# Evaluation of Nonmetallic Components in the Hanford Waste Transfer System - 17287

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## ABSTRACT

Nonmetallic materials are currently being used in the United States Department of Energy's Hanford Site Tank Farm waste transfer system. These materials include the inner primary hoses in the hose-in-hose transfer lines (HIHTLs), Garlock® gaskets, ethylene propylene diene monomer (EPDM) O-rings. These materials are exposed to a number of stressors and the synergistic effects are not well understood.

Florida International University (FIU) engineers have developed an experimental test loop to determine how the nonmetallic materials react to both individual and simultaneous stressors. The initial phase of testing includes exposure of coupons and components to caustic material at various temperatures for varying lengths of time.

The coupons are manufactured from EPDM and Garlock® sheets and will be used to evaluate changes in material data from baseline data. Components (inner hoses, O-rings and gaskets) will also be used to determine the effects from an environment similar to its operational environment.

The test loop utilizes a 25% NAOH solution as the fluid and can accommodate eighteen component assemblies, each consisting of one EPDM HIHTL, EPDM O-ring and Garlock® gasket. There are three assembly aging sets, one for each temperature (37.78°C, 54.44°C and 79.44°C) and each set contains six assemblies; three for each of the two time periods (6 months and 1 year).

Prior to aging, a sample set of the components had baseline mechanical properties tested and a sample set of the coupons had baseline material properties determined as per ASTM standards. After the aging is completed the mechanical and material properties of the aged samples will be measured and compared with the bassline data to obtain an understanding of the synergistic effects of the two stressors.

## INTRODUCTION

Nonmetallic materials are utilized in the waste transfer system at the Hanford tank farms; these include the inner hose of the hose-in-hose transfer lines (HIHTLs), Garlock® gaskets and ethylene propylene diene monomer (EPDM) O-rings. These materials are exposed to simultaneous stressors including β and γ radiation, elevated temperatures, caustic supernatant as well as high pressures during normal use. In 2011, the Defense Nuclear Facilities Safety Board recommended to the U.S. Department of Energy (DOE) to conduct post service examination of HIHTLs and Teflon gaskets to improve the existing technical basis for component service life. Suppliers of the nonmetallic components often provide information regarding the effects of some of the stressors, but information is not provided for simultaneous exposure. An extensive test plan was developed by Sandia National Laboratories to understand the simultaneous effects of the aforementioned stressors [1]; however, this test plan was never executed. Additional studies conducted by Lieberman provides information on HIHTLs at elevated temperature and pressure but little information is gained regarding the synergistic effects with the caustic supernatant [2]. Florida International University (FIU) has been tasked with supporting this effort by conducting multi stressor testing on typical nonmetallic materials used at the Hanford tank farms.

This paper provides results from initial mechanical property testing of EPDM and Garlock® material coupons as well as the initial blowout/leak testing for HIHTL, EPDM O-rings and Garlock® gaskets. In addition, the experimental test loop being used to age the test specimens is described.

## EXPERIMENTAL TESTING

All material samples had baseline mechanical performance and properties tested prior to any exposure. Once the baseline properties were obtained, each material sample was aged, which involved exposure to a chemical simulant at ambient (37.78°C), operating (54.44°C) and design temperatures (79.44°C) for a duration of 180 and 365 days. Tests were conducted on both material coupons as well as in-service configuration assemblies. After aging/conditioning, the mechanical/material properties of the samples were again measured to identify any degradation in the properties.

To assess the baseline material properties of EPDM and Garlock©, sheets of the material were obtained and coupon specimens (Figure 1) were cut using a D412-C die. The specimens were used to determine hardness values obtained using a LECO LMV 50 Series hardness tester. To determine the material hardness, a load of 500 grams was used to create an indention in the sample and hardness values according to the Rockwell scale and Vickers scale were obtained. Multiple measurements were taken from 3 different Garlock© specimens. These results and the corresponding averages are provided in Table 1. Since EPDM material is a soft material, hardness readings were unable to be obtained with existing equipment.

**Figure 1. Coupon dumbbells.**

**Table 1. Baseline Coupon Hardness Test Results - Garlock® Data**

| Vickers | Rockwell HRB/HRC |
|---|---|
| 4 | 54 |
| 3 | 54 |
| 4 | 54 |
| 4 | 54 |
| 4 | 54 |
| 4 | 54 |
| 4 | 54 |
| 4 | 54 |
| 4 | 54 |
| 5 | 54.1 |
| 5 | 54.1 |
| **AVERAGE VALUES** | |
| **4.09** | **54.02** |

Baseline coupon tensile testing was conducted for both un-aged EPDM coupons and un-aged Garlock coupons. All procedures used for testing were derived from ASTM D412-16 [3]and were recorded to provide consistency throughout all tensile testing experiments, for both EPDM and Garlock® material coupons. Figure 2 shows the un-aged EPDM coupon in the tensile testing machine before testing (left) and before rupture (right).

**Figure 2. EPDM coupon testing.**

Table 2 shows the average test results for peak stress, peak load, strain at break and modulus of elasticity for the un-aged EPDM coupons.

**Table 2. Average Test Results from EPDM**

| Average Test Run Results - EPDM | | |
|---|---|---|
| Display Name | Value | Unit |
| Peak Stress | 0.002 | $kN/mm^2$ |
| Peak Load | 0.13133 | kN |
| Strain at Break | 0.76367 | mm/mm |
| Modulus | 0.00833 | $kN/mm^2$ |
| Width | 25 | mm |
| Thickness | 2.381 | mm |

Typical experimental data obtained from the un-aged Garlock® coupons is shown below. The average test results for the un-aged Garlock® coupons are provided in Table 3.

**Table 3. Average Test Results from Garlok® Coupons**

| Average Test Run Results - Garlock | | |
|---|---|---|
| Display Name | Value | Unit |
| Peak Stress | 0.003 | $kN/mm^2$ |
| Peak Load | 0.17367 | kN |
| Strain at Break | 0.0167 | mm/mm |
| Modulus | 3.03967 | $kN/mm^2$ |
| Width | 25 | mm |
| Thickness | 2.381 | mm |

In order to quantify how each sample was affected by the exposure to the caustic stressor, pre-exposure mechanical testing was conducted. Mechanical testing included hose burst and O-ring/gasket leak tests as per ASTM D380-94 [4] and ASTM F2378-05 [5], respectively. The tests were conducted on the 9 test samples (3 from each material). These results will be compared to post-exposure testing to be conducted on samples exposed 6-months and 12-months.

Baseline pressure tests were conducted on hose-in-hose transfer lines (HIHTL), ethylene propylene diene monomer (EPDM) O-rings and Garlock® gaskets. HIHTL pressure tests involved pressurizing each test section at a constant rate until the hose ruptured. Baseline hose pressure testing was conducted on three hose specimens. The results are shown in Table 4.

**Table 4. Baseline HIHTL Pressure Test Results**

| | H-00-1 | H-00-2 | H-00-3 | Average |
|---|---|---|---|---|
| Water Temperature (°C) | 22.00 | 22.00 | 24.00 | 22.86 |
| Ambient Temperature (°C) | 19.44 | 18.89 | 27.22 | 23.89 |
| Humidity % | 37.00 | 36.00 | 67.00 | 50.00 |
| Burst Pressure (Pa) | $1.89x10^7$ | $2.02x10^7$ | $1.94x10^7$ | $1.93x10^7$ |

| | | | | |
|---|---|---|---|---|
| Type of Failure | Rupture | Rupture | Rupture | N/A |
| Time Until Failure (s) | 320.50 | 216.00 | 203.50 | 221.38 |
| Start Length (m) | 0.76 | 0.77 | 0.77 | 0.76 |
| End Length (m) | 0.80 | 0.79 | 0.79 | 0.79 |
| Deformation Length (m) | 0.04 | 0.02 | 0.02 | 0.02 |
| Test Date | 3/21/2016 | 3/21/2016 | 3/25/2016 | N/A |

Each specimen experienced a rupture type failure, with the average maximum pressure at 1.93 x $10^7$ Pa. Each specimen also experienced a permanent deformation in their lengths, which averaged 0.02 m. A photo of a typical failed hose specimen is shown in Figure 3.

**Figure 3. Ruptured HIHTL test specimen.**

The baseline O-ring pressure testing was conducted for three EPDM O-ring specimens. The test rig and the results of the testing are shown in Figure 4 and

**Table 5**, respectively.

**Figure 4. O-ring pressure test rig.**

**Table 5. Baseline O-ring Pressure Test Results**

| | O-00-1 | O-00-2 | O-00-3 | Average |
|---|---|---|---|---|
| Water Temperature (°C) | 22.89 | 25.28 | 24.56 | 24.24 |
| Ambient Temperature (°C) | 27.78 | 29.44 | 29.44 | 28.89 |
| Humidity % | 68.00 | 59.00 | 59.00 | 62.00 |
| Holding Pressure (Pa) | $1.76 \times 10^6$ | $1.69 \times 10^6$ | $1.83 \times 10^6$ | $1.76 \times 10^6$ |
| Pressure Maintained? | Yes | Yes | Yes | N/A |
| Time Until Failure (s) | N/A | N/A | N/A | N/A |
| Test Date | 3/29/2016 | 3/29/2016 | 3/29/2016 | N/A |

Each specimen maintained the allotted pressure for the 5 minute time interval. The average pressure that the O-rings were maintained at was $1.76 \times 10^6$ Pa, which was $1.38 \times 10^5$ Pa over our original desired pressure. The change in the prescribed pressure was due to the large variations in our hand-pump.

The baseline Garlock® gasket pressure testing was conducted for three gasket specimens. The test rig and the results of the testing are shown in Figure 5 and Table 6, respectively.

**Figure 5. Gasket baseline pressure test rig.**

**Table 6. Baseline Gasket Pressure Test Results**

| | **G-00-1** | **G-00-2** | **G-00-3** | **Average** |
|---|---|---|---|---|
| Water Temperature (°C) | 23.89 | 23.89 | 23.89 | 23.89 |
| Ambient Temperature (°C) | 26.11 | 25.56 | 25.56 | 25.74 |
| Humidity % | 50.00 | 54.00 | 52.00 | 52.00 |
| Holding Pressure (Pa) | $1.15 \times 10^6$ | $1.03 \times 10^6$ | $1.02 \times 10^6$ | $1.07 \times 10^6$ |
| Pressure Maintained? | Yes | Yes | Yes | N/A |
| Time Until Failure (s) | N/A | N/A | N/A | N/A |
| Test Date | 4/4/2016 | 4/4/2016 | 4/4/2016 | N/A |

Each specimen maintained the allotted pressure for the 5 minute time interval. The average pressure that the gaskets were held at was 1.069 x $10^6$ Pa, which was only 3.447 x$10^4$ Pa over our desired pressure.

The in-service configuration aging experimental consisted of 3 independent pumping loops with two manifold sections on each loop (Figure 6). Each of the 3 loops was run at a different temperature (37.78°C, 54.44°C and 79.44°C). Each manifold section held three test samples and was used for a corresponding exposure time of 6 months and 1 year. Each test sample consisted of a HIHTL hose section, an EPDM O-ring and a Garlock® gasket placed in a series configuration. Isolation valves on each manifold allowed for removal of samples without affecting the main loop and the rest of the samples. The temperature of the chemical solution circulating within each loop was maintained at a preset temperature by an electronically controlled heater. A 25% sodium hydroxide solution was used as a chemical stressor that circulates in each of the loops. The chemical stressor's pH was checked every 30 days to ensure that the concentration levels were remaining constant.

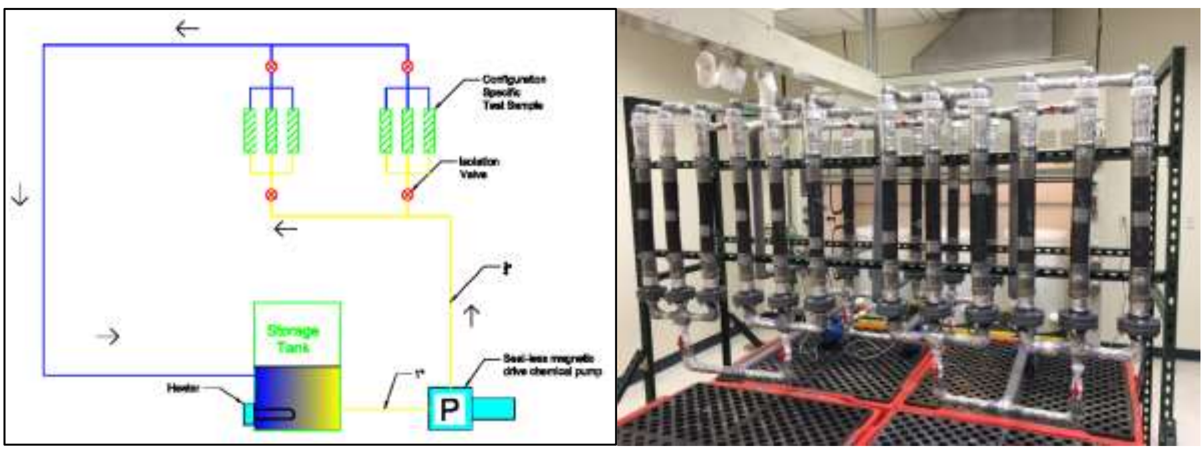

**Figure 6. In-service component aging loop.**

The coupon aging experiment setup consisted of one coupon aging vessel (Figure 7) submerged in each of the three test loop's storage tanks. This resulted in exposing the coupons to the same conditions as the in-service configuration tests; the circulating fluid is the same 25% sodium hydroxide solution. Each vessel contains 10 coupons (5 of each type of EPDM and Garlock® materials) and was submerged in the bath for duration of 180 and 365 days.
Table **7** shows the test coupon aging matrix.

**Table 7. Coupon Aging Matrix**

| Days Exposure | Ambient Temperature (100°F) | Operating Temperature (130°F) | Design Temperature (180°F) | Baseline |
|---|---|---|---|---|
| 0 | | | | 10 coupon samples |
| 180 | 10 coupon samples | 10 coupon samples | 10 coupon samples | |
| 360 | 10 coupon samples | 10 coupon samples | 10 coupon samples | |

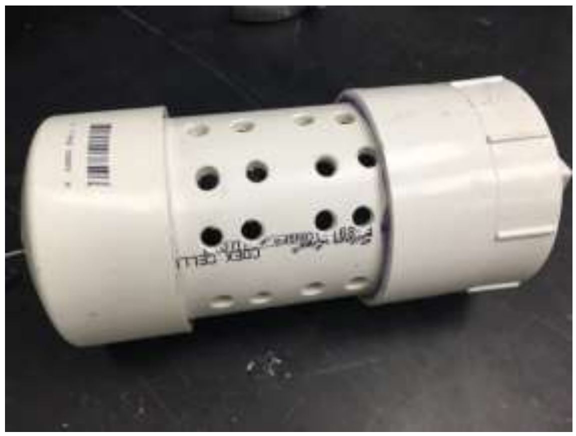

**Figure 7. Coupon aging vessel.**

**CONCLUSIONS**

FIU is assisting the Department of Energy and Hanford by evaluating the effects of multiple stressors on non-metallic materials that includes inner hoses of HIHTLs and gaskets and O-rings. An experimental testbed has been developed that will provide information on the degradation of the materials caused be elevated temperature and exposure to caustic material. Baseline data including material properties and burst pressures of the HIHTLs has been obtained and will be compared to materials that have been aged. The aging is currently in progress and is scheduled to continue for durations of six months and one year. After the aging has completed, the same tests will be conducted with the results being compared with the baseline data to get an understanding of the degradation of the material. After the data has been analyzed, additional testing phases may be considered. This may include the effects of elevated pressure in addition to elevated temperature and exposure to caustic solutions. Additional material may also be evaluated including the use of Teflon and Tefzel.

**REFERENCES**

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