Elevation Delta: When buffer tanks and DHW tanks are located in the basement (Or when heat pumps are rooftop mounted).

More and more people are using hydronic systems these days due to the obvious advantages, especially air-to-water heat pumps. These are not difficult to install but they may require a little more thought than working with a more traditional system. Here we discuss potential considerations that must be undertaken when there is an elevation difference resulting in the heat pumps being at an elevation more than 6-8 ft. higher than the indoor buffer tank or domestic indirect hot water tank.

Basement tank placements (typically 8–15 ft below the heat pump) are common for having available space, noise reduction, easier servicing, and integration with indirect DHW heat exchangers. Sometimes, particularly in commercial applications, the heat pump(s) are on the roof. This is all good, but as usual, basic physics must be considered and certain design considerations must be made. Advanced installers and design engineers will treat the elevation delta as a design variable that influences pump placement, air elimination strategy, and component pressure ratings.

In a closed-loop hydronic supply-side circuit there is fundamentally no “up or down” with respect to total pump head calculations because the elevation gain on the supply line is exactly offset by the elevation drop on the return line; the net static head is zero. However, elevation differences between the outdoor air-to-water heat pump and indoor buffer tanks or domestic hot water (DHW) tanks introduce important secondary effects on local pressures, net positive suction head (NPSH) at the pump, air management, thermosiphon potential, and expansion-tank behavior. These must be provided for on the supply-side loop to prevent cavitation, air binding, unintended flow, or pressure excursions.

Pump Location

When buffer and DHW tanks are located in a much lower area, retaining the Chiltrix factory-provided internal pump inside the outdoor unit can create a suction-lift condition on the return leg and should instead be relocated near the tanks. The pump inlet then sees a hydrostatic pressure reduction equal to ρgh, where ρ is fluid density ($\approx 62.4\ lb/ft^3$ for water at 60 °F; lower with glycol), g is gravitational acceleration, and h is the vertical lift. If this reduction brings absolute pressure at the impeller eye below the fluid vapor pressure plus the manufacturer’s NPSH required (NPSHr), cavitation occurs and the pump may not move water.

Chiltrix units (e.g., CX35/CX40/CX50/CX65 etc.) all ship with a variable-speed Grundfos or Wilo circulator in a separate box and a factory-installed spacer in the piping. For external pump mounting—advantageous when tanks are substantially lower—leave the spacer in place to bypass the internal pump location.

Install the circulator near the buffer tank on the return line that feeds back to the heat pump. This places the pump inlet at or near the lowest system elevation, maximizing available NPSH (NPSHA).

NPSHA is calculated as:

$$\text{NPSHA} = \frac{P_{\text{atm}} + P_{\text{gauge}} - P_{\text{vapor}}}{\rho g} - h_f$$

where

P_{atm} is atmospheric pressure (psia)
P_{gauge} is gauge pressure at the free surface or fill pressure
P_{vapor} is vapor pressure of the fluid at operating temperature
h_f is friction loss in the suction piping.

By moving the pump downward, NPSHA increases by the full elevation head, easily satisfying NPSHA > NPSHR (typically 3-6 ft for these small variable-speed pumps).

Supply-Side Head Calculation and Component Selection

Although net static head is zero, the variable-speed pump must still overcome all dynamic losses in the supply and return piping. Total dynamic head (TDH) is the sum of pipe friction (Darcy-Weisbach or Hazen-Williams), minor losses through fittings, valves, strainers, and heat-exchanger pressure drop. **Use the formula:**

$$\text{TDH} = f\frac{L}{D}\frac{v^2}{2g} + \sum K\frac{v^2}{2g} + \text{other losses}$$

where:

- f = Darcy friction factor
- L= total pipe length (ft)
- D= internal pipe diameter (ft)
- v= fluid velocity (ft/s)
- g= gravitational acceleration (32.2 ft/s²)
- K= sum of minor loss coefficients for fittings, valves, etc.

or use equivalent-length tables.

Advanced designers calculate TDH at the design flow rate (typically 2–4 gpm per ton through the heat pump) and select the pump speed curve that keeps operation in the high-efficiency region. To keep TDH low and allow the pump to run at lower RPM (improving motor life and reducing noise), select every supply-side component with the highest possible Cv rating and minimize turbulence-generating fittings. Use long-radius 90° elbows or sweep bends instead of standard elbows wherever possible, keep pipe runs straight, and avoid unnecessary tees or reducers. Full-port ball valves, low-cracking-pressure spring-check valves, Y-strainers with large screen area and low pressure-drop bodies, and high-Cv automatic air vents or micro-bubble separators are mandatory. A component with Cv < 10 at design flow can add several feet of unnecessary head; always verify published Cv data before finalizing the layout.

Practical installation notes for the field: Use full-port ball valves and unions (or stainless flex hoses) on both sides of the relocated pump so it can be isolated and removed without draining the supply loop.

Thermosiphoning and Check Valves

For a system that is always-on, this may be less of an issue; however, it must be addressed, particularly because of the way customers may use timers, smart thermostats, load shifting strategies, and the like. Significant elevation differences combined with temperature gradients create buoyancy-driven flow (thermosiphoning). Hotter, less-dense fluid rises while cooler, denser fluid sinks. **The driving head can be approximated as:**

$$\Delta P = \rho \cdot \beta \cdot \Delta T \cdot H \cdot g$$

where ($\beta \approx 0.0002/°F$ for water), and H is the vertical distance between the heat source/sink centroids. For a 20 °F temperature difference and 15 ft elevation, this can exceed 0.06 ft of head—enough to drive several GPM of reverse or bypass flow when the main pump is off.

Practical installation notes for the field:

Uncontrolled thermosiphoning when the system is off wastes heat to the mechanical room or allows reverse flow through to the outdoor heat pump, wasting the heat outdoors. Install full-port, low-cracking-pressure spring-check valves (high Cv ≥ 20–30 at design flow) on both the supply and return lines, oriented to allow pump-driven flow only. Face the arrows in the direction of flow. Gravity-type checks are acceptable if mounted vertically, but spring-loaded valves are preferred for reliable seating regardless of orientation. Place checks as close as practical to the heat pump ports to minimize the thermosiphon loop volume. In multi-unit parallel installations, check valves on each unit's supply and return prevent cross-flow between units. Even modest thermosiphon can cool a buffer tank (or DHW tank) 5–10 °F overnight, dropping the heat pump's COP average.

Note: When the pump is off, buoyancy tries to drive flow around the loop. Although one direction may appear "allowed" by both check valves, the light springs still provide enough resistance (cracking pressure + friction) that the very weak natural buoyancy force usually cannot initiate meaningful circulation. In practice, this arrangement reduces thermosiphon to negligible levels. In certain applications and piping configurations, more may be needed. If so, install an actuated zone valve (normally closed) on the return line (the pipe going up from the tank to the heat pump) that is only open when the pump is on.

Air Purging

Air is approximately 800 times less dense than water and therefore migrates upward at a terminal velocity governed by Stokes' law (for small bubbles) or buoyancy-drag balance for larger pockets. In a lower-elevation tank configuration the heat pump and its supply/return headers become the system high points. Fill from the lowest point, i.e. near the indoor relocated pump. Automatic air vents (float-type, high-Cv models) should be installed at any local high point, with particular attention to the heat pump cabinet or external high-point tees.

A micro-bubble air separator (high Cv, coalescing type) on the supply line leaving the heat pump further coalesces and releases entrained air before it reaches the low elevation tanks.

Initial system fill and purge should use a high-head, high-velocity transfer pump to power-purge (≥ 2 ft/s) while venting at the highest points, not the provided circulator. For ongoing operation, automatic vents with shut-off valves and hose connections allow periodic maintenance without system drain-down. Glycol mixtures increase viscosity and reduce bubble-rise velocity, making thorough initial purging even more critical. See the Chiltrix manual for more on fill-purge.

Installer and designer best practices: Use a dedicated fill system as shown in the Chiltrix manual with a 1 hp booster pump, fill from the lowest point (tank drain) while bleeding every high-point vent in sequence. Run the main pump at 100 % speed for 20–30 minutes, then repeat with the Y-strainer isolated if present. Advanced plumbers install a coalescing air separator (high Cv) immediately after the heat pump supply port during commissioning.

Water Pressure, Hydrostatic Effects, and Expansion Tanks

Elevation introduces hydrostatic pressure variation:

$$\Delta P\ (\text{psi}) = 0.433 \times h\ (\text{ft}) \times \text{SG}$$

Propylene Glycol Solution (%)	*by mass*	0	10	20	30	40	50	60
	by volume	0	10	20	29	40	50	60
Specific Gravity - *SG* - [1)]		1.000	1.008	1.017	1.026	1.034	1.041	1.046

The expansion tank establishes the point of no pressure change (PONPC). Best practice is to locate the diaphragm or bladder tank on the pump suction side, ideally at the lowest-pressure point in the system when running. This keeps the entire supply loop pressurized above atmospheric and above the fluid vapor pressure, maximizing NPSHA everywhere.

Tank pre-charge should be set to the cold-fill pressure required to maintain ≥ 5 psig at the highest point (heat pump) under static conditions. For tall systems, increase tank volume beyond the standard ASHRAE formula to limit pressure excursion:

$$V_{\text{tank}} = \frac{V_{\text{system}} \times E}{\left(\frac{P_{\text{max}}}{P_{\text{pre}}} - 1\right)}$$

where:

- V_{system}= total system volume (includes all supply/return piping, tanks, and heat-exchanger volumes)
- E= fractional volume change from cold to hot (≈ 0.025–0.04 for typical ΔT)
- P_{max}= maximum allowable system pressure (psia)
- P_{pre}= tank pre-charge pressure (psia)
- γ ≈ 1.4 for air (polytropic exponent — used in some forms of the formula)

Oversizing the tank also accommodates the higher average system pressure encountered in lower-elevation mechanical room layouts.

Pressure-relief valves must be sized for the highest possible pressure (delta elevation + pump head + thermal expansion) and discharge to a safe location. Gauge ports at the heat pump inlet/outlet and at the tank inlet allow verification that the PONPC is correctly placed and that NPSHA margins are maintained. Use full-port isolation valves (high Cv) around the expansion tank and relief valve for service without disrupting the loop.

Field and design recommendations: Calculate total supply-loop volume (piping + buffer + heat exchanger) before selecting the tank—for example, many installers add 20–30 % extra volume in basement jobs to keep pressure swings under 10 psi. Pre-charge the tank (with the system isolated and drained on the tank side) using a digital tire gauge; set it 2–3 psi below the static fill pressure measured at the tank. Plumbers should pipe the relief-valve outlet to an indirect drain or floor sink with a visible air gap. Include a high-Cv Y-strainer on the return line to protect the heat pump heat exchanger; clean it during commissioning and annually thereafter.

Summary of Design Recommendations & Checklist

- Relocate the circulator to the mechanical room return line when tank elevation exceeds ~6–8 ft below the heat pump.
- Perform a full supply-side head loss calculation at design flow; select only high-Cv components (check valves, Y-strainers, air vents, full-port ball valves) and minimize elbows/fittings.
- Optionally install high-Cv spring-check valves to eliminate thermosiphon.
- Provide high-point air elimination at the heat pump plus a coalescing separator; power-flush and verify with flow/ΔT checks.
- Size and locate the expansion tank on the suction side; oversize for the elevation delta static pressure and follow the pre-charge procedure exactly.
- Add isolation unions, labeled wiring, gauge ports, and a Y-strainer for long-term serviceability and low pressure drop.

Following these physics-based guidelines combined with the practical field techniques above ensures reliable, cavitation-free operation, and prevention of thermosiphoning of the supply-side loop in Chiltrix air-to-water heat pump systems with remote indoor tanks.