Reaction of Hydrazine and Nitrogen Tetroxide in a Low-Pressure Environment

ROBERT A. WASKO*
NASA Lewis Research Center, Cleveland, Ohio

THE use of hypergolic propellants in space vehicle propulsion systems raises questions concerning the effect of a vacuum on the reaction of these propellants.

A preliminary study was made of the reaction of hydrazine and nitrogen tetroxide at pressures as low as 10^{-4} Torr (mm Hg). A steel vacuum tank served as a vessel wherein stoichiometric quantities of these propellants, separately encapsuled in glass tubing under atmospheric pressure and at room temperature, were broken simultaneously (see inset in Fig. 2).

The vacuum tank was 4 ft wide and 6 ft long with one end covered by a glass window for viewing purposes. The capsules were broken by a cleaver device that was remotely actuated by a solenoid release. Temperatures were recorded in the vicinity of the capsules, and tank pressure was measured by an ionization gage and a Pirani gage. High-speed motion pictures also were obtained.

Effects of varying the total propellant quantity on the tank pressure rise are shown in Fig. 1. In all cases, the initial tank pressure was about 4×10^{-4} Torr. With small quantities of propellants (2.3 and 4.6 cm³), the pressure rose to a value predicted from perfect gas equations for complete propellant vaporization, which indicates that there was no reaction. With larger quantities of propellants (19.5 cm³), the initial pressure rise (to the "vaporized-mixture-pressure" point) again could be predicted with complete vaporization assumed. This pressure rise was followed by an explosion pressure fluctuation that occurred when the tank pressure exceeded 4 Torr. The tank pressure ultimately reached a new equilibrium value. As expected, the transient temperature variations show a sharp decrease during propellant vaporization and a sharp rise during the reaction phase. The gradual temperature rise in between was caused by radiant energy from photographic flood lamps. It was apparent from the motion-picture film that the magnitude of the temperature decrease was sufficient to cause freezing of droplets of hydrazine on the capsule support mechanism. Later tests with single capsules of either N_2H_4 or N_2O_4 confirmed the fact that this freezing phenomenon occurred only in the N_2H_4.

Figure 2 shows the change in pressure-time history for various initial tank pressures p_0. In all cases, the reaction occurred at vaporized-mixture pressures greater than 4 Torr. Comparison of the three curves indicates a large reaction delay time for $p_0 = 1$ Torr, whereas for $p_0 = 6 \times 10^{-4}$ and 10^{-1} Torr, the reaction occurred after approximately 0.9 sec, and 2.25 sec were required at $p_0 = 1$ Torr. In addition, the sudden increase in pressure associated with explosion did not occur for an initial ambient pressure of 1 Torr; rather, the pressure increased smoothly from the vaporized-mixture to the reacted-material equilibrium pressure. Evidently, the region from 10^{-1} to 1 Torr is a transition region in which a less violent reaction occurs. Increasing ambient pressure increases the amount of inert gas (nitrogen) in the tank; thus the dilution of the propellant may explain this phenomenon.

Received May 10, 1963; revision received May 27, 1963.
* Aeronautical Research Engineer. Associate Member AIAA.

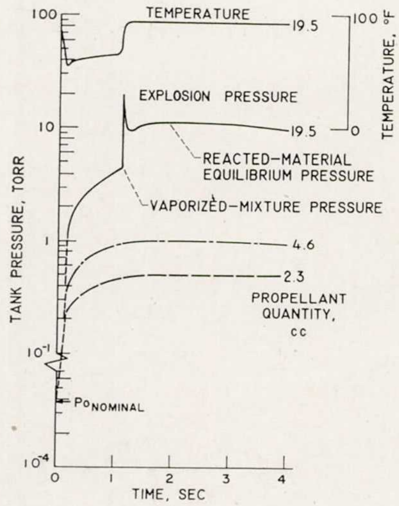

Fig. 1 Effect of varying propellant quantity on tank pressure rise.

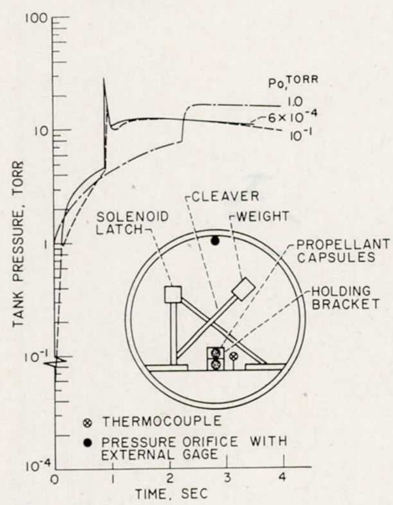

Fig. 2 Tank pressure rise with varying initial pressure; total propellant volume = 19.5 cm³.

Conclusions

1) An explosive reaction occurred only when a sufficient quantity of propellant was used to produce a vaporized mixture pressure greater than 4 Torr.

2) For the decade of initial ambient pressure from 10^{-1} to 1 Torr, the reaction changed from an explosion to a slower reaction, as evidenced by a decrease in the magnitude of the explosion pressure and an increase in the reaction delay time.

3) N_2O_4 vaporized more quickly than N_2H_4, and the temperature decrease due to vaporization was sufficient to cause freezing of a portion of the N_2H_4.

Reprinted from AIAA JOURNAL