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NITROUS OXIDE SAFETY FOR HYBRID ROCKETS

Abstract

In recent years, nitrous oxide has gained popularity as a propellant for hybrid rocket systems due to its ease of handling, storability, and self-pressurization characteristics. Since nitrous oxide is widely used in automobile racing, anesthesia, and the food industry, it is commonly treated as a safe, non-hazardous material. However, exothermic decomposition reactions are possible with nitrous oxide, and have resulted in multiple catastrophic failures, even causing loss of life. In this paper several such incidents involving hybrid rockets are examined, detailing their causes and consequences.

In order to develop guidelines for the safe design and operation of hybrid rockets utilizing nitrous oxide, it is important to first have an understanding of the underlying thermochemical and kinetic mechanisms. Typically with pure nitrous oxide, the activation energy is sufficiently high to prevent thermal decomposition reactions under a wide range of operating conditions. However, contamination with even minute levels of hydrocarbons has been shown to drastically reduce this activation energy, increasing the potential for explosion. Dilution of the vapor with gases such as oxygen or helium has been shown to mitigate this hazard.

As a result of theoretical analysis and experimental data, simple guidelines have been developed to reduce the likelihood of explosive decomposition when using nitrous oxide in hybrid rocket propulsion systems. Some of these guidelines are listed below:

- Use standard oxygen system cleaning procedures on all components contacting nitrous oxide
- Strictly obey material compatibility rules
- Shut down the motor before the liquid is completely consumed
- Minimize flow disturbances in the propellant feed lines
- Eliminate spaces within the motor where gaseous nitrous oxide may accumulate
- Treat nitrous oxide as a hazardous material
- Maintain safe distance for all personnel when running motors, performing cold flow tests, or pumping and transferring nitrous oxide
- Prevent heating of nitrous oxide vapor
- Provide sufficient ullage for liquid expansion due to warming

When these rules are followed, hybrid rockets utilizing nitrous oxide can be simple, safe, and high-performance. However, as with all energetic materials it should be treated with the utmost respect.