

## Measuring Pressure (Differential and Barometric) as a Vapor Intrusion (VI) Indicator

### What Pressures?

- Differential pressure ( $\Delta P$ )—Difference in pressure between two points in space (indoor/outdoor or indoor/subslab).
- Change in barometric pressure ( $\Delta BP$ )—Pressure in the atmosphere (indoor and outdoor), change in BP over time is most important (Figure 1).
- Normal changes in BP can be quite large and create pressure differentials across the building envelope if all else is equal (Figure 2). A regular diurnal variation of up to 300 pascals (Pa) is common and weather fronts can cause BP to change by 1,000 Pa over several days.
- Falling BP leads to vapors flowing out of the ground as pressures seek to equalize, but with a time delay.
- Wind loads and stack effects are also important causes of BP variations.

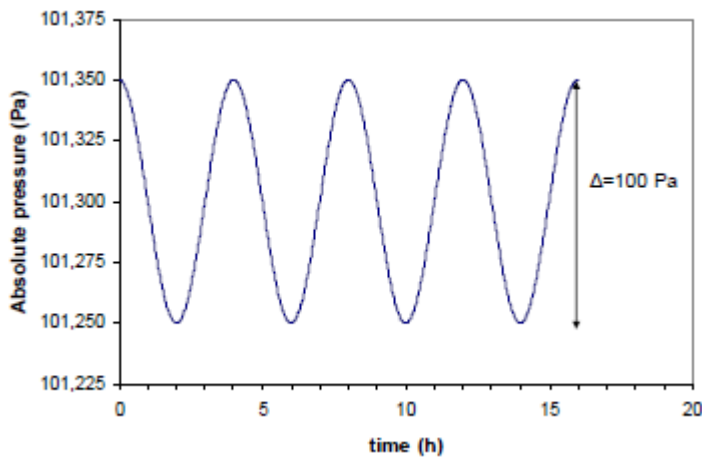


Figure 1: Barometric Pressure Variation Example (from US EPA 2012).

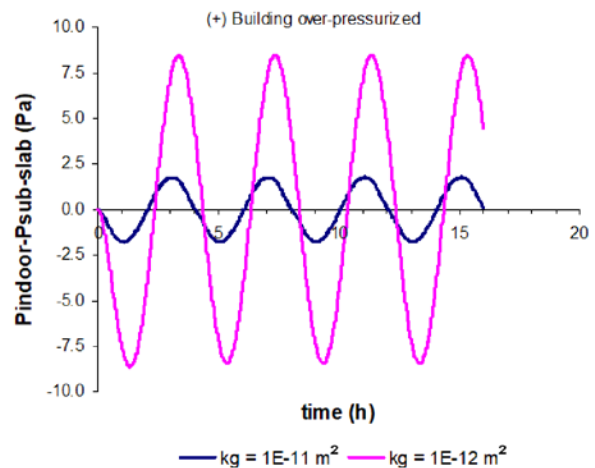
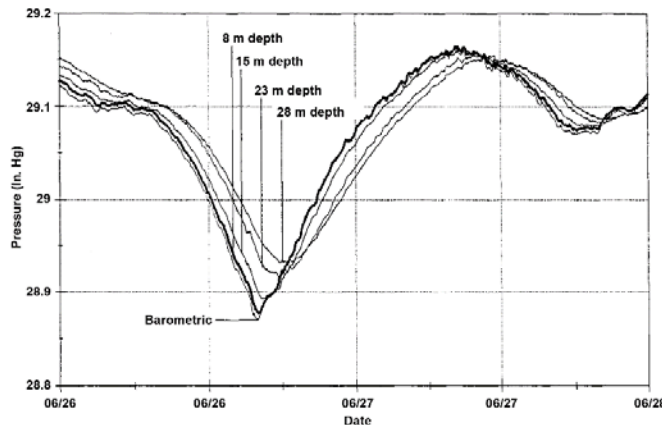


Figure 2: Temporal Variation in the Differential Pressure Between Indoor Air and Subslab Air Resulting from the Fluctuations in Barometric Pressure (Figure 1) for Two Soil Permeabilities (US EPA 2012).



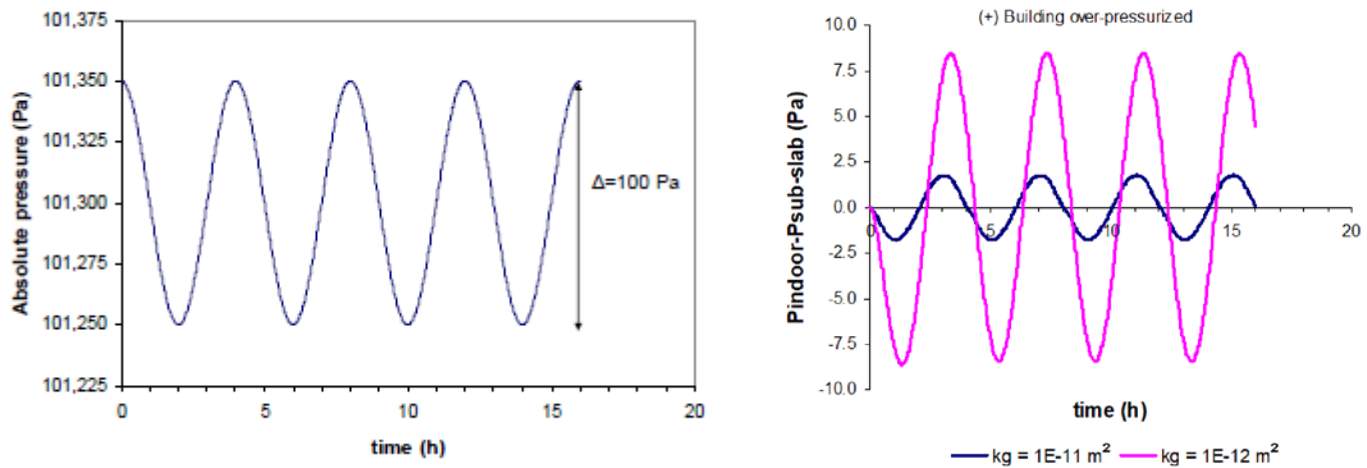


Figure 3: Time Lags in Barometric Pressure Observed in the Atmosphere and Soil Gas (Reprinted from Rohay et al., 1993).

### Where to Measure Indoor Leg of Differential Pressure?

- $\Delta P$  sensor/recorder should be located on surface/wall with little to no vibration.
- Minimize tubing length (to avoid trip hazard, loss of accuracy).
- Select reference points that can be easily repeated, at a similar elevation.
- Barometric pressure to the accuracy that it is usually measured will be the same inside and outside.

### Where to Measure Outdoor Leg of Differential Pressure?

- Seal around tubing that crosses through window, door, or wall.
- Shield outdoor probe from the direct influence of the wind, for example placed pointing toward the ground inside an overturned flower pot or protected by a diffuser (e.g., fish tank bubbler).

### Where to Measure Subslab or Outside Basement Foundation Leg of Differential Pressure?

- Install subslab (or below grade wall) ports in each major foundation section, away from utilities and at least a foot from exterior walls. Expect spatial variability—install at least two subslab ports in even a small building.
- Leak test subslab ports with water dam or helium tracer.

### When to Measure Pressure?

- Differential pressure measurements are typically taken every 5 to 15 minutes as pressure has diurnal, multiday (weather front), and seasonal cycles.
- Barometric pressure measurements taken every 15 minutes to 1 hour should be adequate.
- The operation of windows, HVAC systems, whole house fans, kitchen exhaust fans, and similar devices will affect indoor pressure. Building survey forms describe significant operations and you should take that into account during measurement planning and data interpretation.
- Include a time and date stamp along with the measurement.

**Power interruptions and daylight savings time.** When selecting pressure monitoring equipment for long-term projects, determine ahead of time how those devices will react to power outages and time changes due to daylight savings time. These events can affect the accuracy of date/time stamps, especially when comparing data streams coming from multiple independent devices.

## How to Measure BP?

- Weather station BP is available in near real-time, and archived data are typically hourly measurements (<https://www.ncdc.noaa.gov/cdo-web/>, <https://www.wunderground.com/history/>).
- Barometric pressure is forecast up to 6 days ahead (<https://www.weather.gov/forecastmaps>).
- Digital barometers cost \$130 (e.g., <https://www.fishersci.com/us/en/products/I9C8L6RW/barometers.html>).
- Consumer-grade weather stations cost \$100–\$400 (examples at <https://www.weathershack.com/listing/complete-home-weather-stations.html>).

## How to Measure $\Delta P$ ?

Micromanometers for differential pressure are widely available for purchase or rental:

- Handheld micromanometers, used during surveys, generally are not capable of long-term data logging
  - Example: *Dwyer Series 477AV Handheld Manometer*. Rental: \$80-100/week; Purchase: < \$300. Chose models with sensitive ranges, for example 0-1" w.c. (0-250 Pa), resolution 0.001" w.c. (0.25 Pa), full-scale accuracy  $\pm 0.005$  w.c. ( $\pm 1.2$  Pa).



Figure 4. Example Consumer-Grade Weather Stations

- Stationary micromanometers are best for long-term monitoring with data acquisition/logging capabilities
  - Example: *Omniguard 4 (or 5) Differential Pressure Recorder*. Rental: \$200-350/month; Purchase: \$1,600. Range  $\pm 0.25''$  w.c. or  $\pm 62.5$  Pa, resolution  $0.001''$  w.c. (0.5 Pa), accuracy  $\pm 0.003''$  w.c. ( $\pm 0.7$  Pa).
  - Example: *Omega PRTC110 Differential Pressure and Thermocouple Logger*. Purchase: \$420. Range  $0-2''$  w.c. (0-500 Pa), resolution  $0.002$  w.c. (0.5 Pa), accuracy  $\pm 0.1$  w.c. ( $\pm 2.5$  Pa) over one year.



Figure 5. Example Micromanometers

- How do I calibrate the pressure sensor? Although generally calibrated by manufacturer (annually or as recommended), a zero check is helpful, by connecting inlet and outlet together with a tube.
- Verify directionality of differential pressure measurements with a simple test (i.e., blow into tube).

### Why?

- Differential pressure is the primary driving force for soil gas transport across the building envelope (Figure 6).
- Control of differential pressure (known as pressure field extension) is a widely used predictor of subslab depressurization system effectiveness.
- Short-term increases in indoor air concentrations and subslab-to-indoor  $\Delta P$  following decreases in barometric pressure have been observed.

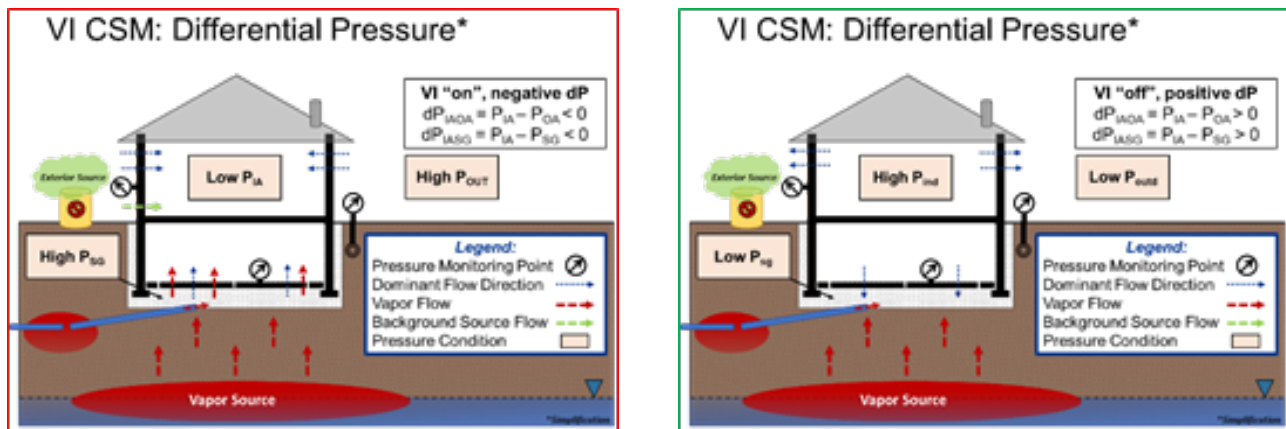


Figure 6. Conceptual Site Model (CSM) Diagrams of Vapor Intrusion (VI) Under Negatively Pressured (Left Diagram) and Positively Pressured (Right Diagram) Indoor Conditions

### Where Can I Get More Detailed Information?

ANSI/AARST Methods: *Protocol for Conducting Measurements of Radon and Radon Decay Products in Homes* (MAH-2014) and *Soil Gas Mitigation Standard for Existing Homes* (SGM-2017).

Le Blancq, F. 2011. Diurnal pressure variation: the atmospheric tide. *Weather* 66(11): 306-307.

Rohay, V.J., J. Rossabi, B. Looney, R. Cameron, and B. Peters. 1993. *Well Venting and Application of Passive Soil Vapor Extraction at Hanford and Savannah River*. Prepared for the U.S. Department of Energy Office of Environmental Restoration and Waste Management, WHC-SA-2064-FP. Richland, WA.

Schuver, H.J., C. Lutes, J. Kurtz, C. Holton, and R.S. Truesdale. 2018. Chlorinated vapor intrusion indicators, tracers, and surrogates (ITS): Supplemental measurements for minimizing the number of chemical indoor air samples—Part 1: Vapor intrusion driving forces and related environmental factors. *Remediation Journal* 28(3): 7-31.

Tillman, F.D., and J.A. Smith. 2005. Site characteristics controlling airflow in the shallow unsaturated zone in response to atmospheric pressure changes. *Environmental Engineering Science* 22(1): 25-37.

U.S. EPA (Environmental Protection Agency). 2012. *Conceptual Model Scenarios for the Vapor Intrusion Pathway*. EPA 530-R-10-003. Section 6.3 "Atmospheric and Indoor Air Pressure Fluctuations." Office of Solid Waste and Emergency Response, Washington, DC.

U.S. EPA. 1993. *Radon Reduction Techniques for Existing Detached Houses, Technical Guidance (Third Edition) for Active Soil Depressurization Systems*. EPA/625/R-93/011. Section 3.5.4 "Pressure Differential Measurements Across the House Shell." Office of Research and Development, Research Triangle Park, NC.

Also see the manufacturer's manuals for any instruments you use.

**Sample Data Quality Goals for Indicator Measurements**

Measurement	Accuracy	Precision	Range	Sensitivity	Resolution
Differential Pressure	+/- 0.5 Pa	+/- 0.3 Pa	-25 Pa to + 25 Pa	0.2 Pa	0.1 Pa; reading at least four times per hour
Barometric pressure	+/- 0.03 inches of mercury (100 Pa)	+/- 0.03 inches of mercury (100 Pa)	28 to 31 inches of mercury	+/- 0.01 inches of mercury (33 Pa)	+/- 0.01 inches of mercury (33 Pa); reading at least once per hour

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