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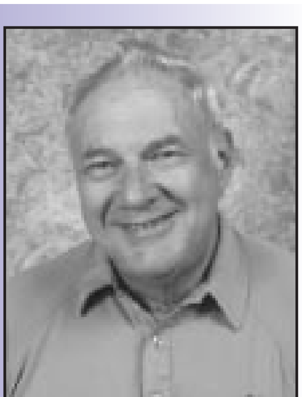
Control of VAV Systems With DX Cooling: A Digital to Analog Conversion



Article by Gil Avery, P.E.

About the Author

Gil Avery is vice president of Kele & Associates, Memphis, Tenn. He received his BSEE from Rensselaer Polytechnic Institute. Avery is a past president of the ASHRAE Memphis chapter. Avery is chairman of GPC-16 (Specifying Outdoor, Return and Relief Dampers for VAV systems) ; a voting member of SSPC-62; and a member of TC-9.1, GPC-11 and GPC-13.

The use of direct expansion cooling coils in VAV air handlers offers many advantages over air handlers with water coils. DX coils can be more efficient, they eliminate the freeze problem, and generally cost less to own and maintain. The major deterrent to their use has been the inability to match the condensing unit capacity with the varying VAV load. This paper addresses this problem and also describes a method of control that minimizes the problem.

DX coils are normally available with two circuits per coil. The circuiting can be arranged for face control as shown in Figure 1, row control as in Figure 2 or by intertwining the rows as shown in Figure 3. Any circuit can incorporate a hot gas bypass system as shown in Figure 4.

The cooling capacity is generally controlled by a four-step controller. The controller for the face, row and intertwined coils shown in Figure 1, 2 and 3 will operate the two refrigerant solenoid valves on each of the two double circuit coils (4 steps). The step controller for the coils with the hot gas bypasses shown in Figure 4 will control the two hot gas bypass valves in sequence with the liquid line solenoid valves to provide four stages of control. The four-stage controller for these coils is generally connected to a temperature sensor in the supply air.

It is obvious that there is no way of maintaining a relatively constant supply air temperature under partial load conditions without rapidly cycling the condensing equipment or artificially loading the system with hot gas. For example, with a 25% AHU cfm (L/s) load, the face velocity of the air through the active coil is only one-fourth the full load coil face velocity. The air leaving the active coil can be 40°F (4.5°C) or less because of this low velocity. When the cold air off the active coil mixes in the fan with the warm outside air and return air that passes through

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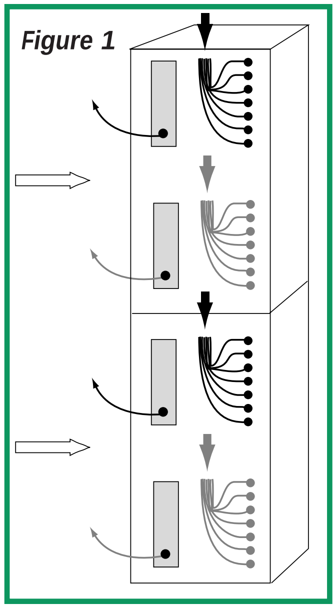

Figure 1

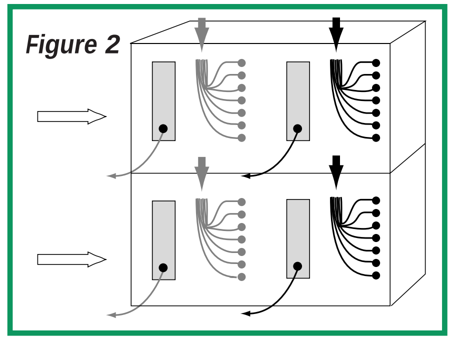

Figure 2

Circuiting for DX coils can be arranged for face control as in Figure 1, row control as in Figure 2, or by intertwining rows as in Figure 3.

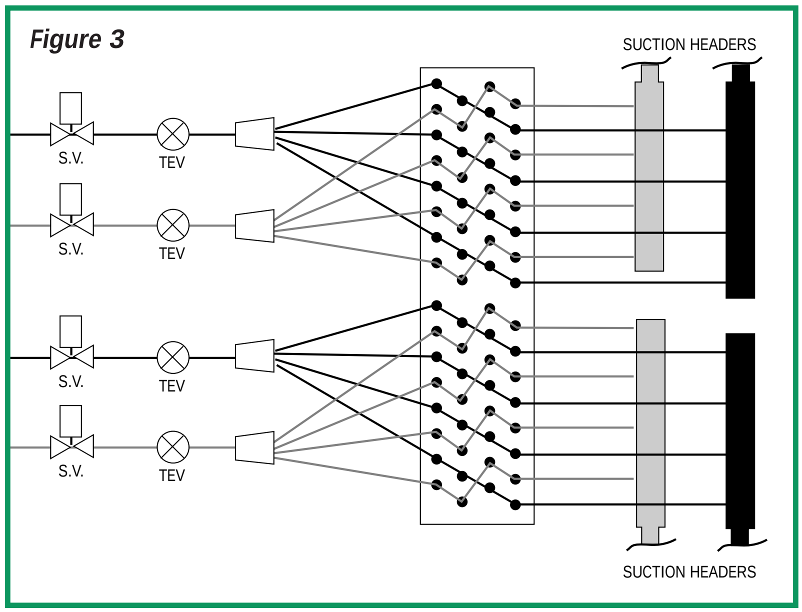

Figure 3

the inactive coils, frost occurs, and condensation collects in the fans. The only way to prevent coil frosting or condensation is to rapidly cycle the solenoid valve or to use hot gas to artificially load the coil. Neither of these methods is acceptable because of the reduced life of the condensing unit when rapid cycling is used or the inefficient use of energy when the hot gas bypass method is used.

A fifth method of control that uses coils with face dampers that close when the coil is deactivated is shown in Figure 5. This system minimizes these problems and therefore enables the engineer to utilize the advantages of direct expansion cooling on almost any VAV system. This paper will not cover the control of the heating coil or the minimum outside air controls for ventilation; however, a small constant volume outside air injection fan is generally used.

The supply duct is sized by the static regain method so that the pressure in the supply duct is relatively constant and the static pressure at the supply fan discharge is approximately the same as at the last VAV terminal.

Most VAV DX air handlers have a cataloged cfm (L/s) ranging from100% down to 40% of the maximum cfm (L/s) capacity as shown in Figure 6. The air flow on this particular unit can be varied from 20,000 to 8,000 cfm (9438 to 3775 L/s) with a resulting change in coil velocity from 440 to 176 fpm (2.2 to 0.89 m/s).

VAV DX air handlers should be selected at or near their maximum cfm (L/s) capacity so as to take advantage of this air flow range.

Coils are shown stacked four high in Figure 5 for clarity. The air handling units are normally furnished with a coil and damper section two high and two wide so that two refrigeration headers and damper control shafts are on each side of the unit.

When the outdoor temperature, sensed by TS-1, is below the design supply air temperature (approximately 60°F/16°C) so that outside air can be used for cooling, the system will operate as follows:

1. All coil dampers will be open.

2. All refrigerant solenoid valves will be closed and the condensing units will be off.

3. Temperature sensor TS-2 will control the

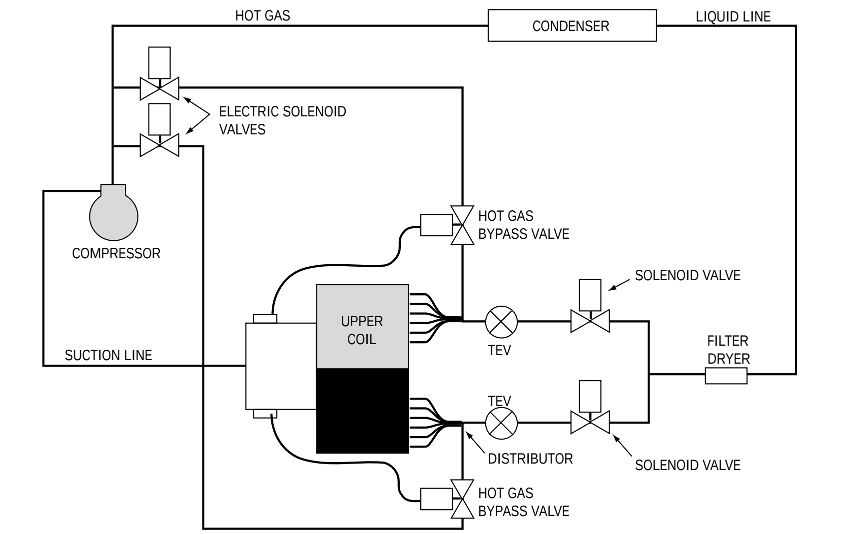

Figure 4: *The hot gas bypass system can provide four stages of control.*

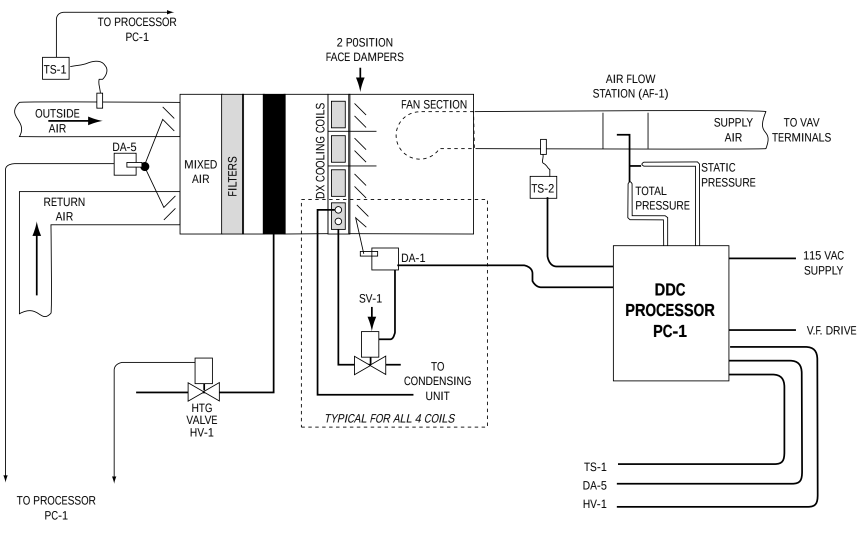

Figure 5: *The face damper controlled system can provide a fifth method of control.*

modulating economizer damper actuator DA-5.

4. Air flow station AF-1 will maintain a constant supply duct pressure by controlling the speed of the supply fan.

When the outdoor temperature is above the setting of TS-1 the system will operate as follows:

1. The outside air economizer damper will be closed and the return damper open.

2. The air flow station AF-1, through processor PC-1, will control the damper actuators DA-1 through 4 and refrigerant solenoid valves SV-1 through 4 so that when the:

a. Air flow is greater than 75%, all dampers and solenoid valves will be open. Coil face velocity can vary from 100 to 75 % of design (440 to 330 fpm/2.2 to 1.7 m/s).

b. Air flow is greater than 50% but less than 75%, three dampers and solenoid valves will be open. Active coil face velocity can vary from 100 to 67% of design (440 to 295 fpm/ 2.2 to 1.5 m/s).

c. Air flow is greater than 25% but less than 50%, two dampers and solenoid valves will open. Active coil face velocity can vary from 100 to 50% of design (440 to 220 fpm 2.2 to 1.1 m/s).

d. Air flow is less than 25%, one damper and solenoid will be open.

3. A constant supply duct pressure will be maintained as specified in paragraph 4 above.

In lieu of using an air flow station, a differential pressure sensor across the DX coils and dampers, can be used to sense load. Controlling the cooling coils from air volume is a truer indication of load than a supply air temperature sensor since the temperature sensor does not sense mass flow. Volume sensing also eliminates the rapid cycling of the condensing units that is inherent with temperature sensing.

The change in duct pressure caused by the change in position of the coil damper can be handled by software time delays in processor PC-1, so that the air volume (load) is not calculated until the supply duct pressure is restored to design after a coil damper changes position.

A VAV DX air handler with four coils will have a minimum cfm (L/s) capacity of 0.25 (sin-

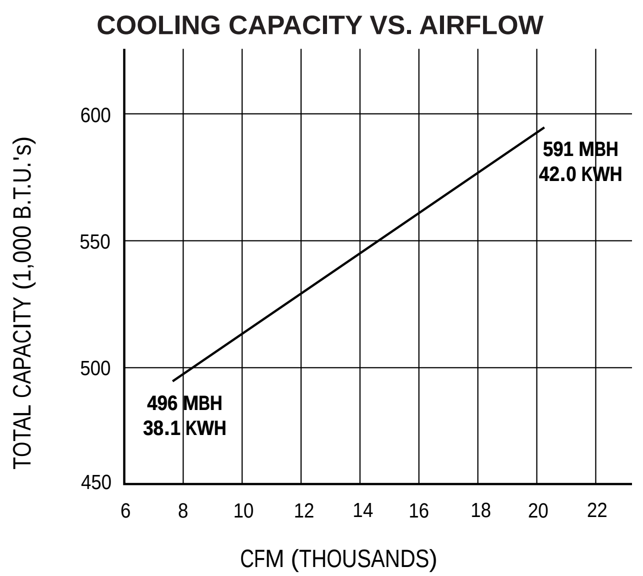

***Figure 6**: Typical VAV DX air handler. 60% change cfm = 16% change cooling capacity.*

gle coil operation) x 0.4 (minimum air flow rating) = 0.1 or a turn down ratio of 10 to 1. The cooling load from the supply fan may be 4% to 5% of the system capacity. If this is accounted for, the turn down of the four-stage VAV DX air handler approaches 20 to 1; sufficient for most applications.

Here are some advantages of the Face Damper Controlled DX system:

- All condensing units operate at normal capacity and efficiency without the use of hot gas bypasses, unloaders, etc…
- No complicated refrigerant piping or oil return problems.
- With normal air flow through every active coil, coil icing is minimized.
- Condensing unit redundancy (4 units)
- More efficient than a chilled water system with an air cooled chiller.
- No pumps, chillers or water coils to freeze or maintain.
- All supply air passes through an active cooling coil and is dehumidified. The ideal system for humid climates.
- Capacities from 10 to over 100 tons (35 to 352 kW).
- Ideal for small to medium-sized commercial buildings with VAV systems up to 80,000 cfm (37,752 L/s).
- Air handler controls are independent of VAV controllers. The unit can serve any number of VAV terminals. The same processor is used with large or small air handlers.
- The ideal unit for VVT (Variable Volume Temperature) heating and cooling systems.
- Condensing unit short cycling is minimized. ◩

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