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A simple aluminum gasket for use with both stainless steel and aluminum flanges*

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A technique has been developed for making aluminum wire seal gaskets of various sizes and shapes for use with both stainless steel and aluminum alloy flanges. The gasket material used is 0.9999 pure aluminum, drawn to a diameter of 3 mm. This material can be easily welded and formed into various shapes. A single gasket has been successfully used up to five times without baking. The largest gasket tested to date is 3.5 m long and was used in the shape of a parallelogram. Previous use of aluminum wire gaskets, including results for bakeout at temperatures from 20 to 660°C, is reviewed. A search of the literature indicates that this is the first reported use of aluminum wire gaskets for aluminum alloy flanges. The technique is described in detail, and the results are summarized.

I. INTRODUCTION

Although the use of aluminum wire gaskets to seal vacuum components began in the early 1950s, these gaskets have never been widely used and have been applied only to sealing stainless steel flanges. Since the base material is inexpensive, the fabrication is relatively easy, and the application is straightforward, it is difficult to understand why such gaskets have not been much more widely used. This lack of application may be attributed to problems encountered during baking. A method has been found to alleviate these problems, thereby expanding the possibilities for use of aluminum wire gaskets. In addition, the use of such gaskets with aluminum alloy flanges has been shown to be practical. This paper reviews previous work, describes the fabrication procedure, presents the results of experiments using aluminum wire gaskets with both stainless steel flanges and aluminum alloy flanges, and finally reviews methods for the general use of aluminum wire as a sealing material as developed in this study.

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II. REVIEW OF PREVIOUS WORK

In 1966, Roth provided a comprehensive review of sealing techniques, which included aluminum wire gaskets.¹ The first use of aluminum gaskets found by the author in the literature was described by Baldock and Sites.² It appears that Holden et al.³ of Edwards High Vacuum International, were the first to make extensive use of aluminum wire gaskets; further work by this group is reported in Refs. 4 and 5. Spees et al. reported the successful use of aluminum gaskets in liquid helium cryogenic systems,⁶ and other groups⁷⁻⁹ have also successfully used these gaskets in varying conditions.

The Edwards group studied the sealing capabilities of aluminum wire gaskets used with stainless steel flanges, including the effects of thermal cycling and surface finish. They found that at temperatures above 250°C the aluminum adhered to the flange surfaces and the flanges had to be pried apart on disassembly. Their explanation of the effect is that once the gasket is compressed and oxygen is removed from the sealing area, interdiffusion between the aluminum and the steel starts at about 250°C and forms a brittle intermetallic alloy. In addition, they observed that "the breaking strength of the joint depends upon the surface finish of the flanges and is greater the smoother the finish" (Ref. 4, p. 173). They also found that the aluminum gaskets sealed to temperatures approaching the melting point of aluminum. The main drawback that they found for this arrangement was that if the temperature was not raised to at least 250°C, to ensure that some interdiffusion occurred, then the joint leaked when the flanges were cooled.

III. FABRICATION OF ALUMINUM GASKETS

Gaskets have been fabricated at Oak Ridge National Laboratory (ORNL) from 0.9999 pure aluminum wire drawn from a 150-cm-diam ingot to a diameter of 3 mm (supplied by Kamis, Inc.). The nominal cost was between \$3 and \$5 per foot. To make a gasket, the wire is cut to the needed length plus about 2 mm, and the wire ends are joined by first squaring the ends of the wire with a file and then welding the ends together in a common bandsaw blade welder. After welding, the joint area is annealed by passing current through it, as is done to anneal bandsaw blades that have been butt welded. The welding process produces a joint with an enlarged diameter that must be filed to near the original diameter and then smoothed to a good finish, e.g., a 63 finish (63 microinches average deviation from the mean surface). An example of a welded joint is shown in Fig. 1.

Because of its high purity and minimum hardening during forming, the "as received" aluminum material is very soft: it can easily be deformed with a fingernail. It is easily work-hardened, so care must be taken to keep bending to a minimum. The annealed region in the weld area is somewhat softer than the remainder of the gasket and will bend more easily. With this precaution, the gasket may be easily formed into almost any shape. A minimum bending radius of about $4\times$ the wire diameter usually works well, although this depends to some extent on the flange finish and the available force that can be applied by the flange bolt system.

IV. EXPERIMENTAL RESULTS

A. Stainless steel flanges

The Advanced Toroidal Facility (ATF) is a magnetic fusion energy experiment; its vacuum system is described in detail in Ref. 10. The toroidal vacuum vessel, shown in Fig. 2, has 12 large outer ports, each in the shape of a parallelogram. The flange system for these ports was designed to use Helicoflex gaskets (Helicoflex Co., Columbia, S.C.). These gaskets have been generally adequate for the experimental conditions; minor problems have been solved by using a backup Viton O-ring with an auxiliary pumping system between the two gaskets. The main drawback is the expense of the Helicoflex gaskets, which can be used only once. The need for frequent openings that arises from the experimental nature of ATF suggested that a different type of seal might be more economical.

The first test of aluminum wire gaskets for ATF was accomplished using a spare ATF outboard flange in a vacuum test stand. These stainless steel flanges are 0.72-m by 1.05-m parallelograms; they are machined flat but have some curvature (due to residual stress) and a surface finish of about 63. The test gaskets were prepared as described in Sec. III. For the first test sequence, the gasket was held in place by using standard aluminum foil cut to a width of about 1 cm, looped around the gasket at appropriate places and taped to the base flange outboard of the gasket, as illustrated in Fig. 3. The flange bolts were $1/2 \times 13$ (0.5 in. in diameter with 13 threads per inch) and used nuts. High-temperature grease was applied to the bolts to prevent freezing during annealing and to provide for reliable and reproducible torque measurements. The bolts were spaced every 6.5 cm. Initial sealing was obtained by applying 25 N•m torque to the bolt-nut combination. The leak detection sensitivity for the system was better than 10^{-8} mbar•L/s. After this seal was successfully tested, the bolts were loosened and the flanges separated. Then the bolts were retightened until a leak-free seal was obtained. The torque required to

accomplish this was about 38 N·m. This retightening reduced the gasket thickness by about 0.25 mm. This test was repeated successfully three more times and was terminated because the gasket became very thin and required excessive torque to seal. An additional torque of about 15 N·m was required to reseal the joint each time, reducing the thickness of the gasket by about 0.25 mm.

Because the ATF flange systems receive a nominal bakeout of about 150°C during conditioning of the vacuum vessel, tests were done to evaluate the gasket seal properties as a function of bake temperature. The flange system was tested from room temperature to 250°C, the limit of the existing test system. The flange system sealed on heating to 250°C, but leaks occurred on cooling when bakeout temperatures exceeded 125°C.

In an attempt to ameliorate this condition, conical spring washers (supplied by Rollex Co., Hillside, N.J.), also known as Belleville washers, were placed under the heads of the bolts and under the nuts. These washers can be used in series to increase the compression distance and/or to increase the compression force, as shown in Fig. 4. When adjacent washers oppose each other, the compression length is increased [Fig. 4(a)]; when adjacent washers are parallel to each other, the compression force is increased [Fig. 4(b)]. Conical spring washers are available in several materials, which respond differently to different environments; some materials show very small changes even at temperatures exceeding 500°C. With these washers, the flange system could be baked and cooled without the creation of leaks. This effect has also been observed by Holland.¹¹

B. Aluminum alloy flanges

A series of tests was performed using a standard 8-in. Conflat™-style stainless steel flange and a 6061 T6 aluminum alloy flange of the same dimensions but with surfaces machined flat to a finish of 63 (the same as that of the large ATF flange). The gasket was made by the technique described in Sec. III and had an i.d. of 15 cm, which placed the gasket just inside of the knife edge of the Conflat flange. Flange bolts, with nuts, were placed in every other hole to test the need to use the full number of bolts (16). Excellent results were obtained using only eight bolts. Initial sealing was obtained with a torque of 35 N·m. As in the case discussed in Sec. IV.A, the gasket could be reused about four times before it became too thin. The aluminum alloy flange was not deformed by sealing with the wire gasket.

The results of baking the aluminum flange with the wire gasket seal were similar to those obtained with stainless steel flanges and are summarized as follows: No leaks were produced by baking to temperatures no higher than 125°C and then cooling to room

temperature; however, at bake temperatures above 125°C leaks did occur on cooling. This problem could be alleviated using conical spring washers under the bolt heads and nuts, as described in Sec. IV.A. This approach worked well to baking temperatures of 250°C, the upper limit for this experimental arrangement. When the flanges were disassembled, no gasket residue was observed on the aluminum flange. (Trace amounts of aluminum were observed on the stainless steel flange after disassembly following baking at 250°C.)

V. SUMMARY AND CONCLUSIONS

Aluminum wire gaskets have been successfully used with both stainless steel and aluminum alloy flanges. Initial sealing required between 25 and 35 N•m of torque on the bolt system, with an increment of about 15 N•m required for each subsequent sealing. The gasket compression that occurred during resealing was about 0.25 mm. No problems were encountered for baking to temperatures up to 125°C. Above this temperature, leaks occurred on cooling but could be eliminated by using conical spring washers.

This study, although limited in scope, provides two examples that differ in many respects; as such, it demonstrates that aluminum wire gaskets should prove very useful in a variety of cases, especially when metal gaskets are desirable but cannot be obtained in the correct shape or are prohibitively expensive. It is hoped that the results of this work will allay previous concerns on use of aluminum wire gaskets, especially with regard to bakeout, and will provide a guide for their effective use.

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REFERENCES

- ¹A. Roth, Vacuum Sealing Techniques (Pergamon, Oxford, 1966).
- ²R. Baldock and J. Sites, Phys. Rev. **81**, 294 (1951).
- ³J. Holden, L. Holland, and L. Laurenson, J. Sci. Instrum. **36**, 281 (1959).
- ⁴L. Holland, Transactions of the AVS National Vacuum Symposium 1960 (Pergamon, Oxford, 1961), p. 168.
- ⁵L. Elsworth, L. Holland, and L. Laurenson, J. Sci. Instrum. **37**, 449 (1960).
- ⁶A. H. Spees et al., Rev. Sci. Instrum. **28**, 1090 (1957).
- ⁷M. J. Higatsberger and W. W. Erbe, Rev. Sci. Instrum. **27**, 110 (1956).
- ⁸R. S. Nelson, J. Sci. Instrum. **37**, 358 (1956).
- ⁹R. P. Henry and I. C. Blaive, Advances in Vacuum Science and Technology (Pergamon, Oxford, 1960), p. 345.
- ¹⁰R. A. Langley, J. Vac. Sci. Technol. A **6**, 1288 (1988).
- ¹¹L. Holland, J. Sci. Instrum. **38**, 339 (1961).

FIGURE CAPTIONS

Fig. 1. Photograph of weld joint area.

Fig. 2. The ATF vacuum vessel.

Fig. 3. Aluminum alloy (6061-T6) flange with compressed gasket and aluminum foil retainer pieces.

Fig. 4. Conical spring washer configurations. (a) Compression length is increased to 6× that of one washer. (b) Compression force is increased to 4× that of one washer.

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CONICAL SPRING WASHER CONFIGURATION

(a)

INCREASE
COMPRESSION
LENGTH

(b)

INCREASE
COMPRESSION
FORCE

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