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Developing a Pressure System to Extract Pressure Coefficients of Electrical Measurement Standards

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Introduction/Motivation

Problem: High-precision electrical standards often show a change in output value with a change in pressure. The pressure coefficient of the standard must be known to correct for pressure differences between the calibrating lab and the standard's intended location for use.

Goal: Using an existing pressure chamber, verify functionality of the chamber's pressure components, design and automate an experiment (pressure setting and voltage/resistance reading), investigate possible hysteretic effects, and calculate pressure coefficient of the test device with consideration for uncertainties. Consider alternative statistical approaches to extracting pressure coefficients and how these approaches affect uncertainty estimates.

Challenges: The existing pressure chamber has been decommissioned for years and includes failed diaphragms for pumps, missing components, improper overpressure protection, outdated pressure safety documentation, no automation, and insufficient system/chamber sealing. Other challenges include developing an uncertainty model for pressure coefficients, determining the most accurate predictive fit, and applying these methods to resistor standards in addition to voltage standards.

Background

- High-precision voltage and resistance standards are used in calibration laboratories, and are often traceable directly to the International System of units (SI)
- Output of the standard changes with pressure
  - Ambient pressure correlated with altitude
  - Calibration lab may be at different altitude than user's lab
- Extracting the pressure coefficient relates pressure change to the output difference from nominal

Procedure/Execution

- Update existing pressure system components, seal chamber, and add overpressure protectio (Fig. 1)
- Use Fluke 8508A multimeter and Programmab Josephson Voltage Standard (PJVS) to record electrical measurements at set pressures (Fig.
- Investigate hysteresis and stabilizing time
- Measure output as a function of pressure
- Automate each experiment using LabVIEW
- Perform data and uncertainty analysis

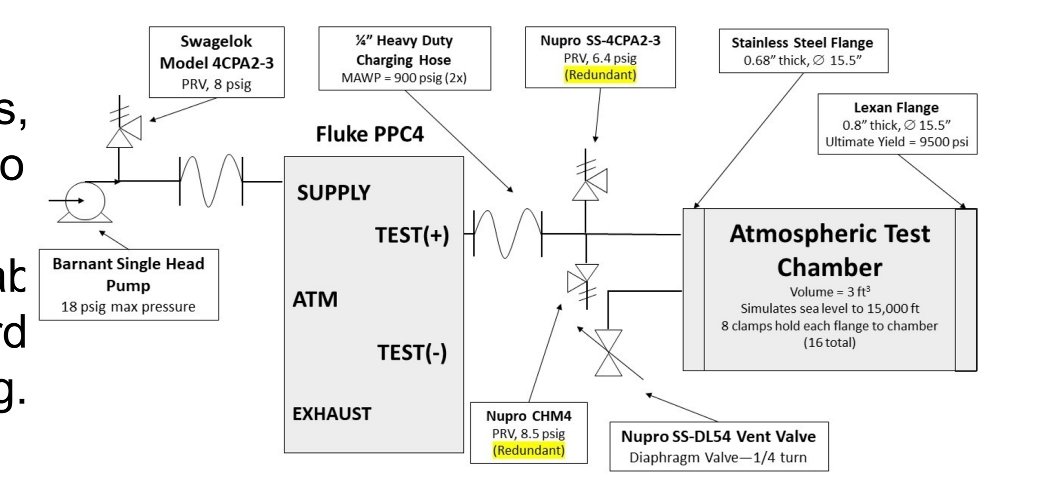

Fig. 1 Pressure system components and connections for each experiment. Pressure relief valves allow overpressure protection, and the limiting max allowable working pressure is 8 psig for the pressure transducer.

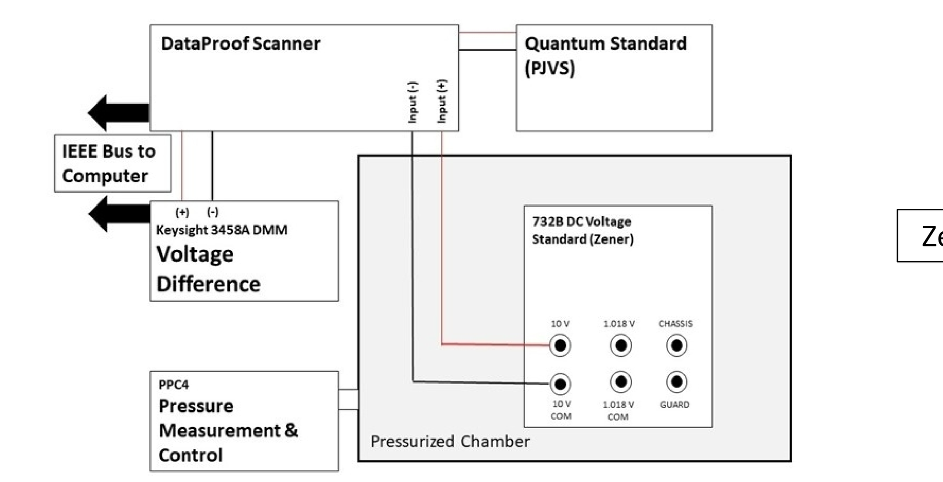

Fig. 2 Measurement equipment and connections for an experiment using the PJVS. This method is preferred to using the digital multimeter because the PJVS is an intrinsic standard with greater accuracy.

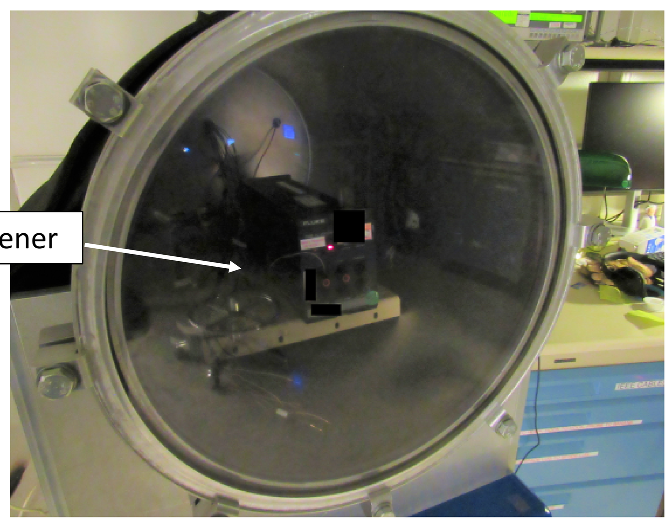

Fig. 3 Image of pressure chamber with DC voltage standard (Zener) inside during a measurement.

Results

- System is now functional (Fig. 3) and can be operated by LabVIEW control to perform a pressure coefficient determination measuring sequence
- DC Voltage Standard (Zener): Voltage measured as a function of time after pressurization (Fig. 4) and voltage as a function of pressure for pressure coefficient determination (Fig. 5)
- Standard deviations dominate coefficient combined uncertaint
- Tested pressure limits: [76 kPa, 108 kPa]
- Minimum stabilization time of 2 hours (Fig. 6)

$$U_V = \sqrt{U_{freq}^2 + U_{stdev}^2 + U_{drift}^2 + \cdots} \quad U_{fit} = \sqrt{\frac{\sum w_i}{\Delta}}, \quad w_i \equiv \frac{1}{U_{V,i}^2}, \quad \Delta \equiv \sum w_i \sum w_i p_i^2 - \left(\sum w_i p_i\right)^2$$

U_V = combined uncertainty of voltage measurement
U_{freq} = uncertainty of PJVS frequency source
U_{stdev} = standard deviation of voltage measurements at a particular pressure
U_{drift} = Zener drift per measurement
U_{fit} = uncertainty of the weighted least squares fitting slope
w_i = weight of voltage uncertainty at pressure p_i
$U_{V,i}$ = combined uncertainty of voltage measurement at pressure p_i
p_i = pressure at which a particular set of voltage measurements are taken
Δ = variable defined above for simplifying formula

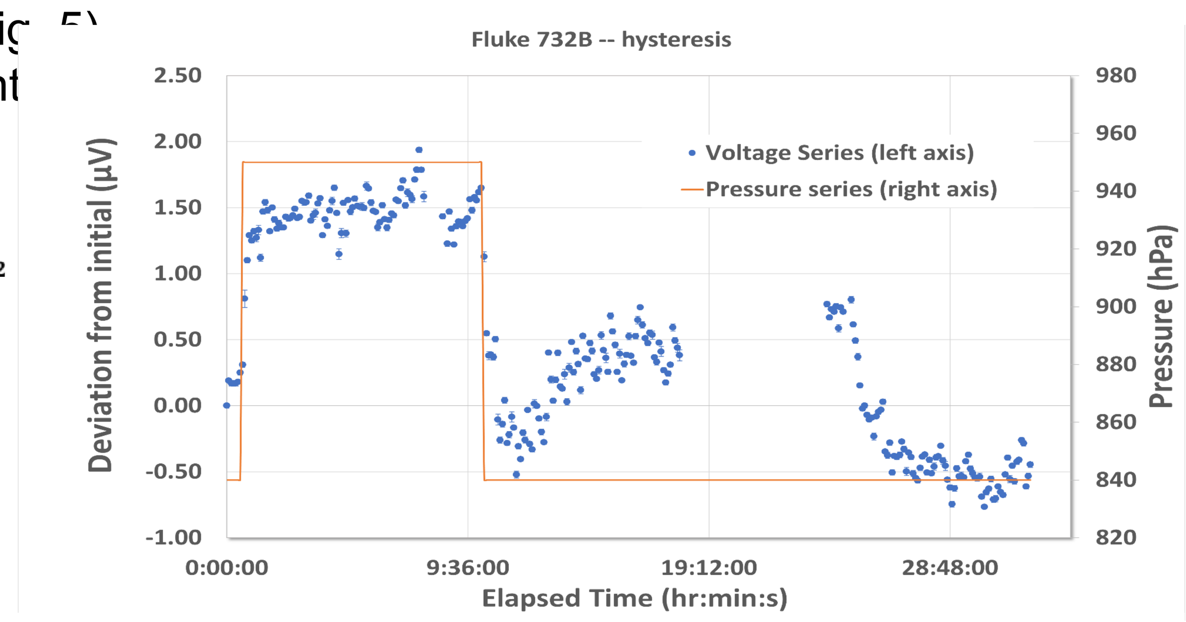

Fig. 4 Zener pressurized to 950 hPa, held for 10 hours, then depressurized to 840 hPa (ambient in Albuquerque, NM) while voltage measurements continued. Voltage increases after return to ambient before returning to expected value after about 16 hours.

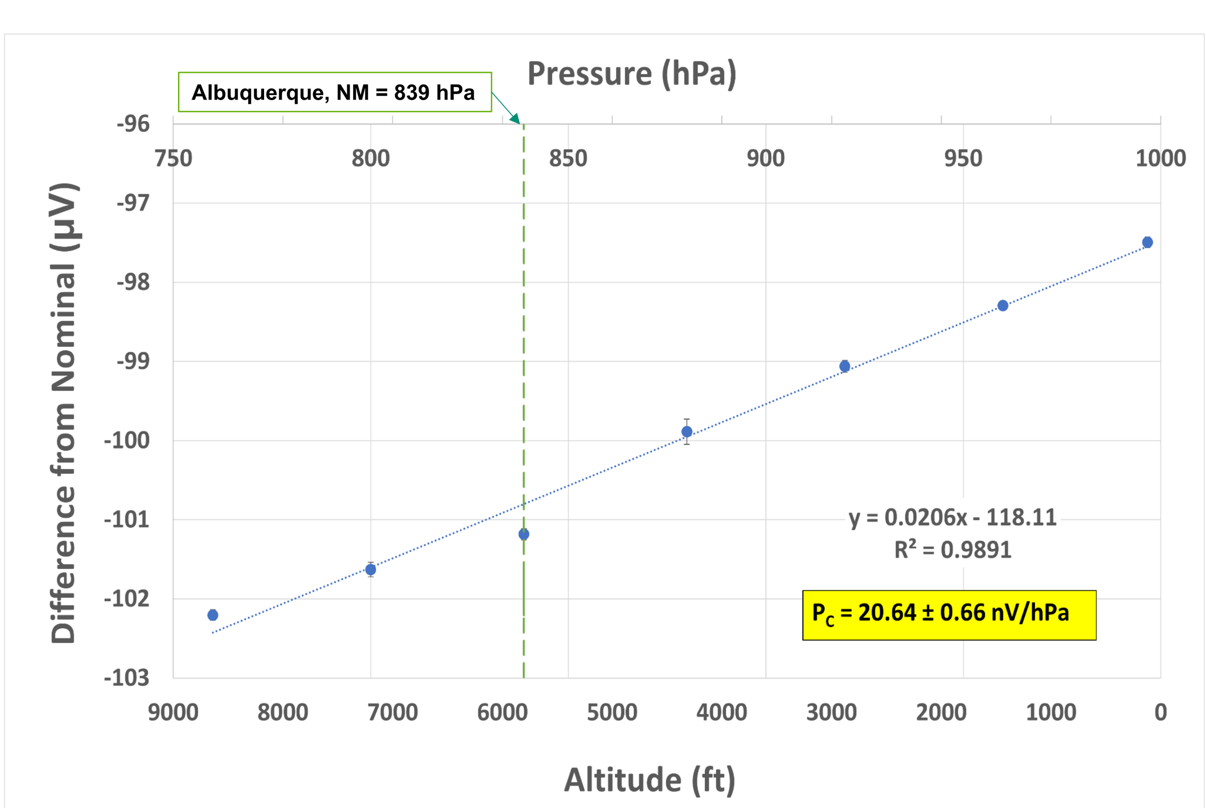

Fig. 5 Pressure coefficient of a Fluke 732B Zener Standard using this system.

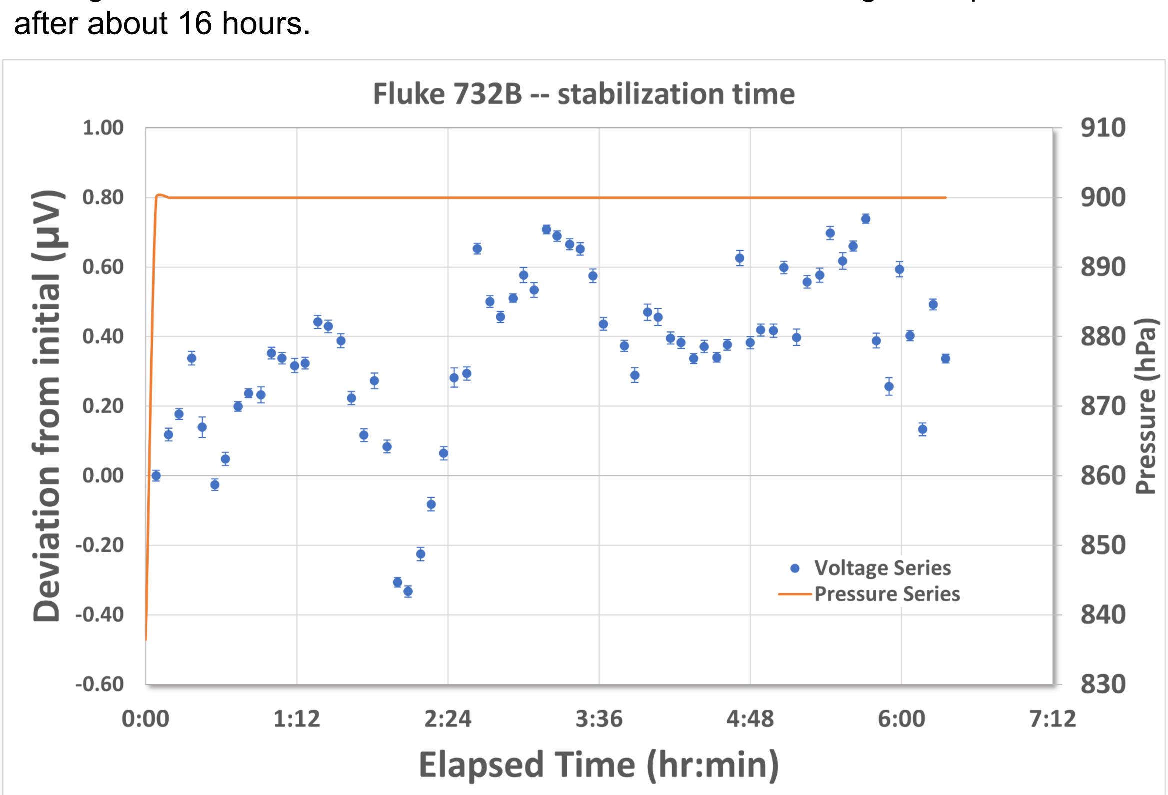

Fig. 6 Stabilization time study suggests at least 2-3 hours of waiting.

Conclusions

- The output of an electrical standard could successfully be predicted using the developed system by taking measurements across a range of pressures and applying a linear regression to determine the pressure coefficient
- After more than 16 hours of pressurization, Zener stabilization shows no long-term hysteresis

Future Work

- Extend exposure time by integrating AC power connection
- Conduct further tests on stabilization time
- Redesign for hand-operated door in place of Lexan flange (Fig. 7)
- Perform standard calibrations at user

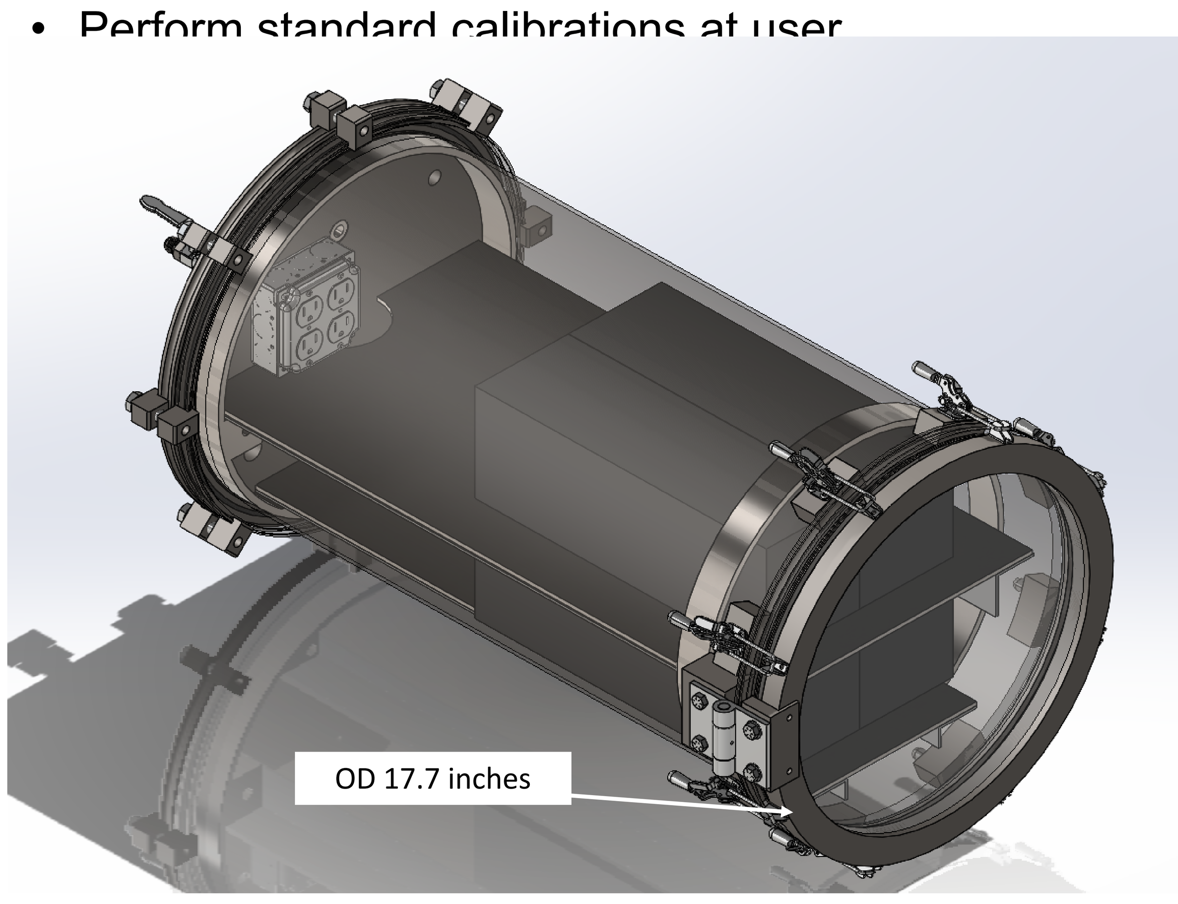

Fig. 7 Working redesign of pressure chamber with added latch clamps, hinged door, AC power access, and removable shelves.

References

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