

# LIFTED PARTIALLY PREMIXED FLAMES IN MICROGRAVITY

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Partially premixed flames are a class of flames that can be established by design through placement of a fuel-rich mixture in contact with a fuel-lean mixture. These flames occur otherwise in many practical systems as well. For instance, initially nonpremixed combustion may involve regions of local extinction followed by partial premixing and re-ignition [1]. Nonuniform evaporation in spray flames can also result in local fuel-rich regions in which burning occurs in the partially premixed mode. The technique of lean direct injection, used to achieve stable combustion and reduced pollutant levels, also involves regions of partially premixed combustion. In addition, unwanted fires can originate in a partially premixed mode when a pyrolyzed or evaporated fuel forms an initial fuel-rich mixture with the ambient air. Partial premixing is also important in nonpremixed flame liftoff phenomena, since the reactants can mix to some extent prior to ignition [2, 3].

Under normal-gravity conditions, the flame heat release produces both flow dilatation and buoyancy effects in partially premixed flames. Gas expansion due to heating causes downstream motion normal to the flamefront. The buoyant gases accelerate the flow in an opposite direction to the gravity vector, causing air entrainment that enhances the fuel-air mixing and, consequently, influences the upstream region. While it is possible to minimize gravitational effects in a premixed flame by isolating buoyancy effects to the lower-density post-flame region or plume, it is not so straightforward to do so in nonpremixed flames. Several investigations have established that partially premixed flames can contain two (even, three) reaction zones [4, 5, 6, 7, 8], one with a premixed-like structure and the other consisting of a transport-limited nonpremixed zone (in which mixing and entrainment effects are significant). For these reasons it is important to understand the interaction between flow dilatation and buoyancy effects in partially premixed flames.

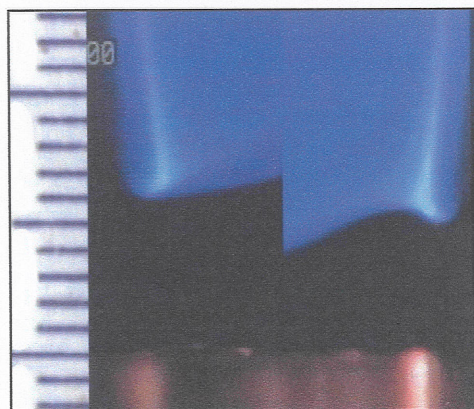
Lifted partially premixed flames offer a deeper insight into the phenomena of lifted nonpremixed flames. Even when the initial streams are nonpremixed, partial premixing occurs in the region upstream of the reacting region and creates a stable base for the diffusion flame [9]. The flame remains anchored around a narrow region of high local reaction (reaction kernel [10]). This anchoring of the nonpremixed flame has been attributed to upstream transport of radical from the reaction kernel. This radical flux increases the chemical reaction rates for important reaction steps near a stabilization point that is located in a small premixing zone [10]. A similitude between burner stabilized and lifted triple flames was suggested by Puri *et al.* [11] as a means to relate burner stabilized flames and lifted flames. Our current paper seeks to validate this idea further by elimination of buoyancy influence in the flame so that the role of other more subtle characteristics affecting the flame are also identified.

Lifted Double and Triple flames are established in the UIC-NASA Partially Premixed microgravity rig. The flames examined in this paper are established above a coannular burner because its axisymmetric geometry allows for future implementation of other non-intrusive

optical diagnostic techniques easily. Both burner-attached stable flames and lifted flames are established at normal and microgravity conditions in the drop tower facility.

Direct imaging of double and triple flame for a range of equivalence ratio is recorded. The structure of the flames is inferred via  $C_2^*$  chemiluminescence measurements using digital image manipulation [12] of the recorded color images. Information regarding the flame speed is also obtained through a comparison of the normal and microgravity lifted flame results.

Figure 1 shows a lifted double flame under normal and microgravity. As can be seen from Figure 1 the flame shifts down slightly in microgravity. This is a result of loss of buoyant acceleration of the hot gases allowing the flame to seek equilibrium between flame speed and flow velocity at a lower axial location. Another key point of interest that can not be observed from the figure, but is seen clearly in the video recorded during the drop is stability. The normal gravity lifted flame in this configuration was observed to oscillate with high amplitude. However the microgravity flame was observed to be visually stable after the initial transient of the drop.



**Figure 1: Lifted Double Flame under Normal (left) and Microgravity (right) conditions;  $\phi_{in}=3.0 \pm 40\%$   $N_2$ ,  $\phi_{out}=0$ ,  $V_{in}=V_{out}=30\text{cm s}^{-1}$**

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