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AEROSPACE RECOMMENDED PRACTICE

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SILVER, COPPER AND NICKEL ALLOY BRAZED JOINTS FOR AEROSPACE PROPULSION SYSTEMS

1. **PURPOSE:** This ARP provides data for silver, copper, and nickel 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, copper or nickel brazed joints. The purpose of establishing a common inside diameter for brazing applications is to facilitate manufacturing and to reduce the cost of related parts.
2. **SCOPE:** This recommended practice covers design requirements for silver, copper and nickel 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.

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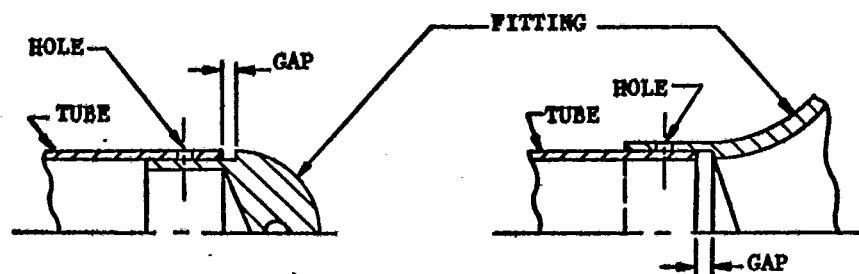
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- 3.4.5 Effect of heat treatment of assembly after brazing.
- 3.4.6 Effect on plating before and after brazing.
- 3.4.7 Areas in the design in which brazing is not permitted.
- 3.4.8 Joint clearance, gaps and tolerances.
- 3.4.9 Venting of the joint 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 surface 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 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 ANSI B46.1-1978). Smooth surfaces do not "wet" evenly.
- 3.5.7 PLATING: If joints 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 2664, AMS 2665, or AMS 2666 as applicable.
- 4.1.1.1 AMS 2664 (SILVER BRAZING UNHARDENED STEELS AND ALLOYS): Joints brazed with AMS 4765 braze material should be limited to operating temperatures less than 800°F. Joints brazed with AMS 4772 braze material should be limited to operating temperatures less than 700°F.
- 4.1.1.2 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.
- 4.1.1.3 AMS 2666 (HIGH TEMPERATURE SILVER BRAZING): Joints brazed with AMS 4772 braze material should be limited to operating temperatures less than 700°F.
- 4.1.1.4 STRENGTH: When AMS 2665 brazing process is used, an extension (or creep) of material occurs under load when the operating temperature exceeds 400°F. Greater ultimate shear strength is available with AMS 2664 or AMS 2666 brazing than with AMS 2665 brazing.
- 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: Greater ultimate shear strength is available with AMS 2670 brazing between room temperature and 700°F than with AMS 2671 brazing. However, AMS 2671 has greater strength than AMS 2670 at temperatures above 700°F.
- 4.1.3 NICKEL BRAZING APPLICATIONS: Brazing should be in accordance with AMS 2675.
- 4.1.3.1 AMS 2675 (NICKEL ALLOY BRAZING): Joints brazed with ASM 4775 braze material should be limited to operating temperatures less than 1200°F for high strength, and corrosion and oxidation resistance.
- 4.2 DESIGN OF JOINTS: See Figure 1 and recommendations stated in the "General Design Features" section above.

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- 4.2.1 JOINT CLEARANCE: The strongest and soundest joints are obtained when brazed with the minimum clearance value. The gaps specified below shall be adjusted as necessary when materials with different coefficients of expansion are used in the joint.
- 4.2.1.1 FLAT AND BUTT JOINTS:
- 4.2.1.1.1 SILVER BRAZE AMS 2664, 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.
- 4.2.1.1.3 NICKEL BRAZE AMS 2675: A clearance gap of 0.0005-0.0030 inch should be maintained.
- 4.2.1.2 DIAMETRAL JOINTS: Table I provides for the following fits as applicable to silver, copper, and nickel brazed joints.
- 4.2.1.2.1 SILVER BRAZE AMS 2664, AMS 2665, or AMS 2666: Joints for tubes and fittings should have a diametral clearance fit of 0.0015-0.0050 inch to permit economical fabrication and ensure adequate strength. A minimum radial clearance of 0.0005 inch should be maintained to facilitate braze flow.
- 4.2.1.2.2 COPPER BRAZE AMS 2670 or AMS 2671: Joints for tubes and fittings should have a diametral clearance fit of 0.0005-0.0040 inch. Complicated assemblies may require greater looseness, but this may adversely affect joint strength.
- 4.2.1.2.3 NICKEL BRAZE AMS 2675: Joints for tubes and fittings should have a diametral clearance fit of 0.0005-0.0040 inch. (For those materials for which AMS 2675 specifies nickel plating prior to brazing, this clearance applies after plating.)
- 4.2.2 STANDARD DIMENSIONS: Table I provides the standard diametral values for swaged tubing to obtain the recommended fit for either silver, copper, or nickel 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 THE SAME COEFFICIENT OF EXPANSION

Nominal Tube OD	Fitting Hole Diameter	Tube Swaged Diameter	
		Silver Braze	Copper and Nickel Braze
.125	.115- .117	.1120- .1135	.1130- .1145
.188	.178- .180	.1750- .1765	.1760- .1775
.250	.240- .242	.2370- .2385	.2380- .2395
.312	.302- .304	.2990- .3005	.3000- .3015
.375	.365- .367	.3620- .3635	.3630- .3645
.438	.428- .430	.4250- .4265	.4260- .4275
.500	.489- .491	.4860- .4875	.4870- .4885
.562	.551- .553	.5480- .5495	.5490- .5505
.625	.614- .616	.6110- .6125	.6120- .6135
.688	.677- .679	.6740- .6755	.6750- .6765
.750	.739- .741	.7360- .7375	.7370- .7385
.875	.864- .866	.8610- .8625	.8620- .8635
1.000	.989- .991	.9860- .9875	.9870- .9885
1.125	1.114-1.116	1.1110-1.1125	1.1120-1.1135
1.250	1.239-1.241	1.2360-1.2375	1.2370-1.2385
1.500	1.484-1.486	1.4810-1.4825	1.4820-1.4835