Oregon Non-Residential Building Energy Code

Hydronic Design and Controls

This fact sheet covers design and control code requirements of hydronic systems that serve space-conditioning systems.

Hydronic System Controls

Two-Pipe Systems. The Oregon Energy Code places restrictions on two-pipe systems that use a common distribution system to deliver both heated and chilled water. The system must include an outside air temperature deadband of at least 15°F for changeover between heating and cooling. For instance, if hot water is supplied at an outside air temperature of 60°F, chilled water can only be supplied when the outside air temperature exceeds 75°F. Two-pipe delivery systems require a significant amount of energy to heat or cool the mass of water in the system when the control changes between heating and cooling. To limit the wasted energy required for changeover, the Code requires that the systems operate in one mode for a minimum of 4 hours. Also, the change in water temperature setpoint when the system changes from cooling to heating, or vice versa, cannot exceed 30°F.

Water Loop Heat Pump Systems. Water-loop heat pumps are typically served by a common condenser water loop and connected to central heat rejection sources (e.g., a cooling tower) and central heating sources, such as a boiler, if the temperature falls too low. To restrict heating and cooling energy use from this equipment, the Code requires that the controls ensure a 20°F deadband between heat rejection from the cooling tower and heat addition from the boiler. However, the deadband between actual setpoints can be set through the use of controls that can determine the most efficient operating temperature based on demand and operating conditions.

For water loop systems with a pumping power of 10 hp or greater, a two-position isolation valve must be installed at each heat pump. The valve is interlocked to shut off water flow when the compressor is off. Since this effectively creates a variable flow system, the Code requires variable-speed drive controls.

Closed-circuit cooling towers (fluid coolers) must have either an automatic bypass valve to bypass the tower or low-leakage dampers to limit heat loss across the heat exchanger. A bypass valve is a much more effective means of isolation. If a bypass valve is used, a minimal amount of water may be circulated through the heat exchanger to prevent freezing.

An open-circuit tower that is directly in the heat pump water loop must have an automatic bypass valve for isolation. If a separate heat exchanger is used to isolate the cooling tower from the water

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Code Language

Documentation: Compliance with hydronic system controls is documented on Form 4b, lines 9 and 13. Compliance with variable-speed drive requirements for variable flow pumping is documented on Form 4a, line 16.

1318.2.8 Hydronic system controls. The heating of fluids in hydronic systems that have been previously mechanically cooled and the cooling of fluids that have been previously mechanically heated shall be limited in accordance with the following:

1318.2.8.1 Three-pipe system. Hydronic systems that use a common return system for both hot water and chilled water shall be prohibited.

1318.2.8.2 Two-pipe changeover system. Systems that use a common distribution system to supply both heated and chilled water shall meet the following:

1. The system is designed to allow a deadband between changeover from one mode to the other of at least 15 °F outside air temperature.
2. The system is designed to operate and is provided with controls that will allow operation in one mode for at least four hours before changing over to the other mode.
3. Reset controls are provided that allow heating and cooling supply temperatures at the changeover point to be no more than 30°F apart.

1318.2.8.3 Hydronic (water loop) heat pump systems. Hydronic heat pumps connected to a common heat pump water loop with central devices for heat rejection (e.g., cooling tower) and heat addition (e.g., boiler) shall meet the following requirements:

1. Controls shall be installed that are capable of providing heat pump water supply temperature dead band of at least 20°F between initiation of heat rejection and heat addition by the central devices (e.g., tower and boiler).
2. Closed-circuit tower (fluid cooler) shall have either an automatic valve installed to bypass all but a minimal flow of water around the tower (for freeze protection) or low-leakage positive closure dampers.

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3. Open-circuit tower installed directly in the heat pump loop shall have an automatic valve installed to bypass all heat pump water flow around the tower. Open-circuit towers used in conjunction with a separate heat exchanger to isolate the tower from the heat pump loop shall be controlled by shutting down the circulation pump on the cooling tower loop.

4. A two-position valve at each hydronic heat pump for hydronic systems having a total pump system power exceeding 10 hp.

1318.2.8.4 Variable flow controls. Controls capable of varying pump flow shall be installed on hydronic pumping systems with motors of 10 hp and greater.

1318.2.4 Chilled and hot water temperature reset controls. Chilled and hot water systems with a design capacity exceeding 300,000 Btu/hr (88 kW) supplying chilled or heated water (or both) to comfort conditioning systems shall include controls that automatically reset supply water temperatures by representative building loads (including return water temperature) or by outside air temperature.

Exceptions:

1. Where the supply temperature reset controls cannot be implemented without causing improper operation of dehumidifying systems.
2. Hydronic systems that use variable flow to reduce pumping energy.

1317.5.4.2 Variable flow controls. Cooling tower fans shall have control devices that vary flow by controlling leaving fluid temperature or condenser temperature/pressure of the heat rejection device.

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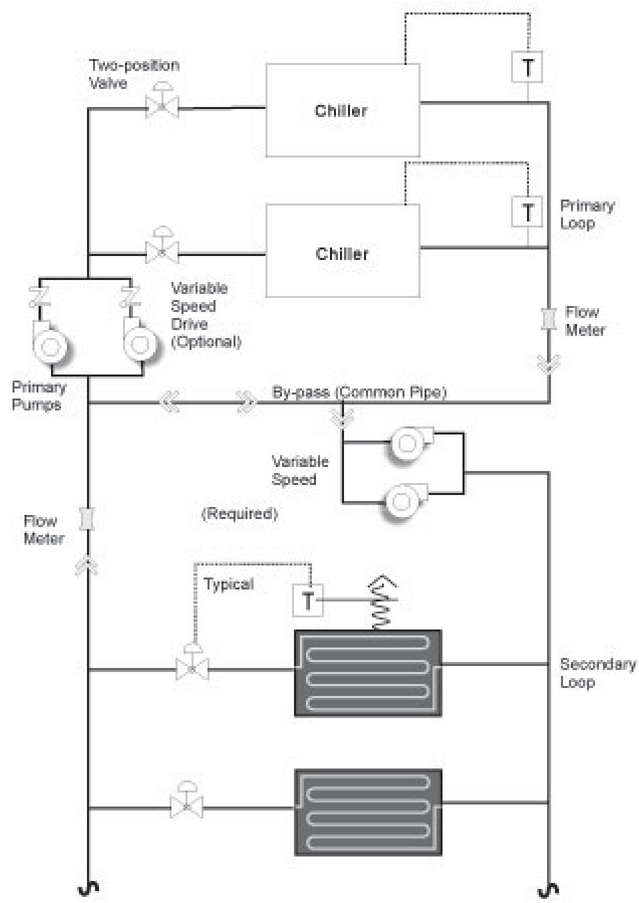
loop, shutting down the circulation pump on the water loop is an acceptable means of controlling heat loss.

Variable Flow Controls. The Code requires variable flow controls on pumps with motors of 10 hp (nameplate) or greater. Section 1317.10.3.1 describes a requirement that such motors serving variable flow systems must be controlled by a variable-speed drive. Exceptions are given to dedicated pumps that serve equipment and are required to maintain a minimum flow rate. An example is a multiple-chiller system with a primary-secondary pumping arrangement.

Primary-Secondary Systems. The primary loop pumps serving the equipment, which maintain the equipment minimum flow rate requirements, can be constant flow. Although not required by code, variable-speed controls can also be used to vary the primary pump water flow through the evaporator since the minimum flow rate is often less than 50 percent of the system design flow rate. The secondary loop that serves the cooling coils must utilize two-way valves and variable-speed drives to save pump energy at part-load conditions.

Primary-Secondary Pumping Arrangement



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Variable-speed drives save a considerable amount of energy, as pumping power varies with the cube of rotational speed. The variable speed drive should be controlled to maintain a minimum system pressure which is generally sensed at the end of the distribution piping. Variable-speed drives will provide the greatest energy savings when coupled with demand-based reset of hydronic control valves. A DDC system can reset system pressure with demand to maintain at least one valve nearly 100 percent open.

Primary-only Systems. A system with primary-only pumping needs to be variable flow. Primary-only, variable flow pumping systems are becoming more popular since they have lower installation and operating costs than a primary-secondary pumping system. However, the control must prevent rapid changes in flow, as a sudden drop in flow would result in a rapid drop in leaving chilled water temperature, and could trigger a low-temperature safety alarm. It is also important to maintain a minimum flow rate through the evaporator to ensure proper heat transfer. Chiller manufacturer Chiller Management System controllers are capable of managing these critical flow and temperature limitations to assure safe chiller operation.

Variable flow controls in chilled water and hot water delivery systems with pumps less than 10 hp and no variable speed drives can also save energy. The use of two-way control valves saves pump energy by allowing the pump to ride its system curve, using less energy at reduced flows. For chilled water systems, however, variable speed drives will be most energy efficient and will normally be cost-effective to install.

Chilled and Hot Water Temperature Reset Controls

The Code requires that chilled and hot water systems with a design capacity exceeding 300,000 Btu/hr include controls to reset supply water temperature by "representative building loads" or by outside air temperature. The Code does not specify how the chilled or hot water temperature is controlled, nor does it require a specific reset amount. There are several methods of controlling water temperature. An efficient method is to control the temperature to just meet the requirement of the zone with the highest demand. The water temperature can be adjusted so that the control valve serving the zone with the greatest demand is nearly 100 percent open. Alternatively, with a central control system, space temperature (and humidity) can be compared to temperature and humidity setpoints, to verify that sensible and latent cooling loads are met. Other control methods include chilled water reset based on return air temperature or on return water temperature. Return water temperature is only indicative of average zone demand and should be used with caution. Reset based on outside air temperature can be an effective method with central heating systems, since there is a strong correlation of heating requirements to outside air temperature. It is less effective for cooling systems.

Reset controls are exempted when systems use variable flow to reduce pumping energy. Since variable flow is required on all systems with pumps of 10 hp or more, this effectively limits the reset

Examples

Q A chiller plant has two chillers piped in parallel in a primary-only piping arrangement. The chillers are is sized in a 1/3 and 2/3 capacity arrangement and each chiller has a minimum flow rate of 50 percent of the chiller design flow rate. The smaller chiller is served by a 7.5 hp pump and the larger chiller a 15 hp pump. Can this system be designed for constant flow and are variable speed drives required on the chilled water pumps?

A Flow Control: The Code requires variable flow controls for systems with motors of 10 hp or greater. The design flow is the total flow through the system, not through each chiller. Since this system has a total flow of 22.5 hp the system must have variable flow controls, i.e. 2-way control valves.

A Pump Control: The Code also requires variable speed drives on pumps of 10 hp or greater. Therefore, only the larger 15 hp chiller pump would be required to have variable speed control. The smaller chiller pump could operate as constant speed with a bypass line (control valve between the chiller supply and return lines), allowing variable flow out into the system. Even though a constant speed pump arrangement is allowed by code, it is unlikely this would function satisfactory in a primary-only arrangement because the bypass flow could cause the dreaded "low chilled return water temperature" syndrome and constrain the chiller's effective cooling capacity

Q A water loop on a heat pump system uses a 15 hp pump for the condenser loop. What flow controls are required for the pump?

A Variable flow controls are required for the system. Specifically, the pump must use a variable-speed drive and two-position valves must be installed at each heat pump.

Q A chiller plant uses a primary-secondary pumping arrangement. The primary circulation pumps are two 10 hp circulation pumps serving two chillers. The secondary pump is a 30 hp circulation pump serving fan coil units. What are the control requirements for this system?

A The Code requires variable-speed drives on the pump serving the fan coil units. The two primary pumps serving the chillers may be constant flow. Since variable flow is used, chilled water reset is optional for this system.

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requirement to smaller systems. Chilled and hot water temperature reset can be still used with variable flow pumping, and is often added to heating loops to enhance heat coil temperature control during low load and to increase the operating efficiency of condensing boilers. An exception is also allowed for cooling loops supplying dehumidification systems that would not operate correctly at reset temperatures. Resetting the chilled water setpoint higher would raise the supply air temperature and reduce the latent heat removal capacity of the system.

Condenser Temperature Control

The code requires controls for cooling tower fans that vary flow to control the leaving fluid temperature or condenser temperature of the heat rejection device. The Code does not require specific flow controls on the condenser pump; rather, it is an airside control. A variable-speed drive on the cooling tower fan will produce the most energy savings, but a two-speed fan can also save energy. Another option for belt-driven fan applications is a dual primary/auxiliary fan motor arrangement, with the two motors installed on the same shaft. The smaller "pony" motor operates during part-load conditions. This dual motor arrangement also allows for some redundancy in the event of motor failure.

With a variable-speed fan, control of condenser water temperature involves a tradeoff between cooling tower energy and chiller energy. Reducing the condenser water setpoint will increase cooling tower energy but reduce chiller energy. The optimum setpoint depends on tower efficiency and the effect that the condenser temperature reset has on chiller efficiency. Commercial control packages are available that dynamically determine the optimum setpoint based on ambient conditions and the relative power consumption of the different system components. Another method is to reset the condenser temperature lower based on outdoor wet-bulb temperature. While this method can be effective, it requires careful design of the control and accurate sensor calibration to work properly.

For More Information:

CoolTools – Chilled Water Plant Design and Specification Guide, PG&E, 2000, http://www.hvacexchange.com/cooltools/.

Find Out More

Copies of Code:
Oregon Building Officials Association
phone: 503-873-1157 fax: 503-373-9389

Technical Support:
Oregon Department of Energy
625 Marion Street NE phone: 503-378-4040
Salem, OR 97301-3737 toll free: 800-221-8035
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Northwest Energy Efficiency Alliance
www.nwalliance.org

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Non-residential code HVAC fact sheets include:

- Ventilation Controls
- Exhaust Air Heat Recovery
- Hydronic Design and Controls
- Large Volume Fan Systems
- Simple vs. Complex HVAC Systems
- Economizers
- Airside System Design Req
- Airside Controls
- Air Transport Energy