ASSESSING THE PERMEABILITY OF CAPPED ELECTRETS AND OFF-POSITION E-PERM SENSORS CONFIGURED WITH L-OO CHAMBERS IN A HIGH-RADON CAVE ENVIRONMENT

Lawrence E. Welch*,
Abigail R. Van Blarcom,
Mark D. Jones, and
Michael J. Lace



The E-PERM - ON

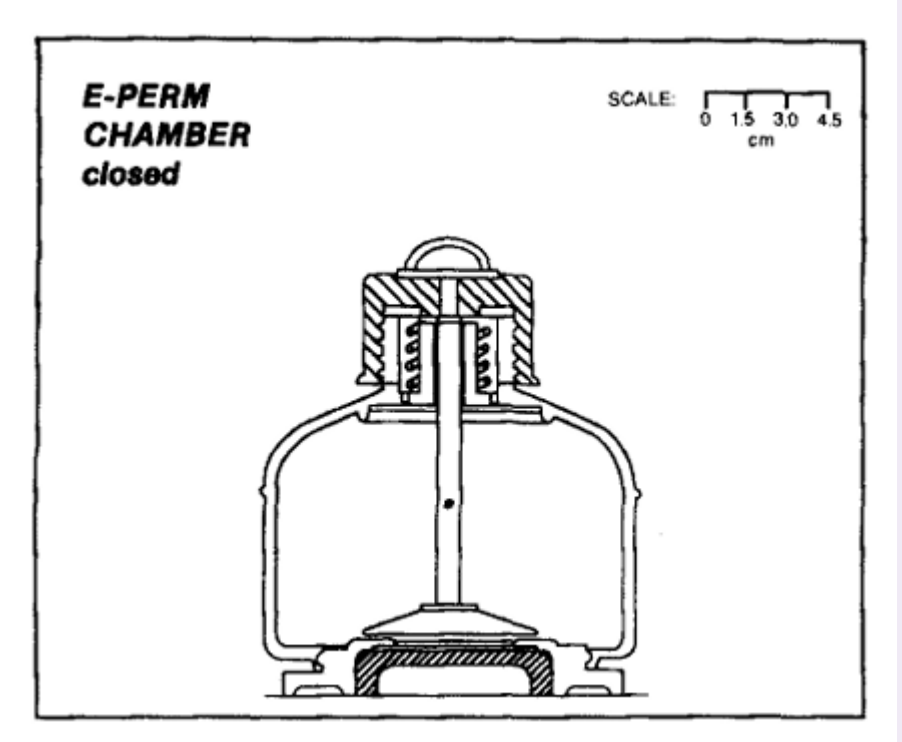
- An EIC sensor (electret ion chamber)
- Can be used to measure ^{222}Rn concentration (RnC)
- Has worked well in the harsh cave environment



Welch, L. E., Van Blarcom, A. R., Andreou, C. P., Jones, M. D., and Lace, M. J., 2025. Evaluating the Off Position for E-PERM Sensors Configured with S Chambers in a High Radon Cave Environment. Proceedings of the 2025 Indoor Environments Radon and Vapor Intrusion Symposium, pp. 1-21. https://aarst.org/proceedings/2025/2025-Welch.pdf.

THE E-PERM - OFF

- Cap is screwed down, blocking ingress of gas
- Plunger drops down and covers electret



Kotrappa, P., Dempsey, J.C., Ramsey, R.W., and Stieff, L.R., 1990. A Practical E-PERM™ (Electret Passive Environmental Radon Monitor) System for Indoor ^{222}Rn Measurement. Health Physics, 58(4), pp. 461-467.

E-PERM Configurations used in 2025

- In Coldwater Cave (known high Radon)
- Multi-day trials
- In the Off Position
- Compared vs. a blank run outside the cave



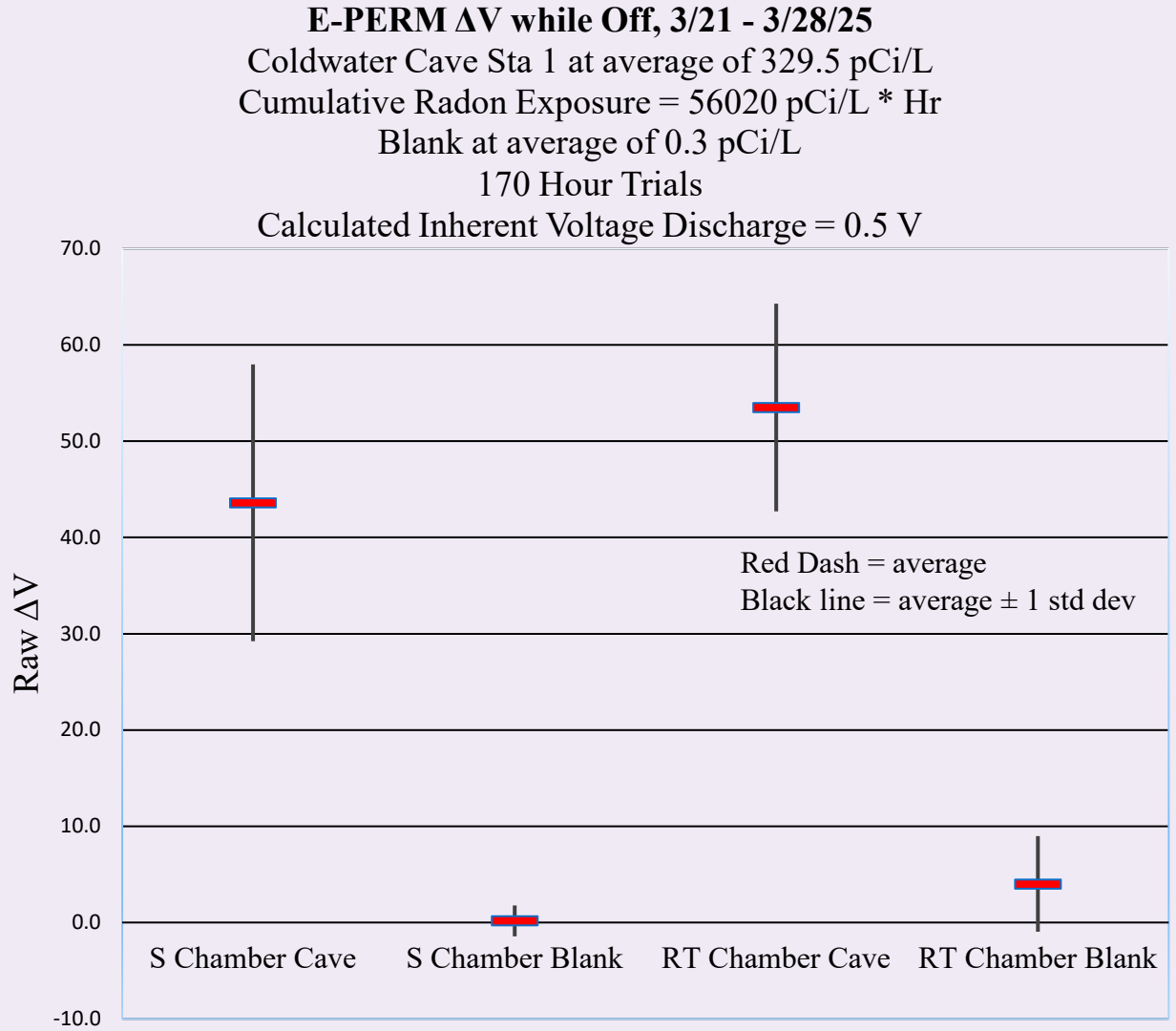
S chamber E-PERM

RT chamber E-PERM

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2025 Data

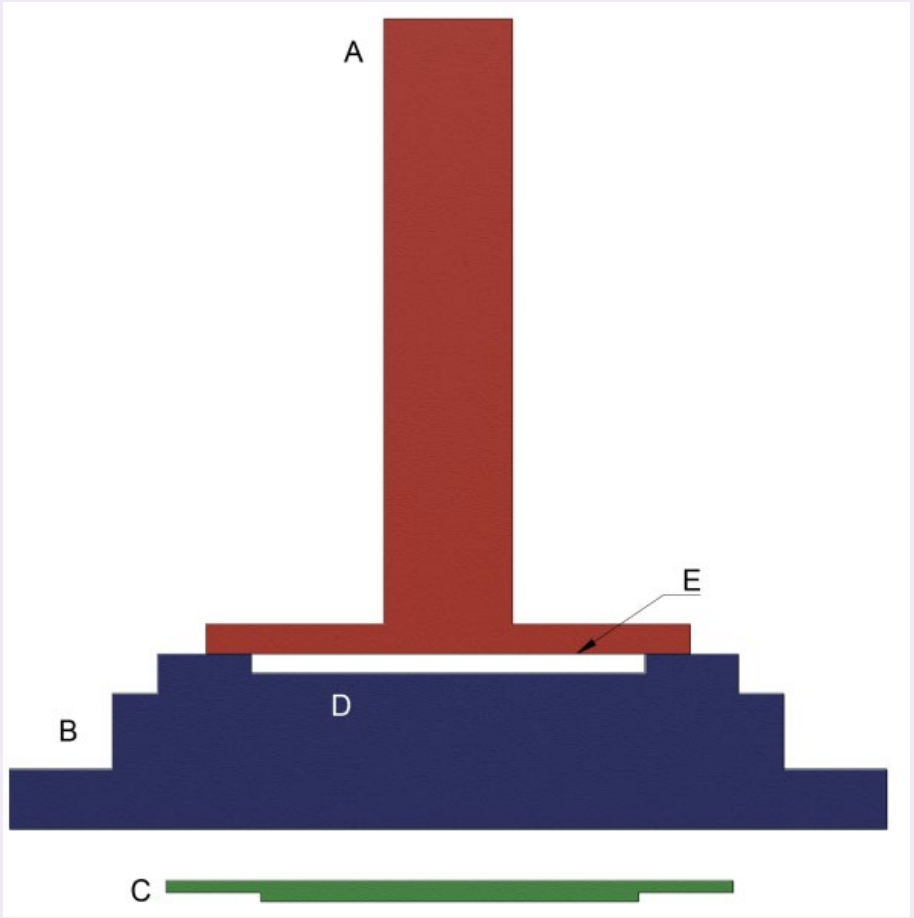
- Signal is acquired even in the off position



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What's happening?

- A 1.3 ml active chamber is formed over the electret when the sensor is in the off position
- Radon is penetrating into the active chamber when in the off position



Scale drawing (side view) of the plunger – electret interface for an E-PERM in the off position

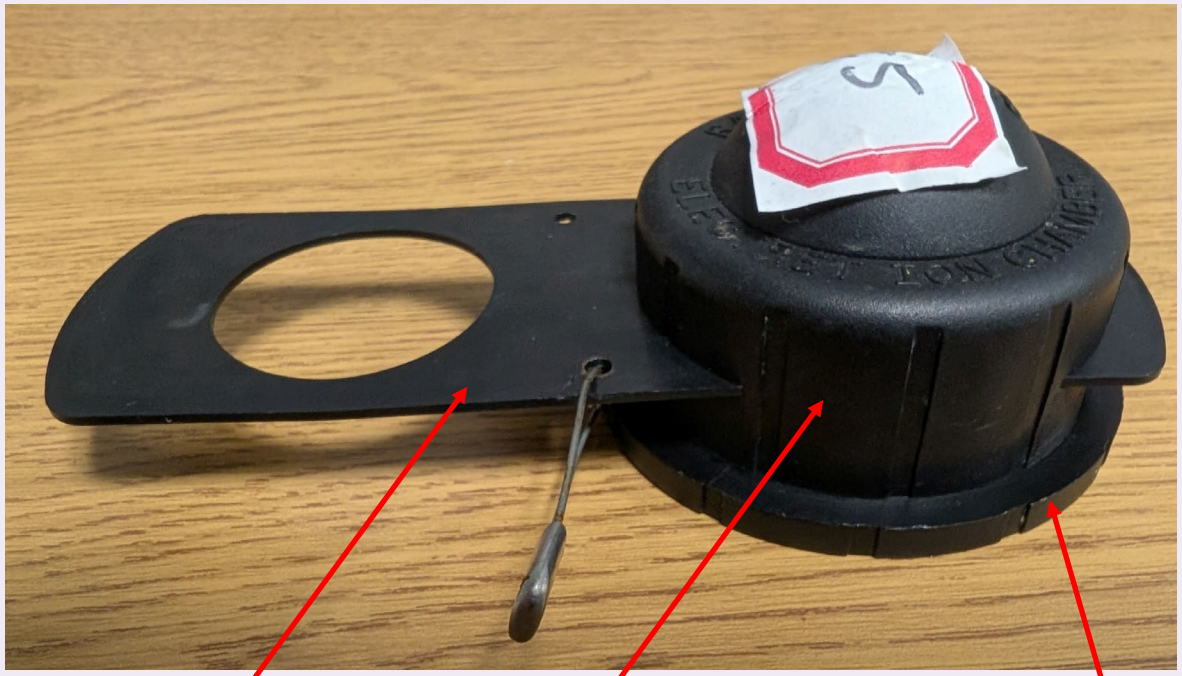
A(red) = plunger
B(blue) = electret
C(green) = spacer
D=positively-charged electret surface
E=active chamber

For scale reference, the plunger bottom width is 1.6 in

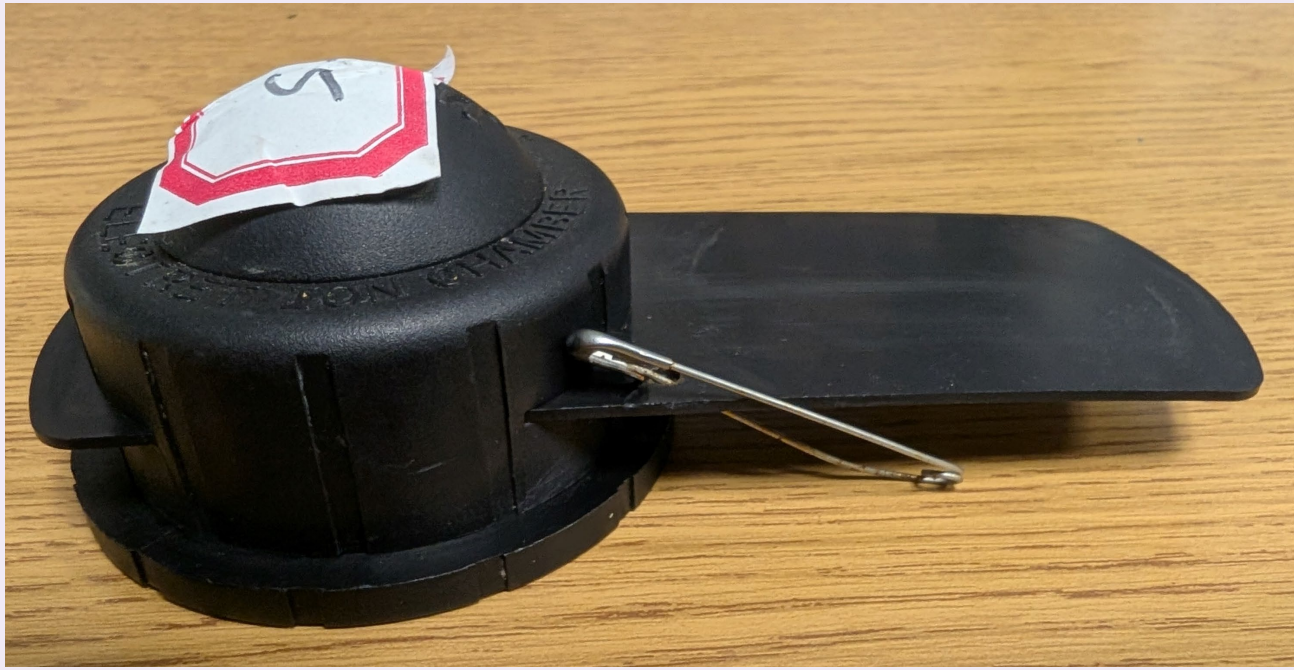
Welch, L. E., Van Blarcom, A. R., Andreou, C. P., Jones, M. D., and Lace, M. J., 2025. Evaluating the Off Position for E-PERM Sensors Configured with S Chambers in a High Radon Cave Environment. Proceedings of the 2025 Indoor Environments Radon and Vapor Intrusion Symposium, pp. 1-21. https://aarst.org/proceedings/2025/2025-Welch.pdf.

This year – Do other configurations show this same phenomenon?

- L-OO Chamber E-PERM -- **Off**



- L-OO Chamber E-PERM -- **On**



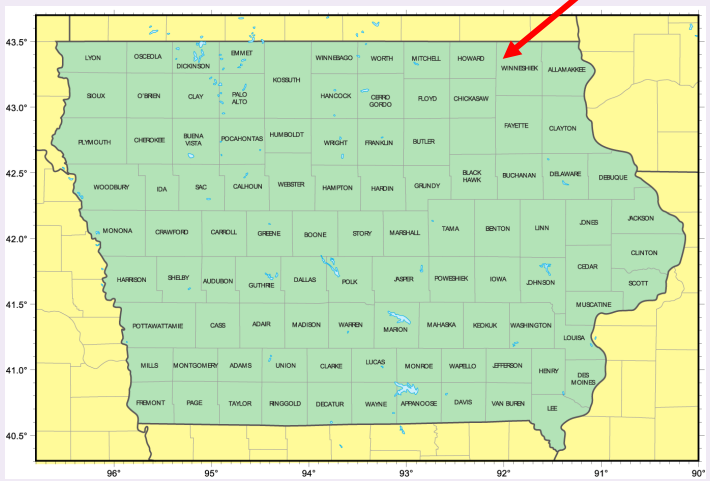
This year Part 2

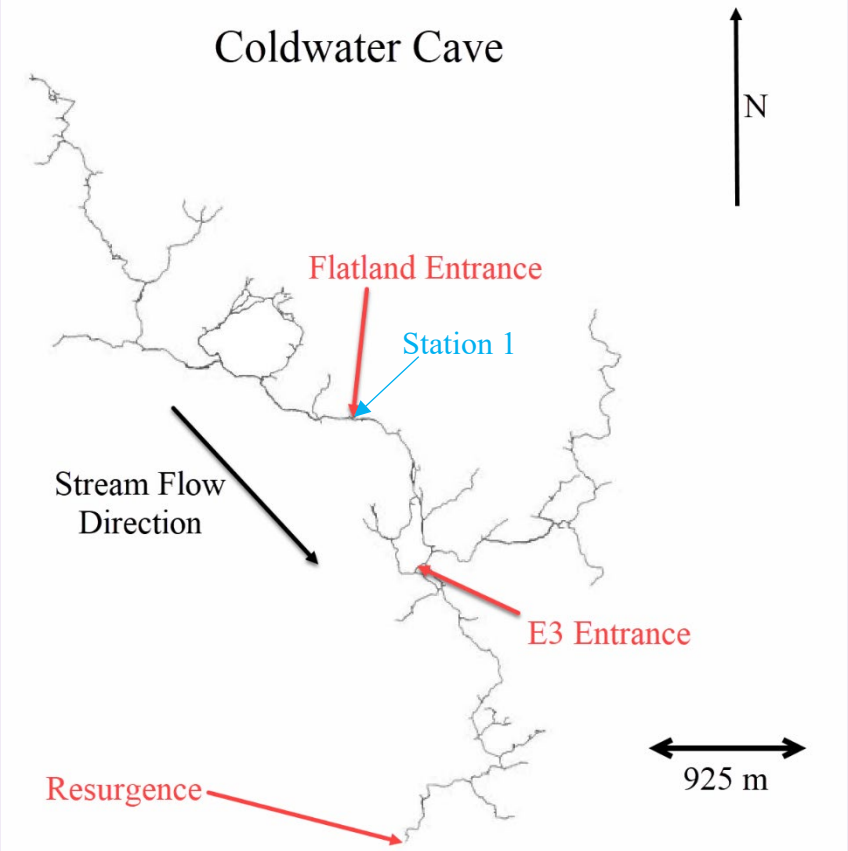
- Capped Electret



Sampling Site: Coldwater Cave, Station 1

- Important Site Information: Radon will be high, but nearly constant within the time frame of the experiments





Welch, L.E., Paul, B.E., Takashima, A., Rau, G.D., Beck, C.L., Klausner, E.C., Miller, E.R., Jones, M.D., and Lace, M.J., 2021. Contextualizing Radon Activity in Northeastern Iowa Caves by Measuring Uranium and Thorium at the Radon Sampling Sites. Proceedings of the 2021 International Radon Symposium, pp. 1-14. https://aarst.org/proceedings/2021/Welch_Contextualizing-Radon-Activity-in-Northeastern-Iowa-Caves-2021.pdf.

Other experimental concerns

- Run many replicates to improve precision
  - Range four to eight, most common = six
- Place in Tyvek bags
- Compare vs a blank set run in a shed on the surface
- Using both L-OO chambers and capped electrets, always ST electrets



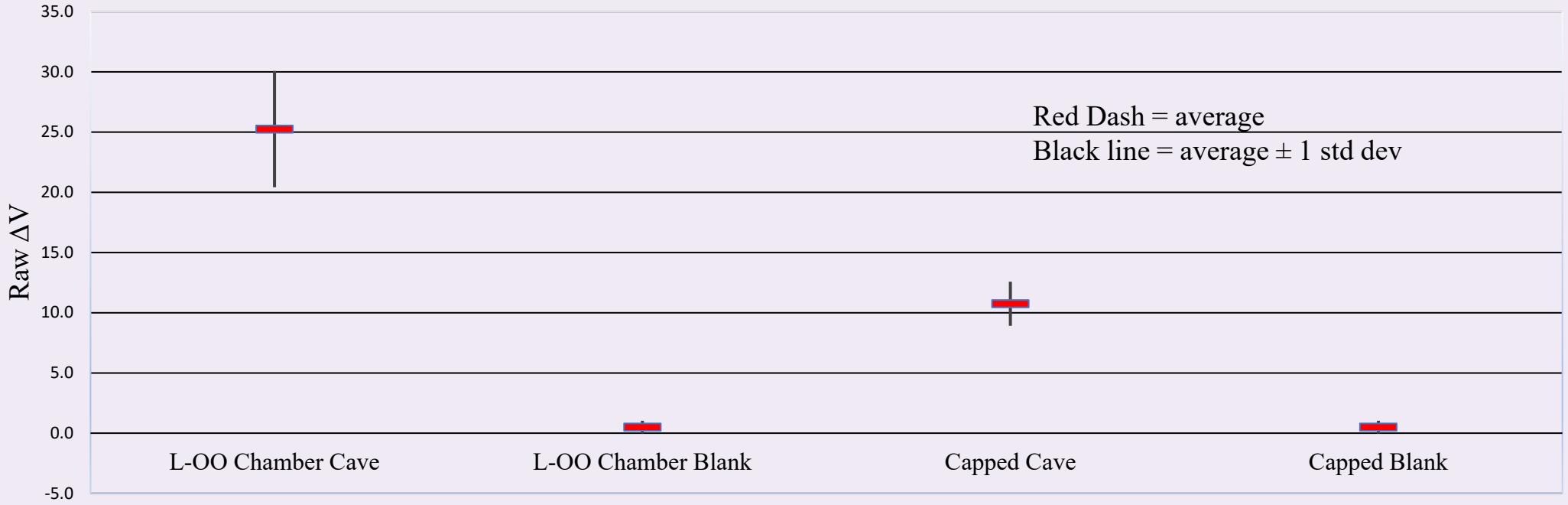
CRE – Cumulative Radon Exposure

- CRE = average radon concentration in pCi/L multiplied by the Hours of experimental duration
- Shooting for a value over 30,000 pCi * Hr / L
- Needed a long duration experiment to achieve this, even in Coldwater Cave.

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Cave Trial: Sensor in cave vs. blank

Coldwater Cave Sta 1 at average of 621.3 pCi/L
CRE = 68467 pCi/L * Hr
Blank at average of 2.7 pCi/L
110 Hour Trials
Calculated Inherent Voltage Discharge = 0.3 V

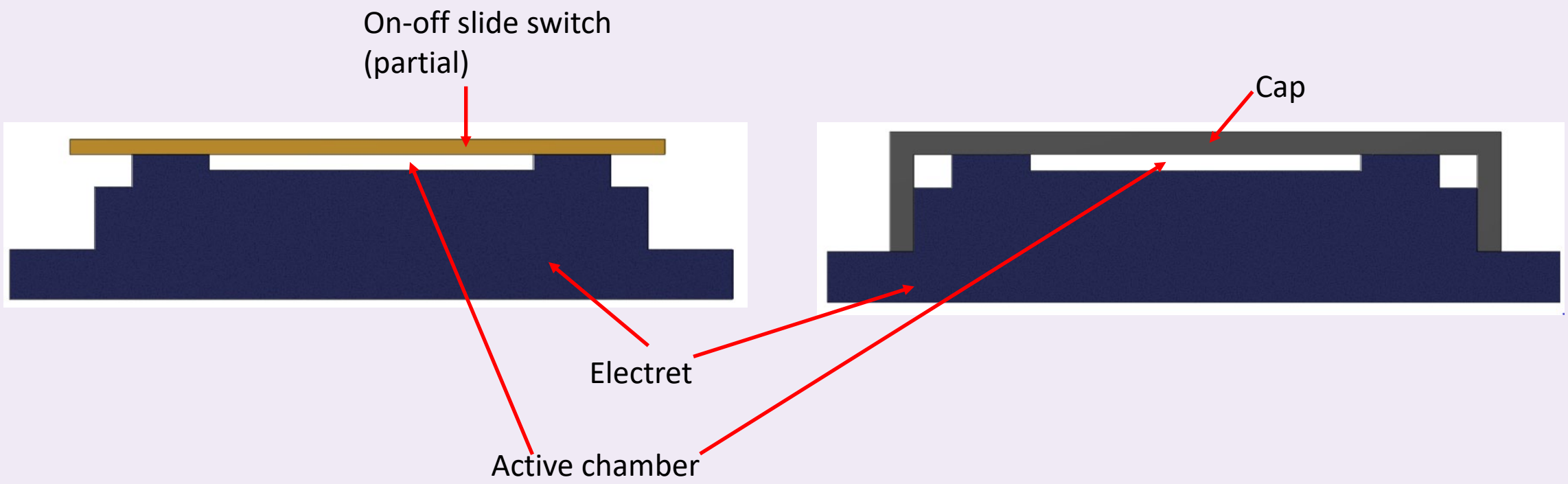


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CAD diagrams showing Active Chambers (side view)

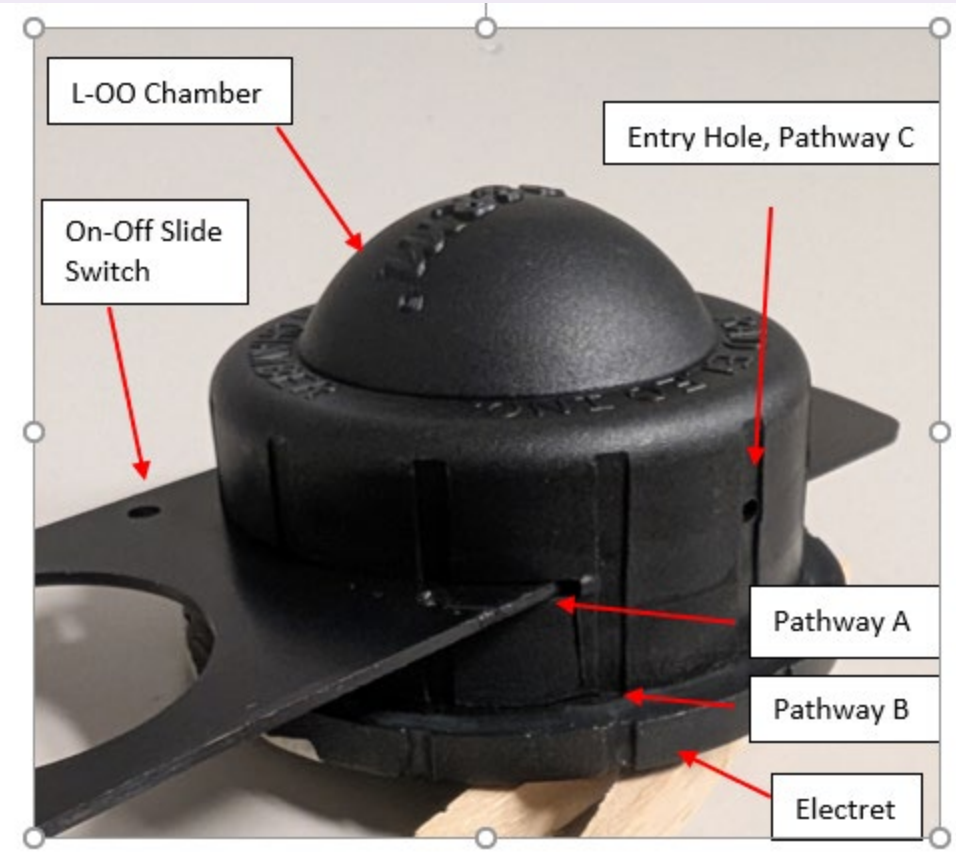
L-OO chamber E-PERM

Capped electret

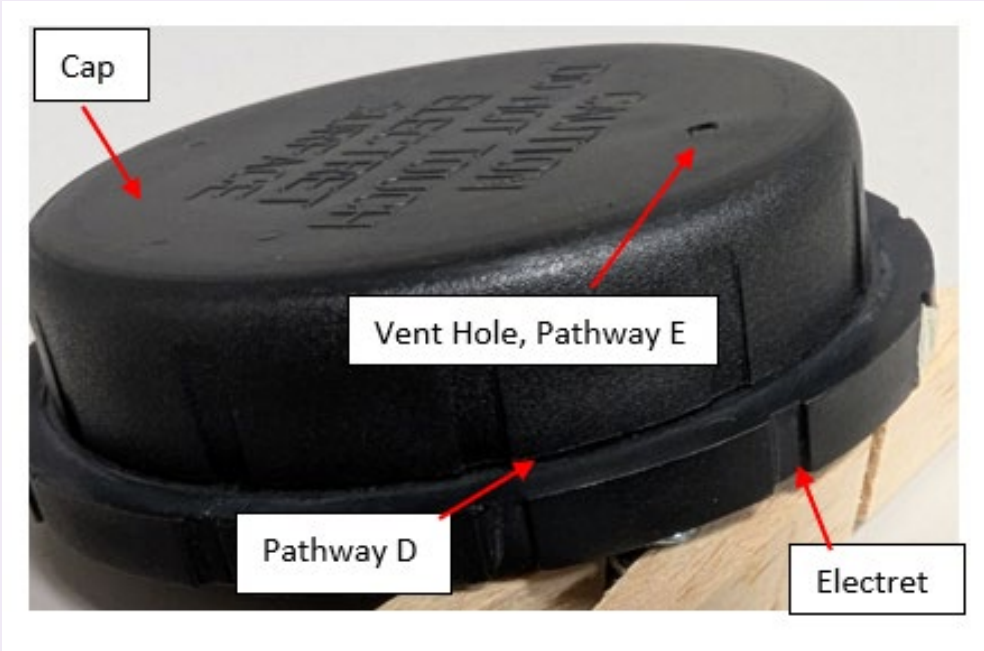


So we have an active chamber. How does radon get in?

L-OO E-PERM



Capped Electret



Pathway Probing

- L-OO
  - Covered the entry hole with butyl rubber tape, ran vs. a set without tape
  - No difference
  - Conclusion: Pathway C not a significant contributor

- Capped
  - Covered vent hole with butyl rubber tape, ran vs. a set without tape
  - No difference
  - Conclusion: Pathway E not a significant contributor

Comparing off-position E-PERM sets with and without polyethylene barriers.

Part 1: L-OO chambers, 4X Ziploc

Set	Avg MPV	SD MPV	CRE	Avg ΔV	SD ΔV	% of Control
11/9 – 11/14/25 E-PERMs in 4X nested Ziploc	485.7	25.0	65052	11.6	2.3	51.8
11/9 – 11/14/25 Control	466.8	19.8	65052	22.4	3.7	
6/7 - 6/11/26 E-PERMs in 4X nested Ziploc	468.8	25.8	46391	8.4	1.6	51.5
6/7 - 6/11/26 Control	441.8	19.6	46391	16.3	2.1	

Comparing off-position E-PERM sets with and without polyethylene barriers.

Part 2: L-OO chambers, 8X Ziploc + Daren Drum

Set	Avg MPV	SD MPV	CRE	Avg ΔV	SD ΔV	% of Control
6/17 - 6/20/26 E-PERMS in 8X nested Ziploc + Daren Drum	725.1	5.9	36553	1.0	0.7	7.9
6/17 - 6/20/26 Control	725.7	3.4	36553	12.7	4.2	
7/12 - 7/15/26 E-PERMS in 8X nested Ziploc + Daren Drum	722.3	5.7	58447	1.2	1.0	5.8
7/12 - 7/15/26 Control	708.1	6.6	58447	20.8	6.1	



Daren Drum

Comparing off-position sensors with and without polyethylene barriers.

Part 3: Capped Electrets, 4X Ziploc

Set	Avg MPV	SD MPV	CRE	Avg ΔV	SD ΔV	% of Control
11/9 – 11/14/25 capped electrets in 4X nested Ziploc	558.5	20.7	65052	5.8	1.0	61.7
11/9 – 11/14/25 Control	541.6	18.4	65052	9.4	2.0	
6/7 - 6/11/26 capped electrets in 4X nested Ziploc	547.5	21.8	46391	4.5	0.8	64.3
6/7 - 6/11/26 Control	528.3	19.0	46391	7.0	1.1	

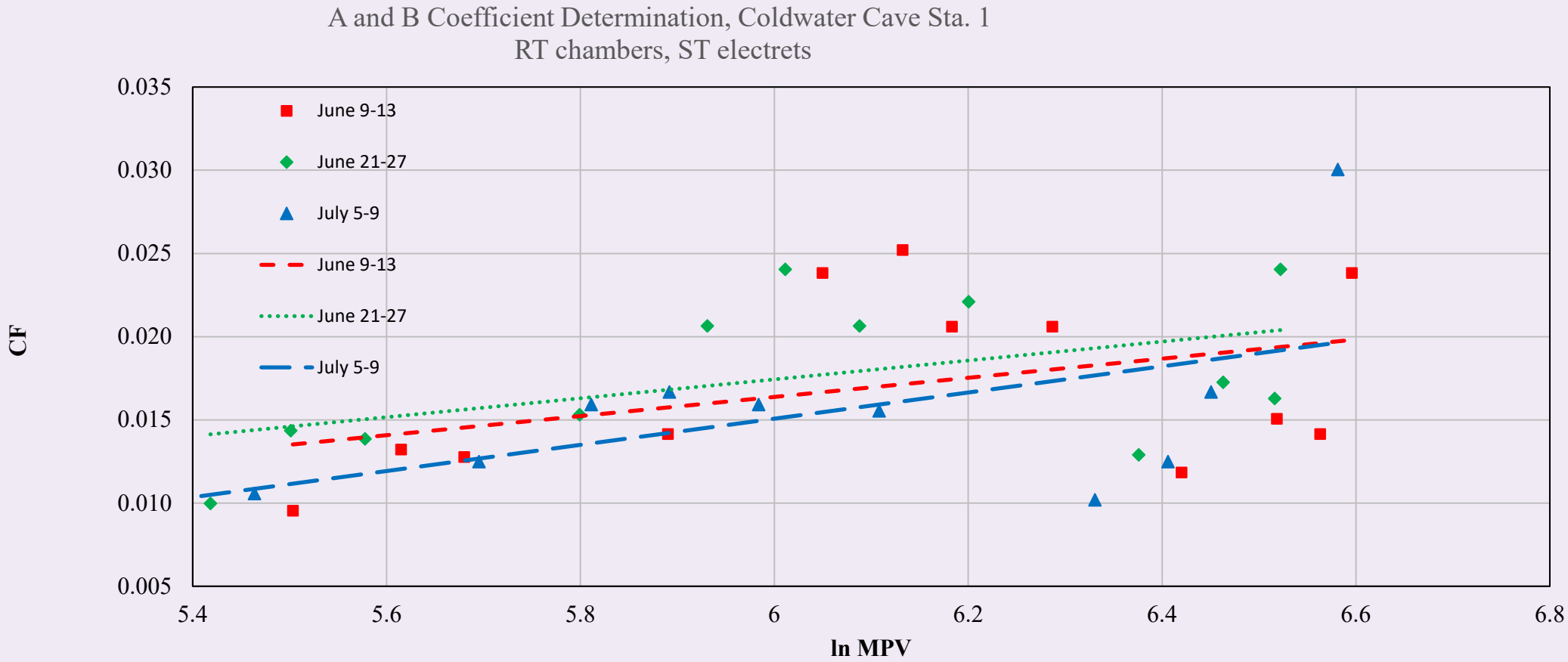
Comparing off-position sensors with and without polyethylene barriers.

Part 4: Capped Electrets, 8X Ziploc + Daren Drum

Set	Avg MPV	SD MPV	CRE	Avg ΔV	SD ΔV	% of Control
6/17 - 6/20/26 capped electrets in 8X nested Ziploc + Daren Drum	702.2	2.9	36553	0.7	0.5	14
6/17 - 6/20/26 Control	706.6	7.0	36553	5.0	1.1	
7/12 - 7/15/26 capped electrets in 8X nested Ziploc + Daren Drum	700.9	3.1	58447	0.8	0.4	9.4
7/12 - 7/15/26 Control	699.1	6.9	58447	8.5	1.0	

A and B Coefficient Determination

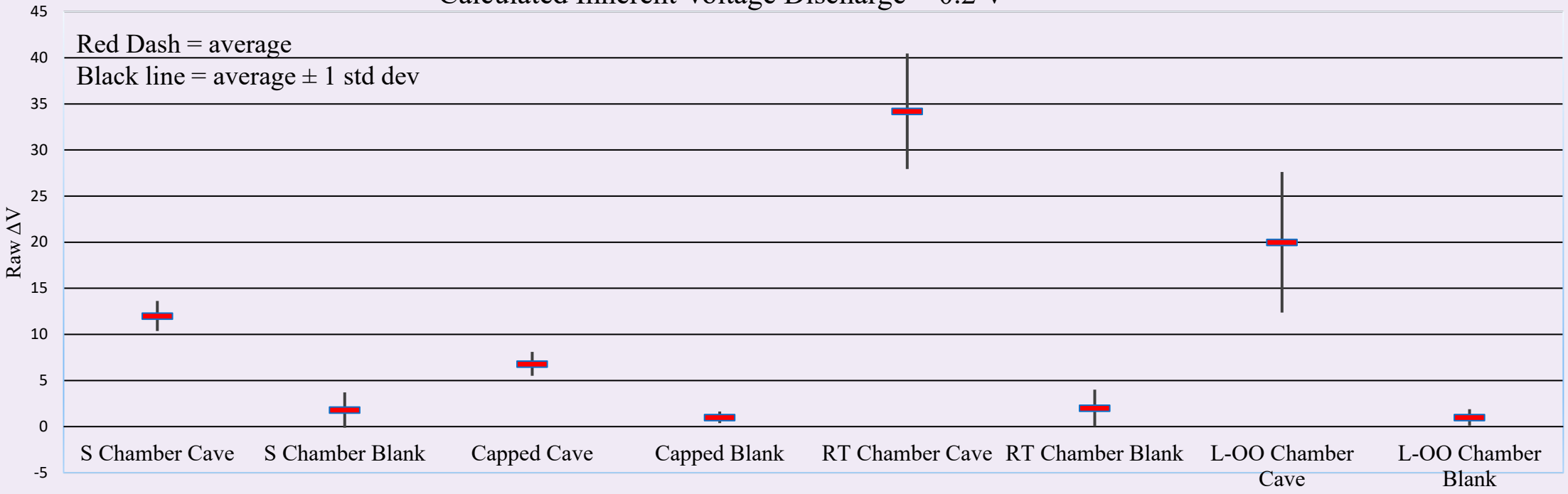
Last year's plot – this year, not enough precision



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Comparison of all Four Sensors from 2025-6

Coldwater Cave Sta 1 at average of 505.8 pCi/L
Cumulative Radon Exposure = 36160 pCi/L * Hr
Blank at average of 1.1 pCi/L
71.5 Hour Trials
Calculated Inherent Voltage Discharge = 0.2 V



Conclusions from the comparison

- RT E-PERMs are the most sensitive
  - Probably why A and B coefficient experiment worked for them while not as good for the other sensor types

- Since all four have sensors with the same active chamber volume, the difference in sensitivity has to be from the permeability of the sensor to radon

General Conclusions

- L-OO chamber E-PERM sensors still accumulate ΔV signal at a very low level when the electret is installed but the chamber is off, as do capped electrets
    - Sufficient active chamber volume exists for the off-position sensor to act like a functioning E-PERM
    - Radon can get in chamber

Practical Conclusions 1

- Need to have a very high CRE to observe these changes
- Requires both a high radon concentration and a very long-duration experiment
- Very uncommon circumstances

Practical Conclusions 2

- Capped Electrets
  - This represents the standard storage form of electrets
  - If not stored in a low-radon environment, the capped electrets will slowly bleed voltage, and therefore experimental capacity

Questions?



Contact Info

Lawrence E. Welch
Clara A. Abbott Distinguished
Professor of Chemistry
Knox College
lwelch@knox.edu
309-341-7333