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Testing of Candidate Polymeric Materials for Compatibility with Pure Alternate Pretreat as Part of the Universal Waste Management System (UWMS)

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March 2018

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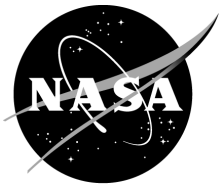

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LIST OF ACRONYMS

C	carbon
CrO_3	chromium trioxide
DMA	dynamic mechanical analyzer
F	fluorine
FEP	fluorinated ethylene propylene
H_2SO_4	sulfuric acid
H_3PO_4	phosphoric acid
ISS	International Space Station
PCTFE	polychlorotrifluoroethylene
PEEK	polyether ether ketone
PFA	perfluoroalkoxy alkane
PTFE	polytetrafluoroethylene
TTS	time-temperature superposition
UPA	Urine Processor Assembly
UWMS	Universal Waste Management System
WCS	Waste Collection System

NOMENCLATURE

E	stress relaxation modulus
E'	DMA storage modulus
$\Delta E'$	change in DMA storage modulus
t_f	final time
t_0	initial time

TECHNICAL PUBLICATION

TESTING OF CANDIDATE POLYMERIC MATERIALS FOR COMPATIBILITY WITH PURE ALTERNATE PRETREAT AS PART OF THE UNIVERSAL WASTE MANAGEMENT SYSTEM (UWMS)

1. INTRODUCTION

NASA has been working with United Technologies Aerospace Systems to develop an improved Waste Collection System (WCS) for low Earth orbit spacecraft. Compared to previous Space Shuttle and existing International Space Station (ISS) WCS hardware, an improved commode for astronaut waste, called the Universal Waste Management System (UWMS), significantly reduces cost, weight, and volume in addition to making the system easier for the astronauts to use.[1,2]

For water recovery on ISS through the Urine Processor Assembly (UPA), urine was previously pretreated with sulfuric acid (H_2SO_4), but the percentage water recovery was eventually reduced due to the formation of salt crystals. Ultimately, urine was pretreated with phosphoric acid (H_3PO_4) instead of H_2SO_4 to become known as 'alternate pretreat.' Polymeric materials for use on UWMS would be for parts such as transfer hoses and O-ring seals. Liquids in contact with UWMS polymeric materials would be somewhat harsher ($pH < 1$) than the typical pretreated urine and brine solutions ($pH \leq 2$) used in the UPA.

Samples of several candidate UWMS polymeric materials were tested for their compatibility with pure alternate pretreat, which is concentrated H_3PO_4 containing a percentage of chromium trioxide (CrO_3) oxidizer. Those polymeric materials were:

- Teflon™ Perfluoroalkoxy Alkane (PFA) 340 fluoropolymer
- Teflon fluorinated ethylene propylene (FEP) fluoropolymer
- Polyether Ether Ketone (PEEK) unfilled polymer
- Polychlorotrifluoroethylene (PCTFE) chloro fluoropolymer
- Parker V747-75 fluorocarbon rubber

1.1 Chemical Resistance of Fluoropolymers: Thermoplastics and Thermosets

The fluoropolymer best known for its exceptional chemical resistance is the semi-crystalline thermoplastic polytetrafluoroethylene (PTFE), due to 'full fluorination' of fluorine (F) atoms attached to carbon (C) atoms on the polymer chain. The C-F bond is one of the strongest found in polymers. When F is substituted with a different atom on the polymer chain, the polymer does not have quite the same exceptional chemical resistance as that of PTFE. The fluoropolymers FEP and PFA are both copolymers made from two different monomers. Polymeric repeat units of PTFE, PCTFE, FEP and PFA are shown figure 1.[3]

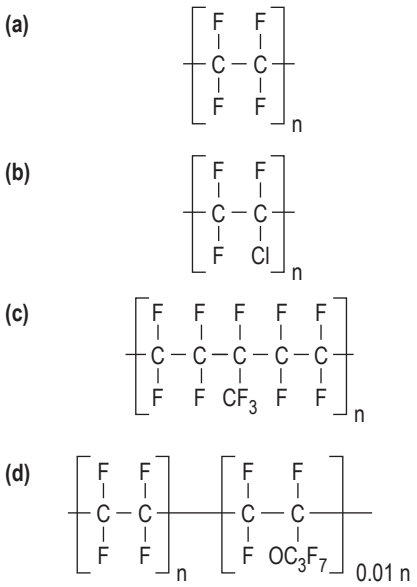

Figure 1. Polymer repeat units for: (a) PTFE, (b) PCTFE, (c) FEP, and (d) PFA.

Fluoropolymers are generally known to have good chemical resistance, and this applies to fluoroelastomer thermoset materials as well. The V747-75 fluorocarbon rubber made by Parker is not synonymous with Viton™ made by The Chemours Company, but the V747-75 is roughly equivalent to Viton A, which is considered a 'standard' fluoroelastomer type containing ≈66% F. Other grades of Viton with higher percentages of F would have even better chemical resistance. For several different components of the UPA on ISS, Material Identification and Usage Lists call out the uses of O-ring rubber seals made of either the V747-75 or Viton materials.

1.2 Polymer-Liquid Compatibility Data From Literature Similar to This Work

The five polymers tested for compatibility in this work were shown in technical literature to have good compatibility with the liquid most similar to that used in this work—concentrated H_3PO_4 of 80–95% at temperatures of 20–120 ºC. This is displayed in table 1.

Table 1. Literature data for compatibility of several polymeric materials with concentrated H_3PO_4 at temperatures of 20 –120 ºC.

Polymeric Material	Data for Compatibility With Phosphoric Acid (PA)
FEP	Resistant in 95% PA at 20–100 °C (ref. 4)
PFA	Resistant in 95% PA at 20–100 °C (ref. 5)
PCTFE	Resistant in 80% PA at RT–100 °C (ref. 6)
	Resistant in 85% PA at cold & hot temps (ref. 7)
Viton or FKM fluoroelastomers	Resistant in 80% PA at RT–80 °C (ref. 6)
	Resistant in > 40% PA (ref. 8)
PEEK	Resistant in 95% PA at 20–100 °C (ref. 9)
	Resistant in 80% PA at RT–120 °C (ref. 6)

2. EXPERIMENTAL METHODS

2.1 Materials Used and Sample Fabrication

All materials used in this work were processed in flat-sheet form. The PEEK, PCTFE and PFA materials were each ≈0.125 in. thick. The V747-75 rubber was ≈0.07 in thick, and FEP film was ≈0.01 in thick. Samples machined or cut from flat-sheet materials were tested with a dynamic mechanical analyzer (DMA) to determine changes in modulus (indicator of material stiffness or toughness) after immersion in the liquid pure alternate pretreat at room temperature for ≈1 yr.

All samples for DMA testing were used with the as-processed thickness and were machined or cut ≈2.5 × 0.5 in. The thicker samples were cut in a machine shop, while the thinner samples (FEP and V747-75) were cut with a sharp utility knife against a stainless-steel ruler with a non-slip cork backing. Enough samples of each material were made for conditioning in the pure alternate pretreat for times (days) of ≈45, ≈90, ≈150, and ≈365. Virgin samples of each material were also machined or cut to the same sizes to test by DMA for comparison to the immersed samples.

2.2 Sample Conditioning Followed by Weight and Dimension Measurements

Soft wire 'hardware cloth' with a 0.5 in^2 grid was used to make racks for storing machined/cut material samples in pure alternate pretreat. Racks containing samples were placed in a 1 L Nalgene™ jar made of chemically-resistant polypropylene. As needed, racks of two different materials were placed in one storage jar to minimize storage space. The liquid was gently poured over the sample racks in each jar until the liquid level was close to the top of the rack. Each jar had a threaded plastic lid that was kept finger tight during sample storage in a laboratory fume hood. Virgin samples of FEP film are shown in figure 2 mounted in a sample rack with the storage jar in the background, and virgin samples of PFA are shown up close in figure 3.

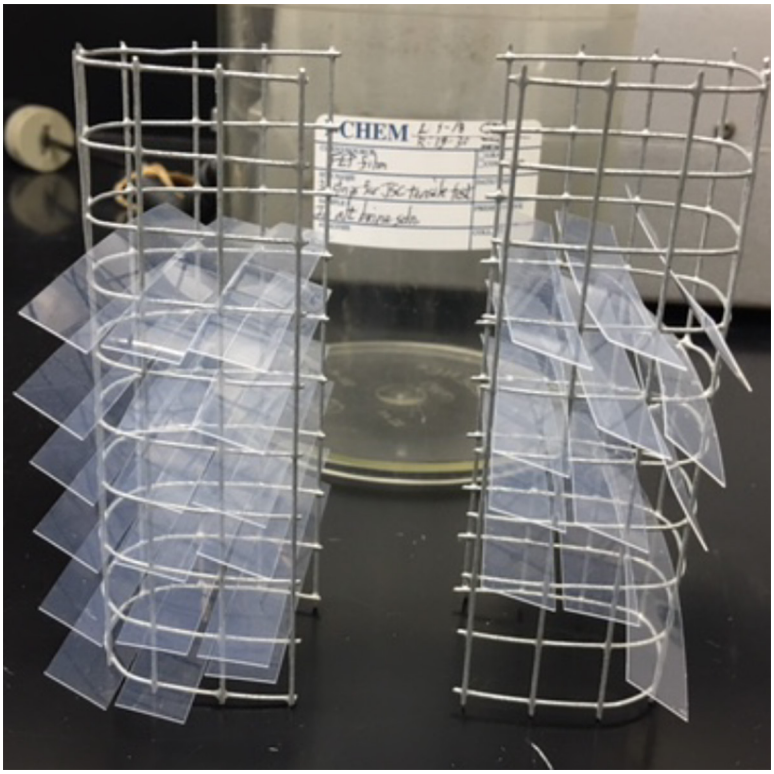

Figure 2. Cut samples of virgin FEP film mounted in soft wire racks made of 'hardware cloth.' The sample racks were stored in a 1 L Nalgene™ jar shown in the background. The liquid pure alternate pretreat was gently poured over the sample racks to near the top of each rack.The white plastic threaded cap was finger tightened on the jar during storage in a laboratory fume hood.

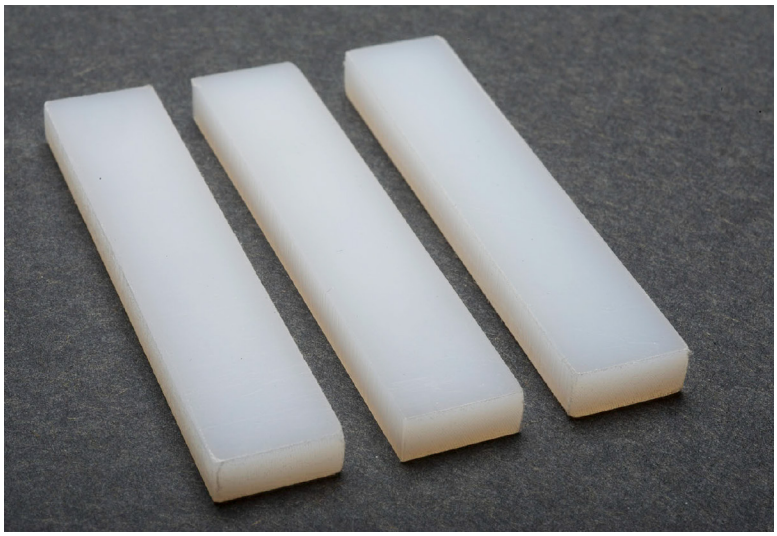

Figure 3. An up-close view of machined samples of virgin PFA. Using as-processed thickness, each sample was machined ≈2.5 in × 0.5 in.

For each sample removed from the liquid in the storage jar, it was squirted with deionized water and patted dry with a lint-free cloth. The sample was then quickly weighed on an analytical balance and measured for each dimension (length, width, thickness) 4–5 times with digital calipers. The weight and dimensional measurements, which were made pre-immersion on each sample, were later used to calculate changes in sample weight and volume after liquid immersion.

2.3 Sample Testing With a Dynamic Mechanical Analyzer

2.3.1 Dynamic Mechanical Analyzer Clamps Used and Sample Sizes Tested

The TA Instruments 2980 Dynamic Mechanical Analyzer (DMA) was used to test each sample soon after it was removed from the liquid, rinsed, dried, weighed and measured for dimensions. Thicker samples (PEEK, PFA and PCTFE) were all tested horizontally by dualcantilever bending using the largest available stainless-steel DMA sample clamp with a fixed sample length of 35 mm. That ensured a sample length/thickness ratio of ≈11 for these thicker samples. A sample length/thickness ratio of at least 10 is recommended for all DMA testing to ensure that no mixed-mode deformation (e.g. some shear) is occurring along with bending. Thinner samples (FEP and V747-75) were tested vertically in the DMA with a film tension clamp, which is limited to samples <2 mm thick. Rectangular samples used in this clamp need to be shorter and narrower than those tested by dual cantilever bending. For testing each sample by DMA film tension after immersion, it was cut further to a width of ≈0.20 in and length of ≈1.25 in. For film tension testing, the sample length/thickness ratio was also kept >10. Virgin samples of each material were also tested with the appropriate test clamp for comparison with samples after immersion in pure alternate pretreat. The DMA clamps for dual cantilever bending and film tension are shown in figure 4.

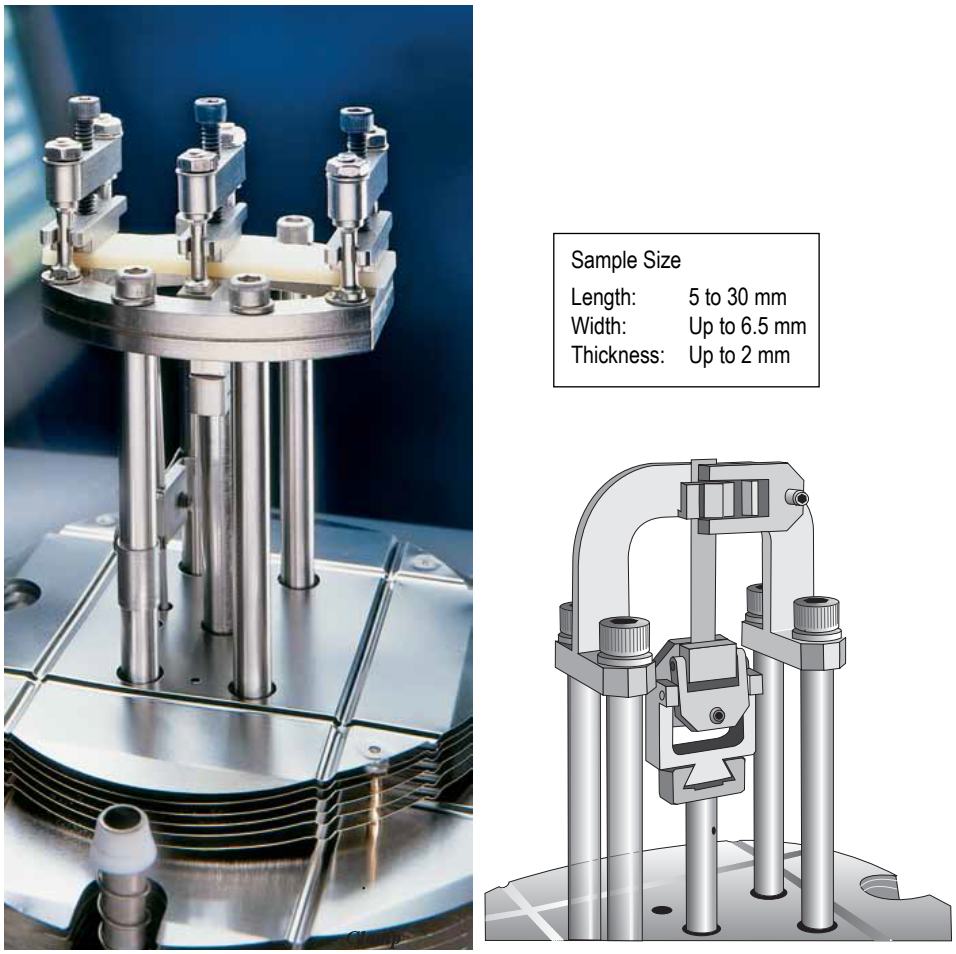

Figure 4. Sample mounted horizontally in the DMA dual cantilever bending clamp (left) and a sample mounted vertically in the DMA film tension clamp (right).

2.3.2 Dynamic Mechanical Analyzer Test Parameters and Conditions Used

2.3.2.1 Proper Pre-Test Tightening of Samples With a Torque Wrench For thicker samples (PEEK, PFA and PCTFE) tested with the dual cantilever bending clamp, a torque wrench was used pre-test to tighten each of three screws across the sample length (fig. 4) to ≈5–6 in-lbf. For thinner samples (FEP and V747-75) tested with the film tension clamp, a torque wrench was used pre-test to tighten both screws at the ends of the vertical sample (fig. 4) to ≈2–3 in-lbf.

2.3.2.2 Gas Used for Operation of Drive Shaft During Dynamic Mechanical Analyzer Testing The drive shaft for the DMA corresponds to the bottom of the vertical film tension sample and the middle point of the horizontal dual cantilever sample as shown in figure 4. For the drive shaft to operate properly during DMA testing, it must float on a gas. Although air can be used, an inert gas (argon) was used for all DMA testing in this work and was plumbed in from an outside argon supply tank. A pressure of ≈65 psi was used to allow the drive shaft to float sufficiently to move it into a position to properly mount and clamp the sample before testing.

3. RESULTS AND DISCUSSION

3.1 Previous Dynamic Mechanical Analyzer Testing on Polymeric Materials in Similar Solutions

In 2014, testing with the 2980 DMA was performed on samples of non-metallic materials used in working parts of the UPA on ISS. This testing evaluated the compatibility of these materials with pretreated urine and brine solutions when the acid pretreat was changed from sulfuric to H_3PO_4. In that work, DMA stress relaxation modulus was obtained on control samples and samples immersed in the two solutions at room temperature for slightly more than 1 yr. The DMA stress relaxation tests were performed between 25 °C and a specified elevated temperature, for a temperature increment of 5 °C and a constant strain.[4]

In the 2014 testing, real-time stress relaxation data from immersed and control samples were used to predict stress relaxation modulus after 10 years, which is helpful in predicting the working life of UPA parts on ISS made from such materials. This 10-yr prediction was made by analyzing DMA data with a software program based on the principle of time-temperature superposition (TTS). Figure 5 is a good illustration from the literature for an application of TTS to a sample of polyisobutylene rubber for determining stress relaxation modulus versus time at several isothermal temperatures from ≈ –80 to +50 °C. Based on a reference temperature of 25 °C, a 'master curve' was created by shifting of the isothermal stress relaxation modulus segments—lower temperature segments to shorter times and higher temperature segments to longer times.[5]

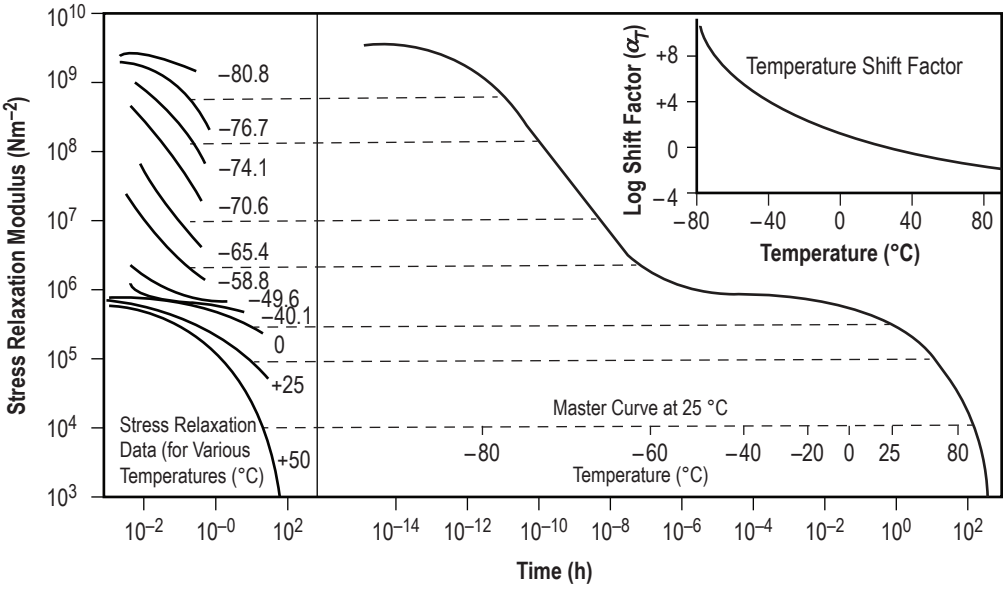

Figure 5. Literature example of DMA stress relaxation test on a polyisobutylene rubber sample (at several isothermal temperatures from ≈ –80 to +50 °C) converted to a TTS 'master curve' based on shifting stress relaxation segments on the time axis.

An example of the 2014 DMA stress relaxation testing is shown in figure 6 for a sample of PTFE polymer after immersion in alternate pretreated urine for 90 days. Based on a reference temperature of 40 °C, a TTS 'master curve' was created by shifting stress relaxation modulus segments at several isothermal temperatures. Points were marked on the time axis for values of stress relaxation modulus *E* corresponding to a very short time and a very long time (87,600 h = 10 yr). Figure 6 shows there was some 'feathering' near the midpoint of the isothermal relaxation segments when the master curve was created. This feathering effect was more pronounced for rigid polymers tested, such as polyimide, polyetherimide, and polysulfone.[4]

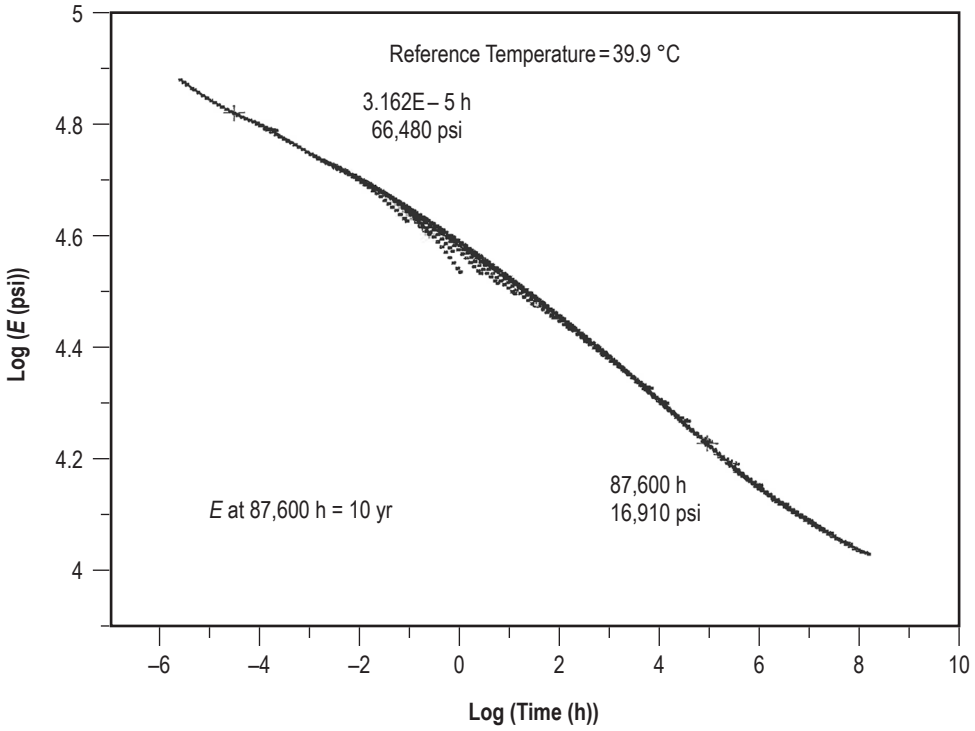

Figure 6. DMA master curve on a PTFE sample from a 2014 stress relaxation test showing some 'feathering' of shifted isothermal segments.

3.2 Current Dynamic Mechanical Analyzer Testing on Polymeric Materials in Pure Alternate Pretreat

Because of the problems in 2014 with feathering of DMA isothermal stress relaxation segments in creating a TTS master curve, a different approach was taken in this current DMA testing on polymeric materials—samples of controls and those immersed in pure alternate pretreat for specified times. Discussions with an application engineer at TA Instruments indicated that a 'smoother' TTS master curve could likely be obtained from a single experiment by using a frequency sweep (instead of stress relaxation) at several isothermal temperatures.

Each DMA test on each sample was performed from 30 ºC to a designated elevated temperature depending on the material. The highest temperature tested was ≈50– 60 ºC below the melting point of a semi-crystalline thermoplastic or near the upper continuous use temperature of an elastomeric material such as V747-75. A constant strain/amplitude was chosen for each test, ranging from 25 μm for rigid polymers to 50 μm for a flexible rubber material (V747-75).

The strain/amplitude chosen for each sample test was within the range of linear viscoelastic behavior and was determined by performing a simple strain sweep at room temperature. At each isothermal temperature during a sample test over a range of temperatures, the following frequency sweep (in Hz) was performed in this order: 10, 7, 5, 3, 1, 0.7, 0.5, 0.3, 0.1.

The DMA stress relaxation modulus measured in 2014 data is not frequency-dependent, but storage moduli measured for this work does depend on frequency. Values of the storage modulus determined by DMA should be very similar in magnitude to those for Young's modulus determined by tensile dog bone samples used on a mechanical test machine. The storage modulus measures both the elastic (dominant) and viscous (very small) components of a polymeric sample.

Figures 7 and 8 are examples of TTS master curves generated for samples of PFA and PCTFE tested by DMA after immersion in pure alternate pretreat for 44 and 46 days, respectively. Starting at 30 ºC with an increment of 5 ºC, the PFA and PCTFE samples were tested at several isothermal temperatures up to 250 ºC and 150 ºC, respectively. For both samples, a constant strain/amplitude of 25 μm and a reference temperature of 50 ºC were used for generating TTS master curves. Each master curve resulted from shifting of data at lower temperatures to higher frequencies and higher temperatures to lower frequencies. It is apparent that the storage modulus of PCTFE decreased less than that of PFA for increasing temperature and decreasing frequency. For all samples tested, as shown in figures 7 and 8, two points were chosen on each TTS master curve such as 10 or 100 Hz and 3.115×10^{-9} Hz (≈10 yr). The change in storage modulus ($\Delta E'$) between these two frequencies was determined for each immersed sample and control/virgin sample. For each material, the virgin samples and samples for each immersion time were tested in duplicate.

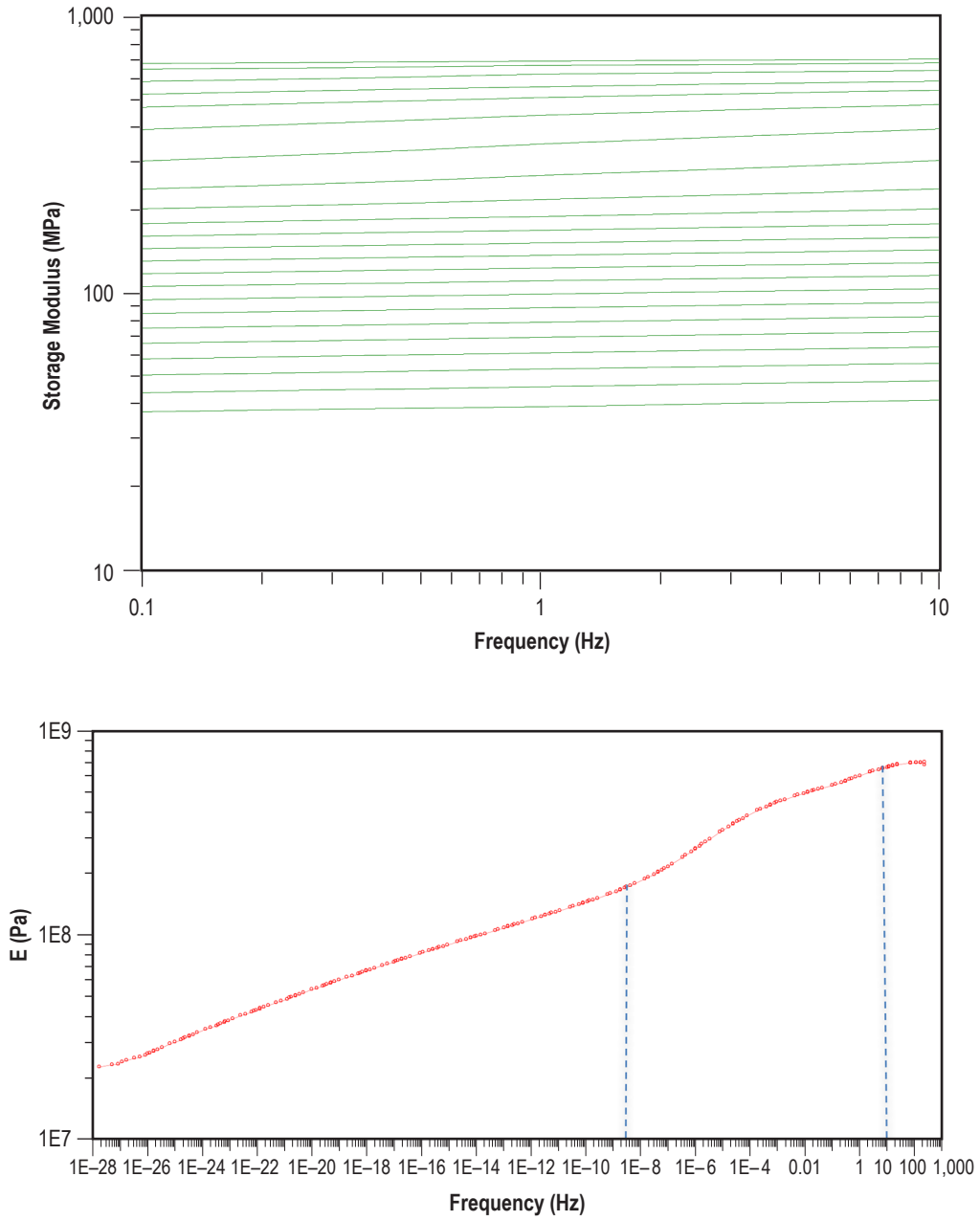

Figure 7. Storage modulus versus frequency of PFA immersed in pure alternate pretreat for isothermal temperatures ranging from 30 to 250 ºC in 5 ºC increments. The TTS master curve (bottom) was created from shifting the individual curves (top). Values of storage modulus on the master curve were determined at designated frequencies of 10 Hz and 3.115×10^{-9} Hz (≈10 yr) to calculate $\Delta E'$ compared to $\Delta E'$ for virgin PFA material.

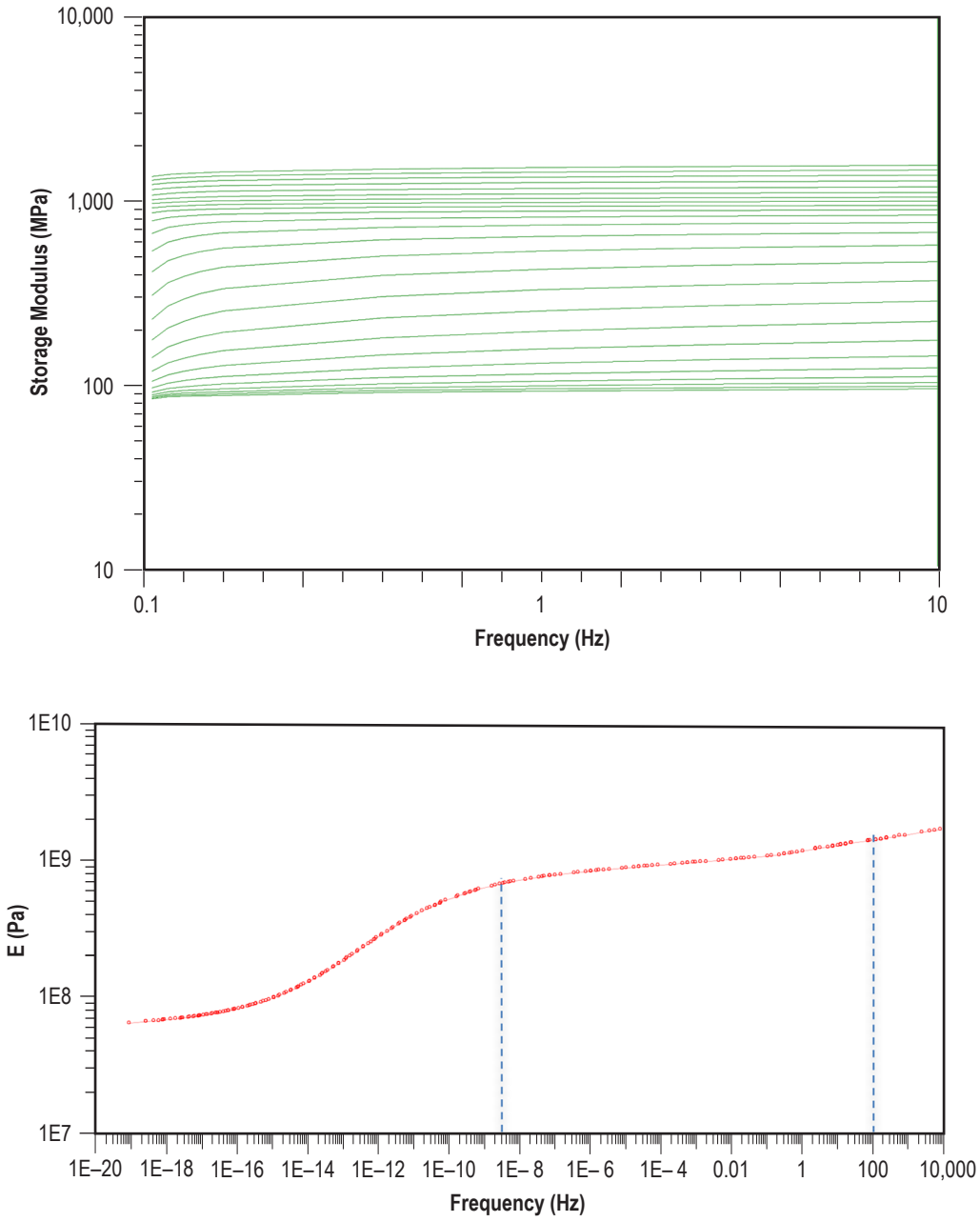

Figure 8. Storage modulus versus frequency of PCTFE immersed in pure alternate pretreat for isothermal temperatures ranging from 30 to 150 ºC and a 5 ºC temperature increment. The TTS master curve (bottom) was created from shifting of individual curves (top). Values of storage modulus on the master curve were determined at designated frequencies of 100 Hz and 3.115×10^{-9} Hz (≈10 yr) to calculate $\Delta E'$ compared to $\Delta E'$ for virgin PCTFE material.

For each of the five polymeric materials tested in this work, the average percentage of the control/virgin value for $\Delta E'$ was determined for each of the four immersion times as summarized in table 2. For the average percentage of the control/virgin value for $\Delta E'$, a value of 100 would indicate 'no change' in storage modulus as a function of immersion time in pure alternate pretreat. The reduction in $\Delta E'$ ranged from ≈6 to 21% for the five materials immersed up to ≈1 yr. This would indicate that all five materials would be considered as useful candidates for UWMS. Figure 9 is a plot of the average percentage of $\Delta E'$ versus immersion time in pure alternate pretreat. For a logarithmic curve fit through the data for each material, the FEP polymer showed the least reduction in $\Delta E'$ with increasing immersion time.

Table 2. Average percentage of the virgin material value for the $\Delta E'$ versus immersion time at different frequencies/times in pure alternate pretreat for the five polymeric materials tested by DMA.

Polymeric Material	Immersion Time in Alternate Pure Pretreat (days)	Average of Virgin Value for $\Delta E'$ ($t_0 - t_f$) (%)
Teflon® FEP copolymer film (fluorinated ethylene propylene)	43	93.1
	88	104.5
	148	95.7
	363	94.2
Teflon PFA copolymer (perfluoroalkoxy)	44	94.1
	89	86.2
	149	88.5
	364	84.0
PEEK (polyether ether ketone)	45	92.6
	90	85.9
	150	83.2
	365	79.2
PCTFE (polychlorotrifluoroethylene)	46	93.2
	91	98.5
	151	89.2
	366	84.8
V747-75 (Parker fluorocarbon rubber)	47	102.7
	92	88.8
	152	88.0
	367	88.2

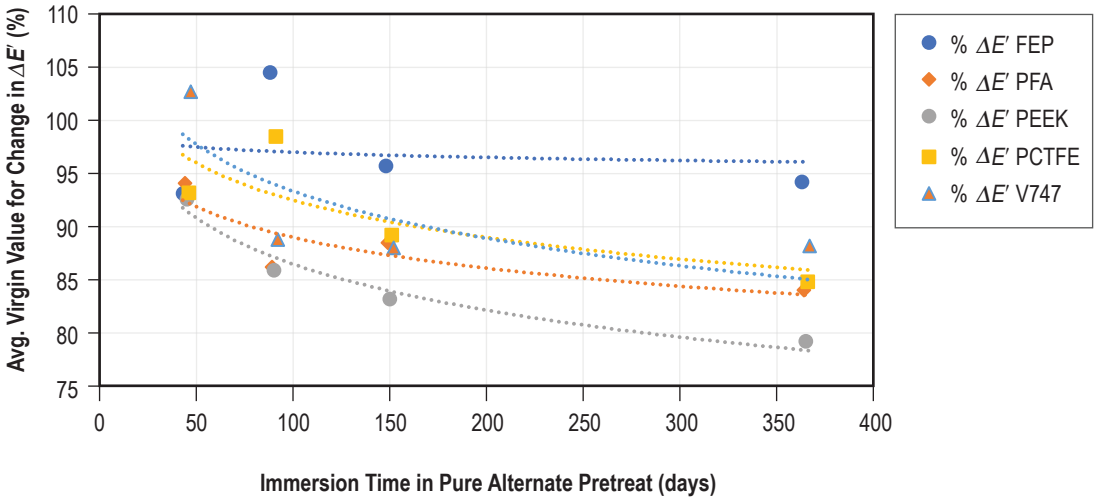

Figure 9. Average percentage of $\Delta E'$ versus immersion time in pure alternate pretreat for the five polymeric materials tested by DMA.

3.3 Appearance and Changes in Weight and Volume After Liquid Immersion

None of the samples of the five polymeric materials showed any signs of chemical degradation after 1 yr immersion, with nothing more than some discoloration from prolonged contact with the liquid. For each of the five materials, the average percentage increases in sample weight and volume (based on dimensional changes) are shown in table 3 for immersion times of ≈150 and ≈365 days. Changes in weight and volume were fairly minimal for FEP, PFA, PCTFE and PEEK. Percent increases in weight and volume were the largest for V747-75, but this was to be expected for an elastomeric material. The FEP material actually showed some slight volume shrinkage between 148 and 363 days of immersion in pure alternate pretreat.

Table 3. Average percentage increases/changes in weight and volume (based on dimension) for immersion times of ≈150 and ≈365 days in pure alternate pretreat for the polymeric materials tested by DMA.

Polymeric Material	Immersion Time in Alternate Pure Pretreat (days)	Average Weight Increase (%)	Average Volume Increase (%)
Teflon FEP copolymer film (fluorinated ethylene propylene)	148 363	0.01 0.01	0.65 −0.25
Teflon PFA copolymer (perfluoroalkoxy)	149 364	0.04 0.05	0.82 0.84
PEEK	150 365	0.35 0.38	1.14 1.22
PCTFE	151 366	0.02 0.05	0.74 0.82
V747-75	152 367	1.20 2.50	4.20 5.75

4. SUMMARY AND CONCLUSIONS

Testing was performed at the NASA Marshall Space Flight Center to determine the compatibility of several candidate polymeric materials with pure alternate pretreat for use on the UWMS developed as an improved WCS for low Earth orbit spacecraft. The polymeric materials, which would be used in parts on UWMS such as transfer hoses and O-ring seals, included FEP, PFA and PCTFE fluoropolymers, PEEK and a Parker Seals fluorocarbon rubber. Pure alternate pretreat is concentrated H_3PO_4 containing CrO_3 oxidizer.

Samples of the five polymeric materials were tested with a DMA after immersion in pure alternate pretreat at room temperature. Samples were tested for four different immersion times out to about 1 yr. In addition to samples tested after immersion, virgin samples of the same five materials were also tested for comparison.

For each material, immersed and virgin samples were tested by DMA from 30 ºC to an appropriate elevated temperature for several isothermal temperatures with a 5 ºC increment. At each isothermal temperature, a frequency sweep was performed for nine frequencies from 10 to 0.1 Hz. Based on a reference temperature of 50 ºC, TTS was used to shift storage modulus (E') segments to produce a 'master curve' of E' versus frequency. Convenient values of higher frequency (10–100 Hz) and lower frequency (≈10 yr) were marked on each master curve to determine a value of $\Delta E'$. The $\Delta E'$ of each immersed sample was compared with that of the virgin sample to determine the percent change in $\Delta E'$ due to immersion.

Percent reduction in $\Delta E'$ due to immersion ranged from ≈6 to 21% for 1 yr immersion, and this would be considered acceptable performance for all five materials. None of the samples showed signs of chemical degradation after a 1-year immersion, and discoloration of samples from the liquid was expected. Changes in weight and volume (from dimensional measurements) prior to DMA testing were fairly minimal for the four more rigid polymers. The fluorocarbon rubber material showed the highest weight gain and volume increase of the five materials, but this was expected from an elastomeric material immersed in a liquid environment for a long time.

REFERENCES

1. UTC Aerospace Systems: "Universal Waste Management System," <http://utcaerospace systems.com/cap/products/Pages/universal-waste-management-system.aspx>, 2017.

2. Stapleton, T.J.; Broyan, J.L.; and Baccus, S.: "Development of a Universal Waste Management System," Paper Presented at the 43rd International Conference on Environmental Systems, AIAA, Vail, Colorado, July 14–18, 2013.

3. Cole-Parmer Instrument Company, LLC.: "Chemical Resistance of Fluoropolymers," <https:// www.masterflex.com/tech-article/fluoropolymers-chemical-resistance>.

4. Chemical Resistance Chart for FEP: <https://www.zeusinc.com/technical-resources/technical-information/chemical-resistance/chemical-resistance-chart-fep>.

5. Chemical Resistance Chart for PFA: <https://www.zeusinc.com/materials/pfa/chemical-resistance-chart-pfa>.

6. "Chemical Resistance Chart," Emerson Process Management, Rosemount Analytical, Inc., 2010: <http://www2.emersonprocess.com/siteadmincenter/PM%20Rosemount%20Analytical%20Documents/Liq_Handbook_41-6018.pdf>.

7. "Technical Information—Chemical compatibility," Habonim Industrial Valves & Actuators, October 2016: <http://habonim.com/pdf/prod_catalogs/Catalog-October-2016/Chemical-compatibility-2016-catalog.pdf>.

8. "Chemical Compatibility Database," Cole-Parmer Instrument Company, LLC, 2017: <https:// www.coleparmer.com/Chemical-Resistance>.

9. Chemical Resistance Chart for PEEK: <https://www.zeusinc.com/materials/peek/chemical-resistance-chart-peek>.

10. Wingard, C. D.: "ECLSS Sustaining Compatibility Testing on Urine Processor Assembly Nonmetallic Materials for Reformulation of Pretreated Urine Solution, NASA/TP— 2015– 218212, Marshall Space Flight Center, Huntsville, AL, September 2015.

11. Tobolsky, A. V. and Catsiff, E.: "Elastoviscous Properties of Polyisobutylene (and Other Amorphous Polymers) From Stress-Relaxation Studies. IX. A Summary of Results," *Journal of Polymer Science,* Vol. 19, No. 91, pp. 111–121, January 1956.

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14. ABSTRACT

The Universal Waste Management System (UWMS) is an improved Waste Collection System for astronauts living and working in low Earth orbit spacecraft. Polymeric materials used in water recovery on International Space Station are regularly exposed to phosphoric acid-treated 'pretreated' urine. Polymeric materials used in UWMS are not only exposed to pretreated urine, but also to concentrated phosphoric acid with oxidizer before dilution known as 'pure pretreat.' Samples of five different polymeric materials immersed in pure pretreat for 1 yr were tested for liquid compatibility by measuring changes in storage modulus with a dynamic mechanical analyzer.

15. SUBJECT TERMS

Universal Waste Management System, polymeric materials, compatibility testing, pure alternate pretreat, dynamic mechanical analysis, frequency sweep, time-temperature superposition

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