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DESIGN OF A SIMPLE THERMAL CONTROL FOR GAS-DIELECTRIC STANDARD CAPACITORS

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Abstract: A two terminal-pair coaxial capacitance bridge was built recently at Inmetro. It operates mainly at 1 kHz and 1.592 kHz and compares decadic capacitors in the range from 10 pF to 1 nF at the ratios 1:1 and 10:1 and 1:10, with an uncertainty of about one part in 10^8. The 1 nF standard capacitors commercially available are made from invar with gas dielectric. Such capacitors have a temperature coefficient of (0 ± 2) µF/F per K. This is too high if one plans to use them in a traceability chain to derive the capacitance unit from the quantum Hall resistance. The design of a simple thermal control for gas-dielectric capacitors to reduce by two orders of magnitude their temperature variation is presented here.

1. INTRODUCTION

The two terminal-pair coaxial ratio bridge built recently at Inmetro with technical support of PTB and CENAM operates mainly at 1 kHz and 1.592 kHz and compares decadic capacitors in the range from 10 pF to 1 nF at the ratios 1:1 and 10:1 and 1:10, with an uncertainty of about one part in 10^8. The bridge operating principle is discussed in [1]-[4].

The 1 nF standard capacitors commercially available are made from invar with gas dielectric. Such capacitors have a temperature coefficient of (0 ± 2) µF/F per K (some may even exceed this specification). This is too high if one plans to use them in a traceability chain to derive the capacitance unit from the quantum Hall resistance where a short term stability of a few mK is needed.

The design of a simple thermal control for gas-dielectric capacitors to reduce by two orders of magnitude their temperature variation is presented in section 2. The conclusions are drawn in section 3.

2. DESIGN

The internal construction of the gas-dielectric standard capacitor GR-1404 is shown in Fig. 1. The output connectors are removed and replaced by coaxial cables. The metallic can containing the gas-dielectric capacitor is covered with just one layer of Kapton tape. The heater is bifilar wound to minimize the magnetic field generated. A few turns of bare 0.25 mm dia. manganin (or constantan) wire were then laid upon the Kapton tape to obtain a resistance of about 30 Ω. The thermistor is part of the thermal controller and is installed in the middle of the metallic can in between two parallel heater wires (without touching them). The heater and the thermistor are then protected with another layer of Kapton tape. Since the heater will be supplied from a 12 V dc source, we expect the dissipated power to be about 5 W. The thermal controller is designed so that the temperature of the standard is about 5 K higher than the ambient temperature of 23 °C.

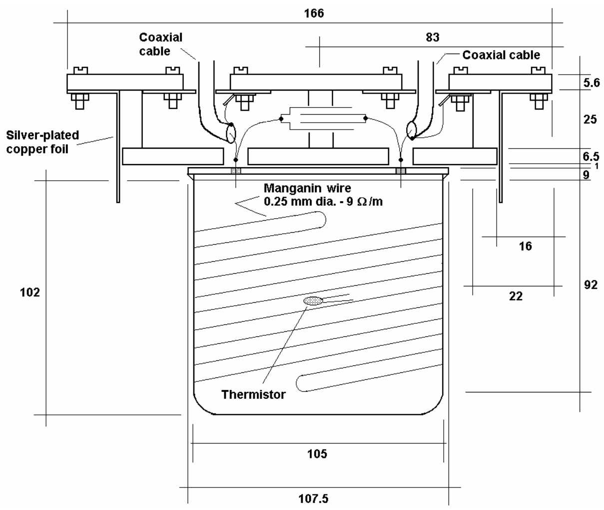

***Fig. 1**. Gas-dielectric capacitance standard (front view of the internal construction).*

A platinum resistance (PT100) is installed in a silver-plated copper cylinder fixed to the top metallic structure near the pump out port (Fig. 2). The PT100 is used to measure the actual temperature of the standard. An electrostatic shield made from silver-plated copper foil is fixed to the metallic structure. Figure 3 shows its top view. This shield protects the coaxial cable leads from external electromagnetic fields (note that the metal box that previously provided such protection was removed).

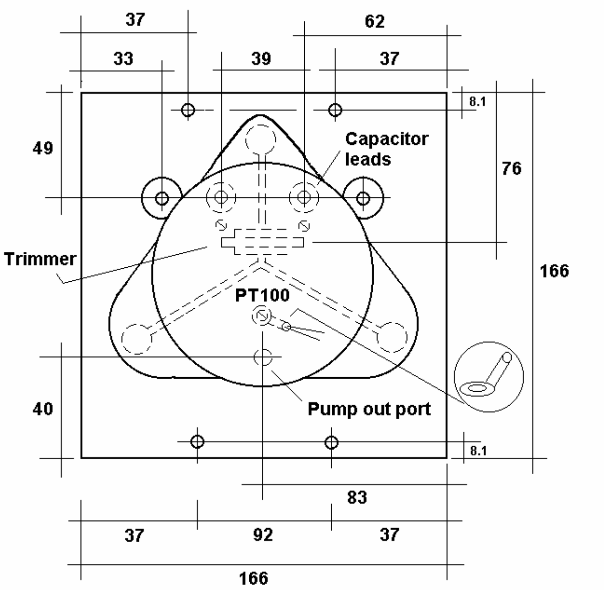

Fig. 2. *Gas-dielectric capacitance standard (bottom view of the internal construction).*

The whole standard is inserted in a thermally-insulated box (Fig. 4). It consists of a box made from brute wood. The standard is isolated from the wooden box by several overlapped 25 mm – thick extruded polystyrene slabs (trade names: Styrodur, Styrofoam or Polyfoam). The thermal controller printed circuit board is placed in the bakelite-resin box located at top right. The thermistor is connected to the temperature controller through a cable (not shown). The controller supplies the heater with a cable (also not shown). All cables including the coaxial ones should have loops to minimize the undesirable thermal conduction. We decided to suppress the guide tube for the trimmer capacitor in order to minimize the heat exchange between the standard and the external environment. Any adjustment shall be made by disassembling the unit.

The circuit schematics of the one-stage temperature controller is shown in Fig. 5. The Wheatstone bridge comprises two resistors, a 10-turn potentiometer (rectangular style) and the thermistor. The bridge error voltage is amplified and compared with a reference voltage. A common-collector transistor is used as a buffer stage to drive the heater. The three diodes are required to shift the quiescent point of the transistor so that the heater current smoothly counteracts the temperature changes. In order to reach a short term stability of a few mK, a thermally-insulated aluminum box is inserted in between the temperature-controlled metallic can and the wooden box (Fig. 4).

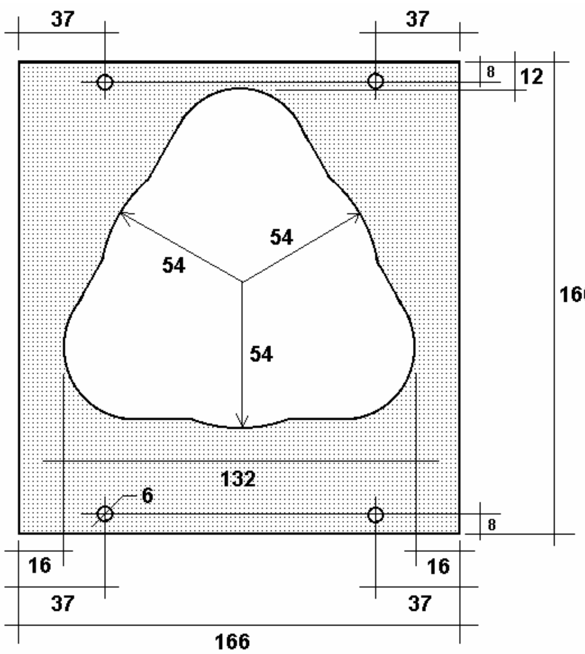

Fig. 3. *Electrostatic shield (top view).*

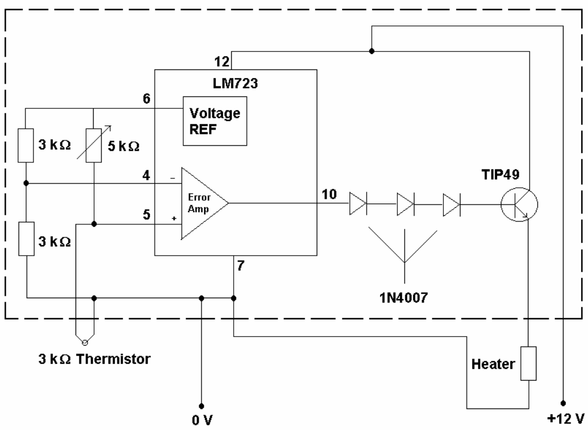

Fig. 5. *Temperature controller.*

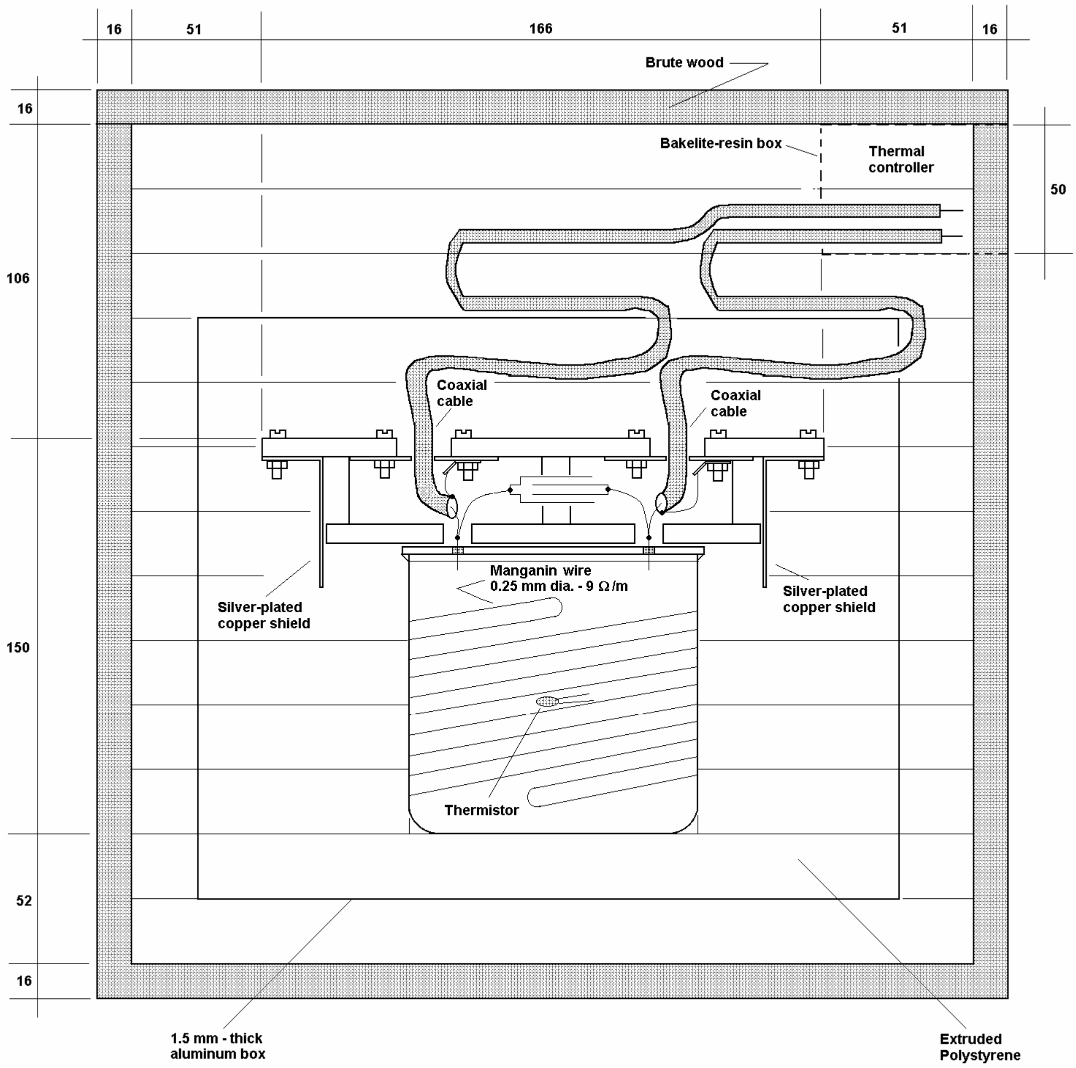

Fig. 4. *Thermal control assembly.*

3. CONCLUSIONS

The design of a simple thermal control for gas-dielectric capacitors to reduce by two orders of magnitude their temperature variation was described. A prototype was built and it is estimated that the design requirement will be attended by the final assembly. Five assemblies are currently under construction at Inmetro.

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