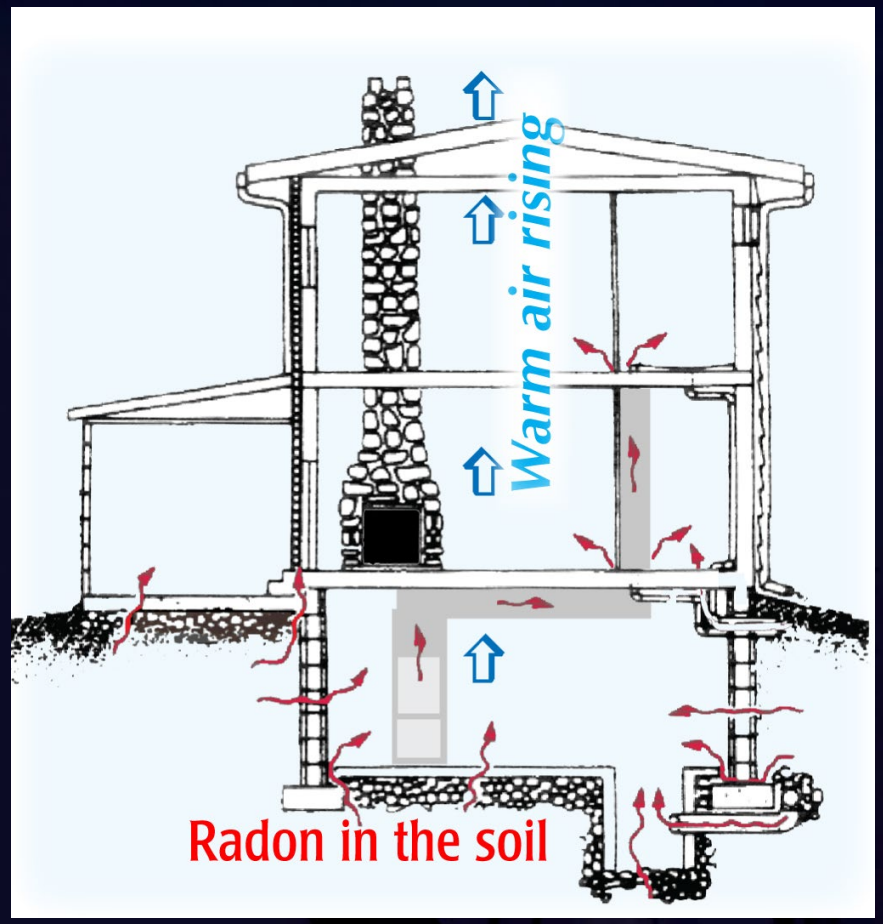
Why So Negative?

Mechanically induced negative pressure as a primary driver of soil gas entry.

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Pressure Relationships



Stack Effect – Due to natural physics, many buildings are inherently negatively pressurized.

- Modern buildings implement engineered systems during construction to minimize this pressurization.

- However, if these systems were not implemented correctly, have not been maintained or have been incorrectly modified, they can mechanically induce enough negative pressure to be THE primary driver of soil gas entry.

- These pressure relationships are as dynamic, variable and can be highly localized.

The primary air pressure relationship that drives soil-borne radon entry is the difference in pressure of the airspace inside the building (or a portion of the building) and the space below the building.

We talk extensively about conducting Pressure Field Extension (PFE) testing but often overlook the bigger picture.

Related Pressure Drivers:

- Indoor/Outdoor Temperature Differential
- Climate Conditions
- Building Usage & Operation
- HVAC Design
- HVAC Usage
- Internal Pathways, Plenums & Chases
- Other factors

....always variable. always symbiotic.

Mechanical Influence

- Inherent in virtually all HVAC designs for buildings is the use of negative pressure, by way of exhaust or air handler duct balancing, to mitigate indoor pollutants.
  - A bathroom exhaust fan is a simple example.
  - An indoor gun range would be an extreme example.
- But in larger buildings, the tradition for HVAC design is to liberally apply negative pressure to virtually all portions of a building.
- While an inexpensive way to control odors and increase air exchange rates, liberally applying negative pressure in a buildings can dramatically increase soil gas entry.

Building remodeling and inherent modifications to HVAC systems can create situations where localized negative pressure can become extreme.

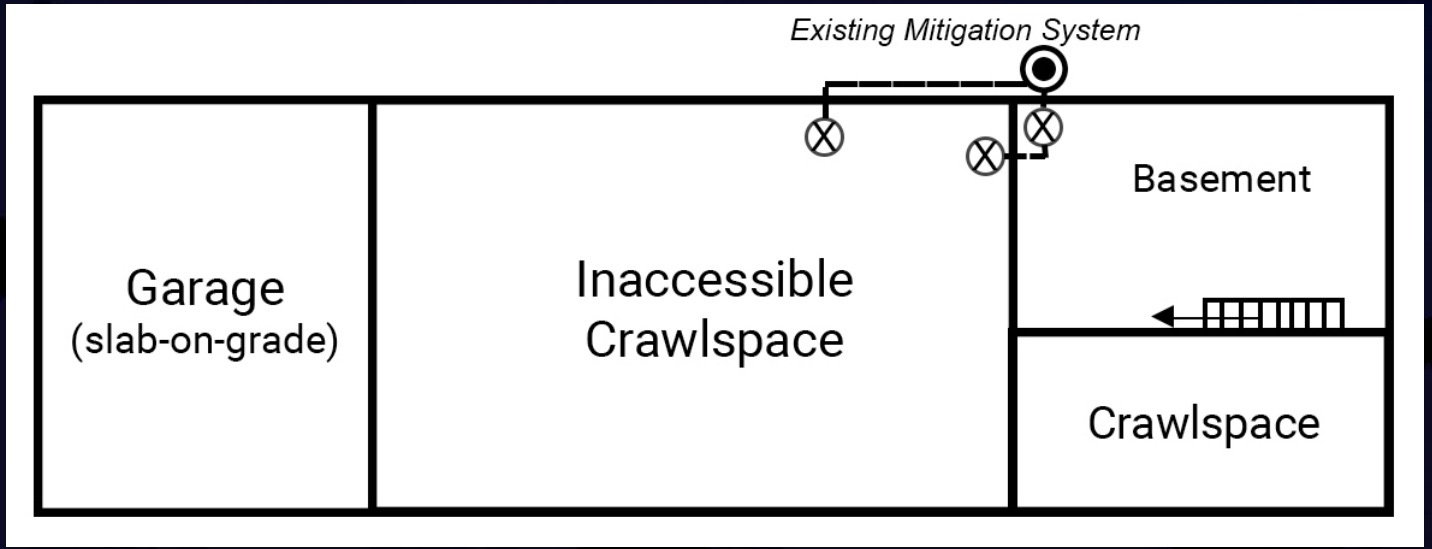
This can drive soil gas entry from that area and dispense it at a nearly even rate throughout the living space.

MINING FOR RADON.

Case Study #1

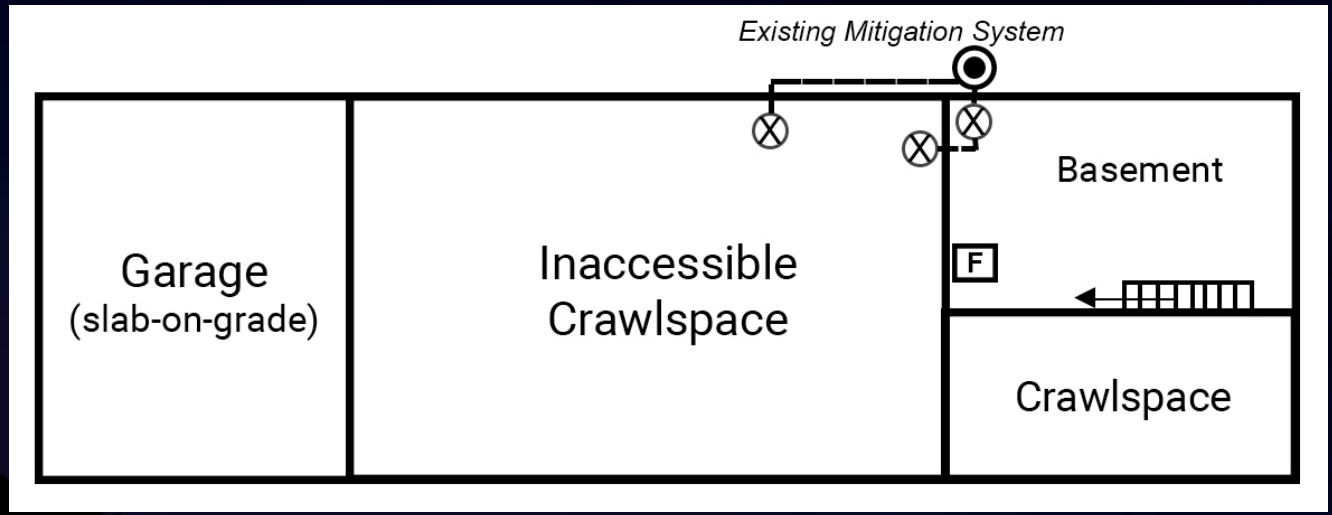
- **Scope:** Radon Mitigation – Existing System Ineffective
- **Type of Building:** 1-story single-family home
- **Year Built:** 1933
- **Location:** NW Missouri, USA
- **Radon Concentrations:** **29.0 pCi/L** *(basement w/system on)*

- **General Summary:** Owner had another contractor install a mitigation system, which was not effective at reducing radon levels in the home. The original contractor had returned several times to make changes to the system yet still failed to ever achieve radon reductions to below EPA action level, then indicated to homeowner that the home was not fixable.



- **Building Description:** Typical ranch-style home that has been added onto and heavily modified during various remodeling projects and additions made to the home since originally constructed. A large portion of the building is constructed over inaccessible crawlspace.

- **Foundation Type:** Mixed
- **Foundation Construction Material:** Poured Concrete & Concrete Blocks



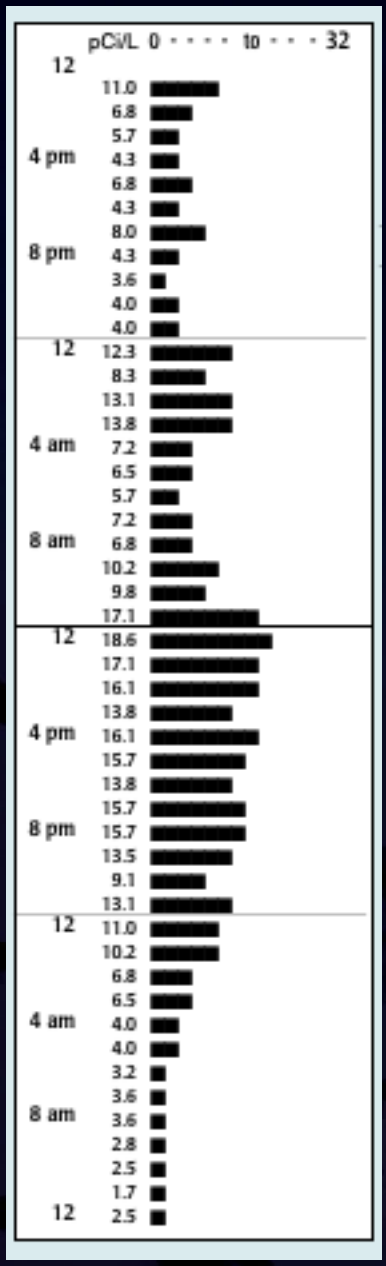




Initial Action:

Conduct building investigation, including HVAC investigation & sub-slab PFE testing.

- PFE testing indicates -4pa to -6pa at all 4 outer corners of the basement slab.
- Pressure measurements in crawlspace are highly variable and less than a pascal difference from basement airspace most of the time.
- HVAC System has been heavily modified. 1 large boxed plenum is now all that exists on the first-floor.
- Encapsulate small crawlspace at rear of home.
- Modify ASD vent piping to larger diameter piping and larger manifold.
- **Test Results: 8.8 pCi/L**



Further Action Needed

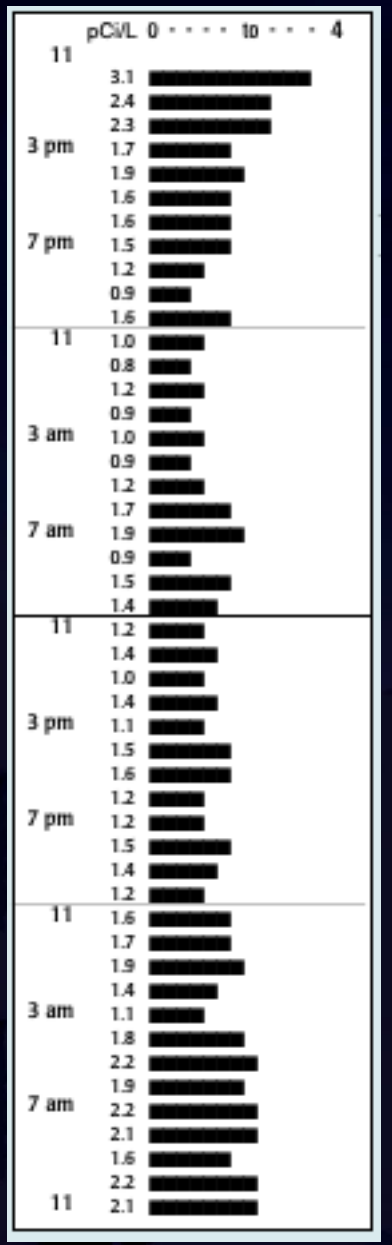
Further building investigation, including smoke checks to help determine HVAC influence.

- Determine that joist bays are open to the inaccessible crawlspace.
- Recognize significant amount of negative pressure in basement *(basement door slams closed behind you)*.
- A little colder outside = increased stack-effect & increased HVAC blower activity.
- Smoke Checks & later pressure measurements confirm HVAC is influencing negative pressure in basement & crawlspace. With HVAC blower active, **crawlspace hovering around -65 pa** compared to ambient outdoor air.



- Confirm return air plenum has been breached in 2 separate locations, allowing HVAC blower to acquire nearly all return air directly from basement & crawlspace.
- Permanently modify & fix breaches in return air plenum. Retest.
- **Test Results: 1.9 pCi/L**





Case Study #2

- **Scope:** VI Mitigation - Superfund Site - Existing Systems Ineffective
- **Type of Building:** 1-story duplex
- **Year Built:** 1942
- **Location:** NE Kansas, USA
- **TCE Concentrations: 220 ug/m^3** *(1st floor living room above crawlspace)*

- **General Summary:** This is a long-haul EPA superfund site situated in the outskirts of Kansas City. In total, there are over 70 privately-owned single-family homes and duplexes. Over several decades of mismanagement, varying attempts at SMD to mitigate these buildings has proven to be ineffective at reducing airborne TCE vapor. Many of the existing SMD systems had not been maintained, or any many cases, were no longer operational.



- **Building Description:** WW2 era single-story duplex. Historically been rental property, so maintenance has been lacking to say the least. Most of the building is constructed over open-soil crawlspace, with a smaller portion (garage & utility area) built slab-on-grade.





Initial Action

Replace existing VI mitigation systems with effective & compliant mitigation systems:

- Replace crawlspace membranes & extend up foundation walls to above outside soil level (grade)
- Remove existing SMD system
- Install new ANSI/AARST compliant SMD system
- Extend secondary suction points to upper-slab
- Conduct sub-membrane & sub-slab PFE testing
- Resample indoor air for VOC’s
- **Test Results: 7.9 ug/m3**

Further Action Needed

Further building investigation, including further pressure differential measurements.

- Determine that when HVAC blower is active, all sub-membrane PFE is lost & crawlspace becomes negatively pressurized.
- Confirm HVAC return air plenum was breached where it routes from 1st floor utility area into crawlspace. While extremely variable, pressure measurements in the crawlspace were between -40 Pa at the lowest, and peaking at times to **-90 Pa**. All measurements were conducted while the HVAC blower was operational.











- **Permanently fix & seal breaches in return air plenum**
- Reconduct sub-membrane & sub-slab PFE testing
- Resample indoor air for VOC's
- **Test Results: N/D ug/m^3**







Residential Considerations

- HVAC Imbalance
  - Improperly installed or modified HVAC systems
  - Large openings in air return plenum
  - Retrofitting additional HVAC systems into additions

In Conclusion

A review of HVAC & Air Handling Systems should be a required activity during initial diagnostic and investigative activities.

Case Study #3

- **Scope:** Radon Mitigation – Basement Office
- **Type of Building:** 15-story Office Building
- **Year Built:** 2008
- **Location:** Kansas City, USA
- **Radon Concentrations: 9.4 pCi/L**

- **General Summary:** The building footprint is about 4 football fields in size. Except for one occupied office area and nearby mechanical rooms, it was represented that all other ground-contact radon measurements were below the action level.



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Observations

- Throughout ground-contact areas, interconnecting open hallways.
- All concrete joints and soil gas pathways were reasonably sealed.
- Green highlights are the area of concern for diagnostics.

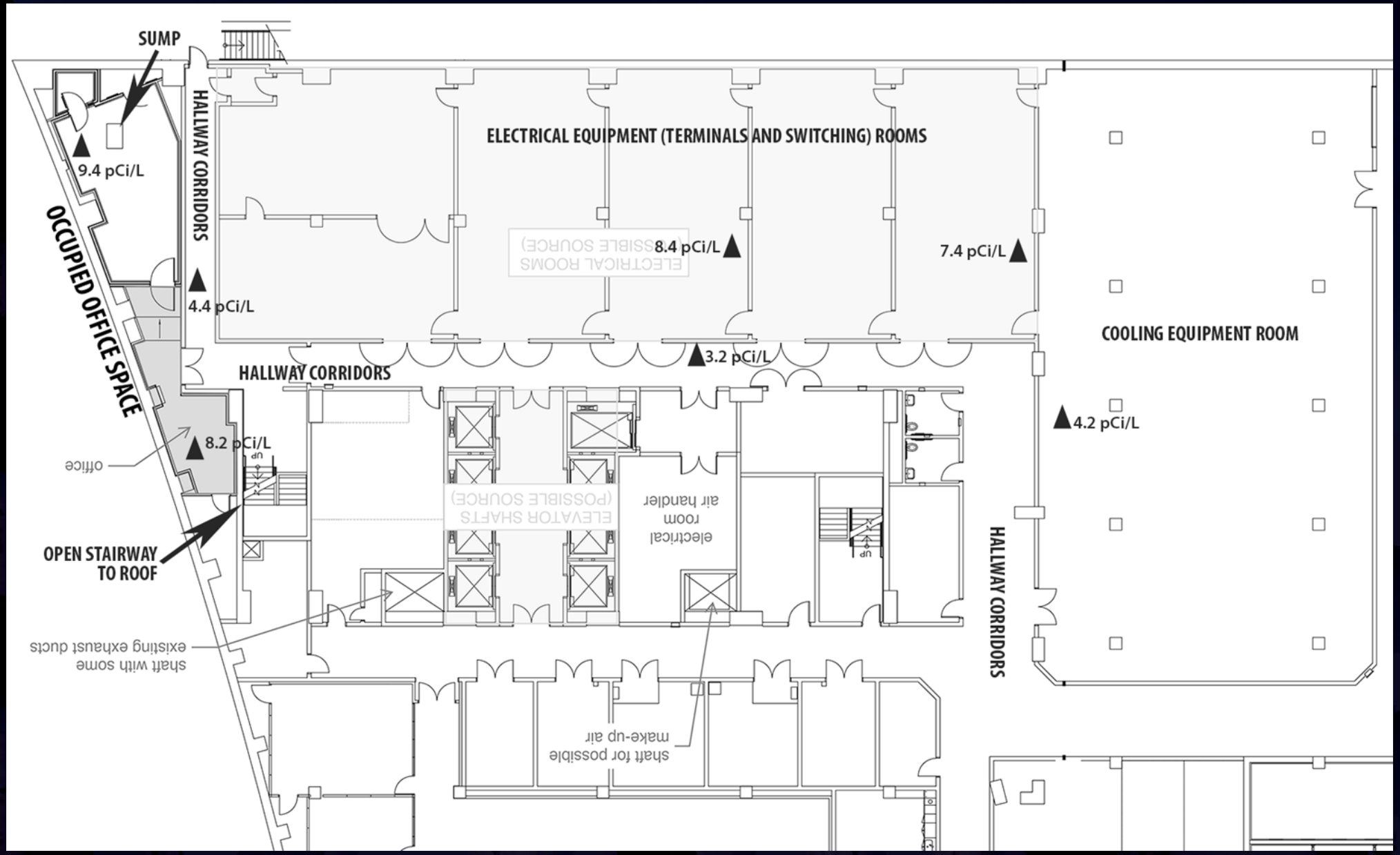


DIAGNOSTIC METHODOLOGY

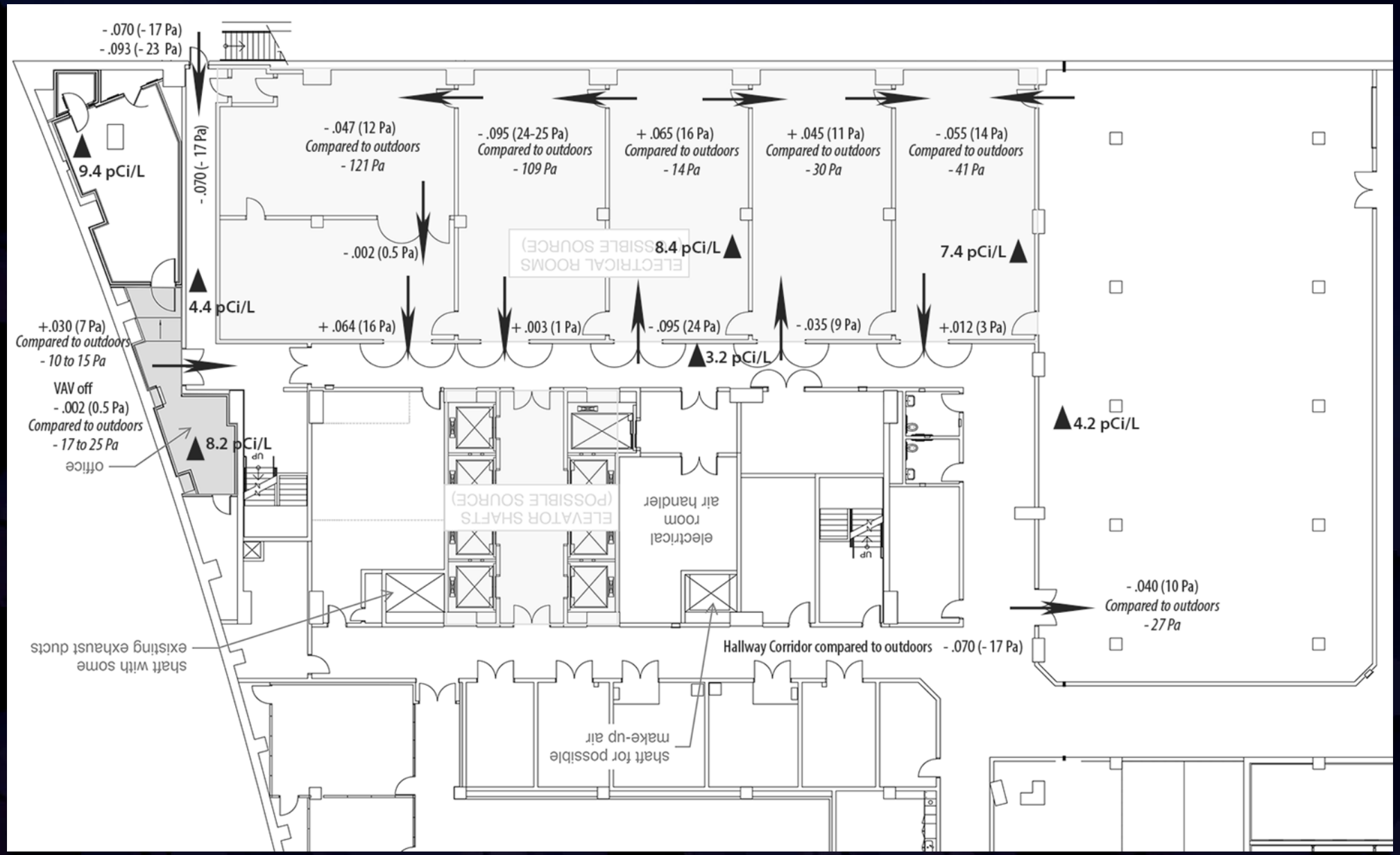
- 7 CRMs were deployed for four days
- Pressure measurements were conducted between multiple rooms and the vast indoor corridor relative to outdoor ambient air pressures.



RADON MEASUREMENTS (2 DAY AVG)



PRESSURE MEASUREMENTS (9 ENCLOSED SPACES - ~8,000 SQ. FT.)



OTHER INVESTIGATIVE DETAILS

- The office had a VAV (Variable Air Volume) system for introducing both recycled and outdoor air.
- The sump basin in this room was reasonable sealed.
- The air handlers for large building spaces can be very large compared to homes. (+/- 10,000 CFM) While opening some doors between electrical rooms, one could feel a breeze hitting our faces.

OTHER INVESTIGATIVE DETAILS

- Hallway pressure relative to outdoor air was used as the midpoint for comparing other rooms to outdoor air as it relates to HVAC.
- No sub-slab PFE measurements relative to indoor air were taken.
  - That is a different air pressure relationship, although it might tell us if the radon source is local or collected from under the entire footprint, but won’t give indication of interior air pressure relationships driving soil gas entry.

RESULTS—PRESSURE MEASUREMENTS

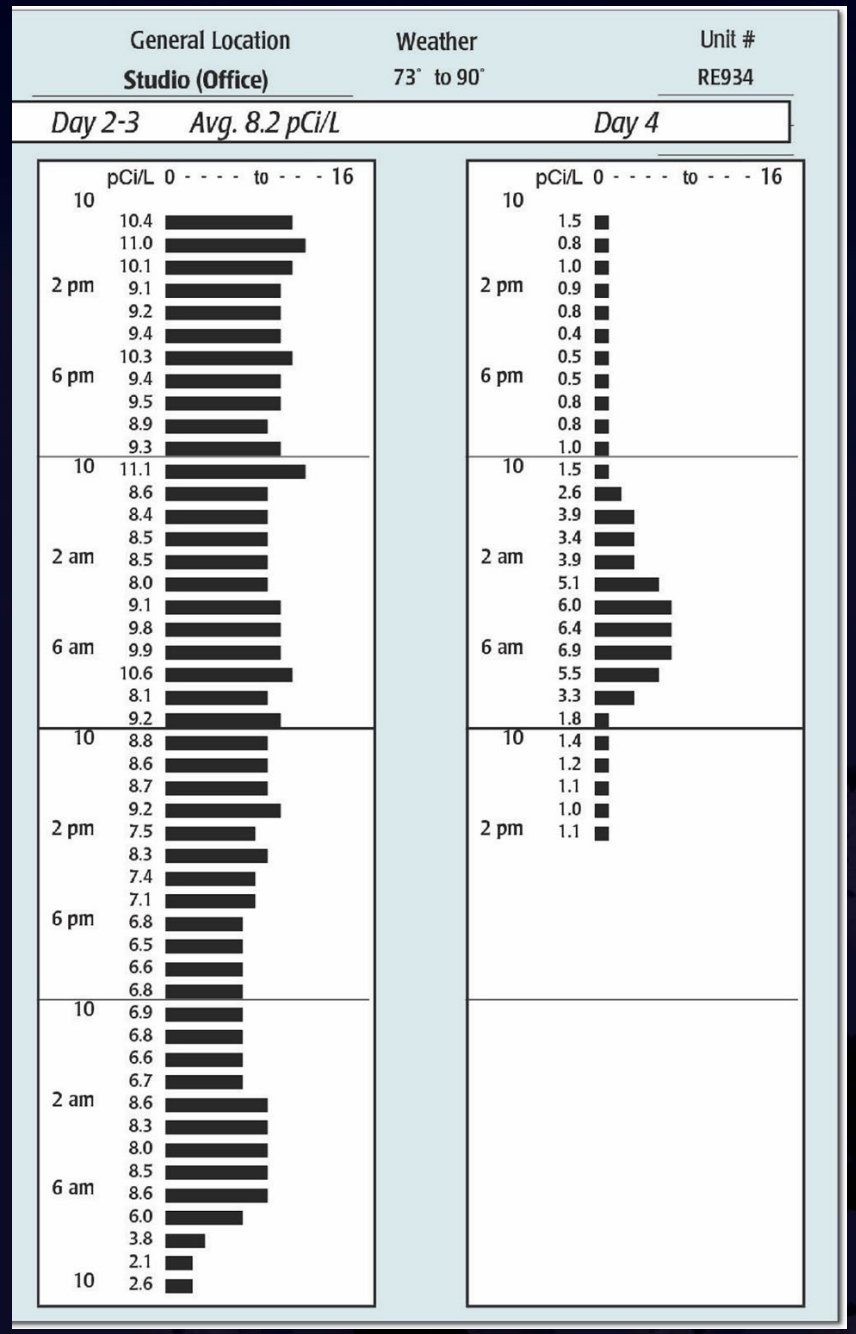
- The office rooms were under greater negative pressure when the VAV was active.
- With the VAV off, the pressure was equal to the hallway.
- So… The HVAC design intentionally sought to induce negative pressure in those rooms.

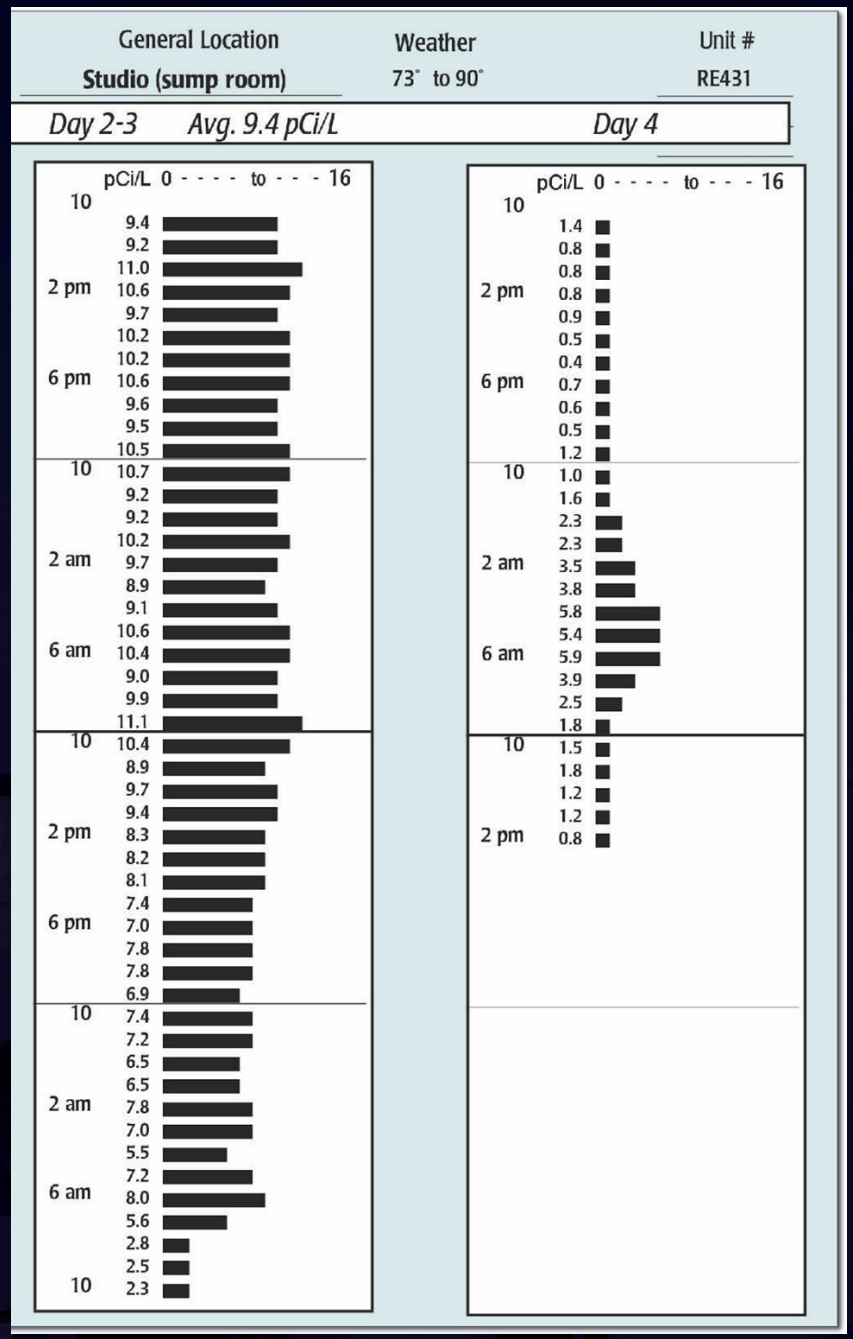
RESULTS—RADON MEASUREMENTS

- 2-day average were somewhat consistent with what was represented from charcoal tests.
- HVAC deactivated for 8 hours the third day.
- Radon concentrations dropped to well below the action level across the entire 8,000 sq. ft. and in the hallways.

OFFICE

BLOWERS ON
BLOWERS OFF

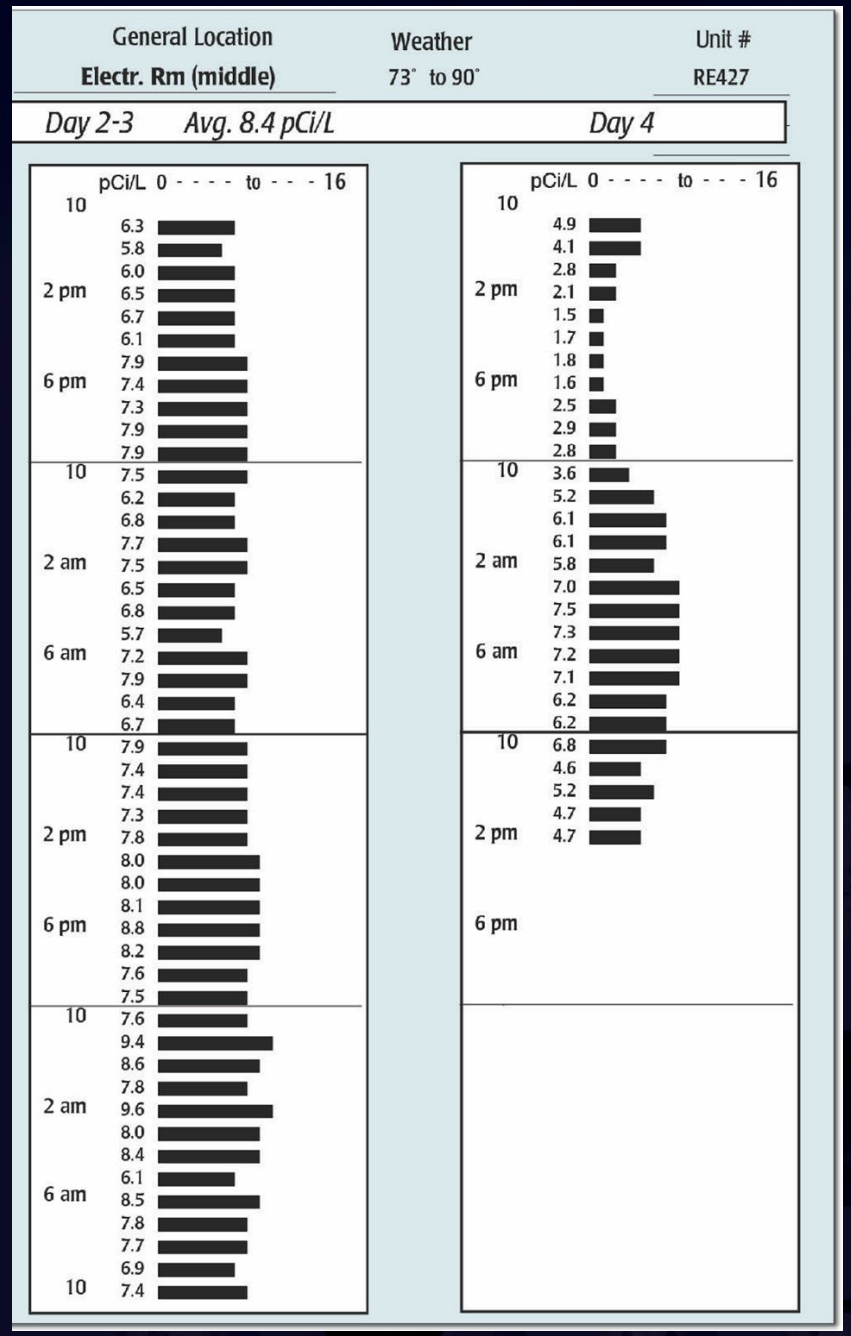


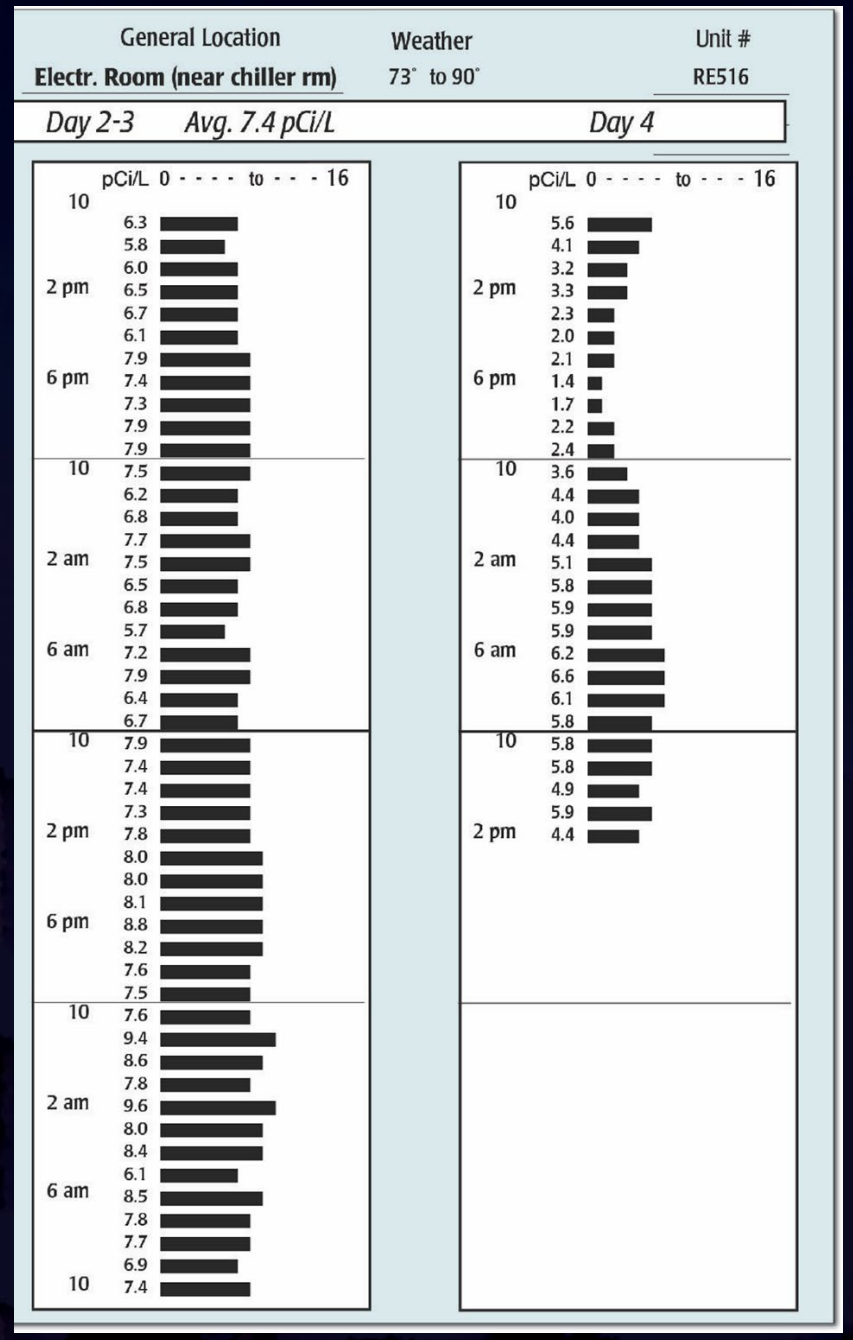


ELECTRICAL BUS ROOMS

BLOWERS ON
BLOWERS OFF

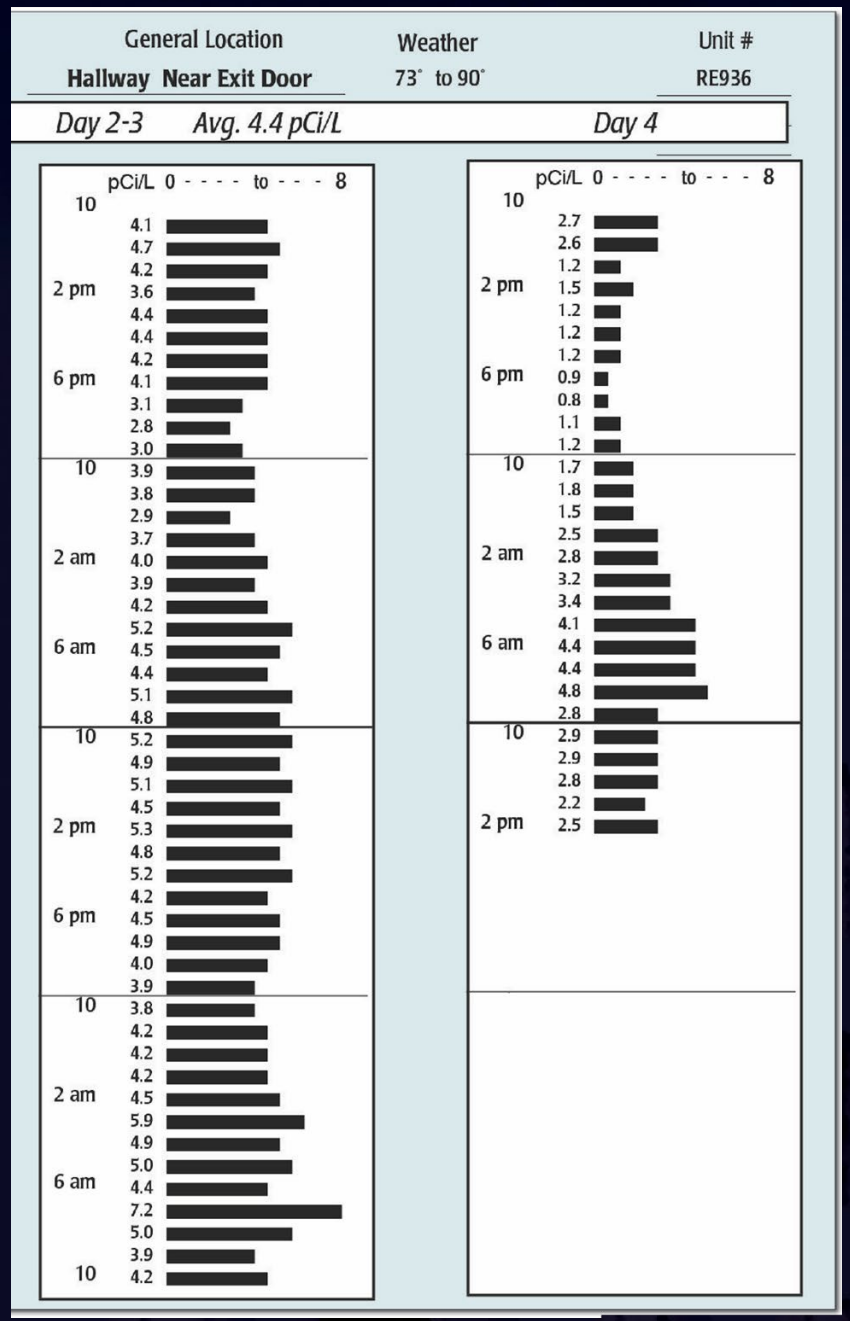
NO VENTILATION.
SLOWER TO DILUTE
AND QUICKER TO
RECOVER.

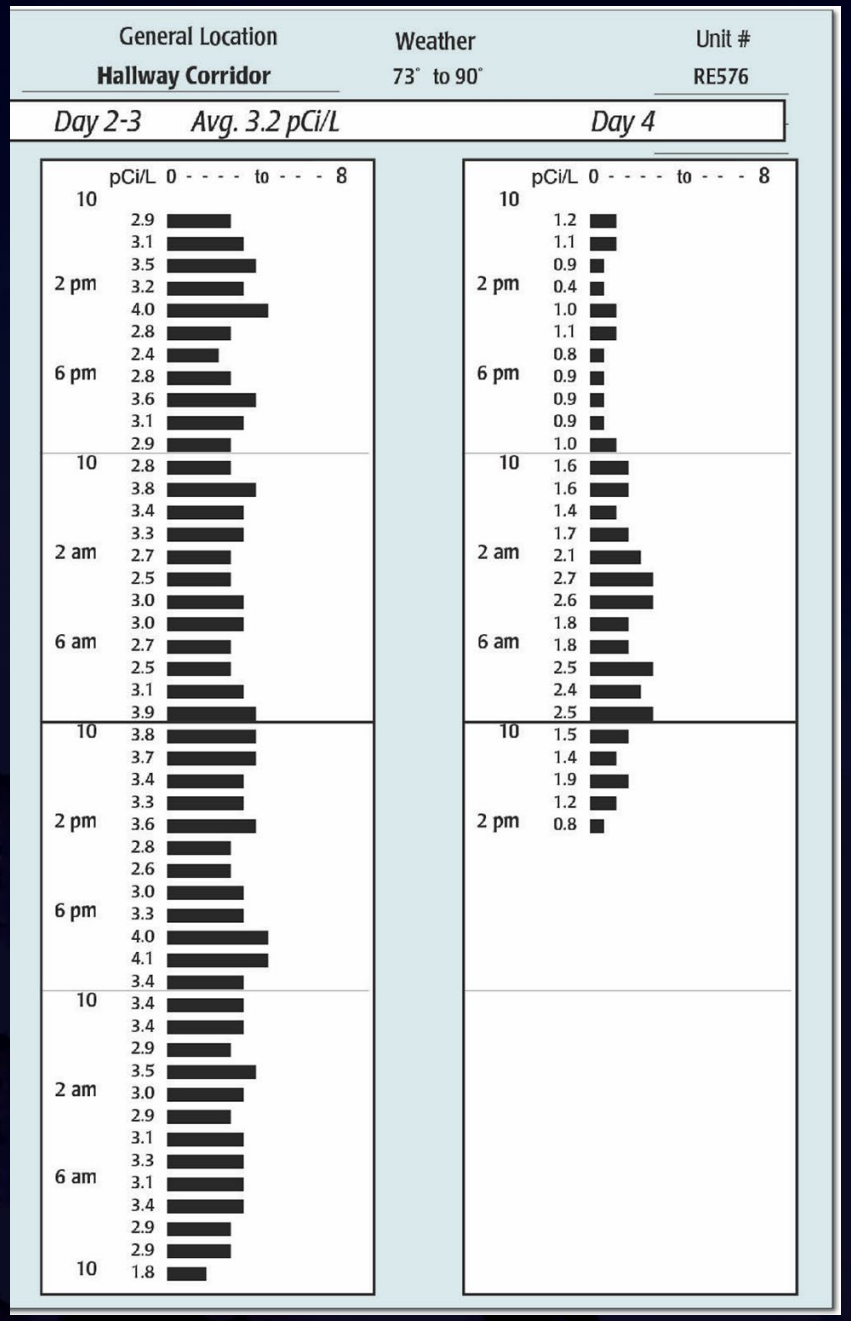




HALLWAYS

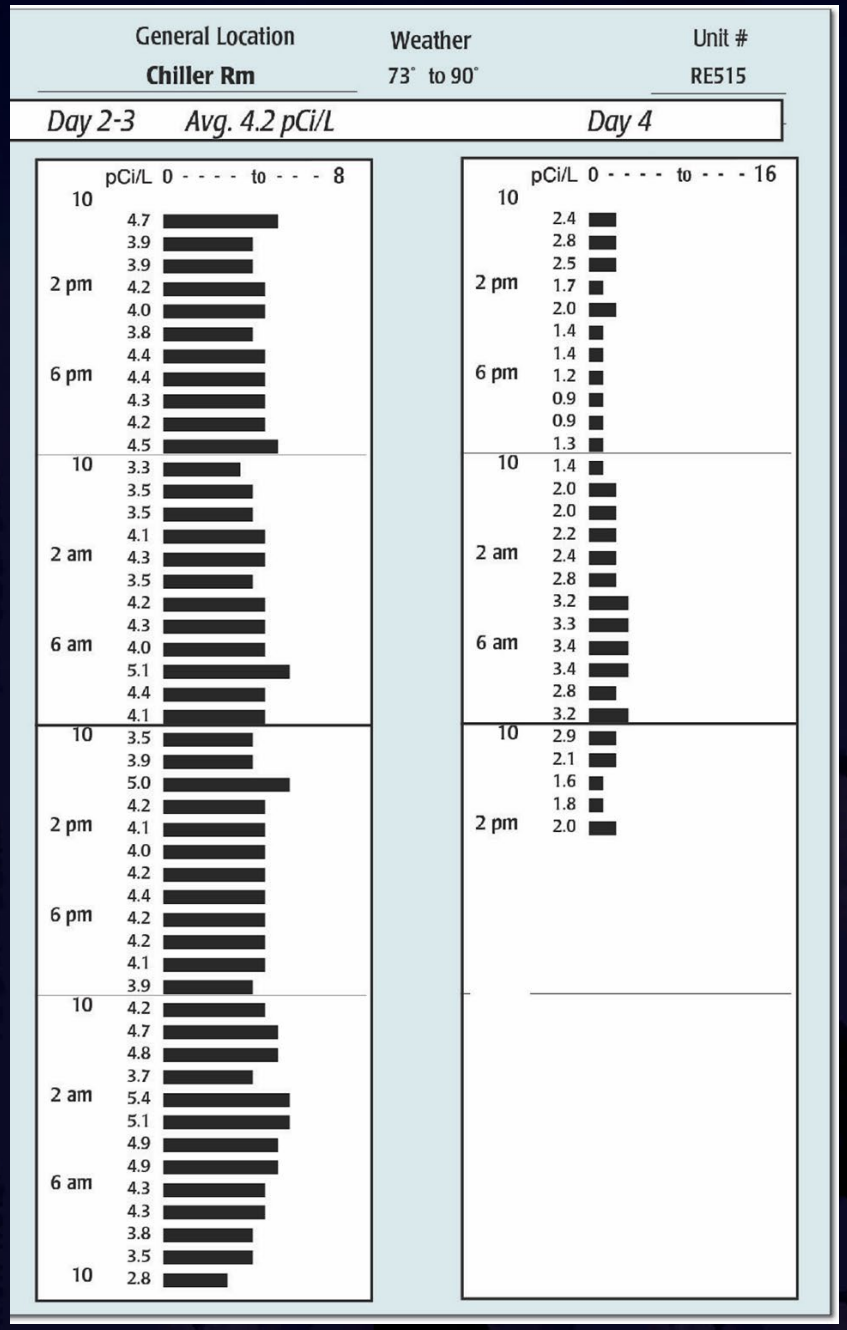
BLOWERS ON
BLOWERS OFF





NEARBY LARGE AREA

BLOWERS ON
BLOWERS OFF



Summary of CRM Observations

The entire wing of the building impacted by one air handling system.

Office rooms Dramatic difference.

Electrical rooms Dramatic difference.

Hallways Noticeable Difference. (These connect to offices and are more than 100 yards long to traverse the entire footprint (four football fields).

Large Room Noticeable Difference. (adjoining area)

Conclusion

- Few ASD systems (approx 150-500 CFM) could ever compete with these large air handlers (7,000-12,000 CFM) unless actions are taken to reduce air handler influence.
- Similar is true for other HVAC systems commonly employed for large buildings.
- Mitigation must include questions of duct balancing and reducing negative pressure so liberally applied in the HVAC design.

Thank You.

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