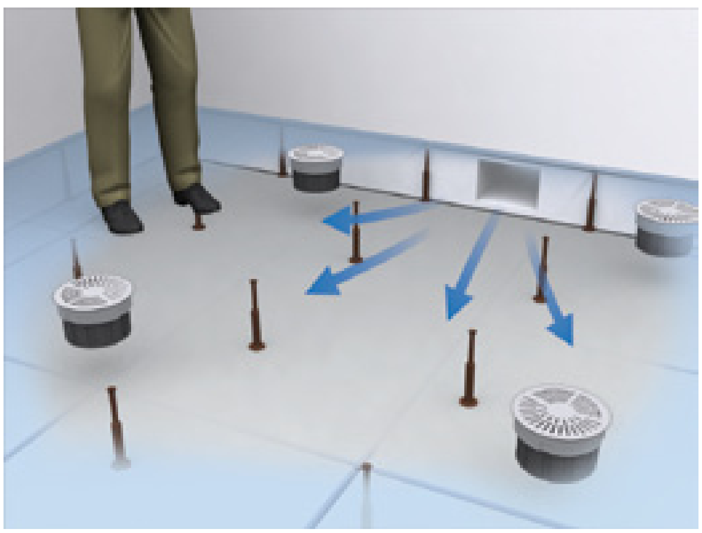
Advantages to Plenum Pressure Regulation

Raised access floor systems and underfloor air distribution (UFAD) have been used for years as a means of creating a flexible workspace with easily accessible and reconfigurable building services. They are applied across a range of applications and tend to be most common in owner-occupied office spaces. The key feature of these systems is their ability to deliver air to zone-specific outlets with minimal ductwork, whether they are mixing displacement, linear or low throw diffusers. This is accomplished by pressurizing the cavity between the building structure and the raised access floor, as shown in the figure below.



Pressurized Plenum

The underfloor plenum is typically maintained at pressures ranging from 0.02 to 0.1 in. w.g. [5 to 25 Pa] relative to the room above. The pressure is maintained in this range for several reasons:

1. Higher pressure may cause significant leakage through the floor, walls and building envelope, thereby wasting energy in the form of conditioned air. It can also cause a loss of control over the zone if the leakage rate is higher than the amount of air required to condition the space.
2. Air outlets designed for use in a raised floor system do not require a lot of pressure to deliver air to the zone. These are often sized to provide air to a single occupant, giving each occupant the ability to control the conditions in his/her local area.
3. Too much pressure can cause excessive diffuser throw, which should be maintained as low as possible in the space, typically below 4ft from the floor. Air patterns that extend beyond this can cause re-entrainment of heat and pollutants stored above the occupied space, thereby reducing the air quality and energy benefit realized from the UFAD system.

Plenum Pressure Regulation

Regulating the plenum pressure is key to maintaining flexibility and controllability in an underfloor system. In both CAV and VAV zones, the amount of air delivered to the space through a standard diffuser is determined by the pressure differential across the diffuser. Referencing the table below, the air flow from an RFTD twist diffuser varies from 63 cfm at 0.03 in. w.g. to 122 cfm at 0.10 in. w.g. This information allows the designer to select either the design static pressure to supply sufficient air through a UFAD diffuser, or sufficient quantities of diffusers to satisfy the air volume requirement at a certain static pressure.

The types of diffusers described allow occupants to control

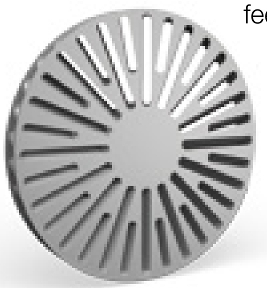
Performance Data - Imperial

	Pressure (in. w.g.)	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
No basket	Air Flow (cfm)	63	74	86	97	103	109	115	122
	Sound (NC)	-	-	-	-	-	-	15	16
DB basket	Air Flow (cfm)	49	59	68	78	83	89	95	101
	Sound (NC)	-	-	-	-	-	-	15	17

Performance Data - Metric

	Pressure (Pa)	7	10	12	15	17	20	22	25
No basket	Air Flow (L/s)	30	35	40	46	49	51	54	58
	Sound (NC)	-	-	-	-	-	-	15	16
DB basket	Air Flow (L/s)	23	28	32	37	39	42	45	48
	Sound (NC)	-	-	-	-	-	-	15	17

the amount of air delivered locally. While this is beneficial in terms of occupant comfort (ASHRAE, 2010), it can also pose some control challenges. For instance, the system receives no feedback as to how the occupants have set their devices. As such, if several diffusers are manually modulated partly or fully closed, a system that controls air volume will see an increase in the plenum static pressure. This will increase the air volume from surrounding diffusers or lead to unpredictable turndown for occupants who manually adjust their outlet.



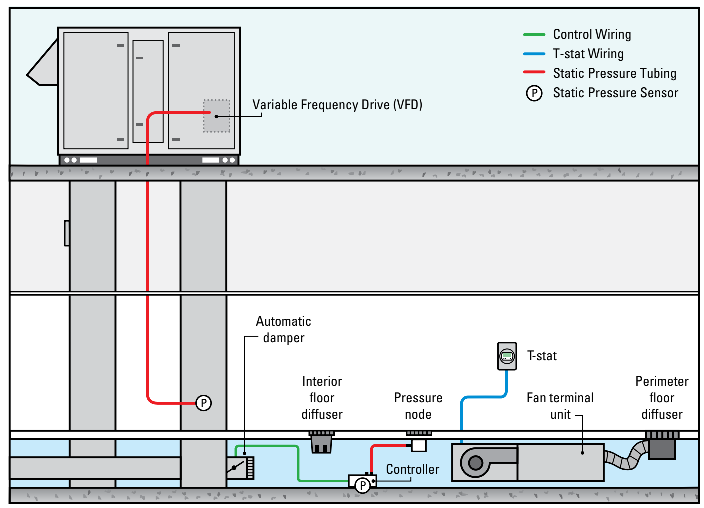
Round Floor Turbulent Diffuser

With UFAD systems, it is preferable to control the plenum pressure as opposed to air flow. This will allow the system to reset if diffusers are opened or closed. When the occupant adjusts his/her diffuser down, the plenum pressure will increase, causing the system to close the dampers, which reduces the air flow delivered to the plenum, returning the plenum pressure to the desired value and the air flow from the diffusers to their designed or predicted flow. Underfloor pressure is typically controlled by a dedicated underfloor pressure controller, which regulates the pressure in the plenum. There are two ways this can be accomplished:

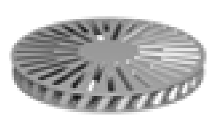
> *"With UFAD systems, it is preferable to control the plenum pressure as opposed to air flow."*

1. Regulate the absolute plenum pressure. If the building pressure is known, it is possible to estimate the pressure difference between the plenum and the space with the absolute pressure.
2. Regulate the relative plenum pressure. If the relative pressure between the zone and the plenum is regulated, as shown in the figure below, the system becomes independent from the building pressure. This enables plenum pressure control in a building with operable windows and is less susceptible to control loss when the building pressure is allowed to fluctuate.

To regulate the pressure differential between the underfloor plenum and the zone, a pressure controller requires two input signals – one from each space. Normally, the pressure controller is located in the underfloor plenum and one or more sensors have direct access to read the pressure beneath the floor. To read the zone pressure above the floor, remote measurement is usually handled by pressure tubing that is routed to an inconspicuous area in the zone.



Plenum Pressure Regulation

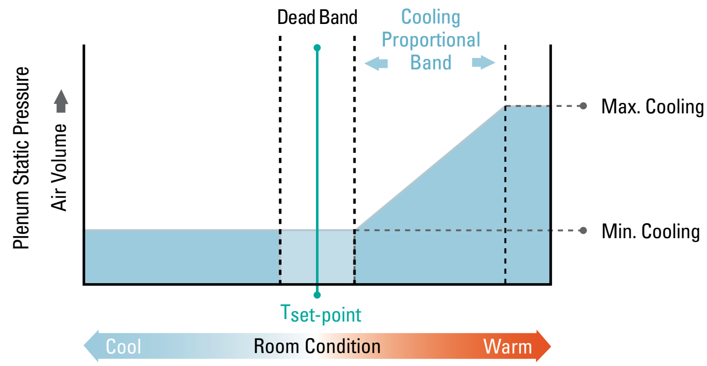


Pressure Node

Once the designer has opted to control pressure–which is essentially the standard–it is fairly straightforward to adapt this controller to provide a simple and cost effective solution for large scale VAV zones. In the case of the constant pressure system above, where the pressure is controlled to a set-point and adjusted based on user demand, air flow is regulated on the pressure signal. If this pressure controller includes a thermostat it is a small step to modulate the pressure based on room temperature. This means of implementing VAV is advantageous because:

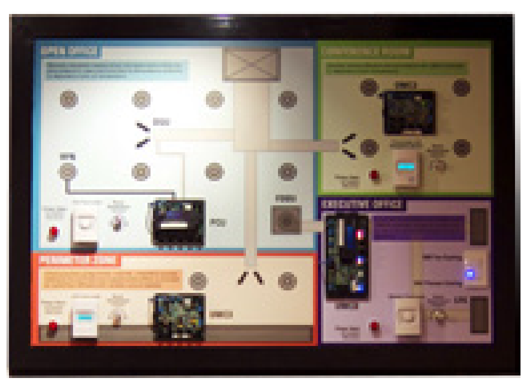
1. It allows for large scale VAV zones. The alternative method of implementing VAV is to use VAV diffusers. This requires an actuator and wiring to each diffuser, which can increase first costs and has ongoing costs associated with the maintenance of mechanical parts at each outlet. By using pressure reset, the only actuators are on the plenum inlet dampers, which are significantly fewer in number.
2. It retains user control, which is often a key feature of the UFAD system. Occupants can still throttle their diffuser as required to get more or less air, with the controller responding with more or less air, to control to the new static pressure set-point without affecting the amount of air delivered to other occupants.

As shown in the following control graph, as the demand for cooling increases past the thermostatic set-point, the pressure in the plenum increases from the minimum flow (pressure) up to the maximum flow (pressure). This might be a range of 0.02 in. to 0.08 in., for example. If the temperature in the zone is below the set-point, the flow is maintained at minimum and heating can be provided, if necessary.



Cooling Only Control Graph

One element of this type of system that is often misunderstood is how the pressure in the plenum affects and is affected by the other systems. The dedicated plenum pressure controller regulates the pressure by adjusting dampered inlets from an air riser. As adjacent zones respond to their own thermostatic signal, whether by a terminal unit drawing from the VAV plenum or by VAV diffusers modulating from the same plenum, as shown in the following figure, the pressure is affected. As the fan increases in speed or VAV dampers open, the pressure in the VAV plenum drops. The controller responds by providing more air to maintain the pressure set-point. In this fashion, the system is able to cope with multiple zones fed from a common VAV plenum.



UFAD display in Atlanta Tech Center

In order to maintain working pressure in the main shaft and allow the air handler to operate in its efficient range, the air handler may be equipped with a variable frequency drive (VFD). In this case, a pressure sensor is placed in the main shaft and sends signals to a controller that modulates either the main fan or the bypass damper. This control system is usually independent of the plenum pressure control system.

This system's ability to communicate pressure readings from each zone to the AHU provides a low cost, robust way to have the building operate in sync. More complex strategies exist where the BAS communicates between zones, but this is difficult to set up and maintain, and is not necessary. The advantages of the variable pressure implementation of temperature control are significant:

- Lower initial and maintenance costs
- User control of the air outlets is maintained
- Simple synchronization of the HVAC zones

For more information about UFAD systems and control, refer to the following resources:

- Sustainable Building Products Website - www.price-hvac.com/sustainable
- Price HVAC handbook, Chapter 17
- Webinars

Reference: ASHRAE (2010). Standard 55-2010 -- Thermal environmental conditions for human occupancy. Atlanta, GA: American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc.