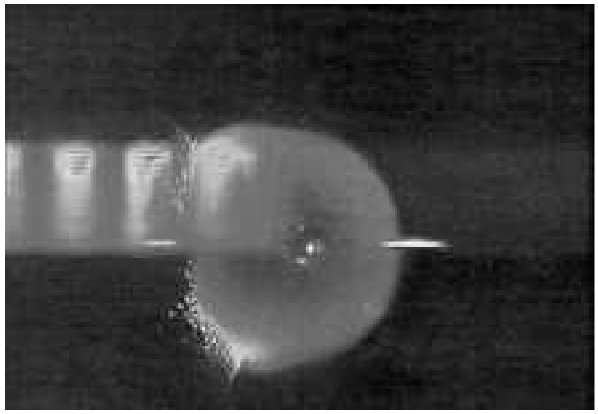
Fiber-Supported Droplet Combustion Experiment-2

A major portion of the energy produced in the world today comes from the burning of liquid hydrocarbon fuels in the form of droplets. Understanding the fundamental physical processes involved in droplet combustion is not only important in energy production but also in propulsion, in the mitigation of combustion-generated pollution, and in the control of the fire hazards associated with handling liquid combustibles. Microgravity makes spherically symmetric combustion possible, allowing investigators to easily validate their droplet models without the complicating effects of gravity. The Fiber-Supported Droplet Combustion (FSDC-2) investigation was conducted in the Microgravity Glovebox facility of the shuttles' Spacelab during the reflight of the Microgravity Science Laboratory (MSL-1R) on STS-94 in July 1997. FSDC-2 studied fundamental phenomena related to liquid fuel droplet combustion in air. Pure fuels and mixtures of fuels were burned as isolated single and duo droplets with and without forced air convection. FSDC-2 is sponsored by the NASA Lewis Research Center, whose researchers are working in cooperation with several investigators from industry and academia.

The rate at which a droplet burns is important in many commercial applications. The classical theory of droplet burning assumes that, for an isolated, spherically symmetric, single-fuel droplet, the gas-phase combustion processes are much faster than the droplet surface regression rate and that the liquid phase is at a uniform temperature equal to the boiling point. Recent, more advanced models predict that both the liquid and gas phases are unsteady during a substantial portion of the droplet's burning history, thus affecting the instantaneous and average burning rates, and that flame radiation is a dominant mechanism that can extinguish flames in a microgravity environment. FSDC-2 has provided well-defined, symmetric droplet burning data including radiative emissions to validate these theoretical models for heptane, decane, ethanol, and methanol fuels. Since most commercial combustion systems burn droplets in a convective environment, data were obtained without and with convective flow over the burning droplet (see the following photos).



Heptane droplet. Left: Without flow. Right: With flow.

Multicomponent droplet burning studies are motivated by the need to understand the burning characteristics of blended fuels and liquid hazardous wastes. Depending on the relative concentrations and volatilities of the components and their miscibility, multicomponent fuels can exhibit peculiar, unsteady burning characteristics such as the formation of vapor bubbles in the droplet if the droplet internal temperature exceeds the bubble nucleation temperature of a fuel component.

The importance of liquid species diffusion in multicomponent droplet burning has also been recognized. In normal-gravity experiments, buoyancy can destroy the spherical symmetry by inducing convective mixing in the gas and liquid phases; therefore, microgravity experiments help to clarify the phenomena occurring during multicomponent droplet burning. Also, product dissolution can change an initially pure fuel into a multicomponent fuel, a behavior observed in alcohol fuels when combustion-generated water is absorbed by the fuel, leading to nonlinear burning. FSDC-2 has provided data on the burning of methanol/water, ethanol/water, and heptane/hexadecane fuel mixtures.

Most combustion systems involve the burning of many droplets. On FSDC-2, droplet interactions were investigated with decane fuel with and without convective flow (see the following photo). Two droplets were placed side by side. The data obtained from the burning of a single stationary droplet and double droplets is helping researchers understand and solve physical processes in more complex combustion systems.

Double decane droplets with flow.

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