LEAKAGE EFFECT AS A SOURCE OF UNCERTAINTY IN SPRTs

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ABSTRACT

Although being a well-known phenomenon, the effect of the leakage current flowing through the insulators in SPRTs is not always concerned in building up the uncertainty budget sheet. When the resistance of the insulators that hold the platinum wire decreases, this would cause a bias in temperature measurement. The leakage effect at high temperatures is discussed in this document.

THE EFFECT OF THE LEAKAGE RESISTANCE

One of the effects that are unable to eliminate in measuring the resistance ratio is the effect of the leakage resistance of the insulators. The leakage resistance is not a new interest: Berry [1] and also many others have already done extensive work on this topic. The resistance of the insulators that hold the platinum wire would form a circuit parallel to the sensor wire. This would cause the resistance measured by the measurement instrument decrease, and consequently a bias in temperature measurement. Leakage effect typically appears at temperatures near 0 °C due to the water content in the thermometer [2], and at high temperatures caused by the decrease of the insulating resistance. In the latter case, the effect increases with the temperature exponentially [3]. This suggests that the leakage effect at high temperatures should be treated differently from other components in the calculation of the uncertainty propagation.

LEAKAGE EFFECT AT HIGH TEMPERATURE FIXED POINTS

In our recent work [3], we have measured the insulating resistance of insulators used in commercially available PRTs. For an alumina insulator, the resistance decreased exponentially. Figure 1 shows the result obtained with a sample. The insulation resistance per unit length was estimated to be $r = 1.5\times10^{19}\exp(-0.022t)\ \Omega\mathrm{m}^{-1}$, where t is the Celsius temperature. Figure 2 shows a calculation of the bias in the temperature measurements for a furnace model, using this experimental formula. The temperature distribution is assumed that the furnace has an isothermal section of 15cm at the temperature of the silver point, and from this to the top of the 60cm well, the temperature is assumed to decrease linearly to the ambient temperature of 25°C. The sensor of the thermometer is assumed to be $R_{\mathrm{tpw}} = 2.5\Omega$ and its resistance changes according to the reference function of the ITS-90. The stem part of the thermometer uses the same alumina tube as measured in the experiments, and the leakage resistance is calculated by (i) calculating the resistance for each unit length along the well using the formula, and (ii) combining each unit length's leakage resistance. The size of the sensor is ignored, and the leakage is assumed to occur at only the stem part of the thermometer.

In Figure 2, the calculated bias changes from 0.6mK to 3.7mK according to the immersion depth of the thermometer. Changing the immersion depth is equivalent to changing the temperature distribution along the thermometer stem, and this indicates that the effect of leakage in the insulators have a significant effect upon the bias in the temperature measurement. In the case of the fixed-point calibration, we can evaluate such uncertainties caused by the leakage in the stem, by measuring the immersion characteristics when the size of the cell is long enough.

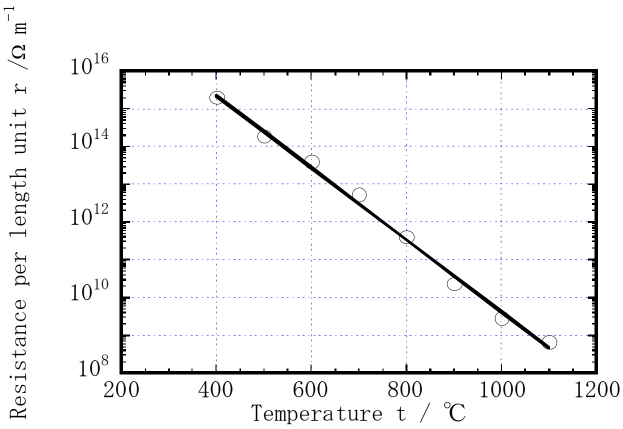

Figure 1: Leakage resistance of an alumina specimen (applied voltage 100mV) [3]

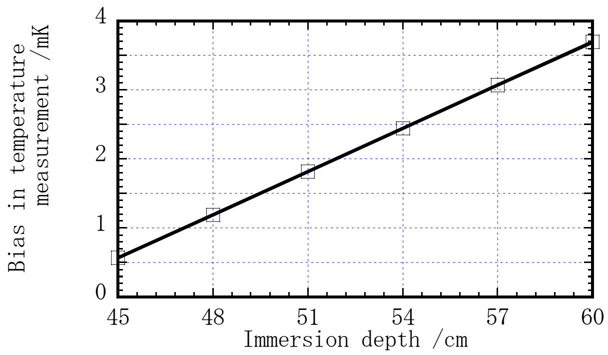

Figure 2: An estimation of the bias in the temperature measurement for an assumed furnace model at 962°C for each immersion depth of the thermometer [3].

DISCUSSION AND CONCLUSION

From our experiments and model calculation, the leakage effect in SPRTs could have a significant effect on the temperature measurement at high temperatures. The immersion characteristic is one of the methods to evaluate the uncertainties due to the leakage. If such uncertainty is considered not ignorable, it should be included in the uncertainty budget.

Another important factor is how the leakage would effect on the temperature scale. This includes not only the uncertainty propagated from the fixed-point calibrations, but also the bias caused by the leakage resistance. Since the leakage resistance would change exponentially by the temperature, the bias on the temperature would drastically change according to the temperature distribution along the thermometer stem. The characteristics would differ between individual thermometers due to the difference in the insulating material and the surface contact between the insulating material and the Pt wire.

REFERENCES

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[3] K.Yamazawa, M. Arai: “Measurement of the resistance of the insulators used in platinum resistance thermometers”, TEMPMEKO 2001(2001)