ITRC Technology Information Sheet

Vapor Intrusion Mitigation Team | December 2020

Rapid Response and Ventilation Subgroup

Heating, Ventilating, and Air Conditioning (HVAC) Modification

ITRC has developed a series of technology information sheets that summarize building mitigation technologies related to vapor intrusion (VI). The purpose of this technology information sheet is to:

- provide an overview of HVAC modification as a method to mitigate VI
- describe the typical components related to HVAC systems
- describe the advantages and limitations of implementing HVAC modifications
- provide general cost considerations related to HVAC modification
- describe other special circumstances to consider when deciding if HVAC modification is applicable for VI mitigation

Overview

HVAC systems refer to the mechanical systems that heat, cool, ventilate, filter, humidify, or dehumidify air in a room or building. For some buildings, mitigation of VI can be accomplished using the HVAC system, which when operated appropriately can act as a VI engineering control by pressurizing the building to prevent vapors from entering, and/or by providing sufficient outdoor air exchange to dilute the effects of VI on indoor air quality. A good understanding of a building's HVAC system configuration and operating conditions is crucial to evaluating its influence on VI and potential for VI mitigation. HVAC systems should be evaluated by qualified HVAC engineers, licensed HVAC contractors, or otherwise qualified professionals experienced with assessment of HVAC systems and their relationship to vapor intrusion and indoor air quality.

HVAC influence on VI potential is fundamentally a function of air pressure gradients and air exchange rate (AER). Air pressure gradients across a floor slab, depending on direction, can act to either suppress VI (when indoor air pressure is greater than subslab pressure) or enhance VI (when indoor air pressure is less than subslab pressure). This concept of positive/negative pressure differential is shown in the diagrams below.

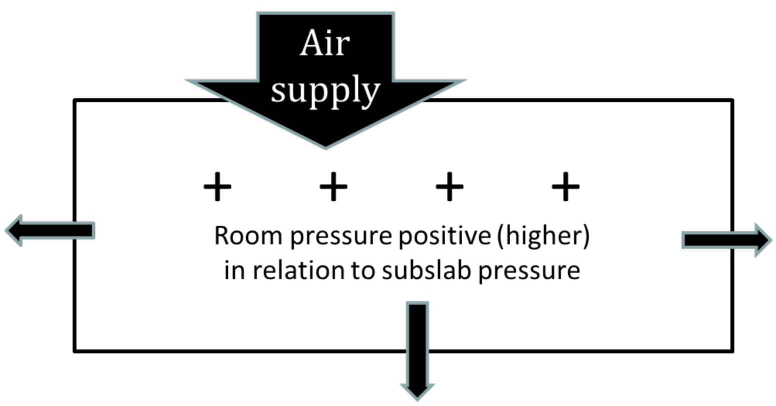

Figure 1 - Positive pressure space conceptualization.
(Source: J. Corsello, Sanborn Head & Associates, Inc., used with permission)

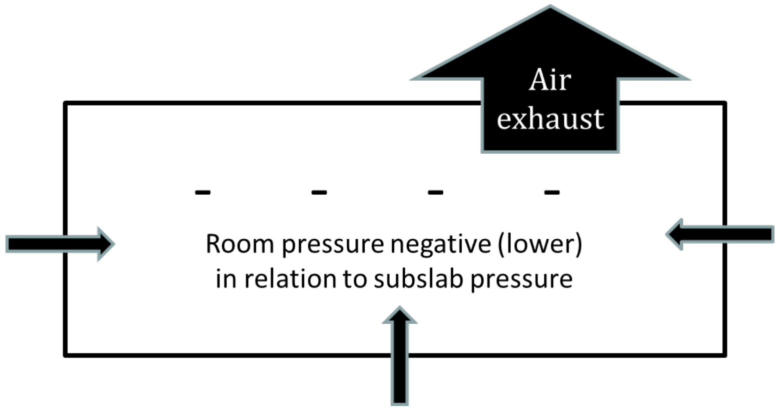

Figure 2 -.
(Source: J. Corsello, Sanborn Head & Associates, Inc., used with permission)

If there is spatial or temporal variability in pressure gradients, either intrusion or suppression of vapor migration may occur in a given location at a certain time within the building, depending on conditions. After VOCs enter a building, air circulation and mixing within the building caused by operation of blowers and fans, or by thermal convection, can act to dilute, transport, and distribute VOCs through the building. Air exchange through mechanical supply of outdoor air can decrease (i.e., dilute) indoor VOC concentrations below levels that would otherwise be present under normal ventilation (e.g., open windows), as may be the case in residential structures, depending on the AER.

While building conditions influencing VI in residential structures do not typically include continuous mechanical ventilation with engineered systems, and are therefore less systematic and less controllable, buildings equipped with engineered HVAC systems represent more controlled environments. Thus, engineered HVAC adjustments can be considered as a component of VI mitigation by either (1) controlling cross-slab pressures by pressurizing the building, or (2) increasing AERs.

Components

The components of an HVAC system will vary depending on the building. In a typical system for a commercial building, outdoor air is drawn into the air handling unit (AHU) and mixed with air recycled from the building space, which is known as return air. The mixed outdoor and return air then passes through filters and across heating and cooling coils before entering the fan, which discharges the conditioned air, known as supply air, to the building space through a network of supply ductwork and diffusers, typically installed in the ceiling. Return air is recycled back to the AHU through a separate duct network connected to intake registers inside the building. In addition, buildings are commonly equipped with separate exhaust fans to serve areas such as laboratories, manufacturing floors, kitchens/cafeterias, mechanical rooms, and restrooms.

HVAC systems can be equipped with special air purifying components/filters to improve indoor air quality. For additional information on other indoor air purification techniques, refer to the ***Indoor Air Treatment*** Technology Information Sheet.

Many variations on this basic description of an HVAC system are in use, and configurations may also vary among multiple AHUs serving different parts of a building. For example, in a variable air volume (VAV) system, often found in office spaces, the amount or “volume” of supply air changes in response to the temperature of the space (e.g., room thermostat). In fact, in a space served by a VAV system, no air pressurization or air exchange will occur if the thermostat is not actively calling for heating or cooling. As a result, building pressurization and AER can vary room-to-room or zone-to-zone depending on VAV status.

A typical HVAC system can potentially be adjusted to mitigate VI through (1) building pressurization, or (2) increase of AERs. Building pressurization is achieved by increasing supply air while decreasing return air. The following actions can be taken to implement building pressurization:

- Adjust outside air/return air damper positions to allow more outside air flow.
- Clean/replace dust filters.
- Increase supply air fan speed, or install a new fan, if needed.
- Re-balance supply/return air.
- Install new supply air ducts and diffusers, if needed.
- Close dampers for return air.
- Decrease/turn off exhaust fans where not needed.
- Seal leaks in building shell.

Increase of air exchange rates within a building is achieved by increasing both the supply air flowrate and building exhaust rate. The following actions can be taken to implement an increase of air exchange rate:

- Adjust outside air/return air damper positions to allow more outside air flow.
- Adjust supply and return air fan speeds, or install new fans, if needed.
- Install new supply and/or return air ducts and diffusers, if needed.
- Increase air exhaust fan capacity.

The HVAC system adjustments described above should be performed by the facility HVAC engineer or a qualified HVAC contractor. Some states may have rules or regulations on who can evaluate/modify HVAC systems to ensure they comply with building and energy code requirements. Any adjustments must maintain the comfort of the occupants.

Advantages

HVAC modification as part of a VI rapid response has several advantages:

- HVAC can be applied to both new and existing buildings.
- Mitigation via HVAC can be used as a rapid response to lower indoor air concentrations quickly, and in some cases, positive pressures can effectively prevent VI.
- Normal HVAC operations in some buildings can maintain acceptable indoor air quality, despite VI potential from sub-slab VOC presence.
- Some buildings subject to VI can be mitigated with HVAC adjustments with less disruption or more favorable cost than sub-slab depressurization (SSD) system installation, even when long-term operating costs are considered.
- Some buildings subject to VI are too technically difficult or costly to mitigate using other mitigation technologies (e.g., active manufacturing constraints, complex subgrade utility networks, complex foundations, very large areas).

Limitations

HVAC modification also has some disadvantages as part of a VI rapid response:

- Mitigation via HVAC does not address/remediate the VI source or pathway.
- These systems are not intentionally designed for VI mitigation.
- This solution leads to dilution of VI rather than prevention, in some cases.
- Many single- or multifamily residences do not have an HVAC system.
- The wide variety of systems (e.g., old, complex) can be challenging.
- There could be many potentially relevant operating parameters to maintain.
- There are multiple points of operating variability/vulnerability.

- This solution is subject to human interference (e.g., building occupants changing system settings for reasons of comfort, operating cost, or other factors).
- Mitigation via HVAC can be energy intensive, resulting in increased cost.
- Manipulating HVAC can alter humidity and cause moisture or mold damage.
- Automatic operating schedules may result in elevated indoor air concentrations when the system is shut off or shortly after it is turned on.
- It can take long periods of time to confirm effectiveness (verification sampling during different seasons).
- An increase in AER can reduce indoor air concentrations only to the degree that AER is increased (i.e., dilution factor is limited by additional available AER).
- For positive pressure systems, the building must have a tight envelope; thus, positive pressure approaches work poorly on older buildings having poor insulation, windows, doors, etc.

Cost Considerations

The costs and sustainability of implementing HVAC modifications are strongly dependent on a variety of factors, including whether existing equipment has available capacity to meet AER or pressurization goals, how air-tight the building may be, and occupant comfort. If new or modified equipment is required, capital costs are building- and space-specific, but can be as much as $100,000 or more for one AHU and some buildings may require multiple AHUs. The building-specific nature of HVAC capital costs is reflected in the cost estimate range of $1 to $15 per square foot published in the ITRC VI-1 guidance (ITRC, 2007a).

Long-term operating costs are also important to consider in evaluating HVAC modifications for VI mitigation. For example, in New England, the average annual cost to condition outdoor air has been reported to range from $6 to $12 per cubic foot per minute (cfm). ITRC reports that additional operating costs to modify HVAC systems to mitigate VI could exceed $1 per square foot annually (ITRC 2007a). Additionally, multiple rounds of verification sampling performed during both the heating and non-heating seasons may contribute to varying costs.

Special Circumstances

HVAC operational variability due to variable air volume systems, automatic variable operating schedule, and the use of economizers present special circumstances that should be considered when implementing HVAC modifications. For example, automatic operating schedules could result in elevated indoor air concentrations when the HVAC system is off and shortly after it is turned on due to less outside air circulating throughout the room. In addition, special indoor air quality or energy conservation requirements (e.g., relative humidity, temperature) based on building use may also need to be considered.

Occupant, Community, and Stakeholder Considerations

It is essential to develop and implement a site-specific community involvement plan that addresses, among other things, how to win trust and gain access to properties, communicate risk to potentially exposed individuals, and minimize the disruption of people's lives and businesses. For more details, see ITRC's ***Public Outreach during Vapor Intrusion Mitigation*** Fact Sheet.

Resources

- Interstate Technology Regulatory Council (ITRC), Vapor Intrusion Pathway: A Practical Guideline, Washington, D.C., January 2007.
- Interstate Technology Regulatory Council (ITRC), Petroleum Vapor Intrusion, Fundamentals of Screening, Investigation, and Management, October 2014.
- Caulfield, S.M., *HVAC Systems and Vapor Intrusion*; Northeast Waste Management Officials' Association (NEWMOA) and Brown University, Workshop on Vapor Intrusion in Commercial and Industrial Buildings: Assessment and Mitigation, Westford, MA, September 23, 2008.
- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), *Ventilation for Acceptable Indoor Air Quality*, ANSI/ASHRAE Standard 62.1-2019, Atlanta, GA, 2019.

- Shea, D., Lund C., and Green, B., *HVAC Influence on Vapor Intrusion in Commercial and Industrial Buildings*, Platform presentation at the Air and Waste Management Association (AWMA) Vapor Intrusion Conference, Chicago, IL, September 2010.
- Shea, D. and Green, B., *HVAC Systems for VI Mitigation in Large Buildings: Reliability and Long-Term Performance Monitoring Considerations*, Platform presentation at the Fourth International Symposium on Bioremediation and Sustainable Environmental Technologies Conference, Miami, FL, May 2017.
- Shea, D., *Long-Term Performance Monitoring for HVAC Engineering Controls for VI Mitigation of Large Buildings*, Platform presentation at the AEHS Foundation's 27th Annual International Conference on Soil, Water, Energy, and Air, Amherst, MA, March 2017.
- Shirazi, E., Hawk, G. S., Holton, C. W., Stromberg, A. J., & Pennell, K. G. (2020). Comparison of modeled and measured indoor air trichloroethene (TCE) concentrations at a vapor intrusion site: influence of wind, temperature, and building characteristics. *Environmental Science: Processes & Impacts*, 22(3), 802-811.
- Tillman Jr, F. D., & Weaver, J. W. (2007). Temporal moisture content variability beneath and external to a building and the potential effects on vapor intrusion risk assessment. *Science of the Total Environment*, 379(1), 1-15.

Related Links:

For more information and useful links about VI mitigation technologies, go to http://www.itrcweb.org/.

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