AWS J1.3/J1.3M:2020
An American National Standard

Specification for Materials Used in Resistance Welding Electrodes and Tooling

American Welding Society®

Approved American National Standard
ANSI

AWS J1.3/J1.3M:2020
An American National Standard

Approved by the
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Specification for Materials Used in Resistance Welding Electrodes and Tooling

First Edition

Prepared by the
American Welding Society (AWS)
J1 Committee on Resistance Welding Equipment

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This standard specifies essential properties of materials used for resistance welding electrodes and related components, the common applications of these materials, and methods of conformance verification.

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T. J. Chandler, Chair	*Cadi Company Inc.*
D. Beneteau	*Centerline Ltd.*
W. H. Brafford	*Consultant*
F. Burton	*Southern Copper & Supply*
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M. D. Gugel	*US Steel Corporation*
R. P. Pratt	*Consultant*
D. Sorenson	*Entron Controls, LLC*

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Foreword

This foreword is not a part of this standard, but is included for information purposes only.

Successful application of the resistance welding process involves accurate control of pressure, current and time. During welding the electrodes are subjected to a variety of mechanical loads, high temperatures, and chemical interactions. Specialized materials for resistance welding tooling have been developed over many years to deliver optimum performance, extended service, and cost effectiveness.

This standard builds upon the globally recognized material classification system described in the Resistance Welder Manufacturers' Association (RWMA) Bulletin 16, *Resistance Welding Equipment Standards*, last published in 1996. The standard provides updated and expanded information useful to material and electrode manufacturers, distributors, and end users.

This document describes common materials to facilitate identification and minimize variation. It is not intended to limit the range of resistance welding products or processes in the marketplace.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS J1 Committee on Resistance Welding Equipment, American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

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Specification for Materials Used in Resistance Welding Electrodes and Tooling

1. General Requirements

1.1 Scope. This standard addresses common copper alloy and composite materials employed in the manufacture of resistance welding electrodes, resistance welding dies, and related components such as adapters, holders, and structural components of the welding circuit.

This standard addresses bar, rod (straight lengths and coils), plate, and casting forms of select materials. The standard does not address material in sheet form.

The standard does not include all copper and copper base materials that may be applied in the construction of resistance welding machines or tooling. Examples of materials not currently covered are: electrolytic tough pitch (ETP) copper, brass, and bronze.

Unique, specialized, and new materials exist in domestic and international marketplaces and their absence here should not be interpreted as a commentary on their suitability for a particular application.

1.2 Units of Measurement. This guide makes use of both the U.S. Customary Units and International System of Units [SI]. The latter are shown within brackets [ ] or in appropriate columns in tables and figures. The measurements may not be exact equivalents; therefore each system must be used independently.

1.3 Safety. Safety and health issues and concerns are beyond the scope of this standard and therefore are not fully addressed herein. Safety and health information is available from the following sources:

American Welding Society:

(1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

(2) AWS Safety and Health Fact Sheets

(3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

(1) Safety Data Sheets (SDS), or Product Safety Data Sheets (PSDS), supplied by materials manufacturers.

(2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies

Work performed in accordance with this standard may involve the use of materials that have been deemed hazardous, and may involve operations or equipment that may cause injury or death. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.

2. Normative References

The documents listed below are referenced within this publication and are mandatory to the extent specified herein. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying.*

ASTM E478, *Standard Test Methods for Chemical Analysis of Copper Alloys*

ASTM E18, *Standard Test Methods for Rockwell Hardness of Metallic Materials*

ASTM E1004, *Standard Test Method for Determining Electrical Conductivity Using the Electromagnetic (Eddy-Current) Method*

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

3. Terms and Definitions

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions*, provides the basis for terms and definitions used herein. However, the following terms and definitions are included below to accommodate usage specific to this document.

age hardening. See **precipitation hardening**.

allowance(s). Additional material provided on casting and forging surfaces to ensure a minimum dimension or to permit machining to the specified finish dimensions.

bar. A solid rectangular section, or one with two plane parallel surfaces and round or other simple regularly shaped edges. Sometimes square, rectangular, or hexagonal bar.

certifications of compliance. A simple document stating the material complies with the purchase order requirements, typically stating the quantity, date shipped, PO number, item description with reference to the applicable material standard. Actual minimal properties may or may not be shown on a Certificate of Compliance.

cold working. The process of changing the form or cross-section of a piece of metal at a temperature below the softening or recrystallization point, but commonly at or about room temperature. It includes rolling, drawing, pressing and stretching.

composition report. A report of the actual composition of the material may be a purchase order deliverable. The values presented shall be determined in accordance with ASTM E478.

copper alloy. Metal for which the specified minimum copper content is generally less than 99.3%, not less than 40%, and having no other element specified in excess of the copper content.

copper composite. A material consisting of a refractory metal distributed in a copper matrix.

drawing. The process of pulling flat products, rod, wire, tube, shapes, etc. through a die. This effects a reduction in size or change in shape of the cross-section and cold works the material.

electrolytic tough pitch (ETP) copper. 99.9% pure high conductivity wrought copper with a conductivity of 100% IACS.

grain. A solid crystal consisting of groups of atoms bound together in a regular geometric pattern. In mill practice grains are usually studied only as they appear in one plane.

hot working. The process of changing the form or cross-section of a piece of metal at a temperature above its recrystallization temperature.

International Annealed Copper Standard (IACS). Standard conductivity of annealed copper where 100% conductivity is defined as 58 MS/m at 68°F [20°C]. (MS/m = mega siemens/meter)

material test report. A report including results of actual tests to this material standard for hardness and electrical conductivity testing.

orange peel surface. Surface roughness resulting from deformation of large metal grains.

plate. A flat rolled product over 0.19 in [5 mm] in thickness and typically over 12 in [0.3 m] in width.

precipitation hardening. A process of increasing the hardness and strength by the precipitation of particles of a phase from a supersaturated solid solution alloy. The hardening cycle usually consists of heating or annealing at a temperature sufficiently high to maintain solid solution, rapid cooling or quenching to retain the supersaturated solid solution and subsequent heating at a temperature lower than the solution anneal to effect the precipitation.

refractory metal. High density metal having a melting point above 3600 °F [2000 °C] and high hardness at room temperature.

resistance welding die, *flash welding*. A resistance welding electrode matching the contour of the workpiece to clamp or shape the workpieces and conduct welding current.

resistance welding electrode. The part of a secondary circuit responsible for the transmission of welding current and force to the workpieces. The electrode may be in the form of a rotating wheel, rotating roll, bar, cylinder, plate, clamp, or modification thereof.

rod. A round, hexagonal or octagonal solid section furnished in straight lengths.

RWMA Class designation. A classification system established by the Resistance Welding Manufacturing Alliance to identify copper alloys having similar mechanical and electrical properties.

sheet. A flat rolled product form up to and including 0.19 in [5 mm] in thickness and typically over 20 in [0.5 m] in width.

softening temperature. The maximum temperature that, if maintained for 2 h, will result in a reduction in ambient temperature hardness exceeding 15 % of the "as received" value.

temper designation. A standardized system for denoting the mechanical properties of metals.

4. RWMA Materials Classification System

The RWMA materials classification system is a simple means to identify materials having similar hardness and electrical conductivity values. This system facilitates the identification of suitable materials for common welding applications. The classification system does not address material chemical composition. The actual properties of particular materials, material shapes and forms, and products may vary considerably from the minimum properties shown in Table 1.

4.1 Group Designations. Groupings are used to classify the materials according to their basic structure: alloys, composites, and specialty materials.

4.1.1 Group A – Copper and Copper Alloys. Alloys gain their properties due to chemical interactions between elements, granular structure resulting from heat treatment, and mechanical working (i.e., cold working or hot working). The principal electrode wear mechanism for these materials is metal flow (i.e., mushrooming), which is accelerated by exposure to temperatures above the softening temperature.

4.1.2 Group B – Refractory Metal and Refractory Metal Composites. The composites consisting of consolidated refractory metal powders infiltrated with copper. The refractory metal gives the material thermal stability and hardness and the copper serves to lock the matrix and improve the conductivity. Since the copper in the matrix has little strength, it will allow the matrix to creep.

4.1.3 Group C – Specialty Materials. Dispersion strengthened copper incorporates aluminum oxide distributed in the copper matrix to improve performance at elevated temperature.

4.2 RWMA Class Designations. Table 1 shows the Group and Class designation assigned to standard alloy designations. Upon request, the J1 Committee will consider a new class designation when there is consensus that a copper alloy or composite is of commercial significance.

Table 1
RWMA Classification System Overview

Group	Classes Possible in Group	Assigned Class Numbers	Minimum Properties[a]	
			% IACS[b]	Hardness[c]
GROUP A	1–9	1	80	65 HRB
		2	75	75 HRB
		3	45	90 HRB
		4	20	33 HRC
GROUP B	10–19	10	45	72 HRB
		11	40	94 HRB
		12	35	98 HRB
		13	30	69 HRA
		14	30	85 HRB
GROUP C	20 and up	20	75	75 HRB
		21	92	62 HRB
		22	87	68 HRB

[a] Round rod fully heat treated and cold worked up to 1 in [25 mm] Diameter. Actual hardness for other sizes is specified in Tables 5, 6, and 7.
[b] % IACS at 68°F [20°C]
[c] HRA = Rockwell Hardness scale A; HRB = Rockwell Hardness scale B; HRC = Rockwell Hardness scale C

4.3 Consideration of New Materials. For a material to qualify for an RWMA designation, the material must be recognized as commercially relevant and available. This is most commonly accomplished by the assignment of a recognized designation such as the unified numbering system (UNS) number. The UNS numbers for copper-based materials are maintained by the Copper Development Association (CDA). Commercial standards for other materials are established by ASTM International (ASTM) and similar internationally based organizations.

4.4 Common Usage. Table 2 provides a general description of classified materials as well as commentary on general usage.

4.5 Material Compatibility. Table 3 identifies materials commonly used to spot weld specific workpiece materials. In rare cases, material compatibility may lead to having electrodes of different materials. Should this be preferred, it would be desirable to have a physical difference between the electrodes to ensure they are not unintentionally switched. This could be using different sizes or different tapers (i.e., one electrode having a male taper and the other a female taper).

Table 2
RWMA Classified Materials – Common Usage

RWMA Class	Common Name	Material Designation[a]	Description	General Application[b]	Availability
Group A – Copper Base Alloys					
1	Zirconium Copper	C15000	A specially heat treated zirconium copper alloy.	Electrodes for welding aluminum alloys, magnesium alloys, coated materials, brass and bronzes. Can be used for both spot and seam welding.	Forgings, Rod and Bar
2	Chromium-Zirconium Copper	C18150	A specially heat treated chromium-zirconium copper alloy that meets the minimum electrical and hardness specifications of Class 2 alloys. Should be used in heat-treated condition.	These materials are stronger than Class 1 materials, have slightly lower conductivity. They are used for spot and seam welding of cold and hot rolled steel, stainless steel and low conductivity brass and bronze. They are also used as flash welding dies, and as electrodes for the welding of galvanized steel and other coated materials.	Castings, Forgings, Rod and Bar, Plate
	Chromium Copper	C18200	A high conductivity chromium copper alloy that obtains its optimum properties from a combination of both heat treatment and cold work. Should be used in heat-treated condition.		Castings, Forgings, Rod and Bar, Plate, Tube
3	Cobalt-Beryllium Copper	C17500	Heat treatable copper alloys with a combination of high tensile strength and good electrical and thermal properties. Should be used in heat-treated condition.	These materials are favored for structural current carrying components because of their high tensile strength and hardness. Welding gun castings, holders and adapters are common applications. The mechanical properties are also frequently exploited to provide a component with preferential wear resistance when connections involve friction fit tapers or threads. The hardness may also yield improved service life of electrodes and dies when welding high hardness workpieces.	Castings, Forgings, Rod and Bar, Plate, Tube
	Nickel-Beryllium Copper	C17510			
	Nickel-Cobalt-Beryllium Copper	C17540			
	Nickel-Silicon-Chromium Copper	C18000			
4	Beryllium Copper	C17200	Heat treatable copper alloy having the unusual combination of very high hardness, high strength and lower electrical conductivity than Class 3 materials. Should be used in heat-treated condition.	Similar to Class 3 but, where the higher hardness is beneficial and the heat exposure is lower.	Castings, Forgings, Rod and Bar, Plate, Tube
Group B-Refractory Metals					
10	Copper Tungsten	N/A[c]	A powder metallurgical combination of 45% copper and 55% of the refractory metal tungsten. Not a true alloy. This combination produces dense, hard metals of superior wear resistance and strength at elevated temperatures. In addition, they possess good thermal and electrical conductivity.	Flash and butt welding electrodes where good electrical and thermal conductivity is necessary and where a degree of malleability is desired.	Rod and Bar, Inserts

(*Continued*)

Table 2 (*Continued*)
RWMA Classified Materials – Common Usage

RWMA Class	Common Name	Material Designation[a]	Description	General Application[b]	Availability
11	Copper Tungsten	ASTM B702 C1 D	A powder metallurgical combination of 25% copper and 75% of the refractory metal tungsten. Not a true alloy. This combination produces dense, hard metals of superior wear resistance and strength at elevated temperatures. In addition, they possess good thermal and electrical conductivity	Projection welding electrodes, flash and butt welding electrodes, light upsetting and seam welding bushings. Harder than Class 10 and used where moderate pressure is required. This material can also be used for spot welding low conductivity steels such as stainless.	Rod and Bar, Inserts
12	Copper Tungsten	ASTM B702 C1 E	A powder metallurgical combination of 20% copper and 80% of the refractory metal tungsten. Not a true alloy. This combination produces dense, hard metals of superior wear resistance and strength at elevated temperatures. In addition, they possess good thermal and electrical conductivity.	Heavy duty projection welding electrodes, electro-forming and electro forging electrode facings for upsetting of studs and rivets, cross wire welding of large diameter wire and rod.	Rod and Bar, Inserts
13	Tungsten	N/A[c]	Tungsten is extremely hard and has low ductility. It cannot be machined with cutting tools but can be ground to required contours. It does not alloy with nonferrous materials.	Cross wire welding of copper and brass, resistance brazing and some upsetting. Welding of braided copper wire to other materials.	Rod and Bar, Plate, Inserts
14	Molybdenum	ASTM B387 type 360	Not as hard as Class 13 and can be drilled and machined to special contours.	Cross wire welding of copper and brass, resistance brazing and some upsetting. Welding of braided copper wire to other materials.	Rod and Bar, Plate, Tube, Inserts
Group C-Specialty Materials					
20	Dispersion Strengthened Copper	C15760	A powder metallurgy material consisting of copper and aluminum oxide with high temperature hardness and physical properties different than copper alloys. Not a true alloy.	Welding of metallic coated metal such as galvanized steel, terne plate, etc.	Rod and Bar, Plate
21	Dispersion Strengthened Copper	C15715		Applications requiring the highest electrical and thermal conductivities along with good elevated temperature strength	Rod and Bar, Plate
22	Dispersion Strengthened Copper	C15725		Alternative to Class 20 where higher electrical conductivity is required at the expense of hardness and strength.	Rod and Bar, Plate

[a] Numbers with the alloy designation Cxxxxx are UNS numbers managed by the Copper Development Association (CDA), numbers with ASTM designations are ASTM.
[b] This table provides general comments about common applications of various class materials. More specific information may be obtained from material, electrode, and equipment manufacturers.
[c] N/A is not assigned.

Table 3
Material Compatibility

	Workpiece Material	Recommended Electrode Class(es)
Similar Ferrous Metals	Chrome Plate	2
	Cold-Rolled Steel	2
	Galvanized Steel	1, 2, 20
	Stainless Steel	2, 3
	Terne Plate	1, 2, 20
	Tin Plate	1, 2, 20
Similar Nonferrous Metals	Aluminum and Aluminum Alloys	1, 2
	Bronze	2
	Copper	13, 14
	Cupronickel	2
	Magnesium	2
	Nickel & Nickel Alloys	2
	Nickel-Silver	2
	Phosphor Bronze	2
	Red Brass	2
	Silicon	13, 14
	Titanium	1, 2
	Yellow Brass	2
Refractory Metals	Tungsten Molybdenum	2

Note: The same electrode alloy should be used on both sides for all materials listed.

5. Material Specifications

5.1 Composition. Standard chemical compositions of RWMA class materials are listed in Table 4. The UNS numbers are assigned and maintained by the Copper Development Association.

5.2 Physical and Mechanical Properties. While the RWMA standard relates to a generic minimum specification, the properties may vary with the size of the material. Cold work and heat treating may, for example, vary with thickness of the product. Tables 5–7 provide minimum physical and mechanical properties.

Table 4
Standard Chemical Compositions of RWMA Class Materials

RWMA Class	UNS Number or Other Designation	Description	Cu[a]	Fe	W	Cd	Co	Ni	Cr	Si	Be	Pb	Zr	Al
Group A – COPPER BASE ALLOYS														
1	C15000	Zirconium Copper	99.80 min.	—	—	—	—	—	—	—	—	—	0.10–0.20	—
2	C18150	Chromium-Zirconium Copper	REM.	—	—	—	—	—	0.5–1.5	—	—	—	0.02–0.20	—
	C18200	Chromium Copper	REM.	0.10 max.	—	—	—	—	0.6–1.2	0.10 max.	–	0.05 max.	—	—
	C17500	Cobalt-Beryllium Copper	REM.	0.10 max.	—	—	—	2.4–2.7	—	0.20 max.	0.4–0.7	—	—	0.20 max.
	C17510	Nickel-Beryllium Copper	REM.	0.10 max.	—	—	1.4–2.2	0.30 max.	—	0.20 max.	0.2–0.6	—	—	0.20 max.
3	C17540	Nickel-Cobalt-Beryllium Copper	REM	0.20 max.	—	—	0.8–1.3	0.8–1.3	—	—	0.4–0.7	—	—	—
	C18000	Nickel-Silicon-Chromium Copper	REM.	0.15 max.	—	—	1.8–3.0	—	0.1–0.8	0.4–0.8	—	—	—	—
4	C17200	Beryllium Copper	REM	—	—	—	Ni+Co = 0.20 min. Ni+Fe+Co = 0.60 max.	—	0.20 max.	1.8–2.0	0.02 max.	—	0.20 max.	
GROUP B – REFRACTORY METAL AND REFRACTORY METAL COMPOSITES														
10		Copper Tungsten	43–47	—	REM.	—	—	—	—	—	—	—	—	—
11	ASTM B702 C1 D	Copper Tungsten	23–27	—	REM.	—	—	—	—	—	—	—	—	—
12	ASTM B702 C1 E	Copper Tungsten	18–22	—	REM.	—	—	—	—	—	—	—	—	—
13		Tungsten	—	—	99.9 min.	—	—	—	—	—	—	—	—	—
14	ASTM B387 alloy 360 or 361	Molybdenum	—	—	(Mo) 99.9 min.	—	—	—	—	—	—	—	—	—
GROUP C – SPECIALTY MATERIALS														
20	C15760	Dispersion Strengthened Copper	98.77	0.01 max.	—	—	—	—	—	—	—	0.01 max.	—	0.58–0.62 as Al_2O_3
21	C15715	Dispersion Strengthened Copper	98.77	0.01 max.	—	—	—	—	—	—	—	0.01 max.	—	0.3 as Al_2O_3
22	C15725	Dispersion Strengthened Copper	98.77	0.01 max.	—	—	—	—	—	—	—	0.01 max.	—	0.5 as Al_2O_3

[a] Including Ag.

Table 5
Group A – Physical and Mechanical Properties for RWMA Class 1, 2, 3, 4

GROUP A COPPER BASE ALLOYS See Note[a]		Minimum Hardness Rockwell B or C as noted See Notes[b]				Minimum Electrical Conductivity %IACS [MS/m]			
SIZE RANGE		CLASS				CLASS			
in	mm	1	2	3	4	1	2	3	4
DIAMETER – ROUND ROD STOCK									
UP TO 1	UP TO 25	65HRB	75HRB	90HRB	33HRC	80% [46]	75% [43.5]	45% [26]	20% [11.6]
OVER 1 TO 2	OVER 25 TO 51	60HRB	70HRB	90HRB	33HRC	80% [46]	75% [43.5]	45% [26]	20% [11.6]
OVER 2 TO 3	OVER 51 TO 76	55HRB	65HRB	90HRB	33HRC	80% [46]	75% [43.5]	45% [26]	20% [11.6]
OVER 3 TO 3-1/2	OVER 76 TO 89	50HRB	65HRB	90HRB	33HRC	80% [46]	75% [43.5]	45% [26]	20% [11.6]
OVER 3-1/2 TO 4	OVER 89 TO 102	48HRB	60HRB	90HRB	33HRC	80% [46]	75% [43.5]	45% [26]	20% [11.6]
OVER 4 TO 4-1/2	OVER 102 TO 114	45HRB	60HRB	90HRB	33HRC	80% [46]	75% [43.5]	45% [26]	20% [11.6]
THICKNESS – SQUARE, RECTANGULAR AND HEXAGONAL BAR STOCK									
UP TO 1	UP TO 25	55HRB	70HRB	90HRB	33HRC	80% [46]	75% [43.5]	45% [26]	20% [11.6]
OVER 1	OVER 25	50HRB	65HRB			80% [46]	75% [43.5]	45% [26]	20% [11.6]
THICKNESS – FORGINGS AND PLATES									
UP TO 1	UP TO 25	55HRB	65HRB	90HRB	33HRC	80% [46]	75% [43.5]	45% [26]	20% [11.6]
OVER 1 TO 2	OVER 25 TO 51	50HRB	65HRB	90HRB	33HRC	80% [46]	75% [43.5]	45% [26]	20% [11.6]
OVER 2	OVER 51	50HRB	65HRB	90HRB	33HRC	80% [46]	75% [43.5]	45% [26]	20% [11.6]

[a] All materials are in the fully heat treated and hardened condition.
[b] Rod and bar hardness is determined at mid radius in accordance with ASTM E18.

Table 6
Group B – Physical and Mechanical Properties for Class 10 – 14 (Rod and Bar)

	HARDNESS ROCKWELL	ELECTRICAL CONDUCTIVITY	ULTIMATE COMPRESSIVE STRENGTH[a]
RWMA Class	min.	min. %IACS [MS/m]	ksi [MPa]
CLASS 10	70 HRB	45% [26]	135 [930]
CLASS 11	94 HRB	40% [23]	160 [1103]
CLASS 12	98 HRB	38% [22]	170 [1172]
CLASS 13	69 HRA	30% [17.4]	200 [1379]
CLASS 14	85 HRB	30% [17.4]	88 [607]

[a] For information only

Note: The conductivity and hardness noted may differ from the ASTM standards.

Table 7
Group C – Physical and Mechanical Properties for Class 20 – 22 (Rod and Bar)

RWMA CLASS	Alloy Number	HARDNESS ROCKWELL	ELECTRICAL CONDUCTIVITY	YIELD STRENGTH 0.2% offset	ULTIMATE TENSILE STRENGTH	TYPICAL ELONGATION %
		Minimum	Minimum % IACS [MS/m]	Typical ksi [Mpa]	Typical ksi [MPa]	2 in [50 mm] or 4×D gage length
Class 20	C15760	75 HRB	75 [43.5]	60 [413]	74 [510]	25
Class 21	C15715	63 HRB	88 [51]	48 [331]	58 [400]	30
Class 22	C15725	69 HRB	85 [49]	54 [372]	65 [448]	27

Note: Acceptance is based on hardness and electrical conductivity only.

6. Material Identification

6.1 Marking. There is no standard requirement for identification marking of the raw material (See color coding.)

6.2 Color Coding. Color may be used to identify the material alloy or condition of bar, rod, and plate. The assignment of colors is by agreement between the Buyer and Seller. An example of colors commonly applied as a paint or ink to one end of each bar is in Annex B, Color Coding of Rod and Bar Stock.

6.3 Packaging. Packaging is at the discretion of the supplier unless specific requirements for packaging or product preservation are specified in the contract documents. Rods and bars may be bundled or boxed to prevent handling damage during shipment. Bundles are securely strapped in sufficient locations to prevent material from shifting. Bundles may be wrapped in paper or other material to further protect the material from shipping and handling damage.

Suitable wood or cardboard cases may be utilized to protect the material from shipping and handling damage.

6.4 Labeling. The material shall be identified by a means that will endure the expected handling. Labeling may be applied as a tag or label secured to the product, bundle, or package, or it may be applied to the material as a printed or imprinted marking.

At a minimum, the product labeling shall provide the:

- supplier name
- purchase order number
- alloy/class/condition
- material size.

The labelling may also include the:

- distributor
- heat or lot number
- package weight
- precautionary instructions

6.5 Documentation

6.5.1 Material Certifications. When requested at the time of order, certifications and test reports may be supplied with the shipment or alternately mailed or electronically transmitted to the buyer. Some common examples are: Certifications of Compliance, Material Test Report, and Composition Report.

6.5.2 Safety Data Sheets. The seller shall be responsible for supplying safety data sheets.

7. Material Testing

Tests may be employed for acceptance inspection or troubleshooting.

7.1 Chemical Analysis. ASTM E478, *Standard Test Methods for Chemical Analysis of Copper Alloys,* shall be used unless an alternative specification is required by the contract.

7.2 Hardness Testing

7.2.1 Rockwell Hardness. ASTM E18, *Standard Test Methods for Rockwell Hardness of Metallic Materials,* shall be used for interpreting Rockwell hardness measurements. Acceptability of Rockwell hardness results shall be based on the average of at least three (3) tests made at mid-radius on round samples or midway between the surface and centerline on other shapes including bar and plate.

7.2.2 Brinell and Vickers Hardness Conversion to Rockwell Hardness. Table D.3 provides conversion factors for approximation of hardness values in alternative measurement units. The hardness measurement method specified in the contract document shall be the basis for compliance determination.

7.3 Electrical Conductivity. Electrical Conductivity shall be determined in accordance with ASTM E1004, *Standard Test Method for Determining Electrical Conductivity Using the Electromagnetic (Eddy-Current) Method*. Alternately, ASTM B193, *Standard Test Method for Resistivity of Electrical Conductor Materials* may be used where sample size precludes the use of ASTM E1004.

7.4 Microstructure – Grain Size. This standard imposes no requirement for grain size. The buyer and seller may agree on a specific requirement outside the scope of this standard. In the case of grain size determination, ASTM E112, *Standard Test Methods for Determining Average Grain Size*, shall be used as the basis for grain size measurement. Grain size requirements may be established

7.4.1 Macroscopic Examination. Macroscopic examination may be utilized to determine or verify grain flow in a wrought product. This requirement is beyond the scope of this standard and shall be agreed between the buyer and the seller.

7.4.2 Bend Testing. In the case where rods or bars will be formed (bent), the buyer and seller may agree on specific bend performance requirements beyond the scope of this standard. Bending requirements, procedures and capabilities may vary considerably; thus, there is no applicable standard.

7.5 Dimensions

7.5.1 Linear Dimensions. Tolerances for linear dimensions are specified in Tables 8-10.

7.5.2 Surface Condition. Unless otherwise specified, all products supplied under this standard will be supplied with a standard commercial mill finish, such as drawn, rolled, or forged. Surfaces shall be free of laminations, inclusions, cracks, and porosity as visible to the naked eye. Special surface conditions, such as a specific surface finish, shall be specified by the buyer and agreed by the seller prior to purchase order placement.

7.5.3 Straightness. Rods, and bars shall be produced commercially straight in accordance with ASTM B249/B249M, *Standard Specification for General Requirements for Wrought Copper and Copper-Alloy Rod, Bar, Shapes and Forgings*. Round rods under 1.5 in [38 mm] shall be produced and supplied in a straightness consistent with screw machine rod as defined by ASTM B249/B249M. Larger sizes and other shapes will be considered for general purpose, with applicable straightness tolerances per ASTM B249/B249M.

Table 8A
Alloy Rod and Bar Stock Products Tolerances (dimensions in inches)

RWMA Class	Size	Tolerance on diameter of round rods	Tolerance across flats on hexagonal	Tolerance on rectangles							
				Up to ½ wide		>1/2 to 1 wide		>1 to 2 wide		>2 to 4 wide	
				Thickness	Width	Thickness	Width	Thickness	Width	Thickness	Width
Class 1 and Class 2	< 5/8	± 0.002	± 0.004	± 0.005	± 0.005	± 0.005	± 0.007	–	–	–	–
	5/8 to 1	± 0.003	± 0.005	–	–	± 0.006	± 0.007	± 0.007	± 0.009	± 0.008	± 0.5%
	>1 to 2-1/2	± 0.004	± 0.006	–	–	–	–	± 0.007	± 0.009	± 0.009	± 0.5%
	>2-1/2 to 3	± 0.006	± 0.012	–	–	–	–	–	–	± 0.5%	± 0.5%
Class 3 and Class 4 Cold Drawn and Annealed	< 1/2	± 0.002	± 0.003	± 0.005	± 0.003	± 0.004	± 0.005	± 0.005	± 0.006	–	–
	1/2 to 1	± 0.003	± 0.004	–	–	± 0.005	± 0.005	± 0.006	± 0.006	–	–
	>1 to 2	± 0.004	± 0.005	–	–	–	–	± 0.006	± 0.006	–	–
	>2 to 2-1/2	± 0.004	–	–	–	–	–	–	–	–	–
Class 3 and Class 4 Heat Treated	< 1/2	± 0.003	± 0.005	± 0.004	± 0.004	± 0.005	± 0.005	± 0.006	± 0.006	–	–
	1/2 to 1	± 0.004	± 0.006	–	–	± 0.005	± 0.005	± 0.006	± 0.006	–	–
	>1 to 2	± 0.005	± 0.007	–	–	–	–	± 0.006	± 0.006	–	–
	>2 to 2-1/2	± 0.005	–	–	–	–	–	–	–	–	–

Note: General suggested tolerances, not to be interpreted as the optimum for any specific application.

Table 8B
Alloy Rod and Bar Stock Alloy Products Tolerances (dimensions in millimeters)

RWMA Class	Size	Tolerance on diameter of round rods	Tolerance across flats on hexagonal	Tolerance on rectangles							
				Up to 13 wide		>13 to 25 wide		>25 to 50 wide		>50 to 100 wide	
				Thickness	Width	Thickness	Width	Thickness	Width	Thickness	Width
Class 1 and Class 2	< 16	± 0.05	± 0.10	± 0.12	± 0.12	± 0.12	± 0.18	–	–	–	–
	16 to 25	± 0.08	± 0.12	–	–	± 0.15	± 0.18	± 0.18	± 0.23	± 0.20	± 0.5%
	>25 to 64	± 0.10	± 0.15	–	–	–	–	± 0.18	± 0.23	± 0.20	± 0.5%
	>64 to 75	± 0.15	± 0.30	–	–	–	–	–	–	± 0.5%	± 0.5%
Class 3 and Class 4 Cold Drawn and Annealed	< 13	± 0.05	± 0.08	± 0.08	± 0.08	± 0.10	± 0.12	± 0.12	± 0.15	–	–
	13 to 25	± 0.08	± 0.10	–	–	± 0.12	± 0.12	± 0.15	± 0.15	–	–
	>25 to 50	± 0.10	± 0.12	–	–	–	–	± 0.15	± 0.15	–	–
	>50 to 64	± 0.10	–	–	–	–	–	–	–	–	–
Class 3 and Class 4 Heat Treated	< 13	± 0.08	± 0.12	± 0.10	± 0.10	± 0.12	± 0.12	± 0.15	± 0.15	–	–
	13 to 25	± 0.10	± 0.15	–	–	± 0.12	± 0.12	± 0.15	± 0.15	–	–
	>25 to 50	± 0.10	± 0.12	–	–	–	–	± 0.15	± 0.15	–	–
	>50 to 64	± 0.12	–	–	–	–	–	–	–	–	–

Table 9A
Tolerances for Cast Shapes (dimensions in inches)

RWMA Class	Pattern Type	Weight of Casting lb	Tolerance as Cast	Suggested Allowance for Subsequent Finishing	Recommended minimum amount of material to be over tube when tube is cast integrally in casting
2, 3, 4	PLATE	All	± 0.03 on all dimensions	0.06 to 0.13	<25 lb castings = 0.25 25 to < 100 lb castings = 0.38 ≥ 100 lb castings = 0.50
	LOOSE	< 50	± 0.06 on all dimensions	0.13 to 0.19	
		50 to <100	± 0.09 on all dimensions	0.19 to 0.25	
		≥ 100	± 0.13 on all dimensions	0.31 to 0.38	

Table 9B
Tolerances for Cast Shapes (dimensions in millimeters)

RWMA Class	Pattern Type	Weight of Casting kg	Tolerance as Cast	Suggested Allowance for Subsequent Finishing	Recommended minimum amount of material to be over tube when tube is cast integrally in casting
2, 3, 4	PLATE	All	± 0.8 on all dimensions	1.6 to 3.2	<11 kg casting = 6 11 to < 45 kg = 10 over 45 kg = 13
	LOOSE	< 22	± 1.5 on all dimensions	3.2 to 4.7	
		22 to 45	± 2.3 on all dimensions	4.7 to 6.4	
		> 45 to 227	± 3.2 on all dimensions	4.7 to 6.4	
		> 227	± 3.2 on all dimensions	8.0 to 9.5	± 0.5%

Table 10A
Allowances for Forged Products (dimensions in inches)

AS FORGED RINGS & DISCS				AS FORGED ROUNDS				AS FORGED RECTANGULAR BARS		
	ALLOWANCES				ALLOWANCES (plus)			FINISH SIZE	ALLOWANCES (plus)	
FINISH DIAMETER	O.D. (plus)	I.D. (minus)	THICKNESS (plus)	FINISH DIAMETER	LENGTH TO 48	LENGTH TO 60	LENGTH OVER 60	THICKNESS	≤ 4 WIDTH	> 4 WIDTH
≤ 12	1/2 ± 1/8	1/2 ± 1/8	1/4 ± 1/16	≤ 3	3/8 ± 1/8	1/2 ± 1/8	5/8 ± 1/8	≤ 1-1/2	1/4 ± 1/8	3/8 ± 1/8
> 12 TO 20	3/4 ± 1/8	5/8 ± 1/4	5/16 ± 1/8	> 3	1/2 ± 1/8	5/8 ± 1/8	3/4 ± 1/8	> 1-1/2	3/8 ± 1/8	3/8 ± 1/8
> 20 TO 30	7/8 ± 1/4	3/4 ± 1/4	1/2 ± 3/16					WIDTH	FOR ALL THICKNESSES	
> 30 TO 36	1-1/4 ± 1/4	1-1/4 ± 1/4	3/4 ± 1/4					≤1-1/2	1/4 ± 1/8	
> 36	1-½ ± 3/8	1-½ ± 3/8	1 ± 1/4					> 1-1/2	3/8 ± 1/8	

FINISH MACHINED RINGS & DISCS		ROUNDS AND RECTANGULAR			
		LENGTH ALLOWANCE		FINISH MACHINED DIA, WIDTH, OR THICKNESS	
I.D.	TOLERANCE	LENGTH	ALLOWANCE (plus)	LENGTH	TOLERANCE
≤ 6	+ 0.002 / – 0.000	≤ 6	1/2	≤ 12	±0.005
> 6 TO 10	+ 0.003 / – 0.000	> 6 TO 12	1	> 12	±0.010
> 10	+ 0.004 / – 0.000	> 12 TO 18	1-1/2		
O.D. (for all sizes)	+0.06 / –0.00	> 18 TO 30	2		
THICKNESS (for all sizes)	± 0.010	> 30	2-1/4		

Table 10B
Allowances for Forged Products (dimensions in millimeters)

AS FORGED RINGS & DISCS				AS FORGED ROUNDS				AS FORGED RECTANGULAR BARS		
	ALLOWANCES				ALLOWANCES (plus)			FINISH SIZE	ALLOWANCES (plus)	
FINISH DIAMETER	O.D. (plus)	I.D. (minus)	THICKNESS (plus)	FINISH DIAMETER	LENGTH TO 1,220	LENGTH TO 1,520	LENGTH OVER 1,520	THICKNESS	≤ 100 WIDTH	> 100 WIDTH
≤ 305	13 ± 3	3 ± 3	7 ± 1.6	≤ 76	10 ± 3	13 ± 3	16 ± 3	≤ 38	7 ± 3	10 ± 3
> 305 TO 508	19 ± 3	13 ± 3	8 ± 3	> 76	13 ± 3	16 ± 3	19 ± 3	> 38	10 ± 3	10 ± 3
> 508 TO 762	22 ± 6.3	19 ± 6.3	13 ± 4.7					**WIDTH**	**FOR ALL THICKNESSES**	
> 762 TO 914	32 ± 6.3	32 ± 6.3	19 ± 6.3					≤38	7 ± 3	
> 914	38 ± 9.5	38 ± 9.5	25 ± 6.3					> 38	10 ± 3	

FINISH MACHINED RINGS & DISCS		ROUNDS AND RECTANGULAR			
		LENGTH ALLOWANCE		FINISH MACHINED DIA, WIDTH, OR THICKNESS	
I.D.	TOLERANCE	LENGTH	ALLOWANCE (plus)	LENGTH	TOLERANCE
≤ 152	+ 0.051, – 0.000	≤ 152	13	≤ 305	±0.13
> 152 TO 254	+ 0.076, – 0.000	> 152 TO 304	25	> 305	±0.25
> 254	+ 0.100, – 0.000	> 304 TO 457	38		
O.D. (for all sizes)	+1.5, –0.00 ON ALL	> 457 TO 762	51		
THICKNESS (for all sizes)	± 0.254	> 762	57		

8. Commercial Order Data Information

When submitting an inquiry, or placing an order, the following information shall be provided:

1) RWMA class or alloy number. See 4.2.

2) Quantity in pieces, weight, length, or another unit.

3) Shape of material: rod, bar (i.e. rectangular, square, or special shape), tube, or plate.

4) Dimensions, including length requirement (i.e., minimum, maximum, or nominal rod or bar length), if any.

5) Are certifications required? See 6.5.1 for options.

6) Are there special condition or properties? Is a special temper other than the RWMA Class specified? Examples: unaged, annealed.

7) Special packaging, if any.

8) Special handling requirements (e.g., maximum package weight or size, access for forks or slings), if any.

9) Special transportation requirements (e.g., specific carrier, open truck for side or overhead unloading), if any.

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Annex A (Informative)
Additional Material Properties Information

This annex is not a part of this standard, but is included for informational purposes only.

Table A.1
Additional Typical Properties for Class 1 thru 4 (Reference only, not intended for specification)

Alloy (UNS Number)	RWMA Class	Temper Condition[b]	Outer Diameter (Rod) or Thickness (Bar) in inches [mm]	Typical Ultimate Tensile Strength ksi [MPa][a]	Typical Yield Strength ksi [MPa][a,c]	Typical Elongation % (2 inch or 4×D gage length)[a]
C15000	1	NA	Up to 1 [25.4]	60–75 [410–520]	45–60 [310–410]	13–20
			Over 1–2 [25.4–50.8]	55–70 [380–480]	42–52 [290–360]	13–20
			Over 2–3 [50.8–76.2]	50–65 [340–450]	40–50 [280–350]	13–20
			Over 3–3–1/2 [76.2–88.9]	45–60 [310–410]	40–50 [280–350]	13–20
			Over 3–1/2–4 [88.9101.6]	42–57 [290–390]	35–45 [240–310]	13–20
C18150 C18200	2	NA	Up to 1 [25.4]	65–80 [450–550]	55–70 [380–480]	13–30
			Over 1–2 [25.4–50.8]	59–74 [410–510]	50–65 [340–450]	13–30
			Over 2–3 [50.8–76.2]	55–70 [380–480]	45–55 [310–380]	13–30
			Over 3–3–1/2 [76.2–88.9]	48–63 [330–430]	42–52 [290–360]	13–30
			Over 3–1/2–4 [88.9–101.6]	45–60 [310–410]	39–49 [270–340]	13–30
			Over 4–4–1/2 [101.6–114.3]	45–60 [310–410]	39–49 [270–340]	13–30
C17500 C17510 C17540	3	AT [TF00]	Over 3 [76.2]	100–130 [690–900]	80–100 [550–690]	10–25
		HT [TH04]	Up to 3 [76.2]	110–140 [760–970]	95–125 [650–860]	5–25
C18000	3	AT [TF00]	Over 3 [76.2]	90–120 [620–830]	70–105 [480–720]	10–20
		HT [TH04]	Up to 3 [76.2]	95–125 [660–860]	75–115 [520–790]	8–25
C17200	4	AT[TF00]	Over 3–14 [76.2–356]	165–200 [1140–1380]	130–175 [900–1210]	3–10
			0.03–3 [0.76–76.2]	165–200 [1140–1380]	145–175 [1000–1210]	4–10
		HT[TH04]	Over 0.375–1.0 [9.5–25.4]	180–220 [1240–1520]	155–195 [1070–1340]	2–9
			Over 1.0–3 [25.4–76.2]	175–215 [1210–1480]	145–190 [1000–1310]	4–9

[a] Mechanical property sets shown are typical and intended for reference ONLY. Certifications shall include hardness & electrical conductivity ONLY.
[b] Temper – equivalent ASTM temper terminology.
[c] Yield Strength for C15000, C18150, C18200 measured at 0.5% Ext, Yield Strength for C17500, C17510, C17540, C18000, and C17200 measured at 0.2% offset.

Table A.2
RWMA Typical Properties for Class 3 and Class 4 in Unaged Condition

RWMA Class	UNS Alloy Number	Temper (ASTM designation)	Heat Treatment Specification	Outer Diameter (Rod) or Thickness (Bar) inches [mm]	Typical Tensile Strength ksi [MPa]	Typical Rockwell Hardness
3 (unaged)	C17510	A (TB00)	850°F–900°F – 3 hr. [450°C–480°C]	over 3 [76.2]	35–55 [240–380]	20–50 B
		H (TD04)	850°F–900°F – 2 hr. [450°C–480°C]	up to/incl 3 [76.2]	65–80 [450–550]	60–80 B
3 (unaged)	C18000	A(TB00)	900°F–950°F – 3 hr. [480°C–510°C]	over 3 [76.2]	35–55 [240–380]	NA
		H (TD04)		up to/incl 3 [76.2]	65–80 [450–550]	65–80 B
4 (unaged)	C17200	A (TB00)	600°F–675°F – 3 hr. [330°C–360°C]	over 3 [76.2]	65–80 [450–550]	45–85 B
		H (TD04)	600°F–675°F – 2 hr. [330°C–360°C]	up to/incl 3 [76.2])	85–120 [590–830]	88–103 B

Notes:
1. Data shown is for reference only. Since fully hardened Class 3 and Class 4 alloys are not suitable for bending and cold forming, these materials are supplied in semi-finished unaged conditions to allow forming prior to age hardening.
2. These materials must be aged hardened (heat treated) after forming to meet requirements as shown in Table 5 before assembly/use. Contact supplier for details of heat treat conditions, protective atmospheres, soak times, and equipment suitability.
3. Alternative specifications for unaged materials may be established between supplier and customer

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Annex B (Informative)
Color Coding of Rod and Bar Stock

This annex is not a part of this standard, but is included for informational purposes only

Table B.1
Color Coding of Rod and Bar Stock

	Color	Alloy Number	Condition
	Grey	C15000	Class 1 Heat treated
	Yellow	C18150	Class 2 Heat treated
	Scarlet	C18200	Class 2 Heat treated
	Purple	C17510	Class 3 Unaged
	Blue	C17510	Class 3 Heat treated
	Pink	C18000	Class 3 Unaged
	White	C18000	Class 3 Heat treated
	Green	C17200	Class 4 Unaged
	Orange	C17200	Class 4 Heat treated
	Black	C15760	Class 20 Dispersion Strengthened

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Annex C (Informative)
Informative References

This annex is not a part of this standard, but is included for informational purposes only.

ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

AWS *Welding Handbook, 9th Edition, Volume 3, Part 2, Chapter xx,*

ASTM B702, *Standard Specification for Copper-Tungsten Electrical Contact Material*

ASTM B387 – 10, *Standard Specification for Molybdenum and Molybdenum Alloy Bar, Rod, and Wire*

ASTM B193, *Standard Test Method for Resistivity of Electrical Conductor Materials*

ASTM E112, *Standard Test Methods for Determining Average Grain Size*

EN 12163, *Copper and copper Alloys – Rod for general purposes*

ISO 693, *Dimensions of seam welding wheel blank*

ISO 5182, *Resistance welding — Materials for electrodes and ancillary equipment*

RWMA Bulletin 16, *Resistance Welding Equipment Standards*

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Annex D (Informative)
Overview of the ISO Standard

This annex is not a part of this standard, but is included for informational purposes only.

D.1 Introduction

Much like the RWMA standard, ISO 5182, *Resistance welding — Materials for electrodes and ancillary equipment* and EN 12163, *Copper and copper Alloys – Rod for general purposes* employ groups and types to classify materials. The group, type, and alloy designations used by the standards do not align so the systems should be used independently. Table D.2 provides some approximate equivalencies.

Table D.1
ISO System for Classification of Materials

Type	Description
	Group A — Classification of copper and copper alloys
1	Non-heat-treatable alloys of high conductivity and medium hardness, the wrought forms of which are given their strengths by cold working during manufacture
2	Alloys which are harder than type 1 and in which the mechanical properties have been developed by heat treatment during manufacture or by a combination of heat treatment and cold working
3	Heat-treated alloys which have superior mechanical properties to type 2 but a lower electrical conductivity than either type 1 or type 2
4	Alloys having certain specialized properties which may, in some cases, be obtained either by cold working or by heat treatment. Alloys of this type are not necessarily interchangeable with each other;
	Group B — Sintered materials
10	Sintered products of copper and tungsten.
11	Sintered products of copper and tungsten.
12	Sintered product of copper and tungsten carbide
13	Sintered and worked product of molybdenum
14	Sintered and worked product of tungsten
15	Sintered product of tungsten and silver
	Group C — Dispersion-strengthened copper (DSC) alloys
C 20/1, C 20/2 and C 20/3	manufactured by internal oxidation
C 20/4, C 20/5 and C 20/6	manufactured by ball milling or mechanical alloying

Table D.2
Material Cross Reference

RWMA Class	UNS Number or Other Designation	ISO 5182 Designation		EN 12163
1	C15000	A2/4	CuZr	CW120C
2	C18150	A2/2	CuCr1Zr	CW106C
2	C18200	A2/1	CuCr1	CW105C
3	C17500	A3/1	CuCo2Be	CW104C
3	C17510	A3/3	CuNi2Be	CW110C
3	C17540	A3/4	CuCo1Ni1Be	CW103C
3	C18000	N/A[a]	N/A[a]	N/A[a]
4	C17200	A4/2	CuBe2Ni	CW101C
10	N/A[a]	N/A[a]	N/A[a]	N/A[a]
11	ASTM B702 C1 D	B10	W75Cu	N/A[a]
12	ASTM B702 C1 E	B11	W78Cu	N/A[a]
13	N/A[a]	B14	W	N/A[a]
14	ASTM B387 alloy 360 or 361	B13	Mo	N/A[a]
20	C15760	C20/1	CuAl2O3	N/A[a]
21	C15715	N/A[a]	N/A[a]	N/A[a]
22	C15725	N/A[a]	N/A[a]	N/A[a]

[a] N/A is not assigned.

Table D.3
Hardness Conversion Reference Table

Brinell HB	Vickers HV	Rockwell C HRC	Rockwell B HRB	Rockwell A HRA
800	—	72	—	
780	1220	71	—	
760	1170	70	—	
745	1114	68	—	
725	1060	67	—	
712	1021	66	—	
682	940	65	—	
668	905	64	—	
652	867	63	—	
626	803	62	—	
614	775	61	—	
601	746	60	—	
590	727	59	—	
576	694	57	—	
552	649	56	—	
545	639	55	—	
529	606	54	—	
514	587	53	120	79
502	565	52	119	77
495	551	51	119	77
477	534	49	118	76
461	502	48	117	76
451	489	47	117	75
444	474	46	116	75
427	460	45	115	74
415	435	44	115	73
401	423	43	114	73
388	401	42	114	72
375	390	41	113	72
370	385	40	112	71
362	380	39	111	70
351	361	38	111	70
346	352	37	110	69
341	344	37	110	69
331	335	36	109	68
323	320	35	109	68
311	312	34	108	67
301	305	33	107	66
293	291	32	106	66
285	285	31	105	66
276	278	30	105	65
269	272	29	104	64

(*Continued*)

Table D.3 (Continued)
Hardness Conversion Reference Table

Brinell HB	Vickers HV	Rockwell C HRC	Rockwell B HRB	Rockwell A HRA
261	261	28	103	63
258	258	27	102	63
249	250	25	101	62
245	246	24	100	62
240	240	23	99	62
237	235	23	99	61
229	226	22	98	61
224	221	21	97	61
217	217	20	96	59
211	213	19	95	58
206	209	18	94	58
203	201	17	94	58
200	199	16	93	57
196	197	15	92	57
191	190	14	92	56
187	186	13	91	56
185	184	12	91	56
183	183	11	90	56
180	177	10	89	55
175	174	9	88	54
170	171	7	87	54
167	168	6	87	53
165	165	5	86	53
163	162	4	85	53
160	159	3	84	52
156	154	2	83	51
154	152	1	82	51
152	150	—	82	50
150	149	—	81	50
147	147	—	80	50
145	146	—	79	49
143	144	—	79	49
141	142	—	78	49
140	141	—	77	48
135	135	—	75	47
130	130	—	72	45
114	120	—	67	42
105	110	—	62	41
95	100	—	56	38
90	95	—	52	36
81	85	—	41	31

Annex E (Informative)
Requesting an Official Interpretation on an AWS Standard

This annex is not part of this standard, but is included for informational purposes only.

E1. Introduction

The following procedures are here to assist standard users in submitting successful requests for official interpretations to AWS standards. Requests from the general public submitted to AWS staff or committee members that do not follow these rules may be returned to the sender unanswered. AWS reserves the right to decline answering specific requests; if AWS declines a request, AWS will provide the reason to the individual why the request was declined.

E2. Limitations

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees. Neither AWS staff nor the committees are in a position to offer interpretive or consulting services on (1) specific engineering problems, (2) requirements of standards applied to fabrications outside the scope of the document, or (3) points not specifically covered by the standard. In such cases, the inquirer should seek assistance from a competent engineer experienced in the particular field of interest.

E3 General Procedure for all Requests

E3.1 Submission. All requests shall be sent to the Managing Director of AWS Standards Development Division. For efficient handling, it is preferred that all requests should be submitted electronically through standards@aws.org. Alternatively, requests may be mailed to:

Managing Director
Standards Development
American Welding Society
8669 NW 36 St, # 130
Miami, FL 33166

E3.2 Contact Information. All inquiries shall contain the name, address, email, phone number, and employer of the inquirer.

E3.3 Scope. Each inquiry shall address one single provision of the standard unless the issue in question involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the request along with the edition of the standard (e.g., D1.1:2006) that contains the provision(s) the inquirer is addressing.

E3.4 Questions(s). All requests shall be stated in the form of a question that can be answered ‘yes’ or ‘no’. The request shall be concise, yet complete enough to enable the committee to understand the point of the issue in question. When the point is not clearly defined, the request will be returned for clarification. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annexes) that bear on the issue in question shall be cited.

E3.5 Proposed Answer(s). The inquirer shall provide proposed answer(s) to their own question(s).

E3.6 Background. Additional information on the topic may be provided but is not necessary. The question(s) and proposed answer(s) above shall stand on their own without the need for additional background information.

E4. AWS Policy on Interpretations

The American Welding Society (AWS) Board of Directors has adopted a policy whereby all official interpretations of AWS standards are handled in a formal manner. Under this policy, all official interpretations are approved by the technical committee that is responsible for the standard. Communication concerning an official interpretation is directed through the AWS staff member who works with that technical committee. The policy requires that all requests for an official interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the procedures that must be followed, some requests for an official interpretation may take considerable time to complete.

E5. AWS Response to Requests

Upon approval by the committee, the interpretation is an official interpretation of the Society, and AWS shall transmit the response to the inquirer, publish it in the *Welding Journal*, and post it on the AWS website.

E6. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning AWS standards should be limited to questions of a general nature or to matters directly related to the use of the standard. The *AWS Board Policy Manual* requires that all AWS staff members respond to a telephone request for an official interpretation of any AWS standard with the information that such an interpretation can be obtained only through a written request. Headquarters staff cannot provide consulting services. However, the staff can refer a caller to any of those consultants whose names are on file at AWS Headquarters.

List of AWS Documents on Resistance Welding

Designation	Title
A10.1M	*Specification of Calibration and Performance Testing of Secondary Current Sensing Coils and Weld Current Monitors Used In Single-Phase Ac Resistance Welding*
C1.1M/C1.1	*Recommended Practices for Resistance Welding*
C1.4M/C1.4	*Specification for Resistance Welding of Carbon and Low-Alloy Steels*
C1.5	*Specification for the Qualification of Resistance Welding Technicians*
D17.2/D17.2M	*Specification for Resistance Welding for Aerospace Applications*
J1.1M/J1.1	*Specification for Resistance Welding Controls*
J1.2M/J1.2	*Guide to Installation and Maintenance of Resistance Welding Machines*
J1.3/J1.3M	*Specification for Materials Used in Resistance Welding Electrodes and Tooling*
RWMA	*Resistance Welding Manual, Revised 4th Ed*
RWPH:2011	*Resistance Welding Pocket Handbook*

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