CONSTANT TEMPERATURE AND HUMIDITY CHAMBER
FOR STANDARD RESISTORS

Presenter
Dean G. Jarrett
National Institute of Standards and Technology
Gaithersburg, MD 20899, USA
Phone: (301) 975-4240 FAX: (301) 926-3972

Paper Author
Dean G. Jarrett
National Institute of Standards and Technology
Gaithersburg, MD 20899, USA

Abstract
An environmental chamber has been developed for housing standard resistors under controlled
temperature and humidity conditions during calibration in air. Temperature is controlled at
23±0.02 °C by a proportional, integral, and derivative (PID) processor which provides proportional
heating. The input circuitry to the PID is a Wheatstone bridge using thermistors in two opposing
arms for added sensitivity. Constant cooling is provided by a convection Peltier air conditioning
unit. Relative humidity is maintained at 35±5% by aqueous salt solutions. The design allows
sufficient space for standard resistors to be housed in a volume of 0.25 cubic meters with sixteen
pairs of coaxial connectors feeding through the chamber wall to the lab environment. The box is of
double-walled construction with the inner box electrically and thermally insulated from the outer
box. Improved insulation and control circuitry along with added volume are some of the
improvements this new air chamber has over other chambers previously used for calibrating standard
resistors at NIST.
Introduction

The resistance of a standard resistor is known to be a function of environmental parameters such as temperature, humidity, and pressure\(^{(1)}\). At resistances above 1 MΩ, temperature and humidity are known to have significant effects on resistance standards. The effects of pressure on resistances above 1 MΩ are assumed to be negligible due to the rugged construction of the resistor containers and large uncertainties associated with multimegohm resistances. Described is the design of an air chamber used to provide a controlled environment for the calibration of standard resistors from 10 MΩ to 1 TΩ at NIST. Temperature and humidity are controlled to reduce the environmental effect on the value of the standard resistors at time of calibration. Precise control of temperature and humidity has application in other measurement areas that could benefit from the use of a chamber similar to the one described in this paper.

General Construction

The chamber has been designed to provide maximum working space with accurate temperature and humidity control of the enclosed space. Interior dimensions of the chamber are 115 cm length, 71 cm depth, and 53 cm height with a raised platform mounted 38 cm from the top. Standard resistors are placed on top of this platform and the temperature and humidity control elements are mounted below as shown in Figure 1.

![Figure 1. Construction of air chamber.](image)

Sixteen pairs of coaxial connectors feed through the front wall to the lab environment permitting connection of standard resistors to measurement systems external to the air chamber. Fans circulate air between the two regions separated by the platform. The box is made of 6.35 mm thick aluminum plate using a double-walled construction allowing the inner box to be electrically...
and thermally isolated from the outer box. The two boxes are separated by 2.54 cm of high density styrofoam with a R-value of 5.0 to minimize heat loss to the laboratory. Both the inner and outer box lids are hinged to allow easy access to the working area and are sealed with rubber gaskets. A pair of hinged access panels are located on the front to allow easy entry to the control elements below the platform without disturbing the resistors loaded inside the box. The control instrumentation is mounted outside the enclosed chamber region below the access panels in an open area to provide cooling for the instrumentation.

**Heating**

Proportional heating is provided to the box by a pair of bifilar nickel-chromium alloy heating elements mounted below the platform. Bare nickel-chromium alloy heaters were used due to their quick response and a bifilar winding technique was used when constructing the heaters to minimize the level of noise injected into the standard resistor measurement system by the heating elements. The current applied to the heaters is provided by a power supply (PS) that receives a voltage signal from the proportional, integral, and derivative (PID) processor to determine the current to be applied to the heating coils. A Wheatstone bridge[2] using thermistors in two opposing arms serves as the input to the PID controller as shown in Figure 2.

![Wheatstone Bridge Diagram](image)

**Figure 2. Heating circuit.**

The resistances of the thermistors $T_1$ and $T_2$ are a function of temperature. When the temperature rises above the bridge set point, the unbalanced Wheatstone bridge supplies a voltage to the PID controller indicating less heat is needed to maintain a balance. A voltage of opposite polarity is produced by the Wheatstone bridge for temperatures below the bridge set point indicating that more heat is required to maintain a constant temperature.

The Wheatstone bridge achieves a null balance within 0.1 °C of the nominal set point. The final adjustment of the set point is made by an offset programmed into the PID controller. This allows fine tuning of the set point and the flexibility of having an adjustable set point. To increase the
sensitivity two thermistors are used in opposite arms of the Wheatstone bridge. Initially these thermistors were placed at opposite ends of the air chamber but a double set point was observed several times during the evaluation of the unit. Placing both thermistors in the same location eliminated the double set point and allows the system to maintain maximum sensitivity.

**Cooling**

A convective Peltier air conditioning unit provides a constant level of cooling to the chamber environment. The unit circulates air from the region above the platform and blows the air out below the platform onto the heater elements to mix the cooled and heated air. The mixed air is then passed over aqueous salt solution pans to control the humidity before being returned to the region above the platform where the standard resistors are housed.

**Humidity**

Humidity is controlled using saturated aqueous salt solutions\(^3\) of magnesium chloride to maintain a relative humidity of 35±5%. Pans containing the salts are positioned below the platform so that the mixed air will pass over the pans before being returned to the working area above the platform. Baffles and fans are used to force air over the pans located at the ends of the chamber. Seasonal variations in relative humidity cause water to collect in the pans during the summer and evaporate from the pans during the winter. Periodic maintenance requires draining off or adding water to the pans to maintain appropriate humidity levels. Opening the box to connect resistance standards allows air from the atmosphere to mix with the chamber air thereby affecting the relative humidity. Variation in humidity and ability to quickly reach equilibrium are dependent upon how long the box is open and the relative humidity of the air outside the chamber. Time required to reestablish equilibrium may vary from thirty minutes to overnight depending on the conditions, but equilibrium is usually obtained in one to two hours.

**Performance**

Periodic temperature measurements taken indicate that the chamber maintains temperature at 23±0.02 °C over a twenty-four hour period provided the chamber is not opened during that time. After the air chamber is opened, about one hour settling time is required for the bath to return to within 0.02 °C of set point temperature, under normal environmental circumstances. Factors such as the temperature differential between the room and the chamber, amount of time the box is open, and temperature of artifacts placed inside the box affect the settling time. Under less conducive circumstances, four hours has been found to be sufficient settling time.

Relative humidity has been observed to stay within 35±5%. Its stability is dependent upon atmospheric conditions and the length of time that chamber air is allowed to mix with the atmosphere. Performance of this new box compared with the air chamber it was designed to replace is greatly improved due to the tighter seals of the box and added airflow control. The chamber will
maintain specified relative humidity for two to three times longer than the old box, thus requiring less maintenance of the saturated salt solution mixtures inside the chamber.

Summary

The added volume and improved control systems of this air chamber have improved the measurement process of multimegohm resistance standards at NIST. Increased volume allows more resistors to be calibrated during a measurement process and improved controls reduce the settling time required for the air chamber to reach equilibrium. The large volume of the chamber will house all of NIST's multimegohm standards and check standards along with several customer resistors, thus reducing calibration turn-around-time for calibrating customer resistors without affecting accuracy. Enhanced temperature and humidity controls increase the precision of measurements since standard resistors are affected by variations in temperature and humidity. Added features such as the PID controller allow the air chamber to be operated at more than one set point by adjusting the offset. The air chamber has application in other measurement areas where an oil bath is not practical to use but accurate temperature control is required to 20 mK.

References

