# WANT REAL HVAC COST SAVINGS?

## Reducing CFM while maintaining flow accuracy nets greater savings than reducing duct pressure

HVAC and building controls engineers' checklists abound with opportunities for saving building owners on operating costs. Popular methods include reducing face velocities on coils, lowering duct velocities and reducing pressures in duct work.

In an attempt to help engineers, achieve this, some airflow control manufacturers market lower pressure-drop devices. Do these devices really save money? And, do they perform as intended in critical environments such as hospitals and laboratories?

***Actually, the best way to save money is by reducing airflow. All airflow control devices that rely on any type of flow measurement cannot reduce airflow like the Phoenix Controls venturi valve; they are not as accurate or maintenance free.***

### The benefits of reducing CFM vs. reducing duct pressure

When lowering duct pressure by using ultra-low-pressure-drop devices, how much money do you really save? One rule-of-thumb is that at $0.10 per KW, the cost per 0.1 in. wc pressure amounts to about $0.011 (1.1 cents) per CFM per year. So, for a 20,000 CFM air handling unit you save $220 per year for every tenth of an inch in water column pressure reduction. To be conservative, when measuring the pressure drop on the worst case devices (devices at the end of a duct run, which are farthest from a fan), if you reduce the minimum pressure from 0.3 in. wc to 0.1 in. wc you save approximately $440 per year.

In comparison, the cost to condition outside air is much higher – from $5.00 - $8.00 per CFM per year. If you can reduce flow drift as we will discuss in a moment, by 2% a year on say a 20,000 cfm system, you will save 400 cfm a year or $2,000-$3,200 a year. This is especially true in critical spaces like laboratories, where the ventilation system is non-recirculating and brings in 100% outside air. The bottom line is, if you can reduce CFM consumption you will net much larger savings year-over-year than you will by reducing duct pressure.

### A confounding problem - drift in traditional airflow controls

While you will net much greater savings by reducing CFM than by reducing system pressure, your choice of airflow control device impacts how much savings you'll achieve.

It is well known that devices that must measure air flow to operate (such as VAV boxes, closed loop valves and anything utilizing a pressure transducer flow measurement) will drift in accuracy over time, and thus end up wasting air you might be unaware of. Such drift happens in two ways:

1. Sensor drift due to normal control (turndown)
2. Sensor fouling due to dirt, lab tissues, dander, lint, etc.

*Drift due to normal control (turndown)* – Sensors naturally drift over time given that they operate in a pressurized environment. As air pushes on the sensor's diaphragm, it stretches and deforms. Think of a balloon: when you blow it up and let the air out, it never returns to its original shape. The greater the pressure range the airflow device is controlling (turndown), the more the sensor will drift.

*Drift / Fouling due to dirt, chemicals, lab tissues, dander, lint, etc.* – As any sensors are placed within the air stream, they are a natural catch point for dirt, lint, cleaning wipes and other foreign matter in the ductwork. When sensors get clogged, they report lower airflow than is really happening, which can then trigger the device to open more, thereby increasing flow further. For example, a device could have a completely clogged sensor and report it is handling 50 CFM, but in reality may be wide open and pulling an unmeasured/unknown amount of airflow, which causes pressurization issues in the space the device serves, as well as in the duct plenum. Any measurement device placed in the air stream can and will collect dirt; flow cross, vortex shedder, flow station, pitot tube, and orifice rings are all susceptible.

**THE MAGNITUDE OF THE DRIFT PROBLEM**

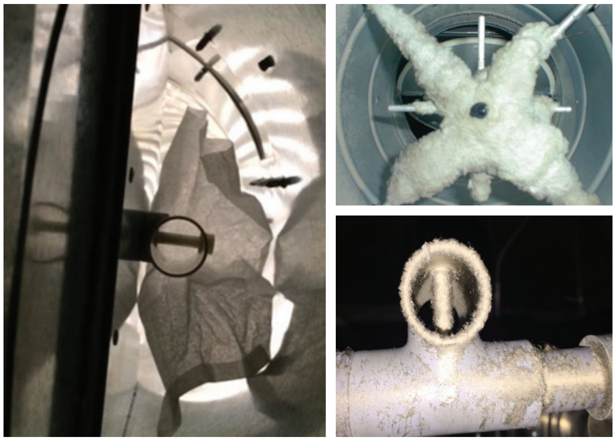
To put the scale of the drift/fouling problem in perspective, consider that in a 20,000 CFM system with very conservative estimate of 2% annual drift, after one year you would have lost 400 cfm (20,000 * 0.02). After the second year, the annual loss increases to 808 CFM as the drift error compounds. And, the losses will keep compounding year-after year until the sensors are calibrated and cleaned or different air control units are installed.

## A better alternative – airflow control devices that don’t drift or require cleaning

In contrast to the ever-compounding energy and dollar losses caused by sensor drift, here are the savings gained by reducing CFM when using airflow control devices like the Phoenix Controls venturi valve that do not drift – or require cleaning.

Because a venturi valve needs a minimum of 0.3 in. wc to operate across its full flow range, it will cost about $440 more per year to operate than a system that claims 0.1 in. wc to control (for purposes of this paragraph we will grant the “claim” of others). However, as venturi valves do not drift over time, and do not need maintenance, you will save thousands of dollars year after year.

Specifically, per the previous example, a 20,000 CFM system with a 2% annual drift will run at 20,400 CFM after year one and 20,808 CFM after two years. At $5.00-$8.00 per CFM, after the first year, that wasted air will cost an extra $2,000-$3,200 to run, and after year two, an additional $4,040-$6,464 to run. The cost of wasted air, thus completely wipes out the claimed $440 savings from lower pressure operations using a device that must sense airflow to operate.



**WATCH OUT!**

When other airflow control device manufacturers say their units out of the box will achieve up to 0.2 in wc savings, consider that you will suffer controllability issues and experience drift losses, which cost far more than reduction in duct pressure. Plus, you will have routine maintenance to try to keep your system running properly as the air sensors become fouled.

What’s more, as discussed below, traditional airflow control devices like VAV boxes and “new” devices like closed loop venturi and bifurcated butterfly valves don’t really operate properly under ultra-low pressure.

## Low pressure performance doesn’t live-up to the marketing hype

Manufacturers have been finding creative ways to sell flow measurement as new, exciting, and better than it was 25+ years ago. The problem is you cannot change the laws of physics. Despite marketing claims, here are four physical realities about airflow control devices that rely on flow measurement to operate:

- The signal will drift, and sensors will need to be cleaned and calibrated for both the zero and span
- Pressure is needed in the duct and terminal device to obtain accurate measurements and turndown, regardless of the sensor type (pressure transducer, thermal anemometer, vortex shedder)
- The low pressure myth debunked: flow control requires pressure drop.
- It is not possible to simultaneously achieve both fast actuation and stability

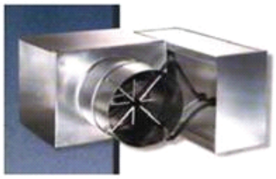
The first item was discussed above, while items two through four are explained in the following sections.

## TURNDOWN AND ACCURACY

A physical reality that marketing cannot overcome is that achieving necessary flow control accuracy will limit turndown capabilities in VAV terminal boxes.

Here's an example, using a 10 in. diameter VAV box / precision transducer with a range of 0.0 - 0.25 in. wc and an advertised 1% full span accuracy in a typical installation.

Damper Airflow Accuracy
10" duct
0 – .25" Transducer
1% Full Scale Accuracy



| Volume | Velocity | Error | Actual VP | Actual Flow | % Flow |
|---|---|---|---|---|---|
| 1000 | 1835 | 0.0025 | 0.2125 | 1006 | < 1% |
| 400 | 734 | 0.0025 | 0.0325 | 416 | 4% |
| 200 | 367 | 0.0025 | 0.0105 | 229 | 15% |
| **100** | **184** | **0.0025** | **0.005** | **141** | **41%** |

Velocity = Volume x Area $\quad$ VP = V/(4005)$^2$

Because the velocity pressure used to calculate the airflow is a function of a square, when the velocity drops below approximately 450 FPM, the flow error drops to an unacceptable level. Recognizing this, some airflow control device manufacturers recommend you select a VAV box size based on the desired accuracy for the flow range the device will be used in. This somewhat backward selection process limits the turndown capabilities of that box, assuming accuracy must be maintained. A case-in-point is for the VAV box discussed above, an acceptable accuracy of approximately 5% of the 10 in. box only yields a 2.5:1 turndown. Such a narrow turndown might be acceptable in air supply systems for office buildings, but it is woefully insufficient in critical environments, such as wet chemistry laboratories, compounding pharmacies, hospital operating rooms and patient isolation rooms – all spaces where greater turndown and accuracy is needed to ensure healthy indoor air and safety. Similar turndown problems apply to thermal anemometry, orifice rings, and vortex shedding .

## THE LOW PRESSURE MYTH

Several airflow control device manufacturers have been telling customers for years that their companies' valves can adequately control air at ultra-low pressure. Under such control, they contend the building owner can dramatically turn down the building's HVAC fans to reduce energy use and design with smaller fan size overall. It's an appealing claim: you can save a lot of energy and money, while still managing air sufficiently. But, as seen in their own product data sheets (PDS) and follow-up testing, it's a myth – the reported operating values are for situations virtually never encountered in the real world. Assuming ultra-low pressure is achievable in the most common applications endangers people by not adequately defending them against airborne hazards and if engineers design the building with smaller fans, they will need to increase the pressure over design to make the airflow devices function, and the fan will max out quicker, also losing the diversity built into the system.

The problem with the published minimum pressures is they are measured when the airflow control device is in a wide-open position, (citing ASHRAE 130 Standard as the test procedure). In such a configuration, though, the device is not in control of the airflow, as the damper/blade must be open and obstruct the airflow some amount to control it. Yet, what happens when the obstruction is created? The pressure across the device increases, and you start to see what the real required operating pressure of these devices is. Another interesting fact is that if you rate your operating pressure by ASHRAE 130 with devices wide open, they also cannot operate at those pressures and adhere to ASHRAE 90.1 since they cannot be 100% open per ASRAE 90.1

Simply put, you cannot operate at ultra-low pressure and still achieve stable and accurate airflow control. For examples of airflow control devices' minimum pressure required for relatively stable control and advertised turndown, see the Appendix – Airflow Control Device Test Results.

## SPEED OF RESPONSE AND STABILITY

An air control device's speed of response and stability are inextricably linked, so they influence the device's overall performance.

*Speed of Response*

Speed of Response means how quickly a device will react to a change in command. For most "fast" flow measurement devices, manufacturers list a one-second speed of response. This is somewhat misleading, as testing proves such devices will start to react to commands within one second, but take 2-3 seconds (or many times much more) to achieve the final position.

In contrast, Phoenix Controls Venturi valves actuate to their final position within one second of receiving a command. This is because our valves do not use a flow measurement technique for flow positioning, but rather follow a 48-point characterized valve curve that does not drift over time and that allows the control algorithm to reposition the valve at the highest possible speed while not over- or under-shooting the final position. (This is known as Digital Closed Loop Control)

*Stability*

Stability refers to the degree to which an airflow control device will remain in the commanded position, regardless of air velocity in the ductwork or pressure changes.

Despite the name, constant volume airflow devices that utilize flow measurement techniques are never truly constant volume as their dampers move to adjust for velocity changes in the ductwork. This adjusting for velocity and pressure changes can cause “hunting.” All devices that rely on flow measurement hunt. The more VAV devices installed in a system, the more they must hunt. Specifically, if the duct pressure changes due to one device opening, all devices on the common plenum must react. This may not be an issue in commercial applications where once the system startup has stabilized, the system changes very little over the day. However, in laboratory applications each time a VAV fume hood sash moves, the flow changes and static pressure are immediately and dramatically impacted. Hence stability is much harder to achieve in these types of active systems.

Flow measurement devices with fast response speeds have additional stability problems. As the damper in the device moves, velocity and pressure change across the device’s sensor, which causes it to hunt more. Manufacturers can slow the actuation to gain more stability, but that would further invalidate their one-second response speed claims. Real world testing shows sometimes up to 200 cfm of hunting in a laboratory environment.

The only device that achieves both a one-second response speed and stability without hunting is the Phoenix Controls venturi valve. The mechanical pressure independence of the cone inside the valve accommodates any changes in duct pressure and velocity without the need to move the actuator to maintain a flow setpoint. This saves money by reducing the energy needed to actuate the device due to hunting (overshoot/undershoot) and by reducing wear and tear on the actuator. Phoenix Controls also uses a proprietary Linear actuator for high speed control, not an “off-the-shelf” commercial actuator.

## Conclusion

While other airflow control manufacturers that utilize flow measurement are selling a lower pressure drop, Phoenix Controls is doing more to save energy and curb the consumption of outside air than any other product on the market. “Owners that know” buy Phoenix Controls for two reasons: repeatable control year after year (no maintenance and stable control), energy efficiency (high turndown), and systems that do not drift. Phoenix Controls systems do not drift because there are no invasive flow elements.

# APPENDIX – AIRFLOW CONTROL DEVICE TEST RESULTS

Given that it is physically impossible to operate at ultra-low pressure and achieve stable and accurate airflow control, following are test results showing the minimum pressure required for relatively stable control and advertised turndown for various airflow control devices. In all examples, testing was done on a NVLAP accredited air station (ISO/IEC 17025:2005 NVLAP LAB CODE: 200992-0).

Note in these examples that the minimum required differential pressure is very different from published minimum pressure drop or minimum operating pressure. Minimum required differential pressure is the pressure at which the airflow control device is both stable and accurate.

Typical VAV box

- Published minimum pressure drop: 0.15-0.2 in. wc
- Minimum differential pressure to control per ASHRAE 90.1: ≥ 0.5-0.7 in. wc
- Average accuracy across flow range: 10-40% +/- at low flow, 10-15% +/- at higher flows
- Turndown approx. 3:1 to maintain approx. 10% accuracy
- Accuracy will degrade as sensors get dirty, and transducer accuracy drifts

Bifurcated Butterfly VAV valve

- Published minimum operating pressure: ≤0.1 in. wc
- Minimum differential pressure to control per ASHRAE 90.1: >= 0.1 in wc to 1.2 in wc for full turndown and control
- Minimum differential pressure to get full turndown: 0.6 - 1.2 in. wc, depending on size
- Average accuracy: 10-20% +/- at low flow, 5-7% +/- at higher flows
- In a perfect duct, expected turndown ratios at various pressures are as follows:
- 0.1 in. wc – 2.5:1 with accuracy ranging from -15% to -9%
- 0.3 in. wc – 4.4:1 with accuracy ranging from -12% to -7%
- 0.5 in. wc – 7.8:1 with accuracy ranging from -15% to -7% and hunts at all flows
- 1.2 in. wc – 10:1
  (which is highest turndown possible with this device, and the accuracy ranges from -15% to -7%, and hunts at all flows)
- Accuracy will degrade as sensors get dirty, and transducer accuracy drifts

Closed Loop Venturi Valve

- Published minimum pressure (maximum pressure loss): 0.15 in. wc
- Minimum differential pressure to control per ASHRAE 90.1: ≥ 0.5-0.7 in. wc
- Average accuracy across flow range: 10-20% +/- at low flow, 5 +/- at higher flows and hunts at all flows
- Turndown – 10:1 at approx. 0.7 in wc and above
- Accuracy will degrade as transducer accuracy drifts

Venturi air valve

- Published minimum operating pressure: 0.3 in. wc
- Minimum differential pressure to control: 0.3 in. wc
- Average accuracy across flow range: 5% +/-
- Turndown up to 20:1 at advertised min differential pressures.
- Accuracy will not degrade over time, no sensors to foul, no drift in signal
- Maintenance Free