ClearAir® AW0350

Air-to-Water Heat Pump Application Guide

CleaverBrooks®

Product Overview

The ClearAir AW0350 is an air-to-water heat pump designed to provide hot water for hydronic heating systems. The AW0350 is a monobloc, self-contained unit intended for installation outdoors on a roof or at ground level. The unit features a steel base, frame and panel structure housing all major components, including the compressor, condenser, electronic expansion valve, evaporator coil and fans, receiver and accumulator tanks, refrigerant filter-drier, and a digital unit controller with a weather-protected touchscreen interface. Each unit is factory-charged with the proper amount of R-513A refrigerant.

The AW0350 is intended for use in closed-loop hydronic heating systems and can be applied in single-unit, multi-unit, or hybrid heat pump + boiler configurations.

Sequence of Operation

The ClearAir AW0350 heat pump uses a vapor compression cycle to absorb heat from outdoor air and release it to system water—raising its temperature for use in hydronic heating applications. The primary components involved in this process are show in **Figure 1**:

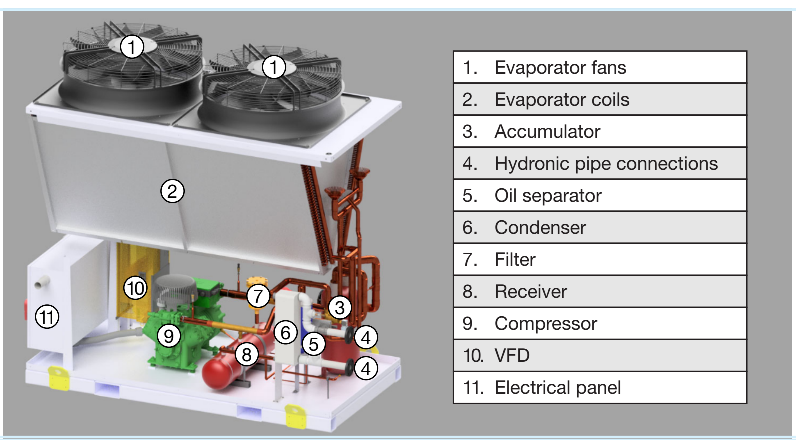


Figure 1: AW0350 Heat Pump Internals

The AW0350 has two operational modes: heating and defrost.

Heating Mode

In heating mode, low-pressure, refrigerant vapor enters the compressor, where its pressure and temperature are increased and then discharged to the condenser—a brazed plate refrigerant-to-water heat exchanger. High-pressure, high-temperature refrigerant vapor enters the condenser, where it condenses into a liquid and releases heat to the system water. High-pressure liquid refrigerant exits the condenser and enters the inlet of the electronic expansion valve. The expansion valve throttles and reduces the refrigerant pressure. Low-pressure liquid refrigerant exits the expansion valve and enters the evaporator coil, where it changes phase into a vapor, absorbing a significant amount of heat from the outdoor air. Fully evaporated and superheated refrigerant vapor exits the evaporator and returns to the compressor, where the cycle repeats until heating demand is satisfied.

The unit controller monitors outdoor air temperature, and entering and leaving water temperatures and sequences the heat pump's components to maintain a supply water temperature setpoint. The unit controller also monitors discharge and suction pressure and other system parameters and ensures the unit cycles the components safely, efficiently, and within their intended operating range. If any problems are detected, the control system takes appropriate action and displays the related fault message on the HMI display.

Defrost Mode

Under certain outdoor air conditions, frost may build up on the evaporator coil. Too much frost prevents effective heat transfer, negatively impacting performance and potentially damaging the unit. When frost conditions are detected, the unit enters a defrost mode. In defrost mode, a solenoid valve opens to bypass the high-pressure, high-temperature refrigerant vapor leaving the compressor into the inlet of the evaporator. Hot refrigerant vapor flowing through the evaporator coils melts the frost. Once the defrost cycle is completed, the solenoid valve closes, and the unit returns to heating mode.

During the defrost cycle, heating output is temporarily reduced as system operation is focused on melting frost rather than delivering heating. Capacity must be managed through system mass, staging, or supplemental heat. For this reason, system volume, multi-unit staging, or hybrid boiler integration are commonly used to maintain stable heating performance during defrost events.

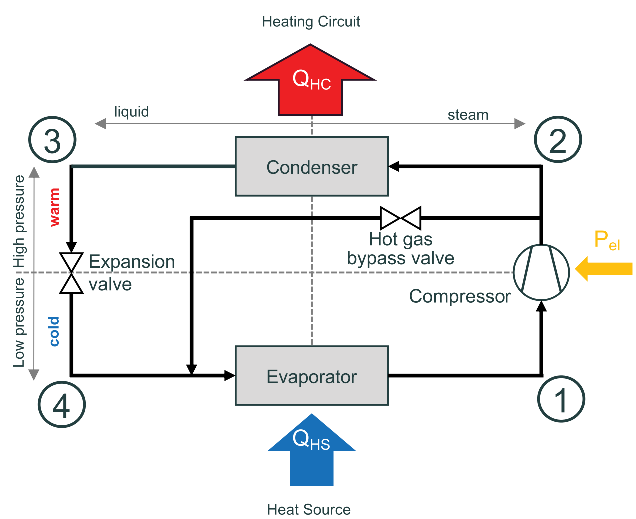


Figure 2: Air-to-Water Heat Pump Vapor Compression Cycle

Expected Performance

The charts below show the AW0350's heating capacity and Coefficient of Performance across a variety of conditions. These performance curves are based primarily on modeled data; select operating points have been validated through laboratory testing.

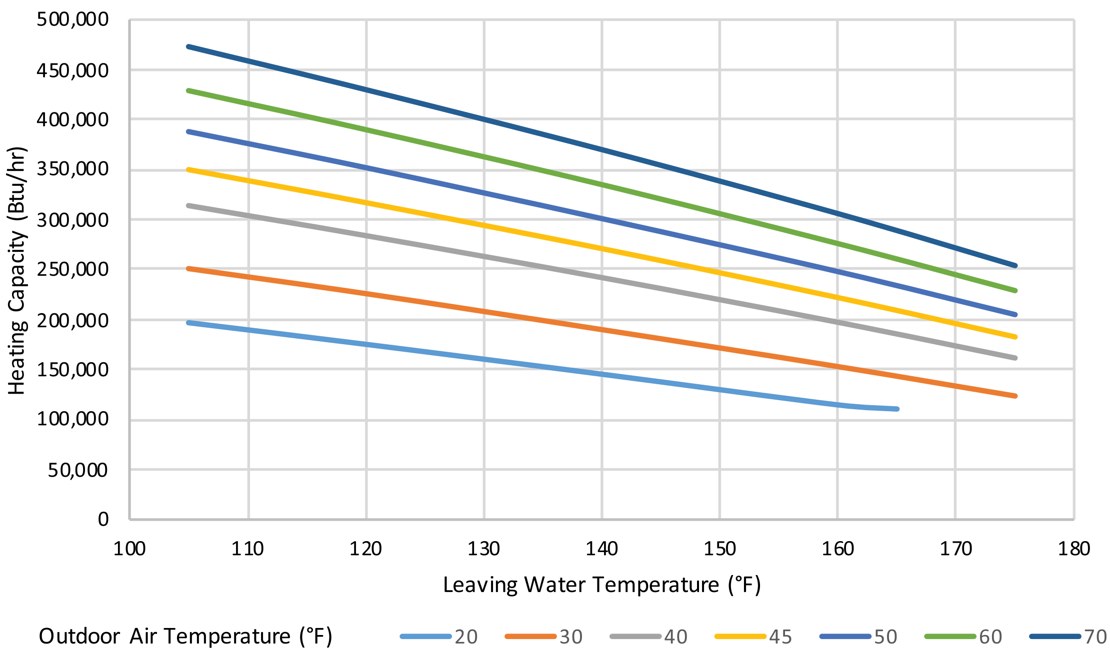


Figure 3: AW0350 Heating Capacity vs. Leaving Water Temperature

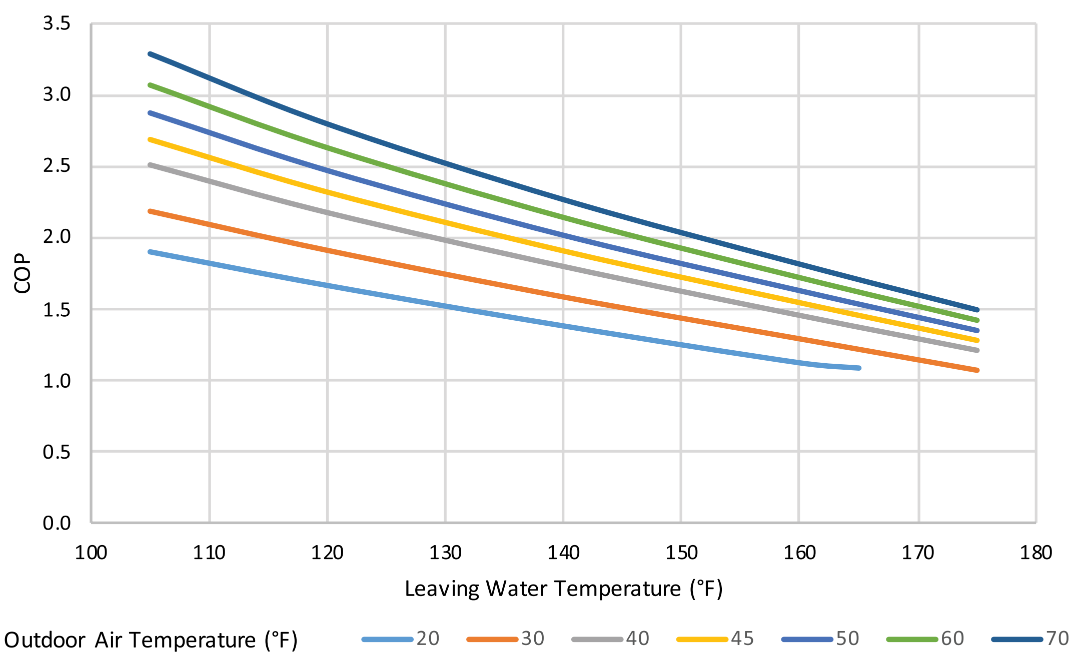


Figure 4: AW0350 COP vs. Leaving Water Temperature

System Design Configurations

The ClearAir AW0350 supports single unit, multi-unit, and hybrid heat pump + boiler system configurations.

Single Heat Pump Design

In a single heat pump design, one AW0350 serves the entire heating load. This configuration is best suited for small loads or mild climates. Consider the following:

» The heating load must not exceed the AW0350's rated capacity at all expected outdoor air temperatures (refer to **Figure 3**). The intended building (or process) must tolerate reduced or zero heat beyond the AW0350's rated capacity.

» A single unit design offers no redundancy.

Multiple Heat Pump Design

In a multiple heat pump design, a bank of two or more AW0350s serves the heating load. A multiple heat pump design overcomes the capacity and redundancy limitations of a single heat pump design. Consider the following:

» The heating load must not exceed the entire bank's rated capacity at all expected outdoor air temperatures (refer to expected performance shown in **Figure 3**). The intended building (or process) must tolerate reduced or zero heat beyond the bank's rated capacity.

» Sequencing may be handled by the unit controller or a dedicated system controller, depending on the number of units.

» Total bank capacity increases proportional to the number of AW0350 units. For example, with a bank of four AW0350s, the total bank capacity would be four times the capacity of a single AW0350. The performance rating chart still applies.

» Multiple heat pump design offers redundancy.

» Effective system turndown depends on the total number of heat pumps in the entire bank.

Hybrid Heat Pump + Boiler Design

In a hybrid design, one or more heat pumps are combined with one or more boilers. This is the preferred system design configuration for most applications. A hybrid design overcomes not only the capacity and redundancy limitations of a single heat pump design, but also the minimum outdoor air temperature limitations of both single and multiple heat pump designs.

In a hybrid heating system design, different parts of the heating load are assigned to the best-suited heat source. The AW0350 performs best (has enough capacity, operates with high COP) when:

» the outdoor air temperature is moderate.
» heating demand is below peak.
» run times are long and steady.
» leaving water temperatures are relatively low.

These conditions typically dominate the majority of annual heating hours. Operating the heat pump(s) during fall and spring, shoulder winter days, and daytime recovery periods provide highly efficient, reliable hydronic heating, and avoids over-cycling. Heat pumps typically result in significantly lower operational emissions than their boiler counterparts. Maximizing the heat pump's operational period results in minimizing the overall system's emissions.

Boilers are fundamentally well-suited for:

- high output over short durations
- very cold outdoor conditions
- high leaving water temperatures
- rapid load changes

When applied to a hybrid system, the boiler(s) are best suited to provide heating during the following important, but much rarer conditions:

- Periods of cold ambient, when outdoor air drops below the AW0350's operating limit of 20°F (-6.7°C).
- When building demand exceeds the heat pump capacity, for example during design days, morning warm-up, or extreme weather events.
- During the heat pump's defrost cycle, when heat pump operation is focused on melting frost versus providing heating.

Minimizing the boiler operation period to only when best suited minimizes the overall system's emissions.

Table 1 summarizes and compares the pros and cons of each supported system configuration type. Note: actual applicability depends on climate, load profile, and project requirements.

System Configuration	When to Use	Key Advantages	Key Tradeoffs
Single heat pump	» Small loads » Mild climates	» Lowest first cost » Simple piping » Minimal footprint	» Limited capacity » No redundancy » No turndown » Loss of heat below low ambient limit » Higher risk of cycling
Multiple heat pumps	» Medium to large loads » Mild climates » Need/preference for redundancy » Variable demand	» Capacity » Redundancy » Improved turndown	» Space » Loss of heat below low ambient limit » More complex piping
Hybrid heat pump + boiler	» Medium to large loads » Cold climates » Need/preference for redundancy » Variable demand	» Maximum flexibility » Ambient coverage » Excellent redundancy » Optimal heat pump runtime	» Space » Most complex piping » Sophisticated design

Table 1: System Configuration Comparison Guide

Selecting the System Design Type and Equipment

Heating Load Determination (Overview)

Selection and sizing of an air-to-water heat pump system begins with an accurate determination of the building or process heating load. Heating loads vary with outdoor air temperature and operating conditions and should be established by the engineer of record using accepted industry methods.

The ASHRAE Handbook—Fundamentals provides recommended winter design temperatures and climate data commonly used for HVAC load calculations. Final heating load values, including consideration of envelope losses, ventilation requirements, internal gains, and process loads, shall be determined by the project design team.

This application guide assumes that a design heating load and load profile are available and focuses on how to apply the ClearAir AW0350 heat pump once those values are known.

Select System Design Type and Size Accordingly

Compare the capacity profile (capacity at all expected outdoor air temperatures) of the AW0350 (refer to expected performance in **Figure 3**) with the heating load profile.

When to Select a Single Heat Pump

» Select a single AW0350 heat pump when the unit's capacity profile (capacity across all expected outdoor air temperatures) at the required leaving water temperatures meets or exceeds the building heating load profile.

» This configuration is best suited for:

  – Smaller heating loads
  – Mild climates
  – Applications where system redundancy is not required

When to Select Multiple Heat Pumps and How to Select the Number of Units

» If a single AW0350 heat pump can meet the heating load profile but N+1 redundancy is desired, select two AW0350 heat pumps.

» If a single AW0350 heat pump cannot meet the heating load profile, select the appropriate number of AW0350 heat pumps such that the aggregate capacity meets or exceeds the heating load profile.

» Add an additional heat pump when N+1 redundancy is required.

When to Select a Hybrid System and How to Size Equipment

» A hybrid heat pump + boiler system offers several advantages over a heat-pump-only system, as described earlier in this guide.

» Size the heat pump(s) to fully cover the heating load above approximately 20°F to 25°F (-6.7°F to -3.9°C) outdoor air temperature.

» Size the boiler(s) to fully cover the heating load below approximately 20°F to 25°F (-6.7°F to -3.9°C) outdoor air temperature.

» Add additional heat pumps or boilers as required when N+1 redundancy is desired.

Consider Cycling Limits and Adjust as Needed

The AW0350 heat pump allows a maximum of 6 cycles per hour. Short cycling risk increases with:

- » Oversized AWHP plant
- » Low system water volume
- » Mild outdoor temperatures

If short cycling is a concern, consider:

- » Selecting multiple smaller heat pumps, instead of one large plant
- » Adding a buffer tank
- » Widening the temperature deadband
- » Hybrid boiler integration

Pumping and System Volume

Pumping Configurations

The following are the key design goals for systems using AW0350 heat pumps:

- » Maintain minimum flow through each heat pump (and boiler, if hybrid).
- » Prevent flow collapse when units stage off.
- » Avoid dead-heading pumps.

As such, the following pump configurations are acceptable for the AW0350 heat pump system:

- » Primary-only pumping
- » Variable primary flow
- » Constant flow with bypass
- » Primary-secondary

System designs that cannot maintain minimum heat pump flow during staging or low-load operation should be avoided.

Unit Cycling, System Volume, and Buffer Tank Considerations

To protect the compressor from starting and stopping too frequently, the system should be designed with the following limits:

- » a maximum of 6 heat pump cycles per hour
- » a minimum cycle time of 10 minutes

System volume acts like a thermal battery in a hydronic system, providing both volume and thermal mass. System volume is critical in preventing short cycling of equipment, and the required system volume needed is defined by the following formula:

$$Required\ System\ Volume = \frac{Heat\ Pump\ Output\ \left(\frac{BTU}{hr}\right) \times Minimum\ Runtime\ (min.)}{500 \times \Delta T}$$

Each hydronic heating system will have an existing system volume, which is the total amount of water contained within system before any supplemental volume is added, and includes the following:

» Supply and return piping.
» Heat emitters and terminal units (radiators, fan coils, unit heaters, etc.)
» Heating coils within air-handling units
» Heat exchangers and internal passages of equipment.
» Ancillary components such as strainers, separators, and headers

The existing system volume represents the existing thermal mass available to the system. If the existing system volume is less than the required system volume needed to prevent short cycling, then adding buffer tanks is strongly recommended. Buffer tanks cushion the temperature fluctuations caused by the heat pump(s) turning on/off or going into defrost mode, and they stabilize water temperature and improve overall system stability. Here are some examples of situations where adding a buffer tank is beneficial:

» System water volume below the required minimum volume
» Process requires precise temperature control.
» Highly variable load

To determine the capacity of the buffer tank, first determine the required system volume, which can be calculated as follows:

$$Required\ System\ Volume = \frac{Heat\ Pump\ Output\ \left(\frac{BTU}{hr}\right) \times Minimum\ Runtime\ (min.)}{500 \times \Delta T}$$

If the existing system volume is less than the required system volume, then add a buffer tank to cover the remaining capacity.

$$Buffer\ Tank\ Volume = Required\ System\ Volume - Existing\ System\ Volume$$

Pipework and Connections

The following piping examples and guidelines are intended to ensure successful operation of the unit(s) and system. These schematics are intended to illustrate functional system concepts and component relationships. Final pipe sizing, valve selection, pump configuration, and control sequences shall be determined by the engineer of record based on project-specific requirements.

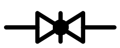
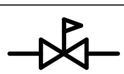
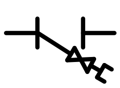
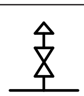
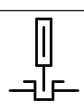
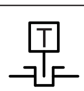
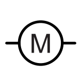
Symbol	Component	Description
HP-#	Heat pump	Air-to-water heat pump providing hot water for space or process heating.
B-#	Boiler	Supplemental or backup heating source providing capacity during peak load conditions, low outdoor air temperatures, or when heat pump operation is limited.
HWP-#	Hot water pump	Circulates hot water through heat pumps, boilers, buffer tanks, and/or building distribution piping.
VFD	Variable frequency drive	Modulates pump speed to match system flow demand and reduce pumping energy.
BT-1	Buffer tank	Increases system water volume, reduces heat source cycling, stabilizes supply temperature, and provides hydraulic separation where required.
AS-1	Air separator	Removes entrained air from circulating water to improve heat transfer and protect pumps and heat exchangers.
ET-1	Expansion tank	Accommodates thermal expansion of system water and maintains stable system pressure across operating temperatures.
WF-1	Water filter	Protects heat pumps, boilers, pumps, and valves from debris and particulate matter.
Pot Feeder	Pot feeder	Provides controlled chemical treatment to manage corrosion, scaling, and long-term water quality.
GMP-1	Glycol make-up pump	Injects a pre-mixed glycol solution into a closed-loop heating or cooling system when system pressure drops, or when fluid is lost due to leaks, venting, maintenance, or relief events.
	Shutoff valve	Allows isolation of individual equipment or system sections and servicing without shutting down the entire heating system.
	Automatic balancing valve	Manages flow distribution and supports proper system hydraulics.
	Check valve	Prevents reverse flow through inactive pumps, heat pumps, or boilers, ensuring stable and predictable system operation.
	Combination valve	Performs two or more functions in one assembly, typically isolation + balancing valve.
	Pressure reducing valve	Automatically maintains minimum system pressure by admitting make-up water when pressure falls below a set value
	Strainer-wye with blowdown valve and hose connection	The Y-strainer removes solid debris from the hydronic fluid before it enters the pump, and the added blowdown valve and hose connection allow the strainer to be cleaned without shutting down or disassembling the system.
	Automatic air vent	Continuously removes trapped air and micro-bubbles that collect at high points in the hydronic system, protecting system performance and reliability.
	Thermometer with well	Provides a direct, local indication of water temperature at key points in the hydronic system.
	Temperature sensor with well	Measures the actual water temperature inside the pipe or vessel and sends that signal to the unit/system controller.
	Water meter	Measures the amount of make-up water added to the system.

Table 2: Configuration Schematics Legend

Single Heat Pump Configuration

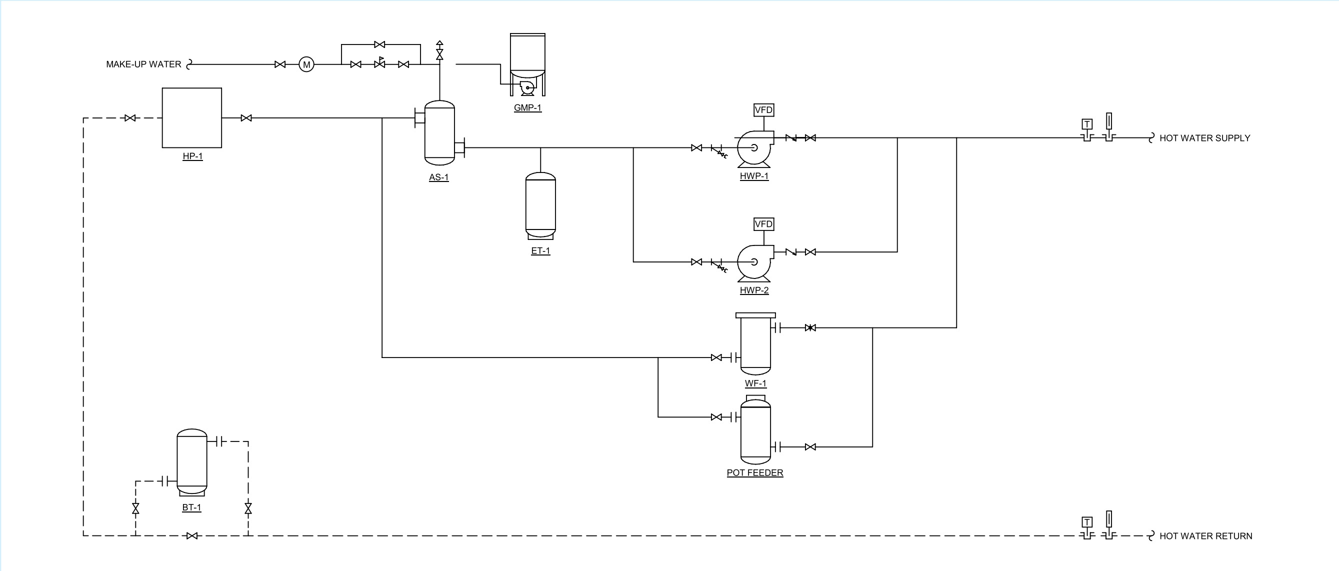


Figure 5: Single Heat Pump Configuration Schematic

Figure 5 illustrates a single air-to-water heat pump serving a closed-loop hot water heating system. In this system diagram, an air-to-water heat pump (HP-1) serves as the sole heating source, providing hot water to the system during normal operating conditions. Hot water supply temperature is maintained by modulating or cycling the heat pump. When outdoor air temperature falls below the heat pump operating limit, heating output is no longer available. This configuration relies on building tolerance or mild climate conditions.

A buffer tank (BT-1) is installed in the heating loop to increase system water volume, stabilize supply temperature, reduce compressor cycling, and smooth load changes. The buffer tank may also be installed on the supply water side, depending on the control strategy. Primary hot water pumps (HWP-1 and HWP-2) circulate hot water between the heat pump plant and the heating distribution system. Dual pumps provide redundancy and allow for lead/lag or standby operation. Variable frequency drives (VFDs) modulate the pumps' speed to match building flow demand, improve part-load efficiency, and maintain stable system differential pressure.

This approach is a simple, low-cost solution suitable for small loads and moderate climates where redundancy is not required.

Multiple Heat Pump Configuration

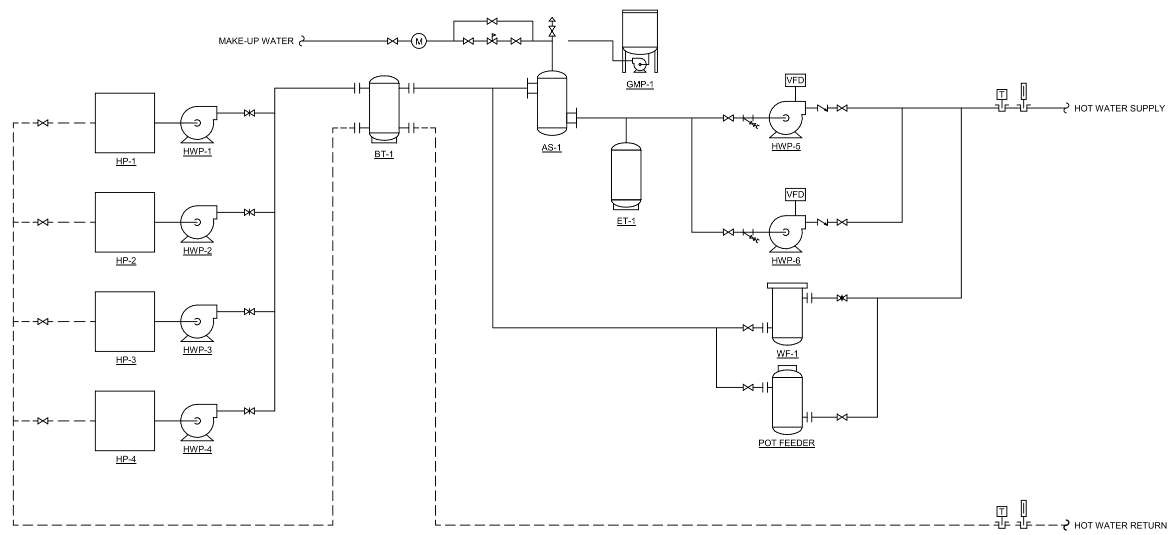


Figure 6: Multiple Heat Pump Configuration Schematic

Figure 6 illustrates multiple heat pumps serving a closed-loop hot water heating system. Multi-unit heat pump plants increase total capacity and improve system reliability, staging flexibility, and part-load performance.

This specific configuration uses primary–secondary pumping, with the heat pumps hydraulically separated from the building distribution loop. Multiple air-to-water heat pumps are shown operating in parallel to provide heating capacity. Four heat pumps are shown, but more can be added if space allows. Units are staged to match load and provide redundancy. Dedicated pumps (HWP-1 through HWP-4) serve each heat pump to maintain required flow through the heat pump heat exchanger regardless of secondary system flow conditions. A common piping loop serves all heat pumps, ensuring stable, minimum flow through operating heat pumps independent of building distribution demands.

A buffer tank BT-1 is installed between the primary and secondary loops to provide hydraulic separation, increase system water volume, reduce heat pump cycling, and stabilize supply water temperature. Secondary system hot water pumps (HWP-5 and HWP-6) circulate hot water from the buffer tank to the heating distribution system. Dual pumps provide redundancy and allow for lead/lag or standby operation. Variable frequency drives (VFDs) modulate the secondary pumps' speed to match building flow demand, improve part-load efficiency, and maintain stable system differential pressure.

Hybrid System with Single Heat Pump and Backup Boiler

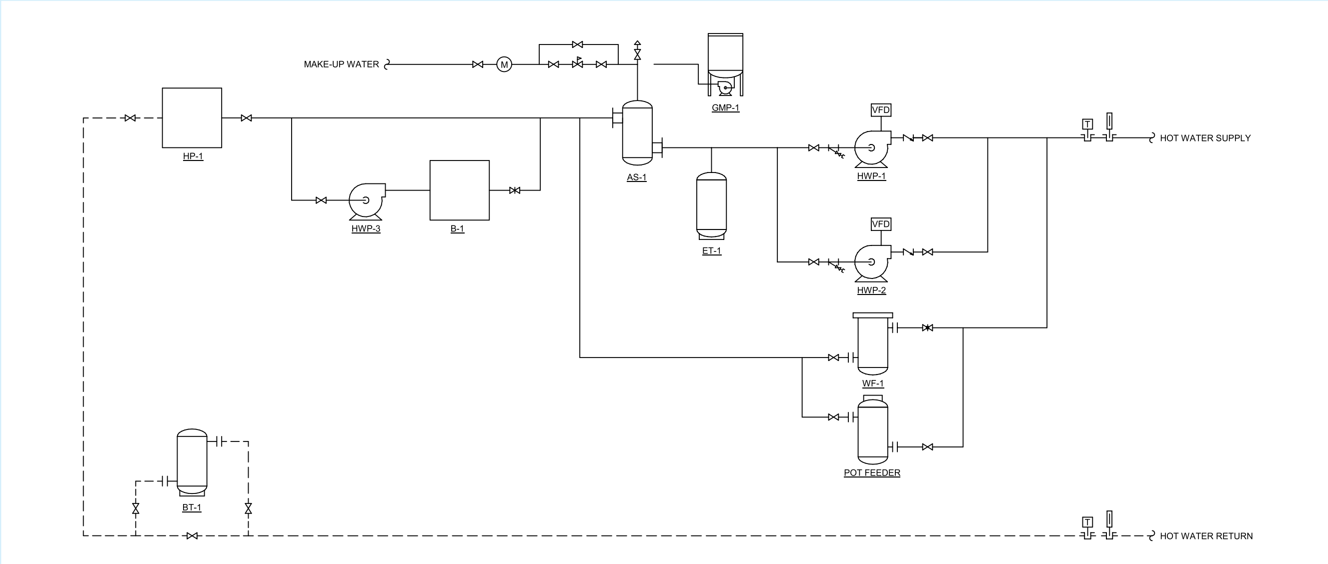


Figure 7: Hybrid System with Single Heat Pump and Backup Boiler Schematic

Figure 7 illustrates a hybrid heating plant consisting of a single air-to-water heat pump (HP-1) combined with a boiler (B-1) serving a closed-loop hot water heating system. The heat pump serves as the primary heating source and is intended to handle base and shoulder heating loads.

The boiler serves as a supplemental heating source, providing additional capacity during peak load conditions, low outdoor air temperatures, and periods when the heat pump is unavailable. The boiler remains off during normal heat pump operation. As heating demand increases and the heat pump reaches its full capacity, the boiler can be staged on to supplement output. When outdoor air temperature drops below the heat pump's operating limit, the heat pump is disabled, and the boiler becomes the sole heat source and carries the full building load. During defrost cycles, temporary heat pump output reduction is absorbed by system mass, and the boiler may operate briefly to stabilize supply temperature.

A primary hot water pump (HWP-3) maintains the required flow through the heat pump heat exchanger independent of system demand. A buffer tank installed in the system return increases total water volume, stabilizes system temperatures, reduces heat pump cycling, and decouples heat pump operation from building load variations. The buffer tank may also be installed in the supply water side, depending on the control strategy. Secondary hot water pumps (HWP-1 and HWP-2) circulate hot water from the plant to the heating distribution system. Dual pumps provide redundancy and support lead/lag operation. Variable frequency drives modulate the secondary pumps speed to match building flow demand, reduce pumping energy, and maintain stable system differential pressure.

This hybrid configuration provides efficient heat pump operation during most annual hours while ensuring full heating capacity during cold or peak conditions.

Hybrid System with Multiple Heat Pumps and Backup Boiler

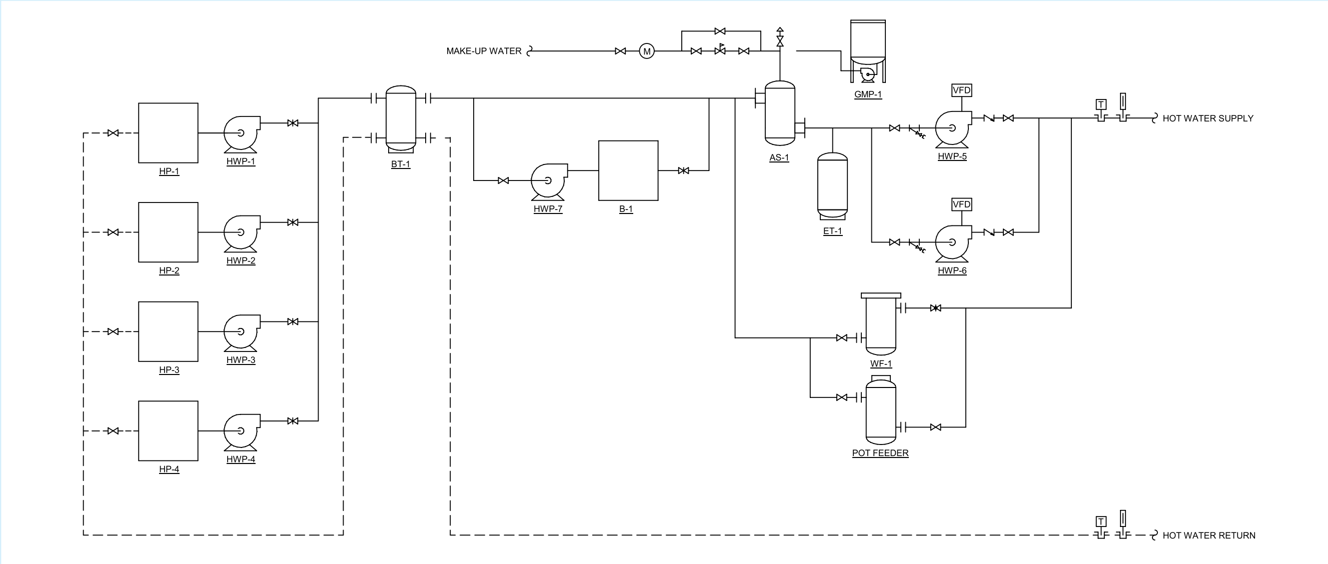


Figure 8: Hybrid System with Multiple Heat Pumps and Supplemental Boiler Schematic

Figure 8 illustrates a hybrid heating plant consisting of multiple air-to-water heat pumps combined with a boiler serving a closed-loop hot water heating system. This configuration uses primary–secondary pumping, with the heat pumps hydraulically separated from the building distribution loop.

The heat pumps serve as the primary heating source and are intended to handle base and shoulder heating loads. Multiple air-to-water heat pumps are shown operating in parallel to provide heating capacity. Four heat pumps are shown, but more can be added if space allows. Units are staged to match load and provide redundancy. Dedicated pumps (HWP-1 through HWP-4) serve each heat pump to maintain required flow through the heat pump heat exchanger regardless of secondary system flow conditions. A common piping loop serves all heat pumps, ensuring stable, minimum flow through operating heat pumps independent of building distribution demands.

The boiler serves as a supplemental heating source, providing additional capacity during peak load conditions, low outdoor air temperatures, and periods when the heat pump is unavailable. A dedicated pump (HWP-7) provides the required minimum flow through the boiler whenever the boiler is enabled. It isolates boiler flow requirements from heat pump primary loop flow and from secondary (building) system flow, and it allows the boiler to be enabled or disabled without disturbing heat pump operation.

A buffer tank BT-1 is installed between the heat pump primary loop and the boiler injection loop to provide hydraulic separation, increase system water volume, reduce heat pump cycling, and stabilize supply water temperature. Secondary system hot water pumps (HWP-5 and HWP-6) circulate hot water to the heating distribution system independently of the heat pumps and boiler pumps. Dual pumps provide redundancy and allow for lead/lag or standby operation. Variable frequency drives (VFDs) modulate the secondary pumps' speed to match building flow demand, improve part-load efficiency, and maintain stable system differential pressure.

Summary

The ClearAir AW0350 air-to-water heat pump can be applied to hydronic heating systems in a number of ways. Careful consideration of available system configurations is required to select the most appropriate approach. Keep in mind the following best practices:

- » Heat pumps are best suited for long, steady operating cycles.
- » Buffer tanks add thermal mass and help prevent short cycling.
- » Primary–secondary separation protects heat sources and pumps by decoupling flow requirements.
- » Banks of heat pumps provide additional capacity, improved turndown, and redundancy.
- » Hybrid solutions overcome many of the tradeoffs associated with heat pump-only system configurations.
- » Boilers are well suited for short-duration, high output operation.
- » In a hybrid system, the load is shifted to the most appropriate heat source based on operating conditions.

When properly applied, the ClearAir heat pump can provide an efficient, flexible, and scalable solution for hydronic heating applications.

The power of total integration.

The **Power of Total Integration** is how Cleaver-Brooks delivers the world's broadest range of integrated, sustainable thermal solutions. In addition to our products, this includes Cleaver-Brooks global authorized sales representatives and independent service contractors, training resources, and trusted expertise that add significant value to your Cleaver-Brooks investment.

CleaverBrooks®

Printed in the USA
CB-8711
01/2026