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Investigation on the realization of an automated and guarded Hamon 10×10 GΩ network

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Abstract **-** Recently at National Institute of Metrological Research (INRIM) a Hamon actively guarded 10×100 MΩ was developed to improve the traceability levels at 1 GΩ level. Utilizing and revisiting this project, a Hamon 10×10 GΩ network is now under realization to extend the capabilities of the Hamon method up to 100 GΩ. Moreover, by means of this Hamon network, it will be possible to extend the capabilities of the measurement method for the calibration of picoammeters already developed at INRIM.

I. Introduction

At National Institute of Metrological Research (INRIM) in the last years, a revision of the resistance scale in the range 100 kΩ÷100 TΩ, due to the needs of better accuracy and to the INRIM participation at CCE and EUROMET international comparisons, was made. In particular, a measurement method, based on the use of a digital voltmeter (DVM) and a dc voltage calibrator for the calibration of resistors in the range 10 MΩ÷1 TΩ was realized [1]. This method is also suitable for the determination of the voltage coefficients of high value resistors [2]. Using this method and a Hamon [3] scaling method, National Electrotechnical Institute (IEN, former name of INRIM) participated at a Comité Consultatif d'Electricité (CCE) inter-comparison on 10 MΩ and 1 GΩ values. The degrees of equivalence of IEN, expressed as differences from the reference values X_{KCRV} (Key Comparison Reference Value), were $(0.9 \pm 5.5)\times10^{-6}$ and $(2.5 \pm 19.3)\times10^{-6}$ respectively for the 10 MΩ and 1 GΩ [4]. Other well known accurate and reliable methods were also implemented at INRIM [5, 6] to participate at the EURAMET.EM-S32 comparison at 1 TΩ and 100 TΩ level.

II. The 10×10 GΩ Hamon network

The Hamon, network, whose scheme is reported in Fig. 1, that is under development consists in a chain of ten resistors with 10 GΩ nominal value to perform the traceability transfer from 1 GΩ to 100 GΩ. The involved resistors are CADDOK type resistance elements (Fig. 2). To individuate ten resistance elements with the best possible matching level a selection among twenty elements belonging to the same production lot was performed. The selected resistors will be then modified to apply the guard circuit of the network: every resistor is placed in a 190×20 mm glass tube closed at the extremities with two aluminium cylinders (Fig. 3) on which the resistors guard chain will maintain a guard voltage. Between the rheophores of the resistors and the aluminium cylinders a PTFE bust is inserted to electrically isolate the measurement and guard circuits. The glass tube, besides to support the guard chain with a suitable insulation, protects the resistors by environment variations, dust, all factors that can sensitively affect high value resistors. The leakage resistances between the various elements of the modified resistor were measured with a teraohmmeter.

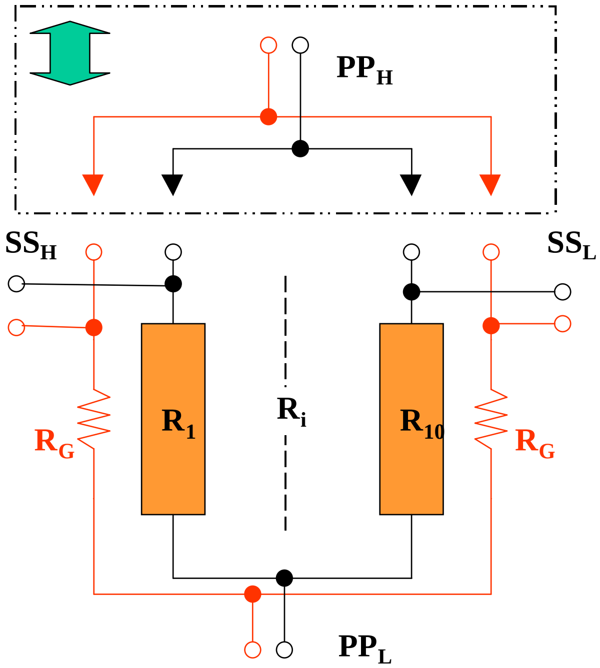

Fig.1 – Scheme of the 10×10 GΩ Hamon network. With R_i are indicated the ten main resistors, with R_G the guard resistors (100 MΩ), with SS_H, SS_L, PP_H e PP_L respectively the high and low outputs of the series configuration and the the high and low outputs of the parallel configuration.

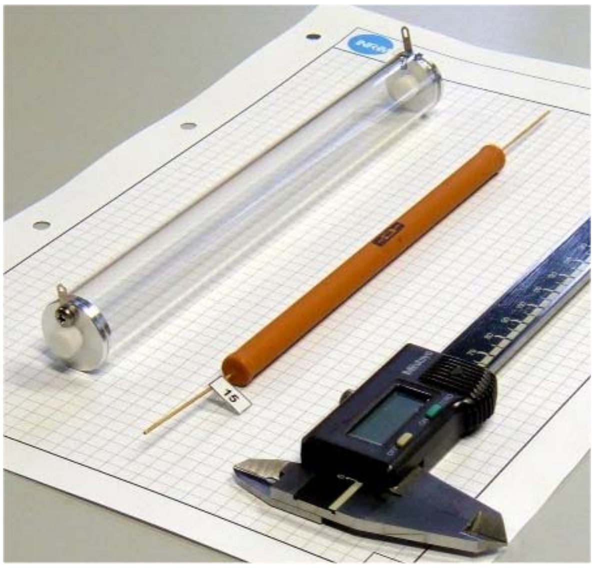

Fig. 2- photos of the glass protection case, with PTFE and aluminium busts and insulators

III Calibration and use of the Hamon 10×10 GΩ resistor to extend the traceability levels of the high resistance at INRIM

The traceability chain in which the resistor is involved is shown in Fig. 4. The chain starts from a high precision 10 kΩ standard resistor with temperature coefficients $\alpha_{23}= -3.4\times10^{-8}$/°C, $\beta = -2.9\times10^{-8}$/°C^2 and drift of about 7.5×10^{-8}/year. This resistor is calibrated with expanded uncertainty of 2×10^{-7} starting from primary 1 Ω resistors group of INRIM referred to the value $R_{K-'90}$. Passing through a 10×10 kΩ transfer box, the parallel output of a Hamon 10×1 MΩ box is calibrated. The parallel output of the 10×100 MΩ Hamon network [7] is compared with the series output of the 10×1 MΩ box. All these comparisons are made in 1:1 ratio to a DMM.

The comparison of the series output of the 10×100 MΩ Hamon network with the parallel output of the 10×10 GΩ and the comparison of the series output of the 10×10 GΩ network with a high performance 100 GΩ used to maintain the unit at this level, will be made with the modified Wheatstone bridge. The 10×100 MΩ and 10×10 GΩ networks are respectively calibrated at 10 V and 100 V while in series are respectively used at 100V and 1000 V to maintain the same voltage on their resistors in the transfer.

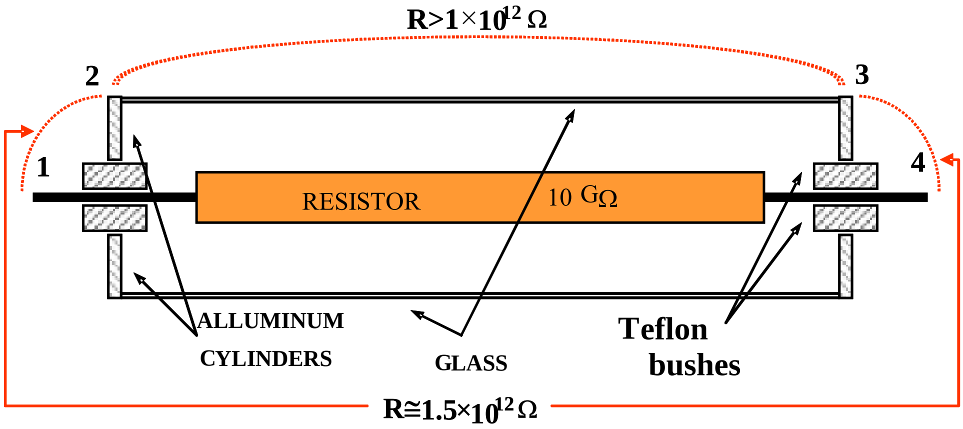

Fig. 3 – Scheme of the resistor inside the protection case. The case consists of a glass tube closed at the extremities with two aluminum cylinders electrically connected to the guard resistors. The insulation among the rheophores of the 10 GΩ resistor is obtained by two PTFE bushes that sustain the resistor maintaining it at the centre of the case.

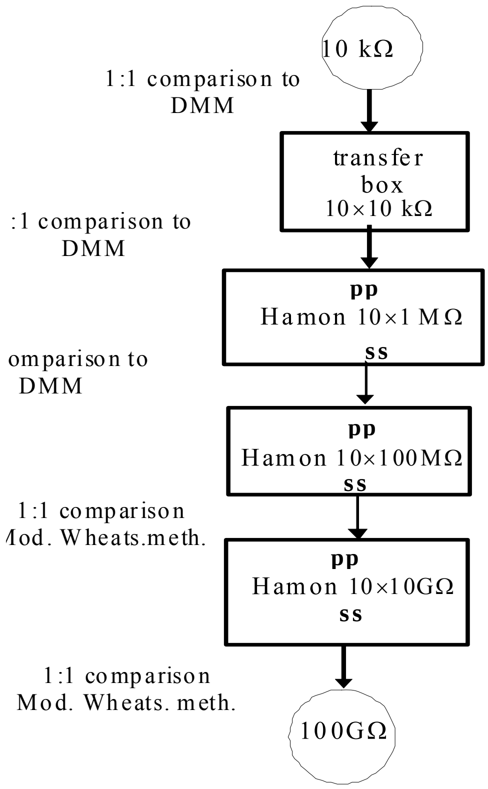

Fig. 4 Traceability chain from 10 kΩ to 100 GΩ.

IV. Hypothesis of uncertainties budget

In the following table the steps, of the Hamon method from 10 kΩ to 100 GΩ at INRIM according to the traceability chain of Fig. 4 along with their relative standard uncertainty components, are reported,. As it can be seen, the limit f the method is the high short time instability of the 100 GΩ standard already experimentally verified in [1].

Step	Uncertainty source	type	1σ ($\times10^{-6}$)
	Uncertainty and drift standard 10 kΩ	B	0.1
10 kΩ	Thermal voltages instability	B	0.2
	Non linearity and instability of the DMM	B	0.2
	tot std dev compar. 10 kΩ→10 kΩ	A	0.2
	1:10 transfer error	B	0.5
Transfer box	Temperature instability and drift	B	0.3
	Thermal voltages instability	B	0.1
10×10 kΩ	Non linearity and instability of the DMM	B	0.3
	Std deviation of the comparison	A	1
Hamon	Temperature instability and drift	B	0.2
box	Thermal voltages instability	B	0.1
10×1 MΩ	1:100 transfer error	B	1.0
	Non linear. and input imped. bias curr. instab. DMM	B	1.0
	Std deviation of the comparison	A	1.0
Hamon network	Temperature instability and drift	B	0.3
10×100 MΩ	Thermal voltages instability	B	0.1
	1:100 transfer error	B	1.2
	Substitution modified wheat. bridge method	B	2.0
	Std deviation of the comparison	A	1.2
Hamon network	Temperature instability and drift	B	0.8
10×10 GΩ	Thermal voltages instability	B	0.5
	1:100 transfer error	B	2.5
	Substitution modified wheat. bridge method	B	3.0
	Std deviation of the comparison	A	20
100 GΩ standard	**Standard uncertainty**		**20.7**

V. Experimental results

The measurements were made by means of a FLUKE mod. 8508 digital multimeter (DMM) on the 20 GΩ range, with a relative accuracy on the of the order of 1.1×10^{-4}. To opportunely utilize the guard circuit of the DMM and to perform the measurements always in the same way the connection support shown in Fig.5 was assembled. The selected resistors have the values reported in Fig. 6.

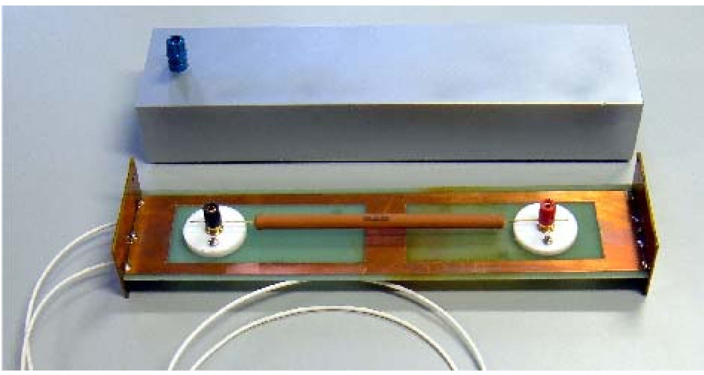

Fig.5 – Connection support between DVM and resistor. This is connected by means of two terminals mounted on a PTFE distancer fixed on a glass plate for printed circuits whith the copper guard geometries.

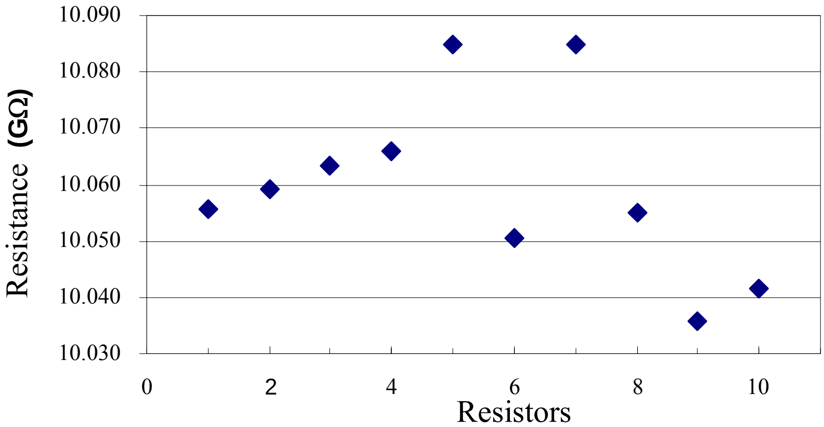

Fig.6 Resistive value of the selected resistance elements.

VI. Conclusions

The project of a Hamon 10×10 GΩ network that will allow to extend the Hamon method at INRIM up to 100 GΩ was described. Aims of the work will be the automation of the series to parallel passage of the main and guard resistors and the verification of the effectiveness of the guard circuit. Moreover with this Hamon network will be possible to extend the measurement method for the calibration of picoammeters already developed at INRIM [8]. In an eventual extended paper will be reported further images and results of the developments and characterization of the new object.

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