The revision of SI units – what it means to you

Information for users of NPL calibration services for electrical quantities

The adoption of the revised SI definitions came into force on 20 May 2019 and requires a small update to the reference values that NPL uses to provide traceability for electrical quantities. The benefit of this change is that the established practice of basing electrical calibrations directly on quantum standards will simply become 'the SI', without the complication of conventional reference constants which has been necessary until now.

The decision in 1990 to adopt internationally agreed values for electrical traceability has been enormously successful, and has allowed the full potential of the quantum references to be exploited by end users. After nearly 30 years, the progress in other areas of measurement science (for example in Kibble balances being used for the redefinition of the kilogram) means that we can finally integrate these advances into a simplified revised SI. The constraints of maintaining continuity with the existing base unit definitions for the kilogram and ampere (which have served the SI since 1889 and 1948 respectively) mean that this update unfortunately cannot be achieved without a small adjustment to electrical references.

There will be no change to the way in which electrical calibrations are carried out at NPL or in the uncertainties offered. The update is in the value of the reference constants used to calculate the results of voltage and resistance calibrations. The changes are small enough that they will be invisible on almost all standards undergoing calibration (i.e. smaller than the expected stability of the standard or the uncertainty of the calibration). The possible exception is the case of the best quality Zener voltage references that have a well characterised calibration history, where a small step change on a drift line might be visible.

The exact changes are described below for completeness. **No action is expected to be necessary for NPL's calibration customers**. All certificates issued before 20 May 2019 continued to use the existing reference values, and those after that date use the new values. The delay between the formal international decision to approve the updated SI unit definitions last year and the implementation date now was agreed to ensure that this transition could be implemented seamlessly. NPL has been actively involved in the planning and coordination of this change through international committees with other National Measurement Institutes (NMIs). All NMIs are implementing the same changes at the same time, so the international compatibility of SI traceable measurements (as ensured by the CIPM Mutual Recognition Arrangement) will be unaffected.

If you have any questions please contact us.

Email: measurement_services@npl.co.uk

If you want to read more, then go to our website:
https://www.npl.co.uk/si-units

Details of the changes to calibration services for electrical quantities

Before 20 May 2019, electrical traceability was based on the agreed 1990 'conventional values' for the Josephson constant, K_J (used in voltage) and the von Klitzing constant, R_K (used in resistance):

$K_{J\text{-}90}$ = 483 597.9 GHz/V
$R_{K\text{-}90}$ = 25 812.807 Ω

In the revised SI, we now have:

$K_J = 2e/h$ = 483 597.848 416 984 GHz/V
$R_K = h/e^2$ = 25 812.807 459 3045 Ω

These numerical values follow directly from two of the defining constants of the revised SI:

The Planck constant h is $6.626\ 070\ 15 \times 10^{-34}$ J s
The elementary charge e is $1.602\ 176\ 634 \times 10^{-19}$ C

Please note that the numerical values for h and e are agreed as exact; the values given for K_J and R_K are rounded to 15 significant digits.

After application of the change, the values shown on a certificate for a recalibration of an ideal (perfectly stable) standard would change thus (relative changes expressed in parts in 10^6, ppm, rounded to 0.0001 ppm):

+ 0.1067 ppm for voltage
+ 0.0178 ppm for resistance

Other quantities rely on voltage and resistance standards, and will therefore be similarly affected:

+ 0.0889 ppm for current
− 0.0178 ppm for capacitance
+ 0.1956 ppm for power

To put these changes in context, we need to consider the best uncertainties offered in NPL's calibration services:

Voltage: 0.02 ppm (dc, 10 V Zeners)
Resistance: 0.02 ppm (100 Ω standard, direct against QHR)
Current: 0.2 ppm (dc 10 mA source)
Capacitance: 0.7 ppm (10 pF fused silica standard at 1 kHz)
AC Power: 28 ppm (single phase, active or reactive, 0-130 kW, <400 Hz)

As noted previously, the change could be significant for a calibration of a Zener voltage reference, or for some standard resistors. However, typically the stability, transport properties and regular drift of even the most stable standards will add to the best case calibration uncertainties, and we would expect the changes to be invisible. In any cases where we expect that this is not the case, NPL will give additional information and individual advice.

Further information about the changes can be found in the guidance document prepared by the CCEM: https://www.bipm.org/utils/common/pdf/CC/CCEM/ccem_guidelines_revisedSI.pdf

The '*mise en pratique*' giving full details on how electrical units are realised is available from BIPM: https://www.bipm.org/utils/en/pdf/si-mep/SI-App2-ampere.pdf