technical DATA

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CARBORUNDUM

JOINING KOVAR® ALLOY TO OTHER METALS

BRAZING - WELDING - SOLDERING

I. INTRODUCTION

Kovar® may be readily welded, brazed or soldered to other metals, but certain precautions must be observed to meet the following conditions:

A) For high vacuum applications it is essential that fluxes be avoided and that no brazing alloy be used that contains a high vapor-pressure constituent, such as cadmium, zinc or lead.

B) Brazed and welded joints must be designed and processed to take into consideration the fact that Kovar® alloy has a considerably lower thermal expansivity than most other metals to which it is joined.

C) Different processing methods must be employed on similar types of joints, depending on whether the joint is made before or after the glass-sealing operation.

D) Uniform heating methods are preferred to minimize thermal stresses which may lead to fracture, especially when joining dissimilar metals.

E) Kovar® has low thermal conductivity:

.0395 cal/sq. cm/cm/°C/sec at 30°C
.0485 cal/sq. cm/cm/°C/sec at 300°C

F) Kovar® in common with other metals must be chemically clean before joining to other metals. Since many joints are made after Kovar® has been sealed to glass, reference is made to Carborundum Bulletin 100EB4 - Cleaning Oxidized Kovar® Alloy.

The information that follows is intended to supplement standard practice and published data on the general techniques of joining metals, emphasizing some of the special points to be observed, due primarily to the lower thermal expansion of Kovar® alloy and the fact that most end-use applications require vacuum-tightness.

II. DEFINITIONS

A) Brazing is the term applied to the process of joining two or more metal parts by filling the intervening gap with a lower melting material by means of capillary attraction, and with material having a melting point over 500°C.

B) Soft Soldering is the same as brazing except employing filler material of melting point under 500°C, and not necessarily involving capillarity.

C) Welding is the term usually applied when there is actual melting of the materials to be joined. (More recent types of welding such as Cold, Ultrasonic and Electron Beam do not necessarily meet this definition.)

D) Intergranular Penetration is a condition in which the grain boundary rather than the grain of metal is penetrated by some element, such as oxygen, carbon, sulphur etc.

E) Stress Corrosion is also penetration of the grain boundary, but usually by a liquid and only when either applied or residual stresses are present in the metal.

F) Wetting is the ability of molten metal to adhere to the surface of metal in the solid state, and make a strong bond when cooled.

G) Flow is the property of the brazing alloy which determines the distance it will travel by capillary attraction from its original position.

III. PREFERRED JOINING MATERIALS AND METHODS

A joint with Kovar® must meet the following conditions:

1. The brazing material must not be injurious to the operation of the device.

2. The method of joining should not disturb the equilibrium of prior joints nor induce appreciable tensional stress on either glass or ceramic insulation.

3. The joint must be capable of withstanding the temperature of subsequent thermal conditions.

III. PREFERRED JOINING MATERIALS AND METHODS (Cont'd.)

4. The cost of brazing material and equipment availability must be compatible with end product and reliability requirements.

Listed below, in order of preference, are recommended filler materials and methods. Final selection is determined by considering the above listed factors and other particular existing conditions:

A) Kovar® Alloy to Copper

Order of Preference			Temperature °C Melting Point	Flow Point
1.	30% Gold,	70% Copper	1015	1035
2.	35% Gold,	65% Copper	1000	1020
3.	18% Nickel,	82% Gold	950	950
4.	3% nickel,	15.5% Copper, Bal. Gold	900	910
5.	28% Copper,	72% Silver	780	780

B) Kovar® Alloy to Kovar®, Steel or Nickel

Order of Preference

1. OFHC Copper
2-6. See items 1 to 5 inclusive shown above
7. Resistance welding (projection type)
8. Inert-gas-shielded arc welding

C) Kovar® Alloy to Metallized Ceramics

Order of Preference

1. OFHC Copper
2. 30% Gold, 70% Copper
3. 28% Copper, 72% Silver (except for certain types of electron tubes on account of high vapor pressure)

D) Soft Soldering

For applications involving low operating temperatures and limited to devices not affected by high vapor pressure constituents of soft solders.

Order of Preference			Max. Operating Temperatures °F
1.	63% Tin,	37% Lead	350
2.	16% Tin,	32% Lead, 52% Bismuth	200
3.	97.5% Lead	2.5% Silver	550

Reference Notes

a. See succeeding sections of this Bulletin for comments on specific joining methods.

b. For more complete listings see Table 12.1 - Brazing Filler Materials for Electron Tubes. See 1960 edition materials and Techniques for Electron Tubes by W. H. Kohl, Reinhold Publishing Company, New York.

c. Other methods of joining Kovar® are in the development stage at this writing. In this category of promising utility are Cold Welding, Ultrasonic Welding and Electron-Beam Welding.

IV. DESIGN OF JOINTS WITH KOVAR®

The details of good designs of brazed and welded joints are covered by a vast amount of literature, such as Brazing Manual, prepared by Committee on Brazing of American Welding Society and published by Reinhold Publishing Company as well as by manufacturers of brazing alloys and manufacturers of welding equipment.

In addition to incorporating the general principles of good design, the following factors require special attention when Kovar® is involved:

1. Tensional stresses on Kovar® at brazing temperatures are to be avoided.

2. Compression joints preferable (higher expansion member on outside).

3. Adequate clearance between metal members especially if higher expansion material is on the inside. (See Section V).

4. Brazing alloy selected to have good "wettability" on Kovar®.

5. Brazing alloy on the primary joint to have sufficiently high melting point so that this original joint does not deform and introduce thermal stresses due to the heating operations of secondary brazes or other thermal cycles which may be introduced.

6. Joint must be designed to permit a method of uniform heat application such as furnace or R. F. coil.

7. When Kovar® is on the outside of a higher expansion member, tapering of the Kovar® cross-section at the joint minimizes transmittal of expansion effects to the glass or ceramic seal.

IV. DESIGN OF JOINTS WITH KOVAR® (Cont'd.)

8. When conditions permit, copper brazing is generally preferred over any other type of joining. (The uniform high temperature insures stress relief, and the technique is less critical than welding.)

9. Butt-type joints are to be avoided whenever possible.

10. Ceramic jigs are preferred over carbon type due to greater wear resistance, longer furnace life, and elimination of contamination on the brazing surface.

V. CLEARANCE ON BRAZED JOINTS

A) When joining Kovar® to Kovar® or with Kovar® on the inside of higher expansion metal the maximum diameter clearance should be:

1. .002" for copper brazing
2. .003" for lower melting brazes

B) When a furnace brazed joint has Kovar® on the outside of a higher expansion member use the following formula for the minimum diameter clearance:

$$D\ (E_1 - E_2) + .003''$$

D - Diameter of joint in inches.

E_1 - Actual expansion in inches per inch of higher expansivity member from room temperature to brazing temperature.

E_2 - Same for Kovar® alloy (see expansion curve).

Example: To find minimum clearance for a 2" diameter joint with Kovar® on outside of copper using 72% silver, 28% copper (eutectic) brazing alloy (780°C) in a furnace:

Clearance - 2 x (.0152 - .0077) + .003
- .018" (minimum clearance between diameters)

C) A high frequency coil (eddy-current concentrator) can be used to concentrate the heat on the joint area for a very short time, thereby permitting smaller clearance between the parts.

V. CLEARANCE ON BRAZED JOINTS (Cont'd.)

The calculations of clearance for this type heating is very complex due to the variables of coil design, magnitude of current and time, thermal conductivities of the different metals etc. Consequently, the optimum clearance should be determined experimentally, possibly starting with a clearance 10% less than the value calculated for furnace brazing.

D. Tolerances on the matching metal pieces must be held rather close to prevent either too much clearance, which would weaken the joint, or too little clearance, which introduces tensile stresses when the higher expansion member is on the inside of the assembly.

When assigning tolerances to the metal parts, consideration should be given to the possibility that one part might have the maximum plus tolerance and the other part the minimum plus value. Generally, a plus or minus .001" tolerance on both metal parts will not introduce injurious effects. For economy, instead of machining a drawn cup, the other part may be machined to a dimension to give the calculated clearance to the actual measurement of the drawn part.

VI. BRAZING OF KOVAR® ALLOY

A) Selection of Brazing Filler Materials

Supplementing the information contained in Section III - Preferred Joining Materials and Methods, the following should be considered:

1. Successful joints can be made with Kovar® using silver-brazing alloys, provided certain precautions are taken.

2. Brazing with OFHC copper is preferred whenever conditions permit.

3. Gold-brazing alloys are used in preference to silver alloys, when subsequent thermal exposure requires the higher melting point, or to secure more thorough relief of induced stress by the higher brazing temperature of the gold alloys.

VI. BRAZING OF KOVAR® ALLOY (Cont'd.)

B) Silver-Brazing Alloys

To understand the precautions that must be observed when silver-brazing to Kovar®, it is well to consider the causes of fractures in the combination.

Experiments on the brazing of Kovar® with various alloys have proved that intergranular cracking is produced only when the Kovar® is under tensional stress at the time of fusion and when the brazing alloy is in the liquid phase. The cracking starts at the point of highest tensional-stress concentration and is progressive. The cracking occurs whether the stresses are externally applied or residual as long as they are tensional. Stress corrosion is also accentuated by subsequent heat treatment. Actual experience has shown cases where Kovar®-brazed joints were under tensional stress but with insufficient penetration of the brazing alloy to cause cracking immediately upon cooling. However, on subsequent thermo-cycling, these joints would leak through cracks extending along the grain boundaries whose roots were in the areas where the brazing alloy had originally penetrated.

Among silver-brazing alloys, the predominantly favored type is the 72% silver and 28% copper eutectic, which has the following advantages:

1. Being a eutectic, the brazing time can be kept low, thereby minimizing intergranular penetration.

2. Will "wet" and "flow" well on Kovar®.

3. Elements have sufficiently low vapor pressure for most applications.

C) Precautions when Silver-Brazing Kovar®

1. Brazing surface to be free of longitudinal scratches (to avoid capillary effects).

2. Anneal Kovar® parts before brazing (when brazing time or temperature does not provide relief of stresses).

3. Plate the brazing surface of Kovar® with nickel or copper (to retard intergranular penetration). The plated surface may be subjected to a sintering operation.

VI. BRAZING OF KOVAR® ALLOY (Cont'd.)

C) Precautions when Silver-Brazing Kovar® (Cont'd.)

4. Allow sufficient clearance (at brazing temperature) when Kovar® is on the outside of the higher expansion member.

5. Preferably use a eutectic brazing alloy (such as 72% silver, 28% copper, melting and flow point 780°C).

6. Heating to brazing temperature to be applied uniformly to avoid thermal stressing, using such methods as inert or reducing atmosphere furnace, R.F. heating coil or resistance coil under bell jar.

7. Keep brazing time at a minimum.

8. Keep the reheating of brazed joints to a minimum.

D) Gold Alloy and Copper Brazing of Kovar®

Stress corrosion can also occur when brazing with pure copper or with gold-brazing alloy, but the effect is minimized since their higher melting points stress-relieve the Kovar® when being brought to brazing temperature. Consequently, the same precautions outlined in Section VI should be followed except that the plating of Kovar® may be omitted, and the choice of brazing materials should be made with the following considerations:

1. Use OFHC copper brazing whenever joining permits exposure of assembly to 1100°C.

2. Gold alloys are preferred over silver when the value of the completed item warrants the additional cost as insurance against stress corrosion.

3. Use OFHC copper or gold alloy on primary joints when the temperature of subsequent joints or other thermal treatment would cause the primary joint to be deformed and, therefore, introduce thermal stresses.

VI. BRAZING OF KOVAR® ALLOY (Cont'd.)

D) Gold Alloy and Copper Brazing of Kovar® (Cont'd.)

4. For special cases when better flow characteristics of the brazing alloy are desired, nickel-bearing brazes are preferred, such as 35% gold, 62% silver and 3% nickel.

5. For a complete study of individual brazed joints reference should be made to equilibrium or phase diagrams of the constituents.

VII. SOFT SOLDERING OF KOVAR® ALLOY

The use of soft solders (melting points under 500°C.) is restricted to those applications where the high vapor pressure of the solder constituents are not objectionable. This rules out the use of soft solder on most electron tubes and other high vacuum devices.

Among the applications for soft soldering Kovar® are:

1. Low temperature electron tubes, such as Geiger Counter types.

2. Covering of welded pinch-off tubes after exhausting.

3. For attaching Kovar® alloy-glass terminals to the cans of such devices as transformers, capacitors, relays, crystal holders, and similar hermetically-sealed devices.

Surface preparation for the actual soldering operation is of primary importance. Generally, solder dipping or electro-tin plating is most easily accomplished although other methods, such as copper plating, are sometimes used.

A) Typical Procedure for Solder-Dipping Kovar®-Glass Assemblies:

1. Remove oxide. (See Carborundum Bulletin 100EB4)

2. Flux in 50% aqueous solution of zinc chloride with 5 to 10% ammonium chloride. Agitate for complete coverage.

VII. SOFT SOLDERING OF KOVAR® ALLOY (Cont'd.)

A) Typical Procedure for Solder-Dipping Kovar®-Glass Assemblies: (Cont'd.)

3. Solder dip in bath of 63-37 solder at approximately 250°C.

4. Remove excess solder, preferably by centrifugal means.

5. Remove flux by dipping in hot water containing a wetting agent, followed by running water rinse. If necessary follow by 5% muriatic acid rinse with another water rinse.

6. Dry in hot-air blast.

7. Oil flow by immersion in vegetable oil at approximately 250°C. until surface is molten. (If necessary, centrifuge and re-flow.) Allow parts to cool in cottonseed oil.

8. Vapor degrease in trichlorethylene. Ultrasonic attachment facilitates oil removal, especially from small tubes.

B) Typical procedure for Electro-Tin Plating:

1. Remove oxide. (See Carborundum Technical Data Sheet 100EB4)

2. Bright dip. (See Carborundum Technical Data Sheet 100EB4)

3. Electro plate in alkaline sodium-stannate bath to a thickness of about .0002", followed by thorough rinsing and drying.

4. Oil flow as soon as possible after the plating, rinsing and drying operation, using the procedure outlined in preceding Section A.

5. Degrease as per Section A.

The soldering of either of the above types of preferred surface treatments may be done by conventional heating methods, using the preferred solders listed in Section III-A. However, it should be borne in mind that although Kovar® alloy and the glass have closely matching thermal expansivity, the thermal conductivities are considerably different. Consequently, the heating should be uniformly applied in such methods as furnace, hot plate, infrared heat, heating coil etc. Torch heating is to be avoided.

VIII. WELDING OF KOVAR® ALLOY

Since welding involves a change in crystalline structure, with different expansion characteristics in the welding area, great precautions must be taken to avoid stresses which will lead to fractures. Additional thermal stresses are introduced by those heating methods which are applied progressively. Therefore, resistance welding is preferred for most high vacuum applications with Kovar® when conditions prevent the use of copper or other high temperature braze.

A) Resistance Welding

Resistance welding, with a projection on one of the matching flanged surfaces, has been found extremely satisfactory, especially for large production. For resistance welding of Kovar® alloy the following facts are pertinent:

1. The projection should be machined or coined. (Embossed projections, with a space underneath, are generally not sufficiently rigid.)

2. Kovar® to Kovar® is ideal. When welding Kovar® to other metals, however, the projection is preferably placed on the Kovar® part for thermal considerations.

3. The matching surfaces of the welding area are to be kept as flat as practical.

4. Surfaces must be smooth, clean and of as uniform thicknesses as practical. High or non-uniform electrical resistivity values will cause difficulties.

5. Welds should be made with minimum heat-input.

6. Due to initial set-up on timing, electrode design, jigging etc., resistance welding is not generally used for items of limited production.

VIII. WELDING OF KOVAR® ALLOY (Cont'd.)

B) Inert-Gas-Shielded Arc Welding

Arc-welding sets up severe thermal stresses due to the fact that, at the point of welding, Kovar® temperatures are above the melting temperature, while other portions may be as low as room temperature. Stress-corrosion effects are accentuated when Kovar® is arc welded to other metals, as well as from the resulting mixture of heterogeneous grains of differing expansivity.

Some designs of vacuum devices do not permit using more preferable types of joints. In these cases, sound arc-welded joints on Kovar® alloy are secured by employing extreme care and precaution as indicated by the following:

1. Kovar® to Kovar® is preferred.

2. Sections in weld area should be as thin as practical, down to about .020" minimum.

3. Preferred design is one in which two flanged sections are butted and a bead welded on the outer circumference. Before arc welding the butted surfaces should have continuous metal to metal contact.

4. When dissimilar thicknesses are joined the thicker material should be bevelled.

5. The joint should be designed to prevent undue stress concentration at the time of making the weld. This includes allowance of sufficient clearance. (See Section V)

6. Before welding, the parts are to be chemically cleaned and free of oxide film, as well as stress-relief annealed.

7. Either helium or argon are satisfactory for shielding, but the gas supply should be ample (30 to 50 cubic feet per hour) and protected from drafts.

8. Electrodes of 1% or 2% thoriated tungsten, ground to an extremely sharp point, are recommended.

VIII. WELDING OF KOVAR® ALLOY (Cont'd.)

B) Inert-Gas-Shielded Arc Welding

9. The electrode must be held very close to the work (preferably within .030"). To cut down turbulent flow, the electrode should be held at an angle of 10 to 15° pointed towards the direction of weld.

10. Copper-jigging rings are sometimes found helpful in keeping the assembly cool during the welding operation.

11. When welding Kovar® to steel or other alloy, the interposition of a thin nickel strip (or by nickel plating the Kovar®) will minimize the formation of the objectionable interface containing two phases (alpha and gamma).

IX. SUMMARY

The aim of this bulletin is to supplement existing literature on the brazing and welding metallurgy by giving practical hints on making the best applicable joints with Kovar® alloy. The field is so great that only most typical problems are covered. The Carborundum Company, Electronics Division, Latrobe, Pa. invites consultation of its engineering service on the more specific problems of application and processing of Kovar® alloy.