Improving the Process: Assessing Reactivity of Nonmetals in Aerospace Fluids

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Reactivity tests generally expose a material to a test fluid under appropriate conditions and measure changes in pressure, temperature, and physical and chemical properties. NASA-STD-(I)-6001A Test 15, *Reactivity of Materials in Hydrazine, Monomethylhydrazine, Unsymmetrical Dimethylhydrazine, Aerozine 50, Nitrogen Tetroxide, and Ammonia*, is the standardized test for assessing aerospace fluid reactivity with a given material. The procedure requires a 2-hour screening test, often called a beaker test, in which a small sample is immersed in a beaker and observed for signs of gross reactivity. Factors that can affect material reactivity include, but are not limited to: exposure duration, surface conditions and geometry, surface area contacted, fluid phase(s) present, pressure, and temperature. If the material passes the screening test, a larger sample is immersed and maintained at 71°C (160°F) for 48 hours. Temperature and pressure are monitored, and both the fluid and the material are analyzed posttest. A test being developed at White Sands Test Facility takes compatibility testing one step further by exposing larger specimens and testing them for changes in mechanical properties while still wetted and/or permeated with the propellant for comparison with control samples. This type of testing is especially important for polymeric materials used in components as seals and valves seats. Very often propellants such as nitrogen tetroxide (NTO) and monomethylhydrazine (MMH) can produce significant changes in physical properties while wetted, making them unsuitable for the intended application.

Screening process

We use a stepwise screening process to ensure it is safe to condition larger material sample sets for use in physical property testing. The steps include

- Evaluating the sample material for known incompatibilities from available data and by similarity with other materials
- Verifying the material composition by using the certifications from the supplier and inspection by Fourier transform infrared spectroscopy
- Testing in accordance with NASA-STD-(I)-6001A Test 15

Specimen conditioning and testing

On completion of the screening process, we prepare two sets of material specimens for the desired physical property tests (e.g., tensile, hardness, flexure, compressive strength). We hold back one "control" set for baseline testing, and condition the other set in the test fluid at 71°C (160°F). After 48 hours, we turn the heater off and the system is allowed to cool to ambient temperature. The fluid is not drained from the conditioning vessel until conditions are right to transport the vessel from the test area to the chemistry lab.

Material specimens are distributed to each of the tests as soon as possible after the fluid is drained from the cooled conditioning vessel. We perform physical property testing without decontaminating specimens to test the material as close to a wetted use condition as possible. As appropriate, we also perform physical property tests in laboratory fume hoods or within local exhaust ventilation systems. Figure 1 shows an Instron® Universal Test Machine with a local exhaust ventilation system built around it to facilitate testing of contaminated specimens.

Fig. 1. *Instron® Universal Test Machine with local exhaust ventilation system.*

Example results with polychlorotrifluoroethylene

We performed the process for assessing reactivity of nonmetals in aerospace fluids on polychlorotrifluoroethylene (PCTFE) procured to the old Kel-F® 81 specification

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continued

Aerospace Material Specification (AMS) 3650C, *Rods, Sheets, and Molded Shapes, Polychlorotrifluoroethylene (PCTFE) Unplasticized*. We compression-molded the material and slow-quenched it in an attempt to replicate Kel-F® 81 physical properties.

We screened the material for NTO service per the process described. We then performed property tests in accordance with the following ATSM methods:

ASTM D 638, *Tensile Properties of Plastics*

ASTM D 2240, *Rubber Property – Durometer Hardness*

ASTM D 695, *Compressive Properties of Rigid Plastics*

ASTM D 790, *Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials*

One example of how a physical property can change on exposure and with the material still saturated with the propellant is illustrated in figures 2 and 3 for the tensile properties. The change from "control" to "conditioned" in each parameter, reported in Table 1 and shown in the two figures, is consistent with the material becoming softer and more pliable with the absorption of nitrogen dioxide. Tests of other physical properties have shown that physical properties for this material in NTO are similarly affected.

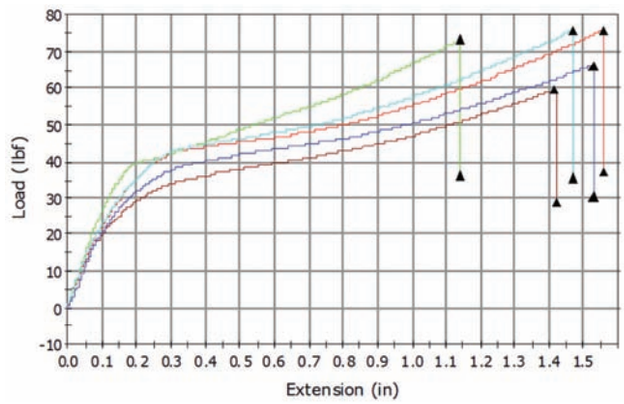

Fig. 2. *Extension-load curves for control samples.*

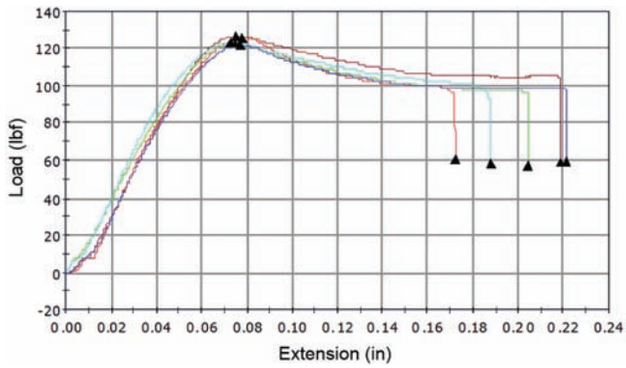

Fig. 3. *Extension-load curves for conditioned samples.*

	Percent Elongation at Yield (%)	Percent Elongation at Break (%)	Tensile Stress at Yield (psi)	Strain at Yield (in./in.)	Modulus (psi)
Control Specimens					
Replicate 1	121	146	6,400	0.18940	440
Replicate 2	120	158	6,400	0.18322	440
Replicate 3	120	154	6,300	0.17697	430
Replicate 4	119	150	6,300	0.17697	450
Replicate 5	120	159	6,200	0.18643	430
Mean	120	154	6,300	0.18227	440
Standard Deviation	0.6	5.6	84	0.00395	8.4
Conditioned Specimens					
Replicate 1	159	515	1,900	0.597	4,000
Replicate 2	293	478	2,000	1.930	3,400
Replicate 3	186	404	2,000	0.865	4,600
Replicate 4	154	492	1,700	0.545	3,800
Replicate 5	148	507	1,500	0.480	3,800
Mean	188	479	1,800	0.879	3,900
Standard Deviation	61	44	220	0.61	440

Table 1. *Tensile results for control and conditioned specimens.*

Conclusions

This example illustrates the importance of performing material tests in near-use situations, especially in the case of nonmetallic materials. Propellants such as NTO and MMH have been shown to affect the physical properties of materials in some cases by "plasticizing" the material. This effect can be missed if the physical testing is performed after decontamination.

The improvement comes from testing conditioned materials as close to a wetted use condition as possible to determine whether material properties are affected by the fluid. The data from the PCTFE physical property tests indicate that material properties can be dramatically affected by exposure to aerospace fluids; and, while exposed, materials may not retain the physical properties for which they were originally selected.

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