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Temperature calibration and MiniSys temperature upgrade for the Risø TL/OSL-DA-15 reader

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Introduction

In both TL and OSL measurements it is important to have accurate control over the thermal treatment of samples. In the Risø TL/OSL reader heating is performed using a low-mass heater strip made of Kanthal (a high resistance alloy) which is shaped with a depression to provide a better contact with the planchet or disc (Bøtter-Jensen 1988). An AC current is passed through the heating element to raise the temperature; this current is regulated by an analogue feedback circuit based a Chromel-Alumel thermocouple mounted underneath the heater strip using a gold rivet. Power is derived from a non-switching continuous full sine wave generator operating at 20 kHz (or 30 kHz). The heating system is able to heat samples to 700°C at constant heating rates from 0.1 to 20°C /s. Usually, N_2 is circulated in the measurement chamber during heating to avoid oxidation of the heating element at high temperatures (for coarse grains) and to avoid spurious TL (for fine grains). The temperature feedback system is designed to compensate for changes in thermal load from one sample to another (e.g. because of sample mass, or variations in gas flow).

However, it was recently discovered that the temperature control system of two models, the Risø TL/OSL-DA-15 and Risø TL/OSL-DA-15A readers, provides insufficient gain in the temperature feedback system. The objective of this note is to bring this to the users' attention (see section 'Hardware Upgrade'). Furthermore, we have improved the temperature calibration of the heating system and thereby reduced the systematic deviation between Actual temperature and Set temperature significantly (see section 'Software Upgrade').

Hardware Upgrade

Calibration of the temperature of the heater element is achieved by measuring the voltage across the thermocouple and adjusting the feedback loop-gain at 300°C and the off-set at 100°C. This temperature calibration is routinely carried out during manufacturing. However, because of the low loop-gain in these models the system does not always compensate fully for changes in gas flow. This is illustrated in Fig. 1 (filled circles) where an example of the deviation of the Actual temperature (the temperature directly determined from the thermocouple voltage) from the Set temperature (the temperature requested by the software) is shown as a function of the N_2 flow rate; the higher the flow rate the larger the deviation from the Set temperature of 300°C. If the N_2 flow rate is set to 1 L/min (the recommended flow rate for coarse grain work) the temperature of the heater plate is only 299°C. This offset is small compared to the thermal lag between heating element and the luminescence sample (see Jain et al. 2007; Betts et al. 1993) and is expected to be of little consequence to the majority of measurements. However, the magnitude of this effect will be dependent on the composition and concentration of the gas.

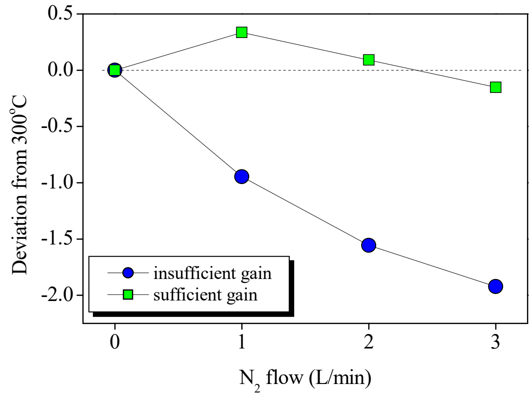

Figure 1: *The difference between Actual and Set temperature (for a Set temperature of 300°C) as a function of Nitrogen flow rate. The Actual temperature is measured using the thermocouple.*

Insufficient gain in the temperature feedback system may also affect the reproducibility of the Actual temperature. This was investigated by requesting a specific Set temperature (at a heating rate of 5°C/s) several times and then measuring the Actual temperature of the heater plate after it reached its equilibrium value. In Fig. 2 the deviation from the average Actual temperature is shown as a function of Set temperature (open circles). These measurements were carried out in the absence of a gas flow. The range of the temperature deviation is 2°C and the standard deviation of all of the measurements was 0.6°C.

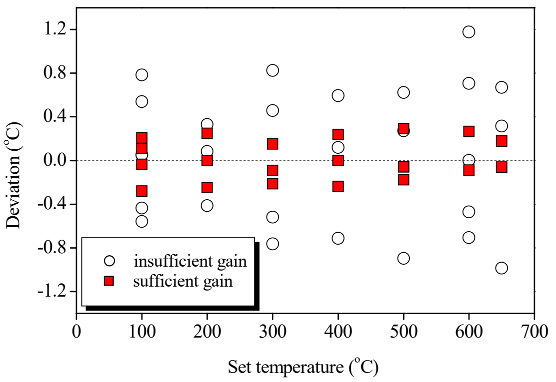

Figure 2: *Deviation around the mean as a function of Set temperature.*

In order to overcome this problem, the gain of the temperature feedback system is easily corrected by bypassing a single resistor on the control box motherboard. After this modification the temperature calibration must be readjusted (see footnotes). The effect of increasing the loop-gain is shown in Figure 1 and 2 (filled squares). The systematic effect on temperature as a function of flow rate is negligible and the reproducibility has improved significantly; the range of temperature deviation is reduced to 0.6°C and the standard deviation is reduced to 0.2°C.

Note, all these tests involve setting a fixed temperature and measuring the Actual temperature. The problem may be worse during heating, but we do not have dynamic data.

Software Upgrade

As mentioned above, temperature calibration during manufacturing is usually carried out at 300°C. Fig. 3a shows the Actual temperature reached after a short equilibration period as a function of Set temperature (heating rate of 5°C/s). In Fig. 3b (triangle symbols) the systematic deviation between Actual temperature and Set temperature is shown as a function of Set temperature. The deviation at 100°C is about -2°C and at 500°C it is about -4°C. This deviation is primarily related to electronic non-linearity; thermocouple non-linearity is negligible on this scale. All systematic deviations are within 2%. However, in the latest version of the MiniSys software (version 2.20 and upwards) it is now possible to correct for these systematic deviations (see Fig. 3b, circular symbols) by first measuring the deviations and then using a polynomial function to derive correction parameters. The resulting calibration is unique to each reader. After implementation of this software upgrade the systematic deviations are all within 0.25°C of the Set temperature.

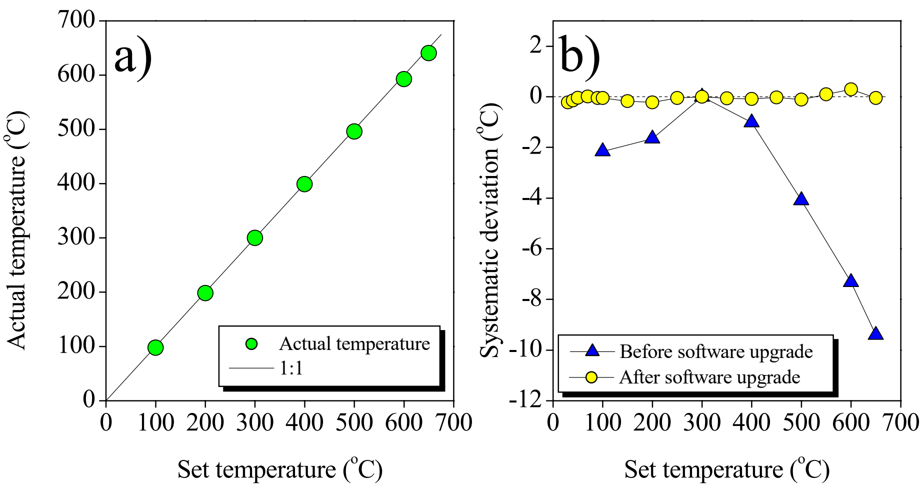

Figure 3: *a) Actual temperature as a function of Set temperature, b) Systematic deviation between Actual and Set temperature as a function of Set temperature.*

Summary

The deviations caused by the low loop-gain are all small compared to the temperatures involved and to the unavoidable variation in thermal contact between the heater plate and the phosphor. Nevertheless, the performance of all TL/OSL DA-15 and DA-15A readers can be slightly improved by modifying the control box's circuit board. Other models are not affected. Upgrading the software now allows the remaining small systematic errors in temperature to be reduced significantly; this software modification is relevant to all models controlled by a Mini-Sys.

How to upgrade

Further information on how to upgrade can be obtained by contacting either Kristina J. Thomsen (kristina.thomsen@risoe.dk) or Henrik E. Christiansen (henrik.christiansen@risoe.dk). Please accompany your enquiry with one photograph of the front plate, and one of the internal layout of the control box (please, remove the lid of the Control Box by unscrewing four screws).

Footnotes

1. All the above applies to heater circuits that have either not been modified or have been repaired at Risø. If the heater amplifier is replaced, the feedback circuit must be recalibrated.
2. The temperature display on the front of the MiniSys (all models) is for guidance only. This display uses an independent thermocouple preamplifier, and is not calibrated when the feedback circuit is set up. The only accurate method of checking the true thermocouple temperature is by direct measurement of the thermocouple voltage using a high impedance digital voltmeter (DVM).

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Reviewer

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