



Designation: B 956 – 07^{e1} B 956 – 07^{e1} ε2

Standard Specification for Welded Copper and Copper-Alloy Condenser and Heat Exchanger Tubes with Integral Fins¹

This standard is issued under the fixed designation B 956; 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.

ϵ^1 NOTE—Added table reference to 5.2.4.

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ϵ^2 NOTE—Paragraph 8.3 editorially updated.

1. Scope

1.1 This specification establishes the requirements for heat exchanger tubes manufactured from forge-welded copper and copper alloy tubing in straight lengths on which the external or internal surface, or both, has been modified by cold forming process to produce an integral enhanced surface for improved heat transfer.

1.2 *Units*—The values stated in either inch-pounds units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems could result in nonconformance with the specification.

1.3 The tubes are typically used in surface condensers, evaporators, and heat exchangers.

1.4 The product shall be produced of the following coppers or copper alloys, as specified in the ordering information.

| Copper or Copper Alloy | Type of Metal |
|------------------------|--|
| UNS No. | |
| C12000 ^A | DLP Phosphorized, low residual phosphorus |
| C12200 ^A | DHP Phosphorized, high residual phosphorus |
| C19200 | Phosphorized, 1 % iron |
| C23000 | Red Brass |
| C44300 | Admiralty, arsenical |
| C44400 | Admiralty, antimonial |
| C44500 | Admiralty, phosphorized |
| C68700 | Aluminum Brass |
| C70400 | 95-5 Copper-Nickel |
| C70600 | 90-10 Copper-Nickel |
| C70620 | 90-10 Copper-Nickel (Modified for Welding) |
| C71000 | 80-20 Copper-Nickel |
| C71500 | 70-30 Copper-Nickel |
| C71520 | 70-30 Copper-Nickel (Modified for Welding) |
| C72200 | Copper-Nickel |

^A Copper UNS Nos. C12000, and C12200 are classified in Classification B 224.

NOTE 1—Designations listed in Classification B 224.

1.5 *The following safety hazard caveat pertains only to the test methods 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.*

2. Referenced Documents

2.1 ASTM Standards:²

- B 153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing
- B 154 Test Method for Mercurous Nitrate Test for Copper Alloys
- B 224 Classification of Coppers
- B 543 Specification for Welded Copper and Copper-Alloy Heat Exchanger Tube
- B 601 Classification for Temper Designations for Copper and Copper Alloys Wrought and Cast

¹ This specification is under the jurisdiction of ASTM Committee B05 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.04 on Pipe and Tube.

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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.

- B 846 Terminology for Copper and Copper Alloys
- B 858 Test Method for Ammonia Vapor Test for Determining Susceptibility to Stress Corrosion Cracking in Copper Alloys
- E 8 Test Methods for Tension Testing of Metallic Materials
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E 53 Test Method for Determination of Copper in Unalloyed Copper by Gravimetry
- E 54 Test Methods for Chemical Analysis of Special Brasses and Bronzes
- E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)
- E 112 Test Methods for Determining Average Grain Size
- E 118 Test Methods for Chemical Analysis of Copper-Chromium Alloys
- E 243 Practice for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes
- E 255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition
- E 478 Test Methods for Chemical Analysis of Copper Alloys
- E 527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

3. Terminology

3.1 For the definitions of terms related to copper and copper alloys, refer to Terminology B 846.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *enhanced tube*—tube having a series of metallic ribs on the outside or inside surface, or both, either parallel to the longitudinal axis or circumferentially extended from the tube to increase the effective surface for heat transfer (Figs. 1-3).

3.2.2 *unenanced tube*—tube made by processing strip into a tubular shape and forge welding the edges to make a longitudinal seam with no enhancements on the O.D. or I.D.

4. Types of Welded Tube

4.1 Reference Specification B 543 for the types of forge welded tube products that will be supplied for the enhancing operation (Section 6).

5. Ordering Information

5.1 Include the following information when placing orders for product under this specification as applicable:

5.1.1 ASTM designation and year of issue,

5.1.2 Copper UNS No. designation (for example, Copper UNS No. C12000),

5.1.3 Tube type (Section 4),

5.1.4 Temper (Section 8),

5.1.5 Dimensions, the diameter, wall thickness, whether minimum or nominal wall, and length (Section 14),

5.1.6 Configuration of enhanced surfaces shall be agree upon between the manufacturer and the purchaser (Figs. 1-3), and

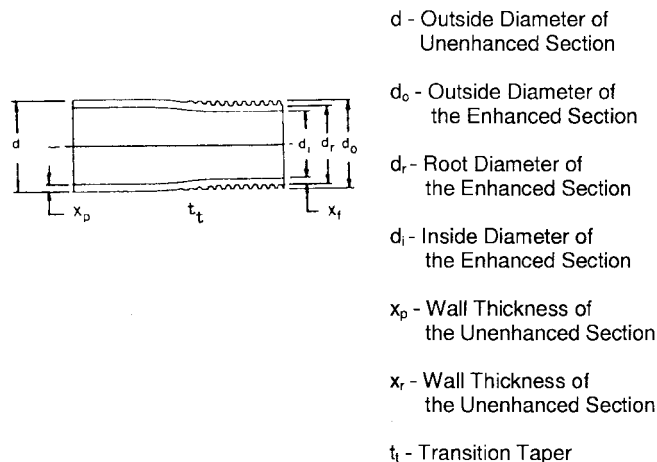
5.1.7 Quantity.

5.2 The following options are available and shall be specified at the time placing the order, when required:

5.2.1 When heat identification or traceability is required,

5.2.2 Whether a pressure test is to be used instead of the eddy-current test (13.1),

5.2.2.1 Whether a pressure test is be used along with the eddy-current test (13.3 and 13.4),



NOTE—The outside diameter over the enhanced section will not normally exceed the outside diameter of the unenhanced section.

FIG. 1 Outside Diameter Enhanced Tube Nomenclature

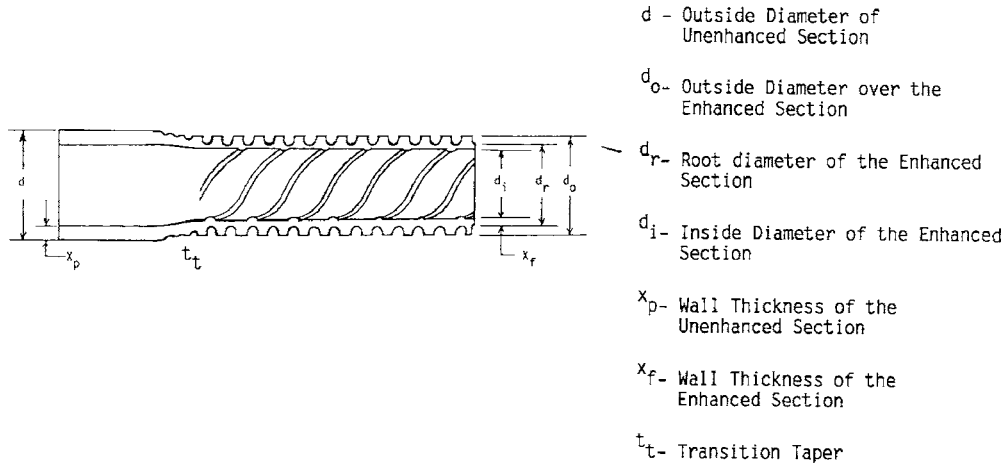


FIG. 2 Outside Diameter and Inside Diameter Enhanced Tube Nomenclature

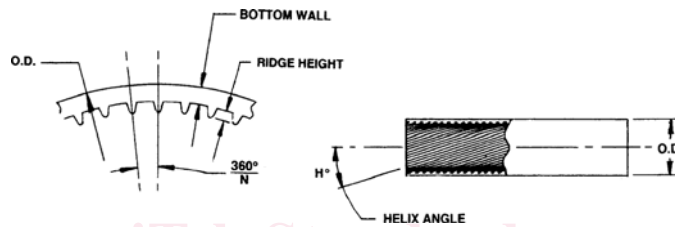


FIG. 3 Inside Diameter Enhanced Tube Nomenclature

- 5.2.3 Whether cut ends of the tube are to be deburred, chamfered, or otherwise treated (Section 15),
- 5.2.4 If the product is to be subsequently welded (see Table 1, Footnote E),
- 5.2.5 Certification, if required (Section 23), and
- 5.2.6 Mill test report, if required (Section 24).

6. Materials and Manufacture

6.1 Material:

ASTM B956-07e2

<https://standards.iteh.ai/catalog/standards/sist/37eccf6c-e402-46bb-9992-8a7afb859e9f/astm-b956-07e2>

TABLE 1 Chemical Requirements

| Copper or Copper Alloy UNS No. | Composition, % | | | | | | | | | | | | |
|---|----------------------------|---------|----------|---------------------------|--------------|----------|-----------|-----------|-----------|-----------|-------------|----------|----------------------------|
| | Copper | Tin | Aluminum | Nickel, incl Cobalt | Lead, max | Iron | Zinc | Manganese | Arsenic | Antimony | Phosphorus | Chromium | Other Named Elements |
| C12000 | 99.90 min ^A | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0.004–0.012 | ... | ... |
| C12200 | 99.9 min ^A | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0.015–0.040 | ... | ... |
| C19200 | 98.5 min ^B | ... | ... | ... | ... | 0.8–1.2 | 0.20 max | ... | ... | ... | 0.01–0.04 | ... | ... |
| C23000 | 84.0–86.0 ^B | ... | ... | ... | 0.05 | 0.05 max | remainder | ... | ... | ... | ... | ... | ... |
| C44300 | 70.0–73.0 ^C | 0.9–1.2 | ... | ... | 0.07 | 0.06 max | remainder | ... | 0.02–0.06 | ... | ... | ... | ... |
| C44400 | 70.0–73.0 ^C | 0.9–1.2 | ... | ... | 0.07 | 0.06 max | remainder | ... | ... | 0.02–0.10 | ... | ... | ... |
| C44500 | 70.0–73.0 ^C | 0.9–1.2 | ... | ... | 0.07 | 0.06 max | remainder | ... | ... | ... | 0.02–0.10 | ... | ... |
| C68700 | 76.0–79.0 ^{A,D} | ... | 1.8–2.5 | ... | 0.07 | 0.06 max | remainder | ... | 0.02–0.06 | ... | ... | ... | ... |
| C70400 | remainder ^{A,D,E} | ... | ... | 4.8–6.2 | 0.05 | 1.3–1.7 | 1.0 max | 0.30–0.8 | ... | ... | ... | ... | ... |
| C70600 | remainder ^{A,D} | ... | ... | 9.0–11.0 | 0.05 | 1.0–1.8 | 1.0 max | 1.0 max | ... | ... | ... | ... | ... |
| C70620 | 86.5 min ^{A,D} | ... | ... | 9.0–11.0 | 0.02 | 1.0–1.8 | 0.50 max | 1.0 max | ... | ... | 0.02 max | ... | 0.05 C max 0.02 S max |
| C71000 | remainder ^{A,D,E} | ... | ... | 19.0–23.0 | 0.05 | 1.0 max | 1.0 max | 1.0 max | ... | ... | ... | ... | ... |
| C71500 | remainder ^{A,D} | ... | ... | 29.0–33.0 | 0.05 | 0.40–1.0 | 1.0 max | 1.0 max | ... | ... | ... | ... | ... |
| C71520 | 65.0 min ^{A,D} | ... | ... | 29.0–33.0 | 0.02 | 0.40–1.0 | 0.50 max | 1.0 max | ... | ... | 0.02 max | ... | 0.05 C max 0.02 S max |
| C72200 | remainder ^{A,B,E} | ... | ... | 15.0–18.0 | 0.05 | 0.50–1.0 | 1.0 max | 1.0 max | ... | ... | ... | 0.30–0.7 | 0.03 Si max 0.03 Ti max |

^A Copper (including silver).

^B Cu + Sum of Named Elements, 99.8 % min.

^C Cu + Sum of Named Elements, 99.6 % min.

^D Cu + Sum of Named Elements, 99.5 % min.

^E When the product is for subsequent welding applications, and so specified in the contract or purchase order, zinc shall be 0.50 % max, lead 0.02 % max, phosphorus 0.02 % max, sulfur 0.02 % max, and carbon 0.05 % max.

6.1.1 The material of manufacture shall be welded tube of one of the Copper Alloy UNS Nos. listed in 1.1 of such purity and soundness as to be suitable for processing into the products prescribed herein.

6.1.2 In the event heat identification or traceability is required, the purchaser shall specify the details desired.

6.2 *Manufacture:*

6.2.1 The product shall be manufacture by cold forming the enhancement of the heat transfer surfaces.

6.3 Product described by this specification shall typically be furnished with unenhanced ends, but may be furnished with enhanced ends or stripped ends from which the O.D. enhancement has been removed by machining.

6.3.1 The enhanced sections of the tube in the as-fabricated temper are in the cold formed condition produced by the enhancing operation.

6.3.2 The unenhanced sections of the tube shall be in the annealed or as-welded temper, and shall be suitable for rolling-in operations.

7. Chemical Composition

7.1 The material shall conform to the chemical compositional requirements in Table 1 for Copper UNS No. designation specified in the ordering information.

7.2 The composition limits do not preclude the presence of other elements. By agreement between the manufacturer and purchaser, limits may be established and analysis required for unnamed elements.

7.2.1 *Copper Alloy C19200*—Copper may be taken as the difference between the sum of results for all specified elements and 100 %. When all elements specified, including copper, are determined, their sum shall be 99.8 % minimum.

7.2.2 For alloys in which copper is specified as the remainder, copper may be taken as the difference between the sum of the results for all specified elements and 100 % for the particular alloy.

7.2.2.1 When analyzed, copper plus the sum of results for specified elements shall conform with the requirements shown in the following table:

| Copper Alloy UNS No. | Copper Plus Named Elements, | |
|----------------------|-----------------------------|--|
| | % min | |
| C70400 | 99.5 | |
| C70600 | 99.5 | |
| C70620 | 99.5 | |
| C71000 | 99.5 | |
| C71500 | 99.5 | |
| C71520 | 99.5 | |
| C72200 | 99.8 | |

7.2.3 For alloys in which zinc is specified as the remainder, either copper or zinc may be taken as the difference between the sum of the results of specified elements analyzed and 100 %.

7.2.3.1 When all specified elements are determined, the sum of results plus copper shall be as follows:

| Copper Alloy UNS No. | Copper Plus Named Elements, | |
|------------------------|-----------------------------|--|
| | % min | |
| C23000 | 99.8 | |
| C44300, C44400, C44500 | 99.6 | |
| C68700 | 99.5 | |

8. Temper

8.1 Tempers, as defined in Classification B 601 and this specification, are as follows:

8.1.1 The tube, after enhancing, shall be supplied, as specified, in the annealed (061) or as-fabricated temper.

8.1.1.1 The enhanced sections of tubes in the as-fabricated temper are in the cold formed condition produced by the fabricating operation.

8.1.1.2 The unenhanced sections of tubes in the as-fabricated temper are in the temper of the tube prior to enhancing, welded and annealed (WO61), welded and light cold-worked (WC55) and suitable for rolling-in operations.

8.2 Tubes of Copper Alloy UNS Nos. C23000, C44300, C44400, C44500, and C68700 shall be furnished in the annealed temper or the stress relieved condition as specified in the purchase order unless otherwise agreed upon between the purchaser and the manufacturer.

8.3 Tubes of Copper Alloy UNS Nos. C12200, C19400, C19200, C70400, C70600, C71000, C71500, and C72200 are normally supplied in the temper specified in the purchase order without stress relief treatment.

NOTE 2—Some tubes, when subjected to aggressive environments, may be subject to stress-corrosion cracking because of the residual tensile stresses developed in the enhancing process. For such applications, it is suggested that tubes of Copper Alloy UNS Nos. C23000, C44300, C44400, C44500, and C68700 are subjected to a stress relieving thermal treatment subsequent to the enhancement process. In Specification B 359 the stress relief anneal is mandatory for brass alloys.

9. Grain Size for Annealed Tempers

9.1 Samples of annealed temper tubes shall be examined at a magnification of 75 diameters. The grain size shall be determined in the wall beneath the internal enhancement. While there is not grain size range, the microstructure shall show complete recrystallization and the weld zone shall have a structure typical of hot-forged welds.

10. Mechanical Property Requirements

10.1 Tensile Strength and Yield Strength Requirements:

10.1.1 Product furnished under this specification shall conform to the tensile and yield strength requirements prescribed in Table 2 when tested in accordance with Test Method E 8.

10.1.2 Acceptance or rejection based upon mechanical properties shall depend only on tensile strength and yield strength.

11. Performance Requirements

11.1 Expansion Test Requirements:

11.1.1 Product in the annealed tempers and the light cold-worked temper shall withstand expansion in accordance with Test Method B 153 and to the extent in Table 3.

11.1.2 The expanded tube area shall be free of defects, but blemishes of nature that do not interfere with the intended application are acceptable.

11.2 Flattening Test:

11.2.1 When specified in the contract or purchase order, the flattening test described in the test method section in 19.2.7 shall be performed.

11.2.2 During inspection, the flattened areas and edges of the test specimen shall be free of defects, but blemishes of a nature that do not interfere with the intended application are acceptable.

11.3 Reverse Bend Test:

11.3.1 When specified in the contract or purchase order, the reverse bend test described in the test method section in 19.2.8 shall be performed on unenhanced tubes.

11.3.2 The sample shall be free of defects, but blemishes of nature that do not interfere with the intended application are acceptable.

12. Other Requirements

12.1 Mercurous Nitrate Test or Ammonia Vapor Test:

12.1.1 The mercurous nitrate or ammonia vapor test is required only for Copper Alloys UNS Nos. C23000; C44300; C44400; C44500; C60800; and C68700; when purchased if not supplied in an annealed temper (**Warning**—Mercury is a definite health hazard and therefore equipment for the detection and removal of mercury vapor produced in volatilization is recommended. The use of rubber gloves in testing is advisable.)

12.1.2 The test specimens, cut 6 in. [150 mm] in length from the enhanced section shall withstand, without cracking, an immersion in the standard mercurous nitrate solution in Test Method B 154 or immersion in the ammonia vapor solution as defined in Test Method B 858.

12.1.3 Unless otherwise agreed upon between the manufacturer, or supplier, and the purchaser, the manufacturer shall have the option of using either the mercurous nitrate test or the ammonia vapor test. If agreement cannot be reached, the mercurous nitrate test standard shall be utilized.

TABLE 2 Tensile Requirements

| Copper or Copper Alloy UNS No. | Temper Designation | | Tensile Strength min ksi ^A [MPa] | Yield Strength ^B min ksi ^A [MPa] |
|--------------------------------------|--------------------|-------------------|---|--|
| | Standard | Former | | |
| C12000, C12200, | WO61 | annealed | 30 [205] | 9 [62] ^C |
| C19200 | WO61 | annealed | 38 [260] | 12 [85] |
| C23000 | WO61 | annealed | 40 [275] | 12 [85] |
| C23000 | WC55 | light cold-worked | 42 (290) | 20 (138) |
| C44300, C44400, C44500 | WO61 | annealed | 45 [310] | 15 [105] |
| C44300, C44400, C44500 | WC55 | light cold-worked | 50 (345) | 35 (241) |
| C68700 | WO61 | annealed | 50 [345] | 18 [125] |
| C68700 | WC55 | light cold-worked | _D | _D |
| C70400 | WO61 | annealed | 38 [260] | 12 [85] |
| C70400 | WC55 | light cold-worked | 40 (275) | 30 (207) |
| C70600 | WO61 | annealed | 40 [275] | 15 [105] |
| C70600 | WC55 | light cold-worked | 45 (310) | 35 (241) |
| C70620 | WO61 | annealed | 40 [275] | 15 [105] |
| C70620 | WC55 | light cold-worked | | |
| C71000 | WO61 | annealed | 45 [310] | 16 [110] |
| C71000 | WC55 | light cold-worked | 50 (345) | 35 (241) |
| C71500 | WO61 | annealed | 52 [360] | 18 [125] |
| C71500 | WC55 | light cold-worked | 54 (372) | 35 (241) |
| C71520 | WO61 | annealed | 52 [360] | 18 [125] |
| C71520 | WC55 | light cold-worked | | |
| C72200 | WO61 | annealed | 45 [310] | 16 [110] |
| C72200 | WC55 | light cold-worked | 50 (345) | 30 (207) |

^A ksi = 1000 psi.

^B At 0.5 % extension under load.

^C Light straightening operation is permitted.

^D Where no properties are shown, strength requirements shall be as agreed upon between the purchaser and the manufacturer.

TABLE 3 Expansion Requirements

| Temper | Copper or Copper Alloy UNS No. | Expansion of Tube Outside Diameter, in Percent of Original Outside Diameter | |
|----------|--------------------------------------|--|----|
| Annealed | C12000 | 30 | |
| | C12200 | 30 | |
| | C19200 | 20 | |
| | C23000 | 20 | |
| | C44300, C44400, C44500 | 20 | |
| | C68700 | 20 | |
| | C70400 | 30 | |
| | C70600, 70620 | 30 | |
| | C71000 | 30 | |
| | C71500, C71520 | 30 | |
| | C72200 | 30 | |
| | Light cold-worked | C12200 | 20 |
| | | C70400 | 20 |
| C70600 | | 20 | |
| C71000 | | 20 | |
| C71500 | | 20 | |
| C71640 | | 20 | |
| C72200 | | 20 | |

12.1.4 If the ammonia vapor test, Test Method B 858 is selected, the appropriate risk level pH value for the test solution shall be agreed upon by the manufacturer and purchaser, or alternately, if the purchaser defers to the manufacturer's expertise for the selection of the test pH value, the minimum value selected shall be 9.8.

13. Nondestructive Testing

13.1 Each tube shall be subjected to an eddy-current test in 13.2. Fully finished tube (see 4.1) may be tested in the as-fabricated or annealed tempers, unless otherwise agreed upon between the manufacturer or supplier and the purchaser. The purchaser may specify either of the tests in 13.3 or 13.4 as an alternative to the eddy-current test.

13.2 *Eddy Current Test*—Each tube shall be passed through an eddy-current testing unit adjusted to provide information on the suitability of the tube for the intended application. Testing shall follow the procedures of Practice E 243, except as modified in 19.2.9.1.

13.2.1 Tubes that do not actuate the signaling device of the eddy-current tester shall be considered as conforming to the requirements of this test. Tubes causing irrelevant signals because of moisture, soil, and like effects may be reconditioned and retested. Such tubes, when retested to the original test parameters, shall be considered to conform if they do not cause output signals beyond the acceptable limits. Tubes causing irrelevant signals because of visible and identifiable handling marks may be retested by the hydrostatic test prescribed in 13.3, or the pneumatic test prescribed in 13.4. Tubes meeting requirements of either test shall be considered to conform if the tube dimensions are within the prescribed limits, unless otherwise agreed to by the manufacturer or supplier and the purchaser.

13.3 *Hydrostatic Test*—(If required on the purchase order), each tube, without showing evidence of leakage, shall withstand an internal hydrostatic pressure sufficient to subject the material in the unenhanced region of the tube to a fiber stress of 7000 psi [48 MPa], as determined by the following equation for thin hollow cylinders under tension:

$$P = \frac{2St}{(D - 0.8t)} \quad (1)$$

where:

P = hydrostatic pressure, psig, [MPa],

t = thickness of tube wall, in., [mm],

D = outside diameter of tube, in., [mm], and

S = allowable fiber stress of the material, psi, [MPa].

13.3.1 The tube need not be tested at a hydrostatic pressure over 1000 psi [6.9 MPa] unless so specified.

13.4 *Pneumatic Test*—(If required on the purchase order), each tube, after enhancing, shall withstand a minimum internal air pressure of 250 psig [1.7 MPa] for 5 s and any evidence of leakage shall be cause for rejection. The test method used shall permit easy visual detection of any leakage, such as having the tube under water, or by the pressure differential method.

13.5 *ASME Pressure Vessel Code*:

13.5.1 When tubes are specified to meet the requirements of the ASME Boiler and Pressure Vessel Code, eddy current testing as described in 13.2 is required on enhanced tube, and a pressure test as described in 13.3 or 13.4 is required.

14. Dimensions, Mass, and Permissible Variations

14.1 *Diameters*—The outside diameter of the tubes shall not vary from that specified by more than the amounts shown in Table