PRESSURE MONITORING AND BUILDING PRESSURE CONTROL FACT SHEET

Introduction

Pressure can be checked in the field to provide another line of evidence to evaluate vapor intrusion (VI) by using a digital micromanometer attached to a sub-slab vapor probe. It is often advisable to use one with data-logging capabilities and assess the response to wind speed and barometric pressure changes if these data are collected. Some models can also deliver this data directly to the internet for near-real-time monitoring and for combining with other data types (Kram et al. 2020).

Pressure Monitoring

Measurements of the pressure gradient between the building and outdoors can help interpret measured indoor concentrations of contaminants. A correlation between indoor air concentration and relative pressure could provide information on the contaminant source. For example, if a building pressure is higher relative to the subsurface, measured indoor concentrations are more likely attributable to aboveground sources. Commercial buildings with large heating, ventilation, and air conditioning (HVAC) systems, and perhaps residences with ducted central HVAC units, may fall into this category. Conversely, if the building pressure is lower relative to the subsurface, measured indoor concentrations might be more likely attributable to subsurface sources. Many buildings in cold environments, especially residences, will fall into this category when they are heated. A dropping barometric pressure can also result in lower indoor pressure relative to the subsurface that results in VI (Kram et al. 2020). The rate of barometric drop can also be correlated with differential pressure and the resulting indoor concentration (Kram and Solgi 2025). These data will usually be used as a line of evidence in support of indoor air quality data or other lines of evidence. Temporal correlation between differential pressure and indoor concentration can represent direct empirical evidence of VI.

Advective flow into the building also occurs due to a pressure gradient caused by natural forces (e.g., barometric pressure dynamics, temperature changes, etc.) as well as anthropogenic factors (e.g., ventilation, HVAC, fans, window and door positions, etc.). This differential pressure can range from less than 1 pascal (Pa) to much greater than 10 Pa, depending on what is occurring at the time of measurement. The differential pressure value can be positive or negative, which can help determine whether vapors are migrating out of or into the subsurface.

Stacked time series analyses of differential pressure, barometric pressure, and concentration (indoors as well as subsurface) collected simultaneously can help resolve key questions regarding whether an indoor concentration detection is related to VI or to an indoor source and allows for the determination of a building-specific attenuation factor based on reasonable maximum exposure in accordance with guidelines from the U.S. Environmental Protection Agency (2015a). Figure 1 is an example of a stacked time series analysis that shows tetrachloroethene (PCE, also called perchloroethene and tetrachloroethylene) concentrations rising when barometric pressure dropped and differential pressure increased (i.e., subsurface pressure is higher than indoor pressure). This differential pressure, which is caused by the drop in barometric pressure, increased the intrusion of subsurface vapor-forming chemicals into the building. For VI mitigation purposes, differential pressure measurement between the subsurface and indoor environment can help installers verify correct design and system performance.

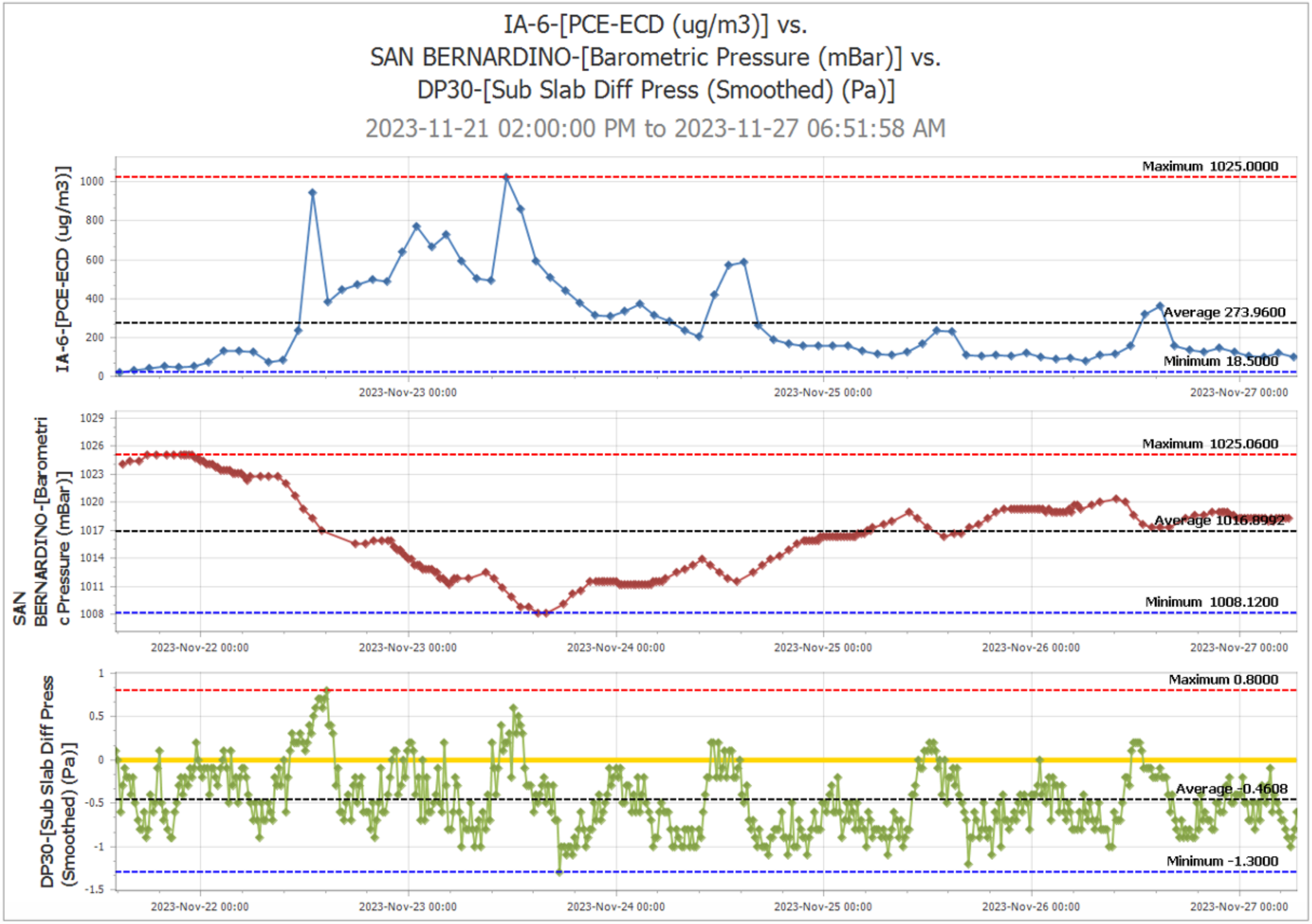

Figure 1. Stacked time series charts for simultaneous indoor air PCE concentration, barometric pressure, and differential pressure patterns.

Source: Team VaporSafe, used with permission.

Building Pressure Control

One possible method for distinguishing subsurface VI from background sources is to collect indoor air samples with and without manipulating the pressure differential from the subsurface to indoor air (Guo et al. 2020; McHugh et al. 2012; USDOD 2017). This can be accomplished by pressurizing the building or depressurizing the region beneath the floor slab. In both cases, if the applied pressure differential is sufficient to prevent subsurface VI, the concentrations of chemicals intruding from the subsurface will be reduced and the concentrations of chemicals from background sources will be largely unaffected (Yao et al. 2020).

Building pressure control (BPC) involves subjecting a building or a building compartment to a series of pressure levels to gain an understanding of potential VI impacts and contributions from background sources. The protocol typically involves using a fan or blower, sealed in a doorway or window, to create negative pressure conditions indoors to promote VI (depressurization) or positive pressure conditions to inhibit VI (pressurization). In some buildings, particularly those with larger footprints, this may be accomplished using the existing HVAC system.

Prior to building pressure manipulation, baseline conditions must be determined by collecting indoor air, outdoor air, and sub-slab soil vapor samples for analysis under natural conditions (if historical data are unavailable). Cross-slab (and/or cross-building envelope) differential pressures should be monitored under natural conditions for as long a period as practical—at least 24 hours or up to a month—to characterize natural ranges of building depressurization. If a correlation between the barometric pressure drop rate and measured differential pressure is observed, a range of anticipated differential pressure may be predicted using local or regional weather records that include barometric pressure (Kram and Solgi 2025). In addition, a building survey is completed to identify appropriate locations for testing, potential vapor entry points, and potential indoor volatile organic compound (VOC) sources. If indoor VOC sources are identified during the building survey, they are removed for the duration of the test (to the extent practical).

Following the baseline evaluation period, the building is quickly progressively depressurized (generally three levels ranging from -5 to -50 Pa) while recording cross-slab differential pressures as well as cross-building envelope differential pressures and flow rates. Be sure to check with the appropriate regulatory agencies for specific target pressure gradients (if any). The relationship between cross-building envelope differential pressure and flow is used to construct a building leakage curve, which characterizes the permeability of the building envelope and is unique to each building. The relationship between the cross-building envelope and cross-slab differential pressure characterizes the relative permeability of the floor slab.

The building is then depressurized over a longer time period (generally three to five building air exchanges) to allow indoor air concentrations to stabilize sufficiently to collect spatially averaged indoor air samples for risk assessment purposes. With steady building pressures and concentrations, a sampling duration of 30 to 60 minutes is adequate to characterize the indoor air concentration. The measured indoor air concentrations multiplied by the air flow rates used to depressurize the building provide a combined measure of the VOC influx via VI and via background emissions. The pressure levels used during BPC testing for indoor air sampling are determined based on the range observed under natural conditions. Building pressures vary from building to building, but generally are in the range of ±20 Pa. In large buildings, compartments that are occupied or areas with the highest baseline indoor air concentrations may be selected for pressure manipulation. Multiple depressurization levels may be tested to more thoroughly evaluate a building’s responses to pressure changes.

Following the depressurization tests, the building is pressurized by reversing the air flow through the blower door or manipulating the building HVAC system. Spatially averaged indoor air samples are collected to characterize the contribution of background (outdoor and indoor) sources to indoor air. The difference between the mass influx measured during depressurization and that measured during pressurization represents the maximum influx due to VI.

Indoor air concentrations may be monitored on a semi-continuous basis using a field portable gas chromatography/mass spectrometry unit or similar field portable VOC analyzing device to determine when indoor air concentrations have stabilized. Alternatively, surrogate compounds (e.g., radon, thoron, carbon dioxide) may be used to estimate when indoor air VOC concentrations have stabilized.

If multiple depressurization steps are employed or indoor air concentrations are monitored semi-continuously, the pattern of indoor air VOC concentrations collected during BPC testing can provide specific insights on the VI pathway, including the following:

- An increase in target VOC concentrations under depressurized conditions suggests the building is susceptible to VI (Liu et al. 2020).
- A steady decline (i.e., multiple concentration readings with each lower than the last) in target VOC concentrations under depressurized conditions suggests the air exchange rate is greater than vapor entry and that other pressure levels should be tested.
- A decrease (essentially a “step change”) in target VOC concentrations under pressurized conditions suggests the building is susceptible to VI since pressurization inhibits vapor entry.
- Minimal changes in target VOC concentrations under depressurized and pressurized conditions suggests insignificant VI relative to indoor source(s).
- Monitoring of concentration from multiple locations at the same time during the BPC campaign can allow for identification/isolation of vapor entry pathway(s).

The building’s air exchange rates during BPC, calculated from the blower door air flow rates used to depressurize the building, provide insight into the amount of dilution occurring during testing. When the air exchange rate is known for baseline conditions, the VOC influx due to VI derived from the BPC testing can be used to estimate long-term average indoor air concentrations attributable to VI under natural conditions. The air exchange rate under natural conditions is often determined using the controlled release and monitoring of a tracer gas (e.g., helium).

It is helpful to consider the following:

- BPC is not exploiting natural vapor fluctuations, so vapor transport pathways may be different from what would naturally occur.
- BPC should not be performed during a rapid drop or rapid rise in barometric pressure, as this could result in unsteady baseline conditions.

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