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Rocket Ignition Demonstrations Using Silane

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Abstract

Rocket ignition demonstration tests using silane were performed at the Penn State Combustion Research Laboratory. A heat sink combustor with one injection element was used with gaseous propellants. Mixtures of silane and hydrogen were used as fuel, and oxygen was used as oxidizer. Reliable ignition was demonstrated using fuel lead and a swirl injection element.

Discussion

As part of the NASA/MSFC Advanced Reusable Transportation Technologies Program, rocket ignition demonstration tests using silane were performed at Penn State's Cryogenic Combustion Laboratory. A heat sink OFHC copper combustor with a uni-element injector was used. The chamber cross-section was 0.875 × 0.875 in. square, and the length from the injector face to the start of the nozzle converging section was 3.25 in. Gaseous propellants were used for the tests. Oxygen was used as the oxidizer, and a fluid supply system which enabled varying proportions of silane and hydrogen was used to provide the gaseous ignition mixture. Nominal target ignition chamber pressure was 150 psia, however, this was varied as proportions of silane and hydrogen were changed. Two types of injection elements were tested, a swirl element and a shear element. Both silane/hydrogen lead and oxidizer lead timing sequences were tested.

Tests were performed by programming a candidate ignition sequence into the laboratory control system and executing the programmed sequence. The time resolution of the laboratory's control system is 0.1 s. The combustor was monitored with video cameras located in the cell, and video signals were recorded on video tape recorders. Combustor pressure was measured with a pressure transducer connected to the combustion chamber through a small connector tube. Propellant pressures and temperatures were measured with pressure transducers and thermocouples close-coupled to the propellant feed lines. Pressure and temperature data were recorded at 200 and 100 Hz, respectively, using the digital data acquisition system. Ignition was confirmed by both visual observation of the combustion plume on video and increase in measured chamber pressure from non-combusting to combusting conditions. A photo of a successful ignition test is shown in figure 1.

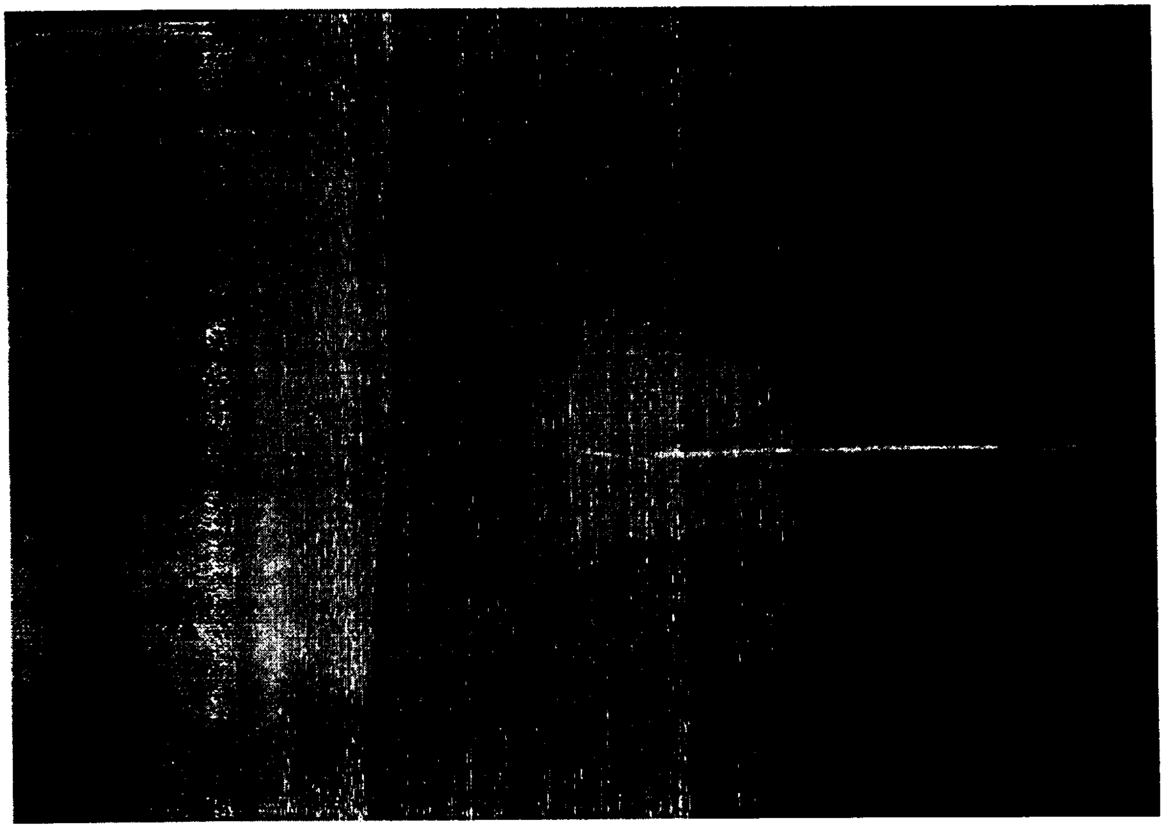

Figure 1. Ignition with silane.

Oxidizer lead test results with the swirl injector are shown in figure 2. Tests were performed over the range of silane/hydrogen proportions 80/20 < silane/hydrogen mass percentage < 100/0 (20/80< silane/hydrogen volume percentage < 100/0). Fifty-seven tests were performed, with ignition observed for ten tests.

Results of silane/hydrogen lead tests with the swirl injector are shown in figure 3. Tests were performed over the range 40/60 < silane/hydrogen percentage by mass < 100/0 (4/96 < silane/hydrogen percentage by volume < 100/0). Thirty-nine tests were performed, with ignition observed in thirty seven tests. The two silane/hydrogen lead tests that did not ignite contained the lowest proportion of silane (4% by volume).

Ignition tests with a coaxial injector were performed over the range 60/40 < silane/hydrogen percentage by mass < 100/0 (9/91 < silane/hydrogen volume percentage < 100/0). The results of oxidizer and silane/hydrogen lead tests for the shear coaxial injector are shown in Figs. 4 and 5, respectively. Seven of fifteen tests showed ignition.

Conclusions

Reliable, repeatable silane ignition was demonstrated over a wide range of

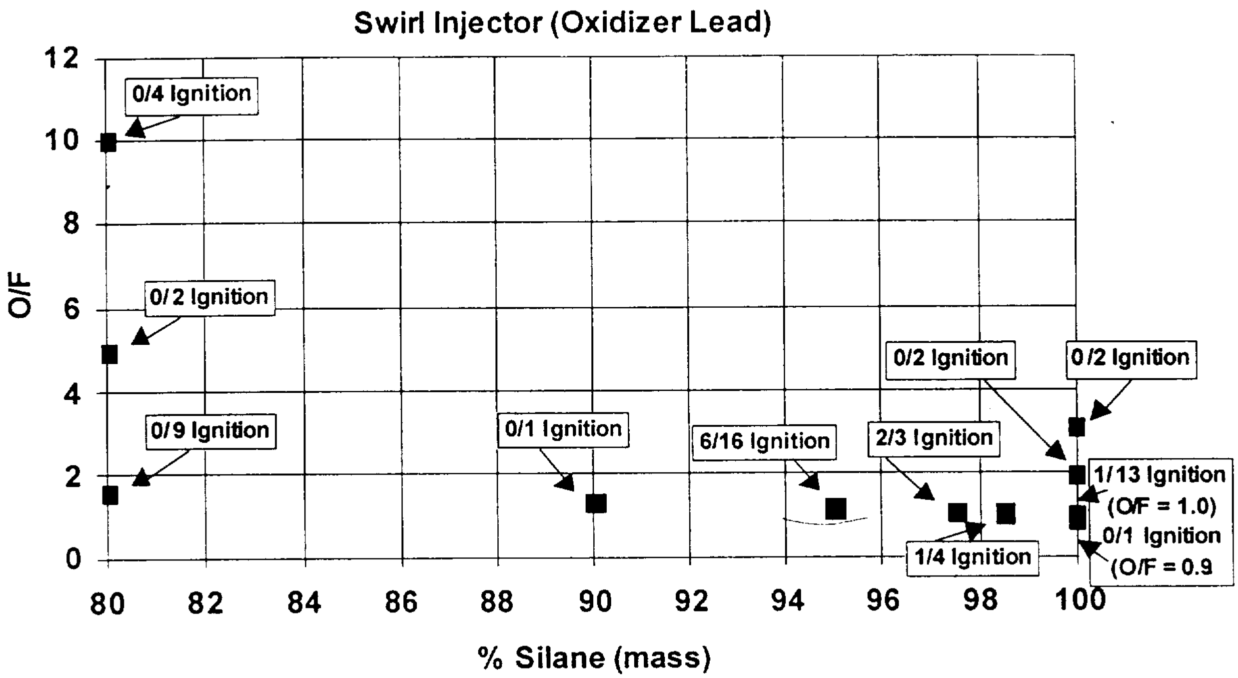

Figure 2. Swirl injector oxidizer lead ignition results.

silane/hydrogen proportions using silane/hydrogen lead and a swirl injection element. Oxidizer lead was not reliable with either injector. The shear coaxial element did not exhibit reliable ignition for either silane/hydrogen or oxidizer lead.

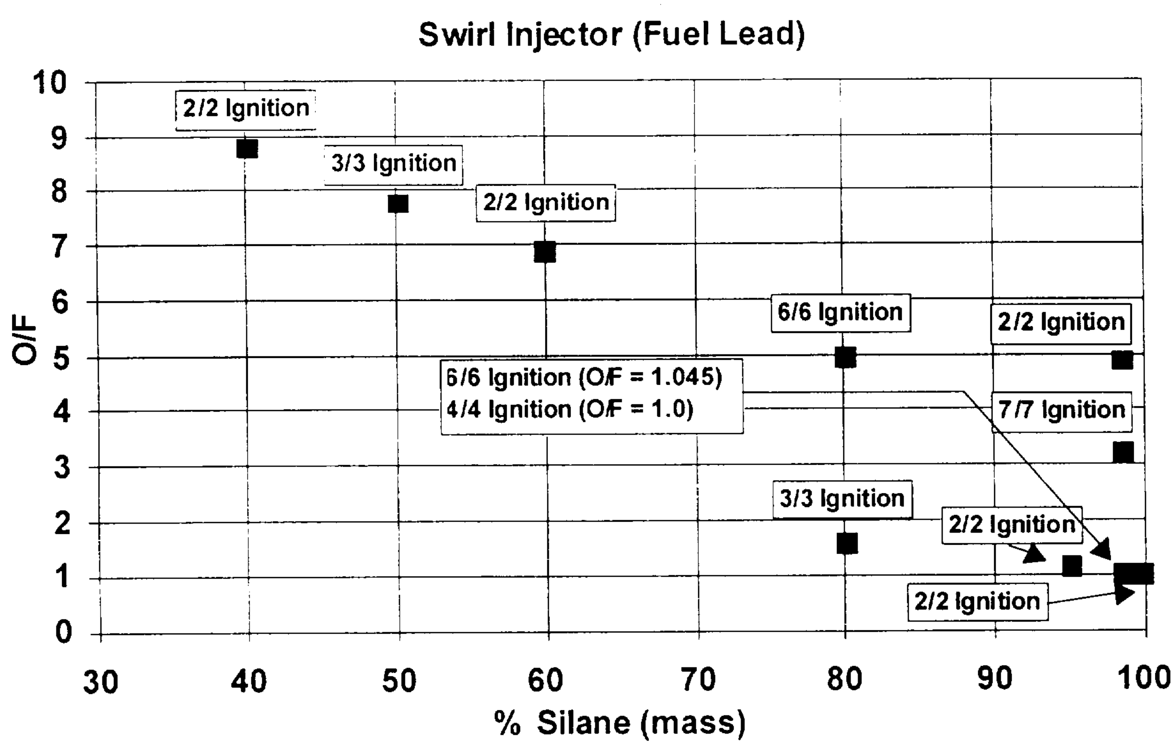

Figure 3. Swirl injector fuel lead ignition results.

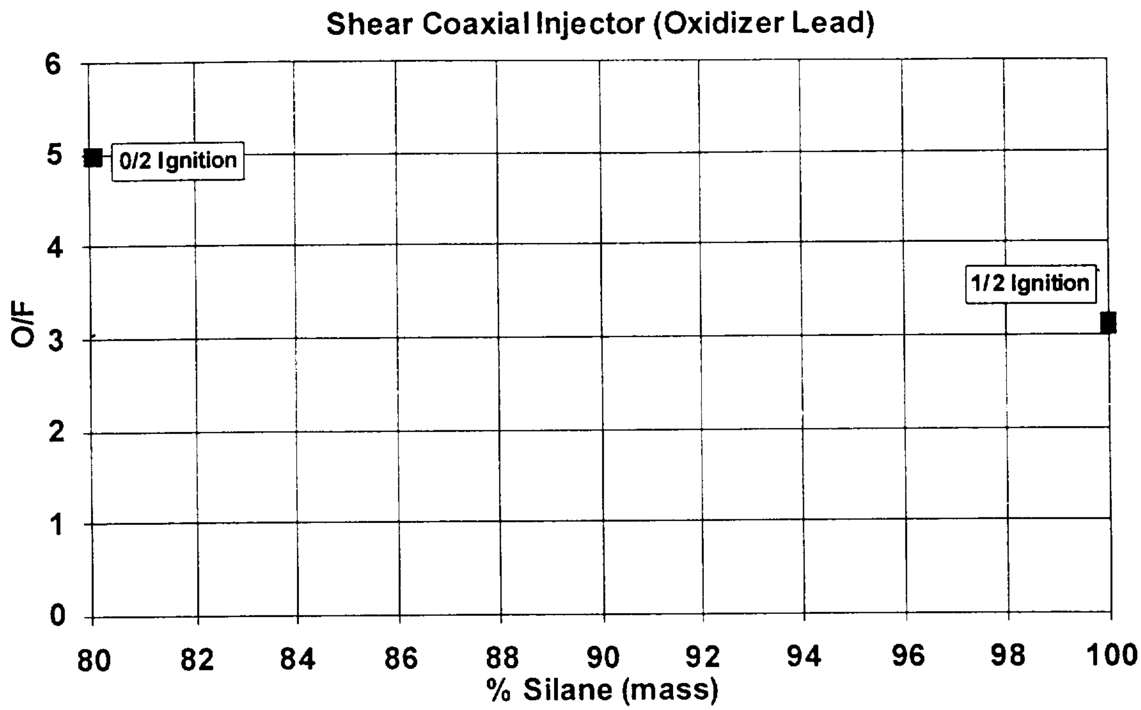

Figure 4. Shear coaxial injector oxidizer lead ignition results.

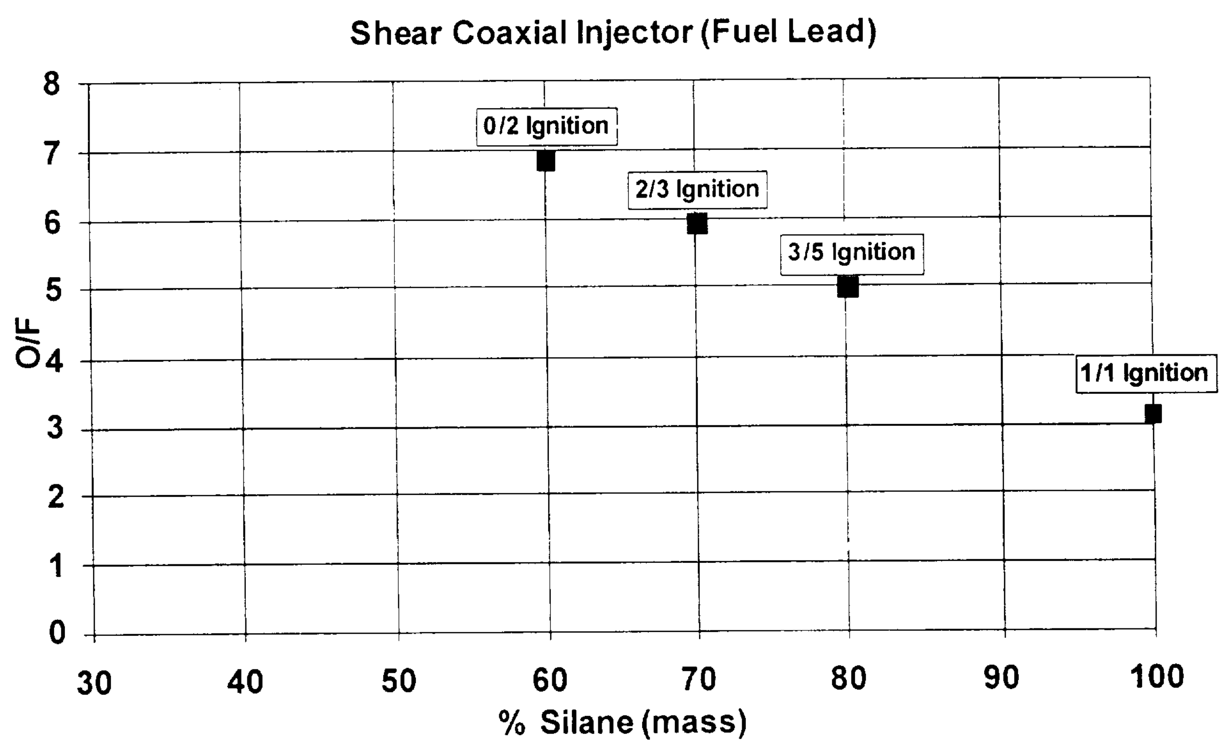

Figure 5. Shear coaxial injector fuel lead ignition results.