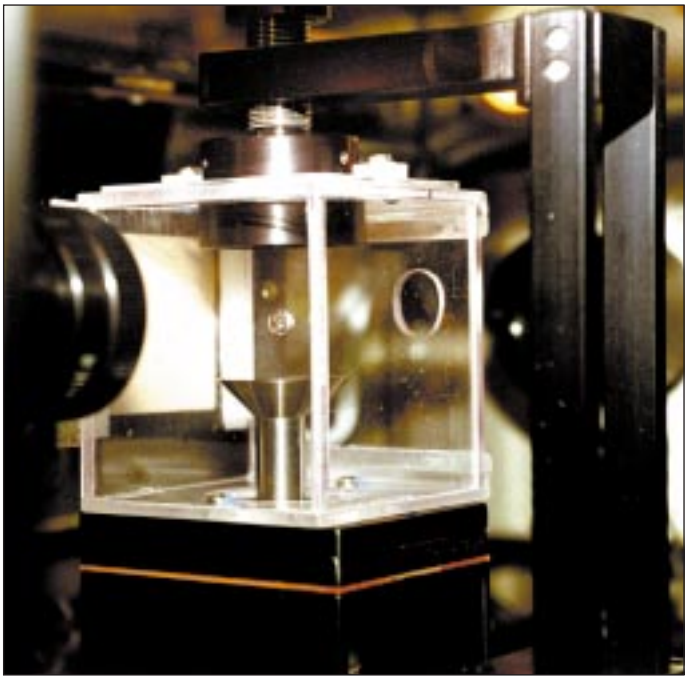
IFFD: Internal Flow in a Free Drop

Containerless experimentation is a technique used to study the way liquid materials behave in the absence of a container. The material is usually levitated by magnetic, electrostatic, or acoustic forces, and so can be manipulated, heated, or cooled without contact between the material and container walls. This method enables the observation of the motion of a totally free, three-dimensional liquid surface. Microgravity scientists are interested in studying a particular type of surface motion that can be induced by the unequal heating of a liquid-gas interface (the boundary between the liquid surface of a drop and the air surrounding the drop). The action of applying heat to one portion of the drop's surface induces flows that move from hotter areas on the liquid surface toward cooler areas. Return flows are induced in the reverse direction inside the liquid. This motion is referred to as thermocapillary flow. The objective of the Internal Flows in a Free Drop (IFFD) investigation is the development of an experimental approach for the observation of thermocapillary flow in a totally free-floating drop of liquid in microgravity.



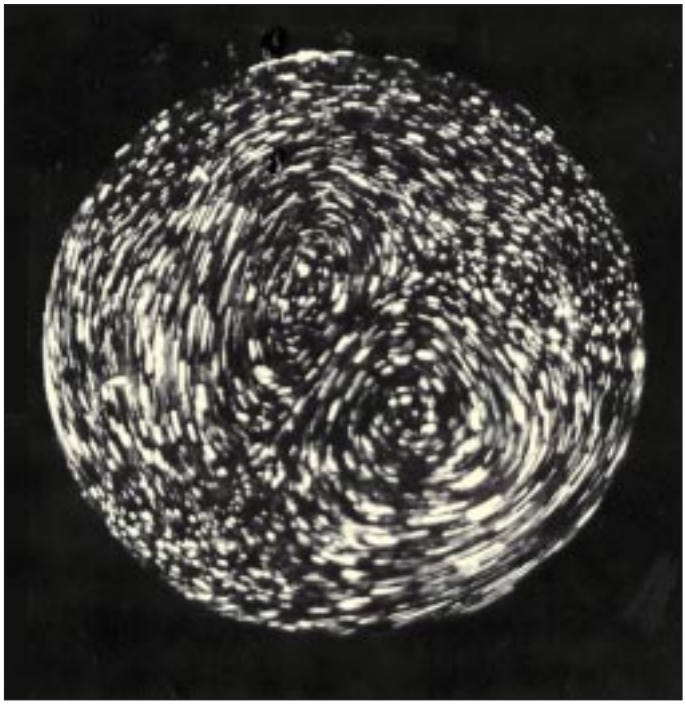
The IFFD levitator and a positioned drop in low gravity

Thermocapillary flow is caused by variations in surface tension, which is the net attractive force between molecules at a liquid's surface. In IFFD, those variations are caused by unequal heating. Although thermocapillary flow is always induced by temperature differences on a free liquid surface, it has been difficult to study accurately on Earth because of the overpowering effect of buoyancy-induced flow. Buoyancy refers to the tendency on Earth for denser (generally colder) particles in a liquid to sink and less dense (generally hotter) particles to rise. This tendency is due to gravity and often causes flows in heated liquids.

In order to observe thermocapillary flow, scientists are conducting experiments in microgravity, where buoyancy-induced flows are virtually eliminated. The IFFD experiment is designed to test the feasibility of a simple, low-cost approach that allows scientists to observe thermocapillary flow in a levitated drop of water and glycerin. During the experiment, a drop will be acoustically levitated and heat will be applied to one side of the drop, creating a temperature difference and thus a surface tension gradient. Thermocapillary flows should result. These flows will be monitored by observing the movement of tracer particles that have been added to the sample drop. A laser beam will illuminate the particles so that their movements can

be captured by video cameras. Analysis of these data will allow researchers to compare the simple observed thermocapillary flow patterns with those predicted by theory. This analytical theory predicts both flow and thermal distributions due to thermocapillary flow in a free drop. The validation of this theory also has the practical benefit of allowing the measurement of the thermal diffusivity of the liquid. Thermal diffusivity is a fundamental material property of great significance for the processing of useful materials.

The IFFD experiment uses low-level sound waves to levitate the water-glycerin drop in air and to keep the drop positioned so that cameras can record the movement of the tracer particles. These sound waves are produced by an ultrasonic levitator. The basic feasibility of accurately positioning a drop with enough control to allow the observation of internal flows was established by a previous investigation using the same apparatus during the STS-94 mission in April 1997.



The movement of tracer particles captured by a video camera allows the visualization of thermocapillary flow in a suspended drop.

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FS-1998-09-59-MSFC