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VACUUMTIGHT AT 77°K

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ABSTRACT

A temperature- and pressure-actuated plastic seal is described. This seal may be used with optical windows that have greater or lesser thermal coefficients of expansion than the material of the flange by which the window is held. These seals showed very low gas leakage at 60 atmospheres test pressure at 77°K.

The cryogenist is often faced with the problem of making dismountable vacuum seals between materials of greatly dissimilar coefficients of expansion, as metal-to-glass or metal-to-plastic. Usually he adopts a technique long employed in high-vacuum work by using two leaky seals (which are the best that he has) in series and maintaining a reasonably low pressure in the space between the two seals by means of a small mechanical vacuum pump.

Glass windows in liquid-hydrogen bubble chambers are commonly sealed by means of two indium gaskets in series and have a maintained pressure of 10 to 1000 μ in this pump-out space.[1] Plastic windows in bubble chambers have been sealed by a somewhat similar technique with two gaskets in series and differential pumping in the interspace.[2]

A recent physics experiment[3] required the use of 130 liters (STP) of He^3. This gas was to be held at 30 atmos pressure at 77°K in a target vessel 6 inches in diameter with optical windows at each end. It was desirable to use one seal of great reliability on each window rather than the typical two-seal system to avoid the awkwardness of scavenging He^3 from the gas pumped from the intergasket space.

The scheme shown in Fig. 1 was tried for a Pyrex window. The metal ring gave a slight initial compression to the Kel-F O ring. This system showed a small vacuum leak at room temperature; when cooled to 77°K the leakage decreased to less than 1×10^{-7} atmos-cc/sec. For this geometry the stainless steel flask shrinks 0.014 inch more than the Pyrex disk when both are cooled to 77°K. That the seal is also pressure actuated was shown during the proof test when the assembly was tested to 60 atmos internal pressure. Each increase in internal pressure caused a transient increase in leak rate to 10^{-6} atmos cc/sec, then in a few minutes the O ring would find a new seat and the leak rate would fall to less than 1×10^{-7} atmos cc/sec.

Because of the experimenters' requirements for windows of lesser density than Pyrex, the arrangement of Fig. 2 was devised to use Plexiglas windows. The seal between the Plexiglas window, the Kel-F O ring, and the stainless steel vessel is shown enlarged in Fig. 3. While the seal on the Pyrex window worked the first time it was tried, the seal on the Plexiglas window worked only after long and arduous development.

It was necessary to have finishes of near optical quality on the sealing surfaces of the metal flange, the Kel-F O ring, and the cavity of the Plexiglas window. The stock for the Plexiglas windows was selected for minimum internal stress by means of a portable polariscope. The finished windows were similarly inspected before and after assembly. The window was rough-machined slowly to minimize local heating and over-stressing of the Plexiglas; the window was then annealed and finish-machined very carefully. The O rings were made from "amorphous" or "quick-quenched" Kel-F because of the improved low-temperature physical properties of that type of Kel-F over those of the "crystalline" or "slow-cooled" type.[4] These O rings were sized with excruciating care to be tangent to both the flat and the 15 deg tapered surface of the stainless steel vessel and also to be a slip fit in the window cavity. Grooves were cut in the O ring to give it more flexibility. Belleville washers were used under the window hold-down bolts to maintain preload during axial shrinkage of the Plexiglas. Teflon shims on both surfaces of the windows minimized friction during radial shrinkage. These shims were sized to give 0.017 inch axial compression on the O ring when assembled.

For this geometry the radial shrinkage of the Plexiglas is 0.044 inch more than the shrinkage of the stainless steel. This shrinkage of the Plexiglas over the stainless is divided as follows: from room temperature down to 180°K (the glass transition temperature of Kel-F) the differential shrinkage of the

Plexiglas is 0.029 inch; from 180°K to 77°K the Plexiglas shrinks an additional 0.015 inch more than the stainless steel. Since the stainless steel vessel was cooled by direct contact with liquid nitrogen, the temperature of the metal flange was always less than that of the Plexiglas window. From 10 to 15 hours were taken to warm the seal to prevent the flange from over-stressing the window by expanding more rapidly than the Plexiglas.

It is hypothesized that the vacuum seal is axial on the O ring at room temperature because of the initial 0.017-inch compression, and that during cooldown the point at which the seal is made shifts around the circumference until the vacuum seal is radial on the O ring at final cooldown. The seal was helium leak-tested both warm and cold at pressures to 60 atmos. Typical leak rates were less than 1×10^{-7} atmos cc/sec. During cooldown there was a transient increase in leak rate by a factor of 100 to 1000, which usually occurred at the maximum temperature difference between the metal flange and the Plexiglas window.

Admittedly the development of this seal was more work than had been anticipated, but the seal performed excellently during the physics experiment for which it was built.

FOOTNOTE AND REFERENCES

*This work was done under the auspices of the U. S. Atomic Energy Commission.

1. L. R. Lucas and H. P. Hernandez, Rev. Sci. Instr. 30, 941 (1959).
2. K. V. Martin et al., Advan. Cryog. Eng. 9, 146 (1963).
3. N. H. Lipman et al., Phys. Rev. Letters 11, 23 (1963).
4. R. Mowers, Advan. in Cryog. Eng. 6, 627 (1960).

FIGURE LEGENDS

Fig. 1. Vacuum seal on Pyrex window.

Fig. 2. Vacuum seal on Plexiglas window.

Fig. 3. Enlarged view of Kel-F O-ring seal on Plexiglas window.

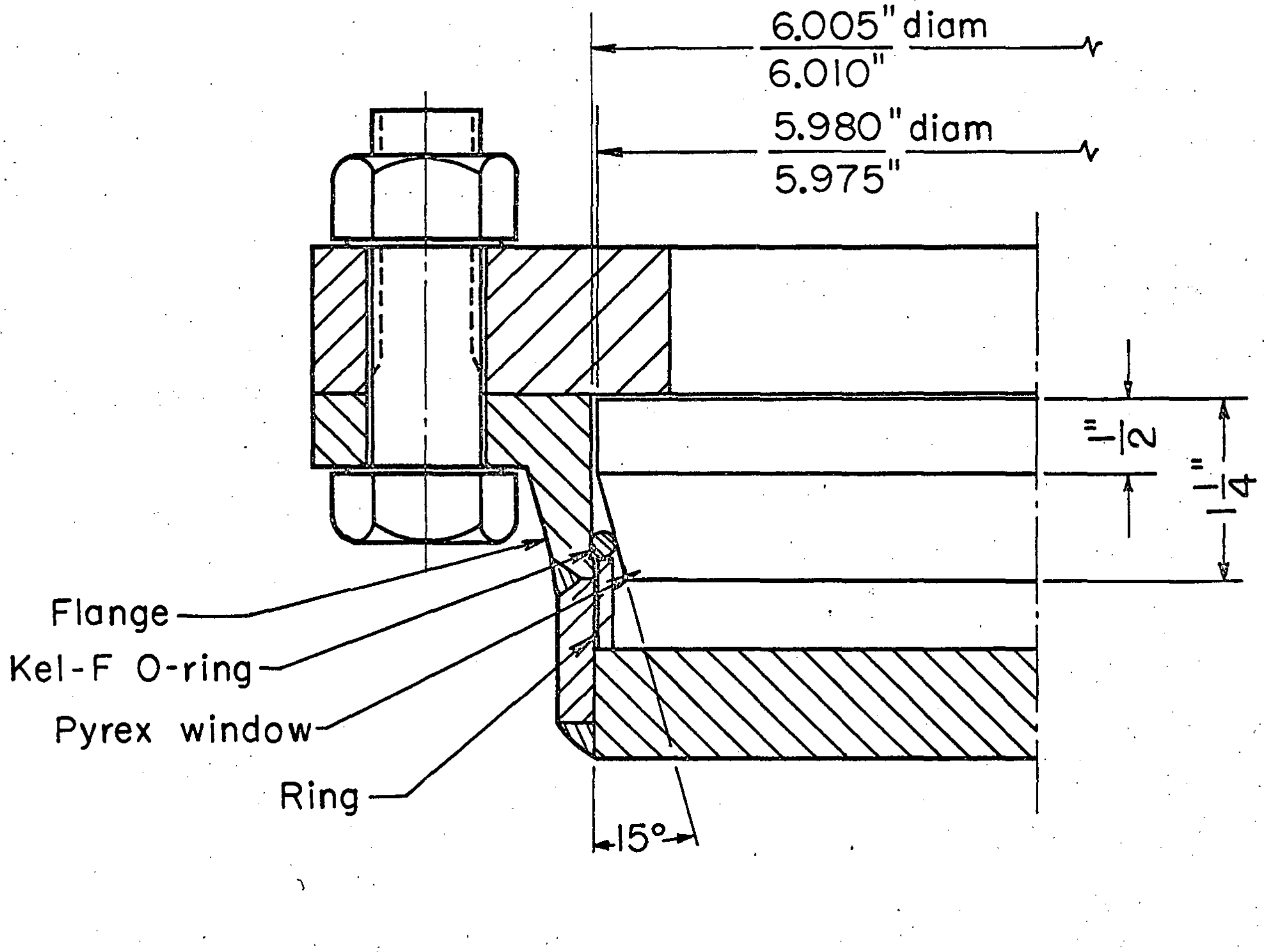

6.005" diam
6.010"
5.980" diam
5.975"
1"/2
1 1"/4
Flange
Kel-F O-ring
Pyrex window
Ring
15°
MUB-4929

Fig. 1.

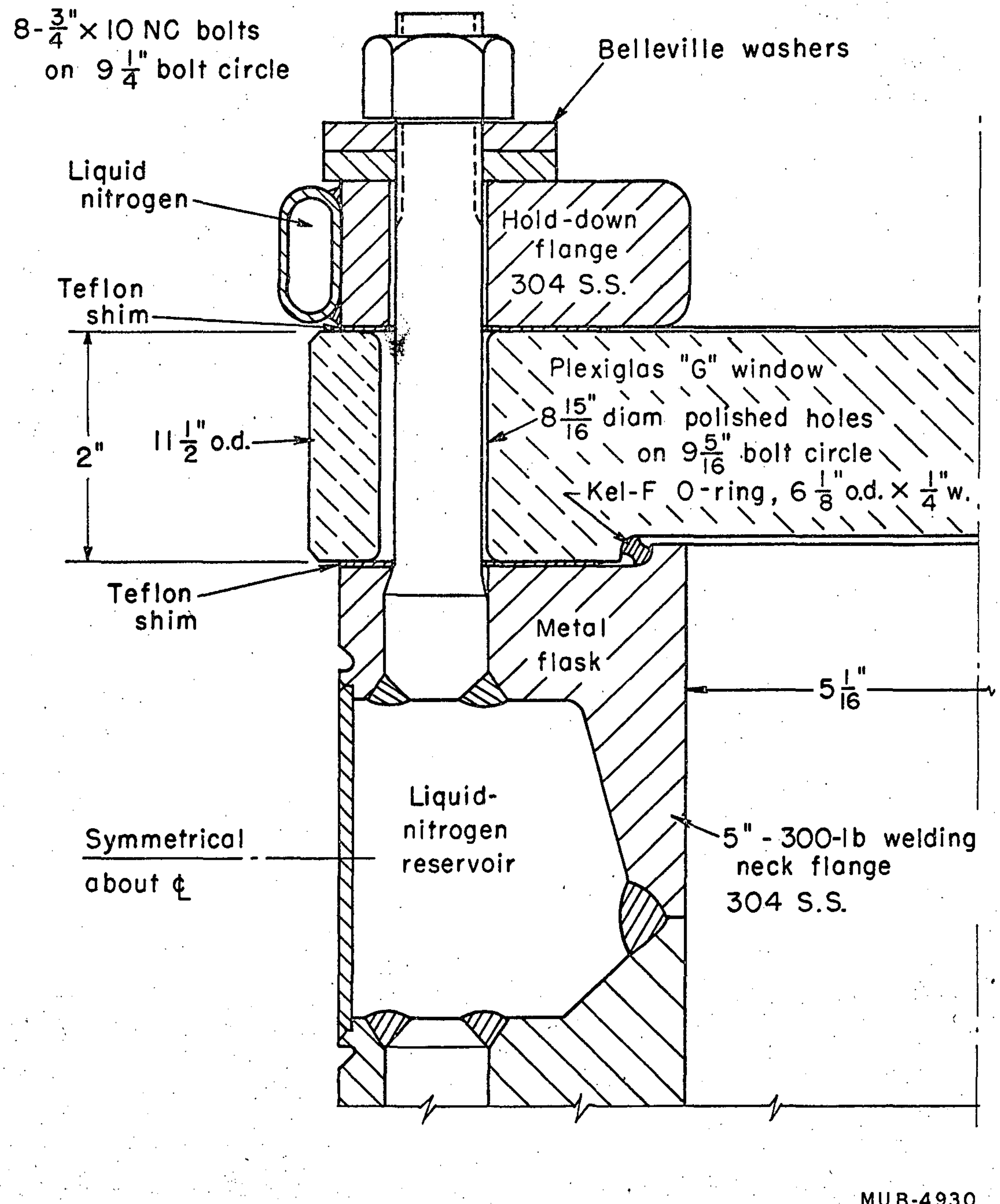
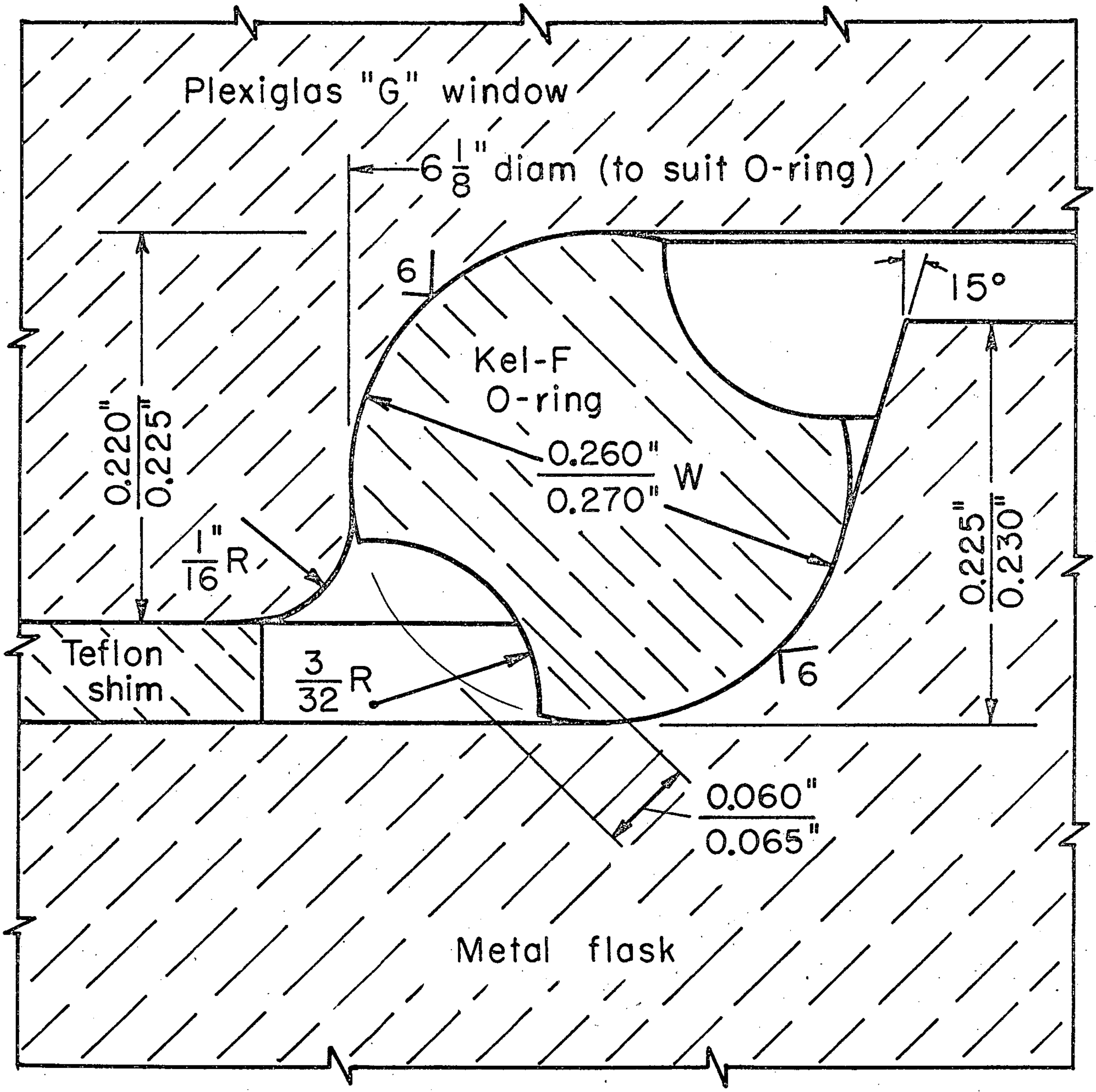

8-3/4" × 10 NC bolts
on 9 1/4" bolt circle
Belleville washers
Liquid
nitrogen
Hold-down
flange
304 S.S.
Teflon
shim
Plexiglas "G" window
8 15/16" diam polished holes
on 9 5/16" bolt circle
Kel-F O-ring, 6 1/8" o.d. × 1/4" w.
2"
11 1/2" o.d.
Teflon
shim
Metal
flask
5 1/16"
Liquid-
nitrogen
reservoir
Symmetrical
about ℄
5" - 300-lb welding
neck flange
304 S.S.
MUB-4930

Fig. 2.



MUB-4931

Fig. 3.