IEEE Transactions on Nuclear Science, Vol. NS-32, No. 5, October 1985

RADIATION RESISTANCE OF ELASTOMERS

Glenn Lee

Fermi National Accelerator Laboratory*
P.O. Box 500
Batavia, Illinois 60510

Abstract

Various data has indicated that some elastomers have much higher radiation resistance than Viton. Nine samples of elastomers were irradiated with gamma rays. Two Ethylene Propylene Diene compounds, EPDM's, were found to exhibit acceptable properties for o-rings after radiation levels of 5×10^8 rads, while Viton failed at 1×10^7 rads. Vacuum tests also were favorable so EPDM o-rings were chosen as seals in the Energy Saver cryostat vacuum system.

Introduction

Viton is commonly used for o-ring seals in high vacuum systems, and failures have occurred in radiation areas such as particle beam transport lines due to radiation from beam loss. In a search for radiation resistant seals suitable for vacuum systems, nine elastomer samples were obtained from Minnesota Rubber Company and irradiated with gamma rays.

Materials Tested

The samples tested were:

Compound #	
559N	EPDM (Ethylene Propylene Diene)
559EQ	EPDM (Ethylene Propylene Diene)
366T	NBR (Nitrile)
514AD	Viton
71417	Silicone
512AJ	Sulfur Cured Urethane
482BJ	Neoprene
560ND	EPDM (tightly cured)
564FP	Peroxide Cured Urethane
564FB	Sulfur Cured Urethane

Affect of Radiation

Minnesota Rubber Company tested the elastomers after irradiation. There are some variances of data due to the size of the samples tested and the results are as follows.

The compound, 512AJ, sulfur cured Urethane, appears to have the best radiation resistance. Even after 10^9 rads 512AJ has some elongation and tensile and little change in hardness. However, the compression set of 512AJ, even originally, is poor which is typical of sulfur cured Urethanes. In a seal application, compression set is a critical property and such extremely poor set resistance will cause part failure.

The EPDM compounds 559N and 559EQ show the best all around properties with radiation levels up to 5.0×10^8 rads. They exhibit good tensile and are still elastomeric though elongation is low and hardness is high. Compression set is excellent even at 5.0×10^8 rads. The EPDM's are not good at levels of 10^9 rads since in the compression set test both samples disintegrated.

The other compounds were brittle at or before 3.0×10^8 rads. Compound 366Y, a NBR, retains good properties at 10^8 rads. Compound 482BJ, a Neoprene; was brittle at 3×10^8 rads though it had good properties at 10^8 rads. Both 71417, silicone, and 514AD, Viton, were significantly affected by the radiation, becoming hard even at 5×10^7 rads and brittle at 3×10^8 rads.

For all radiation applications up to 5.0×10^8 rads the best compounds are 559N or 559EQ, the EPDM's. If radiation levels are higher than 5.0×10^8 rads, then compound 512AJ could be used, but difficulty would be encountered in designing a functional part because of the high set it exhibits.

The test results confirmed that EPDM compounds have the best all around properties with radiation levels up to $.5\times10^9$ rads. They retain reasonable flexibility and strength, hardness, and very good compression set resistance.

A Urethane that is sulfur cured has the best flexibility, strength and hardness even up to 2×10^9 rads. However, they have very poor compression set qualities even before treatment of radiation. The sulfur cured Urethane fail completely by $.85\times10^9$ rads in compression set.

The peroxide cured Urethanes have an initial change of properties but seem to stabilize through to 2.0×10^9 rads and is very brittle at 3×10^9 rads. The initial compression set characteristics is much better than the sulfur cured Urethanes but again failure is seen at $.85\times10^9$ rads.

There are many new compounds now that have not been tested. Quite possibly elastomers with properties superior to the EPDM's could be found.

Vacuum Tests at Fermilab

Urethane o-rings have been used for a few vacuum applications in high radiation areas, but extreme outgassing eliminated their use in high vacuum apparatus. Samples of compounds 560ND, 564FB, 564FP, Viton, and polyurethane cord purchased from Eagle Belting Company were tested for outgassing in a very simple vacuum chamber. The chamber consisted of a spare Fermilab main ring ion pump with a short tube extension and a roughing valve. Equal weights of elastomer samples were placed in the tube extension and the chamber was then roughed down and the ion pump started. The ion pump power supply frequency was used as the pressure indicator since an ion gauge was not available. A frequency of 10 KHz indicated a pressure of approximately 1×10^{-5} Torr. A table of test results indicates the extreme outgassing of the Urethane materials as compared to Viton, while the ethylene propylene compound wasn't so bad. No data was obtained as to actual outgassing rates due to lack of personnel, time, and equipment.

Figure 1 shows the pump-down data for six of the compounds tested. Figures 2,3,4, and 5 shows respectively, the elongation, compression set, tensile, and hardness properties.

*Operated by Universities Research Association, Inc. under contract with the U.S. Department of Energy.

0018-9499/85/1000-3806$01.00© 1985 IEEE

Results

As a result of this investigation, ethylene propylene o-rings were ordered and used in the cryostat vacuum system for the Energy Saver. The EPDM O-rings performed satisfactorily but they are slightly permeable to helium, very similar to neoprene. This has to be noted when leak checking.

Acknowledgements

Thanks to Joe Schuchman of Brookhaven National Laboratory and Tom Kiedrowski of Minnesota Rubber Company for their help in obtaining this data.

ELASTOMER OUTGASSING TEST

MATERIAL	START ROUGHING	START ION PUMP	END OF 1st HR.	END OF 2nd HR.	END OF 3rd HR.	END OF 4th HR.
ION PUMP (clean up)	1035	1040	5×10^{-7} TORR	2×10^{-7} TORR		
COMPOUND 560ND	1243	1258	15.5 KHz	10.5 KHz	9 KHz 9×10^{-6}	7.3 KHz 7×10^{-6}
ION PUMP (clean up)	0850	0855	3×10^{-7}	1×10^{-7}		
COMPOUND 564FB POLYURETHANE	1255	1315	28 KHz	27 KHz	27 KHz	27 KHz
ION PUMP (clean up)	0855	0905	4×10^{-7}	2×10^{-7}		
COMPOUND 564FP	1110	1125	28 KHz	26 KHz	26 KHz	26 KHz
VITON	0840	0855	10 KHz 1×10^{-5}	4×10^{-6}	3.0 KHz 3×10^{-6}	2.5 KHz 2.5×10^{-6}
ORANGE POLYURETHANE	1255	1315	28 KHz	25 KHz	23 KHz	17.7 KHz

Fig. 1: Relative outgassing of elastomers. A frequency of 10 KHz indicates a pressure of 1×10^{-5} Torr, and pressures noted were taken from a pressure vs. frequency curve.

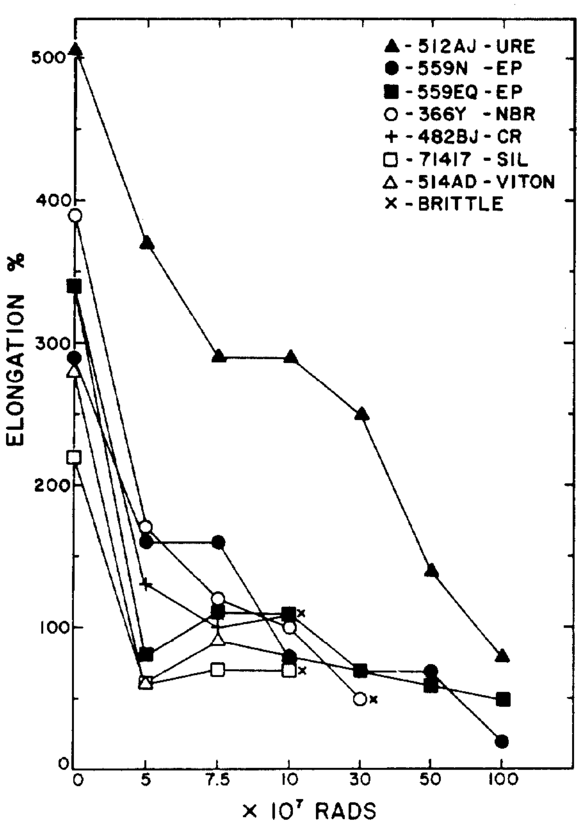

Fig. 2: Elongation of elastomers after irradiation.

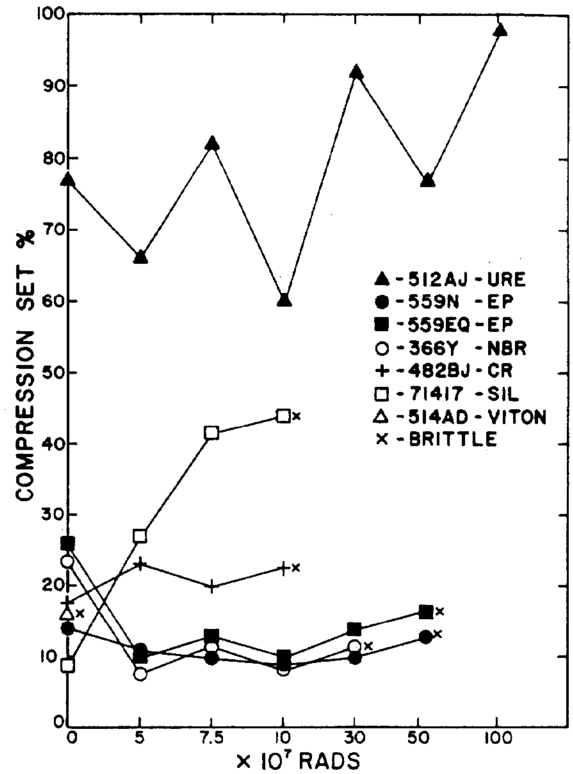

Fig. 3: Compression set for elastomer materials after irradiation.

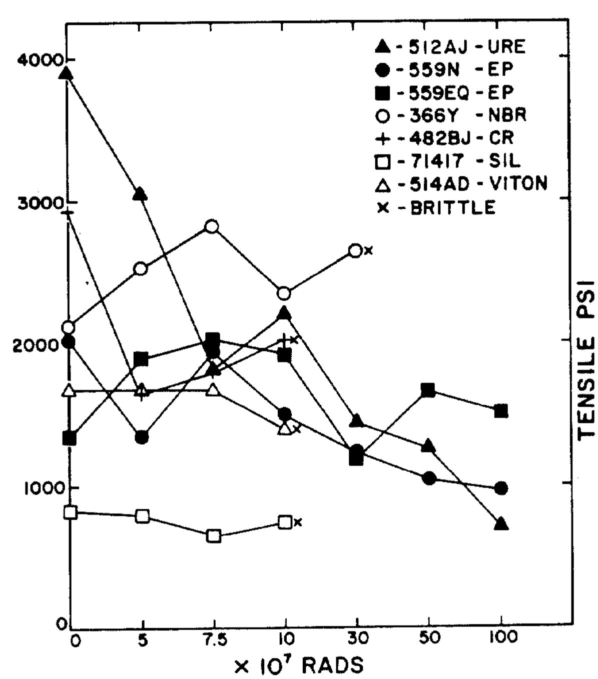

Fig. 4: Tensile strength of elastomers after irradiation.

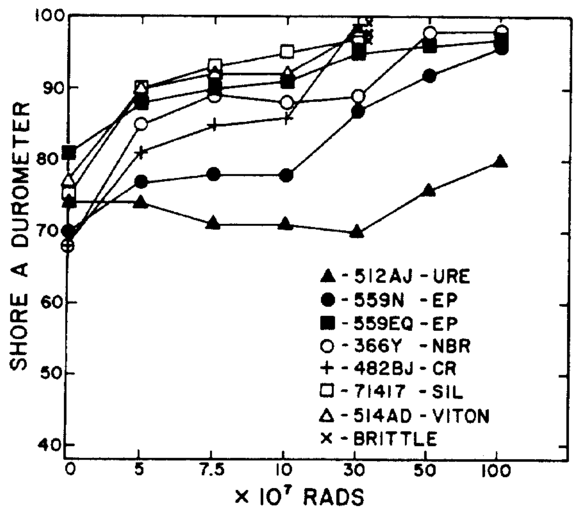

Fig. 5: Shore durometer hardness of elastomers after irradiation.