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MILITARY STANDARD

DIP BRAZING OF ALUMINUM ALLOYS

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AREA THJM

DEPARTMENT OF DEFENSE
WASHINGTON, D.C. 20301

Dip Brazing of Aluminum Alloys

MIL-STD-645B

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2. Recommended corrections, additions, or deletions should be addressed to: Director, Army Materials and Mechanics Research Center, ATTN: DRXMR-SS, Watertown, MA 02172.

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DIP BRAZING OF ALUMINUM ALLOYS

1. SCOPE

1.1 This standard covers the requirements for the joining of aluminum alloys by dip brazing, employing an aluminum base filler metal and a flux bath.

1.2 Classification. Quality of joint shall be of the following grades or as specified on the drawing:

Grade A - Joints for critical fittings and critical structural application. (See A-10.)

Grade B - Joints for non-critical fittings and non-critical structural applications.

1.2.1 Grade A shall apply to all joints where grade quality is not specified.

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, shall form a part of this standard to the extent specified herein.

SPECIFICATIONS

FEDERAL

QQ-A-601	Aluminum Alloy Sand Castings
QQ-B-655	Brazing Alloys, Aluminum and Magnesium Alloys, Filler Metal
QQ-R-566	Rods and Electrodes, Welding, Aluminum and Aluminum Alloys

MILITARY

MIL-H-6088	Heat Treatment of Aluminum Alloys
MIL-I-6866	Inspection, Pentrant, Method of
MIL-I-6870	Inspection Requirements, Non-destructive, for Aircraft Materials and Parts
MIL-STD-453	Inspection, Radiographic

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer).

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.

Aerospace Material Specification (AMS)

AMS 3415 - Flux, Aluminum, Dip Brazing
AMS 3416 - Flux, Aluminum, Dip Brazing
AMS 4054 - Aluminum Alloy Sheet, Clad One Side (No. 21-0)
AMS 4055 - Aluminum Alloy Sheet, Clad Two Sides (No. 22-0)
AMS 4063 - Aluminum Alloy Sheet, Clad One Side (No. 11-0)
AMS 4064 - Aluminum Alloy Sheet, Clad Two Sides (No. 12-0)
AMS 4184 - Brazing Alloy, Aluminum
AMS 4185 - Brazing Alloy, Aluminum

(Applications for copies should be addressed to the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, Pennsylvania 15096).

American Society for Testing and Materials (ASTM)

B-26 - Aluminum-Alloy Sand Castings

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

American Welding Society (AWS)

AWS 2.4 - Symbols For Welding and Nondestructive Testing
AWS 3.0 - Welding Terms and Definitions
AWS A5.8 - Specification For Brazing Filler Metal

(Applications for copies should be addressed to the American Welding Society, 550 LeJeune Road, Miami, FL 33135).

3. REQUIREMENTS

3.1 Terms related to both welding and brazing.

3.1.1 General. Welding terms and definitions used herein shall conform to AWS A2.4 and AWS A3.0.

3.2 Material.

3.2.1 Filler metal. Filler metal shall conform to the specifications listed in 2.

3.2.2 Fluxes. Fluxes may conform to the applicable specifications listed under 2.2. Fluxes shall dissolve or remove any oxides and prevent additional oxidation of the filler metal and base metal during heating. The separate application of flux is generally not required when parts are to be joined by the molten flux (dip) brazing process.

3.2.3 Selection of filler metal, flux combinations. Filler metals and flux combination shall be selected in accordance with Table I.

3.3 Preparation of parts.

3.3.1 Deburring. Burrs shall be removed to permit proper fitting of parts and flow of filler metal.

3.3.1.1 Cleaning. The mating surfaces and adjacent areas of all parts to be joined and the filler metal shall be thoroughly cleaned by vapor degreasing, acid etch or mechanical means to remove all oil, grease, paint, dirt, scale, or foreign substances that might interfere with the bonding action of the filler metal. Cleaning shall always precede chemical dipping.

3.3.1.2 Chemical dipping. Parts to be brazed shall be chemically cleaned prior to brazing. Any method and/or material may be used which achieves the prerequisite cleanliness, provided that the cleaning solution does not cause intergranular attack in excess of 0.0002 inch (0.0051 mm) or end grain pitting in excess of 0.0001 inch (0.0025 mm). A suggested method is as follows:

(a) Immerse parts in 5 percent sodium hydroxide solution at $140^{\circ} \pm 10^{\circ}$F ($60^{\circ} \pm 5^{\circ}$C) for 10 to 60 seconds.
(b) Rinse in cold water.
(c) Immerse in 50 percent solution of nitric acid at room temperature for 30 to 60 seconds.
(d) Rinse in cold water.
(e) Rinse in hot 180° to 200°F (82° to 93°C) water.
(f) Force dry.

Spinning or forced air drying following the hot water rinse is desirable to obtain the required results. Parts and filler metal that have been cleaned shall be stored or protected to prevent contact with contaminative and/or foreign substances that might interfere with the bonding action.

3.3.2 Fit. Joints shall be so designed that the clearance between mating surfaces of parts being brazed, brazing sheet excluded, shall be 0.001 inch to 0.025 inch (0.025 mm to 0.63 mm). In addition, the joint fit-up for brazements shall conform to the following:

Joint Classification	Joint Clearance, inches/mm
Grade A	0.002 -0.008 inches (0.0051 - 0.203 mm) for length of lap less than 0.25 inches (6.35 mm)
	0.008 - 0.0010 inches (0.203 - 0.025 mm) for length of lap greater than 0.25 inches (6.35 mm)
Grade B	0.001 - 0.025 inches (0.025 - 0.635 mm)

For tube assemblies, the above values are radial clearances. These clearances should be maintained at brazing temperatures. The expansion rates of the parts should, therefore, be considered. Parts constructed from brazing sheet should be assembled so as to achieve contact of the cladding with the opposite member comprising the joint.

3.3.3 Assembly. Parts to be brazed may be assembled in fixtures and the filler metal preplaced. Fixtures, if used, shall be made of materials suitable to the process. Heat and corrosion-resistant stainless steels, nickel and nickel alloys are preferred. Consideration should be given to methods of assembly such as staking, swaging, crimping, tack-welding, etc. which will eliminate the use of fixtures. On closed assemblies, vent hole locations shall be specified on drawings. When tack welds are used to hold aluminum assemblies in alignment prior to brazing, welding rod alloy 1100 per QQ-R-566 can be used for all brazing applications or welding rod alloy 5554 per QQ-R-566 may be used when the brazing temperature is controlled below 1115°F (601°C). Cracks in these tack welds shall not be cause for rejection of the part, provided that the crack is removed from the tack weld with a smooth blend out.

3.3.4 Application of filler metal. Brazing filler metal in the form of wire, washers, sheet or powder shall be preplaced in close proximity to the joint, on one side only, if possible. The volume of filler metal shall be sufficient to produce a satisfactory joint and to form required fillets. Joints having one end inaccessible to visual inspection shall have the filler metal placed at the blind end whenever it is practicable to do so. A stop-off paste may be used to restrict the flow of filler metal.

3.3.5 Preheating equipment. Preheating furnaces shall be of suitable design and construction to provide uniform temperatures within the working zone. Automatic temperature-controlling and recording devices, preferably of the potentiometer type, shall be provided to satisfactorily control furnace temperatures. Temperature variations within the working zones shall not be greater than ± 10°F (5.6°C) from the control point. Radiant type tube gas-fired furnaces or electric furnaces are preferred when preheating the heat treatable aluminum alloys. This is desired to avoid contact with products of combustion in direct gas-fired furnaces, which could create a high temperature oxide (HTO) in the base metal.

4. BRAZING PROCEDURE

4.1 General.

4.1.1 Preheating. All assemblies shall be preheated. The preheating furnace temperature shall be approximately 1000°F (538°C) and the assemblies shall be kept in the heating medium only for sufficient time to reach that temperature throughout the assembly.

4.1.2 Brazing. The assembly shall be removed from the preheat furnace and immediately dipped into the molten flux bath. Also, the flux pot shall be capable of maintaining a flux bath temperature range of ± 5°F (2.5°C) within the 1060°F to 1150°F (571°C to 621°C) range, producing uniform heat-up to temperature and filler metal flow. Brazing time shall be established by qualification pilot run so that the assembly is immersed for a time which is sufficient to allow an adequate flow of filler metal. The assembly shall be removed slowly from the bath at a rate that will not cause loss of molten filler metal. The composition and quantity of brazing flux should be adjusted periodically. The operating temperature of the molten flux bath shall conform to Table I.

4.1.2.1 Qualification (preproduction) pilot run. A qualification (preproduction) pilot run shall consist of a brazing procedure using actual parts (or simulated parts made from the same materials, with identical geometry, size, and mass), materials, preheat (if used), times, temperatures and fixturing which has been developed for production brazing each type of part. Complete process data shall be furnished with each qualification pilot run.

4.1.3 Fillet skip. Joints may have one fillet skip for each two inches of braze fillet or one per joint when the braze fillet is less than two inches. The fillet skip shall have a maximum length of 0.125 inches (3.2 mm) and shall not extend in to the joint overlap.

4.1.3.1 Fillet skip definition. A fillet skip is an abrupt interruption of an otherwise uniform continuous fillet.

4.1.4 Bath maintenance. Bath maintenance is of prime importance to consistently obtain good brazements, clean assemblies, and to avoid skips and poor flow in fillets and joints. The composition and quantity of brazing flux shall be adjusted periodically. The bath must be dehydrated at regular intervals; daily if necessary. The bath must be desludged regularly to remove oxides and sludge from the bottom of the salt pot. The intervals for both of the above are determined by both usage and moisture conditions in the vicinity of the bath.

<u>TABLE I</u>

FILLER METAL, FLUX COMBINATION FOR DIP BRAZING ALUMINUM AND ALUMINUM ALLOYS

	Filler Metal Classification							
Base Metal	AWS	Federal	Aluminum Assoc.	Commercial Number	Specification		Flux	Brazing Temp. °F, Range (°C, Range)
High Purity 1100	BAlSi-2	4343	4343	713	QQ-B-655	AWS A5.8	AMS 3415 or AMS 3416	1100-1140 (593-616)
1350	BAlSi-3	4145	4145	716	QQ-B-655 AMS 4184	AWS A5.8	AMS 3415	1060-1120 (571-604)
3003	BAlSi-4	4047	4047	718	QQ-B-655 AMS 4185	AWS A5.8	or AMS 3416	1080-1095 (582-591)
3004 5005 5050 6061 2/	BAlSi-3	4145	4145	716	QQ-B-655 AMS 4184	AWS A5.8	AMS 3415 or AMS 3416	1060-1100 2/ (571-593)
6063 6951 710.0 Cast 2/ 711.0 Cast 713.0 Cast	BAlSi-4	4047	4047	718	QQ-B-655 AMS 4185	AWS A5.8	AMS 3415 or AMS 3416	1080-1095 2/ (582-591)
443.0 Cast 356.0-T4 Cast	BAlSi-3	4145	4145	716	QQ-B-655 AMS 4184	AWS A5.8	AMS 3415 or AMS 3416	1060-1070 (571-577)
No. 11 Brazing Sheet No. 12 Brazing Sheet	BAlSi-2 1/	----	4343 1/	713 1/	AMS 4063 AMS 4064 QQ-B-655	AWS A5.8	AMS 3415 or AMS 3416	1100-1140 (593-616)
No. 21 Brazing Sheet No. 22 Brazing Sheet	BAlSi-2 1/	----	4343 1/	713 1/	AMS 4054 AMS 4055	AWS A5.8	AMS 3415 or AMS 3416	1100-1120 (593-604)
No. 23 Brazing Sheet No. 24 Brazing Sheet	BAlSi-5 1/	----	4045 1/	714 1/	QQ-B-655	AWS A5.8	AMS 3416 or AMS 3415	1080-1120 (582-604)

1/ Cladding on brazing sheet, when added filler alloy is desired, alloy 4047 is recommended.
2/ Maximum brazing temperature for alloys 6061 and casts 710.0 and 713.0 is 1100°F (593°C).

5. POST-BRAZING PROCEDURE

5.1 General.

5.1.1 Cooling rate. Assemblies shall be cooled in air to approximately 400°F (204°C) in such a manner and rate, as determined by qualification pilot run, so that no cracks occur and internal stresses and distortion are minimized. When heat treatment is used in conjunction with brazing, cooling and quenching procedures shall be developed accordingly.

5.1.2 Flux removal. Immediately after brazing and cooling, flux shall be removed by a method which is not injurious to the surface finish, and which will not remove parent metal and filler metal to below drawing tolerances. A suitable test, such as the absence of a typical chloride precipitate in a 5 percent aqueous solution of silver nitrate on the cleaned and rinsed part, shall be used to determine that the flux has been adequately removed.

5.1.3 Quality of joint. Quality of joint shall be Grade A or Grade B or as specified on the drawing.

5.1.3.1 Contour. The contour of an outside fillet joint shall be of a uniform radius with a minimum amount of excess braze or flash over the adjacent surfaces.

5.1.3.2 In process corrections. Brazements containing Grade A joints may be rebrazed once to correct braze defects. After cleaning, add stop-off material and filler metal if needed, then preheat and rebraze in accordance with an approved Brazing Procedure Record. If a satisfactory braze is not achieved on completion of the rebraze cycle, the basement shall be rejected. Brazements containing Grade B joints are allowed two rebraze cycles using the same rebrazing procedure as specified for Grade A brazements. If a satisfactory braze is not achieved on completion of the second rebraze cycle, the brazement shall be rejected.

6. DEFECTS

6.1 External defects. For Grade A and B joints.

6.1.1 External porosity (pinholes). This defect is the result of gases being expelled. It appears as a small, round, smooth-surfaced pocket on the surface of the filler metal. The maximum diameter permissible is 0.050 inch (1.27 mm) with a depth of not more than 10 percent of the braze depth. The total number of pinholes of maximum diameter permitted shall be one per linear inch (25.4 mm) of braze metal, or one per joint when the braze length is less than one linear inch (25.4 mm). There shall be no voids in the joint overlap area that are connected with surface porosity.

6.1.1.1 Concentrated surface porosity. An area of concentrated porosity, the largest dimension of which is 50 percent of the braze fillet width, is acceptable provided that the sum of diameters of the pinholes in the area does not exceed 0.050 inch (1.27 mm). No more than one such area of maximum size or two more with a total equivalent diameter shall occur per linear inch (25.4 mm) of braze fillet.

6.1.1.2 Linear surface porosity. Linear surface porosity is defined as any surface porosity where the majority of the porosity is lined up in straight lines. Linear porosity is acceptable providing its length does not exceed 3/16 inch (4.76 mm) and the sum of the diameters of the pinholes in this length does not exceed 0.015 inch (0.38 mm). Linear porosity shall be acceptable provided that no more than one such defect occurs per linear inch (25.4 mm) of braze or one per joint where the braze circumference or length is less than one linear inch (25.4 mm).

6.1.2 Blisters. This surface condition, resulting from the overheating of the base metal, shall be cause for rejection.

6.1.3 Residual flux. No residual flux shall be permitted on the surface of a brazed assembly.

6.1.4 Excess braze metal. Brazing filler metal in excess of that required for the joint is acceptable providing the excess filler metal does not interfere with the function of the completed assembly or substantially detract from appearance.

6.1.5 Unmelted filler metal. Except where specifically permitted by applicable drawings or specifications, the presence of unmelted filler metal in a joint shall be cause for rejection of the assembly.

6.1.6 Undercutting. Melting or erosion of the base metal, adjacent to the brazed joint, is undesirable and shall be controlled by limiting this to a maximum of 5 percent of the stock thickness, and 15 percent cumulative, of the braze length or as specified on the drawings.

6.1.7 Penetration. Filler metal shall appear at all edges of a joint indicating proper flow through the joint. Lack of penetration shall be cause for rejection of the part.

6.2 Internal defects. For Grade A joints only.

6.2.1 Total aggregate area. The unbrazed area including trapped flux, scattered porosity, and voids shall not exceed 20 percent of the faying surface of the respective joint in any one inch (25.4 mm) of joint length.

6.2.2 Maximum extent of a single defect. No single unbrazed area shall exceed 20 percent of the overlap distance of the joint.

7 TEST METHODS

7.1 Inspection and test. Inspection and test procedure shall be in accordance with the requirements of MIL-I-6870 and as specified herein.

7.1.1 Visual examination. Brazed joints shall be visually examined to determine the quality of joint as specified in 5.1.3.1, 6.1 and 6.2. Fluorescent or dye penetrant MIL-I-6866 procedures may be used as inspection aids. All indicated flaws shall be checked visually under ten power magnification, maximum.

7.1.2 Radiographic examination - for Grade A joints only. Radiographic inspection shall be conducted in accordance with MIL-STD-453 on Grade A joints to determine the quality of brazing as specified in 6.2. This inspection is mandatory for qualification samples. Frequency of inspection (radiographic) shall be as specified on the drawing or as determined by the manufacturing activity.

7.1.3 Ultrasonic inspection of (Grade A joints). Ultrasonic inspection shall be conducted by a method mutually agreed upon by the procuring activity and the contractor to determine the quality of brazing.

7.1.4 Dimensional inspection. Samples from each inspection lot shall be inspected for compliance with dimensional requirements of the applicable drawings and specifications.

7.1.5 Rejection. Brazed assemblies not conforming to the requirements of this standard shall be rejected.

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APPENDIX

10. Critical fittings and structural applications. A critical fitting or structure is one, the single failure of which, would cause significant danger to operating or other personnel or would result in a significant operational penalty. In the case of missiles, aircraft, and other vehicles, this includes loss of major components, loss of control, unintentional release or inability to release armament stores, or failure of weapon installation components.

10.1 Aluminum alloys. This process is intended for the brazing of wrought aluminum alloys 1100, 3003, 3004, 5005, 6061, 6951 and cast aluminum alloys of the compositions corresponding to 356.0, 443.0, 710.0, 711.0, and 713.0 specified in QQ-A-601 and ASTM B-26.

10.2 Heat treating aluminum alloys after brazing. After brazing, all wrought aluminum alloys are in the annealed condition ("o" Temper). When it is desired to have heat-treated alloys in the -T6 temper, brazed parts should be solution heat-treated and aged. When required, such solution heat treatment and aging shall be in accordance with MIL-H-6088 and AMS 2770 for wrought alloys.

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