Dissemination of the European Ultra Low Temperature Scale

(ULT Dissemination)

Contract no. G6RD-CT-1999-00119

REPORT

<u>WP 5</u>
<u>Evaluation of superconductive reference devices</u>

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“Promoting Competitive and Sustainable Growth”

“Measurement and Testing”

RTD Project

INTRODUCTION

In order to test the SRD1000, four different types of devices were installed on a comparison block of a dilution refrigerator: a helium-3 Melting Curve Thermometer (MCT), materialising the PLTS-2000 scale, an Acoustic Thermometer (SST), a rhodium iron thermometer calibrated on the T_{90} scale and the Superconducting Reference Device (SRD-1000) under test.

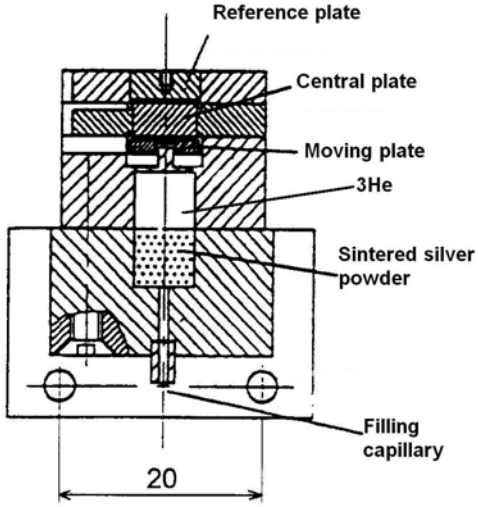

FIGURE 1. The Helium-3 melting curve thermometer, as realised by PTB and used to materialize T_{2000} at BNM-INM/CNAM.

THE EXPERIMENTAL SETUP

The Melting Curve Thermometer (Fig. 1)

The MCT was previously designed and built by the German national Laboratory (PTB – Physikalisch -Technische Bundesanstalt) in Berlin who contributed to the development of the Temperature Scale (PLTS-2000) below 1 K [2]. T_{2000} temperatures are obtained by measuring the helium-3 melting pressure, P, and using the T_{2000}=f (P) polynomial, defined in the scale [3] [4].

The Acoustic Thermometer (Fig. 2)

BNM-INM has been developing a new kind of thermometer using the properties of sound propagation in diluted mixtures of helium-3 in helium-4. The temperature is obtained from the measurements of resonance frequencies of a cylindrical acoustic cavity. After calibration against the MCT, this thermometer is intended to be used as a transfer standard, because of its two main qualities: the ease of transportation (sealed cell) and use (only two coaxials and a lock-in amplifier are needed).

In this experiment, it was used for mainly three purposes:

- to check the thermal homogeneity of the comparison block,
- to cross check the T_{2000} temperature generation,
- to regulate the temperature of the block near all the superconducting transition to be observed in the SRD-1000 (important resolution of the thermometer over all the temperature range – regulation sensitivity about 10 μK).

The Rhodium-Iron Thermometer

The MCT gives the T_{2000} temperatures below 1K. To test the Superconducting Transition Device above 1K, temperature references above 1K are needed. For this purpose, a rhodium-iron thermometer previously calibrated against T_{90} scale, at NPL, was used.

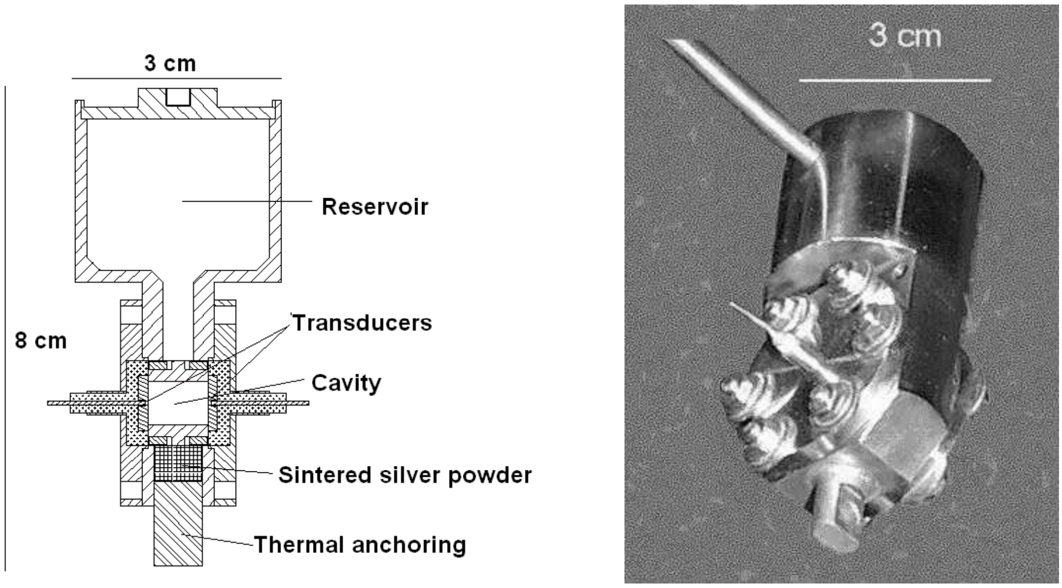

FIGURE 2. The Acoustic thermometer as designed and realised by BNM-INM. In a sealed cell, resonance frequencies of a cylindrical cavity are measured to calculate the temperature according to the theoretical model whose parameters are adjusted by calibration against the MCT.

The Superconducting Reference Device (SRD-1000) Under Test (Fig.3)

A Superconductive Reference Device (SRD1000), providing 10 reference points in the temperature range 15 mK – 1.2 K with dedicated measurement electronics, was developed in Netherlands [1].

THE EXPERIMENTAL PROCEDURE

To minimize a possible temperature non-uniformity effect in the comparison block, the measurements were all static measurements. Near the transitions, the temperature bloc was regulated in order to obtain successive “plateaus” during which the temperature of the block was uniform. In the plateaus, the output of the SRD associated electronics was recorded versus the T_{90} or T_{2000} temperatures.

THE RESULTS

Seven among the ten existing transitions were studied and the results are presented in figure 4,5,6,7, 8, 9 and10.

The results for the different transitions are summarized in table I. The transition width is determined, as indicated in the different above figures after eliminating 10% of the signal near the extremes. The transition temperature is considered at the middle of the curve.

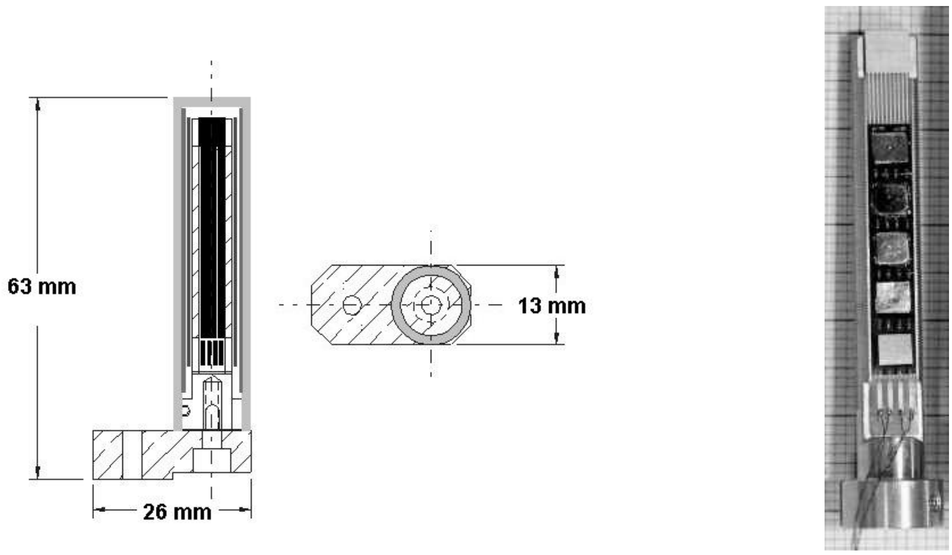

FIGURE 3. The SRD-1000 as designed and realised by HDL, in Netherlands. It contains 10 different transitions from 1180 mK down to 15 mK.

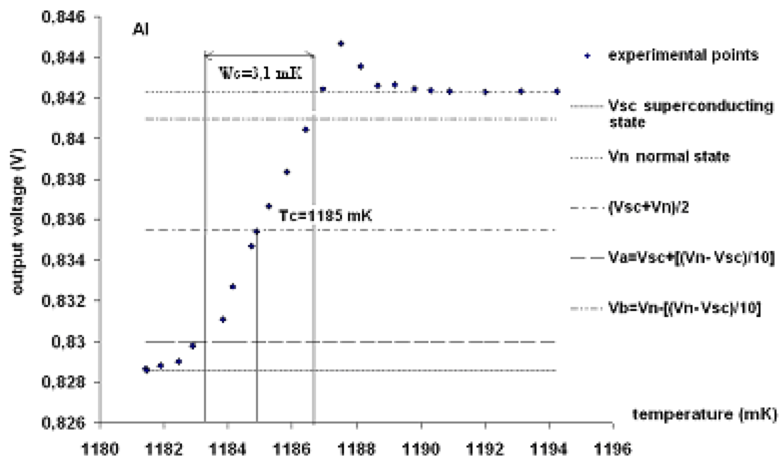

FIGURE 4. The value and the width of the Al superconducting transition.

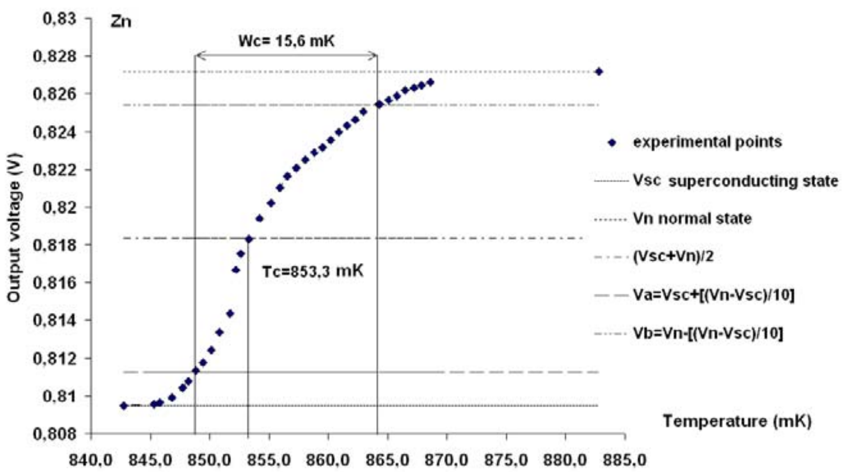

FIGURE 5. The value and the width of the Zn superconducting transition.

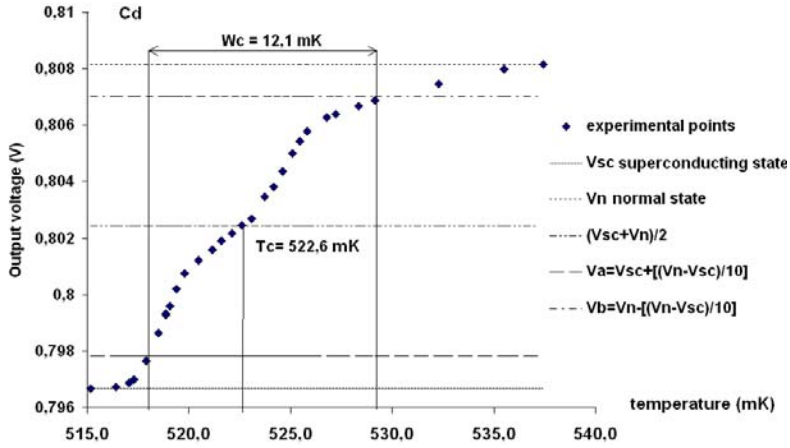

FIGURE 6. The value and the width of the Cd superconducting transition.

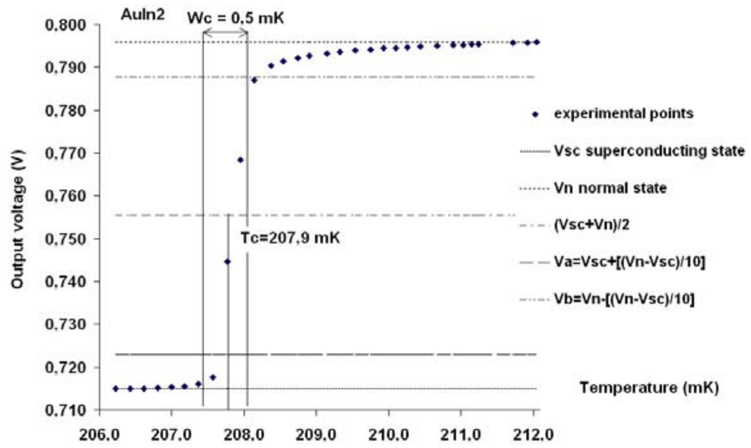

FIGURE 7. The value and the width of the AuIn2 superconducting transition.

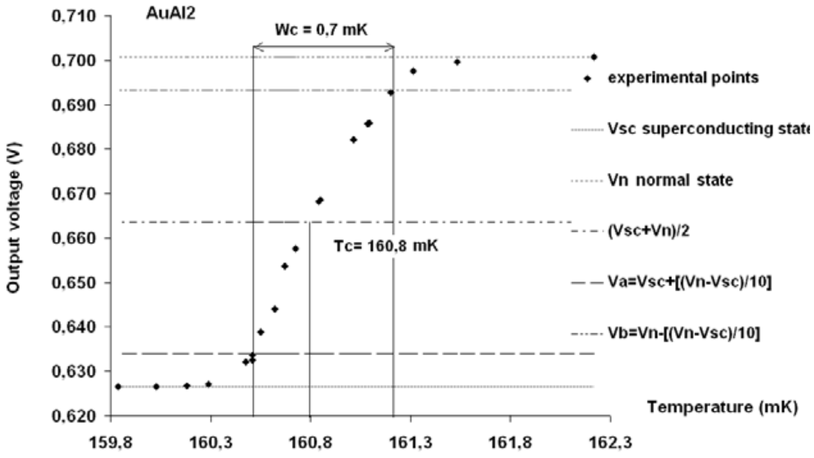

FIGURE 8. The value and the width of the AuAl2 superconducting transition.

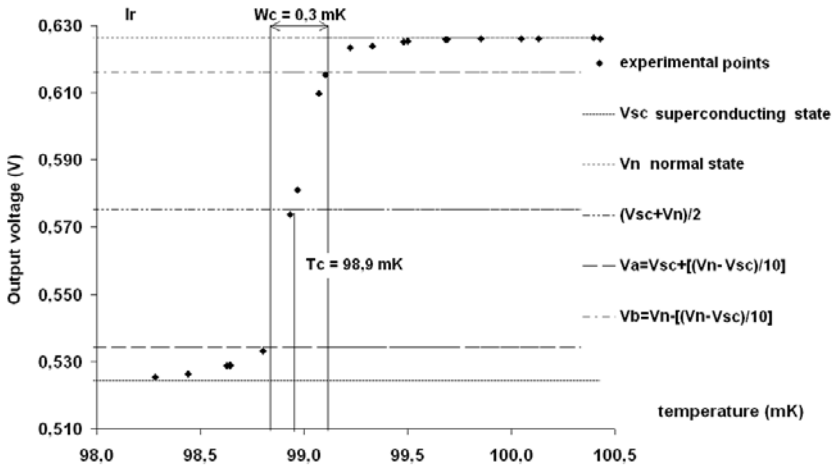

FIGURE 9. The value and the width of the Ir superconducting transition.

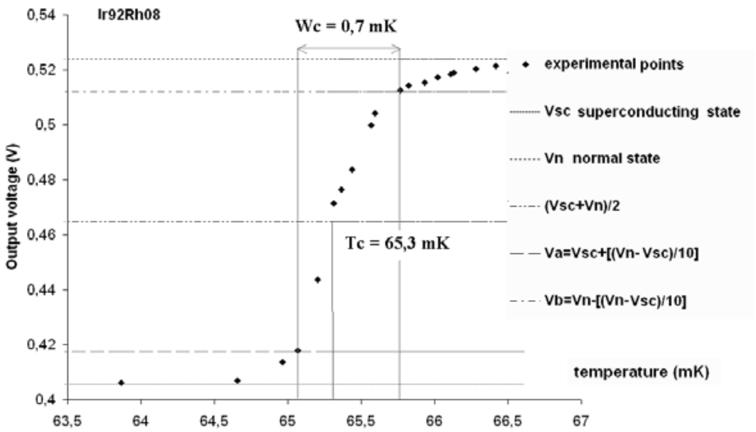

FIGURE 10. The value and the width of the Ir92Rh08 superconducting transition.

TABLE 1. Temperature And Width Of The Superconducting Transitions

Temperature target (mK)	Selected metal sample	Tc (mK)	Wc (mK)
1180	Al	1185	3,1
850	Zn	853,3	15,6
520	Cd	522,6	12,1
210	AuIn2	207,9	0,5
160	AuAl2	160,8	0,7
100	Ir	98,9	0,3
60	Ir92Rh08	65,3	0,7
35	Ir80Rh20	not measured	
20	Be	not measured	
15	W	not measured	

TABLE II. Budget Of Uncertainty On The Transition Temperatures

	Realisation of T_{2000} u_1 (mK)	Temperature uniformity u2 (mK)	Determination of the middle u3 (mK)	Quadratic square means (mK)
Al	0,2	0,2	0,6	0,7
Zn	0,2	0,2	3	3,0
Cd	0,1	0,1	2	2,0
AuIn2	0,1	0,1	0,1	0,2
AuAl2	0,1	0,05	0,1	0,2
Ir	0,1	0,05	0,1	0,2
Ir92Rh08	0,2	0,2	0,2	0,3

The Uncertainties

The uncertainty on the transition temperature is mainly due to:

- the uncertainty on the realisation of T_{2000} (u_1 for one standard deviation).
- the uncertainty due to the lack of temperature uniformity of the comparison block (u_2 for one standard deviation).
- The uncertainty on the determination of the middle of the transition (u_3 for one standard deviation).

This drives to the budget of uncertainty presented table II.

REFERENCES:

1. Bosch, W.A. and al, LT23 proceedings, Hiroshima, Japan, August 20-27, 2002.
2. Schuster G., Hoffmann A. and Hechtfischer D., “*Thermometric basis of the ^{3}He melting pressure equation*”, Proceedings of the CCT Workshop “*Toward and International Temperature Scale from 0.65 K to 1 mK*”, University of Leiden, p 7 (1998).
3. Extension of the International Temperature Scale below 0.65 K, resolution 9, 21st Conférence Générale des Poids et Mesures.
4. Pitre L., Hermier Y., “*Realization of the Provisional Low Temperature Scale of 2000 at BNM-INM*”. Temperature . Its Measurement and Control in Science and Industry, Symposium proceedings, Chicago, 2002.
5. Pitre L., Hermier Y., “*Comparison between a second sound thermometer and a melting curve thermometer from 0.8 K down to 20 mK*”. Temperature . Its Measurement and Control in Science and Industry, Symposium proceedings, Chicago, 2002