Due to complaints about wintertime coil freeze-ups and high summertime humidity, the author proposes that face and bypass dampers be used in unit ventilators rather than control valves

Take A Fresh Look at Face and Bypass

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I'm about to commit heresy. Engineers rely too much on control valves, and I propose we stop this over-dependence. It's possible that we engineers haven't been rigorous enough in questioning conventional wisdom, thereby accepting less than the optimum answer for our clients, and maybe even causing them more problems than we're solving.

My engineering staff, primarily school building designers, visits about 30 different schools a year. We have found that the two biggest complaints voiced by facilities managers and operators are costly wintertime freeze-ups and high summertime humidity that range from uncomfortable to unhealthy. We have discovered that both of these operating nightmares can be avoided by specifying unit ventilators with face and bypass (F&BP) dampers in lieu of valves for space temperature control. There may be some slight added cost, but F&BP dampers will typically pay for themselves through energy savings and lower maintenance costs.

THE TYPICAL SCHOOL MECHANICAL SYSTEM

By far, the most common HVAC system for heating and cooling school buildings is the under-the-window, valve-controlled unit ventilator. It was invented about 70 or 80 years ago by Herman Nelson as a way to incorporate ventilated air and economizer cooling into the classroom. Through the years, Nelson's good idea was expanded and mutated into at least 20 different combinations of various heating and cooling sources. ASHRAE identifies three unit ventilator control schemes, appropriately named I, II, and III (*ASHRAE Systems Handbook*, Chapter 31).

But while unit ventilators may be the most common school HVAC system, they are not the most popular because they frequently experience freeze-ups and high humidity problems.

Few new school buildings in my service area are being designed with unit ventilators, in spite of the fact that most other systems cost more to build, operate, and maintain. Other solutions, specifically VAV or separate makeup air configurations, are now the typical designer recommendations (in my region).

THE FREEZE-UP

"My room is cold, and there's water all over the floor." If you hear that on your answering machine on a cold winter morning, you can guess, often correctly, a freeze-up has occurred.

In the field of valve control, engineers have devised various strategies to address freeze-up problems, including but not limited to mixed-air low-limit thermostats, glycol in the loop, and coil-circulating pumps. Each of these approaches solves part of the problem some of the time; however, they add components to the mechanical system, increasing both equipment and downstream maintenance costs. Freeze-ups can and will occur even when the equipment is in operation, although my experience shows that freeze-ups seldom occur at night. I believe this is because the most common freeze-protection scheme involving nighttime setback opens the control valve to ensure full flow through the coil, closes the outside air damper, and cycles the fan on a call for heat. Under these conditions, freeze-ups won't be a problem as long as the boilers are operating and there's power to the pumps.

But doesn't this tactic mimic the face and bypass process? If a school is "occupied" for 50 hr a week, then it is in night setback mode (and operating in face and bypass) 118 hr per week already, so why not use face and bypass from the beginning?

When specifying units that handle large percentages of outside air, most (maybe all) equipment manufacturers will recommend face and bypass as the only way to ensure freeze-proof operation. A typical unit ventilator will operate at about 30 percent minimum outside air—and more when it operates in economizer mode. It would seem that this is a large enough outside air fraction that the engineer should specify the control scheme with the least potential for problems, namely face and bypass.

HIGH HUMIDITY

"My room smells funny, and papers won't feed through the copy machine." When you hear this from a client, chances are pretty good that they're having a high-humidity problem.

Since the advent of hydronic cooling, unit ventilators have been used to add air conditioning in schools. For many years, this was the typical solution, and valves were used for space temperature control. It did work well, but it seems that the old solution does not work anymore. This is where I typically see humidity problems. What has changed?

ASHRAE Standard 62-1989, *Ventilation for Acceptable Indoor Air Quality*, mandated a three-fold increase in outside air required in a classroom. According to a report published by Carrier Corp., the change upset the natural equilibrium between the sensible/latent occupant load and the cooling available in 5 cfm (the old standard) of dehumidified air.[1] Combine this with the smaller classroom load that is due to improvements in lighting technology and smaller class sizes, and you have an air conditioning system that doesn't work as hard as it used to and doesn't dehumidify the space to 60 percent RH recommended by ASHRAE Standard 62-1989. These factors are causing many of the humidity and indoor air quality problems that seem to plague many schools using unit ventilators.

[1] *Superscript numerals indicate references listed at end of article.*

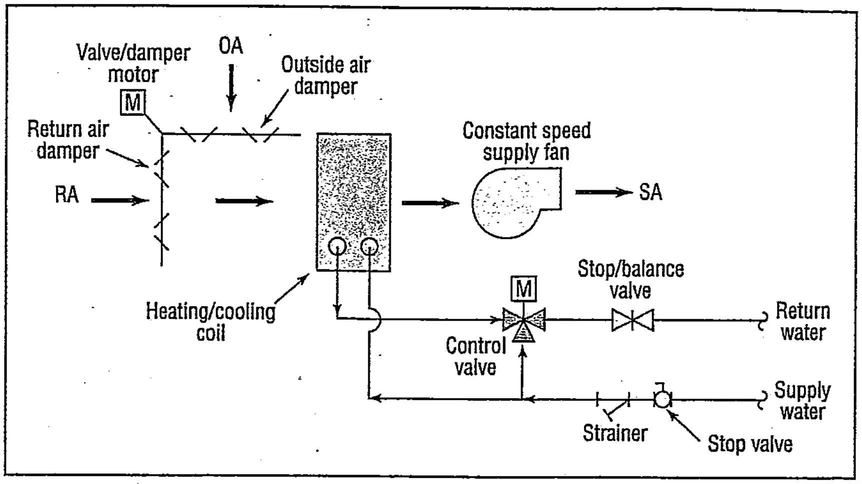

FIGURE 1. Valve Control: space temperature is maintained by varying the amount of supply water that goes through the coil.

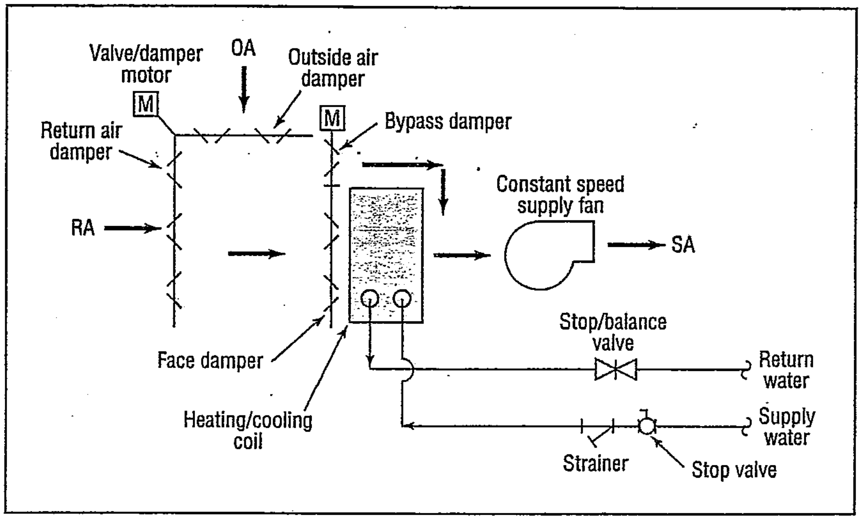

FIGURE 2. Face and Bypass Control: space temperature is maintained by varying the amount of air that goes through the coil.

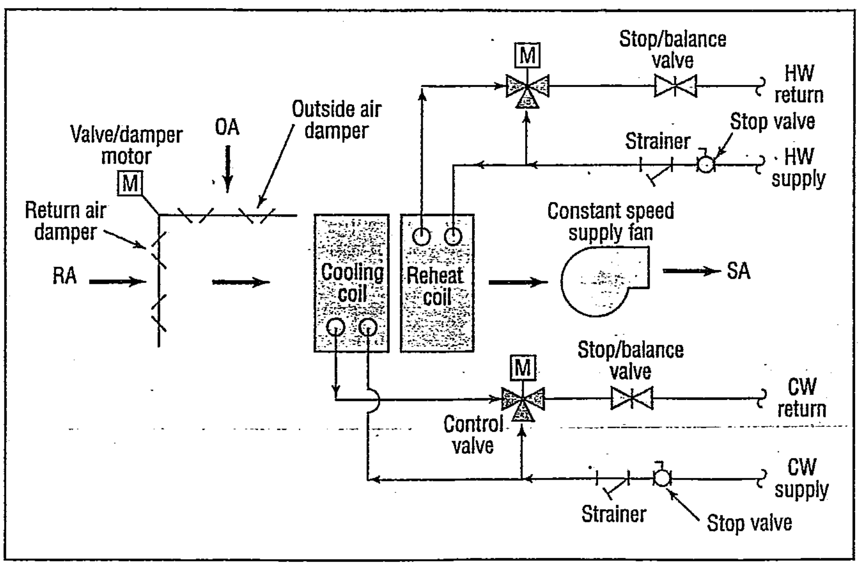

FIGURE 3. Reheat Control: space temperature is maintained by overcooling the air stream and reheating as required.

Here are the common denominators I have found in problem spaces, in descending order of importance. Numbers one and three are design problems; numbers two and four are usually operational problems.

1) Constant volume air handling equipment (unit ventilators or air handlers) with valve control

2) Around the clock operation

3) Oversized equipment

4) Building negative pressure

If valve controlled, constant volume units are the number one problem, what's the solution? Well, there are two parts to the problem—constant volume and valve control. Eliminating either will solve many high-humidity problems.

No matter which HVAC system exists, high humidity is typically not a full-load problem since normal air conditioning operation will handle both latent and sensible loads. But, at any cooling load less than full load, one of three things has to change:

1) Time of operation

2) Volume of air

3) Temperature of the air

Varying the amount of time the equipment runs will give effective humidity control, but it is not an acceptable strategy because of the continuous ventilation requirements of ASHRAE 62-89.

Varying the volume of the air (VAV system) is an excellent system choice if there is adequate head room and budget, which may not be the case in an existing school building.

Varying the temperature of the air could be done in at least three ways: valve control, face and bypass control, or reheat control (Figures 1-3). Consider the following classroom example:

- 4.5 ton cooling load, 1250 cfm unit ventilator
- 450 cfm outside air
- 75 F space temperature
- 95 F-DB, 78 F-WB outdoor conditions.

Table 1 shows the performance of the three common variable temperature options at both full- and part-load conditions. Because a thermostat will respond only to space-sensible load, "part load" is defined in this example as the sensible load in the space that would be satisfied by a 65 F air stream.

Obviously, reheat will work for humidity control, but it puts the cooling coil first in the air stream where it would be more prone to freezing than if it was upstream of the heating coil. It will also increase cooling cost, and most (maybe all) energy codes do not allow for reheating with new energy. So, if reheat is your choice, waste heat has to be captured and routed where it can be utilized, adding cost and complexity to the system.

TABLE 1—

Example of evaluating the performance of the three common variable temperature options at both full and part load conditions.

	Valve control		F&BP control		Reheat control	
	Full load	*Part load	Full load	*Part load	Full load	*Part load
LAT,DB	55 F	65 F	55 F	65 F	55 F	65 F
LAT, WB	55.4 F	63 F	55.4 F	59.5 F	55.4 F	59 F
Relative humidity, percent (1)	50	63	50	52	50	50
Relative humidity, percent (2)	54	68	54	56	54	54
Cooling energy, kW (3)	5.7	2.9	5.7	3.1	5.7	5.7
Heating energy (4)	0	0	0	0	0	21.2 MBH
Op. cost/HR (5,6)	$0.40	$0.20	$0.40	$0.22	$0.40	$0.41

Notes:
1) Percent relative humidity at 75 F space temperature with no latent contribution from the space.
2) Percent relative humidity at 75 F space temperature with 190 Btuh latent load from each of 30 occupants.
3) Chiller at 1.2 kW per ton and chiller water pumps at 6 percent of chiller load.
4) Boilers operating on gas air 80 percent efficiency and hot water pumps at 6 percent of heating load.
5) Electric cost at 7 cents per kWh and gas cost at 50 cents per 100 cu ft.
6) Assumes constant-speed pumps.
*For purposes of this example, "part load" is defined as the sensible load in the space that would be satisfied by 65 F air stream, since the thermostat will respond only to space sensible load.

This analysis is predicated on properly sized equipment. Oversizing of air handlers will cause the sensible load to be satisfied before the latent and will result in higher humidity. Face and bypass is more forgiving than valve control when dealing with the problems of oversizing. The air-side of constant-speed cooling units is one of those design decisions where "more" is definitely not "better."

Concerning the other two common humidity causes—around the clock operation and building negative pressure—owners need to understand the problems presented by these operational decisions. Nighttime operation of unit ventilators (when the outside temperature is below room temperature and outside humidity is high enough to form dew on the grass) will bring untreated outside air into the classroom as well as latent load without any corresponding sensible load to create a cooling demand.

Building negative pressure is a closely related problem, but the source of the unwanted humidity is usually exhaust fans operating continually instead of being interlocked with a makeup air method to treat the humidity. The designer needs to make sure that the control sequences give the operator the ability to maintain space temperature without bringing in outside air as well as check that the exhaust fans are included in the occupied/unoccupied schedule. These are potential problems in both valve and F&BP schemes.

DRAWBACKS OF F&BP?

Through the years, I've heard three criticisms of face and bypass, specifically: "It's more expensive," "control isn't as good," and "it's prone to overheating." None of these is necessarily true.

First cost—The cost difference between F&BP and valve control is minimal. On single-coil units (heating only or two-pipe change over), the F&BP damper is about the same cost as a modulating control valve. If the design calls for both heating and cooling, valve control should be out of the question because this approach does not handle humidity. Two-coil F&BP units will have minor added cost.

- *Operating cost*—Pumping energy of a valve-control system will only be less in a well-designed variable speed scheme. Pumping energy is the only variable in estimating operating costs. Face and bypass doesn't require a control valve, which is a significant part of the total pumping system head. Control valves are usually selected with a full-flow pressure drop of 5 to 15 ft. Considering usual total system head of about 50 to 80 ft, the control valve is at least 10 percent and possibly as much as 20 percent of the total pumping energy. In the projects I've worked on, HVAC pumps have been as much as 5 percent of a school's energy bill, so the savings can be worthwhile.
- *Controllability*—I've never experienced any control problems with F&BP—control is as effective as a properly sized control valve. Last year, a competitor told me that he felt that F&BP dampers were excessively sloppy after a few years, and that's what caused the control problems. Since then, I've been on the lookout for old units to see for myself. The F&BP dampers on 45-year-old units were admittedly shot (they were original), but as a comparison, I didn't find any damper problems on 20-year-old unit vents.
- *Overheating*—A coil with full flow of 180 or 200 F water, at low-space heating demand, will cause overheating. The unit ventilator housings may even get too hot to touch. The solution is to lower the water supply temperature. This not only solves the overheating, it also lowers the heating bill.

CONCLUSION

Face and bypass has been frequently overlooked as a primary control scheme in HVAC systems. But, the three-fold increase in outside air mandated by ASHRAE 62-89 has made valve control of constant speed air handling equipment a less than ideal solution for heating systems (freeze problems) and cooling systems (high humidity). It's time to take a fresh look at F&BP. **HPAC**

REFERENCES

1) Carrier IEQ, Volume 2, No. 1, 1994, *Indoor Environmental Quality*, published by the Environmental Systems Marketing Group, The Carrier Corp.