Designation: B283/B283M – 17

Standard Specification for Copper and Copper-Alloy Die Forgings (Hot-Pressed)[1]

This standard is issued under the fixed designation B283/B283M; 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 U.S. Department of Defense.

1. Scope*

1.1 This specification establishes the requirements for copper and copper alloy die forgings produced by the hot pressing method. The following copper and copper alloys are included:

Copper or Copper Alloy UNS No.	Name
C11000	copper
C14500	copper-tellurium
C14700	copper-sulfur
C27450	plumbing brass
C27451	plumbing brass
C27453	copper zinc alloy
C28500	copper-zinc brass
C35330	leaded brass
C36500	leaded Muntz metal
C37000	free-cutting Muntz metal
C37700	forging brass
C46400	naval brass
C46750	tin brass
C48200	medium leaded naval brass
C48500	leaded naval brass
C48600	naval brass
C49250	copper-zinc-bismuth alloy
C49255	copper-zinc-bismuth-nickel alloy
C49260	copper-zinc-bismuth alloy
C49265	copper-zinc-tin-bismuth, low leaded
C49300	copper-zinc-tin-bismuth alloy
C49340	copper-zinc-tin-bismuth alloy
C49345	copper-zinc-tin-bismuth, low leaded
C49350	copper-zinc-tin-bismuth alloy
C49355	bismuth brass
C61900	aluminum bronze
C62300	aluminum bronze, 9 %
C63000	aluminum-nickel bronze
C63200	aluminum-nickel bronze
C64200	aluminum-silicon bronze
C64210	aluminum-silicon bronze, 6.7 %
C65500	high-silicon bronze (A)
C67500	manganese bronze (A)
C67600	. . .
C69300	copper-zinc-silicon
C70620	copper-nickel 90-10
C71520	copper-nickel 70-30
C77400	nickel silver, 45-10
C87700	silicon bronze
C87710	silicon bronze

1.2 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

NOTE 1—Nominal composition and relative forgeability ratings are given in Appendix X1. Copper-nickel alloys C70620 and C71520 are intended for welded applications with seawater exposure.

NOTE 2—Guidelines for design and development of forgings are included in Appendix X2.

NOTE 3—Wrought product intended for hot forging is described in Specification B124/B124M.

1.3 The following safety caveat pertains only to Section 10 of 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.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B124/B124M Specification for Copper and Copper Alloy Forging Rod, Bar, and Shapes

B249/B249M Specification for General Requirements for Wrought Copper and Copper-Alloy Rod, Bar, Shapes and Forgings

B846 Terminology for Copper and Copper Alloys

E8/E8M Test Methods for Tension Testing of Metallic Materials

E62 Test Methods for Chemical Analysis of Copper and

[1] This specification is under the jurisdiction of ASTM Committee B05 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.02 on Rod, Bar, Wire, Shapes and Forgings.

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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.

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

Copper Alloys (Photometric Methods) (Withdrawn 2010)[3]
E75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys (Withdrawn 2010)[3]
E478 Test Methods for Chemical Analysis of Copper Alloys
2.2 *Other Standards:*
ASME Boiler and Pressure Vessel Code[4]
ISO 7602 Determination of Tellurium Content (High Content)—Flame Atomic Absorption Spectrometric Method[5]
JIS H 1068:2005 Method for Determination of Bismuth in Copper and Copper Alloys[6] (Japanese Industrial Standards)
2.3 *Military Standards:*[7]
MIL-STD-792 Identification Marking Requirements for Special Purpose Components
NAVSEA T9074-AS-GIB-010/271 Requirements for Nondestructive Testing Method

3. General Requirements

3.1 The following sections of Specification B249/B249M constitute a part of this specification:
3.1.1 Terminology,
3.1.2 Materials and Manufacture,
3.1.3 Workmanship, Finish, and Appearance,
3.1.4 Sampling,
3.1.5 Number of Tests and Retests,
3.1.6 Specimen Preparation,
3.1.7 Test Methods,
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,
3.1.13 Packaging and Package Marking, and
3.1.14 Supplementary Requirements.
3.1.15 In addition, when a section with a title identical to one of those referenced in 3.1, above, appears in this specification, it contains additional requirements that supplement those appearing in Specification B249/B249M.

4. Terminology

4.1 *Definitions:*
4.1.1 For definitions of terms related to copper and copper alloys, refer to Terminology B846.
4.2 *Definitions of Terms Specific to This Standard:*
4.2.1 *hot pressed forging, n*—a product made by pressing a heated blank or section of wrought or cast copper or copper alloy in a closed impression die.

5. Ordering Information

5.1 Include the following information when placing orders for products to this specification, as applicable:
5.1.1 ASTM designation and year of issue,
5.1.2 Copper or Copper Alloy UNS No. designation (Scope),
5.1.3 Drawing showing the shape dimensions and tolerances (Dimensions and Permissible Variations),
5.1.4 Temper (as specified herein),
5.1.5 Quantity: total weight or number of pieces for each form, temper, and copper or copper alloy,
5.1.6 When product is purchased for agencies of the U.S. government (as specified herein), and
5.1.7 When product must adhere to the requirements of *ASME Boiler and Pressure Vessel Code* (Mechanical Property Requirements).

5.2 The following requirements are optional and shall be specified in the contract or purchase order.
5.2.1 Certification (as specified herein and Supplementary Requirements),
5.2.2 Mill test report (as specified in Specification B249/B249M), and
5.2.3 Ultrasonic inspection report (Supplementary Requirements).

6. Materials and Manufacture

6.1 *Materials:*
6.1.1 The material of manufacture shall be a form of rods, billets, or blanks cut from cast or wrought material of one of the copper or copper alloys listed in the Scope of this specification and of purity and soundness as to be suitable for processing in to the products prescribed herein.
6.1.2 In the event heat identification or traceability is required, the purchaser shall specify the details desired.

NOTE 4—Due to the discontinuous nature of the processing of castings into wrought products, it is not always practical to identify specific casting analysis with a specific quantity of finished material.

6.2 *Manufacture:*
6.2.1 The product shall be manufactured by hot pressing material between the upper and lower sections of a set of dies conforming to the configuration defined by the purchaser's submitted drawings.
6.2.2 Product of Copper Alloy UNS No. C63000 and C63200 shall be heat treated (as specified herein).

7. Chemical Composition

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

7.2 These composition limits do not preclude the presence of other elements. By agreement between manufacturer and purchaser, limits may be established and analysis required for unnamed elements.
7.2.1 For alloys in which copper is listed as "remainder," copper is the difference between the sum of results of all elements determined and 100 %.

[3] The last approved version of this historical standard is referenced on www.astm.org.
[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.
[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[6] Available from Japanese Standards Association (JSA), Mita MT Bldg., 3-13-12 Mita, Minato-ku, Tokyo, 108-0073, Japan, http://www.jsa.or.jp.
[7] Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, http://quicksearch.dla.mil/.

TABLE 1 Chemical Requirements

Copper or Copper Alloy UNS No.	Composition, %													
	Copper	Lead	Tin	Iron	Nickel (incl Co)	Aluminum	Silicon	Manganese	Zinc	Sulfur	Tellurium	Phosphorus	Arsenic	Bismuth
C11000	99.90[A] min	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
C14500[B]	99.90[C] min	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.40–0.7	0.004–0.012[D]	. . .	. . .
C14700[B]	99.90[E] min	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.20–0.50	. . .	0.002–0.005[D]	. . .	. . .
C27450	60.0–65.0	0.25 max	. . .	0.35 max	. . .	. . .	. . .	. . .	remainder	. . .	. . .	. . .	. . .	. . .
C27451	61.0–65.0	0.25 max	. . .	0.35 max	. . .	. . .	. . .	. . .	remainder	. . .	. . .	0.05–0.20	. . .	. . .
C27453	61.5–63.5	0.25 max	0.15 max	0.15 max	. . .	. . .	. . .	. . .	remainder	. . .	. . .	. . .	0.02–0.15	
C28500	57.0–59.0	0.25 max	. . .	0.35 max	. . .	. . .	. . .	. . .	remainder	. . .	. . .	. . .	. . .	. . .
C35330	59.5–64.0	1.5–3.5	. . .	. . .	. . .	. . .	. . .	. . .	remainder	. . .	. . .	. . .	0.02–0.25	. . .
C36500	58.0–61.0	0.25–0.7	0.25 max	0.15 max	. . .	. . .	. . .	. . .	remainder	. . .	. . .	. . .	. . .	. . .
C37000	59.0–62.0	0.8–1.5	. . .	0.15 max	. . .	. . .	. . .	. . .	remainder	. . .	. . .	. . .	. . .	. . .
C37700	58.0–61.0	1.5–2.5	. . .	0.30 max	. . .	. . .	. . .	. . .	remainder	. . .	. . .	. . .	. . .	. . .
C46400	59.0–62.0	0.20 max	0.50–1.0	0.10 max	. . .	. . .	. . .	. . .	remainder	. . .	. . .	. . .	. . .	. . .
C46750[F]	59.2–62.5	0.25 max	1.00–1.80	0.10 max	0.50 max	. . .	. . .	. . .	remainder	. . .	. . .	0.05–0.15	. . .	. . .
C48200	59.0–62.0	0.40–1.0	0.50–1.0	0.10 max	. . .	. . .	. . .	. . .	remainder	. . .	. . .	. . .	. . .	. . .
C48500	59.0–62.0	1.3–2.2	0.50–1.0	0.10 max	. . .	. . .	. . .	. . .	remainder	. . .	. . .	. . .	. . .	. . .
C48600	59.0–62.0	1.0–2.5	.30–1.5	. . .	. . .	. . .	. . .	. . .	remainder	. . .	. . .	. . .	0.02–0.25	. . .
C49250[G]	58.0–61.0	0.09 max	0.30 max	0.50 max	. . .	. . .	. . .	. . .	remainder	. . .	. . .	. . .	. . .	1.8–2.4
C49255[H]	58.0–60.0	0.01 max	0.50 max	0.10 max	0.10-0.30	. . .	0.10 max	. . .	remainder	. . .	. . .	0.10 max	. . .	1.7–2.9
C49260[G]	58.0–63.0	0.09 max	0.50 max	0.50 max	. . .	. . .	0.10 max	. . .	remainder	. . .	. . .	0.05-0.15	. . .	0.50–1.8
C49265[G]	58.0–62.0[A]	0.09–0.25	0.50 max	0.30 max	. . .	. . .	0.10 max	. . .	remainder	. . .	. . .	0.05–0.12	. . .	0.50–1.3
C49300[I]	58.0–62.0	0.01 max	1.0–1.8	0.10 max	1.5 max	0.50 max	0.10 max	0.03 max	remainder	. . .	. . .	0.20 max	. . .	0.50–2.0
C49340[G]	60.0–63.0	0.09 max	0.50–1.5	0.12 max	. . .	. . .	0.10 max	. . .	remainder	. . .	. . .	0.05-0.15	. . .	0.50–2.2
C49345[G]	60.0–64.0[A]	0.09–0.25	0.50–1.5	0.30 max	. . .	. . .	0.10 max	. . .	remainder	. . .	. . .	0.05–0.12	. . .	0.50–1.3
C49350[J]	61.0–63.0	0.09 max	1.5–3.0	0.12 max	. . .	. . .	0.30 max	. . .	remainder	. . .	. . .	0.04-0.15	. . .	0.50–2.5
C49355[K]	63.0–69.0	0.09 max	0.50-2.0	0.10 max	. . .	. . .	1.0-2.0	0.10 max	27.0–35.0	. . .	. . .	. . .	. . .	0.50–1.5
C61900	remainder	0.02 max	0.6 max	3.0–4.5[L]	. . .	8.5–10.00	. . .	. . .	0.8 max	. . .	. . .	. . .	. . .	. . .
C62300	remainder	. . .	0.6 max	2.0–4.0	1.0 max	8.5–10.0	0.25 max	0.50 max	. . .	. . .	. . .	. . .	. . .	. . .
C63000	remainder	. . .	0.20 max	2.0–4.0	4.0–5.5	9.0–11.0	0.25 max	1.5 max	0.30 max	. . .	. . .	. . .	. . .	. . .
C63200	remainder	0.02 max	. . .	3.5–4.3[M]	4.0–4.8	8.7–9.5	0.10 max	1.2–2.0	. . .	. . .	. . .	. . .	. . .	. . .
C64200	remainder	0.05 max	0.20 max	0.30 max	0.25 max	6.3–7.6	1.5–2.2	0.10 max	0.50 max	. . .	. . .	. . .	0.09 max	. . .
C64210	remainder	0.05 max	0.20 max	0.30 max	0.25 max	6.3–7.0	1.50–2.0	0.10 max	0.50 max	. . .	. . .	. . .	0.09 max	. . .
C65500	remainder	0.05 max	. . .	0.8 max	0.6 max	. . .	2.8–3.8	0.50–1.3	1.5 max	. . .	. . .	. . .	. . .	. . .
C67500	57.0–60.0	0.20 max	0.50–1.5	0.8–2.0	. . .	0.25 max	. . .	0.05–0.50	remainder	. . .	. . .	. . .	. . .	. . .
C67600	57.0–60.0	0.50–1.0	0.50–1.5	0.40–1.3	. . .	. . .	. . .	0.05–0.50	remainder	. . .	. . .	. . .	. . .	. . .
C69300	73.0–77.0	0.09 max	0.20 max	0.10 max	0.10 max	. . .	2.7–3.4	0.10 max	remainder	. . .	. . .	0.04–0.15	. . .	. . .
C70620[N]	86.5[A] min	0.02 max	. . .	1.0–1.8	9.0–11.0	. . .	. . .	1.0 max	0.50 max	0.02 max	. . .	0.02 max	. . .	. . .
C71520[N]	65.0[A] min	0.02 max	. . .	0.40–1.0	29.0–33.0	. . .	. . .	1.0 max	0.50 max	0.02 max	. . .	0.02 max	. . .	. . .
C77400	43.0–47.0	0.09 max	. . .	. . .	9.0–11.0	. . .	. . .	. . .	remainder	. . .	. . .	. . .	. . .	. . .
C87700[O]	87.5 min	0.09 max	2.0 max	0.50 max	0.25 max	. . .	2.5–3.5	0.8 max	7.0–9.0	. . .	. . .	0.15 max	. . .	. . .
C87710[O]	84.0 min	0.09 max	2.0 max	0.50 max	0.25 max	. . .	3.0–5.0	0.8 max	9.0–11.0	. . .	. . .	0.15 max	. . .	. . .

[A] Silver counting as copper.
[B] Includes oxygen-free or deoxidized grades with deoxidizers (such as phosphorus, boron, lithium, or others) in amount agreed upon.
[C] This includes copper plus silver plus tellurium plus phosphorus.
[D] Other deoxidizers may be used as agreed upon, in which case phosphorus need not be present.
[E] This includes copper plus silver plus sulfur plus phosphorus.
[F] Includes antimony 0.05–0.15.
[G] Includes cadmium 0.001 % max.
[H] Includes cadmium 0.01 max, selenium 0.02–0.07.
[I] Includes antimony 0.50 % max, and selenium 0.20 % max.
[J] Includes antimony 0.02–0.10 %.
[K] Includes Boron 0.001 % max.
[L] For boiler code application maximum iron content shall be 4.0 %.
[M] Iron content shall not exceed nickel content.
[N] Carbon shall be 0.05 % max.
[O] Antimony shall be 0.10 Max.

7.2.2 For alloys in which zinc is listed as "remainder," either copper or zinc may be taken as the difference between the sum of results of all other elements determined and 100 %.

7.3 When all elements in Table 1 are determined for Copper Alloy UNS No. C36500, C37000, C46400, C48200, C48500, C48600, the sum of results shall be 99.6 % min, for Copper Alloy UNS No. C28500, the sum of results shall be 99.1 % min, for all other alloys the sum of results shall be 99.5 % min.

8. Temper

8.1 The standard tempers for products described in this specification are as follows:

8.1.1 As hot forged-air cooled M10,

8.1.2 As forged-quenched M11,

8.1.3 Hot forged and annealed O20.

8.2 UNS Alloy Nos. C63000 and C63200 shall be furnished as:

8.2.1 Quench hardened and temper annealed, TQ50.

8.3 Alloys C70620 and C71520 shall be furnished in the following tempers:

8.3.1 As hot forged-air cooled M10, unless,

8.3.2 Hot forged and annealed O20 is specified.

8.4 Other tempers, shall be subjected to agreement between the manufacturer and the purchaser.

9. Mechanical Property Requirements

9.1 Mechanical property requirements are subject to agreement between the manufacturer and the purchaser.

9.2 Product furnished to this specification for UNS Alloy No. C70620 and C71520 and specified to meet the requirements of the *ASME Boiler and Pressure Vessel Code* shall conform to the tensile requirements prescribed in Table 2, when tested in accordance with Test Methods E8/E8M.

9.2.1 Acceptance or rejection based upon mechanical properties for UNS Alloy No. C70620 and C71520 shall depend only on tensile strength.

10. Heat Treatment

10.1 Product produced from Copper Alloy UNS No. C63200 shall be heat treated as follows:

10.1.1 Heat to 1550°F [843°C] minimum for 1 h minimum and quench in water or other suitable medium.

10.1.2 Temper Anneal at 1300 ± 25°F [704 ± 14°C] for 3 to 9 h as required to meet mechanical properties.

TABLE 2 Tensile Requirements

Diameter or Section Thickness, in. [mm]	Temper Designation Standard Former	Tensile Strength, min		Yield Strength at 0.5 % Extension Under Load, min		Elongation in 4 × Diameter or Thickness of Specimen, min, %
		ksi	[MPa][A]	ksi	[MPa][A]	
Copper Alloy UNS No. C27450, C27451						
All Sizes	M10 As Hot Forged-Air Cooled	50	[345]	18	[124]	25
Copper Alloy UNS No. C27453						
All Sizes	M10 As Hot Forged-Air Cooled	49	[340]	29	[200]	30
Copper Alloy UNS No. 28500						
All Sizes	M10 As Hot Forged-Air Cooled	58	[400]	24	[165]	20
Copper Alloy UNS Nos. C35330 and C37700						
Up to 1½ [38.1], incl	M10 As Hot Forged-Air Cooled	50	[345]	18	[124]	25
Over 1½ [38.1]	M10 As Hot Forged-Air Cooled	46	[317]	15	[103]	30
Copper Alloy UNS No. C46400						
All sizes	M10 As Hot Forged-Air Cooled	52	[358]	22	[152]	25
Copper Alloy UNS No. C46750						
All sizes	M10 As Hot Forged-Air Cooled	45.7	[315]	22.0	[152]	15
	O20 Hot Forged and Annealed	45.7	[315]	22.0	[152]	15
Copper Alloy UNS Nos. C48200, C48500, C48600, C49250, C49255, C49260, C49265, and C49300						
All sizes	M10 As Hot Forged-Air Cooled	52	[358]	22	[152]	25
Copper Alloy UNS Nos. C49340, C49345, and C49350						
All sizes	M10 As Hot Forged-Air Cooled	50	[345]	20	[140]	20
Copper Alloy UNS No. C49355						
All Sizes	M10 As Hot Forged-Air Cooled	50	[345]	20	[140]	15
All Sizes	O20 Hot Forged and Annealed	50	[345]	20	[140]	15
Copper Alloy UNS No. C64200						
Up to 1½ [38.1], incl	M10 As Hot Forged-Air Cooled	70	[483]	25	[172]	30
Over 1½ [38.1]	M10 As Hot Forged-Air Cooled	68	[469]	23	[156]	35
Copper Alloy UNS No. C69300						
All sizes	M10 As Hot Forged-Air Cooled	65	[450]	26	[180]	15
Copper Alloy UNS No. C70620						
Up to 6 [152], incl	M10 As Hot Forged-Air Cooled	45	[310]	18	[124]	30
Over 6 [152]	M10 As Hot Forged-Air Cooled	40	[276]	15	[103]	30
All sizes	O20 Hot Forged and Annealed	40	[276]	15	[103]	30
Copper Alloy UNS No. C71520						
Up to 6 [152], incl	M10 As Hot Forged-Air Cooled	50	[345]	20	[138]	30
Over 6 [152]	M10 As Hot Forged-Air Cooled	45	[310]	18	[124]	30
All sizes	O20 Hot Forged and Annealed	45	[310]	18	[124]	30
Copper Alloy UNS No. C87700 and C87710						
All sizes	M10 as Hot Forged-Air Cooled	40	[310]	15	[103]	15

[A] See Appendix X5.

10.2 Heat treatment of other alloys, if needed, to be established by specific agreement between supplier and purchaser.

11. Special Government Requirements

11.1 Product purchased for agencies of the U.S. government shall conform to the additional requirements prescribed in the Supplementary Requirements section of this specification.

12. Dimensions, Mass, and Permissible Variations

12.1 The dimensions and tolerances for forgings shall be those agreed upon between the manufacturer and the purchaser, and such dimensions and tolerances shall be specified on the drawings which form a part of the contract or purchase order.

NOTE 5—Typical tolerances commonly used for forgings are shown in Table X2.1.

NOTE 6—Typical deviations for mismatch, flatness, ejector marks, flash projection, and die parting line are included in the Appendix X2.

13. Workmanship, Finish, and Appearance

13.1 The forging process gives to the forgings a surface condition related to the hot forging process itself. Ridges, indentations, folds, shocks from automatic hot forging, smooth flow lines due to brass rod slug positioning and material flow, that do not have deleterious effect in use, shall not be cause for rejection.

13.2 Customer specific requirements for as-forged surface quality shall be by agreement between purchaser and supplier.

14. Test Methods

14.1 *Chemical Analysis:*

14.1.1 In case of disagreement, determine the composition using the following methods:

Element		ASTM Test Method
Aluminum		E478
Antimony		E62
Arsenic		E62
Bismuth		JIS H 1068:2005
Copper		E478
Iron	<1.3 %	E478, E75 for CuNi
	>1.3 %	E478, E75 for CuNi
Lead		E478 (AA)
Manganese		E62, E75 for CuNi
Nickel	<5 %	E478 (photometric)
	>5 %	E478 (gravimetric)
Phosphorus		E62
Silicon		E62 (perchloric acid)
Tin	<1.3 %	E478
	>1.3 %	E478
Zinc	<2 %	E478 (AA)
	>2 %	E478 (titrimetric)
Tellurium		ISO Test Method 7602

NOTE— < = less than: > = greater than

14.1.2 Test method(s) to be followed for the determination of element(s) resulting from contractual or purchase order agreement shall be as agreed upon between the manufacturer or supplier and purchaser.

15. Certification

15.1 Certification to this specification is mandatory for product purchased for *ASME Boiler and Pressure Vessel* applications.

16. Keywords

16.1 copper and copper alloy die forgings (hot pressed); die forgings (hot pressed); UNS No. C11000; UNS No. C14500; UNS No. C14700; UNS No. C27450; UNS No. C27451; UNS No. C27453; UNS No. C28500; UNS No. C35330; UNS No. C36500; UNS No. C37000; UNS No. C37700; UNS No. C46400; UNS No. C46750; UNS No. C48200; UNS No. C48500; UNS No. C48600; UNS No. C49250; UNS No. C49255; UNS No. C49260; UNS No. C49265; UNS No. C49300; UNS No. C49340; UNS No. C49345; UNS No. C49350; UNS No. C49355; UNS No. C61900; UNS No. C62300; UNS No. C63000; UNS No. C63200; UNS No. C64200; UNS No. C64210; UNS No. C65500; UNS No. C67500; UNS No. C67600; UNS No. C69300; UNS No. C70620; UNS No. C71520; UNS No. C77400; UNS No. C87700; UNS No. C87710

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract or order, for agencies of the U.S. government.

S1. Supplementary Requirements S1, S2, and S4 of ASTM B249/B249M shall apply.

S2. **Identification Marking**—Individual forgings shall be marked with the producer's name or trademark, this ASTM specification number, the UNS number, and the heat number or serial number. The method and location of marking shall be in accordance with MIL-STD-792. If approved by the purchaser, the forgings may be bundled or boxed and each bundle or box provided with a metal or oil-proof tag showing the above information.

S2.1 **Sampling**—The lot size, portion size, and selection of sample pieces shall be as follows:

1. *Lot Size*—For forgings weighing 250 lbs [114 kg] or less, a lot shall be 2000 lbs [909 kg] or less, and shall consist of forgings of the same design and alloy forged from the same material heat and heat treated at the same time. For forgings exceeding 250 lbs [114 kg], each individual forging shall constitute a lot.

S2.2 *Portion Size*—For forgings less than 250 lbs [114 kg], two forgings per lot shall be selected for tensile testing. Tensile tests shall be performed on each forging over 250 lbs [114 kg].

S2.3 *Chemical Analysis*—If heat identification is required, one sample for chemical analysis shall be taken for each heat at the time of pouring or from semifinished or finished product.

S2.4 *Tensile Testing*—The tensile specimens shall be taken from integral forging prolongations or shall be removed from the forgings by trepanning. Alternatively, samples may be taken from separately forged test bars of the same heat as the forgings in the lot provided the wall thickness and amount of working for the test bar are equivalent to those for the forgings. The axis of the tensile specimen shall be located at any point midway between the center and the surface of solid forgings and at any point midway between the inner and outer surfaces of the wall of hollow forgings, and shall be parallel to the direction of greatest grain flow to the greatest extent possible.

S2.5 **Liquid Penetrant Inspection**—When specified by the purchaser, each piece of each lot shall be inspected in accordance with NAVSEA T9074-AS-GIB-101/271.

S2.6 **Ultrasonic Inspection**—When specified by the purchaser, each piece of each lot shall be inspected.

1. *General Requirements*—Ultrasonic testing shall be performed in accordance with NAVSEA T9074-AS-GIB-101/271. Acoustic compatibility between the production material and the calibration standard material shall be within 75 %. If the acoustic compatibility is within 25 %, no gain compensation is required for the examination. If acoustic compatibility difference is between 25 and 75 %, a change in the gain or dB controls shall be accomplished to compensate for the differences in acoustic compatibility. This method cannot be used if the ultrasonic noise level exceeds 50 % of the rejection value.

S3. *Calibration:*

S3.1 *Shear Wave*—The shear wave test shall be calibrated on two notches, one notch cut into the inside and one into the outside surface. The notches shall be cut axially and shall have a depth of 5 % of the material thickness or ¼ in. [6.4 mm], whichever is less. Notch length shall not exceed 1 in. [25.4 mm]. Notches shall be made either in the piece to be examined or in a separate defect-free specimen of the same size (within ±⅛ in. [3.2 mm]), shape, material, and condition, or acoustically similar material. The position and amplitude of the response from each notch shall be marked on the instrument screen or a transparent overlay, and these marks shall be used as the evaluation reference. Indications that appear between these points shall be evaluated on the basis of a straight line joining the two peak amplitudes.

S3.2 *Longitudinal Wave*—The longitudinal wave test shall be calibrated on a flat-bottomed reference hole of a given diameter in accordance with Table S5.1 for specified material thickness drilled either into the piece to be tested or into a separate defect-free specimen of the same size (within ±⅛ in. [3.2 mm]), shape, material, and condition or acoustically similar material. Holes are to be drilled to midsection and the bottom of the hole shall be parallel to the entrant surface. The ultrasonic test instrument shall be adjusted so that the response from the reference hole shall not be less than 25 % and not more than 75 % of screen height.

TABLE S5.1 Ultrasonic Testing Reference Hole for Rod, Bar, Disk Pancake Forgings, and Forgings

Material Thickness, in. [mm]	Hole Diameter, in. [mm]
Up to and including 6 [152]	⅛ [3.2]
Over 6 [152] and including 16 [406]	¼ [6.4]
Over 16 [406]	As agreed upon

S3.3 *Recalibration*—During quality conformance inspection, any realignment of the search unit that will cause a decrease in the calibrated sensitivity and resolution, or both, or any change in search unit, couplant, instrument settings, or scanning speed from that used for calibration shall require recalibration. Recalibration shall be performed at least once per 8-h shift.

S4. *Procedure:*

S4.1 *Ring and Hollow Round Products*—Rings and other hollow cylindrical products shall be tested using the shear wave method by the contact or immersion technique. The shear wave entrant angle shall be such to ensure reflection from the notch or notches used in calibration. For contact testing, the search unit shall be fitted with a wedge or shoe machined to fit the curvature of the piece being inspected. The product also shall be inspected with a longitudinal wave test from the external circumferential and end surfaces.

S4.2 *Disk or Pancake Forgings*—Disk or pancake forgings shall be inspected with a longitudinal wave technique from both parallel surfaces.

S5. *Acceptance Criteria:*

S5.1 *Shear Wave*—Any material that produces indications equal to or larger than the response from the reference notch or higher than the straight line joining the two peak amplitudes shall be rejected.

S5.2 *Longitudinal Wave*—Any material that produces indications equal to or larger than the response from the reference hole or that produces a complete loss of back reflection shall be rejected. Material shall be tested using a square, rectangular, or circular transducer having an effective area of 1 $in.^2$ or less, but no dimension shall be smaller than the diameter of the reference hole. In the event of disagreement on the degree of back reflection loss, it shall be determined by the contact method using a 1- to 1⅛-in. [25.4- to 28.6-mm] diameter transducer or one whose area falls within this range.

S5.3 *Reference Notch Removal*—If reference notches or flat-bottomed holes are made in the material to be tested, they shall be so located that their subsequent removal will not impair the suitability of the material for its intended use.

APPENDIXES

(Nonmandatory Information)

X1. NOMINAL COMPOSITION AND RELATIVE FORGEABILITY RATINGS

X1.1 The nominal composition of the various forging materials are shown in Table X1.1.

TABLE X1.1 Nominal Compositions and Relative Forgeability Ratings

Copper or Copper Alloy UNS No.	Nominal Composition, %														Forgeability Rating[A]
	Copper	Lead	Tin	Iron	Nickel	Aluminum	Silicon	Manganese	Zinc	Sulfur	Tellurium	Phosphorus	Arsenic	Bismuth	
C11000	100	...	...	...	...	...	...	...	...	...	...	...	...	...	65
C14500	99.45	...	...	...	...	...	...	...	...	...	0.55	...	...	...	65
C14700	99.5	...	...	...	...	...	...	...	...	0.35	...	...	...	...	65
C27450	62.5	0.12	...	...	...	...	...	...	37.4	...	...	...	...	...	95
C27451	61.0–65.0	0.12	...	...	...	...	...	...	36.8	...	...	0.05–0.20	...	...	95
C27453	62.5	...	...	...	...	...	...	...	...	...	...	...	0.8	...	90
C28500	58.0	0.10	...	0.30	...	...	...	...	41.0	...	...	...	...	...	100
C35330	61.7	2.5	...	...	...	...	...	...	35.7	...	...	...	0.13	...	95
C36500	60	0.6	...	...	...	...	...	...	39.4	...	...	...	...	...	100
C37000	60	1	...	...	...	...	...	...	39	...	...	...	...	...	100
C37700	60	2	...	...	...	...	...	...	38	...	...	...	...	...	100
C46400	60	...	0.8	...	...	...	...	...	39.2	...	...	...	...	...	90
C46750	60.9	...	1.4	...	...	...	...	...	37	...	...	0.1	...	...	95
C48200	60	0.7	0.8	...	...	...	...	...	38.5	...	...	...	...	...	90
C48500	60	1.8	0.8	...	...	...	...	...	37.4	...	...	...	...	...	90
C48600	60.5	1.7	0.9	...	...	...	...	...	36.8	...	...	...	0.13	...	90
C49250	60.0	...	...	...	...	...	...	...	37.9	...	...	...	...	2.2	90
C49255	59	...	...	...	0.2	...	...	...	38.5	...	...	...	...	2.3	90
C49260	60.5	...	...	...	...	...	...	...	38.3	...	...	...	...	1.1	90
C49265	60.0	0.17	...	...	...	...	...	...	39.0	...	...	0.08	...	0.9	90
C49300	60	...	1.6	...	1	...	...	...	37.3	...	...	...	...	1.2	95
C49340	61.5	...	1	...	...	...	...	...	36.2	...	...	...	...	1.3	90
C49345	62.0	0.17	...	...	...	...	...	...	36.9	...	...	0.08	...	0.9	90
C49350	62	...	2.2	...	...	...	...	...	34.2	...	...	...	...	1.5	95
C49355	66.0	...	1.0	...	...	...	1.5	...	31.0	...	...	...	...	0.7	80
C61900	87.5	...	...	3.5	...	9	...	...	...	...	...	...	...	...	75
C62300	88	...	...	3	...	9	...	...	...	...	...	...	...	...	75
C63000	81	...	...	3	5	10	...	1	...	...	...	...	...	...	75
C63200	81	...	...	4	4.5	9	...	1.5	...	...	...	...	...	...	75
C64200	91	...	...	...	...	7	2	...	...	...	...	...	...	...	75
C64210	91.3	...	...	...	...	6.7	2	...	...	...	...	...	...	...	75
C65500	96	...	...	[B]	...	...	3	90	[B]	...	...	...	...	...	40
C67500	58.5	...	1	1	...	...	...	0.10	39.4	...	...	...	...	...	80
C67600	58.5	0.75	1	1	...	...	...	0.10	39.6	...	...	...	...	...	80
C69300	75.0	...	...	...	...	...	3.0	...	21.9	...	...	0.10	...	...	95
C70620	86.5	...	...	1.4	10.0	...	...	1	...	...	...	...	...	...	75
C71520	65.0	...	...	0.7	31.0	...	...	1	...	...	...	...	...	...	40
C77400	45	...	...	...	10	...	...	...	45	...	...	...	...	...	85
C87700[O]	88.5 min	...	...	...	...	...	3.0	...	8.0	...	...	...	...	...	80
C87710[O]	86.0 min	...	...	...	...	...	4.0	...	10.0	...	...	...	...	...	80

[A] Relative forgeability rating takes into consideration such variable factors as pressure, die wear, and plasticity (hot). Since it is impracticable to reduce these variables to common units, calibration in terms of a percentage of the most generally used alloy, forging brass (100 %), is considered the most practical basis for such ratings. The values shown represent the general opinion and are intended for information to enable the designer to better understand the forging characteristics of these various alloys. Intricate parts are more likely to be available in alloys having a high rating.

[B] One or more of these elements may be present as specified in Table 2.

X2. DIMENSIONAL TOLERANCES

X2.1 The data in Table X2.1 do not constitute a part of this specification. They are given merely to indicate to the purchaser the various forging types and some dimensional tolerances used on commercially designed hot-pressed forgings up to 2 lb [0.9 kg] in weight. For tolerances applicable to heavier forgings, the manufacturers should be consulted.

X2.2 Mismatch

X2.2.1 The mismatch shall be determined with respect to the largest nominal dimension (w max) in the forging direction (see Fig. X2.1) not associated with a particular dimension. Tolerances for dimensions within the die cavity are independently applied.

X2.3 Flatness

X2.3.1 Deviation from flatness may result from distorsion, heat treatment, ejection from the mold, or trimming. This deviation is in addition to the tolerances caused by the forging process itself. (See Fig. X2.2.)

X2.3.2 The flatness shall be determined with respect to the largest nominal dimension (w max), in the forging direction, and applied independent of the tolerances for form or position.

X2.4 Ejector Marks

X2.4.1 Ejectors may be necessary in the forging process to eject the forging from the die cavity. Ejector marks may be

TABLE X2.1 Dimensional Tolerances

	Tolerances, Plus and Minus, in. [mm] Except as Indicated[A]			
	Copper or Copper Alloy UNS Nos.			
	C11000 C14500 C14700 C61900 C62300 C64200 C64210	C27450 C27451 C27453 C28500 C35330 C36500 C37000 C37700 C46400 C46750 C48200 C48500 C48600 C49250 C49260 C49265 C49300 C49340 C49345 C49350 C49355 C67500 C67600 C69300	C77400	C63000 C63200 C65500 C70620 C71520 C87700 C87710
Forging types:				
Solid	0.010 [0.25]	0.008 [0.20]	0.008 [0.20]	0.012 [0.30]
Solid, with symmetrical cavity	0.010 [0.25]	0.008 [0.20]	0.008 [0.20]	0.012 [0.30]
Solid, with eccentric cavity	0.012 [0.30]	0.008 [0.20]	0.008 [0.20]	0.012 [0.30]
Solid, deep extrusion	0.012 [0.30]	0.010 [0.25]	0.010 [0.25]	0.014 [0.36]
Hollow, deep extrusion	0.012 [0.30]	0.010 [0.25]	0.010 [0.25]	0.014 [0.36]
Thin section, short (up to 6 in. [152 mm] incl.)	0.012 [0.30]	0.010 [0.25]	0.010 [0.25]	0.014 [0.36]
Thin section, long (over 6 in. [152 mm] to 14 in. [356 mm] incl.)	0.015 [0.38]	0.015 [0.38]	0.015 [0.38]	0.020 [0.51]
Thin section, round	0.012 [0.30]	0.010 [0.25]	0.010 [0.25]	0.014 [0.36]
Draft angles, outside and inside 1 to 5°	½ °	½ °	½ °	½ °
Machining allowance (on one surface)	1/32 [0.79]	1/32 [0.79]	1/32 [0.79]	1/32 [0.79]
Flatness (maximum deviation per inch [per 25.4 mm])	0.005 [0.13]	0.005 [0.13]	0.005 [0.13]	0.005 [0.13]
Concentricity (total indicator reading)	0.030 [0.76]	0.020 [0.51]	0.030 [0.76]	0.030 [0.76]
Nominal web thickness:	5/32 [4.0]	1/8 [3.2]	1/8 [3.2]	3/16 [4.8]
Tolerance	1/64 [0.40]	1/64 [0.40]	1/64 [0.40]	1/64 [0.40]
Nominal fillet and radius:	3/32 [2.4]	1/16 [1.6]	1/16 [1.6]	1/8 [3.2]
Tolerance	1/64 [0.40]	1/64 [0.40]	1/64 [0.40]	1/64 [0.40]
Approximate flash thickness	1/16 [1.6]	3/64 [1.2]	3/64 [1.2]	5/64 [2.0]

[A] If tolerances all plus or all minus are desired, double the values given.

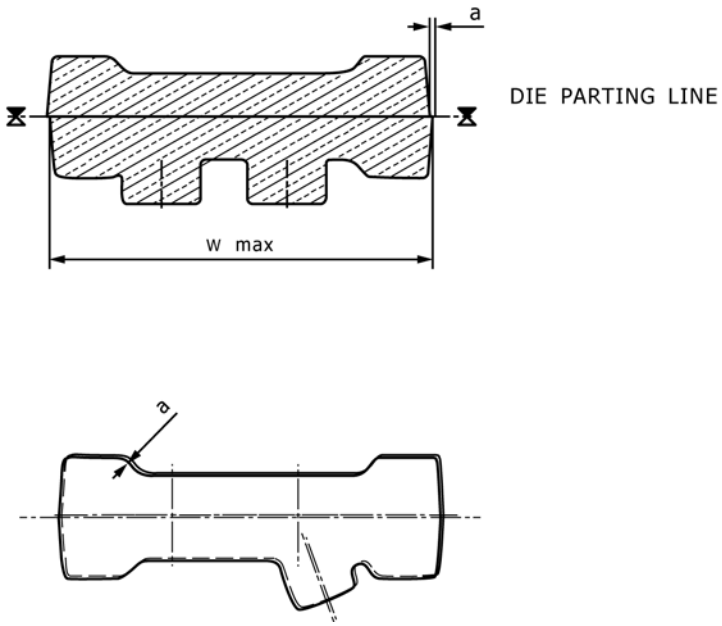


FIG. X2.1 Mismatch at Die Parting Line

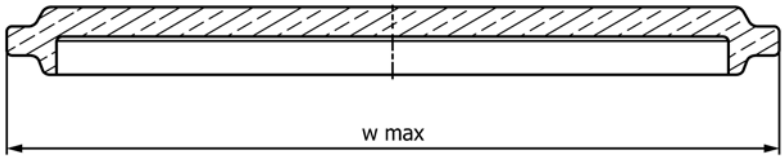


FIG. X2.2 Deviation from Flatness

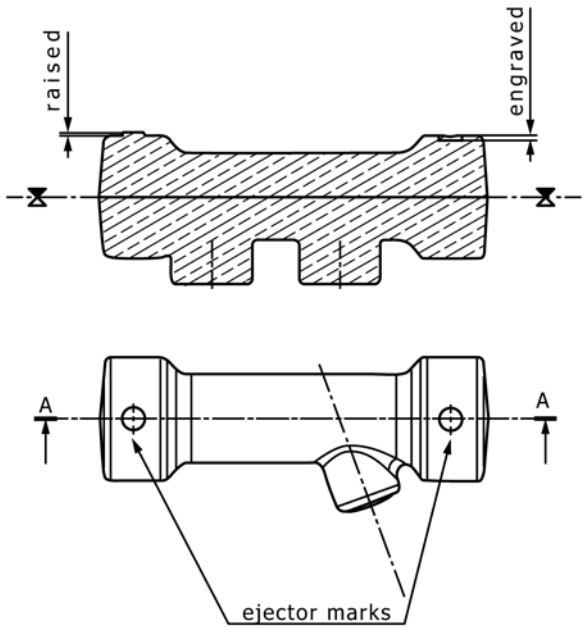


FIG. X2.3 Ejector Marks

raised or indented. When an ejector mark is either fully raised or fully indented, the full range of the tolerance applies. For example, if the tolerance is ±0.0118 in. [0.3 mm], the ejector mark may be raised up or indented to 0.0236 in. [0.6 mm]. (See Fig. X2.3.)

X2.5 Flash Projection

X2.5.1 The flash projection is determined from the largest nominal dimension, (w max), perpendicular to the forging direction.

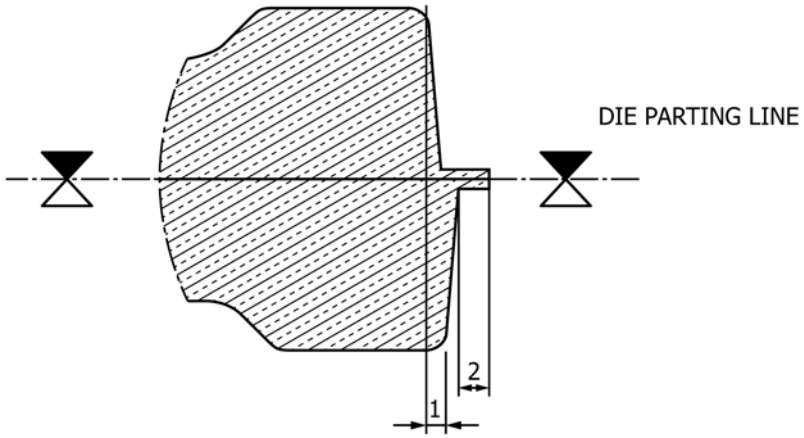


FIG. X2.4 Flash Projection

X2.5.2 The flash on the die parting line shall be removed by trimming. (See Fig. X2.4.)

X2.5.3 Other flashes generated from operations such as punching, piercing, or left by die-inserts, are permissible if removed during machining, or not detrimental to the finished part. Permissible flash should be indicated on the product drawing, but should not exceed 0.059 in. [1.5 mm].

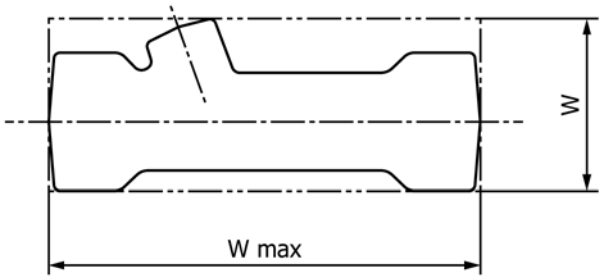
X2.5.4 Flash projection applies independently from dimensional tolerances.

X2.6 Area

X2.6.1 The area A shall be determined as follows:

X2.6.1.1 For round parts, the area shall be equal to the area of the circumscribed circle.

X2.6.1.2 For irregular shapes, the area shall be calculated by the area of the circumscribed rectangle (A = Wmax × W). (See Fig. X2.5.)



AREA A = Wmax × W

FIG. X2.5 Area

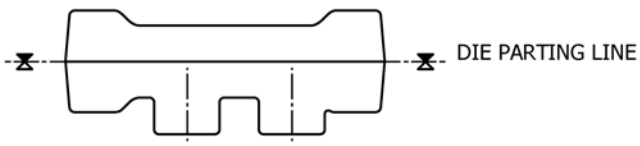


FIG. X2.6 Die Parting Line

X2.7 Die Parting Line

X2.7.1 The parting line is the line identifying the matching flats of the two half dies.

X2.7.2 The flatness shall be determined in regards to the largest nominal dimension (w max), in the forging direction, and applied independently from all tolerances of form or position.

X2.7.3 The mismatch shall be determined in regards to the largest nominal dimension (w max), in the forging direction, not associated to a particular direction. (See Fig. X2.6.)

X2.8 Angular Tolerances

X2.8.1 Table X2.2 and Fig. X2.7 provide guidelines for angular tolerance.

X2.9 Polygonal Shapes Tolerances

X2.9.1 Refer to Table X2.3 for guidelines for polygonal shapes tolerances.

TABLE X2.2 Angular Tolerances

Nominal Dimension, W_1 (length) of Shorter Leg Over in. [mm]	Up to Including in. [mm]	Ref. Fig. X2.7 Angular Tolerance α°
...	0.787 [20]	±2°
0.787 [20]	1.575 [40]	±1°
1.575 [40]	2.362 [60]	±1°
2.362 [60]	3.937 [100]	±0° 30'
3.937 [100]	7.874 [200]	±0° 30'
7.874 [200]	11.811 [300]	±0° 25'

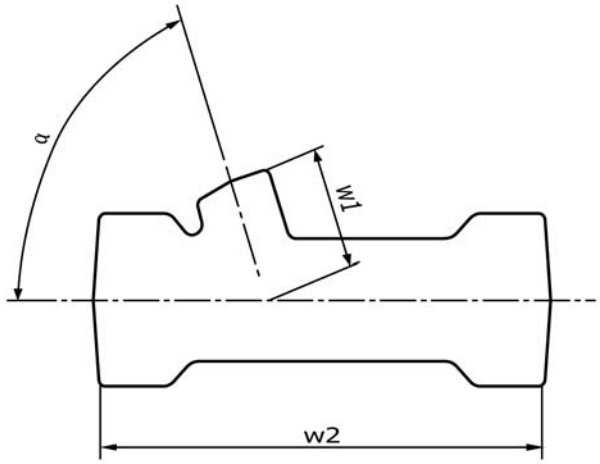


FIG. X2.7 Shorter Leg Example for Angular Tolerances

TABLE X2.3 Polygonal Shapes Tolerances

Nominal Dimension Across Flats Over in. [mm]	Up to Including in. [mm]	Dimensional Tolerance in. [mm]
...	0.394 [10]	+ 0 + [0] - 0.008 - [0.2]
0.394 [10]	0.984 [25]	+ 0 + [0] - 0.012 - [0.3]
0.984 [25]	1.969 [50]	+ 0 + [0] - 0.016 - [0.4]
1.969 [50]	3.150 [80]	+ 0 + [0] - 0.020 - [0.5]
3.150 [80]	3.937 [100]	+ 0 + [0] - 0.024 - [0.6]
3.937 [100]	4.724 [120]	+ 0 + [0] - 0.028 - [0.7]

X3. TYPICAL MECHANICAL PROPERTIES

X3.1 Mechanical properties of any forging are influenced by shape and size. Unless otherwise specified in the purchase order or specifically guaranteed by the manufacturer, acceptance of forgings under this specification shall not depend on the mechanical properties determined by tension or hardness tests. (Frequently, the design of forgings will not permit adequate test sections.) Therefore, the data in Table X3.1 do not constitute a part of this specification, and are given for general information only. They are typical of forgings up to 2 lb [0.9 kg] in weight.

TABLE X3.1 Typical Mechanical Properties of Forgings as Hot Pressed, Temper M10, M11, or TQ50[A]

Copper or Copper Alloy UNS No.	0.505-in. [128-mm] Diameter Test Section					Rockwell Hardness (Filed Surface, 1/8-in. [3.2-mm] Chord, min)	
	Tensile Strength		Yield Strength (0.5 % Extension Under Load)		Elongation in 4 × Diameter, %	F Scale	B Scale
	ksi	[MPa][B]	ksi	[MPa][B]			
C11000	33	[230]	11	[75]	40	37	. . .
C14500	34	[235]	12	[85]	35	40	. . .
C14700	34	[235]	12	[85]	35	40	. . .
C27450	56	[386]	26	[180]	46	. . .	46
C27451	56	[386]	26	[180]	46	. . .	46
C27453	52	[360]	35	[240]	30	. . .	110
C28500	66	[455]	28	[190]	25	. . .	72
C35330	58	[400]	23	[160]	40	. . .	45
C36500	58	[400]	23	[160]	40	. . .	45
C37000	58	[400]	23	[160]	40	. . .	45
C37700	58	[400]	23	[160]	40	. . .	45
C46400	64	[440]	26	[180]	40	. . .	55
C46750	59.5	[410]	29.0	[200]	20	. . .	55
C48200	64	[440]	26	[180]	40	. . .	55
C48500	62	[425]	24	[165]	40	. . .	55
C48600	62	[425]	24	[165]	40	. . .	55
C49250	62	[425]	24	[165]	40	. . .	55
C49260	62	[425]	24	[165]	40	. . .	55
C49265	62	[425]	24	[165]	40	. . .	55
C49300	62	[425]	24	[165]	40	. . .	55
C49340	60	[415]	22	[150]	35	. . .	50
C49345	60	[415]	22	[150]	35	. . .	50
C49350	60	[415]	22	[150]	35	. . .	50
C49355	64	[443]	36	[250]	17	. . .	84
C61900	82	[565]	37	[255]	32	. . .	82
C62300	82	[565]	37	[255]	32	. . .	82
C63000	95	[655]	48	[330]	15	. . .	90
C63200	92	[635]	45	[310]	18	. . .	88
C64200	83	[570]	41	[285]	35	. . .	77
C64210	83	[570]	41	[285]	35	. . .	77
C65500	52	[360]	18	[125]	70	. . .	62
C67500	72	[495]	34	[235]	33	. . .	69
C67600	72	[495]	34	[235]	33	. . .	69
C69300	80	[550]	41	[285]	28	. . .	78
C71520	55	[380]	20	[138]	45	. . .	35
C77400	83	[570]	36	[250]	25	. . .	73
C87700	55	[380]	20	[138]	40	. . .	75
C87710	57	[393]	26	[180]	19	. . .	72

[A] For Copper Alloy UNS Nos. C63000 and C63200.
[B] See Appendix X5.

X4. GUIDELINES FOR FORGINGS DESIGN AND DEVELOPMENT

INTRODUCTION

The following guidelines are provided for the design and development of forgings, including die design.

X4.1 Draft Angles

X4.1.1 To allow an easy ejection of forgings (areas lying in the forging direction) from the die, draft angles are necessary. It is suggested to use as a best practice the following draft angles. See also Fig. X4.1.

External areas 30'
Internal areas 1°

X4.1.2 Smaller or greater draft angles may be adopted according to particular needs or cases.

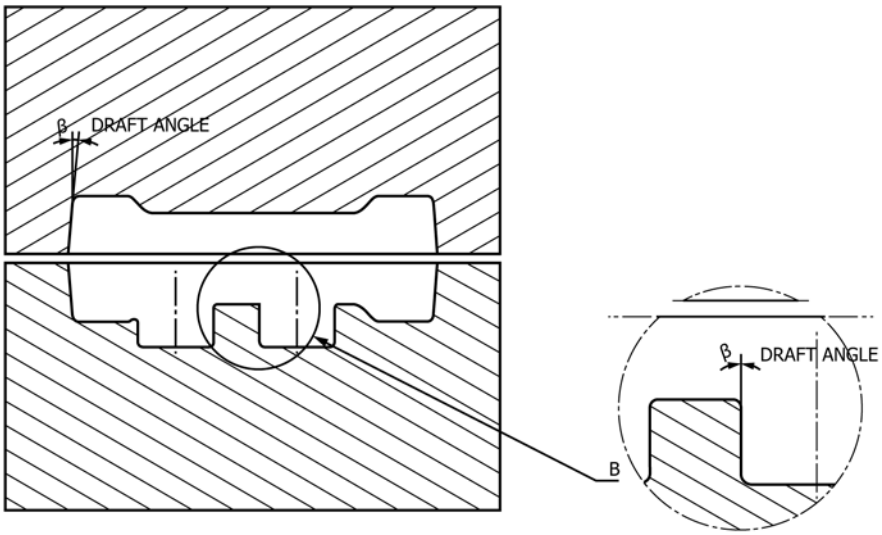


FIG. X4.1 Draft Angles in Example Forging Die

X5. METRIC EQUIVALENTS

X5.1 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 ($N = kg \cdot m/s^2$). 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 ksi = 6 894 757 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 (B283/B283M – 16a) that may impact the use of this standard. (Approved April 1, 2017.)

(1) Added UNS Alloy No. C28500 to 1.1, 7.3, Table 1, Table 2, Section 16, Appendix Table X1.1, Appendix Table X2.1, and Appendix Table X3.1.

Committee B05 has identified the location of selected changes to this standard since the last issue (B283/B283M – 16) that may impact the use of this standard. (Approved Oct. 1, 2016.)

(1) Added UNS Alloy Nos. C49265 and C49345 to 1.1, Table 1, Table 2, Section 16, Appendix Table X1.1, Appendix Table X2.1, and Appendix Table X3.1.

Committee B05 has identified the location of selected changes to this standard since the last issue (B283/B283M – 14a) that may impact the use of this standard. (Approved April 1, 2016.)

(1) Added Note 2 to Section 1 referencing appendix for tolerance data.
(2) Added clause in Section 10 for heat treatment of alloys.
(3) Added further description to Section 13 on Workmanship, Finish, and Appearance.
(4) Added to Appendix X2, sections, tolerances, Table X2.2 and Table X2.3, and Fig. X2.1, Fig. X2.2, Fig. X2.3, Fig. X2.4, Fig. X2.5, Fig. X2.6, Fig. X2.7, and Fig. X4.1.
(5) Added Appendix X4 on Guidelines for Forgings Design and Development.
(6) Editorially modified other section numbers as needed.