What You Don’t Know You Don’t Know About (Hot) Water

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Gary Klein, President
Gary Klein and Associates, Inc.
Rancho Cordova, CA 95742
gary@garykleinassociates.com
916-549-7080

Goal of this Session:

- Identify at least 5 things you didn’t know you didn’t know about (hot) water
- Any specific topics you want me to address?
- Are you ready?

1. Water Heaters Have Air Filters

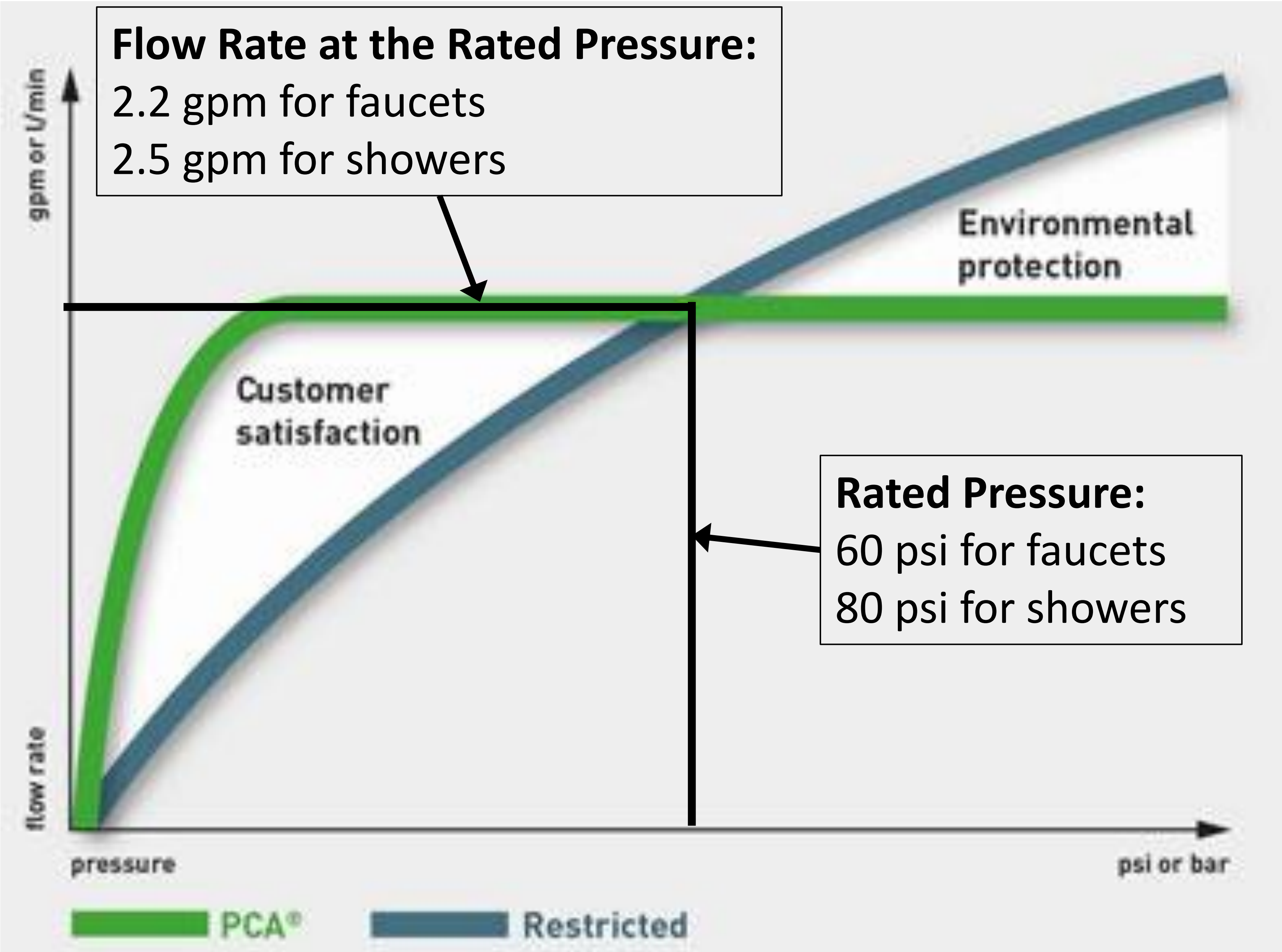
- Well, not all of them, but a very large and growing percentage
- Atmospheric Gas-fired Storage Heaters
  - Flammable Vapor Ignition Resistance (FVIR)
    - Closed combustion chamber, screen with tiny air holes, easily clogged with dust and lint
    - Large particle screen surrounds the bottom of the heater
- Electric Heat Pump Water Heaters
  - Filter on the inlet side of the air path through the heat pump coils.
- Filters need to be cleaned regularly!

2. Fixed vs. Variable Orifices

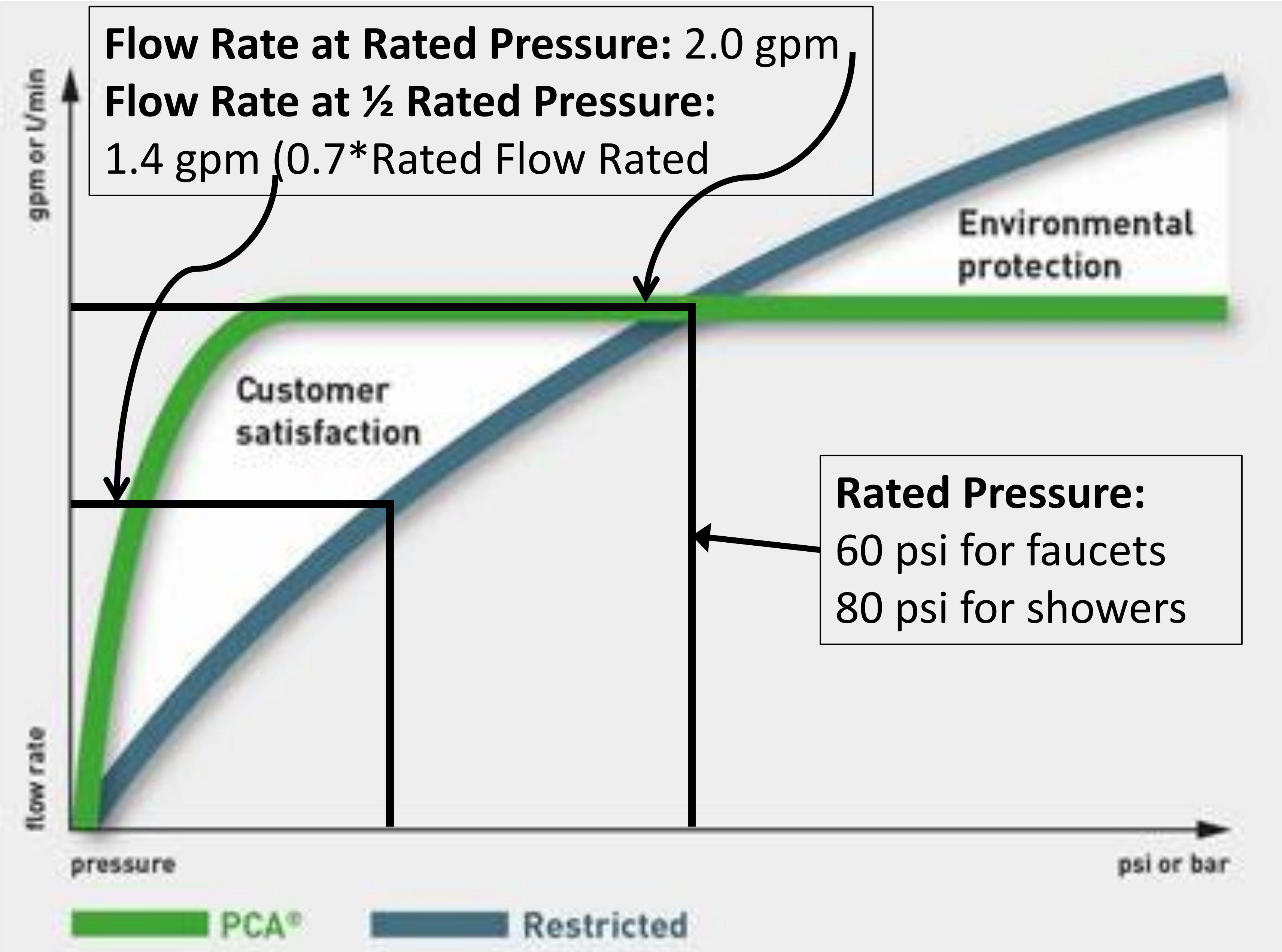
- **Fixed Orifice:**
  - High pressure: High flow rate
  - Low pressure: Low flow rate
  - Before 2000, practically all fixture fittings and appliances
- **Pressure Compensating Aerators**
  - Adjusts flow rate to compensate for available pressure
  - Almost the same flow rate for all pressures above 20-25 psi
  - Ramped up from 2000-2012 for showerheads
  - Today more than 90% and many faucet aerators

Pressure Compensating Aerators - 1

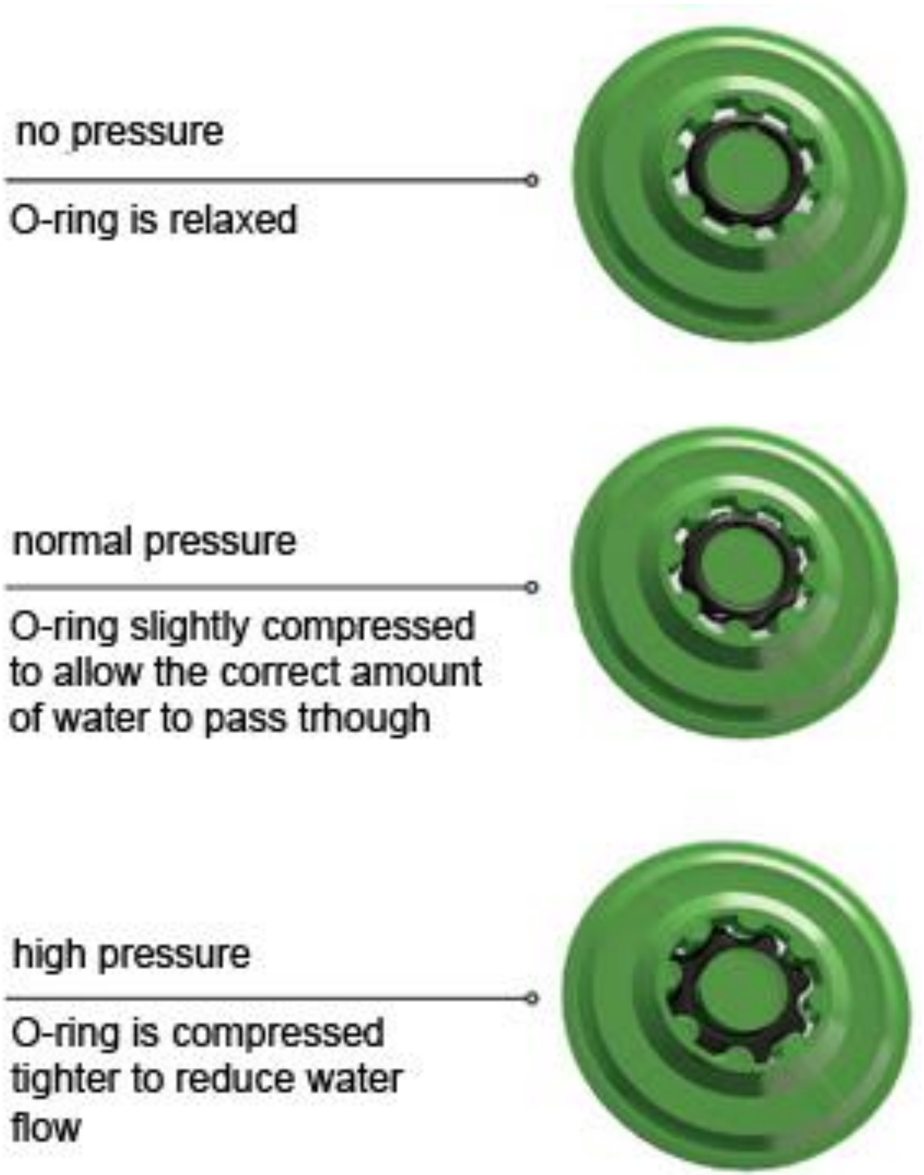
Pressure Compensating Aerators - 2



Pressure Compensating Aerators - 3



Pressure Compensating Aerators - 4



A pressure compensating flow regulator maintains a constant flow regardless of variations in line pressure thereby optimizing system performance and comfort of use at all pressures.

Source: Neoperl's website for this and the pressure-flow diagrams

3. (Hot) Water Flow in Buildings

- What percent of the time does water flow through the meter into the building?
  - Most normal condition is off – zero flow!
    - Depending on occupancy, more than 96% of the time
  - 2nd most normal is 1 fixture fitting or appliance
    - Probably cold, say a toilet
    - Of the remaining 4%, this happens more than 3.9% of the time
    - Hot water is roughly half of this.
  - Flows greater than 3 gpm occur less than 0.1% of the time

3. (Hot) Water Flow in Buildings (cont.)

- Pipe sizing rules were written down in the 1940s
  - Pressure and temperature balanced shower valves became widely available in the 1980s
  - Pressure compensating orifices became widely available in the 2010s
- These two devices mitigate many of this issues that occurred with peak flow rates
  - Relatively constant, safe flow rates for showers and faucets
  - Little impact on the fill rates for toilets, tubs and machines.
- Let’s use these technologies to help with revising the rules for pipe sizing.

4. Time-to-Tap and Volume-until-Hot

- More water than is in a pipe comes out of it before hot water arrives. How much more?
  - Carl Hiller measured this in the early 2000s for 3/8 to 3/4 inch copper, CPVC and PEX piping
  - Zhang recently reviewed the data and has found that for flow rates of 0.5 to 2 gpm in 3/4 inch pipe, 1.5-2.5 times the pipe volume comes out before hot water (>105F) comes out the other end. Roughly 2:1.
- Conclusion: if you want hot water to arrive within 10 seconds, make sure there is no more than 5 seconds of volume in the pipe between the source of hot water and the use.

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

Cut the volume in half to get these times!

ASPE Time-to-Tap Performance Criteria

	Acceptable Performance	1 – 10 seconds
	Marginal Performance	11 – 30 seconds
	Unacceptable Performance	31+ seconds

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

5. Pressure Drop Through 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.*

Pipe from ¼ inch to ¾ inch Nominal

Pipe from ¼ inch to ¾ inch Nominal

90 Degree Elbows

Pressure Drop - 1

- Elbows widely spaced and close together
- Velocities from 1-12 feet per second
- So far, we have not yet measured any published numbers
  - Are our measurements higher or lower than what is published? Yes!
  - Do our numbers have the same trends as what is published? No!
- It matters if we want to right-size piping systems.

Pressure Drop - 2

- Is there a minimum radius of curvature through which there is no additional pressure drop other than that due to the length of the bend?
- Wouldn't that be the most water, pressure, energy and time efficient bend?
- Ask me about the Swoop®

6. Viscosity of Hot and Cold Water

- What is the viscosity of hot water compared to cold water?
  - Is the difference small or large?
  - Cold water is 1.8-3.2 times more viscous than hot water for a wide range of temperatures typically found in buildings!
- It is almost as though there are 2 different fluids moving through the same pipe.
  - Slippery hot water and sluggish cold water.
  - This helps explain much of the extra volume and time to get hot water from the source to the use.

Dynamic viscosity of water at various temperatures

Temperature (°C)	(°F)	Viscosity (mPa·s)
10	50	1.308
20	68	1.002
30	86	0.7978
40	104	0.6531
50	122	0.5471
60	140	0.4658
70	158	0.4044
80	176	0.3550

Ratios

50:122 = 1.308/0.5471
= 2.39
50:140 = 1.308/0.4658
= 2.81
50:158 = 1.308/0.4044
= 3.23

68:122 = 1.002/0.5471
= 1.83
68:140 = 1.002/0.4658
= 2.15
68:158 = 1.002/0.4044
= 2.48

7. Converting Volume to Height

Most of us are between 5’– 7’ tall. This means we are roughly equal to:

- 1/8” pipe: 1 shot of liquor (1 ounce)
- 1/4” pipe: A “double” of liquor (2 ounces)
- 3/8” pipe: 1 glass of wine (4-6 ounces)
- 1/2” pipe: 1 cup of water (8 ounces)
- 3/4” pipe: 1 pint of beer (16 ounces)
- 1” pipe: 1 bottle of wine (750 ml)

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

Questions?

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