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HVAC system designer

ENGINEERS
NEWSLETTER

Volume 55-3 // May 2026

Hydronic System Loop Volume

A common question when designing a hydronic system is how much loop volume is required. Minimum loop volume recommendations exist to give equipment controls sufficient time to react to changes in the system load or available capacity and keep the system fluid temperature within an acceptable range. The more fluid volume in a loop, the less these changes impact the loop temperature.

Typically, more loop volume is better, but there are cost and space considerations when increasing loop volume. This usually leads the engineer to design for the minimum recommended loop volume to maintain the desired loop temperature and avoid excessive equipment cycling. This Engineers Newsletter will dive into how equipment and loop types, loads, and critical setpoints affect minimum loop volume recommendations.

The total volume of fluid in a hydronic system loop includes the volume in the coil, pipes, chiller, or storage tanks that are always "active" in that loop. A component is "active" if it is not isolated from the loop during certain operating modes or load conditions.

Fluid volume in a coil or chiller can be obtained from the manufacturer, while Table 1 can be used to estimate fluid volume in piping by multiplying the length of each pipe size by the corresponding gallons-per-foot value.

Table 1. Pipe volume per linear foot

Pipe Diameter (in)	Volume (gallons/ft)
1	0.04
1-1/2	0.12
2	0.17
3	0.38
4	0.66
6	1.50
8	2.60
10	4.10
12	5.81
16	7.03

When BTUs are added to or removed from a loop, the fluid temperature changes. This temperature change is directly related to the amount of fluid in the loop. For example, if the loop contains water:

$$\Delta\text{Temperature} = \frac{\Delta\text{BTU}}{\text{lbs of Water} \times 1\,\frac{\text{BTU}}{\text{lb°F}}}$$

During steady-state operation, chiller or heat pump controls modulate capacity to match the current cooling or heating load. This keeps the loop temperature steady (ΔT = 0°F). However, operation is not always at steady state. If the load changes faster than the controls are able to modulate capacity, or if available system capacity is temporarily impacted, then the loop temperature will deviate.

For example, in a chilled-fluid loop with lower loop volume, a small reduction in cooling load results in a significant increase in the temperature of the fluid returning to the chiller. This satisfies the chiller's differential-to-start requirement and the chiller turns on to lower the fluid temperature back to the desired setpoint. Because the loop volume is small, however, the loop temperature reaches this setpoint quickly and the differential-to-stop shuts the chiller off again. This cycle continues repeatedly (Figure 1 and Figure 2). If this happens faster that the compressor's minimum on/off time limit between starts and stops, the loop temperature will drift farther from the setpoint between cycles.

Figure 1. On/off compressor in a system with lower loop volume

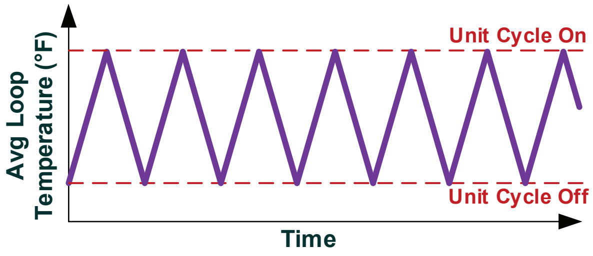
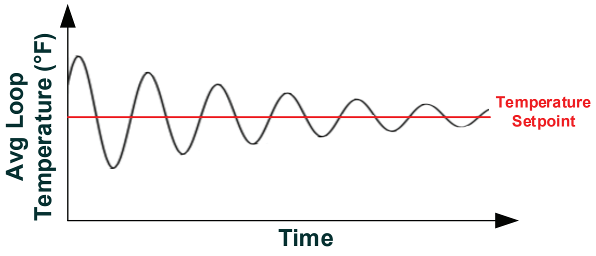


Figure 2. Continuous unloading compressor in a system with lower loop volume



If the system has a higher loop volume, a takes longer for the temperature of the fluid returning to the chiller to reach the differential-to-start and turn on the chiller. And it takes longer for the fluid to cool down and cause the chiller to turn back off again. The result is less equipment cycling (Figure 3 and Figure 4)

In general, more loop volume is better. If a system has insufficient volume, a buffer tank may be installed to increase the total fluid volume.

To make loop volume recommendations easier to apply across systems with varying fluid flow rates, loop volume is measured by minutes of loop time. If you imagine following a drop of fluid as it flows through the system depicted in Figure 5, the time it takes to move from point A to point B is the loop time. This represents the time (expressed in minutes) it takes for the fluid to leave the chiller or heat pump, move through the system to the load, and return to the unit.

Loop time is calculated by dividing the total gallons of fluid in the loop by the design fluid flow rate (in gallons/minute). For example, a system with 4,000 gallons (15,141 Liters) of water and a design flow rate of 1,000 gallons (3,785 Liters) per minute has a loop time of 4 minutes.

$$\text{Loop Time (Minutes)} = \frac{\text{Loop Volume (Gallons)}}{\text{Loop Design Flow Rate (GPM)}}$$

Manufacturers' product catalogs typically list the recommended minimum loop time for specific equipment, but many system applications have additional variables to consider. There is no one-size-fits-all solution, and ultimately, the loop volume is for the design engineer to decide.

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Figure 3. On/off compressor in a system with higher loop volume

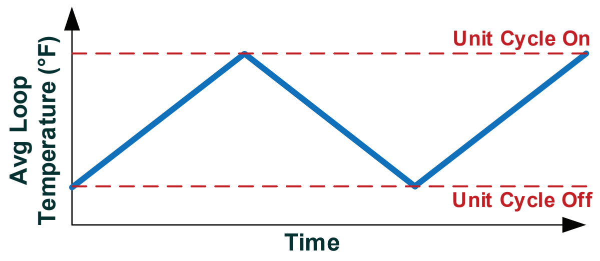


Figure 4. Continuous unloading compressor in a system with higher loop volume

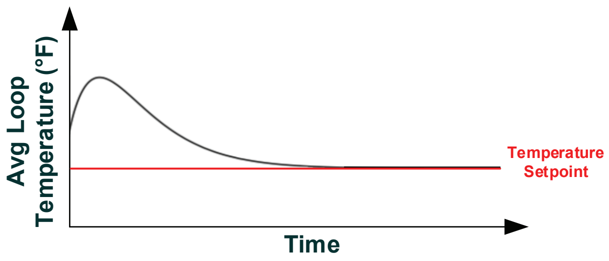
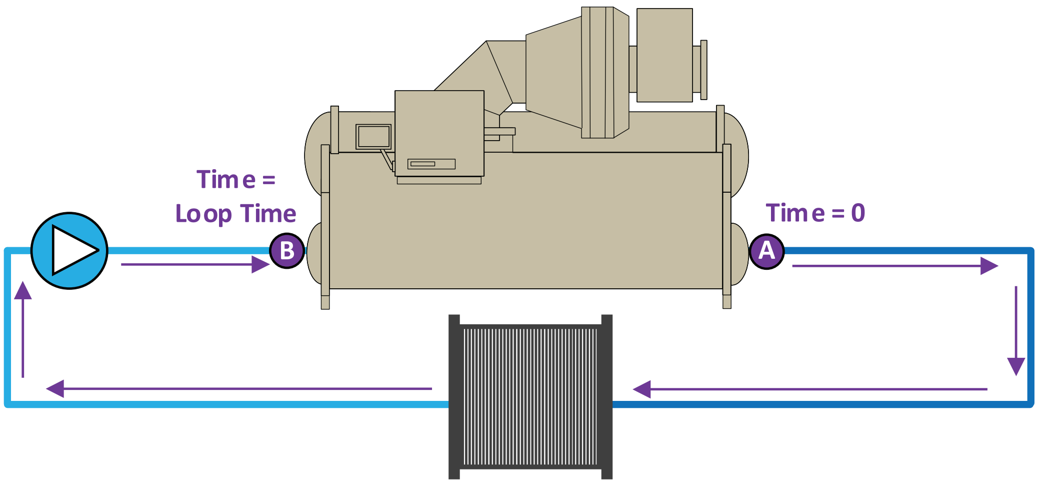


Figure 5. Path of a drop of fluid (depiction of loop time)



Key Considerations for Loop Volume

1. Temperature regulation

If an application requires a constant, tightly-controlled fluid supply temperature, such as a healthcare or process application, more loop volume may be required.

2. Load stability

A load that varies dramatically results in greater changes to the fluid loop temperatures than a steady, constant load. Therefore, variable loads require more loop volume than stable loads. Examples include spaces with highly-variable occupancy or industrial process loads.

3. Number and type of compressors

A system with fewer compressors should have more loop volume (longer loop time). When there are fewer total compressors, cycling a single compressor on or off has a greater impact on the fluid supply temperature.

Compressor types vary in their capacity control capabilities. Many scroll compressors vary capacity by staging on and off, each with a timer between starts and stops (Figure 6). Consider a chiller with two scroll compressors. When the cooling load decreases and the fluid temperature drops, one compressor is staged off. That compressor remains off until the fluid temperature rises (indicating that more capacity is needed) and the on/off timer expires. If the load increases and calls for more capacity before the timer has expired, the compressor remains off and the supply fluid temperature will drift away from setpoint until the compressor is allowed to turn back on. Some scroll compressors are equipped with variable frequency drives (VFDs), which control the speed of the orbiting scroll and allow more precise capacity control (Figure 7).

Screw and centrifugal compressors can modulate capacity whether or not a VFD is used. In a screw compressor, capacity is controlled using a slide valve to adjust the total volume of the compression cavity, or a VFD to vary the rotational speed of the rotors. In a centrifugal compressor, capacity is controlled using inlet guide vanes to restrict refrigerant flow at part load, or a VFD to reduce impeller speed at part load and part lift conditions. Because these compressor types can continuously unload, they generally provide more stable temperature control compared to on/off compressor cycling.

4. Equipment and loop type

Recommendations for minimum loop time vary depending on the type of chiller or heat pump, unit controller response time, loop type, and system configuration.

Figure 6. Scroll compressor staging

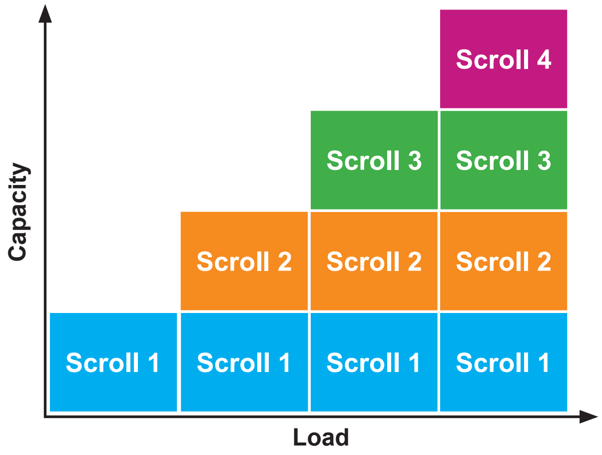
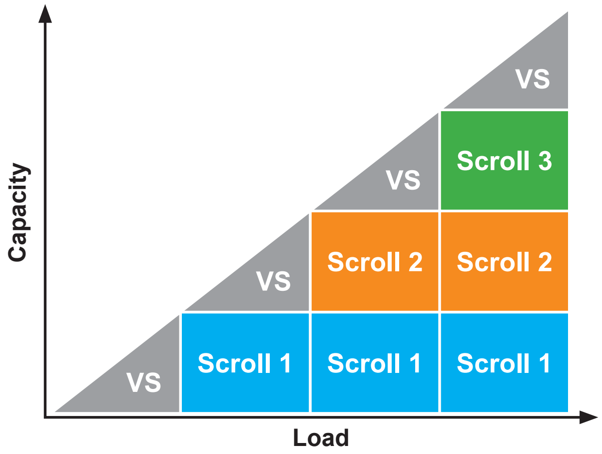


Figure 7. Scroll compressor staging with variable frequency drives



Chillers

In chiller plants, the main concern with insufficient loop volume is that changes in load may impact the loop temperature faster than the chiller controls can react. This can result in loss of temperature control and, in some cases, cause a chiller to trip off due to a low entering fluid temperature. Most chiller controllers have a response time of 2 to 3 minutes; therefore, this is the recommended minimum chilled fluid loop time for both air-cooled and water-cooled chillers.

For a water-cooled chiller, there are also cases where the condenser loop requires a minimum loop time. If controlling the leaving condenser fluid temperature to a setpoint, a minimum loop time of 2 to 3 minutes is recommended to maintain a stable temperature. It is also important to consider this loop volume when controlling head pressure. During low lift conditions, some method of head pressure control may be used to maintain the minimum differential pressure between the chiller evaporator and condenser. Common methods include:

- Increasing the entering condenser fluid temperature using a tower or chiller bypass valve
- Reducing the condenser flow rate using a throttling valve or a VFD on the condenser pump

During head pressure control, more loop volume takes longer to warm up, so locating head pressure control valves closer to the chiller reduces the time spent in head pressure control mode.

As mentioned in the “Key Considerations” section, additional loop time may be required to maintain a stable loop temperature, depending on the application.

Buffer Tank Location

In the chilled fluid loop, the buffer tank should be located upstream of the chiller evaporator in the chilled fluid return piping. This prevents fluid entering the chiller at a temperature below the minimum limit, which would result in the chiller turning off on alarm.

In the hot fluid loop, the buffer tank should be located upstream of the chiller condenser in the hot fluid return piping.

Modular Chillers and Water-to-Water Heat Pumps

Modular equipment is separated from traditional chillers in this discussion of loop volume because a bank of modules functions like multiple chillers with on/off compressors operating in parallel.

As mentioned earlier, on/off compressors adjust capacity by staging on and off and enforce a minimum time between stops and starts. Therefore, if the load changes immediately following staging a compressor on or off the response is delayed by this timer, resulting in less stable temperature control than with other compressor technologies.

Many modular chillers and heat pumps use a 5-minute timer. Therefore, for modular cooling-only chillers, heat recovery chillers, and water-to-water heat pumps, the recommended chilled and hot fluid loop time is 2 to 5 minutes. In general, modular chillers are able to supply a more consistent temperature, and do so with less compressor cycling, when loop times are longer.

A bank of modular chillers or heat pumps is comparable to multiple chillers operating in parallel. For this reason, the minimum loop time guidance discussed in the “Multiple Chiller Plant” section should be followed.

For a bank of 10 modules with a stable load profile and non-critical temperature setpoints, a loop volume of 2 minutes may suffice. But a bank of 3 modules with a variable load profile and critical temperature setpoints requires more loop time.

Buffer Tank Location

For modular chillers, heat recovery chillers, and water-to-water heat pumps, the recommended location of a buffer tank is the same as for traditional chillers: upstream of the evaporator in the chilled fluid return piping and upstream of the condenser in the hot fluid return piping.

Air-to-Water Heat Pumps

During cooling mode, the refrigeration cycle of an air-to-water heat pump is similar to that of an air-cooled chiller: an air-cooled condenser rejects heat to the ambient air and an evaporator source heat from the space cooling load. During heating mode, a refrigerant reversing valve (or a series of ball valves) changes which heat exchanger functions as the condenser and evaporator: the evaporator is now sourcing heat from the ambient air and the condenser is rejecting heat to the space heating load. Air-to-water heat pumps can be configured as either two-pipe or four-pipe units and can be piped for either two-pipe or four-pipe distribution.

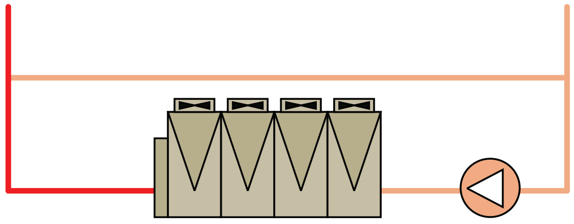
Air-to-water heat pumps with two-pipe distribution (Figure 8) are changeover systems, meaning there is one set of pipes to distribute either hot fluid or chilled fluid. Therefore, the heat pump cannot provide simultaneous heating and cooling. In a system with two-pipe changeover distribution, the loop volume must be based on the larger of the required heating or cooling loop volumes.

Additional valving and controls can allow multiple two-pipe units to work together to provide cooling, heating, or simultaneous heating and cooling with four-pipe distribution (Figure 9). In this system, there are two distribution loops: one for heating and one for cooling. For more information on this system configuration, refer to the Trane application guide, *Air-to-Water Heat Pump System with Cascade Option* (SYS-APG003*-EN).

Four-pipe, or multipipe, air-to-water heat pumps can provide cooling, heating, or simultaneous heating and cooling with one unit (Figure 10). These units have three heat exchangers: a chilled fluid coil, hot fluid coil, and a refrigerant-to-air heat exchanger. The chilled fluid coil serves the chilled fluid loop and the hot fluid coil serves the hot fluid loop. For more information on systems with modular four-pipe air-to-water heat pumps, refer to the Trane application guide, *Thermafit™ Modular (AXM/MAS) Air-to-Water Heat Pump System* (APP-APG021*-EN).

Figure 8. Two-pipe air-to-water heat pump piped in two-pipe distribution

Heating mode



Cooling mode

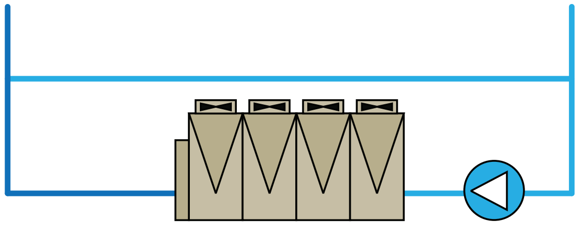


Figure 9. Multiple two-pipe air-to-water heat pumps piped in four-pipe distribution

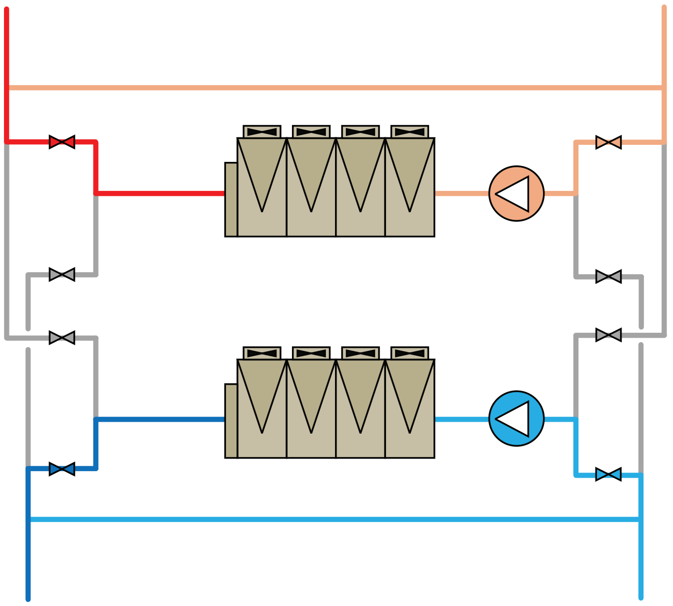


Figure 10. Four-pipe air-to-water heat pump piped in four-pipe distribution

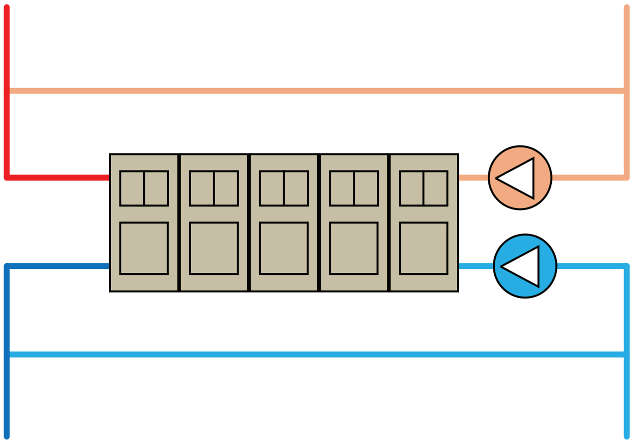
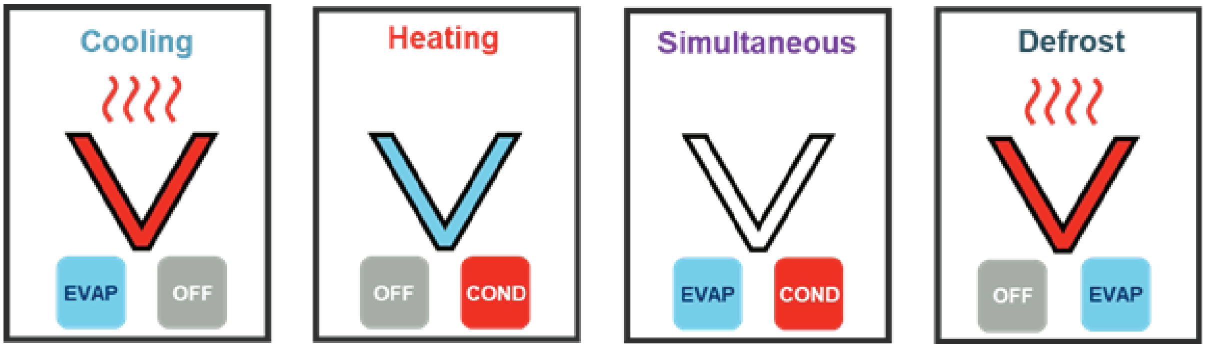


Figure 11 depicts the following modes of operation for a modular multipipe air-to-water heat pump:

- Cooling mode: The chilled fluid coil is on and heat is rejected to the ambient air via the refrigerant-to-air heat exchanger.
- Heating mode: The hot fluid coil is on and the refrigerant-to-air heat exchanger sources heat from the ambient air.
- Simultaneous mode: The refrigerant-to-air heat exchanger is off, and the chilled fluid coil sources heat for the hot fluid coil.
- Defrost mode: The heat is sourced from the hot fluid loop and rejected to the ambient air.

Figure 11. Modular Multipipe air-to-water heat pump modes of operation



Defrost Mode

While operating in heating mode, frost can accumulate on the refrigerant-to-air heat exchanger, which is sourcing heat from ambient air. This typically begins to occur at ambient temperatures of 47°F (8°C) and below when enough moisture is in the air. To melt this frost, the unit temporarily switches into defrost mode, which is a net cooling mode.

The defrost cycle typically lasts 5 to 10 minutes, depending on ambient conditions and equipment type. The unit does not operate at 100 percent cooling capacity while in defrost mode; instead it supplies hot water at a temperature that is cooler than design for the brief time that the unit is in defrost mode. For many comfort heating applications, this may not be a concern.

However, for applications where tight temperature control is needed, or where defrost cycles occur often due to ambient conditions, this temperature variation during defrost mode may be a concern.

With additional loop volume, the change in supply temperature has less impact on the overall loop temperature and can help prevent additional equipment from cycling on during defrost. If the heating loop time is longer than the defrost time, the heat pump entering fluid temperature is held constant throughout the defrost cycle (Figure 12). If the loop time is shorter than the defrost time (Figure 13), the fluid will pass through the heat pump a second time during defrost mode, further cooling down the fluid.

Figure 12. Defrost cycle with longer loop time

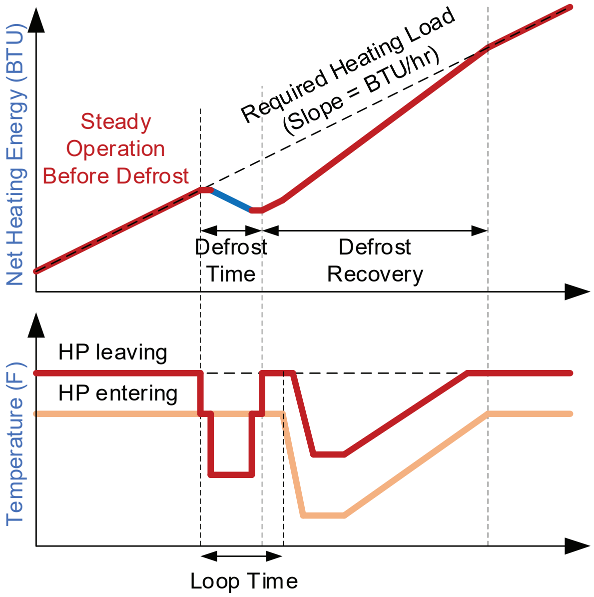
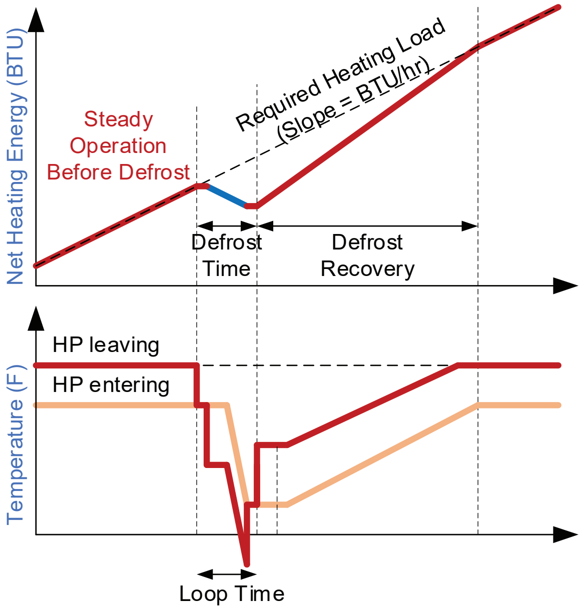


Figure 13. Defrost cycle with shorter loop time



A packaged, two-pipe heat pump (such as the Trane model ACX) contains a refrigerant reversing valve that switches the evaporator and condenser functions between modes. In this unit, a defrost cycle averages 4 to 7 minutes. Since this unit has two refrigeration circuits, only one circuit is allowed to defrost at a given time. In addition, systems with multiple air-to-water heat pumps can use a defrost delay control strategy to ensure that only one heat pump operates in defrost at a time. If one heat pump is already in defrost and another heat pump meets the conditions to enter defrost, the system controller delays the second unit from going into defrost mode, usually by 10 to 15 minutes. This gives the first air-to-water heat pump time to finish its defrost cycle and regain heating capacity before the other heat pump enters defrost, thereby limiting the effect on system fluid temperatures. As the number of air-to-water heat pumps in the plant increases, the less impact defrost cycles will have.

For air-to-water heat pumps, the recommendation is 2 to 3 minutes of loop volume for the chilled fluid loop and 4 to 10 minutes for the hot fluid loop. This longer loop time for the hot fluid loop is intended to mitigate the effects of defrost.

For a modular, four-pipe air-to-water heat pump (such as the Trane model MAS), a defrost cycle can last as long as 10 minutes. This is partly because it takes a few minutes for a module to switch modes, since it uses four ball valves instead of a refrigerant reversing valve. Also, only 50 percent of operating modules in a bank are allowed to go into defrost at a given time.

Four-pipe units do not use an outdoor heat exchanger to source heat during the simultaneous heating and cooling mode, so frost does not accumulate during this mode. If a four-pipe air-to-water heat pump spends little time in heating-only mode, it is less affected by defrost cycles and can reduce the hot fluid loop volume compared to a two-pipe air-to-water heat pump. Of course, if the load profile requires the four-pipe air-to-water heat pump to operate in heating-only mode often, then defrost will likely occur more frequently.

If the system includes supplemental heating, such as a boiler, this can help reduce the effects of defrost cycles, as long as the boiler is sized to make up for the loss of system heating capacity. When both the boiler and air-to-water heat pump are operating, and the air-to-water heat pump goes info defrost mode, the boiler can increase capacity so that the supply fluid temperature remains at the desired setpoint.

For more information on air-to-water heat pump system defrost cycles, refer to the Trane *Engineers Newsletter* “Heat Pump Considerations for Low Ambient Operation” (ADM-APN095-EN).

Buffer Tank Location

For an air-to-water heat pump, the recommended location of a buffer tank depends on the loop type.

With four-pipe distribution, the location of a chilled fluid buffer tank is the same as for traditional chillers: upstream of the air-to-water heat pump in the chilled fluid return piping. A hot fluid buffer tank should be located downstream of the heat pump in the hot fluid supply piping. This is to reduce the effects of defrost mode. When operating in defrost mode, the resulting cool fluid enters this buffer tank and mixes with hot fluid already inside the tank, therefore reducing fluctuation of the hot fluid supply temperature.

With two-pipe distribution, there is only one loop so only one buffer tank is needed. This buffer tank should be located based on which is the greatest concern for the specific project:

1. Upstream of the heat pump in the fluid return piping, if the main concern is to prevent too cold of fluid from entering the heat pump during cooling mode.

2. Downstream of the heat pump in the fluid supply piping, if the main concern is to minimize fluctuation of the hot fluid supply temperature during defrost mode.

Decoupled Systems

A common question when designing a decoupled system is whether to include both primary and secondary loops when calculating the system loop volume. In theory, as long as the pumps in both the primary and secondary loops are always operating whenever a chiller or heat pump is on, both loop volumes could be included in the total system loop volume, since heat is being transferred between the loops.

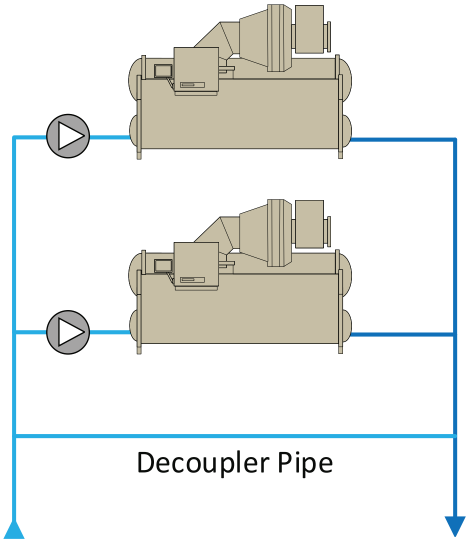
However, variables such as how the system is decoupled, load profiles, and chiller technology are important to consider when evaluating loop volume. In some scenarios, only the primary loop should be considered when calculating minimum loop volume.

In many cases, a good approach is to use a middle-ground option: ensure that the primary loop volume accounts for 50 percent of the total recommended loop volume and that the secondary loop accounts for at least the remaining 50 percent.

Primary-Secondary Decoupled

In primary-secondary decoupled systems, a decoupler pipe separates the primary and secondary loops (Figure 14). This section uses a decoupler in a chiller plant (chilled fluid loop) as an example, although the same principles apply to decouplers in other loop types.

Figure 14. Primary-secondary decoupled chiller plant



When the cooling load increases and the flow rate through the secondary loop is greater than the flow rate through the primary loop, chilled fluid flows from the return to the supply through the decoupler; this is called deficit flow. The chiller plant responds by turning on another chiller to prevent too much deficit flow. In this case, the entire system volume is active, meaning that one loop is not isolated from the other. Therefore, the entire system volume can be counted toward the recommended minimum loop volume, regardless of how it is distributed between the primary and secondary loops. However, if the system is small or has large loads that change quickly, the primary loop volume may need to be increased. For example, if a large load suddenly disappears in a primary-secondary system without a buffer tank, or if a buffer tank is located on the load side of the decoupler, a large amount of chilled fluid will flow from the supply to the return through the decoupler. This will quickly reduce the fluid temperature entering the chiller, possibly causing it to trip off.

When the cooling load decreases and the flow rate through the secondary loop is less than the flow rate through the primary loop, chilled fluid flows from the supply to the return through the decoupler; this is called surplus flow. As long as the amount of surplus flow remains reasonable, the secondary loop is still engaged, and the entire system volume can be counted toward the recommended minimum loop volume, regardless of how it is distributed between the primary and secondary loops. However, if a large percentage of the system flow becomes surplus flow, the primary loop no longer truly engages the secondary loop, and this can cause short cycling and supply temperature fluctuations if the primary loop has a small loop volume.

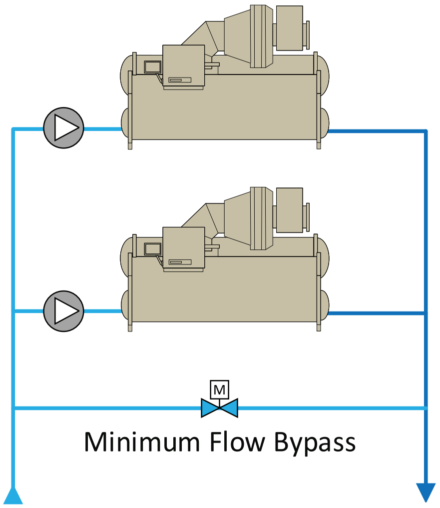
Consider the example of a low load scenario on a chiller with minimal flow turndown. In a modular chiller bank with two modules, the minimum allowable flow through the chiller is 50 percent of the design flow rate. If the building load decreases to 5 percent of design load, the majority of the flow will be surplus flow: 10 times more flow through the primary loop than through the secondary loop (90 percent of the system flow is surplus flow). If the primary loop time is only 1 minute, the chiller will quickly cool down the primary loop, resulting in the chiller shutting off and then cycling back on soon after. Or if the compressor has not operated for its minimum run time, the chiller will continue to overcool the loop until it trips off on a safety low limit. In this scenario, only the volume in the primary loop should be considered when calculating minimum loop volume.

If the chiller bank consists of 10 modules instead, the minimum flow rate through the chiller is only 10 percent of the design flow rate. At the same load condition, the primary loop flow would only be 2 times the secondary loop flow (only 50 percent of the system flow is surplus flow). This would still engage a reasonable amount of the secondary loop, so it would likely not cause excessive cycling, even if the primary loop time is less than the minimum recommended system loop time.

Variable Primary Flow Decoupled with Minimum Flow Bypass

Variable primary flow systems (Figure 15) have considerations similar to primary-secondary systems when it comes to minimum loop volume. Since variable primary flow systems are decoupled only when the bypass valve is open to maintain minimum flow through the operating chiller(s), the entire system volume is active whenever the system flow rate exceeds this chiller minimum flow requirement. But at low load conditions, when the system flow rate is less than the chiller minimum flow, the same cycling and safety shutoff concerns apply, so a higher primary loop volume should be considered.

Figure 15. Variable primary flow chiller plant



Decoupled with Heat Exchangers

In some systems, chillers are decoupled from the distribution system using an isolation heat exchanger. This is often done to isolate glycol in the primary loop from water in the secondary loop, or to maintain primary loop water quality when used with an open secondary loop. Variables that may make it advisable to ensure a minimum loop volume on the chiller/heat pump side of the heat exchanger include:

1. Heat exchanger control valve speed
2. Chiller unloading capabilities (on/off scroll versus screw or centrifugal, for example)
3. Low load operation

Of these, low load operation has the most impact on the loop volume decision.

Ensuring a minimum loop volume on the primary side of the heat exchanger helps prevent excessive cycling. For example, if the primary loop time is 1 minute, the chiller will rapidly cool the fluid on the primary side of the heat exchanger. At low loads, this overcooled fluid will quickly meet the temperature setpoint of the secondary loop, causing the control valve on the heat exchanger to close and stop heat transfer between the loops. The chiller will then cycle off, only to turn on again soon after. If the compressor has a 5 minute minimum run time, it will continue to overcool the primary loop, and because it has such a small volume, the fluid temperature may get cold enough to cause the chiller to trip off on a safety low limit.

Ensuring a higher loop volume on the primary side of the heat exchanger is advised if the equipment has on/off compressors, a fast-acting control valve on the isolation heat exchanger, and a high likelihood of low load operation. However, if the equipment does not have on/off compressors, a slow-responding control valve is used on the heat exchanger, and low load operation is not expected, then the loop volume on the primary side is less of a concern than the overall system volume.

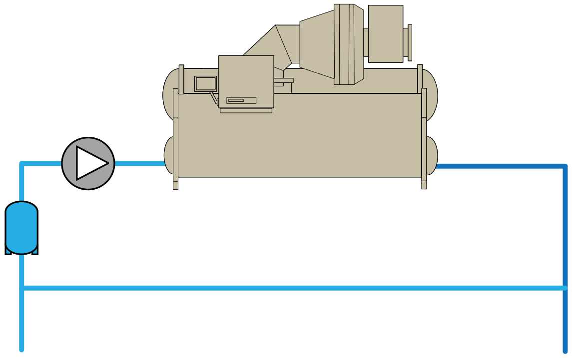
Buffer Tank Location

In systems with a decoupler pipe or a minimum flow bypass, the recommended location of a buffer tank is between the equipment and the decoupler or bypass.

For an air-to-water heat pump, the hot fluid buffer tank should be located downstream of the heat pump in the hot fluid supply piping upstream of the decoupler.

For a chiller, the chilled fluid buffer tank should be located upstream of the chiller in the chilled fluid return downstream of the decoupler (Figure 16). This location reduces the impact of any sudden temperature changes caused by excess fluid flowing through the bypass, particularly if the system is small or has large loads that change quickly.

Figure 16. Chilled fluid loop buffer tank upstream of chiller and downstream of decoupler



Hydronic Cascade Intermediate Loops

In a hydronic cascade system, there is an additional loop besides the chilled fluid and hot fluid distribution loops: the intermediate loop. This system configuration combines a low-temperature unit with a high-temperature booster unit to efficiently increase overall system lift and provide high-temperature hot fluid for distribution. The condenser of the low-temperature unit connects to the evaporator of the high-temperature unit, forming this intermediate loop (shown in green in Figure 17).

These two units do not directly coordinate their capacity control, so temperatures can swing quickly if there is not enough volume in this intermediate loop. It is crucial that the leaving condenser temperature of the low-temperature unit remains within the evaporator entering temperature limits of the booster unit, and that the leaving evaporator temperature from the booster unit remains within the condenser entering temperature limits of the low-temperature unit. The overlap between the low-temperature unit's minimum and maximum condenser temperatures and the booster unit's minimum and maximum evaporator temperatures is the acceptable temperature range for the intermediate loop. This overlap should be more than a few degrees to allow for mismatches in load, but is usually not a wide temperature range.

Because maintaining an acceptable intermediate loop temperature is critical, the recommended minimum loop time for the intermediate loop should match with the equipment type. For example, if the low-temperature unit and booster unit are both water-to-water heat pumps with screw compressors, 2 to 3 minutes is the recommended minimum loop time. If the low-temperature unit is a modular air-to-water heat pump, 4 to 10 minutes is the recommended minimum loop time.

For more information on cascade systems, refer to the Trane *Engineers Newsletter Live* video "High Temperature Heating Solutions" (APP-CMC099-EN).

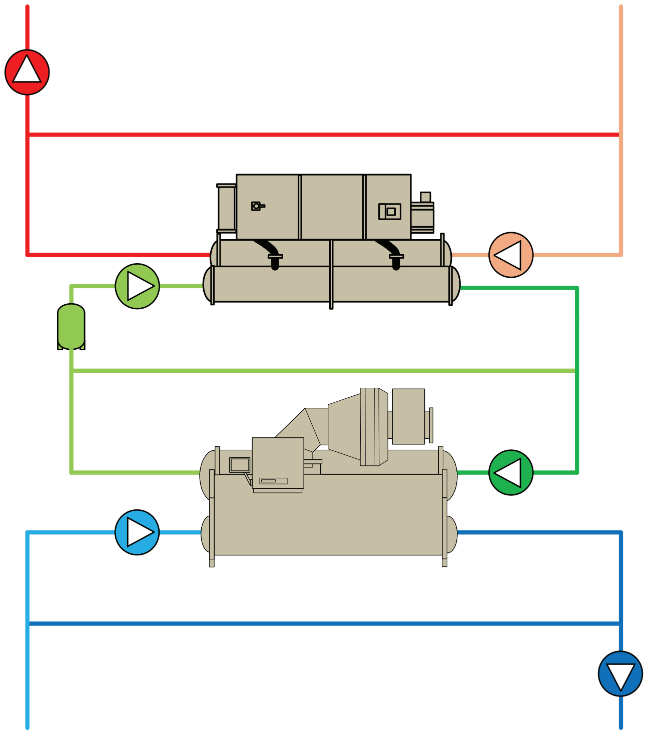
Buffer Tank Location

One major benefit of a hydronic cascade system is its flexibility, since various types of equipment can be used as either the booster or low-temperature unit. However, the location of the buffer tank in the intermediate loop depends on the equipment type selected.

In a cascade system that uses an air-to-water heat pump as the low-temperature unit, the intermediate loop buffer tank should be located downstream (supply side) of the air-to-water heat pump, to reduce the impact of defrost mode.

In a cascade system that uses a water-to-water heat pump as the low-temperature unit, the intermediate loop buffer tank should be located upstream (return side) of whichever unit is more sensitive to changes in temperature and flow. For example, if the low-temperature unit is operating at its maximum leaving condenser temperature, the intermediate loop buffer tank should be located upstream (return side) of the low-temperature unit. Oftentimes, the booster unit operates at very high-lift conditions, so maintaining a more consistent evaporator condition for the booster unit is prioritized. In this case, the intermediate loop buffer tank should be located upstream (return side) of the booster unit (Figure 17).

Figure 17. Cascade system with buffer tank on inlet of booster unit



Multiple Chiller Plant

Having multiple chillers installed together in parallel does not change the recommended minimum loop time for a given chiller, but it does impact the minimum loop volume for the system. If all chillers in the plant are operating, more system volume is required to maintain the same loop time for each chiller. A conservative approach is to use the sum of the chillers' design flow rates (excluding redundant chillers) when calculating the minimum loop volume.

However, in a very large chiller plant, installing one or more buffer tanks large enough to meet the volume calculated using this conservative approach can be costly and require a large footprint. When many chillers operate in parallel, the number of compressors and the level of system turndown increase, such that a lower loop volume has less impact on the stability of the loop temperature. Therefore, as the number of chillers in the plant increases, it becomes less important to use the total system flow rate when calculating the required loop volume.

Summary

Ensuring that a hydronic system loop has sufficient fluid volume enables stable loop temperatures and avoids excessive equipment cycling. Recommendations vary based on equipment type, unloading capabilities, load variability, acceptable deviation from fluid temperature setpoints, number of compressors in the system, system configuration, and loop type. While ensuring a minimum loop time is an important consideration, this must be balanced with cost, space requirements, and application needs.

By Michelle Hull, applications engineer, Trane. You can find this and previous issues of the *Engineers Newsletter* at www.trane.com/EN. To comment, send e-mail to ENL@trane.com.

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