Calibration of AC resistance thermometry bridges traceable to national standards

WIKA data sheet IN 00.30

There are used three used techniques for checking/calibrating the bridges or instruments used in the resistance thermometry, which have different uncertainties. All of these can be used with AC resistance thermometry bridges.

1. Calibration method: Calibrated reference resistors

Calibrated reference resistors can be used (with AC or DC instruments) to check calibration. The calibration uncertainty available (values from national institutes) on these resistors is typically 0.05 ppm DC and 0.5 ppm AC.
It appears therefore that this technique will not work as well with AC instruments as their DC counterparts.

However, the standards used are typically Wilkins resistance standards or equivalents and these have stabilities of 2 ppm per year so that the measurement uncertainty associated with the reference resistor is dominated not by the initial calibration uncertainty but by the long-term stability.

The RMS (root mean square) combination of uncertainties means that for calibrations in which the standard is calibrated annually by a national standards laboratory the contribution of the reference resistor to the total measurement uncertainty is:

1. DC: uncertainty, $uR = 2^2 + 0.05^2 = 2.0$ ppm
2. AC: uncertainty, $uR = 2^2 + 0.5^2 = 2.1$ ppm

As a consequence, there is very little difference between the uncertainty that can be achieved for AC and DC instruments using this technique.
ASL uses this technique only on the industrial level products (F150, CTR2000 and CTR5000), WIKA does not use it on the precision metrology bridges where it is inadequate for the target performance of 1 ppm or better.

This technique is recommended by some manufacturers of DC resistance thermometry instruments for linearising their instruments. This therefore casts doubt on the calibration accuracy of such products.

2. Calibration method: The resistance bridge calibrator (RBC)

The resistance bridge calibrator (RBC) can be used (with AC or DC instruments) to check the linearity of a bridge by generating a set of resistance values that exercise the bridge over its working range.
This instrument was invented by Rod White of the New Zealand national laboratory. The RBC contains four precision resistors, which can be connected in various series and/or parallel combinations.

Although the actual value of each resistor is not known to more than a few ppm, it is possible to determine the linearity of the instrument to much better uncertainty. The resistors are used to generate 35 discrete resistance values from the four base resistors.

These are measured using the instrument under test and although there will be uncertainty in the measured value due to the instrument, this generates 35 simultaneous equations with just four unknowns (the four resistor values).

It is then possible to derive a best-fit determination of the four resistor values and from this to derive the 35 resistances (as a proportion of the maximum resistance) used to check the bridge. This enables the linearity (but not the scale accuracy) to be checked.

The scale accuracy of an AC resistance thermometry bridges can be checked using the internal unit check function. Using this technique it is possible to check a ASL CTR9000 bridge (0.1 ppm accuracy) with residual linearity errors of less than 0.03 ppm.

3. Calibration method: Ratio test unit (RTU)

Such a instrument (RTU) can be used (AC resistance thermometry bridges only) to check the accuracy and linearity of a resistance bridge. This instrument is produced by ASL and simulates the reference and thermometer resistances using an inductive voltage divider (transformer) to generate ratios of AC voltages.

Effectively this technique compares the measurement made by the bridge's ratio transformer with a more accurate external ratio transformer.

The advantage of this technology is that the voltage ratio generated by the inductive voltage divider (IVD) depends only on the turns ratio, which is stable with time and temperature (you cannot lose or gain turns).
Also, the uncertainty of these ratios and therefore of the RTU calibration is calculable and again is stable with time and temperature. IVD techniques are used in national standards laboratories as inherent standards, not requiring calibration.

This instrument, the RTU, used by ASL to calibrate its products was sent to the national standards laboratory of Germany (PTB) for checking against their own IVDs so we do have traceability of the calibrations at ASL back to a leading national standards laboratory.
The uncertainty offered ranges from 0.09 ... 0.13 ppm across the operating range and is limited by the uncertainty of the PTB standards.

In summary, ASL's bridges are checked using the RTU that we have determined is linear to < 0.001 ppm and which has been calibrated by a national standards laboratory to an uncertainty of 0.13 ppm (uncertainty limited by their standards).

The calibrations from WIKA offer are therefore traceable to national standards. DC-based instruments usually use standard resistors to calibrate their equipment and based on an annual calibration program the uncertainty for their traceable calibration would be limited to 2 ppm (due to the drift rate of their standards).

08/2014 GB

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