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MILITARY STANDARD

SOLDERING PROCESS GENERAL (NON-ELECTRICAL)

NO DELIVERABLE DATA REQUIRED BY THIS DOCUMENT.

FSC SOLD

DEPARTMENT OF DEFENSE
WASHINGTON, DC 20301

Soldering Process, General (Non-Electrical)
MIL-STD-1866 (AT)

1. This Military Standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: US Army Tank-Automotive Command, ATTN: DRSTA-GSS, Warren, MI 48090, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document, or by letter.

FORWARD

This Military Standard contains instructions intended to standardize the recording and use of soldering procedures for joining metal parts of non-electrical assemblies.

CONTENTS

CONTENTS - Continued

CONTENTS - Continued

6. TABLES

1. SCOPE

1.1 Coverage. This standard represents general fabrication and soldering requirements for soldering of non-electrical assemblies of steel, coated steel (tinned; terne; galvanized; or electroplated with zinc, cadmium, or nickel) clad copper, copper alloys, lead and lead alloys, zinc and zinc alloys, nickel and nickel alloys, tin and tin alloys, and aluminum and aluminum alloys. The foregoing are produced by soldering processes using solder filler metals having a lower melting point than the base metal. Filler metals used for making soldered joints have a flow temperature below 800°F (426° C). The filler metal is distributed between the joint surfaces, usually by capilary action in closely fitted components, and by gravity in cases of air gaps.

1.2 Classification of soldering methods. Soldering methods shall be classified as follows:

Type I	- Conduction (soldering iron) soldering
Type II	- Flame heat (oil or gas burner) soldering
Type III	- Dip soldering
Type IV	- Resistance soldering
Type V	- Oven or furnace soldering
Type VI	- Induction soldering
Type VII	- Ulstrasonic soldering
Type VIII	- Spray gun soldering
Type IX	- Wave soldering

1.3 Usage (see 5.7). Examples of solder joining of metals for which this standard is intended to be used are:

a. Heat exchangers (low pressure)
b. Automotive radiators
c. Brackets
d. Finned tubing
e. Waterlines
f. Flexible metal hose
g. Fuel tanks and cans
h. Metal pails
i. Radio chassis
j. Air cleaners
k. Grids
l. Frames
m. Electronic equipment chassis

1.4 Method of reference. When referencing this standard in component specifications, drawings or procurement documents, the following details shall be specified:

a. This standard number.
b. Type of soldering method (see 1.2).
c. Solder metal, if different (see 5.1).
d. Fluxes, if different (see 5.2).
e. Fit, if different (see 5.3.6).
f. If preheating is required for dip soldering (see 5.4.3.1).
g. Passivation, if different (stainless steel) (see 5.5.3).
h. Humidity test, if required (see 5.6.17).

NOTE: Because of the comprehensive nature of procedures contained in this standard, some latitude has been allowed in paragraphs referenced in the foregoing method of referencing. Normally, only the first two references need be included.

2. REFERENCED DOCUMENTS

2.1 Issues of documents. The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of this standard to the extent specified herein.

SPECIFICATIONS

FEDERAL

O-F-506	- Flux, Soldering: Paste and Liquid.
W-S-564	- Soldering Gun.
W-S-570	- Soldering Iron, Electric.
QQ-S-571	- Solder; Tin-alloy, Lead-tin Alloy and Lead Alloy.
GGG-S-595	- Soldering Iron: Non-electric (Coppers).
GGG-T-750	- Torch Kit, Soldering (Propane Gas).

MILITARY

MIL-M-3800	- Metallizing Outfits (Wire-gas), Guns and Accessories.
MIL-I-6866	- Inspection, Penetrant Method of.
MIL-I-6870	- Inspection Program Requirements, Nondestructive for Aircraft and Missile Materials and Parts.
MIL-S-12204	- Solder, Lead-tin Alloy.
MIL-F-12784	- Flux, Soldering (Stearine Compound IC-3).
MIL-F-14256	- Flux, Soldering, Liquid (Rosin-base).

STANDARDS

FEDERAL

FED-STD-151	- Metals: Test Methods.

MILITARY

MIL-STD-105	- Sampling Procedures and Tables for Inspection by Attributes.
MIL-STD-454	- Standard General Requirements for Electronic Equipment.

2.2 Other publications. The following documents form a part of this standard to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

SOCIETY OF AUTOMOTIVE ENGINEERS, INC. (SAE)

AMS-4750	- Solder - Tin-lead 45 Sn-55 Pb.
AMS-4755	- Solder - Lead-silver 94 Pb-5.5 Ag.
AMS-4756	- Solder - 97.5 Pb-1.5 Ag-1 Sn.

(Information as to the availability of the above standards may be obtained from the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM B32	- Solder Metal.
ASTM B284	- Rosin Flux Core Solder.

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

3. DEFINITIONS

3.1 Contractor/manufacturer. The term "contractor" as used in this standard is defined as the organization having a direct contact with one Government agency. The term "manufacturer" is defined as the organization actually performing the operations covered by this standard. The contractor may, or may not be, the manufacturer.

4. GENERAL REQUIREMENTS

4.1 Soldering equipment - operator. The contractor shall be responsible for the qualification of soldering equipment operators, and for the suitability of the equipment to be used.

4.2 Procedure. When specified, the soldering procedure shall be established, recorded and certified prior to initiation of a quantity production run. The procedure shall be maintained on file for reference as required by authorized persons.

4.2.1 Procedure record. The recorded procedure shall include, but not be limited to, the following factors:

a. Drawing or sketch of item to be soldered.
b. Basis metal(s).
c. Solder type.
d. Flux type.
e. Heating medium.
f. Heat range.
g. Flux removal method.

4.2.2 Sample specimen. A sample specimen, prepared in accordance with the established procedure, shall be retained and made available for comparative evaluation of follow-on items of like design to be produced by the established procedure.

5. DETAIL REQUIREMENTS

5.1 Solder metals. Unless otherwise specified (see 1.4), solder metal shall conform to QQ-S-571, MIL-S-12204, ASTM B32, ASTM B284, AMS 4750, AMS 4755 or AMS 4756, as applicable (see tables I through VI). With the approval of the procuring activity, other solder metals may be used, provided the detailed requirements contained herein are complied with.

5.1.1 Tin-lead solders. Selection of tin-lead solders (see table I) shall depend upon types of metals to be joined. Tin-lead solders have good corrosion resistance to most of the common media. Fluxes of all types may be used with these solders. Treatment of flux residues with the tin-lead solders shall be dictated by flux used.

5.1.2 Tin-antimony-lead solders. The tin-antimony-lead solders (see table II) shall not be used on aluminum and aluminum alloys, zinc and zinc alloys and galvanized (zinc-coated) steel, unless otherwise specified.

5.1.3 Tin-antimony, tin-silver, and lead-silver solders. Tin-antimony solders (see table III) have a higher electrical conductivity than the tin-lead solders, and shall be used where lead contamination must be avoided; such as food containing vessels. Tin-lead solders (see table III), similar to the tin-antimony, should be used for fine instrument work, as they are applied with a rosin flux. Lead-silver solders (see table III) will readily wet steel and copper but their flow characteristics are very poor. The lead-silver solders shall be protected against humid atmospheric conditions in storage, as they are susceptible to such corrosion conditions and may become unusable as solders. Zinc chloride base fluxes shall be used with the lead-silver solders, as rosin fluxes are readily decomposed.

5.1.4 Tin-lead-zinc, tin-zinc, tin-zinc-aluminum and zinc-aluminum solders. The tin-lead-zinc, tin-zinc and tin-zinc-aluminum solders (see table IV) should be used for the joining of aluminum. The tin-zinc solders, especially those with a zinc content of 20 to 30 percent, should be used to minimize the electrogalvanic corrosion of soldered joints. By increasing the zinc contents, or with the addition of aluminum, these solders will exhibit greater corrosion resistance; however, greater application difficulty will be experienced because of the high liquidus temperature. Similarly, zinc-aluminum solders with high solidus temperatures, limit application where such solders may be used. The flux for the zinc-aluminum solder should be limited to the reaction type.

5.1.5 Fusible alloys. Where a soldering temperature below 360°F is required, fusible alloy temperature solders (see table V) shall be used. Fusible alloy solders should be used on heat-treated surfaces where higher temperature solders would result in softening of parts, where adjacent material is temperature sensitive, in step soldering operations to avoid destroying nearby joints, or on temperature sensitive devices where failure of a soldered joint is required at low temperature.

5.1.6 Indium solders. The indium solders (see table VI) shall be used for special applications when specified. Lead-silver solder conforming to QQ-S-571, composition AG 2.5, does not wet most metal well, but with the addition of 1 to 2 percent indium, the wetting properties of the lead-silver solder are improved. Lead-silver-indium solder shall be used where alkaline corrosion is a problem. Low melting indium solder containing bismuth should not require acid fluxes or precoating.

5.2 Fluxes. Fluxes are classified into three major groups, based upon the corrosive nature of residue. From these three groups, namely highly corrosive, intermediate, and noncorrosive, good soldering practice requires the selection of the mildest flux that will perform satisfactorily in a specific application (see 5.7.9.1 and 5.7.9.2).

5.2.1 Selection of fluxes. Unless otherwise specified (see 1.4), fluxes shall conform to O-F-506, QQ-S-571, MIL-F-12784, or MIL-F-14256, as applicable. Fluxes shall be employed as necessary to promote wetting of the parent metal surfaces. The quantity of the flux or fluxes employed shall be no more than necessary to obtain satisfactoryily soldered joints. Fluxes shall dissolve or remove any oxides, and prevent additional oxidation of the solder metal and the base metal during heating. Fluxes may be applied in the form of paste, liquid, powder, or as the core of filled solder. With approval of the procuring activity, other solder fluxes may be used, provided the flux or fluxes employed are no more active chemically than necessary to obtain satisfactorily soldered joints that comply with the detailed requirements contained herein.

5.2.2 Corrosive fluxes. Soldering flux conforming to O-F-506 is classified as a highly corrosive flux. This flux may be used where conditions require a rapid and highly active fluxing, to be stable over various temperature ranges and when using the higher melting temperature solders. As the residue remains chemically active after soldering, the residue must be removed to prevent severe corrosion at the joint. Corrosive fluxes shall not be used in the soldering of closed containers such as thermostats or bellows.

5.2.3 Intermediate fluxes. Soldering flux conforming to MIL-F-12784 is classified as an intermediate flux. This flux shall be used in quick spot soldering operations, where minimum controlled quantities may be applied and where sufficient heat can be applied to fully decompose or volatilize the corrosive constituents. Intermediate fluxes shall not be used where undecomposed flux may be spread onto undesirable areas, or in soldering closed systems where corrosive fumes may deposit on critical parts of the assembly. Intermediate fluxes should not be used with torch or flame heating, due to the tendency to char, burn, or volatilize when heated.

5.2.4 Noncorrosive fluxes. Soldering fluxes conforming to MIL-F-14256 and types R, RMA and RA of QQ-S-571 are classified as noncorrosive fluxes. The noncorrosive or rosin flux, consisting of the resin and a suitable organic solvent, becomes protective at soldering temperatures. As the residue is hard, nonhygroscopic, does not cause corrosion, and is electrically nonconductive, it is mainly used for electrical and electronic systems. The plain noncorrosive flux, type R, has a slow fluxing action on anything but clean or precoated metal surfaces. Type A of MIL-F-14256, or types RMA and RA of QQ-S-571 should be used for more active cleaning, as these fluxes contain small amounts of complex organic compounds which increase the fluxing action without altering the noncorrosive nature of the residue.

5.3 Joint preparation.

5.3.1 Cleaning. The mating surfaces and adjacent areas of all parts to be joined shall be thoroughly cleaned to remove all oil, grease, paint, pencil marking, drawing or cutting lubricant, dirt, scale, artificial oxide or rust film, and any other foreign substance. For the removal of oil or greases from surfaces, either solvent or alkaline degreasing shall be used. Acid cleaning or pickling shall be used to remove rust, scale, and oxide or sulfide from the parts to provide a chemically cleaned surface. When pickling treatment is used, articles shall be thoroughly washed in hot water, and dried as quickly as possible to prevent subsequent corrosive action. Abrading by grit or shot blasting, mechanical grinding or sanding, filing, wire brushing or other mechanical methods may be used where effective. Shot or grit blasting should be preferable to sand blasting. Blast cleaning shall not be used with lead, or lead alloys.

5.3.2 Deburring. Burrs shall be removed to permit proper fitting of parts and metal flow. Hand filing, scraper, shave hook, or power-driven abrasive wheels or discs shall be used.

5.3.3 Precoating. Precoating should be used so that soldering will be more rapid and uniform, as well as to avoid the use of strong acid fluxes for assembly. Metals, such as aluminum, aluminum bronzes, highly alloyed steels and cast iron shall be precoated, unless otherwise specified. Steel, brass and copper should be precoated, if the application warrants and when specified. To facilitate soldering, coatings of tin, copper, silver, cadmium, iron, nickel and alloys of tin-lead, tin-zinc, and tin-copper shall be applied to basis metal surfaces. Precoating by electrodeposition, chemical conversion, or hot dipping shall be in accordance with applicable specifications.

5.3.4 Joint design. Two basic types of joint design shall be used for soldering, namely the lap joint and the butt joint. The lap joint shall be used whenever possible, as this joint offers the greatest possibility of obtaining maximum strength joints in an assembly. Butt joints cross section shall be equal to the cross sectional area of the smaller member. The butt joint must be free of defects to be efficient, and may only be used where sealing is the primary requirement.

5.3.5 Joint selection. The selection of a joint design for a specific application shall depend largely on the requirements of the assembly, as well as heating method to be used, fabrication techniques prior to soldering, quantities to be soldered, and method of applying solder.

5.3.6 Fit. Unless otherwise specified (see 1.4), clearance between mating surfaces of furnace soldered steel parts shall not exceed 0.003 inch. When other methods are used, clearance between mating surfaces shall not exceed 0.006 inch, with the following exceptions: In areas of a joint where one or both mating surfaces are intentionally beveled, or when precoated metals are used, a clearance of 0.001 inch or less shall be required. In fabrication of aluminum assemblies where sheets clad with soldering metal are employed, joints shall make contact as the cladding material provides sufficient clearance. When a cladding material is not employed, parts shall be positioned and assembled so that the clearance between mating surfaces is 0.005 to 0.015 inch, when a chemical flux is used, and between 0.002 to 0.010 inch when a reaction flux is used, unless otherwise specified on drawing (see 5.7.9.2). Unless otherwise specified, joint clearance for copper and copper alloys shall be maintained from 0.003 to 0.005 inch.

5.3.7 Assembly of parts. Parts to be joined shall be held in position by jigs, clamps, supports, or by self-fixturing. Fixtures used to hold parts and assemblies in alignment during soldering shall be designed to allow expansion and contraction. Jigs, fixtures, and clamps shall be of noncontaminative materials and should only involve point or line contact. When authorized by the procuring activity, staking, pinning, riveting, tack-welding or spot-welding may be used for positioning of parts, but shall not be located in areas subject to high stresses in service. On closed assemblies, vent holes shall be located and drilled as specified. Stop-off materials may be used to restrict the flow of solder metal when required.

5.3.8 Application of flux. Flux shall be applied to the surfaces to be soldered. The flux, used alone or from a flux cored solder, when heated, shall be fluid and effective in removing and excluding oxides and other impurities from the joint being soldered. The flux should allow lowering of the surface tension of the molten solder, so that the solder will flow readily and adhere to the metal. The flux shall be readily displaced from the metal by the molten solder.

5.3.9 Application of solder metal. Sufficient soldering alloy, in the form of wire, shims, strip, powder with a residue free of chemical agents, or plated form (solder-flux paste), shall be preplaced or fed in close proximity to the joint, preferably on one side only, in sufficient quantity to produce a satisfactory joint. Joints having one end inaccessible to visual inspection, shall have the solder metal placed at the blind end prior to assembly, whenever it is practicable to do so.

5.4 Soldering methods.

5.4.1 Type I - Conduction soldering. Conduction soldering (soldering iron) shall be performed with soldering irons having copper bits which may be heated electrically, or by oil, coke or gas flame. Regardless of the type of iron used, the copper bit shall store and transmit heat from the source to the part being soldered, shall store and convey molten solder and shall withdraw surplus molten solder as required. Internally fired gas-flame-heated soldering irons may be used where electric power is not readily available, or where soldering is done automatically at high rates of speed. Electrically heated irons, often more convenient than gas-heated irons, should be used in manual high-speed repetitive operations, where light weight and ease of manipulation are desirable and open flames are objectionable. Selection of iron shall be such as to perform the necessary soldering operations with the greatest efficiency. For soldering process, electric soldering irons, conforming to W-S-570, soldering guns, conforming to W-S-564, or non-electric soldering irons, conforming to GGG-S-595 may be used.

5.4.1.1 Procedure. The areas to be joined shall be heated above the liquidus temperature of the solder. To deliver maximum heat to the part, the copper bit of the soldering iron shall be applied at the correct angle. The flat side of the bit shall be applied to secure the maximum area of contact. Excessive time and temperature shall be avoided to prevent unreliable joints and damage to parts. If required, thermal shunts (heat sinks) shall be used for protection of parts. The parts to be joined shall be held together in such manner that parts shall not move in relation to one another during the soldering operation. The solder shall be applied to the joint and not to the soldering iron. The joint shall not be disturbed until the solder has completely solidified.

5.4.2 Type II - Flame soldering. The selection of a gas or oil burning torch for soldering shall be controlled by the size, mass, and configuration of the assembly to be soldered. Time for performing the operation will also be a factor in equipment selection. Depending upon the temperature and amount of heat required, fuels such as acetylene, propane, butane, and natural gas, may be used in open air, or with compressed air or oxygen. Portability will be another factor in selection of a torch. For field work, a soldering torch kit, GGG-T-570, using propane gas, may be used for torch soldering.

5.4.2.1 Procedure. Parts shall be preheated with a neutral or slightly reducing flame to bring the entire joint unifrmly to the liquidus temperature of the solder, but no higher than necessary to provide a satisfactory joint. Localized overheating shall be avoided. The solder may be introduced at one edge of the interstice, or in a groove provided for one of the mating surfaces, and shall flow by capillary action to fill the interstice.

5.4.3 Type III - Dip soldering. Dip soldering shall be performed by immersing the assembled joint with preplaced solder metal in a bath of molten flux, by immersing the assembled joint into a flux solution and then into a bath of molten solder, or by dipping the parts into a bath of molten solder alloy covered with a layer of flux. Pots for the bath, either electrically heated or gas heated units, shall be of such capacity and construction as to allow production without appreciably lowering the temperature of the bath. The flux shall be of a type which has a stable flowability within the soldering temperature range, and possesses satisfactory fluxing properties. The flux bath shall be free of metallic impurities.

5.4.3.1 Procedure. When required or specified (see 1.4), assemblies shall be preheated in a suitable furnace and atmosphere to a temperature of 25 to 100°F below the solidus temperature of the soldering alloy. Generally when a molten bath of solder is employed, no preheating is required. The assembly, together with jigs or fixtures, when used immediately upon removal from the preheat furnace, shall be dipped into the molten bath at a uniform rate so that the position of the prepared solder metal is not disturbed. Soldering times are dependent upon the shape and cross section of the assembly. Soldering is complete when the solder metal has flowed evenly into the joints. At this point, the assembly shall be removed slowly from the bath at a rate that will not cause loss of the molten solder metal. The composition and quantity of solder flux or molten slder shall be adjusted periodically. The operating temperature of the molten flux bath shall not exceed the liquidus temperature of the specified soldering alloy by more than 20°F.

5.4.4 Type IV - Resistance soldering. The transformer, electrode, and voltage/amperage controls shall be of sufficient size and capacity to provide adequate heat over an area large enough to permit free flow of the solder alloy over the area to be soldered, without overheating.

5.4.4.1 Procedure. Assembled parts shall then be placed between a ground and a moveable electrode, or between two moveable electrodes, and the current passed through the system. Heating of the joint is generated by contact with the electrodes, and the heat energy evolved is a direct product of the resistance of the work and the current passing through it (Q = I R). Resistance soldering electrode bit generally cannot be turned; therefore, flux and solder must be in proper position before heating. Heating shall be discontinued as soon as the solder metal has flowed an(formed fillets.

5.4.5 Type V - Oven and furnace soldering. Ovens and furnaces shall be of suitable design and size to maintain uniform constant temperature within the soldering area. Automatic temperature control and recording devices shall be utilized. Devices shall control the working temperature within one and one half percent of the temperature required for the item or items to be soldered. Ovens and furnaces shall be equipped with a means of controlling the atmosphere within the oven or furnace, as required, to prevent oxidation of the basis metals.

5.4.5.1 Procedure. Parts shall be assembled with proper fit in alignment as required with proper clamping fixtures. Flux may be used in addition to control of oven or furnace atmosphere. Assemblies, cradled and racked, shall be placed in the oven or furnace in such manner that the atmosphere can reach all parts of the soldering assembly readily, and bring the entire assembly to soldering temperature in the shortest possible time. Parts shall be held in the oven or furnace until the filler metal has melted and formed the desired bond. After soldering has been accomplished, assemblies shall be cooled in protective atmosphere, as required, to prevent oxidation. The cooling of parts may be accelerated on removal from the oven or furnace by the use of an air blast on the hot parts, caution being taken to prevent warpage.

5.4.6 Type VI - Induction soldering. Induction coils shall be of such design and construction as to provide suitable heating of the joint areas. Coil design must allow for corner effects on rectangular parts, surface irregularities which must be in the heat zone, and for joining of dissimilar metals, particularly joints composed of both magnetic and non-magnetic components.

5.4.6.1 Procedure. The mating surfaces shall be coated with flux, either corrosive or noncorrosive, containing a minimum percentage of solvent in order to reduce the amount of volatile matter driven off during heating. Alternately, parts may be enclosed in a suitable atmosphere. The filler metal shall be placed in position and the joint heated by placing within, or near, a suitable induction heating coil.

5.4.7 Type VII - Ultrasonic soldering. Oscillators for generating electrical impulses, magnetostrictive transducers, shall be of such design and construction as to provide suitable cavitation erosion on the surface of the metal, permitting molten solder to wet the surface. The ultrasonic vibrations shall be transmitted from the laminated nickel core, which is used to reduce eddy currents, to the joint. A metal rod of suitable length, which connects the transducer to the soldering bit, shall be attached to the core so that maximum disturbance will result at the free end. The free end of the metal rod, which forms the soldering bit, shall be immersed in a small pool of molten solder that contacts the surface to be soldered. The metal rod shall then be moved across the surface of the base metal or joint so that ultrasonic vibrations break up the oxide on the surface, exposing the underlying metal to the wetting action of the molten solder.

5.4.7.1 Procedure. The area to be coated shall be heated to soldering temperature. A suitable quantity of solder shall then be melted on the surface to form a molten puddle. The end of the transducer rides over the surface. Two such solder-coated areas shall then be placed together and heated, until the solder coat melts and forms a bond.

5.4.8 Type VIII - Spray gun soldering. Spray guns shall be of suitable design and construction, so as to permit heating and spraying a continuous feed solid solder wire. Depending upon gun design, propane, acetylene, or natural gas with oxygen may be used for heating and spraying. Equipment shall be similar to that specified in MIL-M-3800.

5.4.8.1 Procedure. Parts shall be assembled with proper fit and fixed in alignment as required. Using ordinary metal spraying techniques, the vast majority of solder is melted by the neutral flame of the gun. The solder should contact the part in a semi-liquid form. The balance of heat required, to melt the filler metal and bring the entire joint uniformly to the liquidus temperature of the solder for flowing, is to be supplied by the part.

5.4.9 Type IX - Wave soldering. Wave soldering equipment shall be of a suitable design and construction to permit an automatic application of solder. A continuous stream of solder shall be pumped up into the spout, forming a head of solder through which the work can be passed. The equipment and materials used shall pump a fresh amount of solder into the solder head at all times, so that dross will not accumulate on the solder surface or come in contact with the work. All flux and flux residues, which are wiped off the work and normally stay on top of the solder bath, shall be carried down with the wave into a special reservoir, where they shall not come in contact with any future work. Means shall be provided so that solder which is pumped out of the bottom of the solder container is always at the same temperature, and the solder reaching the head has no time to be cooled down by air drafts and other incidental side effects. The equipment shall be such that the temperature of the solder touching the work shall be uniform and can easily be controlled and maintained.

5.4.9.1 Procedure. Parts shall be fluxed by suitable application methods such as brushing, rolling, spraying, foaming, dipping or wave fluxing. The work shall then be passed through the equipment so that the molten solder and oil are pumped together to hit the work simultaneously and prevent rapid oxidation. Oil dispersion shall be smooth and evenly distributed, by injection where the velocity of the solder is greatest. It is important that preheating prior to soldering be performed, in order to give the flux enough temperature and time to clean and prepare the surfaces, because of the reduced time of the wave. After wave soldering has been accomplished, assemblies must be adequately post-treated to remove oil, whenever used in conjunction with this method.

5.5 Post-soldering treatment.

5.5.1 Cooling. Proper jigging, assembly, or controlled cooling, shall be employed to prevent excessive deformation of the joint, or failure of the joint, during solidification of the solder. The cooling method may be varied to suit each individual application process.

5.5.2 Flux removal. Immediately after soldering and cooling, flux shall, or shall not, be removed depending upon the degree of corrosiveness. Fluxes conforming to MIL-F-14256, or those meeting the requirements of type R and RMA of QQ-S -561, having a rosin base do not generally rquire removal of the residue, except if appearance is a prime factor or if the joint areas is to be painted or otherwise coated. Fluxes conforming to O-F-506, identified as corrosive because of having a zinc chloride or other corrosive base, leave a fused residue. Flux residue shall be removed by a method which is not injurious to the surface finish, and which will not remove parent metal and solder metal to below tolerances specified on applicable drawings. Areas soldered using chloride-containing flux residues should be tested for completeness of flux removal by leaching the area with a small quantity of distilled or deionized water. Industrial or tap water from pipe lines or conduits, as used for processing tanks and vats, shall not be used because of impurities. A few drops of nitric acid and a few drops of 5 percent silver nitrate solution shall be added to the leach. If a white precipitate is formed, in an amount greater than that formed in an equal volume of standard sodium chloride solution (equivalent to 125 ppm as chloride) treated in a like manner, the flux removal is not complete.

5.5.3 Passivation of soldered stainless steel assemblies. Unless otherwise specified (see 1.4), stainless steel assemblies that have been soldered shall not be given a nitric acid treatment for passivation. Assemblies joined with lead-tin, lead-tin-antimony, and lead-antimony solders are attacked by the passivation treatment, thus they shall not be passivated.

5.6 Quality considerations.

5.6.1 Workmanship. Soldered assemblies shall be processed in a careful and workmanlike manner. The soldering shall be free of scratches, roughness, sharp edges, dullness, looseness, blistering, foreign matter and other evidence of poor workmanship that will render the assemblies unsuitable for the purposes intended. Defects in quality of workmanship, as detailed in 5.6.2 through 5.6.15, shall be considered as failure at some point in the process, and the part shall be rejected unless it can be repaired prior to final inspection.

5.6.2 Appearance. A solder joint shall have a bright, non-crystalline, metallic appearance (the degree of brightness may vary with the solder used) with good adherence, and shall be clean and smooth. Solder shall cover the joint, and form a slight fillet between the terminal area and each side of the joint. The joined surfaces shall be covered with a coating of solder that leaves the general outline of the surfaces visible, although the joint itself may be obscured.

5.6.3 Flow and wetting action. The solder connection shall indicate compatability between the solder and the surfaces being joined, evidenced by good flow and wetting action. Wetting and proper compatability shall be achieved when the solder fillet feathers and thins out at the edges, and bonds to the base material in those areas where sufficient joint area exist to allow solder spread. Solder fillets at cylindrical surfaces, formed at a direction other than parallel with the cylinder axis, shall form a fillet which blends to the cylindrical surface tangentially.

5.6.4 Lines of demarcation. A line of demarcation, where solder fillet blends to surfaces being joined, shall be acceptable provided wetting has been achieved.

5.6.5 Contour. The contour of an outside solder joint shall be of a uniform radius, with a minimum amount of excess solder or flash, over the adjacent surfaces. All sharp projections shall be removed.

5.6.6 Porosity. A porosity defect is the result of gases being expelled. It appears as small, round, smooth-edged pockets on the surface of the solder metal. The presence of porosity is undesirable but is acceptable, unless otherwise specified, provided the number, depth and area of concentration does not interfere with the function of the completed assembly.

5.6.7 Blisters. A blistered surface condition, resulting from the overheating of the base metal, shall be cause for rejection.

5.6.8 Residual flux. No residual flux shall be permitted on the surface of a soldered joint, except those from organic-based or rosin-based fluxes where residues are noncorrosive. In the foregoing cases, residual flux may be left in place unless removal is dictated by the applicable drawing or specification, appearance, or because the joint area is to be painted or otherwise coated.

5.6.9 Excessive solder alloy. Soldering metal in excess of that required for the joint is acceptable, provided the excess solder metal does not interfere with the function of the completed assembly.

5.6.10 Unmelted solder alloy. The presence of unmelted soldering alloy in a joint is undesirable, and may be cause for rejection of the part.

5.6.11 Penetration. Solder alloy must appear on all edges of a joint, indicating proper flow through the joint. Lack of penetration shall be cause for rejection of the part.

5.6.12 Cold solder joint. Solder shall adhere smoothly to the parts being joined. The joint shall not be chalky in appearance, lacking metallic luster, nor shall it have a rough, gritty, piled up surface. A cold solder joint shall be cause for rejection of the part.

5.6.13 Disturbed solder joint. The solder connection shall not have an irregular, dull, rough appearance caused by movement of the joint before the solder has fully solidified. This defect shall be cause for rejection, as there may be a poor mechanical connection.

5.6.14 Total aggregate area. When specified, the unsoldered area including trapped flux, scattered porosity, and voids shall not exceed 20 percent of the faying surface of the respective joint for aluminum and aluminum alloys, and 15 percent for all other metals.

5.6.15 Maximum extent of a single defect. When specified, no single unsoldered area shall exceed 20 percent of the overlap distance of the joint for aluminum and aluminum alloys, and 15 percent in all other metals.

5.6.16 Resoldering. Resoldering of joints shall be avoided. If for any reason a satisfactory joint is not initially obtained, the joint shall be taken apart and the parts shall be cleaned. The entire soldering operation shall be repeated so that the quality standards for a resoldered joint shall be the same as for an original joint. Excessive solder, unmelted solder, lack of penetration, cold solder, and disturbed solder at the joints will require only reheating and reflowig of the solder.

5.6.17 Humidity test. When specified (see 1.4), soldered areas shall be tested for completeness of flux removal residue, and corrosive action on the materials involved, by standard humidity test per MIL-STD-810.

5.6.17.1 Test cabinet. The humidity test cabinet shall be lined with sheet metal, with soldered or welded joints, to form a vapor tight chamber. The walls shall be heavily insulated to minimize heat loss and condensation. Temperature and humidity controls shall be automatic, and shall be capable of maintaining a dry bulb temperature of 100 $\pm$ 2°F and a wet bulb temperature of 98 $\pm$ 2°F. There shall not be more than 2°F temperature difference between any two points in the test area at anytime.

5.6.17.2 Procedure. Selected samples shall be placed in the humidity cabinet and exposed to the conditions specified in 5.6.17.1 for a period of 72 hours. The samples at the end of the test period shall be examined visually, or at a magnification of 4 X, to determine evidence of corrosion caused by contamination from flux residues or cleaning solutions.

5.7 Applications data. This standard is intended for use in the control of non-electrical soldering processes as applied to various metals and alloys in manufacturing. These soldering procedures are used to obtain desired properties, such as leak tightness, pressure tightness, and heat conductivity within the limits of the respective materials. The solders required for the processes detailed in this standard, as structural materials, are weak when compared to the materials which they are generally used to join. To avoid depending upon the strength of the solder, joints for sheet metal structural assemblies should be so designed that surfaces to be soldered by the various methods will require the solder only to seal and stiffen the assembly.

5.7.1 Copper and copper alloys. Copper and copper alloys are soldered to form simple economical joints on equipment such as heat exchangers, automotive radiators, heating units, finned tubing, water lines, and flexible metal hose that requires leak tighness with good heat conductivity.

5.7.2 Steels. Tin plated steel used for air ducts, amplifier frames, condensor and capacitor cans, air filters, and gas meter cases are often soldered by the dip soldering process. Terne steel is soldered for assembly into air cleaners, gasoline tanks, cans, radiator parts, oil pans, fire extinguisher bodies and burial caskets. Frames, tube covers, and chassis for electronic equipment, made of galvanized steel, are soldered for assembly. Stainless steel cans, pails and buckets are often soldered after spot welding or riveting to provide leak tight joints.

5.7.3 Nickel and nickel alloys. Nickel and nickel alloys are solderable. Application should be used only where resistance to corrosion is not an important factor. Solder can be used for sealing non-pressurized water containers, provided the strength of the joints is supplied by rivets, bolts, staking, lock seams, spot welds or other mechanical means. The soldering process should be limited to joints in sheet metal not more than 5/8 inch wide. Since the solders are weak compared to the basis nickel and nickel alloys, they should not be used for attaching fittings to nickel-copper fuel tanks or pressurized water containers. In the event soldering must be used for joining nickel and nickel alloys, only the corrosive fluxes (see 5.2.2), are recommended.

5.7.4 Lead and lead alloys. Lead pipe with soldered joints, or soldered copper fittings, are used to convey water underground, or in drainage and venting systems. Leaded sheathed cables for telephone, telegraph, and electrical power transmission conduit also require solder processing for joining purposes and waterproofing.

5.7.5 Aluminum and aluminum alloys. Tube fin assemblies and cellular assemblies of aluminum and aluminum alloys are joined by dip soldering.

5.7.6 Magnesium and magnesium alloys. Soldering processes are sometimes used for sealing of electronic components encased in tin, or copper plated magnesium alloy containers.

5.7.7 Cast iron. Solderig processes may be used for repair of broken or worn cast iron equipment. Surface cracks and depressions caused by inclusions of metal-mold reaction may be filled with solder, if the defects are superficial and application is not critical. Zinc chloride flux should be applied to the cast iron part prior to soldering application.

5.7.8 Cadmium-silver and cadmium-zinc solders. Cadmium-silver and cadmium-zinc solders have been used for the joining of aluminum and its alloys to itself, or to dissimilar metals, by processes detailed in this standard. These solders are extremely dangerous and are of a highly toxic nature. Overheating the solder during joining can vaporize the cadmium to produce highly dangerous and practically odorless fumes. Precautions must be taken for proper ventilation which may not be suitable or available, during soldering processes. There use is not recommended as there are other materials, non-toxic in nature, that are available if soldering of aluminum is required. Also ultrasonic techniques for soldering (see 5.4.7) have been developed, and are being used commercially, which would not require the use of these toxic solder types.

5.7.9 Fluxes.

5.7.9.1 Noncorrosive. Noncorrosive, as used in 5.2.4 to classify fluxes of this type, is only a relative term. The noncorrosive fluxes are not as corrosive as the other fluxes listed, namely highly corrosive (see 5.2.2), or intermediate (see 5.2.3), but all fluxes must be corrosive in order to perform their function. In general, the amount of corrosion resulting from nonremoval of noncorrosive fluxes may not be harmful to the soldered part or article.

5.7.9.2 Chemical and reaction fluxes. Chemical and reaction fluxes are a special group of corrosive fluxes developed for soldering aluminum. A chemical flux is generally composed of an organic fluoboride (such as boron trifluoride monoethanolamine), a metal fluoborate (such as cadmium fluoborate), a vehicle (such as methyl alcohol), and a plasticizer (such as stearic acid). Modifiers such as zinc fluoride, zinc chloride, or ammonium chloride may also be incorporated into the formulation. Reaction fluxes usually are composed of zinc chloride, tin chloride, or combinations of other metallic halides and ammonium chloride.

5.7.10 For electrical and electronic soldering. This standard does not cover electrical and electronic soldering requirements, and applies to mechanical soldering only. For soldering of electrical and electronic connections, Requirement 5 of MIL-STD-454, MIL-S-45743, MIL-S-46844 or MIL-S-46860 should be used.

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TABLE I. Tin-lead solders.

Nominal composition (percent)		Temperature °F			Specification classification			Application
Tin	Lead	Solidus	Liquidus	Pasty range	QQ-S-571	ASTM B32 ASTM B284	AMS	
5	95	586	594	76	Sn 5	5B	---	General purpose
10	90	514	570	56	----	10B	---	For coating and joining metals
15	85	440	550	110	----	15B	---	
20	80	361	531	170	Pb 80	20B	---	
25	75	361	511	150	----	25A, 25B	---	Machine and torch soldering
30	70	361	491	130	Pb 70	30A, 30B	---	
35	65	361	477	116	Pb 65	35A, 35B	---	General purpose and wiping
40	60	361	460	99	Sn 40	40B 1/	---	Wiping for joining lead pipes and cable sheath
45	55	361	441	80	----	45A, 45B	4750	Automobile radiator and roofing seams
50	50	361	421	60	Sn 50	50B 1/	---	General purpose (most used)
60	40	361 2/	374	13	Sn 60	60B 1/	---	Fine solder, general purpose
63	37	361 2/	361	0	Sn 63	63B 1/	---	
70	30	361 2/	378	17	Sn 70	70B 1/	---	Coating metals

1/ The "A" classification of these solders requires a lower antimony content than that specified in QQ-S-57
2/ These solders should be considered as having practically no mechanical strength at 361°F.

TABLE II. Tin-antimony lead solders.

Nominal composition			Temperature °F			Specification classification		Application
Tin	Antimony	Lead	Solidus	Liquidus	Pasty range	SS-S-571	ASTM B32 ASTM B284	
20	1.0	79.0	363	517	154	Sn 20	20 C	Machine soldering and coating of metals, except on galvanized iron
25	1.3	73.7	364	504	140	---	25 C	Torch and machine soldering, except on galvanized iron
30	1.6	68.4	364	482	118	Sn 30	30 C	
35	1.8	63.2	365	470	105	Sn 35	35 C	Wiping and all uses, except on galvanized iron
40	2.0	58.0	365	448	83	---	40 C	General purpose, except on iron

TABLE III. Tin-antimony, tin-silver, and lead-silver solders.

Nominal composition				Temperature °F			Specification classification			Application
Tin	Antimony	Lead	Silver	Solidus	Liquidus	Pasty range	QQ-S-571	ASTM B32 ASTM B284	AMS	
95	5	---	---	452	464	12	Sb 5	95 TA	---	Joints on copper; electrical conduit, plumbing and heating 1/
96	---	---	4	430	430	0	Sn 96	96	---	Fine instrument work 2/
95	---	---	5.0	430	473	43	---	---	---	
---	---	97.5	2.5	579	579	0	Ag 2.5	2.5 S	---	On copper, brass, and similar metals using torch heating. Susceptible to corrosion.
---	---	94.5	5.5	579	689	110	Ag 5.5	---	4755	
1.0	---	97.5	1.5	588	588	0	Ag 1.5	1.5 S	4756	On copper, brass and similar metals using torch heating

1/ May be used for cryogenic purposes to -400°F (-240°C). Soldered joint has a tensile strength of 12,000 psi at -300°F (-184°C); however, solders containing antimony should not be used in liquid oxygen environments because of its impact sensitivity in such environment.

2/ Soldered joint has a tensile strngth of 10,610 psi at room temperature.

TABLE IV. Tin-lead-zinc, tin-zinc, tin-zinc-aluminum, and zinc-aluminum solders.

Nominal composition				Temperature °F			Specification classification	Application
Tin	Lead	Zinc	Aluminum	Solidus	Liquidus	Pasty range	MIL-S-12204	
34	63	3	---	335	500	165	Comp A	Aluminum joining
91	---	9	---	390	390	0	---	Aluminum joining, electro-galvanic corrosion can be minimized
85	---	15	---	390	445	55	Comp B	
80	---	20	---	390	518	128	Comp B	
70	---	30	---	390	592	202	Comp B	
60	---	40	---	390	645	255	Comp B	
50	---	50	---	390	675	285	Comp B	
30	---	70	---	390	708	318	---	
73-87	---	8-15	5-12	380	780-950	400-570	Comp C	Aluminum joining
---	---	95	5	720	720	0	Comp D	High strength aluminum joints

TABLE V. Fusible alloy solders. 1/

	Nominal composition					Temperature °F			
Name	Tin	Lead	Antimony	Bismuth	Cadmium	Solidus	Liquidus	Pasty range	Application
Lipowitz	13.3	26.7	---	50	10	158	158	0	Where a soldering temperature below 360°F is required.
Bending (Wood's)	12.5	25	---	50	12.5	158	165	7	
Eutectic	---	40	---	52	8	197	197	0	
Eutectic	15.5	32	---	52.5	---	203	203	0	
Rose's	22	28	---	50	---	204	229	25	
Matrix	14.5	28.5	9	48	---	217	440	223	
Mold and pattern	---	44.5	---	55.5	---	255	255	0	

1/ No applicable specifications

TABLE VI. Indium solders. 1/

Nominal composition					Temperature °F			
Tin	Indium	Bismuth	Lead	Cadmium	Solidus	Liquidus	Pasty range	Application
8.3	19.1	44.7	22.6	5.3	117	117	0	Special purposes
12	21	49	18	---	136	136	0	
12.8	4	48	25.6	9.6	142	149	7	
50	50	---	---	---	243	260	17	Glass to metal, or glass to glass soldering
48	52	---	---	---	243	243	0	

1/ No applicable specifications

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