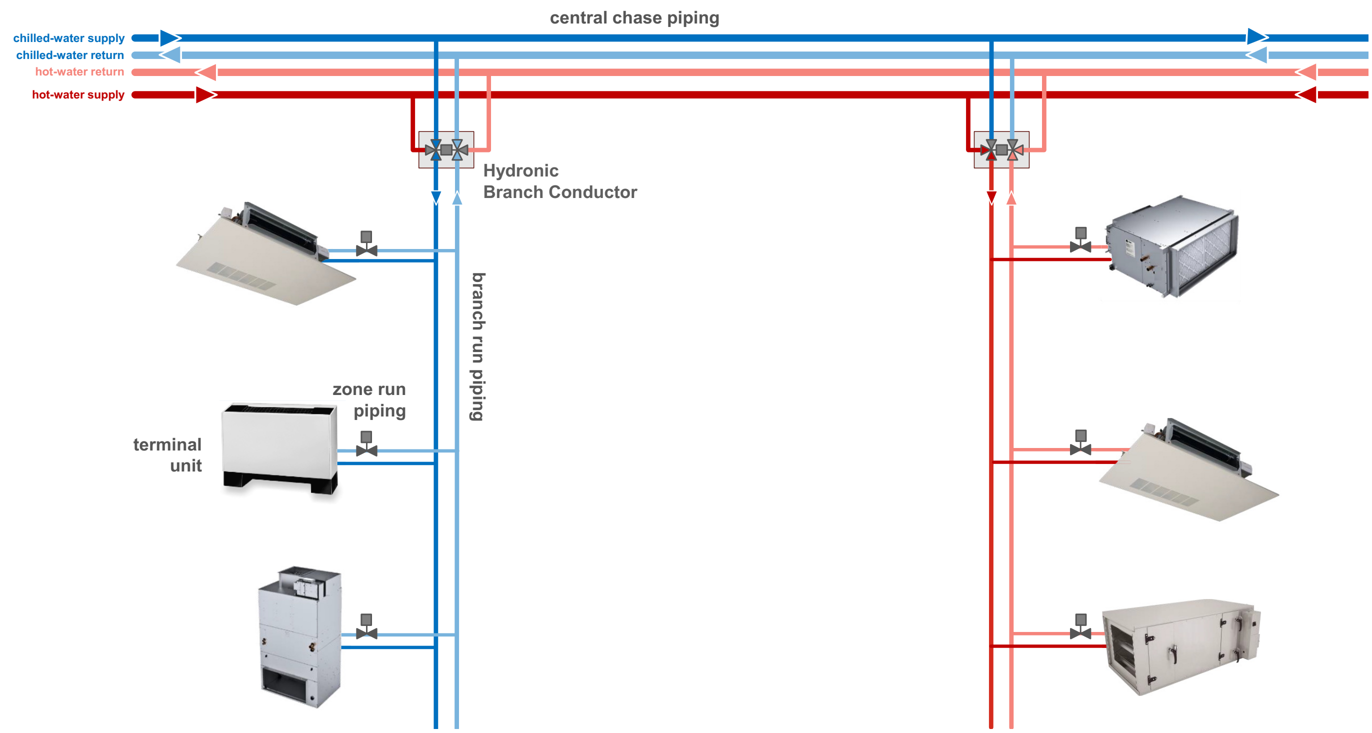
# Application Guide

## Hydronic Branch Conductor




**⚠ SAFETY WARNING**

**Only qualified personnel should install and service the equipment. The installation, starting up, and servicing of heating, ventilating, and air-conditioning equipment can be hazardous and requires specific knowledge and training. Improperly installed, adjusted or altered equipment by an unqualified person could result in death or serious injury. When working on the equipment, observe all precautions in the literature and on the tags, stickers, and labels that are attached to the equipment.**


October 2024

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# Preface

As a leading HVAC manufacturer, we deem it our responsibility to serve the building industry by regularly disseminating information that promotes the effective application of building comfort systems. For that reason, we regularly publish educational materials, such as this one, to share information gathered from laboratory research, testing programs, and practical experience.

This publication focuses on the Hydronic Branch Conductor and its use in distributed hydronic heating and cooling systems.

We encourage engineering professionals who design building comfort systems to become familiar with the contents of this guide and to use it as a reference. Architects, building owners, equipment operators, and technicians may also find this publication of interest because it addresses system layout and control.

Trane® has a policy of continuous product and product data improvements and reserves the right to change design and specifications without notice. As such all data in this application guide should be considered for reference only, please consult with a Trane® sales associate for current equipment operating range and performance.

# Table of Contents

# Overview of the Hydronic Branch Conductor

The Hydronic Branch Conductor is a valve control unit used in a distributed hydronic heating and cooling system to direct either hot water or chilled water to-and-from an area of the building, based on that area's current need for heating or cooling.

The Conductor connects two-pipe branch (area) piping to a central four-pipe chase, which is served by a central hydronic heat pump plant. The Conductor receives a call for either Heat Mode or Cool Mode from the system-level controller (or a binary input, if communicating controls are not present) and then sends the appropriate-temperature fluid to satisfy that area's need for heating or cooling, while isolating this flow from the unused supply and return flows in the central four-pipe distribution chase.

## FOUR-PIPE VERSUS TWO-PIPE DISTRIBUTION

Many terminal-based hydronic systems use one set of pipes (supply and return) to distribute chilled water to the cooling coil in each terminal unit, and another set of pipes to distribute hot water to a separate heating coil in each terminal unit. This is commonly called a **four-pipe distribution** system. The primary benefit of a four-pipe system is that some terminal units can receive chilled water for cooling while the remaining terminal units simultaneously receive hot water for heating.

Alternatively, some terminal systems use a common set of pipes to distribute either chilled water or hot water to a dual-purpose (shared) coil in each terminal unit. This is commonly called a **two-pipe distribution** system, and all of the terminal units in the building receive only chilled water or only hot water. During mild weather, this may result in comfort problems in some zones. Of course, the primary benefit of a two-pipe distribution system is reduced installation costs, since only one set of pipes needs to be installed throughout the building and each terminal unit is equipped with only one, dual-purpose coil.

## COMBINING FOUR-PIPE AND TWO-PIPE DISTRIBUTION USING THE HYDRONIC BRANCH CONDUCTOR

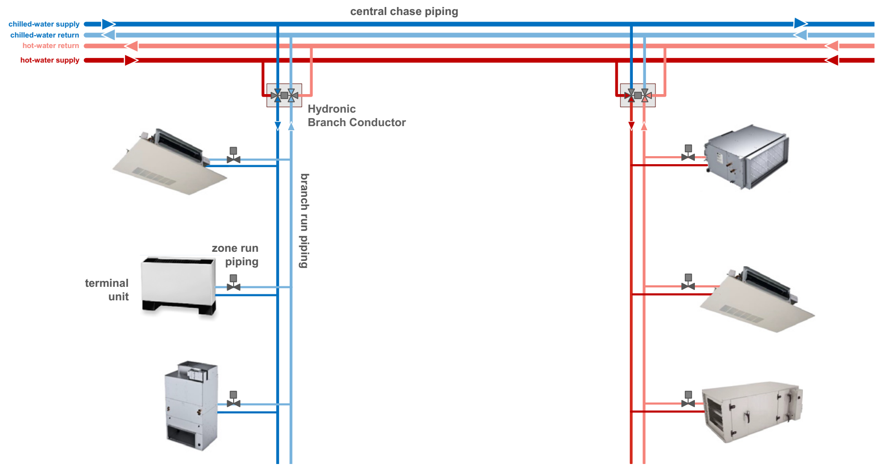
A **zone** is served by a terminal unit that is controlled to maintain the desired temperature in that zone.

Adjacent zones that are likely to need either cooling or heating at the same time can be grouped together into a **thermal area**. See "Grouping Zones Together into an Area,"(p. 37).

An alternate approach combines four-pipe and two-pipe distribution, to balance the benefits of each. In this case, separate sets of chilled-water and hot-water pipes are routed to a Hydronic Branch Conductor that serves each unique thermal area of the building (Figure 1). Downstream of each Conductor, a branch run consisting of one set of pipes connects to a single dual-purpose coil in each terminal unit.

Each thermal area is comprised of one or more zones that have similar thermal loads and temperature setpoints; each zone being served by a terminal unit.

**Figure 1. Example of a distributed hydronic heating and cooling system with Hydronic Branch Conductors**




Based on information communicated from the terminal unit controllers, the system-level controller determines if that area currently requires cooling or heating. If the terminal units are not equipped with communicating controllers, this decision can be made external to the zone-level terminal equipment based on a time-of-day schedule (or calender), the current outdoor-air temperature, or some other indicator.

When cooling is required, the Hydronic Branch Conductor is instructed to position its valves to draw chilled water from the central chilled-water supply pipe and deliver it to the coils in all the terminal units in that area; water returning from these coils is directed back into the central chilled-water return pipe.

When heating is required, the Conductor is instructed to position its valves to draw hot water from the central hot-water supply pipe and deliver it to the coils in all the terminal units in that area; water returning from these coils is directed back in to the central hot-water return pipe.

Benefits of this combined approach include:

- Each terminal unit need only be equipped with a single (dual-purpose) coil and a single control valve, which reduces its cost.
- Since four-pipe distribution is centralized, and two-pipe distribution is used to serve the zones, less piping is routed throughout the building, further reducing installation costs.
- Eliminating the separate hot-water coil in a terminal unit also reduces air pressure drop, which results in terminal fan energy savings and lower sound levels.
- Since cooling coils in terminal units are constructed of multiple rows, the added rows allow for the use of lower-temperature hot water and more-efficient heat pump operation.

Hydronic Branch Conductors enable the use of hydronic heat pumps for centralized heating, instead of electric heaters in the terminal units, which can lower the overall energy use of the building.

# Distributed Heating and Cooling Systems Using the Hydronic Branch Conductor

Distributed hydronic heating and cooling systems use zone-level terminal equipment to cool or heat air that is then supplied to the zone being conditioned. These terminal units are provided with chilled water or hot water from a central plant. Examples of such terminal equipment include fan-coils, blower-coils, unit ventilators, small air-handling units, and CoolSense™ terminal units.

Since the terminal unit is located in, or very near, the occupied space there is typically limited room for installation. Some of this equipment is mounted in the ceiling plenum, which limits its height; while some is mounted along a wall in the occupied space, or in an adjacent closet, which limits its footprint.

Equipping a terminal unit with a dual-purpose coil—a single coil that can be used for either heating or cooling—allows this equipment to be smaller than if it contained separate heating and cooling coils. But this can also improve overall system efficiency by allowing for the use of lower-temperature hot water, which is particularly beneficial in systems that use heat pumps in the central plant.

As noted above, there are many different types of hydronic terminal units, each serving specific building requirements in terms of cabinet type, mounting location, and space availability. For this type of equipment, a dual-purpose coil can typically achieve a 90°F supply-air temperature using only 100°F hot-water supply (HWS) temperature. If a zone requires 95°F supply air, this can typically be achieved using 105°F HWS. However, 90°F supply air, at the design airflow needed for cooling, often provides more heating capacity than the actual heating load of the zone. For many applications, 80°F to 85°F supply air is often adequate for heating.

For terminal units that deliver air to the space through ceiling-mounted diffusers, and return air through ceiling-mounted grilles, supplying air warmer than 20°F above the space temperature setpoint results in some of this air "short circuiting" from the diffusers to the grilles, thus never reaching the occupied portion of the space. This reduces how efficiently that hot air heats the space, and also impacts how much outdoor air reaches the breathing zone:

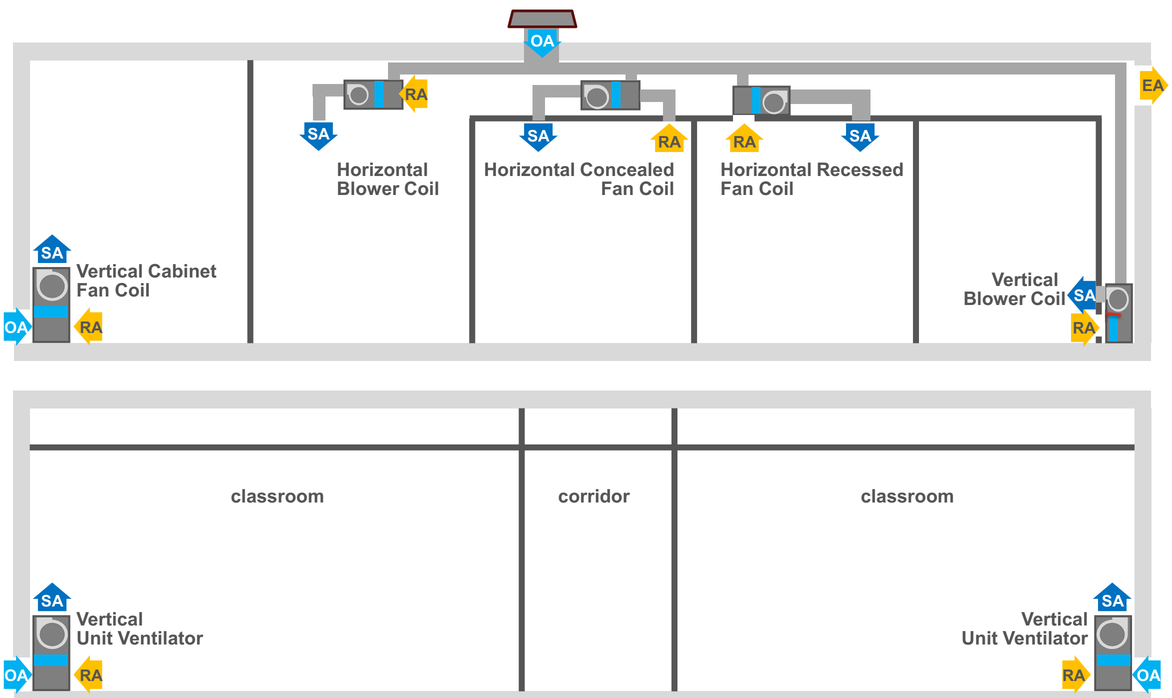
- **ASHRAE® Standard 90.1 (Section 6.5.2.1.1)** prescribes that a system "shall not supply heating air more than 20°F above the space temperature setpoint," except for during morning warm-up or unoccupied (setback) heating modes.
- **ASHRAE Standard 62.1(Section 6.2.1.2)** uses the term Zone Air Distribution Effectiveness ($E_Z$) to correct for any outdoor air that may not reach the "breathing zone" of an occupied space. If air is supplied to the space via ceiling-mounted diffusers at a temperature ≥ 15°F warmer than the space temperature, and returned via ceiling-mounted grilles, a value of 0.8 must be used for $E_Z$. This means that more outdoor air must be conditioned and delivered to the diffusers to overcome this inefficiency.

While there are many variations of distributed hydronic systems, following are four common arrangements that are often good candidates for the use of Hydronic Branch Conductors:

## DISTRIBUTED HYDRONIC HEATING/COOLING USING MIXED-AIR TERMINAL UNITS

In this configuration, unconditioned outdoor air (OA) is ducted to (or directly enters) each terminal unit (Figure 2). Typically, the terminal unit is equipped with variable-speed fan control (single-zone VAV operation). Dehumidification is dependent on the zone's sensible cooling load; however, variable-speed fan control reduces airflow at part load, which improves coincidental dehumidification.

**Figure 2. Distributed hydronic heating/cooling using mixed-air terminal units**




A primary advantage of this configuration is the opportunity to use airside economizing. The system-level controller's decision about whether to direct the Hydronic Branch Conductor to operate in Cool Mode or Heat Mode is simplified when outdoor conditions are beneficial for full economizing ($DBT_{OA}$ < 55°F, for example). During such economizing conditions, if any zone calls for heat the system-level controller directs the Conductor to operate in Heat Mode. (Note that this does not dictate the operating mode for every terminal unit, just the Conductor itself.) If the other zones need cooling, they will use airside economizing.

Following are example design criteria for the terminal units (assuming 35 percent Ethylene Glycol solution) in this system configuration:

**Cooling**

- Mixed-air conditions entering coil = 80°F DBT, 67°F WBT
- Supply-air temperature = 55°F DBT
- CWS temperature = 44°F with a design ΔT = 10°F to 15°F

**Heating**

- Heating design airflow = cooling design airflow
- Mixed-air conditions entering coil = 55°F DBT
- Supply-air temperature = 90°F DBT
- HWS temperature = 100°F with a design ΔT = 12°F to 17°F

or

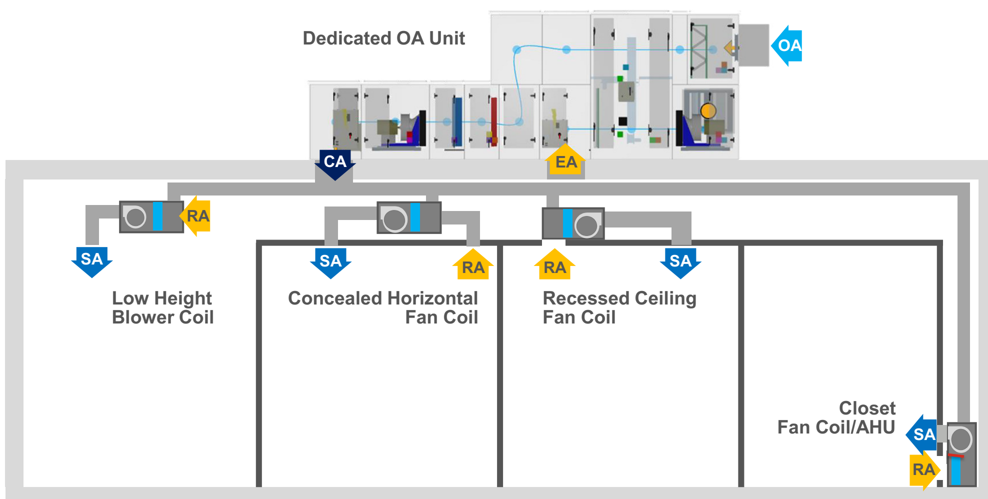
- Supply-air temperature = 95°F DBT
- HWS temperature = 105°F with a design ΔT = 12°F to 17°F

Alternatively, an 8-row dual-purpose coil in a ceiling-concealed (or exposed) blower coil can be used if a higher system design ΔT (chilled water ΔT = 20°F, hot water ΔT = 30°F) is needed due to infrastructure constraints.

## DISTRIBUTED HYDRONIC HEATING/COOLING USING DOAS DUCTED TO TERMINAL UNITS

In this configuration, ventilation and dehumidification are provided by a centralized dedicated outdoor-air unit that ducts conditioned outdoor air (CA) directly to each terminal unit (Figure 3). The dedicated OA unit uses the same chilled water and hot water as is provided to the terminal units.

**Figure 3. Distributed hydronic heating/cooling using DOAS ducted to terminal units**




A primary benefit of using a DOAS is independent humidity control. The conditioned OA is mixed with recirculated return air (RA) in each terminal unit, which is equipped with a continuously-operating fan; this avoids the need for separate supply-air diffuser(s) to deliver outdoor air to each zone.

The DOAS delivers cool air ($DBT_{CA}$ = 50°F to 55°F) year-round, but can reset this setpoint warmer if all zones require heating. This reduces the heating and cooling loads on the terminal units, which can allow for a higher system ΔT compared to a system without a DOAS.

Airside economizing is generally not available, however, the cool air delivered by the DOAS year-round can provide some cooling capacity if a zone requires cooling when a Hydronic Branch Conductor is providing hot water to its thermal area.

Following are example design criteria for the terminal units (assuming 35 percent Ethylene Glycol solution) in this system configuration:

**Cooling**

- Mixed-air conditions entering coil = 71.5°F DBT, 61°F WBT
- Supply-air temperature = 55°F DBT
- CWS temperature = 44°F with a design ΔT = 14°F to 16°F

**Heating**

- Heating design airflow = cooling design airflow
- Mixed-air conditions entering coil = 65°F DBT
- Supply-air temperature = 90°F DBT
- HWS temperature = 100°F with a design ΔT = 14°F to 18°F

or

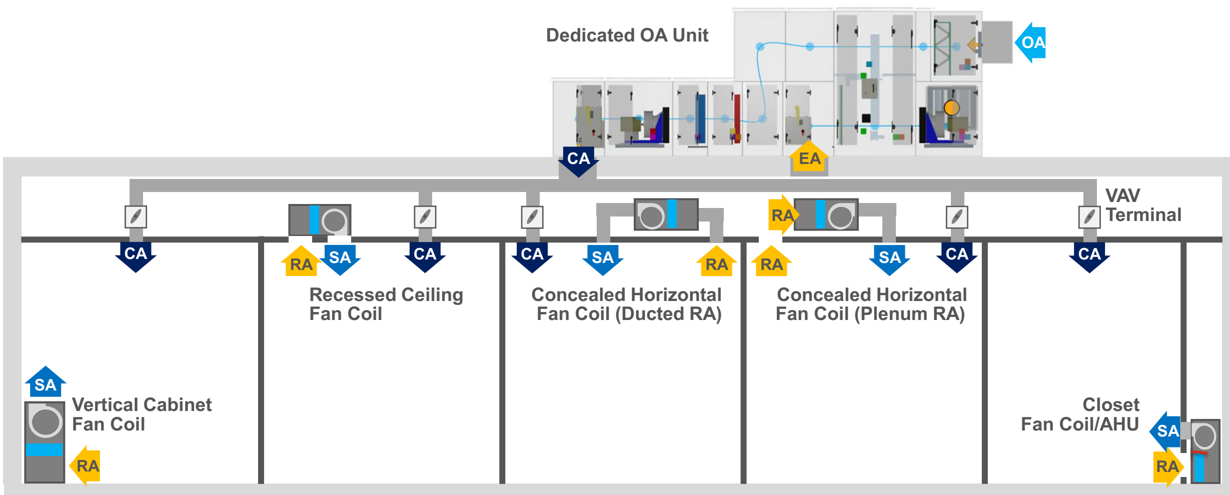
- Supply-air temperature = 95°F DBT
- HWS temperature = 105°F with a design ΔT = 14°F to 18°F

Alternatively, an 8-row dual-purpose coil in a ceiling-concealed, or exposed, blower coil can be used if a higher system design ΔT (chilled water ΔT = 20°F, hot water ΔT = 30°F) is needed due to infrastructure constraints.

## DISTRIBUTED HYDRONIC HEATING/COOLING USING DOAS DUCTED DIRECTLY TO ZONES

In this configuration, ventilation and dehumidification are provided by a centralized dedicated outdoor-air unit that ducts conditioned outdoor air (CA) directly to each zone (Figure 4). The dedicated OA unit uses the same chilled water and hot water as provided to the terminal units.

**Figure 4. Distributed hydronic heating/cooling using DOAS ducted directly to zones**




A primary benefit of using a DOAS is independent humidity control. The conditioned OA is ducted to separate ceiling-mounted diffuser(s) in each zone. A VAV terminal in the ductwork for each zone enables demand-controlled ventilation to be implemented. In this configuration, the terminal unit conditions only recirculated return air (RA). Because the terminal unit fan is not used to deliver outdoor air to the zone, it can cycle off when the zone does not require cooling or heating. And when heating, the terminal unit can supply air warmer than 15°F above the space setpoint without impacting the zone air-distribution effectiveness ($E_Z$).

The DOAS delivers cool air ($DBT_{CA}$ = 50°F to 55°F) year-round, but can reset this setpoint warmer if all zones require heating. This reduces the heating and cooling loads on the terminal units, which can allow for a higher system ΔT compared to a system without a DOAS.

Airside economizing is generally not available, however, the cool air delivered by the DOAS year-round can provide some cooling capacity if a zone requires cooling when a Hydronic Branch Conductor is providing hot water to its thermal area.

Following are example design criteria for the terminal units (assuming 35 percent Ethylene Glycol solution) in this system configuration:

**Cooling**

- Return-air conditions entering coil = 75°F DBT, 62.5°F WBT
- Supply-air temperature = 55°F DBT
- CWS temperature = 44°F with a design ΔT = 14°F to 16°F

**Heating**

- Heating design airflow = cooling design airflow
- Return-air conditions entering coil = 65°F DBT
- Supply-air temperature = 90°F DBT
- HWS temperature = 100°F with a design ΔT = 14°F to 18°F

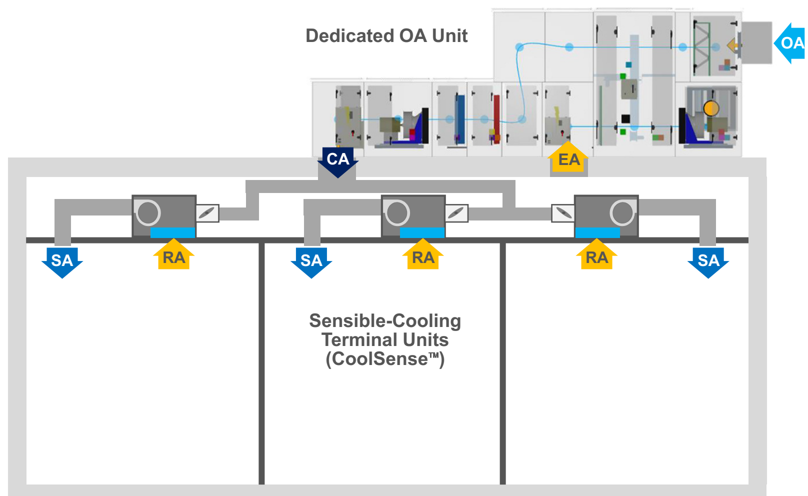
or

- Supply-air temperature = 95°F DBT
- HWS temperature = 105°F with a design ΔT = 14°F to 18°F

## DISTRIBUTED HYDRONIC HEATING/COOLING USING DOAS DUCTED TO SENSIBLE-COOLING TERMINAL UNITS

In this configuration, ventilation and dehumidification are provided by a centralized dedicated outdoor-air unit that ducts conditioned outdoor air (CA) directly to each CoolSense™ terminal unit (Figure 5). The DOAS dehumidifies the space such that the zone dew point temperature is below the terminal unit's CWS temperature. Therefore, the dedicated OA unit and terminal units are supplied with different chilled-water temperatures: 40°F to 45°F CWS to the dedicated OA unit and 55°F to 57°F CWS to the sensible-cooling terminal units.

**Figure 5. Distributed hydronic heating/cooling using DOAS ducted to sensible-cooling terminal units**




A primary benefit of using a DOAS is independent humidity control. The conditioned OA is ducted to an airflow-measuring damper integral to each CoolSense™ terminal unit; this enables demand-controlled ventilation to be easily implemented. Recirculated return air (RA) is drawn through the dual-purpose (heating or cooling) coil mounted on the side of the terminal unit, and this heated or cooled air then mixes with conditioned OA from the DOAS. This allows for a very low face velocity across the dual-purpose coil and a low-profile terminal unit.

The DOAS delivers cool air ($DBT_{CA}$ = 45°F to 55°F) year-round, but can reset this setpoint warmer if all zones require heating. Because the DOAS is providing all of the dehumidification capacity, it requires chilled water in the range of 40°F to 45°F. Since the terminal units provide only sensible cooling, they require chilled water in the range of 55°F to 57°F.

Airside economizing is generally not available, however, the cool air delivered by the DOAS year-round can provide some cooling capacity if a zone requires cooling when a Hydronic Branch Conductor is providing hot water to its thermal area.

Following are example design criteria for the terminal units (assuming 35 percent Ethylene Glycol solution) in this system configuration:

**Cooling**

- Return-air conditions entering coil = 75°F DBT, 62°F WBT
- Air temperature leaving coil = 60°F DBT
- CWS temperature = 57°F with a design ΔT = 6°F to 8°F

**Heating**

- Heating return airflow = cooling return airflow
- Return-air conditions entering coil = 68°F DBT
- Air temperature leaving coil = 90°F DBT
- HWS temperature = 98°F with a design ΔT = 11°F to 15°F

or

- Air temperature leaving coil = 95°F DBT
- HWS temperature = 103°F with a design ΔT = 13°F to 17°F

# Example Applications of the Hydronic Branch Conductor

Hydronic Branch Conductors can be used in both new system designs or when retrofitting existing systems. This section demonstrates a few example applications.

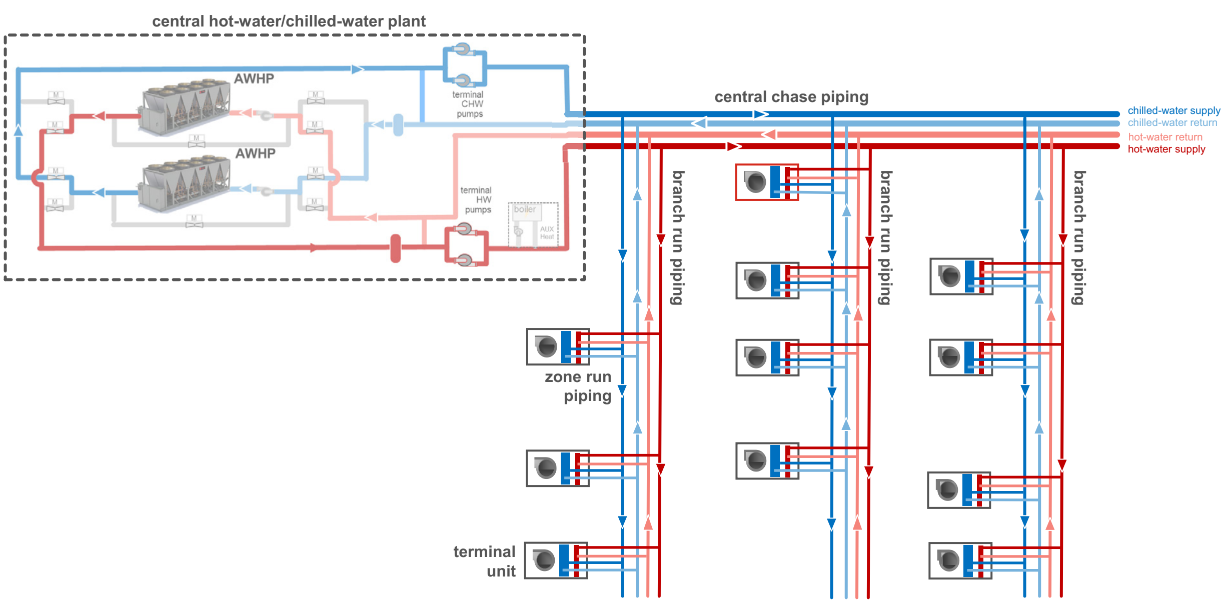
## RETROFITTING AN EXISTING FOUR-PIPE HYDRONIC SYSTEM TO ELECTRIFY HEATING

When retrofitting a centralized hot-water/chilled-water plant to electrify the source of heating, modifying the central plant to use heat pump heating is only part of the challenge. The hydronic distribution system and the zone-level heating/cooling terminal units also need to be addressed.

This four-pipe distribution system is not dependent on the type of equipment used in the central plant. For example, a two-pipe air-to-water heat pump can still be used in a four-pipe distribution system.

Most existing buildings with a hydronic heating/cooling system use four-pipe distribution (Figure 6). In this case, there is typically one (or a few) central chases, in which very large pipes are routed through the center of the building to distribute hot water and chilled water (or a glycol solution) to and from the central plant. Four pipes are inside this chase: hot water supply (HWS), hot water return (HWR), chilled water supply (CWS), and chilled water return (CWR).

**Figure 6. Example existing four-pipe hydronic distribution system**




Branch pipe runs then route hot water and chilled water from this central chase to the various areas of the building. Finally, a zone pipe run routes these fluids from the branch pipes to-and-from each zone-level heating/cooling terminal unit.

Many zone-level terminal units contain a hot-water coil and a separate chilled-water coil (i.e., a four-pipe unit). Historically, these hot-water coils have been sized for 140°F (or hotter) HWS temperature, while the chilled-water coils have been sized for 45°F (or colder) CWS temperature.

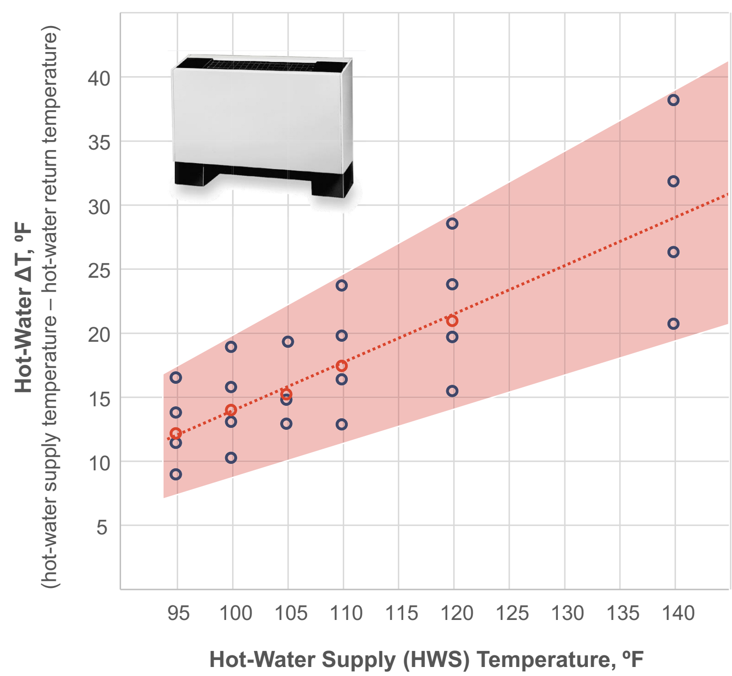
*When retrofitting this system to use heat pumps for heating, rather than a gas-fired boiler, what changes?*

There is a significant heat pump efficiency gain by using a lower hot-water supply (HWS) temperature. Therefore, when replacing the zone-level terminal units, the hot-water coils should NOT be sized for 140°F. In most cases, when properly selected, a terminal unit can adequately heat a zone using 105°F HWS, and maybe even as low as 95°F. A HWS temperature of 105°F, rather than 140°F, results in as much as a 45 percent improvement in the heating efficiency of an air-to-water heat pump.

*How are terminal units selected to use 105°F HWS temperature?*

The chart in Figure 7 depicts hot-water coil performance in a cabinet-style fan-coil. Each dot on the chart represents a coil selection, with HWS temperature on the X axis and the fluid temperature drop (ΔT) on the Y axis, with the average plotted along the dotted line. In this example, with a HWS temperature of 140°F, the ΔT of a coil sized for this HWS temperature is approximately 30°F. But with a HWS temperature of 105°F, the ΔT is only 15°F; so this will require twice the fluid flow rate at design conditions. This higher fluid flow rate will impact pumping power, but the heat pump's efficiency benefit overshadows this impact (see "Impact on pumping power," p. 24).

**Figure 7. Hot-water coil selections for an example cabinet-style fan-coil**



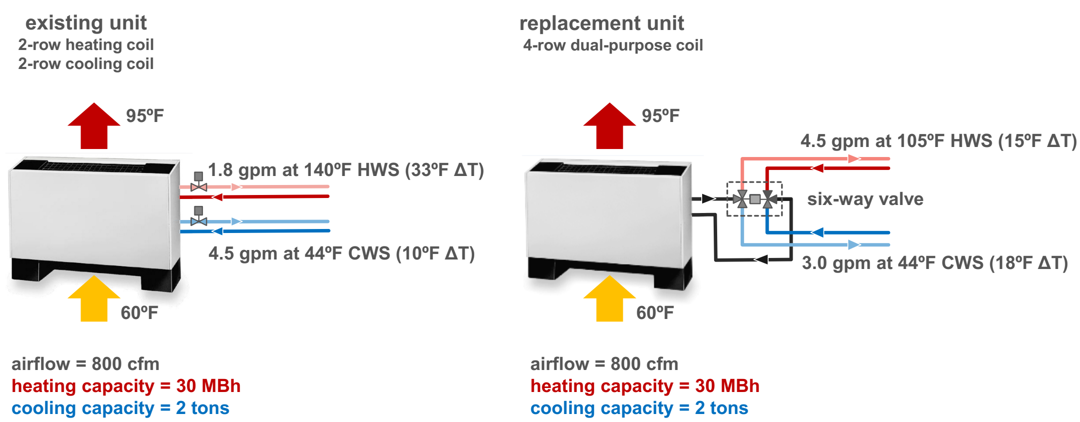
Note that a cabinet-style fan-coil is generally considered to be the most challenging (worst-case) application for using a lower HWS temperature. Since this type of equipment is installed on the floor in the occupied space, it is typically the most space-constrained equipment.

In contrast, hot-water coils in central air-handling units can usually be designed for a 30°F ΔT when the HWS temperature is 105°F, since they typically have space available for additional rows and fins.

Most existing fan-coils will likely have four rows of coil: either a three-row cooling coil and a one-row heating coil, or a two-row cooling coil and a two-row heating coil.

For this example, the existing cabinet-style fan-coil has a two-row preheat coil sized for 140ºF HWS and a 33ºF ΔT, and a two-row cooling coil sized for 44ºF CWS and a 10ºF ΔT (Figure 8). The replacement fan-coil has a single, four-row dual-purpose coil. It is selected to provide the same heating capacity with 105ºF HWS (glycol solution) and a 15ºF ΔT. In cooling mode, this dual-purpose coil provides the same cooling capacity, while requiring 33 percent less flow and an 18ºF ΔT.

**Figure 8. Example replacement of a cabinet-style fan-coil**




The replacement fan-coil is selected for the same airflow (800 cfm), and is able to provide the same heating capacity and the same 95°F discharge-air temperature, while using only 105°F HWS temperature.

When replacing cabinet-style fan-coils, a typical constraint is that it not take up any additional floor space than the existing unit, due to the value of finished space in a commercial building. For this reason, there is typically no extra space for eight rows of coil; so this example used only a four-row coil. Because both hot water and chilled water are supplied by the same central equipment, the same dual-purpose coil is used for either heating or cooling.

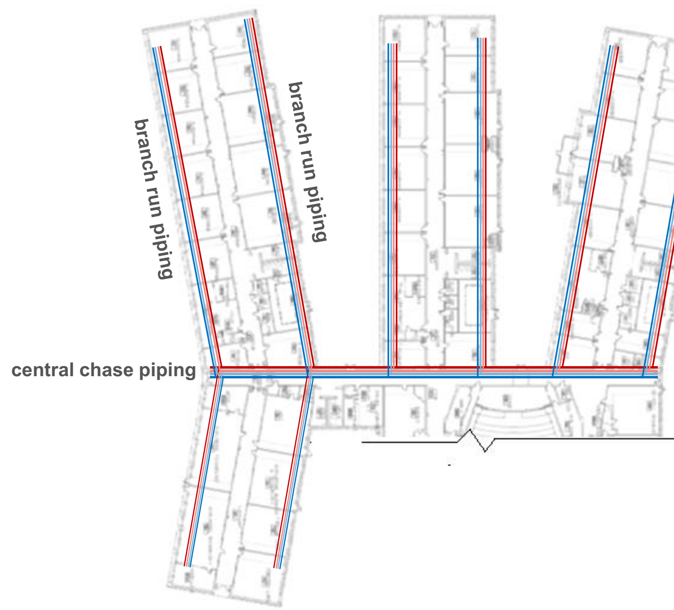
### *Using six-way control valves to serve the dual-purpose coils*

One approach to enable use of a dual-purpose coil is a **six-way control valve** (as shown in Figure 8). However, this requires significant space to accommodate both the piping and the valve itself, and a six-way valve is typically more expensive than a pair of two-way valves and zone controls.

Even if space is available to accommodate a six-way control valve, the other issue is the required size of the distribution piping. For this example, changing from 140°F to 105°F HWS temperature requires increasing the hot-water flow rate from 1.8 gpm to 4.5 gpm. This means that the branch and zone hot-water piping would need to be replaced.

To demonstrate, Figure 9 depicts a common architectural design often referred to as a “finger school.” This type of building is characterized by classroom wings branching off from a center core of the building. This building has existing four-pipe distribution with a fan-coil or unit ventilator in each classroom. In the center core of the building is a central chase with large distribution piping. Each classroom wing has two sets of branch piping runs, one set for each facade. Each branch feeds 5 to 10 zones, with four-pipe zone piping runs to each fan-coil or unit ventilator.

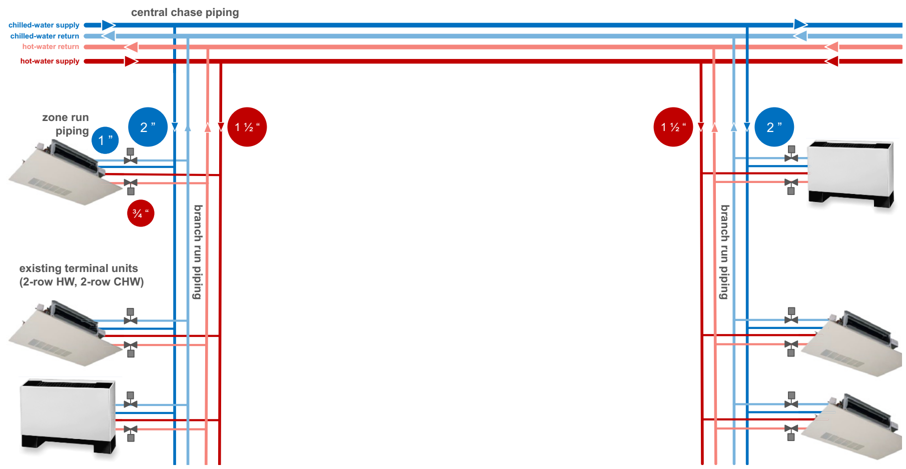
**Figure 9. Example finger-style school with existing four-pipe distribution**




The zone hot-water piping runs to the existing terminal units, which were sized for 140°F HWS temperature and a 30°F ΔT, are 0.75-in. diameter. The branch hot-water piping runs are 1.5-in. diameter (Figure 10).

The zone chilled-water piping runs to the existing terminal units, which were sized for 45°F CWS temperature and a 10°F ΔT, are 1-in. diameter, while branch chilled-water piping runs are 2-in. diameter.

**Figure 10. Branch and zone piping runs in the existing four-pipe distribution system**

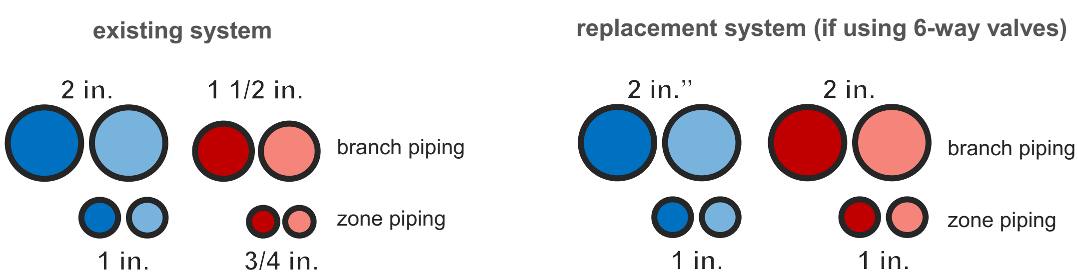



In order to use a dual-purpose coil and a six-way control valve in the replacement terminal units, both the branch and zone hot-water piping would need to be upsized to handle to higher fluid flow rates associated with 105°F HWS temperature and a 15°F ΔT (Figure 11):

- The zone hot-water piping runs, which are 0.75-in. diameter, would need to be replaced with 1-in. diameter pipes.
- The branch hot-water piping runs, which are 1.5-in. diameter, would need to be replaced with 2-in. diameter pipes.

Replacing the branch and zone hot-water piping is costly and requires construction work in (or above) the occupied spaces of the building.

**Figure 11. Upsizing branch and zone hot-water piping**




| pipe diameter, in. | nominal fluid flow rate, gpm | fluid ΔT = 10ºF capacity, Btu/h | fluid ΔT = 15ºF capacity, Btu/h | fluid ΔT = 20ºF capacity, Btu/h | fluid ΔT = 30ºF capacity, Btu/h |
|---|---|---|---|---|---|
| 3/4 | 4 | 18,000 | 27,000 | 36,000 | 54,000 |
| 1 | 8 | 36,000 | 54,000 | 72,000 | 108,000 |
| 1 1/2 | 25 | 112,500 | 168,750 | 225,000 | 337,500 |
| 2 | 50 | 225,000 | 337,500 | 450,000 | 675,000 |

In cooling mode, the four-row dual-purpose coil allows for a lower fluid flow rate and a larger cooling ΔT, so the existing branch and zone chilled-water piping can be reused.

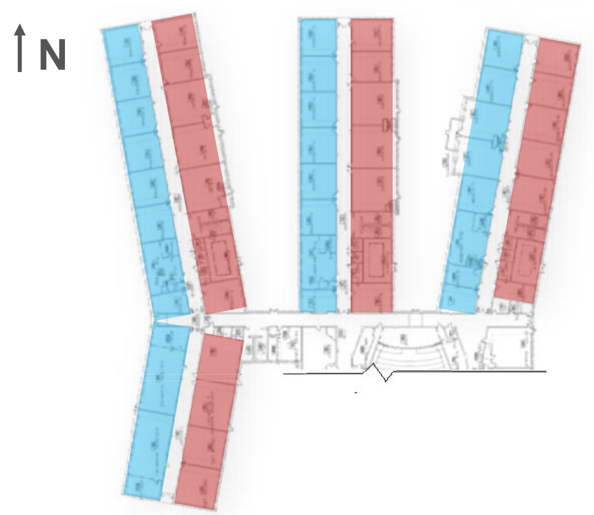
### *Using Hydronic Branch Conductors to serve the dual-purpose coils*

Rather than reverting to 140°F HWS temperature (which would sacrifice heat pump efficiency) to avoid the need to replace the branch and zone hot-water piping, an alternative approach might be to use a **Hydronic Branch Conductor**.

The use of four-pipe distribution is desirable because it allows some zones to provide heating while others provide cooling. However, the simultaneous need for heating and cooling is typically rare in this type of building; and when it does occur, it's usually in non-adjacent areas of the building.

For this example school building, the classroom wings can be divided into eight thermal areas (Figure 12). Throughout most of the year, all the thermal areas will require either cooling or heating. But in the Spring or Fall, there might be late afternoon solar loads that cause the West-facing areas of the building (shaded blue) to require cooling, while the East-facing areas (shaded red) require heating. This is more likely to occur if there is a dedicated outdoor-air system (DOAS) used for ventilation and if the terminal units are not equipped with airside economizers.

**Figure 12. Dividing a building into thermal areas**

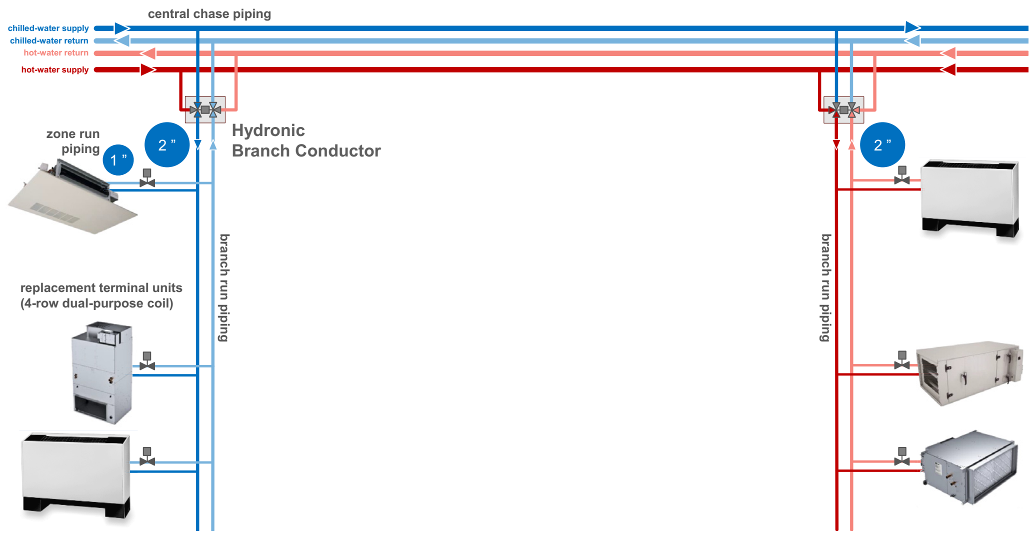



Instead of replacing the existing branch and zone hot-water piping to accommodate the new, higher hot-water flow rates required by the lower HWS temperature, there is existing piping already in place that matches the need for heating: the existing branch and zone chilled-water piping could be used to also supply hot water to the dual-purpose coils.

As depicted in Figure 13:

- The replacement terminal units are equipped with a single dual-purpose coil and a single control valve. This coil can switch over between cooling or heating operation.
- The 1-in. zone chilled-water piping is large enough to accommodate the higher hot-water flow rate needed for heating with 105°F HWS. Therefore, the zone hot-water piping and second control valve are no longer needed.
- The 2-in. branch chilled-water piping is also large enough to accommodate the higher hot-water flow rates needed for heating, so the branch hot-water piping is no longer needed. It can be disconnected, drained, capped, and left in place to prevent disruption of the occupied spaces; or it can remain in use if there is heating-only equipment (such as baseboard or entryway heaters) still installed in the building.
- Switchover from cooling to heating, or vice versa, occurs at the chase-to-branch connection for each separate thermal area, inside the Hydronic Branch Conductor. This valve control unit directs either hot water or chilled water to-and-from all the terminal units in that thermal area, based on its current need.

**Figure 13. Branch and zone piping runs in the replacement distribution system**

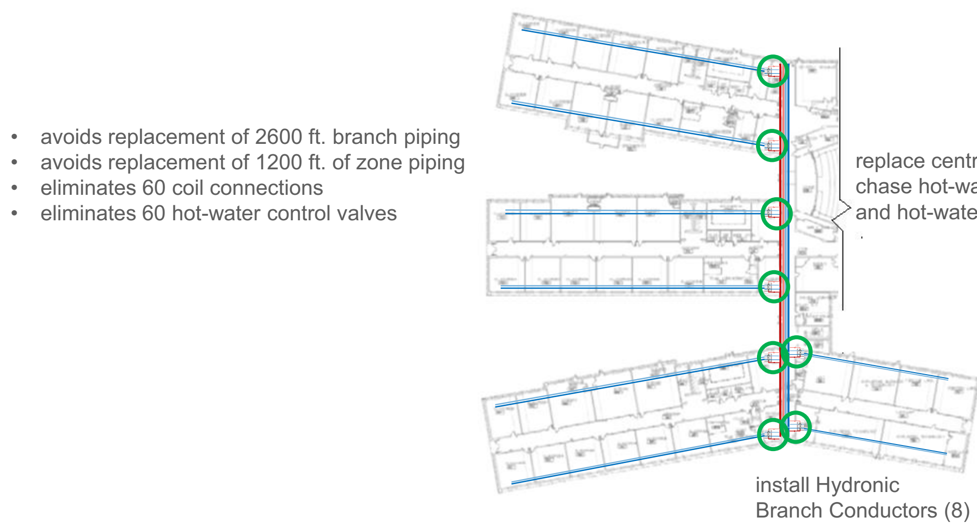



Each terminal unit is controlled using a traditional two-way modulating valve, but requires only one control valve per zone. It's important to note that the Hydronic Branch Conductor does not control the zone-level terminal units. Each terminal unit is equipped with a unit controller that modulates its control valve to provide independent temperature control for the zone it serves.

As depicted in Figure 13, thermal areas can be in different modes. The left-side area is in Cool Mode, so the Conductor directs chilled water to the dual-purpose coils in the terminal units that make up this area. The right-side area is in Heat Mode, so the Conductor directs hot water to the coils in this area. This allows for simultaneous heating and cooling in different areas of the building, if needed.

For this example finger school, using a Hydronic Branch Conductor for each classroom wing avoids the need to replace 2600 ft of branch hot-water piping and 1200 ft of zone hot-water piping, and eliminates the need for 60 zone coil connections (due to the use of a single dual-purpose coil in the replacement terminal units) and 60 hot-water control valves. A Hydronic Branch Conductor is installed for each of the eight thermal areas, and the central chase hot-water piping and hot-water distribution pumps will need to be replaced to handle the higher flow rate that results from using the lower HWS temperature (Figure 14).

**Figure 14. Summary of impacts on distribution system renovation**




Note that this approach does not require a Hydronic Branch Conductor to be used in every area of the building. For example, other areas of this school building (such as the gym and cafeteria) can continue to be served by traditional four-pipe air-handling units, in which the hot-water coils have been selected to use the lower HWS temperature.

**Impact on pumping power**

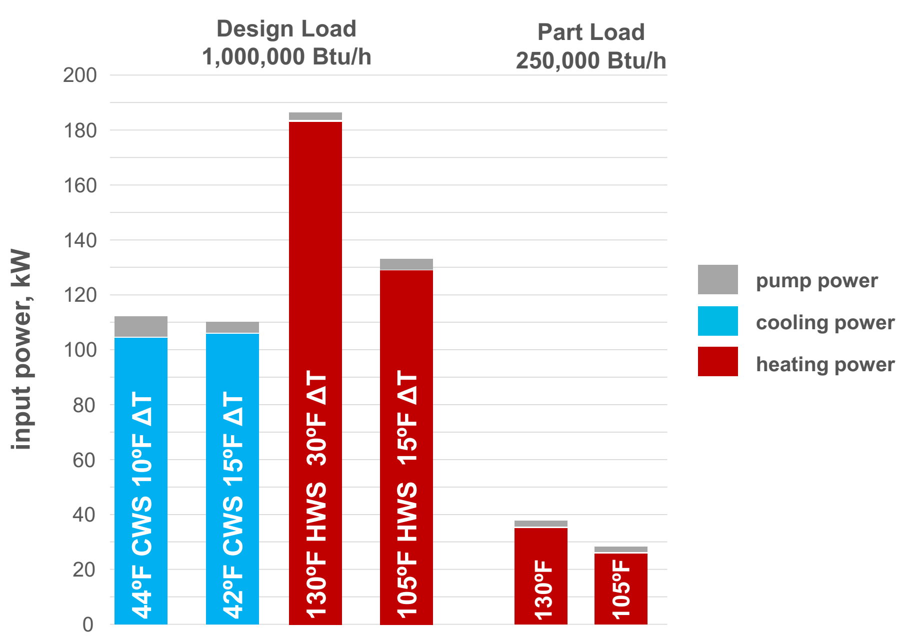
In the previous example, the existing terminal units were sized for a 10°F chilled-water ΔT. The replacement units are selected for a 15°F ΔT, which reduces the chilled-water flow rate by 33 percent. Chilled-water pumping energy will be further reduced by reusing what is now oversized branch and zone chilled-water piping. However, the existing terminal units were sized for a 33°F hot-water ΔT, while the replacement units are selected for a 15°F ΔT. This doubles the hot-water flow rate and increases hot-water pumping energy. But when the entire system is analyzed, the increase in hot-water pumping power is likely to be relatively small compared to the reduction in heat pump power that results from using the lower (105°F) HWS temperature.

To demonstrate, the first two columns in Figure 15 depict power draw for an example hydronic system operating at design cooling conditions (1,000,000 Btu/h cooling load). Changing from a 10°F chilled-water ΔT to a 15°F ΔT saves significant pumping power (depicted in grey). For this example, this requires lowering the CWS temperature from 44°F to 42°F, which increases the compressor power of the air-to-water heat pump (depicted in blue); but this increase is smaller than the pump power savings, resulting in a reduction in the overall system power when cooling.

The red bar in the third column depicts the air-to-water heat pump power at design heating conditions (1,000,000 Btu/h heating load), when operating at 10°F ambient temperature and a 130°F HWS temperature. The red bar in the fourth column depicts the large power reduction when the heat pump supplies only 105°F HWS. As shown in gray, there is a significant increase in pumping power when using 105°F HWS and a 15°F ΔT, but the combined heat pump plus pumping power is still 30 percent less than for a system designed with 130°F HWS and a 30°F ΔT.

The fifth and sixth columns depict heating operation at part load (25 percent of the design heating load) and 35°F ambient. The power savings is not as great at this warmer ambient temperature, but the system with the lower HWS still results in overall system power savings.

**Figure 15. Comparison on combined system power**



## RETROFITTING A EXISTING HIGH-RISE FAN-COIL SYSTEM TO ELECTRIFY HEATING

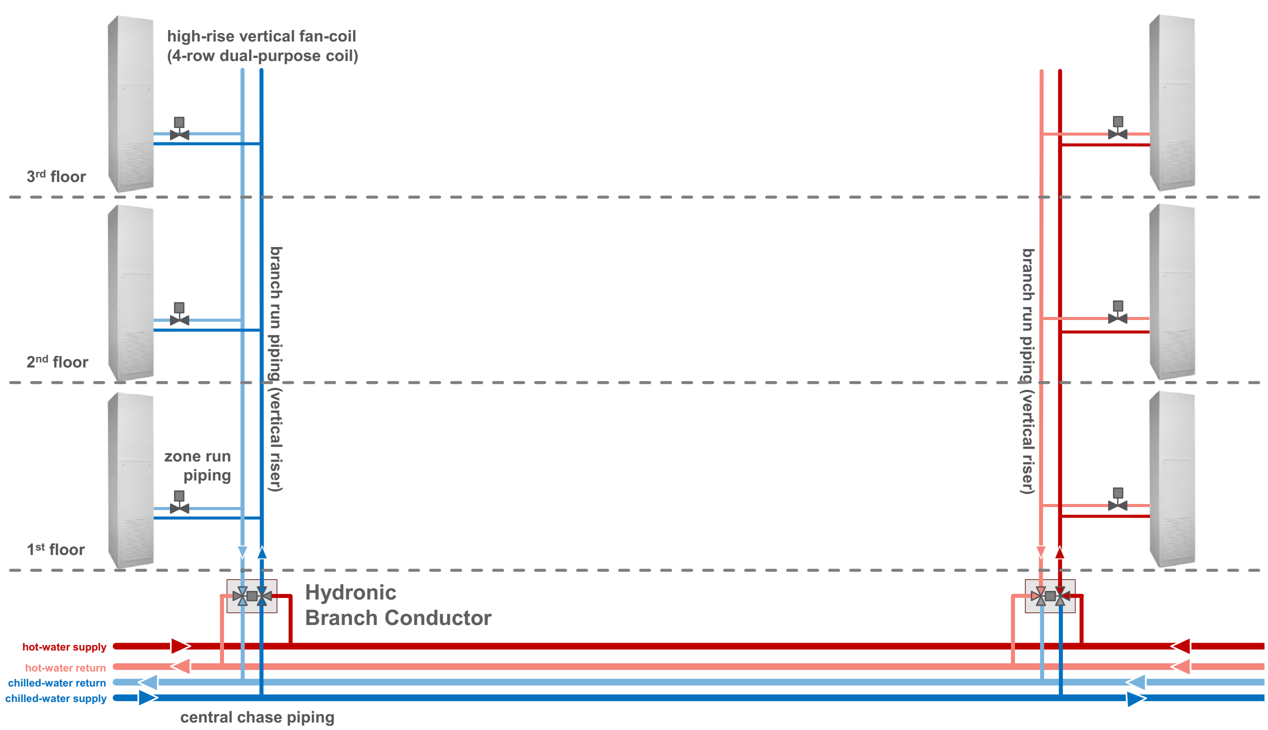
A similar application is an existing building equipped with high-rise (or vertical-stack) fan-coils. This type of fan-coil is designed to be recessed into the wall in a multiple-story building, and they are specifically designed to be aligned above each other to minimize the cost of installing piping and electrical service.

If the central hot-water/chilled-water plant is being modified to use heat pump heating, Hydronic Branch Conductors might enable the use of a lower HWS temperature, while avoiding the need to replace the hot-water piping risers.

For this application, the zones on each facade of the building comprise one (or more) thermal area. Each of the new terminal units is equipped with a dual-purpose coil and a single control valve. The branch (vertical riser) chilled-water piping is typically large enough to accommodate the higher hot-water flow rate needed for heating with a lower HWS temperature. Therefore, the hot-water piping risers are no longer needed.

Area switchover is provided by adding a Hydronic Branch Conductor for each thermal area (Figure 16). Only the central chase hot-water piping and hot-water distribution pumps will need to be replaced to handle the higher flow rate that results from using the lower HWS temperature.

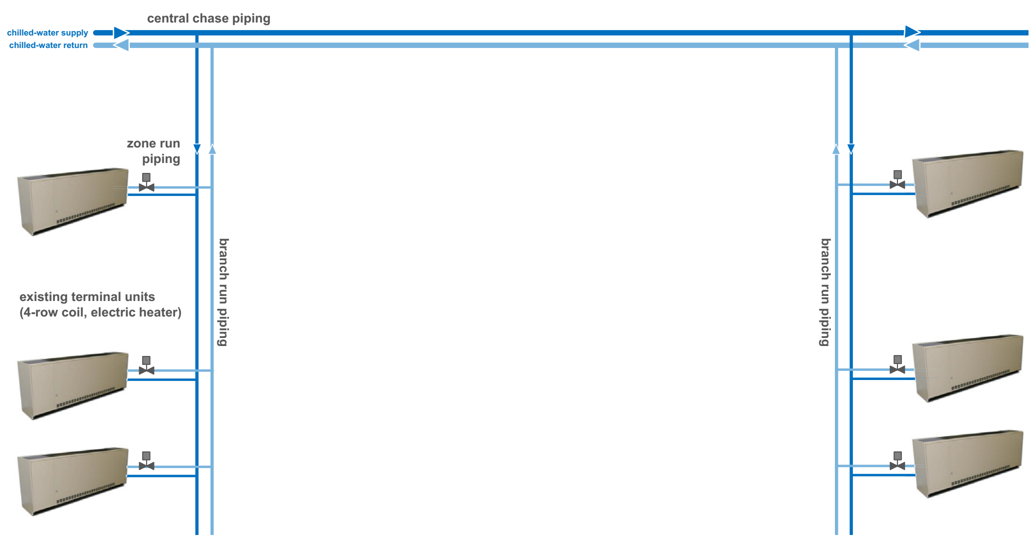
**Figure 16. Renovated high-rise fan-coil system to incorporate Hydronic Branch Conductors**



## RETROFITTING AN EXISTING TWO-PIPE HYDRONIC SYSTEM (WITH LOCAL ELECTRIC HEATERS) TO USE CENTRALIZED HEAT PUMP HEATING

Another example application for the Hydronic Branch Conductor is an existing building that includes a centralized water chiller for cooling, using a two-pipe distribution system, and an electric heater in each zone-level terminal unit (Figure 17).

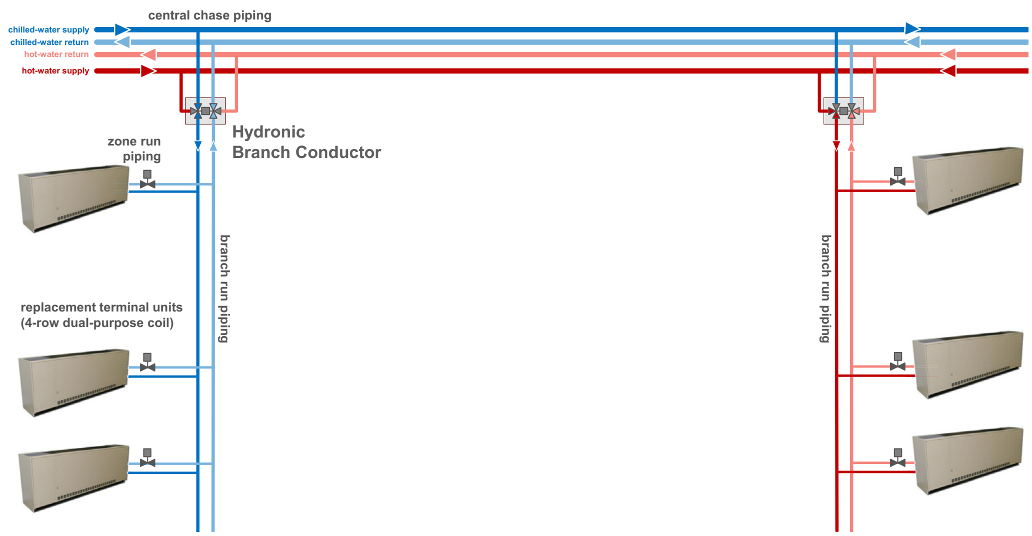
**Figure 17. Example existing two-pipe hydronic distribution system with electric heaters in the terminal units**




The building owner is interested in renovating this system to make use of heat pump heating (rather than electric resistance heaters) to reduce energy use and cost, while still using electricity as the source of heating. The Hydronic Branch Conductor enables the use of a centralized heat pump for heating, without needing to install new hot-water pipes all the way to every terminal unit.

In this case, each of the new terminal units is equipped with a dual-purpose, four-row coil and a single control valve. Area switchover is provided by adding a Hydronic Branch Conductor for each thermal area (Figure 18). The only new hot-water supply and return piping needed is located in the central chase. Hot-water distribution pumps are also needed in the central plant.

**Figure 18. Renovated distribution system to incorporate Hydronic Branch Conductors**

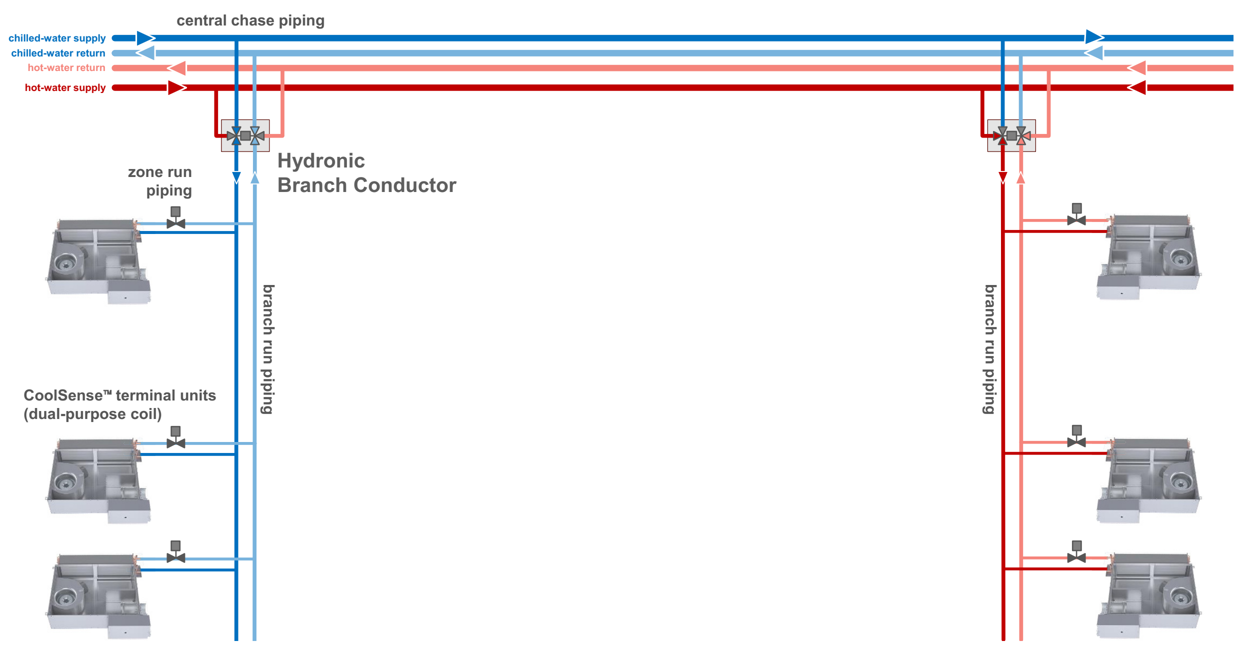


## USING HYDRONIC BRANCH CONDUCTORS IN A NEW COOLSENSE™ SYSTEM

In a system that uses sensible-cooling terminal units, like Trane® CoolSense™, the sensible-only cooling coil is typically constructed with either four or six rows. Using this same (dual-purpose) coil for heating enables the use of a lower HWS temperature (which results in more-efficient heat pump operation) while avoiding the air pressure drop of a separate hot-water coil.

As with the other system examples, use of the Hydronic Branch Conductor also eliminates the cost of including a separate hot-water coil (or electric heater) and control valve in each terminal unit, and avoids the need to install branch and zone hot-water supply and return piping (Figure 19).

**Figure 19. CoolSense™ system with dual-purpose coils and Hydronic Branch Conductors**



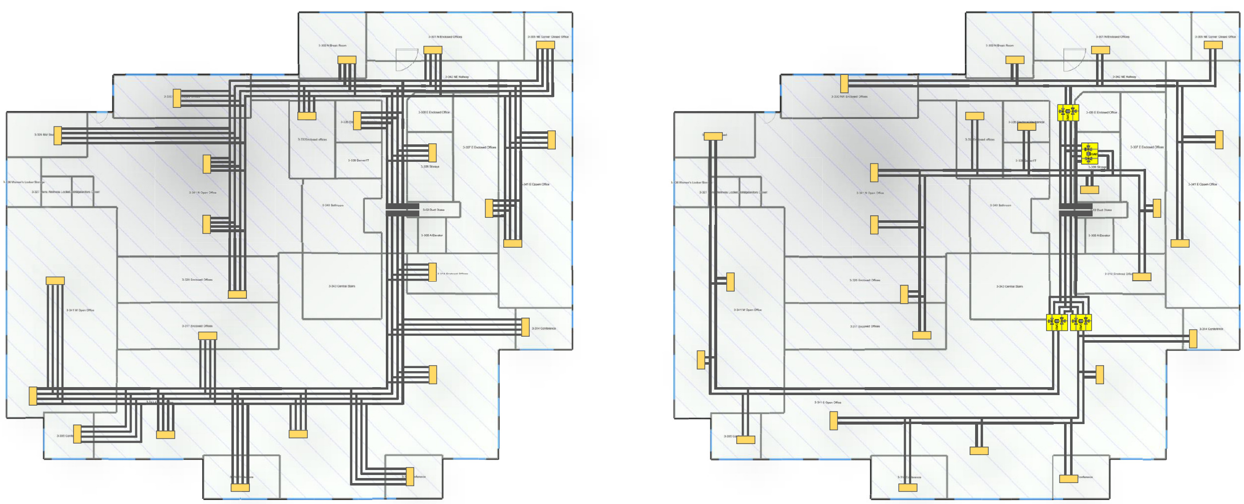
To demonstrate, Figure 20 depicts a floor plate of a multiple-story office building. This floor is divided into 25 independent thermal zones, each served by a CoolSense™ terminal unit. The design on the left uses traditional four-pipe distribution, in which each terminal unit is equipped with separate chilled-water and hot-water coils, each with its own control valve (for a total of 50 control valves on this floor).

The design on the right uses four Hydronic Branch Conductors to serve the four distinct thermal areas (groupings of zones) of the floor. In this case, each terminal unit is equipped with a single, dual-purpose coil and a single control valve (for a total of 25 control valves on this floor). Each area has one set of branch pipes, and each terminal unit has one set of zone pipes. This results in a significant reduction in piping and fittings.

**Figure 20. Summary of impacts on distribution system installation for a new CoolSense™ system**

traditional four-pipe distribution

Hydronic Branch Conductors



traditional four-pipe distribution:

- 25 CoolSense™ terminals with separate chilled-water and hot-water coils
- 50 control valves
- 2780 ft. of steel pipe (majority 2 in., some 1.5 in.)
- 254 fittings (Ts, elbows)

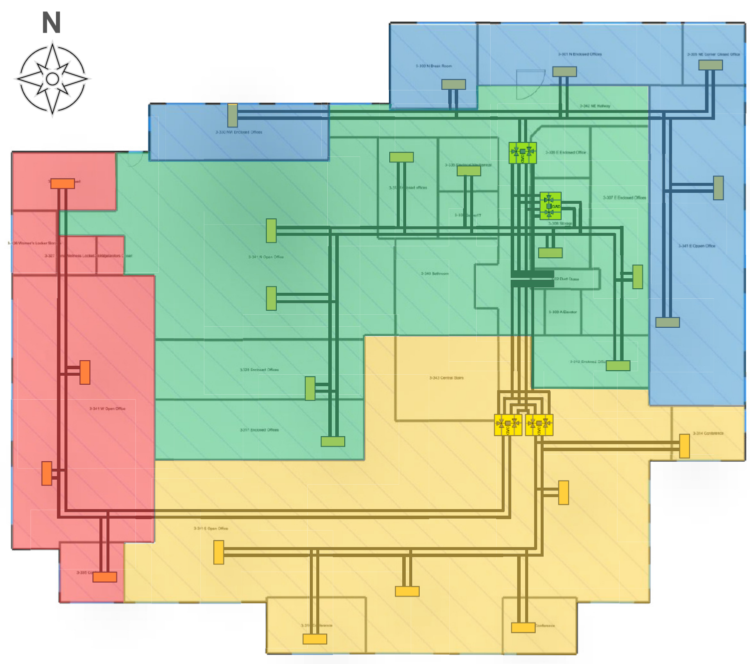
Hydronic Branch Conductors:

- 25 CoolSense™ terminals with single, dual-purpose coil
- 25 control valves
- 4 Hydronic Branch Conductors
- 1660 ft. of steel pipe (majority 1.5 in., some 2 in.)
- 174 fittings (Ts, elbows)

For the design using Hydronic Branch Conductors, the 25 zones (terminal units) on this floor are grouped into four distinct thermal areas (Figure 21):

- The South area (shaded in yellow) consists of six independent zones.
- The West area (shaded in red) consists of four independent zones.
- The North/East area (shaded in blue) consists of six independent zones.
- The Central area (shaded in green) consists of nine independent zones.

**Figure 21. Example of thermal areas served by Hydronic Branch Conductors**



# Re-Use of Central Chase Piping

As demonstrated in Figure 15, the increase in pumping power that results from using a 15°F hot-water ΔT is small compared to the decrease in heat pump power that results from using a lower HWS temperature. In new buildings, or buildings in which central chase piping can be added or replaced, the new central chase hot-water piping should be specified to be large enough to meet the higher required hot-water flow rates.

However, if the central chase piping must be reused in a retrofit, this may dictate the design ΔT for the hot-water system, the HWS temperature, or both. This constraint is more common in mid-rise and high-rise buildings that have a central pipe chase in the core of the building.

The branch and zone hot-water piping in an existing building will typically be a small diameter, limiting the ability to reuse it with a lower HWS temperature that benefits both heat pump efficiency and capacity. Terminal units with dual-purpose coils, Hydronic Branch Conductors, and re-using branch and zone chilled-water piping for both cooling and heating helps alleviate this constraint.

When **re-use of the central chase piping is required** or strongly desired, the first step is to determine how much heat can be transported by the existing central chase hot-water piping to the branches. Table 1 and Table 2 list the maximum allowable fluid flow rates for various nominal pipe diameters in a variable-flow distribution system, as prescribed by ASHRAE Standard 90.1 (Table 6.5.4.6). These tables also calculate the maximum heating capacity that can be transported by each flow rate (assuming pure water), for various system design ΔT's. For example, if the central chase contains existing 8-in. hot-water pipes, the maximum allowable fluid flow rate for a heating system that operates ≤ 2000 hours/year is 1800 gpm. If the new hot-water system is being designed for a 15°F ΔT, the maximum heating capacity that can be transported by this 1800-gpm flow rate is 13,500 MBh.

**Table 1. Maximum heat transport capacity for a system operating ≤ 2000 hours/year**

| Nominal Pipe Size, in. | Maximum Fluid Flow Rate, gpm | Heat Transport Capacity, MBh* | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | ΔT = 10°F | ΔT = 15°F | ΔT = 20°F | ΔT = 25°F | ΔT = 30°F | ΔT = 35°F | ΔT = 40°F |
| 2.5 | 180 | 900 | 1350 | 1800 | 2250 | 2700 | 3150 | 3600 |
| 3 | 270 | 1350 | 2025 | 2700 | 3375 | 4050 | 4725 | 5400 |
| 4 | 530 | 2650 | 3975 | 5300 | 6625 | 7950 | 9275 | 10600 |
| 5 | 620 | 3100 | 4650 | 6200 | 7750 | 9300 | 10850 | 12400 |
| 6 | 1100 | 5500 | 8250 | 11000 | 13750 | 16500 | 19250 | 22000 |
| 8 | 1800 | 9000 | 13500 | 18000 | 22500 | 27000 | 31500 | 36000 |
| 10 | 2700 | 13500 | 20250 | 27000 | 33750 | 40500 | 47250 | 54000 |
| 12 | 3800 | 19000 | 28500 | 38000 | 47500 | 57000 | 66500 | 76000 |

* Assuming pure water: Heat Transport Capacity (MBh) = 500 × GPM × ΔT (°F) / 1000

**Table 2. Maximum heat transport capacity for a system operating > 2000 hours/year but ≤ 4400 hours/year**

| Nominal Pipe Size, in. | Maximum Fluid Flow Rate, gpm | Heat Transport Capacity, MBh* | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | ΔT = 10°F | ΔT = 15°F | ΔT = 20°F | ΔT = 25°F | ΔT = 30°F | ΔT = 35°F | ΔT = 40°F |
| 2.5 | 130 | 650 | 975 | 1300 | 1625 | 1950 | 2275 | 2600 |
| 3 | 210 | 1050 | 1575 | 2100 | 2625 | 3150 | 3675 | 4200 |
| 4 | 400 | 2000 | 3000 | 4000 | 5000 | 6000 | 7000 | 8000 |
| 5 | 470 | 2350 | 3525 | 4700 | 5875 | 7050 | 8225 | 9400 |
| 6 | 860 | 4300 | 6450 | 8600 | 10750 | 12900 | 15050 | 17200 |
| 8 | 1400 | 7000 | 10500 | 14000 | 17500 | 21000 | 24500 | 28000 |
| 10 | 2000 | 10000 | 15000 | 20000 | 25000 | 30000 | 35000 | 40000 |
| 12 | 2900 | 14500 | 21750 | 29000 | 36250 | 43500 | 50750 | 58000 |

* Assuming pure water: Heat Transport Capacity (MBh) = 500 × GPM × ΔT (°F) / 1000

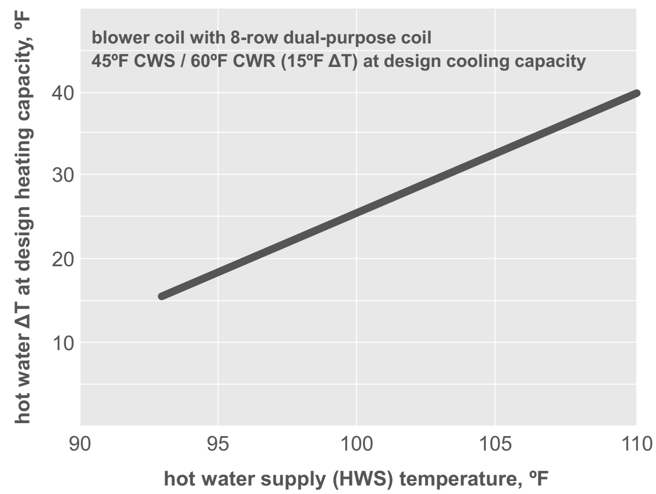
Most existing central hydronic heating systems are oversized. When determining if the existing central chase hot-water piping is large enough, use the actual expected peak heating load for the building, not the currently-installed boiler capacity. Also note that the design fluid flow rate for the central chase piping is not a sum of the design flow rates for all the terminal units, since most terminal heating equipment is also greatly oversized.

Oversizing terminal (zone-level) heating equipment is common as a means for providing a margin of safety. For example, a design engineer might choose to size a terminal unit for 150 percent of the zone's peak (design) heating load, but this does not mean that the central chase hot-water piping and pumps need to be sized for 150 percent of required capacity. For instance, the central chase piping and pumps could be sized for 120 percent of design, without affecting the ability of several “rouge” zones to provide 150 percent of their design capacities.

If the existing hot-water distribution system was sized for a 30°F or 40°F ΔT, historic practices of oversizing and designing for conservative fluid velocity in piping means that the existing central chase hot-water piping will likely be sufficiently large enough to be used in a 15°F or 20°F ΔT system design. In this case, a Hydronic Branch Conductor installed between the main chase piping and the branch piping will allow for reuse of the existing branch chilled-water piping for both cooling and heating.

If it is determined that the central chase hot-water piping is indeed undersized for the re-designed system, and cannot be replaced, this will dictate the design HWS temperature and what types of terminal heating equipment can be used downstream of the Hydronic Branch Conductors. Recall that Figure 7 depicted the performance of a cabinet-style fan coil, which is generally considered to be the most challenging type of terminal heating equipment to use with a lower HWS temperature. Figure 22 shows what is achievable when using an 8-row dual-purpose coil in a blower coil, which is often considered to be the best-case scenario for terminal heating equipment, due to the availability of coils with more rows while still being a low enough height for mounting in a ceiling plenum. Notice that a ΔT of over 30°F is possible with a 105°F HWS temperature.

**Figure 22. Hot-water coil selections for an example blower coil**




Using blower coils in just a few of the largest zones could lower the required branch flow rate for that area of the building where flow is constrained by the existing central chase hot-water piping.

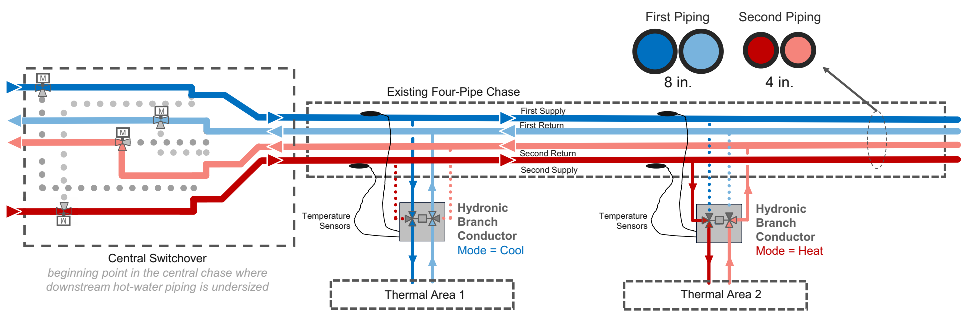
## CENTRAL CHASE SWITCHOVER

If the central chase hot-water piping is indeed undersized for the retrofit (lower HWS temperature) system design, such that it will exceed the desired fluid velocity, there is another option that can enable re-use of the existing central four-pipe chase to transport the needed hot-water and chilled-water flows to the branches and zones: central chase switchover.

For most buildings, peak heating capacity is only needed for a few hours of the year, and these hours are isolated to one or two months. During those times, the cooling load is usually very low, if present at all. During this one or two month peak heating season, the central chase chilled-water and hot-water piping could be switched over.

A group of four valves (central switchover) is installed in the central chase piping at the location where the downstream hot-water piping is undersized. During most of the year (the non-peak heating months of March through December), these valves are positioned to deliver chilled water through the larger supply and return pipes (Figure 23). In this configuration, the central chase piping can provide a maximum capacity of 13,500 MBh for cooling and 3975 MBh for heating (see Table 1, assuming nominal flow rates for the stated pipe diameter and a 15°F ΔT).

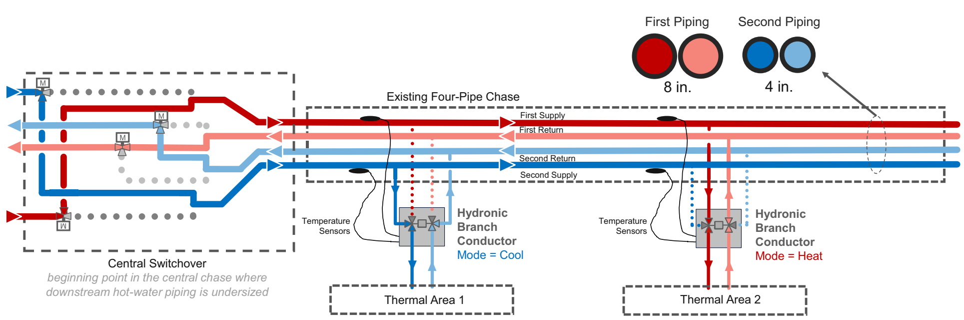
**Figure 23. Central chase switchover (non-peak heating months: March through December)**




**Non-Peak Heating Month(s)**
- CWS/CWR = First Supply / First Return
- HWS/HWR = Second Supply / Second Return

Then during the peak heating months (January through February in this example), these valves are positioned to deliver hot water through the larger supply and return pipes (Figure 24). When switched over to use the larger pipes for heating, the central chase piping can provide a maximum capacity of 3975 MBh for cooling and 13,500 MBh for heating (assuming nominal flow rates for the given pipe diameter and a 15°F ΔT).

**Figure 24. Central chase switchover (peak heating months: January through February)**




**Peak Heating Month(s)**
- CWS/CWR = Second Supply / Second Return
- HWS/HWR = First Supply / First Return

This central switchover could be automated by the system-level controller based on an annual schedule, or in lieu of installing motorized valves, this switchover could be performed manually by the building operating staff.

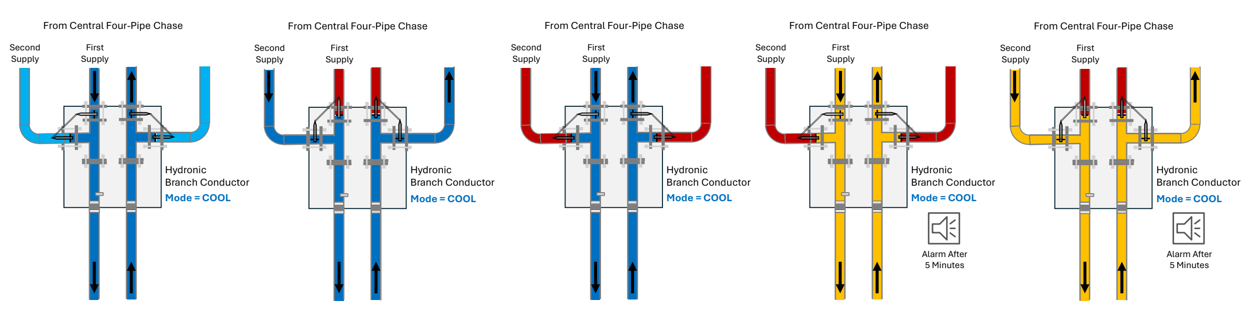
A Hydronic Branch Conductor is installed for each branch downstream of this central switchover point. The Conductor's controller continually senses the temperature in the first and second supply pipes, determining the temperature of fluid (CWS or HWS) that is currently available from each set of pipes.

The Conductor will then automatically position its valves to meet the current need (Cool Mode or Heat Mode) of the thermal area it serves. This "auto-detect" feature of the Conductor's controller allows flexibility to use dual-purpose piping (via central switchover) in the building, reducing the risk of delivering chilled water to an area where heating is needed or hot water to an area where cooling is needed.

*Heat Cool Mode Fluid Determination (Auto-Detect)*

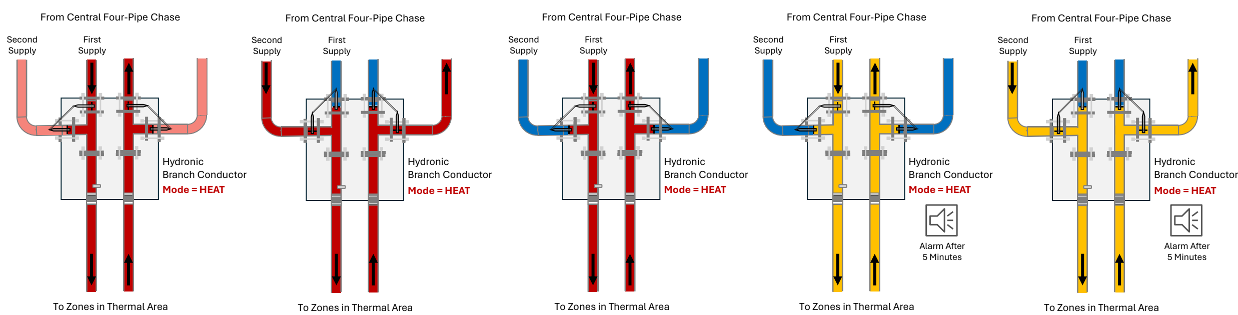
*During Cool Mode, the Hydronic Branch Conductor will continuously monitor the First and Second Supply fluid's Heat, Cool, or Neutral status, and send the appropriate temperature fluid to the thermal area.*

- *If both the First and Second Supply have Cool status, the Hydronic Branch Conductor will send cool fluid from the First Supply to the thermal area.*
- *If the First Supply has Hot or Neutral status and the Second Supply has Cool status, the Hydronic Branch Conductor will send cool fluid from the Second Supply to the thermal area.*
- *If the First Supply has Cool status and the Second Supply has Hot or Neutral status, the Hydronic Branch Conductor will send cool fluid from the First Supply to the thermal area.*
- *If the First Supply has Neutral status and the Second Supply has Hot status, the Hydronic Branch Conductor will send fluid from the First Supply to the thermal area, but if the First Supply is not Cool status after 5 minutes an alarm will be sent to the BAS.*
- *If the First Supply has Hot status and the Second Supply has Neutral status, the Hydronic Branch Conductor will send fluid from the Second Supply to the thermal area, but if the Second Supply is not Cool status after 5 minutes an alarm will be sent to the BAS.*



During **Heat Mode**, the Hydronic Branch Conductor will continuously monitor the First and Second Supply fluid's Heat, Cool, or Neutral status, and send the appropriate temperature fluid to the thermal area.

- *If both the First and Second Supply have Heat status, the Hydronic Branch Conductor will send warm fluid from the First Supply to the thermal area.*
- *If the First Supply has Cool or Neutral status and the Second Supply has Heat status, the Hydronic Branch Conductor will send warm fluid from the Second Supply to the thermal area.*
- *If the First Supply has Heat status and the Second Supply has Cool or Neutral Status, the Hydronic Branch Conductor will send warm fluid from the First Supply to the thermal area.*
- *If the First Supply has Neutral status and the Second Supply has Cool status, the Hydronic Branch Conductor will send fluid from the First Supply to the thermal area, but if the First Supply is not Heat status after 5 minutes an alarm will be sent to the BAS.*
- *If the First Supply has Cool status and the Second Supply has Neutral status, the Hydronic Branch Conductor will send fluid from the Second Supply to the thermal area, but if the Second Supply is not Heat status after 5 minutes an alarm will be sent to the BAS.*




If an area of the building is served by VAV terminals equipped with hot-water coils, this area must also include a Hydronic Branch Conductor, even though only hot water will ever be sent to the VAV terminals. For this area, the Conductor will always remain in Heat Mode and will never change. But the Conductor is used to independently determine which set of pipes to use for delivering hot water to the VAV terminals, and to also monitor and report the fluid temperature being sent to the thermal area.

# Grouping Zones Together into an Area

Each thermal zone is served by a terminal unit that is controlled to maintain the temperature in that zone. Adjacent zones that are likely to need either cooling or heating at the same time can be grouped together into a thermal area without sacrificing occupant comfort. The following criteria should be used to determine if zones can be grouped into a thermal area.

For perimeter zones (or interior zones on the top floor of the building):

- Are there adjacent zones in which the perimeter wall and/or roof have the same exposure (east-facing, west-facing, etc.)?
- If so, do these zones have a similar percentage and type of glass?
- If so, do these zones have a similar density of occupants, lighting, and heat-generating equipment?

For interior zones (not including the top floor of the building):

- Are there adjacent zones that have a similar density of occupants, lighting, and heat-generating equipment?

There is no limit to the minimum number of terminal units (or zones) that comprise a thermal area; it could be as few as one. The maximum number of terminal units is dictated by the fluid flow limit of the Hydronic Branch Conductor valves and piping. The most common size of branch piping is 2-in. diameter; as shown in Figure 11, this could provide up to 20 or 30 tons of cooling capacity. That would be a fairly large section of a building to be combined into a single thermal area, but the Conductor is capable of serving such a large area, if desired. A Conductor might serve one zone with a 30-ton single-zone VAV air handler or it might serve 50 fan-coils of various sizes.

Because the Hydronic Branch Conductor does not directly control the zone-level terminal units to which it provides hot water or chilled water, the number of terminal units (or zones) is irrelevant to its operation.

# Unit- and System-Level Control Requirements When Using Hydronic Branch Conductors

It is important to note that the Hydronic Branch Conductor does not control the zone-level terminal units. Each terminal unit still provides independent temperature control for the zone it serves.

## UNIT-LEVEL CONTROL

The terminal unit controller (or thermostat) compares its current zone temperature to the desired setpoint, and determines if the zone should be in Cool Mode or Heat Mode.

The capacity of the dual-purpose coil in each terminal unit is controlled using a traditional two-way modulating valve, requiring only one valve per zone. This control valve modulates, as needed, to maintain the desired temperature setpoint in the zone it serves.

**Auto-sampling sequence.** Whenever the control valve is commanded to open, the terminal unit controller's auto-sampling sequence compares the entering fluid temperature—using a locally-mounted temperature sensor or a communicated value from the system-level controller—to the current zone temperature, and confirms that the desired heating or cooling function can be accomplished:

- When the terminal unit is in Cool Mode, if the entering fluid temperature is warmer than the current zone temperature minus 5°F, the control valve will be closed and the controller will repeat this sampling after 60 minutes (adjustable).
- When the terminal unit is in Heat Mode, if the entering fluid temperature is colder than the current zone temperature plus 5°F, the control valve will be closed and the controller will repeat this sampling after 60 minutes (adjustable).

If the fluid temperature provided by the Hydronic Branch Conductor is not appropriate for the zone's current need (Cool Mode or Heat Mode), closing the control valve avoids further loss of temperature control and prevents adjacent zones from "fighting" each other.

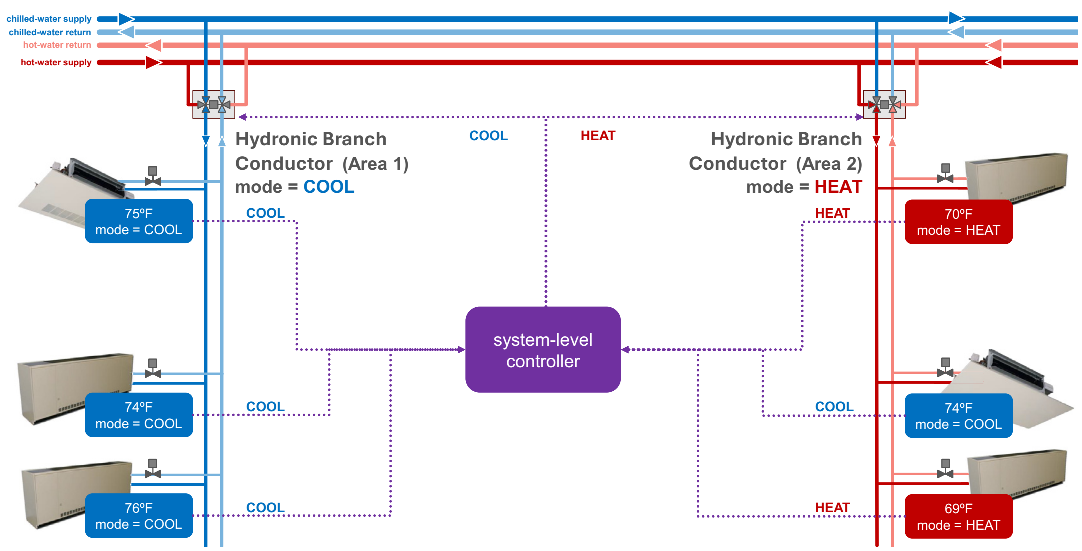
If a terminal unit is in Cool Mode, but the Conductor is currently delivering hot-water to that thermal area, this zone could be cooled via airside economizing (if equipped) or by the conditioned outdoor air supplied by the dedicated outdoor-air system.

## SYSTEM-LEVEL CONTROL

**Terminal units equipped with communicating controls.** Each terminal unit controller communicates its current mode (Cool Mode or Heat Mode) to the system-level controller. Based on the requested modes of all the zones included in a specific thermal area, the system-level controller (BAS) determines if the Hydronic Branch Conductor serving that area should direct either chilled water or hot water to those terminal units.

For the example in Figure 25, the terminal units that make up Area 1 (left side of the diagram) are all calling for cooling (Cool Mode), so the system-level controller instructs the Hydronic Branch Conductor serving Area 1 to supply chilled water to all the dual-purpose coils in that area. Meanwhile, two of the terminal units that make up Area 2 (right side of the diagram) are calling for heating (Heat Mode), while one is calling for cooling (Cool Mode), so the system-level controller instructs the Conductor serving Area 1 to supply hot water to all the dual-purpose coils in that area.

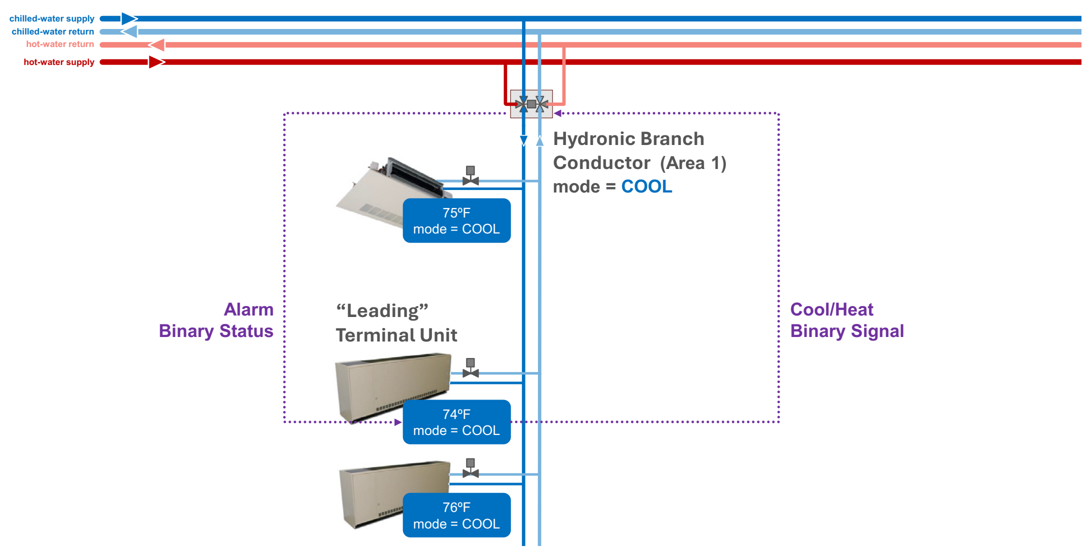
**Figure 25. System-level control of Hydronic Branch Conductors**




**Terminal units NOT equipped with communicating controls, but a system-level controller (BAS) is present.** If the terminal units are not equipped with communicating controls, there is no ability for a system-level controller to survey the current modes (Cool Mode or Heat Mode) of all the terminal units in a thermal area. In this case, the system-level controller makes the decision to send either hot water or chilled water to a given thermal area, and sends the requested mode to the Hydronic Branch Conductor. This decision might be made based on the current month or time of day, the current outdoor temperature, or some other indicator. All remaining control logic is self-contained in the Conductor, so it will function the same as in a system with communicating terminal unit controls.

**No system-level controller (BAS) present.** In this case, the standalone Hydronic Branch Conductor can use a binary input signal directly wired from the "leading" terminal unit controller's relay (Figure 26): Heat Mode (relay open) or Cool Mode (relay closed). This one zone will dictate whether the Conductor supplies hot water or chilled water to all terminal units in the thermal area, so the zone selected should best represent the needs of all zones in that area.

**Figure 26. Control of Hydronic Branch Conductors if no system-level controller (BAS)**




All remaining control logic is self-contained in the Conductor, so it will function the same in this standalone mode as in a system with a system-level controller. The controller on the Hydronic Branch Conductor will send a binary signal if an alarm condition occurs at the Conductor itself. This should be wired back to the "leading" terminal unit controller to provide visibility if an alarm is present for that thermal area.

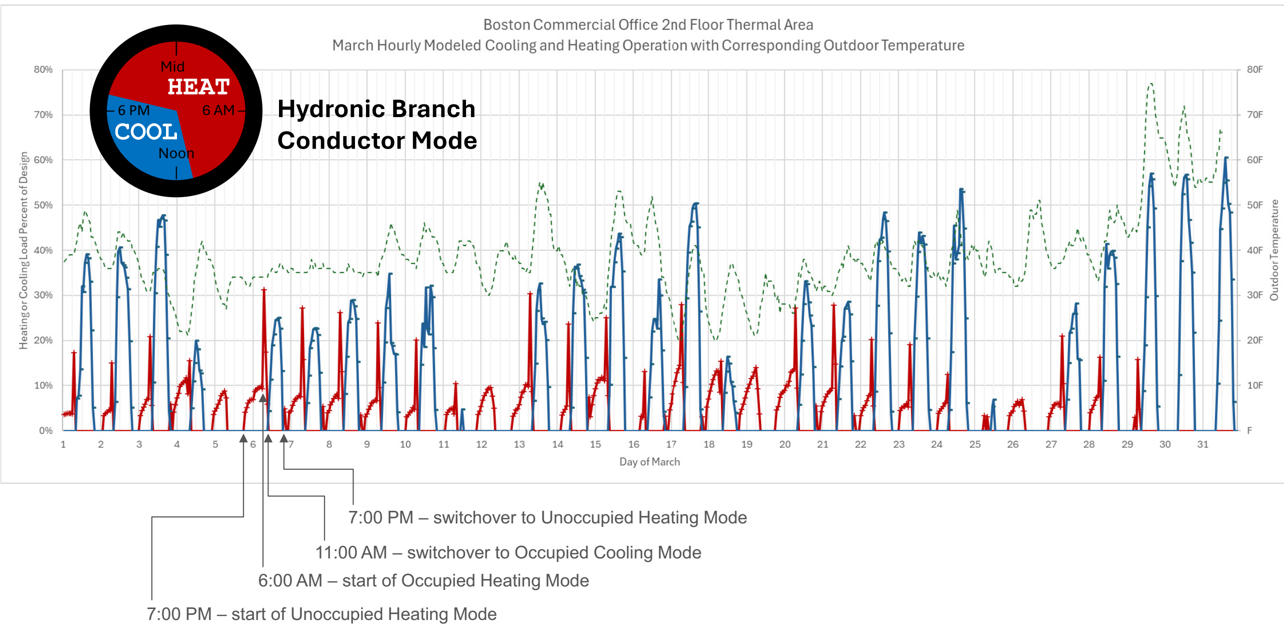
**Frequency of thermal area switch over.** To minimize energy waste associated with heating or cooling the mass of fluid inside the branch and zone piping, a thermal area should typically operate in one mode for at least four hours before switching over to the other mode.

For comfort conditioning of commercial buildings, thermal areas may not change from Cool Mode to Heat Mode (or vice versa) for months at a time. For instance, most zones in a commercial building will likely only require cooling from June to September.

But some buildings or climates may need to switch modes once or twice a day during certain times of the year. An example might be a commercial office building or school located in a moderate climate zone.

[Figure 27](#) depicts the simulated hourly cooling and heating loads for a given thermal area, during the month of March, in a commercial office building located in Boston, Massachusetts.

**Figure 27. Simulated example of thermal area switchover**




This thermal area requests to operate in Cool Mode on the first day of June and does not request to switch over to Heat Mode again until the last week of September. However, in the month of March, the outdoor dry-bulb temperature (green dashed line) ranges between 20°F and 35°F during the night (when the building is unoccupied) and between 35°F and 75°F during the day (when the building is occupied). The blue (cooling load) and red (heating load) lines depict the sum of loads for the terminal units in this thermal area. The terminal units are not equipped with airside economizing, and the zones in this area are served by a DOAS that operates during occupied hours.

For the vast majority of the days in March, this thermal area requires Heat Mode overnight, switches to Cool Mode by mid-day, and then switches back to Heat Mode late at night. For example:

- At 7:00 PM on March 5, several terminal units request Heat Mode (controlling to their Unoccupied Heating Setpoints), while the remaining units are satisfied (zone temperature is within the Unoccupied Deadband). The system-level controller directs the corresponding Hydronic Branch Conductor to send hot water to this thermal area, and for those zones that need heat the terminal unit controller modulates its control valve open to warm the space.
- At 6:00 AM on March 6, the building transitions to Occupied Mode, and the individual zones in this thermal area begin warming up to their Occupied Heating Setpoints. This results in an increased demand for heating. The Conductor was already in Heat Mode, so no switchover is necessary.

- At 11:00 AM, the zones in this thermal area have become occupied with people and internal cooling loads increase. Some of the zones request a switch to Cool Mode and the system-level controller directs the Conductor to switch over and send chilled water to this thermal area.
- At 7:00 PM on March 6, the temperatures in the zones begins to drop below the Unoccupied Heating Setpoint, and the system-level controller directs the Conductor to switch over and send hot water to this thermal area.

For this example office building, even during the most variable time of year, the duration between switching over between Cool Mode and Heat Mode (or vice versa) was rarely less than eight hours for this thermal area. For most buildings, the time between switching over between modes is not expected to be less than four hours.

**Reducing switch over between Heat Mode and Cool Mode in existing building zones**

Using hydronic terminal units and centralized hydronic heat pumps can help reduce the risk of frequent switchover between cooling and heating.

Today's fan-coil units can be specified with modulating valve control. Pre-packaged unit controls also include the option for single-zone VAV control, which makes use of a variable-speed fan, a modulating hydronic valve, and discharge-air temperature (DAT) control. SZVAV control is less likely to overshoot heating or cooling setpoints compared to cycling DX or two-position valve control with staged fans. Modulating hydronic valve control prevents discharging air that is too cold or too hot, and this is especially true in Heat Mode since most zones rarely need more that 25 percent of design heating capacity. DAT control also improves occupant comfort and reduces the risk of occupants regularly adjusting temperature setpoints.

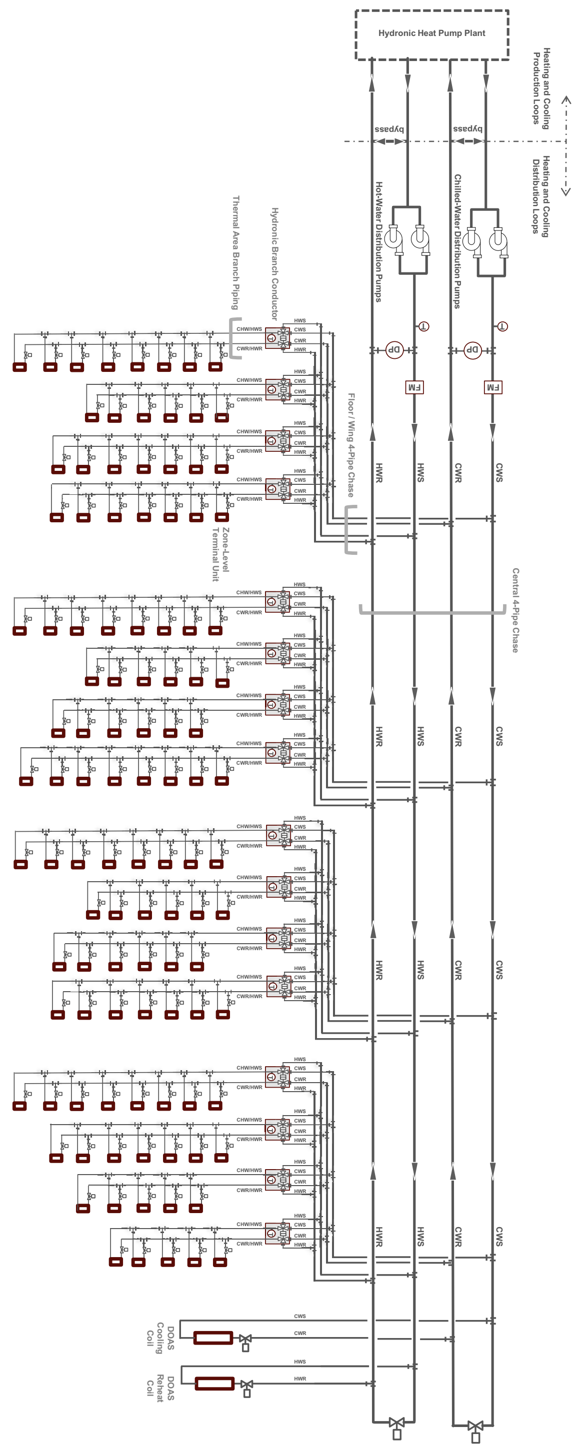
In contrast, VRF terminals have modulating control, but do not use DAT control. Modulation of refrigerant flow to the zone terminal is primarily intended to maintain refrigerant conditions, and can result in very hot air in Heat Mode or very cold air in Cool Mode. This can result in more frequent switchover between cooling and heating modes.

# Distribution System Design

This section discusses how to design specific elements of a distributed hydronic system with Hydronic Branch Conductors (Figure 28).

> This is a sample diagram to show placement of the distribution control valves; all other valves (isolation, balancing, shut off, etc.), reducers, drains, and strainers are not shown, but may be needed per project requirements.

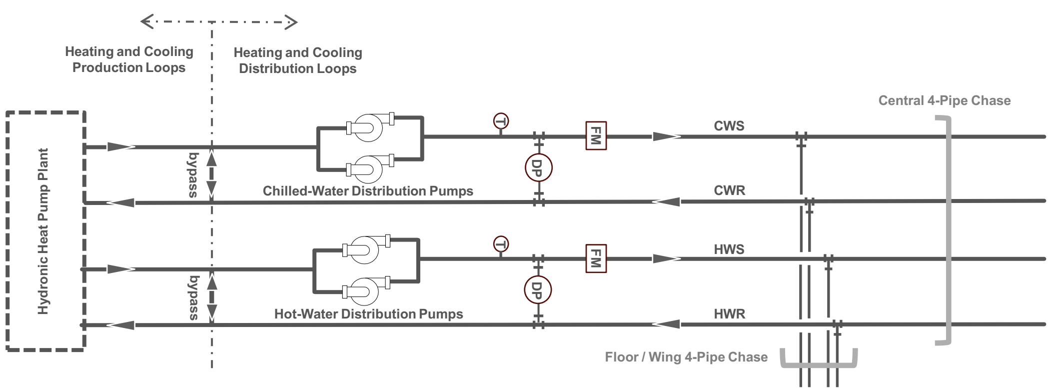
**Figure 28. Sample piping diagram for a distributed heating and cooling system with Hydronic Branch Conductors**



## CENTRAL PLANT AND CENTRAL PIPING CHASE

Hydronic Branch Conductors are used in a distributed hydronic heating and cooling system that has a central plant consisting of heat pumps. Heat pump plants require a decoupled distribution system. The hot-water and chilled-water distribution loops will each have dedicated pumps to circulate the hot water and chilled water to-and-from the zone-level terminal units. Each set of distribution pumps are controlled based on the measured differential pressure (DP) between the corresponding supply and return pipes (Figure 29).

**Figure 29. Distribution pumps and central four-pipe chase piping**



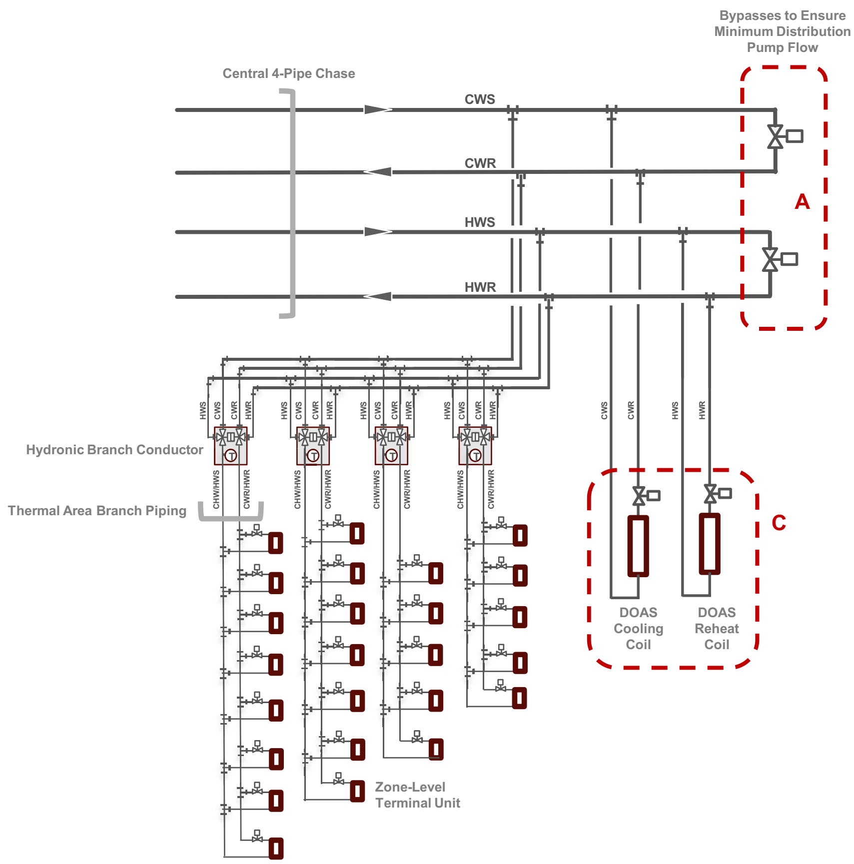

Central chase piping for systems that use Hydronic Branch Conductors does not vary much from traditional four-pipe distribution designs. There are two supply pipes (CWS and HWS) and two return pipes (CWR and HWR) to transport chilled water and hot water to-and-from the central plant. Each floor or wing of the building will have connections to these four pipes to transport these fluids to that part of the building (Figure 29).

**Bypass to ensure minimum distribution pump flow.** Distribution pumps have a minimum flow rate, which limits how much the pumps can be turned down.

In a system with dual-purpose coils, a bypass is needed in the central chase piping to ensure minimum hot-water distribution pump flow and another bypass is needed to ensure minimum chilled-water distribution pump flow. In this sample diagram, these bypass pipes are shown at the end of the central chase pipes (labeled A in Figure 30). However, they can be located elsewhere in the central chase piping, as long as they are located on the central plant side of the Hydronic Branch Conductors. Locating them immediately downstream of the distribution pumps is discouraged, as this may result in unstable control.

In a system without dual-purpose coils, some designers choose to use a three-way control valve on a few terminal units as a means of ensuring the required minimum distribution pump flow. However, in a system with Hydronic Branch Conductors, a three-way control valve should NOT be used at the end of each branch run, since that bypass flow would only apply the Conductor's current operating mode (Heat Mode or Cool Mode) and would not help ensure the required minimum distribution pump flow for the pump(s) associated with the apposite operating mode.

**Figure 30. Minimum flow bypasses for distribution pumps**



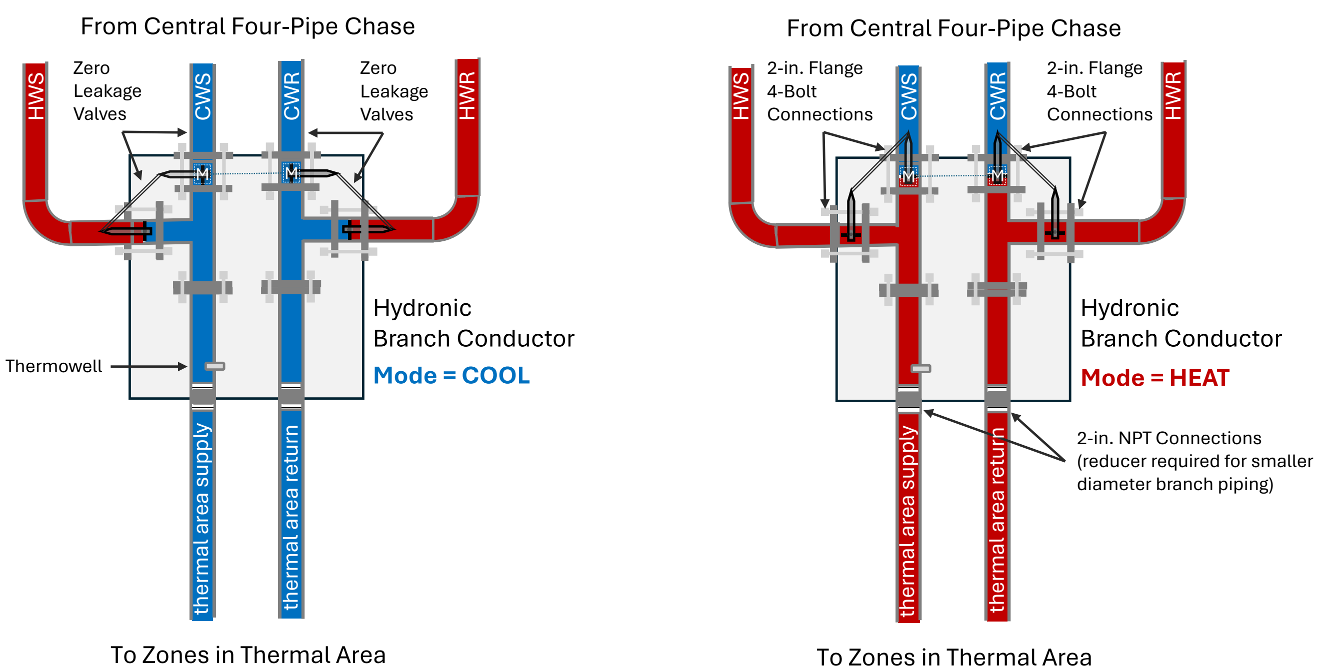

## HYDRONIC BRANCH CONDUCTOR VALVES AND PIPING CONNECTIONS

The type of valves used in the Hydronic Branch Conductor is very important. These valves must fully shut off unwanted flow, while allowing the desired flow to pass through. Zero-leakage valves are needed in all four pipes from the central chase (Figure 31). This is different than the three-way bypass valves that are commonly used in hydronic systems. Three-way bypass valves may have zero leakage for the fluid inlet path, to shut off flow in one direction, but the bypass path may leak up to two percent. In conventional systems, leakage through the bypass path is inconsequential to system performance.

The valves in the Trane Hydronic Branch Conductor, however, are used to divert and isolate the two flows. The assembly uses four commercial-grade, zero-leakage butterfly valves. The supply piping has two, two-way butterfly valves, one in the chilled-water supply (CWS or First Supply) pipe and one in the hot-water supply (HWS or Second Supply) pipe. They are arranged in a tee configuration and mechanically cross-linked to ensure proper supply flow orientation. The return piping has two, two-way butterfly valves, one in the chilled-water return (CWR or First Return) pipe and one in the hot-water return (HWR or Second Return) pipe. They are also arranged in tee configuration and mechanically cross-linked to ensure proper return flow orientation. The corresponding supply and return butterfly valve actuators are electronically linked by the unit controller on the Hydronic Branch Conductor.

When opened, a butterfly valve has a low pressure drop (high $C_v$ value). When fully open at nominal flow rate, the pressure drop is less than 1 ft. $H_2O$, so these valves have minimal impact on pump sizing and pump power.

**Figure 31. Hydronic Branch Conductor valves and piping connections**




A Hydronic Branch Conductor is installed between the central chase piping and the branch piping. For most buildings, this is typically where the hydronic distribution system will change from flanged pipe connections to threaded connections.

Therefore, the Trane Hydronic Branch Conductor includes flanged connections for the four incoming pipes from the central chase, and threaded connections for the two pipes serving the branch or thermal area (Figure 31). The typical diameter of most branch piping is 2 in., so the Trane Hydronic Branch Conductor has 2-in. connections for all six pipes. Branch piping of this diameter (2 in.) can serve a thermal area with a nominal cooling capacity of up to about 30 tons at nominal flow rate (see table in Figure 10). This capacity would typically correspond to a relatively large portion of the building being grouped into a single thermal area, so most thermal areas are likely to be less than 30 tons.

If a thermal area requires a design cooling capacity of less than 10 tons, 1.5-in. diameter branch piping might be sufficient. In this case, a 2-in. to 1.5-in. reducer will need to be installed to connect the Hydronic Branch Conductor to the branch supply and return piping.

*Why not use smaller valves in the Conductor?*

Commercial-grade, zero-leakage butterfly valves are not manufactured any smaller than 2-in. diameter. The valves used in the Trane Hydronic Branch Conductor have a 200 psig (460 ft. $H_2O$) shutoff pressure rating, which should be more than adequate for most buildings when the Conductors are installed close to the central chase piping. In contrast, 1.5-in. diameter valves are designed for zone piping, and typically have a much lower shutoff pressure rating, in the range of 50 psig (115 ft. $H_2O$). Therefore, if the design flow rate for a thermal area is relatively low, and 1.5-in. branch piping is to be used, the Hydronic Branch Conductor will still contain 2-in. valves, since the location of the Conductor (shutoff pressure requirement when installed close to central chase piping) dictates the valve size. For more details and the latest product data, see the Trane Hydronic Branch Conductor product catalog (TD-PRC007*-EN).

## BRANCH AND ZONE PIPING

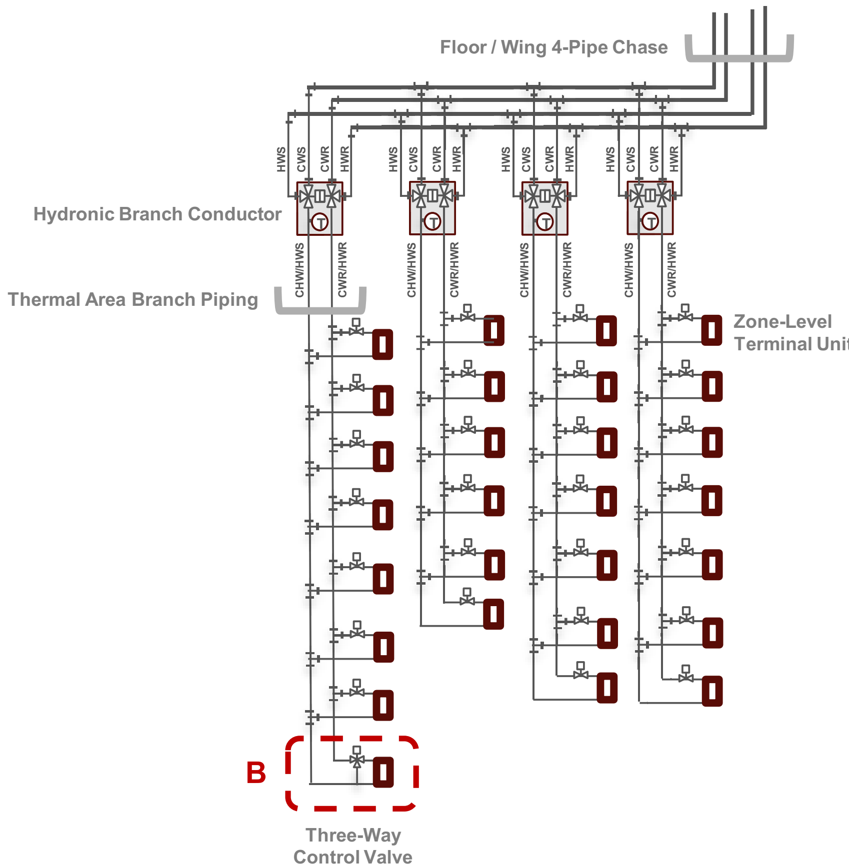
For each thermal area, a Hydronic Branch Conductor connects to the four pipes in the central (or floor/wing) chase (chilled-water supply, hot-water supply, chilled-water return, and hot-water return), and also to the two branch pipes: supply (CWS/HWS) and return (CWR/HWR). Each zone-level terminal unit (fan-coil, fan terminal, blower coil, unit ventilator, single-zone VAV AHU, CoolSense™ terminal, etc.) is equipped with a single dual-purpose coil and a single two-way control valve.

In most zone-level equipment, a modulating control valve will be used for capacity control, since most of today's terminal equipment uses continuous fan operation and/or discharge-air temperature (DAT) control. But some equipment might use two-position (open/closed) valves for capacity control.

The terminal unit's controller periodically pulse the control valve open to measure the temperature of the entering fluid, via a unit-mounted water temperature sensor, and determine if either chilled water or hot water is currently available, see "Unit-level control,"(p. 38).

For longer branch piping runs, in which the thermal area is expected to switch over between Cool Mode and Heat Mode often during the same day, consider installing a three-way control valve (labeled B in Figure 32) on the terminal unit at the end of the branch piping run. This will result in a small amount of flow through the branch piping, reducing the time for the auto-sampling sequence by the terminal units. Note that this valve is not used to ensure minimum distribution pump flow (see “Bypass to ensure minimum distribution pump flow,” p. 44).

Figure 32. Branch (thermal area) and zone piping




## EQUIPMENT WITHOUT A DUAL-PURPOSE COIL

Terminal units connected downstream of a Hydronic Branch Conductor must be equipped with a dual-purpose coil. However, traditional four-pipe equipment, with separate chilled-water and hot-water coils, can still be used in the building.

In this sample piping diagram, the zone-level terminal units are equipped with dual-purpose coils, while the dedicated outdoor-air unit contains separate chilled-water cooling and hot-water reheat coils. In this case, the DOAS coils (labeled C in Figure 30) are connected to the central chase (or floor/wing) piping, without a Hydronic Branch Conductor.

Another common example might be a K-12 school, where terminal units serving the classrooms are equipped with dual-purpose coils, while the gymnasium, theater, and cafeteria are served by larger, four-pipe air-handling units that contain separate chilled-water and hot-water coils.

# Resources


[1] ASHRAE Standard 62.1-2022. *Ventilation for Acceptable Indoor Air Quality*. Atlanta, GA: ASHRAE. 2022

[2] BSR/ASHRAE/IESNA Standard 90.1-2022. *Energy Standard for Buildings Except Low-Rise Residential Buildings.* Atlanta, GA: ASHRAE. 2022A

[3] Murphy, J. and D. O'Brien. *Chilled-Water Terminal Systems* application manual. SYS-APM010*-EN. La Crosse, WI: Trane. 2020.

[4] Trane. *Hydronic Branch Conductor* product catalog. TD-PRC007*-EN. La Crosse, WI: Trane. 2024.

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