N92-23637

THE CRITICAL POINT FACILITY (CPF)

The Critical Point Facility (CPF) is an ESA multi-user facility designed for microgravity research onboard Spacelab. It has been conceived and built to offer investigators opportunities to conduct research on critical point phenomena in microgravity. This facility provides the high precision and stability temperature standards required in this field of research. It has been primarily designed for the purpose of optical investigations of transparent fluids. During a Spacelab mission, the CPF automatically processes several thermostats sequentially, each thermostat corresponding to an experiment. The CPF is now integrated in Spacelab at Kennedy Space Center, in preparation for the IML-1 mission.

Scientific Objectives

Pure fluids near the gas-liquid transition and binary mixtures may undergo a phase separation. Their miscibility or coexistence curve exhibits the general features shown in Figure 1. At high temperatures, the system is formed as a single phase. When the temperature is lowered and the coexistence curve reached, instability sets in: a phase separation is initiated in the form of density fluctuations, until two distinct equilibrium phases, located on the coexistence curve, are formed. The peak of this curve is the critical point.

The CPF has been designed to submit transparent fluids to an adequate, user-defined thermal scenario, and to monitor their behavior by using thermal and optical means. For instance, the density fluctuations mentioned above may produce scattered light which can be monitored by two of the CPF diagnostics. In addition, variations of the index of refraction (related to temperature or density inhomogeneities) can be analyzed with an interferometer.

Because they are strongly affected by gravity, a good understanding of critical phenomena in fluids can only be gained in low gravity conditions. First, fluids at the critical point become compressed under their own weight because their isothermal compressibility diverges at that point. As a consequence, fluids cannot be maintained in a critical state under gravity conditions. Secondly, the role played by gravity in the formation of interfaces between distinct phases is not clearly understood. Hence, the microgravity environment of Spacelab is very appropriate for this type of experiment.

CPF Design

The CPF has been designed for installation in a Spacelab rack. It is composed of two interconnected drawers: the experiment and the electronic drawers (Figs. 2 & 3). The electronic drawer provides the power supply, the electronics, and the data handling capabilities, whereas the experiment drawer contains the complete optical diagnostic system which surrounds the exchangeable thermostat. The thermostat houses the test cell which contains the fluid to be investigated and provides interfaces for the stimuli (thermal, acoustic, or magnetic mixer) and for the diagnostic devices (thermal, optical).

The CPF is fully automated: it runs experiments according to a pre-recorded timeline, defined by the investigator, and which can be modified in real-time at the investigator's request during the experiment run. This method, which requires minimum crew involvement, is particularly adapted to the very long experiment durations typical of this field of research.

The thermostat (Fig. 4) provides an excellent thermal control of the test fluid, with an accuracy of one thousandth of a degree (0.001 °C). This is achieved by using three co-axial cylinders, the second of which is surrounded by Joule heating wires and by torus-shaped Peltier elements at the top and bottom. The thermostat control electronics are also temperature controlled. Besides its thermal role, the thermostat has optical and electrical interfaces to enable stimuli and diagnostics to interact with the test fluid. It has a built-in identification number which ensures it will be processed in conjunction with the proper pre-recorded timeline.

The thermal capabilities provided by the thermostat within the test fluid are given below:

- temperature controlled between 30 °C and 70 °C
- heating and cooling with minimum step size of 1 mK
- maximum heating/cooling rate: 36 K/hr/10 K/hr
- temperature stability: 0.1 mK/hr
- temperature gradients within fluid: <0.1 mK/cm
- quenching rate: up to 25 mK/sec
- quenching step size: between 4 and 100 mK

An acoustic mixer at 1.7 MHz or a magnetically-driven mixing bar can be activated to eliminate any fluid density or concentration inhomogeneity.

The temperature of the test fluid is monitored with a precision of 0.1 mK relative to the critical temperature (T_c), which is determined beforehand but can be updated during the experiment onboard Spacelab.

The optical diagnostic methods are:

- direct visualization (transmission of collimated light)
- small angle scattering between 0 °C and 30 °C
- wide angle scattering between -38 °C and 90 °C
- interferometry (Twyman-Green type)
- beam attenuation in transmission
- monitoring of the intensity of the input laser beam

The performance of these diagnostics is described in detail in Table 1, and their geometry with regard to the thermostat are shown in Fig. 5. The direct visualization and the interferometric images can be acquired simultaneously by a CCD and by a photocamera in any combination controlled by the automatic program which runs the CPF.

Operations

During the CPF experiments onboard Spacelab, the investigator on the ground is fully aware of the way his experiment is running thanks to the following:

- the CPF housekeeping and scientific data are displayed in real time
- the CCD images from CPF are displayed in real time, at TV rate (30 fps) during short, preselected periods and continuously at a reduced rate of 1 image every 6 sec
- voice contact is foreseen when a crew member is working on CPF

The investigator can also modify the automatic program running his experiment at any stage.

All data sent to the ground are recorded and made available to the investigator after the mission, together with the photocamera pictures.

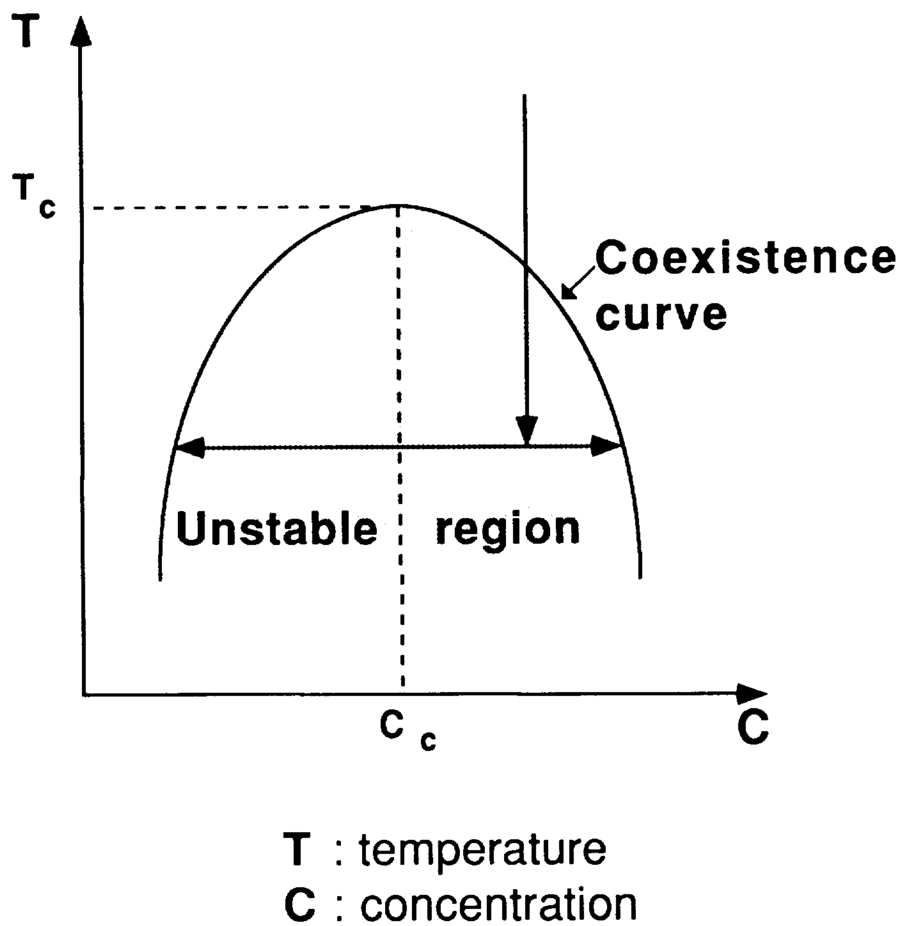

Figure 1. Coexistence curve.

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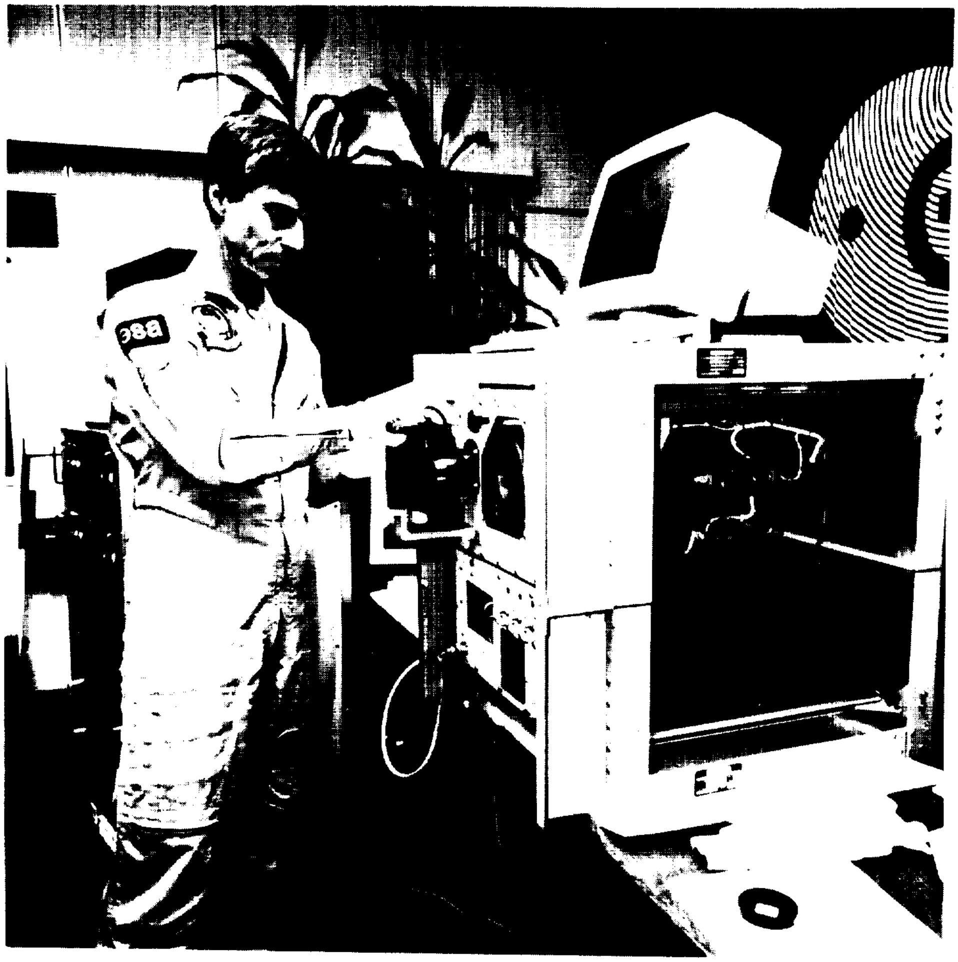

Figure 2. ESA's scientist astronaut Ulf Merbold, who has been nominated Payload Specialist for the IML-1 mission, training on the CPF.

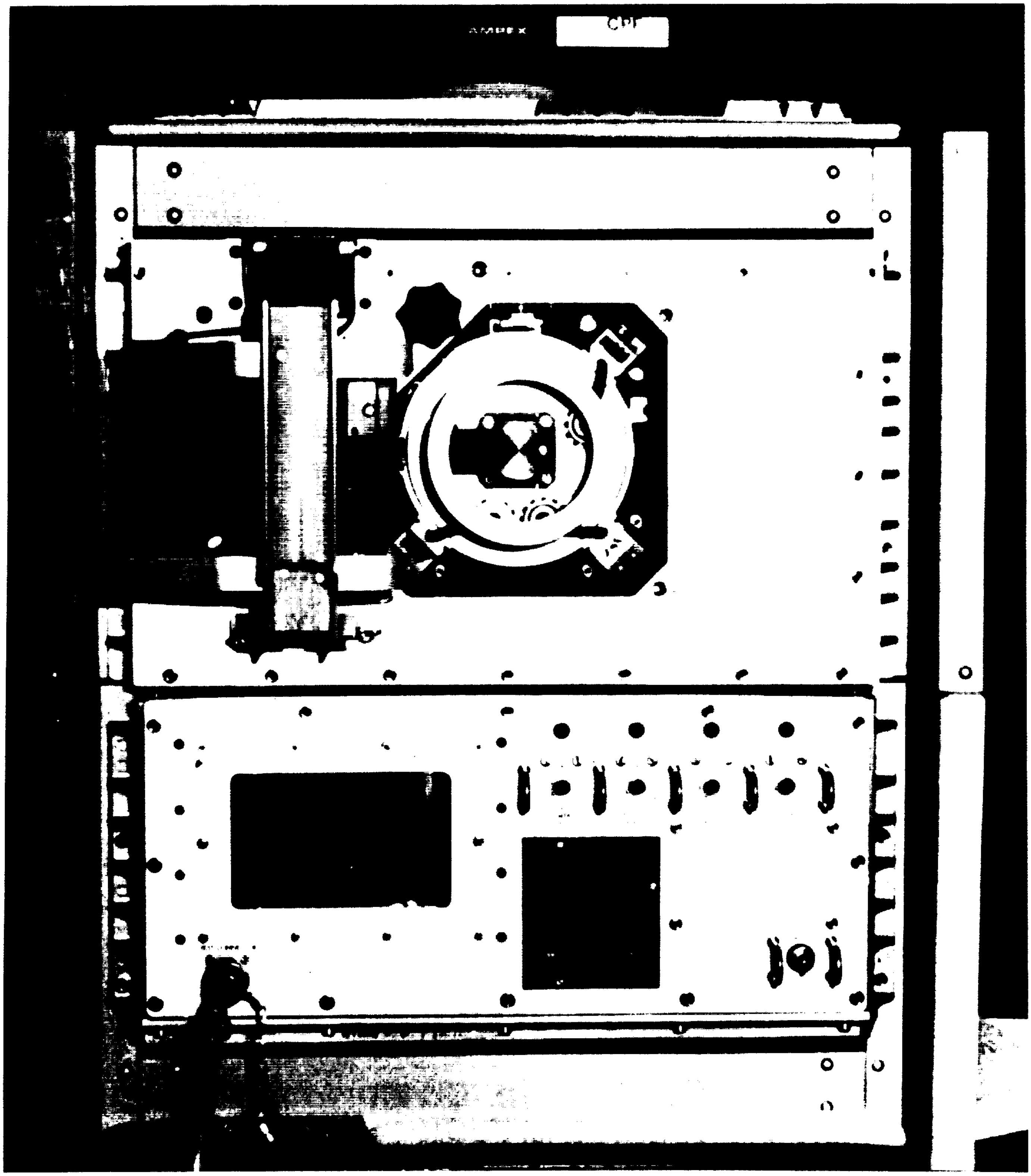

Figure 3. The CPF front panel showing the thermostat (with the protective cover plate removed) in the center of the upper (experiment) drawer. The photocamera can be seen to the left of the thermostat. On the left-hand side of the lower (electronics) drawer, the display panel can be seen with the keypad to its right. The overall dimensions are: height: 49 cm, width: 48 cm, depth: 58 cm.

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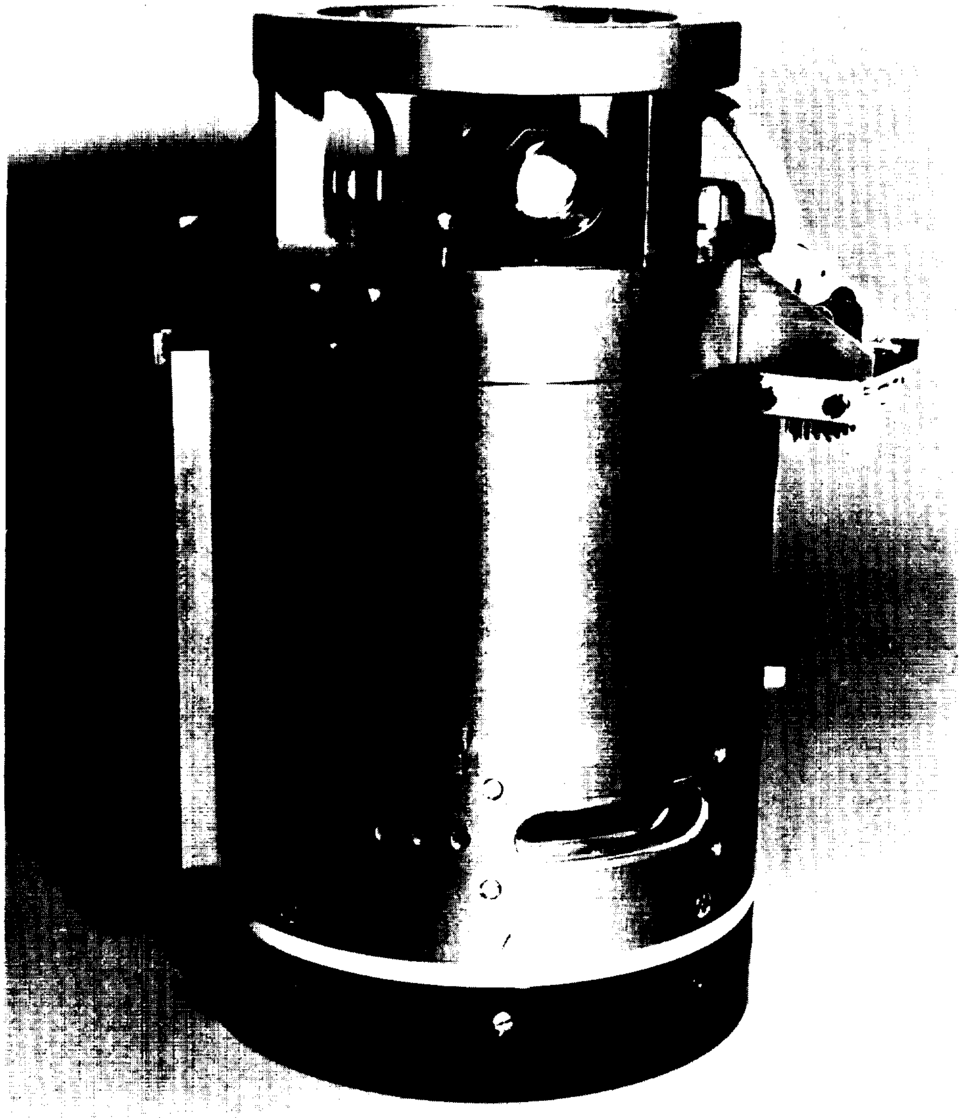

Figure 4. The CPF thermostat. The output of the interferometric channel is on top; the output of the SALS is on the bottom, the three holes on the side are used for wide angle scattering.

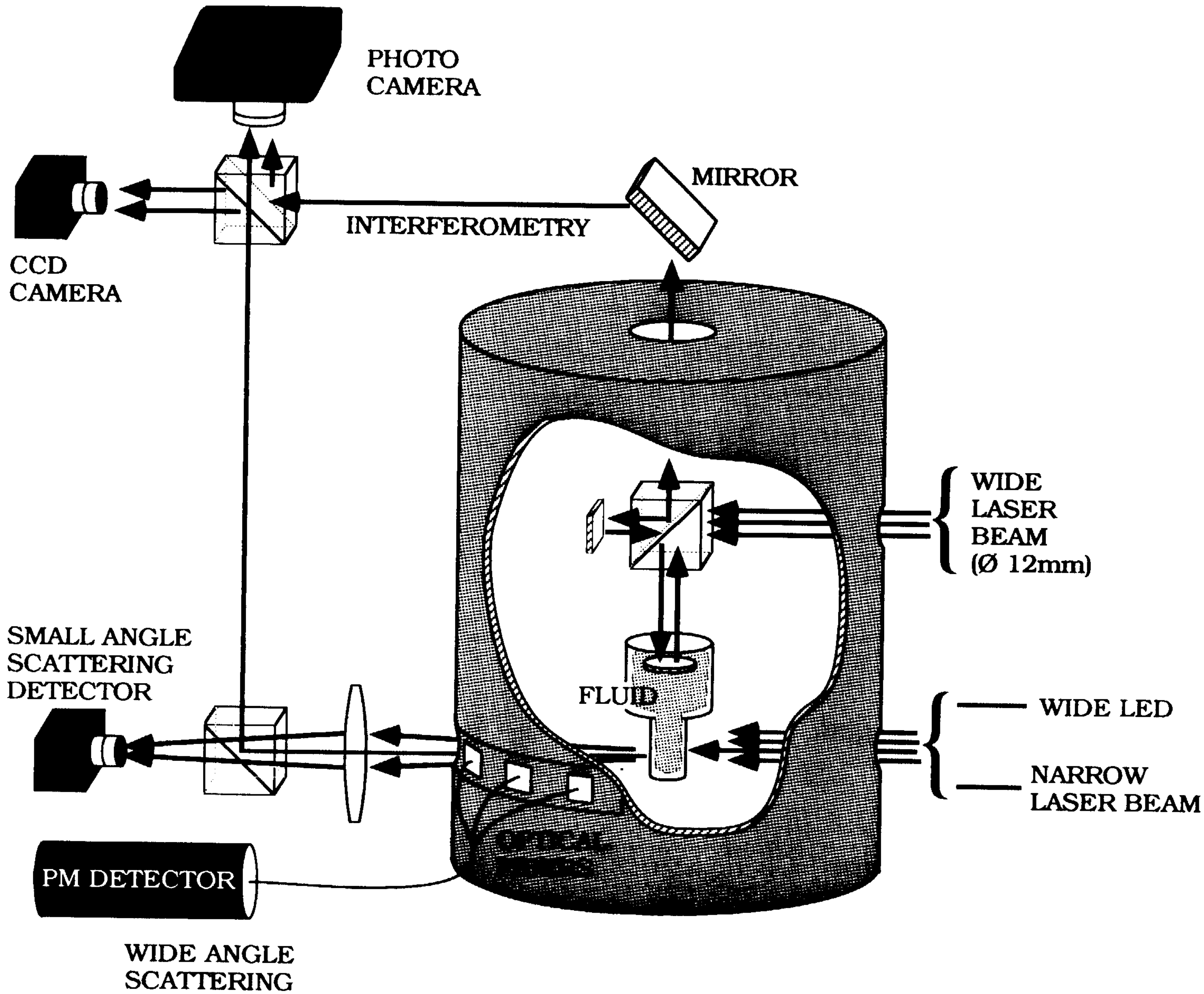

Figure 5. Schematic of the thermostat.

CPF : OPTICAL DIAGNOSTICS	VISUAL	ATTENUATION	INTERFEROMETRY (TWYMAN - GREEN)	SMALL ANGLE SCATTERING (SALS)	WIDE ANGLE SCATTERING (WALS)
SOURCE	LED light collimated .6 & 1.5 micro W (selectable)	He-Ne laser 1.0 mW	He-Ne laser .06 mw	He-Ne laser 1.0 mW .6 mm diam	He-Ne laser 1.0 mW .6mm diam
FIELD OF VIEW AT OBJECT	12 mm diameter	.6 mm diameter	12 mm diameter		1°
DETECTION : •DETECTOR	CCD camera photo camera	16 pixels of SALS CCD	CCD camera photo camera	linear CCD 512 pixels	Photomultiplier
•ANGLES	NA	NA	NA	0° -> 30°	-22°, -30°, -38,° 66°, 74°, 82°, 90°; laser input ref. , dark signal
•SENSITIVITY		10^{-4} -> 10^{-6} W		4 10^{-7} -> 10^{-9} W	10^{-8} -> 10^{-12} W
•INTENSITY RESOLUT.	6 bits/pixel for CCD	6 bits	6 bits/pixel for CCD	6 bits (linear)	12 bits (linear)
•AQUISITION RATE	30 fps	1 Hz	30 fps	1 Hz or 0.1 Hz	5 cycles/minute
RESOLUTION AT OBJECT:					
•SPATIAL	25 μm with CCD	NA	fringe density: 25 mm^{-1} with camera 10 mm^{-1} with CCD	NA	NA
•ANGULAR	NA	NA	NA	.25°	2°

Table 1. CPF Optical Diagnostics.