N92-23640

CRITICAL FLUID THERMAL EQUILIBRATION EXPERIMENT
(19-IML-1)

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Gravity sometimes obscures interesting physical phenomena or, in some cases, blocks all experimental techniques of making a desired measurement. It is the later case that drives low-gravity experiments in critical point fluid systems. The feverish activity in fluid critical phenomena of the 1970's slowed to a near standstill in part due to gravitational limitation on acquiring further expeimental data closer to the critical temperature. The availability of low-gravity on longer and longer duration space missions has brought back to life experimental effort. A recent international workshop sponsored by NASA and NIST concluded that unexpected behavior of near critical fluids in low-gravity brings to the fore equilibration dynamics as a frontier in critical phenomena research. How long does it take for a fluid sample to relax to equilibrium after a temperature step near the critical point?

Any pure fluid possesses a liquid-vapor critical point. It is uniquely defined by a temperature, pressure, and density state in thermodynamics. For states with either temperature, pressure, or density greater than the critical values; liquid and vapor are no longer distinguishable. At the critical point a fluid fluctuates spatially and temporally in small domains between liquid and vapor. The consequence is that the fluid is infinitely compressible.

Such compressibility is the root of the troubles caused by gravity. A constant volume sample loaded on average to the critical density can not maintain a large portion of the sample at the critical point because the weight of the fluid is enough to compress half of the sample to a density above the critical density, leaving the other half below the critical density. There then remains a thin portion between the two halves that is at the critical density. However, the closer to the critical temperature, the more compressible the fluid, and the thinner is the critical zone. At some temperature the zone is too small to use any known experimental probe to measure thermodynamic properties. Low- gravity reduces the weight of the fluid on itself and widens the critical zone for a given temperature. Or best of all allows one to go closer to the critical temperature before experimental probe dimension limits are reached.

The crucial issue that this experiment attempts to understand is the time it takes for a sample to reach temperature and density equilibrium as the critical point is approached; is it infinity due to mass and thermal diffusion, or do pressure waves speed up energy transport while mass is still under diffusion control? The time scales involved (tens of hours to days) necessitate long duration experiments in space.

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The experiment being developed involves a small (0.078 cm^3) constant volume sample of sulfur-hexaflouride thermostated with milli-Kelvin control near its critical temperature of 45.54 °C and observed via interferometry, visualization, and light attenuation. One sample cell supports interferometry and another cell supports visualization. The two cells are integrated into a precision thermostat before launch. The thermostat is inserted into the experiment facility (Critical Point Facility) while on orbit at the initiation of the 60 hour experiment window. Video recording will occur for one or the other cells at all times. Such recording of long duration low gravity spatially and temporally varying compressible fluid dynamics has not been seen before. To respond to the unexpected, telescience will be exploited to the limits available on a Space Lab.

The science objectives are to observe: (1) large phase domain homogenization without and with stirring, (2) time evolution of heat and mass after a temperature step is applied to a one-phase equilibrium sample, (3) phase evolution and configuration upon going two-phase from a one-phase equilibrium state, (4) effects of stirring on a low-g two-phase configuration, (5) two-phase to one-phase healing dynamics starting from a two-phase low-g configuration, (6) effects of shuttle acceleration events on spatially and temporally varying compressibile critical fluid dynamics, and (7) quantifying the mass and thermal homogenization time constant of a one-phase system under logarithmic temperature steps.

Bibliography

M. R. Moldover, et al.: Gravity Effects in Fluids Near the Gas- Liquid Critical Point. Rev. Mod. Phys. vol. 51, no. 1, January 1979, pp. 79-99.

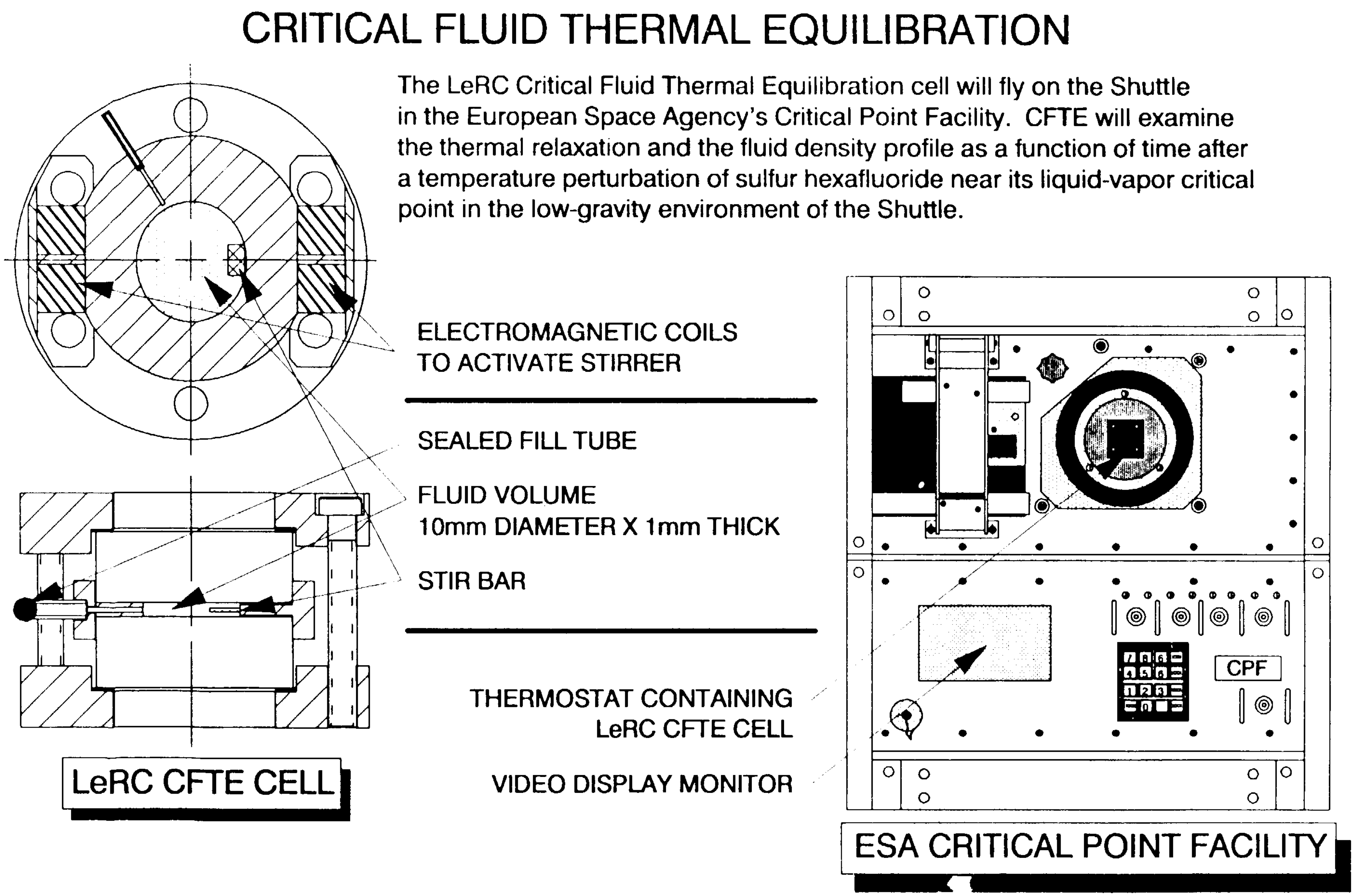

Figure 1. Critical fluid equilibration.