X-713-66-280

ALUMINUM O-RINGS

FOR HIGH VACUUM USE

Benjamin Seidenberg
Alfred J. Hobbs
J. J. Webb

Radiometry Group
Thermal Systems Branch
Spacecraft Technology Division

June 1966

GODDARD SPACE FLIGHT CENTER
Greenbelt, Md.

ALUMINUM O-RINGS

FOR HIGH VACUUM USE

Benjamin Seidenberg
Alfred J. Hobbs
J. J. Webb

Radiometry Group
Thermal Systems Branch
Spacecraft Technology Division

ABSTRACT

30860

Vacuum tests were performed on various annealed aluminum O-rings in an effort to find a type of metal ring that would be more economically attractive than the copper, indium, and gold rings widely used in vacuum systems today. The rings were constructed from aluminum welding rods, with the joints formed by various techniques of soldering, brazing, and welding. Three types, the butt-joint brazed, the wiped, dip-brazed, and the butt-welded, were found to hold a vacuum in the 10^{-6} torr range. A welded ring was also successfully tested on a G. E. system to 10^{-9} torr. The economic advantage of using these rings was proven when it was found that the cost of copper welded rings was approximately four times as great for comparable aluminum welded types.

Author

PRECEDING PAGE BLANK NOT FILMED.

TABLE OF CONTENTS

PRECEDING PAGE BLANK NOT FILMED.

ALUMINUM O-RINGS FOR HIGH VACUUM USE

Benjamin Seidenberg
Alfred J. Hobbs
J. J. Webb

Radiometry Group
Thermal Systems Branch
Spacecraft Technology Division

INTRODUCTION

During recent years, the rapidly expanding aerospace program has produced a tremendous increase in activity in the field of vacuum technology. Many systems have been developed for such purposes as environmental testing of spacecraft and components. The O-ring seals used in these systems have been manufactured primarily from oxygen-free copper, and also indium and gold to a more limited extent. However, recent increases in the price of copper, together with its increased limit of availability for commercial use, have made the cost of these rings relatively expensive. Indium is also economically unappealing and has the added drawback of being extremely toxic and dangerous to handle. Gold is by far the most expensive, and the user must also go through a cumbersome reclaimation process. Polymeric O-rings, such as viton or neoprene, have been used extensively in certain applications, but cannot be used in systems where ultra-violet radiation is involved because of the probability of scissioning[1]. Also, they cannot be used in systems that are baked out above 150°C.

Thus, a type of metal O-ring that would be comparable or superior in most respects to the above mentioned materials but more economical to manufacture is desirable. The purpose of this report is to describe an investigation of aluminum as a possible substitute for the more expensive types.

Aluminum was chosen as the most likely material because its physical properties are somewhat similar to those of copper, and also because of its relatively cheap cost and abundance in the earth's crust (1200 times that of copper). In addition, it is known that aluminum is easier to weld and braze for vacuum use than is copper.

[1]Scissioning is the breaking of chemical bonds in polymeric materials, usually by irradiation. The by-product is gas evolution, or out-gassing.

TEST PROCEDURE

The aluminum O-rings used in the tests were fabricated from type 1100 welding rods of .093 inch diameter. The rods were cut to the desired length and the ends machined to form a pin and socket joint. Several different techniques of brazing, welding, and soldering were used to make the joints. The rings were then annealed for softness (650°F for two hours) and shaped on a mandrel just prior to use.

The test chamber was a small stainless steel cylinder (see Figure 1) attached to a Veeco model MS-AB mass spectrometer helium leak detector, capable of maintaining a vacuum in the 10^{-6} torr range. Each of the rings was tested by placing it in the chamber with the glass port resting directly upon it. An outer gasket of viton or neoprene was then positioned between the glass and the outer metal seal. The order of assembly is illustrated in Figure 2 (without the polymeric ring).

All the rings were fabricated in one dimension so that the only variable was in the method of making the joint. The various methods are as follows:

A. Soft-soldered.

B. Stay-bright, low temperature, silver bearing soldered.

C. Aluminum soldered.

D. Butt-joint brazed.

E. Friction joint.

F. Butt-welded.

G. Wiped, dip-brazed.

The butt-joint brazed and butt-welded rings were joined by merely placing the two ends together, cut at an angle. All the others were pin and socket joints. (The above list should not be taken as all inclusive. Other welding techniques are in existence and could have been used.)

RESULTS

The soft-soldered ring initially held a vacuum of a few microns, but when the outer plate was further tightened, the glass port cracked radially. Post-test

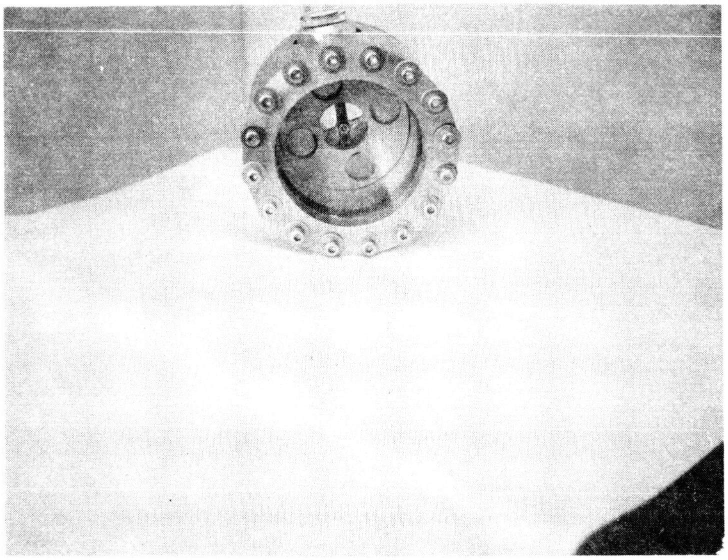

Figure 1. Assembled Vacuum Cell

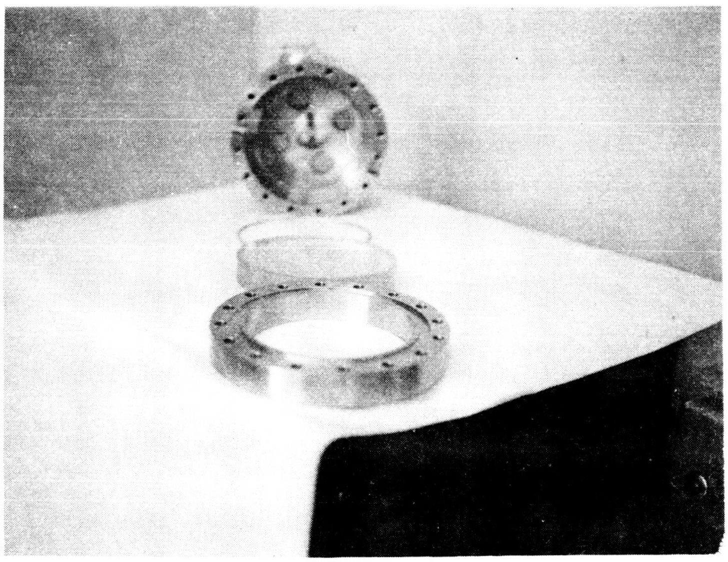

Figure 2. Order of Assembly of Cell

examination of the joint showed a large crack that was apparently caused by the initial tightening. This type of joint seems too brittle to withstand the stresses needed for vacuum use. A micro-photograph is shown in Figure 3.

The stay-bright, low temperature, silver bearing soldered joint was not even tested because the joint apparently did not take and was easily pulled apart before testing. It appears too difficult to produce a smooth joint with this technique. A picture of the joint is shown in Figure 4.

Similarly, the aluminum soldered joint was not tested for the same reason; i.e., a crack in the joint was found prior to the test. Its photograph is shown in Figure 5.

The butt-joint brazed ring successfully held a vacuum in the 10^{-6} torr range, and showed no leaks when placed in a helium atmosphere for 15 minutes. The picture is shown in Figure 6.

The ring formed by simply forcing the pin into the socket was tested but would not hold a vacuum below 100 microns. The aluminum would not deform enough to provide a good seal. The joint is shown in Figure 7.

The butt-welded ring was successfully tested down to the 10^{-6} range and no leaks were found with the helium probe and bag. No picture is available for this joint.

The wiped, dip-brazed ring was also successfully tested in the 10^{-6} range and again, no leaks were detected with the helium. The joint is shown in Figure 8. (It is important to note that the dip-braze must be wiped to eliminate the lump that forms at the joint.)

In addition to the Veeco tests, a 21 inch diameter aluminum ring was fabricated and used in a G. E. vacuum system that contained samples of thermal control coatings being irradiated with a xenon source. Operating in the 10^{-9} torr range, the system appeared to be similar in every respect to the performance previously attained with OFHC copper O-rings. After a bake-out of 230°C, the aluminum ring showed less oxidation than normally occurs with the copper types.

DISCUSSION

It seems apparent that the joints formed with the soldering and friction techniques were not suitable for vacuum use. Some were so brittle that they developed cracks even prior to testing, and the ones tested required too much

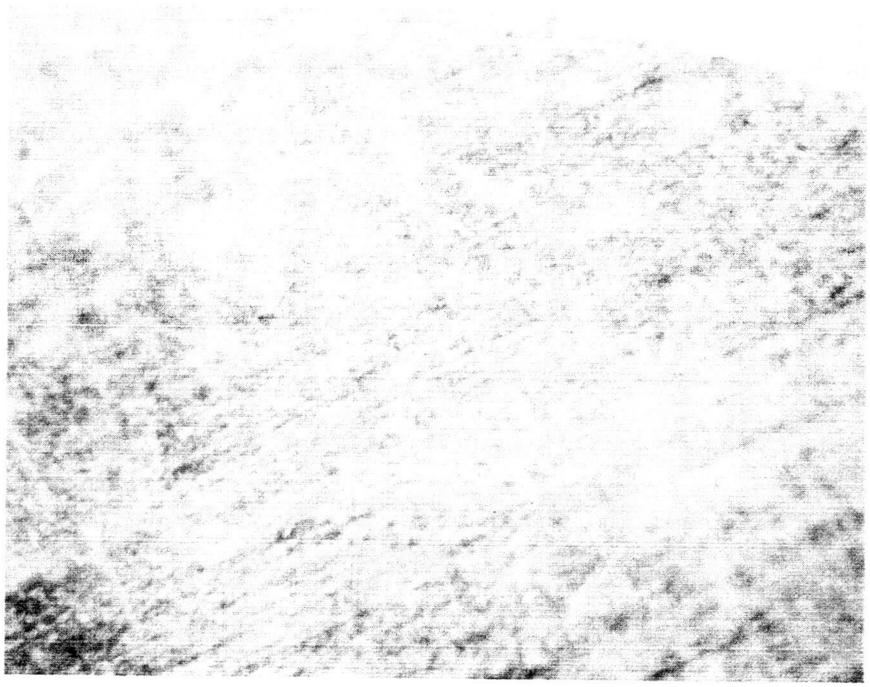

Figure 5. Aluminum Soldered Joint

Figure 6. Butt-Joint Brazed Joint

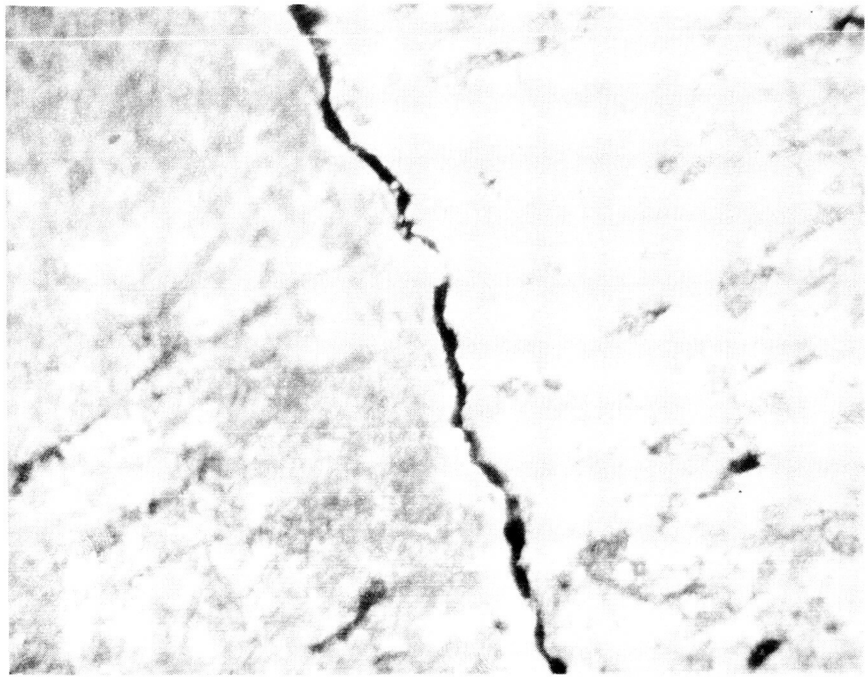

Figure 3. Soft-Soldered Joint

Figure 4. Stay-Bright, Low Temperature, Silver Bearing Soldered Joint

Figure 7. Friction Joint

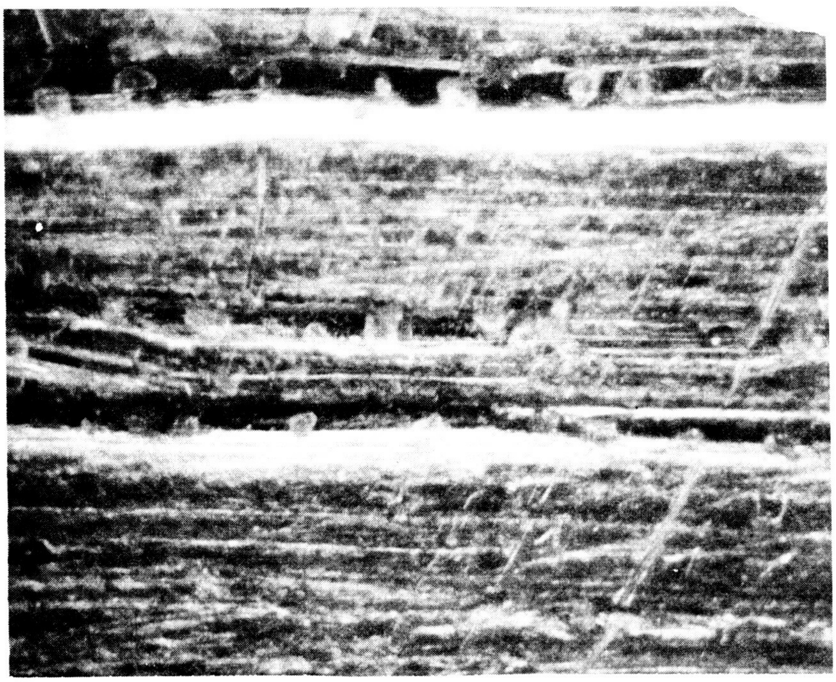

Figure 8. Wiped, Dip-Brazed Joint

pressure to form even a slight seal. However, the brazed and welded joints held a satisfactory vacuum and seem suitable for general vacuum use.

Some difficulty was encountered with the polymeric outer ring when the tests were first begun. The original viton ring was not large enough (in cross section) and consequently too much pressure was applied to the glass plate in and effort to obtain a seal. Teflon was then tried but it too was unsuccessful. Once the proper diameter was obtained, no further trouble resulted from either the viton or the neoprene which was later used.

The diameter of the aluminum rings was found to be fairly critical. The ring cannot be allowed to overhang the glass port or a poor seal will result, and the glass may even crack. Making the rings of a slightly smaller diameter easily solved the difficulty.

CONCLUSION

From the results obtained with the Veeco and G. E. tests, it seems reasonable to conclude that O-rings made from relatively pure (99%) aluminum and joined by either brazing or welding can be satisfactory substitutes for the more expensive metals in most instances. It was determined that cost of manufacturing a copper O-ring is approximately four times that of making a comparable aluminum ring.[2] A search of the literature and personal communications with vacuum manufacturers failed to discover any reason for not using aluminum except where extremely high (above 450°C) bake-out temperatures are encountered

It should be recognized that no attempt has been made in this report to make a thorough analytical study, but rather to merely show the feasibility of using aluminum O-rings as a substitute for those made from copper, indium, and gold.

ACKNOWLEDGMENT

The authors would like to acknowledge the assistance rendered by C. Madison, B. Paxson, and W. Hargrove of T & E Division, and W. Jenkins and A. Marshall of Fabrication Division.

[2] Price comparison – Linde Division, Union Carbide.