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THERMALLY-CONTROLLED GAS-DIELECTRIC STANDARD CAPACITORS CONSTRUCTED AT INMETRO

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Abstract

Gas-dielectric standard capacitors have a temperature coefficient of (0 ± 2) μF/F per K. This is too high for deriving the capacitance unit from the quantum Hall resistance. A standard capacitor was thermally controlled to reduce by two orders of magnitude its temperature variation. The construction details and the experimental results are discussed.

Construction details

The internal construction of the gas-dielectric standard capacitor GenRad-1404 is shown in Fig. 1. The output connectors were removed and replaced by coaxial cables. The NTC thermistor (with 2.4 mm body dia.) is part of the thermal controller (Fig. 2) and is installed in close contact with the metallic can containing the gas-dielectric capacitor. Both the metallic can and the thermistor are covered with just one layer of Kapton tape. The heater is bifilar wound to minimize the magnetic field generated. Five turns of bare 0.25 mm dia. manganin wire (with resistance of 9 Ω/m) were then laid upon the Kapton tape to obtain a resistance of about 30 Ω. The thermistor is positioned in between two parallel heater wires in the middle of the metallic can. The heater and the thermistor are then protected with another layer of Kapton tape.

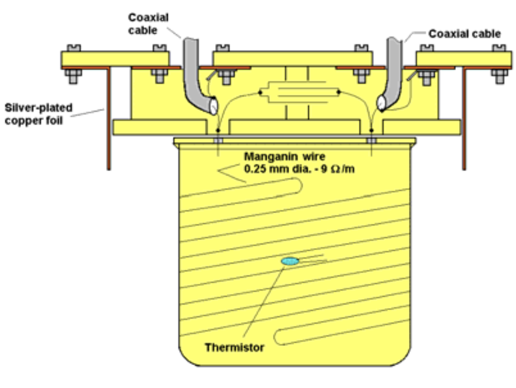

Fig. 1. Gas-dielectric standard capacitor.

The heater is supplied from the controller output buffer. The thermal controller (Fig 2) is designed so that the temperature of the standard is a few degrees higher than the ambient temperature of 22.5 °C. Attention was given to the design of the transistor heat sink. The transistor is fixed to the black-painted front panel (which also acts as a heat sink) (see Fig. 3). The transistor metallic body (collector) is insulated from the front panel with a thin mylar foil.

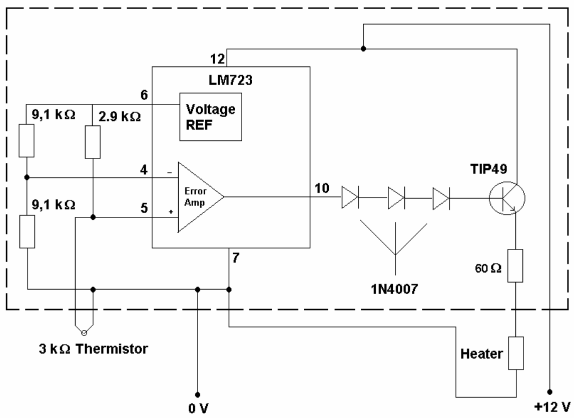

Fig. 2. Thermal controller schematics.

A platinum resistance probe (PT100) is installed (with thermal paste) in a silver-plated copper tube fixed to the top metallic structure near the pump out port. The PT100 is used to measure the actual temperature of the metallic can. An electrostatic shield made from silver-plated copper foil is fixed to the metallic frame (Fig. 1). This shield protects the coaxial cable leads from external electric fields.

The whole standard is inserted in a thermally-insulated box (Fig. 3). It consists of a box made from enameled brute wood. The standard is insulated from the wooden box by several vertically overlapped 25 mm – thick extruded polystyrene slabs. In order to reach a short term variation of a few mK, a 1 mm – thick aluminum box is inserted between the temperature-controlled metallic can and the wooden box (distance between the aluminum wall and the metallic can – 50 mm; distance between the aluminum wall and the wooden wall – 25 mm). The aluminum box acts as an idle second-stage thermal isolation.

All cables including the coaxial ones have loops to minimize the thermal conduction. The coaxial cables are soldered to the isolated BPO/MUSA connectors located at the front panel (Fig. 3).

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Fig. 3. Thermally-controlled standard capacitor.

Performance tests

The unit assembled at Inmetro is shown in Fig. 3. The figure shows the twisted-pair coaxial cables connected to the BPO/MUSA panel connectors (HI and LO terminals of the standard capacitor). The intermediate banana terminals are connected to the PT100 used for sensing the metallic can temperature. The banana terminals on the right are used for energizing the unit with an external 12 V battery.

The two-terminal resistance of a PT100 suspended freely in ambient air was monitored for one week with a digital multimeter (DVM) (Fig. 4). A peak-to-peak temperature variation of about 1 K is shown. The four-terminal resistance of the PT100 fixed to the metallic can was monitored simultaneously with another DVM (Fig. 5). A peak-to-peak temperature variation of about 10 mK is shown. The working day (8 h) is represented by the ranges 0-500 min and 1400-1900 min.

The thermally-controlled, gas-dielectric standard capacitor was compared with a 100 pF fused-silica standard capacitor using a two terminal-pair coaxial capacitance bridge [1]. The results for two consecutive days are listed in Tables I and II. On the same day the morning average differ by two parts in 10^8 from the afternoon average. This is related to the difference between the morning (1500-1700 min) and the afternoon (1700-1900 min) temperatures. But two morning averages (or two afternoon averages) differ by less than two parts in 10^9.

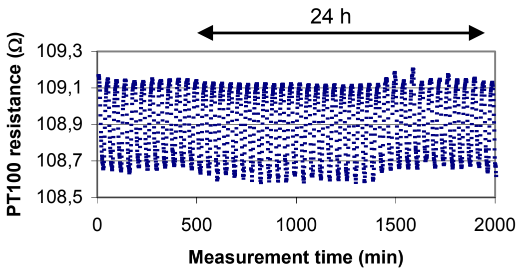

Fig. 4. PT100 resistance (ambient temperature).

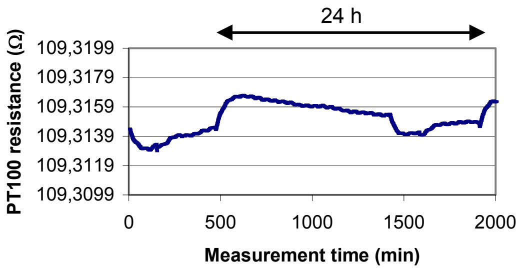

Fig. 5. PT100 resistance (metallic can).

Table I. Capacitance of the standard capacitor.

05Sep2007 morning		05Sep2007 afternoon	
reading 1	0,987807	reading 1	0,987798
reading 2	0,987807	reading 2	0,987784
reading 3	0,987808	reading 3	0,987784
reading 4	0,987808	reading 4	0,987784
reading 5	0,987804	reading 5	0,987784
Average	0,987807	Average	0,987787
St. dev.	1,64E-09	St. dev.	6,26E-09

Note: Add the figure 999 to all readings and averages above.

Table II. Capacitance of the standard capacitor.

06Sep2007 morning		06Sep2007 afternnon	
reading 1	0,987810	reading 1	0,987790
reading 2	0,987810	reading 2	0,987790
reading 3	0,987810	reading 3	0,987786
reading 4	0,987810	reading 4	0,987786
reading 5	0,987806	reading 5	0,987786
Average	0,987809	Average	0,987788
St. dev.	1,74E-09	St. dev.	2,19E-09

Note: Add the figure 999 to all readings and averages above.

Conclusion

The design and construction of a thermally-controlled, gas-dielectric standard capacitor to reduce by two orders of magnitude its temperature variation was described. A unit was built and the experimental results show that the design requirements were satisfied. Four additional units are under construction.

References

[1] G.A. Kyriazis, R.T.B. Vasconcellos, L.M. Ogino *et al.*, "A two terminal-pair coaxial capacitance bridge constructed at Inmetro", in *CPEM Digest*, pp. 94-95, Turin, 2006.