A Study of Immiscible Liquids, Liquid Behavior at Zero Gravity, and Dynamic Contact Lines and Angles

Thesis by

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To my family

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ABSTRACT

The work reported here covers three topics that were investigated as part of preparation for a space based experiment. The intention of the proposed experiment was to study the relationship between container geometry and interface geometry for a free liquid surface at zero gravity.

A mathematical theory proposed by Paul Concus and Robert Finn in 1974 and recently developed by Finn yields explicit geometrical criteria for the position of the free surface of a liquid at zero gravity in a cylindrical container of specified cross section. It is possible to find geometrical criteria that promise a particular liquid location. A unified graphical presentation of four geometries is given that can be used directly for the design of containments for liquids at zero gravity. As one application of these design curves, a container was built and tested in a series of 2 second drop-tower experiments at NASA Lewis Research Center.

It was apparent that the space based experiment would require use of sophisticated optical instrumentation that would be most effective if a pair of immiscible liquids were used rather than a single liquid under its vapor. This work identifies 121 transparent immiscible liquid pairs that have properties compatible with optical instrumentation based on laser-induced fluorescence. Physical data such as specific gravity, index of refraction, viscosity, flash point, and toxicity were found in the literature. Compatibility with plexiglas (PMMA), contact angles of the internal meniscus on glass and PMMA, meniscus formation times, and clearing times were measured. A useful non-invasive technique for determining interfacial tensions is explained and used.

The contact angle is a critical parameter in the consideration of liquid behavior at zero gravity, therefore, a technique, based on laser light refraction, was developed to objectively measure it. Dynamic contact line experiments were conducted at various velocities, both advancing and receding, using one of the 121 immiscible liquid pairs (nonane/formamide) in contact with glass.

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