ITS-90 MEASUREMENT BY MEANS OF NON-STANDARD PLATINUM RESISTANCE THERMOMETERS

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Many laboratories are using Platinum Resistance Thermometers (PRTs) that do not satisfy the requirements of the ITS-90 for its Standard Platinum Resistance Thermometers (SPRTs) for temperature measurements, mostly as so-called check thermometers dedicated to one (or a few) fixed point baths. These are either ex-standard thermometers no more satisfying the purity requirements of the ITS-90, or good laboratory thermometers with an a value a little below $3{,}9244 \cdot 10^{-3}$ °C^{-1}, or even IPRTs with good stability.
Although these thermometers are calibrated (by comparison with a SPRT), the direct application of the Callendar-Van Dusen (CVD) equation, widely-used for non-standard thermometers, may cause errors as large as almost 0,1 °C, a highly unsatisfactory situation. See in Fig. 1 the application of the CVD on 38 working standard thermometers of the Italian Calibration Services (SIT), where the results are largely depending on the calibration range.

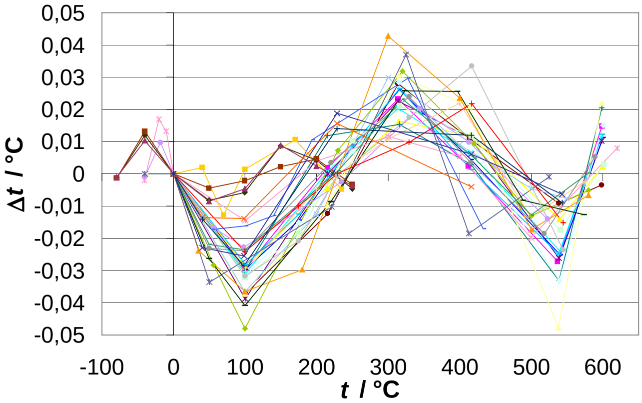

Figure 1 Residuals from the application of the CVD equation to 38 working standard thermometers of SIT laboratories. Δ*t* represents the temperature equivalent of $(R_t/R_0)_{DVD} - (R_t/R_0)_{meas}$.

At Tempmeko 2001 [1] a solution was presented. This solution uses a correction function that allows the application of the CVD to these thermometers with largely reduced errors, of the order of a few millikelvin between -10 °C and 655 °C (2,5 mK for Eq. 3). Even down to -75 °C this error is limited (for Eq. 3) to about 8 mK only. With Eq. 2 the residuals are a little larger: lower than 6 mK from –10 °C up to 365 °C, lower than 18 mK up to 655 °C and lower than 11 mK down to –77 °C. In contrast to other methods to limit these errors (e.g. a higher order interpolating equation) no dependence at the above levels has been found on the calibration range *without introducing extra calibration points*. See in Fig. 2 the results of the application of the Eq. 1 and 3 on the 38 working standard thermometers of Fig. 1. Most of the 20 thermometers calibrated above 250 °C and having residuals in Fig. 1 at 100 °C larger than 0,03 °C, show now residuals well within 0,01 °C at 100 °C. Also in the range above 100 °C, all thermometers show a large reduction of the residuals.

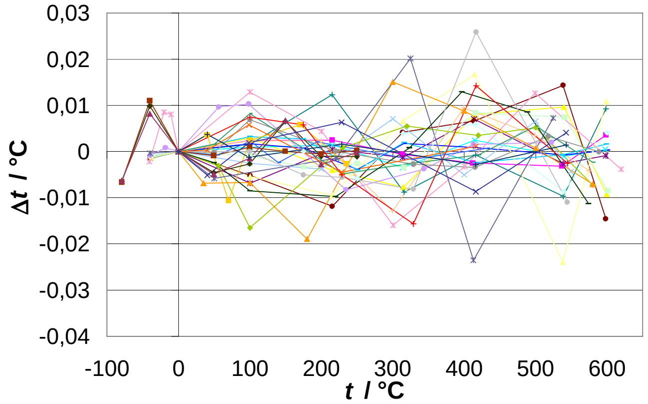

Figure 2 Residuals of the application of Equations (3) and (4) to 38 working standard thermometers of SIT laboratories. Δt represents the temperature equivalent of $(R_t/R_0)_{DVD,\ mod} - (R_t/R_0)_{meas}$.

The correction function is, above 0 °C, essentially an approximation to the residual of a quadratic regression (CVD) on the ITS-90 reference function with as coefficients the constants A and B of the CVD. Below 0 °C it is an approximation to the residual of the linear regression used to determine the constant C of the 4th order Van Dusen equation. I.e. before applying the CVD, temperature t_{90} is substituted with t':

$$t' = t_{90} + f(t_{90}) \quad (1)$$

where

$$f(t') = \gamma \left(\frac{t'}{100}\right)\left(\frac{t'}{t_1} - 1\right)\left(\frac{t'}{t_2} - 1\right)\left(\frac{t'}{t_3} - 1\right)\left(\frac{t'}{t_4} + 1\right) \quad (2)$$

or

$$f(t') = \gamma \left(\frac{t'}{100}\right)\left(\frac{t'}{t_1} - 1\right)\left(\frac{t'}{t_2} - 1\right)\left(\frac{t'}{t_3} - 1\right)\left(\frac{t'}{t_4} - 1\right)\left(\frac{t'}{t_5} + 1\right). \quad (3)$$

The values of the various parameters are:

	Equation (2)	Equation (3)
γ	-0,034	-0,043
t_1	205	190
t_2	412	393
t_3	652	660
t_4	125	905
t_5		99

The application of the Eq. 1 and 2 on the 38 working standard thermometers of Fig. 1 gives a result comparable to that of Fig. 2, because of the limited uncertainty level of the calibration points.
An important result of the study is that no systematic differences beyond 0,01 °C appear among thermometers having different α values.

References:

[1] *ITS-90 Approximation by means on Non-standard Platinum Resistance Thermometers*, P. Marcarino, P.P.M. Steur, G. Bongiovanni, B. Cavigioli, **Proc. TEMPMEKO 2001** in press.