Determination of the Pressure Coefficients of High Precision Standard Resistors

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Abstract-In this paper is presented a system, developed at IEN, for determination and measure of pressure coefficients of high precision standard resistors used to maintain the unity of dc electrical resistance, and to transfer the traceability during the periodic international key comparisons established to verify the degree of equivalence of standard among different National metrological Institutes results (NMIs). Preliminary results of the utilisation of the system for the characterisation of high precision standard resistors vs. environment pressure are also given.

I. Introduction

From January 1990, after the an international agreement among NMIs, the unity of electrical resistance is obtained starting from the Hall quantum effect experiment(QHE) [1]. Adopting, as value of the von Klitzing constant a value conventionally established, NMIs, utilising the QHE can perform resistance measurements with a compatibility level, among them, of two orders better respect to the methods used to realise the SI unit. This significant step, performed in order to improve the measurement capabilities of a modern metrological laboratory, does not put to an end the use of material standard resistors for metrogical activities of maintenance and dissemination of the electrical resistance unit. Nevertheless, new accuracy and reproducibility limits of the measurements caused the fact that parasitic effects and dependence from environment parameters that act on standard resistors began more critic. These facts led the metrologists to consider new effects. Among these, there is the dependence of standard resistors from atmospheric pressure [2]. The effects of atmospheric pressure can be due to climatic changes. Also the immersion of an resistor in an oil bath can change the pressure on the resistor itself. Thomas resistors (built with manganine), commonly adopted by NMIs, have a pressure of about $2\cdot 10^{-9}$ hPa^{-1} [3] that can cause a significant change due to an atmospheric perturbation with consequent variation of the environment pressure of about 30 hPa An exact knowledge of the pressure coefficient of high precision standard resistors is highly important for example in international key comparisons, when such resistors can be transported from National laboratories at considerably different altitudes above the sea level. To make an example of a limit case, a resistor could be transported from the National laboratory of NMI in Delft (Nederlands) at about 50 m above the sea level corresponding to a pressure of about 1000 hPa to the National laboratory IBMETRO in La Paz (Bolivia) at about 3600 m above the sea level corresponding to a pressure of about 650 hPa. For the above considered resistor, the travel considered, can led to a relative variation of about $7\cdot 10^{-7}$.

The measurement system

The developed measurement system, visible in Fig. 1, is constituted by a cylindrical container with hermetic seal, a pressure source and some devices and transducers to set and check the environment conditions with which measurements are carried on. The resistor to be characterised is placed inside the container with hermetic seal and connected to the measurement system by means of cables with low thermal EMFs terminals (Fig. 2 and 3).

Figure1. Measurement equipment to determine pressure coefficients of high precision standard resistors.

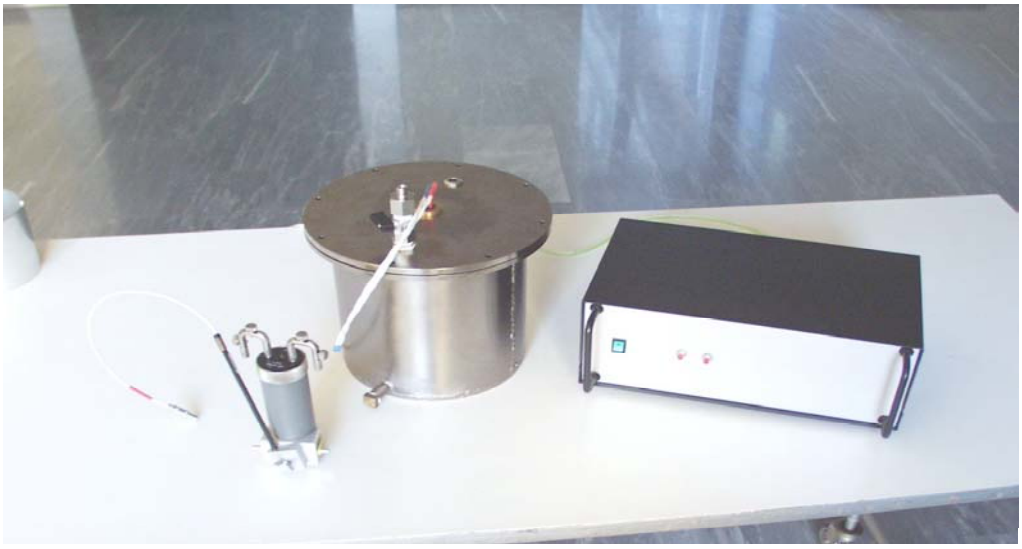

Figure2. View of the box constituting the pressure source and the connected hermetic container.

Inside the container a platinum thermometer (PT100) is inserted and thermally connected to the standard under measure. The container is filled with mineral oil when the characteristics of the resistor under measure allow this operation. The container has a flange with an o_ring for sealing and all passages of cables were realised with passing tight connections Fig 3. During the measurements the container is placed inside an oil bath Guildline mod. 9732 VT at a temperature of 23,000±0,005 °C.

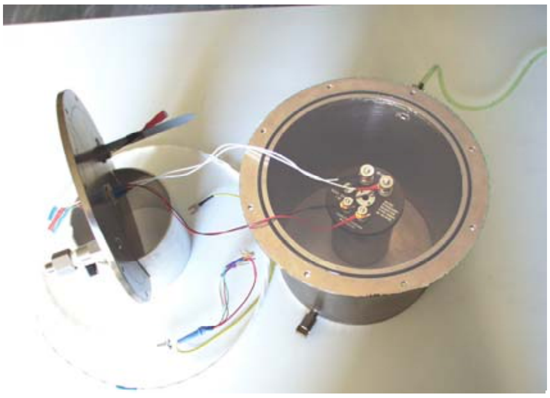

Fig 3 – Internal view of the hermetic container: in the figure are also visible the low EMF cables utilised for the measurements.

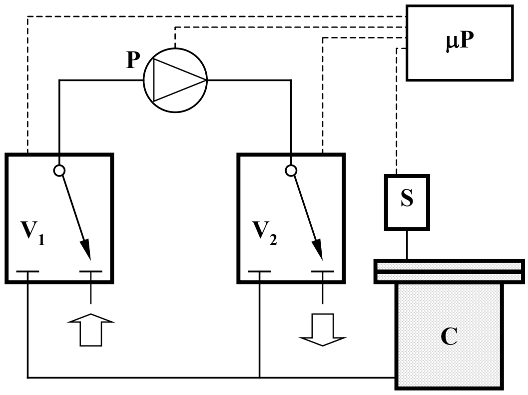

Fig 4 – System for the control of the pressure: P is is the pump in neoprene, V_1 and V_2 two electric-valves, S is a pressure transducer, C is the container and uP is the electronic circuit of control and regulation.

The pressure source was developed using a KNF NMP 50 pump and two valves Bosch connected as in scheme of Fig. 4. The direction of pumping never changes and the regulation of pressure is obtained acting on the two valves. In a case, selecting one valve, environment air is moved inside the container increasing the pressure. The acting of the second valve determines the decreasing of the pressure. During the resistance high precision measurements the valves are not acted and stay in stand-by. The obtained pressure is measured by means of the Druck PDR800 transducer whose output is connected to a multimeter. The measure of the resistance is performed by a current comparator bridge Guildline mod. 6675 with which also temperature measurements are performed with platinum thermometers. All components of the system are connected to a PC and the measurement procedure is completely automatic

III. Preliminary results

By using the hermetic container, varying the pressure inside the container at three pressure values (600 mbar, 1000, mbar and 1350 mbar) and maintaining the temperature at the level of 23,00 °C, we observed the pressure behaviour of three high precision standard resistors. The measurements were performed using a Guildline bridge mod. 6675 by comparison with the group of 1 Ω resistors constituting the maintained national standard of dc electrical resistance at IEN.[1, 2] and only increasing the pressure values starting from a pressure of about 600 hPa to a pressure of about 1350 hPa. In Fig. 5 is reported the behaviour versus pressure condition of a Thomas type Leeds & Northrup 1Ω high precision standard resistor.

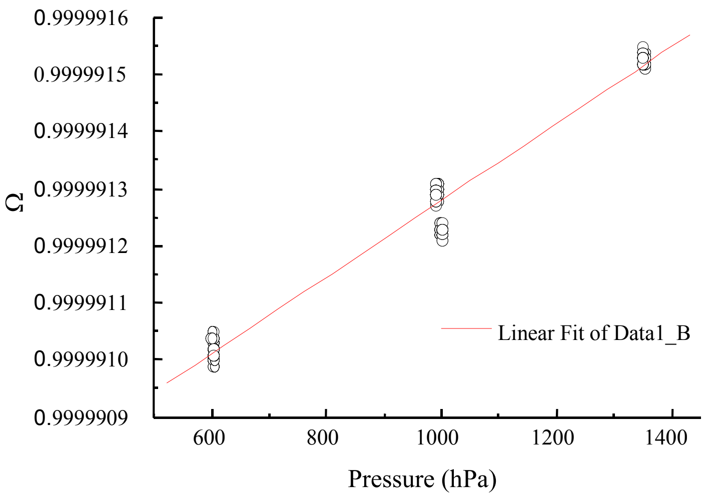

Fig. 5 - Behaviour of the Leeds & Northrup 1Ω resistor (s/n 1723158) at three pressure conditions.

Also in Fig. 6 is reported the behaviour versus pressure condition of another 1Ω type Thomas high precision standard resistor.

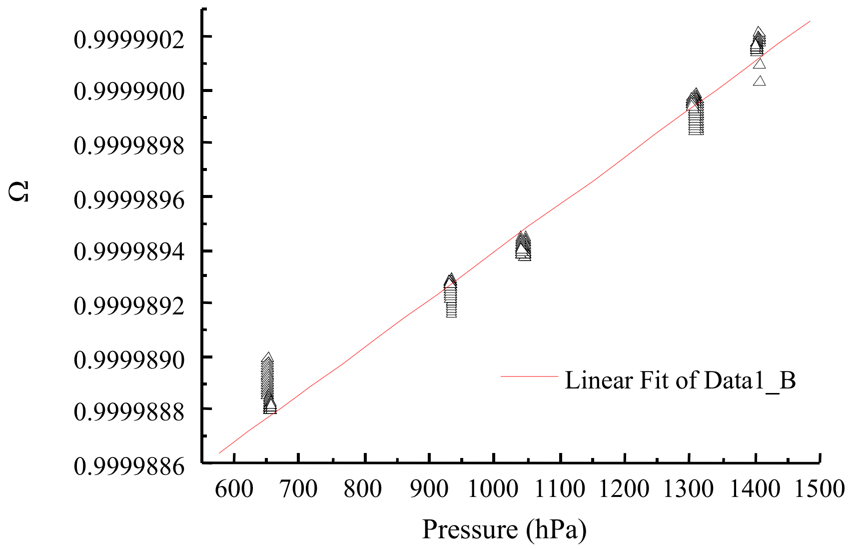

Fig. 6 - Behaviour of the Leeds & Northrup 1Ω standard resistor (s/n 169855) vs. pressure conditions.

From the analysis of these two figures the resistive values seem to have a simple linear behaviour versus pressure condition following a relation as:

$$R(p) = \mathrm{R}(p_0)\cdot(1+\varphi\cdot p) \qquad (1)$$

where R is the resistance value and p the pressure in the hermetic container in which the resistors are maintained and φ the pressure coefficients of the resistors.

We determined, for the two considered resistors, the following pressure coefficients:

Table 1 - Pressure coefficients of the two investigated resistors.

Resistor	Pressure coefficient
Thomas 1Ω s/n	$\cong 6{,}5\cdot 10^{-10}$Ω/hPa
Thomas 1Ω s/n 169855	$\cong 1{,}9\cdot 10^{-9}$Ω/hPa

In Fig. 5 and 6 we can see a significant spread of the measurements when the pressure value in the hermetic container is varied: this is probably due to a transitory variation of the temperature in the container at the moment of the programmed variation of pressure due for example to the moving of environment air inside the container to increase the pressure.

As a matter of fact in Fig. 7 are reported the measurements performed at a pressure of about 1000 hPa.

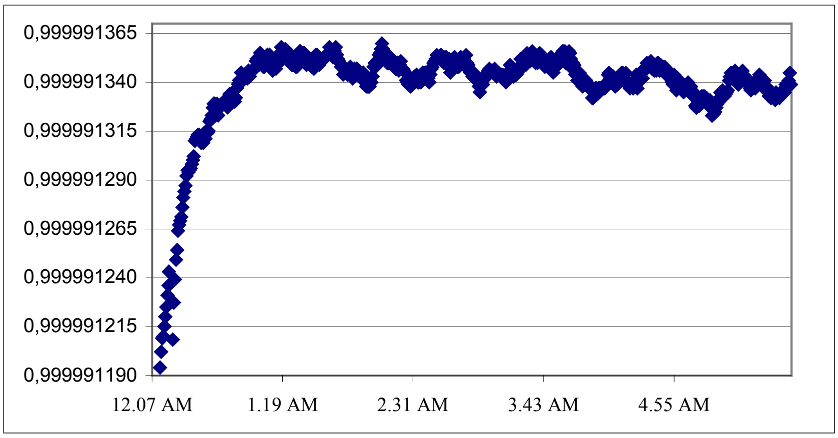

Fig. 7 - Behaviour of the Thomas type Leeds & Northrup 1Ω standard resistor (s/n 1723158) during the time period in which the environment pressure was maintained at a pressure of about 1000 hPa.

With the same measurement system a Leeds & Northrup mod. 4030-B 100 Ω (s/n 681955) high precision standard resistor was also measured with the same measurement procedure. In this case it was not possible to detect a significant variation of the value of the resistor vs. and the to determine a pressure coefficient. At the moment it is not possible to say if this result was due to an effective insensibility to pressure variation of the considered resistor or to a defect in the measurement system and procedure.

IV Acknowledgements

The authors wish to thank D. Serazio and F. Francone for their competent and precious contributes for the development of the equipment for the measurements of resistance versus pressure.

V Conclusions

The paper describes the development and the characteristics of a measurement system of pressure coefficients of high precision standard resistors. The system is employed to characterise and for a better definition of the behaviour of standard resistors with respect the influence environment parameters. Future aims of the work with this system will be the characterisation vs. pressure of more different kinds of resistors, the study of the time period whit which a standard resistor reaches a stabilisation value at a definite pressure value and the verification of possible hysteresis phenomena on the value of a resistor when the pressure in on the resistor itself is increased and then decreased.

References

[1] CIPM, 1988, Recommendation 2 "*Representation of the ohm by means of the quantum Hall effect*",(PV, 56, 45).

[2] F. Delahaye, "*DC and AC Techniques for Resistance and Impedance Measurements*", Metrologia 1992, 29, 81-93.

[3] H.Karlsson, T, Sorsdal, "Pressure coefficient of 1 Ω Thomas-type resistance standards", Metrologia 1996-96, 32, 389-391.