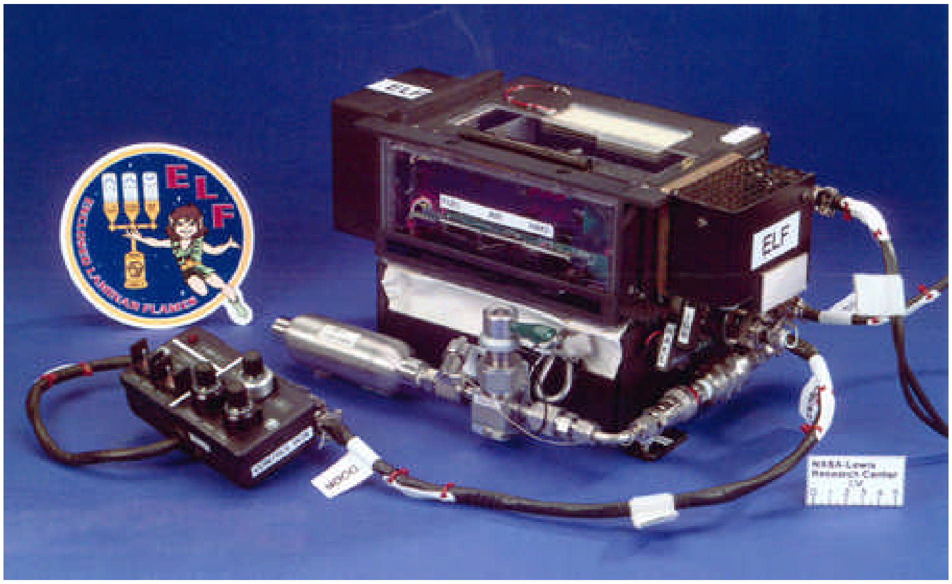
Stability of Enclosed Laminar Flames Studied in Microgravity



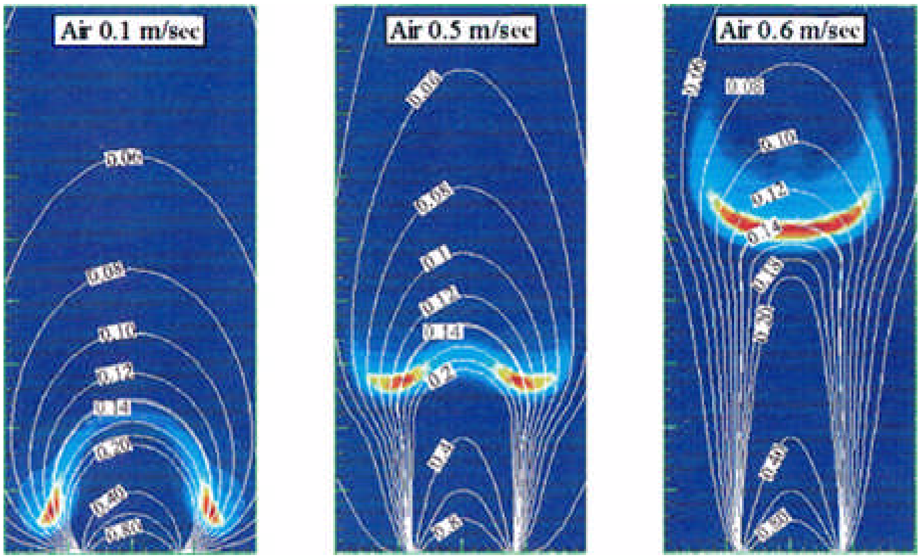
ELF flight hardware assembled for testing.

In practical combustion systems, the flame is often anchored at the inlet where the fuel is injected into an air duct. This type of system is found in powerplant combustors, gas turbine combustors, and the jet engine afterburner. Despite its successful use, this configuration is vulnerable to adverse flow conditions that can cause the flame to literally lift off from the inlet or even blowout. Poor flame stability is, of course, unwanted, especially where safety has a high priority. Our understanding of the mechanisms that control flame stability is incomplete in part because the interaction of buoyant (i.e., gravity-induced) convection makes it difficult to interpret normal-gravity results. However, a comparison of normal-gravity and microgravity results can provide a clear indication of the influence of forced and buoyant flows on flame stability. Therefore, a joint microgravity study on the stability of Enclosed Laminar Flames (ELF) was carried out by researchers at The University of Iowa and the NASA Lewis Research Center. The microgravity tests were conducted in the Microgravity Glovebox (MGBX), during the STS-87 space shuttle mission in late 1997, using hardware designed and produced at Lewis and shown in the preceding photo.

The primary objective of the ELF investigation was to determine the mechanisms controlling the stability of round, laminar, gas-jet diffusion flames in a coflow air duct. The study specifically focused on the effect of buoyancy on the flame characteristics and velocities at the lift-off, reattachment, and blowout of the flame. When the fuel or air velocity is increased to a critical value, the flame base abruptly jumps downstream, and the flame is said to have reached its lift-off condition. Flow conditions are such that the flame cannot be maintained at the burner rim despite the presence of both fuel and oxygen.

When the velocity is further increased, the flame eventually extinguishes at its blowout condition. In contrast, if the velocity is reduced, the flame base eventually returns to anchor at the burner rim, at a velocity lower than that of lift-off, indicating a hysteresis effect.

During the STS-87 shuttle mission, approximately 50 tests were conducted, using a 50/50 mixture (by volume) of methane and nitrogen as the fuel. Stable lifted flames were observed in microgravity, except at high fuel flows where the microgravity flames blew out immediately after lift-off. The experimental results verify the hypothesis that substantially greater velocities are required to destabilize a flame in microgravity because of the absence of buoyant acceleration in the flow. Preliminary results reveal that the increase in air velocity required to induce lift-off in microgravity (in comparison to normal gravity) was nearly equal to the increase required to induce blowout. Furthermore, the air velocity increase was relatively independent of the fuel flow, except at low fuel flows. Preliminary numerical predictions are in qualitative agreement with the experimental results; an example is shown in the following figure. Further analysis is underway, and on the basis of ELF's success on STS-87, a ground-based proposal has been approved, offering ELF researchers the opportunity to compete for a reflight on the space shuttle.



Numerical predictions of flame lifting and shape change with increasing air velocity. Heat release rate and mixture fraction for attached (left), lifted (center), and near blowout (right) condition. Fuel-jet velocity, 0.2 m/sec.

Learn more about the Enclosed Laminar Flames (ELF) experiment http://exploration.grc.nasa.gov/expr/elf.htm.

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