Domestic Hot Water Recirculation Systems

The American Society of Plumbing Engineers (ASPE) says:

"A poorly designed hot water recirculation/maintenance system wastes large amounts of energy and potable water; and creates time delays for those using the plumbing fixtures."

Tim Campbell, CPD

Sales Executive

McMillan James Equipment Company

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Agenda

- Definitions
- Fundamentals
- Components
- System Types
- Best Practices
- References

Definitions

- **Hot Water Temperature Maintenance:** There are three types which may be used separately or combined into a hybrid system: Hot water circulation system, Self-regulated electrically heated system (heat trace), and Point-of-use water heater. These systems are utilized to counteract the effects of heat loss from hot water piping by conduction, convection, and radiation. *Insulation reduces heat loss, but does not eliminate it.*
- **Circulating Hot Water System**: As defined by the IPC, a specifically designed water distribution system where one or more pumps are operated in the service hot piping to circulate heated water from the water heating equipment to the fixture supply and back to the water heating equipment.
- **Demand Recirculation Water System:** As defined by the IPC, a water distribution system where one or more pumps prime the service hot water piping with heated water upon a demand for hot water. *This type will not be discussed in this session.*

Definitions

- **Hot Water:** As defined by the IPC, water at a temperature greater than or equal to 110°F. Generally, all plumbing fixtures are supplied hot water.
- **Tempered Water:** As defined by the IPC, water having a temperature range between 85°F and 110°F. Tempered water may be supplied to nonresidential occupancies for bathing and washing purposes.

- **Tepid Water:** As defined by ANSI/ISEA Z358.1, water having a temperature range between 60°F and 100°F for emergency fixtures.
- **Circulator**: Canned Rotor or Wet Rotor Pumps for circulating hot water.

- **Multistage Pump**: Multiple shaft-mounted impellers for high head applications.
- **Balancing Valve**: Adds adjustable resistance to equalize the pressure between the intake and outflow to maintain proper flow rate.
- **Note:** All domestic water pumps must be bronze or stainless steel fitted.

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Fundamentals – Water Management

- The favorable growth range of Legionella bacteria is between 68-122°F (CDC, ASHE, and ASHRAE)
- Available information indicates that almost all bacteria die at temperatures above 130°F
- ASHRAE Guideline 12 Managing the Risk of Legionellosis Associated with Building Water Systems, recommends the circulating hot water system should not drop below 120°F
- ANSI/ASHRAE Standard 188, Legionellosis: Risk Management for Building Water System:
  - Establishes minimum legionellosis risk management requirements for building water systems
  - Does not recommend an Aquastat to control the circulating pump(s)
  - Requires that all water systems shall be balanced and a balance report for all water systems shall be provided to the building owner or designee
- Store and distribute domestic hot water at or above 140°F
- Maintain a hot recirculating return temperature of at least 124°F
- Eliminate piping dead legs in cold and hot water systems

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Fundamentals – Circulating Hot Water Systems

- The purpose of a circulating hot water system is to utilize the water heating system, circulating pump(s), controls, piping system, and balancing valves to maintain the desired temperature in the piping system and to supply hot water in a timely manner
- The circulating pump flow is a function of the heat loss over time of the piping system and unfired hot water storage tank(s) at an acceptable temperature drop when no fixtures are used
- The pump head is determined from the piping system's friction and pressure loss, no static head
- Smaller supply and return piping is assumed until the flow is determined, it is not always 3/4"
- The temperature drop across the system affects the pump flow, higher ΔT = less flow
- An increased temperature drop will cause the fixtures to use greater volumes of hot water
- Balancing valves must be sized for each branch and riser to provide the desired temperature drop

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Fundamentals – Pump Flow

To determine the pump flow, we must define two parameters:

1. The heat loss from the piping system and unfired hot water storage tanks, water heaters are not included because they maintain temperature
2. The acceptable temperature drop across the piping system

Equation: GPM = System heat loss, Btuh / (500 x Temperature drop, °F)

- Consult Manufacturer's data or ASPE Tables for heat loss per foot
- Most heat loss tables use copper piping
- Thermoplastic piping will have less heat loss because of the material's inherent insulative qualities

Fundamentals – Pump Flow

Example – Large volume loop, Type L Copper, Single Pump, Water Heater, No Tank

1. Hot water supply temperature of 140°F with a Temperature drop of 5°F
2. 1,500 ft. of 2 in. supply piping with 2 in. insulation (8.90 btuh/ft = 13,350 btuh)
3. 1,000 ft. of 1-1/2 in. supply piping with 2 in. insulation (7.59 btuh/ft = 7,590 btuh)
4. 500 ft. of 1 in. supply piping with 1-1/2 in. insulation (7.25 btuh/ft = 3,625 btuh)
5. 100 ft. of 3/4 in. return piping with 1-1/2 in. insulation (6.33 btuh/ft = 633 btuh)

GPM =25,198 btuh of heat loss / (500 x 5°F) = 10.1 gpm

Type L Copper with 10.1 gpm in 1 in. has a friction loss of 6.8 ft/100 ft and a velocity of 4 fps; 3/4 in. has a friction loss of 24 ft/100 ft at 6.6 fps
This scenario may cause premature failure of the return piping and high pump head
Consider 1-1/4 in. which results in a friction loss of 2.5 ft/100 ft at 2.6 fps

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Fundamentals – Pump Flow

Example – Recalculated, revised the 3/4 in. and 1 in. to 1-1/4 in.

1. Hot water supply temperature of 140°F with a Temperature drop of 5°F
2. 1,500 ft. of 2 in. piping with 2 in. insulation (8.90 btuh/ft = 13,350 btuh)
3. 1,000 ft. of 1-1/2 in. piping with 2 in. insulation (7.59 btuh/ft = 7,590 btuh)
4. 600 ft. of 1-1/4 in. piping with 1-1/2 in. insulation (8.14 btuh/ft = 4,884 btuh)

GPM = 25,824 btuh of heat loss / (500 x 5°F) = 10.3 gpm

By changing the 1 in. and 3/4 in. to 1-1/4 in. piping, we added 0.2 gpm to the pump flow, reduced the pump head by more than 40 ft hd, and decreased the probability of piping leaks (and litigation)!

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Fundamentals – Pump Head

To determine the pump head, we must define two parameters:

1. The friction loss of the piping system
2. The pressure loss of the piping system's fittings and valves

Equation: Add the friction and pressure losses from the piping system

- Include losses for a Strainer, Shutoff Valve, Balancing Valve, and Check Valve on the return connections to the Water Heater and Thermostatic Mixing Valve (TMV) cold water inlets and at the Pump
- Consult the Plumbing Codes (Hazen-Williams formula) or Manufacturer's data
- Static head should not be included because the calculation is for a closed system
- Hydraulic pressure should be calculated as required, refer to Best Practices

Fundamentals – Pump Head

Example:

1. We determined our pump flow is 10.3 gpm
2. Fittings are two 90-deg ells and two 90-deg tees on each run
3. Valves are two Strainers, Shutoff Valves, Balancing Valves, and Check Valves on the 1-1/4 in return piping for the Water Heater and Pump
4. 2 in.: 1,500 ft. + fittings = 1,529 ft (0.3 ft/100 ft = 4.6 ft)
5. 1-1/2 in.: 1,000 ft. + fittings = 1,022 ft (1.1 ft/100 ft = 11.2 ft)
6. 1-1/4 in.: 600 ft. of + fittings + valves = 628 ft (2.5 ft/100 ft = 15.7 ft)

Pump Head (Friction and pressure loss) = 31.5 ft hd

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Fundamentals – Pump Control

- As mentioned, an Aquastat is not recommended by OSHA or ASHRAE 188 to control a circulating pump
- The 2021 IECC requires that “Heated water circulation systems shall be provided with a circulation pump. Controls for circulating hot water system pumps shall automatically turn off the pump when the water in the circulation loop is at the desired temperature and when there is not a demand for hot water.”
- It is recommended to discuss with the AHJ how the IECC conflicts with the project stakeholder’s Water Management criteria
- Consider the building occupant’s time schedule, hot water demand, and, most importantly, the effectiveness of the hot water temperature for suitable Water Management

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Fundamentals – Self-Regulated Heat Trace

- A heat trace system may be used for hot water temperature maintenance
- Practical on small piping systems, long or dead-legged hot water supply pipe runouts, and/or where recirculation piping is not feasible
- Hybrid hot water temperature maintenance systems may be utilized with a circulated main and heat traced branches to reduce piping, optimize pump energy usage, and simplify balancing
- All hot water piping must be insulated, heat traced piping is no exception
- The temperature sensor is attached to the pipe which signals the controller to regulate the power to the heat trace to reach the temperature setpoint
- Heat trace systems should be UL Listed and designed for hot water temperature maintenance
- Most manufacturers offer design guidelines and engineering assistance
- Coordination with the Electrical Engineer is critical

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Fundamentals – Point-of-use Water Heaters

- Point-of-use water heaters may be used for hot water temperature maintenance
- While not widely used, some high rise designs incorporate point-of-use water heaters to regulate the temperature of individual hot water pressure zones in combination with a heat exchanger
- Other designs may apply point-of-use water heaters at remote fixture(s) where hot water recirculation piping or heat trace systems are not feasible
- Point-of-use water heaters are typically electric, but may be gas-fired

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Components – Balancing Valve

- **Manual Balancing Valve:** Pressure Dependent, Does not react to varying temperatures
- **Automatic Balancing Valve:** Pressure Dependent, Cartridge Type, Fixed flow
- **Thermostatic Balancing Valve:** Similar to a Thermostatic Mixing Valve, Adjusts flow based on temperature, Requires a variable speed circulator
- **Automated Balancing Valve:** Provides continuous feedback to provide Water Management data

Manual
Pressure Dependent

Automatic
Pressure Independent

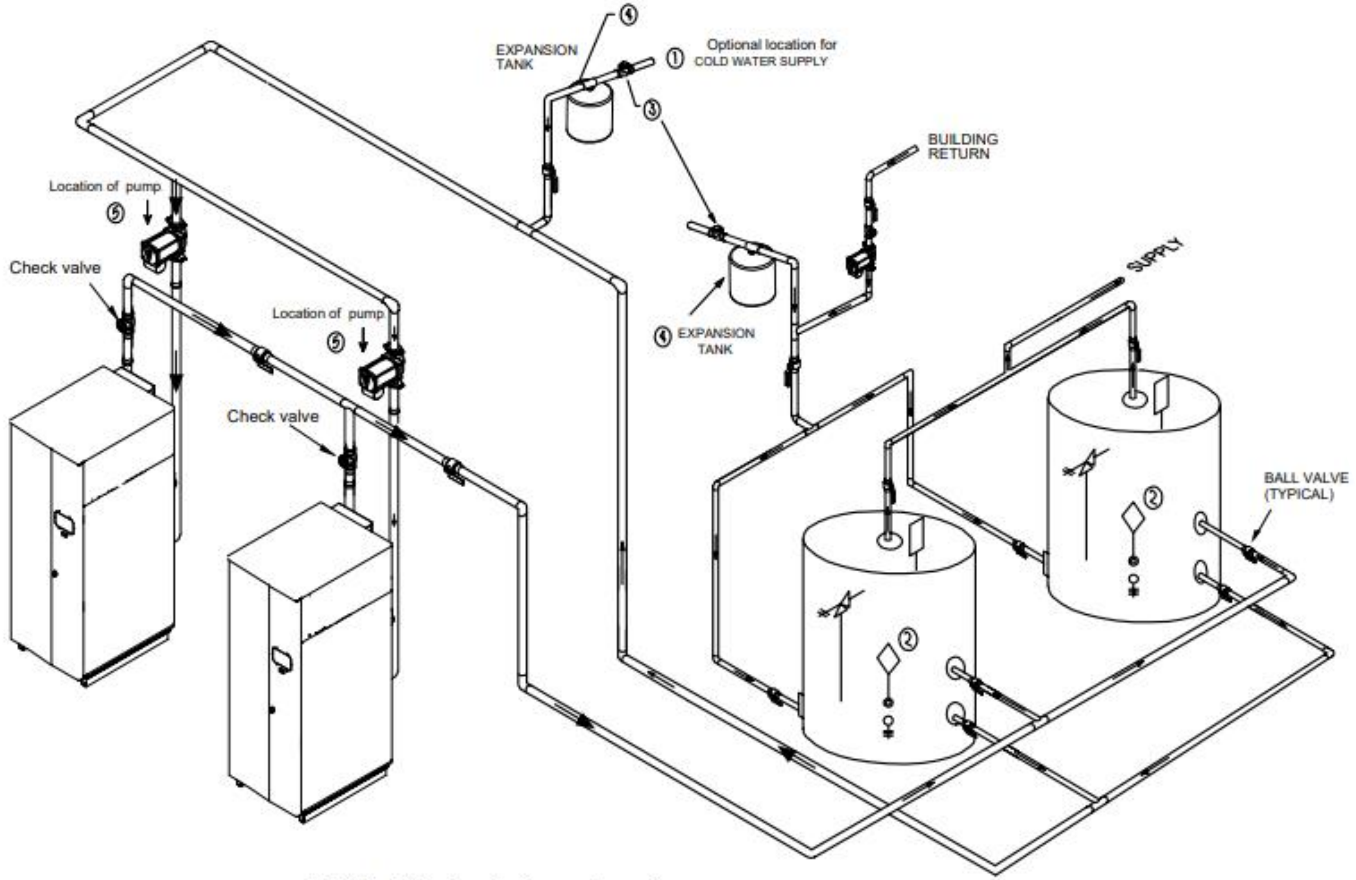
Thermostatic
Fixed

Thermostatic
Adjustable

Automated
Data Controlled

Components

- Water Heaters (Volume Water Heaters with Storage shown)
- Water Heater Circulator
- System Recirculation Pump
- Storage Tanks – Calculate the Heat Loss!
- Tank Temperature Sensor
- Thermal Expansion Tank



NOTE: This drawing is a schematic representation of a piping style and is not intended to be used as a working installation drawing. Local code requirements must be met.

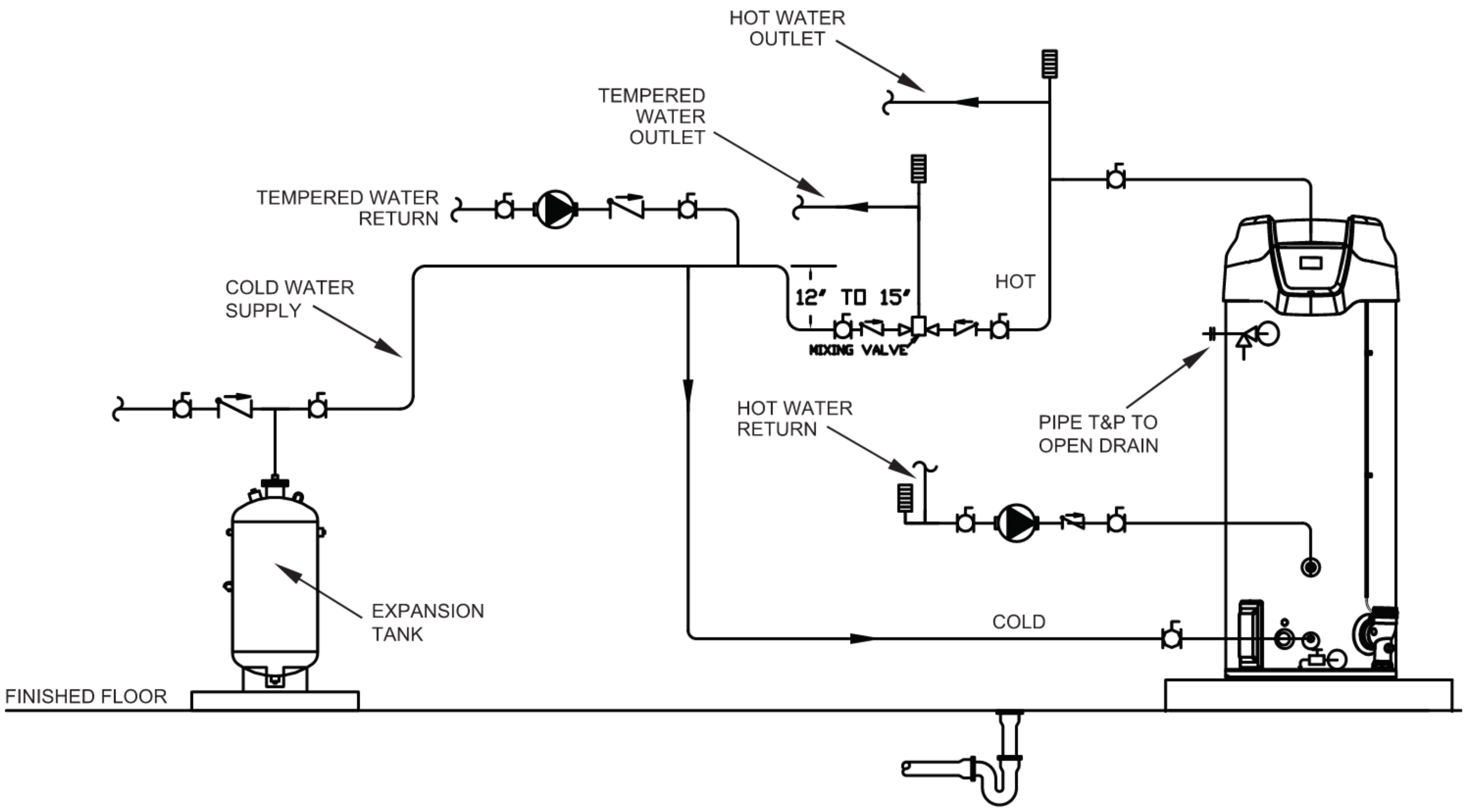
Courtesy of Laars

NOTES:
1. Optional CWMU & recirculation line location.
2. Locate NTV DHW sensor or remote aquastat well in lower 1/3 of tank.
3. Back Flow Preventer may be required. Check local codes.
4. Thermal expansion tank may be required. Check local codes.
5. Factory mounted pumps are sized for a max pipe length of 30' total, 6-90° elbows, full pipe size.
6. **CAUTION: Pump sizing must be based upon water hardness at job site.**

Figure 14. DHW Piping - Two Heaters, Two Vertical Tanks

Components

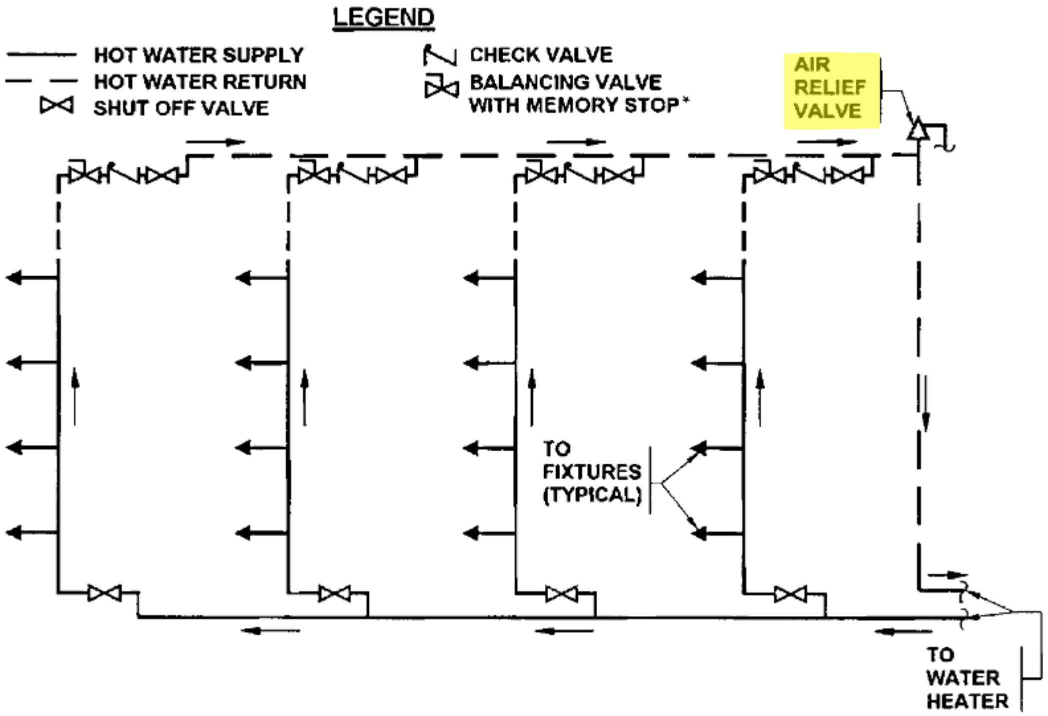
- This detail shows a dual-temp system which is typically required for a hospital, kitchen, or other system with multiple hot water supply temperatures
- Each hot water system has a dedicated return pump



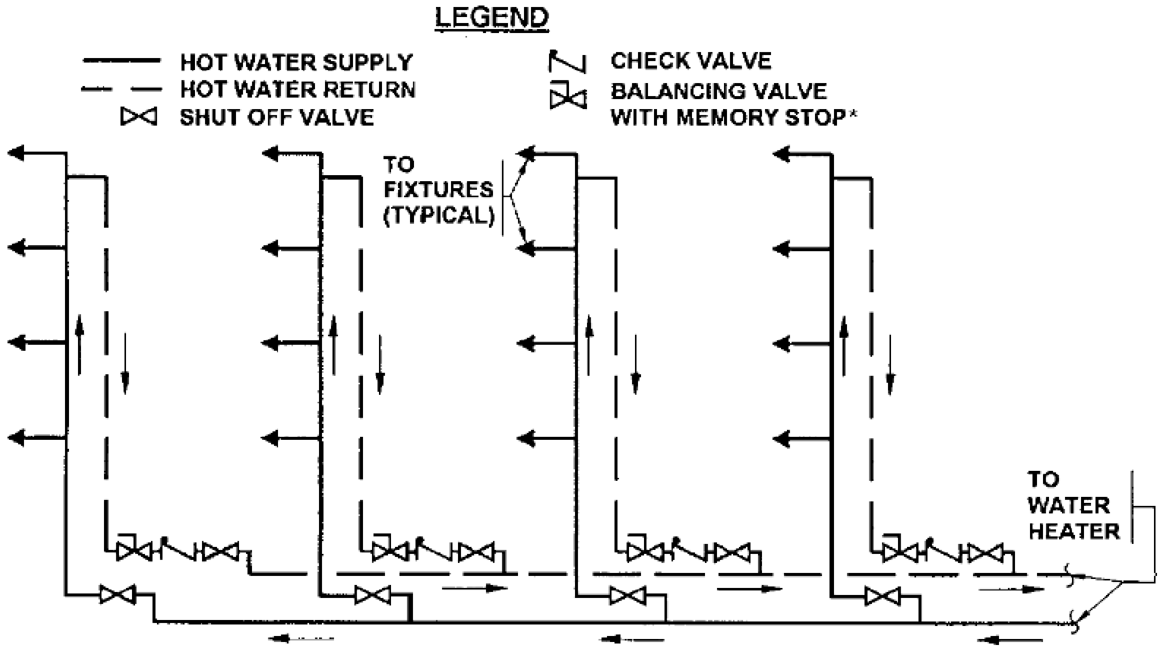
Courtesy of AO Smith

System Types

- Upfeed with Top Return



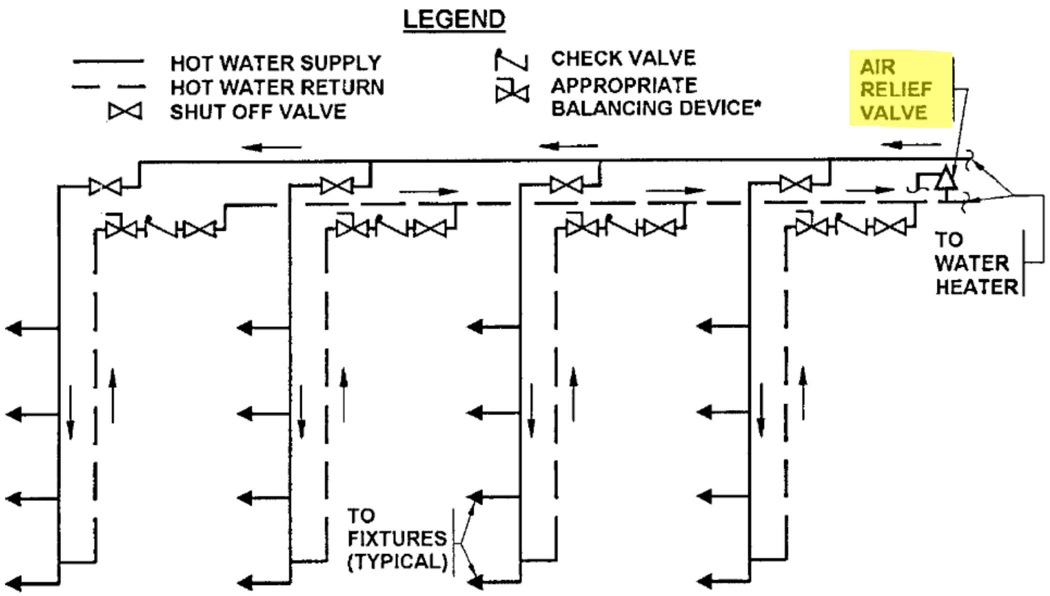
- Upfeed with Bottom Return



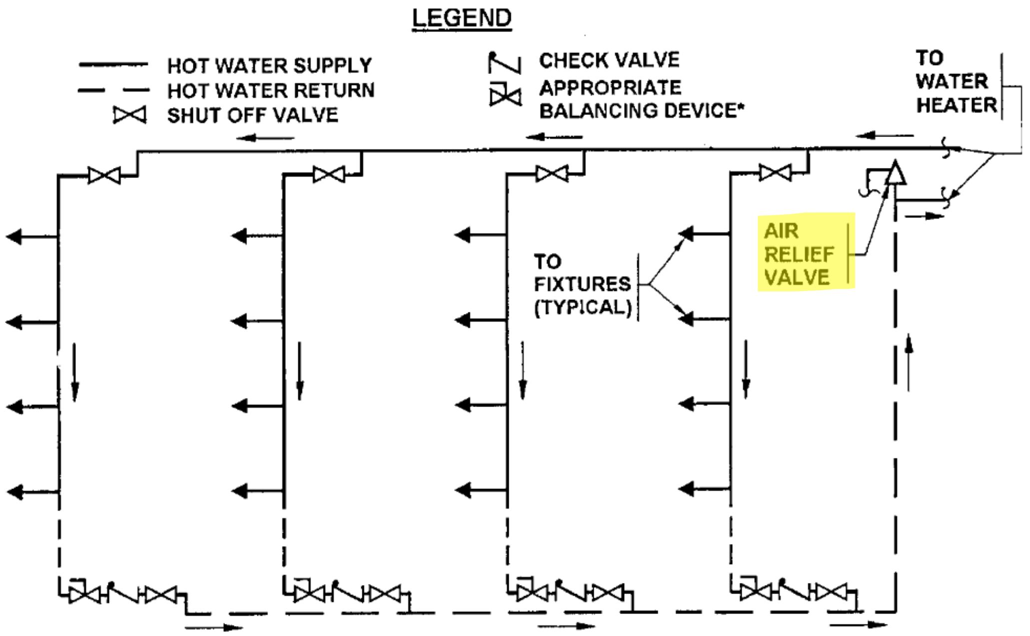
Strainers not shown for clarity

System Types

- Downfeed with Top Return



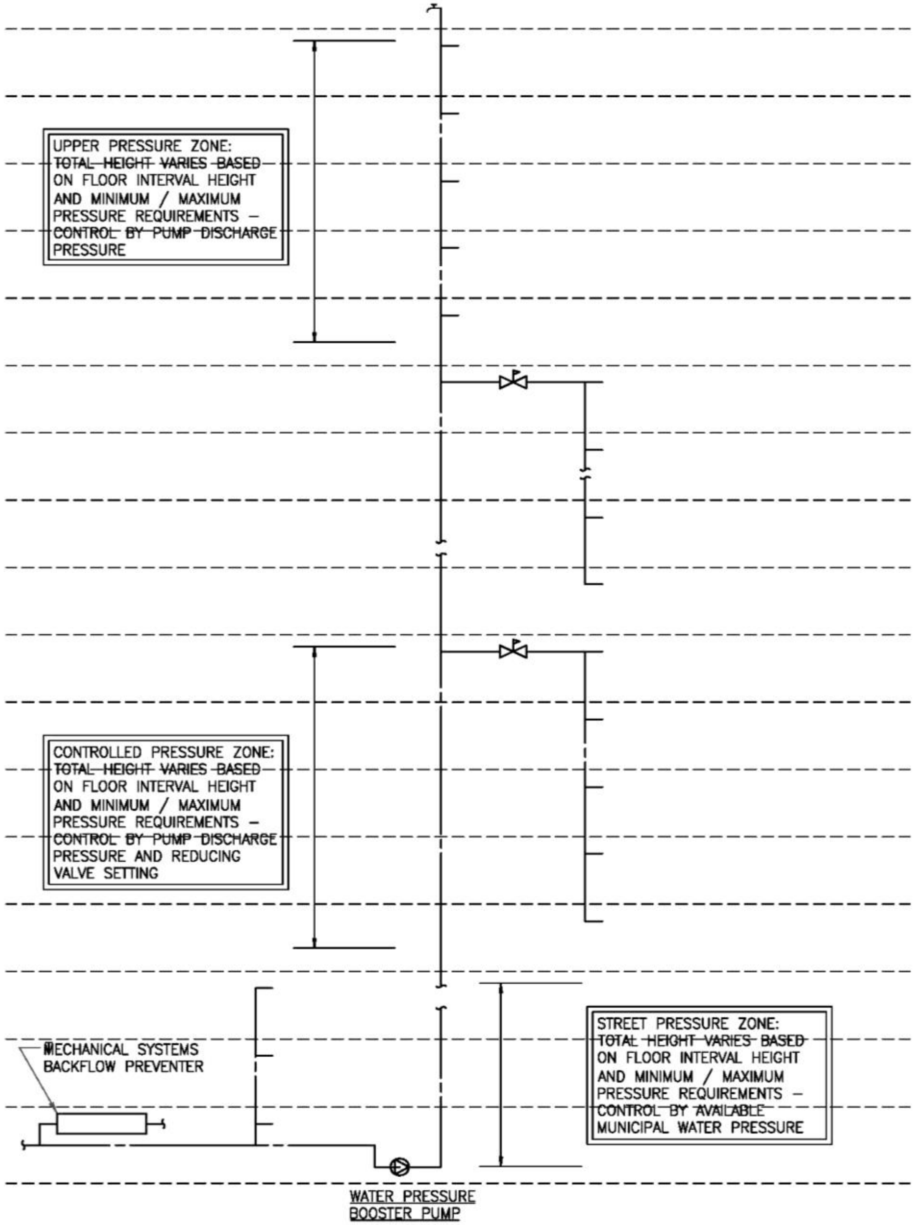
- Downfeed with Bottom Return



Strainers not shown for clarity

System Types

- High-Rise designs present many challenges
- Typically 5 to 7 floors are supplied in pressure zones
- Hot Water Return System pressures must be calculated similar to the Cold Water Supply System
- Refer to ASPE Advanced Plumbing Technology II, Ch. 12, High-Rise Plumbing Systems



COMMON HIGH-RISE WATER SUPPLY SCHEMATIC

Best Practices – Schematic Riser Diagram

- Consider a Schematic (flat riser) for larger systems
- Note the flow rates, pressures, pipe/floor-to-floor lengths, and main/riser sizes
- Indicate Balancing Valve locations with flow rates
- Show the Pressure Zones including PRV Stations and Hot Water Return Pump locations
- Calculate the Thermal Expansion Tank using the volume of the system and the system pressures
  - Refer to ASPE Domestic Water Heating Design Manual, Ch. 23 Expansion Tanks
  - Use manufacturer's sizing software
  - Utilize BIM to determine the volume of the system

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Best Practices

- Avoid piping/fitting erosion and corrosion
- Hot water recirculation is continuously moving water whereas fixture supply is intermittent
- Per ASPE, hot water recirculation piping should be sized between 1 and 3 feet per second (fps) to reduce piping/fitting erosion and reduce pump energy
- Reduce pump head to optimize energy performance
- After determining the pump flow, evaluate the piping system sizes and subsequent velocities before calculating the pump head
- Larger pipe sizes will have less friction loss thereby reducing pump energy usage, smaller hot water supply piping and hot water return piping may need to be increased.

Best Practices

- It is recommended to provide a Strainer with blowoff and a Shutoff Valve upstream of Balancing Valves and a Check Valve downstream to prevent flow reversal caused by fixture usage and allow for Balancing Valve service/maintenance
- The hot water return piping from the pump discharge must be connected to the cold water supply to the Water Heater
- If a Thermostatic Mixing Valve (TMV) is used for hot water supply temperature control, the hot water return piping from the pump discharge must be connected to the cold water supply at both the TMV and Water Heater, and a Balancing Valve is required at each connection to regulate flow
- On High Rises, the hydraulic pressure must be overcome with high head pumps to boost the water pressure
- If the circulating hot water system has multiple branches or risers, each segment's flow must be calculated as prescribed and must have a Balancing Valve

References

- ASPE Domestic Water Heating Design Manual, 2nd Ed., Chapter 14 Recirculating Domestic Hot Water Systems
- ASPE PEDH, 2021, Vol. 2 Plumbing Systems, Ch. 6 Domestic Water Heating Systems
- ASPE PEDH, 2020, Vol. 4, Ch. 3 Valves, Ch. 4 Pumps, Ch. 5 Piping Insulation, Ch. 10 Water Treatment
- ASPE Advanced Plumbing Technology II, Ch. 8 Pumps, Ch. 10 Water Treatment, Ch. 12 High-Rise Plumbing
- ASPE Engineered Plumbing Design II, Ch. 17, Sizing the Hot Water Circulation System
- ASPE Practical Plumbing Engineering, Chapter 14, Hot Water Supply Systems
- ASHRAE HVAC Applications, 2015, Ch. 50 Service Water Heating
- ASHRAE Guideline 12-2020, Managing the Risk of Legionellosis Associated with Building Water Systems
- ANSI/ASHRAE Standard 188, Legionellosis: Risk Management for Building Water Systems

PEDH = Plumbing Engineering Design Handbook

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Thank you!

Q & A

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