Objectives
The combustion of heterogeneous media in general and liquid fuels in particular is an important topic of interest on both fundamental and practical grounds. On the practical side, most accidental fires and energy conversion systems rely upon condensed phase fuel. From a theoretical standpoint, there are a number of physical processes associated with heterogeneous combustion, such as extinction, which are still not well understood. For this work in progress, experimental data were examined in order to gain additional knowledge regarding important physical processes in isolated droplet combustion. This understanding was then applied to the question of fire suppression and prevention in microgravity environments.

Comparaison
•Initial discrepancy attributed to thermal radiative transfer between the droplet surface and the duct walls. In some experimental configurations, the ratio of the estimated incident thermal radiation from the far-field as compared to the total energy flux of the unperturbed, simulated system reached 25%. By assuming the bath gas to be optically thin to thermal radiation wavelengths, an effective heat source term was introduced to the droplet surface to mimic the gray-body radiative exchange between the liquid surface and far-field solid boundary.
•This modified the burning rate by a nearly constant amount over the droplet lifetime, which is to be expected of the radiative influence scales with droplet surface area.
•Within the experimental accuracy, the emissivity of the liquid phase was estimated to be 1.0.

The modification was sufficient to account for the discrepancy in droplet behavior and to bring the experimental results in line with previous experimental work conducted under true microgravity conditions.

References

Shaw and co-workers have recently studied experimentally the combustion of isolated droplets of n-heptane, n-decane, and n-hexadecane in these configurations, with both constant duct cross-section and with duct cross-section properly shaped such that the post flame gases have an acceleration on the duct centerline equivalent to that of gravity. The purpose of these experiments was to provide direct comparisons of droplet combustion parameters under the more commonly freely falling configuration with constant duct cross-section and the shaped duct configuration, which should achieve the low Grashof/Reynolds number characteristics similar to those found in typical drop tower experiments that require larger diameter droplets. To address the duct flow heat loss issue, the duct walls in both configurations were heated using electrical resistance heaters and insulation to approximate an isothermal field surrounding the droplet combustion event. Establishing minimal heat loss from the flow is also critical to determining the appropriate duct shape for achieving flow acceleration equivalent to gravity. The experimental measurements appear to support the low Grashof/Reynolds number result differs from the straight duct result; however, the droplet combustion parameters in the low gravity configuration as directly measured appear to also differ from those found in actual drop tower experiments.

Physical versus Kinetically-Limited Extinction
•Simulations of 2 mm n-heptane droplets in the listed mole fraction of CO2 mixed with air (21% O2/79% N2).
•As CO2 mole fraction is increased, extinction, as characterized by a region of high negative curvature, begins at higher temperatures. This extinction onset is accompanied by a rapid decrease in burning rate.
•The rapid decrease in standoff ratio which occurs near extinction corresponds exactly with 1250 K. It therefore deconfines from extinction time as the mole fraction of CO2 increases.
•As visible in the temperature profiles at differing times within a characteristic burning history, we see the fundamental difference between the temperature profile before the decrease in standoff and thereafter is the loss of a sharp peak. This peak is associated with local heat generation, and thus chemical reaction.
•We therefore have a simple technique for differentiating kinetically-limited extinction from extinction resulting from other effects.
•The suppressant effect of carbon dioxide is therefore not only because of an increase in local heat capacity, but also due to some more active source of heat loss. These issues could most easily be attributed to an increase in spectral radiative heat transfer from the flame zone.

Effect of Far-Field Radiation on Flame Suppression by Carbon Dioxide
•The temperature at infinity was held constant at 280 K while the equivalent blackbody temperature of the incoming radiation was modified.
•The increased energy flux into the system only couples with the liquid surface and thus, while significantly increasing the vaporization rate, has no effect upon flame zone temperature.
•Since the flame zone is largely unaffected, the extinction diameter is constant.