Acronym: SPICE

Title: Smoke Point In Co-flow Experiment

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Sponsoring Agency: National Aeronautics and Space Administration (NASA)

Increment(s) Assigned: 18, 19, 20

Brief Research Summary (PAO): The Smoke Point In Co-flow Experiment (SPICE) determines the point at which gas-jet flames (similar to a butane-lighter flame) begin to emit soot (dark carbonaceous particulate formed inside the flame) in microgravity. Studying a soot emitting flame is important in understanding the ability of fires to spread and in control of soot in practical combustion systems space.

Research Summary:

- Previous experiments show that soot dominates the heat emitted from flames in normal gravity and microgravity fires. Control of this heat emission is critical for prevention of the spread of fires on Earth and in space for the design of efficient combustion systems (jet engines and power generation boilers).

- The onset of soot emission from small gas jet flames (similar to a butane-lighter flame) will be studied to provide a database that can be used to assess the interaction between fuel chemistry and flow conditions on soot formation. These results will be used to support combustion theories and to assess fire behavior in microgravity.

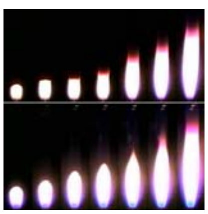
- The Smoke Point In Co-flow Experiment (SPICE) will lead to a
    - improved design of practical combustors through improved control of soot formation;
    - improved understanding of and ability to predict heat release, soot production and emission in microgravity fires;
    - improved flammability criteria for selection of materials for use in the next generation of spacecraft.

Detailed Research Description: The Smoke Point In Co-flow Experiment (SPICE) will continue the study of fundamental phenomena related to understanding the mechanisms controlling the stability and extinction of jet diffusion flames begun with the Laminar Soot Processes (LSP) on STS-94. SPICE will stabilize an enclosed laminar flame in a co-flowing oxidizer, measure the overall flame shape to validate the theoretical and numerical predictions, measure the flame stabilization heights, and measure the temperature field to verify flame structure predictions.

SPICE will determine the laminar smoke point properties of non-buoyant jet diffusion flames (i.e., the properties of the largest laminar jet diffusion flames that do not emit soot) for several fuels under different nozzle diameter/co-flow velocity configurations. Luminous flame shape measurements would also be made to verify models of the flame shapes under co-flow conditions. The smoke point is a simple measurement that has been found useful to study the influence of flow and fuel properties on the sooting propensity of flames. This information would help support current understanding of soot processes in laminar flames and by analogy in turbulent flames of practical interest.

Project Type: Payload

Images and Captions:


Top: Onset of the closed-tip smoke point for flames in quiescent ambient from the LSP experiment. Bottom: Onset of the open-tip smoke point for flames in quiescent ambient from the LSP experiment on STS-94. Similar behaviors are expected with SPICE. Images courtesy of Glenn Research Center, Cleveland, OH.


SPICE Hardware inside of the Microgravity Science Glovebox at Marshall Space Flight Center (MSFC). Image courtesy of Glenn Research Center.


NASA Image: ISS018E026974 Astronaut Sandra Magnus works with the Smoke Point In Co-flow Experiment (SPICE) in the Microgravity Sciences Glovebox (MSG) during Expedition 18.

Operations Location: ISS Inflight

Brief Research Operations:

- The crewmember will unstow and assemble the SPICE hardware on the base plate within the Microgravity Science Glovebox (MSG) working volume and connect electrical and data harnesses.

- During course of experiment, the crew will install and exchange fuel bottles, exchange burner tubes, control fuel flow and flame ignition.

- For each test point the crew will set the burner diameter and air flow before ignition. After ignition, the crew will adjust the fuel flow rate until the flame is at the smoke point.

- The crew will control video and still camera functions, some photos are down-linked for near-real time coordination with the investigator. The crewmember will uninstall experiment from the MSG and stow the hardware once SPICE is completed.

Operational Requirements: SPICE will be conducted inside the sealed MSG work volume. The crewmember is involved throughout the experiment to load fuel bottles, initiate tests, ignite the fuel, adjust flame to smoke point, monitor and record data, exchange burner tubes, exchange fuel bottles and replace the igniter. Six test sequences covering six different fuels with three different burner tubes, for a total of fifty-four (54) test points will be performed by the crewmember. Periodic repeat points are desired if time is available. Data will be downlinked via video during or immediately after each flame test. Digital photos are downlinked after selected flame tests for ground confirmation before proceeding. SPICE testing session must be conducted during periods when no major reboost or docking procedures are underway on the International Space Station.

Operational Protocols: The crewmember installs the SPICE hardware in the MSG work volume. The SPICE hardware consists of a small flow duct with an igniter and a small nozzle. Outside the flow duct are 2 cameras, the fuel supply bottle and various electronic boxes. Each test is conducted by the crewmember who installs the correct diameter nozzle and sets the air flow rate through the duct before igniting the flame. When the flame is ignited, (it will look similar to a butane-lighter flame) the crewmember adjusts the flame size (by controlling the fuel flow rate) until the flame is just at the smoke point (the size where the flame just begins to emit a small stream of soot from the tip). After triggering the high resolution camera, the crewmember turns off the fuel and prepares for the next test. The science team on the ground will monitor the video downlink to assist the crewmember in determining the smoke point and will review the sensor data overlaid on the video image. Between test sessions the crew will change the fuel bottle to a different fuel (six will be tested). Upon completion of the tests the crewmember stows the hardware and the stored images and data are returned to Earth for analysis.

Review Cycle Status: PI Reviewed

Category: Physical Sciences in Microgravity

Sub-Category: Combustion Science

Space Applications: Current NASA spacecraft materials selection is based upon a simplified test method that segregates material based upon behavior on Earth without real consideration of microgravity effects. A critical element of this understanding is the radiative heat emission from the flame. This heat emission is strongly influenced by the extent of soot formation. Improved understanding of soot formation and thereby the heat release from microgravity fires will allow more complete and effective utilization of the flammability test results. These results can be used in first-order models and predictions of heat release in spacecraft fires and as a means to extend heat release data from tests like the NASA cone-calorimeter test to microgravity fires to a performance based material selection process.

Earth Applications: The smoke-point phenomena is a classical metric in the understanding of the heat release and spread rate of fires. It is commonly used in fire modeling on Earth and to understand the soot growth and emission by flames. The dominant characteristics of many flames of practical interest are nonbuoyant. The LSP experiment has shown that the onset of the microgravity smoke point in a quiescent environment is very different from that seen in normal gravity. SPICE seeks to extend our understanding by looking at the interaction of ambient flow with the smoke point, enabling us to better predict heat release from non-buoyant flames in practical combustors (e.g. jet engines and furnaces).

Manifest Status: Continuing

Supporting Organization: Exploration Systems Mission Directorate (ESMD)

Previous Missions: This is a new investigation for research on the ISS.

Web Sites:
SPICE

Related Payload(s): SAME

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