Energy, Water, and Time Efficient Hot Water Systems

2017 MREC Conference

55th Annual Conference on Rural Energy Issues

Bloomington, MN

February 9-10, 2017

Gary Klein

Gary Klein and Associates, Inc.
Tel: 916-549-7080
Email: Gary@GaryKleinAssociates.com

What Are We Aiming For?

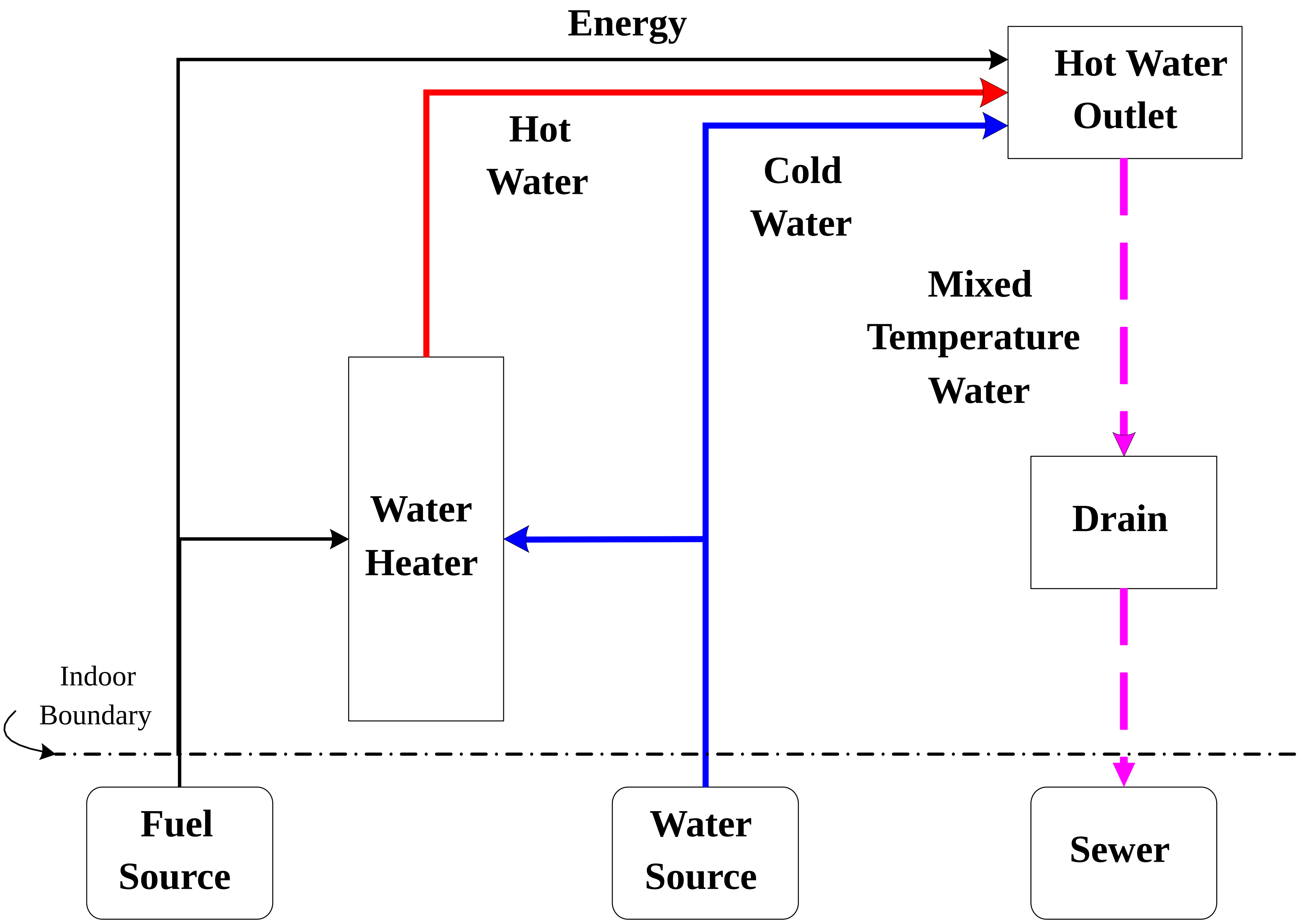
- People want the service of hot water, as efficiently as possible.
- It does not make sense to discuss efficiency until the desired service has been provided.

The delivery of hot water ends at the plumbing fixture or appliance, not at the customer's meter

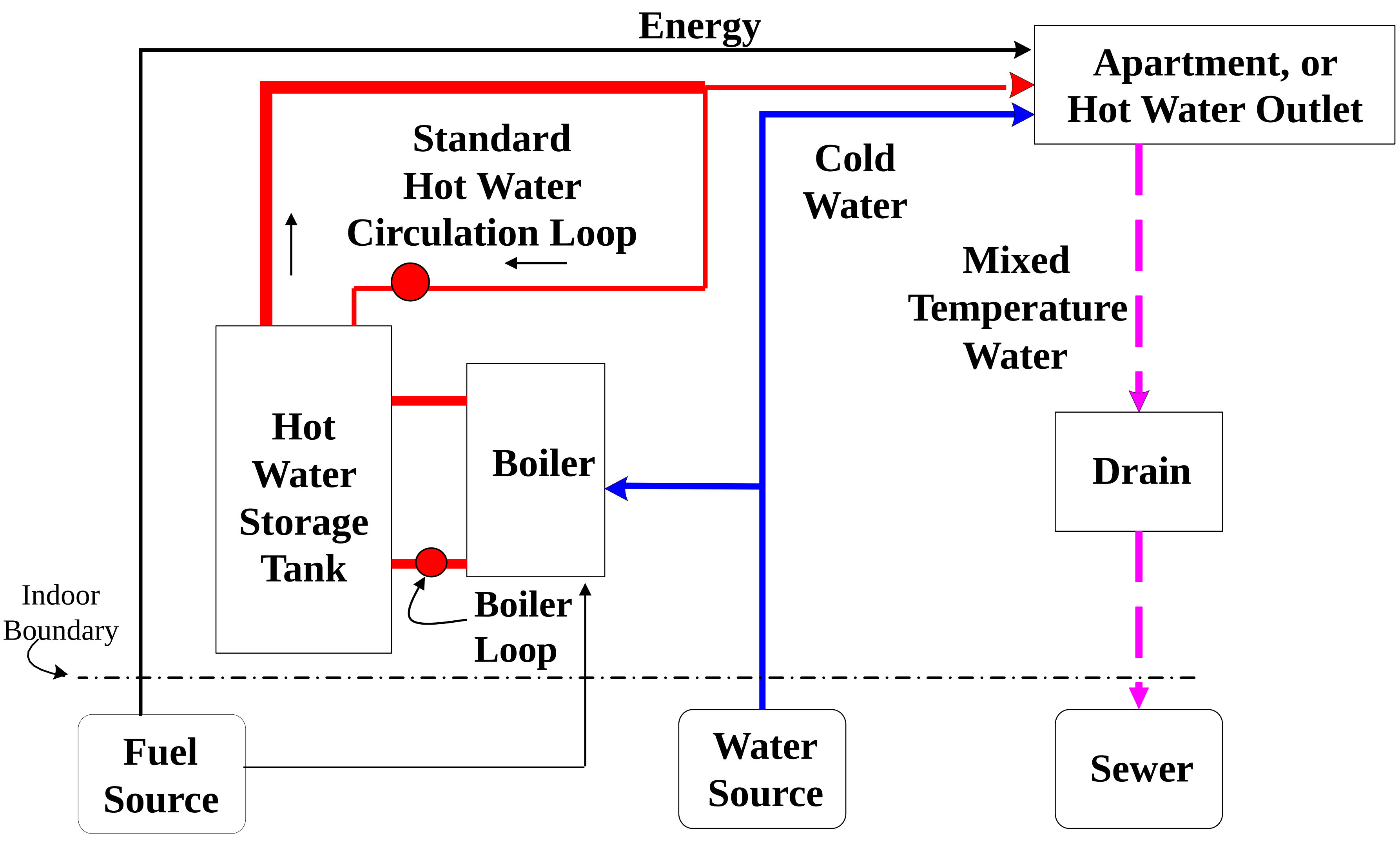
The 2 Key Services…

- 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

Typical “Simple” Hot Water System

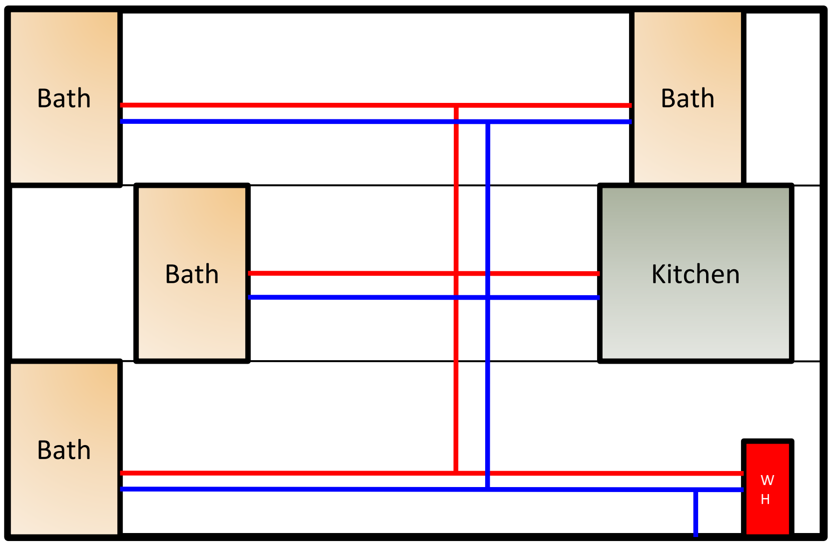


Typical Central Boiler Hot Water System

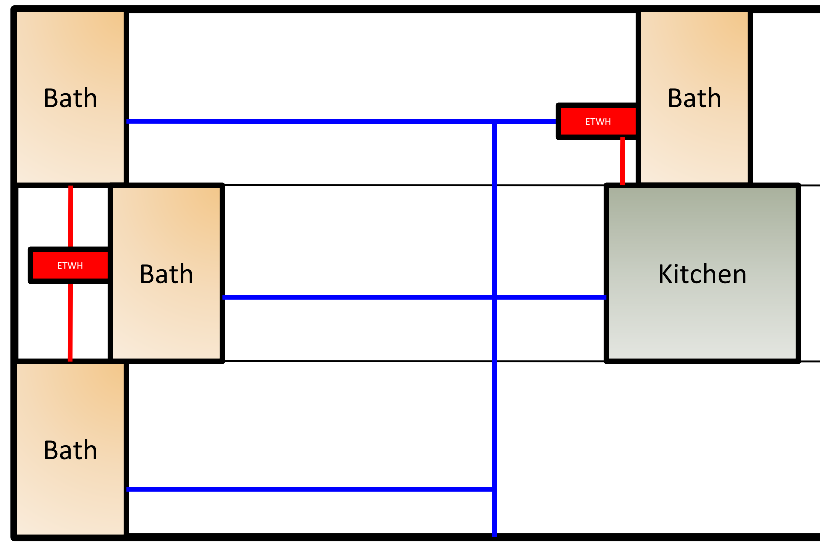


The Case for Multiple Water Heaters

Single Water Heater



Multiple Water Heaters



<u>Hot Water Produced at the "Point of Use" Results in:</u>

- **Less wasted water waiting for it to "heat-up"**
- **Energy Savings from wasted hot water**
- **Less piping – only cold water runs to point of use**

Courtesy of Kevin Ruppelt, Eemax, Coalition for Energy Efficient Electric Tankless Water Heaters, 2010

Why Do I Work on Hot Water?

- Energy Intensity of Indoor Cold Water
  - Range from 5 to 25 kWh per 1000 gallons
- Energy Intensity of Hot Water

	Electric		Natural Gas	
	Resistance (85% Efficient)	Heat Pump (COP = 2)	(50% Efficient)	(95% Efficient)
kWh/1,000 Gallons	201	85	342	180
Relative Energy Intensity compared to 5 kWh/1,000 gallons	40	17	68	36

- Typically 40-68 times more energy intensive than indoor cold water.

How do we use hot water?

- Frequent short, low flow-rate draws
- Occasional long draws at low flow-rates
- High flow-rate and high volume draws are rare
- Draws are highly clustered
- The potential for simultaneous draws at a combined high flow rate is very small

What Reduces Hot Water Use?

- Insulating hot water supply piping
- End uses closer to water heater(s)
- Lower flow rate plumbing fixtures
- Lower volume plumbing appliances
- Using waste heat running down the drain to preheat cold water
- Truly "Instantaneous" water heaters
- Warmer incoming cold water
- Anything else?

What Increases Hot Water Use?

- Uninsulated hot water supply piping
  - More uses start out with colder water
- End uses further from water heater(s)
  - More volume to clear
- Lower flow rate plumbing fixtures
  - Increases waste while waiting for hot water to arrive
- “Instantaneous” water heaters
  - Cold water runs through while ramping up to temp
- Colder incoming cold water
  - Increases the percent of hot water in the mix
- Anything else?

What Increases Customer Satisfaction?

- Instantaneousness
- Continuousness
- Hot water systems that are predictable and easy to "learn"
- Plumbing fixtures that provide rated flow even at low pressures
- Plumbing appliances that do their job with lower amounts of water.
- Lower energy bills for their hot water
- Anything else?

The Ideal
Hot Water Distribution System

- Has the smallest volume (length and smallest “possible” diameter) of pipe from the source of hot water to the hot water outlet.
- Sometimes the source of hot water is the water heater, sometimes a trunk line.
- For a given layout (floor plan) of hot water locations the system will have:
  - The shortest buildable trunk line
  - Few or no branches
  - The shortest buildable twigs
  - The fewest plumbing restrictions
  - Insulation on all hot water pipes, minimum R-4

The Challenge

Deliver hot water

to every hot water outlet

wasting no more energy

than we currently waste running water down the drain and

wasting no more than 1 cup

waiting for the hot water to arrive.

Length of Pipe that Holds 8 oz of Water

	3/8" CTS	1/2" CTS	3/4" CTS	1" CTS
	ft/cup	ft/cup	ft/cup	ft/cup
"K" copper	9.48	5.52	2.76	1.55
"L" copper	7.92	5.16	2.49	1.46
"M" copper	7.57	4.73	2.33	1.38
CPVC	N/A	6.41	3.00	1.81
PEX	12.09	6.62	3.34	2.02
Ave	**8 feet**	**5 feet**	**2.5 feet**	**1.5 feet**

SoCalGas Hot Water Demonstration Lab

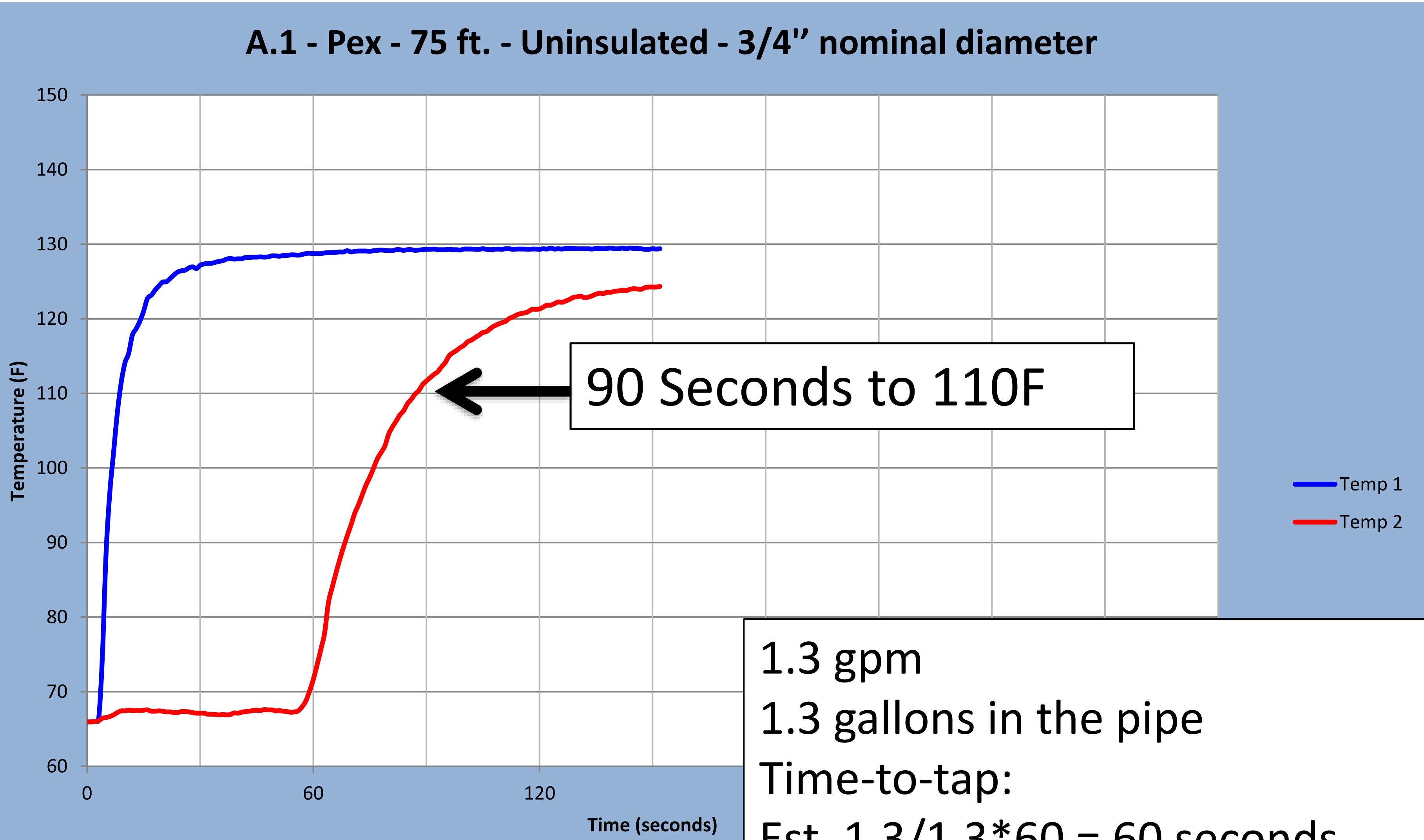
Entering Section of Experiment:

1. Flushing and Priming
2. Flow Rate
3. Pressure 1
4. Temperature 1

Exiting Section of Experiment:

1. Pressure 2
2. Temperature 2
3. Discharge through Plumbing Fixture

Demonstrating Performance



1.3 gpm

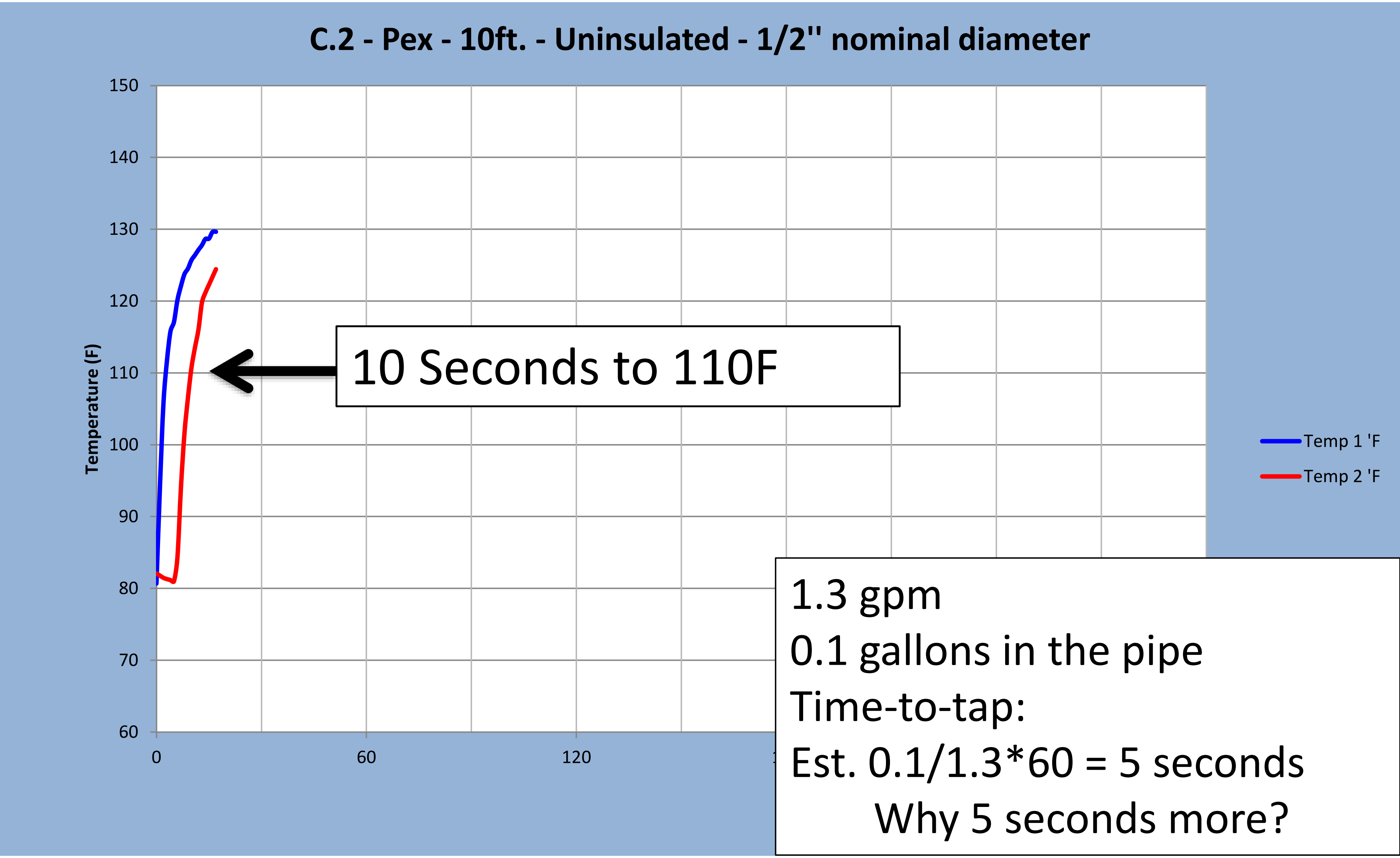
1.3 gallons in the pipe

Time-to-tap:

Est. 1.3/1.3*60 = 60 seconds

Why 30 seconds more?

Demonstrating Performance



How Long Should We Wait?

Volume in the Pipe (ounces)	Minimum Time-to-Tap (seconds) at Selected Flow Rates					
	0.25 gpm	0.5 gpm	1 gpm	1.5 gpm	2 gpm	2.5 gpm
2	4	1.9	0.9	0.6	0.5	0.4
4	8	4	1.9	1.3	0.9	0.8
8	15	8	4	2.5	1.9	1.5
16	30	15	8	5	4	3
24	45	23	11	8	6	5
32	60	30	15	10	8	6
64	120	60	30	20	15	12
128	240	120	60	40	30	24

ASPE Time-to-Tap Performance Criteria

(green)	Acceptable Performance	1 – 10 seconds
(orange)	Marginal Performance	11 – 30 seconds
(pink)	Unacceptable Performance	31+ seconds

Source: Domestic Water Heating Design Manual – 2nd Edition, ASPE, 2003, page 234

For realistic wait times: add 25 – 100% to the time-to-tap and the volume until hot

Pressure Drop in Pipe and Fittings

- Many materials and types of fittings
- Calculations vs. measured data
- Are the data we use representative of present day materials and fittings?

From the current ASHRAE Fundamentals Pipe Sizing chapter

- *Hegberg (1995) and Rahmeyer (1999a, 1999b) discuss the origins of some of the data shown in Tables 4 and Table 5.*
- *The Hydraulic Institute (1990) data appear to have come from Freeman (1941), work that was actually performed in 1895.*
- *The work of Giesecke (1926) and Giesecke and Badgett (1931, 1932a, 1932b may not be representative of current materials.*

Pressure Drop Due to Elbows

	Equivalent Feet of 1/2" Tubing			
	Water Velocity in Tubing Feet per Second			
90° Elbow Type	2 FPS	4 FPS	5 FPS	8 FPS
PEX Crimp Insert	8.6	10.1	9.8	11.9
PEX Poly SS Press	7.9	8.9	8.9	9.6
PEX Cold Expansion	6.6	7.3	8.0	9.1
CPVC (Std Elb)	1.7	0.8	0.9	1.3
Copper (Std Tight Elb)	0.0	0.4	0.3	0.6

Pressure Drop Due to Elbows

Tight Spacing of Elbows	Equivalent Feet of 1/2" Tubing			
	Water Velocity in Tubing Feet per Second			
90° Elbow Type	**2 FPS**	**4 FPS**	**5 FPS**	**8 FPS**
PEX Poly SS Press	7.9		8.9	9.6
Tight Spacing	8.4		10.8	11.7
PEX Cold Expansion	6.6		8.0	9.1
Tight Spacing	7.9		9.3	9.4
CPVC (Std Elb)	1.7		0.9	1.3
Tight Spacing	0.7		1.3	1.5

Pressure Drop Due to Elbows

	Equivalent Feet of 3/4" Tubing			
	Water Velocity in Tubing Feet per Second			
90° Elbow Type	2 FPS	4 FPS	5 FPS	8 FPS
PEX Poly SS Press	7.0	6.3	6.7	7.1
PEX Cold Expansion	4.8	4.5	4.9	5.2
PEX Push to Connect	2.3	2.0	2.6	2.6
CPVC (Std Elb)	N/A	N/A	N/A	N/A
Copper (Std Tight Elb)	N/A	N/A	N/A	N/A

Hot Water Circulation Systems

There are six types of circulation systems:

- Thermosyphon (gravity convection with no pump),
- Continuously pumped systems,
- Timer controlled,
- Temperature controlled,
- Time and temperature controlled, and
- Demand controlled.

Given the same plumbing layout,
all of these systems will waste the same amount
of water at the beginning of a hot water event.

The difference in these systems
is in the ***energy*** it takes to keep the trunk line
primed with hot water.

The Unintended Consequences of Increasing Water Use Efficiency

Imagine 75% reduced flow rates and volumes

What is the impact in buildings on the

- Hot water system
- Cold water system

What is the impact in buildings on the

- Water supply system
- Waste water system

What changes are needed in future designs to account for these flows?

Draw a line in the sand…

	Existing	New
Buildings		
Water Supply Infrastructure		
Waste Water Treatment Infrastructure		

The most valuable water to conserve
is hot water
at the top of the tallest building, with
the highest elevation,
in the area with the greatest
pressure drop.

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

Thank You!

Gary Klein
Gary Klein and Associates, Inc.

Tel: 916-549-7080
Email: gary@garykleinassociates.com