



Standard Specification for Copper-Nickel-Tin Alloy, Copper-Nickel-Zinc Alloy (Nickel Silver), and Copper-Nickel Alloy Plate, Sheet, Strip, and Rolled Bar¹

This standard is issued under the fixed designation B 122/B 122M; 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 establishes the requirements for copper-nickel-tin alloy, copper-nickel-zinc alloy (nickel silver), and copper-nickel alloy plate, sheet, strip, and rolled bar. The following alloys are covered:

Copper Alloy UNS No. ²	Previously Used Designation	Nominal Composition, %				Chro- mium
		Copper	Nickel	Zinc	Tin	
C70600	...	90	10	...	...	...
C70620	...	86	10	...	...	...
C71000	6	80	20	...	...	...
C71500	5	70	30	...	...	...
C71520	...	65	31	...	...	...
C72200	...	85	15	...	...	0.5
C72500	...	89	9	...	2	...
C73500	1	72	18	10	...	...
C74000	9	70	10	20	...	...
C74500	3	65	10	24	...	...
C75200	2	65	18	17	...	...
C76200	8	59	12	29	...	...
C77000	4	55	18	27	...	...

NOTE 1—Plates of copper-nickel alloy Copper Alloy UNS Nos. C70600, C70620, C71500, C71520, and C72200 for use as tube plates in surface condensers and heat exchangers are covered by Specification B 171/B 171M.

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as 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

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² 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.

be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.2.1 When the product is ordered in inch-pound units, the inch-pound units are to be regarded as the standard except grain size is always specified in millimetres.

1.2.2 When the product is ordered in SI units, the SI units are to be regarded as the standard.

2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.2 ASTM Standards:

B 171/B 171M Specification for Copper-Alloy Plate and Sheet for Pressure Vessels, Condensers, and Heat Exchangers³

B 248 Specification for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar³

B 248M Specification for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar (Metric)³

B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast³

B 846 Terminology for Copper and Copper Alloys³

E 8 Test Methods for Tension Testing of Metallic Materials⁴

E 8M Test Methods for Tension Testing of Metallic Materials [Metric]⁴

E 112 Test Methods for Determining Average Grain Size⁴

E 255 Practice for Sampling Copper and Copper Alloys for Determination of Chemical Composition⁵

³ Annual Book of ASTM Standards, Vol 02.01.

⁴ Annual Book of ASTM Standards, Vol 03.01.

⁵ Annual Book of ASTM Standards, Vol 03.05.

*A Summary of Changes section appears at the end of this standard.

E 478 Test Methods for Chemical Analysis of Copper Alloys⁶
 E 527 Practice for Numbering Metals and Alloys (UNS)⁷

3. General Requirements

3.1 The following sections of Specification B 248 constitute a part of this specification:

- 3.1.1 Terminology—Definitions,
- 3.1.2 Materials and Manufacturing,
- 3.1.3 Workmanship, Finish, and Appearance,
- 3.1.4 Sampling—except for chemical analysis,
- 3.1.5 Number of Tests and Retests,
- 3.1.6 Specimen Preparation,
- 3.1.7 Test Methods—except for chemical analysis,
- 3.1.8 Significance of Numerical Limits,
- 3.1.9 Inspection,
- 3.1.10 Rejection and Rehearing,
- 3.1.11 Certification,
- 3.1.12 Test Reports (Mill),
- 3.1.13 Packaging and Package Marking, and
- 3.1.14 Supplementary Requirements,

3.2 In addition, when a section with a title identical to that referenced in 4.1 appears in this specification, it contains additional requirements, which supplement those appearing in Specification B 248.

4. Terminology

4.1 *Definitions*—For standard terms related to copper and copper alloys, refer to Terminology B 846.

5. Ordering Information

5.1 Orders for products under this specification should include the following information:

5.1.1 ASTM designation and year of issue (B 122/B 122M–01),

- 5.1.2 Copper (alloy) UNS number designation,
- 5.1.3 Temper (Section 8),
- 5.1.4 Dimensions: thickness and width (see Section 12),
- 5.1.5 Type of edge, if required: slit, sheared, sawed, square corners, rounded corners, rounded edges, or full rounded edges,
- 5.1.6 How furnished: flat or rolls,
- 5.1.7 Length (see Section 12), and
- 5.1.8 Weight: total for each size.

5.2 In addition, when material is purchased for agencies of the U.S. government, it shall conform to the Supplementary Requirements as defined in Specification B 248 when specified in the contract or purchase order.

6. Materials and Manufacture

6.1 *Material*

6.1.1 The material of manufacture shall be a cast bar, cake, slab, and so forth of Copper Alloy UNS No. C70600, C70620, C71000, C71500, C71520, C72200, C72500, C73500, C74000, C74500, C75200, C76200, or C77000 as specified in the ordering information.

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

NOTE 2—Because of the discontinuous nature of the processing of castings into wrought products, it is not always practical to identify a specific casting analysis with a specific quantity of finished material.

6.2 *Manufacture:*

6.2.1 The product shall be manufactured by such hot-working, cold-working, and annealing processes as to produce a uniform wrought structure in the finished product.

6.2.2 The product shall be hot or cold worked to the finished size and subsequently annealed, when required, to meet the temper properties specified in the ordering information.

6.2.3 *Edges*—Slit edges shall be furnished unless otherwise specified in the contract or purchase order.

7. Chemical Composition

7.1 The material shall conform to the chemical composition prescribed in Table 1.

TABLE 1 Chemical Requirements

Copper Alloy UNS No.	Composition, %								
	Copper, incl Silver	Nickel, incl Cobalt	Lead, max	Iron, max	Manganese, max	Zinc	Tin	Chromium	Other Named Elements
C70600	remainder	9.0–11.0 ^A	0.05 ^B	1.0–1.8	1.0	1.0 ^B max	...	...	^B
C70620	86.5 min	9.0–11.0	0.02	1.0–1.8	1.0	0.50 max	...	...	^C
C71000	remainder	19.0–23.0	0.05 ^B	1.0 max	1.0	1.0 ^B max	...	...	^B
C71500	remainder	29.0–33.0 ^A	0.05 ^B	0.40–1.0	1.0	1.0 ^B max	...	...	^B
C71520	65.0 min	28.0–33.0	0.02	0.40–1.0	1.0	0.50 max	...	...	^C
C72200	remainder	15.0–18.0	0.05 ^B	0.50–1.0	1.0	1.0 ^B	...	0.30–0.70	^B
C72500	remainder	8.5–10.5	0.05	0.6	0.2	0.5 max	1.8–2.8	...	^D
C73500	70.5–73.5	16.5–19.5	0.10	0.25 max	0.50	remainder	...	...	...
C74000	69.0–73.5	9.0–11.0	0.10	0.25 max	0.50	remainder	...	...	...
C74500	63.5–66.5	9.0–11.0	0.10	0.25 max	0.50	remainder	...	...	...
C75200	63.5–66.5	16.5–19.5	0.05	0.25 max	0.50	remainder	...	...	...
C76200	57.0–61.0	11.0–13.5	0.10	0.25 max	0.50	remainder	...	...	...
C77000	53.5–56.5	16.5–19.5	0.05	0.25 max	0.50	remainder	...	...	...

^A Copper plus elements with specific limits, 99.5 % min.

^B When the product is for subsequent welding applications and so specified by the purchaser, zinc shall be 0.50 % max, lead 0.02 % max, phosphorus 0.02 % max, sulfur 0.02 % max, and carbon 0.05 % max.

^C Phosphorus at 0.2 % max, sulfur at 0.02 % max, and carbon at 0.05 % max.

^D Silicon and titanium each at 0.03 % max.

7.2 These specification limits do not preclude the presence of other elements. Limits may be established for unnamed elements by agreement between manufacturer or supplier and purchaser.

7.2.1 For copper alloys for which copper is specified as a remainder, copper may be taken as the difference between the sum of all the elements analyzed and 100 %. When all the elements in Table 1 are analyzed, their sum shall be as follows:

Copper Alloy UNS No.	Copper Plus Named Elements, % min
C70600	99.5
C70620	99.5
C71000	99.5
C71500	99.5
C71520	99.5
C72200	99.8
C72500	99.8

7.2.2 For copper alloys for which zinc is specified as a remainder, either copper or zinc may be taken as the difference between the sum of all elements analyzed and 100 %. When all elements in Table 1 are analyzed, their sum shall be as follows:

Copper Alloy UNS No.	Copper Plus Named Elements, % min
C73500	99.5
C74000	99.5
C74500	99.5
C75200	99.5
C76200	99.5
C77000	99.5

8. Temper

8.1 *As Hot-Rolled (M20) Tempers*—The standard temper of sheet and plate produced by hot rolling and is as designated in Table 2.

8.2 *Cold Rolled (H) Tempers*—The standard tempers of cold rolled tempers are as designated in Table 2 with the prefix “H.” Former designations and the standard designations as defined in Practice B 601 are shown. Special or nonstandard tempers are subject to negotiation between manufacturer and purchaser (See 5.1.2).

8.3 *Annealed Tempers*—The standard tempers are indicated in Table 3.

9. Grain Size for Annealed Tempers

9.1 Grain size shall be the standard requirement for all products in the annealed tempers.

9.2 Acceptance or rejection based upon grain size shall depend only on the average grain size of test specimens taken from each of two sampling portions and each specimen shall be within the limits prescribed in Table 3 when determined in accordance with Test Methods E 112.

9.3 Grain size shall be determined on a plane parallel to the flat surfaces of the product.

10. Mechanical Property Requirements

10.1 Tensile Strength Requirements:

10.1.1 Products ordered to this specification in inch-pound units shall be tested in accordance with Test Methods E 8 and shall conform to tensile strength requirements prescribed in ksi units in Table 2.

10.1.2 Products ordered to this specification in SI units shall be tested in accordance with Test Methods E 8M, and shall conform to tensile strength requirements prescribed in MPa units in Table 2.

10.1.3 Acceptance or rejection based on mechanical properties shall depend only on the tensile strength.

10.1.4 The tension test specimens shall be taken so the longitudinal axis of the specimens is parallel to direction of rolling.

10.2 Rockwell Hardness:

10.2.1 The approximate Rockwell hardness values given in Tables 2 and 4 are for general information and assistance in testing and shall not be used as a basis for product rejection.

NOTE 3—The Rockwell hardness test offers a quick and convenient method of checking for general conformity to the specification requirements for temper, tensile strength, and grain size.

11. Other Requirements

11.1 *Purchases for U.S. Government Agencies*—When identified in the contract or purchase order, product purchased for agencies of the U.S. government shall conform to the special government requirements stipulated in the supplemental requirements given in Specification B 248.

12. Dimensions, Mass, and Permissible Variations

12.1 The inch-pound dimensions and tolerances for products covered by this specification shall be as prescribed in the current edition of Specification B 248, and the SI dimensions and tolerances covered by this specification shall be as prescribed in the current edition of Specification B 248M.

12.2 *Thickness*—When special thickness tolerances for Copper Alloy UNS No. C72500 are required, see appropriate table.

12.3 Width:

12.3.1 *Slit Metal and Slit Metal with Rolled Edges.*

12.3.2 *Square-Sheared Metal.*

12.3.3 *Sawed Metal.*

12.4 Length:

12.4.1 *Specific and Stock Lengths With and Without Ends.*

12.4.2 *Schedule of Lengths (Specific and Stock) with Ends.*

12.4.3 *Length Tolerances for Square-Sheared Metal.*

12.4.4 *Length Tolerances for Sawed Metal.*

12.5 Straightness:

12.5.1 *Slit Metal or Slit Metal Either Straightened or Edge-Rolled.*

12.5.2 *Square-Sheared Metal.*

12.5.3 *Sawed Metal.*

12.6 Edges:

12.6.1 *Square Edges.*

12.6.2 *Rounded Corners.*

12.6.3 *Rounded Edges.*

12.6.4 *Full-Rounded Edges.*

13. Workmanship, Finish and Appearance

13.1 The product shall be free of defects, but blemishes of a nature that does not interfere with the intended application are acceptable.

TABLE 2 Tensile Strength Requirements and Approximate Rockwell Hardness Values for Rolled Tempers

NOTE 1—Plate is generally available in only the as hot-rolled (M20) tempers. Required properties for other tempers shall be agreed upon between manufacturer and purchaser at the time of placing the order.

Temper Designation		Tensile Strength, ksi ^A [MPa ^B]		Approximate Rockwell Hardness ^{C,D}		
Standard	Former	Min	Max	G Scale	B Scale	Superficial 30-T
Copper Alloy UNS No. C70600† and C70620						
M20	as hot-rolled	40 [275]	62 [425]	...	...	...
H01	quarter hard	51 [350]	67 [460]	...	51–78	52–70
H02	half hard	58 [400]	72 [495]	...	66–81	61–72
H04	hard	71 [490]	83 [570]	...	76–86	67–74
H06	extra hard	73 [505]	85 [585]	...	80–88	71–77
H08	spring	78 [540]	88 [605]	...	83–91	72–78
Copper Alloy UNS No. C71000						
M20	as hot-rolled	38 [260]	56 [385]	...	...	...
H01	quarter hard	47 [325]	63 [435]	...	45–72	46–65
H02	half hard	56 [385]	70 [485]	...	64–78	59–69
H04	hard	67 [460]	79 [545]	...	76–84	67–73
H06	extra hard	72 [495]	84 [580]	...	79–87	69–75
H08	spring	76 [525]	87 [600]	...	82–88	71–75
Copper Alloy UNS No. C71500 and C71520						
M20	as hot-rolled	45 [310]	65 [450]	...	...	...
H01	quarter hard	58 [400]	72 [495]	...	67–81	61–71
H02	half hard	66 [455]	80 [550]	...	76–85	67–74
H04	hard	75 [515]	88 [605]	...	83–89	72–76
H06	extra hard	80 [550]	92 [635]	...	85–91	73–77
H08	spring	84 [580]	94 [650]	...	87–91	74–77
Copper Alloy UNS No. C72200						
M20	as hot-rolled	42 [290]	62 [425]	...	...	...
H01	quarter hard	55 [380]	67 [460]	...	63–78	58–70
H02	half hard	58 [400]	72 [495]	...	66–85	61–73
H04	hard	71 [490]	85 [585]	...	76–88	67–78
H06	extra hard	73 [505]	90 [620]	...	79–90	69–78
H08	spring	78 [540]	91 [625]	...	81–91	71–79
Copper Alloy UNS No. C72500						
M20	as hot-rolled	50 [345]	70 [485]	...	...	...
H01	quarter hard	55 [380]	75 [515]	...	Up to 85	Up to 72
H02	half hard	65 [450]	80 [550]	...	70–90	62–75
H04	hard	75 [515]	90 [620]	...	75–90	66–75
H06	extra hard	80 [550]	95 [655]	...	80–95	70–80
H08	spring	85 [585]	100 [690]	...	85–95	72–80
H10	extra spring	90 [620]	105 [725]	...	87–95	76–80
H14	super spring	100 [690]	125 [860]	...	92 and over	78 and over
Copper Alloy UNS No. C73500						
M20	as hot-rolled	48 [330]	63 [435]	...	...	...
H01	quarter hard	56 [385]	69 [475]	20–47	66–80	60–70
H02	half hard	63 [435]	75 [515]	38–53	75–84	67–73
H04	hard	73 [505]	84 [580]	51–61	83–88	72–75
H06	extra hard	79 [545]	90 [620]	57–65	86–90	74–76
Copper Alloy UNS No. C74000						
M20	as hot-rolled	48 [330]	63 [435]	...	...	...
H01	quarter hard	55 [380]	70 [485]	...	60–80	...
H02	half hard	63 [435]	77 [530]	...	70–85	...
H04	hard	73 [505]	87 [600]	...	79–91	...
H06	extra hard	79 [545]	91 [625]	...	83–93	...
Copper Alloy UNS No. C74500						
M20	as hot-rolled	48 [330]	65 [450]	...	...	...
H01	hard	56 [385]	73 [505]	...	51–80	50–70
H02	half hard	67 [460]	82 [565]	...	72–87	65–75
H04	hard	80 [550]	94 [650]	...	85–92	73–78
H06	extra hard	89 [615]	102 [700]	...	90–94	76–79
H08	spring	95 [655]	108 [740]	...	92–96	77–80
Copper Alloy UNS No. C75200						
M20	as hot-rolled	52 [355]	65 [450]	...	...	...
H01	quarter hard	58 [400]	72 [495]	...	50–75	49–67

TABLE 2 Continued

Temper Designation		Tensile Strength, ksi ^A [MPa ^B]		Approximate Rockwell Hardness ^{C,D}		
Standard	Former	Min	Max	G Scale	B Scale	Superficial 30-T
H02	half hard	66 [455]	80 [550]	...	68–82	62–72
H04	hard	78 [540]	91 [625]	...	80–90	70–76
H06	extra hard	86 [595]	98 [675]	...	87–94	74–79
H08	spring	90 [620]	101 [700]	...	89–96	75–80
Copper Alloy UNS No. C76200						
M20	as hot-rolled	55 [380]	75 [515]	...	...	...
H01	quarter hard	65 [450]	81 [560]	...	61–85	57–74
H02	half hard	75 [515]	91 [625]	...	78–91	69–77
H04	hard	90 [620]	105 [720]	...	90–95	76–79
H06	extra hard	99 [685]	114 [790]	...	94–98	79–81
H08	spring	107 [740]	122 [840]	...	97–100	80 and over
Copper Alloy UNS No. C77000						
M20	as hot-rolled	60 [415]	80 [550]	...	...	...
H01	quarter hard	69 [475]	87 [600]	23–62	70–88	63–75
H02	half hard	78 [540]	95 [655]	51–69	81–92	71–78
H04	hard	92 [635]	109 [750]	67–76	90–96	76–80
H06	extra hard	102 [700]	117 [810]	73–80	95–99	79–82
H08	spring	108 [740]	123 [850]	77–83	97–100	80 and over

^Aksi = 1000 psi.

^BSee Appendix X1.

^CRockwell hardness values apply as follows: The B and G scale hardness values apply to metal 0.020 in. (0.508 mm) and over in thickness, and the 30-T scale hardness values apply to metal 0.012 in. (0.305 mm) and over in thickness.

^DStandard designation defined in Practice B 601.

TABLE 3 Grain Size Requirements for Annealed Material

Copper Alloy UNS No.	Standard Temper Designa- tion ^A	Grain Size, mm		
		Nomi- nal	Min	Max
C70600, C70620, C71000, C71500, C71520, C72200, C72500, C73500, and C76200	OS035	0.035	0.025	0.050
	OS015	0.015	^B	0.025
C74000, C74500, C75200, and C77000	OS070	0.070	0.050	0.100
	OS035	0.035	0.025	0.050
	OS015	0.015	^B	0.025

^AStandard designation defined in Practice B 601.

^BAlthough no minimum grain size is required, this material shall be fully recrystallized.

14. Sampling

14.1 Chemical Analysis:

14.1.1 The sample for chemical analysis shall be taken from the pieces selected and combined into one composite sample in accordance with Practice E 255 for product in its final form. The minimum weight of the composite sample shall be 150 g.

14.1.2 Instead of sampling in accordance with Practice E 255, the manufacturer shall have the option of taking samples at the time the castings are poured or by taking samples from the semifinished product.

14.1.2.1 When composition of the material has been determined during the course of manufacture, sampling of the finished product by the manufacturer is not required.

14.1.3 The number of samples to be taken for determination of chemical composition shall be as follows:

14.1.3.1 When sampled at the time the castings are poured, at least one sample shall be taken for each group of castings poured from the same source of molten metal.

14.1.3.2 When sampled from the semifinished product, at least one sample shall be taken to represent each 10 000 lb, or fraction thereof, except that not more than one sample shall be required per piece.

14.1.3.3 Only one sample need be taken from the semifinished product of one cast bar from a single furnace melt charge continuously processed.

14.1.3.4 When the material is cast in the horizontal continuous casting mode, at least one sample will be taken to represent the composition of the holder per cast coil.

15. Test Methods

15.1 Chemical Analysis:

15.1.1 Chemical composition shall be determined, in case of disagreement, by the following appropriate methods:

Element	Test Method
Copper	E 478
Nickel	E 478 (gravimetric)
Chromium	E 478 (AA)
Tin	E 478 (photometric)
Zinc	E 478 (AA)

15.1.2 Test methods(s) used for the determination of other element(s) required by contractual or purchase order agreement shall be as agreed upon between the manufacturer and the purchaser.

16. Keywords

16.1 copper-nickel plate; copper-nickel rolled bar; copper-nickel sheet; copper-nickel strip; copper-nickel-tin plate; copper-nickel-tin rolled bar; copper-nickel-tin sheet; copper-nickel-tin strip; copper-nickel-zinc plate; copper-nickel-zinc rolled bar; copper-nickel-zinc sheet; copper-nickel-zinc strip

**TABLE 4 Approximate Rockwell Hardness of Annealed Material**

Standard Designation	Temper		Approximate Rockwell Hardness ^A		
	Nominal Grain Size, mm		B Scale	F Scale	Superficial 30-T
Copper Alloy UNS No. C70600 and C70620					
OS035	0.035		10–27	55–72	15–34
OS015	0.015		16–48	65–83	25–45
Copper Alloy UNS No. C71000					
OS035	0.035		18–35	67–76	28–40
OS015	0.015		35–58	76–90	40–55
Copper Alloy UNS No. C71500 and C71520					
OS035	0.035		23–45	70–85	31–46
OS015	0.015		37–63	74–93	40–58
Copper Alloy UNS No. C72200					
OS035	0.035		14–31	...	24–36
OS015	0.015		18–42	...	26–41
Copper Alloy UNS No. C72500					
OS035	0.035		24–39	70–81	32–42
OS015	0.015		37–61	78–92	41–58
Copper Alloy UNS No. C73500					
OS035	0.035		20–35	70–80	29–40
OS015	0.015		28–55	76–90	34–53
Copper Alloy UNS No. C74000					
OS070	0.070		5–20	...	...
OS035	0.035		20–40	...	...
OS015	0.015		35–55	...	...
Copper Alloy UNS No. C74500					
OS070	0.070		15–30	63–73	26–36
OS035	0.035		23–41	70–80	31–44
OS015	0.015		41–59	80–90	44–56
Copper Alloy UNS No. C75200					
OS070	0.070		25–40	70–80	32–43
OS035	0.035		35–55	75–88	40–53
OS015	0.015		45–70	83–93	46–64
Copper Alloy UNS No. C76200					
OS035	0.035		20–35	70–80	...
OS015	0.015		28–55	76–90	...
Copper Alloy UNS No. C77000					
OS070	0.070		29–45	72–83	35–46
OS035	0.035		37–60	76–91	41–57
OS015	0.015		47–73	84–98	47–65

^ARockwell hardness values apply as follows: The B and F scale hardness values apply to metal 0.020 in. (0.508 mm) and over in thickness and the 30-T scale hardness values apply to metal 0.015 in. (0.381 mm) and over in thickness.

APPENDIX

(Nonmandatory Information)

X1. METRIC EQUIVALENTS

X1.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ($N = \text{kg}\cdot\text{m}/\text{s}^2$). The derived SI unit for pressure or

stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since $1 \text{ ksi} = 6\,894\,757 \text{ Pa}$, the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2 .

SUMMARY OF CHANGES

Committee B05 has identified the location of selected changes to this standard since the last issue (B 122/B 122M-95) that may impact the use of this standard.

- | | |
|---|--|
| (1) Changed scope (covers). | (6) Added section on other requirements. |
| (2) Added terminology section. | (7) Added section on sampling. |
| (3) Changed ordering information to match outline of form. | (8) Added alloys C70620 and C71520 to this standard in |
| (4) Added section on materials and manufacturing. | Section 1 (Scope) and Tables 1-4. |
| (5) Revised sections on grain size and mechanical properties. | |

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