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EFFECT OF TEMPORARY TEMPERATURE CHANGE ON STABILITY OF WIRE-WOUND RESISTANCE STANDARDS

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Abstract: Irreversible resistance changes of Thomas type 1 ohm resistors according to temporary temperature change is about 0.03 ppm/y in average by reported results of PTB, IEN and NIST, but the behavior did not occur in NML 1 ohm resistors under the same condition. By qualitative analysis based on thermal stress and strain, it is considered that a major element of the behavior is thermal stress by different thermal expansions of coils and mandrels.
Keywords: irreversible resistance changes, Thomas type resistors, NML type resistors, thermal stress

1 INTRODUCTION

In July 1993, maintenance temperature of our 1 group composed of 7 Thomas type 1 resistors and NML 1 resistors is temporarily changed from 25°C up to 34°C and down to 25°C again. As the results, irreversible resistance changes of group mean value of our legal ohm produced during the temperature cycle is -0.30 ppm and so the change rate of resistance by temperature is about 0.03 ppm/y. Also, drift slope of the legal ohm was changed from +0.06 ppm/year at 25°C to -0.08 ppm/year after temporary temperature change.

2 PREVIOUS RESULTS BY PTB, IEN AND NIST

In PTB results, the irreversible resistance changes of Thomas type one ohm resistors were as large as several parts in 10^7[1] and so average irreversible resistance changes for several temperature cycle is about 0.03 ppm/y. In IEN results, the same irreversible behavior of the resistors was observed for small temperature change from 20°C to 23°C and drift slope of primary group of the resistors was also changed[2]. The irreversible change in IEN is about 0.02 ppm/y. In NBS results, the value is about 0.03 ppm/y[3]. From these results, it can be considered that irreversible resistance changes of Thomas resistors by temporary temperature change near room temperature is about 0.03 ppm/y in average. We also had similar results to them as mentioned in the above introduction and we will give an explanation on the mechanism of the irreversible behavior by thermal stress and strains.

3 AN ANALYSIS ON IRREVERSIBLE BEHAVIORS BY THERMAL STRAINS

In Thomas resistors Manganin coils are mounted on the brass container impregnated with shellac varnish and thermal expansion of coils, brass and shellac is different during temporal temperature change. Coils of NML resistors have clearance fit for stress-free mounting and only radial expansion is allowed. Fig. 1 shows mounting structure of Thomas and NML type one ohm resistors. We consider, by comparison of these two structure, main factor on the irreversible behavior is coating of shellac-varnish because expansion coefficent of the coating is about 60×10^{-6}/°C, but that of Manganin is about 18×10^{-6}/ and that of brass container is about 14-18×10^{-6}/°C and thus the coils suffer from large thermal stress. This stress produces microscopic thermal strains and the strains influences on resistivity change which result in irreversible resistance changes[4].

4 EXPERIMENTAL RESULTS

A. XRD analysis

To simulate real mounting structure we prepared three type of bare Manganin wire, Manganin coated with shellac-varnish and Manganin on brass blocks coated with shellac-varnish. The samples of three type annealed at 100° during 30 minutes.

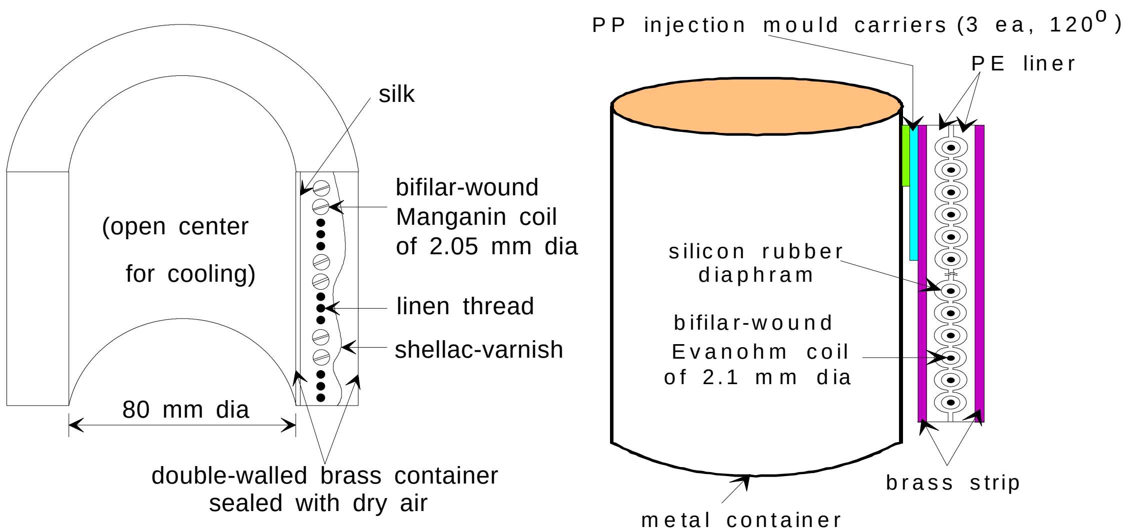

Figure 1. Mounting structure of Thomas type(left) and NML type 1 ohm resistors(right)

We used RIGAKU D/MAX 2200V in Japan as XRD equipment and experimental condition is as followings.

- Radiation : Cu ká, Load : 30 kV, 30 mA
- Scanning range(2è) : 40 ~ 140 °
- Scan speed : 5 sec. / 0.05 °

We analysed the measurement results using RIETAN program, one of the Rietveld method[5], and then we obtained lattice parameters as followings. Here, value in parenthesis means measurement uncertainty.

- bare Manganin : 3.6578(7) ,
- Manganin coated with shellac : 3.6575(6)
- Manganin on brass container coated with shellac : 3.6542(26)

The third value of the above results simulate real structure and the difference between the first value and the third value is about -0.0036, that is, compressive lattice strain. It means decreasing irreversible resistance change as shown in the drift behavior of KRISS legal ohm as previously described. Even Manganin coated with shellac, its lattice parameter is nearly the same as that of bare Manganin. It means that mounting structure the coils fastened tightly by insulation coating on metal container is not good for reversible behavior or resistance stability.

B. Drift rate of Thomas and NML one ohm resistors

Since 1990, we determined the drift rate of one ohm group and NML one ohm resistors as QHR-based SI values by comparison with BIPM, NML, ETL and NIST as shown in figure 2. In the results, drift rates of three NML resistors are little changed after temporary temperature change while that of KRISS one ohm group is severely changed and this is also supported by compressive lattice strain obtained by experiment A

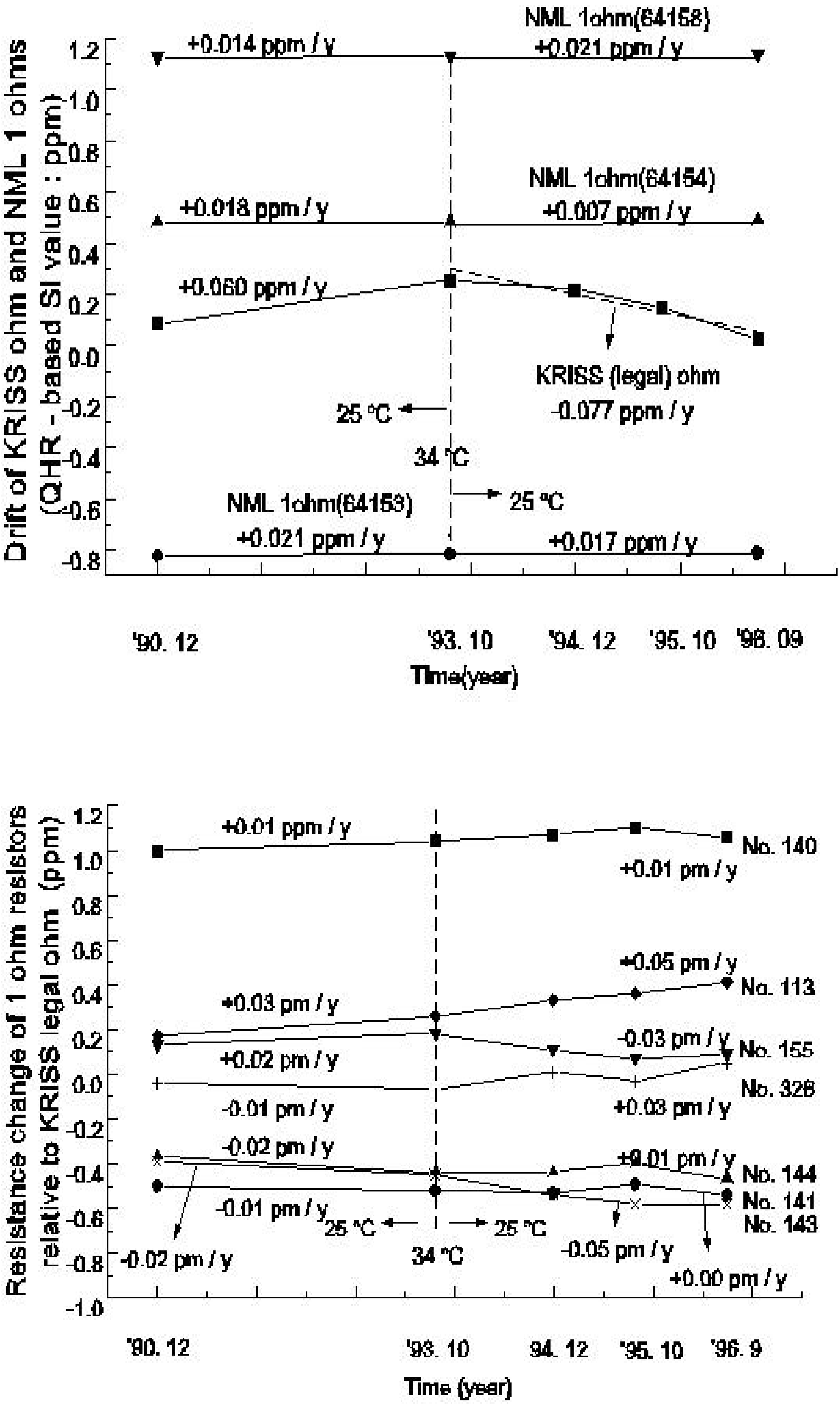

Figure 2. Drift rate of KRISS legal ohm and NML one ohm resistors(above) and Thomas one ohm resistors(below)

5 CONCLUSIONS

Irreversible resistance changes of the mean value of the legal ohm and the Thomas resistors is about 0.03 ppm/y in average according to our experiments. We analysed the mechanism of the irreversible behavior by thermal strain of Manganin coils resulted from different thermal expansions of elements of mounting structures. It can be considered that fastening or encapsulating of resistor coils by insulation coatings is not good to make wire-wound resistors with resistance stability of order of 10^{-8} and for resistance measurements of the level because of irreversible behavior. Long-term creep effect may not be influenced on the behavior because of the irreversible resistance change is very small. It is thus concluded that plastic strain of Manganin coils by mounting structure may be a origin of irreversible resistance changes of Thomas resistors.

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