DEPARTMENT OF THE ARMY TECHNICAL MANUAL

DEPARTMENT OF AIR FORCE TECHNICAL ORDER

TM 9-237/1

TO 34W4-1-10

MATERIALS USED FOR BRAZING WELDING, SOLDERING ARC CUTTING, AND METALLIZING

DEPARTMENTS OF THE ARMY AND THE AIR FORCE

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AND THE AIR FORCE

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***This technical manual supersedes TB ORD 1011, 13 January 1958 and TB ORD 3432-30-1, 21 March 1958.**

CHAPTER 1

INTRODUCTION

1. Scope

a. This manual is published for the use of personnel who require a general knowledge of the materials used in brazing, welding, soldering, arc cutting, or metallizing operations. This manual, however, does not provide data regarding procedures or tools and equipment for these operations.

b. The data provided herein are for information and guidance and they are not to be considered as mandatory instructions. These data include the description, application, and other information pertaining to—

(1) Brazing alloys.
(2) Metal-arc welding electrodes.
(3) Brazing, soldering, and welding fluxes.
(4) Welding rods.
(5) Solders.
(6) Metallizing wires.
(7) Carbon blocks, paste, and rods.
(8) Carbon-arc cutting and welding electrodes.
(9) Fuse-bonding electrodes.
(10) Steel tubular cutting electrodes.

c. These materials are classified in Federal supply class 3439 (formerly 3432) and are listed in SM 9–1–3439.

d. The appendix contains a list of current references, including supply manuals, technical manuals, forms, and other available publications applicable to the materials covered herein.

e. A glossary of metallurgical terms follows the appendix.

f. This first edition is being published in advance of complete technical review. Any errors or omissions will be forwarded on DA Form 2028 direct to Commanding Officer, Raritan Arsenal, Metuchen, N. J., ATTN: ORDJR-OPRA.

2. Reports

Any deficiencies detected in the items covered herein, which occur under the circumstances indicated in AR 700–38, should be reported immediately in accordance with instructions in the cited regulations.

CHAPTER 2

DESCRIPTION, APPLICATION, AND DATA

Section I. BRAZING ALLOYS

3. General

a. This section contains data pertaining to metal alloys used in brazing operations. Brazing is the term applied to a group of welding processes in which the filler metal used is a nonferrous metal or metal alloy whose melting point is higher than 800° F. but lower than that of the metals to be joined. The joint is made by the distribution of filler metal by capillary attraction between closely fitted surfaces. The term "hard soldering" is sometimes used interchangeably with brazing. According to some terminology, however, brazing is understood to mean the uniting of metal objects by a coating of brass; hard soldering is understood to mean the uniting of metal objects by a coating of a silver alloy. In the former case, the brazing alloy generally is called "spelter" and in the latter case, "silver solder." The terms brazing and brazing alloy are preferred to "hard soldering," "spelter," and "silver solder."

b. The brazing alloys described herein have the melting characteristics, flow properties, homogeneity, and stability required to minimize the effects of liquation (*d* below) and to permit the efficient distribution of the filler metal between closely fitted surfaces of the joint.

c. A pure metal melts (transforms from the solid to the liquid state) at a given temperature. An alloy, however, melts over a range of temperatures, that is, there is a span between the highest temperature at which the alloy is completely solid (solidus) and the lowest temperature at which the alloy is completely liquid (liquidus). For example; class 3 or FS–BCuP–5 silver brazing alloy starts to melt at a temperature slightly higher than 1,200° F., but the alloy does not become completely liquid until a temperature of 1,500° F. is reached.

d. If the brazing alloy's melting temperature range is wide and if heat is applied slowly, the liquid portion of the alloy tends to separate from the solid portion. This effect, called liquation, may cause an inferior brazed joint because the liquid portion of the alloy can drain through the joint by capillary action, leaving a "skull" or residue.

e. With the exception of class 3 of FS–BCuP–5, the alloys described herein have a narrow melting-temperature range, the span between solidus and liquidus being 15° F. for some to 70° F. for others.

f. Refer to TM 9–237/TO 34W4–1–5 for data pertaining to brazing processes.

4. Silver Brazing Alloys

a. Class 3 or Class FS–BCuP–5.

(1) *Description.* This alloy contains copper, silver, and phosphorus (table I) and has a melting point of approximately 1,200° F. It has good corrosion-resisting properties and, when used on copper, it affords joints with good electrical and thermal conductivity. This alloy, however, has a wide melting-temperature range, the span between solidus and liquidus (par. 3*c*) being approximately 300° F.

Table 1. Chemical Composition of Silver Brazing Alloy (Class 3 or Class FS–BCuP–5)

Percentage of elements			
Silver	Phosphorus	Other (maximum)	Copper
14.5 to 15.5	4.75 to 5.25	0.15	remainder

(2) *Application.*

(*a*) This brazing alloy is intended primarily for joining copper and copper alloys and it has limited use on silver, tungsten, and molybdenum. It is particularly suitable for use where very close fits cannot be held. Joint clearances of 0.003 to 0.005 inch are recommended. This alloy should not be used on ferrous metals or on nickel alloys. It should not be used in sulfurous atmospheres above room temperature, e.g., furnaces fueled by coal, gas, or oil.

(*b*) Because this alloy has a tendency to liquate (par. 3*d*) it is important that heat be applied as rapidly as possible.

(*c*) The recommended brazing temperature range is from 1,300° to 1,500° F.

(*d*) This brazing alloy, which is suitable for all brazing processes, has self-fluxing properties when used on copper. A flux, however, is required when used on other metals, including the copper alloys.

(3) *Data.* This brazing alloy is supplied in the forms and sizes indicated in table II. The item name is BRAZING ALLOY, SILVER.

Table II. Silver Brazing Alloy (Class 3 or Class FS–BCuP–5)

Specification	Form	Size (in inches)	Unit of issue
QQ–S–561d, class 3	strip	0.050 (3/64) x 1/16	each (½-lb spool)
QQ–S–561d, class 3	strip	0.050 (3/64) x 1/8	can (1-oz)
QQ–B–00655a, class FS–BCuP–5.	strip	0.050 (3/64) x 1½ x 20	each
QQ–S–561d, class 3	wire	1/8 square	pound

b. Class O.

(1) *Description.* This alloy contains copper, zinc, and silver (table III) and has a melting point of approximately 1,430° F. It has a fairly narrow melting-temperature range, the span between solidus and liquidus (par. 3*c*) being approximately 70° F.

Table III. Chemical Composition of Silver Brazing Alloy (Class O)

Percentage of elements			
Copper	Zinc	Silver	Other (maximum)
44.0 to 46.0	33.0 to 37.0	19.0 to 21.0	0.15

(2) *Application.* This brazing alloy is intended for ordinary brazing where an alloy is required that provides better physical properties than those provided by other brazing alloys and where the service or appearance does not require a brazing alloy of high silver content. The recommended brazing temperature range is from 1,520° to 1,620° F.

(3) *Data.* This brazing alloy is supplied in the form and size indicated in table IV. The item name is BRAZING ALLOY, SILVER.

Table IV. Silver Brazing Alloy (Class O)

Specification	Form	Size (in inches)	Unit of issue
QQ–S–561d, class O	strip	0.003 x 3/4 (max dimensions).	each (1-oz box)

c. Classes 1 or FS–BAg–5, 2, 4, 6, and FS–BAg–1.

(1) *Description.*

(*a*) These alloys contain silver, copper, and zinc; class 4, 6, and FS–BAg–1 alloys also contain cadmium. The chemical composition and melting point for each class of alloy is indicated in table V.

(*b*) These alloys, with the exception of class 1 or FS–BAg–5, generally are rapid melting and free flowing and they have a narrow melting-temperature range, the span between solidus and liquidus (par. 3*c*) being from 15° to 45° F. The class 1 or FS–BAg–5 alloy is not as free flowing as other silver brazing alloys and has a wide melting-temperature range with a span of approximately 120° F. between solidus and liquidus.

Table V. Chemical Composition and Melting Points of Silver Brazing Alloys (Classes 1 or FS-BAg-5, 2, 4, 6, and FS-BAg-1)

Class	Chemical Composition (percentage of elements)					Melting Point (approximate)
	Silver	Copper	Zinc	Cadmium	Other (max)	
1 or FS-BAg-5	44.0 to 46.0	29.0 to 31.0	23.0 to 27.0		0.15	1,250° F.
2	64.0 to 66.0	19.0 to 21.0	13.0 to 17.0		0.15	1,280° F.
4	49.0 to 51.0	14.5 to 16.5	14.5 to 18.5	17.0 to 19.0	0.15	1,160° F.
6	49.0 to 51.0	14.5 to 16.5	23.0 to 27.0	9.0 to 11.0	0.15	1,166° F.
FS-BAg-1	44.0 to 46.0	14.0 to 16.0	14.0 to 18.0	23.0 to 25.0	0.15	1,125° F.

(2) *Application.*

(*a*) *General.* These brazing alloys are used for joining ferrous and non-ferrous metals except aluminum, magnesium, tin, zinc, and other metals or alloys that have melting temperatures below 1,500° F. These brazing alloys are used for refrigeration, electrical, automotive, plumbing, heating, and similar equipment and the alloys are suitable for all brazing processes. A flux is generally required. Joint clearances of 0.002 to 0.005 inch are recommended.

(*b*) *Class 1 or FS-BAg-5 alloy.* This alloy is intended for the general range of silver-brazing-alloy requirements and is particularly suitable for food processing equipment where the use of cadmium-containing alloys might be prohibited. It is suitable also for electrical equipment, turbine blades, and for bridging gaps or forming fillets. The recommended brazing temperature range is from 1,370° to 1,550° F.

(*c*) *Class 2 alloy.* This alloy provides a high silver content and should be used only where the application requires high strength, resistance to corrosion, and good appearance. The alloy is particularly suitable for joining sterling silver. The recommended brazing temperature range is from 1,325° to 1,550° F.

(*d*) *Class 4, 6, and FS-BAg-1 alloys.* These are general purpose alloys intended for joining copper, brass, ferrous metals (including alloy steels) and nickel-copper alloys. The recommended brazing temperature range for the class 4 alloy is from 1,175° to 1,400° F; for the class 6—from 1,190° to 1,400° F; and for class FS-BAg-1—from 1,145° to 1,400° F.

(3) *Data.* These brazing alloys are supplied in the classes, forms, and sizes indicated in table VI. The item name is BRAZING ALLOY, SILVER.

Table VI. Silver Brazing Alloys (Classes 1 or FS-RAg-5, 2, 4, 6, and FS-BAg-1)

Specification	Form	Size (in inches)	Unit of issue
QQ-S-561d, class 1	strip	0.003 x ¾ (max dimensions)	can (1-oz)
QQ-B-00655a, class FS-BAg-5.	wire	1/16	each (1-oz coil)
QQ-S-561d, class 2	strip	0.003 x ¾ (max dimensions)	ounce
QQ-S-561d, class 4	wire	1/32	ounce
QQ-S-561d, class 4	wire	1/32	coil (2-oz)
QQ-S-531d, class 4	wire	1/16	ounce
QQ-S-561d, class 6	strip	0.03 (1/32) x ¼ (max dimensions)	ounce
QQ-B-00655a, class FS-BAg-1.	wire	1/16	each (1-oz coil)

Section II. WELDING ELECTRODES

5. General

a. Discussion. This section contains data pertaining to electrodes, metal rods or wires, used in shielded-metal-arc welding. Shielded-metal-arc welding is an arc-welding process in which (1) the electrode itself, when melted by the electric arc, supplies the filler metal for the weld and (2) both the filler metal and the weld metal are protected from the ambient atmosphere by a gaseous and/or slag shield (fig. 1). This shielding is required because molten metal, when exposed to the atmosphere, tends to combine chemically with oxygen and nitrogen in the air, forming oxides and nitrides which embrittle and weaken the metal. By shielding the arc, which is accomplished by the action of the cellulose or mineral coating of the electrode, the undesired chemical actions cannot readily take place.

Note. Carbon-arc welding and cutting electrodes, fuse-bonding electrodes, and steel arc-cutting electrodes are covered in section VII, Miscellaneous Materials.

b. Arrangement of Data.

(1) The data in this section are arranged according to the application of the welding electrodes; that is, a separate paragraph is provided for data pertaining to electrodes used for each family of metals and their alloys and for each special application. In some cases, as in the bronze electrodes, the electrodes are intended for a particular family of metals and their alloys, such as copper and copper alloys, but have application also in another family of metal alloys, such as ferrous metals. In these cases, cross references from one paragraph to another are provided in the form of notes. For example, under paragraph 8, Electrodes for Carbon and Alloy Steels, a note appears inviting attention to paragraph 10, Electrodes for Copper and Copper Alloys.

(2) It will be noted that paragraph 8, Electrodes for Carbon and Alloy Steels, includes data on electrodes that are prescribed generally for carbon and/or alloy steels. Data on electrodes that are prescribed for a specific type of alloy steel (such as corrosion-resisting steel, molybdenum-alloy steel, etc.),

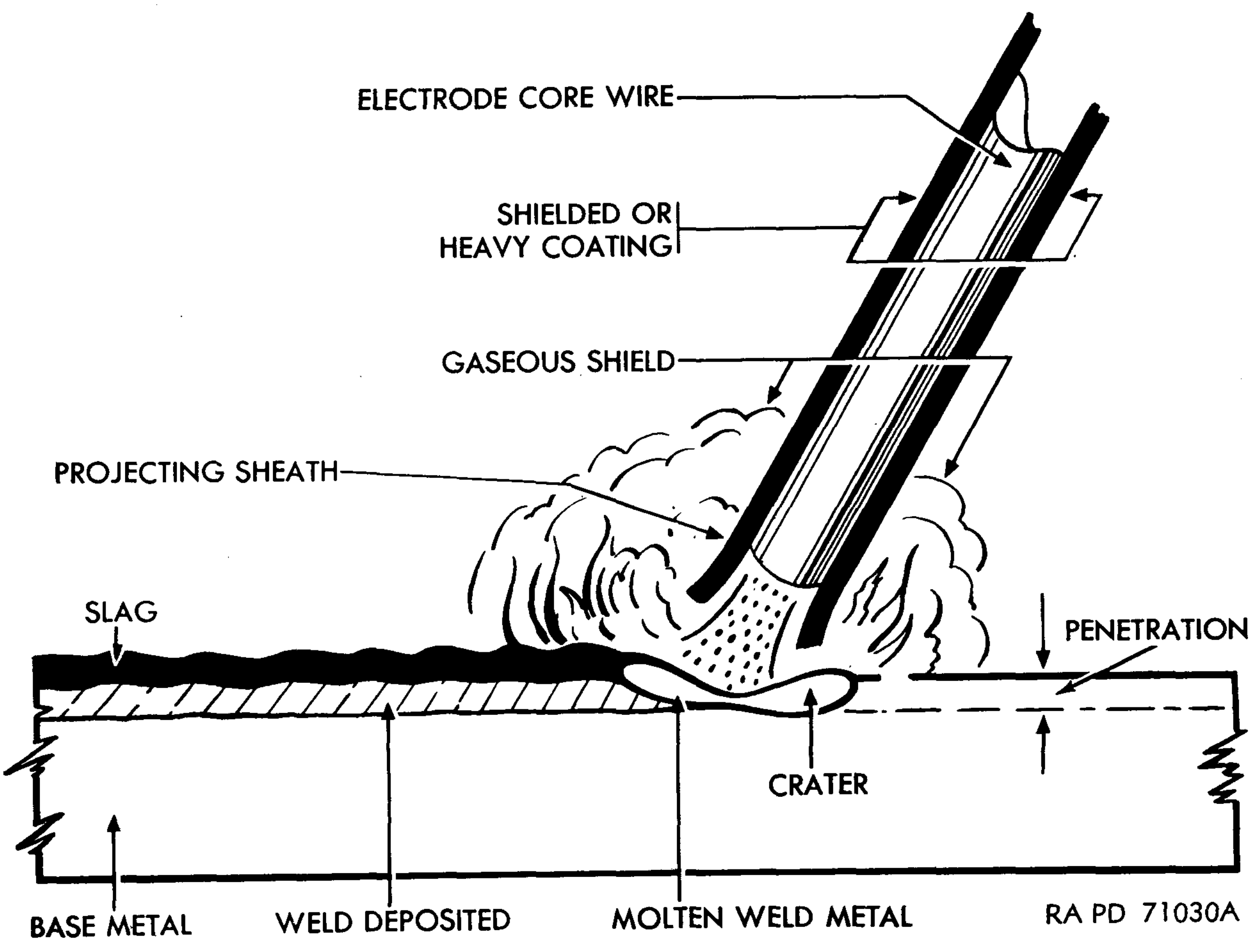

Figure 1. Action of shielded-arc welding electrode.

however, are not included in paragraph 8, but are included in paragraphs pertaining to the specific type of steel.

c. Color Identification Markings. To facilitate proper identification of arc-welding electrodes, a color marking system is utilized for most covered electrodes supplied by the Ordnance Corps. This marking consists of bands and/or spots of color applied to the electrode as shown in figure 2. Each type of electrode so identified is assigned a specific combination of group, end, and/or spot colors by MIL–STD–123. Table VII provides a cross reference of color identification markings and the corresponding electrode types. A reference to the paragraph in which the electrode is discussed is also provided. The color identification marking system, however, does not include all types of electrodes supplied by the Ordnance Corps.

Note. In cases where the marking system is not used, it is of prime importance that the electrodes be kept in their original container so that markings on the container will provide easy identification.

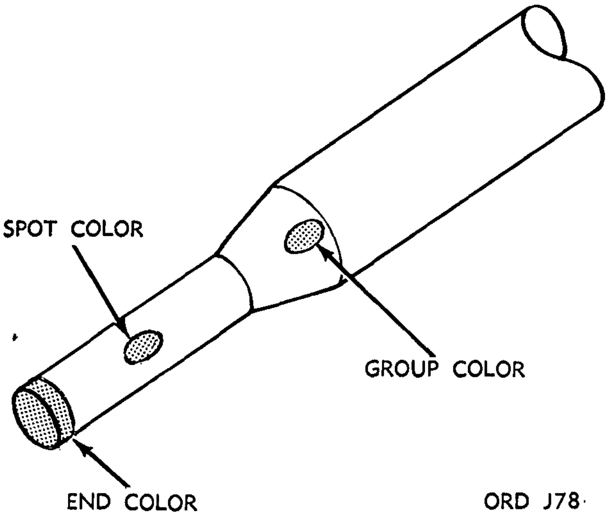

Figure 2. Color identification markings.

Table VII. Color Identification Markings of Covered Arc-Welding Electrodes

Material	Color identification markings			Electrode type	Paragraph No.
	Group color	End color	Spot color		
Steel (except electrodes with low-hydrogen-type coverings in series other than 60XX).	None	None	None	MIL–6010[1]	8
		None	White	MIL–6012	8
		None	Brown	MIL–6013	8
		None	Green	MIL–6020	8
		None	Red	E–6015	8
		None	Blue	MIL–6011	8
		Blue	White	MIL–7010–A1	13
		Orange	None	"Sureweld Type CI–8," or equal, and "Ferroweld," or equal.	9
		Orange	Red	"Mangjet," or equal	12
Steel (low-hydrogen-type coverings except series 60XX)	Green	White	Black	MIL–22–16	13
		Green	Orange	MIL–10016	8
		Black	Orange	MIL–7018	8
Chromium-nickel steel (direct-current type)	Black	None	Black	MIL–307L–15	7
		Yellow	None	MIL–308–15	11
		Yellow	Blue	MIL–347–15	11
Chromium-nickel steel (alternating- and direct-current type)	Yellow	Yellow	None	E–308–16	11
Bronze	Blue	Yellow	None	E–CuSn–A	10
		Yellow	Blue	MIL–E–CuSn–C	10
		Silver	Brown	MIL–E–CuA1–B	10
		Silver	Red	MIL–E–CuA1–D	10
Nickel and nickel alloy	White	Blue	White	MIL–3N10	14
		Orange	Blue	"Softweld," or equal	9
		Orange	Brown	"Ni-Rod 55," or equal	9

[1] It cannot be assumed that an unmarked electrode is type MIL–6010 because there are other types of electrodes in use which are unmarked.

d. Selection Guides.

(1) To the inexperienced welder, the array of welding electrodes from which to choose tends to confuse him in the choice of the proper electrode for the job at hand. Accordingly, tables VIII and IX have been compiled to facilitate electrode selection. It must be remembered, however, that these selection guides are general in nature and that all possible welding situations cannot adequately be covered.

(2) Even in tables as simplified as these, it is evident that in most cases there are more than one electrode prescribed for a metal or metal alloy. For example, there are five different types of electrodes prescribed for low-alloy steel. The choice among various electrodes will depend on the type of welding apparatus available, i.e., alternating-current type or direct-current type; polarity desired (for direct current), i.e., reverse (electrode positive) or straight (electrode negative); and last, but not least, the physical properties desired in the deposited weld metal, e.g., tensile strength, ductility, hardenability, notch toughness, corrosion resistance, machineability, thickness of metal, etc.

(3) Information regarding type of current and polarity is provided by the tables. However, for information regarding

Table VIII. Electrode Selection Guide for Ferrous Metals

Material to be arc welded	Electrode type, current, and polarity (*see notes*)																	
	MIL-22-16	MIL-308-15	E-308-16	MIL-347-15	MIL-6010	MIL-6011	MIL-6012	MIL-6013	E-6015	MIL-7010-A1	MIL-7018	MIL-10016	E-CuSn-A	MIL-E-CuSn-C	"Ferroweld," or equal	"Ni-Rod 55," or equal	'Softweld," or equal	"Sureweld type CI-8," or equal
CAST IRON:																		
alloy	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	AD+	-----	-----
gray	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	D+	D+	AD+	-----	AD	AD+
high-strength	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	AD+	-----	-----
STEELS:																		
carbon:																		
free-cutting	-----	-----	-----	-----	-----	-----	-----	-----	D+	-----	AD+	-----	-----	-----	-----	-----	-----	-----
low	-----	-----	-----	-----	D+	AD+	AD−	AD−	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
medium	-----	-----	-----	-----	D+	AD+	AD−	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
alloy:																		
chromium-molybdenum	AD+	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
chromium-nickel	-----	D+	AD+	D+	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
high-carbon	-----	-----	-----	-----	-----	-----	-----	-----	D+	-----	AD+	-----	-----	-----	-----	-----	-----	-----
low-alloy	-----	-----	-----	-----	D+	AD+	-----	AD−	-----	-----	-----	AD+	D+	-----	-----	-----	-----	-----
manganese	-----	D+	AD+	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
molybdenum	AD+	-----	-----	-----	-----	-----	-----	-----	-----	D+	-----	-----	-----	-----	-----	-----	-----	-----
silicon	-----	-----	-----	-----	-----	-----	-----	-----	-----	D+	-----	-----	-----	-----	-----	-----	-----	-----

Notes:
1. Electrodes for surfacing and for armor applications are not included in this table.
2. "AD+" designates electrodes for use with alternating or direct current, electrode positive (reverse polarity).
3. "AD—" designates electrodes for use with alternating or direct current, electrode negative (straight polarity).
4. "D+" designates electrodes for use with direct current, electrode positive (reverse polarity).
5. "AD" designates electrodes for use with alternating current or direct current, either polarity.

TABLE IX. Electrode Selection Guide for Nonferrous Metals

Material to be arc welded	Electrode type				
	MIL-3N10	MIL-E-CuAl-B	E-CuSn-A	MIL-E-CuSn-C	Aluminum alloy
ALUMINUM AND ALUMINUM ALLOYS:					
aluminum	-------------	-------------	-------------	-------------	X
aluminum alloys	-------------	-------------	-------------	-------------	X
COPPER AND COPPER ALLOYS:					
brass:					
low brass	-------------	-------------	X	X	-------------
high brass	-------------	X	X	X	-------------
bronze:					
commercial bronze	-------------	-------------	X	X	-------------
aluminum bronze	-------------	X	-------------	-------------	-------------
phosphor bronze	-------------	-------------	X	X	-------------
copper	-------------	-------------	X	X	-------------
NICKEL-COPPER ALLOYS:					
Monel	X	-------------	-------------	-------------	-------------

Notes:
1. Electrodes for surfacing applications are not included in this table.
2. All electrodes are for use with direct current, electrode positive (reverse polarity).

other characteristics of the electrodes, refer to the pertinent paragraph in this section.

(4) Of prime importance in electrode selection, obviously, is the type of metal or metal alloy to be welded. In some cases, the welder has available technical instructions or engineering drawings that specify the material used in construction of the article. For the most part, however, such information is not available, but simple shop tests will be helpful in identifying the material. These tests are described in TM 9-237/TO 34W4-1-5.

e. Welding Procedures.

(1) General procedural data are beyond the scope of this manual. For such data, refer to TM 9-237/TO 34W4-1-5.

(2) Coverage is provided, however, on procedural data that apply specifically to a particular type of electrode. These data include welding positions, type of current and polarity to be used, welding current ranges, and notes on special technique.

(3) For any given type of electrode, welding current recommendations vary from one manufacturer to another. Accordingly, it is advisable to adhere to the manufacturer's recommended amperage range when such information is furnished with the electrodes. When such information is not available, use the amperage range suggested herein as a guide.

f. Storage of Electrodes. When unprotected, most electrode coatings absorb moisture from the atmosphere. Wet coatings cause electrodes to sputter, spatter, and flake during welding operations, thereby resulting in unsound welds. It is advisable, therefore, once the unit pack is opened, to store the electrodes in a heated cabinet. Such a cabinet should be provided with vent holes and a 60- to 100-watt lamp (as a source of heat). The temperature inside the cabinet should be at least 20° F. warmer than the surrounding air. If necessary, use a lamp of higher wattage to achieve the desired heating.

Note. Electrodes with low-hydrogen-type coverings —E-6015, MIL-22-16, MIL-1006, and MIL-7018—are particularly susceptible to moisture adsorption. Moisture adsorbed in only a short period of time may render the electrode unfit for use because such moisture has a tendency to produce cracks in the weld. Accordingly, caution should be exercised to prevent moisture pick up in the coatings of these electrodes.

6. Electrodes for Aluminum and Aluminum Alloys

a. Description. These shielded-arc, end-grip electrodes are supplied in one type only—an aluminum alloy containing approximately 5 percent silicon (table X).

Table X. *Chemical Composition of Core Wire of Aluminum-Alloy Electrodes*

Percentage of elements (all percentages are maximum unless otherwise indicated)								
Silicon	Copper	Magnesium	Manganese	Iron	Zinc	Titanium	Other	Aluminum
4.5 to 6.0	0.3	0.05	0.05	0.8	0.1	0.2	0.15	remainder

b. Application.

(1) These electrodes are intended for general welding of aluminum and aluminum-alloy castings, sheets, structural shapes, extrusions, etc.

(2) The class 2 electrodes (3/32- through 3/16-inch sizes) are recommended for horizontal fillets and flat-position work; the class 3 (1/4-inch size) for flat-position work only.

(3) Use direct current with electrode positive—work negative (reverse) polarity. Hold a short arc with the coating nearly touching the molten pool. The suggested amperage range is indicated in table XI.

c. Data. These electrodes are supplied in the classes and sizes indicated in table XI. The item name is ELECTRODE, WELDING and the unit of issue is pounds.

Table XI. *Electrodes for Aluminum and Aluminum Alloys*

Specification	Size (in inches)	Suggested amperage range (amperes)
MIL-E-15597A, grade II, class 2.	3/32 x 14	20 to 55
MIL-E-15597A, grade II, class 2.	1/8 x 14	45 to 125
MIL-E-15597A, grade II, class 2.	5/32 x 14	60 to 170
MIL-E-15597A, grade II, class 2.	3/16 x 14	80 to 235
MIL-E-15597A, grade II, class 3.	1/4 x 14	125 to 360

7. Electrodes for Armor Applications

a. Description. These shielded-arc, end-grip electrodes are supplied in one type only—a modified 19–9 chromium-nickel steel (austenitic stainless steel) containing approximately 19 percent chromium and 9 percent nickel (table XII).

Table XII. *Chemical Composition of Deposited Weld Metal of Austenitic Steel Electrodes*

Percentage of elements (all percentages are maximum unless otherwise indicated)								
Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Sulfur	Phosphorus	Other
0.07 to 0.17	3.30 to 4.75	0.8	18.0 to 20.5	9.0 to 10.7	0.5 to 1.5	0.03	0.04	[1]

[1] The remainder is not specified, but a large percentage is iron.

b. Application.

(1) These electrodes are intended for welding of armor and other steels of high hardenability.

(2) The class 1 electrodes (1/8- and 5/32-inch sizes) are recommended for all-position welding; the class 2 (3/16-inch size) for horizontal fillets and flat-position work only.

(3) Use direct current with electrode positive—work negative (reverse) polarity. Hold as short an arc as possible without touching the molten pool with the electrode's covering. When welding in the flat position, weaving, if required, should not exceed two and one-half times the nominal diameter of the electrode. When welding in all other positions, keep the width of the weave to an absolute minimum. The suggested amperage range is indicated in table XIII.

c. Data. These electrodes are supplied in the classes and sizes indicated in table XIII. The item name is ELECTRODE, WELDING and the unit of issue is pounds.

Table XIII. Electrodes for Armor Applications

Specification	Size (in inches)	Suggested amperage range (amperes)
MIL–E–13080A, type MIL–307L–15, class 1.	⅛ x 14	90 to 100
MIL–E–13080A, type MIL–307L–15, class 1.	5/32 x 14	120 to 160
MIL–E–13080A, type MIL–307L–15, class 2.	3/16 x 14 (or 3/16 x 18)	150 to 190

8. Electrodes for Carbon and Alloy Steels

Note. See also paragraph 7, Electrodes for Armor Applications; paragraph 10, Electrodes for Copper and Copper Alloys; paragraph 11, Electrodes for Corrosion-Resisting Steels; paragraph 12, Electrodes for Surfacing Applications; and paragraph 13, Electrodes for Molybdenum-Alloy, Chromium-Molybdenum-Alloy, and Silicon-Alloy Steels.

a. Description.

(1) These shielded-arc, end-grip steel electrodes are supplied in three groups—MIL– and E–60, MIL–70, and MIL–100.

(2) In the MIL– and E–60 group (60,000 psi minimum tensile strength of deposited weld metal in the as welded condition), six types of electrodes are supplied—6010, 6011, 6012, 6013, 6015, and 6020. The differences among most of these are in the type and polarity of current with which the electrodes are to be used and in the welding position to be employed (table XV). The differences between the 6010 and 6015; and between the 6012 and 6013; however, require some clarification.

(*a*) *6010 and 6015.* The important difference between these lies in the compounding of the electrodes' coatings. In the 6010, the coating is such that the electrode is suitable for most mild and some low-alloy steels. In the 6015, however, the coating is specifically compounded to permit the use of the electrode for higher strength, high-carbon alloy steels.

(*b*) *6012 and 6013.* These are quite similar. The important difference lies in the fact that the arc can more readily be established and maintained with the 6013 electrode. Also, slag can more easily be removed from welds deposited with the 6013.

(3) In the MIL–70 group (70,000 psi minimum tensile strength of deposited weld metal in stress-relieved condition), the type supplied is MIL–7018.

(4) In the MIL–100 group (100,000 psi minimum tensile strength of deposited weld metal in stress-relieved condition), the type supplied is MIL–10016.

(5) The chemical composition for the MIL– and E–60 group electrodes is not specified. (These electrodes are classified by physical properties of the deposited weld metal, e.g., tensile strength, yield strength, etc.)

(6) The chemical compositions of the deposited weld metal of the MIL–7018 and MIL–10016 electrodes are indicated in table XIV.

Table XIV. Chemical Composition of Deposited Weld Metal of Types MIL–7018 and MIL–10016 Electrodes

Type	Percentage of elements (all percentages are maximum unless otherwise indicated)									
	Carbon	Manganese	Silicon	Phosphorus	Sulfur	Chromium	Nickel	Molybdenum	Vanadium	Other
MIL–7018	0.12	0.4 to 1.0	0.8	0.03	0.03	0.15	0.25	0.35	0.05	[1]
MIL–10016	0.1	0.75 to 1.1	0.05 to 0.6	0.03	0.04	0.15	1.4 to 1.8	0.35	0.2	[1]

[1] The remainder is not specified, but a large percentage is iron.

b. Application.

(1) *Types MIL–6010 and 6011.*

(*a*) These electrodes are intended for general welding of carbon steels and nonhardenable low-alloy steels. Typical applications include machinery repair, structural fabrication and repair, storage-tank fabrication and repair, pressure-vessel fitting installation, and piping. The electrodes are particularly suitable for applications requiring deep penetration and/or high tensile strength and ductility, as well as easy slag removal. The electrode is suitable for multiple-pass applications.

(*b*) For flat-position welding, hold a medium or short arc, insuring that electrode does not touch the molten pool. A weaving motion may be used, if desired, but such weaving should be held to a minimum. Move forward rapidly enough to keep ahead of molten pool.

(*c*) For vertical-position work, up welding is generally recommended. Down welding, however, may be used for sheet-metal welding. Use either weaving or stringer-bead technique. In vertical fillets, use stringer bead in corner and weave succeeding passes.

(*d*) For overhead-position work, use stringer beads and keep the molten pool as small as possible.

(2) *Type MIL–6012.*

(*a*) This electrode is intended for general welding of medium and mild steels where high ductility is not an important consideration. Typical applications include automotive parts repair, railroad car repair, and light-gage work. Its ability to bridge gaps and its handling ease make this electrode particularly suitable for horizontal fillet welding of poorly fitted joints. The electrode, however, is not recommended for multiple-pass applications.

(*b*) Hold a short arc and use the stringer-bead technique. Move forward rapidly enough to keep ahead of the molten pool. Vertical-position work can be welded either up or down, depending on the type of bead desired.

(3) *Type MIL– or E–6013.*

(*a*) This electrode is intended for general welding of mild- and nonhardenable low-alloy steel sheet, strip, and plate where shallow penetration is desired and where parts fit-up is only fair. Typical applications include aircraft fabrication and repair, body and fender repair, machinery guards, and ducting. It is suitable for single-pass applications on sheet and strip (with $1/16$ and $3/32$ electrodes only) and for multiple-pass applications on plates of $3/16$- to $3/8$-inch thickness.

(*b*) Hold a short arc and move forward rapidly enough to keep ahead of molten pool. Vertical-position work can be welded either up or down, depending on the type of bead desired. The stringer-bead technique is preferred for over-head position welding. For sheet metal, position the work in a vertical or inclined position, where possible, and weld downward.

(4) *Type E–6015.*

(*a*) This electrode is intended for welding of high strength, high-carbon, alloy steels; high-sulfur steels; and other "difficult-to-weld steels." Typical applications include welding of rail, free-cutting steel, malleable iron, heavy steel castings, spring steel, and mild-steel sides of clad plates.

(*b*) Hold as short an arc as possible with a minimum of manipulation. For vertical-position work, up welding generally is recommended.

(5) *Type MIL–6020.*

(*a*) This electrode is intended for welding of medium- and high-tensile steels, except molybdenum-alloy and chromium-molybdenum-alloy steels (par. 13). Typical applications include repair of transmission cases, gear reducer housings, bulldozer push beams, and dump-truck bodies. Because this electrode can be used with high current, it is particularly suitable for making horizontal or flat fillets where deep penetration is required and for groove welds of heavy sections where rigid X-ray examination must be met.

(*b*) Hold a very short arc, dragging the electrode's coating against the work. Move forward rapidly enough to keep ahead of the molten pool. On flat groove or fillet joints, do not weave on first pass. The weave technique may be used, however, for succeeding passes.

(6) *MIL–7018.*

(*a*) This electrode, like the type E–6015, is intended for welding of high strength, high-carbon steels; high-sulfur steels; and other "difficult-to-weld steels." The tensile strength of the weld metal deposited by this electrode, however, is considerably higher than that of weld metal generally deposited by the type E–6015. Typical applications include repairing of heavy machinery parts, harrow teeth, sprocket teeth, and automotive parts such as bumpers.

(*b*) Hold a very short arc or drag the electrode's coating against the work. Use stringer bead or weave technique.

(7) *Type MIL–10016.*

(*a*) This electrode is intended for welding of low-alloy high-tensile steels that have a high degree of hardenability or high notch toughness.

(*b*) Hold as short an arc as possible.

Note. Data regarding type of current, polarity, recommended welding positions, and suggested amperage range for each electrode are given in table XV.

c. Data. These electrodes are supplied in the types and sizes indicated in table XV. The MIL–60 series electrodes are covered by specification MIL–E–15599C; the E–6015 electrode is covered by American Society for Testing Materials specification A233–55T; the MIL–7018 electrode is covered by specification MIL–E–19322; and the MIL–10016 electrode is covered by specification MIL–E–18038A. The item name is ELECTRODE, WELDING and the unit of issue is pounds.

Table XV. Electrodes for Carbon and Alloy Steels

Type	Current	Polarity	Recommended welding positions	Size (in inches)	Suggested amperage range (amperes)
MIL–6010	dc	reverse	all	1/8 x 14	80 to 105[1]
				5/32 x 14	115 to 145[1]
				3/16 x 14	140 to 185[1]
			HF and F[2]	1/4 x 18	200 to 320
MIL–6011	ac	—	all	3/32 x 12	30 to 60[1]
	or			1/8 x 14	75 to 100[1]
	dc	reverse		5/32 x 14	115 to 145[1]
				3/16 x 14	135 to 175[1]
MIL–6012	ac	—	all	3/32 x 12	30 to 60[1]
	or				
	dc	straight			
MIL–6013	ac	—	all	1/16 x 9	20 to 40
	or			3/32 x 12	40 to 80
	dc	straight		1/8 x 14	70 to 120
				5/32 x 14	115 to 170
				3/16 x 14	145 to 225
E–6015	dc	reverse	all	1/8 x 14	100 to 130[1]
				5/32 x 14	135 to 180[1]
				3/16 x 14	160 to 205[1]
MIL–6020	ac	—	HF and F[2]	1/8 x 14	105 to 140
	or			5/32 x 14	140 to 190
	dc	straight[3]		3/16 x 18	175 to 260
				1/4 x 18	270 to 390

See footnotes at end of table.

Table XV. Electrodes for Carbon and Alloy Steels—Continued

Type	Current	Polarity	Recommended welding positions	Size (*in inches*)	Suggested amperage range (amperes)
MIL–7018	dc	reverse	HF and F[2]	7/32 x 18	190 to 350
MIL–10016	ac or	—	all	1/8 x 14 5/32 x 14 3/16 x 14	80 to 120 140 to 190 180 to 250
	dc	reverse	HF and F[2]	1/4 x 18	300 to 350

[1] For horizontal fillets and flat-position welding, the current may be increased by 20 amperes in the 3/32 to 5/32 sizes and 35 amperes in the 3/16 size.
[2] HF and F indicates horizontal fillets and flat-position welding only.
[3] Reverse polarity may be used for flat-position welding.

9. Electrodes for Cast Iron

Note. See also paragraph 10, Electrodes for Copper and Copper Alloys.

a. Description. Four types of shielded-arc, end-grip electrodes are supplied for arc-welding of cast iron. "Ferroweld," or equal, and "Sureweld Type CI–8," or equal, are mild-steel electrodes; "Softweld," or equal, is a nickel electrode; and "Ni-Rod 55," or equal, is a nickel-alloy electrode.

b. Application.

(1) *"Ferroweld," or equal.*

(*a*) This electrode is intended for general welding of cast iron where machineability of the resultant weld is not an important consideration. It can be used where studding is required because the weld metal fuses with the studs equally as well as with the casting, resulting in a strong, ductile weld. The electrode is suitable for joining cast iron to steel.

(*b*) It is recommended for all-position welding.

(*c*) Use direct current with electrode positive—work negative (reverse) polarity or use alternating current. Hold a close arc but do not allow coating to touch the molten pool. Weld short beads of 1/2 to 1 inch in length. The suggested amperage range (1/8-inch electrode) is from 80 to 100 amperes.

(2) *"Sureweld Type CI–8," or equal.*

(*a*) This electrode is intended for general welding of cast iron where machineability of the resultant weld is not an important consideration. The electrode is suitable for joining cast iron to steel and it can be used where studding is required since the weld metal will fuse readily both with cast iron and steel.

(*b*) It is recommended for all-position welding.

(*c*) Use direct current with electrode positive—work negative (reverse) polarity or use alternating current. Hold a short arc and deposit short stringer beads, the length of which is to be determined by the size of the casting. Time should be allowed between beads to permit the metal to cool sufficiently to be able to touch the work with the hand. The suggested amperage range (1/8-inch electrode) is from 90 to 110 amperes for flat-position work and from 90 to 105 amperes for all other positions.

(3) *"Softweld," or equal.*

(*a*) This electrode is intended for general welding of cast iron where extreme machineability is required. A single-layer deposit can be machined, but it is recommended that at least two layers be used to obtain a zone of soft fusion. With multilayer welds (two or more layers) the entire weld area can be machined, sawed, drilled, or tapped with relative ease.

(*b*) The electrode is particularly suitable for filling up defects, correcting machining errors, and making repairs on gray cast iron.

(c) Where a large or deep area is to be filled or where a high-strength weld is required, use "Ferroweld," or equal, up to 1/8-inch from the surface to be machined and then complete the weld with several layers of "Softweld," or equal.

(d) This electrode is recommended for all-position welding.

(e) Use direct current with either polarity or use alternating current. Use a fairly long arc of approximately 1/8 inch, weaving the electrode slightly from side to side. The suggested amperage ranges (1/8-inch electrode) are from 60 to 125 amperes for direct current and from 65 to 120 amperes for alternating current.

(4) *"Ni-Rod 55," or equal.*

(a) This electrode is intended for welding of ductile cast iron, heat- and corrosion-resistant cast iron (such as "Ni-Resist"), high-strength cast iron, and for joining cast iron to other metals where machineability is required. It is suitable for filling up defects and for correcting machining errors in castings.

(b) The electrode is recommended for all-position welding.

(c) Use direct current with electrode positive—work negative (reverse) polarity or use alternating current. The suggested amperage range (1/8-inch electrode) is from 80 to 100 amperes for direct current and from 90 to 110 amperes for alternating current. In overhead welding, reduce the current 5 to 15 amperes; in vertical welding, reduce the current 10 to 20 amperes.

c. Data. These electrodes are supplied in the types and sizes indicated in table XVI. The item name is ELECTRODE, WELDING and the unit of issue is pounds.

Table XVI. Electrodes for Cast Iron

Type	Size (in inches)
"Ferroweld," or equal	1/8 x 14
"Sureweld Type CI–8," or equal	1/8 x 14
"Softweld," or equal	1/8 x 14
"Ni-Rod 55," or equal	1/8 x 14

10. Electrodes for Copper and Copper Alloys

a. Description. These shielded-arc, end-grip electrodes are supplied in two types—aluminum bronze and phosphor bronze. In the former the alloying elements are aluminum and iron; in the latter—tin and phosphorus (table XVII).

Table XVII. Chemical Composition of Bronze Electrodes

Type	Class	Percentage of elements (all percentages are maximum unless otherwise indicated)							
		Aluminum	Iron	Phosphorus	Lead	Silicon	Tin	Other	Copper
Aluminum bronze[1]	MIL–E–CuAl–B	8.0 to 10.0	2.5 to 5.0		0.02	1.0		0.6	remainder
	MIL–E–CuAl–D	10.0 to 13.0	3.5 to 6.5		0.02	1.0		0.6	remainder
Phosphor bronze[2]	MIL–E–CuSn–A			0.15 to 0.35			4.8 to 5.8	0.5	remainder
	MIL–E–CuSn–C			0.35			7.0 to 9.0	0.5	remainder

[1] Chemical composition given is for the deposited weld metal.
[2] Chemical composition given is for the electrode core wire.

b. Application.

(1) *Aluminum bronze.*

(a) The class MIL–E–CuAl–B electrode is used primarily for joining aluminum bronzes and high-strength brasses. It is also used for many ferrous metals; combinations of dissimilar metals; and for surfacing where corrosion and wear resistance are required, but where hardness is not an important consideration. It will provide an overlay with a hardness between 140 and 180 Bhn (Brinell hardness number). (The Bhn given is based on overlays three or more layers high.)

(b) The class MIL–E–CuAl–D electrode is intended for surfacing where good bearing qualities and wear resistance are required. It will provide an overlay with a hardness between 230 and 280 Bhn. (The Bhn given is based on overlays three or more layers high.)

(c) Aluminum-bronze electrodes (classes MIL–E–CuAl–B and –D) are recommended for flat-position welding only.

(d) Use direct current with electrode positive—work negative (reverse) polarity.

(2) *Phosphor bronze.*

(a) Phosphor-bronze electrodes are used for joining copper, brasses, and bronzes, and also for cast iron, many ferrous metals, and combinations of dissimilar metals. They are especially suitable for joining phosphor bronzes of similar composition.

(b) The class MIL–E–CuSn–A electrode is particularly suitable for joining plates of similar composition in the fabrication of pressure vessels and for chemical processing equipment. Other applications include the joining of copper, brasses, and bronzes to mild steel and the braze-welding of hardenable low-alloy steels. The deposited weld metal will have a hardness between 70 and 85 Bhn.

(c) The class MIL–E–CuSn–C electrode is intended for use where there is a need for a higher degree of hardness and higher tensile and yield strengths than provided by the MIL–E–CuSn–A electrode. The deposited weld metal will have a hardness between 85 and 100 Bhn.

(d) Phosphor-bronze electrodes (classes MIL–E–CuSn–A and –C) are recommended for all-position welding.

(e) Use direct current with electrode positive—work negative (reverse) polarity. The suggested amperage range is indicated in table XVIII.

c. *Data.* These electrodes are supplied in the classes and sizes indicated in table XVIII. The item name is ELECTRODE, WELDING and the unit of issue is pounds.

Table XVIII. Electrodes for Copper and Copper Alloys

Specification	Size (in inches)	Suggested amperage range (amperes)
MIL–E–278B, class MIL–E–CuAl–B.	5/32 x 14	Not available
MIL–E–278B, class MIL–E–CuAl–D.	5/32 x 14	Not available
MIL–E–13191A, class MIL–E CuSn–A.	1/8 x 14	Not available
MIL–E–13191A, class MIL–E CuSn–A.	3/16 x 14	Not available
MIL–E–13191A, class MIL–E CuSn–C.	1/8 x 14	50 to 125
MIL–E–13191A, class MIL–E CuSn–C.	5/32 x 14	70 to 170
MIL–E–13191A, class MIL–E CuSn–C.	3/16 x 14	90 to 220

11. Electrodes for Corrosion-Resisting Steels

a. *Description.*

(1) These shielded-arc, end-grip chromium-nickel steel (stainless steel) electrodes are supplied in three types —MIL–308–15, E–308–16, and MIL–347–15.

(2) The MIL–347 electrode contains columbium as a stabilizer to minimize intergranular corrosion resulting from carbide precipitation; the MIL– or E–308 electrodes do not contain columbium and, accordingly, are not so stabilized (table XIX).

(3) The basic difference between the MIL–308–15 and the E–308–16 is in the compounding of the electrodes' coatings. In the –15, the coating is such that the electrode is suitable for use with direct current only. In the –16, the coating is specifically compounded to permit the use of the electrodes with either alternating or direct current.

Table XIX. Chemical Composition of Deposited Weld Metal of Chrome-Nickel Steel Electrodes

Type	Percentage of elements (all percentages are maximum unless otherwise indicated)										
	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Columbium	Copper	Other
MIL-308-15 and E-308-16	0.08	2.5	0.04	0.03	0.9	18.0 to 21.0	9.0 to 11.0	------	------	------	[1]
MIL-347-15	0.08	2.5	0.04	0.03	0.9	18.0 to 21.0	9.0 to 11.0	0.75	1.0[2]	0.5	[1]

[1] The remainder is not specified, but a large percentage is iron.
[2] Includes tantalum. Minimum of columbium and tantalum specified is 10 times actual carbon present.

b. Application.

(1) *Types MIL-308-15 and E-308-16.*

(*a*) These electrodes are intended for general welding of unstabilized 18 percent chromium—8 percent nickel corrosion resisting steels (18-8 stainless steels). They are suitable, also, for 19-9 stainless steels and high-manganese steels, and they can be used on aluminum-coated steels for applications where temperatures do not exceed 800° F.

(*b*) These electrodes (1/16- through 5/32-inch sizes) are recommended for all-position welding.

(*c*) With the -15 electrodes, use direct current with electrode positive—work negative (reverse) polarity only. With the -16 electrodes, either alternating or direct current (reverse polarity) can be used.

(*d*) Hold a short arc, assuring that the electrode's coating does not touch the molten pool. Use either the stringer-bead or weaving technique. When weaving, however, hold the width of the weave to a minimum. Use the smallest size electrode and lowest current feasible to facilitate rapid cooling. The suggested amperage range is indicated in table XX.

(2) *Type MIL-347-15.*

(*a*) These electrodes are intended for general welding of 18 percent chromium—8 percent nickel corrosion-resisting steels (18-8 stainless steels) that are stabilized by columbium. Such stabilized stainless steels are used where conditions of welding or service make unstabilized base metals susceptible to carbide precipitation with consequent intergranular corrosion. The use of these electrodes, however, will not prevent intergranular corrosion alongside a weld in unstabilized 18-8 stainless steel. These electrodes can be used also on aluminum-coated steels for applications where temperatures exceed 800° F.

(*b*) The class 1 electrodes (1/8- and 5/32-inch sizes) are recommended for all-position welding; the class 2 (3/16-inch size) for horizontal fillets and flat-position welding only.

(*c*) Use direct current with electrode positive—work negative (reverse) polarity.

(*d*) The information in (1) (*d*) above applies also to these electrodes.

c. Data. These electrodes are supplied in the types, classes, and sizes indicated in table XX. The item name is ELECTRODE, WELDING and the unit of issue is pounds.

Table XX. Electrodes for Corrosion-Resisting Steels

Specification	Size (in inches)	Suggested amperage range (amperes)
MIL-E-16715B type MIL-308-15, class 1.	1/16 x 9	20 to 40
MIL-E-16715B type MIL-308-15, class 1.	1/8 x 14	60 to 100
ASTM A298-55T, class E-308-16.	5/32 x 14	100 to 140
MIL-E-16715B type MIL-347-15, class 1.	1/8 x 14	60 to 100
MIL-E-16715B type MIL-347-15, class 1.	5/32 x 14	100 to 140
MIL-E-16715B type MIL-347-15, class 2.	3/16 x 14	120 to 170

12. Electrodes for Surfacing Applications

Note. See also paragraph 10, Electrodes for Copper and Copper-Alloys.

a. Description. These shielded-arc end-grip electrodes are supplied in three types—"Mangjet" or equal, an austenitic-type alloy (high-manganese) steel electrode; "Toolweld A and O," or equal, a martensitic-type tool-steel electrode; and MIL–E–13865 (Ord)—Class A, an alloy-steel electrode whose structure (such as austenitic, martensitic, etc.) is not specified.

b. Application.

(1) *"Mangjet," or equal.*

(*a*) This electrode is intended for resurfacing and building up of high-manganese steels. The hardness of the weld metal normally will be between 43 and 48 Rockwell C in the cold-worked condition. Deposits normally are used in the as-welded condition, but they may be ground if a smooth surface is required.

(*b*) This electrode is recommended for all-position welding.

(*c*) Use direct current with electrode with either polarity or use alternating current. The suggested amperage ranges (3/16-inch electrode) are from 150 to 260 amperes with direct current and from 165 to 285 amperes with alternating current.

(*d*) Wherever possible, deposit beads 1/2- to 1-inch wide and not more than 3 inches long. Use the lowest heat possible and allow the work to cool between beads. In manganese steel castings, the beads should be so placed that the heat will be well distributed.

(2) *"Toolweld A and O," or equal.*

(*a*) This electrode is intended for alteration and repair of metal working, forming, and cutting tools such as shears, punches, dies, etc. This electrode is suitable for use where high metal-to-metal impact resistance is required. The hardness of the deposited weld metal normally will be between 58 and 65 Rockwell C. Deposits may be machined after annealing.

(*b*) The electrode is recommended for all-position welding.

(*c*) Use direct current with electrode negative—work positive (straight) polarity or use alternating current. The suggested amperage range (1/8-inch electrode) is from 65 to 130 amperes.

(*d*) The deposit may be hardened by air cooling or oil quenching. When the weld is to be heat-treated by tempering only, allow work to cool to room temperature before tempering.

(3) *MIL–E–13865 (Ord)—class A.*

(*a*) This electrode is intended for building up carbon steels and low-alloy steels where resistance to abrasion is required but where machineability is not required. The hardness of the deposited weld metal normally will be approximately 50 Rockwell C.

(*b*) This electrode is recommended for all-position welding.

(*c*) Use direct current with electrode positive—work negative (reverse) polarity.

(*d*) The suggested amperage ranges are from 110 to 250 amperes for the 3/16-inch size and from 150 to 385 amperes for the 1/4-inch size.

(*e*) Hold a fairly close arc, but do not allow the electrode's coating to touch the molten pool. Use the weaving technique, but limit the width of the weave to approximately 3/4 inch.

(*f*) Avoid thick, multilayer deposits. For best results use single-layer deposits.

c. Data. These electrodes are supplied in the types and sizes indicated in table XXI. The item name is ELECTRODE, WELDING and the unit of issue is pounds.

Table XXI. Electrodes for Surfacing Applications

Specification or type	Size (in inches)
"Mangjet," or equal	3/16 x 14
"Toolweld A and O," or equal	1/8 x 14
MIL–E–13865 (Ord) class A	3/16 x 14
MIL–E–13865 (Ord) class A	1/4 x 14

13. Electrodes for Molybdenum-Alloy, Chromium-Molybdenum-Alloy, and Silicon-Alloy Steels

a. Description. These shielded-arc, end-grip electrodes are supplied in two types—a molybdenum-alloy steel containing approximately ½ percent manganese and ½ percent silicon (type MIL–7010–A1); and a chromium-molybdenum-alloy steel containing approximately ½ percent silicon (type MIL–22–16) (table XXII).

Table XXII. Chemical Composition of Weld Metal of Molybdenum-Alloy and Chromium-Molybdenum-Alloy Steel Electrodes

Type	Percentage of elements (all percentages are maximum unless otherwise indicated)							
	Carbon	Chromium	Molybdenum	Manganese	Silicon	Phosphorus	Sulfur	Other
MIL–7010–A1	0.15	------------	0.4 to 0.6	0.35 to 0.60	0.4	0.04	0.035	[1]
MIL–22–16	0.1	0.4 to 0.6	0.4 to 0.6	------------	0.6	----------	----------	[1]

[1] The remainder is not specified, but a large percentage is iron.

b. Application.

(1) *Type MIL–7010–A1.*

(*a*) This electrode is intended for welding of molybdenum-alloy steel piping, forgings, castings, etc. It is suitable, also, for structural silicon-alloy steels.

(*b*) This electrode (¼-inch size) is recommended for horizontal fillets and flat-position welding only.

(*c*) Use direct current with electrode positive—work negative (reverse) polarity. Hold as close an arc as possible without touching the electrode's coating to the molten pool. The suggested amperage range is indicated in table XXIII.

(2) *Type MIL–22–16.*

(*a*) These electrodes are intended for welding of ½ percent chromium—½ percent molybdenum-alloy steel or ½ percent molybdenum-alloy steel piping, castings, structural shapes, etc., where resistance to high temperatures (850° to 900° F.) is required.

(*b*) The class 1 electrodes (⅛- and 5/32-inch sizes) are recommended for all-position welding; the class 2 (3/16-inch size) for horizontal fillets and flat-position work only.

(*c*) Use direct current with electrode positive—work negative (reverse) polarity or use alternating current. Hold as short an arc as possible without touching the electrode's coating to the molten pool. The suggested amperage range is indicated in table XXIII.

c. Data. These electrodes are supplied in the types and sizes indicated in table XXIII. The item name is ELECTRODE, WELDING and the unit of issue is pounds.

Table XXIII. Electrodes for Molybdenum-Alloy, Chromium-Molybdenum-Alloy, and Silicon-Alloy Steels

Specification	Size (in inches)	Suggested amperage range (amperes)
MIL–E–15716B, type MIL–7010–A1, class 2.	¼ x 18	220 to 300
MIL–E–16589A (SHIPS) type MIL–22–16, class 1.	⅛ x 14	120 to 180
MIL–E–16589A (SHIPS) type MIL–22–16, class 1.	5/32 x 14	140 to 200
MIL–E–16859A (SHIPS) type MIL–22–16, class 2.	3/16 x 14	220 to 280

14. Electrodes for Nickel-Copper Alloys

a. Description. These shielded-arc, end-grip electrodes are supplied in one type only—a nickel alloy containing approximately 25 percent copper (table XXIV).

Table XXIV. Chemical Composition of Deposited Weld Metal of Nickel-Copper-Alloy Electrodes

Percentage of elements (all percentages are maximum unless otherwise indicated)									
Nickel	Manganese	Silicon	Carbon	Sulfur	Titanium	Aluminum	Iron	Other	Copper
62.0 to 70.0[1]	4.0	1.0	0.4	0.025	1.0	1.5	2.5	0.5	remainder

[1] Includes incidental cobalt.

b. Application.

(1) These electrodes are intended for use in joining wrought nickel-copper alloys (Monel) to themselves and for welding nickel-copper-alloy castings (Monel) (welding grade).

(2) The class 1 electrodes (3/32- through 5/32-inch sizes) are recommended for all-position welding; the class 2 (3/16-inch size) for horizontal fillets and flat-position work only.

(3) Use direct current with electrode positive—work negative (reverse) polarity. Hold a short arc. Vertical-position work can be welded either up or down. Sheet metal (0.062 to 0.093 inch thick), however, should be welded by starting at the top and by proceeding straight downward. Weaving is desirable, but the stringer-bead technique can be used for single-pass work or for welding in close quarters. The suggested amperage range is indicated in table XXV.

c. Data. These electrodes are supplied in the classes and sizes indicated in table XXV. The item name is ELECTRODE, WELDING and the unit of issue is pounds.

Table XXV. Electrodes for Nickel-Copper Alloys

Specification	Size (in inches)	Suggested amperage range (amperes)
MIL-E-17496B (SHIPS) type MIL-3N10, class 1.	3/32 x 12	45 to 60[1]
MIL-E-17496B (SHIPS) type MIL-3N10, class 1.	1/8 x 14	60 to 95[1]
MIL-E-17496B (SHIPS) type MIL-3N10, class 1.	5/32 x 14	80 to 150[1]
MIL-E-17496B (SHIPS) type MIL-3N10, class 2.	3/16 x 14	140 to 190

[1] In the overhead position, reduce current 5 to 15 amperes. In the vertical position reduce current 10 to 20 percent.

Section III. FLUXES

15. General

a. This section contains data pertaining to fluxes. Fluxes are chemical compounds used in brazing, soldering, and welding to dissolve and facilitate removal of oxides, nitrides, and other undesirable substances existing in the area of the joint and to prevent formation of these substances in the process of making the joint. Fluxes are not intended for the primary removal of oxides, grease, oil, and dirt. Parts to be brazed, soldered, or welded must be cleaned thoroughly by the appropriate cleaning method prior to the application of the flux.

b. Generally, a flux must be used in all brazing and soldering operations and in the welding (except shielded-metal-arc welding and inert-gas arc welding) of aluminum and aluminum alloys, copper alloys, cast iron, stainless steel, and tool steel. A flux sometimes is required in welding carbon and alloy steels.

c. Fluxes are available in powdered, paste, liquid, granular, or stick form. Selection of the form depends on specific work requirements and the process and procedure to be used. For the most part, brazing and welding fluxes that are in the powdered form are mixed with water or alcohol (in accordance with the mixing instructions on flux container) to make a smooth paste for easy application. In some cases, however, the powdered flux is used dry. In brazing, for example, dry powdered flux is sometimes applied to the brazing alloy strip or wire by dipping the end of the heated strip or wire in the flux container. Liquid, stick, and paste fluxes generally are used "as is."

d. In order to prevent contamination and/or deterioration of the flux, containers should remain open only as long as necessary.

16. Selection and Application

a. It is of prime importance that the flux selected be one that is suitable for the metal to be joined and for the process (i.e., brazing, soldering, or welding) to be used. Refer to tables XXVI, XXVII, and XXVIII. It is advisable to use a general-purpose flux (one that is suitable for nearly all metals), where appropriate. Use of a general-purpose flux will reduce "switching" from one flux to another each time a different metal is to be joined.

Note. Do not use paste-, acid-, or salt-type fluxes for soldering in electronic equipment. Refer to TB SIG 222.

b. Immediately after cleaning the surfaces to be joined, apply the proper flux to the joint with a brush, swab, or by other prescribed methods. Also, dip the brazing alloy strip or wire or the gas welding rod in flux or apply flux to strip, wire, or rod with a brush. Refer to TM 9–237/TO 34W4–1–5 for detailed instructions pertaining to application of fluxes.

Note. Aluminum-alloy welding flux, specification MIL–F–6939A, should be mixed to a thin paste with distilled water.

17. Removal

a. Since fluxes generally contain acids, salts, or other chemical compounds (such as chlorides and fluorides), which have a corrosive action, some method of cleaning is required to remove all traces of flux from surfaces after brazing, soldering, or welding. Even the so-called "noncorrosive" fluxes, for the most part, have a corrosive action. "Noncorrosive" fluxes usually contain salts, such as ammonium chloride or zinc chloride, and, while such fluxes are not as corrosive as acid fluxes, they do have a definite corrosive action.

b. Fluxes can be removed by one or more of the following methods, as applicable. The choice of method(s) will depend on the type of work, the type of flux used, and the tenacity of the flux residue. For example, the method indicated in (4) below would not be used for delicate components; the method in (1) below would not be used for fluxes other than those supplied in paste form and those in acid-core solders; and the method in (2) below would not be effective where heavy, glass-like flux residues have formed.

(1) *Degreasing.* Remove grease and oils used in paste fluxes (fluxes supplied in paste form and in acid-core solders) by immersing small parts in trichloroethylene. Where immersion is not feasible, clean affected surfaces with brush or swab saturated with trichloroethylene. Rinse parts or surfaces thoroughly in flowing water.

***Warning:* Provide adequate ventilation while working with trichloroethylene.**

(2) *Boiling water bath.* Immerse affected parts or surfaces in boiling water and clean with a fine fiber brush.

(3) *Acid bath.* To remove stubborn flux residues after boiling water bath, immerse affected parts or surfaces in dilute acid solution, such as a 10 percent sulfuric acid-cold water solution, and agitate the solution. Allow surfaces to remain in acid bath only long enough to remove all flux residues. Approximately 30 minutes will be required with the 10 percent sulfuric acid-cold water solution. Rinse parts thoroughly in flowing water.

***Caution:* Do not use acid bath where the base or filler metal is likely to be adversely affected by the acid solution.**

***Warning:* When working with acids or acid solutions, wear protective goggles, rubber aprons, and rubber gloves. If acid comes in contact with the skin, flush the affected area immediately with clean water for a period of at least 20 minutes and then immediately obtain medical attention.**

(4) *Mechanical methods.* To remove heavy, glass-like residues, clean affected surfaces with wire brush, sandblast, or chip off with hammer and chisel.

***Caution:* Use these methods on sturdy parts that can take such**

mechanical working. Do not use these methods on soft metals, such as aluminum, because these metals are susceptible to flux residue particle embedment. Use the hammer and chisel as a last resort only.

(5) *Drying.* Dry thoroughly all parts or surfaces that have been cleaned or rinsed in water.

18. Data

Fluxes are supplied in three basic types—brazing, soldering, and welding—and in the forms and sizes indicated in tables XXVI, XXVII, and XXVIII. The item names are FLUX, BRAZING; FLUX, SOLDERING; and FLUX, WELDING; respectively. For general information, the basic chemical constituents, where specified, are indicated in the notes column of the tables.

Table XXVI. Brazing Fluxes

Used on	Specification and type	Form	Unit of issue	Notes
All metals except aluminum and aluminum alloys; magnesium and magnesium alloys; and aluminum bronze.	O-F-499	paste	jar (8 oz) pound	1
Aluminum and bronze		powdered	can (1 lb)	
Cast iron (including malleable cast iron) and steel		powdered	can (1 lb)	
Copper alloys and mild steel	"Eutector Autochemic Flux 1800," or equal.	paste	jar (8 oz)	2
Gold, platinum, and silver	"Swarthchild 55202," or equal.	paste	each (1-oz glass)	1

[1] For use with silver brazing alloys.
[2] For use with "EutecRod 1800," or equal, brazing alloy only.

Table XXVII. Soldering Fluxes

Used on	Specification and type	Form	Unit of issue	Notes
All metals except aluminum.	L. B. Allen Co. "Soldering Salt," or equal.	granular	each (1-lb can)	
		liquid	jar (1 gal)	
	O-F-506b, type I	paste	can (2 oz) can (4 oz) can (1 lb)	Zinc chloride and ammonium salts in grease or wax base.
Aluminum	Eng PD-332A	liquid	bottle (8 oz)	1
Brasses, copper, terne plate, tin plate, and zinc.	MIL-F-20329, type II.	paste	can (2 oz)	Rosin, stearic acid, and benzoic acid in petrolatum base.
Brasses, copper, tin, and steel	Ruby Chemical Co. "Rubyfluid," or equal.	liquid	can (1 qt)	
Copper, copper alloys, and carbon steels	MIL-F-20329, type III.	liquid	bottle (4 oz)	Rozin and benzoic acid in cyclohexanol.
Heat-resistant and high-chromium steels	MIL-F-4995, type III.	liquid	bottle (4 oz)	
Lead	MIL-F-12784A	stick	stick (1/6 lb) stick (1/4 lb)	Stearic acid[2]

[1] For use with tin-lead-zinc solder for aluminum.
[2] For use in soldering lead surfaces, wiping of joints, and floating seams in lead covered telephone cables. This flux is commonly called stearine compound IC-3 or stearine.

Table XXVIII. Welding Fluxes

Used on	Specification and type	Form	Unit of issue	Notes
Aluminum	—	powdered	can (1 lb)	—
Aluminum alloys	MIL–F–6939A	powdered	each (¼-lb bottle) each (1-lb bottle)	Compounds of sodium, potassium, lithium, chlorine, and fluorine.
Brass, bronze, cast iron, copper, and steel.	—	powdered	can (1 lb) carton (5 lb) can (5 lb)	100-mesh size 10-mesh size 100-mesh size
Cast iron	MIL–F–16136A type C	powdered	can (1 lb)	Sodium nitrate, sodium carbonate, and sodium tetraborate.
Cast iron (including malleable cast iron) and steel (including stainless steel).	—	paste	jar (5 lb)	—
Copper alloys (except those containing aluminum or nickel).	MIL–F–16136A type A	powdered	each (1-lb can)	—

Section IV. WELDING RODS

19. General

a. Discussion. This section contains data pertaining to welding rods used as filler metal in gas, carbon-arc, and inert-gas arc welding.

(1) Gas welding is a process wherein fusion is produced by heat generated by a gas flame, such as an oxy-acetylene flame. Where required, a welding rod of suitable composition is used as filler metal.

(2) Carbon-arc welding is a process wherein fusion is produced by heat generated by an electric arc between a carbon electrode and the work (fig. 3) or between two carbon electrodes. No shielding is used. Where required, a welding rod of suitable composition is used as filler metal.

(3) Inert-gas arc welding is a process wherein fusion is produced by heat generated by an electric arc between a carbon or metal electrode and the work. Shielding is obtained from an inert gas such as argon, helium, or mixtures thereof. Where required, a welding rod of suitable composition is used as filler metal.

Note. Graphite (carbon) welding and cutting electrodes are covered in section VII, Miscellaneous Materials.

b. Arrangement of Data. The data in this section are arranged according to the application of the welding rods; that is, a separate paragraph is provided for data pertaining to rods used for each family of metals and their alloys. In addition, a paragraph is provided for data pertaining to rods used in surfacing applications. In some cases, as in the brass welding rods, the rods are intended for a particular family of metals and their alloys, such as copper and copper alloys, but have application also in another family of metal alloys, such as steel. In these cases, cross references from one paragraph to another are provided in the form of notes. For example, under paragraph 21, Welding Rods for Carbon and Alloy Steels, a note appears inviting attention to paragraph 23, Welding Rods for Copper and Copper Alloys.

c. Identification Markings. To facilitate proper identification of welding rods, a marking system is utilized for most welding rods supplied by the Ordnance Corps. This marking consists of the welding-rod class, such as FS–RCuZn–1 (usually less the "FS–R"), or the commercial alloy designation, such as 5052 or 52S, stamped or molded at one end of the rod or stamped or embossed on a metal tag attached to each container. In cases where each rod is not individually marked, it is of prime importance that the rods be kept in their original container so that markings on the container or on the tag attached to container will provide easy *identification.*

d. Refer to TM 9–237/TO 34W4–1–5 for data pertaining to welding processes.

20. Welding Rods for Aluminum and Aluminum Alloys

a. Description. These welding rods are supplied in two classes—a 99 percent aluminum rod and an aluminum-silicon-alloy rod containing approximately 93 percent aluminum and 5 percent silicon (table XXIX).

Table XXIX. Chemical Composition of Aluminum and Aluminum-Alloy Welding Rods

Class	Percentage of elements (all percentages are maximum unless otherwise indicated)								
	Copper	Magnesium	Manganese	Silicon	Iron	Zinc	Titanium	Other	Aluminum
FS–RA12	0.2	----------	0.05	[1]	[1]	0.1	----------	0.15	99.0
FS–RA143	0.3	0.05	0.3	4.5 to 6.0	0.8	0.3	0.2	0.15	remainder

[1] Silicon plus iron 1 percent maximum.

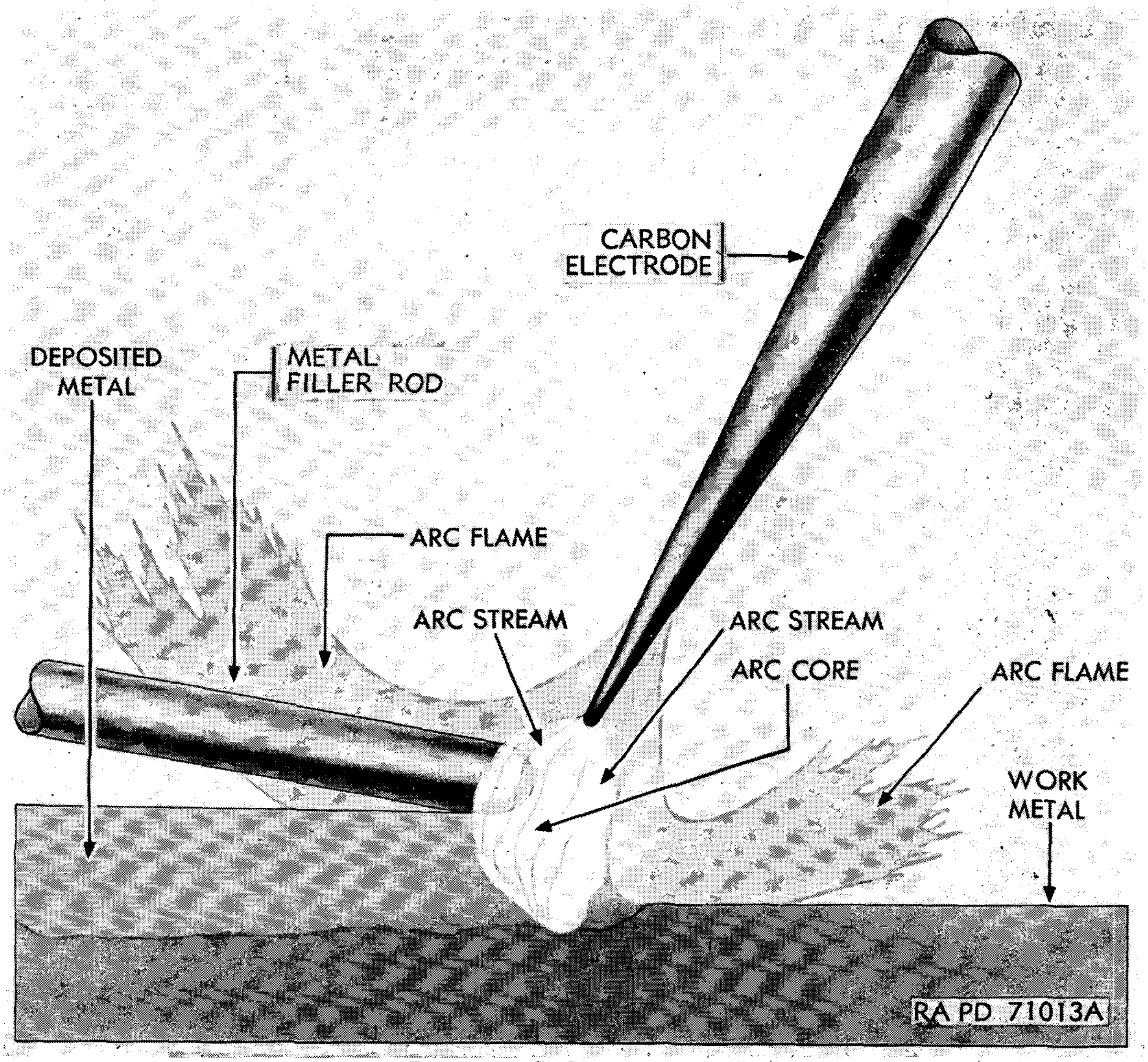

Figure 3. Carbon-arc welding.

b. Application.

(1) *Aluminum (class FS–RA12).*

(*a*) These welding rods are intended for use as filler metal in gas, carbon-arc, and inert-gas arc welding of 1100 (2S) aluminum and 3003 (3S) aluminum-manganese alloy.

(*b*) These rods are recommended for flat-position welding only. An aluminum or aluminum-alloy flux is required, except in inert-gas arc welding.

(2) *Aluminum-silicon alloy (class FS–RA143).*

(*a*) These welding rods are intended for use as filler metal in gas, carbon-arc, and inert-gas arc welding of most aluminum alloys, including 3003 (3S) aluminum-manganese alloy, 5052 (52S) aluminum-magnesium-chromium alloy, 6053 (53S) and 6061 (61S) aluminum-magnesium-silicon-chromium alloys, and 4043 (43) aluminum-silicon-alloy castings.

(*b*) These rods are recommended for all-position welding. An aluminum-alloy flux is required, except in inert-gas metal-arc welding.

c. Data. These welding rods are supplied in the classes and sizes indicated in table XXX. The item name is ROD, WELDING and the unit of issue is pounds.

Table XXX. Welding Rods for Aluminum and Aluminum Alloys

Specification	Size (in inches)
QQ–R–566, type I, class FS–RA12	1/8 x 36
QQ–R–566, type I, class FS–RA143	1/8 x 36
QQ–R–566, type I, class FS–RA143	3/16 x 36
QQ–R–566, type I, class FS–RA143	1/4 x 36

21. Welding Rods for Carbon and Alloy Steels

Note. See also paragraph 23, Welding Rods for Copper and Copper Alloys.

a. Description. These welding rods are supplied in three classes—a carbon-steel rod for aircraft use, a low-alloy-steel rod for aircraft use, and a carbon-steel rod for other than aircraft use (table XXXI). These rods are supplied either plain or copper coated.

Table XXXI. Chemical Composition of Steel Welding Rods

Type and class	Percentage of elements (all percentages are maximum unless otherwise indicated)					
	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Other
Class 1 (MIL–R–5632)[1]	0.06	0.25	0.04	0.04		[2]
Class 2 (MIL–R–5632)[1,3]	0.1 to 0.2	1.0 to 1.2	0.04	0.04	0.2 to 0.3	[2]
Class I, type A (MIL–R–908)[4]			0.04	0.04		

[1] Chemical composition given is for welding rod (not deposited weld metal).
[2] Remainder is not specified, but a large percentage is iron.
[3] Except for phosphorus and sulfur limits, the chemical composition of the class 2 rod is not mandatory.
[4] Except for phosphorus and sulfur limits in the deposited weld metal, the chemical composition of the class I, type A, rod is not specified.

b. Application.

(1) *Class 1 (MIL–R–5632).*

(*a*) These welding rods are intended for gas welding of low- and medium-carbon steels (for aircraft structures) which will not require postweld heat-treatment.

(*b*) These rods are recommended for all-position welding. A flux is not required.

(2) *Class 2 (MIL–R–5632).*

(*a*) These welding rods are intended for gas welding of stressed joints in low-alloy-steel aircraft structures which require postweld heat treatment to obtain high mechanical properties.

(*b*) These rods are recommended for all-position welding. A flux is not required.

(3) *Class I, type A (MIL–R–908).*

(*a*) These welding rods are intended for gas welding of low- and medium-carbon steels for other than aircraft use.

(*b*) These rods are recommended for all-position welding. A flux is not required.

c. Data. These welding rods are supplied in the classes and sizes indicated in table XXXII. The item name is ROD, WELDING and the unit of issue is pounds.

22. Welding Rods for Cast Iron

Note. See also paragraph 23, Welding Rods for Copper and Copper Alloys.

a. Description. These welding rods are supplied in one class only—a cast-iron rod containing approximately 3 percent silicon (table XXXIII).

Table XXXII. Welding Rods for Carbon and Alloy Steels

Specification	Size (in inches)
MIL–R–5632, class 1	1/16 x 36
MIL–R–5632, class 1	1/8 x 36
MIL–R–5632, class 1	3/16 x 36
MIL–R–5632, class 2	1/16 x 36
MIL–R–5632, class 2	3/32 x 36
MIL–R–5632, class 2	1/8 x 36
MIL–R–5632, class 2	3/16 x 36
MIL–R–908 (SHIPS), class I, type A	1/16 x 36
MIL–R–908 (SHIPS), class I, type A	3/32 x 36
MIL–R–908 (SHIPS), class I, type A	1/8 x 36
MIL–R–908 (SHIPS), class I, type A	5/32 x 36
MIL–R–908 (SHIPS), class I, type A	3/16 x 36
MIL–R–908 (SHIPS), class I, type A	1/4 x 36

Table XXXIII. Chemical Composition of Cast-Iron Welding Rods

Percentage of elements					
Carbon	Manganese	Phosphorus	Sulfur	Silicon	Other
3.0 to 3.5	0.50 to 0.75	0.5 to 0.7	0.08 max	2.75 to 3.50	[1]

[1] Remainder is not specified, but a large percentage is iron.

b. Application.

(1) These welding rods are intended for general gas welding of cast-iron parts.

(2) These rods are recommended for all-position welding. A cast-iron flux is required.

c. Data. These welding rods are supplied in the sizes indicated in table XXXIV. The item name is ROD, WELDING and the unit of issue is pounds.

23. Welding Rods for Copper and Copper Alloys

Note. See also paragraph 26, Welding Rods for Nickel-Copper Alloys.

a. Description. These welding rods are supplied in three classes—phosphor bronze (FS–RCuSn–1), naval brass (FS–RCuZn–1), and high-strength brass (FS–RCuZn–3) (table XXXV).

Table XXXIV. Welding Rods for Cast Iron

Specification	Size (in inches)
MIL–R–908 (SHIPS), class II	1/8 x 20
MIL–R–908 (SHIPS), class II	3/16 x 18
MIL–R–908 (SHIPS), class II	1/4 x 18

Table XXXV. Chemical Composition of Copper-Alloy Welding Rods

Class	Percentage of elements (all percentages are maximum unless otherwise indicated)									
	Tin	Silicon	Manganese	Iron	Nickel	Lead	Phosphorus	Other	Copper[1]	Zinc
FS–RCuSn–1	3.5 to 8.0[2]	----	----	----	----	0.02	0.05[2]	0.5	remainder[2]	----
FS–RCuZn–1	0.5 to 1.5	----	----	0.1	----	0.05	----	0.5	57.0 to 63.0	remainder
FS–RCuZn–3	1.0[3]	0.04 to 0.25	0.9[3]	1.0[3]	1.0[3]	0.05	----	0.5	56.0 min	remainder

[1] Including silver (copper plus silver).
[2] Copper (including silver sulfide) plus tin plus phosphorus—99.5 percent, minimum.
[3] Sum of these elements (tin, manganese, iron, and nickel)—1.25 percent, minimum.

b. Application.

(1) *Phosphor bronze (class FS–RCuSn–1).*

(*a*) These welding rods are intended for use as filler metal in gas, carbon-arc, and inert-gas arc welding of phosphor bronzes and also for the braze welding of steel and cast iron. Strength of weld metal will be between 30,000 and 60,000 psi.

(*b*) These rods are recommended for all-position welding. A brazing flux is required, except in inert-gas arc welding.

(2) *Naval brass (class FS–RCuZn–1).*

(*a*) These welding rods are intended for gas welding of copper, bronzes, and brasses and also for braze welding of steel and cast iron. Strength of weld metal will be between 50,000 and 60,000 psi.

(*b*) These rods are recommended for all-position welding. A brazing flux is required.

(3) *High-strength brass (class FS–RCuZn–3).*

(*a*) These welding rods are intended for gas welding of high-strength bronzes and brasses. Strength of weld metal will be between 55,000 and 70,000 psi.

(*b*) The rods are recommended for all-position welding. A brazing flux is required.

c. Data. These welding rods are supplied in the classes and sizes indicated in table XXXVI. The item name is ROD, WELDING and the unit of issue is pounds.

Table XXXVI. Welding Rods for Copper and Copper Alloys

Specification	Size (in inches)
QQ-R-571a, type I, class FS-RCuSn-1	3/16 x 36
QQ-R-571a, type I, class FS-RCuZn-1	1/16 x 36 (Packaged in 1-lb carton).
QQ-R-571a, type I, class FS-RCuZn-1	1/16 x 36 (Packaged in 10-lb bundle).
QQ-R-571a, type I, class FS-RCuZn-1	3/32 x 36
QQ-R-571a, type I, class FS-RCuZn-1	1/8 x 36
QQ-R-571a, type I, class FS-RCuZn-3	1/16 x 36
QQ-R-571a, type I, class FS-RCuZn-3	1/8 x 36
QQ-R-571a, type I, class FS-RCuZn-3	3/16 x 36
QQ-R-571a, type I, class FS-RCuZn-3	1/4 x 36

24. Welding Rods for Corrosion-Resisting Steels

a. Description. These welding rods are supplied in two classes—a columbium stabilized chromium-nickel-steel rod and a columbium stabilized chromium-nickel-steel rod containing molybdenum and tungsten (table XXXVII).

Table XXXVII. Chemical Composition of Chromium-Nickel-Steel Welding Rods

Class	Percentage of elements (all percentages are maximum unless otherwise indicated)										
	Carbon	Manganese	Silicon	Phosphorus	Sulfur	Chromium	Nickel	Molybdenum	Columbium	Tungsten	Iron
5	0.07	2.0	1.0	0.03	0.03	19.0 (min)	9.5 (min)	------	[1]	------------	remainder
6	0.12	2.0	1.0	0.03	0.03	19.0 (min)	8.0 (min)	0.75	1.0 (min)	1.0 to 2.0	remainder

[1] Minimum of columbium specified is 12 times actual carbon present.

b. Application.

(1) *Class 5.*

(*a*) These welding rods are intended for gas welding of AISI 347 corrosion-resisting steel (stainless steel).

(*b*) The rods are recommended for all-position welding. A flux is required.

(2) *Class 6.*

(*a*) These welding rods are intended for use as filler metal in gas welding and inert-gas arc welding of 19–9 Wx corrosion-resisting steel (stainless steel).

(*b*) These rods are recommended for all-position welding. A flux is required.

c. Data. These welding rods are supplied in the classes and sizes indicated in table XXXVIII. The item name is ROD, WELDING and the unit of issue is pounds.

Table XXXVIII. Welding Rods for Corrosion-Resisting Steels

Specification	Size (in inches)
MIL-R-5031A, class 5	1/16 x 36
MIL-R-5031A, class 5	1/8 x 36
MIL-R-5031A, class 6	1/16 x 36

25. Welding Rods for Magnesium Alloys

a. Description. These welding rods are supplied in one type only—a magnesuim-alloy rod containing aluminum and zinc (table XXXIX).

Table XXXIX. Chemical Composition of Magnesium-Alloy Welding Rods

Percentage of elements (all percentages are maximum unless otherwise indicated)								
Aluminum	Manganese	Zinc	Silicon	Copper	Nickel	Iron	Other	Magnesium
8.3 to 9.7	0.15 (min)	1.7 to 2.3	0.05	0.05	0.005	0.005	0.3	remainder

b. Application.

(1) These welding rods are intended for use as filler metal in gas welding and inert-gas arc welding of forgings, castings, extrusions, sheet, plate, and tubing of most magnesium alloys, including compositions AZ31B, AZ61A, AZ80A, AM100, AZ91C, AZ92A, AZ63A, and AZ81A. These rods are not suitable for compositions M1A, HK31A, HZ32A, and EZ33A.

(2) These rods are recommended for all-position welding. A magnesium-alloy flux is required.

c. Data. These welding rods are supplied in the sizes indicated in table XL. The item name is ROD, WELDING and the unit of issue is pounds.

Table XL. Welding Rods for Magnesium Alloys

Specification	Size (in inches)
MIL-R-6944A, grade AZ92A	3/32 x 24
MIL-R-5944A, grade AZ92A	1/8 x 24
MIL-R-6944A, grade AZ92A	3/16 x 24
MIL-R-6944A, grade AZ92A	1/4 x 24

26. Welding Rods for Nickel-Copper Alloys

a. Description. These welding rods are supplied in one type only—a nickel-copper alloy (Monel) rod containing from 63 to 70 percent nickel (table XLI).

Table XLI. Chemical Composition of Nickel-Copper-Alloy Welding Rods

Percentage of elements (all percentages are maximum unless otherwise indicated)								
Nickel	Iron	Aluminum	Carbon	Silicon	Manganese	Sulfur	Other	Copper
63.0 to 70.0	2.5	0.5	0.3	0.5	2.0	0.02	0.2	remainder

b. Application.

(1) These welding rods are intended for gas welding of nickel-copper to itself or to cupronickel. Strength of weld metal will be from 60,000 to 70,000 psi.

(2) These rods are recommended for all-position welding. A brazing flux is required.

c. Data. These welding rods are supplied in the sizes indicated in table XLII. The item name is ROD, WELDING and the unit of issue is pounds.

Table XLII. Welding Rods for Nickel-Copper Alloys

Specification	Size (in inches)
QQ-R-571a, type II, class FS-RNiCu	1/8 x 36
QQ-R-571a, type II, class FS-RNiCu	3/16 x 36
QQ-R-571a, type II, class FS-RNiCu	1/4 x 36

27. Welding Rods for Surfacing Applications

a. Description. These welding rods are supplied in two types—a surfacing brass rod (type I, class FS-RCuZn-2) and a nickel-chromium-boron alloy rod (type MIL-RNiCr-C) (table XLIII).

Table XLIII. Chemical Composition of Surfacing Brass and Nickel-Chromium-Boron-Alloy Welding Rods

Type	Percentage of elements (all percentages are maximum unless otherwise indicated)												
	Copper	Tin	Silicon	Manganese	Iron	Nickel	Lead	Chromium	Cobalt	Boron	Carbon	Other	Zinc
I, class FS-RCuZn-2	56.0 to 61.0	0.5 to 1.5	0.2	0.5	0.5 to 1.3	------	0.05	------	------	------	------	0.5	remainder
MIL-RNiCr-C	------	------	3.5 to 5.5	------	3.5 to 5.5	65.0 to 75.0	------	12.0 to 18.0	1.0	2.5 to 4.5	0.5 to 1.0	1.0	------

b. Application.

(1) *Surfacing brass (type I, class FS-RCuZn-2).*

(*a*) These welding rods are intended for repairing and building up bearing surfaces on iron and steel. Strength of weld metal will be between 55,000 and 70,000 psi.

(*b*) These rods are recommended for all-position welding. A brazing flux is required.

(2) *Nickel-chromium-boron alloy (type MIL-RNiCr-C).*

(*a*) These welding rods are intended for surfacing applications where resistance to wear, impact, abrasion, erosion, or corrosion is required. Hardness of overlay will be a minimum of 50 Rockwell C.

(*b*) These rods are recommended for all-position welding.

c. Data. These welding rods are supplied in the types and sizes indicated in table XLIV. The item name is ROD, WELDING and the unit of issue is pounds.

Table XLIV. Welding Rods for Surfacing Applications

Specification	Size (in inches)
QQ-R-571a, type I, class FS-RCuZn-2	1/8 x 36
QQ-R-571a, type I, class FS-RCuZn-2	3/16 x 36
QQ-R-571a, type I, class FS-RCuZn-2	1/4 x 36
MIL-R-17131A, type MIL-RNiCr-C	1/4 x 12 to 18
MIL-R-17131A, type MIL-RNiCr-C	5/16 x 12 to 18

Section V. SOLDERS

28. General

a. This section contains data regarding low-melting alloys used in soldering operations. Soldering is a process wherein common metals are joined with a nonferrous alloy whose melting point is below 800° F. The term "soft soldering," is sometimes used to distinguish this process from "hard soldering" (brazing).

b. The common solders are alloys of tin and lead or tin, lead, and antimony. In these solders, the conventional designations used by industry refer to the percent by weight of tin, the percent by weight of lead, and the percent by weight of antimony, if present, in the alloy. Thus, a 60-40 solder contains approximately 60 percent tin and 40 percent lead; a 40-60 solder contains approximately 40 percent tin and 60 percent lead; and a 35-63-2 solder contains approximately 35 percent tin, 63 percent lead, and 2 percent antimony. The practice in the military, however, is to designate tin-lead and tin-lead-antimony solders by their nominal tin content only. Thus, an Sn 60 (Sn is the chemical symbol for tin) solder contains approximately 60 percent tin. Similarly, tin-antimony solder is designated by its antimony content. The Sb 5 (Sb is the chemical symbol for antimony) solder contains approximately 5 percent antimony.

c. A pure metal melts (transforms from the solid state to the liquid state) at a given temperature. An alloy, however, melts over a range of temperature; that is, there is a span between the highest temperature at which the alloy is completely solid (solidus) and the lowest temperature at which the alloy is completely liquid (liquidus). For example, an Sn 20 solder starts to melt at a temperature slightly higher than 360° F. (the solidus temperature) but the solder does not become completely liquid until a temperature of 530° F. (the liquidus temperature) is reached.

d. In tin-lead alloys, this span between solidus and liquidus decreases as the tin content increases from 19.5 to 61.9 percent (fig. 4). At the 61.9 tin composition, referred to as the tin-lead eutectic, the liquidus temperature is the same as the solidus temperature. Thus, at the eutectic, the liquidus temperature is lower than that of any other tin-lead alloy. As the tin content is increased beyond 61.9 percent, the span between solidus and liquidus increases (fig. 4).

e. Accordingly, where temperature limitations are critical or where an extremely short melting range is desired, an alloy which corresponds closely to the tin-lead eutectic should be used. Of the solders supplied, the Sn 60 (59.5 to 61.5 tin) corresponds most closely to the eutectic composition.

f. All soldering operations require a flux to obtain a strong, efficient joint. In flux-cored solders (acid, rosin, or stearine core), it is important that a solder be selected not only with the proper alloy composition, but also with the proper flux core for the job at hand. Sev-

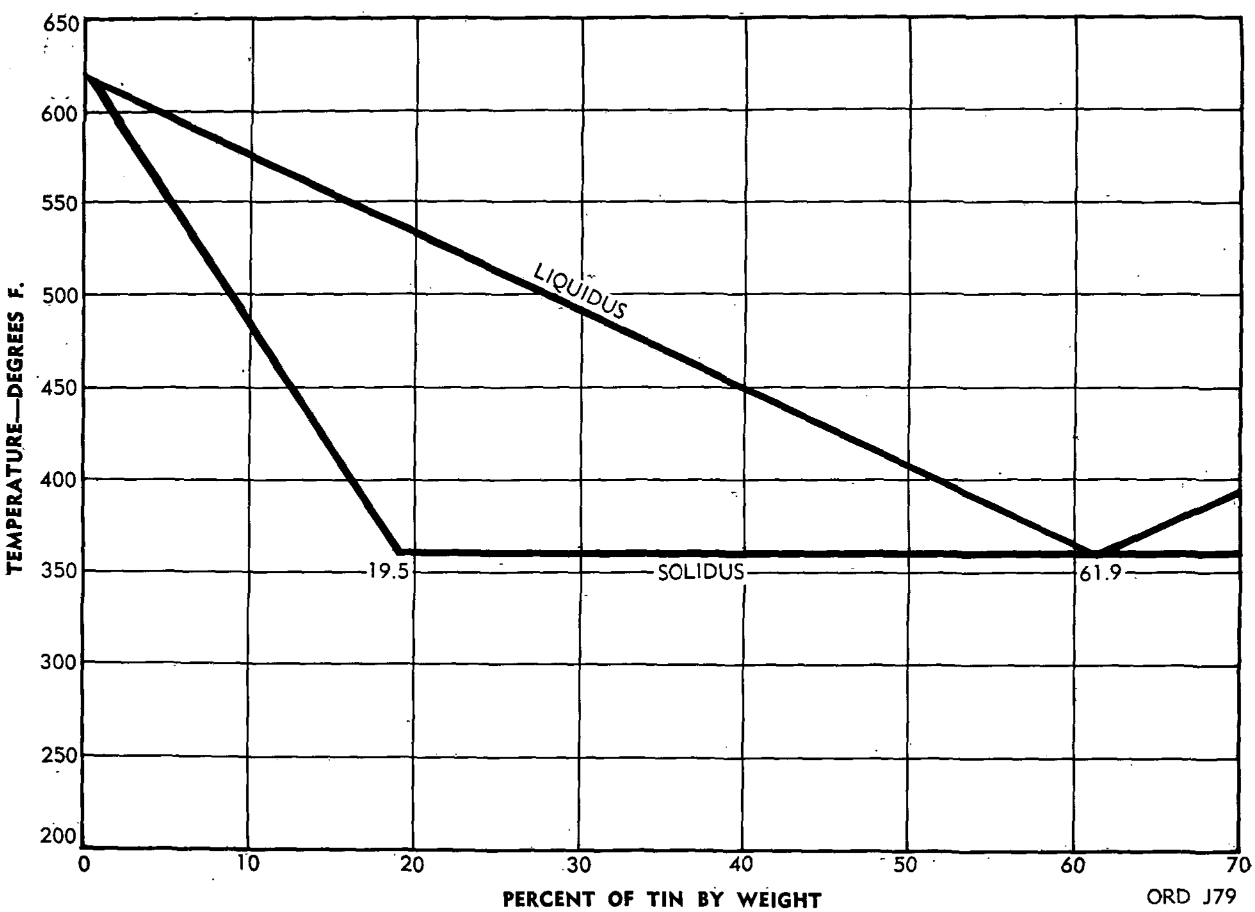

Figure 4. Solidus—liquidus temperatures of tin-lead alloys.

eral types of fluxes are available for use with the solders described herein. In general, only rosin-base fluxes that are free of grease or wax (such as the flux contained in rosin-core solders) should be used in the assembly of electrical and electronic equipment. It should be borne in mind that other types of fluxes, including the so-called "noncorrosive" fluxes, may be more active than rosin fluxes in removing oxides from the metals to be soldered, but the residues usually are corrosive and must be completely removed immediately after the soldering operation is completed. These fluxes should not be used where their vapors or residues of spattered flux may come in contact with electrical insulation. Paste fluxes, including those in acid-core solder, contain organic binders which add to the problem of flux removal. Refer to section IV for data regarding selection of fluxes (for use with bar and solid wire solders) and for information concerning flux removal.

g. Refer to TM 9–237/TO 34W4–1–5 and TB SIG 222 for data pertaining to soldering processes.

29. Description

a. Low-melting alloy solders are supplied in four basic types—(1) tin-lead and tin-lead-antimony (common solders), (2) tin-antimony, (3) tin-lead-zinc, and (4) bismuth-lead (table XLV).

Table XLV. Chemical Composition and Solidus—Liquidus Temperatures of Solders

Composition or type	Percentage of elements by weight (all percentages are maximum unless otherwise indicated)								Approximate melting range	
	Tin	Lead	Antimony	Bismuth	Zinc	Aluminum	Cadmium	Other	Solidus	Liquidus
Tin-Lead & Tin-Lead-Antimony.										
Sn 10	9.0 to 11.0	remainder	0.2	0.03	0.005	0.005	--------	2.58[1]	514	570
Sn 20	19.5 to 21.5	remainder	0.8 to 1.2	0.25	0.005	0.005	--------	0.18[2]	360	530
Sn 30	29.5 to 31.5	remainder	1.4 to 1.8	0.25	0.005	0.005	--------	0.18[2]	360	490
Sn 35	34.5 to 36.5	remainder	1.6 to 2.0	0.25	0.005	0.005	--------	0.18[2]	360	475
Sn 40	39.5 to 41.5	remainder	0.2 to 0.5	0.25	0.005	0.005	--------	0.18[2]	360	460
Sn 50	49.5 to 51.5	remainder	0.2 to 0.5	0.25	0.005	0.005	--------	0.18[2]	360	420
Sn 60	59.5 to 61.5	remainder	0.2 to 0.5	0.25	0.005	0.005	--------	0.18[2]	360	375
Tin-Antimony										
Sb 5	94.0 (min)	0.2	4.0 to 6.0	--------	0.03	0.03	0.03	0.19[3]	450	464
Tin-Lead-Zinc	33.0 to 35.0	remainder	--------	--------	2.0 to 4.0	--------	--------	0.2	335	500
Bismuth-Lead	25.0[4]	38.0[4]	--------	37.0[4]	--------	--------	--------	[5]	--------	--------

[1] Includes 1.7 to 2.4 silver and 0.08 (max) copper.
[2] Includes 0.08 (max) copper and 0.02 (max) iron.
[3] Includes 0.08 (max) copper and 0.08 (max) iron.
[4] Nominal composition.
[5] Not specified.

b. The common solders are supplied in bars, paste, solid wire, or flux-cored wire. Flux-cored wire solders are available with acid core, rosin core, or stearine core.

(1) *Acid-core solder.* Acid-core solders generally contain a soft, paste-like flux composed of one or more salts, such as stannous chloride or zinc chloride, and a binder such as petrolatum. This flux has a mild corrosive action.

(2) *Rosin-core solder.* Rosin-core solders generally contain a commercial grade of rosin of grade WW, ASTM Standard D509, or better, either in a dry form (powder) or combined with a clear, volatile solvent such as turpentine. This flux is considered neutral and has no corrosive action.

(3) *Stearine-core solder.* Stearine-core solders contain stearic acid.

30. Application

a. Tin-Lead and Tin-Lead-Antimony Solders (Common Solders).

(1) *Sn 10.* This is a high-melting point solder intended for making electrical connections in equipment that in service will operate at high ambient temperatures.

(2) *Sn 20.* This solder is intended as an automotive-body solder for filling dents and seams and for applying protective coatings on sheet steel where a high tin content is not required.

(3) *Sn 30.* This solder, like the Sn 20, is intended as an automotive-body solder for filling dents and seams. This solder is not suitable for soldering zinc or cadmium or zinc- or cadimum-coated iron or steel. Because of the high antimony content, the zinc or cadimum form intermetallic components with the antimony. Such components, having higher melting points than that of soldering alloy, hinder flow of the solder and render the joints brittle.

(4) *Sn 35 (stearine core).* This solder is intended for use in soldering lead surfaces and for wiping joints in lead-covered telephone cables. This solder is not suitable for soldering zinc or cadimum or zinc- or cadmium-coated iron or steel for the reason discussed in (3) above.

(5) *Sn 40.* This is a general-purpose solder and can be used for joining plain, tinned, or galvanized iron or steel, copper, and copper alloys. It is not quite as workable as Sn 50 solder for bit soldering or sweating. It is not suitable for electrical connections.

(6) *Sn 50.* This is the customary "50–50" or "half and half" solder. It is intended for general purpose applications as indicated in (5) above and for soldering fittings for copper water tubing. Sn 50 *rosin-core* solder is suitable for electrical connections.

(7) *Sn 60.* This solder's composition corresponds closely to the tin-lead eutectic (par. 28*d*) and has a narrow melting range. The Sn 60 *rosin-core* solder is preferred over Sn 50 solder for the general range of soldering of electrical connections. Sn 60 solder is particularly suitable for applying coatings to metals and for applications where a very low-melting alloy is required.

b. Tin-Antimony Solder (Sb 5). This solder is intended for soldering electrical connections that in service will be subjected to peak temperatures of approximately 400° F. and for soldering copper-tube joints in refrigeration equipment. This solder is not suitable for zinc or cadimum or zinc- or cadimum-coated iron or steel for the reason discussed in *a*(3) above.

c. Tin-Lead-Zinc Solder. This solder is intended for general soldering of aluminum and aluminum alloys.

d. Bismuth-Lead Solder. This solder is intended for use where materials might be damaged by heat, e.g., wax-filled capacitors, and for low-melting alloys such as pewter and "Britannia metal."

31. Data

These solders are supplied in the types, forms, and sizes indicated in table XLVI.

Note. For the purpose of technical discussion in paragraphs 28 and 29, solders containing tin and lead, in any proportions, are referred to as tin-lead solders; solders containing tin, lead, and antimony, in any proportions, are referred to as tin-lead-antimony solders; and solders containing tin, lead, and zinc are referred to as tin-lead-zinc solders. However, the approved item names (see footnotes to table XLVI) for these solders are: SOLDER, LEAD ALLOY (main constituent being lead); SOLDER, LEAD-TIN ALLOY (lead and tin being in nominally equal proportion), and SOLDER, TIN ALLOY (main constituent being tin). These item names will be used in connection with supply operations.

Table XLVI. Solders

Designation	Specification and type	Form	Wire type	Size (in inches)	Unit of issue	Notes
Sn 10	QQ-S-571c, type Sn 10 WAR	wire	rosin core	1/16	spool (1 lb)	1
Sn 20	QQ-S-571c, type Sn 20B —	bar paste	— —	1/4 x 1/4 x 14 —	bar tube (2 oz)	1 solder combined w/flux[2]
Sn 30	QQ-S-571c, type Sn 30B	bar	—	1/4 x 1/4 x 14	bar	1
Sn 35	—	wire	stearine core	1/8 x 3/16	spool (5 lb)	wire has elliptical cross section[1]
Sn 40	QQ-S-571c, type Sn 40B	bar	—	3/4 x 1/2	bar (1 1/4 lb)	1
	QQ-S-571c, type Sn 40 WAC	wire	acid core	3/32 3/32 1/8 1/8	spool (1 lb) spool (5 lb) spool (1 lb) spool (5 lb)	1
	QQ-S-571c, type Sn 40 WAR	wire	rosin core	1/16 3/32 3/32 1/8	spool (5 lb) spool (1 lb) spool (5 lb) spool (1 lb)	1
	QQ-S-571c, type Sn 40 WS	wire	solid	3/32 1/8 1/8	spool (1 lb) spool (1 lb) spool (5 lb)	1
Sn 50	QQ-S-571c, type Sn 50B	bar	—	3/4 x 1/2 x 13 1/2	bar	3
	—	wire	acid or rosin core	3/32	spool (1 lb)	3
	QQ-S-571c, type Sn 50 WAR	wire	rosin core	1/16 3/32	spool (1 lb) spool (1 lb)	3
	QQ-S-571c, type Sn 50 WS	wire	solid	1/8 1/8	spool (1 lb) spool (5 lb)	3
Sn 60	QQ-S-571c, type Sn 60B	bar	—	3/8 x 3/4 x 13 5/16	bar	4
	QQ-S-571c, type Sn 60 WAC	wire	acid core	0.162	spool (1 lb)	4
	QQ-S-571c, type Sn 60 WAR	wire	rosin core	1/32 1/16 3/32 1/8	spool (1 lb) spool (1 lb) spool (1 lb) spool (1 lb)	4
SB 5	QQ-S-571c, type SB 5 WS	wire	solid	1/8	spool (1 lb)	4
Tin-lead-zinc	MIL-S-12204B, type I, composition A.	wire	solid	1/8	spool (1 lb)	1
Bismuth-lead	—	bar	—	1/4 x 1/4 x 13 1/2	bar	5

Notes:
The item name is indicated by footnotes, as follows:
[1] SOLDER, LEAD ALLOY.
[2] SOLDER, PASTE.
[3] SOLDER, LEAD-TIN ALLOY.
[4] SOLDER, TIN ALLOY.
[5] SOLDER, BISMUTH-LEAD ALLOY.

Section VI. METALLIZING WIRES

32. General

a. This section contains data pertaining to metallic wires used in metallizing operations. Metallizing is a process in which a metal or metal alloy, in wire form, is melted by a gas flame, usually oxy-acetylene or oxy-propane, and atomized into a fine spray by a jet of compressed air. The atomized metal is sprayed onto a surface to form a coating.

b. Sprayed metal is entirely different metallurgically from the original metal wire. Generally, the sprayed metal is harder, more brittle, and more porous than the original metal. Because of its porosity, the sprayed metal has good oil retention and thus good bearing qualities.

c. As the sprayed metal cools, it tends to shrink slightly, thereby developing stresses between the sprayed coating and the base metal. Such stresses tend to deform the base metal and/or loosen the bond between the coating and the base metal. Sprayed metals that shrink the least develop the least internal stresses. Accordingly, sprayed metals that have high tensile strengths and low shrink factors will provide the strongest coatings that are least likely to crack or separate.

d. For ordinary work where relatively thin coatings (up to 1/16 inch) are required, any metallizing wire can be sprayed successfully. In these cases, the material should be selected on the basis of physical properties required, e.g., hardness, wear resistance, machineability, corrosion resistance, etc.

e. Metallizing is commonly used for building up worn parts, for correcting machining errors, and for coating iron and steel surfaces with a metal that offers corrosion resistance.

f. Refer to TM 9–1834E for information regarding metallizing operations.

33. Description

Metallizing wires are supplied in nine types —aluminum, naval brass, molybdenum, 0.10 carbon steel, 0.25 carbon steel, 0.85 carbon steel, 13 chromium stainless steel, 18–8 chromium-nickel stainless steel, and babbit (tin base) (table XLVII).

Table XLVII. Chemical Composition of Metallizing Wires

Type	Percentage of elements (all percentages are maximum unless otherwise indicated)																
	Aluminum	Tin	Antimony	Arsenic	Copper	Lead	Zinc	Silicon	Carbon	Phosphorus	Sulfur	Chromium	Nickel	Manganese	Molybdenum	Iron	Other
Aluminum	99.0 (min)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	[1]
Naval brass	-----	0.5 to 1.0	-----	-----	59.0 to 62.0	-----	36.0 to 41.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Molybdenum	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	99.0 (min)	-----	-----	[1]
Carbon steel																	
0.10 carbon	-----	-----	-----	-----	-----	-----	-----	-----	0.05 to 0.15	0.045 (max)	0.05 (max)	-----	-----	0.3 to 0.6	-----	remainder	-----
0.25 carbon	-----	-----	-----	-----	-----	-----	-----	-----	0.18 to 0.30	0.045 (max)	0.05 (max)	-----	-----	-----	-----	remainder	-----
0.85 carbon	-----	-----	-----	-----	-----	-----	-----	-----	0.8 to 0.9	0.045 (max)	0.05 (max)	-----	-----	0.4 to 0.7	-----	remainder	-----
Stainless steel																	
13 chromium	-----	-----	-----	-----	-----	-----	-----	-----	0.3 to 0.4	0.02 (max)	0.02 (max)	12.0 to 14.0	-----	-----	-----	remainder	-----

See footnote at end of table.

Table XLVI. Chemical Composition of Metallizing Wires—Continued

Type	Percentage of elements (all percentages are maximum unless otherwise indicated)																
	Aluminum	Tin	Antimony	Arsenic	Copper	Lead	Zinc	Silicon	Carbon	Phosphorus	Sulfur	Chromium	Nickel	Manganese	Molybdedum	Iron	Other
18–8 chromium-nickel.	-----	-----	-----	-----	0.5 (max)	-----	-----	0.7 (max)	0.10 (max)	0.03 (max)	0.04 (max)	17.0 to 20.0	8.0 to 12.0	2.0 (max)	-----	remainder	-----
Babbitt (tin base)	-----	87.5 to 89.5	7.0 to 8.0	0.1 (max)	3.5 to 4.5	0.35 (max)	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.08 (max)	-----

[1] Impurities—1.0 percent maximum.

34. Application

a. Aluminum Metallizing Wire. This wire is intended for general industrial and salt-water corrosion work. Typical applications include protection of hot-water storage tanks, aircraft engine cylinders, exhaust manifolds, mufflers, and ships, piers, and other steel structures subject to salt atmosphere.

b. Naval Brass Metallizing Wire. This wire is intended for general metallizing work where machineability is required. Because of its relatively high shrink factor (approximately 0.0104 inch per linear inch of coating), this material is not recommended for applying coatings over 1/16-inch thick, except where grooving methods are used for surface preparation, in which case coatings of 1/8 inch or more can be applied. This material provides a coating with a hardness of Rockwell B27, approximately. Typical applications of this wire include repairing pump casings and impellers and building up outside diameters of split bushings.

c. Molybdenum Metallizing Wire. This wire is intended to provide a bonding surface between the base metal and other metallizing coatings. It is recommended, also, for building up wear surfaces where thin coatings are desired and where machineability is not required. It is particularly suitable for building up journals that will be used with bronze bearings. This material is not recommended for applications where temperatures over 600° F. may be encountered. These coatings can be ground to a porous finish. This material has a low shrink factor (approximately 0.003 inch per linear inch of coating) and provides a coating with a hardness of Rockwell C38, approximately. Typical applications of this wire include preparing surfaces for subsequent spraying of other metallizing wires, building up journals, restoring worn press-fit areas, and facing the wearing surfaces of aluminum, magnesium, and steel parts, such as V pulleys.

d. 0.10 Carbon Steel Metallizing Wire. This wire in intended for general metallizing where machineability and light wear resistance are required. This material has a relatively low shrink factor (approximately 0.008 inch per linear inch of coating) and provides a coating with a hardness of Rockwell B89, approximately. Typical applications of this wire include building up armature shafts, journal bearing surfaces, ball-bearing housings, pistons, and valve stems, and correcting machining errors.

e. 0.25 Carbon Steel Metallizing Wire. This wire is intended for general metallizing where machineability and medium wear resistance are required. This material has a relatively low shrink factor (approximately 0.006 inch per linear inch of coating) and provides a coating with a hardness of Rockwell B90, approximately. Typical applications include correcting machining errors, restoring worn press-fit areas, and building up worn moving parts of all kinds.

f. 0.85 Carbon Steel Metallizing Wire. This wire is intended for general metallizing where heavy wear resistance is required but where machineability is not required. These coatings can be ground satisfactorily. This material has a very low shrink factor (approximately 0.0014 inch per linear inch of coating) and provides a coating with a hardness of Rockwell C36, approximately. Typical applications of this wire include building up cylinder liners, pump plungers, gland castings and sleeves, hydraulic rams, and crankshaft bearings.

g. 13 Chromium Stainless Steel Metallizing Wire. This wire is intended for metallizing where heavy wear-resistance, along with a degree of corrosion resistance, is required, but where machineability is not required. It is not recommended for applications where high corrosion resistance is required. These coatings can be ground satisfactorily. This material has a very low shrink factor (approximately 0.0018 inch per linear inch of coating) and provides a coating with a hardness of Rockwell C29, approximately. Typical applications of this wire include building up seal rings, valve plugs, and pistons.

h. 18–8 Chromium-Nickel Stainless Steel Metallizing Wire. This wire is intended for metallizing where high corrosion resistance, along with good wearing qualities, is required. These coatings can be machined readily. This material has a relatively high shrink factor (approximately 0.012 inch per linear inch of coating) and provides a coating with a hardness of Rockwell B78, approximately. Typical applications of this wire include building up of water seal gland housings, hydraulic rams, and valve wedges.

i. Babbit (Tin Base) Metallizing Wire. This wire is intended for metallizing bearings of all types.

35. Data

Metallizing wires are supplied in the types and sizes indicated in table XLVIII. The materials are covered by specification MIL–W–6712A.

Table XLVIII. Metallizing Wires

Type	Size (in inches)	Unit of issue	Notes
Aluminum	⅛	coil (25 lb)	1
Naval brass	⅛	coil (25 lb)	2
Molybdenum	0.0907	coil (5 lb)	3
Molybdenum	⅛	coil (5 lb)	3
0.10 carbon steel	⅛	coil (25 lb)	4
0.10 carbon steel	⅛	coil (50 lb)	4
0.25 carbon steel	⅛	coil (50 lb)	4
0.85 carbon steel	⅛	coil (25 lb)	4
0.85 carbon steel	⅛	coil (50 lb)	4
13 chromium stainless steel	0.0907	coil (25 lb)	4
13 chromium stainless steel	⅛	coil (25 lb)	4
18–8 chromium-nickel stainless steel.	⅛	coil (25 lb)	4
Babbitt (tin base)	⅛	coil (25 lb)	5

Notes:
The item name is indicated by footnotes, as follows:
[1] WIRE, SPRAY GUN, ALUMINUM.
[2] WIRE, SPRAY GUN, BRASS.
[3] WIRE, SPRAY GUN, MOLYBDENUM.
[4] WIRE, SPRAY GUN, STEEL.
[5] WIRE, SPRAY GUN, TIN ALLOY.

Section VII. MISCELLANEOUS MATERIALS

36. General

a. This section contains data pertaining to carbon blocks, paste, and rods; cutting and welding electrodes; fuse-bonding electrodes; and tubular cutting electrodes.

b. Refer to TM 9–1834E for information pertaining to processes with which fuse-bonding electrodes are used.

37. Carbon Blocks, Paste, and Rods

a. Description and Application. Carbon blocks, paste, and rods are made from a high-grade carbon or graphite and are fire retardant. The paste is of such a consistency that it can be molded by hand. These materials are intended for use as backing strips, molds, or plugs to restrict the flow of molten weld metal.

(1) Carbon blocks are recommended for use as backing strips, where the use of metal backing strips is undesirable or infeasible, to prevent fluid weld metal from dropping through open grooves.

Note. Carbon conducts heat poorly as compared to common metals. Thus, with the use of a carbon backing strip, a greater degree of heat will be concentrated at the root of the joint. Accordingly, carbon backing strips should not be used where excessive concentration of heat may adversely affect the welded joint.

(2) Carbon paste is recommended for use in forming molds to guide the flow of weld metal and assist in building up parts, such as gear teeth, to nearly finished size and shape.

(3) Carbon rods are recommended for use as plugs to protect holes in parts on which weld metal is to be deposited.

(4) Carbon blocks, paste, and/or rods can be used to protect machined surfaces, such as screw threads, mounting pads, etc., from damage by the welding

flame or arc or by spattered weld metal.

(5) Carbon rods are not suitable for use as carbon-arc welding electrodes.

b. Data. These materials are supplied in the forms and sizes indicated in table XLIX. The materials are covered by specification MIL–C–1143A.

Table XLIX. Carbon Blocks, Paste, and Rods

Form	Size (in inches)	Unit of issue	Notes
block	¼ x 6 x 12	ea	1
block	½ x 6 x 12	ea	1
block	1 x 6 x 12	ea	1
paste	--------------	pail (5 lb)	2
rod	¼ x 12	ea	3
rod	½ x 12	ea	3
rod	⅝ x 12	ea	3
rod	¾ x 12	ea	3
rod	⅞ x 12	ea	3
rod	1¼ x 12	ea	3
rod	1½ x 12	ea	3
rod	2 x 12	ea	3

Notes:
The item name is indicated by footnotes, as follows:
[1] CARBON BLOCK, WELDING.
[2] CARBON PASTE, WELDING.
[3] CARBON ROD, WELDING.

38. Cutting and Welding Electrodes

a. Description and Application. These electrodes are supplied in two types—(1) an uncoated graphite electrode and (2) a copper-coated graphite electrode for carbon-arc cutting and welding. Carbon-arc cutting is a process wherein severing (cutting) or gouging of metals is accomplished by melting with the heat generated by an electric arc between a carbon electrode and the work. (The copper-coated graphite electrode is particularly suitable for arc cutting and gouging operations.) Carbon-arc welding is a process wherein fusion is produced by heat generated by an electric arc between a carbon electrode and the work (fig. 3) or between two carbon electrodes. Where required, a welding rod of suitable composition is used as filler metal.

Note. Carbon is a generic term and includes all modifications in structure, electrical conductivity, etc. Graphite is a specific form of carbon.

b. Data. These electrodes are supplied in two types and sizes indicated in table L. The item name is ELECTRODE, CUTTING AND WELDING and the unit of issue is each. These electrodes are covered by specification MIL–S–17777A.

Table L. Cutting and Welding Electrodes

Type	Size (in inches)
uncoated	$\frac{3}{16}$ x 12
uncoated	¼ x 12
uncoated	$\frac{5}{16}$ x 12
uncoated	⅜ x 12
uncoated	½ x 12
uncoated	¾ x 12
copper coated	⅜ x 12

39. Fuse-Bonding Electrodes

a. Description and Application. These electrodes are supplied in one type only—a nickel-alloy electrode intended to provide a bonding surface on metal parts for the subsequent application of sprayed metal (metallizing). This bonding process, called "Fuse-Bond" (trade name of the Metallizing Engineering Company), is a process wherein electrical resistance heating of the fuse-bonding electrode causes the electrode metal to "explode" into a foam and to fuse firmly to the base metal being prepared. This metal foam as seen through a magnifying glass has the appearance of frozen soap suds with many irregularly shaped cavities which range from 0.004 to 0.03 inch in height. This extremely rough and porous surface provides a good bond for subsequent coatings of sprayed metal.

b. Data. These electrodes are supplied in the sizes indicated in table LI. The item name is ELECTRODE, WELDING and the unit of issue is pounds.

Table LI. Fuse-Bonding Electrodes

Size (in inches)
⅛ x 18
⅛ x 36

40. Tubular Cutting Electrodes

a. Description and Application. These electrodes are supplied in one type only—nonmetallic-coated-tubular steel electrode intended for use in underwater oxy-arc cutting of steel plates and structural shapes. Oxy-arc cutting is a process wherein heat is generated by an electric arc between a tubular electrode and the work and wherein oxygen, fed to the work through the bore of the electrode, reacts with the metal chemically to effect the severing of the metal. These electrodes are consumed in use. For example, the 5/16-inch electrode is consumed at a rate of not more than 1 inch of electrode per inch cut in 1/2-inch plate (based on 300-ampere current, 37–40-volt potential, and 30-psi oxygen pressure).

b. Data. These electrodes are supplied in the sizes indicated in table LII. The item name is ELECTRODE, CUTTING, TUBULAR and the unit of issue is pounds.

Table LII. Tubular Cutting Electrodes

Specification	Size (in inches)
------------	3/16 od x 18 lg[1]
MIL-E-17764	5/16 od x 0.112 id x 14 lg

[1] Inside diameter of electrode is not specified.

APPENDIX

REFERENCES

1. Publication Indexes

The following DA pamphlets should be consulted frequently for latest changes or revisions of references given herein and for new publications relating to the materials covered in this manual.

Index of Administrative Publications (AR, SR, Cir, and Pam).	DA Pam 310–1
Index of Blank Forms	DA Pam 310–2
Index of Technical Manuals, Technical Bulletins, Supply Bulletins, Lubrication Orders, and Modification Work Orders.	DA Pam 310–4
Index of Supply Manuals—Ordnance Corps.	DA Pam 310–29

2. Supply Manuals

The following Department of the Army Supply Manuals pertain to these materials:

FSC Group 34 Metalworking Machinery (Stock List of All Items).	SM 9–1–3400
FSC Group 34 Metalworking Machinery (Price List).	SM 9–2–3400
Introduction	ORD 1

3. Forms

Unsatisfactory Equipment Report.	DA Form 468
Recommended Changes to DA Technical Manual parts lists or Supply Manual 7, 8, or 9.	DA Form 2028

4. Other Publications

Military Terms, Abbreviations, and Symbols:

Authorized Abbreviations and Brevity Codes.	AR 320–50
Dictionary of United States Army Terms.	AR 320–5
Unsatisfactory Equipment Report.	AR 700–38

Technical Manuals and Technical Bulletins:

Solder and Soldering	TB SIG 222
Welding Theory and Application.	TM 9–237/TO 34W4–1–5
Ordnance Maintenance: Vehicular Maintenance Equipment; Cleaning Equipment; Hydraulic Jacks; Boring Bars; Bond Saws; Metallizing and Fuse Bonding Equipment.	TM 9–1834E

GLOSSARY OF METALLURGICAL TERMS

Alloy cast iron—Cast iron containing certain alloying elements, such as nickel, chromium, molybdenum, etc., in various combinations to increase resistance to corrosion and/or wear, to facilitate heat treatment, or to meet other metallurgical requirements.

Austenitic-type steel—An alloy steel whose alloying elements, such as manganese or nickel, cause the alloy, for the most part, to take up an advanced form of crystalline structure (face-centered cubic) at ordinary room temperatures. The high-manganese austenitic steels are known for their exceptional toughness and their excellent resistance to abrasion. For these reasons, high-manganese austenitic steels are often used for surfacing. The stainless (chromium-nickel) austenitic steels are known for their ductility, high notch toughness, and good forming and fabricating characteristics. A nonmagnetic steel.

Carbide precipitation (in stainless steel)—The segregation of chromium carbides at the grain boundaries (the area between grains and crystals) when the steel is heated to 800°–1500° F. Such segregation causes corrosion at the grain boundaries (called intergranular corrosion), resulting in embrittlement of the steel and loss of corrosion resistance. The addition of columbium or titanium in the steel tends to minimize these conditions. Such modified stainless steels are called stabilized stainless steels.

Cupronickel—A copper-base alloy containing from 2.5 to 30 percent nickel in solid solution.

Eutectic—An alloy (of a specific composition) whose liquidus temperature is lower than that of any other like alloy. For example, in tin-lead alloys, the 61.9 percent tin—38.1 percent lead composition (the tin-lead eutectic) has the lowest liquidus temperature of all tin-lead alloys.

Free-cutting carbon steel—A carbon steel in which sulfur has been added (as an alloying element) in amounts greater than 0.08 percent but not exceeding 0.4 percent. The addition of sulfur augments the free-cutting properties of the steel.

Gray cast iron—Cast iron in which a relatively large percentage of the carbon content is in the graphitic form (graphite). The name is derived from the fact that the fracture (the irregular surface obtained when the metal is broken) is gray in color.

High brass—A high-strength brass (yellow brass), usually containing from 60 to 72 percent copper and 28 to 40 percent zinc, whose ductility and good machineability enable it to be used in the fabrication of a wide variety of products.

High-carbon alloy steel—An alloy steel that has a relatively high carbon content, such as high-carbon high-chromium steel which contains between 1.4 and 2.5 percent carbon and high-carbon low-tungsten steel which contains between 0.9 and 1.3 percent carbon.

High-manganese steel—Steel in which manganese, the basic alloying element, is contained in amounts greater than 7 percent (usually 10 to 16 percent).

High-sulfur steels—See free-cutting carbon steel.

Intergranular corrosion—Corrosion at the grain boundaries (the area between grains and crystals) in a metal or metal alloy.

Liquation—While melting an alloy, an effect resulting in the liquid portion of the alloy tending to separate from the solid portion. See paragraph 3*c* and *d*.

Liquidus—The lowest temperature at which an alloy is completely liquid.

Low-alloy steel—An alloy steel that contains between 0.07 and 0.15 percent carbon and, sometimes, a higher phosphorus content than other steels. To minimize brittleness, the sum of carbon and phosphorus is limited to 0.25 percent. Many low-alloy steels (also called mild-alloy structural steels) contain various combinations of alloying elements, such as chromium, nickel, manganese, molybdenum, silicon, and vanadium.

Low brass—A brass containing at least 80 percent copper, up to 20 percent zinc, and sometimes small amounts of other elements. Low brass, sometimes called red brass, has a bright golden color when polished and, because of its ductility, it is used widely in fabrication.

Low-carbon steel—Steel in which the carbon content is between 0.08 and 0.35 percent. It is also called mild-carbon steel or mild steel.

Low-hydrogen-type covering—A welding electrode covering (or coating) that is low in hydrogen content.

Martensitic-type steel—A hardened steel whose microstructure is characterized by a needle-like pattern. It is sometimes defined as a steel in which iron carbide is dispersed in "alpha" iron (body centered cubic crystalline form of iron that is stable below 1663° F). Because of its high degree of hardness, it is particularly suitable for surfacing of tool steel.

Medium-carbon steel—Steel in which the carbon content is between 0.35 and 0.50 percent. It is also referred to as medium steel.

Medium steel—Medium-carbon steel.

Metallizing—A process whereby a metal or metal alloy, in wire form, is melted by a gas flame, usually oxy-acetylene or oxy-propane, and atomized into a fine spray by a jet of compressed air. The atomized metal is sprayed onto a surface to form a coating.

Mild steel—Low-carbon steel.

Notch toughness—In metals, the quality or state of being resistant to rupture when stresses are applied by impact and to propagation of existing cracks and notches.

Penetration—The depth of fusion in welding, that is, the depth measured from the original surface of the base metal to the point where fusion ends. See figure 1.

Shielded-arc electrode—A welding electrode having a thick coating which tends to stabilize the arc and to protect both the filler metal and the weld metal from the ambient atmosphere by a gaseous and/or slag shield.

Solidus—The highest temperature at which an alloy is completely solid.

Stabilized chromium-nickel steel—A chromium-nickel steel (stainless steel) in which columbium or titanium has been added as a stabilizer to minimize the effects of intergranular corrosion resulting from carbide precipitation. See carbide precipitation.

Studding—A process whereby studs or dowels are inserted into abutting parts to be welded in order to obtain good bonding and a high-strength joint. Studding is often used to repair fractured castings.

Tool steel—A carbon or aloy steel capable of being hardened sufficiently to be suitable for use in working parts of metal cutting and forming tools and other similar tools.

Unstabilized chromium-nickel steel—A chromium-nickel steel (stainless steel) that has not been stabilized by the addition of columbium or titanium. See carbide precipitation.

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For explanation of abbreviations used, see AR 320–50.

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