Reference Document for Assessing and Managing Risks of Hydrazine, Monomethylhydrazine, Nitrogen Tetroxide, and Ammonia on Spacecraft

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A reference document has been published by NASA Johnson Space Center's White Sands Test Facility for assessment and management of risks associated with hydrazine, monomethylhydrazine (MMH), nitrogen tetroxide (NTO), and ammonia on spacecraft. Hydrazine is used for monopropellant propulsion and power, MMH and NTO are used in bipropellant propulsion systems, and ammonia is used in spacecraft cooling systems. Because of the performance, fire, explosion, reactivity, and safety aspects of these fluids, extensive risk assessments and risk management strategies are required to assure safe and reliable mission performance (on-ground, pre-launch, launch, on-orbit, landing, and recovery). The information is compiled primarily from the Apollo, Space Shuttle, and Constellation Programs, and from uncrewed U.S. satellite exploration programs, with some information from international programs.

Definitions and references, guidelines, historical examples, and technical data are provided for assessing and managing risks associated with these hazardous materials. The content provides engineering information; lessons learned; possible options to address technical issues; classification of similar items, materials, or processes; interpretative direction and techniques; and other guidance information that may help assess and manage risks of hydrazine, MMH, NTO, and ammonia on spacecraft.

Cited and fully referenced sources of information include textbooks, journals, books, conference proceedings, reputable websites, and technical reports. Every reasonable effort has been made to present accurate information; however, users are urged to assess each situation carefully and to use the information in this document for guidance only.

The reference document—approximately 200 pages—is divided into three parts and includes appendices and an extensive reference list. It begins with an overview of risk assessment and risk management requirements and tools, and provides examples of range safety, spacecraft risks, surveys of spacecraft reliability, and failures relevant to these fluids.

Part I provides a general overview of hydrazine, MMH, NTO, and ammonia use on spacecraft. The focus is on the identification of risks associated with mission profile phases, passivation and decommissioning of spacecraft, orbital debris (including that resulting from hypergolic propellant explosions), and mission abort scenarios.

Part II addresses risk assessment and includes topics such as the aerospace environment, freeze-thaw hazards, thruster plume impingement zones, chemical reactivity, hard starts and explosion hazards, ignition hazards, auxiliary power unit hydrazine risks, and decontamination in spacecraft.

Part III focuses on risk management and acceptance including spacecraft design considerations, procedures to minimize risk, spill management, debris strikes, extravehicular activities, pressure hazards (water hammer and adiabatic compression), toxicity hazards, mitigation of hydrazine, MMH, and ammonia fires on spacecraft, personal protective equipment, and medical management of hydrazine, MMH, NTO, and ammonia exposures.

Appendices provide detailed information on case histories and summary lessons learned from mishaps, accidents, and relevant anomalies. Representative data, diagrams, graphs, and chemical equations are provided. Table 1 is a representative sample of useful chemical information provided.

The *Reference Document for Assessing and Managing Risks of Hydrazine, MMH, NTO and Ammonia on Spacecraft* may be obtained from the Laboratories Office at NASA White Sands Test Facility, Las Cruces, New Mexico (*www.nasa.gov/centers/wstf/laboratories*).

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continued

Table 1. *Selected Properties of Hydrazine, Monomethylhydrazine, Ammonia, and Nitrogen Tetroxide 1*

Property	Hydrazine	Monomethylhydrazine	Ammonia	Nitrogen Tetroxide
Vapor-pressure (at specified temperature)	1.89 kPa	6.60 kPa	909 kPa	(20°C) 0.95 atm
Autoignition Temperature	438-673 K (165-400°C)	457 K (184°C)	924 K (651°C)	N/A
Flammability Limits in Air	Lower Flammability Limit (LFL) 2.9% v/v Upper Flammability Limit (UFL) 100% v/v	LFL 2.5% v/v UFL 98% v/v	LFL 15.0% v/v UFL 33.5% v/v	N/A
Heat of Vaporization	43.43 kJ mole^{-1}	40.38 kJ mole^{-1}	23.33 kJ mole^{-1} (351.4 K)	99 cal/g (21.2°C)
Critical States	Temperature 653 K (380°C) Pressure 14,692 kPa Density 0.231 g/mL	Temperature 585 K (312°C) Pressure 8,237 kPa Density 0.29 g/mL	Temperature 405.6 K (132.5°C) Pressure 11,370 kPa Density 0.235 g/mL	Temperature 158.2°C Pressure 100 atm Density 0.557 g/mL
Melting Point	274.63 K (1.48°C)	220.79 K (-52.36°C)	195.4 K (-77.7°C)	-11.2°C
Boiling Point	387.3 K (114.2°C)	360.81 K (87.66°C)	239.8 K (-33.3°C)	21.2°C
Liquid Density	1.004 g/mL	0.8702 g/mL	0.6819 g/mL (-33.3°C)	1.447 g/mL (-20°C)
Flash Points	Open Cup 324 K (51°C) Closed Cup 311 K (38°C)	Open Cup 294K (21°C) Closed Cup 24K (20°C)	210 K (-60°C) (approx.)	N/A
Heat Capacity of Liquid	3.077 J g^{-1} K^{-1}	2.93 J g^{-1} K^{-1}	(239.8 K) 4.39 J g^{-1} K^{-1}	33.71 cal/deg/mole (290 K)
Heat of Combustion	-577 kJ mole^{-1}	1304 kJ mole^{-1}	-383 kJ mole^{-1}	N/A
Heat of Formation	50.37 kJ mole^{-1}	54.836 kJ mole^{-1}	-45.6 kJ mole^{-1}	2.309 kcal/ mole^{-1}

[1] *Properties are at 298 K (25°C [77°F]) and pressure of 101.3 kPa (14.7 psia) unless otherwise specified.*