Propellant Specification and Manual Development to Enable Testing

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New propellant initiatives require special quality, engineering, and safety considerations. NASA White Sands Test Facility (WSTF) is one of NASA's leading centers of excellence for the development of hypergolic propellant specifications and manuals to enable their safe use (figure 1). Specifications are explicit sets of requirements to be satisfied by the propellant; they contain information on sampling, analysis, and quality criteria for the different grades, as applicable. Manuals enable the user to assess the hazards of the fluids under a variety of conditions. Propellants are used to power crewed and crewless spacecraft, and their performance, quality, and reliability is of utmost importance to mission assurance and astronaut safety.

Fig. 1. *WSTF produces numerous manuals and handbooks.*

Not only must propellants meet the most stringent specifications, but because they are potentially quite hazardous, their fire, explosion, and safety hazards must be well understood and documented to enable safe handling and testing. WSTF has developed numerous manuals that cover the fire, explosion, and safety hazards of liquid propellants. These manuals, sometimes referred to as handbooks, consolidate valuable data and allow users to perform hazard assessments of the propellants under various conditions. These documents provide engineering information, lessons learned, and options to address technical issues; classification of similar items, materials, or processes; and interpretative direction and techniques. This type of guidance may help the government or its contractors in the design, construction, selection, management, support, or operation of systems, products, processes, or services. WSTF analyzes and tests the propellants according to their specifications, while the hazards manuals are extremely helpful to engineers, chemists, field personnel, test conductors, safety personnel, and industrial hygienists in existing test programs.

WSTF has been involved in the development of two new propellant specifications and corresponding manuals, in addition to the review and update of numerous other propellant specifications. In recent years, there has been ever-increasing interest in "green" space propellants that are environmentally less damaging and have reduced toxicity when compared to commonly used solid propellants (including ammonium perchlorate), liquid hypergols (including monomethylhydrazine/nitrogen tetroxide), and liquid monopropellants (including hydrazine). Ideally, green propellants are easier and safer to handle than conventional propellants, and are expected to drive down the costs associated with propellant transport and storage as well as spacecraft development, ground support, and operations. Hydrogen peroxide was regarded as a green propellant because of its relatively benign exhaust products and low vapor pressure when compared to propellant hydrazine fuels and nitrogen tetroxide oxidizers in bipropellant systems, and also when compared to hydrazine in monopropellant systems.

A resurgence in interest in hydrogen peroxide propellant led to the development of MIL-PRF-16005.F *Performance Specification Propellant, Hydrogen Peroxide*. Previous and related specifications were obsolete or inadequate to cover the requirements of this challenging and hazardous propellant, which has a rich history of periods of use and nonuse. This specification covers four types and two grades of hydrogen peroxide propellant intended for use as an oxidizer or monopropellant in rocket engines. WSTF propellant chemists were active in the development of this specification, and ensured that it was not only technically achievable but practical and cost-effective. Incorporated in the specification is a method for performing one of the

more time-consuming procedures in the previous military specification. This method is for the continuous, unattended decomposition of the propellant in a closed-loop system using a platinum wire enclosed in a loop of inert tubing. The previous method was performed using a manual, drop-wise method by the gradual addition of hydrogen peroxide to a platinum crucible that required continuous attendance.

Concurrent with the effort to develop the hydrogen peroxide specification, NASA initiated a program for WSTF to prepare a hydrogen peroxide hazards manual. WSTF scientists researched and coordinated the development of NASA/TM-2005-213151 *Fire, Explosion, Compatibility, and Safety Hazards of Hydrogen Peroxide* to provide data for hydrogen peroxide propellant users. Addressed in this manual are fire, explosion, compatibility hazards, and overall safety and environmental considerations in addition to physical and thermodynamic data and lessons learned.

More recently, liquid oxygen-liquid methane propellant was proposed for use in the Crew Exploration Vehicle propulsion system. While programmatic requirements are subject to change, the potential for methane as a viable propellant that could be synthesized in extraterrestrial environments using various in-situ propellant production techniques kept it on the forefront as a propellant candidate for space exploration to Mars and beyond. Stringent use requirements led to the development of a new specification for the propellant methane. WSTF chemists participated in the development of MIL-PRF-32207 *Performance Specification Propellant, Methane*. This participation ensured the ability of a laboratory to perform the required analyses. In addition, WSTF chemists developed a novel chamber in which to collect liquid methane samples for the nonvolatile residue determination and observation of visual appearance, which were requirements of the specification that could be done in the field. The chamber's use was validated at WSTF Test Stand 401, where liquid methane was used and tested (figure 2).

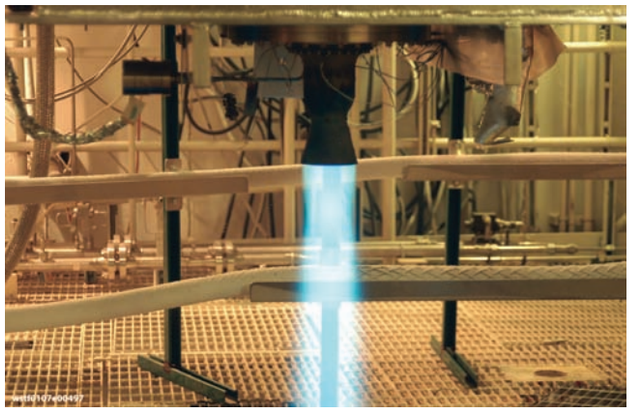

Fig. 2. *Liquid oxygen-methane engine firing.*

Along with the effort to develop the liquid methane specification, a program was initiated for WSTF to prepare a liquid methane hazards manual, which includes liquefied and gaseous natural gas and methane. The program's goal was to summarize the existing hazards of liquid methane and liquefied natural gas in one document. WSTF-RD-1056-001-07 *Fire, Explosion, Compatibility, and Safety Hazards of Liquid and Gaseous Methane and Natural Gas* was accordingly developed and relied on for engine testing at WSTF. The document included: fire and explosion, materials and reactivity, personnel and environmental hazards, chemical and physical properties, analytical spectroscopy, specifications, analytical methods, and summaries of accidents, close calls, and lessons learned.

The military specifications for hydrogen peroxide and liquid methane are available to the public; the WSTF hazards manuals are subject to export control and are available to other government agencies. WSTF previously authored *Fire, Explosion, Compatibility, and Safety Hazards of Hydrazine* (RD-WSTF-0002), *Fire, Explosion, Compatibility, and Safety Hazards of Monomethylhydrazine* (RD-WSTF-0003), and *Fire, Explosion, Compatibility, and Safety Hazards of Nitrogen Tetroxide* (RD-WSTF-0017).

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