Radioactive Material Package Seal Technology Experiments*

M. Kincy and D. Humphreys

Sandia National Laboratories, Albuquerque, New Mexico, United States of America

INTRODUCTION

Preliminary experiments have been conducted to determine the performance of several classes of seal materials under conditions representative of radioactive material package environments. Measurements of helium leak rates of seals in fixtures exposed to various environments are used to compare seal materials and seal geometries. In addition, material properties of the seals are being measured to attempt to correlate sealing performance to specific material characteristics. Initial experiments have focused on temperature effects on elastomeric O-rings.

TEST PARAMETERS

Many parameters influence the sealing performance of static seals. The following list identifies several that were considered to establish test variables for the O-ring experiments.

<u>Gland Design</u>
- Configuration:
  - Face seal
  - Bore seal
  - Tapered glands
- Compression (squeeze)
- Groove width
- Flange surface finish
- Thermal expansion

<u>Elastomer Material Properties</u>
- Durometer hardness
- Compressive modulus
- Low temperature retraction
- Low temperature brittleness
- High temperature behavior
- Thermal expansion coefficient
- Fatigue resistance
- Permeability

<u>Environments</u>
- Pressure
- Temperature
- Radiation
- Contained substances
- Assembly: sliding, stretch, lubrication

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After reviewing these parameters, the following test variables were selected for initial tests.

Geometry. O-rings with a nominal inside diameter of 12 inches and cross section diameters of 0.139, 0.210, 0.275, and 0.375 inches have been tested. Face seal test fixtures as shown in Figure 1 have been used for the majority of the tests. Some comparisons of bore seal performance have been made using the fixtures shown in Figure 2 with the same size O-rings. O-ring compression has been varied from 10% to 50% of the cross section diameter. Flange surface finishes ranging from 16 microinch to 250 microinch roughness have been evaluated.

Figure 1. Face Seal Test Fixture

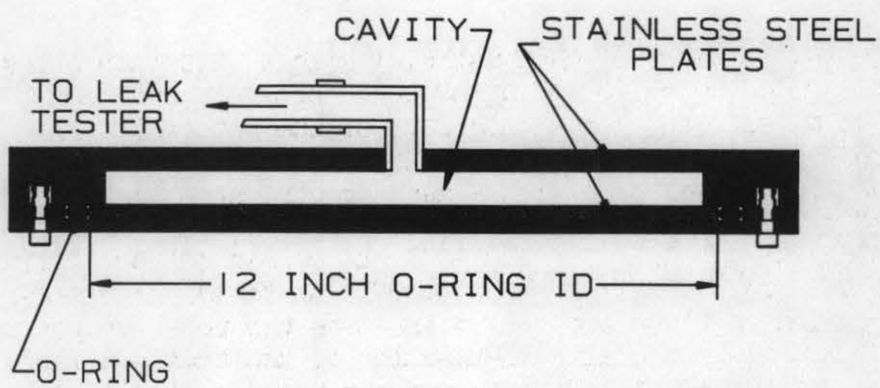
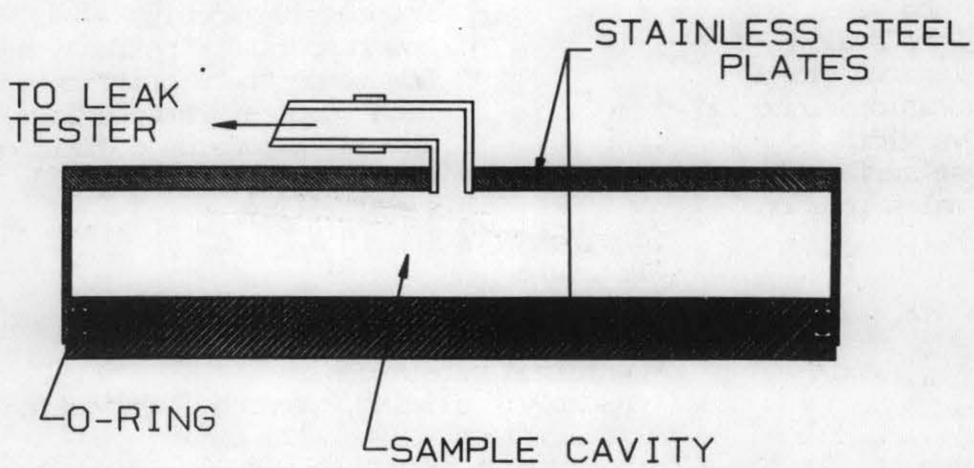


Figure 2. Bore Seal Test Fixture



Materials. O-ring materials selected have included several commonly used in radioactive material packages and others with properties of interest. All materials tested have been standard commercially available products. These include the following materials:

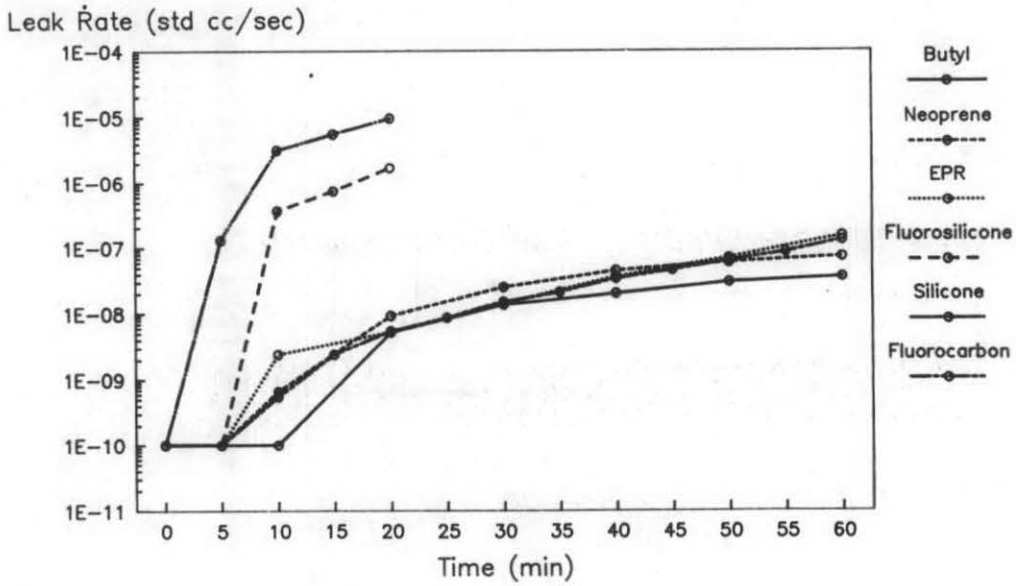
General purpose butyl	General purpose silicones
General purpose neoprene	Low temperature silicones
Low temperature neoprene	General purpose fluorocarbon
Ethylene propylene compounds	High performance fluorocarbon
Fluorosilicone	Nitrile

Environments. Initial tests have focused on room temperature and low temperature behavior of the seals. Temperatures as low as -97 F have been reached. A few high temperature tests (up to 650 F) have been performed. A pressure differential of one atmosphere across the seal has been used for all tests.

TEST RESULTS

Permeation Tests. O-rings of each material with a .210 inch cross section were exposed to helium at atmospheric pressure and room temperature to measure the permeation rate of the material. Face seal fixtures were used with compressions of 25% and 50%. Measurement of the helium in the fixture was made with a mass spectrometer leak detector for these and subsequent tests. The detection limits of the leak detector are approximately 10^{-10} and 10^{-5} std cc/sec helium. Figure 3 shows the permeation rates as a function of time for different materials with a compression of 25%. These data indicate the relative permeation rates for the materials and allow estimation of the time available for bypass leakage measurements before permeation becomes significant.

Figure 3. Permeation Measurement Results



Low Temperature Tests. Seals have been exposed to low temperatures in an environmental chamber to determine the limit of sealing ability. Each material was evaluated using a .275 inch cross section O-ring in a face seal fixture with 25% compression and a 64 microinch roughness flange finish. The leak rates as a function of temperature for some of these tests are presented in Figures 4 and 5. For silicone materials, much of the total helium detected is the result of permeation through the seal. For other materials, the leak rate indicated is largely bypass leakage around the seal. In cold tests, failure typically occurred very rapidly, with only a small temperature drop between leaktight and leakage beyond measurement sensitivity.

Figure 4. Low Temperature Test Results
64 Finish, 25% Compression, .275" Cross Section

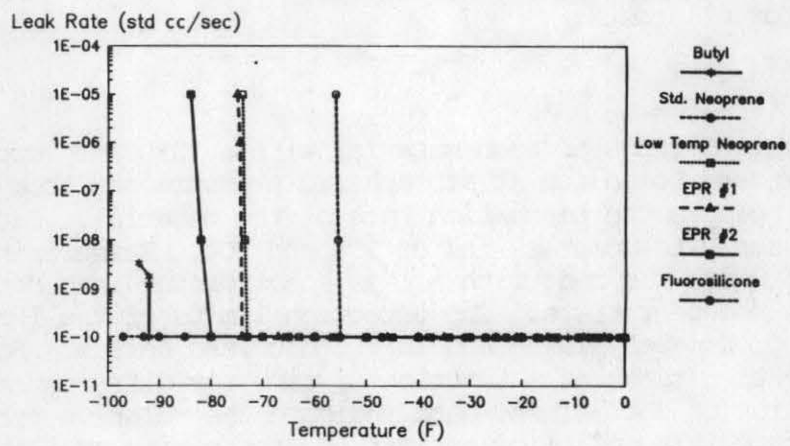


Figure 5. Additional Low Temperature Tests
64 Finish, 25% compression, .275" Cross Section

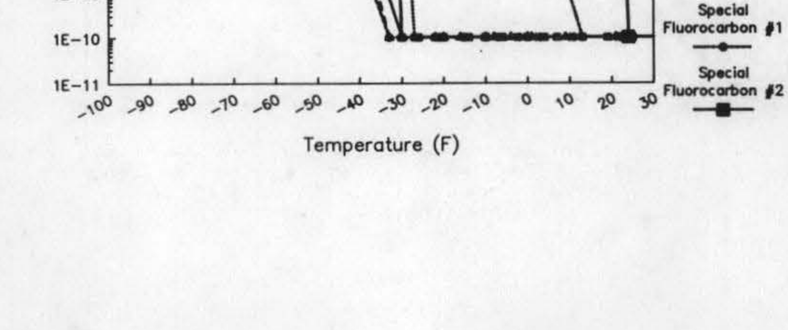
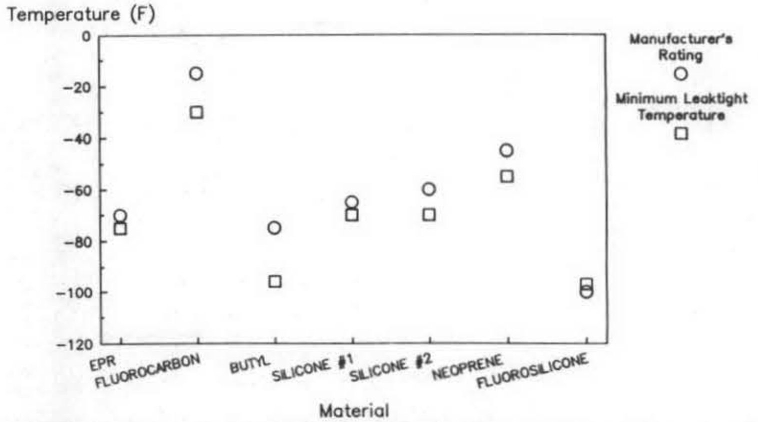


Figure 6 shows the manufacturer's recommended low temperature limit compared to the temperature at which a 10^{-7} std cc/sec leak rate was reached in the cold tests. There is close agreement between the measured performance and the manufacturer's rating, and in most cases the manufacturer's rating appears conservative.

Figure 6. Low Temp Performance vs. Ratings

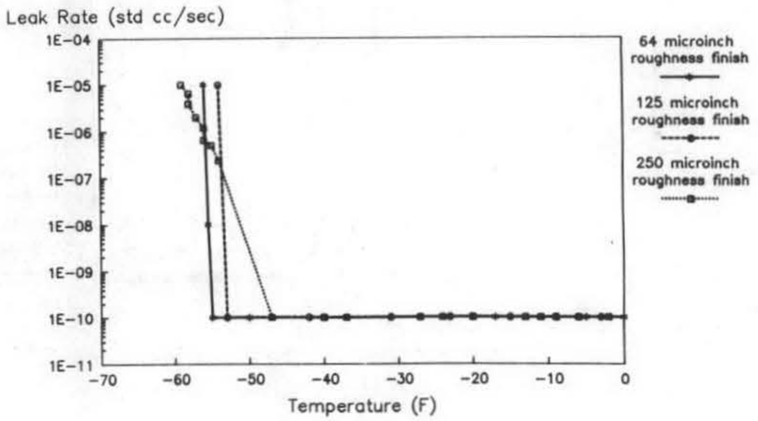


For several O-ring types on which multiple tests were performed, there was considerable variation in performance. For example, temperatures at which one material reached a leakage of 10^{-7} std cc/sec varied between +8 F and -70 F; even though samples were manufactured in the same batch of elastomer and all test parameters were identical. These data identify a need to further examine O-ring manufacturing process control.

The effects of compression and flange finish were evaluated for selected materials. Figure 7 shows the results of three tests on neoprene O-rings with varying flange finishes. These data are typical of results with other materials. The difference in the temperature at which failure occurs for varying finishes is small.

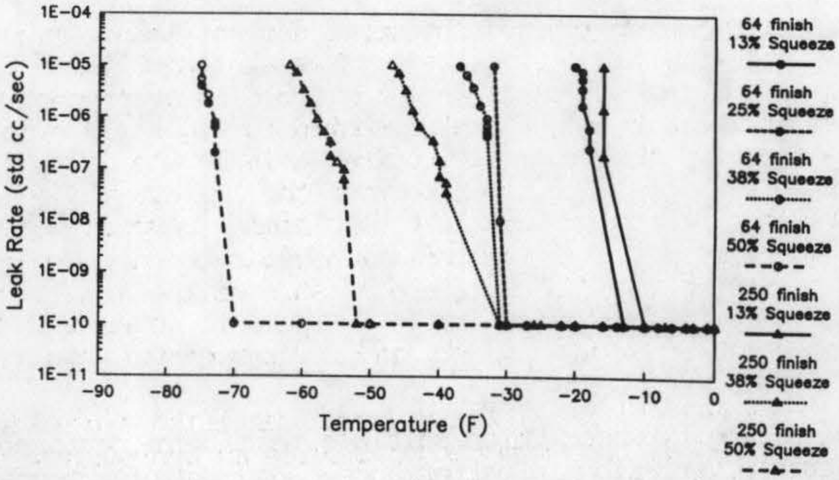
Figure 7. Effect of Flange Surface Finish

Neoprene, 25% Compression, .275" Cross Section



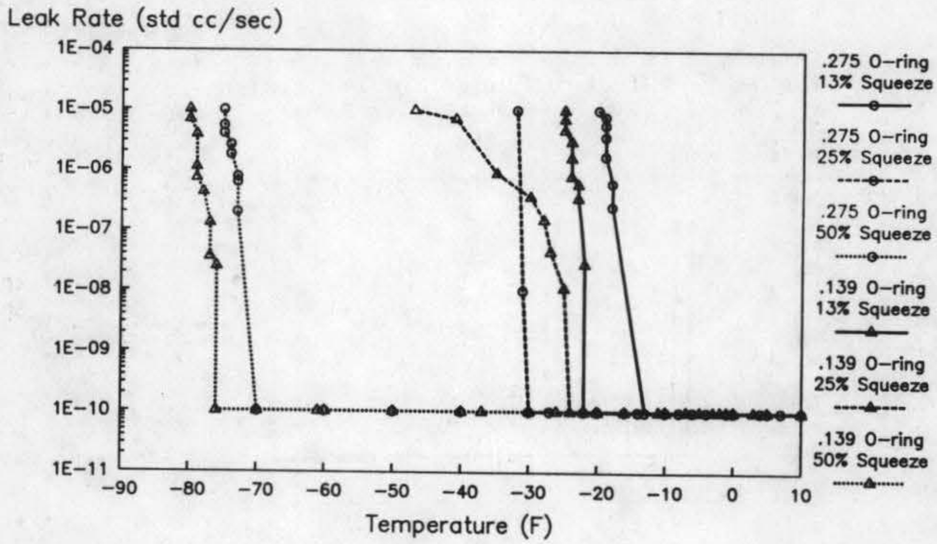
Compression has a much greater effect than flange finish. Figure 8 shows the results of several tests on fluorocarbon O-rings with varying compressions and finishes. The most significant trends are related to compression.

Figure 8. Effect of Compression and Finish
Fluorocarbon Material, .275" Cross Section



A limited number of tests have been used to evaluate the effect of O-ring cross section on performance. Figure 9 shows the results of tests on a fluorocarbon material in O-rings of .139 and .275 cross section. There is not a significant difference in performance.

Figure 9. Effect of O-ring Cross Section Size
Fluorocarbon Material, 64 Finish



The bore seal fixture has been used to evaluate the performance of a small number of seals relative to the face seal fixture. For the five bore seal tests, the low temperature sealing ability was better than for the face seal fixture. It was expected that the bore seal configuration would be more flexible and more prone to leakage than the face seal. While this has not been evident in the tests performed so far, the small, precisely machined fixtures tested may not be representative of large packages closures.

Material Property Measurements. Durometer and resilience measurements on specimens cut from the O-rings were taken at temperatures of 70 F, 20 F and -20 F. Durometer tests were performed in accordance with ASTM D2240. Durometer measurements are presented in Figure 10 along with the temperature at which the materials reached a leak rate of 10^{-7} std cc/sec. While there is some trend between the leakage and durometer (higher durometer materials generally have higher temperature leakage failures), there is no consistent relationship between the two. Resilience testing per ASTM D2632 is a measure of the amount of elastic rebound of a mass impacting the sample. Figure 11 shows that there is no correlation between this property and low temperature performance.

Conclusion. The results of this work have identified a need for additional analyses and experiments to provide an appropriate seal data base for cask designers. Based on these preliminary experiments, designers should exercise caution in selecting seal materials for cask applications.

Figure 10. Durometer vs. Low Temp Sealing

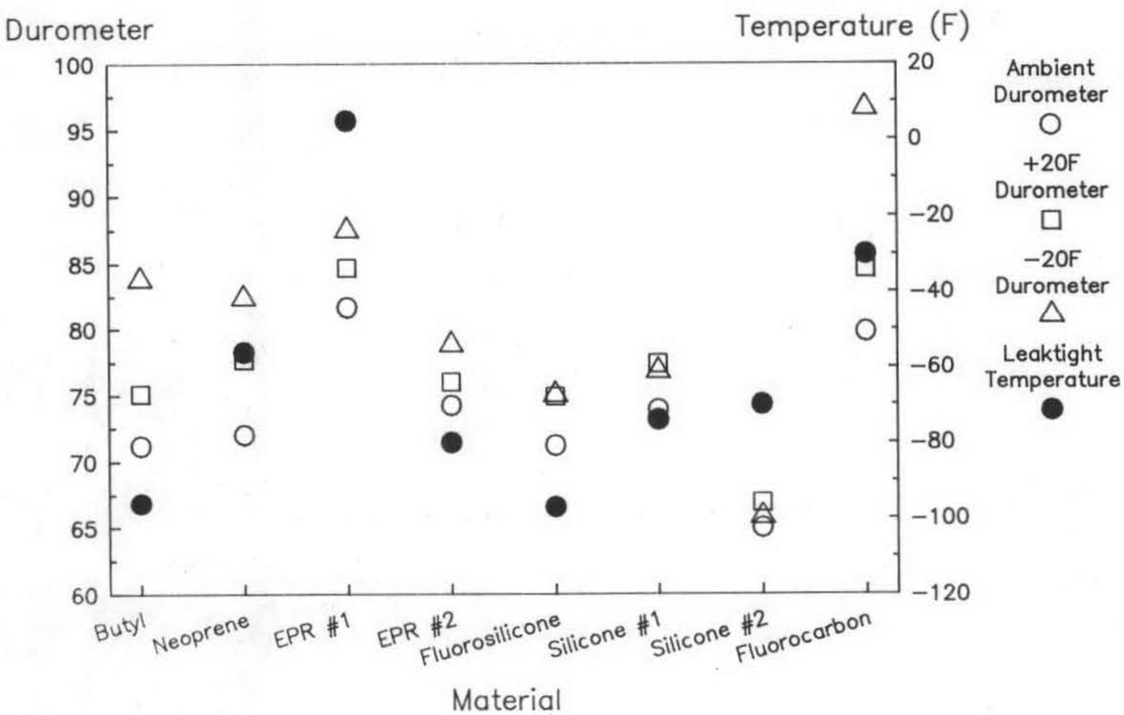


Figure 11. Resilience vs. Low Temp Sealing