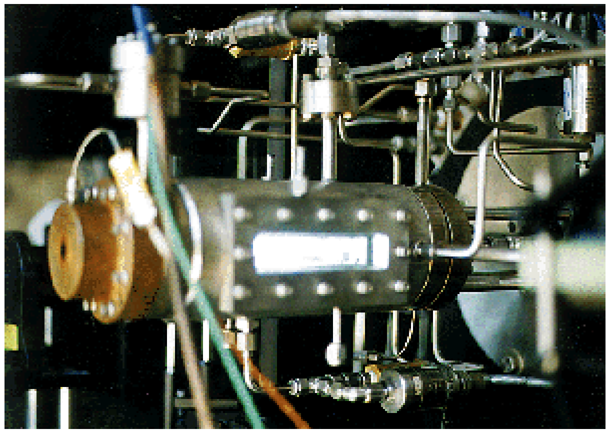
Cooperative Testing of Rocket Injectors That Use Gaseous Oxygen and Hydrogen



Gas-gas windowed combustion chamber during test firing.

Gaseous oxygen and hydrogen propellants used in a special engine energy cycle called Full-Flow Staged Combustion are believed to significantly increase the lifetime of a rocket engine's pumps. The cycle can also reduce the operating temperatures of the engine. Improving the lifetime of the hardware reduces its overall maintenance and operations costs, and is critical to reducing costs for the joint NASA/industry Reusable Launch Vehicle (RLV). The work in this project will demonstrate the performance and lifetime of one-element and many-element combustors with gaseous O_2/H_2 injectors. This work supporting the RLV program is a cooperative venture of the NASA Lewis Research Center, the NASA Marshall Space Flight Center, Rocketdyne, and the Pennsylvania State University.

Information about gas-gas rocket injector performance with O_2/H_2 is very limited (ref. 1). Because of this paucity of data, new testing is needed to improve the knowledge base for testing and designing new injectors for the RLV and to improve computer models that predict the combusting gas flows of new injector designs. Therefore, detailed observations and measurements of the combusting flow from many-element injectors in a rocket engine are being sought. These observations and measurements will be done with three different tools: schlieren photography, ultraviolet imaging, and Raman spectroscopy. The schlieren system will take photos of the density differences in combusting flow, the ultraviolet movies will determine the location of the hydroxyl (OH) radical in the combustion flow, and the Raman spectroscopic measurements will provide the combustion temperature and amount of water (H_2O), hydrogen (H_2), and oxygen (O_2) in the combustor.

Marshall is providing overall program management, design and computational fluid dynamics (CFD) analyses, as well as funding for the work at Penn State. An existing, windowed combustor and several injectors will be provided by Rocketdyne--two injectors for the initial screening tests and one with an optimized design based on the best design found in the screening tests.

Lewis will provide a nozzle and several injectors for the screening test program. The configuration of the injectors will be based on a design chosen by all the participants, and their elements will be based on the coaxial and impinging flow. Lewis also will provide the instrumentation for the flow-field measurements: schlieren, ultraviolet imaging, and Raman spectroscopy. In addition, thermocouples will measure heat flow on the injector face. Other traditional measurements of rocket performance will be made as well: chamber pressure, mass flow of each propellant, purge flow, and the barrier cooling gas flow. Penn State will conduct single-element testing with the injector elements from both the Rocketdyne and the jointly designed injectors.

A wide variety of traditional and nontraditional injector designs will be tested in this program. The results will be valuable in computational fluid dynamics code validation and overall rocket combustion efficiency measurements. Correlations between combustion efficiency, laser measurements of species, and ultraviolet and visible light photography will also be made.

Thus far, several different single-element injectors have been tested at Penn State and Lewis. The figure shows the experimental setup of a rocket engine with a viewing window. The combusting flow is shown in the rectangular window. The results are helping engineers design the many-element injectors.

References

1. Calhoon, D.F.; Ito, J.I; and Kors, D.L.: Investigation of Gaseous Propellant Combustion and Associated Injector-Chamber Design Guidelines. NASA CR-121234, 1973.