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JOINING ZIRCONIUM TO STAINLESS STEEL BY FLASH WELDING, BRAZING AND SOFT SOLDERING

by R. Keen

I. INTRODUCTION

The present design for the Hanford safety device makes use of an inner stainless steel expansion chamber. This piece is made from tubing, welded to the stainless steel pressure cell and to the end cap as shown in Figure 1. When tripped by a dangerous reactor situation, gaseous $B^{10}F_3$ is released into the larger volume. Greater neutron absorption results from this larger exposure of the $B^{10}F_3$ to the reactor flux, thus decreasing the reactivity a desired amount.

In order to improve the neutron economy under normal reactor operation with the safety device in the "cocked" or ready condition, it has been suggested that zirconium replace stainless steel for the expansion chamber. The total reactivity change from the normal to the tripped condition will be greater with the zirconium expansion chamber than with the stainless steel chamber.

II. WELDING

In the temperature and pressure range of interest, zirconium has satisfactory mechanical properties to make this substitution for stainless steel. The rub comes, however, in making a metallurgical joint to anything but zirconium, and even fusion welding of this sort must be done in such a way as to prevent adsorption of gases such as nitrogen. The usual processes for welding and brazing when used to join zirconium to stainless steel, for instance, generally produce a high concentration of intermetallic compounds in the heated zone. On cooling, such material is so brittle that it will often shatter on dropping a few feet to a hard floor.

The welding situation is not hopeless, however, since it was found that flash welding produced a very narrow region of intermetallics in the zirconium-stainless steel combinations, minimizing the brittle effect.

Flash welding is carried out by completing a low voltage, high current electric circuit through the surfaces to be joined. Local heating to the pressure welding temperature results from the rather high initial contact resistance. The soft, heated surfaces are simply pushed together in a continuous motion, forming the "upset" condition shown in Figure 2. For the safety device, external finishing will be required for assembly into the aluminum jacket. The inside lump can be left alone.

Flash welding needs special fixtures, but is well suited to volume production. Some stock is used in joining, so that about 2 times the tube wall thickness must be added to the cut length. An end finishing operation may be required to hold finished length tolerance.

III. BRAZING

In spite of warnings given in the Reactor Handbook - Materials, an alloy and a technique were found which produced satisfactory brazed joints between zirconium and stainless steel. A nickel-manganese alloy melting at about 1900° F was used, applied in a vacuum of about 10^{-5} mm. Hg. absolute pressure.

The tubular joint should be stepped as shown in Figure 3, with slight metal-to-metal interference on the diameters. The brazing alloy, commercially obtainable in wire form, can then be placed in a ring around the tube at the external joint. Local heating to the brazing temperature is carried out by enclosing the prepared joint in a quartz tube which is connected to a vacuum system, then positioning the inductor coil of a high frequency converter opposite the joint, outside of the quartz tube. This braze material has a very low surface tension when melted under these conditions, so that it will completely penetrate the tightly fitted joint and produce a vacuum tight connection having satisfactory mechanical strength.

This type of fabrication requires some precision machining, but little or no cleanup and sizing after the braze is completed. No special fixtures are required, but more time is required to produce a joint of this sort than a flash welded joint, for instance. The process is most suitable for limited production, using readily available facilities.

IV. SOLDERING

The thermal conductivity bridge between the fusible plug and the inner wall of the expansion chamber must be soft-soldered, since the danger of melting the fusible plug during this operation must be minimized. When zirconium is used for the expansion chamber, soft soldering presents quite a problem since the usual techniques and materials will not produce a metallurgical bond, the solder balling up rather than wetting the surface. Supersonic soldering equipment also fails to do the job. It is possible that a vacuum technique similar to that used for brazing would do the job, but initial preheat necessary to break down the oxide layer would likely melt the fusible trigger plug. Preheating and then positioning within the vacuum chamber would be difficult to say the least.

A possible solution lies with the process of depositing the solder with a heliarc machine, using argon gas, low welding current and the H.F. starting current. The solder must be so positioned in the arc that it is actually carried by the arc, rather than having it melt dropwise. Figure 4 is a photomicrograph, showing an apparent metallurgical bond. Once the zirconium has been "tinned" in this way, the conventional soldering technique of "sweating" can be used to complete the joint. Overheating and prolonged heating during "sweating" must be avoided to prevent rapid diffusion of the solder into the zirconium.

V. CONCLUSION

The substituting of zirconium tubing for stainless steel tubing in the expansion chamber of the Hanford safety device presents additional fabrication difficulties; these do not appear to be insurmountable, however, at this time.

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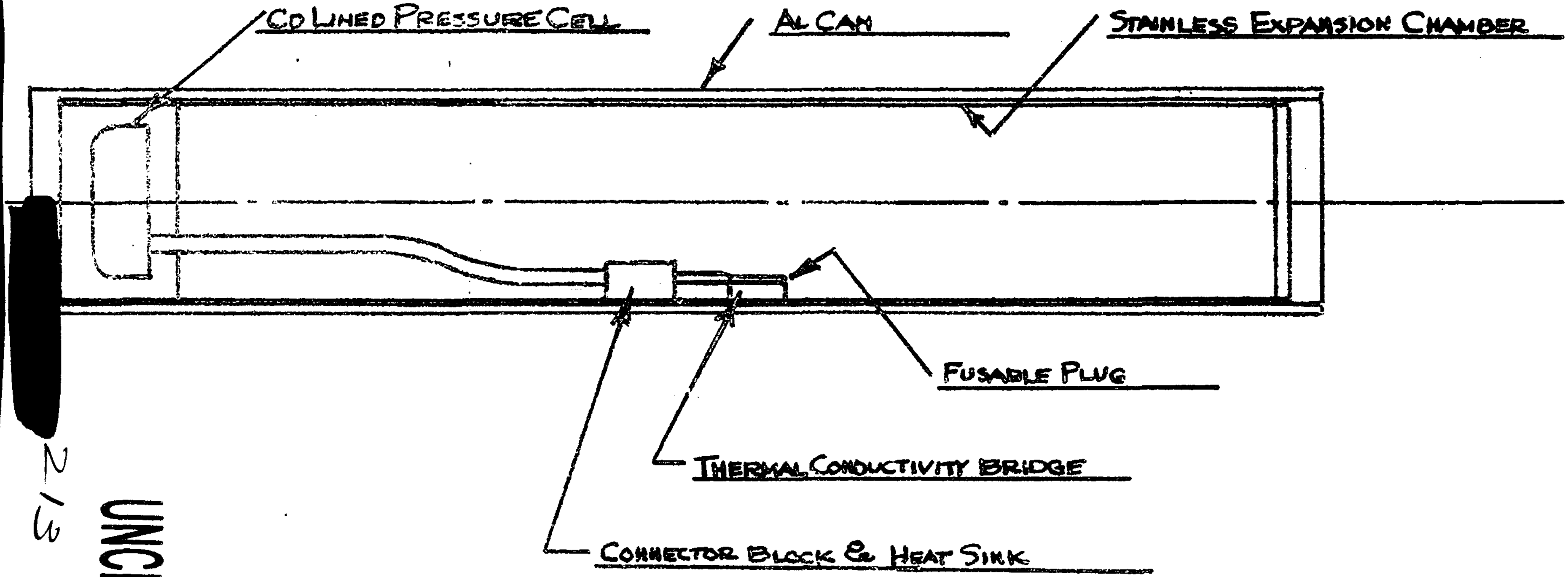

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FIGURE 1

GENERAL ARRANGEMENT ~ SAFETY DEVICE

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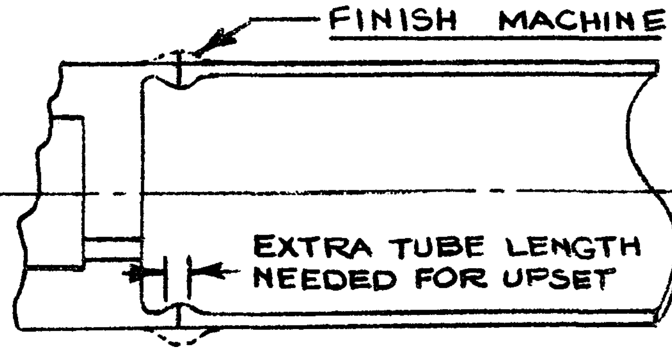

FIGURE 2 FLASH WELDED DESIGN

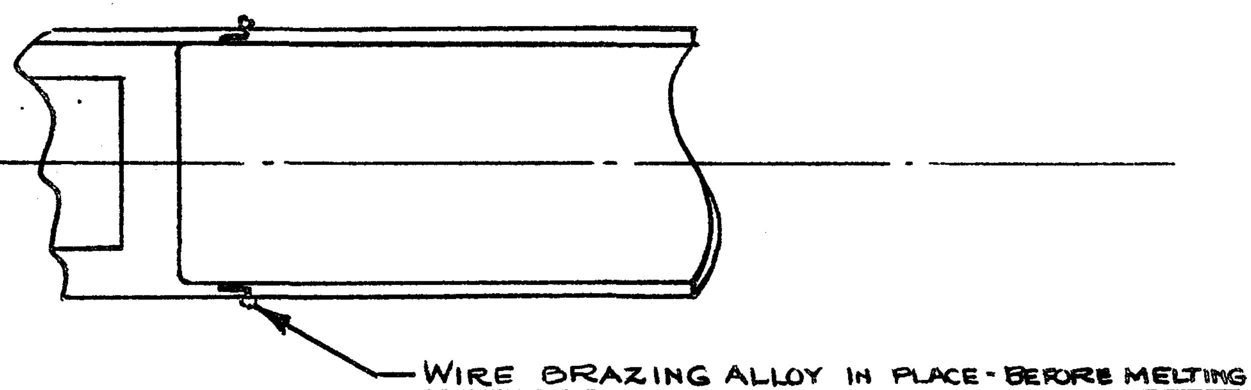

FIGURE 3 DESIGN FOR BRAZING

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