Material Compatibility Assessment with Hypergolic Propellants and Anhydrous Ammonia

J. Clay Cantrell, *White Sands Test Facility*
Mark B. McClure, *White Sands Test Facility*

NASA Johnson Space Center's White Sands Test Facility (WSTF) has developed a process for analyzing the compatibility of systems, components, and materials in contact with hypergolic propellants; e.g., hydrazine fuels, nitrogen tetroxide, and anhydrous ammonia. These media are known to react with many materials, which can result in material degradation or decomposition of the propellant. In addition, these propellants are highly toxic; human exposure can occur by absorption through the skin, inhalation, or ingestion. Due to these hazards, it is important to exercise caution when selecting components and materials for use with hypergolic fluids, whether they be wetted, non-wetted, or for long- or short-term use in system design.

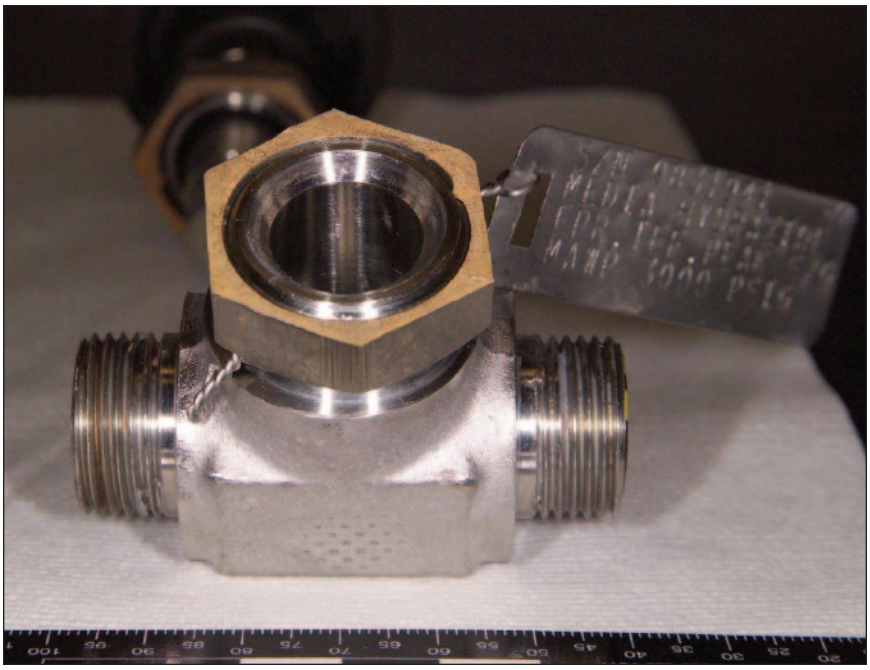

Fig. 1*. Failed CPV valve resulting from reaction with decomposed propellant.*

When selecting materials, it is also imperative to consider the materials' compatibility with decomposition products such as ammonium hydroxide produced from hydrazine and monomethylhydrazine, and nitric acid produced from nitrogen tetroxide. These products can be formed when the media comes into contact with moisture in the atmosphere. The reactivity of these by-products can sometimes be more hazardous than the original fluid. For example, figure 1 illustrates the bonnet failure of a valve after 10 years of service in hydrazine. This failure resulted from the decomposition of hydrazine, which permeated the seal and produced ammonium hydroxide, corroding the bonnet. Ultimately, the material cracked and failed.

The WSTF Hypergol Material Approval Committee has performed hypergol material compatibility assessments on many of the systems at WSTF. The goal in performing one of these assessments is to prevent these types of valve and other failures from occurring in the future. These precautions ensure systems can be operated safely without presenting undue risk to personnel or the system itself.

WSTF performs compatibility analyses for individual components as well as for entire systems for varying use conditions. A compatibility analysis consists of performing a material breakdown of each component within a system. The compatibility of each separate material with the fuel or oxidizer is then determined based on WSTF testing and available data. Parts within components that lie on the media boundary, located just beyond the soft goods sealing the media from the atmosphere, are assessed for compatibility hazards with decomposition products associated with the specified media. Based on such an analysis, the Hypergol Material Approval Committee makes recommendations concerning the incompatible part or component.

The compatibility and functionality of a soft good material may be assessed through mechanical property tests by using a screening process if the material is unknown, new, or if there are limited data on that material. The first step is to review documentation and identify incompatibilities

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continued

and potential reactivity the material may have with the fuel or oxidizer fluid. The next step is to verify the general class of the material through reviewing previous certifications, inspections, and specifications. In a third step, a small sample of the material is immersed in a beaker with the fuel or oxidizer fluid to determine whether the material demonstrates any adverse reactions at ambient temperature and pressure.

For samples being screened for oxidizer compatibility, the exposed material will be characterized by using Differential Scanning Calorimetry to identify potentially sensitive and reactive materials. A post-test Fourier Transform Infrared Spectroscopy is performed to look for evidence of nitration. Screening is then performed per Ambient Pressure Screening (Test 15) – NASA-STD-6001B (or latest revision). During Test 15, the sample is immersed in the fluid in which it is to be used at the vapor pressure of the medium at that temperature for 48 hours. Test 15 is performed for both fuel and oxidizer samples. For oxidizer samples, a final Differential Scanning Calorimetry and Fourier Transform Infrared Spectroscopy are performed.

Compatibility assessments are not conducted solely within WSTF systems. WSTF has performed system hazard assessments for the Ares I Reaction Control and Roll Control Systems per the protocol identified in American Institute for Aeronautics and Astronautics SP-084-1999 *Fire, Explosion, Compatibility, and Safety Hazards of Hypergols – Hydrazine*, Annex A. This assessment addresses possible failures—and their consequences—of system components. Hazards considered include possible failure modes and effects of fire, explosion, reactivity, and personnel and equipment exposure to hydrazine.