STABILITY OF ELASTOMERS SUBJECTED TO GEOTHERMAL WELL-LIKE CONDITIONS

E. M. Redline[a], T. Sugama[b], T. Pyatina[b]

[a] Sandia National Laboratories, Albuquerque, NM
[b] Brookhaven National Laboratory, Upton, NY

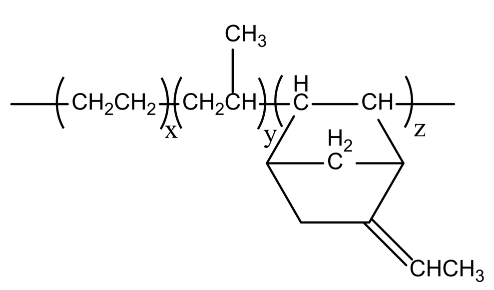
Sandia National Laboratories

1. INTRODUCTION

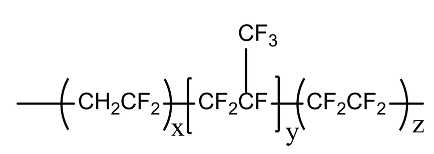
The emphasis on sustainable energy has brought with it challenges associated with materials performance. In particular, geothermal wells push the boundaries of elastomer stability due to harsh environmental conditions, where temperatures around 300°C and pressures of 5000 psi or greater are not uncommon. Additionally, well brines and drilling fluids subject these materials to very severe chemical environments, which also impacts elastomer degradation and stability. The aim of this study is to understand how commercially available elastomers perform under geothermal well-like conditions and make recommendations to the community based on these results. This poster highlights the mechanical performance of several elastomers after aging at elevated temperature, pressure, and in well brine and drilling solutions.

2. MATERIALS

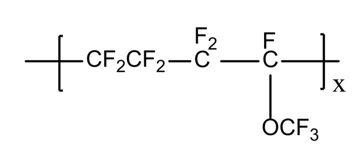
EPDM



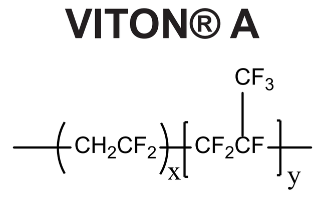
VITON® B



FFKM



VITON® A



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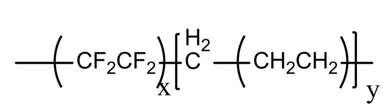


3. EXPERIMENTAL METHODS

Aging in Drilling Fluid:
300°C, 7 days, ~1000 psi submerged in a drilling fluid mimic with pH 9-10.
Drilling fluid composition:

Major Components	Percent
Water	74-83
Barite	10-15
Bentonite	5-7
Caustic soda	0.3
Soda ash	1
Polyanionic cellulose	0.3-1.2
Xanthan gum	0.3-0.5
Starch	0.5-1

Aging in Brine:
300°C, 7 days, ~1000 psi submerged in a brine with pH 4-5.
Brine composition:

Major Components	Percent
Chlorine	13.5
Sodium	6
Calcium	2
Potassium	1.5
Magnesium	0.9
Minor Components	**PPM**
Carbon dioxide	15,000
Iron (ferrous)	1000
Mangnese	930
Lithium	410
Zinc	370
Boron	330
Silicon	250
Barium	130
Dihydrogen sulfide	70

Thermal Cycle Aging:
24 hours at 300°C with water quenching to 25°C and hold for 5 hours - repeated five times.

Thermogravimetric Analysis (TGA):
Sample sizes ranged from approximately 10 - 50 mg. Ramp 20°C/min to 700°C on a TA Instruments TGA Q50 V20.10

Modulus Profile Testing:
Modulus profiles were taken using a home-built instrument. The machine operates by scanning the surface with a parabolic tip at user-defined intervals (0.2 mm) and using displacement from a known force applied to each point on sample to calculate modulus. Samples are cross-sectioned and embedded in epoxy prior to running the experiment.

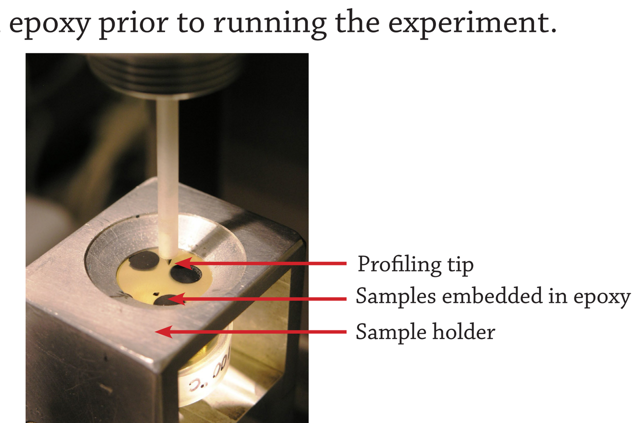
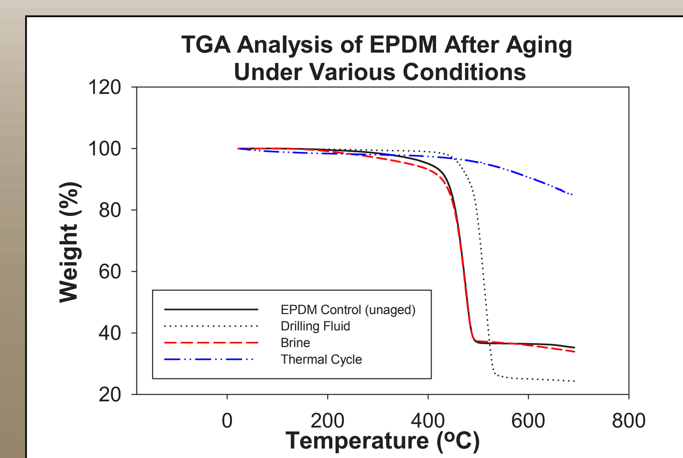


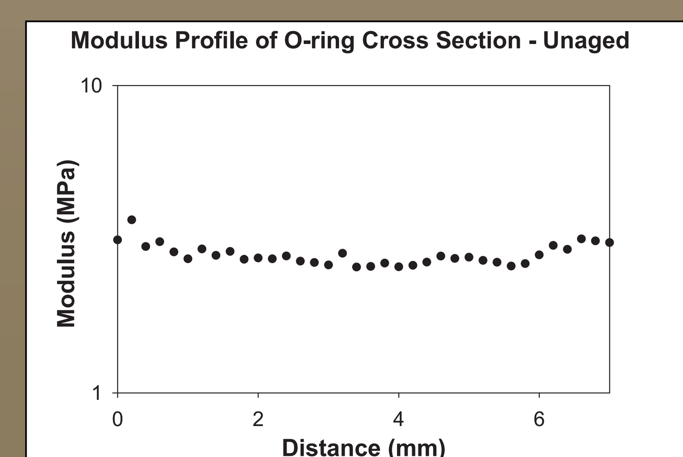
Figure 1. *Close-up view of modulus profiler set-up.*

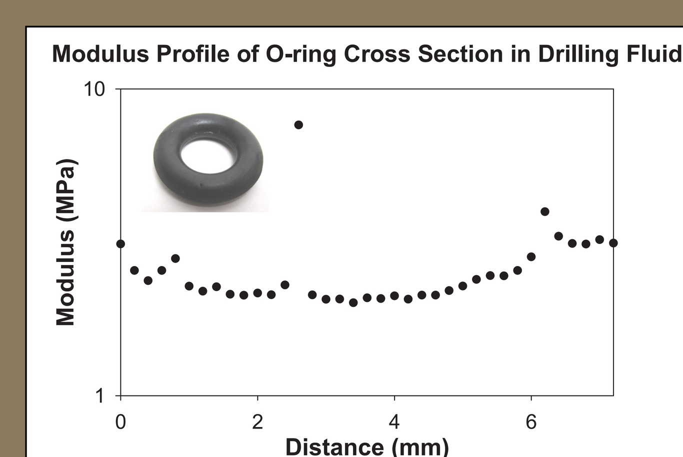
Figure 2. *Top: top-down, Bottom: side view of cross-sectioned o-rings embedded in epoxy.*

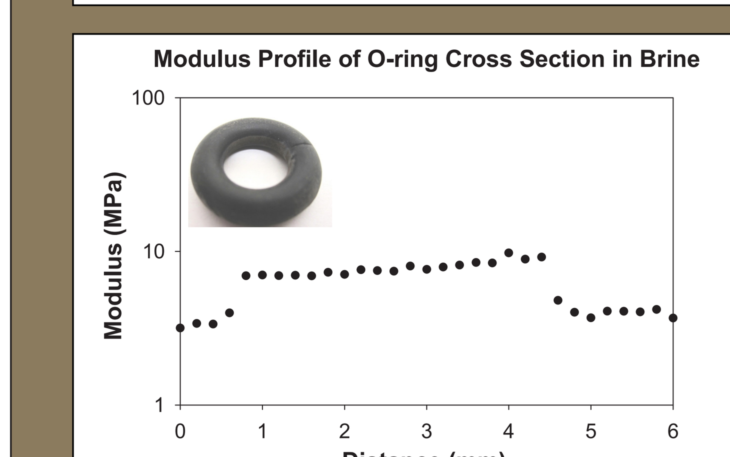
4. RESULTS & DISCUSSION

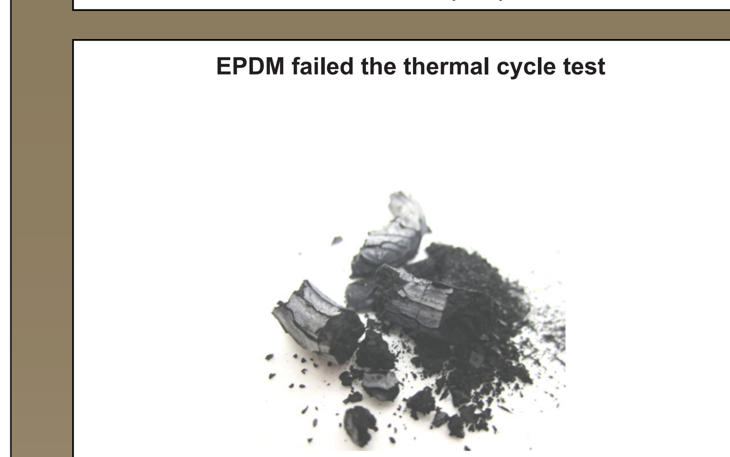
EPDM



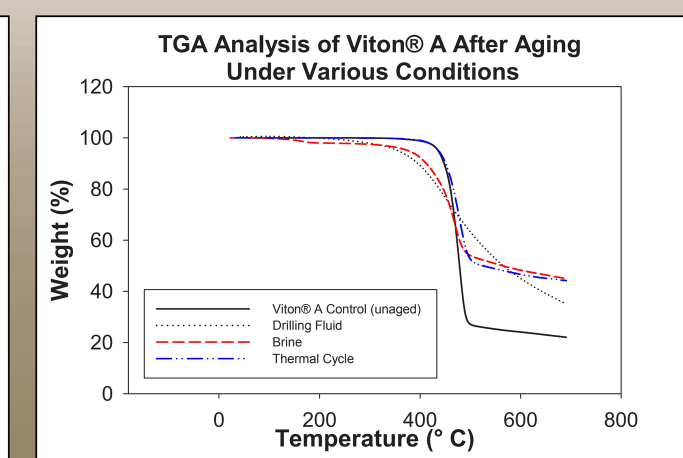


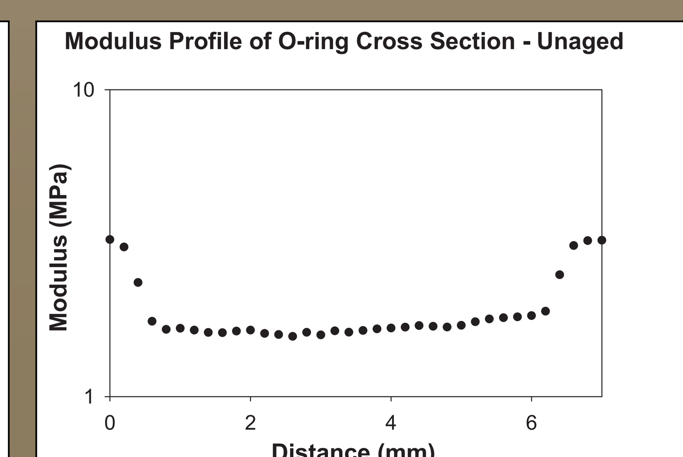


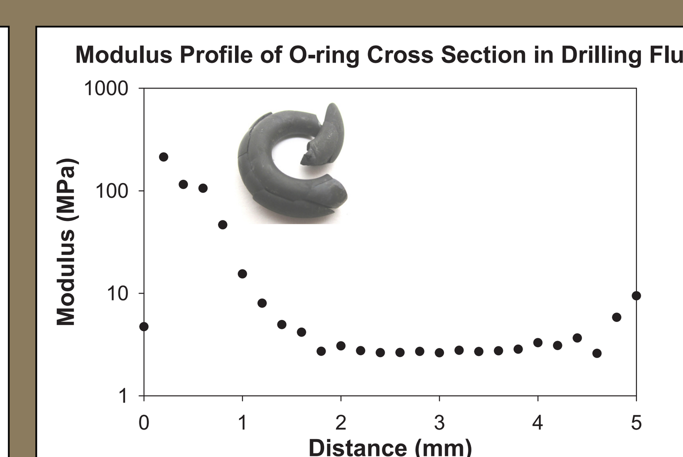


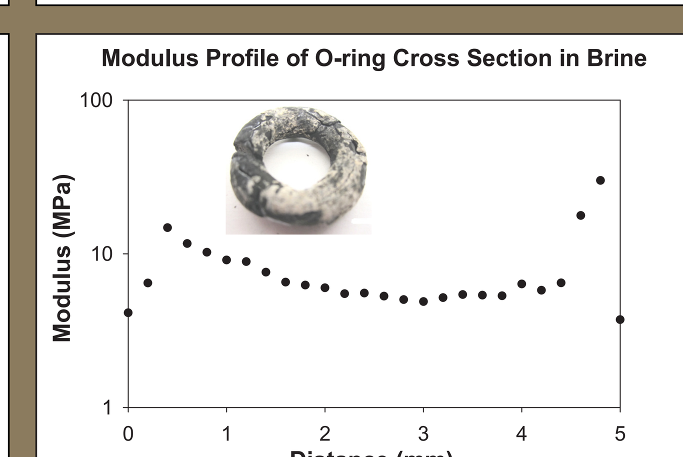


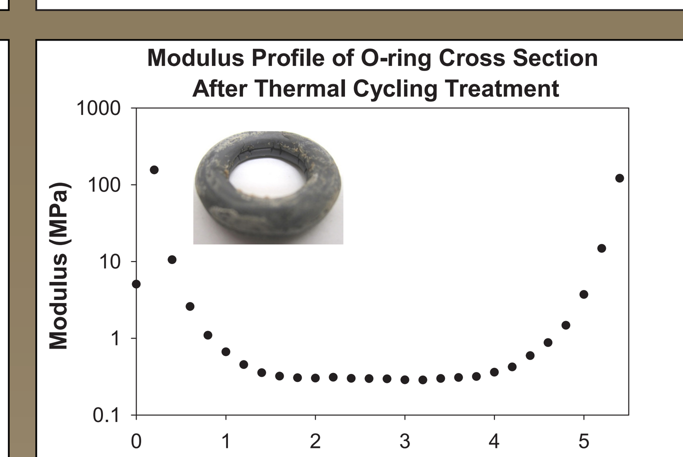
Viton® A











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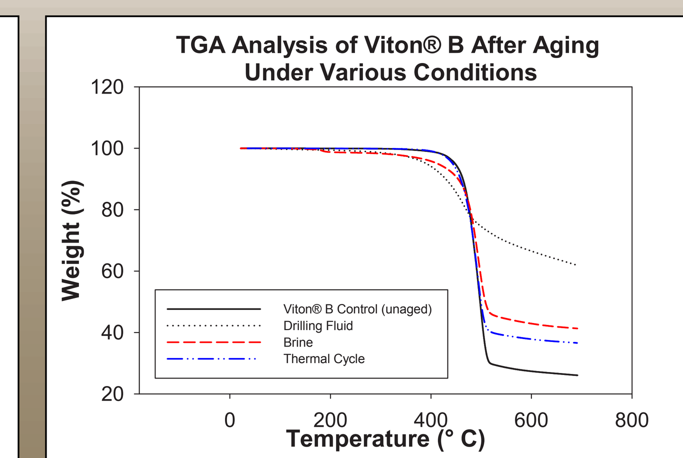

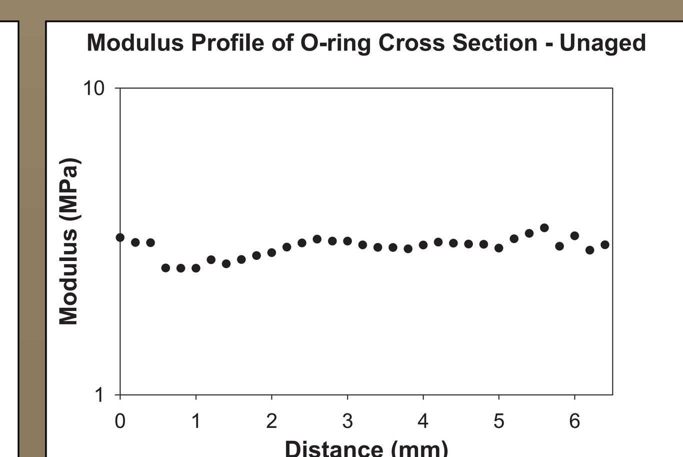

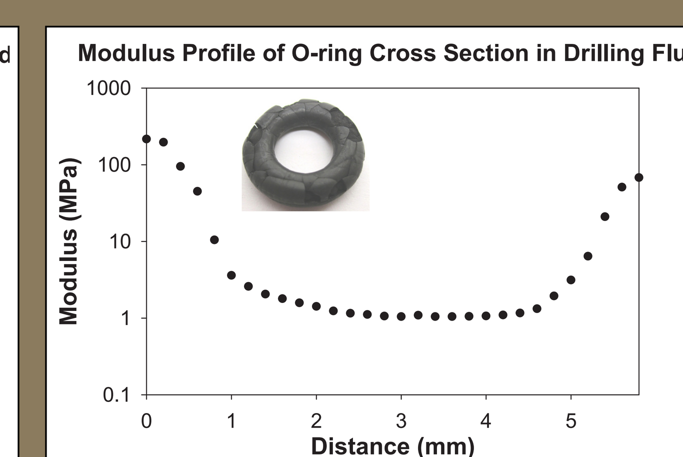

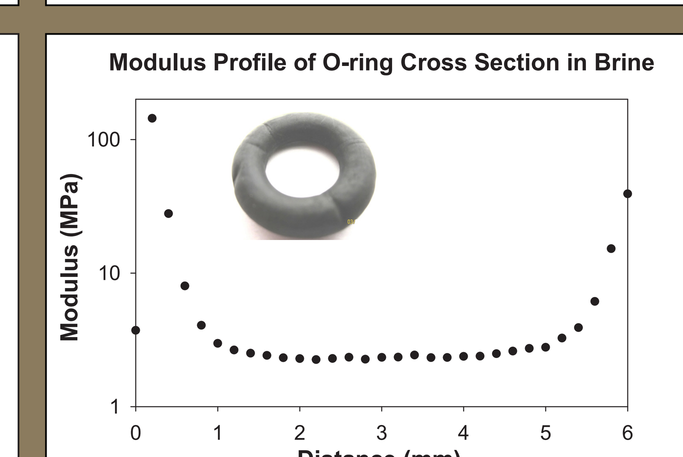

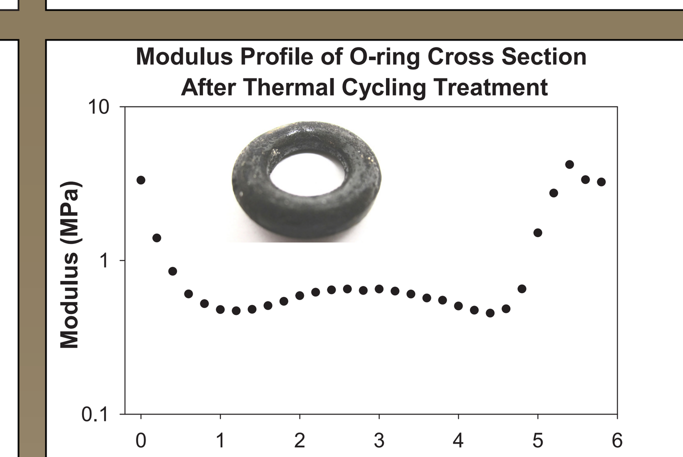

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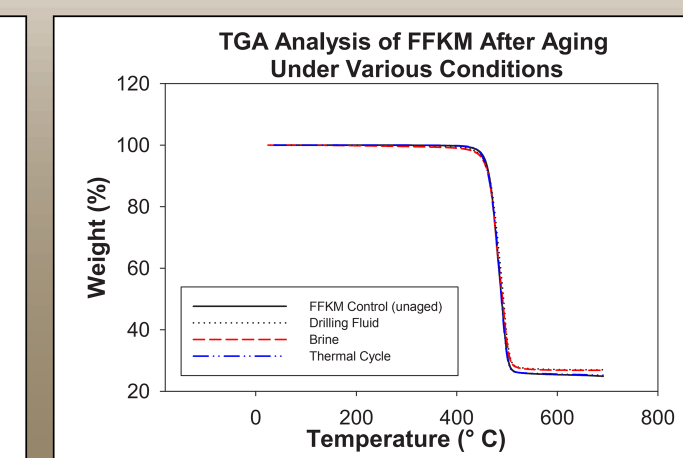
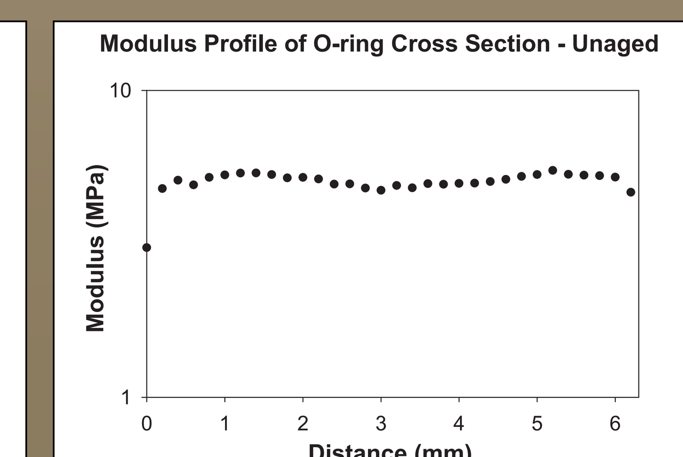
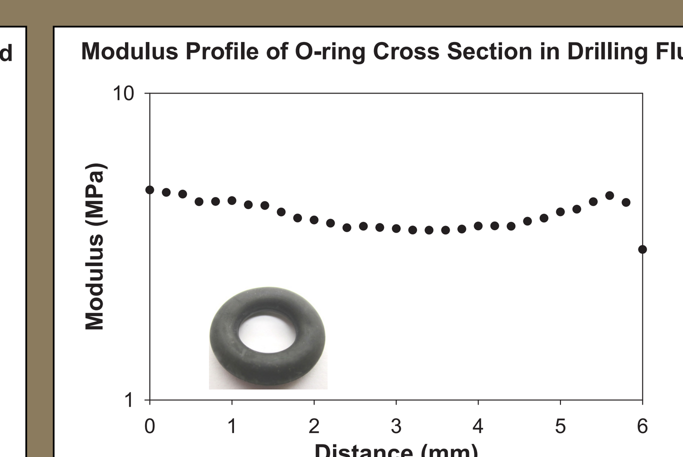
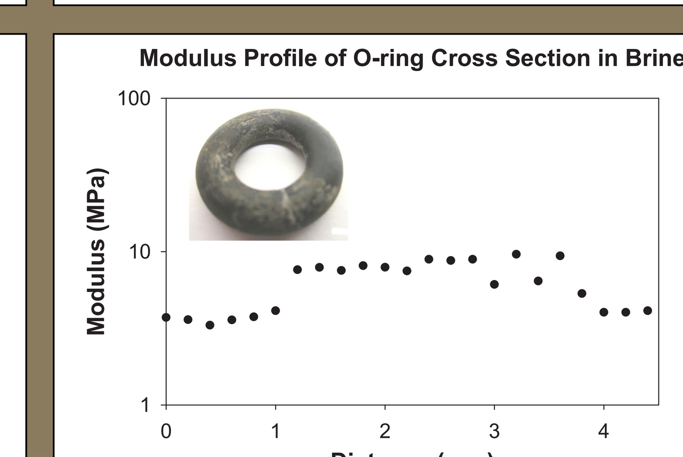
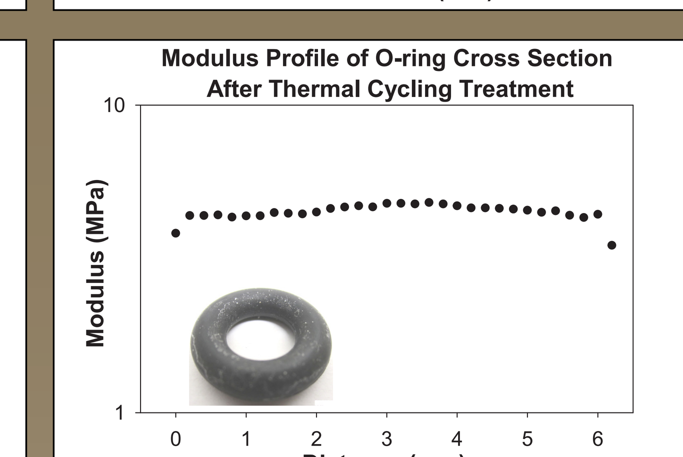


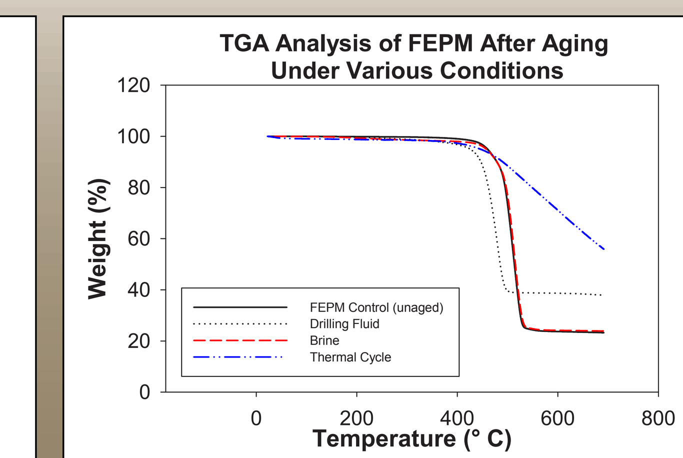


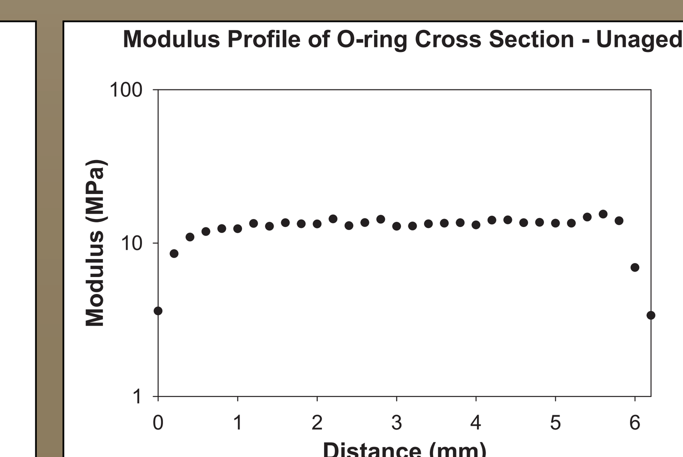


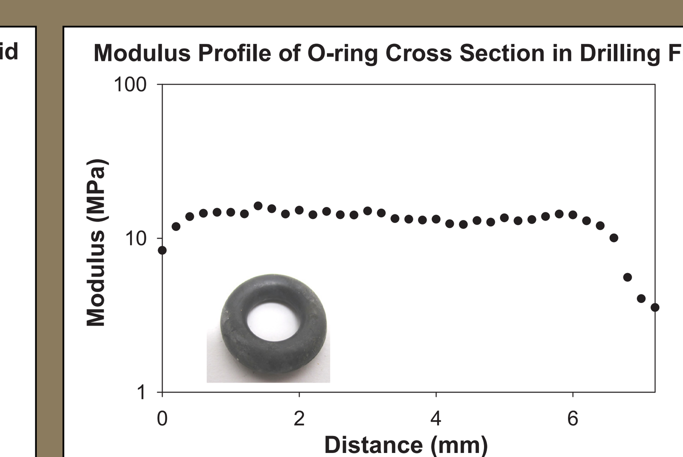


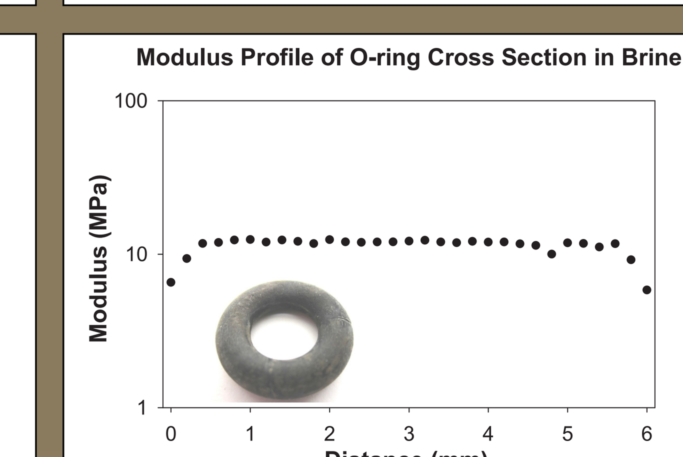


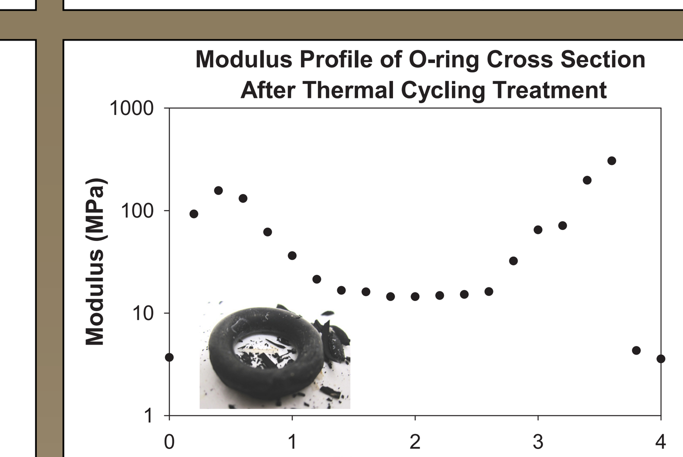
FEPM











EPDM Summary:
Improved thermal resistance when aged in drilling fluid mimic.
Small amounts of edge hardening in drilling fluid and brine. Overall modulus increase when exposed to brine.
Failed the thermal cycle test.

Viton®A Summary:
Good thermal resistance up to about 200°C.
Edge hardening under all aging conditions, often with material flaking off of outer surface.
Scale formation in brine.
Increase in modulus with brine aging throughout the sample, including the center.

Viton®B Summary:
Good thermal resistance up to about 200°C.
Edge hardening under all aging conditions with some material flaking off of outer surface.
Decrease in overall modulus after thermal cycle test.

FFKM Summary:
Thermal resistance above 300°C
Little to no change in modulus under all aging conditions.
Some scale formation after brine aging.
FFKM offered the best mechanical and thermal stability under all of the conditions studied.

FEPM Summary:
Thermal resistance above 300°C
Little to no change in modulus with drilling fluid and brine aging.
Edge hardening after thermal cycle test.
Some scale formation after brine aging.

5. CONCLUSIONS

EPDM is a low-cost alternative to fluoropolymers for geothermal well applications when conditions similar to the drilling fluid mimic are encountered. However, this material is not appropriate for applications that mimic the brine and thermal cycle tests. This material is the lowest cost of all materials in the study.

Viton®A showed edge hardening in all of the conditions studied. The edge hardening and resulting flaking behavior could cause a reduction in the sealing force, making this material unsuitable for o-ring applications. However, the material may be adequate for other areas where integrity of the bulk is more important than that of the surface and also at lower use temperatures.

Viton®B was also observed to have edge hardening in all of the conditions studied. Again, this behavior could cause a reduction in the sealing force, making this material unsuitable for o-ring applications. However, the material may be adequate for other areas where integrity of the bulk is more important than that of the surface and at lower use temperatures.

FFKM remained relatively stable after aging at high temperatures in drilling fluid and brine and also passed the thermal cycle test, as evidenced by a lack of change in modulus. However, the scale formation observed in the brine could lead to mechanical instability after further aging. While this is the best choice of all materials studied, it is also the most expensive.

FEPM remained relatively stable after aging in drilling fluid and brine, but showed edge hardening in the thermal cycle test. As with the Viton® materials, the edge hardening makes this unsuitable as an o-ring material in conditions similar to the thermal cycle test. This polymer is priced between the FFKM and EPDM and could be a good alternative to FFKM for some applications.