# How HVAC Effects Building Envelopes

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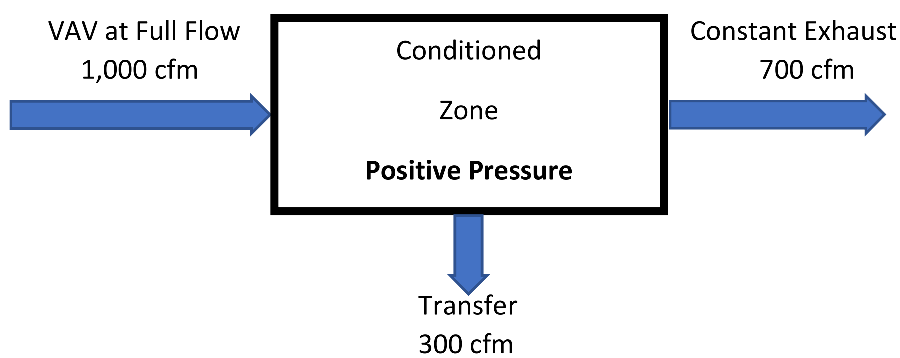
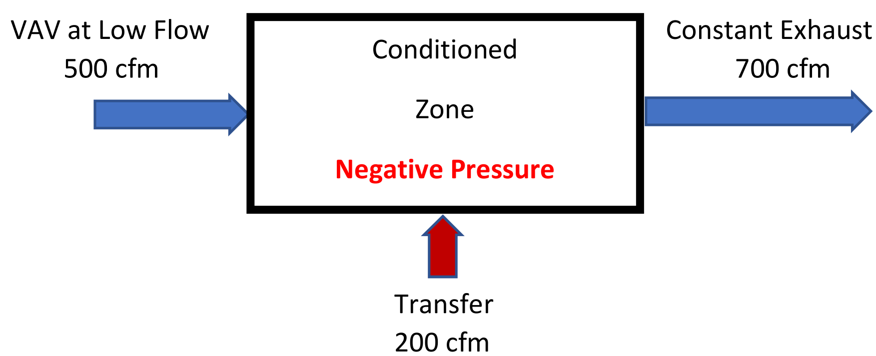
Heating, ventilating, and air conditioning (HVAC) systems have a direct effect on the building envelope, specifically the ability of the envelope to seal against water penetration. It is a rare for contractors to seal an envelope completely, even though specifications and drawings require it. Human error and the need to expedite a project frequently result in small holes and incomplete sealing of the envelope. Some of these holes are too small to be seen by the naked eye, but large enough to pass water droplets. If the HVAC system is not effective in maintaining positive or neutral pressure in the building, water leaks will occur. These leaks are frequently blamed on faulty sealing and detailing of the building envelope when they are more likely the outcome of a building with negative indoor air pressure.

An HVAC system moves air into a building for ventilation while exhausting air out of a building to remove airborne contaminants. Negative pressure results whenever the exhaust air systems are trying to exhaust more air out of the building than the amount being brought in through air handling units and rooftop units. HVAC designers typically design to achieve a positive indoor air pressure whenever a building is occupied; however, they frequently fail to take several dynamic operating conditions into account, conditions that will lead to negative pressure.

## **VAV – A Very Bad Idea**

Variable air volume (VAV) systems have been a standard in the HVAC industry since the 1970's. These systems were developed to save on energy by selectively reducing air flow to rooms and zones in the building to match the cooling demand in that zone. This can result in negative pressure as shown below:



In many cases, the HVAC designer neglects to consider how air will move through a room or zone when the VAV system is delivering minimum design air volume. If the minimum design flow is less than the amount of air being exhausted from that zone, negative air pressure will result.

**You Can't Control What You Don't Measure**

Most HVAC designers don't include a means for measuring the pressure difference between the building interior and exterior. If this pressure difference is not measured, it cannot be maintained. In these cases, the positive pressure is simply inferred based on the air balancing report. If the air balancing report shows more air was moving into the building, through air handling units and rooftop units, then was being removed from the building, through exhaust air systems, then it can be inferred that the building has a positive pressure relative to the outdoors.

**Positive Pressure: (Sum of Air Entering) – (Sum of Air Leaving) > 0**

The balancing report shows static measurements made at one point in time for each piece of equipment. This low-cost approach does not make allowance for air handling unit, rooftop unit, and exhaust air system operation through a typical day where these systems get switched on and off and vary the air that they deliver or exhaust. Furthermore, the actual air flows change with equipment age and modifications to spaces, such as the addition of fume hoods, which requires rebalancing, something that is rarely done.

**Don't Go With The Flow**

Some HVAC designers use flow measuring stations to infer positive building pressure. Once again, the idea is to sum the air entering the building, subtract the sum of all the air leaving the building, and infer positive pressure if the net result is greater than zero. This method can fail for many reasons including errors in measurement. Air flow is difficult to measure with a high degree of accuracy, particularly at low flows. It is not uncommon for an air flow station to be +/-15% off from the true flow. If you have multiple air flow stations, this error is compounded. Consider the compound error of a simple building with just three air handling units, each with its own air flow measuring station:

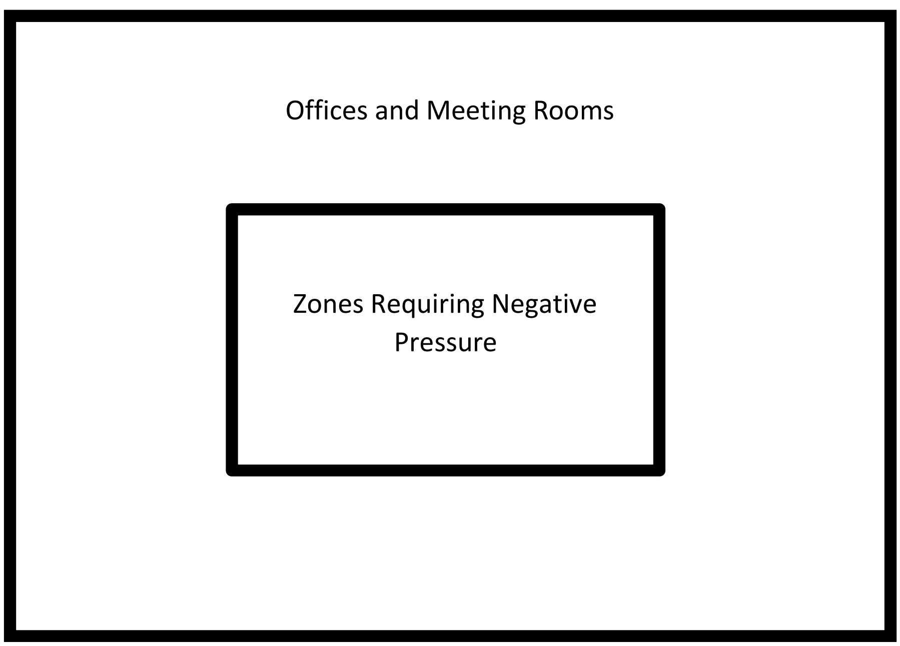
$$\textbf{Compound Error} = (0.15^2 + 0.15^2 + 0.15^2)^{1/2} = +/- 26\%$$

Building pressure needs to be measured directly with multiple pressure sensors and those sensors need to be calibrated at least once every five years. The sensors typically modulate outdoor air dampers to change the amount of air entering a building, maintaining positive pressure whenever exhaust systems are going on and off, exterior doors are being opened and closed, and varying wind loads are present. Sensors should be located where they can sense the difference in pressure between the exterior zones and the outside, not centrally in a building. Negative pressure in the core areas does not lead to water penetration. Negative pressure along the perimeter leads to water penetration. Ideal sensor locations are along large zones with north/west and south/east exposures (2 sensors minimum). Sensors should not be located near exterior doors and vestibules or near operable windows.

**<u>How Can Architects Mitigate These Problems?</u>**

So, how can an architect deal with these potential issues with negative pressure? The first step is to find a capable, experienced HVAC design engineer who insists on a hands-on approach to their designs. Find someone who is passionate, but not defensive, about their work. Also make sure they are hands-on in that they do not delegate the work to apprentices and spend most of their time supervising other jobs. Then, inquire frequently about air flows and pressure at varying loads. Ask the engineer if the VAV system will maintain positive building air pressure at the perimeter zones even when the VAV is operating at minimum flow. Ask the engineer if they are including pressure differential measurement control as part of their system and how many points they will measure. If they say pressure is not going to be monitored, or only one central point of measurement is included, or simply get defensive: **red alert!**

Architects can also be proactive in developing floor plans that are hardened against these issues. Specialty areas that require negative pressure, like TB patient rooms and laboratories, should be located away from exterior walls and interior to the building. Other areas such as office spaces and meeting rooms, which require positive pressure, can be located along the perimeter as shown in the following simplified plan view:




If an architect wants daylight and views for the zones requiring negative pressure, the floor space outside of these areas can be dedicated to corridors with interior windows transferring light and views to the interior zones.

If neither of these approaches is practical, consider specifying thorough field inspections to make sure windows are sealed properly. Ask the HVAC designer to use constant volume air distribution in these areas if local codes allow it. The designer will likely object to the added reheat energy, but a constant volume system will be easier to control which should keep the negative pressure from spiking. Also, consider having a Commissioning Authority (CAx) provide building envelope commissioning where the final wall assembly is tested for water leaks and heat gains/losses. For complex buildings like hospitals, laboratories, and large office buildings, HVAC commissioning is also recommended where the air distribution systems are reviewed and tested by a third party CAx.

These same approaches can be used to deal with spaces that require humidification to keep them at 30 to 50% relative humidity year-long. Examples of these spaces include laboratories and operating theatres. When the outdoor air temperature drops below $0^{o}$F, water will deposit inside the wall and along metal window frames if you try to maintain this higher humidity indoors. Either place these zones within the building core and surround them with zones that do not have the same high humidity requirements or make sure to add envelope testing to your specifications.

**<u>Learning Objectives</u>**

After completing this course, participants will be able to:

1. Explain basic VAV operation and how it can lead to negative air pressure in a zone
2. Identify when pressure control is not part of an HVAC design
3. Identify the characteristics of a good HVAC design engineer
4. Describe how negative pressure issues can be avoided with good floor plan layout
5. Explain how zones with humidification requirements should be treated in the same way as zones with negative air pressure requirements