ON THE ADVANTAGES OF USING THE "TEMPERATURE AMPLIFIER" FOR ACCURATE TEMPERATURE MEASUREMENTS BETWEEN 660 °C AND 960 °C.

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In the course of a study on the behavior of coupled heat-pipes [1], for the first time perfect agreement has been obtained between measurements on the immersion characteristics in a mercury heat-pipe and the Clausius-Clapeyron profile. This result opens the perspective of using coupled heat-pipes to thermodynamically relate two different temperature ranges, with the possibility of redefining one temperature range in terms of another.

By controlling the helium pressure by means of a SPRT inserted in the thermometer well of a mercury heat-pipe, any temperature in the range between 240 °C and 400 °C can be "amplified" in a sodium heat-pipe connected to the same helium line, to one, unique and very reproducible temperature in the range between 660 °C and 962 °C. The reproducibility of the temperature amplification has been tested at 962 °C by a HTSPRT in the sodium heat-pipe with 12 temperature determinations, each lasting about 30 min, during 2 days of pressure control obtained using a SPRT in the mercury heat-pipe as sensor. A standard deviation of 0.5 mK was found, while the freeze-to freeze standard deviation (6 temperature determinations by means of one HTSPRT) of the silver point was measured to be ±0.86 mK.

The temperature amplification system realizes the transfer of the very high reproducibility of the SPRTs below 400 °C, within $2 \cdot 10^{-7}$, to high temperature, obtaining between 660 °C and 961 °C a reproducibility surpassing that of the HTSPRTs. The technique described here opens the prospect of realizing the ITS in a different way [2]. Any accurate reproducible temperature range may be used to generate another temperature range, the relationship between the two ranges being thermodynamically related by the two pure substances used for the vapor-liquid transitions. For pure mercury and sodium, the relationship was determined and the results presented at the "Temperature Symposium" held in Chicago in 2002 [3]. With such a realization of the temperature range between the aluminum and the silver freezing points, the standard thermometer could be calibrated at any temperature in this range. Two main advantages might be achievable: (1) any problem of the ITS-90 non-uniqueness can be overcome; (2) the temperature calibration of the standard thermometer can be limited to the maximum required operating-range.

A new generation of "Temperature Amplifier", based on two new manufactured heat-pipes and an innovative pressure controller, is in course of realization at IMGC.

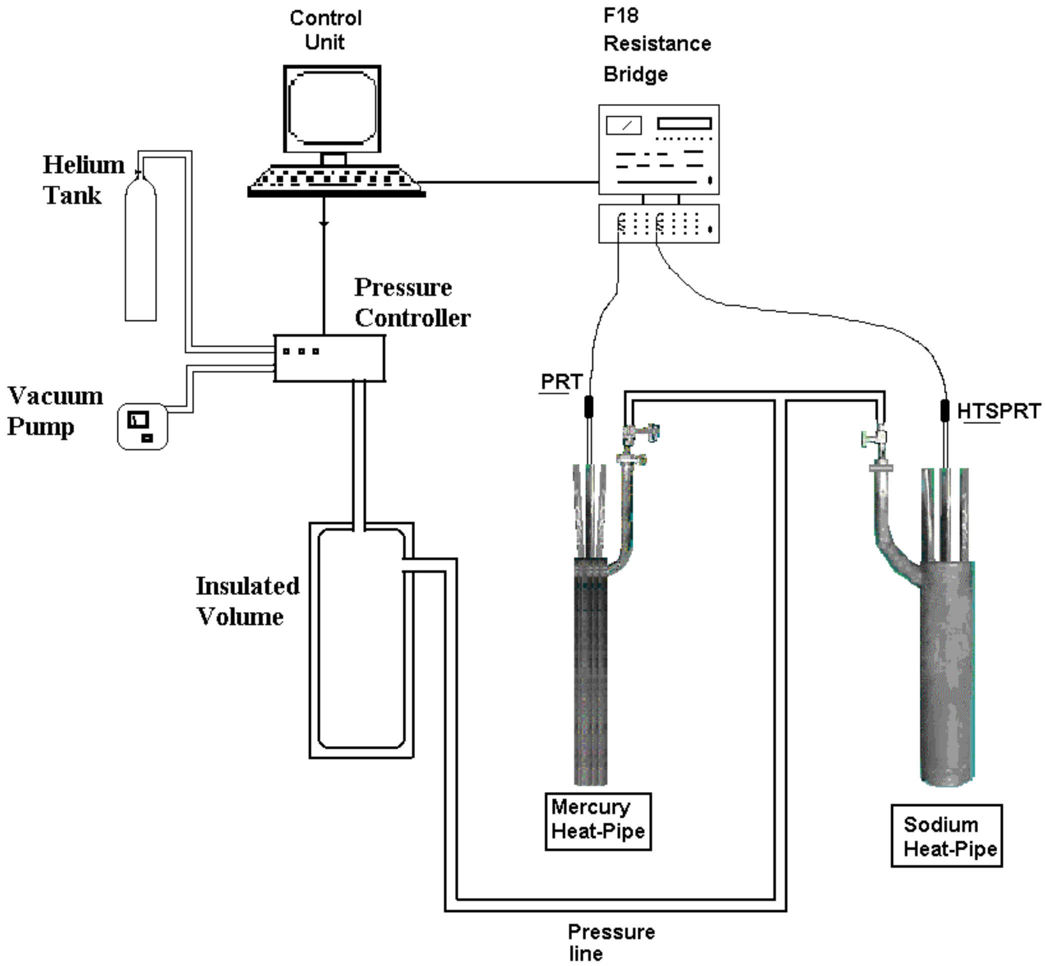

Fig. 1. The new generation of "Temperature Amplifier".

From previous measurements [4], the *P-T* relationship for pure sodium has been determined using a gas-controlled heat pipe. The sodium vapor temperature was measured by HTSPRTs calibrated at the ITS-90 fixed points, while an interferometric standard manobarometer was used for the pressure measurements. A differential pressure gauge has to be used as a diaphragm to separate the helium in the heat pipe from the nitrogen in the manobarometer.

The total uncertainty on the vapor pressure equation determination has been evaluated from both the contributions of temperature and pressure measurements. The uncertainties on the pressure measurement, due to the manobarometer and the diaphragm, influenced the temperature uncertainties. This influence can be evaluated from the d*T*/d*P* relation. The uncertainty budget for the BIPM/JAEGER manobarometer of IMGC has been estimated at 1 σ level [5], taking into account all standard deviations. The overall standard deviation for the manobarometer as a function of pressure can be represented by:

$$u\ (\text{BIPM/JAEGER manobarometer}) = \pm\,(0.03 + 2.4\cdot 10^{-6}\cdot p/\text{Pa})\text{Pa}. \qquad (1)$$

The uncertainty of the diaphragm pressure transducer, having a 1330 Pa full scale, was evaluated, from the data sheet, to be within ± 0.1 Pa being the measuring range always within 10% of the full scale.

During recent measurements, a Ruska piston gauge was used instead of the manobarometer. The piston gauge can directly measure the helium gas pressure in the heat pipe, without any diaphragm. The calibration reports [6] states that the 1 σ uncertainty on the effective piston area measurement, the predominant source of uncertainty in pressure measurements, is estimated to be:

$$u\ (\text{RUSKA piston gauge}) = \pm\ (4.4 \cdot 10^{-6} \cdot p/\text{Pa})\text{Pa}. \qquad (2)$$

This value is declared to be traceable to the National Institute of Standards and Technology.

As seen, the temperature amplification system realizes the transfer of the very high reproducibility of the SPRTs at low temperature, in the mercury heat pipe, to high temperature, in the sodium heat pipe. This reproducibility only depends on the SPRT uncertainty at the triple point of water, propagated to the range between 225 °C and 400 °C in the mercury heat pipe. Applying the previously evaluated amplification relationship, this low temperature reproducibility is then transferred to high temperature, in the sodium heat pipe. The obtained reproducibility at high temperature, at 1 σ level, is compared in the following diagram with the temperature equivalent of the uncertainty budget of the standard manobarometer with the diaphragm, and of the piston gauge.

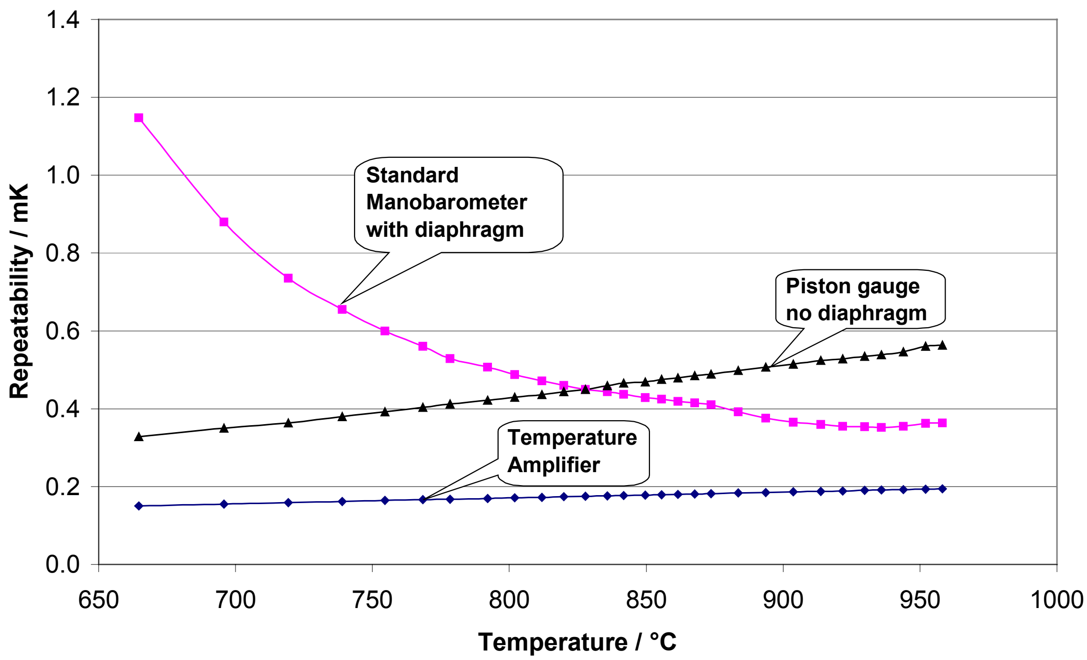

Fig. 2. High temperature reproducibility in the sodium heat pipe obtained with the "Temperature Amplifier", the standard manobarometer with the diaphragm, or the piston gauge as pressure sensors.

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