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# A SIMPLE LOW-PRESSURE BURST DIAPHRAGM FOR ULTRA-HIGH VACUUM APPLICATION*

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## SUMMARY

The purpose of this note is to report results of tests on a simple and effective low-pressure burst diaphragm. Rupture of the diaphragm is achieved when on deflection it makes electrical contact with a puncture needle between which 110 volts ac are maintained in series with a 4-amp fuse. Also a convenient method of sealing thin foil diaphragms of both copper and aluminum to all metal vacuum systems was found in developing the burst diaphragm.

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## I. INTRODUCTION

Instrumentation sensitive to pressure differences such as mechanical manometers, thin diaphragms and glass envelopes must have some form of protection from excessive pressure or risk being damaged. Also, situations exist when pressure buildups within closed systems could prove dangerous to personnel. Both of these considerations led to the development of this burst diaphragm system; in one case for use in a gas-mixing system, and in another on a closed cryogenic pumping system.

## II. THE DIAPHRAGM SEAL

Figure 1 is a cross sectional view of the burst diaphragm assembly. Table I lists the components of this assembly in detail. The flanges, (2) and (4), are commercial items using conventional crushed copper gasket seals of the type used extensively here at SLAC. Of course, flange (2) was initially blank and had to be machined to accommodate the vacuum manifold (1) and the diaphragm support bushing (3).

Initially an attempt was made to braze thin copper diaphragms to the commercial gaskets (5). This was never completely successful as a vacuum seal, due in part to the adverse annealing effect of the braze cycle.

Thin aluminum and gold foil apparently have been used with some success as a vacuum gasket between hard metal flanges.[1] At the same time, by using discs instead of foil washers, the seal could serve as a diaphragm. However, special seal flanges would have to be machined and tested. Also problems of shearing of gaskets and wrinkling of the diaphragms tend to seriously complicate matters from a reliability standpoint as a seal, and for repeatability as a burst diaphragm.

As another approach a 2-mil-thick aluminum disc, the burst diaphragm, was mechanically sandwiched between the needle mounting flange (4) and the copper gasket (5). It was felt that the copper gasket would yield enough to prevent shearing the foil, and as this gasket was deformed by the radius knife edge it would tend to stretch the diaphragm into a wrinkle-free working surface. On first leak-checking this seal, a slight leak was observed ($10^{-8}$ - $10^{-7}$ atmos - cc/sec of He @ $25^{o}$C). The flange bolts were tightened more securely and a vacuum-tight seal was achieved (i.e., leak rate < $10^{-9}$ cc/sec).

As a final approach the diaphragm was mechanically sandwiched between the manifold flange (2) and the copper gasket (5). In this case there is only one vacuum seal to be achieved, where in the first approach two vacuum seals must be achieved.

A total of twelve such seals were made, six using 2-mil copper foil and six using 2-mil aluminum foil, during the course of puncture tests. Without exception all twelve seals were mass spectrometer leak-tight on the first try (i.e., without additional securing of flange bolts). Three different assemblies as shown in Fig. 1 were used in these tests, four seals made on each assembly. A torque wrench was not used and just the normal care taken in uniformly tightening the flange bolts.

## III. BURST DIAPHRAGM TESTS

Table II summarizes all test results. The first two tests were conducted without voltage applied between the puncture needles (7) and the needle frame (6). In the first test a furnace-brazed copper gasket and diaphragm were used. The diaphragm punctured readily. The second diaphragm, the aluminum foil bolted between flange (4) and the gasket (5), gave first indication of puncture at a $\Delta P$ (pressure difference ) of 8 psi. However, even with a $\Delta P$ of 35 psi only slight puncture occurred and not the pronounced bursting effect hoped for.

The following twelve tests, using diaphragms mechanically sandwiched between flange (2) and the copper gasket, indicated that for reliable operation voltage should be used on the needle, and that at minimum a 4-amp fuse be used in the circuit with 2-mil foil. Results of these tests are numbered 3 through 14 of Table II.

In each case location of the needle with respect to the diaphragm was done by eye and estimated to be spaced initially at approximately 10 mils. Variations in rupture pressure differences which were indicated with the same material were probably due to differences in gap spacings. Micrometer mounting of the needle and use of different foil thicknesses would probably afford finer control of burst pressures if required.

## IV. CONCLUSIONS

A simple and apparently very reliable method of sealing thin aluminum and copper diaphragms to all metal systems has been given. Also tests indicate that reliable diaphragm rupture is achieved with copper diaphragms at pressure differences of less than 1.4 psi. The aluminum diaphragms tended to burst at pressures three to four times higher.

## REFERENCE

1. A. Roth, Vacuum Sealing Techniques (Pergamon Press, New York, 1966); p. 440.

TABLE I. Burst Diaphragm Assembly Parts List

| Part Number | Item | Material and Model Number |
|---|---|---|
| 1 | Vacuum Manifold | 1 inch o.d., 304 Stn. Stl. Tubing |
| 2 | Manifold Flange (Reworked Blank) | 304 Stn. Stl., ULTEK CURVAC #48-065 or equiv. |
| 3 | Diaphragm Support Bushing | 304 stn. stl. |
| 4 | Needle Mounting Flange | 304 Stn. Stl., ULTEK CURVAC #48-066 or equiv. |
| 5 | Copper Gasket | OFHC Copper, ULTEK #48-109 or equiv. |
| 6 | Needle Mounting Frame | 304 Stn. Stl. |
| 7 | Puncture Needle | Drill Rod |
| 8 | Needle Insulator Bushing | WESGO AL-300, PF-700-233-01 (SLAC) |
| 9a | Burst Diaphragm | 2-mil OFHC Copper |
| 9b | Burst Diaphragm | 2-mil Aluminum (Kaiser Alloy #5056, 97.5% pure with impurities primarily magnesium). |

TABLE II. Burst Diaphragm Test Results

| Test Number | Diaphragm Material | Approx. $\Delta P$ At Puncture (psi) | Fuse Size (amps) | Approx. Dia. Of Puncture (inches) | Comments |
|---|---|---|---|---|---|
| 1 | Cu | 5.0 | --- | Not Measured | Gasket and foil furnaced-brazed. Voltage not applied to needle. |
| 2 | $A\ell$ | 8.0 | --- | 0.010* | Pressurized to $\Delta P$ of 35 psi* after initial leak. Voltage not used. |
| 3 | $A\ell$ | $\leq 1$ | 1-1/4 | 0.045 | |
| 4 | $A\ell$ | 5.5 | 1-1/4 | 0.045 - 0.050 | |
| 5 | Cu | 0.5 | 1-1/4 | 0.005 - 0.010 | |
| 6 | $A\ell$ | 3.0 | 4 | 0.105 | At start used 1-1/4 amp fuse but did not rupture. Then used 4 amp fuse. |
| 7 | $A\ell$ | 3.9 | 4 | 0.110 | |
| 8 | Cu | 0.7 - 0.8 | 4 | 0.080 - 0.090 | "Touched Up" all needle points after this test. |
| 9 | Cu | 0.6 | 1-1/4 | minute | |
| 10 | Cu | 1.2 | 4 | 0.075 - 0.085 | Also second smaller hole (~20 mil) next to larger hole. |
| 11 | $A\ell$ | 1.3 | 4 | 0.100 | |
| 12 | Cu | 1.3 | 4 | 0.060* | *Two holes of ~60 mil and one of ~25 mil. |
| 13 | $A\ell$ | 4.2 | 4 | 0.095 - 0.120 | Also many smaller holes about main puncture. |
| 14 | Cu | 1.2 | 4 | 0.045 | |