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Evaluation of Seals for a Geothermal Logging Tool*

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The seal efficiency and environmental resistance of various elastomeric o-rings and a metallic joint that were immersed in geothermal brine or water at elevated temperatures and pressures were determined. A leakproof seal was maintained with a stainless steel Conoseal-joint for 100 hours in water and 24 hours in geothermal brine at 275°C and 34.5 MPa (5000 psi). Only very small quantities of moisture penetrated o-ring seals made from Kalrez, a perfluoroelastomer, ethylene/propylene rubber and a Parylene C coated Viton o-ring. All other rubbers seals failed catastrophically.

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Evaluation of Seals for a Geothermal Logging Tool

Geothermal logging tools capable of functioning at 275°C and pressures up to 48.3 MPa (7000 psi) are needed to accelerate the near-term development of our Nation's geothermal resources. These tools will require seals to protect the internal electronic circuitry from moisture. There are electronic components which can function at 275°C, but would probably fail under the combined influence of both heat and moisture. Although stainless steel seals are generally preferred in applications of this kind because of their resistance to heat and corrosion, elastomeric seals have the advantage that they are generally less likely to fail in the presence of particulate matter. The problem with most elastomeric seals is that they will degrade thermally and chemically in a geothermal borehole which ultimately results in failure. The purpose of this study was two fold: 1) to identify viable elastomeric or metallic seals to be used in the high temperature cable head of a geothermal logging tool, and 2) to define the cause of failure of seals that leaked.

Elastomeric o-ring seals were tested in a fixture shown in Figure 1 which was designed to simulate the high temperature cable head of a geothermal logging tool. After molecular sieves (Linde 5A) were placed in chamber A of the fixture to trap any water vapor that penetrates the seal, the fixture was immersed in geothermal brine and heated to 275°C and 34.5 MPa pressure for 24 hours. Because of the pressure limitation of the autoclave used in this work it was not possible to carry out these experiments at the extreme pressures that may prevail in a geothermal borehole, i.e., 48.3 MPa (7000 psi). The brine was obtained from the Salton Sea basin (Mesa Well No. 6) and contained 26,000 ppm of dissolved salts. The results obtained with various commercial rubber formulations are summarized in Table I.

Table I. Seal Efficiency of Commercial O-Rings

Elastomer	Supplier	Uptake of Moisture by Molecular Sieves (mg)
Perfluoroelastomer, Kalrez 1050	Dupont	3.8
Fluoroelastomer, Viton: V-747-75	Parker Seal	F
Fluoroelastomer, Viton: V-709-80	Parker Seal	F
Ethylene/Propylene, E-692-75	Parker Seal	6.2
Ethylene/Propylene, E-540-80	Parker Seal	3.4
Fluorosilicone, L449-70	Parker Seal	F

(F = Catastrophic Failure of Seal)

It is clear from these results that o-rings fabricated from fluoroelastomers (Viton V-747-75 and Viton V-709-80) and a fluorosilicone (L449-70) are not viable seals for this particular application. These results were not entirely unexpected since there are a number of literature references which report on the hydrolytic instability at high temperatures of both silicones and fluoroelastomers.[1,2] The visual appearance of Kalrez o-rings, which maintained an adequate seal in this test and fluorosilicone o-rings ~~while~~ which failed catastrophically is shown in Figure 2. These photographs illustrate not only what happened to o-rings used in the fixture but also what happened to loose unstressed o-rings when exposed to brine at elevated temperatures and pressures.

Although both the Kalrez 1050 o-ring, a perfluoroelastomer, and the two ethylene/propylene rubber o-rings (E-692-75, E-540-80) can be said to have passed this test in that catastrophic failure of the seal did not occur and only milligram quantities of moisture penetrated the seal, it should be noted that Kalrez retained a much larger fraction of its tensile strength than did the EPR rubber. Although EPR rubber lost mechanical strength, its elongation increased after exposure to brine which may account for the ability of this material to maintain a seal. Data illustrating these effects are shown in Figure 3. In addition, the EPR rubbers outgassed as evidenced by the fact that organic gumlike substances were distributed throughout the chamber of the test failure at the completion of the test. The occurrence of outgassing by EPR rubbers can be attributed to the fact that 275°C is considerably above the recommended maximum use temperature for this elastomer.[3]

Environmental exposure tests were also carried out with Viton o-rings that were coated with 1.25 mil of Parylene C (polychloroxylylene). This coating was 1.25 mil thick and was applied by means of a pyrolytic vapor phase technique that was developed by Union Carbide. The intent here was to enhance the environmental resistance of Viton, which, as described above, degraded under conditions that simulate those found in a geothermal borehole. The results obtained were mixed. Thus, Parylene C coated Viton (V-709-80) excluded moisture from the fixture chamber when exposed to brine at 275°C/4500 psi, but Parylene C coated Viton (V-747-75) did not. The failure of Parylene C coated Viton (V-747-75) has been tentatively ascribed to the presence of particulate matter in the fixture. Additional exposure tests are planned to more fully define the feasibility of using Parylene C coatings to improve the chemical resistance of elastomeric seals.

The metal seal that was tested was a Conoseal-joint made by Aeroquip Corp. Conoseal-joints form a seal by compression of a conically shaped gasket between two flanges which causes the gasket to act like a spring and also induces plastic flow at the sealing edge. This joint was made from

316 stainless steel and is recommended where severe service conditions prevail (1093°C or 20,000 psi). We tested this seal with molecular sieves for 24 hours in brine and in tap water for 100 hours at 275°C and 5000 psi. No water uptake was observed in either test.

Conclusions

These tests indicate that stainless steel Conoseal-joints can be used to protect the internal electronic circuitry of a geothermal logging tool against moisture. Elastomeric o-ring seals formulated from Viton and fluoro-silicone failed catastrophically after a 24 hours exposure to geothermal brine at 275°C/34.5 Mpa and are not recommended for geothermal logging applications. Promise was shown with rubber seals made from Kalrez, a perfluoroelastomer, and Parylene C coated Viton. Studies on these better seals are continuing.

References

1. I. Gebhardt, B. Lengyel and F. Torok, Mag. Kem. Folyoirat 68, 159 (1962).
2. L. F. Pelosi and E. T. Hackett, "Improved Steam Resistance for Fluoro-elastomers," Paper No. 13, presented at the 110th Meeting of the Rubber Division, American Chemical Society, San Francisco, California, October 5-8, 1976.
3. Parker O-Ring Handbook, OR 5700, January 1975.

Figure Captions

Figure 1 Schematic diagram of fixture used to determine seal efficiency in brine and water.

Figure 2 Appearance of o-rings before and after exposure to geothermal brine: a) Kalrez 1050; b) Fluorosilicone, L449-70.

Figure 3 Tensile properties of o-rings exposed to geothermal brine at 275°C/34.5 MPa (5000 psi) for 24 hours.

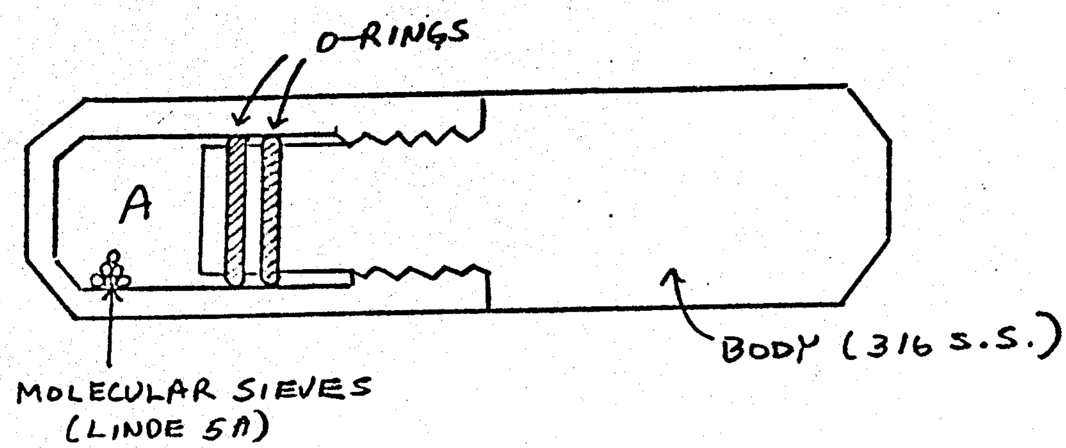

FIG. 1

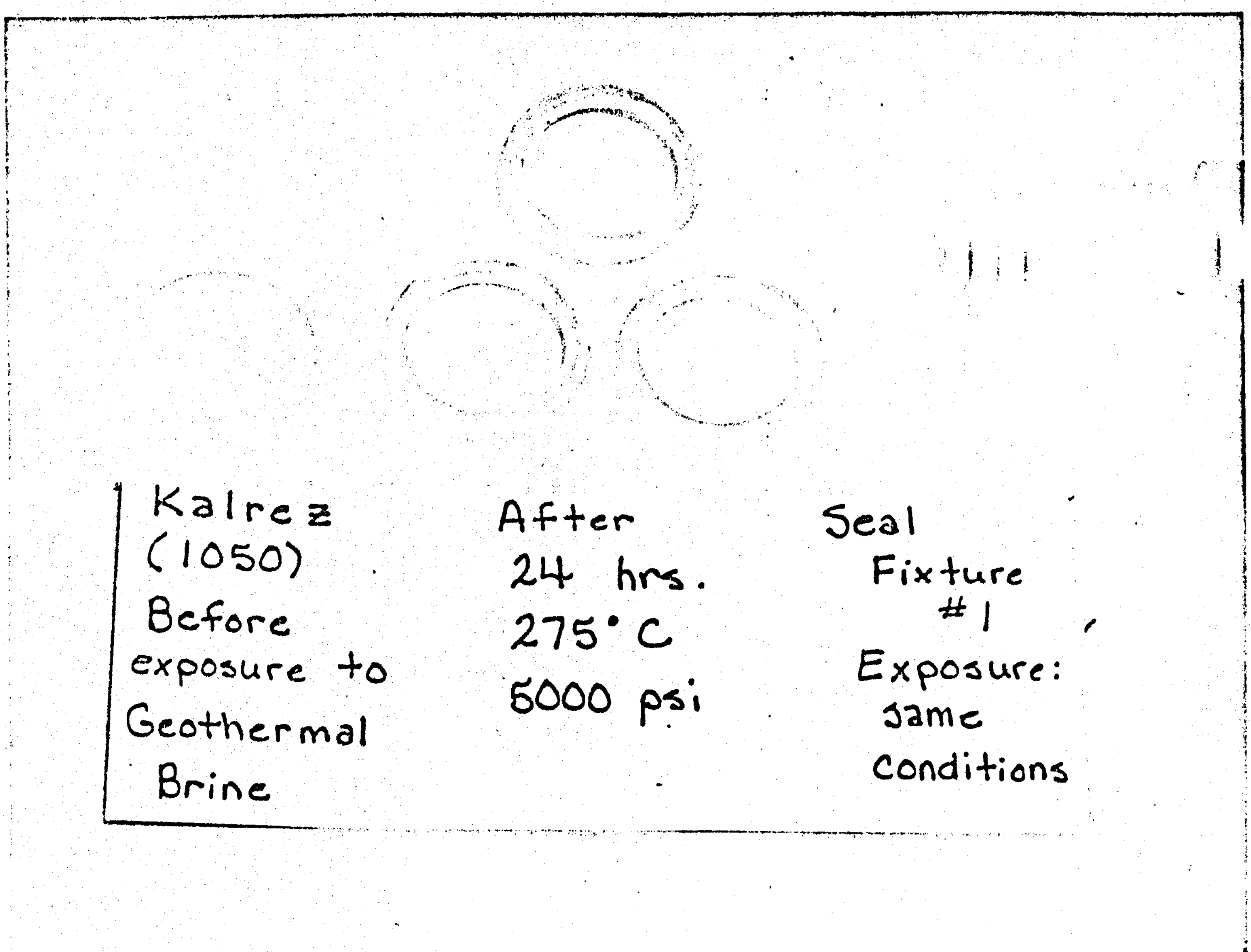
Kalrez
(1050)
Before
exposure to
Geothermal
Brine
After
24 hrs.
275° C
5000 psi
Seal
Fixture
#1
Exposure:
same
conditions

Fig. 2a

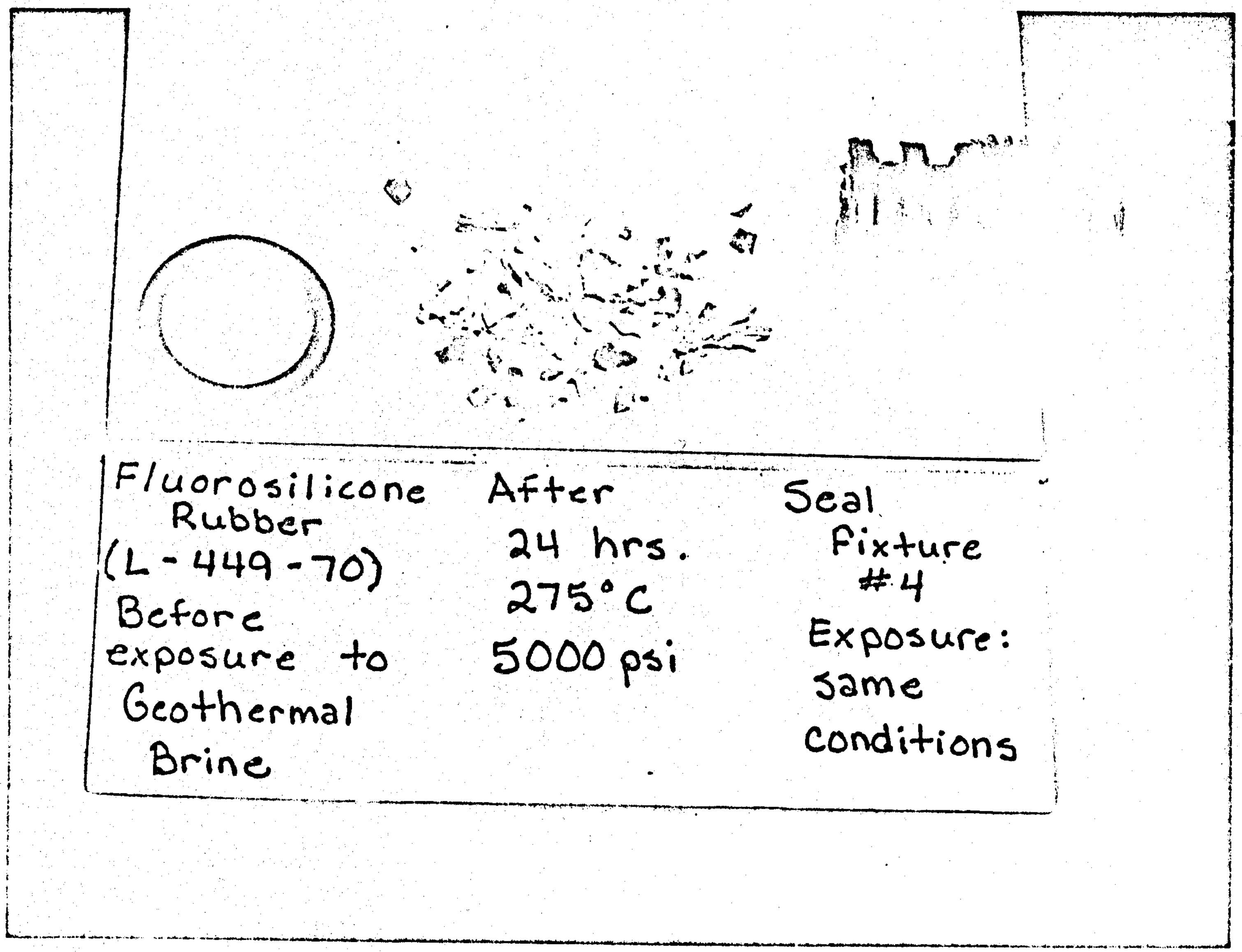
Fluorosilicone Rubber (L-449-70) Before exposure to Geothermal Brine
After 24 hrs. 275°C 5000 psi
Seal Fixture #4 Exposure: same conditions

Fig 2a

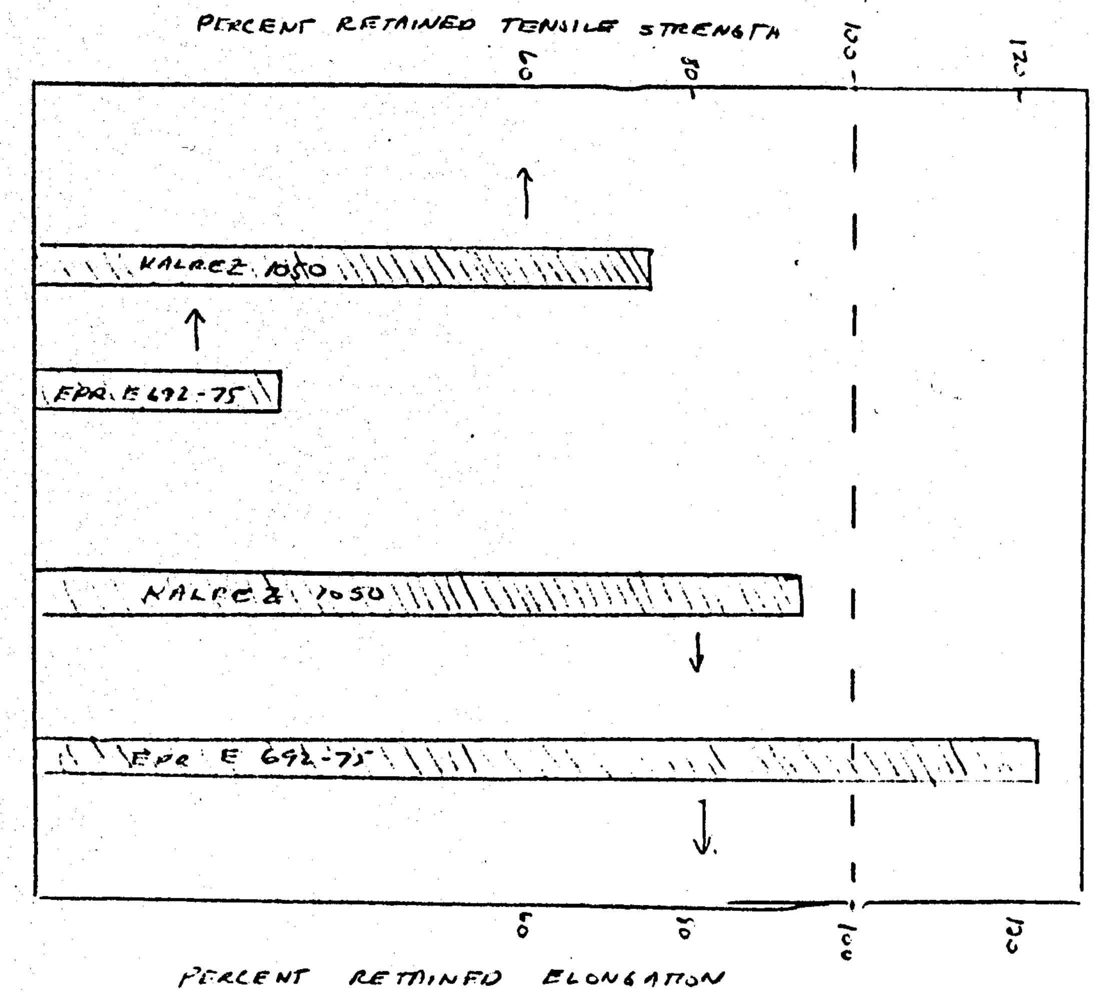
PERCENT RETAINED TENSILE STRENGTH
60
80
100
120
KALREZ 1050
EPR E 692-75
KALREZ 1050
EPR E 692-75
60
80
100
120
PERCENT RETAINED ELONGATION

Fig. 3