UNDER PRESSURE
WHY DYNAMIC MONITORING IS ESSENTIAL TO RESIDENTIAL HVAC ZONING AND VENT CONTROL

A WHITEPAPER

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This paper discusses fundamental aspects of modifying airflow in residential heating, ventilation, and air conditioning (HVAC) systems. We have found that homeowners who close vents in systems that lack dynamic monitoring of system load, flow conditions, and system efficiency may experience increased system pressure, increased noise, inefficient air leakage, decreased comfort, and the potential for system damage and shortening of equipment life. In short, things that are not the best for an HVAC system.
Several HVAC and “smart home” manufacturers are introducing new products that increase control of home heating and cooling systems. These products enable homeowners to redirect airflow within their homes by utilizing internet-controlled thermostats and vents, as well as other features. At first glance, these may seem pretty cool or like a hot new trend (pun intended). Unfortunately, not all of these systems account for the delicate balance of system pressure and air flow within a home. In fact, a 2003 study of previous-generation vent technology conducted by Lawrence Berkeley National Laboratory advises against unmonitored vent closure.¹

It is important to note that the Berkeley Lab study was conducted more than a decade ago and does not reflect the latest device designs and controls on the market. Even so, these results should caution homeowners against investing in vent-control systems that do not monitor HVAC system operating conditions when closing vents.
OVERVIEW OF TYPICAL HOME HVAC SYSTEM

A typical single-zone residential forced air HVAC systems consists of several components illustrated in Figure 1:

1. Heating/Cooling Unit
2. Duct Work
3. Master Unit
4. Plenum Sensor
5. Thermostat
6. Vent

The user has two primary points of control—the thermostat and the vent. He or she can change the temperature setting on the thermostat display, or alternatively, adjust the louvers to increase or reduce airflow to specific rooms or areas of the home.

Some consumers have been advised to close vents in unoccupied rooms as a way to conserve energy. In order to test this claim, the Berkeley Lab researchers conducted a series of tests ultimately finding that vent closures had unintended effects on the health of the overall HVAC system:

“Closing registers nearer the air handler tends to increase the pressures and air leakage for the whole system.” (Walker, 2003)

The report goes on to note that excessive vent closure can lead to equipment damage and questionable effects in terms of energy efficiency. The following section describes some of the complications of unmanaged vent closure.

FIGURE 1: TRADITIONAL HVAC SYSTEM
In a forced air HVAC system, proper distribution of air is essential to healthy operations. Closing vents without understanding the characteristics of an individual system can cause serious damage to homeowners’ HVAC systems. This section describes several of the issues associated with unmonitored vent closure.
EQUIPMENT DAMAGE
Residential HVAC systems rely on well-managed airflow to transfer heat to and from the living space. If the airflow is restricted, the heat transfer element (coils) can freeze over entirely on an air conditioning unit, limiting system function and threatening equipment life. When coils freeze as illustrated in Figure 2, refrigerant can enter the compressor and contaminate the motor’s oil thereby shortening the compressor lifespan.\(^2\)

![Figure 2: Frozen Coils (Image Credit: MonsterVac)](image)

This dangerous reduction of airflow can be the result of a combination of closing too many vents, bad ducting, a clogged air filter, a poorly performing fan, indoor conditions, and outside weather. Most HVAC systems are designed to withstand most of these conditions, but without monitoring, it is impossible to know when the system is entering a dangerous state. Closing vents without knowing the precise state of the system can aggravate a system that is already struggling and eventually cause it to fail. In a heat pump-based system, a similar effect to freezing coils can occur when the refrigerant gets too warm.

OVERHEATING SYSTEMS
Damage by freezing coils is not the only way a system can be harmed by unmonitored vent closures. When in heating mode, reduced airflow can lead oil, gas, or electric heaters to reach their high temperature limits. This causes the heating system to shut down to maintain safety. During this shutdown period, the homeowner will lose heat until the circuit resets or a technician comes out to reset it. Even though a reset can restore the unit to normal operations, repeatedly triggering high temperature limits can decrease the lifespan of the system.

INCREASED NOISE
Even if closing vents without monitoring the system does not damage HVAC equipment, it has other negative effects, including increasing operating noise. HVAC systems’ fans are sized to move a certain volume of air through the home, and the system is calibrated to keep airspeeds in the ducts under control to minimize noise. Closing vents reduces the area that air can get out of the ducts. This increases the speed of air coming out of the remaining open vents, and along with it, noise.

As air flows over sharp edges and rough surfaces, it becomes turbulent. Turbulent air is noisy air. That means that vents with louvers and grilles create additional noise with increasing airspeed. Traditional louver designs also do not seal well. Small cracks and openings accelerate the air even more causing
whistling and rattling. Figure 3 depicts the rise in decibel (dB) level, as velocity increases. Figure 4 illustrates noise-generating surfaces on a traditional vent in blue. The potential increase in temperature comfort is overcome by the noise generated by the increased airflow in the whole home.

**FIGURE 3: NOISE INCREASE WITH AIR SPEED AT VENT FACE**

![Graph showing noise increase with air speed at vent face]

**FIGURE 4: NOISE-GENERATING SURFACES ON TRADITIONAL LOUVERED VENTS**

![Images illustrating noise-generating surfaces on traditional vents]

**AIR LEAKAGE AND INFILTRATION**

In addition to increasing noise, traditional louvers do not stop much of the forced air from escaping the vent, even when closed. There is still a significant amount of air leaking through the closed louvers, as Figure 5 illustrates.

Another potential issue with an unmonitored HVAC system is air infiltration. A clogged filter can cause the unconditioned air around the system to be sucked into the system. Too much blockage due to bad ducting or closing vents will force air into spaces with closed vents.
Both of these effects can reduce efficiency and increase cost if they are not taken into consideration. All vents inherently block some amount of air. If vents block more than the average airflow, the system has more blocked airflow before a single vent is closed.

**REDUCED COMFORT**

If the goal is to increase comfort, closing vents without knowing how the air is distributed in the system can be ineffective. There are many types of air distribution systems including branch (Figure 6A), star (Figure 6B), and perimeter loop (Figure 6C). Depending on the type of system and which vents are closed, the comfort situation in the home can be exacerbated.

As previously discussed, the fan will try to push the same volume of air and without knowing where the air from the closed vents is going, reaching an optimal balance in the home can be impossible without real time measurements.

Not only are all of these negative effects possible or likely when closing vents without checking the resulting system state, but they are also dynamic. The changes in the system with time of day, day of year, and current heat load change how these effects manifest. It is essential to constantly monitor and change the airflow of a system to succeed in improving the system performance as external conditions change.
A common method for alleviating pressure problems is the use of bypass ducts in home HVAC systems. In addition to being inefficient, these bypass systems may soon be out of code in major states, like California. Citing energy efficiency concerns, the California Energy Commission recently proposed a code change that would prohibit the use of bypass ducts in zoned heating and cooling systems. According to *Air Conditioning, Heating, and Refrigeration News*:

“The code change could largely affect manufacturers who specialize in the production of bypass ducts and zoning systems, distributors who sell the units, and contractors who install them.”

Clearly there is a need for a better way to manage system pressure.
Although each of these issues poses problems for traditional HVAC system designs, each of them can be overcome with a combination of advanced software and hardware. Existing solutions that enable zoned heating and cooling can cost tens of thousands of dollars, more than most homeowners are wanting to pay. Other, newer wireless vent solutions are less expensive, but have yet to incorporate dynamic sensing into their designs. Still others are seeking the right combination of cost, control, and system flexibility.

To truly address HVAC zoning at the vent register level, an equipment manufacturer must account for the real-time conditions affecting the home and its mechanical systems. A mechanized vent register that does not incorporate dynamic sensing and control will put the system at risk and will not address the concerns we reviewed previously.

Advanced zoning systems must improve homeowner comfort by incorporating environmental data analytics and control algorithms that respond to user behavior without threatening system function.

Anything less would be a waste of consumers’ time and money. And that’s the last thing any homeowner wants.
