A TEMPERATURE, HUMIDITY AND PRESSURE INDEPENDENT 1 GΩ STANDARD RESISTOR: REALIZATION AND PRELIMINARY RESULTS

Abstract – At IEN a temperature, humidity and pressure controlled standard resistor starting from a 1 GΩ commercially available resistive component was developed; it is particularly suitable as travelling standard for high value resistance measurement inter-comparisons.

It was developed inserting the component in a hermetic container in which temperature, relative humidity and pressure are maintained at level of respectively $(25 \pm 0,01)°C$, $(7 \pm 1)\%$ and 980 hPa.

The preliminary results of the measurements with four measurement voltages performed on the standard showed a short-term stability (24 hour) of about $5 \cdot 10^{-7}$ and mid-term stability (1 month) of about $3 \cdot 10^{-6}$.

Keywords: standard resistor, temperature, humidity and pressure dependence, resistive value stability.

1. INTRODUCTION

In the last period, the need of making more accurate measurements in the field of high dc resistance due to the requests of the secondary and industrial laboratories, is sensitively increased.

Normally, in national laboratories the resistance scale spans from $1 \cdot 10^{-5}$ Ω to $1 \cdot 10^{14}$ Ω. To perform very accurate measurements in so a large interval is only possible if we can determine smaller measurement intervals in which to use suitable projected standards, suitable measurement techniques and dedicated instrumentation.

The realization and development of electrical resistance high stability standards implies geometrical and technological problems. From geometry depends a good thermal insulation or a good thermal contact according to the use of the standard that can be in air or in thermo-regulated oil baths. To geometry is also related the problem of the electrical definition of the standard, that can be at 4, 3 or 2 terminals: from the technological point of view it is also important the choice of the alloy of the resistive element.

In Fig. 1 a diagram that shows the distribution of the effects of the environment and measurement parameters that can affect the measure of a electrical resistance, is reported.

In this work the realization of a 1 GΩ experimental standard resistor with a technology oriented to enhance the time stability of its resistive value and minimize its dependence from the environment parameters, is described.

2. DEVELOPMENT OF THE STANDARD

The adopted resistive element is a commercially available thick film component with the following characteristics, as declared by the manufacturer:
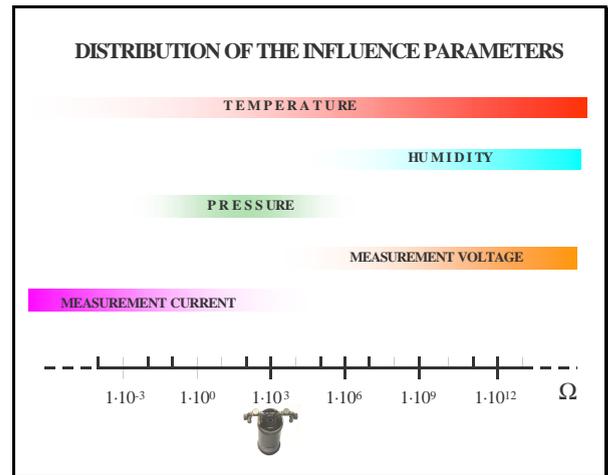

Fig. 1. Distribution of environment and measurement parameters on the resistance scale.

- nominal value of 1 GΩ ± 0,25%, temperature coefficient < $5 \cdot 10^{-5}/°C$, voltage coefficient < $0,3 \cdot 10^{-6}/V$.

The project of the standard resistor considers all environment parameters and minimizes the effects of the variations of these parameters in order to improve resistor's stability. Block diagram of the realization is reported in Fig. 2. The standard is a three-terminal resistor.
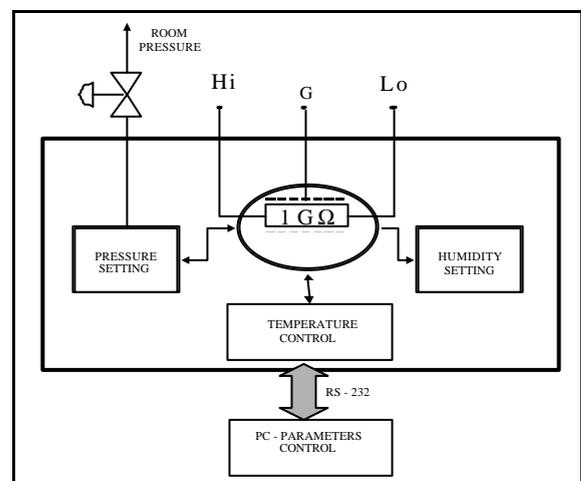

Fig. 2 – Block diagram of the standard resistor.

This resistive component was mounted inside a metal cylinder that represents both the thermal sensor and the heating system (Fig. 3): these elements were all placed in a hermetic container (Fig. 4).
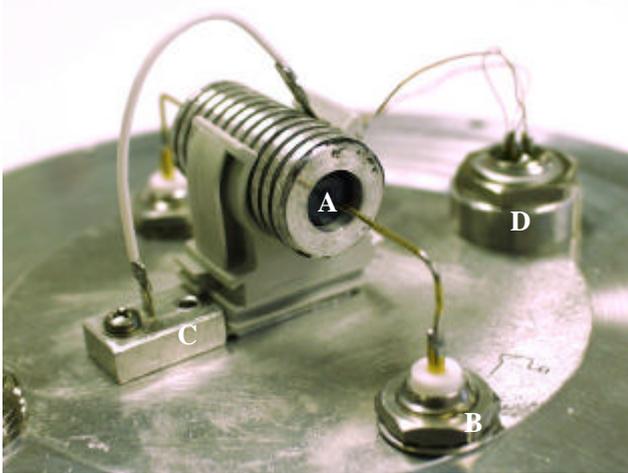

Fig. 3 – View of the standard: the resistive element is placed inside the thermal-regulation cylinder (A) and soldered to the measurement terminals (B). In the picture are also visible: the third terminal (C) and the connector (D) used for temperature control.
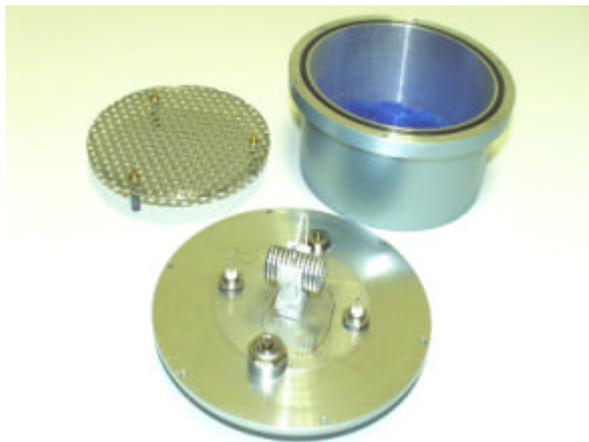

Fig. 4 – The hermetic container of the resistor: is also visible the grid under which there is the silica gel for humidity control.

The resistor, before to be put inside the container, was treated with an accurate washing in pure ethylic alcohol and acetone, to remove grease trails or other impurities and then it was definitely placed in the hermetic container in an environment with dry nitrogen at a pressure of 980 hPa and with the presence of silica gel for a quick removal of humidity trails and for the maintenance of the humidity inside the container at a constant value.

The silica gel that, as we can see in Fig. 4, is placed in the container separated from the resistor by means a very thin grid, maintains the relative humidity at a level of $(7 \pm 1)\%$.

2.1. Temperature control

The electronic circuit of the temperature control is external from the resistor container while the soldering of the resistor to BNC measurement terminals was performed with a tin alloy with low f.t.e.m. Fig. 5 shows the whole system with the standard resistor and the external temperature control.

The circuit that measures the temperature of the cylinder holding the resistor has, as sensitive element, a negative coefficient (NTC) thermo-resistor with nominal value of 10 kΩ at 25 °C. The thermo-resistor, with three 10 kΩ resistors, forms the measurement bridge balanced at 25 °C. The disposition of the resistors and the connection of the amplifier guarantees a direct proportionality between the output voltage from the circuit and the temperature of the container.

The used amplifier is characterized by small noise, small voltage offset (50 µV max) and small temperature coefficient (0,5 µV/°C).

Fig. 5 – The 1 GΩ standard resistor with its external active temperature control.
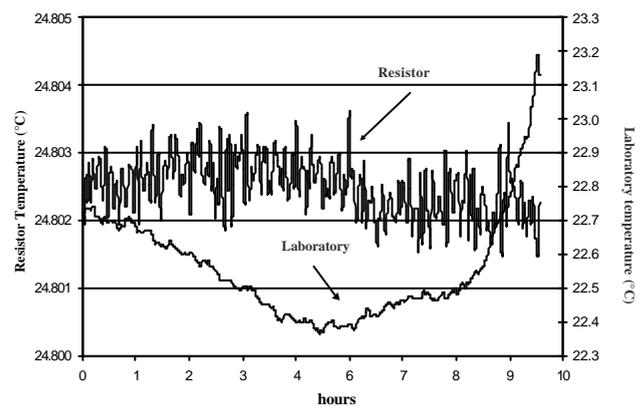

Fig. 6 – Behaviour of the temperature inside the container vs. the temperature of the laboratory.

The long term stability of the temperature inside the container, with this active control, can be maintained at a level of $(25 \pm 0,01)$°C. Fig. 6 shows a graph of the acquisition of the temperature inside the laboratory and inside the standard resistor in a period of ten hours: as we

can see, a variation of about 0,8 °C of the laboratory temperature corresponds to a variation inside the container of about 0,002 °C.

2. PRELIMINARY RESULTS OF CHARACTERIZATION

The resistor was assembled in the month of december 2001 and immediately it has been measured at four measurement voltages (250 V, 500 V, 750 V and 1000 V) making a measure about every week: the measurements are made with the DMM measurement method developed at IEN [1 ÷ 3].

In the first weeks its value varied sensibly probably for the mechanical shock due to its assembly and due to the change of temperature and humidity of the 1 GΩ resistive component (from 23 °C and about 35 % U_r before the insertion in the container to 25 °C and 7 % U_r after the insertion). After about 50 days the resistor seemed to reach a stabilization (Fig. 7) point with a short-term relative stability (24 hour) of about $5 \cdot 10^{-7}$ a mid-term relative stability (1 month) of about $3 \cdot 10^{-6}$.
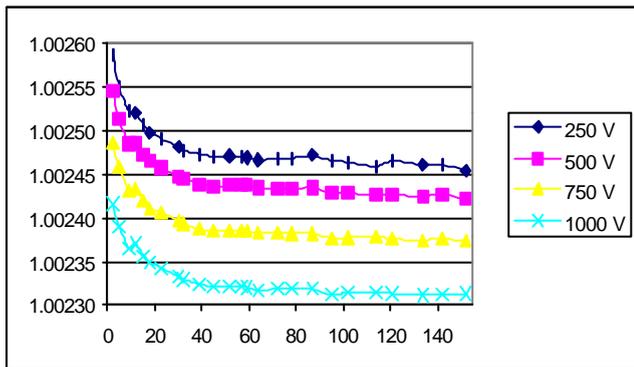

Fig. 7 – Behaviour of the resistive value of the 1 GΩ at four measurement voltages after its assembly.
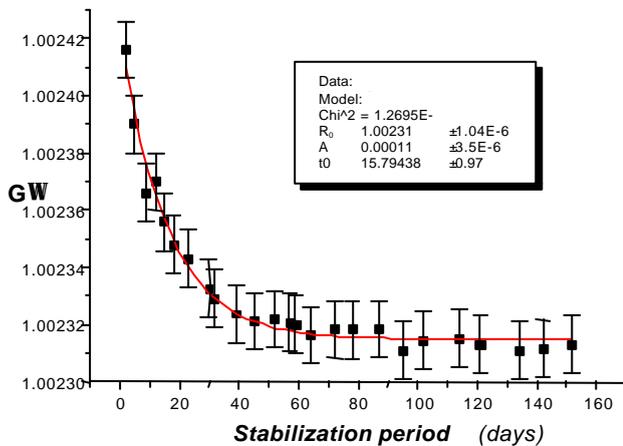

Fig. 8 – Behaviour of the resistive value of the 1 GΩ at 1000 V from its assembly.

In Fig. 8 is reported the behaviour of the resistor versus the stabilization period (in days) and with a measurement voltage of 1000 V. This figure shows a decaying exponential behaviour of the resistive value vs. time period as:

$$R(t) = R_0 + Ae^{-t/\boldsymbol{t}} \qquad (1)$$

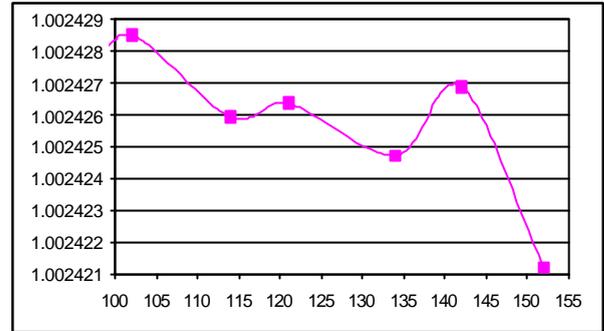where t is the time in days and $\boldsymbol{t}$ the time costant of the decaying.

Fig. 9 – Behaviour of the resistive value of the 1 GΩ at 500 V in the last two months.

The performance of this developed standard resistor was also compared with the behaviour of a top level standard, the Guildline mod. 9334W, n. 63246, also available at IEN with temperature coefficient of $1.8 \cdot 10^{-6}/°C$, voltage coefficient of $-4 \cdot 10^{-8}/V$.

This standard was also measured in the same period in an environment with temperature of $(23 \pm 0.2)°C$ and relative humidity of $(15 \pm 5)\%$. Fig. 10 shows its behaviour versus the stabilization period: in this case the standard deviation of the measurements in the last month resulted of $2.3 \cdot 10^{-6}$.

For our resistor, despite there is still a drift in the behaviour, the standard deviation of the measurements in the last month resulted of $2.5 \cdot 10^{-6}$.
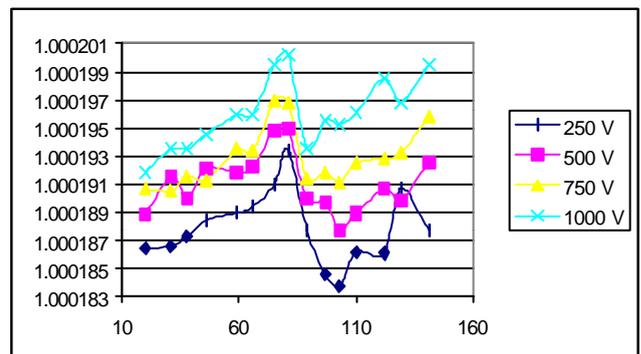

Fig. 10 – Behaviour of the resistive value of the 1 GΩ at four measurement voltages in the same period of the measurements of the developed resistor.

From the comparison of Fig. 9 and 10 and from the evaluation of the last month stability of the two resistors, we

can observe that, despite we started with a commercially available resistive element with much lower metrological characteristics, the temperature, pressure and humidity controls allowed us to realise a standard with quite comparable performance of the top level 1 GΩ Guildline standard resistor with absolutely lower costs.

3. CONCLUSIONS

At IEN a temperature, humidity and pressure independent standard resistor was developed starting from a commercially available resistive component.

In future we will continue the work of evaluation of its mid-term and long-term stability in order to check if, with this kind of control of the environment parameters, its performance can effectively be at the same level of the 1 GΩ Guildline, considered the top level standard.

Another aim we have is to plan a circulation in Italy among secondary calibration laboratories, denoted as SIT Centres, accredited for high resistance measurements, in order to evaluate the stability of the standard during transportation and in the different environment conditions present in each laboratory.

AKNOWNLEDGMENTS

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