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Bilateral Comparison of 1 Ω Standards between the NML (Forbairt) and the BIPM, April 1998

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A comparison of the reference standards of electrical resistance of the BIPM and the National Metrology Laboratory (NML, Forbairt), Dublin, Ireland was carried out from 2 February to 8 June 1998. Two BIPM CSIRO 1 Ω travelling standards, designated S-60905 and S-64171, were shipped by air freight. The BIPM measurements were carried out by comparison with 100 Ω reference resistors whose values are known with respect to the BIPM Quantized Hall Resistance (QHR) standard. The current in the 1 Ω resistors during the measurements is 50 mA. The combined standard uncertainty of the link from the travelling standards to the QHR is less than 15 nΩ. The NML carried out measurements of the travelling standards by the substitution method using a current comparator resistance bridge. The NML resistance standard is maintained with respect to $R_{K\text{-}90}$ by means of periodic calibrations and comparisons with the BIPM and by extrapolation of the secular behavior of its reference group. The measuring current used was 30mA. Results of all measurements were corrected for the temperature dependence of the resistance. The reference temperature is 23°C. The NML measurements, carried out near 20 °C, are referred to 23°C.

Figure 1 shows the results of the measurements of standard S-60905 in both laboratories. The measurements were analyzed using a linear least-squares fit to the resistances as a function of time. The straight lines on the graph show the predicted values. The results are referenced to the mean date of the NML measurements, 15 April 1998. In this way, the values and uncertainties of the NML measurements are essentially the same whether we use a least-squares fit or a simple average. The BIPM value and uncertainty for the reference date are also calculated from a linear least-squares fit. The value of the travelling standard appears to have shifted downward by about 100 nΩ after its return to the BIPM. The values measured for the difference of resistance between the two

travelling standards indicates that this occurred after the NML measurements. We have therefore retained only the results of the BIPM measurements made *before* shipment to calculate the final result. Figure 2 shows the results for this standard if the return measurements at the BIPM were retained. Figure 3 shows the results for travelling standard S-64171.

Table 1 lists the results of the 1 Ω comparison and the component uncertainty contributions. In combining the uncertainties we apply the usual method of combining variances to calculate the uncertainty of the mean value of the result. Thus, the final result is calculated from the mean of the results from each travelling standard. Its type A variance is the sum of the type A variances of the travelling standards divided by the square of the number of travelling standards. The total variance is the sum of 1) the type A variance, 2) the type B variances and 3) the variance deduced from the transfer uncertainty.

The final results of the comparison are presented as the difference between the value assigned to a 1 Ω standard by the NML, R_{NML}, and that assigned by the BIPM, R_{BIPM}, on the reference date. The result is

at 1 Ω: $R_{NML} - R_{BIPM} = 0.03\ \mu\Omega$; $u_c = 0.2\ \mu\Omega$ on 1998/04/15,

where u_c is the combined type A and type B standard uncertainty from both laboratories.

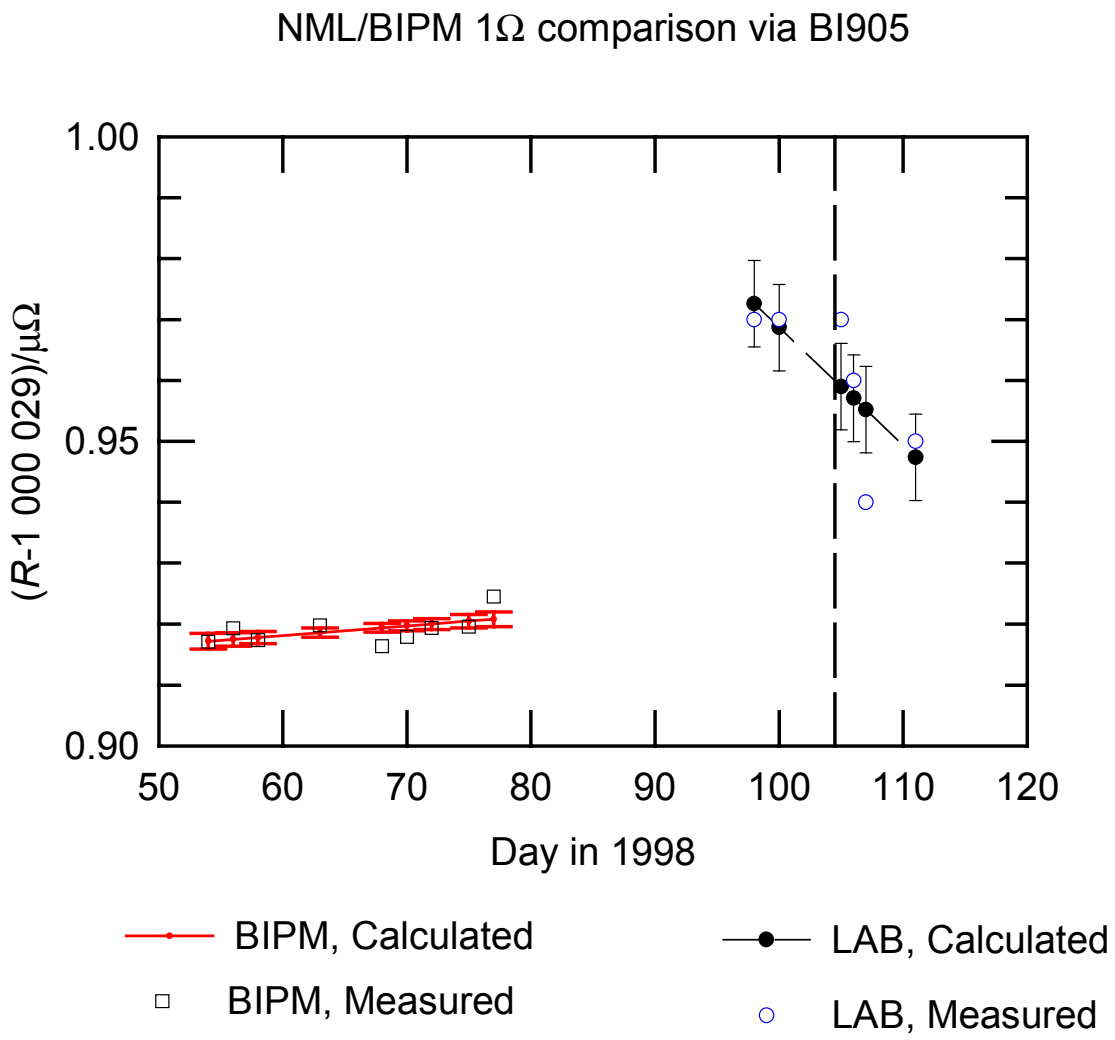

Figure 1. Results of the measurements of S-60905 including only the BIPM measurements carried out before shipping the travelling standard. These results were used in the calculation of the final comparison result. The lines represent the linear least-squares fit to the results of each laboratory. The uncertainty bars represent the type A standard uncertainty. The vertical line near the center represents the mean date of the comparison.

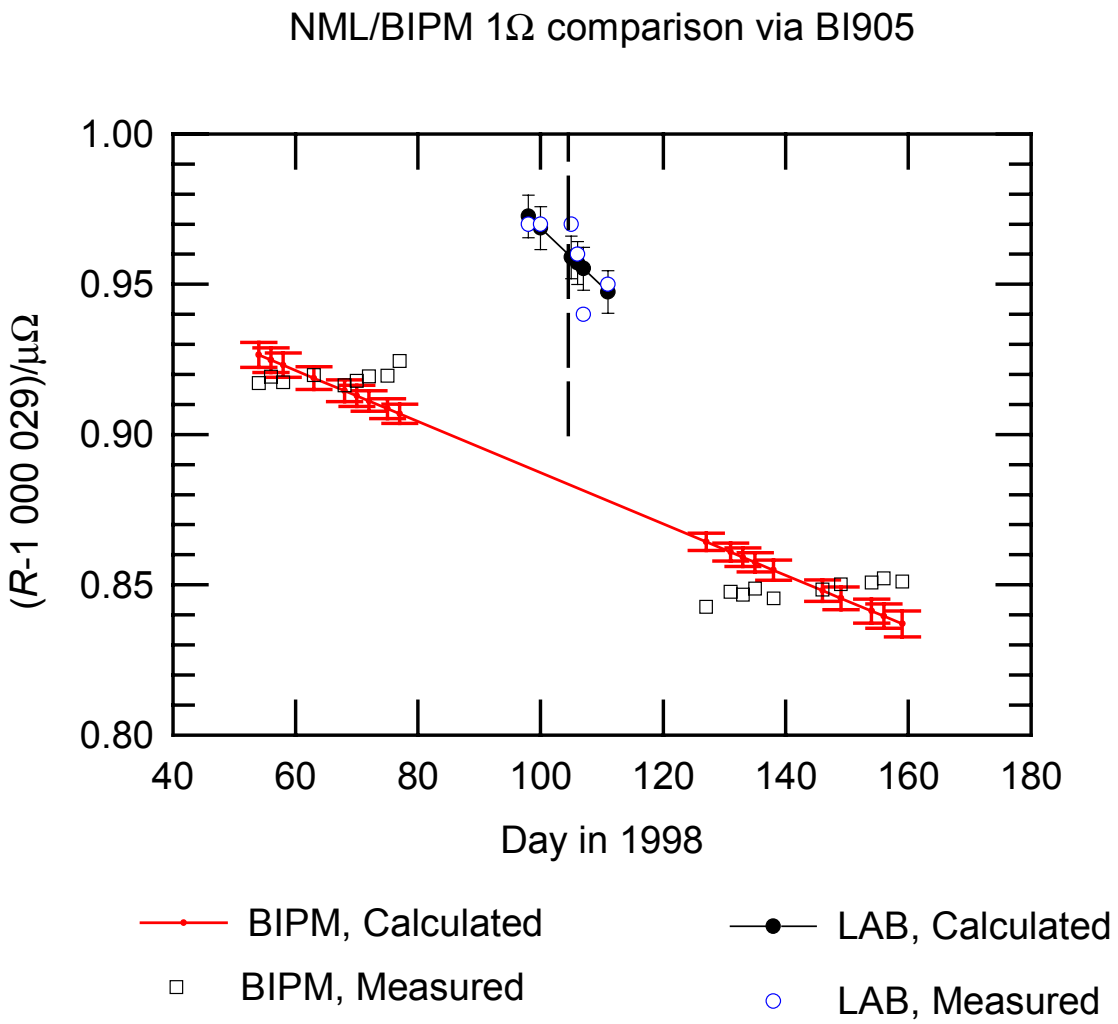

Figure 2. Results of the measurements of S-60905 including the return measurements at the BIPM. These results were not included in the calculation of the final comparison result. The lines represent the linear least-squares fit to the results of each laboratory. The uncertainty bars represent the type A standard uncertainty. The vertical line near the center represents the mean date of the comparison.

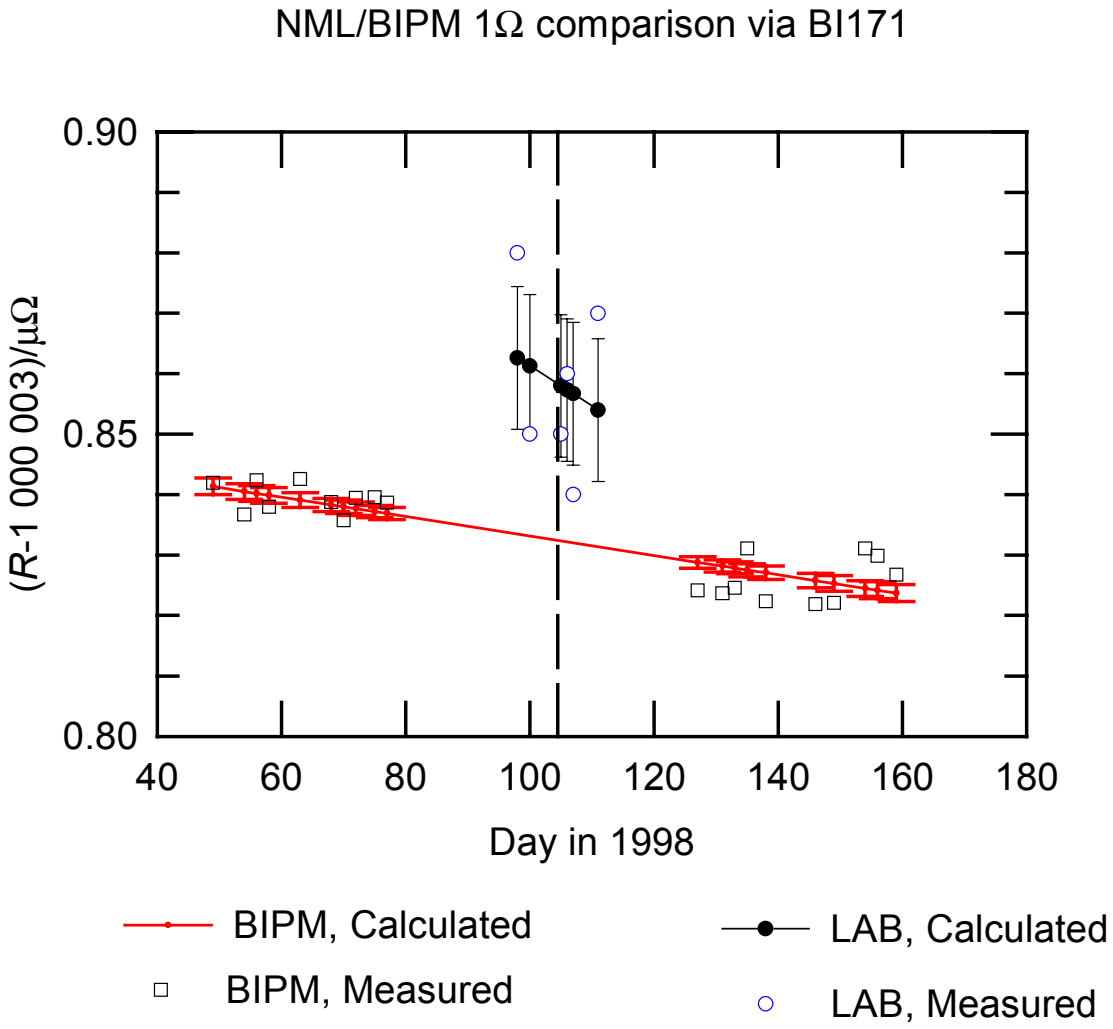

Figure 3. Results of the measurements of S-64171. The lines represent the linear least-squares fit to the results of each laboratory. The curves above and below each line represent the type A standard uncertainty. The vertical line near the center represents the mean date of the comparison.

Table 1. Results of the NML/BIPM bilateral comparison of 1 Ω standards using Zener travelling standards. Mean Date: 15 April 1998.

1 Ω comparison: units are μΩ

		S-60905	S-64171
1	NML value, drift model	1000029.96	1000003.86
2	NML unc (A), drift model	0.004	0.007
3	NML unc (B)	0.2	0.2
4	BIPM value, drift model	1000029.925	1000003.832
5	BIPM unc (A), drift model	0.004	0.001
6	BIPM unc (B)	0.01	0.01
7	$U_{NML} - U_{BIPM}$	0.035	0.026
8	Unc (A) of $U_{NML} - U_{BIPM}$	0.005	
9	mean $U_{NML} - U_{BIPM}$	0.03	
10	unc of transfer	0.005	
11	Total unc of comparison	0.2	
12	mean date yy/mm/dd	98/04/15	

References to Table 1.

1. Results from a linear least-squares fit to the NML data.
2. The type A standard uncertainty following from the least-squares fit to the NML data.
3. The type B uncertainty estimated by the NML.
4-6. Same as 1-3. But for the BIPM results.
7. The comparison result following from each travelling standard.
8. The combined type A uncertainty in 7; the root-sum-square of the contributions from both laboratories.
9. The mean of the results on line 7.
10. The standard deviation of the mean of the results from the two travelling standards.
11. The root-sum-square combination of items in lines 3,6,8 and 10.
12. The mean date of the comparison, the mean date of the NML measurements.