore, necessary that the coating be continuous. The test in the sodium polysulfide is for the purpose of determining whether or not the wire carries a continuous envelope of pure tin. Although the thickness of the tin coating on the same wire varies, the thickness of the coating on the various sizes applied under similar conditions is approximately the same. It is not, therefore, correct to apply a larger number of cycles in the coating test on coarse wire than is applied to the smaller wire. It is probable that one cycle of the dip test would be sufficient to discover defects in tinned wire, but in order to make certain that no partially covered spots may escape attention, provision has been made for two cycles. It has been found that the tin coating on copper wire consists of two parts, an envelope of pure tin on the outside, with an intermediate layer of copper-tin alloy. This tin alloy, as well as the amount of tin present, has an effect on the resistivity of the wire. Since the relative amount of tin coating and alloy is greater on the small wire than it is on the coarser wire, the resistivity of the wire increases as the size decreases.

NOTE 5—The values of wire diameters in Table 1 which correspond to gage numbers of the American Wire Gage are given to the nearest 0.0001 in. 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 6—**Caution:** Consideration should be given to toxicity and flammability when selecting solvent cleaners.

NOTE 7—It is important that the polysulfide solution be of proper composition and strength at the time of test. A solution which is not saturated with sulfur or which has been made from decomposed sodium sulfide crystals may give a false indication of failure. Therefore, the requirement that the solution be tested by observing its blackening effect on a bright copper wire is significant. Significant also is the requirement that the solution be saturated with sulfur by allowing the solution to stand at least 24 h after preparation. Attention is called also to the necessity for the use of sodium sulfide which has not deteriorated through exposure to

**TABLE 4 Resistivity Values**

| Conductivity at 20°C, % | 100.00 | 93.22 | 92.72 | 92.51 | 91.96 |
|---|---|---|---|---|---|
| $\Omega \cdot lb/mile^2$ | 875.20 | 938.85 | 943.92 | 946.06 | 951.72 |
| $\Omega \cdot g/m^2$ | 0.15328 | 0.16443 | 0.16532 | 0.16569 | 0.16668 |
| $\Omega \cdot$cmil/ft | 10.371 | 11.125 | 11.185 | 11.211 | 11.278 |
| $\Omega \cdot mm^2/m$ | 0.017241 | 0.018495 | 0.018595 | 0.018637 | 0.018748 |
| $\Omega \cdot$in. | 0.67879 | 0.72816 | 0.73209 | 0.73375 | 0.73814 |
| $\Omega \cdot$cm | 1.7241 | 1.84949 | 1.85947 | 1.86369 | 1.87484 |

air; and if exposure has occurred, the crystals should be tested for purity. The "Standard Reagents Tests" of the American Chemical Society are useful in this connection.[5]

NOTE 8—Mechanical joints made during inspection at the request of the purchaser are permissible if agreed upon at the time of placing the order.

NOTE 9—The value of density of copper is in accordance with the International Annealed Copper Standard. The corresponding value at 0°C (32°F) is 8.90 g/cm$^3$(0.32150 lb/in.$^3$). In computation involving density it must be borne in mind that apparent density of coated wire is not a constant but a variable function of wire diameter. The smaller the diameter the greater the percentage of coating present and hence the greater the departure from the density of copper.

NOTE 10—Attention is called to the desirability for agreement between the manufacturer and the purchaser on package sizes which will be sufficiently large and yet not so heavy or bulky that the wire may likely be damaged in handling.

[5] *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmaceutical Convention, Inc. (USPC), Rockville, MD.

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