INL/CON-24-76380-Revision-0

Fabrication and Testing of DOE Standard Canister Closure Leak Test Assembly

March 2024

Devin D Imholte, Nathan Levine Hofmeister, Samuel Jackson Trost

Changing the World's Energy Future

INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance, LLC

DISCLAIMER

This information was prepared as an account of work sponsored by an agency of the U.S. Government. Neither the U.S. Government nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness, of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. References herein to any specific commercial product, process, or service by trade name, trade mark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the U.S. Government or any agency thereof.

INL/CON-24-76380-Revision-0

Fabrication and Testing of DOE Standard Canister Closure Leak Test Assembly

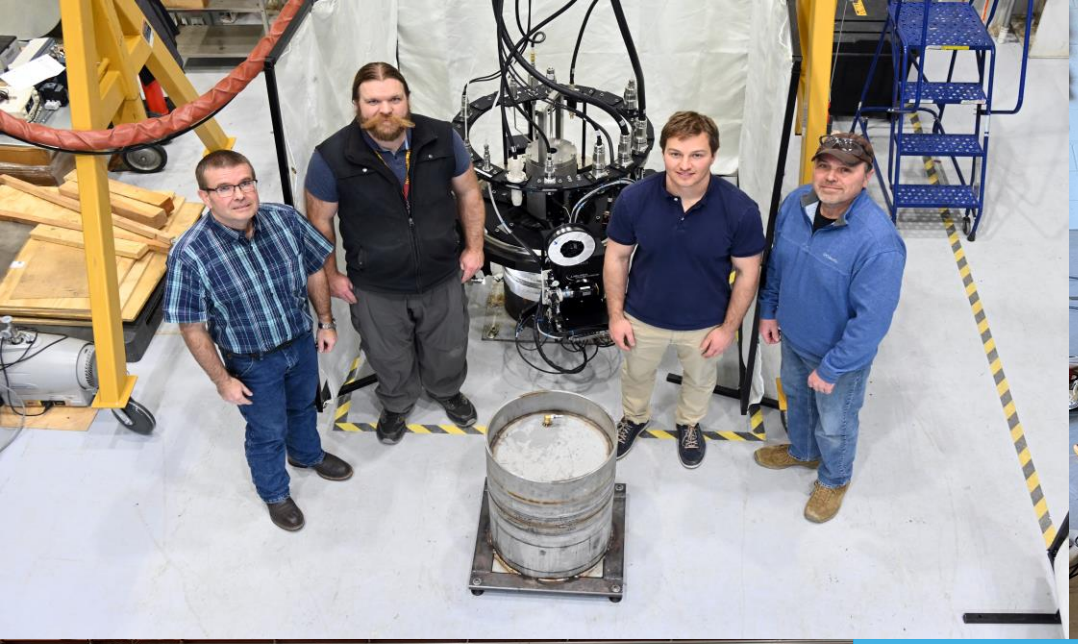
Devin D Imholte, Nathan Levine Hofmeister, Samuel Jackson Trost

March 2024

Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517



March 13th, 2024

D. Devin Imholte, Nate Hofmeister, Sam Trost

WM2024

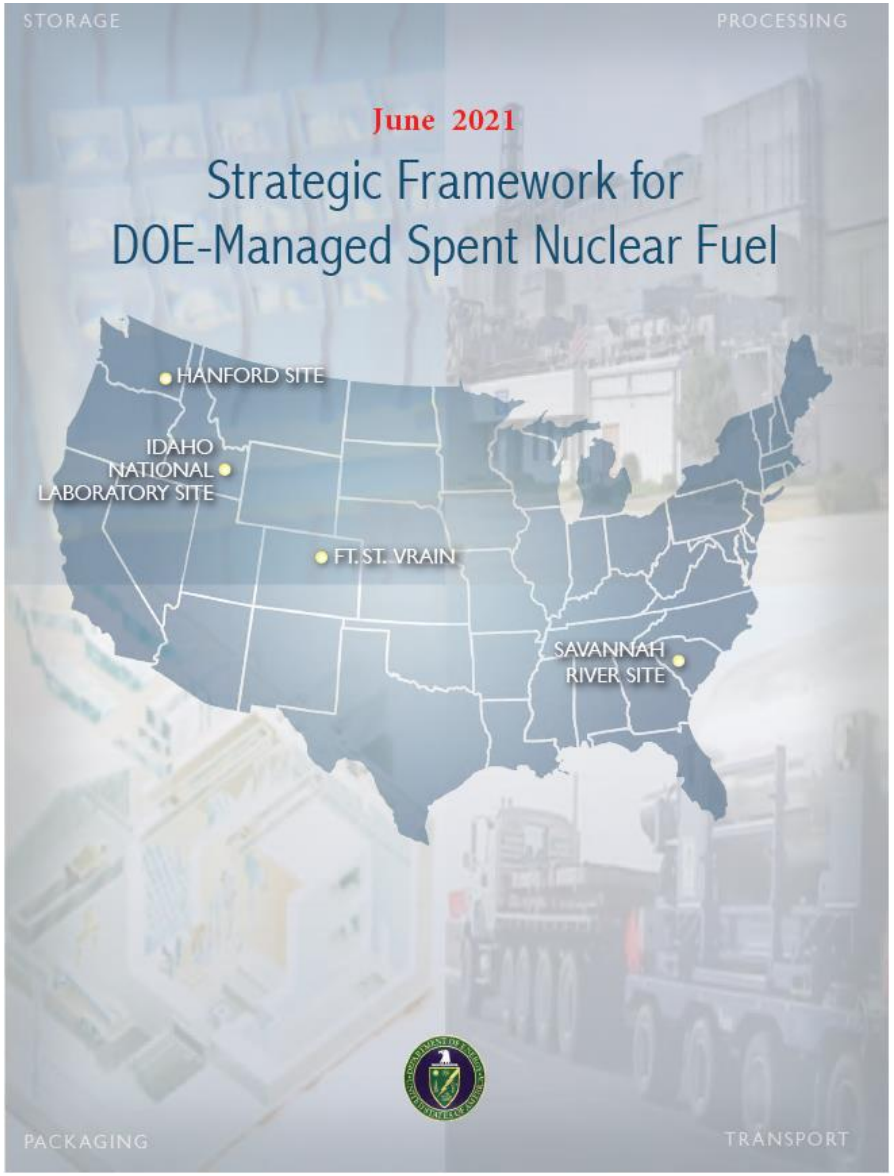
Fabrication and Testing of DOE Standard Canister Closure Leak Test Assembly

Battelle Energy Alliance manages INL for the
U.S. Department of Energy's Office of Nuclear Energy

INL Idaho National Laboratory

DOE SNF Road-Ready Demonstration Project

- 1995 Department of Energy (DOE)-Idaho Settlement Agreement
- *Strategic Framework for DOE-managed Spent Nuclear Fuel* (SNF) → Road-Ready Dry Storage (RRDS)*
- Road-Ready Demonstration Project**
  - Idaho Environmental Coalition-led with Battelle Energy Alliance support
  - Develop hardware, processes, and regulatory framework for packaging SNF for RRDS



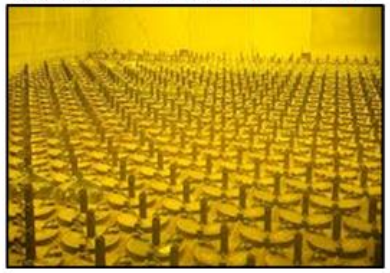
*Road-ready dry storage meaning packages capable of long-term storage, transportation, and disposal with minimal handling.

**Formerly DOE SNF Packaging Demonstration

DOE SNF Road-Ready Demonstration Objectives

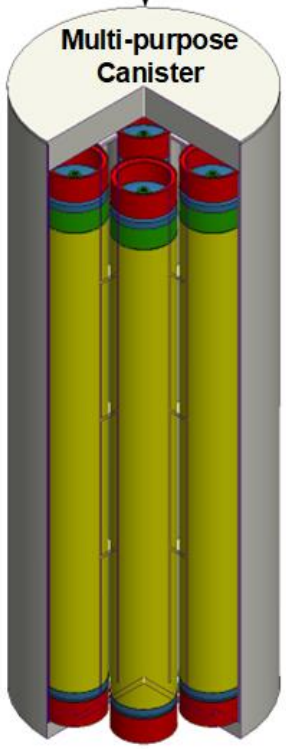
CPP-603 IFSF

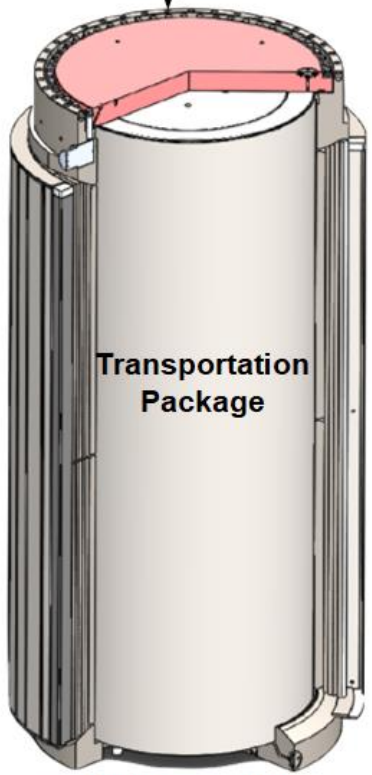
(Irradiated Fuel Storage Facility)



4X Fort Saint Vrain (FSV) Elements

7X DOE Standard Canisters





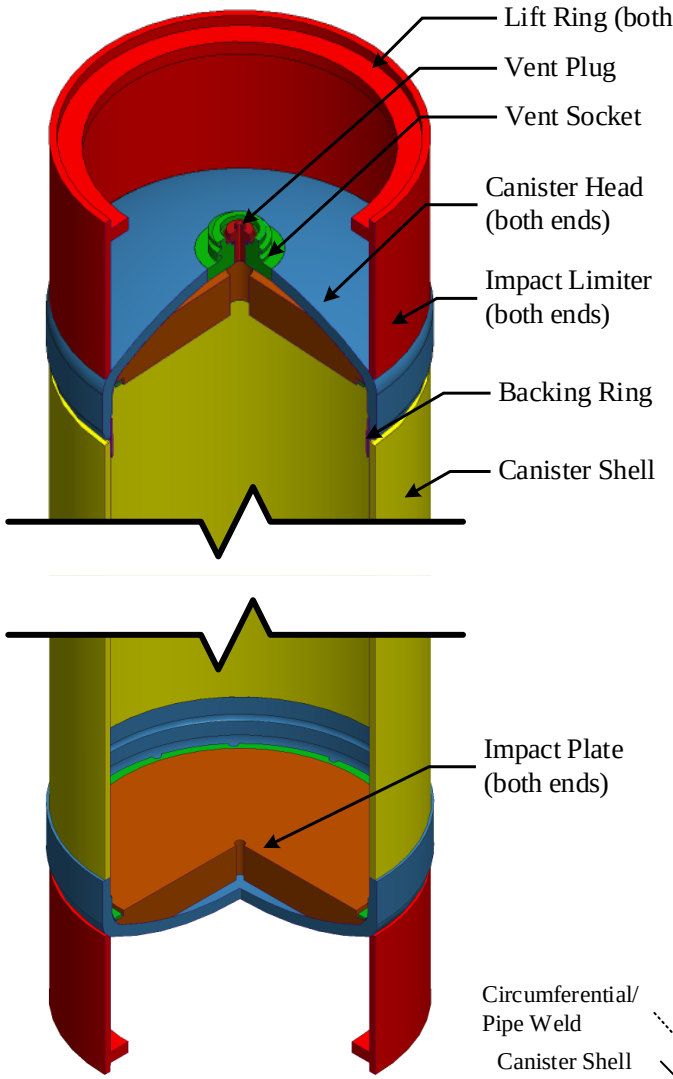
Example transportation package, Holtec International

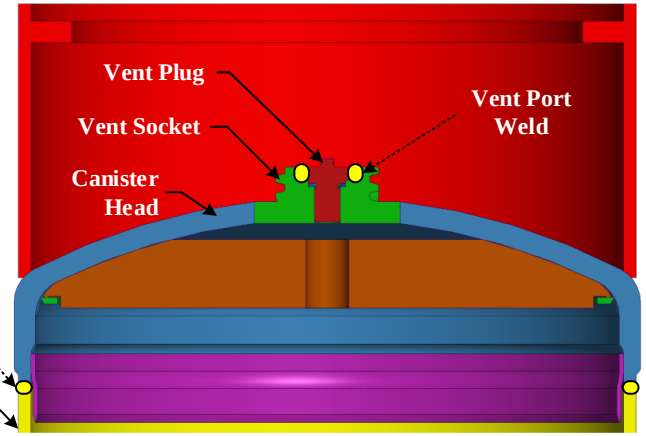
CPP-2707

(Outdoor Fuel Storage Facility, "Cask Pad")

DOE Standard Canister

- Sealed canister for diverse SNF.
- No safety credit to SNF characterization
- Certified with the storage and transport system.
- Stainless steel
- Impact protection
- No shielding





Material: 316L Stainless Steel

Nominal Outside Diameter: Ø18 in.

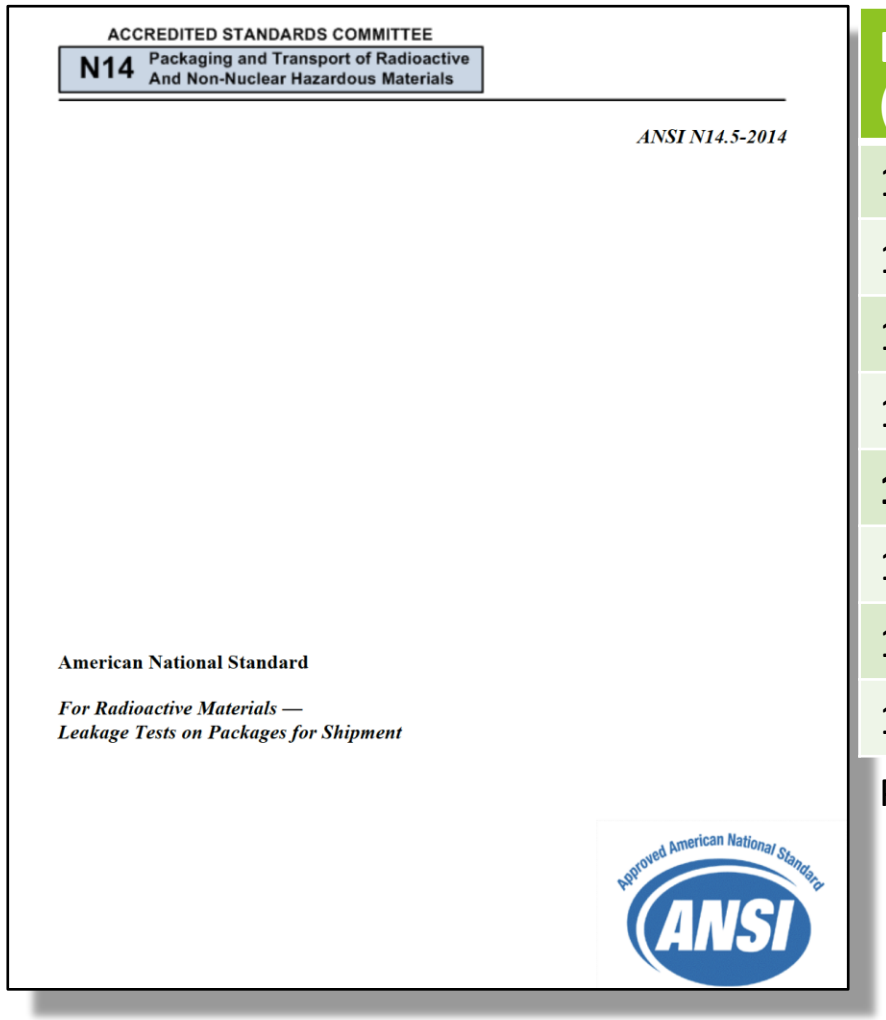
Overall Length: 15 ft.

Wall Thickness: 3/8 in.

Maximum Gross Weight: 6,000 lb

DOE Standard Canister Closure Weld Leak Test

- Driven by ANSI N14.5 Standard
  - 10 CFR 71, NUREG-2216
  - 10 CFR 72, NUREG-2215
- Acceptance criteria: **1E-07 std-cc/sec** (“leak tight”).
- Helium leak test performed via “inside-out” technique.


ACCREDITED STANDARDS COMMITTEE
N14 Packaging and Transport of Radioactive And Non-Nuclear Hazardous Materials

ANSI N14.5-2014

American National Standard

For Radioactive Materials —
Leakage Tests on Packages for Shipment

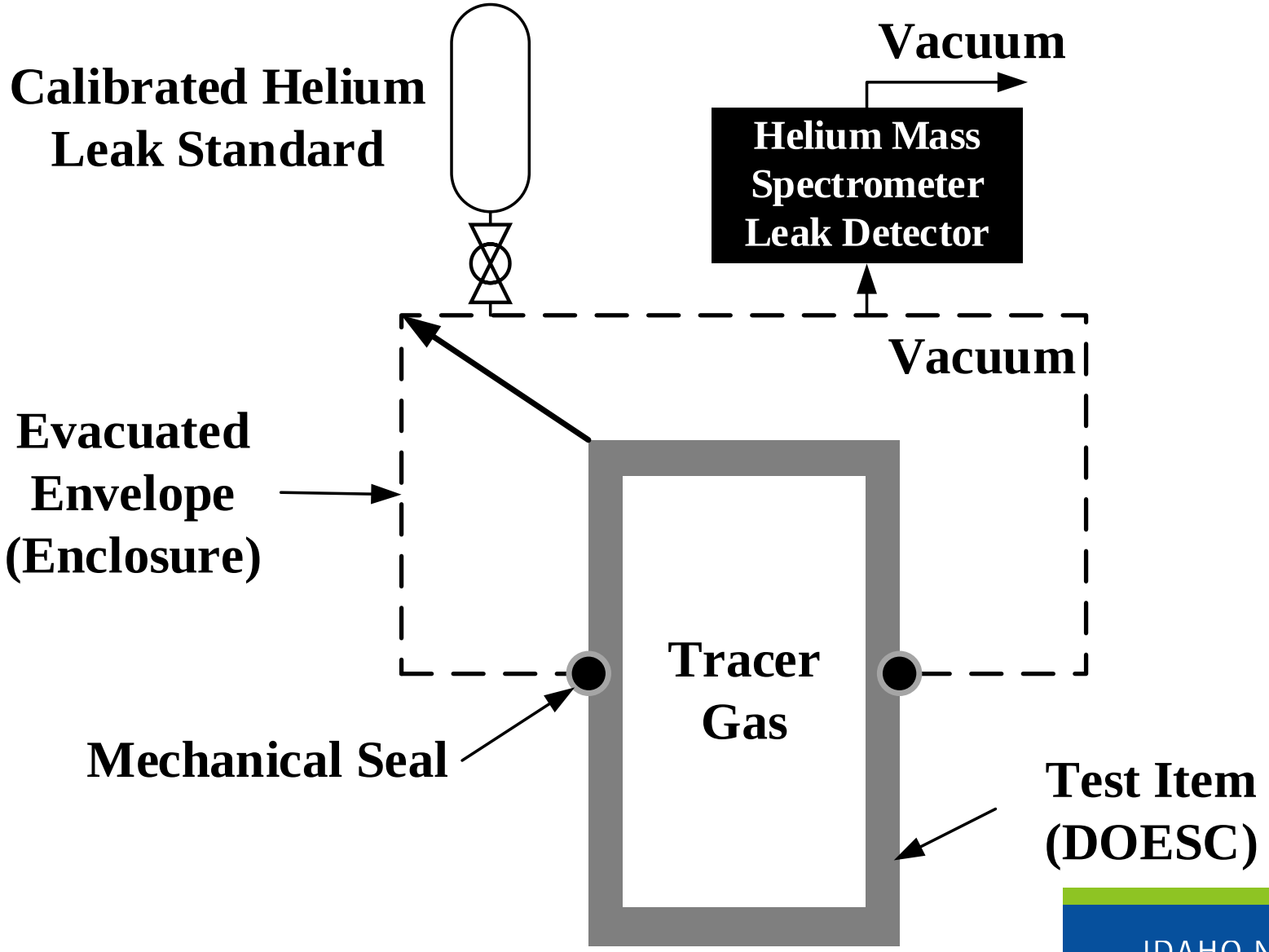
Approved American National Standard
ANSI

Leak Rate (std-cc/sec)	Description	Escape time of 1 cc bubble
1	Water running	.1 sec
10^{-2}	Water dropping	10 sec
10^{-4}	Water tight	> 15 min
10^{-6}	Bacteria tight	> 1 day
10^{-7}	**“Leaktight”**	-
10^{-8}	Virus tight	> 100 days
10^{-10}	Gas tight	> 30 years
10^{-12}	Technically tight	> 1000 years

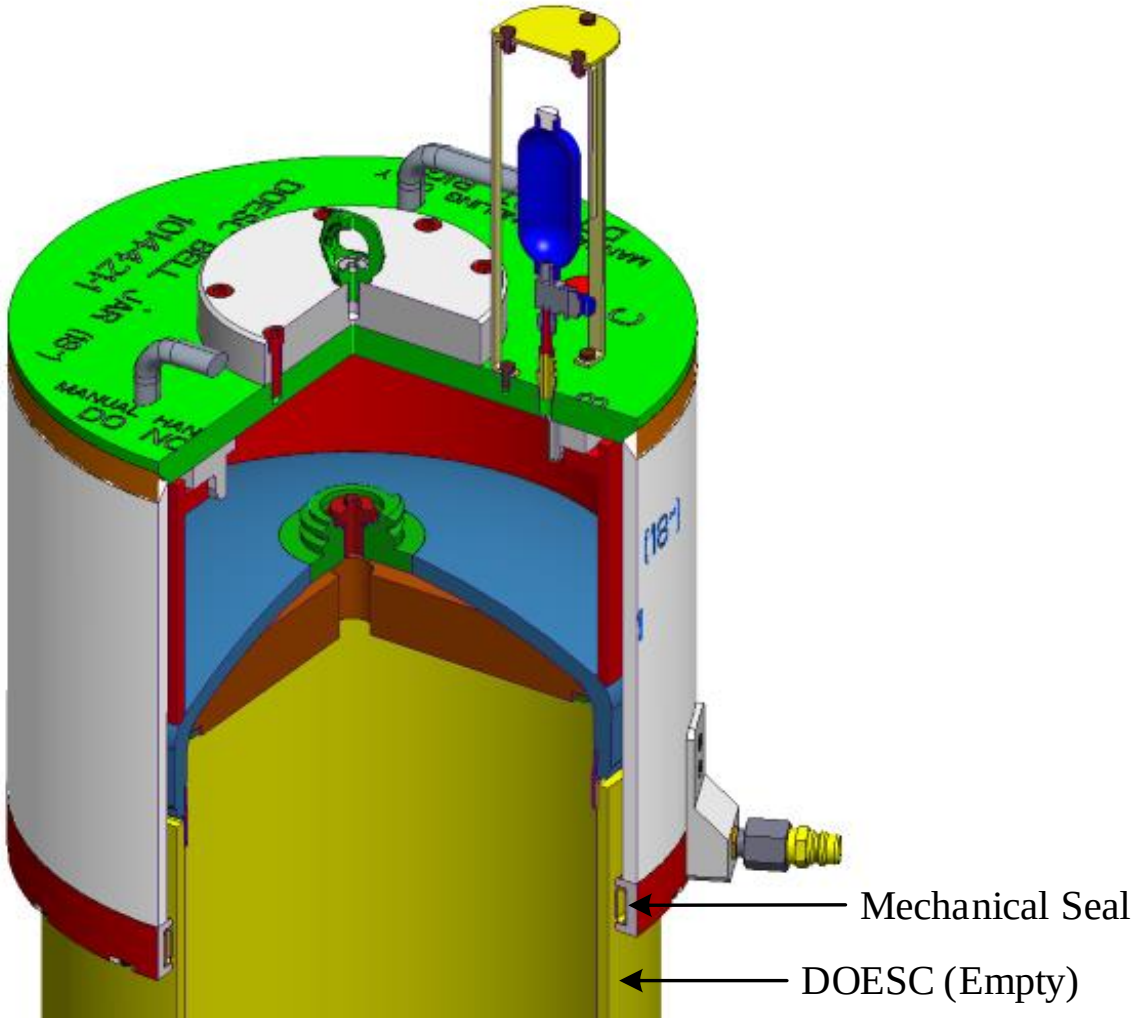
Pfeiffer Vacuum, *Leak Detection Compendium, 2013*

ANSI - American National Standards Institute

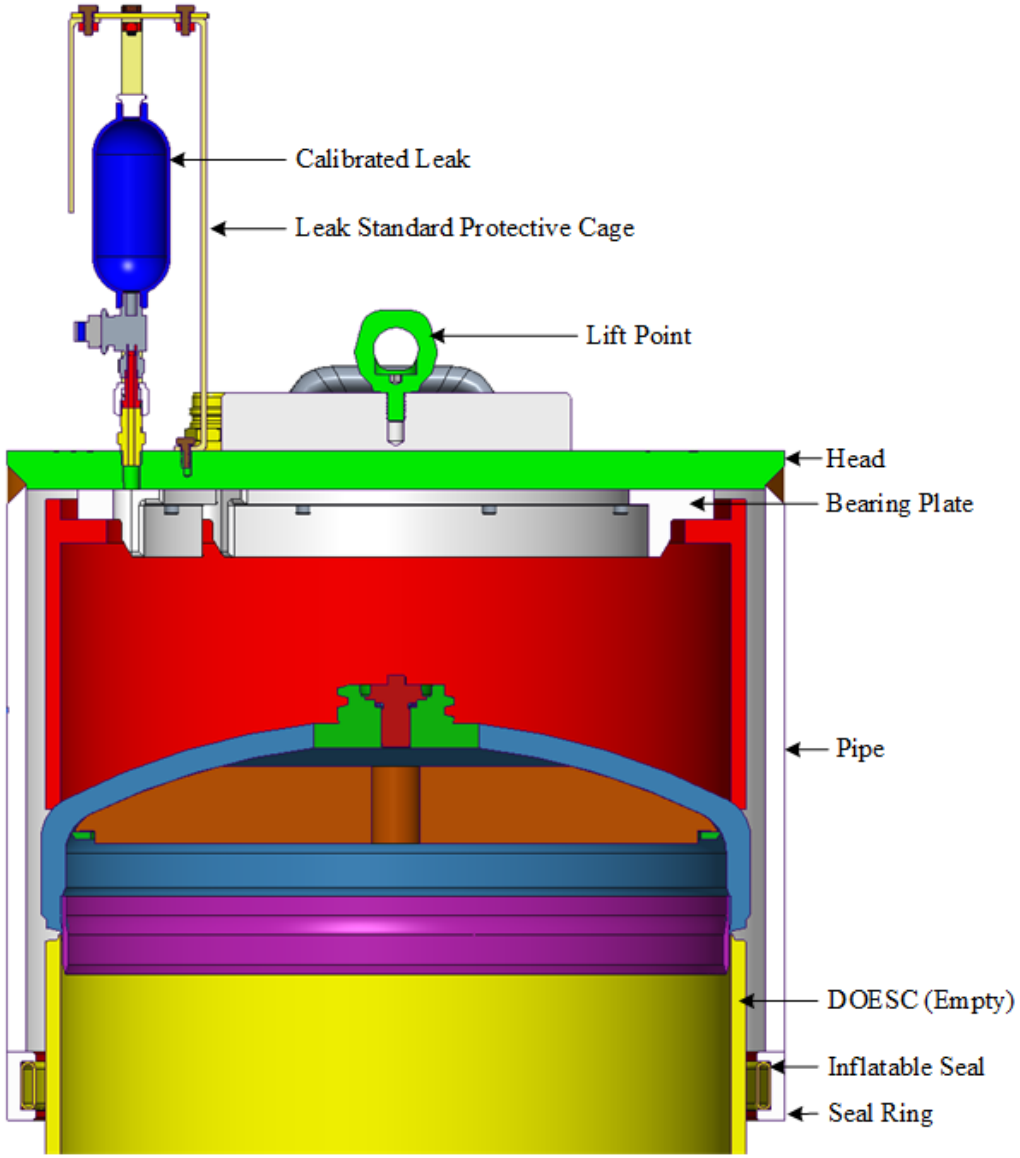
Closure Weld Leak Test – Helium-Filled Container (“Cup Test”)

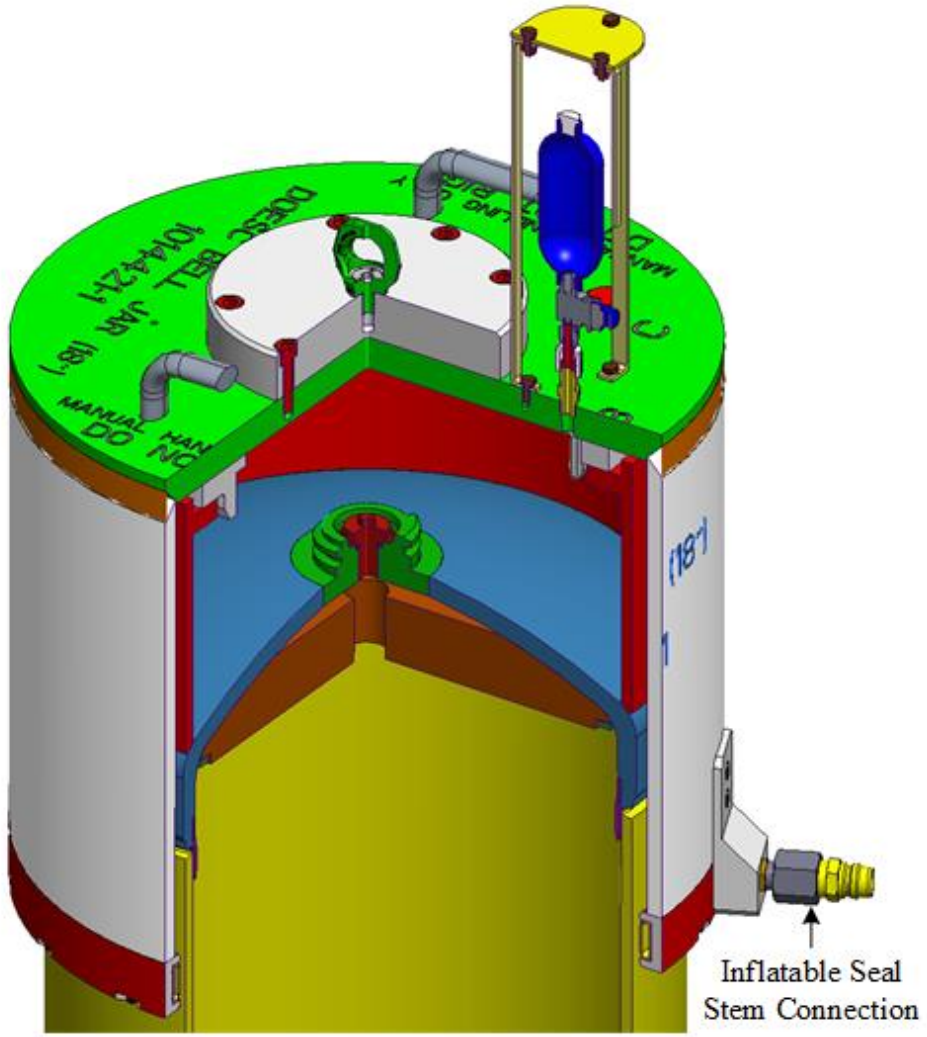


Closure Weld Leak Test Handling Concept

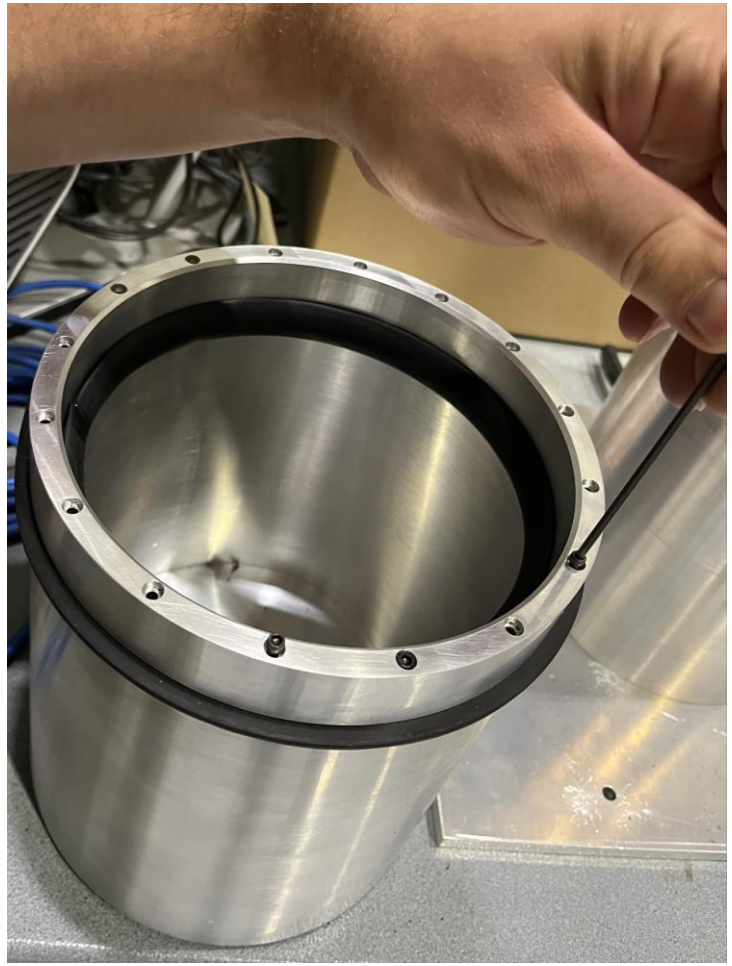


Closure Leak Test Assembly Design





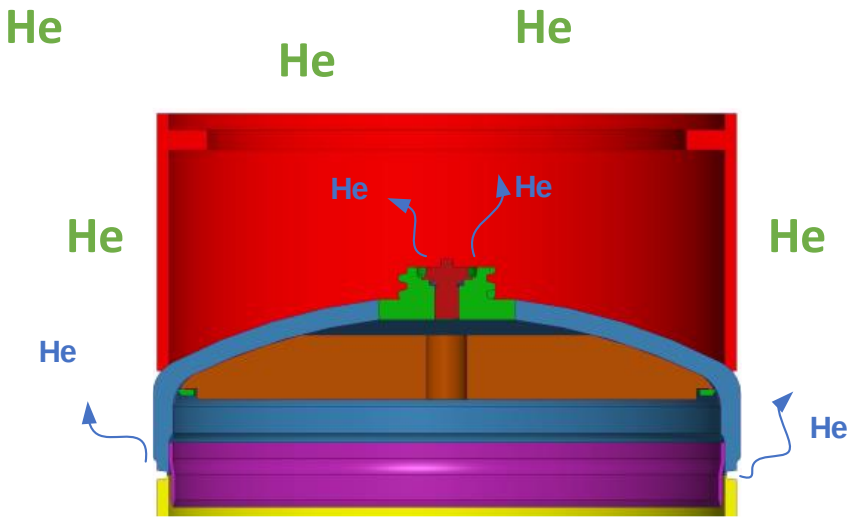
Mechanical Seal Testing



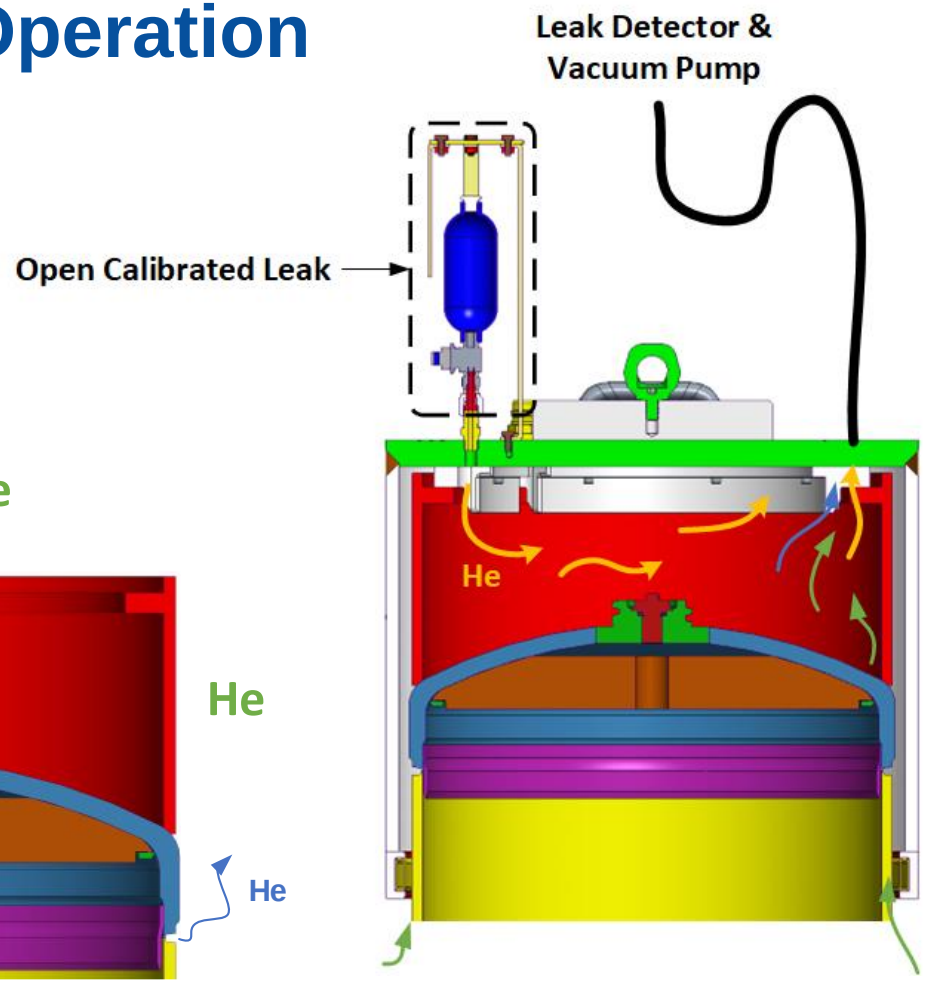
Bolting on Seal Ring and T-Seal on 1:3 Scale Leak Test Enclosure Assembly

Testing Leak Tightness of Full Scale Leak Test Assembly Enclosure (No Inflatable Seal)

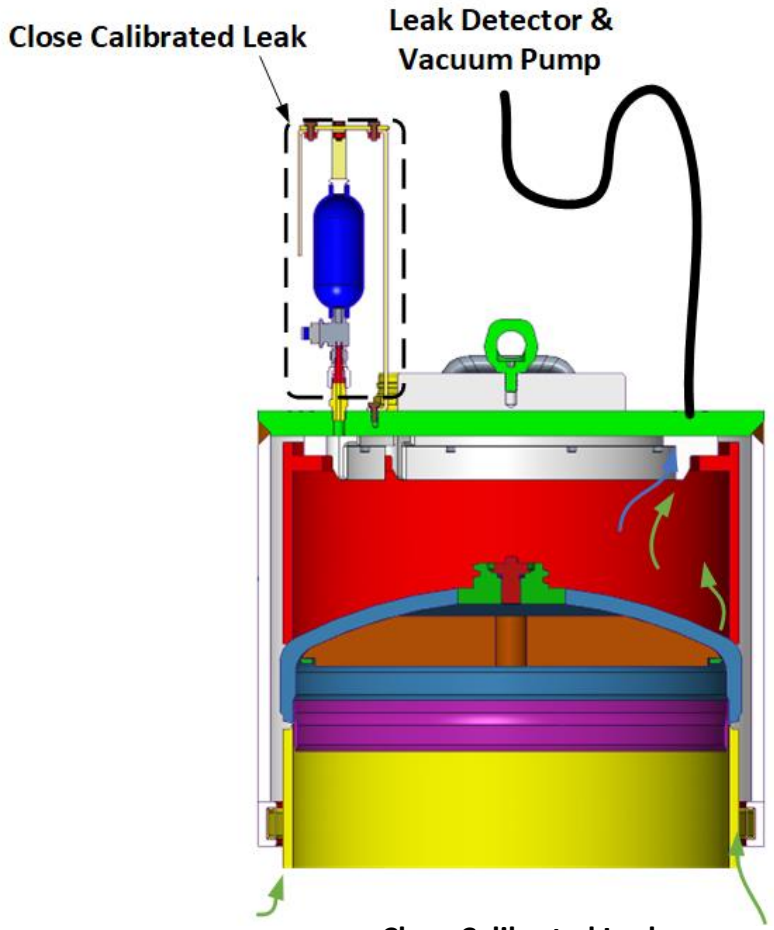
Leak Test Operation



Sealed/Pressurized DOE Standard Canister
Standard Temperature/Pressure Environment (~5 ppm He)



Place Leak Test Assembly
Inflate Seal
Open Calibrated Leak

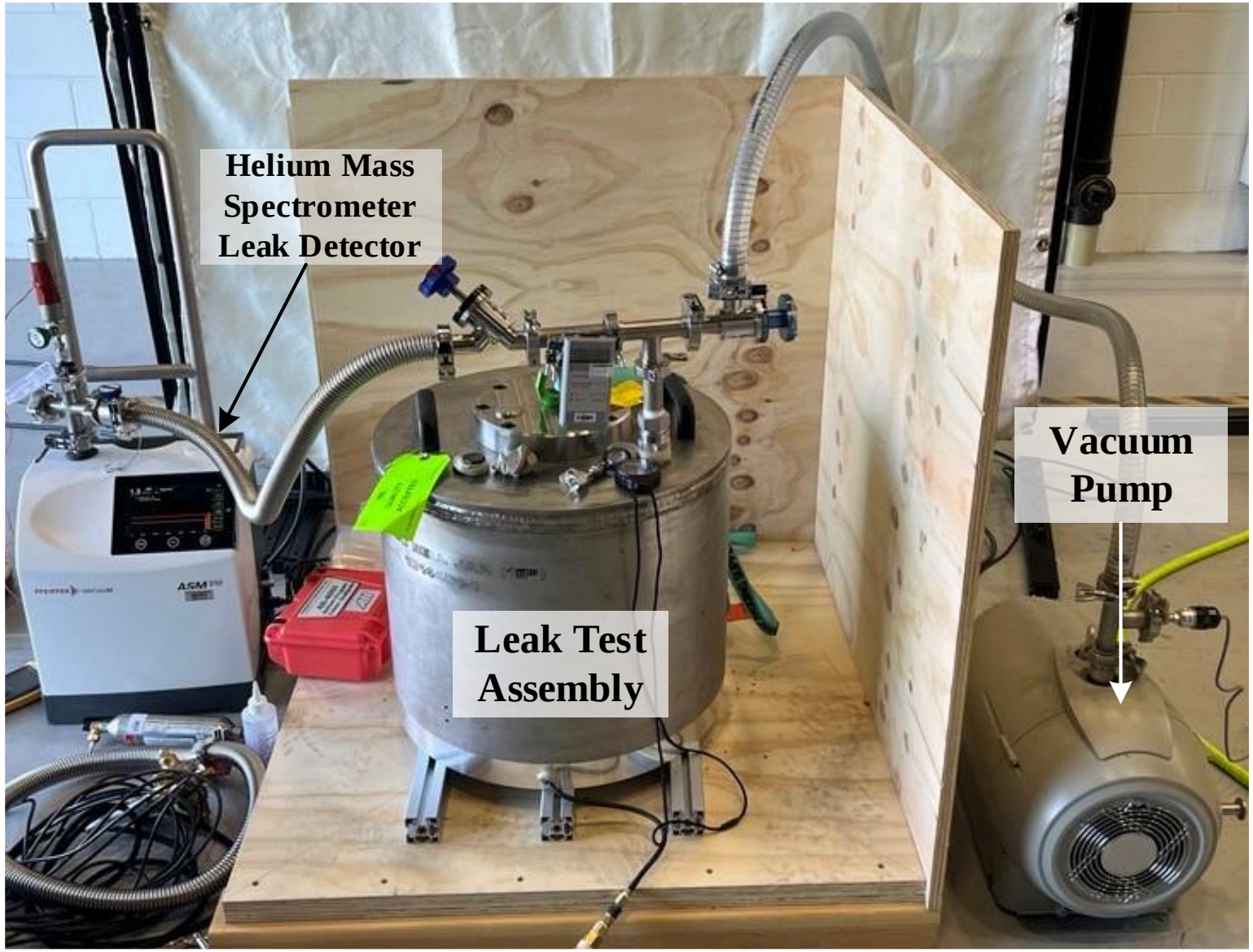


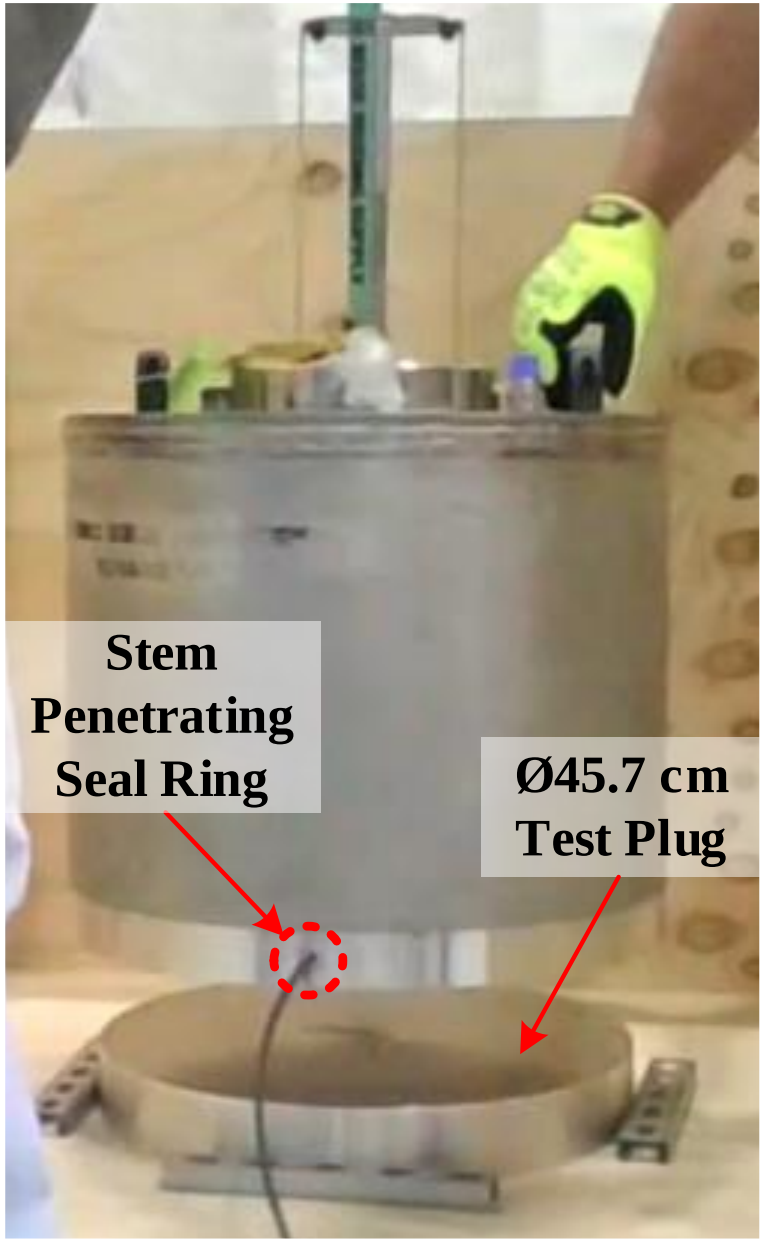
Close Calibrated Leak
Establish Background + Test Article Leakage

If Leak Rate (Background + Test Article)
> 1E-07 std-cc/sec → FAIL

Background Helium (Unknown Rate)
Test Article (Canister) Leakage (Unknown Rate)
Calibrated Leak (2.4E-08 std-cc/sec)

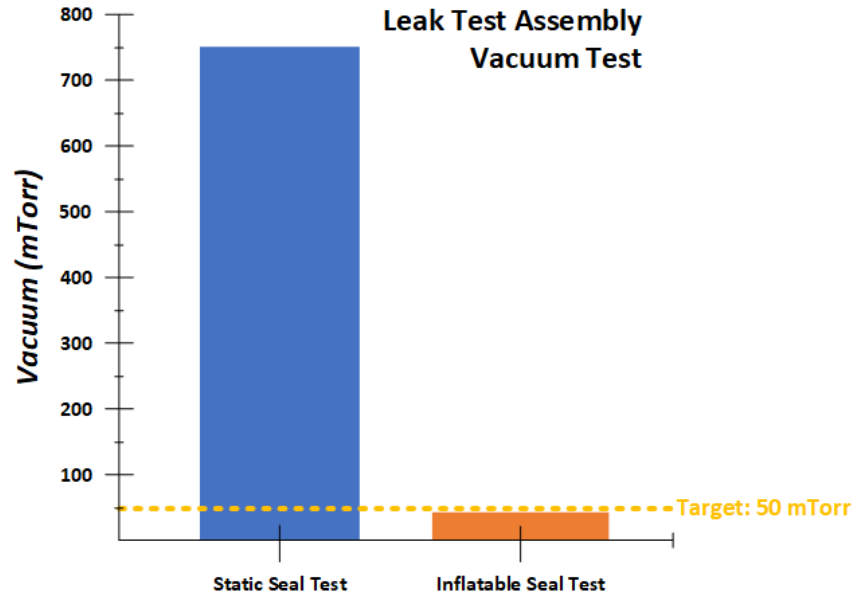
Inflatable Seal Leak Test

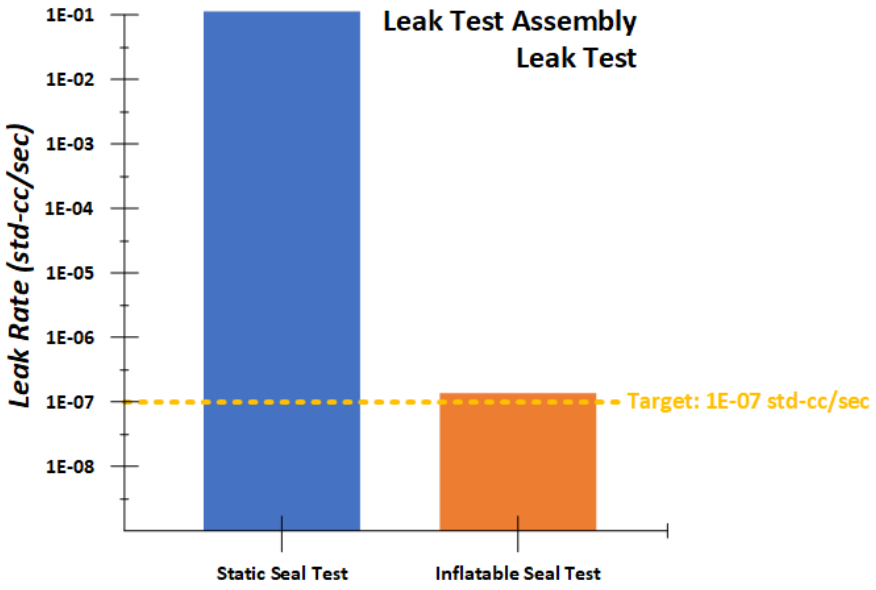




Inflatable Seal Leak Test Results

- Background leakage through inflatable seal exceeds acceptance criteria
- Background signal “masks” any potential test article leakage → automatic fail





Test Date	Parameter	Target	Result	Pass/Fail
10/22/23	Leak Rate	≤1E-07 std-cc/sec	1.1E-07 std-cc/sec	**Fail**
	Vacuum	≤50 mTorr	40 mTorr	Pass
5/06/23	Leak Rate	≤1E-07 std-cc/sec	1E-01 std-cc/sec	**Fail**
	Vacuum	≤50 mTorr	750 mTorr	**Fail**

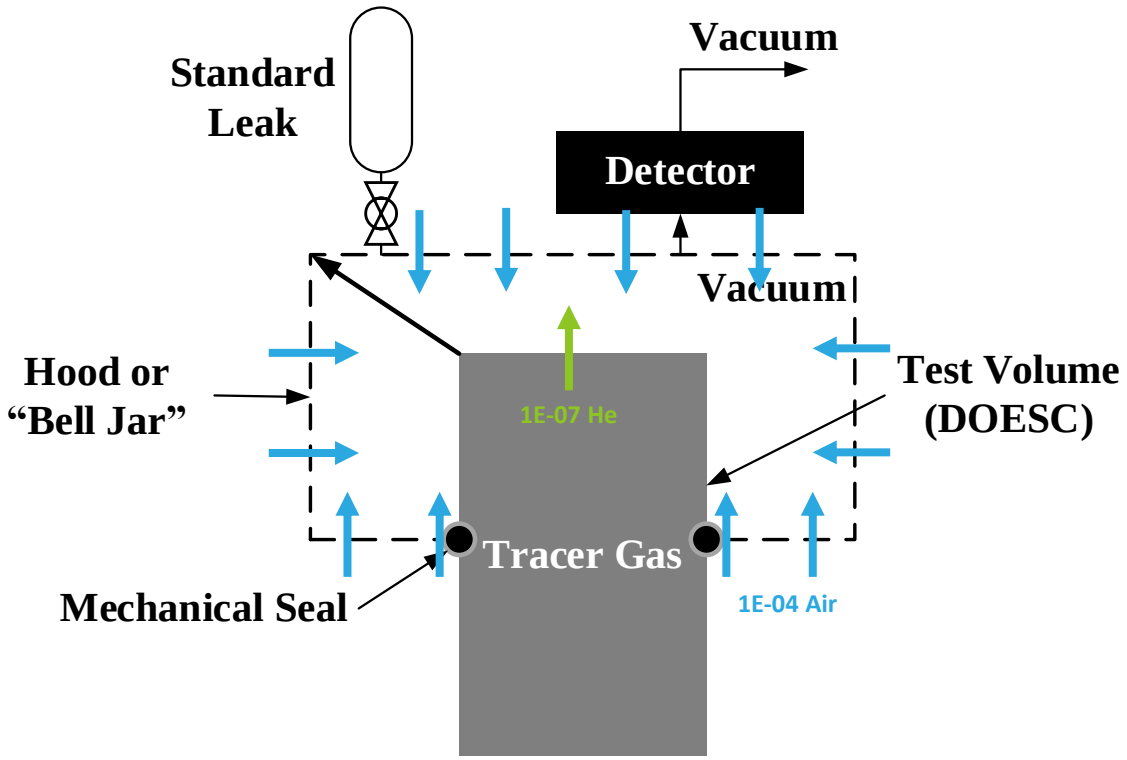
Further Work

- Further inflatable seal testing
  - Fiber-reinforcement (high operating pressure)
  - Superior seal profile (higher pressure differential)
- Response time testing
  - ~30 ft. vacuum tubing
- Design modifications
  - Lead-in for crane operation
  - Vented fasteners for artificial leaks
  - Welded plumbing penetrations

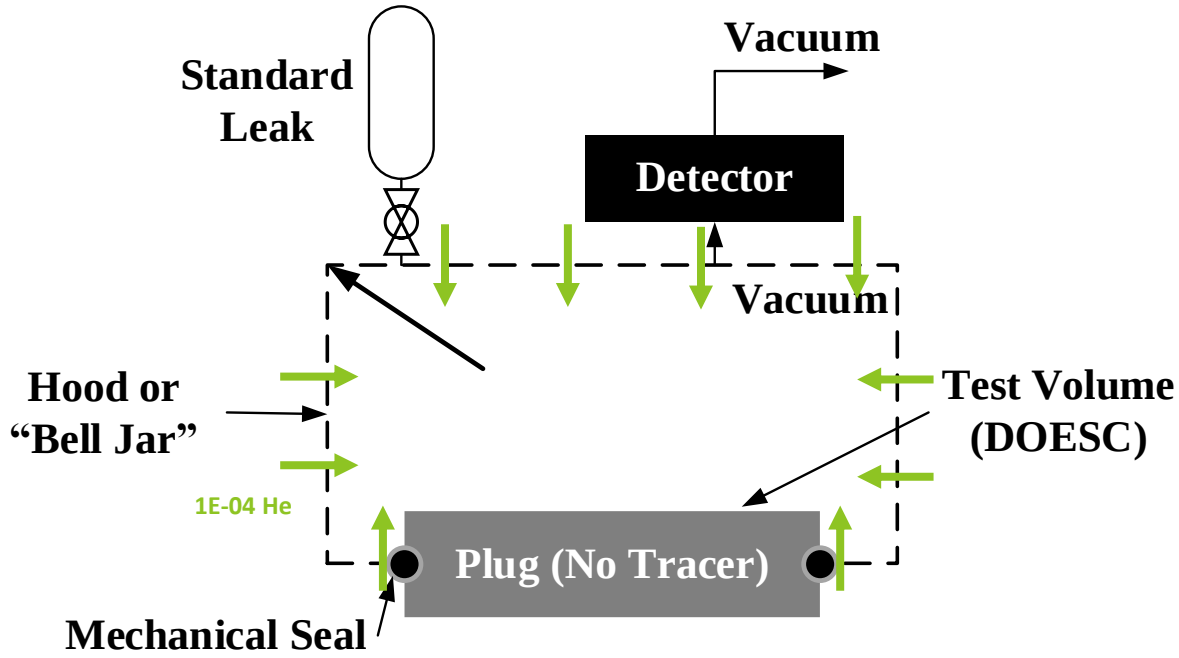
Extra Slides

Field Test vs. Shop Test

FIELD TEST



SHOP TEST

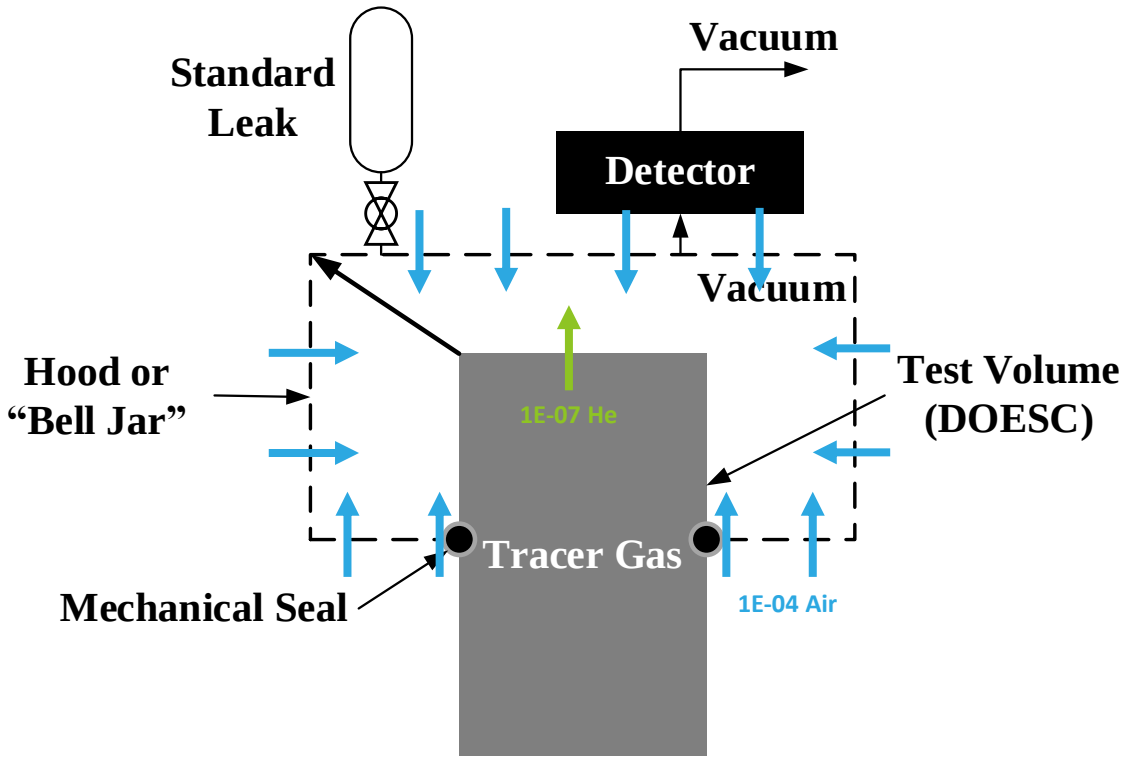


FIELD TEST

SHOP TEST

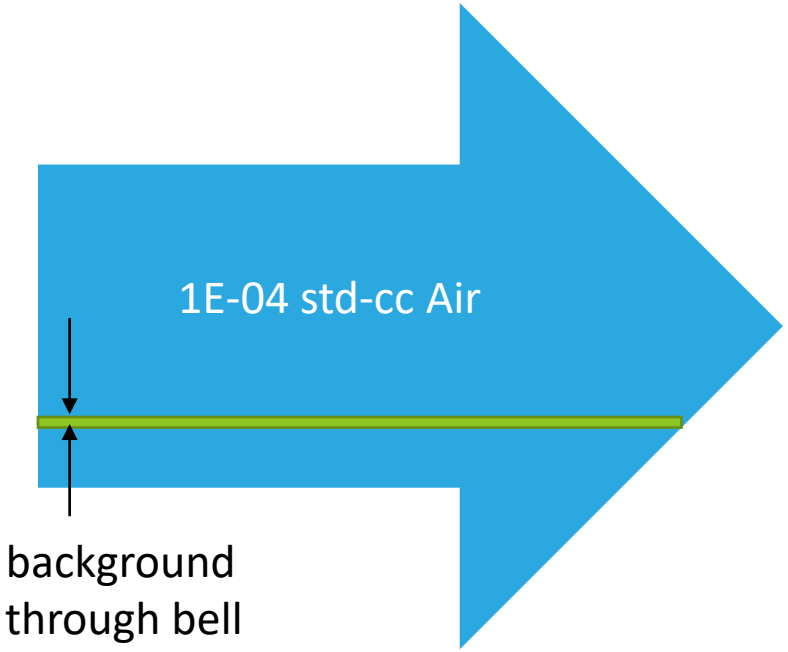
Field Test vs. Shop Test

FIELD TEST



FIELD TEST

Only a very small fraction of air leaking into the Leak Test Assembly is helium. This means only a small fraction is contributing to background.



Helium background leaking through bell jar (5 ppm)

Field Test vs. Shop Test

$$L = L_m \cdot \frac{P_m}{P_t}$$

ANSI N14.5-2022, Equation B.15 (Correct for tracer gas partial pressure)

$L := 1 \cdot 10^{-4} \cdot atm \cdot \frac{cm^3}{sec}$ Volumetric leak rate (**air leak**) pass inflatable seal during closure leak test

$P_m := 1 \cdot atm$ Atmospheric pressure of air outside Bell Jar during closure leak test

$$C_{He} := \begin{pmatrix} 5 \\ 50 \\ 100 \\ 500 \\ 1000 \end{pmatrix} \cdot 10^{-6}$$

Background concentration of He in air (ppm)

$std := 1$

$$C_{std} := \left(\frac{atm \cdot cm^3}{sec} \right)^{-1} \cdot \frac{59.8}{60} \cdot \frac{std \cdot cm^3}{sec}$$

Dimensional factor for converting atm-cc/sec to std-cc/sec

Leak rate

	atm·cc/s	mbar·L/s	Torr·L/s	Pa·m³/s	sccm
atm·cc/s	1	1.013	0.759	0.101	59.8
mbar·L/s	0.987	1	0.75	0.1	59.2
Torr·L/s	1.32	1.33	1	0.133	78.9
Pa·m³/s	9.87	10	7.5	1	592
sccm	0.0167	0.0169	0.0127	0.00169	1

Assume that the absolute partial pressure of Helium remains constant at varying pressure.

$P_t := P_m \cdot C_{He}$

$$L_m := \frac{L \cdot P_t}{P_m}$$

ANSI N14.5-2022 Equation B.15 solved for measured leak rate

5 ppm He

50 ppm He

$$L_{m\_std} := L_m \cdot C_{std} = \begin{pmatrix} 4.98 \times 10^{-10} \\ 4.98 \times 10^{-9} \\ 9.97 \times 10^{-9} \\ 4.98 \times 10^{-8} \\ 9.97 \times 10^{-8} \end{pmatrix} \cdot \frac{std \cdot cm^3}{sec}$$

100 ppm He

500 ppm He

1000 ppm He

Measured leak rate converted to std-cc/sec. Recall that acceptance criteria is 1E-07 std-cc/sec

Detector reading with a 1E-04 std-cc/sec air leak assuming different He backgrounds

Idaho National Laboratory

Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy. INL is the nation's center for nuclear energy research and development, and also performs research in each of DOE's strategic goal areas: energy, national security, science and the environment.