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# Determining the Influence of Temperature on Various Types of Standard Resistors

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## Abstract

The temperature coefficient of standard resistors of various types is well-known to within an acceptable uncertainty, for the purposes that these resistors are used for in most calibration laboratories. There are instances where this information is insufficient, or not available from the manufacturer.

A set of pre-used high precision resistors was recently acquired by the CSIR National Metrology Laboratory (CSIR NML) for maintenance of the resistance scale above 1 Ohm. These resistors were received without any data of their temperature coefficients, and it was decided to measure the temperature coefficient of these resistors with as high a precision as possible. A high precision oil bath was available for this purpose, and a general procedure for this determination was developed.

## 1. Introduction

The CSIR NML is the custodian of the national measurement standards for South Africa. In the dc Low Frequency (dclf) laboratory of the CSIR NML the following parameters are maintained: dc voltage, dc resistance, impedance, ac/dc difference, power and energy.

For dc resistance, the current national standard is a set of eight 1 Ohm Thomas type wire-wound resistors, maintained at 25 °C in an oil bath. Traceability for the resistance scale is obtained by regular calibration of two of these resistors at the International Bureau of Weights and Measures (Bureau International des Poids et Mesures – BIPM).

A set of high precision resistors, covering the range from 1 mOhm to 10 kOhm was acquired recently for the purpose of maintaining the resistance above and below 1 Ohm (see figure 1). A second set of resistors (Yokogawa), covering the same range will be used to assist in the maintenance of the scale. The scale is currently maintained using Fluke type 742A and other resistors. It is planned to introduce the new resistors into the scale, as these will be maintained at a stable temperature, and as such should provide a better realisation than that currently available.

It was planned to have the temperature coefficient evaluations completed before the deadline for the paper, but extreme pressure on the CSIR NML mechanical workshop delayed the manufacture of the required resistor holders. The holders will hopefully be delivered to the dclf laboratory before the end of September. This will enable us to perform some of the experiments, and the results of experiments performed will be reported at the conference. It is also planned to build a rudimentary air-bath to perform temperature coefficient experiments on resistors that cannot be immersed in oil.

Experiments with measurement with different excitation currents are also planned. The oil will produce significantly better cooling compared to having the same resistors in air, and the differences between measurements at different power levels will be interesting. It will also allow the measurement of client resistors at these higher powers with reduced system uncertainties.



Figure 1: The set of recently acquired resistors.

## 2. Work to date

The oil bath was characterised for temperatures from 18 °C to 28 °C. This was done using four platinum resistance thermometers (PRT), a four terminal scanner and a digital voltmeter. The reason for performing this experiment was primarily to determine the thermostat setting that corresponds to every temperature of interest. It also allowed the characterisation of the bath for temperature profile, and to determine the settling time of the bath after a step change in set temperature.

The experiment was performed with the bath empty, so it is reasonable to assume that the characterisation will have to be repeated once the resistors are installed. The data did show that the bath has good uniformity (within 0,04 °C at most temperatures), and that the settling time is reasonable. A typical settling time of about 22 minutes for a step of 1 °C was observed, as shown in figure 2. The typical uniformity of the bath for several temperatures is shown in table 1 below. The difference in stabilities between temperatures is most likely due to the difference in stabilisation times.

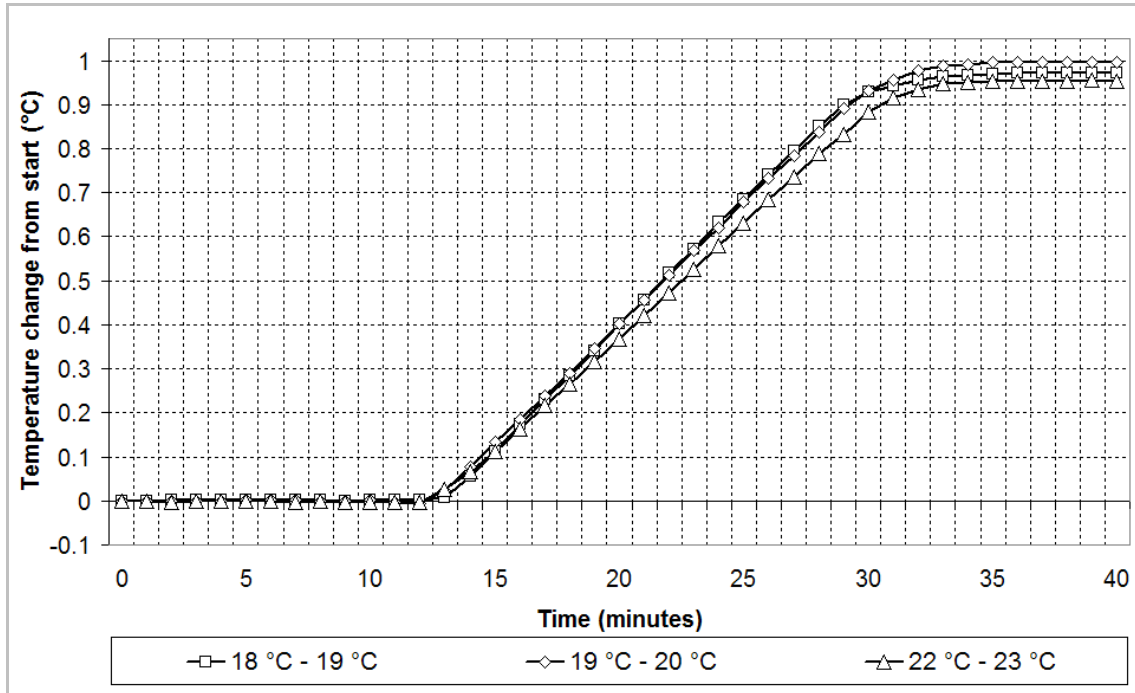


Figure 2: Typical settling time of the bath at several temperatures.

Table 1: Typical uniformity of the bath at several temperatures.

Nominal temperature setting (°C)	Maximum to minimum temperature within oil bath (°C)
18	0,012
19	0,004
20	0,014
22	0,006
26	0,036
28	0,005

The data was collected over a period of several weeks, and some changes with time between the applied setting and the actual bath temperature was noted during this time. The reason for this is not clear, and since the observed changes are very small, it may contribute negligible uncertainty to the measured values of the resistors.

A holding structure for the resistors was designed in May 2006. The holder is designed such that all the resistors will have the same level of oil over the top of the resistors, with easy access to all connecting terminals. Some of the resistors will hang from the holder, and others will stand on different level stands manufactured for the resistors. The design of the holder is shown in figure 3.

The resistors will have permanent connections made to them to reduce the “dirty” (oily) work. The bath is covered with a Perspex cover to remove drafts across the resistors, and to ensure as little disturbance to the temperature of the resistors as possible. The cover also reduces the ingress of dust into the oil, prolonging the oil change period.

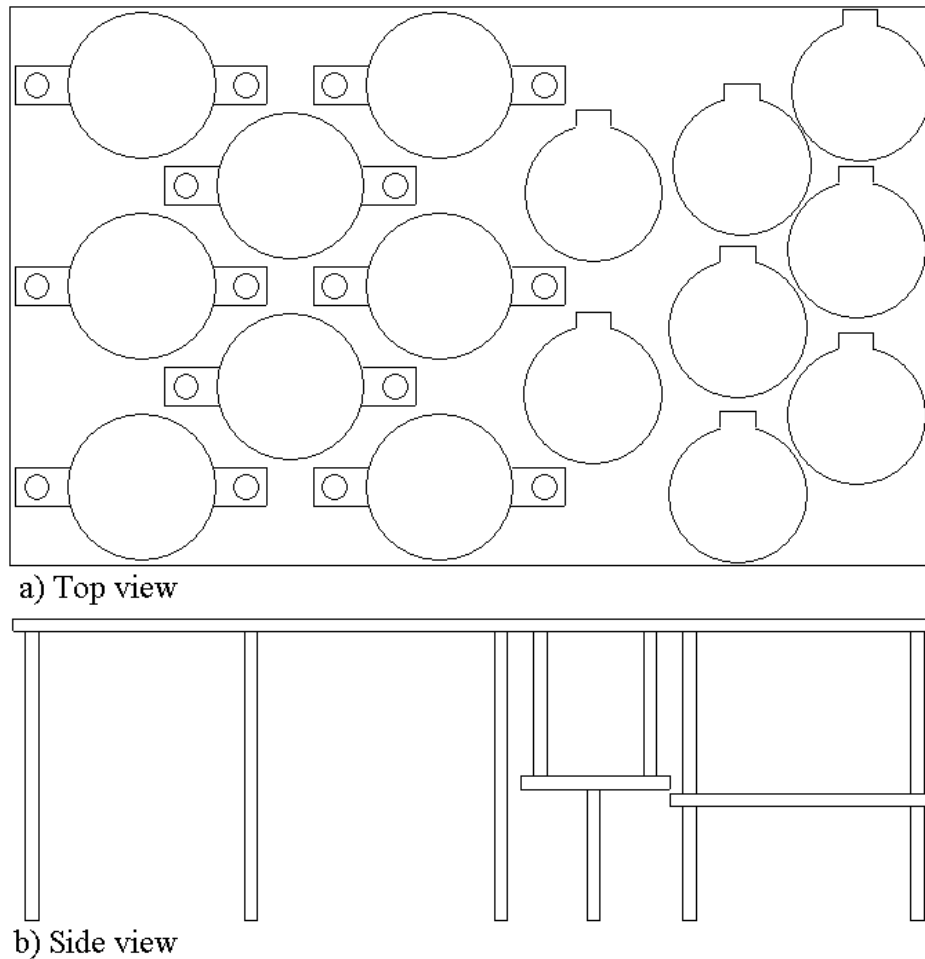


Figure 3: Design of resistor holder.

### 3. Planned work

The resistor holder will be assembled as soon as the parts are received from the CSIR NML workshop. The resistors will be mounted in the holder, and the holder will be adjusted using shims if it is required to get the top plates of the resistors all on the same level.

The temperature profile of the bath will be measured with the resistors in place, to determine the influence of the resistors on the temperature profile. It is expected that the influence will be significant. If this is the case, the temperature of each resistor will have to be measured during measurement.

The temperature of the resistors will be varied between 18 °C and 28 °C in steps of 1 °C. This will provide sufficient data to determine the temperature coefficients of the resistors in the bath. It is planned to fit a second order polynomial to the data, to analyse the uncertainty of this fit, and to determine the influence that this error will have on the resistance of a unit under test resistor when the resistors in the oil bath are used as reference standards for calibration. It is expected that the implementation of these resistors will reduce the uncertainties offered by the CSIR NML for resistances above and below 1 Ohm.

If there is interest in the temperature characterisation data it will be presented at the next conference.

In addition to this work it is planned to move all resistance measurements into a single laboratory. High resistance is currently housed in a laboratory separate from the lower value resistance standards and the Quantum Hall Resistance standard. It is hoped that this consolidation will significantly improve efficiency in the laboratory.

### **Disclaimer**

The use of specific manufacturer and model names does not imply an endorsement of these manufacturers or their instruments by the CSIR NML, nor does it imply that these are the only or best instruments for the tasks described in this paper.