

AN ALL-PRESSURE FLUID-DROP MODEL: VALIDATION AND SPECIES SYSTEM DEPENDENCY

K. Harstad and J. Bellan
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109-8099

A model of fluid drop behavior at all-pressures is presented and validated with experimental data from microgravity experiments. The model is very general: it contains Soret and Dufour effects, does not assume mass transfer quasi-steadiness at the drop boundary, or necessarily the existence of a drop surface (i.e. phase discontinuity). Moreover, the model includes accurate equations of state and transport properties over a wide range of thermodynamic variables. Consistent with low-pressure conditions, the drop boundary is identified *a posteriori* of the calculations with the location of the largest density change. Validation of the model is conducted for a heptane drop in nitrogen over the entire range of the data consisting of moderate to high temperature drop-surroundings and at reduced pressures ($p_r \equiv p/p_c$ where the subscript c denotes the critical state of the initial fluid in the drop) of 0.04 to 1.8. In agreement with the existing experimental data, the drop lifetime increases monotonically with pressure at low far field temperatures (470 K), but exhibits a maximum as a function of pressure at high temperatures (1000 K). On an appropriate scale, the slope of the diameter squared versus time is shown to be independent of the drop size at all pressures. An examination of the assumption of linear dependency of the drop diameter squared with time shows that this functional behavior is approximately encountered only at atmospheric pressure; for higher pressure, the diameter squared versus time has a negative curvature for the heptane/nitrogen system. As the pressure increases, the slope of the diameter squared becomes an increasing function of time, and progressively increases with pressure at subcritical far-field temperatures (i.e. $T_r \equiv T/T_c < 1$), however, at supercritical temperatures ($T_r > 1$) a maximum is reached. The results show that at locations arbitrarily near the boundary, the drop does not reach the mixture critical point within the wide range of conditions investigated. An examination of the relaxation time at the drop boundary shows that quasi-steadiness of the mass transfer prevails for drops of radius as small as 2×10^{-3} cm. A similar investigation conducted for oxygen drops in hydrogen at p_r ranging from 0.3 to 3.97 reveals that while at $p_r < 1$ the diameter squared variation is nearly linear, with increasing pressure it departs considerably from the linear behavior and has a positive curvature; the largest departure occurs in the vicinity of the oxygen critical point. The slope of the diameter squared was fitted for the oxygen/hydrogen system using both a constant and a linear fit, and it was shown that the linear fit provides a better alternative for correlation purposes. Given that the drop diameter squared versus time exhibits different behavior with p_r for the two species systems studied herein, it is concluded that care must be exercised in extrapolating high-pressure behavior from one species system to other species systems.