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NEW DESIGN OF HIGH RESISTANCE TRANSFER DEVICES AND MODERNIZATION OF EXISTING ONES

In order to ensure the traceability of measurements of the high resistance standards in relation to the basic QHR standard, for the new double-track system, new transfers devices for the second track were designed. The previously constructed transfer devices for the single-track system were also modernized. Design of new transfer devices and modernization solutions of already developed ones have been presented.

Keywords: resistance transfer device, resistance scaling system, high resistance.

NOWE TRANSFERY DUŻYCH REZYSTANCJI ORAZ MODERNIZACJA ISTNIEJĄCYCH

W celu zapewnienia spójności pomiarowej wzorców dużych rezystancji w stosunku do wzorca pierwotnego QHR, opracowano nowy dwutorowy system przekazywania jednostki rezystancji z nowoopracowanymi transferami rezystancji dla drugiego toru tego systemu. Wcześniej opracowane transfery rezystancji dla systemu jednotorowego zostały zmodernizowane. Projekt nowych transferów oraz rozwiązania modernizacyjne wcześniej opracowanych transferów zostały przedstawione.

Słowa kluczowe: transfer rezystancji, system przekazywania jednostki rezystancji, wysoka rezystancja

1. INTRODUCION

Research work on high resistances transfer devices was initiated at the Wroclaw University of Technology in 2008. The purpose of this work was to create in Poland a system of transferring the unit of resistance from the QHR (*Quantum Hall Resistance*) standard to high resistances up to 100 TΩ. First, a one-path system was developed [1]. This system had a significant drawback. The transfer of the unit from the primary standard to the witness standards with only one path was implemented, therefore its accuracy couldn't be verified experimentally. To verify the results, a new concept for a two-path transfer system was developed [2]. In the first path in the range of 10 kΩ - 100 TΩ, transfer devices developed as part of the previously developed one-path system [3] have been used, but after significant modernization. This path includes two transfer devices with single insulation (10-100-1000) kΩ and (1-10-100) MΩ and three transfer devices with double insulation (0.1-1-10) GΩ, (10-100-1000) GΩ and (1-10-100) TΩ [4]. For the second 100 kΩ - 1 TΩ path, new transfer devices were developed, one with single insulation (0.1-1-10) MΩ and three with double insulation (10-100-1000) MΩ, (1-10 -100) GΩ and (0.1-1-10) TΩ.

2. TRANSFER DEVICES WITH SINGLE INSULATION

In transfer devices with single insulation, changes of the transfer configuration, from serial to parallel and serial-parallel, are made with copper bars tightened with binding posts. In the design solutions of new and modernized transfer devices with single insulation, PE 300 polyethylene insulation has been used, which has low susceptibility to accumulate charge, but high volume resistivity of 10^{17} Ω·cm, which is an order of magnitude less than the volume resistivity of PTFE, used in previous designs. However, relative errors from insulation leakage do not exceed approx. 2×10^{-7}, and therefore an acceptable value.

Similarly to the previous designs [3, 4] to minimize the impact of air humidity changes, the resistors are placed in hermetic aluminum enclosures, which also provide protection against external electromagnetic interference.

To minimize the influence of temperature on the resistance value in transfer devices, precise resistors of 100 kΩ and 10 MΩ with the smallest temperature coefficient of resistance TCR = ±1 ppm/° type HR5032N, made by PRC Precision Resistor were used. On the other hand temperature of resistors inside transfer device housing is controlled. To prevent heat transfer between the metal housing of the transfers and the surroundings, the outer sides of the housing were covered with thermal insulation (foamed PVC). The constant temperature in transfers (23 ± 0.01) °C is maintained by means of two Peltier elements, placed on a metal transfer device housing. Peltier elements are connected to the temperature controller, controlled from the Pt-100 sensor located inside the casing [3, 4].

The new (0.1-1-10) MΩ transfer device and upgraded transfer devices (10-100-1000) kΩ, (1-10-100) MΩ are use four-terminal connection. This eliminates the influence of the resistance of the connecting cables and contact resistance. The external view of this transfer device is shown in Figure 1.

Fig. 1. New design of four-terminal single insulation transfer device

3. TRANSFER DEVICES WITH DOUBLE INSULATION

In the new design solution of double-insulated transfer devices, the basic layout of connections has not changed, but at the input and output of the transfer device, Triax type connectors have been doubled (Fig. 2).

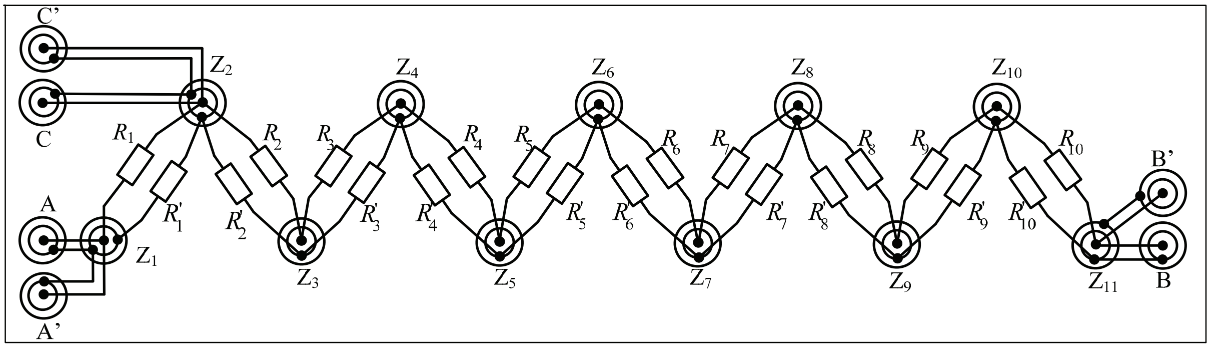

Fig. 2. Schematic diagram of new double insulation transfer device

For the construction of transfer devices with double insulation, high-precision resistors made to our order by the Swiss company Nicrom Electronic were used. In the main network, these are 400.5 type resistors with a maximum power of 7.5 W and parameters: 1 MΩ ± 0.05%, *TCR* = 10 ppm/°C, *VCR* = 0.15 ppm/V, 100 MΩ ± 0.05% , *TCR* = 10 ppm/°C, *VCR* = 0.15 ppm/V and 1 TΩ ± 0.1%, *TCR* = 25 ppm/°C, *VCR* = 0.30 ppm/V. In the guarded network, analogous resistors were used but with nominal values 100 times smaller.

In modernized transfer devices (10-100-1000) GΩ and (1-10-100) TΩ, guarded network resistors were replaced with ones with 100 times smaller resistance, which ensured a significant improvement in their metrological parameters. However, the main network of the transfer device (1-10-100) TΩ is still composed of 10 TΩ resistors from Welwyn type 3812 with *TCR* = (-500 ÷ -3500) ppm/°C. The guarded network uses 100 GΩ resistors type 3811 of the same company with the same *TCR*. Large values of *TCR* and *VCR* coefficients significantly reduce accuracy. Unfortunately, 10 TΩ resistors with better parameters are not offered by any company. Even the most specialized in the production of high-resistive resistor company Nicrom Electronic did not make more precise 10 TΩ resistors.

Resistors with the highest resistance values are susceptible to the influence of humidity, which causes the appearance of noticeable currents on their surfaces. Therefore, to eliminate this effect on the accuracy of the transfer, additional electrodes were used on the glass cover of the resistors which were connected to the guarding network in the manner shown in Fig. 3.

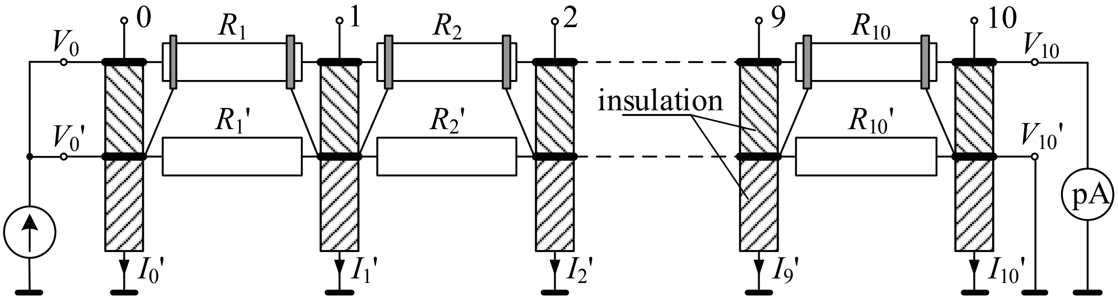

Fig. 3. Elimination of surface currents of resistors in high resistance transfer devices with double insulation

The new transfer devices, intended for the second path of the system, have a changed mechanical structure (Fig. 4).

Fig. 4. New design of double insulation transfer device

These transfer devices differ, from previous designs, the front plates and shortening bars for parallel and serial-parallel connections. Shortening bars design uses adapted Triax coaxial plugs, originally intended for mounting on coaxial cables. This allowed to eliminate short intermediate cables and increase the reliability of the connection, as well as reduced the cost of the shortening bars by half, because only half of the connectors used before are used to make the shortening bars. In this design solution, the plugs and sockets are rigidly attached to their plates. However, this requires precise alignment of the pins of the jumpers and sockets mounted on the front plates. That is why front panels and shortening bars were designed with computer aided design (CAD) software and made with numerically controlled (CNC) machine tools. This ensures high precision of dimensions in the construction.

The adaptation of the Triax coaxial plugs consisted of adding a fine-thread on the outside of the plug and making three knurled nuts with the same thread (Fig. 5).

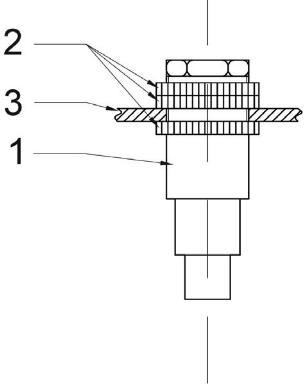

Fig. 5. Modernized mechanical design of the Triax plug: 1- threaded plug cover, 2 - knurled nuts, 3 - shortening bar mounting plate

4. CONCLUSION

The main goal of our work on the design of transfer devices is to ensure their highest transfer accuracy and reliability. The presented high resistance transfer devices are the next third generation design. Designing them, we based not only on the knowledge drawn from the available literature, but above all on our own experience and the results of our research. We have made every effort to ensure that these are transfer devices with the best possible metrological parameters. Practical use of them in the Central Office of Measures will allow us to evaluate the design of these devices and, if necessary, make further improvements.

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