Pump Sizing for Commercial Hot Water Recirculation Systems

Lunch & Learn

Course Learning Objectives

1. Describe how a hot water recirculation pump system works
2. Cite advantages and benefits of these systems
3. Identify applicable codes, standards, and guidelines — and know where to locate associated tools
4. Explain the importance of mixing valves, balancing valves, anti-scald protection, and prevention of Legionella
5. Describe control modes and potential for energy savings
6. Select a hot water recirculation pump

Common Abbreviations

DHW = Domestic Hot Water

HWR = Hot Water Recirculation

DHWR = Domestic Hot Water Recirculation

Domestic = Potable Water

HWR System Benefits

1

Comfort

Hot water when you need it

2

Convenience

No wait time

3

Water Savings

How water is available in seconds instead of minutes

Overview

- DHWR System Benefits:
  - Comfort
  - Time Saved
  - Convenience
  - Power Consumption
  - Water Used
  - Protect from Pathogens
- Consistent supply of hot water with varying building demand
- Done by using balancing valves to minimize flow rate to the lowest possible level in each circuit
- Using variable speed ECM circulators (balancing) increases energy optimization more!

Proper Installation is Imperative for …

1. Ensuring rapid delivery of hot water to all fixtures upon demand

2. Reducing water waste

3. Assuring that the water temperature is safe (non-scalding)

4. Preventing growth of Legionella and other pathogens

How much water is wasted?

Water Waste for Residence without HWR					
Pipe Type	**Supply Pipe Length** (ft)	**Pipe Volume** (US gal)	**Draws / Day**	**Wasted Water / Day** (US gal)	**Wasted Water / Year** (US gal)
3/4″ Copper Type L	100′	2.5	10	25	9,125
3/4″ Copper Type L	135′	3.38	10	33.8	12,337
3/4″ Pex	135′	2.45	10	24.5	8,943
3/4″ Copper Type L	180′	4.5	10	45	16,425

How much water is wasted?

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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3/4″ Pex	135′	2.45	10	24.5	8,943
3/4″ Copper Type L	180′	4.5	10	45	16,425

How much more water is wasted annually in a commercial building?

Systems *Without*
Hot Water Recirculation

Hot water that has cooled in the piping:

1. Typically sent to drain and wasted
2. Creates an annoying wait for hot water to arrive at fixture
3. Heightens potential for Legionella growth

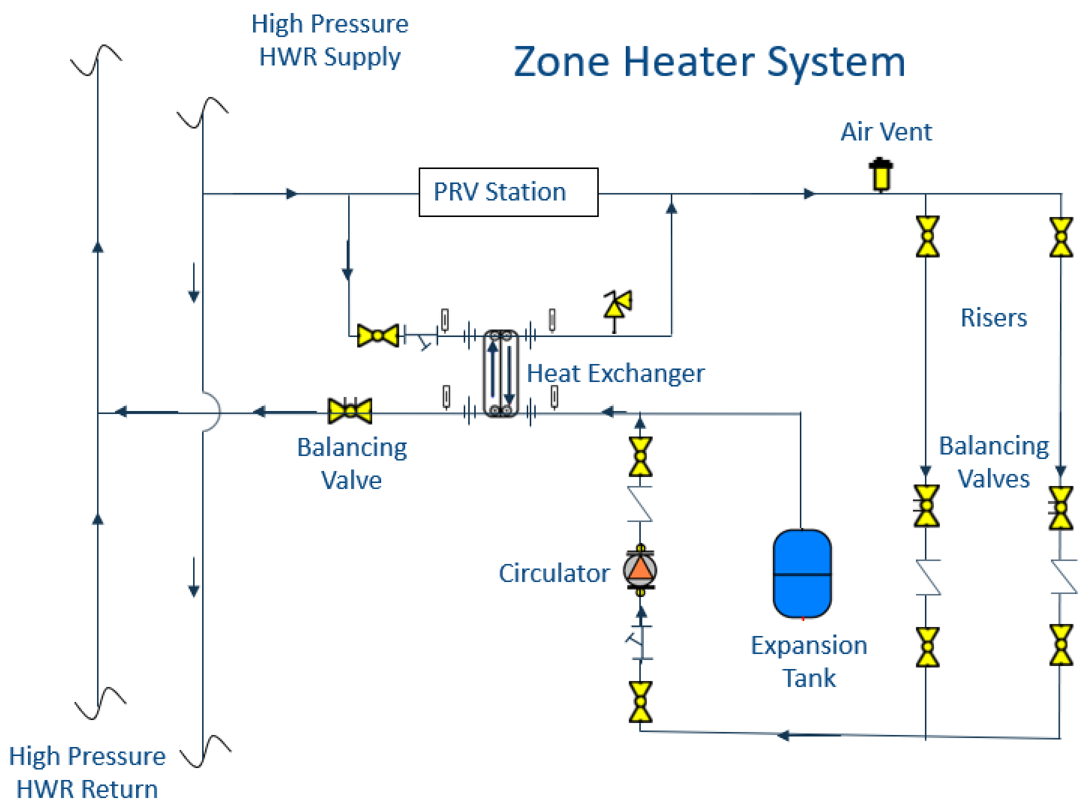
Typical Questions for HWR Sizing

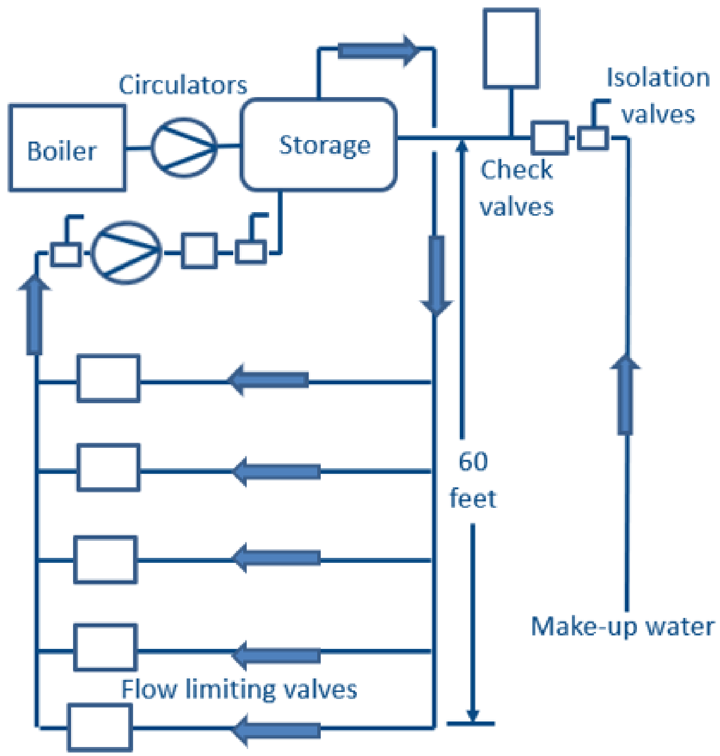
1. In what type of building will the system be installed?
2. Where is the building located?
3. What codes should be followed?
4. Do any local code amendments apply?
5. Does the owner or operator of the building have any unusual requirements?
6. Does the owner or operator of the building prefer a particular type of system?
7. How much system redundancy does the owner or operator of the building want?
8. Does the building have any other hot water systems?
9. What area of the building will the system serve?
10. What is the area used for?
11. How many plumbing fixtures will be installed?
12. Who will be using the plumbing fixtures
13. Are any high-usage fixtures, such as hot tubs, included?
14. Does the owner plan to expand the facility in the future?
15. Does the building include laundry, foodservice, or health club areas?
16. How many areas will be used simultaneously?

Typical Questions for HWR Sizing (Cont'd)

17. How much space is available for the system?
18. What energy sources are available?
19. Where in the building will the equipment be placed?
20. Will flues or combustion air be a problem due to the location?
21. What is the building's cold water source?
22. What are the water hardness, pH, total dissolved solids, and other water quality parameters?
23. Will the system be inactive for long periods?
24. How far from the heater will the furthest fixture be?
25. How many showers will be used simultaneously and for what duration?

High- vs. Low-rise Buildings



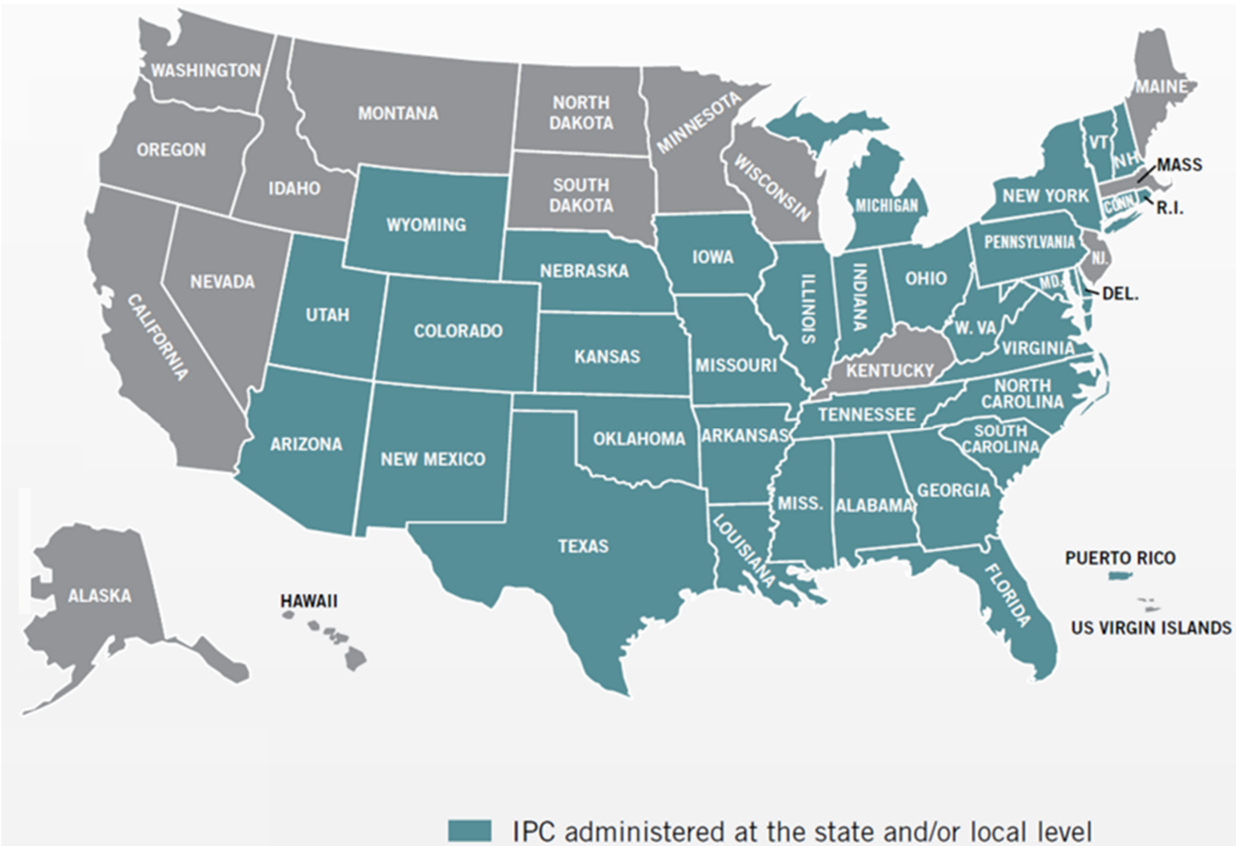


Codes, Standards and Guidelines

1. Regional, state, and local plumbing codes — including International Plumbing Code
2. ASHRAE / IES 90.1
3. OSHA addresses Legionella
4. ASME code for fired and unfired pressure vessels
5. ASME and AGA codes for relief valves
6. Underwriters' Laboratories (UL) Listing for electrical components
7. National Sanitation Foundation (NSF) listing
8. AGA approval for gas burning components
9. National Fire Protection Association (NFPA)
10. National Electrical Code (NEC)

International Plumbing Code Adoption

As of May 7, 2019

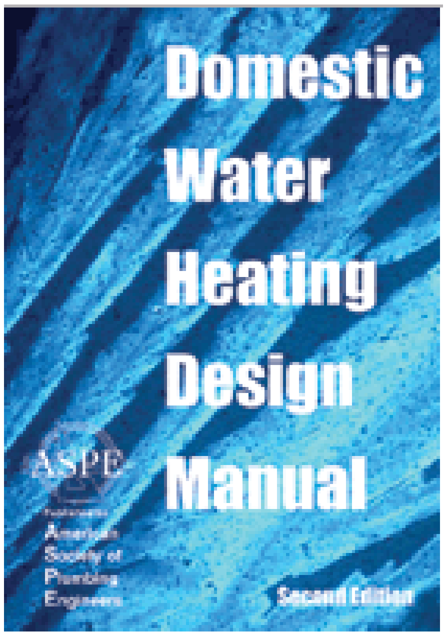


IPC in use or adopted in:

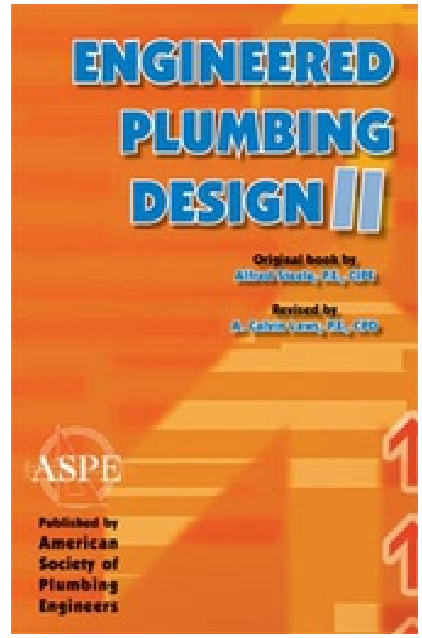
- *35 states*
- *District of Columbia*
- *Guam*
- *Puerto Rico*

Image courtesy of International Code Council®

Tools from ASPE



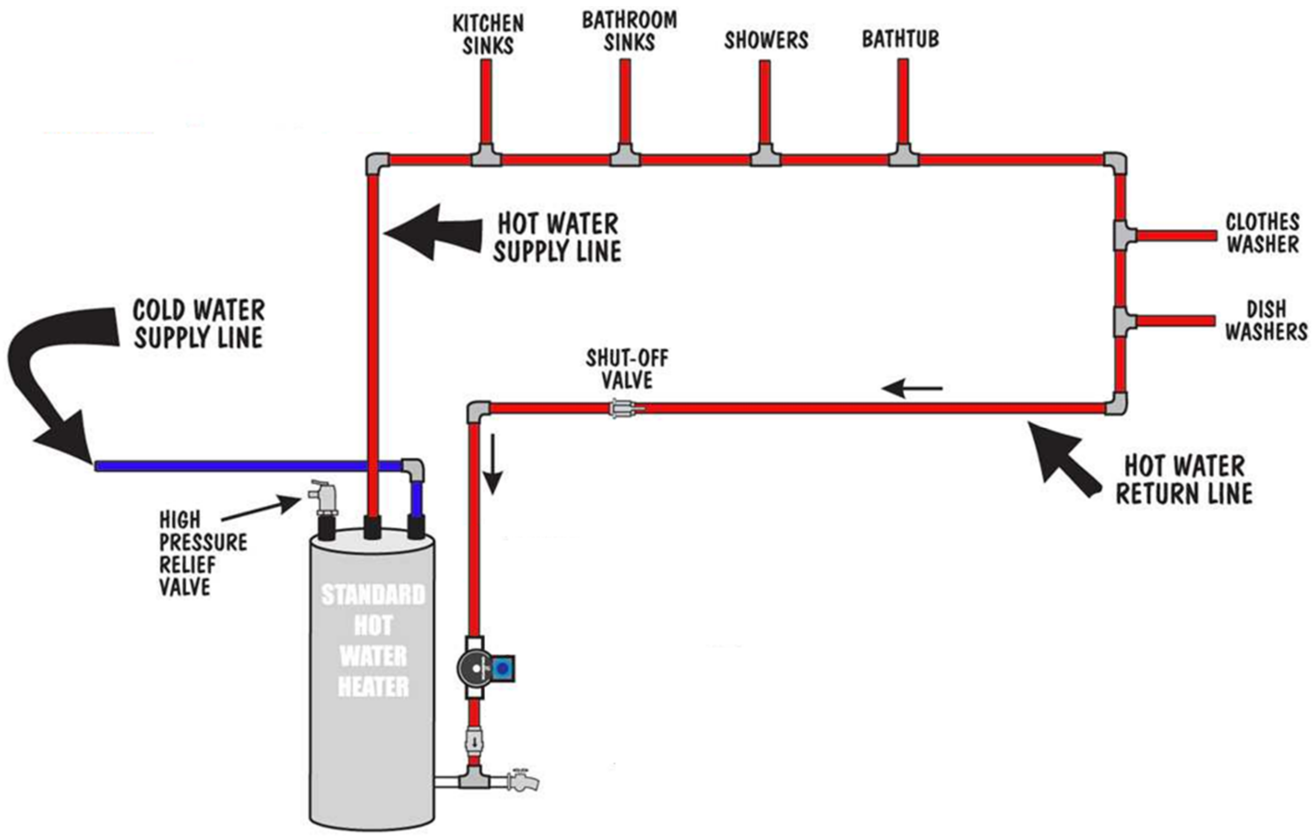
ASPE Domestic Water Heating Design Manual
Second Edition



ASPE Engineered Plumbing Design II

How does HWR work?

Simplified System



What temperature do we want at the fixture?

Table 1.2 Typical Delivered Hot Water Temperatures for Plumbing Fixtures and Equipment

Use	Temp. (°F)
Lavatory	105
Showers and tubs	110
Commercial and institutional laundry	140–180
Residential dishwashing and laundry	140
Commercial spray type dishwashing (as required by the NSF):	
Single or multiple tank hood or rack type: Wash	150
Final rinse	180–195
Single tank conveyor type: Wash	160
Final rinse	180–195
Single tank rack or door type:	
Single temperature wash and rinse	165
Chemical sanitizing glassware: Wash	140
Rinse	75

Note: Be aware that temperatures, as dictated by codes, owners, equipment manufacturers, or regulatory agencies, will occasionally differ from those shown.

Safety Concern: Risk of Scalding

Scalding — 1st Degree:

- 3 Seconds at 140° F
- 20 Seconds at 130° F
- 8 Minutes at 120° F

Scalding. A research project by Moritz and Henriques at Harvard Medical College

Safety Concern: Legionella

- Legionella Pneumophila (Legionnaires' Disease)
- Temperature range for bacteria growth varies across organizations and the country:
  - **Centers for Disease Control and Prevention (CDC):** 90–113° F
  - **ASHRAE:** 77–108° F
  - **Legionella Control in Healthcare Facilities:** 68–122° F (ideal = 95–115° F)
  - **American Society for Healthcare Engineering & Joint Commission list:** 77–108° F
  - Combined ranges of 68–122° F may survive municipal water treatment

Legionella Prevention

- Need to do heat loss calculation since long pipe runs can influence how low temperature can go
- All available information indicates that almost all bacteria die at temperatures above 130° F
- The higher the temperature, the faster the bacteria die
- High temperature treatment often performed in middle of night

Mixing Valves

- Mixing can occur at:
  - Mixing valves at fixtures
  - Mixing stations

- Be sure that the system design includes appropriate mixing valves in accordance with local codes

- Thermostatic mixing valves listed to the ASSE (American Society of Sanitary Engineering) 1070 standard are designed to be installed close to the fixture from which hot water will be drawn

Mixing Valves: Why we use them

1. Assure that the water delivered by the fixtures will **not** scald
2. Enable the water to have sufficiently high temperature throughout the system to kill Legionella bacteria

Mixing Valves: 3 Types

1

Point of Use
Mixing Valve

2

Point of Delivery
Thermostatic
Mixing Valve

3

Electronically Controlled Motorized
Mixing Valve

Note: There are other system designs for providing safe and effective HWR.

Why System Balance is a MUST!

- Multiple piping risers; numbers of fixtures; varying elevations
- Differing circuit lengths and fixtures quantities
- Unbalanced circuits create inappropriate temperature drops and inadequate temperatures at some fixtures
- Use of only one circulator can be problematic
- Balancing creates a common temperature drop between the start and stop of each circuit

Balancing Valves: 4 Types

1

Fixed orifice manually-adjustable balancing valves with pressure ports designed to give a pre-determined flow

2

Variable orifice manually-adjustable balancing valves with pressure ports

3

Dynamic valves configured to maintain a specific and fixed flow rate — open and close to maintain a ΔT

4

Manually-adjustable balancing valves with integral flow meters

Balancing Differences

Hydronic Balancing:

- Assumes stable flow through all branches when all zones are open
- Provides proper flow under partial load conditions

vs.

HWR Balancing:

- Provides minimum hot water temperature at all points in system
- Provides hot water quickly
- Prevents stagnant areas where bacteria can build up

Balancing Valves: New Trends

New Trends/Advancements:

- Use ***thermally*** actuated balancing valve
- With a variable speed circulator
- Using proportional differential pressure control

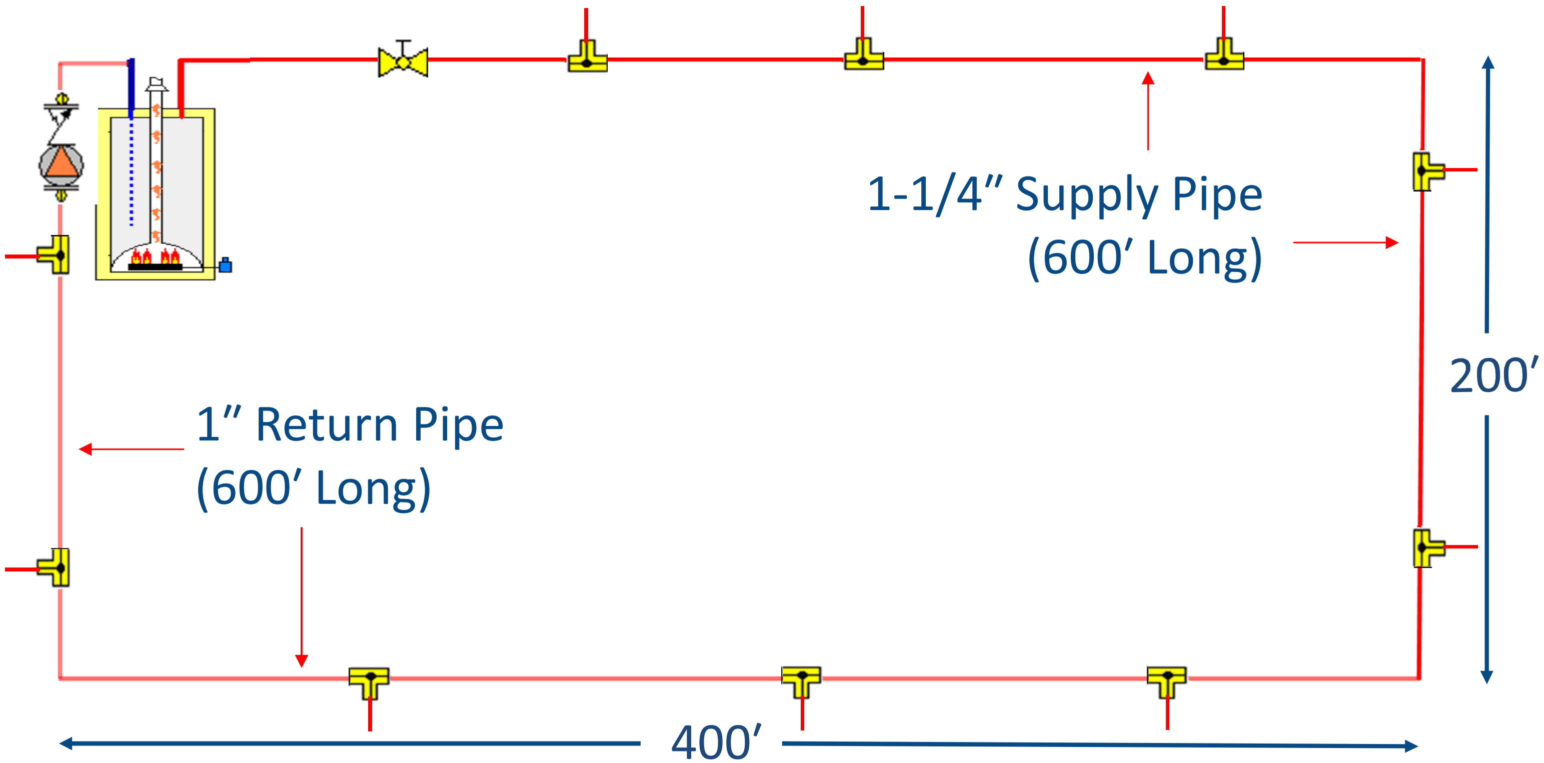
Benefits:

- Optimize system performance
- Minimize energy use

Selection Exercise:
Specifications for Pump Selection with Insulated Tubing

- Hot water supply piping is 1.25″ Type L Copper Tubing
- Return piping is 1″ Type L Copper Tubing
- The piping circuit is 600′ of supply line and 600′ of return line
- Water supplied at 140° F
- Provide 10° F ΔT from heater to fixtures and back to heater

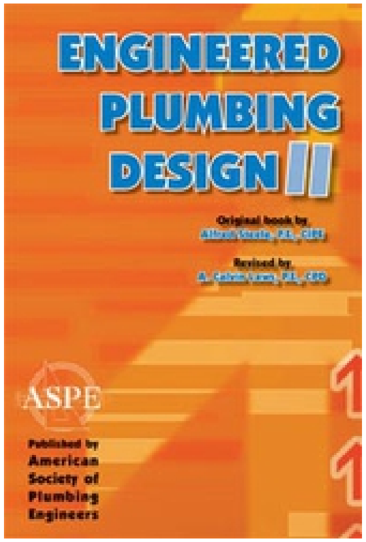
Selection Exercise:
Piping Schematic



Where do we begin?

STEP 1: Calculate BTUh → **STEP 2:** Determine gpm → **STEP 3:** Select Pipe → **STEP 4:** Determine Head → **STEP 5:** Preliminary Pumps → **STEP 6:** Apply System Curve → **STEP 7:** Select Pump

Reference:
Engineered Plumbing Design II manual's Heat Loss Chart (pg. 204), will help determine heat loss for a given length of pipe



STEP 1: Calculate BTUh | STEP 2: Determine gpm

STEP 1:
Calculate BTUh
Determine Heat Loss from Pipe

This heat loss chart is used for both **insulated** and **uninsulated pipe**

Engineered Plumbing Design II

Table 17-1 Piping Heat Loss
(Btu/hr. Per Lineal Ft. For 140°F. Water Temp and 70°F. Room Temp.)

Nominal Pipe Size	Insulated Pipe (½" Fiberglass)	Bare Pipe		
		Sched. 40 Steel	Brass, Copper, T.P.	Type K Copper
½"	15	35	26	19
¾"	17	43	32	26
1"	19	53	38	32
1¼"	21	65	46	39
1½"	25	73	53	46
2"	28	91	65	58
2½"	32	108	75	68
3"	38	129	90	81
4"	46	163	113	103
5"	55	199	138	127
6"	63	233	161	149
8"	80	299	201	188

STEP 1: Calculate BTUh | STEP 2: Determine gpm

STEP 1:
Calculate BTUh

Using 21 and 19 BTUh / foot of copper tubing to determine heat output for the system:

$600\ {}^{feet}/_{pipe} \times 21\ {}^{BTUh}/_{foot}$ = 12,600 BTUh

$600\ {}^{feet}/_{pipe} \times 19\ {}^{BTUh}/_{foot}$ = 11,400 BTUh

TOTAL = 24,000 BTUh

STEP 1: Calculate BTUh | **STEP 2: Determine gpm** | STEP 3: Select Pipe

STEP 2:

Determine gpm

Calculate gpm Flow Rate

$$gpm = \frac{BTUh}{(500 \times \Delta T)}$$

STEP 1: Calculate BTUh → **STEP 2: Determine gpm** → STEP 3: Select Pipe

STEP 2:

Determine gpm

Calculate Required Flow Rate

$$\text{gpm} = \frac{24{,}000 \text{ BTUh}}{(500 \times 10° \text{ F})} = 4.8 \text{ gpm} = 5 \text{ gpm}$$

Note: Round up

STEP 2: Determine gpm | STEP 3: Select Pipe | STEP 4: Determine Head

STEP 3:
Select Pipe

GOLDEN RULE:

Velocity through the pipe network **should *NOT exceed***

4 ft/sec

STEP 2: Determine gpm → STEP 3: Select Pipe → STEP 4: Determine Head

STEP 3:
Select Pipe:
Flow Rate & Velocity in Piping

1. High water velocity combined with hot water can lead to erosion and pin holes in copper piping and brass or copper fittings

2. Small pipe diameters can lead to temperature differentials other than your target ΔT

3. Above 180° F is not recommended for most applications primarily because of the potential for scalding

   Also this high a temperature causes faster erosion

STEP 3: Select Pipe | STEP 4: Determine Head | STEP 5: Preliminary Pumps

STEP 4:
Determine Head

Head = Length × Friction Loss Values

Length: (Circuit of pipe including fittings)

Friction Loss Values: (Plus aging factor for pipe)

These can be found in the Grundfos *HVAC Technical Guide*

STEP 3: Select Pipe | STEP 4: Determine Head | STEP 5: Preliminary Pumps

STEP 4:
Determine Head
Friction Loss Charts

Based on friction loss charts and calculations, the total pumping head for our example is 19'

1-1/4 INCH

	TYPE K TUBING		TYPE L TUBING		TYPE M TUBING		PIPE*	
	1.245" Inside Dia. .065" Wall Thickness		1.265" Inside Dia. .055" Wall Thickness		1.291" Inside Dia. .042" Wall Thickness		1.368" Inside Dia. .146" Wall Thickness	
FLOW U.S. GPM	VELOCITY (Ft./Sec.)	**HEAD LOSS (Ft./100 Ft.)**	VELOCITY (Ft./Sec.)	**HEAD LOSS (Ft./100 Ft.)**	VELOCITY (Ft./Sec.)	**HEAD LOSS (Ft./100 Ft.)**	VELOCITY (Ft./Sec.)	**HEAD LOSS (Ft./100 Ft.)**
5	1.31	**0.79**	1.28	**0.74**	1.22	**0.67**	1.09	**0.51**
6	1.58	**1.09**	1.53	**1.01**	1.47	**0.92**	1.31	**0.70**
7	1.84	**1.43**	1.79	**1.32**	1.71	**1.20**	1.53	**0.91**
8	2.11	**1.81**	2.04	**1.67**	1.96	**1.52**	1.75	**1.15**
9	2.37	**2.22**	2.30	**2.06**	2.20	**1.87**	1.96	**1.42**
10	2.63	**2.67**	2.55	**2.48**	2.45	**2.25**	2.18	**1.71**
12	3.16	**3.69**	3.06	**3.42**	2.93	**3.10**	2.62	**2.35**
15	3.95	**5.47**	3.83	**5.07**	3.66	**4.60**	3.27	**3.49**
20	5.26	**9.13**	5.10	**8.46**	4.89	**7.67**	4.36	**5.81**

1 INCH

	TYPE K TUBING		TYPE L TUBING		TYPE M TUBING		PIPE*	
	.995" Inside Dia. .065" Wall Thickness		1.025" Inside Dia. .050" Wall Thickness		1.055" Inside Dia. .035" Wall Thickness		1.062" Inside Dia. .1265" Wall Thickness	
FLOW U.S. GPM	VELOCITY (Ft./Sec.)	**HEAD LOSS (Ft./100 Ft.)**	VELOCITY (Ft./Sec.)	**HEAD LOSS (Ft./100 Ft.)**	VELOCITY (Ft./Sec.)	**HEAD LOSS (Ft./100 Ft.)**	VELOCITY (Ft./Sec.)	**HEAD LOSS (Ft./100 Ft.)**
2	0.82	**0.47**	0.78	**0.41**	0.73	**0.36**	0.72	**0.35**
3	1.24	**0.95**	1.17	**0.82**	1.10	**0.72**	1.08	**0.70**
4	1.65	**1.56**	1.56	**1.35**	1.47	**1.18**	1.45	**1.14**
5	2.06	**2.30**	1.95	**2.00**	1.83	**1.74**	1.81	**1.69**
6	2.48	**3.17**	2.34	**2.75**	2.20	**2.40**	2.17	**2.32**
7	2.89	**4.15**	2.72	**3.60**	2.56	**3.14**	2.53	**3.04**
8	3.30	**5.25**	3.11	**4.56**	2.93	**3.97**	2.89	**3.85**
9	3.71	**6.47**	3.50	**5.61**	3.30	**4.89**	3.25	**4.74**
10	4.12	**7.79**	3.89	**6.76**	3.66	**5.89**	3.61	**5.71**

STEP 4: Determine Head | STEP 5: Preliminary Pumps | STEP 6: Apply System Curve

STEP 5:
Preliminary Pump Selection

- Must meet system flow requirement of 5 gpm
- At head of 19’

STEP 4:
Determine
Head

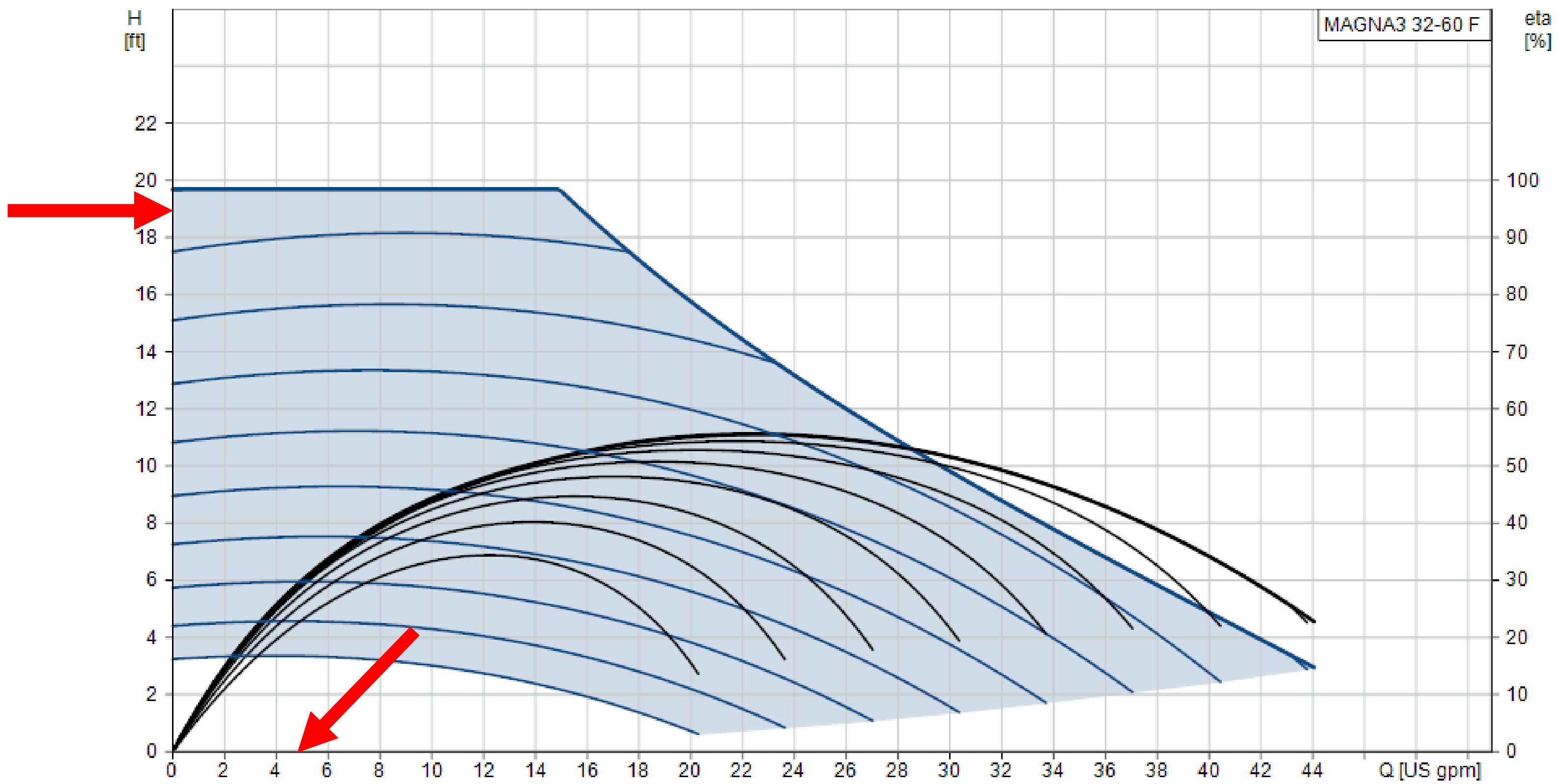
STEP 5:
Preliminary
Pumps

STEP 6:
Apply System
Curve

STEP 5:

Preliminary Pump Selection

Locate Suitable Curve(s)



STEP 5: Preliminary Pumps | **STEP 6: Apply System Curve** | STEP 7: Select Pump

STEP 6:
Apply System Curve

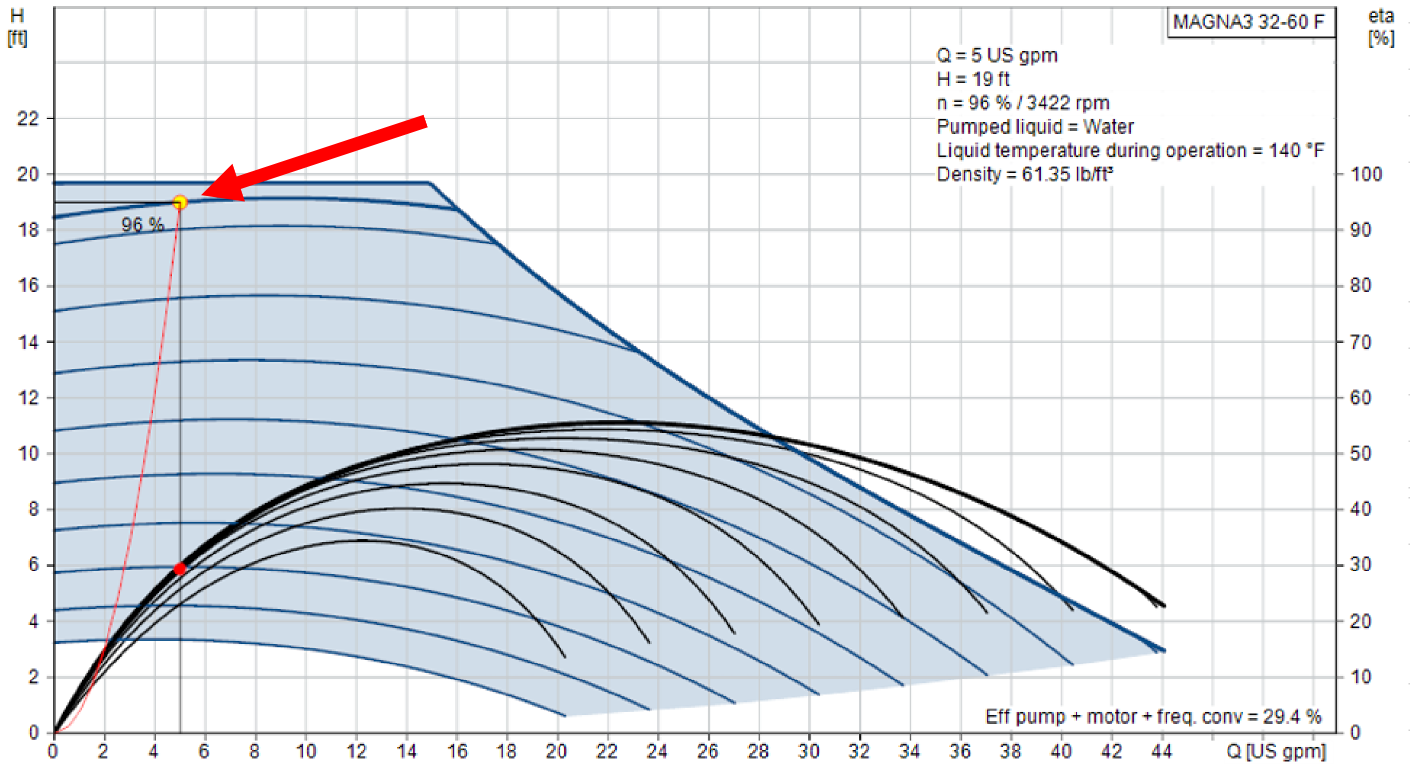
- Plot the system's feet and head point.
- Follow the system curve through the design point to narrow pump selection

STEP 5: Preliminary Pumps

STEP 6: Apply System Curve

STEP 7: Select Pump

STEP 6:
Apply System Curve
System Curve Overlay



STEP 7:
Select a Pump

STEP 1:	STEP 2:	STEP 3:	STEP 4:	STEP 5:	STEP 6:	STEP 7:
Calculate BTUh	Determine gpm	Select Pipe	Determine Head	Preliminary Pumps	Apply System Curve	Select Pump

STEP 6:
Apply System Curve

STEP 7:
Select Pump

STEP 7:
Select a Pump
Power Consumption

- Compare power consumption on the pump curves
- If comparing efficiency — compare wire-to-water!
- Consider a pump with an ECM (Electronically Commutated Motor) for superior efficiency

STEP 6: Apply System Curve → STEP 7: Select Pump

STEP 7:
Select a Pump
Comparing BTUh Consumption

INSULATED PIPE:

What's the BTUh loss with Insulation?

24,000 BTUh

VS.

UNINSULATED PIPE :

What's the BTUh loss without Insulation?

50,400 BTUh

STEP 6: Apply System Curve → STEP 7: Select Pump

STEP 7:
Select a Pump
Comparing BTUh Consumption

INSULATED PIPE:

What flow and head is required with Insulation?

5 gpm at 19’

VS.

UNINSULATED PIPE :

What flow and head is required without Insulation?

10 gpm at over 50’

ASPE Guidelines

#1 Rule of Thumb

- ½ gpm for each SMALL riser: ¾″ and 1″
- 1 gpm for each MEDIUM riser: 1 ¼″ and 1 ½″
- 2 gpm for each LARGE riser: 2″ and greater

#2 Rule of Thumb

- An allowance of 1 gpm for each group of 20 hot water fixtures

Common Circulator Sizing Mistakes

❌ DON'T

- Size pump inlet and outlet based on size of piping (which usually results in an oversized pump)
- Determine TDH based on height of building
  Ex: If a 3-story building is 30' tall — choose a pump based on 30' of head

✓ DO

- Size the pump based on flow and head required
- Perform complete TDH calculation (do the math!) using friction loss charts and calculations

Things to Watch For

- Conservative friction tables mean oversized pumps
- ECMs enable speed reduction to provide appropriate flow rate and return temperature

Common Control Modes

- Fixed speed
- Three fixed speeds
- Constant temperature at one point out in system or at pump
- Constant differential pressure at one point out in the system or across the pump
- ***<u>Proportional differential pressure</u>***

See the Grundfos Technical Guides for control modes available with each pump series

Choosing the Right HWR Pump

Popular Models

- UP(S) Wet Rotor Circulators
- MAGNA1 (with ECM)
- MAGNA3 (with ECM)
- CR Multistage

Primary Selection Criteria for Pumps:

1. Flow Rate
2. Head
3. Power Consumption
4. Control Mode
5. Footprint

Properly Piped Recirc System:

Pump Considerations

1. **Traditional UP:** Cost effective — broad performance range
2. **ECM Circulators:** Maximum energy savings
3. **MAGNA3:** Advanced control modes and low power consumption
4. **CR & CRE:** High pressure applications
5. **Stainless Steel & Bronze Construction:** Corrosion resistance

Course Learning Objectives

1. Do you add vertical lift to the calculation for pump head sizing?
2. What is the maximum velocity of a recirc loop?
3. How long does it take to scald someone at 140 degrees?
4. What is the temperature that Legionella best grows?
5. What is the maximum temperature drop you want to allow in a recirc loop to avoid Legionella?

Answers:

1. No!
2. 4 ft/sec
3. 3 seconds
4. 77-108 degrees
5. 10 degrees - Starting at 120 degrees Fahrenheit

Thank You

Grundfos by the Numbers

#1
Pump Manufacturer in the World

74
Years Old (Founded in 1945)

83
Local Companies Worldwide

17M
Units Produced Each Year

19K
Employees Worldwide

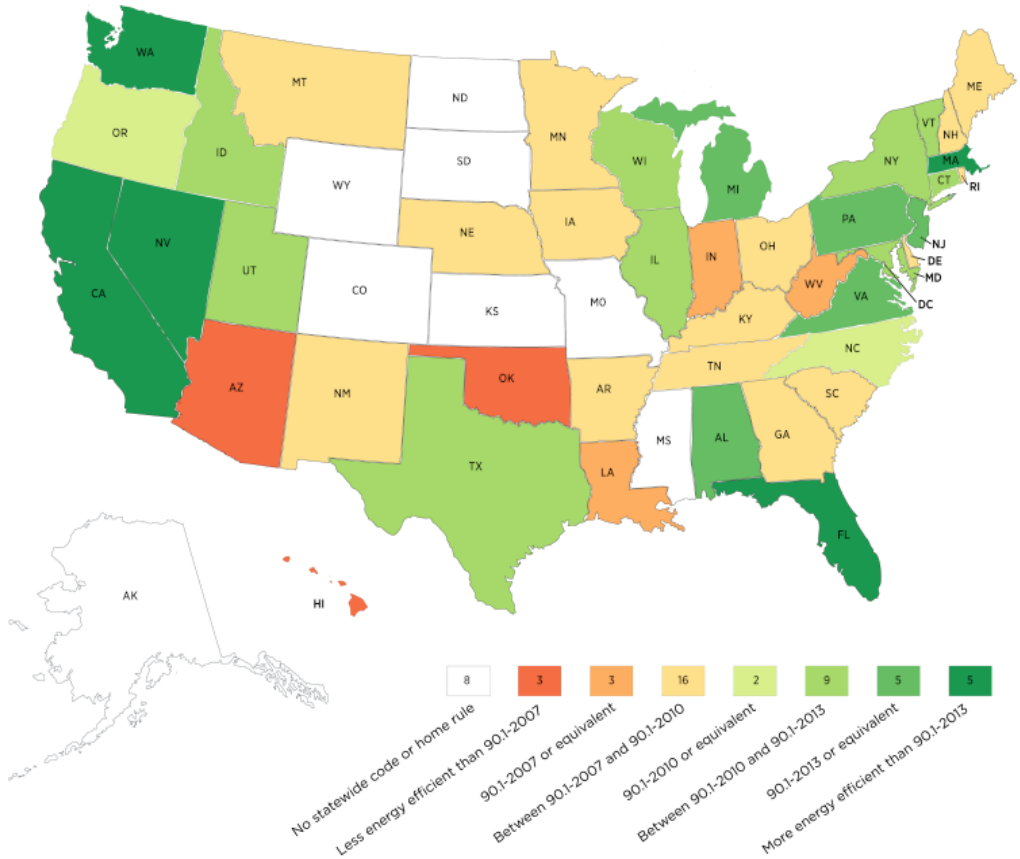
$4B
Turnover in 2018

100%
Privately Held

Appendix

Status of ASHRAE 90.1 Energy Code Adoption

As of April 9, 2019



Source: U.S. Department of Energy

Overview of How to Manually Balance a HWR System

1. Assume 4 recirculation circuits with 1 recirculation pump
2. When recirculation is required, as an example the 4 circuits require target flow rates of 4, 3, 2, and 1 gpm, respectively
3. Note that the total required ideal flow is 10 gpm (4 + 3 + 2 + 1)
4. A manually actuated balancing globe valve is installed on each return line
5. Install the systems and prepare to balance
6. Turn pump on; because of the “as-built” nature of the piping system, the flow rates are not exactly 4, 3, 2, and 1, respectively
7. Assume that the total actual flow is 14.2 gpm, and that the actual flow through each circuit has also been determined
8. A calculation is made, and proportional adjustment is planned for each circuit — in order to achieve the correct 4, 3, 2, and 1 flow rates
9. Each balancing globe valve is adjusted and a new respective and total flow is established
10. We will still probably not be at exactly 10 gpm with the right flow through each circuit
11. This becomes a reiterative process — and we will keep repeating until 4, 3, 2, and 1 gpm is achieved, respectively
12. Note: globe valves used for balancing are always open
13. The pump will turn on/off in reaction to a temperature sensor — located on supply main
14. Any time the ΔT gets too great (low temperature at main) the pump turns on and ALL circuits are open and so get their pre-set flow rates of 4, 3, 2, and 1 gpm, respectively.
15. Whether or not fixtures are using water is irrelevant