IMPROVEMENTS TO AUTOMATED SYSTEM FOR MEASURING STANDARD RESISTORS AT NIST

Dean G. Jarrett and Theodore P. Moore
National Institute of Standards and Technology*
Gaithersburg, MD 20899, USA

Abstract

Improvements to an automated measurement system at NIST for calibrating four-terminal standard resistors in the range 1 kΩ to 1 MΩ have been made as a result of data analysis. Changes in hardware have included upgrading of instruments and remounting the instrumentation to protect relays from contamination due to mineral oil wicking through the cables connecting instrumentation and standard resistors. A study of data taken over several years has indicated differences in the measured values of 1 MΩ standard resistors depending upon the relative positions the resistors occupied in the bridge circuit. Leakages to ground and the immersion of the ring stands in mineral oil introduce resistances that shunt the bridge. A correlation has been made between this positional effect and the resistance shunting the bridge in each test resistor position. A guarded scanner could contribute towards minimizing this positional effect.

Introduction

An automated system for the measurement of four-terminal standard resistors in the range 1 kΩ to 1 MΩ has been used for several years at NIST [1,2]. Since the bridge was put into service in 1988, several situations developed that required updating the hardware used in the measurement system. Factory upgrades to the commercial instrumentation used in the system have improved component performance, reducing down time for maintenance. Oil wicking through the cable shields to the scanners, coupled with the wearing of relay contacts, reduced the reliability of the system. Eliminating the oil wicking problem and refurbishing of the relays have improved the reliability of the unbalanced bridge.

This recent overhaul of the system has resulted in an investigation of factors that limit the uncertainties achievable by the unbalanced bridge method. This paper will address solutions implemented to improve the system, and propose steps that may lead to reducing the uncertainties assigned to standard resistors calibrated using the system.

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*Electricity Division, Electronics and Electrical Engineering Laboratory, Technology Administration, U. S. Department of Commerce. Official contribution of the National Institute of Standards and Technology;

Oil Wicking

The standard resistors are housed in an oil bath that maintains the temperature at 25.000 ± 0.005 °C, thus providing better temperature control than the ± 0.05 °C that an airbox is able to maintain. The oil bath also allows for more accurate temperature measurements of the resistors due to better thermal coupling between the resistors and the medium. While eliminating the need to correct for variations in temperature, the use of an oil bath does introduce several other problems into the measurement process.

Wicking of the oil through the cables** used to connect resistors in oil baths to instrumentation has been a common problem when the instrumentation is mounted below the level at which the oil rises because of capillary action [5]. In the short term this presents the mess of oil having to be periodically cleaned up as it pools at the instrumentation end of the cables. However, over an extended period of time, this capillary action of the oil has allowed the oil to enter and contaminate the instrumentation. If not attended to, this condition could cause costly and permanent damage to instrumentation. One scanner sent back to the manufacture for refurbishing, after having been in the system for five years, was found to have had oil contamination of its binding posts, internal wiring, and relay boards. A successful cleaning removed the oil and resulted in no permanent damage to the instrument. To avoid this problem in the future, all of the instrumentation was subsequently mounted several feet above the oil level, consequently the wicking of oil ceased. Eliminating the oil wicking not only protects instrumentation but also eliminates the safety hazard of having mineral oil pooled on the laboratory floor.

The scanners and DVM of the system were sent back to the respective manufacturers for refurbishing. This included upgrading the relay drive circuitry of the scanners and updating the firmware of the DVM.

Positional Effect

The presence of the mineral oil also affects the measurement results. The oil shunts the standard resistors along with the leakage resistances of the connecting cables and scanner relays. A correlation has been observed between variations in the values of the standards and their positions on the resistance stand. The variations caused by leakage resistances was verified by measuring the leakage resistance at each position of the stand using a dummy header.*** Figure 2 shows variations of up to 0.4 ppm for several standard resistors at the 1 MΩ level calibrated in different positions of the bridge network. All resistors showed repeatable variations of similar magnitudes when calibrated at various positions in the bridge network. This positional variation

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**Twelve-conductor shielded Teflon cable.

***A standard resistor body with the resistance element removed (open circuit).

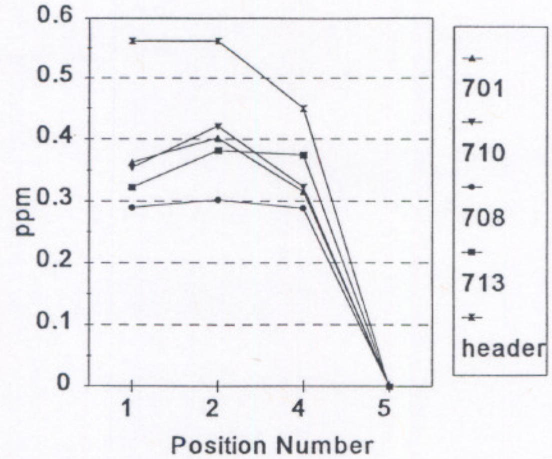

Figure 3. Correlation with shunt resistance for 1 MΩ resistors relative to position 5.

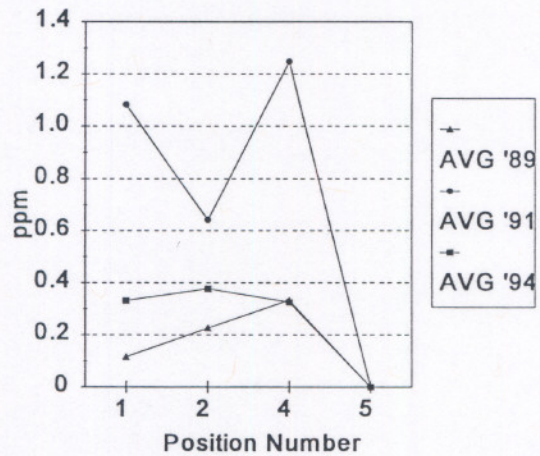

Figure 4. Average deviation of 1 MΩ resistors from position 5.

Proposed Solutions and Conclusions

At the 1 MΩ level, shunt and ground circuit leakage are the dominating factors in the overall uncertainty of measurements on this bridge. Complete guarding of the bridge circuit would reduce this Type B uncertainty. A guarded ring stand would need to be designed along with a guarded scanner to provide full guarding from the resistors to the DVM. The use of a guarded scanner would also have application in bridge networks above 1 MΩ and could be used to do the