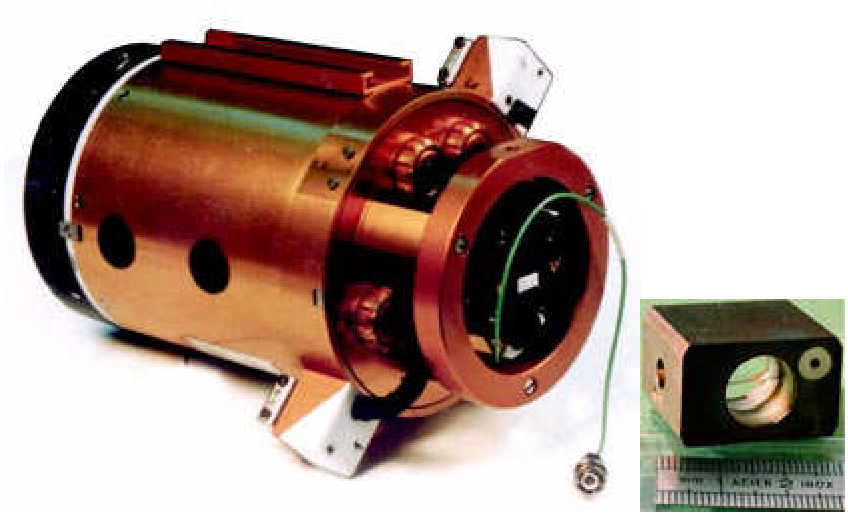
Growth and Morphology of Supercritical Fluids, a Fluid Physics Experiment Conducted on Mir, Complete

The Growth and Morphology of Supercritical Fluids (GMSF) is an international experiment facilitated by the NASA Glenn Research Center and under the guidance of U.S. principal investor Professor Hegseth of the University of New Orleans and three French coinvestigators: Daniel Beysens, Yves Garrabos, and Carole Chabot. The GMSF experiments were concluded in early 1999 on the Russian space station Mir. The experiments spanned the three science themes of near-critical phase separation rates, interface dynamics in near-critical boiling, and measurement of the spectrum of density fluctuation length scales very close to the critical point. The fluids used were pure CO_2 or SF_6. Three of the five thermostats used could adjust the sample volume with the scheduled crew time. Such a volume adjustment enabled variable sample densities around the critical density as well as pressure steps (as distinct from the usual temperature steps) applied to the sample.

The French-built ALICE II facility was used for these experiments. It allows tightly thermostated (left photograph) samples (right photograph) to be controlled and viewed/measured. Its diagnostics include interferometry, shadowgraph, high-speed pressure measurements, and microscopy. Data were logged on DAT tapes, and PCMCIA cards and were returned to Earth only after the mission was over.

The ground-breaking near critical boiling experiment has yielded the most results with a paper published in Physical Review Letters (ref. 1). The boiling work also received press in Science Magazine (ref. 2). This work showed that, in very compressible near-critical two-phase pure fluids, a vapor bubble was induced to temporarily overheat during a rapid heating of the sample wall. The temperature rise in the vapor was 23-percent higher than the rise in the driving container wall. The effect is due to adiabatic compression of the vapor bubble by the rapid expansion of fluid near the boundary during heatup. Thermal diffusivity is low near the critical point, so getting heat out of the compressed bubble is observably slow. This gives the appearance of a backward heat flow, or heat flow from a cold surface to a warm fluid.



Left: ALICE II Thermostat for critical fluid samples enables stable temperature control (±50 µ°C rms) and optical diagnostics like interferometry and microscopy. Right: Typical copper-bodied cell with sapphire windows and filled with SF_6 to roughly 38 atm and a density of 0.73 g/cm^3. The typical fluid volume is less than 1 cm^3.

References

1. Wunenburger, et al.: Thermalization of a Two-Phase Fluid in Low Gravity: Heat Transferred From Cold to Hot. Phys. Rev. Lett., vol. 84, no. 18, May 2000, p. 4100.

2. Science Magazine, May 5, 2000, p. 789.

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Programs/Projects: Microgravity Science