The accuracy of length measurement limited by unknown temperature

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THE ACCURACY OF LENGTH MEASUREMENT LIMITED BY UNKNOWN TEMPERATURE.

by

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SUMMARY

A short discussion on the definition of temperature and its consequence for accurate length measurement.

ZUSAMMENFASSUNG

Im vorliegenden Beitrag wird der Temperaturbegriff hinsichtlich seiner Konsequenzen für genaue, Längenmessung kurz erörtert.

RÉSUMÉ

Une discussion de la conception de temperature et ses consequences pour la métrologie.
Although the subject of this note may be well known, the author should like to enlarge on it, because of its technical importance in metrology.

The knowledge of temperature is essential to precise length measurement. At present, the best accuracy realised on industrial standards may be about $10^{-7}$. If it is acceptable that half of this value is caused by inaccuracy of temperature measurement, temperature must be known to 5 mK or better \(^*\).

As a rule length measurements are stated to be corrected to $20^\circ$C, but often it is not made clear what is meant by $20^\circ$C. Temperature is defined in physics by thermodynamic relations, together with the value $273.16 \, K = 0.01 \, ^\circ$C for the temperature of the triple point of water. In practice, however, temperature is measured following the routine of the international practical temperature scale (IPTS). Therefore it can be taken for granted that $20^\circ$C normally stands for $20^\circ$C IPTS.

It is well known that the IPTS in the region of $20^\circ$C is defined by interpolation between certain fixpoints by means of a platinum resistance thermometer, using a quadratic equation.

Recent measurements (1) have shown this scale to differ 8 mK from true (thermodynamic) temperature at $20^\circ$C. The latest version of the IPTS (IPTS 1968) (2) takes this difference into account. This means, however, that there exists a difference of $10^{-7}$ in length measurements performed before and after October 1968. IPTS cannot be more than an approximation to true (thermodynamic) temperature. The accuracy of the fixpoints, as stated (ref. 2, table 7), limits the accuracy of this approximation at $20^\circ$C to 2 mK.

It seems advisable to state explicitly that $20^\circ$C is meant to be true temperature. IPTS is used, of course, as a practical approximation. In that case the symbol $t_{68}$ is to be used.

\(^*\) note: Kelvin for a temperature difference of 1 degree Celsius = 1 degree Kelvin; thus 5 mK = 0.005 degree).
The properties of platinum resistance thermometers being well known, it seems advisable to use such thermometers for the more exacting work. Thermometers are available with dimensions down to 2 mm of diameter and 50 mm of length and maybe smaller. If such a thermometer, having $R_o = 100 \, \Omega$, is supplied with a current of 2.5 mA, a potential difference of 1 mV per K results, which can be measured and registrated conveniently.

REFERENCES

(1) Preston/Thomas, H. and C.G.M. Kirby
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