AEROSPACE RECOMMENDED PRACTICE

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SILVER AND COPPER ALLOY BRAZED JOINTS FOR AEROSPACE PROPULSION SYSTEMS

1. PURPOSE: This ARP is intended to contain all data known to be pertinent to good design for silver and copper alloy brazed joints, based on sound engineering principles currently used throughout the aerospace propulsion systems industry, and provides a recommended practice for appropriate design configurations, engine and propeller standard utility parts, as applicable, and other propulsion systems components.

1.1 It further establishes a common standard practice for swaged tubing and a common standard for the inside diameter of the mating part of fittings for either silver or copper brazed joints. The purpose of establishing a common inside diameter for both brazing applications is to facilitate manufacturing and to reduce the cost of related parts.

2. SCOPE: This recommended practice covers design requirements for silver and copper brazed joints, primarily for tube connections, for aerospace propulsion systems. The environmental conditions stated herein, and those given in the applicable AMS specifications, provide the limitations of this ARP.

3. GENERAL REQUIREMENTS:

3.1 Applicable Specifications: The AMS specifications mentioned herein should be complied with in all respects.

3.2 Material and Workmanship:

3.2.1 Materials: Materials should be of a quality which experience and tests have demonstrated to be suitable and dependable for aerospace propulsion systems.

3.2.2 Workmanship: Workmanship should be consistent with high-grade aerospace propulsion systems manufacturing practice.

3.3 Environmental Conditions: The environmental conditions and temperatures stated herein and in the applicable AMS specifications cover these requirements.

3.4 Considerations: The following sets forth some of the considerations which should be given to all brazed joints and the selection of brazing alloys. Certain fundamental design rules must be followed if good brazing joints are to be obtained. Some cases may occur which are not covered by this recommended practice. Such cases should be referred to a materials engineer.

3.4.1 Material combination comprising the joint.

3.4.1.1 Brazeability (wetting or flow characteristics).

3.4.2 Design of the joint and method or process of brazing for uniform heating during brazing so that all parts of the joint can be brought up to brazing temperature evenly.

3.4.3 Effect of the braze temperature on any work hardening gained during fabrication and hardness obtained by heat treatment.

3.4.4 Effect of hardness on the bonding surfaces of the parts before brazing. This can result in a poor bond and joint failure.

3.4.5 Effect of heat treatment of assembly after brazing.

3.4.6 Effect on plating before and after brazing.

3.4.7 Areas in the design in which brazing is not permitted.

3.4.8 Joint clearance, gaps and tolerances.

3.4.9 Venting of the joint bonding area or clearance space.

3.4.10 Lap or engaged length (or depth) of joint.

3.4.11 Positioning or centering of parts to be joined.

3.4.12 Ratio of tube diameter and wall thickness to engaged length of joint.

3.4.13 Strength of joint.

3.4.14 Temperature of the joint under operating conditions.

3.4.15 Natural frequency and vibration characteristics under operating conditions.

3.4.16 Type and degree of stress to be applied to the joint at the brazing heat and under operating conditions.

3.4.17 Effect of creep on the joint when it is subjected to a continuous load.

3.4.18 Coefficients of expansion of the materials to be joined together.

3.4.18.1 Use of the member having the larger coefficient of expansion as the inside part of a sleeve joint where adequate joint clearance and tolerances permit.

3.4.19 Difficulty and methods of cleaning surfaces and type of finish.

3.4.20 Surface roughness of the joint surfaces.

3.5 General Design Features:

3.5.1 Engaged Length of Joints: The joint should be calculated to be 1-1/4 times as strong as the tube or component when high strength joints are required, but not less than 6t in length (where "t" is thickness of thinner component part). Where no other appreciable force is acting on the joint but a straight tension load, this value may be reduced to 3t. Minimum length joints should be used wherever practicable to obtain maximum brazing penetration. Brazing material should not be expected to penetrate a joint length in excess of 0.450 inch from a single source of braze material. If the joint is overlapped greater than 0.450 inch for some design reason, then penetration beyond the 0.450 inch point will not be assured and should be waived by a drawing note.

3.5.2 Joint Clearance: For flat, butt, and diametral joint design clearances, see detail requirements for applicable brazing.

3.5.3 Joint Gap or Shoulder: Joints may have a gap or shoulder at one of the edges of the part to allow placement of braze materials (see Figure 1).

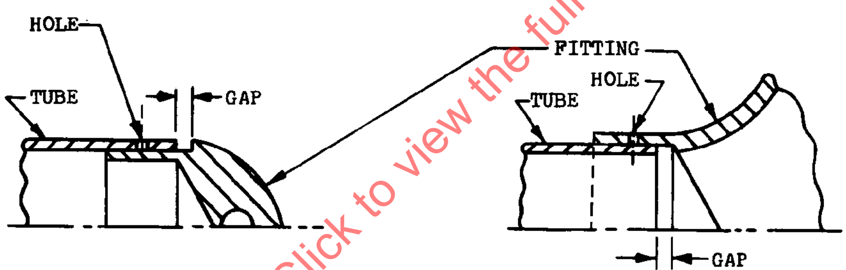

FIGURE 1

3.5.4 Joint Vent Holes: In order to improve the penetration at the braze by permitting entrapped gases and flux to escape, it is permissible to employ vent holes (see Figure 1).

3.5.5 Design of joints to provide for the advantage of using the effect of gravity on the flow of the braze material at the time of brazing, such that the braze material will flow downward, may be found beneficial.

3.5.6 Strength of Joints: The joint strengths of various brazing materials may be determined from the curves given for various temperatures in Figures 3, 4, and 5 as a guide. These values are based on 80% effective braze area and have been modified by slightly reducing the ultimate strength of the brazed joint in order to facilitate manufacturing and reduce the cost of the related parts. The ultimate shear strength values in pounds per square inch of area (PSI) are based on the maximum diametral clearance of the brazed joint as stated on the applicable strength curves. The joint is stronger when the minimum clearance value is approached.

3.5.7 Surface Roughness of Joint Surfaces: In order to develop strong joints, the surface roughness of the surfaces to be brazed should be between 32 and 125 microinches AA (see USAS B46.1-1962). Smooth surfaces do not "wet" evenly. Surfaces may be vapor or shot blasted, if required, but not sand blasted or tumbled.

3.5.8 Plating: If joints are to be plated after brazing, all braze and flux should be cleaned from surfaces.

4. DETAIL REQUIREMENTS:

4.1 Brazing Process:

4.1.1 Silver Brazing Applications: Brazing should be in accordance with AMS 2665 or AMS 2666 as applicable.

4.1.1.1 AMS 2665 (Low Temperature Silver Brazing): Joints brazed with AMS 4770 braze material should be limited to operating temperatures less than 400°F for high strength joints, and less than 500°F for low strength joints.

4.1.1.2 AMS 2666 (High Temperature Silver Brazing): Joints brazed with AMS 4772 braze material should be limited to operating temperatures less than 800°F.

4.1.1.3 Strength: When AMS 2665 brazing process is used, an extension (or creep) of material occurs under load when the operating temperature exceeds 400°F. Strength curves in Figure 3 (for austenitic stainless steels) and Figure 4 (for carbon and martensitic stainless steels) indicate that greater ultimate shear strength is available with AMS 2666 brazing (curve B) than with AMS 2665 brazing (curve A).

4.1.2 Copper Brazing Applications: Brazing should be in accordance with AMS 2670 or AMS 2671 as applicable.

4.1.2.1 AMS 2670 (Copper Furnace Brazing - Carbon and Low Alloy Steels): Joints brazed with AMS 4500 or AMS 4701 braze material should be limited to operating temperatures less than 500°F for high strength joints, and less than 1000°F for low strength joints.

4.1.2.2 AMS 2671 (Copper Furnace Brazing - Corrosion and Heat Resistant Steels and Alloys): Joints brazed with AMS 4500 or AMS 4701 braze material should be limited to operating temperatures less than 700°F for high strength joints, and less than 1000°F for low strength joints. Copper brazing of titanium-bearing corrosion and heat resistant steels, such as Type 321 stainless steels, is not generally recommended but some success has been reported using a carefully controlled pure dry hydrogen atmosphere.

4.1.2.3 Strength: Strength curves in Figure 5 (for carbon and low alloy steels and corrosion and heat resistant steels and alloys) indicate that greater ultimate shear strength is available with AMS 2670 brazing (curve C) between room temperature and 700°F than with AMS 2671 brazing (curve D). However, AMS 2671 has greater strength than AMS 2670 at temperatures above 700°F.

4.2 Design of Joints: See Figure 1 and recommendations stated in the "General Design Features" section above.

4.2.1 Joint Clearance: The strongest and soundest joints are obtained when brazed with the minimum clearance value.

4.2.1.1 Flat and Butt Joints:

4.2.1.1.1 Silver Braze AMS 2665 or AMS 2666: A clearance gap of 0.001-0.004 inch should be maintained.

4.2.1.1.2 Copper Braze AMS 2671: A clearance gap of 0.0000-0.0015 inch should be maintained.

4.2.1.2 Diametral Joints: Table I provides for the following fits as applicable to silver and copper brazed joints.

4.2.1.2.1 Silver Braze AMS 2665 or AMS 2666: Joints for tubes and fittings should have a diametral clearance fit of 0.002-0.008 inch to permit economical fabrication and ensure adequate strength. A minimum radial clearance of 0.0005 inch should be maintained to preclude metal-to-metal contact.

4.2.1.2.2 Copper Braze AMS 2670 or AMS 2671: Joints for tubes and fittings should have a diametral fit of 0.0005 to 0.004 inch loose. Complicated assemblies may require greater looseness for ease of assembly, such as up to 0.005 inch loose. This may adversely affect joint strength.

4.2.2 Standard Dimensions: Table I provides the standard diametral values for swaged tubing to obtain the recommended fit for either silver or copper brazing of tubes into a common standard hole size for all fittings when the materials to be joined have the same coefficient of expansion.

TABLE I

Dimensions of hole and swaged tubing for materials having same coefficient of expansion			
Nominal tube OD	Fitting hole diameter	Tube swaged diameter	
		Silver braze diametral fit .002L-.008L	Copper braze diametral fit .0005L-.004L
.125	.115- .117	.109- .113	.1130- .1145
.188	.178- .180	.172- .176	.1760- .1775
.250	.240- .242	.234- .238	.2380- .2395
.312	.302- .304	.296- .300	.3000- .3015
.375	.365- .367	.359- .363	.3630- .3645
.438	.428- .430	.422- .426	.4260- .4275
.500	.489- .491	.483- .487	.4870- .4885
.562	.551- .553	.545- .549	.5490- .5505
.625	.614- .616	.608- .612	.6120- .6135
.688	.677- .679	.671- .675	.6750- .6765
.750	.739- .741	.733- .737	.7370- .7385
.875	.864- .866	.858- .862	.8620- .8635
1.000	.989- .991	.983- .987	.9870- .9885
1.125	1.114-1.116	1.108-1.112	1.1120-1.1135
1.250	1.239-1.241	1.233-1.237	1.2370-1.2385
1.500	1.484-1.486	1.478-1.482	1.4820-1.4835

4.2.2.1 Tube Ends: A tube end which must be sized to fit with mating part will normally be swaged and the drawing should specify "wall thickness must not be reduced". If grinding is permitted, the following minimum wall thicknesses should be maintained at the affected tube ends, it being permissible to grind straight jumper tubes for their entire length:

Basic wall (inches)	Minimum wall (inches)
.028	.020
.035	.022
.049	.030
.058	.035
.065	.040

4.2.2.2 Straight Length at End of Bent Tube: Design should provide as much straight length of tube as possible beyond the end of the fitting. The following minimum straight length B of tube (Figure 2) should be maintained.

(a) Minimum swaged length A of tube plus 0.250 inch for tubes 0.500 inch OD and under.

(b) Minimum swaged length A of tube plus half the OD for tubes over 0.500 inch OD.

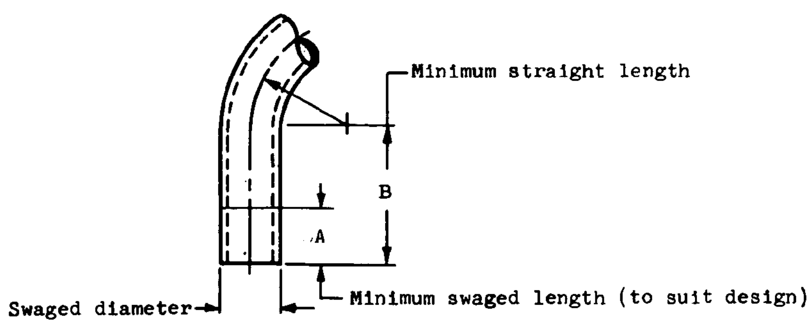

FIGURE 2

4.2.3 Recommended Material Combinations: Table II shows the recommended combinations of material for design and the maximum operating limits for the applicable brazed joint. Refer to paragraph 3.5.6, Strength of Joints, for data on ultimate shear strength characteristics.

5. QUALITY: The quality of the brazing should conform to the requirements given in the applicable AMS brazing specifications.

6. INSPECTION: Inspection should be consistent with high-grade aerospace propulsion systems manufacturing practice.

TABLE II

Recommended material combinations								
Tubing	Fittings							
	AISI 316 FM AMS 5649	AISI 321 AMS 5645	AISI 347 AMS 5646	AISI 410 AMS 5613	INCONEL AMS 5665**	AISI 1006-1022 AMS 5062	AISI 4130 AMS 6370	AISI 8630 AMS 6280
AISI 321 AMS 5570 AMS 5576	A, B	A, B	A, B		A, B			
AISI 347 AMS 5571 AMS 5575	A, B, D	A, B	A, B, D		A, B, D			
AISI 410 AMS 5591				A, B*,D*	A, B*,D*			
INCONEL AMS 5580**	A, B, D	A, B	A, B, D	A, B*,D*	A, B, D			
AISI 1010 AMS 5050 AMS 5053						A, B, C	A, B*,C*	A, B*,C*
AISI 4130 AMS 6360						A, B*,C*	A, B*,C*	A, B*,C*
AISI 8630 AMS 6530 AMS 6550						A, B*,C*	A, B*,C*	A, B*,C*

A. Silver braze AMS 2665. Maximum operating temperature 400°F high stress, 500°F low stress

B. Silver braze AMS 2666. Maximum operating temperature 800°F.

C. Copper braze AMS 2670. Maximum operating temperature 500°F high stress, 1000°F low stress

D. Copper braze AMS 2671. Maximum operating temperature 700°F high stress, 1000°F low stress

* Stress relief required in zone affected by brazing temperature.

** Limiting aluminum to 0.15% maximum and aluminum plus titanium to 0.50% maximum may facilitate copper brazing this material.