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Wrought and Cast Copper Alloys

RATIONALE

The technical report covers technology, products, or processes which are mature and not likely to change in the foreseeable future.

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1. ***Scope***—For convenience, this SAE Information Report is presented in two parts as shown below. To avoid repetition, however, data applicable to both wrought and cast alloys is included only in Part 1.

Part I—Wrought Copper and Copper Alloys

Types of Copper (Table 1)
General Characteristics (Table 3)
Electrical Conductivity
Thermal Conductivity
General Mechanical Properties (Table 10)
Yield Strength
Fatigue Strength
Physical Properties (Table 2)
General Fabricating Properties (Table 3)
Formability
Bending
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Machinability
Joining
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Typical Uses (Table 3)

Part II—Cast Copper Alloys

Types of Casting Alloys
Effects of Alloy Elements and Impurities
General Characteristics (Table 11)
Physical Properties (Table 12)
Typical Uses (Table 11)

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest version of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J463—Wrought Copper and Copper Alloys

2.1.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM B 3—Specification for Soft or Annealed Copper Wire
ASTM B 16—Specification for Free-Cutting Brass Rod, Bar, and Shapes for Use in Screw Machines
ASTM B 21—Specification for Naval Brass Rod, Bar, and Shapes
ASTM B 36—Specification for Brass Plate, Sheet, Strip, and Rolled Bar
ASTM B 68—Specification for Seamless Copper Tube, Bright Annealed
ASTM B 75—Specification for Seamless Copper Tube
ASTM B 97—Specification for Copper-Silicon Alloy Plate, Sheet, Strip, and Rolled Bar for General Purposes
ASTM B 98—Specification for Copper-Silicon Alloy Rod, Bar, and Shapes
ASTM B 103—Specification for Phosphor Bronze Plate, Sheet, Strip, and Rolled Bar
ASTM B 111—Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock
ASTM B 121—Specification for Leaded Brass Plate, Sheet, Strip, and Rolled Bar
ASTM B 122—Specification for Copper-Nickel-Tin Alloy, Copper-Nickel-Zinc Alloy (Nickel Silfer) and Copper-Nickel Alloy Plate, Sheet, Strip, and Rolled Bar
ASTM B 133—Specification for Copper Rod, Bar, and Shapes
ASTM B 134—Specification for Brass Wire
ASTM B 135—Specification for Seamless Brass Tube
ASTM B 138—Specification for Manganese Bronze Rod, Bar, and Shapes
ASTM B 139—Specification for Phosphor Bronze Rod, Bar, and Shapes
ASTM B 150—Specification for Aluminum Bronze Rod, Bar, and Shapes
ASTM B 151—Specification for Copper-Nickel-Zinc Alloy (Nickel Silver) and Copper-Nickel Rod and Bar
ASTM B 152—Specification for Copper Sheet, Strip, Plate and Rolled Bar
ASTM B 154—Method of Mercurous Nitrate Test for Copper and Copper Alloys
ASTM B 159—Specification for Phosphor Bronze Wire
ASTM B 169—Specification for Aluminum Bronze Plate, Sheet, Strip, and Rolled Bar
ASTM B 171—Specification for Copper-Alloy Condenser Tube Plates
ASTM B 194—Specification for Copper-Beryllium Alloy Plate, Sheet, Strip, and Rolled Bar
ASTM B 196—Specification for Copper-Beryllium Alloy Rod and Bar
ASTM B 280—Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service
ASTM B 283—Specification for Copper and Copper-Alloy Die Forgings (Hot-Pressed)
ASTM B 301—Specification for Free-Cutting Copper Rod and Bar
ASTM B 441—Specification for Copper-Cobalt-Beryllium and Copper-Nickel-Beryllium Rod and Bar
ASTM B 453—Specification for Copper-Zinc-Lead Alloy (Leaded-Brass) Rod
ASTM B 534—Specification for Copper-Cobalt-Beryllium Alloy and Copper-Nickel-Beryllium Alloy Plate, Sheet, Strip, and Rolled Bar

3. Part I—wrought Copper And Copper Alloys—Factors influencing the uses of wrought copper and copper alloys concern electrical conductivity, thermal conductivity, machinability, formability, fatigue characteristics, strength, corrosion resistance, the ease with which alloys can be joined, and the fact that these materials are nonmagnetic. Copper and its alloys also have a wide range of rich, pleasing colors. The only other metal with such distinctive coloring is gold. These materials are all easily finished by buffing, scratch brushing, plating or chemically coloring, or clear protective coating systems.

When it is desired to improve one or more of the important properties of copper, alloying often solves the problem. A wide range of alloys, therefore, has been developed and commercially employed, such as the high copper alloys, brasses, leaded brasses, tin bronzes, heat treatable alloys, copper-nickel alloys, nickel silvers, and special bronzes.

The various types of copper and the principal alloys are listed in Tables I and 3, along with information describing composition, fabricating properties, and applications.

3.1 Types of Wrought Copper-—Copper UNS Nos. C11000, C11100, C11300, C11400, C11500, and C11600[1] are either electrolytically or fire-refined, cast in the form of refinery shapes, containing a controlled amount of oxygen for the purpose of obtaining a level set on the top of the casting. It generally contains 0.01–0.04% oxygen, which exists as a coppercuprous oxide eutectic surrounding the crystals of copper. Within these limits, the oxygen has only a very slight effect on the electrical, mechanical, and physical properties of copper. Because of the oxidizing effect of oxygen on impurities, its presence in copper indicates a reduction or elimination of certain impurities which would otherwise have adverse effects on conductivity.

Copper UNS No. C10200 is electrolytically refined and specially produced to be free from cuprous oxide although it is made without the use of residual metallic or metalloidal deoxidizers. Because of its freedom from residual deoxidizers, it has high electrical conductivity.

Copper UNS Nos. C12000 and C12200 are cast in the form of refinery shapes, free from cuprous oxide, produced through the use of metallic or metalloidal deoxidizers. Because it is necessary to use some excess of reducing agent, the electrical and thermal conductivity of the copper is lowered, and this fact should be considered when high conductivity is needed.

Copper UNS Nos. C10200, C12000 and C12200 possess only slightly different mechanical properties from the C11XXX types. They differ little in respect to tensile strength when cold worked to similar extents, but do have somewhat higher ductility and also are not normally subject to hydrogen embrittlement.

3.2 Electrical Conductivity—The greatest single area of use for copper itself results from the high electrical conductivity of the metal. The combination of the property of high electrical conductivity with ease of forming and high corrosion resistance makes copper the preferred material for current-carrying members. The conductivity of copper for electrical conductors is 101% IACS (see Table 2) in the annealed or soft condition. The tensile strength of the soft copper, 220 MPa (32 ksi) can be increased to 345/380 MPa (50/55 ksi) by cold rolling, in which condition the electrical conductivity is decreased to about 97%. Heating such copper above 200 °C for an extended period of time will soften it to a tensile strength of 205/240 MPa (30/35 ksi).

1. Since the nomenclature used in the nonferrous metals trade is not always consistent, copper and copper base alloys are referenced by specification numbers described in SAE J463.

TABLE 1—GENERAL INFORMATION—NAME, NOMINAL COMPOSITION, AND COMPARABLE STANDARDS OF WROUGHT COPPER ALLOYS

Copper or Copper Alloy UNS No.[a]	Name[b]	Nominal Composition Percent by Weight		SAE No.	ASTM Standard No.[c]	Former SAE No.
		Cu	Other			
C10200	Oxygen free copper (OF)	99.9	—	CA102	B75, B152, B280	—
C11000	Electrolytic tough pitch copper (ETP)	99.9	—	CA110	B3, B133, B152, B283	71, 83
C11100	Electrolytic tough pitch, anneal resistant copper	99.9	(Trace elements)	CA111	—	71
C11300	Tough pitch copper with Ag (STP)	99.9	0.03 Ag	CA113	B152	71
C11400	Tough pitch copper with Ag (STP)	99.9	0.04 Ag	CA114	B152	71
C11500	Tough pitch copper with Ag (STP)	99.9	0.06 Ag	CA115	B152	—
C11600	Tough pitch copper with Ag (STP)	99.9	0.09 Ag	CA116	B152	71
C12000	Phosphorus deoxidized copper (DLP)	99.9	0.0008 P	CA120	B68, B75, B152, B280	75
C12200	Phosphorus deoxidized copper (DHP)	99.9	0.02 P	CA122	B68, B75, B152, B280	—
C14500	Phosphorus deoxidized tellurium copper (DPTE)	99.5	0.5 Te, 0.008 P	CA145	B283, B301	—
C14700	Sulfur bearing copper	99.7	0.3 S	CA147	B301	—
C15000	Zirconium copper	99.8	0.15 Zn	CA150	B301	—
C16200	Cadmium copper	99.0	1 Cd	CA162		—
C17000	Beryllium copper	98.0	1.7 Be	CA170	B194	—
C17200	Beryllium copper	98.0	1.9 Be	CA172	B194, B196	—
C17500	Beryllium copper	97.0	0.5 Be, 2.5 Co	CA175	B441, B534	—
C17600	Beryllium copper	97.0	0.4 Be, 1.5 Co, 1 Ag	CA176	B441	—
C18400	Chromium copper	99.0	0.8 Cr	CA184		—
C18700	Leaded copper	99.0	1 Pb	CA187	B301	—
C19200	High copper alloy	99.0	1 Fe, 0.03 P	CA192	B111	—
C21000	Gilding, 95%	95.0	5 Zn	CA210	B36	—
C22000	Commercial bronze, 90%	90.0	10 Zn	CA220	B36, B135	—
C23000	Red brass, 85%	85.0	15 Zn	CA230	B36, B135	74D, 79A
C24000	Low brass, 80%	80.0	20 Zn	CA240	B36	79B
C26000	Cartridge brass, 70%	70.0	30 Zn	CA260	B36, B134 B135	70A, 74C, 80A
C26800	Yellow brass, 66%	66.0	34 Zn	CA268	B36	70C
C27000	Yellow brass, 65%	65.0	35 Zn	CA270	B134	80B
C33000	Low leaded brass, (tube)	66.0	34 Zn, 0.5 Pb	CA330	B135	74B
C33100	Leaded brass	66.0	33 Zn, 1 Pb	CA331		
C34200	High leaded brass	65.0	33 Zn, 2 Pb	CA342	B121	
C34500	Leaded brass	63.0	35 Zn, 2 Pb	CA345	B453	
C35000	Medium leaded brass, 62%	63.0	36 Zn, 1 Pb	CA350	B121, B453	
C36000	Free cutting brass	62.0	35 Zn, 3 Pb	CA360	B16	72
C37700	Forging brass	60.0	38 Zn, 2 Pb	CA377	B283	88
C46400	Naval brass, unhibited	60.0	39 Zn, 0.8 Sn	CA464	B21, B283	73
C46500	Naval brass, arsenical	60.0	40 Zn, 0.5 As	CA465		
C46600	Naval brass, antimonial	60.0	40 Zn, 0.5 Sb	CA466		
C46700	Naval brass, phosphorized	60.0	40 Zn, 0.5 P	CA467		
C51000	Phosphor bronze, 5% A	95.0	5 Sn, 0.2 P	CA510	B103, B139, B159	77A, 81
C51100	Phosphor bronze	96.0	4 Sn, 0.2 P	CA511	B103	
C52100	Phosphor bronze, 8% C	92.0	8 Sn, 0.2 P	CA521	B103	77C
C52400	Phosphor bronze, 10% D	90.0	10 Sn, 0.2 P	CA524	B103	
C54400	Phosphor bronze, B-2	88.0	4 Sn, 4 Zn, 4 Pb	CA544	B103, B139	—
C60800	Aluminum bronze	95.0	5 Al	CA608	B111	
C61400	Aluminum bronze, D	91.0	7 Al, 2 Fe	CA614	B150, B169	701D
C61800	Aluminum bronze	89.0	10 Al, 1 Fe	CA618		
C62300	Aluminum bronze	88.0	9 Al, 3 Fe	CA623	B150, B283	701B
C62400	Aluminum bronze	86.0	11 Al, 3 Fe	CA624		701B
C63000	Aluminum bronze	82.0	10 Al, 3 Fe, 5 Ni	CA630	B150, B283	701C
C64200	Aluminum silicon bronze	91.0	7 Al, 2 Si	CA642	B150, B283	
C65500	High silicon bronze, A	97.0	3 Si	CA655	B97, B98, B283	—

(Table continued on next page)

TABLE 1—GENERAL INFORMATION—NAME, NOMINAL COMPOSITION, AND COMPARABLE STANDARDS OF WROUGHT COPPER ALLOYS (CONTINUED)

Copper or Copper Alloy UNS No.[a]	Name[b]	Nominal Composition Percent by Weight		SAE No.	ASTM Standard No.[c]	Former SAE No.
		Cu	Other			
C67000	Manganese bronze, B	65.0	24 Zn, 4 Mn, 4 Al, 3 Fe	CA670	B138	—
C67300	Manganese bronze	60.0	34 Zn, 3 Mn, 2 Pb, 1 Si	CA673		—
C67400	Manganese bronze	58.0	37 Zn, 3 Mn, 1 Al, 1 Si	CA674		—
C67500	Manganese bronze, A	58.0	40 Zn, 0.3 Mn, 1 Fe, 1 Sn	CA675	B138	—
C70600	Copper nickel, 10%	90.0	10 Ni	CA706	B111, B171	—
C71000	Copper nickel, 20%	80.0	20 Ni	CA710	B111, B122	—
C71500	Copper nickel, 30%	70.0	30 Ni	CA715	B111, B122, B171	—
C75200	Nickel silver, 65–18	65.0	18 Ni, 17 Zn	CA752	B122, B151	—
C77000	Nickel silver, 55–18	55.0	18 Ni, 27 Zn	CA770	B122, B151	—

[a] Unified numbering system.
[b] Alloy names are shown for information only, and should not be used. Use the appropriate designation only. (Example: Copper Alloy UNS No. C21000 Copper Alloy).
[c] ASTM Standard numbers listed are only those forms or shapes covered in the specification *ed.* for wrought copper or copper alloy.