TRACEABLE LOW AND ULTRA-LOW TEMPERATURES IN THE NETHERLANDS

Andrea Peruzzi[1] and Wim Bosch[2]

[1]NMi VSL, Nederlands Meetinstituut van Swinden Laboratorium, Delft, The Netherlands,
[2]HDL, Hightech Development Leiden, Leiden, The Netherlands

Abstract. The basis for worldwide uniformity of low and ultra-low temperature measurements is provided by two international temperature scales, the International Temperature Scale of 1990 (ITS-90) for temperatures above 0.65 K and the Provisional Low Temperature Scale of 2000 (PLTS-2000) for temperatures in the range 0.9 mK to 1 K. Over the past 10 years, the thermometry research in the Netherlands provided substantial contributions to the definition, realization and dissemination of the international temperature scales. We first review the Dutch contributions to the ITS-90 realization and to the PLTS-2000 dissemination, and then we present the current status of the Dutch calibration facilities and dissemination devices providing for traceable low and ultra-low temperatures for use in science and industry.

TEMPERATURE SCALES REALIZATION

^{3}He and ^{4}He vapour pressure thermometer for the ITS-90 range from 0.65 K to 5 K (1997)

From 0.65 K to 5.0 K, the ITS-90 temperature T_{90} is defined in terms of the vapour pressure p of liquid and vapour ^{3}He or ^{4}He at equilibrium, using a specified interpolation equation $T_{90} = f(p)$.

^{4}He interpolating constant volume gas thermometer for the ITS-90 range 3 K to 24.5 K (2007)

Between 3.0 K and 24.5561 K, the ITS-90 is defined by means of a helium interpolating constant-volume gas thermometer (ICVGT, Fig. 1 and 2) calibrated, using a specified interpolation equation $T_{90} = f(p)$, at three defining fixed points: 1) the triple point of neon (24.5561 K), 2) the triple point of equilibrium hydrogen (13.8033 K), 3) a temperature between 3.0 K and 5.0 K to be determined using a ^{3}He or a ^{4}He vapour pressure termometer.

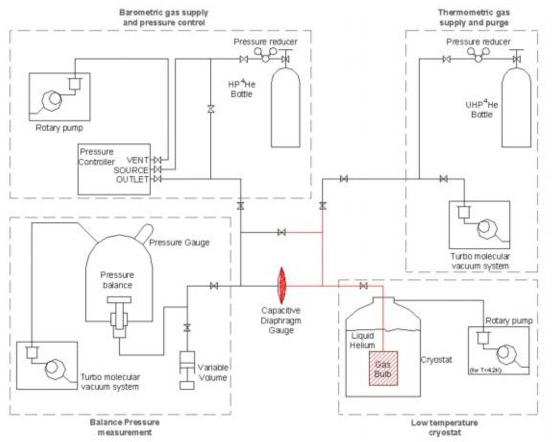


Fig. 1 Experimental set-up of the ^{4}He interpolating constant volume gas thermometer

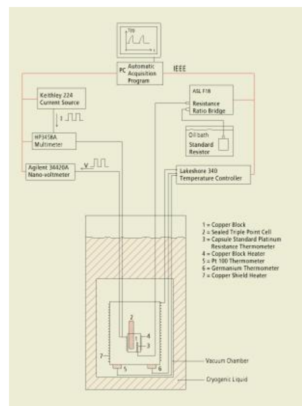
Fig. 2 Interpolating constant volume gas thermometer.

Cryogenic fixed points for the ITS-90 range from 13.8 K to 273.16 K (2005)

For the range 13.8033 K to 273.16 K, the interpolation instrument specified by the ITS-90 is the capsule standard platinum resistance thermometer (CSPRT), calibrated at 8 defining fixed points: the triple points of equilibrium hydrogen (13.8033 K), neon (24.5561 K), oxygen (54.3584 K), argon (83.8058 K), mercury (234.3156 K), and water (273.016 K) and at two additional temperatures close to 17.0 K and 20.3 K, to be determined with the ICVGT.
The cryogenic fixed points (hydrogen, neon, oxygen and argon) are realized at NMi-VSL by using state-of-the-art sealed triple-point cells (STPCs) of the corresponding high-purity gases (99.999% to 99.9995%) in an adiabatic calorimeter (Fig.3).

Fig. 3 (left) Adiabatic calorimetry for the realization of the cryogenic fixed points.

Fig. 4 (right) Experimental set up for the realization of the cryogenics fixed points.



Realization of the PLTS-2000 in the range 10 mK to 1 K (2003)

The practical realization of the PLTS-2000 requires a ^{3}He melting pressure thermometer (MPT) to be operated. The MPT (Fig. 6) is essentially a closed compression chamber, containing both liquid and solid ^{3}He at equilibrium. An in situ capacitive pressure sensor measures the melting pressure p_m inside the chamber, and the measure melting pressure is transformed into temperature T_{2000} by applying the inverse of the agreed equation $p_m = p_m(T_{2000})$ (Fig. 5).

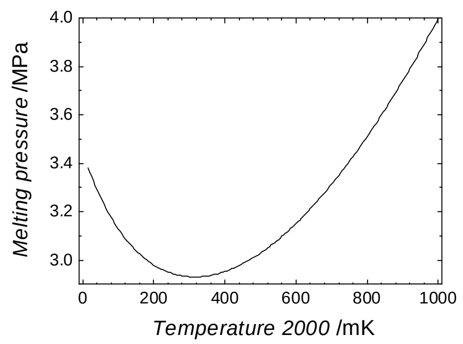


Fig. 5 ^{3}He equilibrium melting pressure as a function of temperature.

Fig. 6 Experimental set up for the realization of the PLTS-2000.

TEMPERATURE SCALES DISSEMINATION

NMi-VSL cryogenic calibration facility for the range 0.65 K to 273.16 K

The output of the experiments described before (the so-called *"materialization of the scale"*) is a set of reference thermometers carrying the ITS-90 (the so-called *"wire scale"*). These reference thermometers are then used in the calibration facility to calibrate users' thermometers by direct comparison. Typically the user delivers its thermometers (Pt100 thermometers, germanium thermometers, rhodium-iron thermometers, etc...), together with the required calibration range and uncertainty. The user's thermometers are mounted in a copper comparator block (Fig. 7) in good thermal contact with the reference thermometers carrying the ITS-90, and the calibration is performed by direct comparison according to the user's requirements.

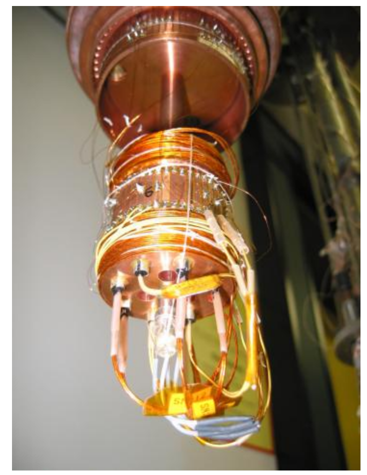


Fig. 7 Comparator block for the calibration of customers thermometers.

Superconductive reference device SRD1000 for the range 10 mK to 1 K

In the period from 2000 to 2003 a Dutch consortium comprising NMi-VSL, the company HDL, Leiden University and the University of Twente developed technology for a superconductive reference device SRD1000 and related detection electronics. The device includes 10 stable reference points that are provided by the superconductive transitions of samples of several materials in the range from 10 mK to 1 K. The output voltage of the electronics versus sensor temperature shows distinct transitions at the reference temperatures T_C (Fig. 8). In 2008 a new system was introduced that integrates the concept of realizing calibrated reference points and that of a continuous temperature reading between 10 mK and 1 K with a CMN (Cerium Magnesium Nitrate) paramagnetic susceptibility thermometer (Fig. 9 and 10).

Fig. 9 Combined SRD and CMN sensor block.

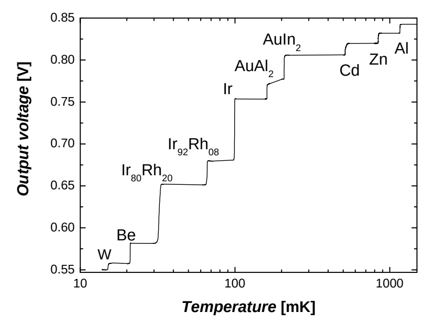


Fig. 8 Output voltage of the SRD1000 electronics versus temperature.

Fig. 10 Detection electronics to measure simultaneously SRD and CMN sensor signals.