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Optimizing the Performance of the Compare II Leak Calibration System

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Introduction

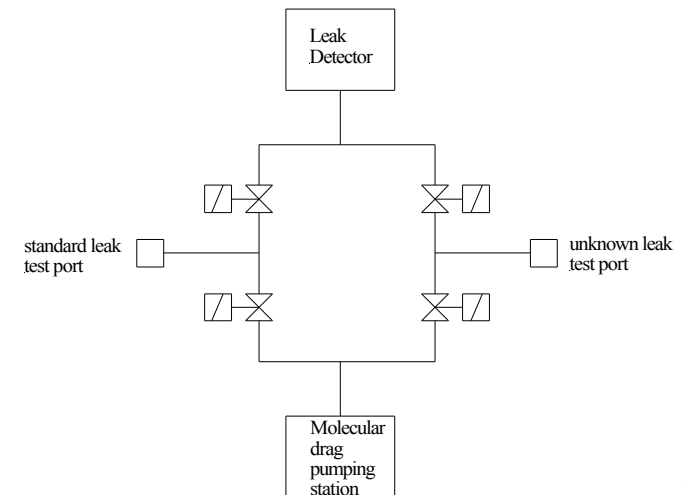
- The Compare II Leak Calibration System
- Optimization Goals
- Tests to Achieve Optimization
- Results

*Certain commercial equipment, instruments, or materials are identified in this paper in order to adequately describe the experimental procedure. Such identification does not imply recommendation or endorsement by the authors, Sandia National Laboratories, or NCSL International, nor does it imply that the materials or equipment identified are the only or best available for the purpose.

Compare II Leak Calibration System

Background

- Calibrates He leaks using the comparison method
- Calibrates leaks with leak rates between 10^{-6} to 10^{-10} cc/s @ STP
- Determines leaks' temperature coefficient in a small temperature range, typically ± 5 °C
- Uses a Leybold-Heraeus Ultratest F leak detector
 - 30 years old
 - Updated years ago from an oil diffusion pump to a turbomolecular pump backed by a rotary vane pump
 - For the entire world - repairs are done by one person and we are the only customer



Optimization Goals of Compare II

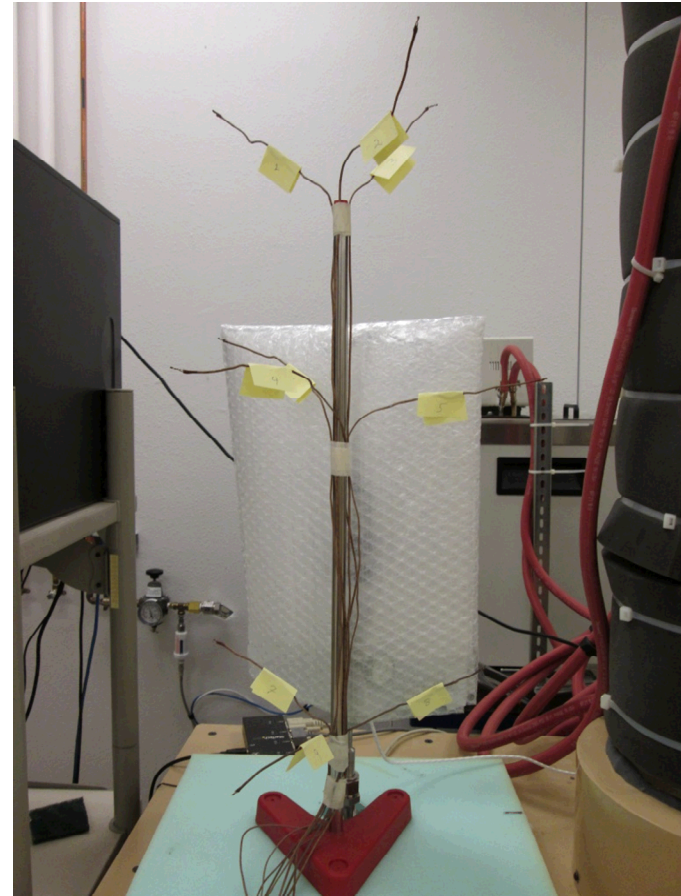
Optimizing system process will decrease the time to complete a calibration thereby reducing turnaround time

Optimization goals

- Temperature map both temperature chambers
- Optimize calibration process

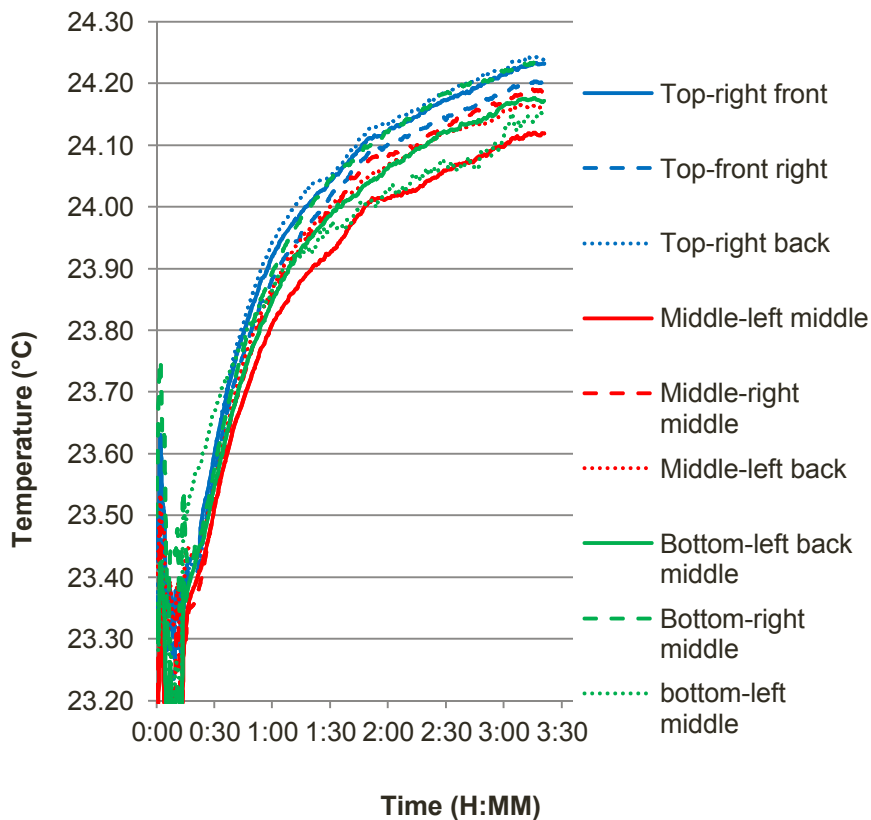
Optimization Test: Standard Leak Chamber Temperature Map

- Chamber is a box made of 2" thick rigid Styrofoam
 - Inside dimensions of 11"x10.5"x30"
 - No active temperature control
- Thermocouple tree placed inside the chamber
 - 9 type T TC's in groups of three, top, middle, and bottom
 - Fluke 1586 Super-DAC data acquisition
 - Combined accuracy of ± 0.71 °C

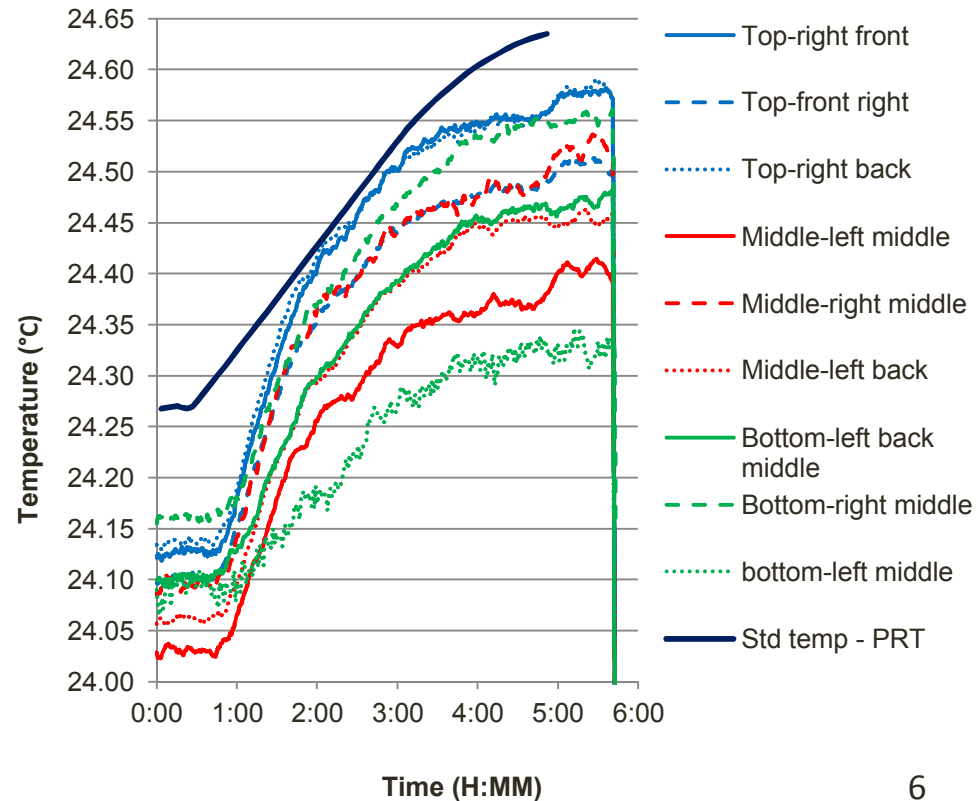


Optimization Test: Standard Leak Chamber Temperature Map, Results

Temperature map of standard leak chamber when placed over newly installed leak

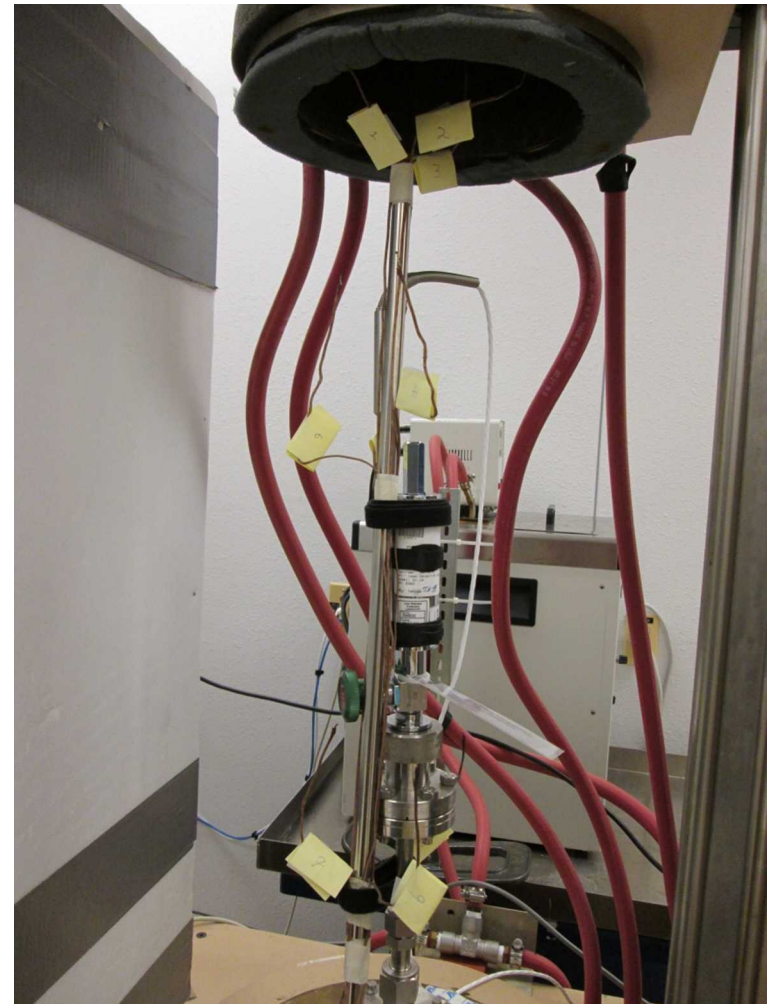


Temperature map of standard leak chamber during last half of a normal calibration run



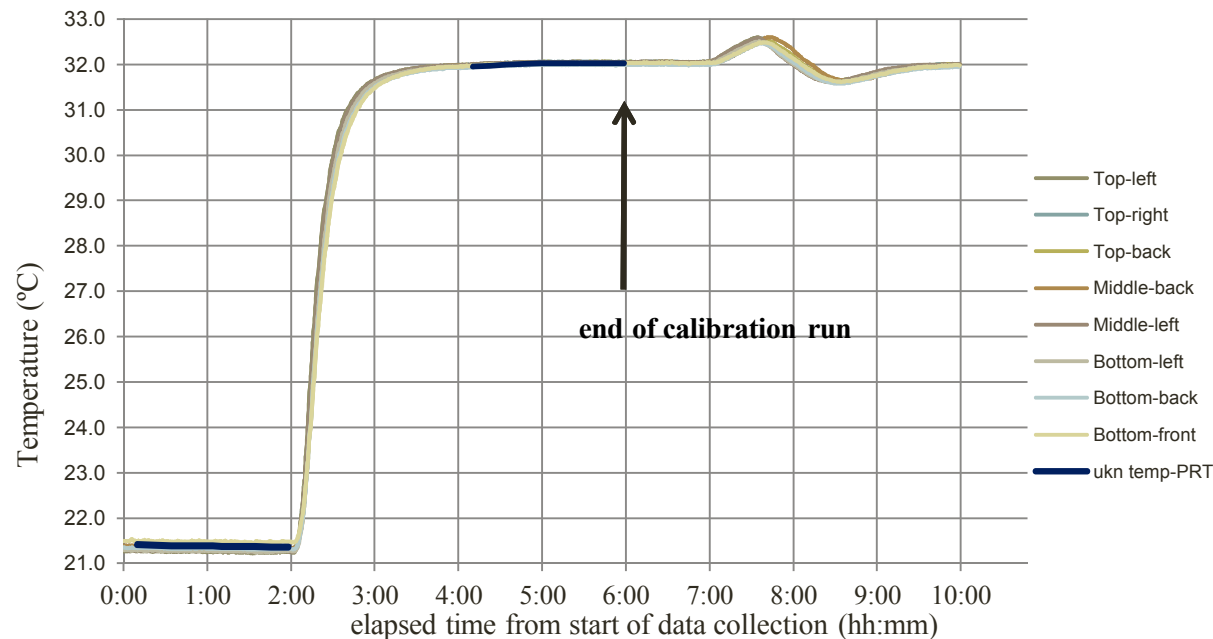
Optimization Test: Unknown Leak Chamber Temperature Map

- Unknown temperature chamber:
 - ¼" thick copper cylinder 7.625" ID, 29.75" high
 - soldered 3/8" copper tubing spiral wound on the outside
 - Recirculating water bath used to control chamber temperatures
 - Circulation fan inside the chamber
- Same TC tree in same configuration placed inside the chamber



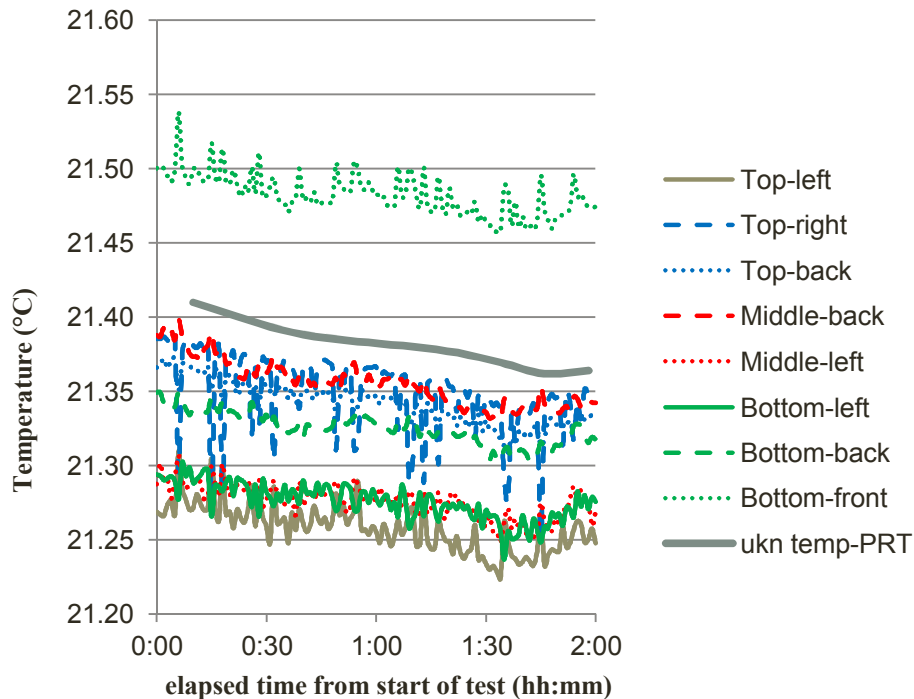
Optimization Test: Unknown Leak Chamber Temperature Map, Results I

Temperature data from a normal calibration using the TC tree.
Data was still collected after the end of the calibration.

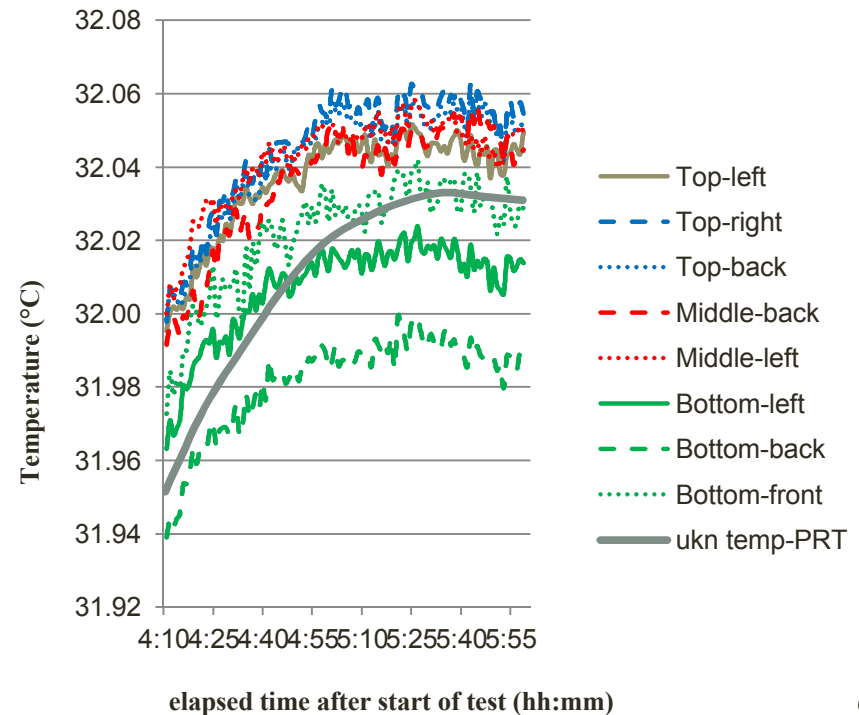


Optimization Test: Unknown Leak Chamber Temperature Map, Results II

Temperature map of unknown leak chamber during first half of a normal calibration run



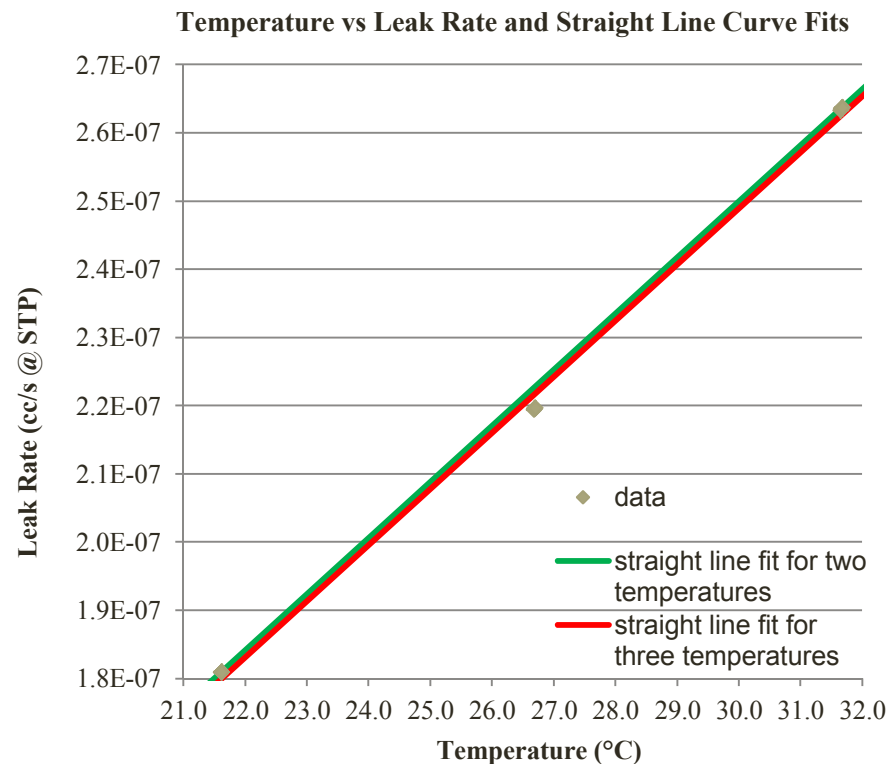
Temperature map of unknown leak chamber during last half of a normal calibration run



Optimization Test: Two vs. Three Temperatures During a Calibration

Permeation leaks have a significant temperature coefficient – 3 to 4% / °C

- Originally the leak rate is measured at two temperatures, typically 10 °C apart
 - Leaks are certified at the midpoint temperature using a straight line fit
 - Leak rate corrected using its straight line fit within its specified temperature range
- Leak rate vs. temperature is nonlinear
- Measuring leak rate at three temperatures
 - Lowered the calculated leak rate 0.44 to 0.45% on three separate leak rates

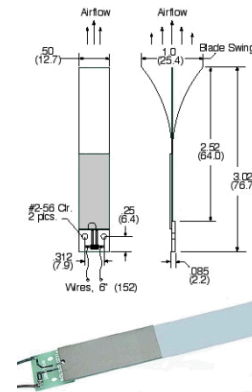


Optimization Test: Circulating Fan

Circulating fan's affect on temperature stability

- Original fan a two bladed piezoelectric fan
 - Fan over 30 years old
 - Flow rate of ~ 4 CFM with both blades
 - Uses 120 VAC
- Replaced with blower
 - Flow rate of 2.8 CFM (roughly 3.5 air exchanges/min)
 - Uses 12 VDC
- A second identical DC blower added

Piezoelectric Fan



Mini DC Blower



fan	time to reach temperature stability (min.)	Temperature stability over a 1 hour time frame (°C)
original with two blades	155	0.092
original with one blade	270	0.161
One DC blower	137	0.058
Two DC blowers	65	0.015

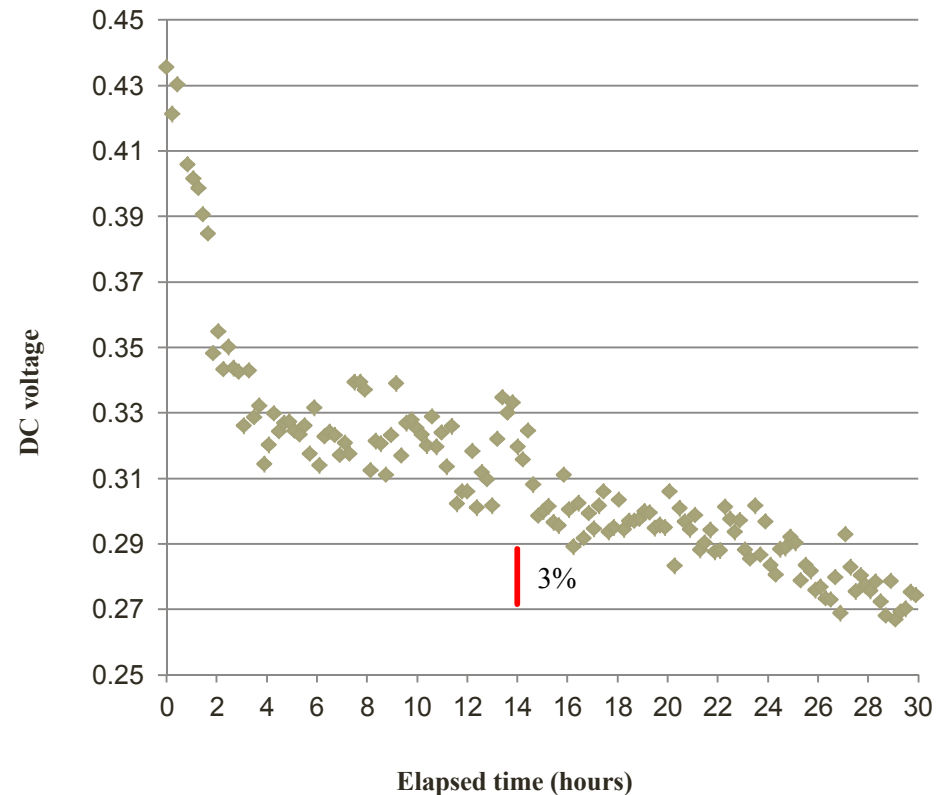
Optimization Test: Leak Rate Stabilization Time

Length of time for a newly installed 10^{-10} leak to stabilize – constant temperature

Original configuration

- Pump side: an Adixen Drytel 1025 Molecular drag pumping station
 - Pumping speed of 7.5 ℓ/s , for N_2
 - He compression ratio of 250
- Leak Detector side: a Leybold-Heraeus Turbovac 151 turbomolecular pump
 - Pumping speed of 150 ℓ/s , for N_2
 - He compression ratio of 20,000

Leak Detector Output vs Time

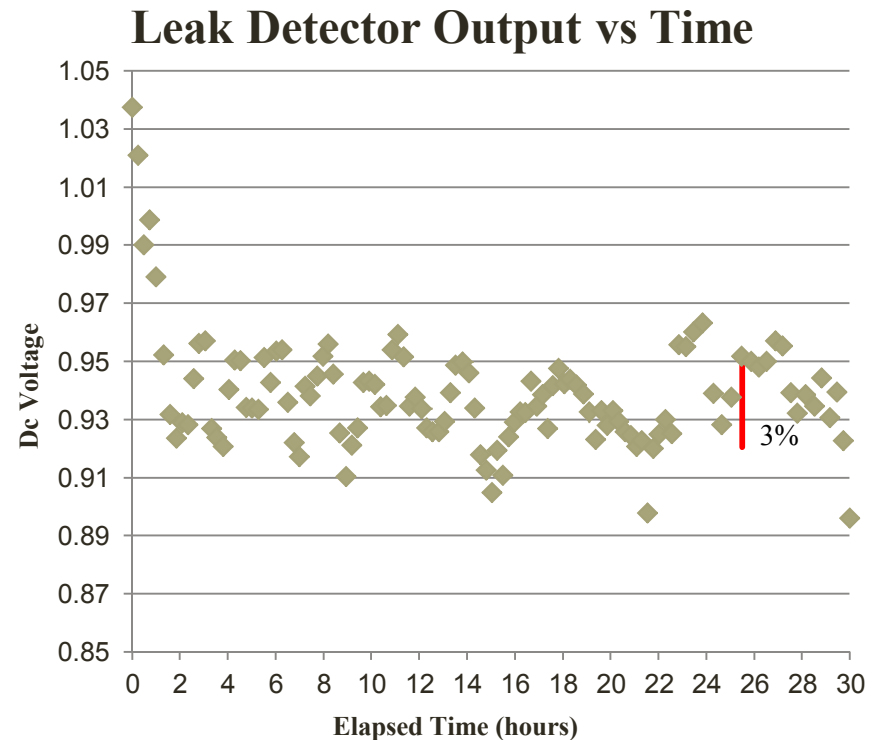


Optimization Test: Leak Rate Stabilization Time, cont.

Length of time for a newly installed 10^{-10} leak to stabilize – constant temperature

New configuration

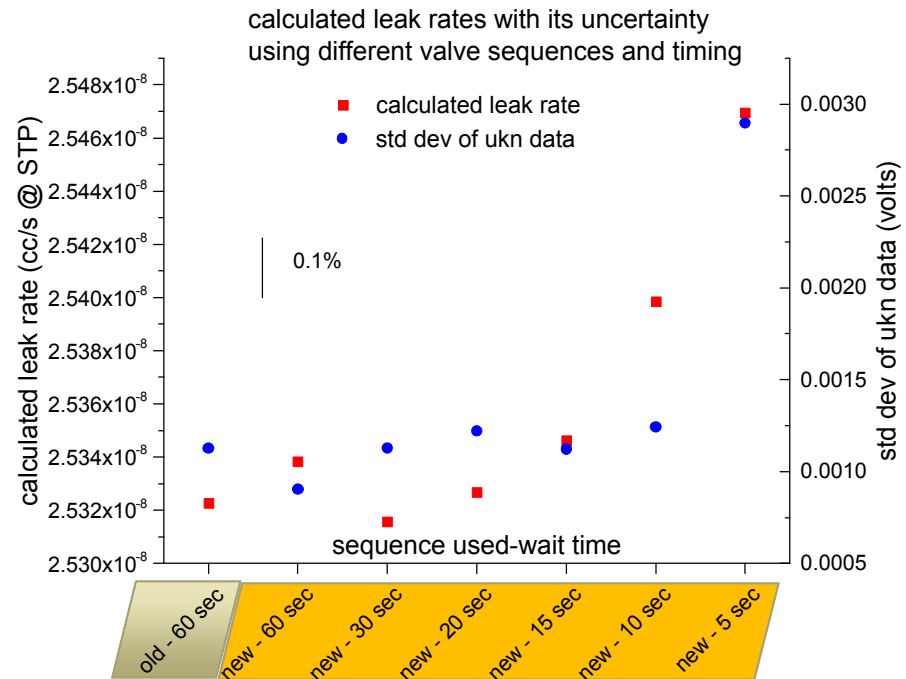
- Pump side: Pfeiffer HiPace 80 turbomolecular pumping station
 - Pumping speed of $67 \ell/s$, for N_2
 - He compression ratio of 13,000,000
- Leak Detector Side: Leybold-Heraeus Turbovac 151 turbomolecular pump
 - Pumping speed of $150 \ell/s$, for N_2
 - He compression ratio of 20,000



Optimizing Test: Wait Time After Switching Leaks

Appropriate wait time for the signal to stabilize after switching leaks

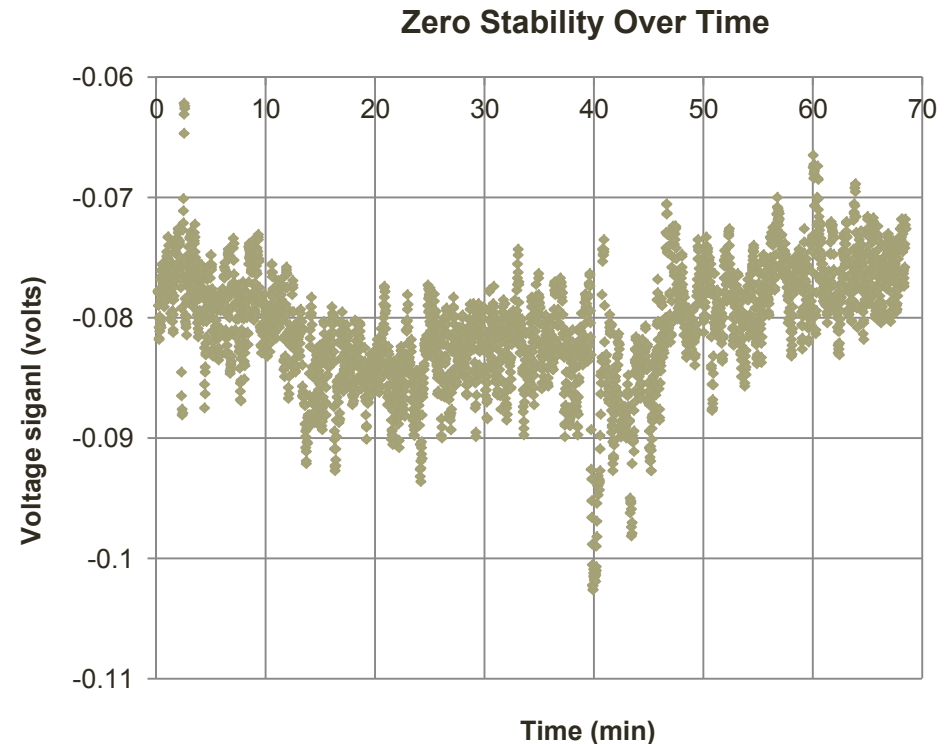
- Wait time varied - 60 (default), 30, 20, 15, 10, and 5 seconds
- Unknown leak rate changed 0.6% between 60 and 5 seconds
- biggest change was the data's standard deviation



Wait times lowered to 20 seconds

Optimization test: Zero Stability of Leak Detector

- Importance of zero stability
 - Typical calibration consists of 10 runs at each temperature
 - Each run takes 12.5 minutes
 - Zero reading taken only at beginning and end of each run
- Tests showed the zero may change significantly during a run
 - To minimize zero drift effects the run sequence was changed:



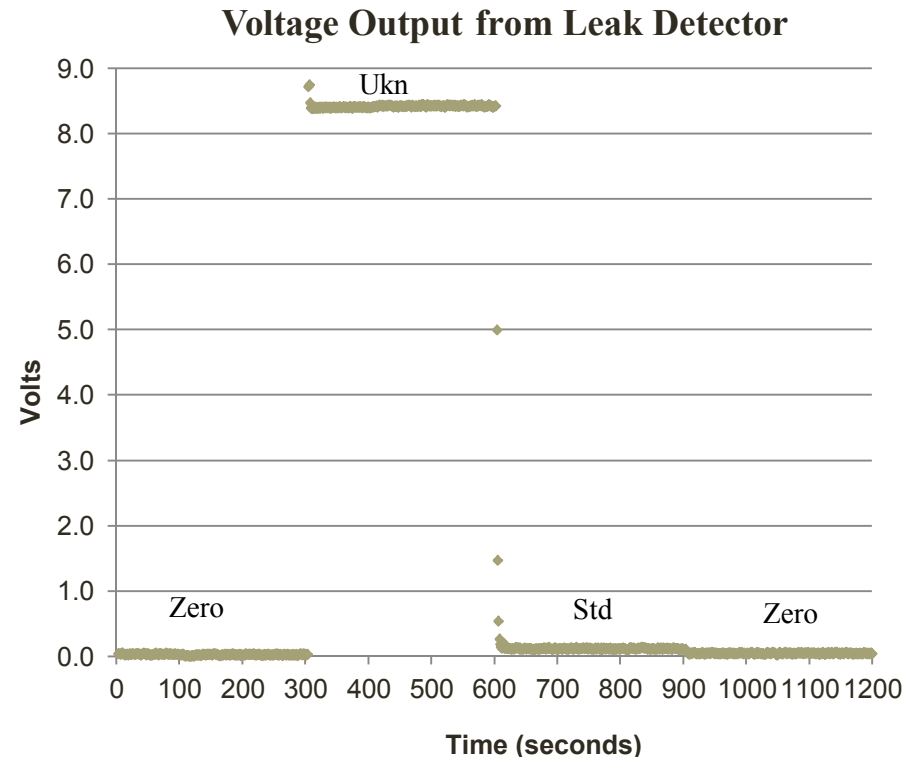
Original - zero 1, std 1, ukn 1, sum 1, ukn 2, std 2, ukn 3, sum 2, ukn 4, std 3, zero 2

New - zero 1, std 1, ukn 1, sum 1, zero 2, ukn 2, std 2, sum 2, zero 3, std 3, ukn 3, sum 3, zero 4

Optimization Test: Leak Detector Sensitivity Test

Increasing interest in calibrated leaks with leak rates less than 10^{-10} cc/s @ STP

- Current procedure is the standard to be within a factor of 3 of the unknown
 - Cannot get a standard with a leak rate less than 10^{-9} cc/s @ STP
- Expand difference to two orders of magnitude
 - Good characterization test for a replacement leak detector
 - Standard leak - 2.5×10^{-10} cc/s @ STP
 - Unknown leak – 2.8×10^{-8} cc/s @ STP
 - Used new sequence to minimize zero drift
 - Three separate tests consistently determined the unknown leak rate within 2% of certified value



Results

The calibration process of the Compare II system was improved resulting in reducing turnaround time by:

Replaced the molecular drag pump with a turbomolecular pump	Reduced pump down times from 30 to 1 hour increasing the number of calibrations from three per week to five per week
Include more zero readings	more accurately capture drift in the zero readings
Added a third temperature during calibration	Greater accuracy in calculating leak rates at different temperatures
Reduced wait time between leak measurements from 60 to 20 seconds New fan in the unknown temperature chamber reduced the time to reach a set temperature as well as reducing drift	Reduced the time to complete a calibration from 9 hours at two temperatures to 5 hours at three temperatures