PHRC Webinar Series | Tuesday, September 12 @ 1pm

Residential Domestic Hot Water: Generation & Distribution

Brian Wolfgang | PHRC Associate Director

Pennsylvania Housing Research Center
219 Sackett Building | University Park, PA 16802
P: 814-865-2341
phrc@psu.edu
www.PHRC.psu.edu

Description

- As homes become more energy efficient it is important that the mechanical systems in the home are able to respond to the needs of the building. HVAC systems typically get the most attention, however hot water generation and distribution is often overlooked. These systems, when not properly designed, can waste significant amounts of energy through standby and distribution losses. This webinar will discuss some of the principles of hot water generation (including equipment selection), analyze current code requirements for hot water systems, and will examine best practices for creating an efficient overall domestic hot water system.

9

Learning Objectives

- Explore the components of a domestic hot water system in residential structures, including performance, efficiency, and safety features.
- Analyze current options for generating domestic hot water and compare energy efficiency and utility costs of each option.
- Discuss common distribution strategies in residential structures for delivering hot water to necessary spaces in a home.
- Examine current code requirements and federal standards related to domestic hot water.

10

What do Homeowners Expect & Want?

- **Guest Speaker: Gary Klein**
  - Gary Klein and Associates, Inc.

11

What Do You Want from your Hot Water System?

- Clean clothes
- Clean dishes
- Clean hands
- Clean body
- Relaxation
- Enjoyment

The service of hot water

What Do You Expect from your Hot Water System?

Safety
- Not too hot
- Not too cold
- No harmful bacteria or particulates
- Sanitation

Reliability
- Little or no maintenance
- Last forever
- Low cost

Convenience
- Adjustable temperature and flow
- Never run out
- Quiet
- Hot water now

What Are We Aiming For?

- People want the service of hot water, as efficiently as possible.
- It does not make sense to discuss efficiency until the desired service has been provided.

The 2 Key Services…

Hot Water Now = "Instantaneousness"
- Need hot water available before the start of each draw.
  - A tank with hot water
  - Heated pipes
- Need the source of hot water close to each fixture or appliance
- Point of Use is not about water heater size, its about location

Never Run Out in My Shower = "Continousness"
- Need a large enough tank or a large enough burner or element
- Or, a modest amount of both

How Long to Wait?

- **Depends on:**
  - Distance from water heater
  - Pipe size
  - Flow rate

16

Distribution Performance

Flow rate = Volume / Time

therefore

Time = Volume / Flow rate

Volume = π x radius^2 x Length

18

Distribution Performance

Time = Volume / Flow rate

Low-flow fixtures = Lower flow rate

Lower flow rate = Longer time for hot water

19

What is (Generally) Out of Your Control on a Project?

- **Occupant expectations and wants**
- **Federal regulations**
- **Code requirements**
- **Equipment and labor cost**

20

"Given human nature, it is our job to provide the infrastructure that supports efficient behaviors."

- Gary Klein

21

What Can You (Attempt to) Control on a Project?

- Subcontractor selection
- Equipment selection
- System design
- Floor plan

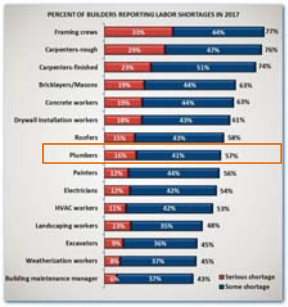
22

Subcontractor Selection

- Are mechanical drawings required in your jurisdiction?
- Is qualified labor accessible for your project?
- Are they affordable?

23

Is Qualified Labor Accessible?

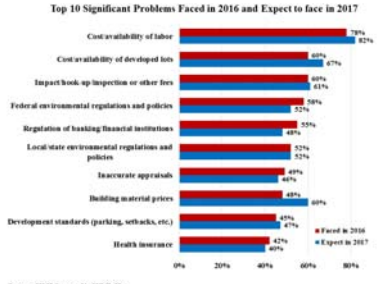


24 Emrath, P. (2017). *Share of Builders Reporting Labor Shortages Rises Again*, NAHB Eye on Housing.

Labor Shortages

25 Emrath, P. (2017). *Share of Builders Reporting Labor Shortages Rises Again*, NAHB Eye on Housing.

Labor Cost



26 Chaluvadi, A. (2017). *Top Challenge for Builders is Labor Cost/Availability*, NAHB Eye on Housing.

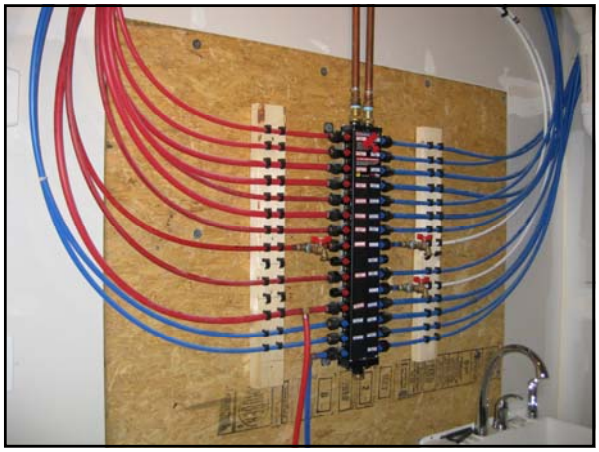
Distribution Performance

Time = Volume / Flow rate

Random / inefficient pipe runs = Greater volume

Greater volume = Longer time for hot water

28



How Big?

- **For a given flow rate, when comparing to the time it takes for hot water to arrive in 3/8" pipe**
  - ~1.5 times as long in ½" pipe
  - ~3 times as long in ¾" pipe
  - ~6 times as long in 1" pipe

30

Klein, G. (2005). *Hot-Water Distribution Systems – Part II.*

Distribution Performance

Time = Volume / Flow rate

Oversized pipes = Greater volume

Greater volume = Longer time for hot water

31

Equipment Selection

- **General options**
  - Storage units
    - Electricity
    - Natural gas
  - On-demand units (tankless)
    - Natural gas
    - Electricity

32

Distribution System Design

- Trunk & branch systems
- Core systems
- Whole-house manifold systems
- Demand-initiated recirculation systems

33

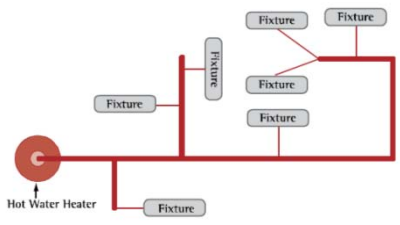
What is the Goal?

"…no more than 0.5 gallons of water are stored between the water heater and each fixture."

34

Office of Wastewater Management. (2014). *Guide for Efficient Hot Water Delivery Systems*, EPA WaterSense.

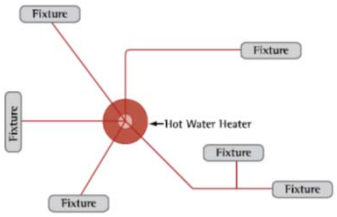
Trunk & Branch Systems



35

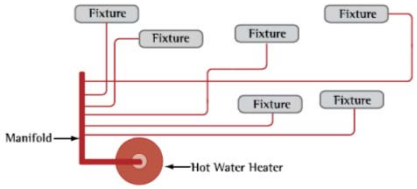
Office of Wastewater Management. (2014). *Guide for Efficient Hot Water Delivery Systems*, EPA WaterSense.

Core Systems



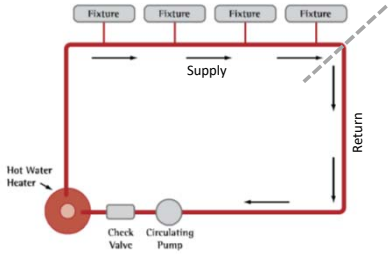
36 Office of Wastewater Management. (2014). *Guide for Efficient Hot Water Delivery Systems*, EPA WaterSense.

Whole-House Manifold Systems



37 Office of Wastewater Management. (2014). *Guide for Efficient Hot Water Delivery Systems*, EPA WaterSense.

Demand-Initiated Recirculation Systems



38 Office of Wastewater Management. (2014). *Guide for Efficient Hot Water Delivery Systems*, EPA WaterSense.

Pipe Sizing

Table 1.Internal Volume of Various Water Distribution Piping

Ounces of Water Per Foot of Hot Water Tubing								
Nominal Diameter in inches (in)	Copper M	Copper L	Copper K	CPVC CTS SDR 11	CPVC SCH 40	PEX-Al-PEX ASTM F 1281	PE-AL-PE	PEX CTS SDR 9
⅜	1.06	0.97	0.84	N/A	1.17	0.63	0.63	0.64
½	1.69	1.55	1.45	1.25	1.89	1.31	1.31	1.18
¾	3.43	3.22	2.90	2.67	3.38	3.39	3.39	2.35
1	5.81	5.49	5.17	4.43	5.53	5.56	5.56	3.91
1 ¼	8.70	8.36	8.09	6.61	9.66	8.49	8.49	5.81
1 ½	12.18	11.83	11.45	9.22	13.20	13.88	13.88	8.09
2	21.08	20.58	20.04	15.79	21.88	21.48	21.48	13.86

Source: Modified from *2009 International Plumbing Code Table E202.1. International Code Council. January.*

Conversions: 1 gallon (3.8 liters) = 128 ounces
1 ounce = 0.00781 gallons (0.0296 liters)
0.5 gallons (1.9 liters) = 64 ounces
0.6 gallons (2.3 liters) = 76.8 ounces

39 Office of Wastewater Management. (2014). *Guide for Efficient Hot Water Delivery Systems*, EPA WaterSense.

Floor Plan

- **Where is the equipment located?**
- **How does the floor plan impact system performance?**
  - Length of pipe
- **Is there enough space to run mechanical systems effectively?**

41

Distribution Performance

Time = Volume / Flow rate

Longer pipe runs = Greater volume

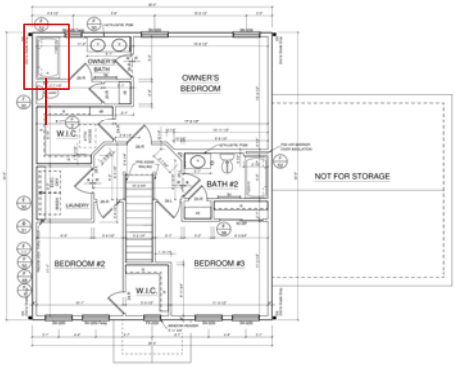
Greater volume = Longer time for hot water

42

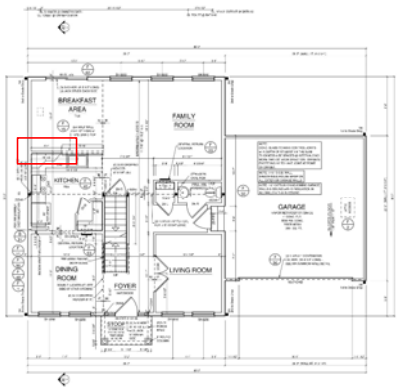
Example Calculations

- **Two scenarios**
  1. Master bath shower
  2. Powder room sink

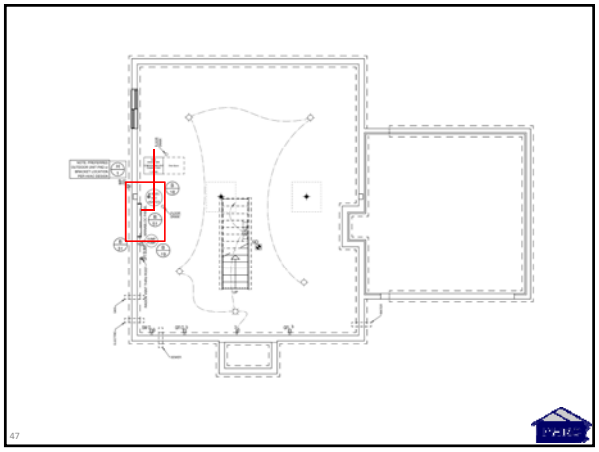
43

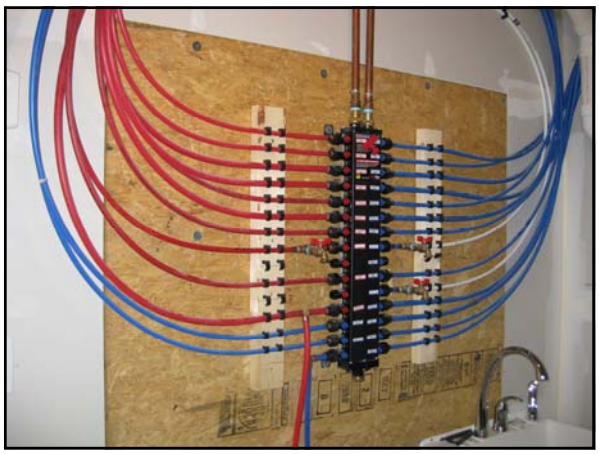


44



45


47



Pipe Sizing

Table 1.Internal Volume of Various Water Distribution Piping

Ounces of Water Per Foot of Hot Water Tubing								
Nominal Diameter in inches (in)	Copper M	Copper L	Copper K	CPVC CTS SDR 11	CPVC SCH 40	PEX-Al-PEX ASTM F 1281	PE-AL-PE	PEX CTS SDR 9
⅜	1.06	0.97	0.84	N/A	1.17	0.63	0.63	0.64
½	1.69	1.55	1.45	1.25	1.89	1.31	1.31	1.18
¾	3.43	3.22	2.90	2.67	3.38	3.39	3.39	2.35
1	5.81	5.49	5.17	4.43	5.53	5.56	5.56	3.91
1 ¼	8.70	8.36	8.09	6.61	9.66	8.49	8.49	5.81
1 ½	12.18	11.83	11.45	9.22	13.20	13.88	13.88	8.09
2	21.08	20.58	20.04	15.79	21.88	21.48	21.48	13.86

Source: Modified from *2009 International Plumbing Code Table E202.1. International Code Council. January.*

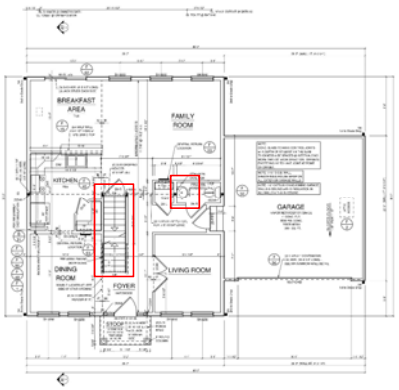
Conversions: 1 gallon (3.8 liters) = 128 ounces
1 ounce = 0.00781 gallons (0.0296 liters)
0.5 gallons (1.9 liters) = 64 ounces
0.6 gallons (2.3 liters) = 76.8 ounces

49 Office of Wastewater Management. (2014). *Guide for Efficient Hot Water Delivery Systems*, EPA WaterSense.

Calculation

- **Distribution = 1/2" PEX**
- **Total length from manifold = 35 feet**
  - Volume = 35 ft x 1.18 oz/ft = 41.3 oz = 0.32 gallons
- **Length within manifold = ~ 12"**
  - Volume = 1 ft x 5.81 oz/ft = 5.81 oz = 0.045 gallons
- **Supply to manifold = 10 feet of ¾" PEX**
  - Volume = 10 ft x 2.35 oz/ft = 23.5 oz = 0.184 gallons
- **Tub faucet flow rate = ~ 5 gpm**
- **Time for hot water = 0.549 gal / 5 gpm = 0.11 minutes**
  - 0.11 minutes = **6.6 seconds**

50



51

Pipe Sizing

Table 1.Internal Volume of Various Water Distribution Piping

Nominal Diameter in inches (in)	Ounces of Water Per Foot of Hot Water Tubing							
	Copper M	Copper L	Copper K	CPVC CTS SDR 11	CPVC SCH 40	PEX-Al-PEX ASTM F 1281	PE-AL-PE	PEX CTS SDR 9
¾	1.06	0.97	0.84	N/A	1.17	0.63	0.63	0.64
1	1.69	1.55	1.45	1.25	1.89	1.31	1.31	1.18
¾	3.43	3.22	2.90	2.67	3.38	3.39	3.39	2.35
1	5.81	5.49	5.17	4.43	5.53	5.56	5.56	3.91
1 ¼	8.70	8.36	8.09	6.61	9.66	8.49	8.49	5.81
1 ½	12.18	11.83	11.45	9.22	13.20	13.88	13.88	8.09
2	21.08	20.58	20.04	15.79	21.88	21.48	21.48	13.86

Source: Modified from *2009 International Plumbing Code Table E202.1. International Code Council. January.*

Conversions: 1 gallon (3.8 liters) = 128 ounces
1 ounce = 0.00781 gallons (0.0296 liters)
0.5 gallons (1.9 liters) = 64 ounces
0.6 gallons (2.3 liters) = 76.8 ounces

53 Office of Wastewater Management. (2014). *Guide for Efficient Hot Water Delivery Systems*, EPA WaterSense.

Calculation

- **Distribution = 3/8" PEX**
- **Total length from manifold = 55 feet**
  - Volume = 55 ft x 0.64 oz/ft = 35.2 oz = 0.275 gallons
- **Length within manifold = ~ 12"**
  - Volume = 1 ft x 5.81 oz/ft = 5.81 oz = 0.045 gallons
- **Supply to manifold = 10 feet of ¾" PEX**
  - Volume = 10 ft x 2.35 oz/ft = 23.5 oz = 0.184 gallons
- **Fixture flow rate = 1.5 gpm**
- **Time for hot water = 0.504 gal / 1.5 gpm = 0.336 minutes**
  - 0.336 minutes = **20.2 seconds**

54

Hand Washing Behavior

- **Michigan State study** (Borchgrevink, Cha, & Kim, 2013) **found that people who washed their hands only washed for ~6 seconds**
- **CDC recommendation is to scrub your hands for 20 seconds**
  - Hum "Happy Birthday" twice!
- **What does this mean for your distribution system?**

55

Borchgrevink, C., Cha, J., & Kim, S. (2013). *Hand Washing Practices in a College Town Environment*, Journal of Environmental Health.

So What Does This All Mean?

- **Many things have changed in homes that have changed the performance of hot water distribution systems**
  - Crucial to understand the factors that contribute to this performance, including occupant behavior
- **Effective design isn't impossible, but requires effort**

56