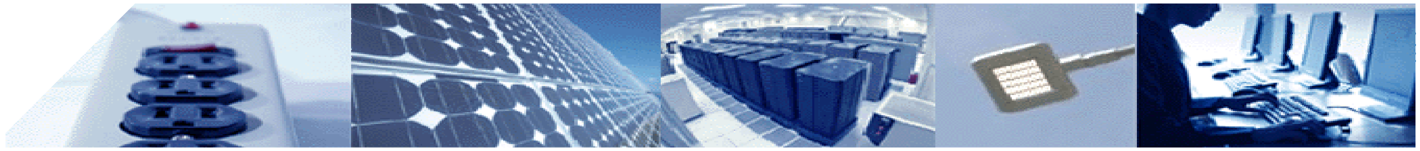

PG&E's Applied Technology Services' Hot Water Technology Performance Laboratory

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Senior Mechanical Engineer

PG&E Applied Technology Services

ACEEE Hot Water Forum

February 23, 2016

gti FISHER NICKEL inc. Pacific Gas and Electric Company® PIER PUBLIC INTEREST ENERGY RESEARCH "Research Powers the Future"

Presentation Objectives

- Describe the history of hot water testing at PG&E's Applied Technology Services (ATS)
- Summarize the results of the last effort
- lab testing effort on Identify the opportunities for future research presented at the conclusion of the last study
- Describe the vision of PG&E's Upgraded Hot Water Technology Performance Laboratory
- Identify how PG&E's laboratory will be modified to support of commercial kitchen field performance characterization research

PG&E Applied Technology Services (ATS)

End use Equipment Testing

Non-Destructive Examination

Vibration Analyses

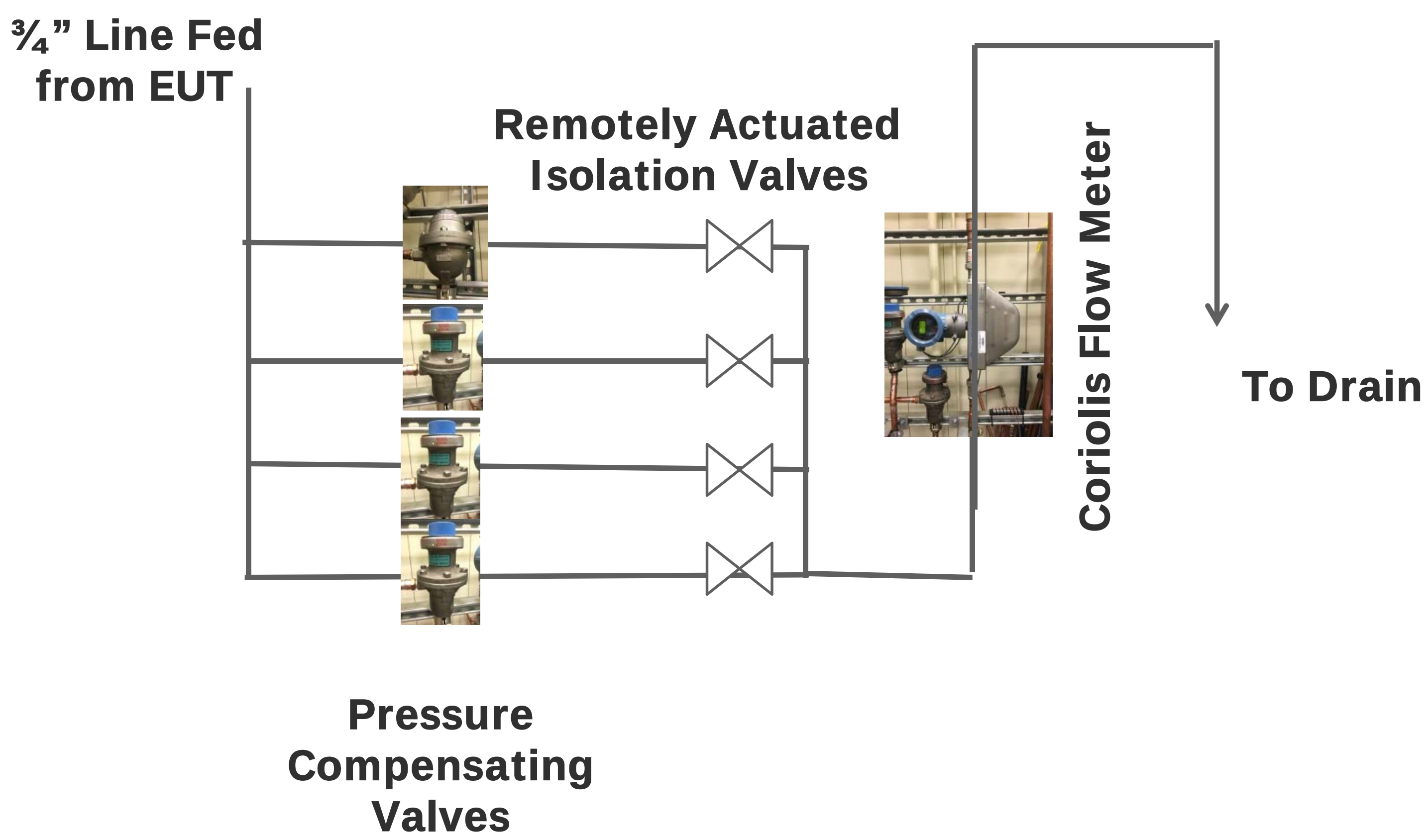
- Multidisciplinary team of Engineers, Technologists, Technicians and Scientists
- Act as an internal PG&E consultant, also perform some 3rd Party work

History of Hot Water Testing at ATS – Residential Water Heater Testing

- Started off supporting the development of ASHRAE standards

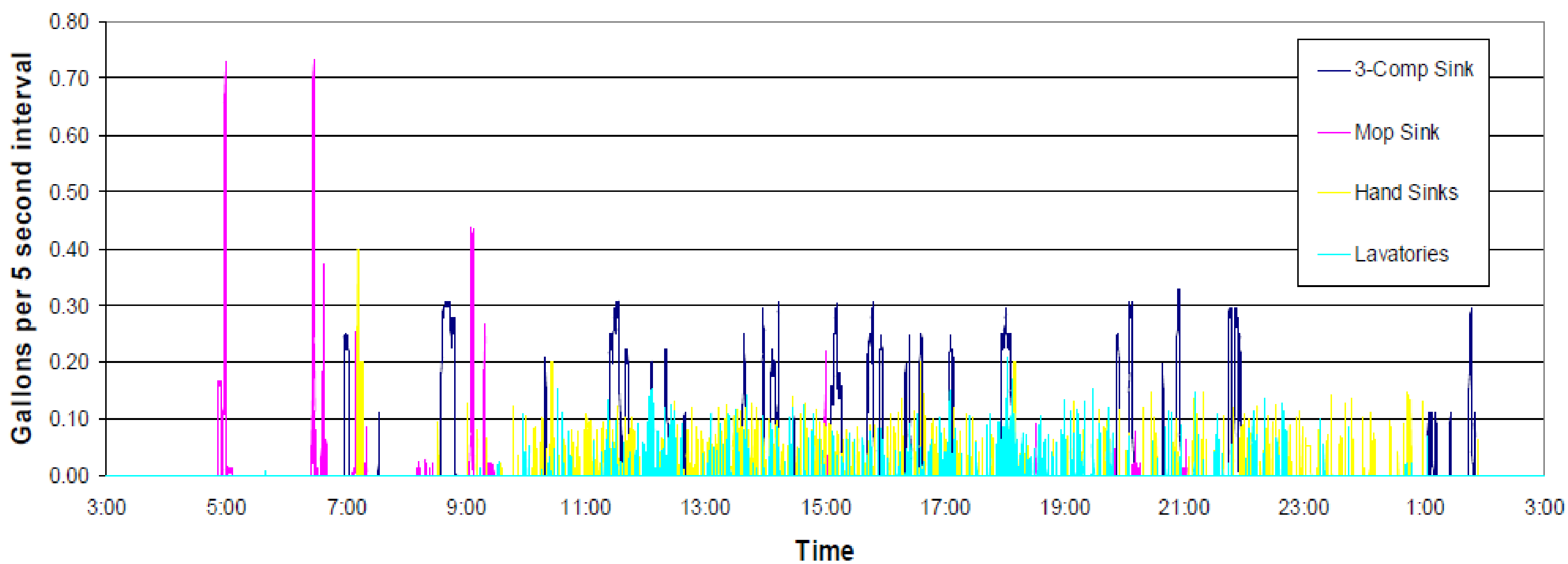
Residential Hot Water Draw Simulation – Flow Measurement and Control

Residential Lab Hot Water Draw Simulation – Flow Measurement and Control (Staged Volume Draws)



Field Characterization of Restaurant Hot Water Use (Completed by Fisher Nickel - FSTC)

Time	3-Comp Sink	Mop Sink	Hand Sinks	Lavatories	24hr Total
Gallons	322.0	60.8	62.1	55.4	500.37
# of Draws	1793	810	1258	1161	5022.00
Average GPM	2.16	0.90	0.59	0.57	



- Fisher-Nickel conducted field monitoring at a quick service restaurant to gather a high resolution 24-hour "real world" hot water use profile

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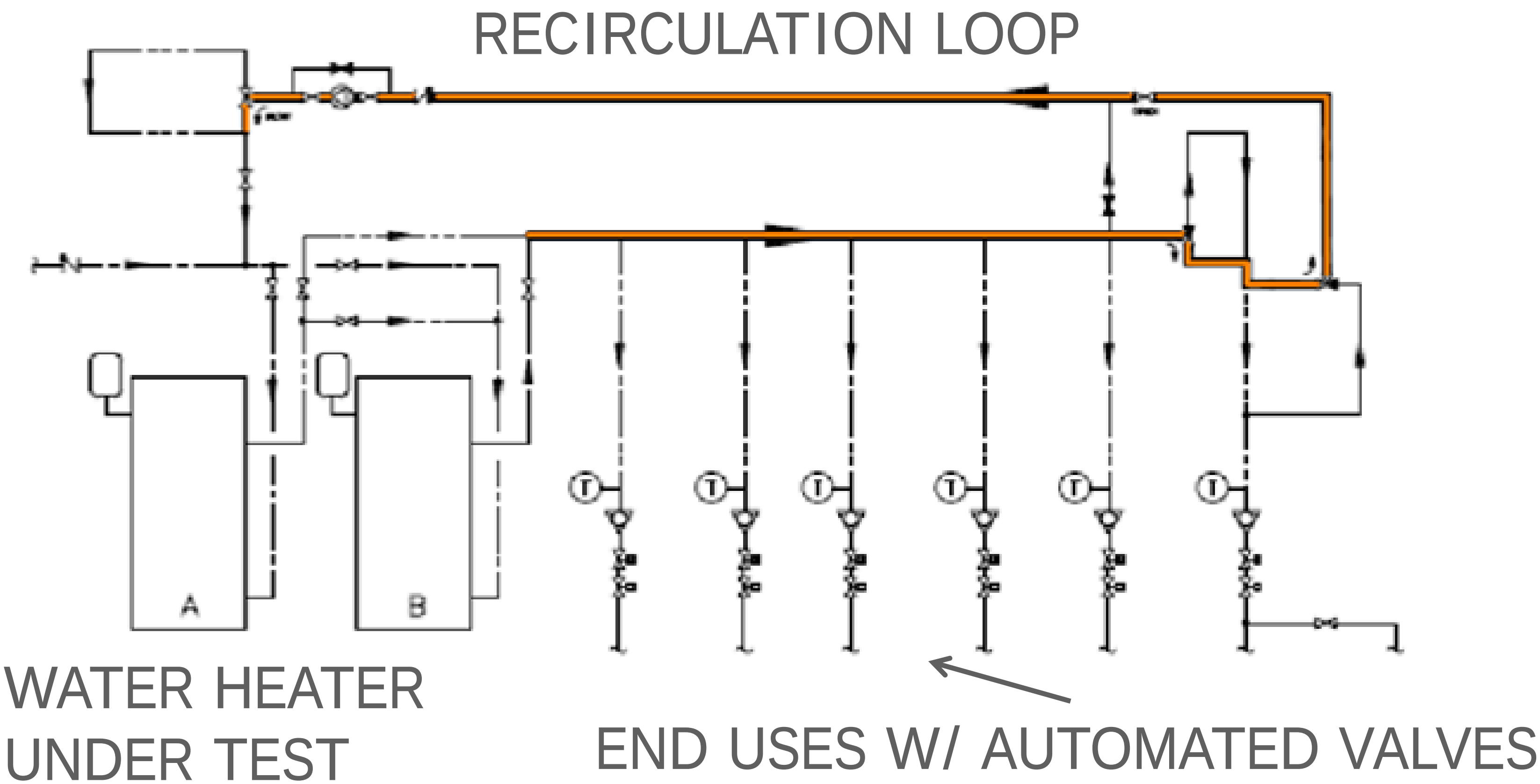
PG&E Applied Technology Services
Commercial Water Heater Laboratory Configuration



- PG&E installed and fully instrumented and functional replication of the hot water system monitored in the field study. Tested various retrofit and RCx measures.

PG&E Applied Technology Services
Commercial Water Heater Laboratory Configuration (cont'd)

- Commercial and Residential Testing in same lab space

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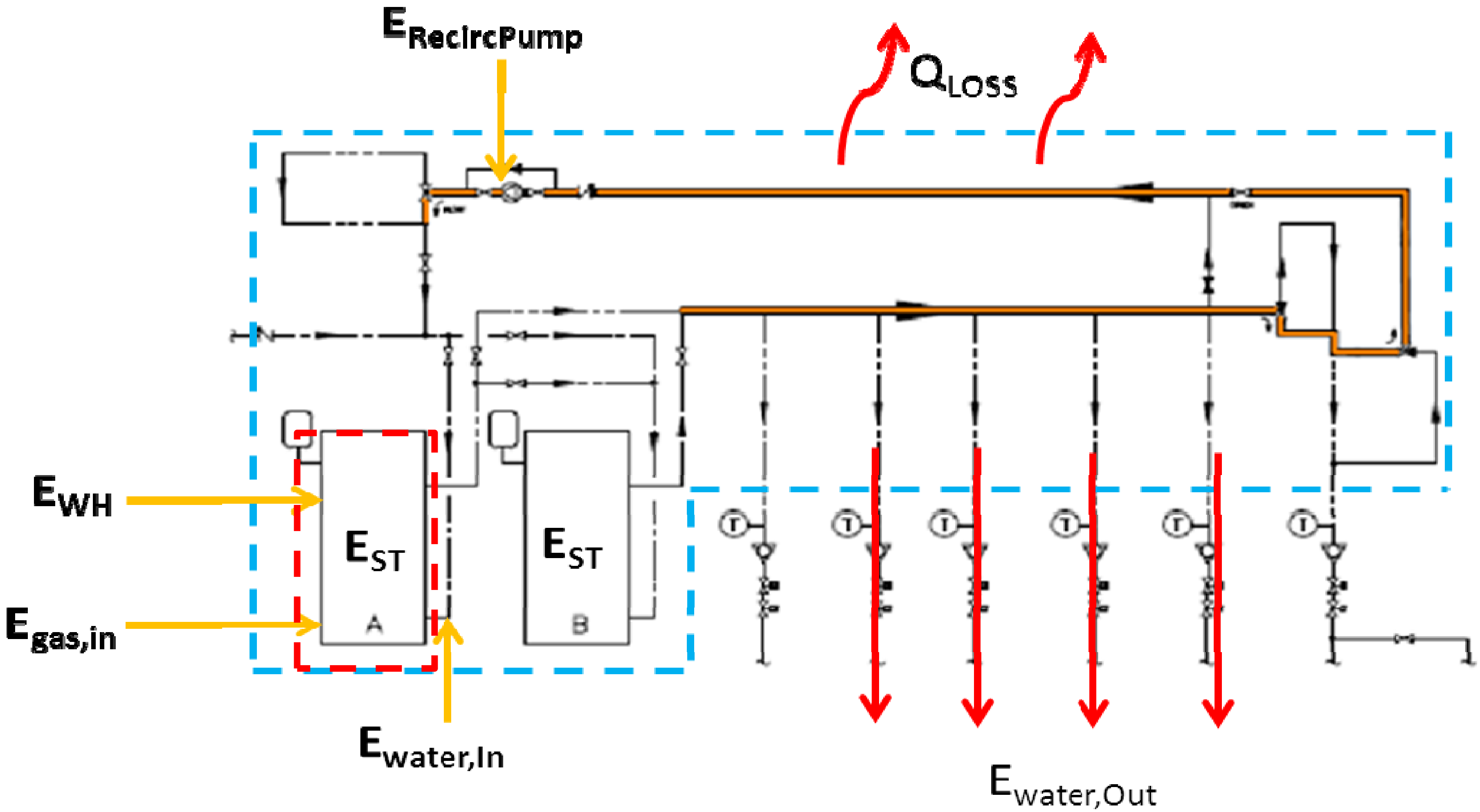
Measuring Commercial Hot Water System Performance: System Delivery Efficiency vs. WH Thermal Efficiency



$$\eta_{\cdot DELIVERY-TEST-TANK-TYPE} = \frac{O.E._{TEST} + \Delta E_{Storage}}{I.E._{TEST}}$$

~ Output Energy/Input Energy

Measuring Commercial Water Heater System Performance: System Delivery Efficiency vs. WH Thermal Efficiency

Heater 3: High Efficiency Tankless

QSR Profile Test - With Recirculation

Summary of Test Results		Test Information	
Normalized Delivery Efficiency:	84.76%	Test ID:	[illegible]
Non-Normalized Delivery Efficiency:	80.57%	Test Start:	[illegible]
Total System Energy Input (Btu):	[illegible]	Test End:	[illegible]
Total System Energy Output (Btu):	[illegible]	Test Duration (hrs):	24
Estimated Total System Heat Loss (Btu):	[illegible]	Sampling Interval (s):	6.0

System Energy Input

Measurement Parameter	[illegible]	[illegible]	[illegible]	[illegible]	H	[illegible]	Total Input
Units	[illegible]	unitless	unitless	[illegible]	[illegible]	Avg Watts	Btu
Avg Value	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Water Heater Operating Conditions

Measurement Parameter	K	[illegible]	[illegible]	[illegible]	Inlet Water
Units	[illegible]	F	F	F	Energy (Btu)
Avg Value During Draws	[illegible]	[illegible]	[illegible]	67.4	[illegible]

QSR Profile Flow

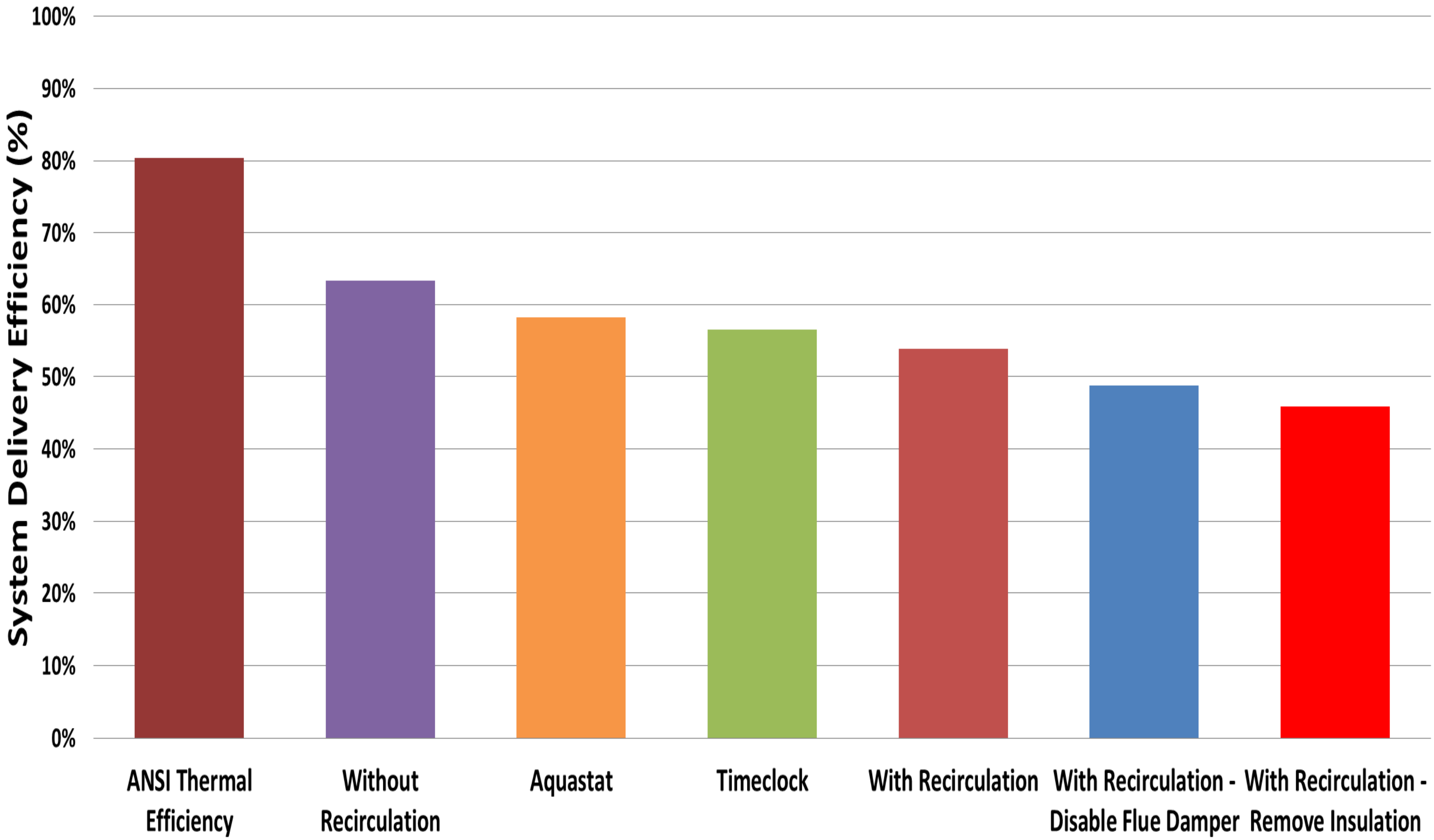
Fixture	Hand Sink	3 Comp. Sink	Mop Sink	Lavatory	TOTAL
Flowrate at Fixture (gpm)	[illegible]	[illegible]	[illegible]	[illegible]	
Gallons Delivered	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Density at Meter [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Water Delivered [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Energy Delivered to Fixtures

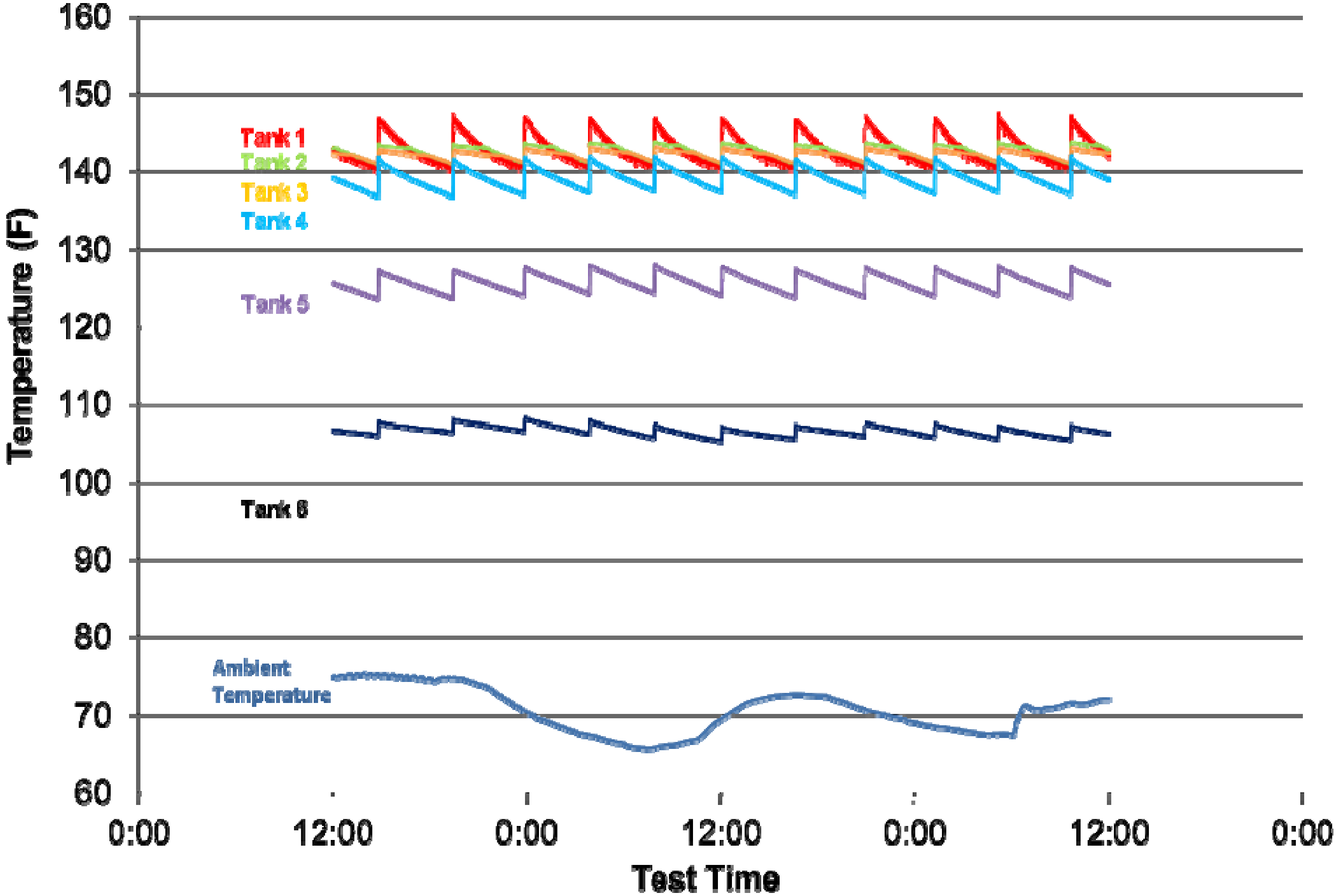
Fixture	Hand Sink	3 Comp. Sink	Mop Sink	Lavatory	Total
Nozzle Temperature (F)	[illegible]		[illegible]	[illegible]	Delivered
Tap Temperature (F)	[illegible]	[illegible]	[illegible]	[illegible]	Energy (Btu)
Energy Delivered per Fixture (Btu)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

PG&E CUSTOMER ENERGY EFFICIENCY EMERGING TECHNOLOGIES

Energy Performance Impact Summary: Standard Efficiency Tank-Type Water Heater - RCx and Retrofit Measures

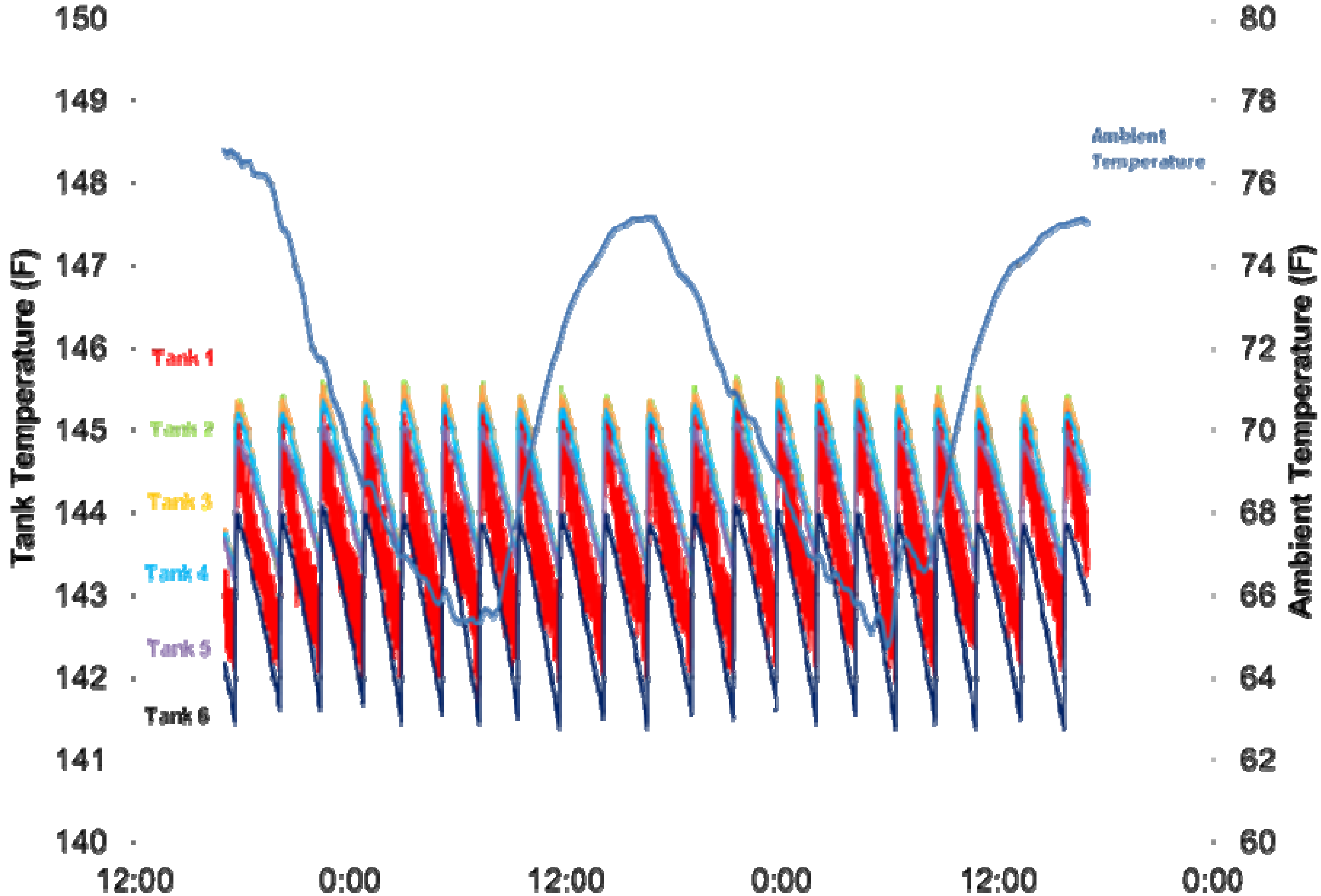


Energy Performance Impact: Stratification in High Efficiency Tank-Type Water Heater – Standby Loss & T.E.



Standby Loss - 1.28% - 670.0 Btu/h

Energy Performance Impact: Stratification in Standard Efficiency Tank-Type Water Heater – Standby Loss & T.E.



Standby Loss - 2.58% - 1654.0 (Btu/h)

Opportunities for Future Research – Distribution System Scenarios – PG&E CHWH

Distribution System Scenarios

Simple Distribution (Quick Service):
100' supply to lavatory sink stub out, no return.

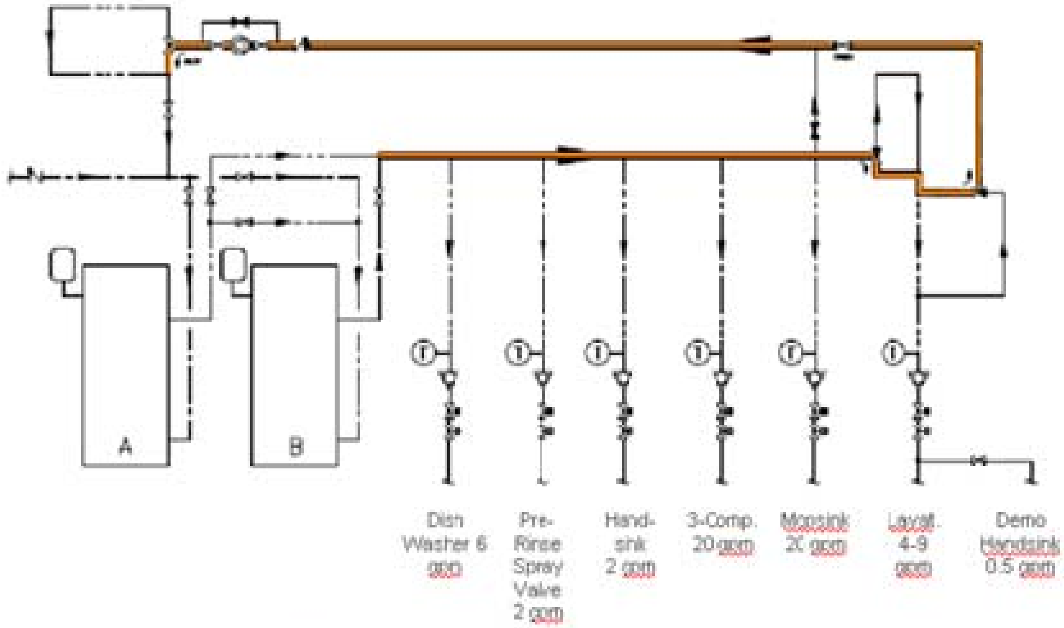
Standard Recirculation (Quick Service):
94' supply + 56' return = 150' total.

Standard Recirculation (Full Service):
108' supply + 92' return = 200' total.

Hybrid System (Full Service):
Shortened Recirculation at mop sink with point-of-use electric heating at lavatory sink.
84' supply + 47' return = 131' total.

Demand Circulation (Quick Service):
114' supply + 56' cold water return = 170' total.

Extended Recirculation (Quick Service):
100' supply to stub out + 62' return = 162' total.



Standard Recirculation (Quick Service) = 150ft

PG&E Applied Technology Services
Hot Water Technology Laboratory Vision

Vision for PG&E's Upgraded Hot Water Technology Laboratory

- Include capabilities of past residential and commercial test systems
- Employ modular laboratory design, easily adaptable to changing test setups, specifically distribution system
- Design instrumentation plan and DAS system for versatility
- Automation of tests via National Instruments Labview DAS
- Continued focus maintaining high instrument accuracy and control of test variables
- Rely on industry for guidance and new ideas, also attempt to develop our own

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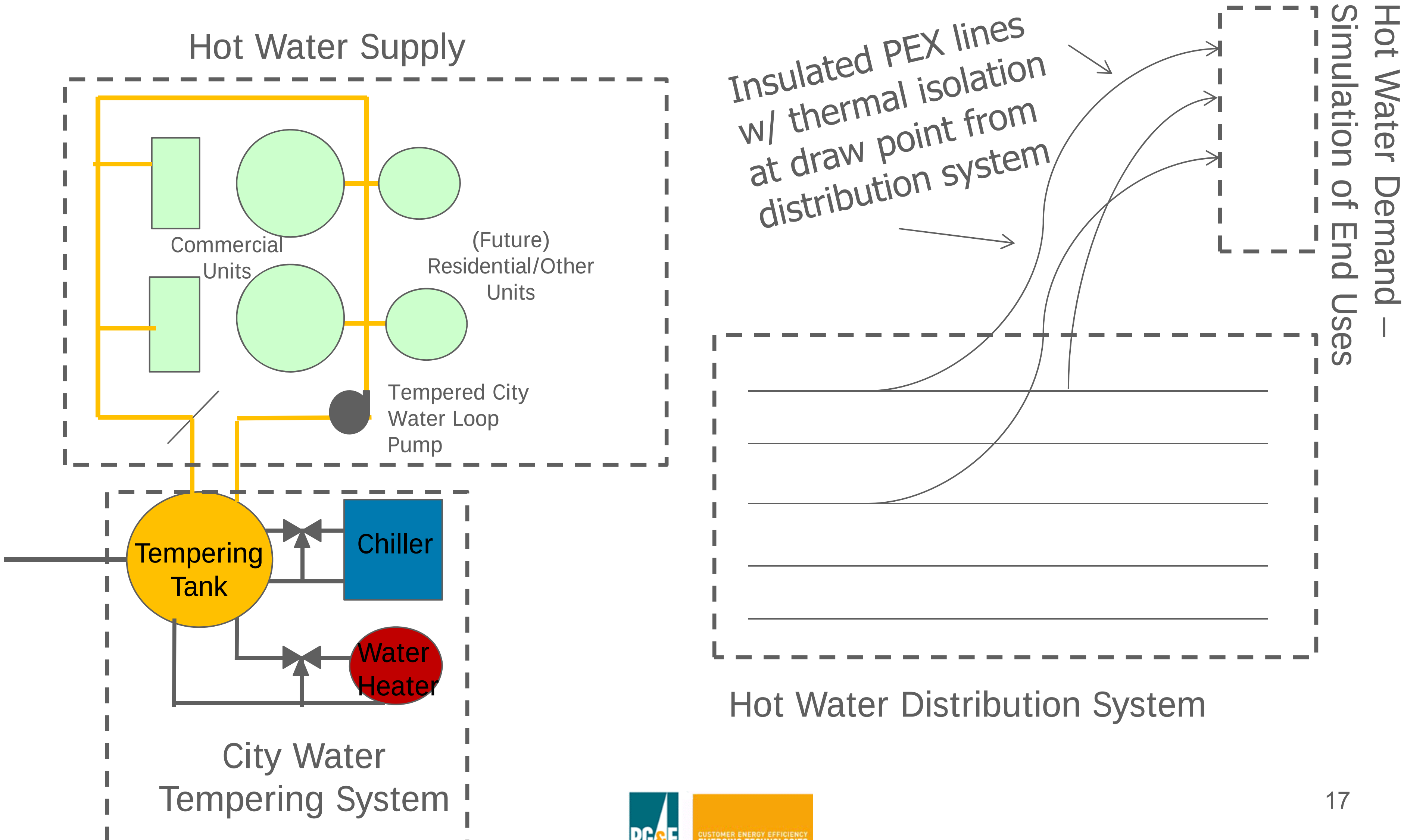
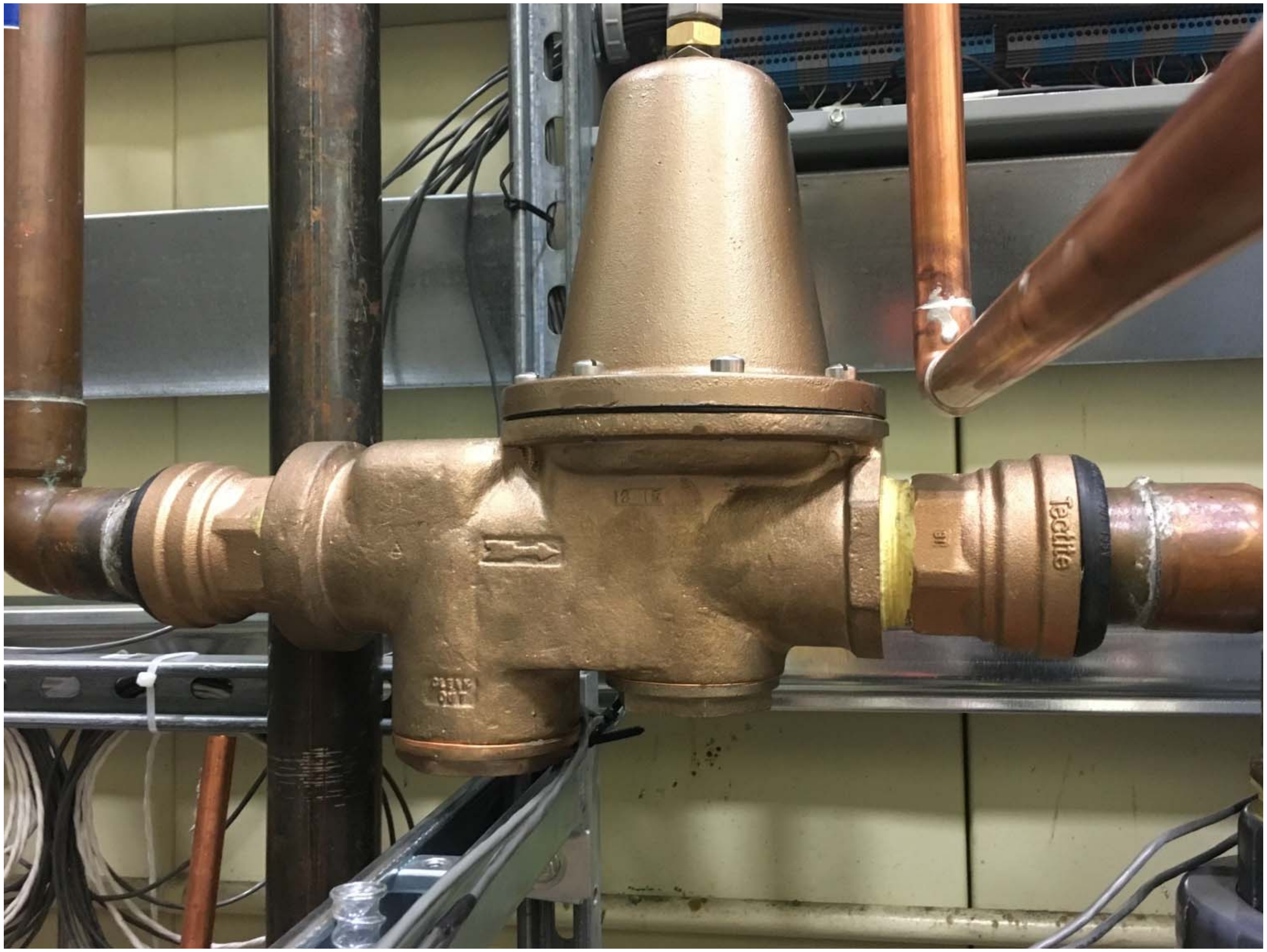
PG&E Applied Technology Services
Implementing the Hot Water Technology Laboratory Vision

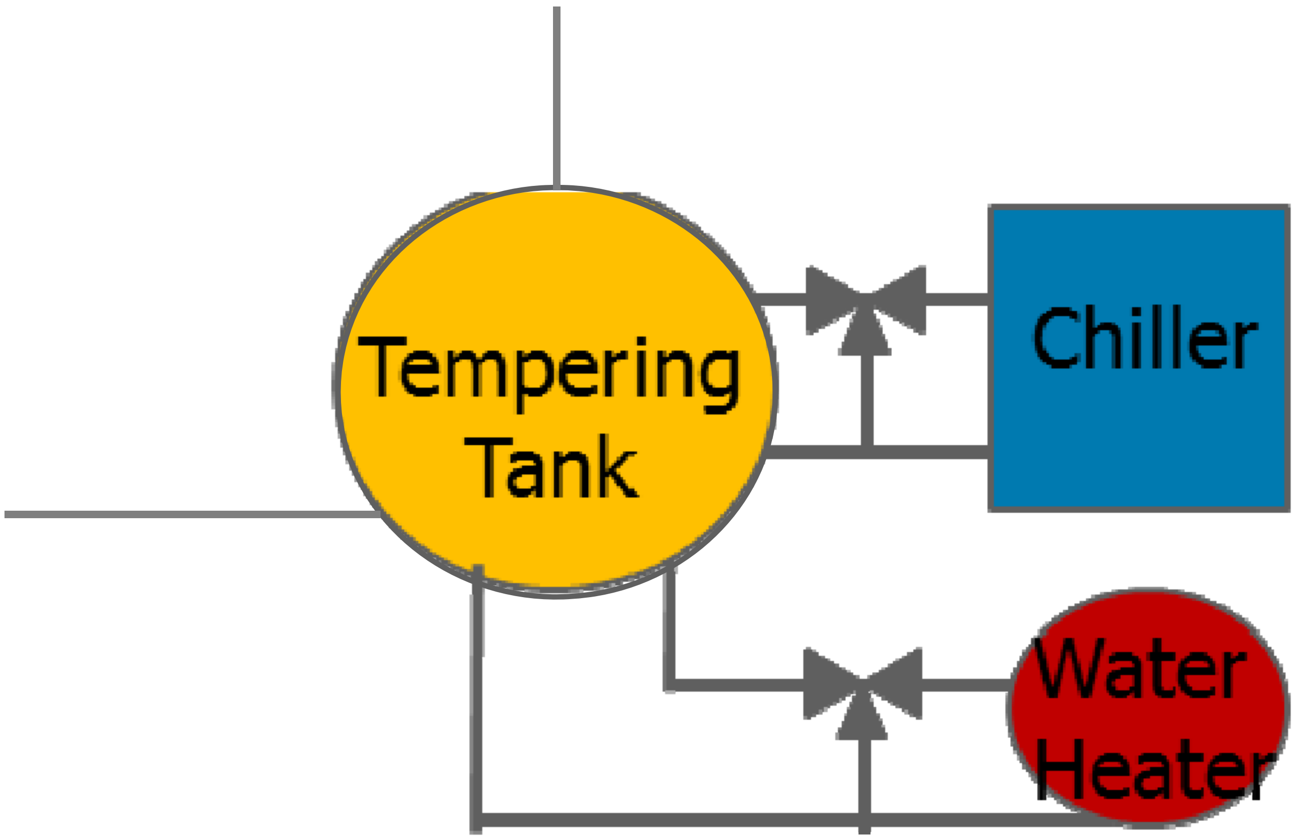


Regulating City Water Pressure



Conditioning City Water - Tempering System

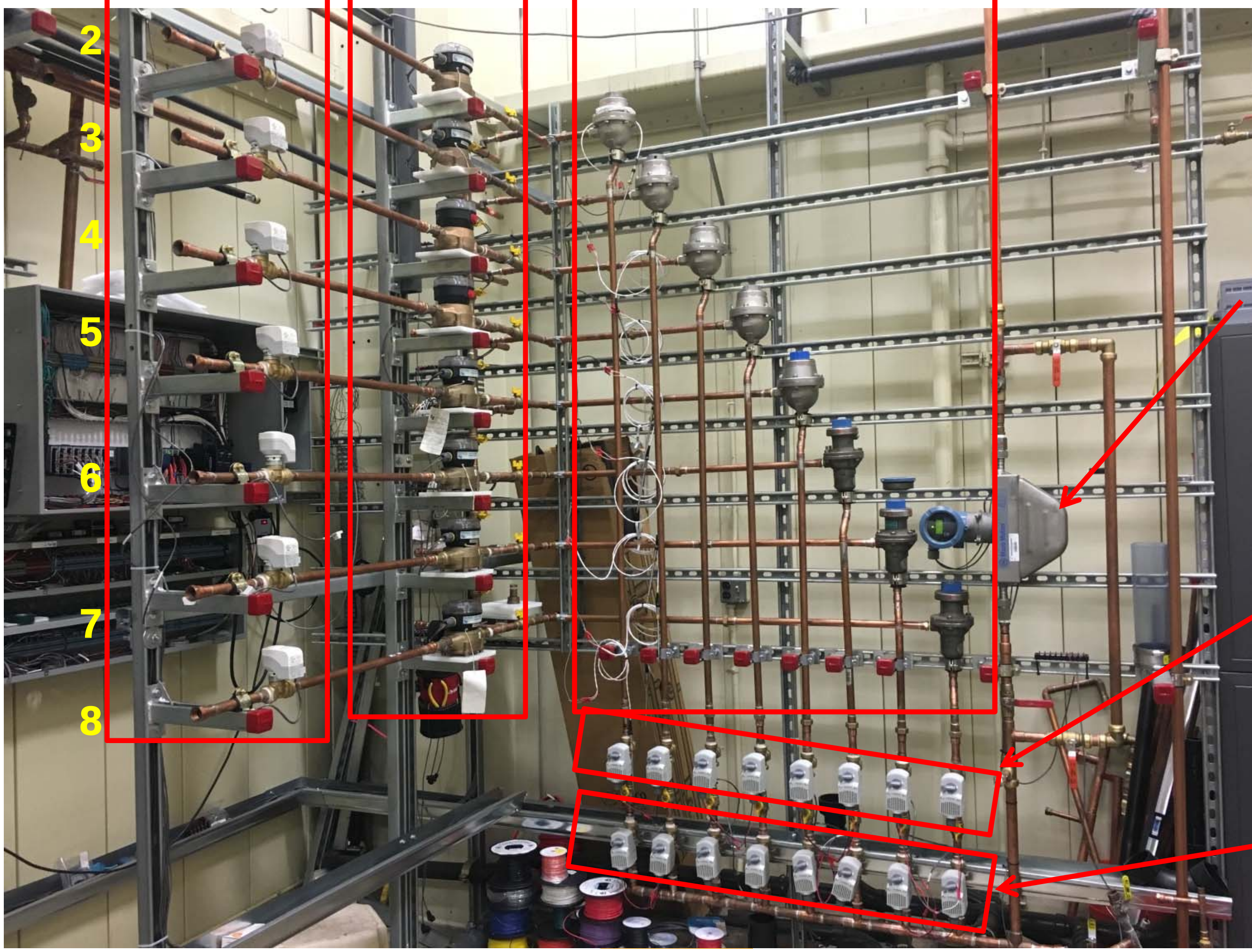
Conditioning City Water - Tempering System



Distribution System – Piping Rack

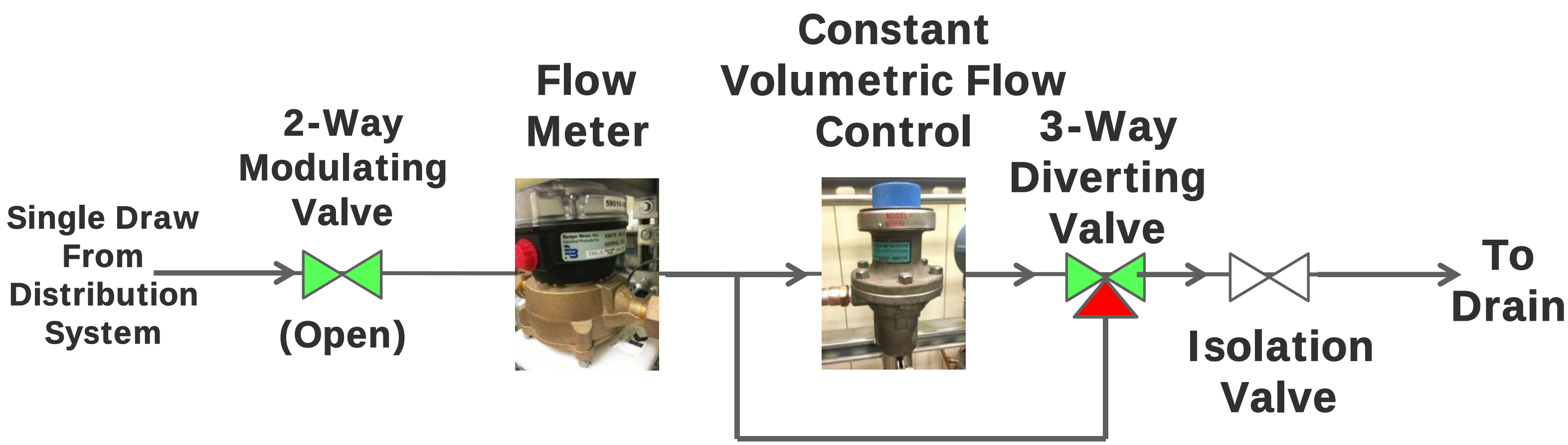
Hot Water Draw Simulation – Flow Measurement and Control (Constant, Staged and Variable Volume)

Hot Water Draw Simulation – Flow Measurement and Control (Constant, Staged and Variable Volume)



*ATS Likely to add additional end uses

Hot Water Draw Simulation – Flow Measurement and Control (Constant Volume Draws)

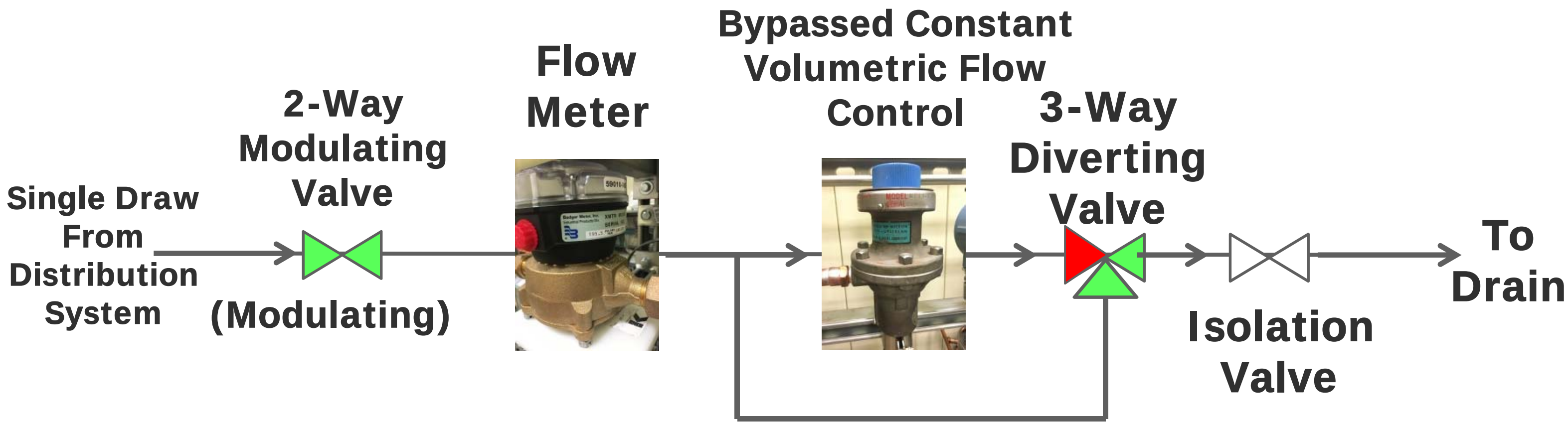


"Larger" Pressure Compensating Valve

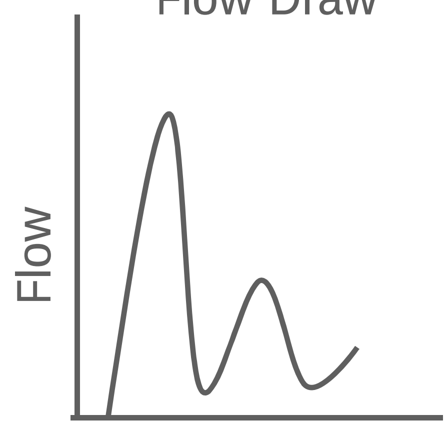
"Smaller" Pressure Compensating Valve

Volumetric Flow between
.2 – 3.0 gpm (smaller valves)
.7 – 20 (larger valves)

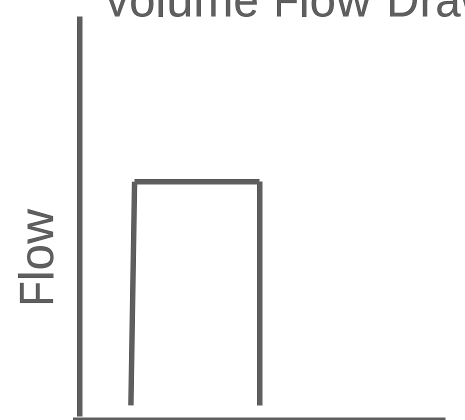
Hot Water Draw Simulation – Flow Measurement and Control (Variable Volume Draws) (Not Implemented Yet)



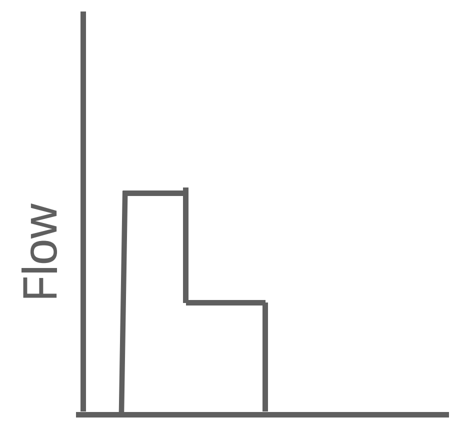
Variable Volume Flow Draw



Equivalent Constant Volume Flow Draw



Equivalent Staged Volume Flow Draw



Temperature Measurement and Calibration

4-wire RTD’s Almost Exclusively Used

Isothermal Block for Temperature Calibration

Pressure Measurement and Calibration

Rosemount Pressure Transmitters for Natural Gas Flow Compensation

*Omega pressure transmitters purchased for measuring pressure drop in piping network

Dead Weight Tester – Calibration Standard

Flow Measurement and Calibration

Diaphragm Meter w/
Pulsing Transmitter

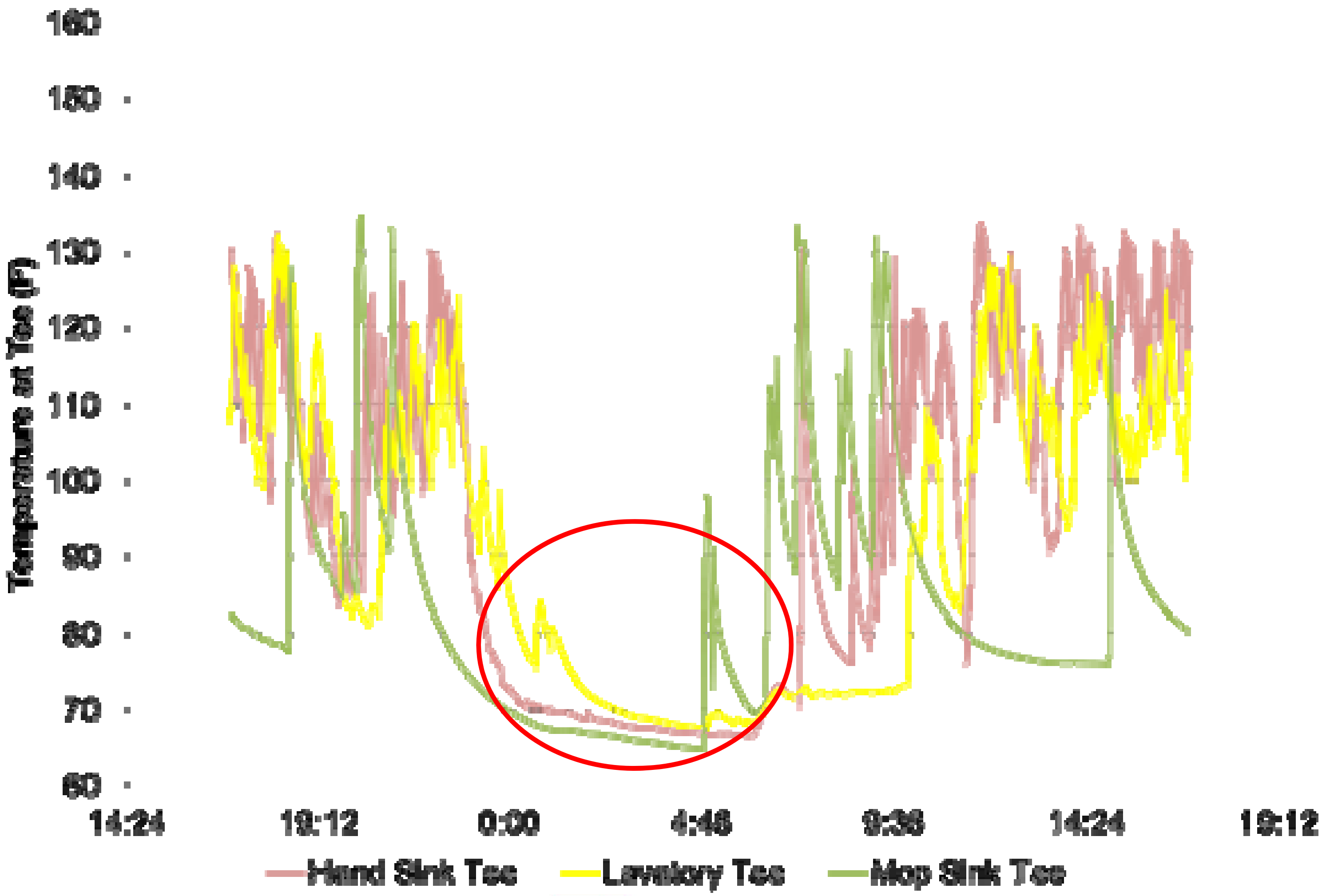
Coriolis Flow Meter

Nutating Disc Hot
Water Meter

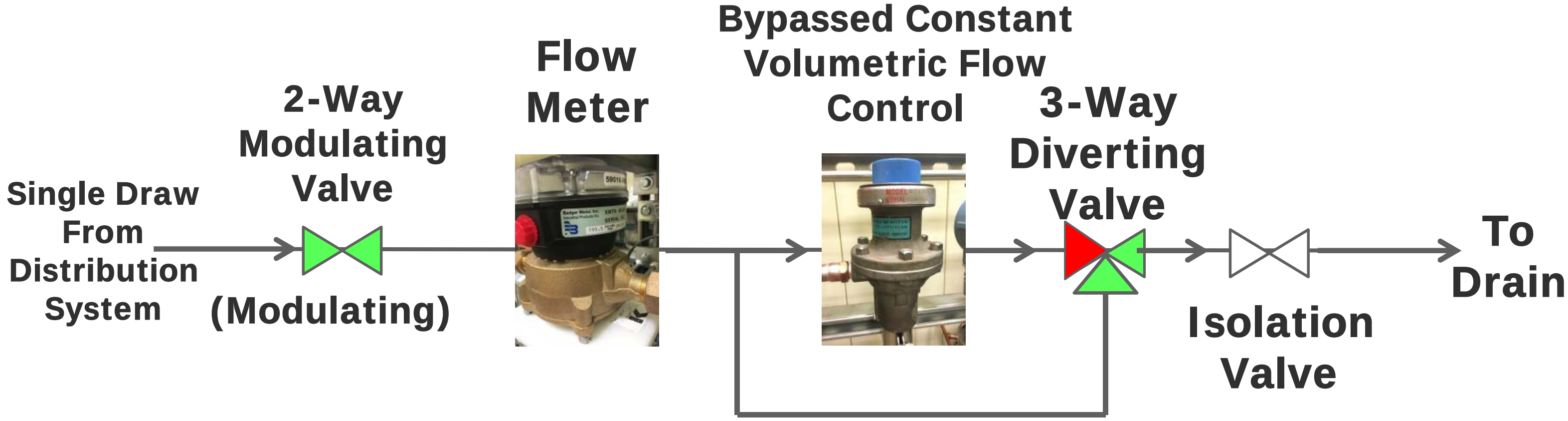
Coriolis Flow
Calibration Standard

CUSTOMER ENERGY EFFICIENCY
EMERGING TECHNOLOGIES

Opportunities for Future Research – Account for Human Factors



Accounting for Human Factors – Temperature Feedback and Min Temperature Criteria



- Force solenoid valve to remain open until water reaches specified temperature, and for a specified duration/volume

Summary of Test Conditions

Build Baseline and Optimized Distribution System on Rack

- Run Tests using each of the following
  - (2) Standard Efficiency Tankless Units (199,000 Btuh ea)
  - (1) Condensing Tankless (250,000 Btuh)
  - (1) Standard Efficiency Tank (199,000 Btuh)
  - (1) Condensing Tank (199,000 Btuh)
    - If possible, vary recirc return port location (upper/lower)
- Add insulation, program timeclock, aquastat, D'mand circulation, modify drop dimensions
- Run a variety of flow profiles if time permits

Thank You

Questions?

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