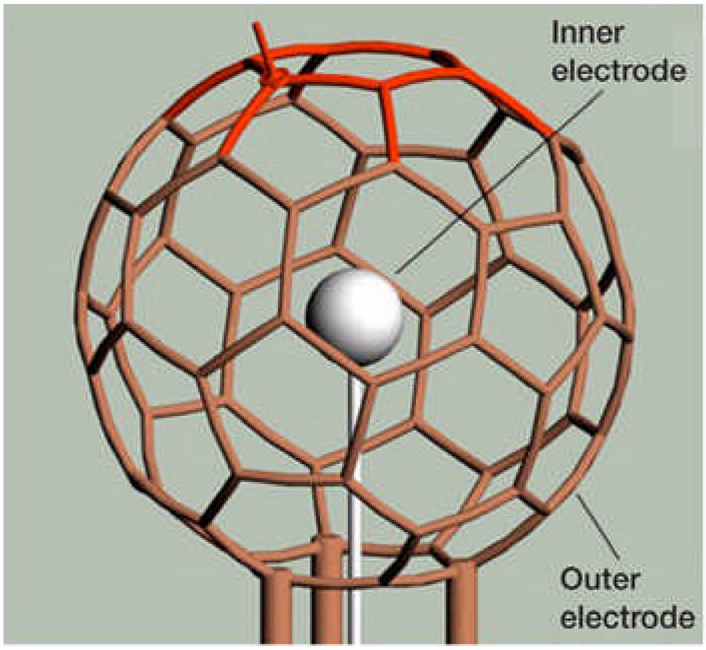
Interaction Between Flames and Electric Fields Studied

The interaction between flames and electric fields has long been an interesting research subject that has theoretical importance as well as practical significance. Many of the reactions in a flame follow an ionic pathway: that is, positive and negative ions are formed during the intermediate steps of the reaction. When an external electric field is applied, the ions move according to the electric force (the Coulomb force) exerted on them. The motion of the ions modifies the chemistry because the reacting species are altered, it changes the velocity field of the flame, and it alters the electric field distribution. As a result, the flame will change its shape and location to meet all thermal, chemical, and electrical constraints. In normal gravity, the strong buoyant effect often makes the flame multidimensional and, thus, hinders the detailed study of the problem.

This project utilizes the microgravity environment provided by the 2.2-Second Drop Tower at the NASA Glenn Research Center to create a one-dimensional, spherically symmetric flame and electric field. In the experiments, the fuel gas (methane, propane, or ethylene) is issued from a spherical porous brass burner that also acts as an inner electrode. The burner is surrounded by a concentric spherical Faraday cage serving as an outer electrode (see the following figure), and an adjustable, dc, high-voltage source feeds the desired voltage to the two electrodes. The established electric field has spherical equipotential surfaces between the two electrodes, except in the local area where a thin stainless steel tube is connected to the burner to provide the fuel passage and electrical connection. In microgravity, flames with large spherical portions can be established between the two electrodes.



Spherical electrodes between which spherical flames will be established and studied in *microgravity.*

Results from these studies are clarifying the effects of electric field strength and polarity and the effects of fuel type on (1) flame shape and size, (2) flame sooting propensity, (3) flame unsteadiness, and (4) flame extinction behavior. For a given type of fuel with a fixed-mass flow rate, the flame radius of the spherical portion and the flame shape of the nonspherical portion strongly depend on the electric field strength and polarity. For example, for ethylene flames, when the outer electrode is positively charged with respect to the inner electrode, the flame radius is affected little, whereas for the reversed polarity, the flame radius shrinks significantly and the nonspherical portions of the flame sometimes undergo unsteady pulsations. At high field intensities, local flame extinction is also observed. The following figure shows images of ethylene flames burning in air at atmospheric pressure at a fuel flow rate of 2.3 mg/s under various applied voltages, 1.8 s after the drop commenced.

Images of ethylene flames burning in 1 atm pressure in microgravity subject to different dc voltages between the two electrodes (voltage of the outer electrode with respect to the inner electrode). The dark lines in the images are the out-of-focus member of the outer electrode. Left: -1.8 kV. Center: 0 V. Right: 1.8 kV.

National Center for Microgravity Research contacts: Dr. Zeng-Guang Yuan, 216-433-2838, Zengguang.Yuan@grc.nasa.gov; and Dr. Uday Hegde, 216-433-8744, Uday.Hegde@grc.nasa.gov
Authors: Dr. Zeng-Guang Yuan and Dr. Uday Hegde
Headquarters program office: OBPR
Programs/Projects: Microgravity Science