

FULL REAL-TIME TEMPERATURE MAPPING SYSTEM FOR 1.3 GHZ 9-CELL CAVITIES*

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Abstract

The mapping of outer-wall temperatures during the vertical test of a superconducting radio-frequency (SRF) cavity has been one of the most successful tools in studying the cavity loss mechanisms. However, due to the excessive number of sensors needed, no fixed-type temperature mapping (T-mapping) system that covers all cells has been built for 9-cell cavities. With the consensus that T-mapping analysis is needed in order to improve the yield of high-gradient cavities, a system with a reduced data acquisition time and increased temperature sensitivity, compared to rotating-arm systems, has been developed at LANL. The system consists of 4608 100-ohm 1/8W Allen-Bradley resistors placed azimuthally every 10 degrees, a similar number of other resistors and diodes that implement the switching scheme, and data acquisition codes written in LabView. The details of the system and first results are presented and discussed.

INTRODUCTION

This paper continues the description of the system initially presented in [1]. The entire system has finally been assembled and the first tests are being performed. The system consists of 4608 sensors that cover the entire 9-cell cavity. The top cells have 12 each, bottom cells have 11 each and middle cells have 15 each sensors covering one meridian.

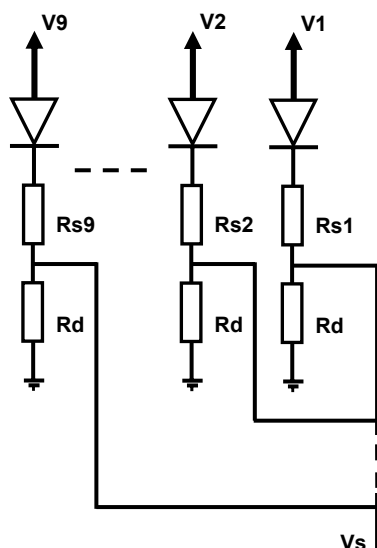


Figure 1: 9-channel switching schematic of temperature sensor resistors R_s .

*Work supported by the US Department of Energy.

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SYSTEM OVERVIEW

The 4608 sensor-resistors are measured through a multiplexed scheme that combines 9 sensor signals into one. This concept is represented in Fig. 1. Only one of the nine bias voltages is provided at a given time, allowing reading the information of the resistance variation of any given sensor. For example, if V_1 is provided, making the other eight ($V_2, V_3 \dots V_9$) equal to zero, the expected sensor voltage in terminal V_s can be expressed as

$$V_s = \frac{V_1 - V_d}{R_{s1} + \left(\frac{9}{R_d}\right)^{-1}} \cdot \left(\frac{9}{R_d}\right)^{-1},$$

where V_d is the voltage drop across the diode and R_d is the driving resistance. Since the resistance of the Allen-Bradley resistors changes with temperature, as shown in Fig. 2, the voltage V_s will increase with increasing temperature.

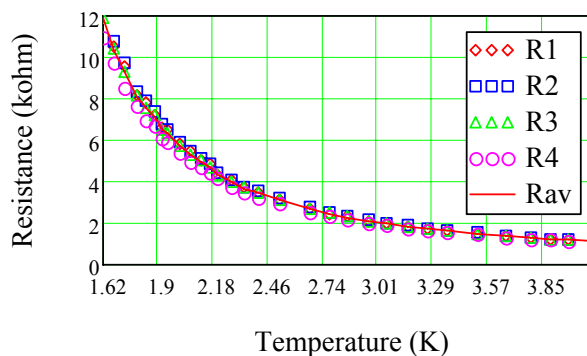


Figure 2: Temperature dependence of 4 Allen-Bradley resistors and its average value.

It is important to mention that the voltage drop across the diodes also change with temperature, but a simple circuit in each board (covering three cells) monitors this voltage drop. This voltage drop is used to determine the bias voltage to be delivered to each of the 9 voltage lines, which for optimal performance should be 1.2V over the voltage drop according to self heating limitations [1]. The same temperature dependence also applies to the driving resistors (450k Ω). However, the change of these resistors is minimal, although it is also monitored.

The design of the boards takes this into consideration and the diodes and driving resistors are placed far from the cavity surface (at least 2 inches). This guarantees that the diodes and driving resistors have a constant value

(whichever these are) throughout each experiment. Therefore, the only elements that will be affected by a change of temperature on the cavity surface will be the Allen-Bradley resistors. In Fig. 3 a picture of two sensor boards covering three cells and the electrical layout of these are shown.

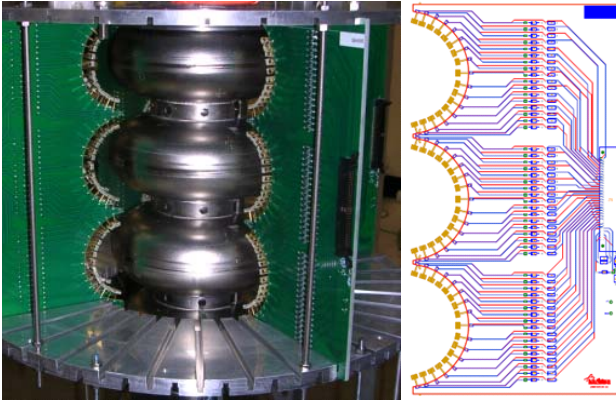


Figure 3: Temperature sensors attached along the contour of cavity cells (left). Electrical printed circuit board layout for a T-map sensor board (right).

SYSTEM ASSEMBLY

In order to perform the sensor switching inside the cryostat to minimize the number of cables coming out, all the wires from the sensor boards go to a common board called “mixing” board. This board combines all the signals and the 9 voltage supply lines plus ground to perform the scheme presented in Fig. 1.

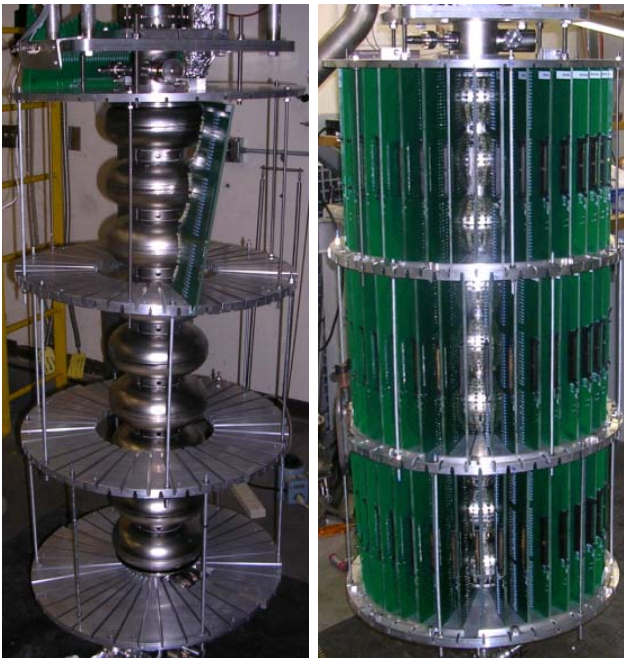


Figure 4: A 1.3 GHz, 9-cell cavity with T-mapping boards supporting plates (left) and full assembly of boards around the cavity (right).



Figure 5: Cryostat insert showing the T-mapping boards along with connecting cables.

From the “mixing” board only 12 ribbon cables of 60 wires each plus one ribbon cable of 10 wires (carrying the 9 voltages and ground) are run from the mixing board all the way to the top of the cryostat, right below the cryostat lid. Here, another board connects these cables and bridges over to the outside of the cryostat where another board is placed. A special KF40 hermetic feedthrough including 678 manganin wires was made in house to connect the cables between inside and outside of the cryostat. These cables present a low thermal conductivity, allowing for a tolerable heat conduction into the cryostat. Finally, from the board outside the cryostat, ~80 feet long cables carrying the 720 signals connect to a final board that interfaces with the data acquisition hardware. Figure 4 shows the 9-cell cavity before and after all the sensor boards are attached. In Fig. 5, all the cables connecting the sensor boards to the mixing board (behind) are shown, along with the 12 ribbon cables going to the top of the cryostat insert.

DATA ACQUISITION HARDWARE

The data acquisition hardware is based on a National Instruments (NI) 8-PXI & 4-SCXI chassis configuration system. The PXI modules are:

- 1 × embedded controller (dual core)
- 4 × digital multimeters (DMMs)
- 1 × power supply
- 1 × 48-multiplexer

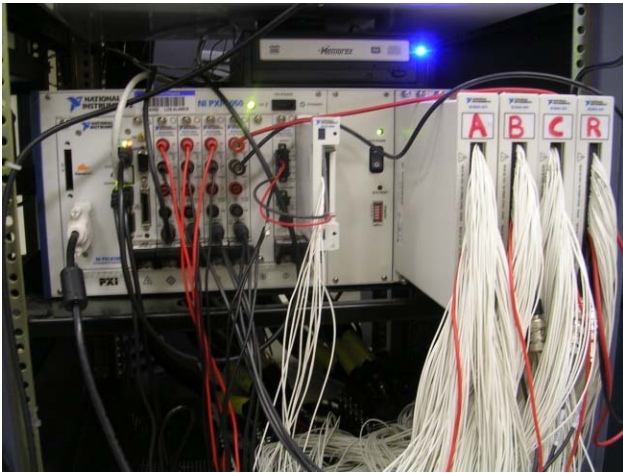


Figure 6: Front view of National Instruments' T-mapping data acquisition hardware.

The SCXI modules are:

- 4 × 256 multiplexer

The PXI power supply voltage is switched 9 ways through the PXI 48-multiplexer to bias each of the 9 sectors of the cavity (40 degrees). This can be seen in Fig. 6, which shows a photograph of the NI equipment with all the wiring.

DATA ACQUISITION SOFTWARE

The software was written in Labview, which performs the acquisition of 624 1-wire voltages plus 48 2-wire resistance measurements. The first 3 DMMs/Multiplexers acquire the 1-wire voltages and the last DMM/Multiplexer acquires the 2-wire resistances. The 1-wire measurement also includes monitoring of the voltage drop across diodes. To acquire and process the 4608 sensor voltages (whole cavity), 9 whole acquisitions through the multiplexers are required. This is done by switching the power supply to one of the 9 voltage lines after an acquisition of the 624 voltages and 48 resistors. Before feeding RF power into the cavity, a data from all sensors are collected and used as a reference state. Then, all the data acquired thereafter with RF power on are subtracted from this reference state since only the increases in measured voltages of interest. The switching of the 9 power lines along with the acquisition of all the data takes under 5 seconds.

PRELIMINARY RESULTS

A preliminary test on a cavity loaned by Fermilab (AES03) shows two clear hot spots in sector 5, which corresponds to 160-190 degrees. Figure 7 shows a screenshot of the Labview code running with the two hot spots on the 2-D Temperature mapping graph. The software also allows stopping the switching of the power supply and thus locking into one determined sector.

These hot spots are located close to the lower iris of the third cell and around the equator of the fourth cell. The first spot, in the third cell appear before the second one.

This might have shown heating due to field emission since during the test X-rays were generated and detected by the X-ray monitoring system in place. Future tests will further study this cavity.

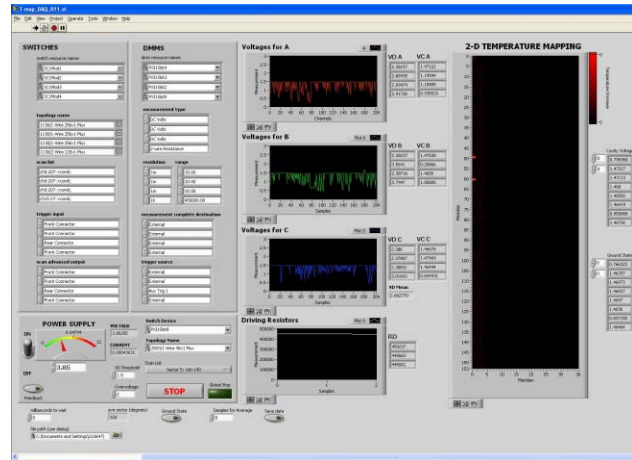


Figure 7: Screenshot of Labview's T-mapping data acquisition and processing software.

CONCLUSIONS

A fixed-type T-mapping system for 1.3 GHz, 9-cell SRF cavities thermometry system has been designed, fabricated and commissioned at LANL. Preliminary test results have been encouraging. The identified hot spots will soon be inspected with an inner surface inspection system being developed at LANL.

ACKNOWLEDGEMENTS

We would like to thank Phil Chacon and Jim Witt for helping with the design of the PCB boards and the mechanical structure. Also special thanks go to David Bonal from National Instruments for his help in understanding the NI equipment along with his expertise in LabView as well as to Bill Biswell and Phil Biswell of BiRa Systems for their effort on timely delivery of parts and good suggestions. We also appreciate the help from John Chamberlin, John Harrison, Heather Martinez, JW Isern, Alan Shapiro and Mike Madrid in putting all the system together as well as the hard work of Robert Montoya and machinists for fabricating parts in a timely manner. Finally, we would like to thank Camille Ginzburg, Mark Champion, Joe Ozelis, Shekhar Mishra of FNAL, Gigi Ciovati of JLab and Grigory Eremeev of Cornell for their help during the commissioning of the system.

REFERENCES

- [1] A. Canabal et al., "Development of a Temperature Mapping System for 1.3-GHz 9-Cell SRF Cavities," Proceedings of the 22nd Particle Accelerator Conference (PAC07), Albuquerque, NM, June 25-29, 2007.