Structure and Liftoff In Combustion Experiment (SLICE)

Dissection of a Flame

The SLICE experiment investigates the structure of lifting and lifted flames, where flow conditions and the combustion chemistry cause the flame to detach from the burner and stabilize at a downstream position. It is a precursor to the Coflow Laminar Diffusion Flame (CLD Flame) experiment, where the SLICE results will be used to maximize the scientific return of that upcoming space station experiment.

Objectives

For diffusion flames of methane, ethylene, and selected nitrogen dilutions of each fuel burning in a coflow of air:

(1) Characterize the structure of the flame, especially its base (i.e., stabilizing region), from attached through lifted conditions as a function of the fuel, burner diameter, and flow conditions.

(2) Identify the liftoff velocity limits as a function of the fuel and burner diameter.

Approach

A flame of gaseous fuel is ignited within a low-speed flow duct and photographed. The fuel flow or air velocity is adjusted to assess its effect on the flame structure and liftoff. Other experimental parameters include the gaseous fuel (including nitrogen dilution) and the diameter of the circular burner tube. Flame measurements include the structure (e.g., size and shape), soot temperature, soot volume fraction, and thermal radiation. The results will be used to refine computational models of the flames.

Detailed Research Description

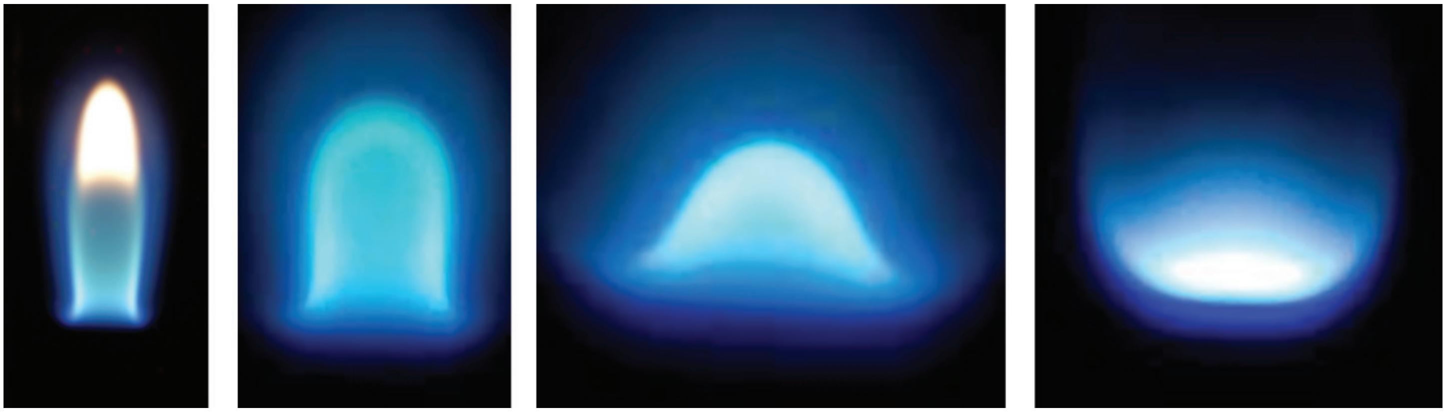
The goal of the SLICE experiment is to improve our understanding of the physical and chemical processes controlling diffusion (i.e., nonpremixed) flame structure and lifting phenomena (i.e., stabilization) and to provide for rigorous testing of numerical models including thermal radiation, soot formation, and detailed chemical kinetics. Good agreement between experimental and computational results has been demonstrated for lifted flames at moderate flame conditions, but that agreement breaks down when the fuel is highly diluted or the soot production is high. SLICE is a precursor for the CLD Flame experiment, which is one of four experiments in the Advanced Combustion via Microgravity Experiments (ACME) project that are currently in development for conduct in the Combustion Integrated Rack (CIR). A common goal of the two experiments is to improve computational techniques such that a broader range of flame conditions can be effectively modeled than is currently possible.

Hardware

The SLICE investigation will be conducted using the Smoke Point In Coflow Experiment (SPICE) hardware, which has been on orbit, with fuel bottles, a digital camera, recording media, and additional hardware delivered via ULF–5 (STS–133). The experiment will be set up within the Microgravity Science Glovebox (MSG) on the International Space Station.

The SPICE hardware in the MSG on the International Space Station.

structure and liftoff in combustion experiment



Lifted microgravity flames (where the scale is not consistent). The lifted nature of the flames can be discerned from the flame shape and the distance from the nozzle tip (which is not visible). While the flames on the left may look like attached flames, the outward fuel-lean flare of each flame's base reveals its lifted nature.

Operations

SLICE is a crew-operated experiment, where the crew first installs the SPICE hardware in the MSG work volume. The SPICE hardware consists of a small fan-driven flow duct equipped with an exchangeable burner tube and igniter. Outside of the flow duct are two cameras, the fuel supply bottle, and supporting electronics boxes. Before each test, the crewmember installs the specified burner tube and a supply bottle with the selected fuel. The astronaut then sets the fuel flow and air velocity as indicated in the test matrix and ignites the flame. A small number of flame conditions are studied in each test; the crewmember will adjust either the fuel flow or airflow to achieve different flame conditions, as in the sample images (from SPICE operations in 2009). At each flow condition, the crewmember will photograph the flame with a high-resolution digital still camera that has been calibrated with a blackbody source, enabling determination of the soot temperature and soot volume fraction via pyrometry. The fuel flow is shut off upon completion of a test. Throughout the SLICE operations, the science team on the ground will monitor video downlink, which includes overlaid sensor data, to guide the crewmember in lifting the flame and selecting flow conditions that will yield the most useful results. The still images and data will be downlinked to the ground for analysis following each session of operations.

Applications

The twin purposes for the SLICE research are increased fuel efficiency and reduced pollutant emission in practical combustion devices. More explicitly, the experiment is being conducted to advance combustion modeling capability, which "allows system designers to improve efficiency and reduce harmful pollutants in ways never before possible" (as stated by an external reviewer of the SLICE experiment). In other words, the SLICE research is being conducted to advance energy technology and improve our global environment.

Glossary

Nonpremixed flame—a type of flame where the fuel and oxidizer (e.g., air) are not mixed, but are found on opposite sides of the flame surface where they react and are chemically transformed into heat, light, and product species such as carbon dioxide and water vapor. A synonym is *diffusion flame*, while the antonym is *premixed flame*, i.e., where the fuel and oxidizer are mixed, for example in the burner tube, such that both are on the same side of the flame surface. A candle flame is an example of a nonpremixed flame, where the flame is a shell encompassing the vaporized wax.

Soot—solid carbon-rich particles formed within a flame when the fuel reacts in the absence of oxygen because of the high flame temperatures. Soot normally burns up, forming carbon dioxide and water, as it passes through the flame surface, but can sometimes escape the flame, e.g., because of a draft. The yellow to red colors within a typical flame are the result of broadband thermal emission from soot particles (while the blue color is the result of the combustion chemistry).

The SLICE hardware was designed and developed by ZIN Technologies, Inc., under contract to the NASA Glenn Research Center.

Principal Investigator—Professor Marshall B. Long
Yale University
203–432–4229

Co-Investigator—Professor Mitchell D. Smooke
Yale University
203–432–4344

Co-Investigator—Dr. Fumiaki Takahashi
National Center for Space Exploration Research
216–433–3778

Co-Investigator/Project Scientist—Dennis P. Stocker
NASA Glenn Research Center
216–433–2166

Project Manager—Robert W. Hawersaat
NASA Glenn Research Center
216–433–8157

National Aeronautics and Space Administration

Glenn Research Center
21000 Brookpark Road
Cleveland, Ohio 44135

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