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Changeover Controls & Coils

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Systems such as radiant floors, radiant ceilings, and chilled beams are often designed to have both heating and cooling capability and thus must have connections to both the hot water and chilled water systems. This month's column addresses how to design the "changeover" controls that manage the switch from one hydronic system to the other. Also addressed is the use of changeover controls to allow a single coil in an air-handling or fan-coil system to provide both heating and cooling, a design option that can reduce both first costs and energy costs.

Changeover Controls

The primary concern with piping two hydronic systems together is water from one system mixing with that of the other. Occasionally, there are two incompatible water treatment regimens used in the two systems (such as glycol in one system and not the other) which might preclude any mixing, and thus changeover piping is not possible without adding a heat exchanger. But more commonly the concern is sending hot water (HW) into the chilled water (CHW) system and vice versa, thus negatively impacting temperature control of adjacent coils and increasing load and energy use at the HW and CHW plants. Three changeover control designs are shown in *Figures 1* to *3* and discussed below. All three designs include features to minimize the chance of crossflow between the HW and CHW systems.

Figure 1 includes two 2-way modulating control valves on the HW and CHW return connections and a 3-way* two-position valve on the supply connections. Valve actuators are spring return or electronic fail-safe type with their "normal" position shown as NC (normally closed) or NO (normally open), defined here as the position of the valve when there is no power to the actuator. Non-fail-safe actuators could be used with some additional wiring changes to power the valves to the desired position, but fail-safe actuators make the design simpler and more resilient, e.g., if power to the control panel feeding the valves failed, the valves would fail to positions that ensure HW and CHW systems are not interconnected. The 2-way valves would usually have different flow coefficients (C_v [K_v]) corresponding to the design flow rate and full-open pressure drop for HW and CHW needed to provide good valve authority in each mode. Since only one valve actuator is active (enabled with control power) at a time, a single analog output (AO) from the control system can be used to control both valves. Prior to changing over from one mode to the other, both 2-way valves would be shut, allowing the coil/radiant system temperature to equalize with the air temperature to reduce the load and energy impact of mixing HW and CHW and vice versa during the changeover. In many applications where there is a dead band between heating and cooling setpoints, this equalization occurs naturally. Changeover is then initiated using the changeover digital output (DO) from the control system and relay R-1. This causes the 3-way valve to switch from HW to CHW (or vice versa), provides power to (thus enabling) the 2-way valve for the associated mode, and disables power to (thus closing) the 2-way valve for the opposite mode. In any mode, including in a power outage, the 3-way valve is open to one of the two hydronic systems to ensure water from the coil/radiant system can expand and contract as temperature changes without creating excessive pressures.

The design in *Figure 2* is the same as that in *Figure 1* except the 3-way valve is replaced by two 2-way valves

* This should be a near-zero leakage 3-way valve. Some 3-way characterized ball valves have significant leakage from one input port to the other; they should not be used for changeover applications.

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FIGURE 1 Two 2-way modulating valves and 3-way two-position valve.

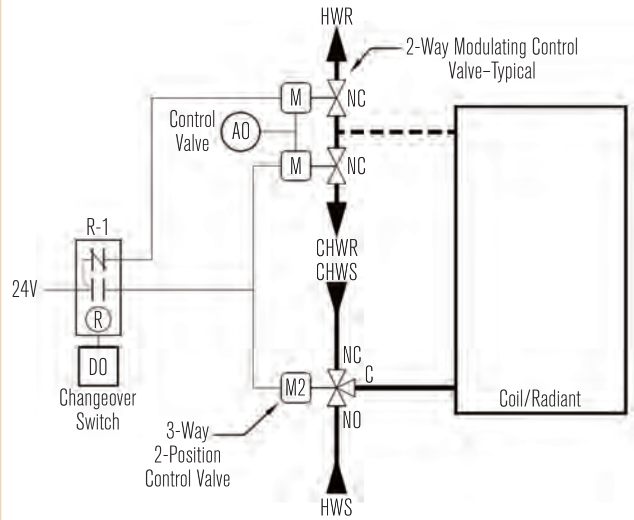
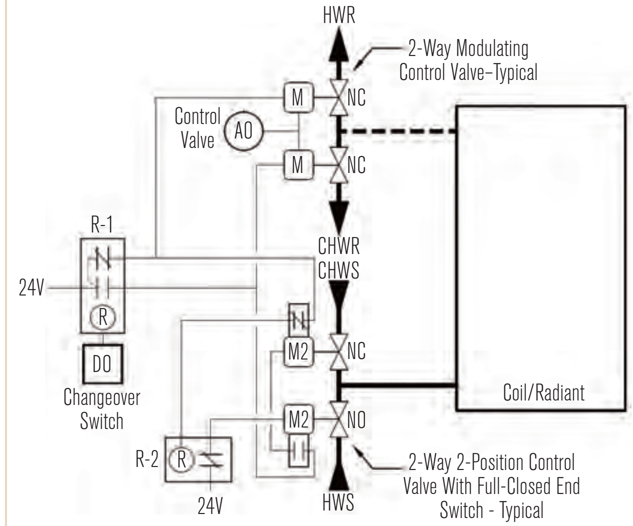


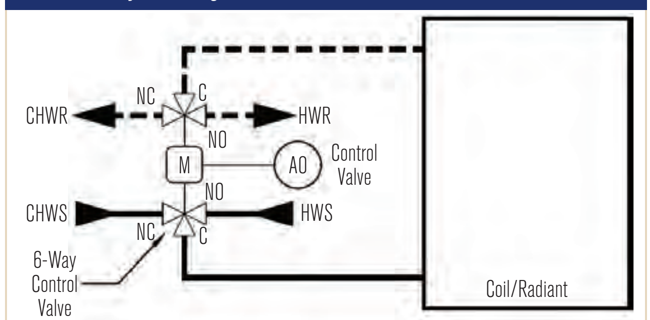
FIGURE 2 Two 2-way modulating valves and two 2-way two-position valves.



with full-closed actuator end-switches (contact closes when the valve is fully closed). Relay R-2 is provided to allow the HW supply two-position valve to be normally open, ensuring that water in the coil/radiant system can expand and contract with temperature changes in case of a loss of power to the controls. This design costs more due to the extra valve, end-switches, added relay, and associated wiring, but it solves a potential problem with the design in *Figure 1*: as the 3-way valve changes position, a process that typically takes between 20 and 75 seconds, the HW and CHW systems are open to each other. Even when the systems have similar operating pressures (e.g., where elevations and expansion tank locations and precharge pressures are similar), there will inevitably be a pressure difference between the two at the 3-way valve, so crossflow will occur until the expansion tank pressure on the lower pressure system rises to equalize the two system pressures at the 3-way valve. The volume of water transferred from one system to the other will be small where elevations and expansion tank locations and precharge pressures are similar, a prerequisite when using the *Figure 1* design, but still will result in some inefficiency as HW and CHW mix. The design in *Figure 2* solves this problem by essentially sequencing the valves using the full-closed actuator end-switches to ensure one valve is fully closed before the other is allowed to open.

Figure 3 shows a relatively new product offering from a few manufacturers: a 6-way valve. The typical sequence is as follows: when the signal from the AO modulates from 2 to 5 Vdc, CHW flow is modulated from full open to zero flow; from 5 to 7 Vdc, all ports are closed (dead band); from 7 to 10 Vdc, HW flow is modulated from zero flow to full open. This design provides all of the benefits of that shown in *Figure 2* at a lower first cost and with less chance of failure due to simpler controls and fewer moving parts. In the control dead band, all ports are closed, which could cause pressure issues due to thermal expansion of water in the coil/radiant system, but the valves include a pressure relief on one port to relieve excess pressure. The only major disadvantage of this option is that there is a limited range of valve flow coefficients (C_v [K_v]) available, so it is not always possible to find a valve that has the desired flow coefficient for both HW and CHW; one or the other is oversized or undersized. But it can be an ideal solution for small coils, radiant panels, chilled beams, etc.

FIGURE 3 6-Way Modulating Valve



Changeover Coils

Using changeover piping is common for radiant floors, radiant ceilings, chilled beams, and the like. But it is not common to use changeover controls in air handlers and fan-coils with a single coil serving as both the unit's heat/preheat and cooling coil. As with most design options, there are both advantages and disadvantages. The discussion below assumes coils are all 8-row (or the maximum available, such as 6 rows in fan-coils) as recommended in my December 2011 article.[2]

Advantages of using a single coil with changeover controls include:

- Less space is required in the air handler since there is only one coil. This was the main driver for using changeover coils for the unique underfloor air handlers described in my March 2016 column.[3] Because of the constraint of fitting into a 2 ft (0.6 m) floor module, the air handlers were too small to fit two coils.
- Extremely high temperature difference (ΔT) can be achieved on the HW side. On a recent project, design ΔTs ranged from 90°F (50°C) to 110°F (60°C) at 160°F (70°C) HW supply temperature. This reduces flow rates by about 60%, making HW pumps and piping smaller, and it improves condensing boiler efficiency by about 5% due to lower HW return temperatures.
- For small fan-coils serving small residential and hotel applications, a single 6-row coil can be used to achieve high ΔTs on both the HW and CHW side. Most small fan-coil manufacturers limit the total number of coil rows to 6, so if separate coils are used, the CHW coil would be 4-row and HW coil would be 2-row, resulting in low ΔT on both HW and CHW sides.
- First costs are lower. Added controls costs are more than offset by the savings from the eliminated coil plus the significant reduction in HW distribution system costs due to lower HW flow rates.
- Energy costs are lower due to lower pump energy costs, improved condensing boiler efficiency, and a small fan energy savings due to the eliminated HW coil pressure drop.

Disadvantages include:

- Extreme stratification will likely occur in heating mode. The HW is cooled within the first few inches from the coil header because the coil is so "oversized" for the load. Using a draw-through coil location will improve mixing but stratification can persist even through the fan. So if the AHU has a duct split close to the discharge,

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comfort problems may result and this design should not be used. The supply air temperature sensor used to control the coil must be located well downstream of the coil and an averaging type sensor might be required.

- Because the coil is so effectively oversized in heating mode, "two-positioning" of the modulating control valve is likely, with resulting fluctuating supply air temperature. The HW flow rate will be so small, in most cases the controls will not be readily tunable, and thus will overshoot setpoint, shut off, overshoot, shut off, etc. But this is similar to 2-position valves very commonly used for hotel and residential fan-coils, so not usually a comfort issue.

Controls are more complex where the designs in *Figure 1* and *Figure 2* are used, such as at large air handlers. (The 6-way valve in *Figure 3* is arguably simpler than a traditional design using two 2-way valves.)

- There is the risk of crossflow between CHW and HW systems as discussed above. But all three suggested designs minimize that risk if controlled as indicated.
- Coil freezing is possible in cold climates, and even likely on 100% outdoor air coils when outdoor air temperature is below freezing, due to the very low HW flow rates. Changeover coils should not be used in these applications unless the systems are protected with glycol. But in that case, both systems would have to have glycol at similar concentrations; as noted above, changeover systems are precluded when the water treatment regimens differ.

Conclusions

Changeover controls have been used for many years on radiant floors, radiant ceilings, etc., that provide both heating and cooling. Three controls designs have been proposed that provide reasonable assurance that crossflow will not occur between hot water and chilled water systems, the primary concern with changeover designs. These designs can also be extended to air handlers and fan-coils in many applications, allowing a single coil to provide both heating and cooling, resulting in lower first costs and energy costs.

References

1. Taylor, S. 2011. "Optimizing design and control of chilled water plants, part 3: pipe sizing and optimizing Delta *T*." *ASHRAE Journal* 53(12).
2. Taylor, S. 2016. "Making UFAD systems work." *ASHRAE Journal* 58(3). ■