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Response of Elastomeric Packaging Components to a Corrosive Simulant Mixed Waste

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INTRODUCTION

The purpose of hazardous and radioactive materials packaging is to enable these materials to be transported without posing a threat to the health or property of the general public. To achieve this aim, regulations in the United States have been written establishing general design requirements for such packagings. While no regulations have been written specifically for mixed waste packaging, regulations for the constituents of mixed wastes, i.e., hazardous and radioactive substances, have been codified by the U.S. Department of Transportation (U.S. DOT, 49 CFR 173) and the U.S. Nuclear Regulatory Commission (NRC, 10 CFR 71). Based on these national requirements, a Chemical Compatibility Testing Program was developed in the Transportation Systems Department at SNL.

In this paper, we present the results of Part B of the second phase of this testing program. The first phase screened five liner materials and six seal materials towards four simulant mixed wastes. Part A of the second phase involved the comprehensive testing of five candidate liner materials to an aqueous Hanford Tank simulant mixed waste. Part B involved similar testing on elastomeric materials, ethylene-propylene and butadiene-acrylonitrile rubber. The comprehensive testing protocol involved exposing the respective materials to a matrix of four gamma radiation doses (~1, 3, 6, and 40 kGy), three temperatures (18, 50, and 60°C), and four exposure times (7, 14, 28, and 180 days). Following their exposure to these combinations of conditions, the materials were evaluated by measuring six material properties. These properties were specific gravity, dimensional changes, hardness, vapor transport rates, compression set, and mechanical properties.

EXPERIMENTAL

Materials

The selected materials were six elastomers having known chemical resistance to a large number of classes of chemicals. The elastomers were butadiene-acrylonitrile rubber, ethylene-propylene rubber (EPDM), epichlorohydrin rubber, isobutylene-isoprene copolymer rubber (Butyl), styrene-butadiene rubber, and Viton™ rubber. Of the six elastomers to be tested, only EPDM and butyl rubber have been studied so far in this multi-year program.

Simulant Preparation

The simulant mixed waste form used in this testing phase was an aqueous alkaline simulant Hanford Tank waste. It was prepared by dissolving 179 g (2.10 moles) of sodium nitrate and 50 g (0.73 moles) sodium nitrite in deionized water (600 mL) using a 4-L beaker. After these salts had completely dissolved, 82 g (2.05 moles) sodium hydroxide was added under stirring and slight heating using a magnetic stirrer. To this hot (~70°C) stirred solution, 17 g (0.107 moles) cesium chloride and 16 g (0.0952 moles) strontium chloride were added. Finally, 32 g (0.301 moles) of

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DISCLAIMER

sodium carbonate was added to the solution. To the resulting mixture was added another 400 mL of deionized water to bring the total volume of water used to 1 L. After cooling to near ambient temperature, the stirred mixture was stored in Amber Glass Bottles.

Sample Preparation

Standardized test methods were used to cut, condition, and test the materials. The geometry of the material samples was specified by the test method. The samples were cut using an expulsion press and dies manufactured by Testing Machines Inc., Amityville, NY. The use of the press and dies permitted the cutting of multiple samples of uniform dimensions. The individual samples were visually checked to assure that none had nicks or other imperfections prior to their use. As recommended by ASTM D618, the elastomers were conditioned at a standard temperature of 23°C and relative humidity of 50% for at least 24 hours prior to the testing process.

Sample Irradiation

The above mentioned samples were exposed to gamma radiation from an underwater ^{60}Co source at SNL. These samples were loaded into a metal basket in the same configuration as was used to condition the samples, i.e., the samples were stacked atop each other and separated by a metal spiral. The basket was then inserted into a water-tight stainless steel canister (volume ~4 L). The canister was sealed and lowered into the pool to a depth of ~ 2 meters, purged with slow steady flow (~ 30 mL/min) of dry air, and allowed to come to thermal equilibrium at either ambient, 50, or 60°C. Once thermal equilibrium was obtained, the canister was lowered into its irradiation location in the pool and the exposure time was started to obtain the desired radiation dosage. The highest dose rate available at the Low Intensity Cobalt Array (LICA) Facility was ~7 kGy/hr but the array used to irradiate these materials had dose rates of 0.95 kGy/hr. Thus for irradiations where a gamma-ray dose of 1.43 kGy was required, the samples were exposed for approximately 1.5 hours. For doses of ~3, 6, and 40 kGy, the corresponding longer exposure times were needed. After the samples received the calculated radiation dosage, the canister was removed from the pool and the samples were again placed in the conditioning chambers.

Sample Exposure to Chemicals

The general exposure protocol for all tests involved placing the specimens of each elastomer material into a container, and exposing them to the specific testing conditions. Care was taken to ensure that sufficient simulant waste was present to expose the entire surface area of all the samples. After adding the liquid simulant waste, the plastic lid was attached to the jar and tightened. The containers were placed in the respective enviromental chambers maintained at 18, 50, and 60°C. The containers were kept in these environmental chambers for 7, 14, 28, and 180 days.

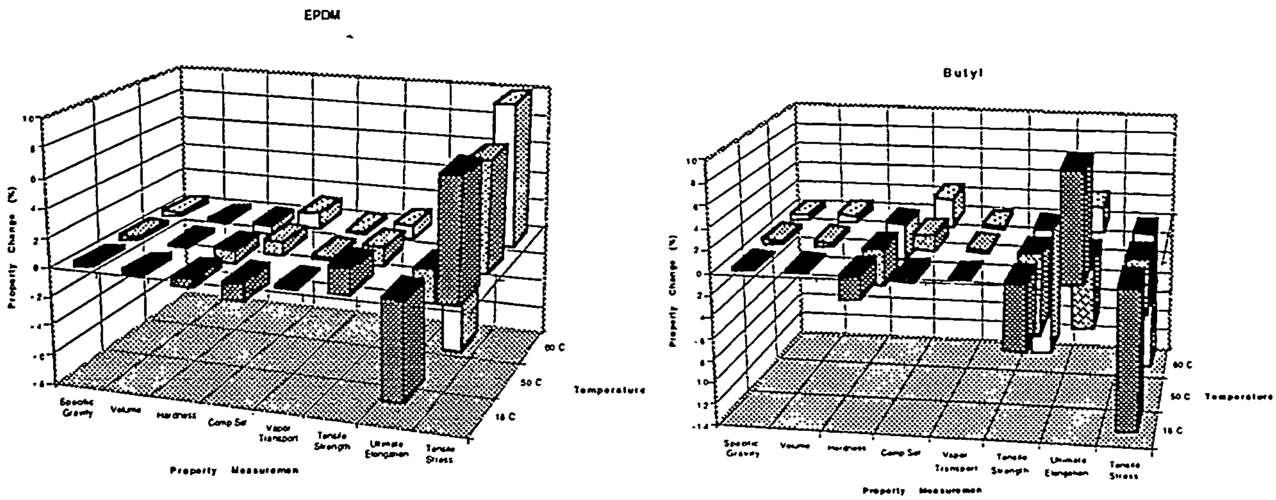
DISCUSSION

The material properties that should be evaluated to assess the suitability of potential elastomeric materials in mixed waste packaging designs are mass, dimensional and density changes, hardness, compression set, Vapor Transport Rates (VTR), tensile strength, elongation, and tensile stress (100% modulus). Since the measurement of all these material properties was expected to be costly and time-consuming, screening tests with relatively severe exposure conditions such as high temperatures (60°C) and high radiation levels (~3 kGy) were implemented to quickly reduce the number of possible materials for full evaluation. The screening criteria used were density changes for liners and vapor transport rates for elastomers. From this screening study, it was found that all of the selected liner and seal materials had passed the screening criteria in the aqueous simulant mixed waste. This then resulted in a need to test these materials by exposure to a matrix of four radiation doses, three temperatures, and four times in the simulant waste. The results on the liner materials were previously presented at the 20th Aging, Compatibility and Stockpile Stewardship Confrerence. The properties were evaluated using standardized test methods such as those developed by the American Society for

Testing and Materials (ASTM). For specific gravity changes, ASTM D792 was used. In evaluating dimensional and mass changes, ASTM D543 was used. For hardness changes, ASTM D2240 was used. In evaluating compression set, ASTM D395-Method B was used. For VTR measurements, ASTM D814 was used. Finally, for evaluating tensile properties, ASTM D412-Method A was used.

RESULTS

In Figure 1, we present the results of six measurements: specific gravity changes, dimensional changes (volume changes), hardness changes, compression set, VTR, and tensile property changes for EPDM and butyl rubber. Note that tensile properties include tensile strength, ultimate elongation, and tensile stress (100% modulus) changes.



(a) (b)

Figure 1. Comprehensive testing results for EPDM (a) and butyl rubber (b) Note: These results represent average values after exposure to four gamma radiation doses and the aqueous simulant waste over the four exposure times at 18, 50, and 60°C.

Based on the results presented here, it is worthwhile to attempt to identify the one material which displayed the greatest compatibility towards the corrosive simulant mixed waste under these conditions. In order to accomplish this, a close inspection of the data is required. In view of the extensive amount of data generated in this program and the limited space available in this paper, a summary of the experimental data is shown in Fig. 1. The values given in the 3-D bar graphs were obtained by calculating an average value from the individual values at the four gamma doses and four exposure times. These results therefore represent average values at the exposure conditions. The material with the lowest property change represents the most compatible material. Using this very simplistic approach, it can be seen that EPDM has the best response for these environmental conditions.

CONCLUSIONS

We have developed a chemical compatibility program for the evaluation of plastic packaging components which may be incorporated in packaging for transporting mixed waste forms. From the data analyses performed to date in this study, we have identified the thermoplastic, polychlorotrifluoroethylene, as having the greatest chemical compatibility after having been exposed to gamma radiation followed by exposure to the Hanford Tank simulant mixed waste. The most striking observation from this study was the poor performance of polytetrafluoroethylene under these conditions. In the evaluation of the two elastomeric materials, EPDM and butyl rubber, we have concluded that while both materials exhibit remarkable resistance to these environmental conditions, EPDM has a geater resistance to this corrosive mixed waste.