Central Hot Water Distribution Systems in Multifamily Buildings

Proposed Code Changes 2008

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Current (2005) Standards

- Don’t accommodate temperature modulation or demand controls
- Based on very scarce data about MF draw patterns.
- Based on almost no data about failure modes for recirculation systems

Current Research Project

- “Water heaters and hot water distribution systems”
  - Characterize multi-family water heating design practice
  - Characterize existing installations with storage systems
  - Evaluate energy performance of demand and modulating boiler controls
  - Collect short term field data on hot water recirculation system energy performance and water usage patterns
  - Understand failure modes of recirculation systems

Characteristics of Monitored Bldgs

Location	St. Helena	Oakland	Emeryville
Floors	2	3	3
Units/Hot water system	8	121	20
Type of system	Single water heater (135,000 Btu/hr, 81 gallons)	Three water heaters (300,000 Btu/hr each, 130 gallons each)	Boiler and storage tank (399,000 Bth/hr, 175 gallons)
Existing control	Broken timeclock	None (recirc pump unplugged)	None (continuous pumping)
Pipe insulation	Minimal	Extensive	Average
HWS pipe diam	1.5”	4”	2.5”
CW makeup pipe diam	1.5”	4”	2.5”
HWR pipe diam	0.75”	2”	0.75”

Condition of Monitored Systems

- Three out of three control systems were in failure
- Highly variable amount and quality of pipe insulation
- One heater (in Oakland) failed intermittently throughout the project due to problems with power vent gas pressure

Proposed Code Changes 2008

- **Reverse Flow Prevention** (Mandatory measure - inspection)

  The cold water make-up pipe shall have a spring-loaded check valve between the point where it joins with the hot water return pipe (or storage tank) and the next closest tee

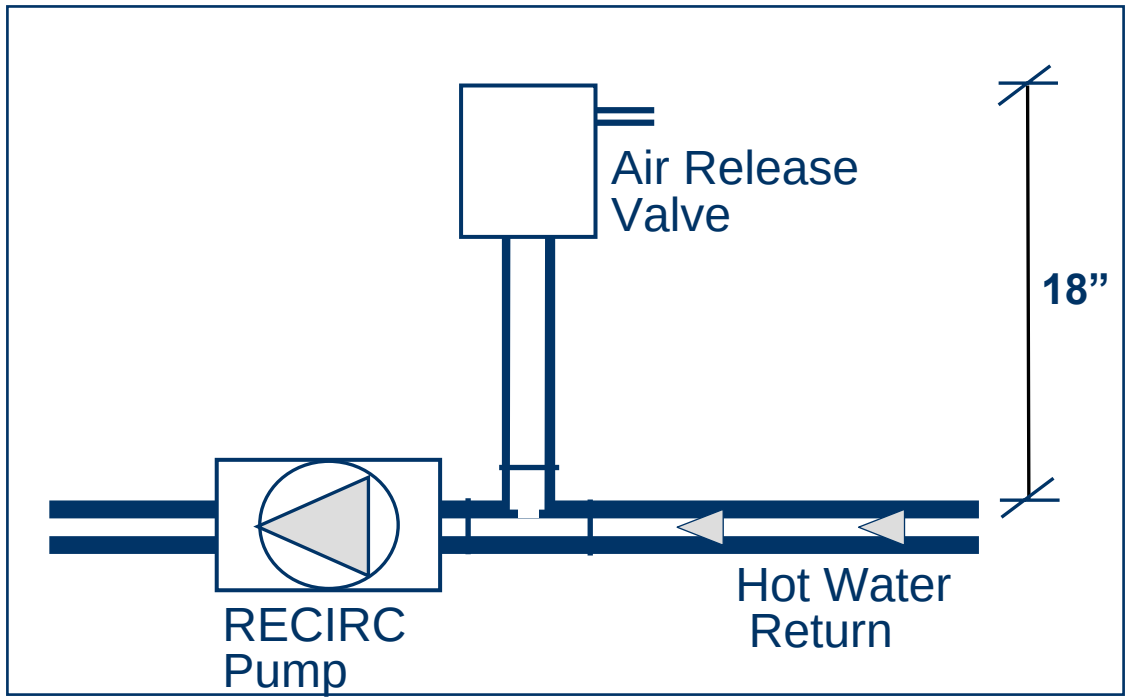
- **Air Release Provision** (Mandatory measure - inspection)

  A vertical riser (tee and 12” to 18” pipe) with an automatic air release valve at the top must be installed on the hot water return pipe just before the recirculation pump

- **Crossover Prevention** (Mandatory measure - inspection)

  Single-lever faucets and shower mixing valves that allow crossover between the hot and cold water systems should not be installed. When such valves are used, backflow prevention valves are required on the hot and cold water lines

Air Release Provision



Vertical riser with an automatic air release valve at the top

Crossover Prevention

- Crossover is due to pressure differences created by the pump

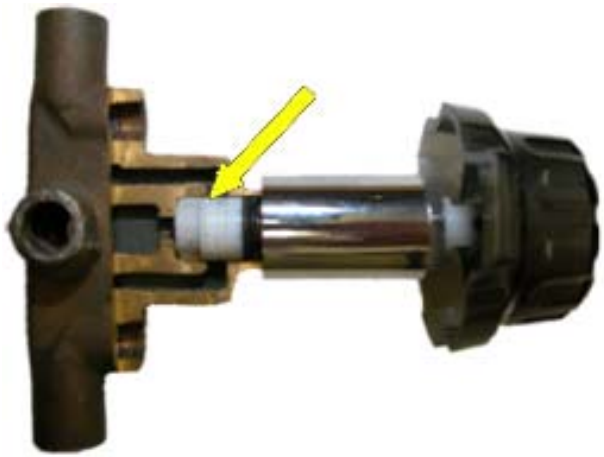
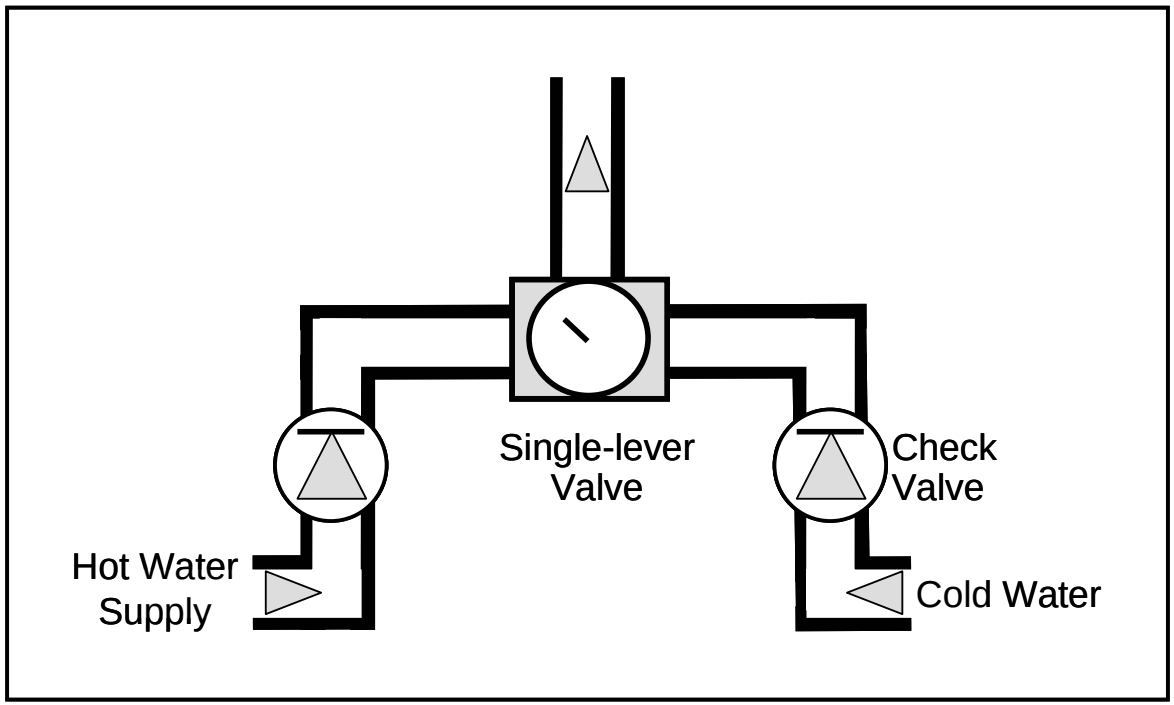


Image: EDC Technologies Inc., www.savegas.com

- In faulty mixing valves, erosion takes place in the valve area or in the seat area. One available fix is a retrofit quadruple seal between the valve area and the cartridge.
- Crossover also occurs under normal conditions in counter-top dishwashers and shower head taps.

Crossover Prevention

- An alternative crossover prevention measure is to put check valves on both the cold and hot water pipes into the single-lever valve.



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- **Demand or Temperature Modulation Controls**
  (Prescriptive requirement – acceptance testing)

  Recirculating hot water systems in multifamily buildings should have either temperature modulation controls or recirculation pump demand controls. Acceptance testing:

  - Test that all the sensors are communicating with the controller correctly. For temperature modulation controls this includes the pump operation signal (pump on and off) and the temperature sensor(s). For demand controls this includes the flow sensor and temperature sensor(s).
  - Test that the system is functioning within the bounds established by the design documents

Proposed Code Changes 2008

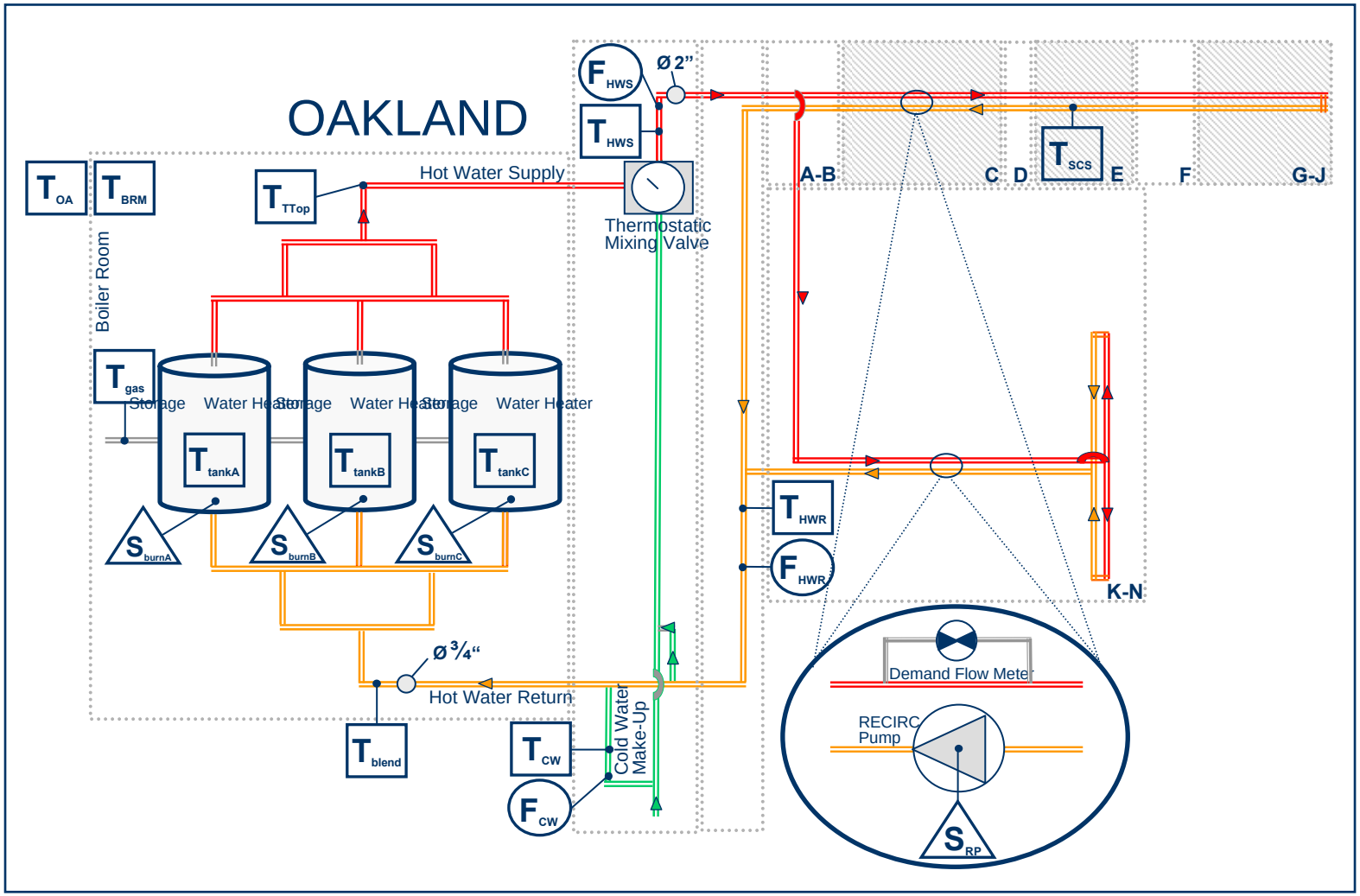
- **Heat Loss from Recirculation Loop** (Modeling)

  Improve the Heat Adjusted Recovery Load (HARL) equations in the Alternative Compliance Method (ACM) Manual to more closely model heat loss from the recirculation loop

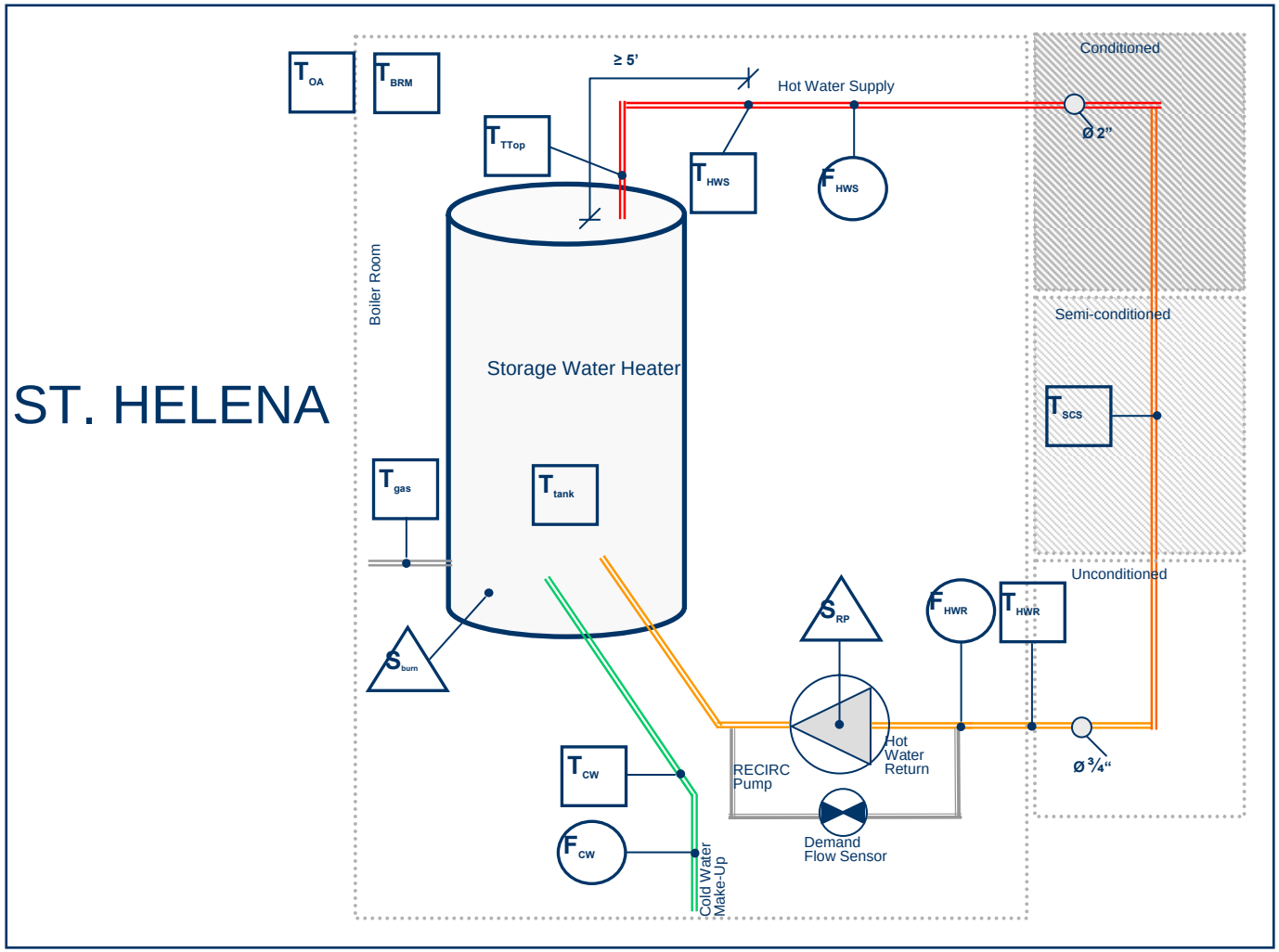
- **MF Draw Schedule for Hot Water** (Modeling)

  Define a draw schedule for hot water in multifamily buildings in the ACM Manual

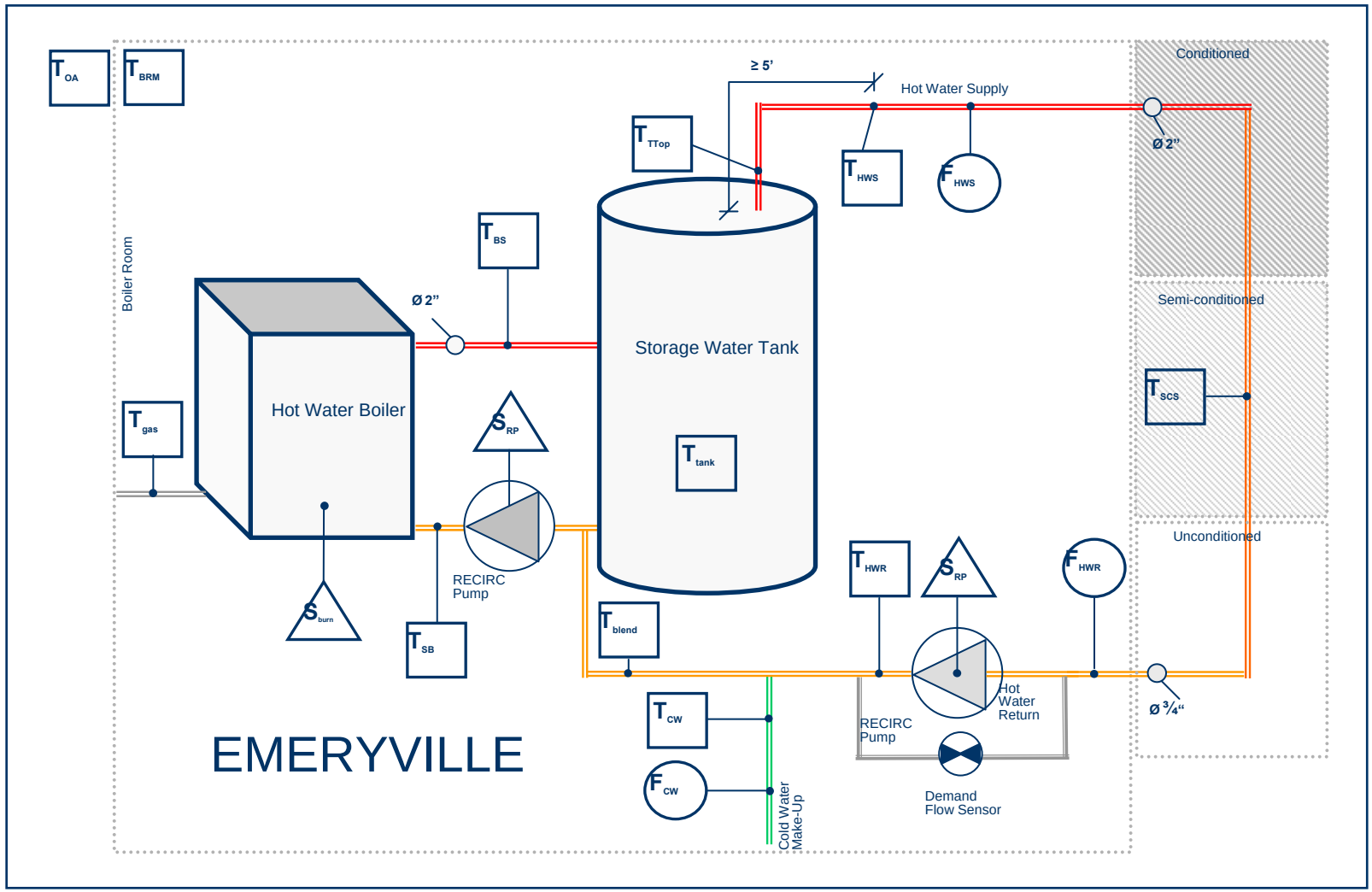
DHW System Schematic – Oakland



DHW System Schematic – St Helena



DHW System Schematic –Emeryville

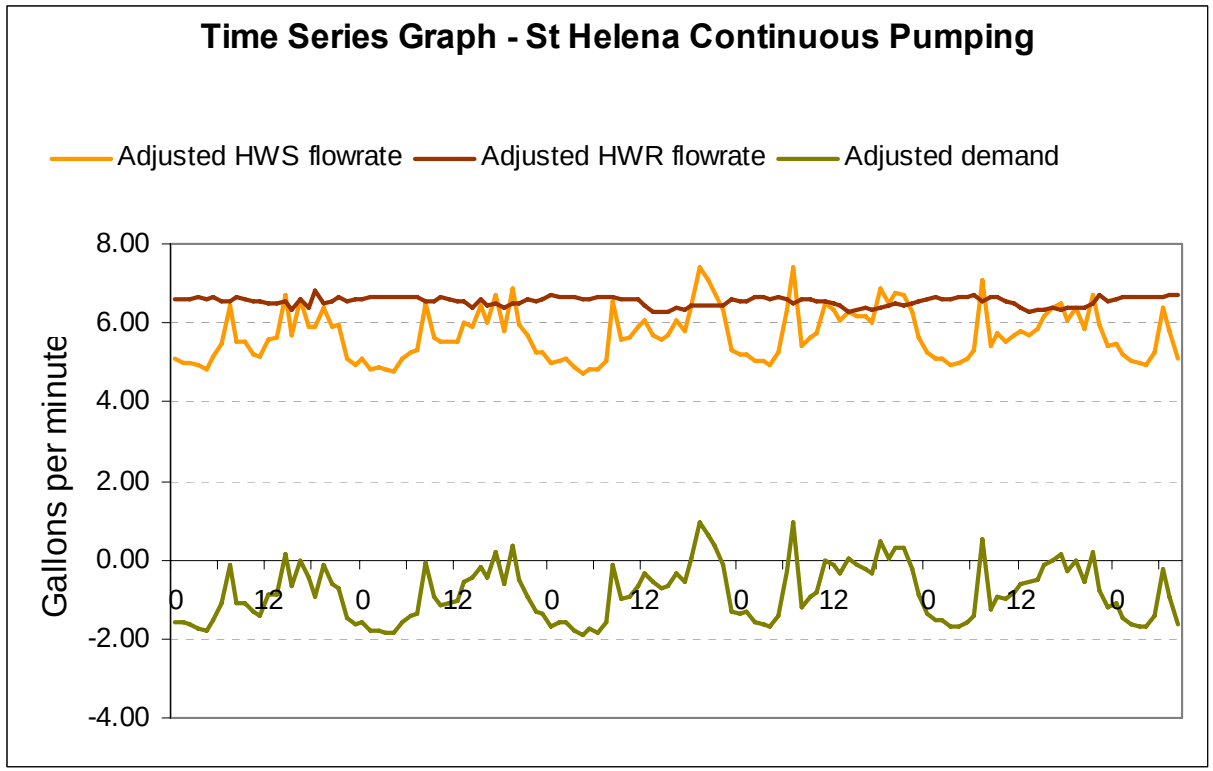


Control Regimes Monitored

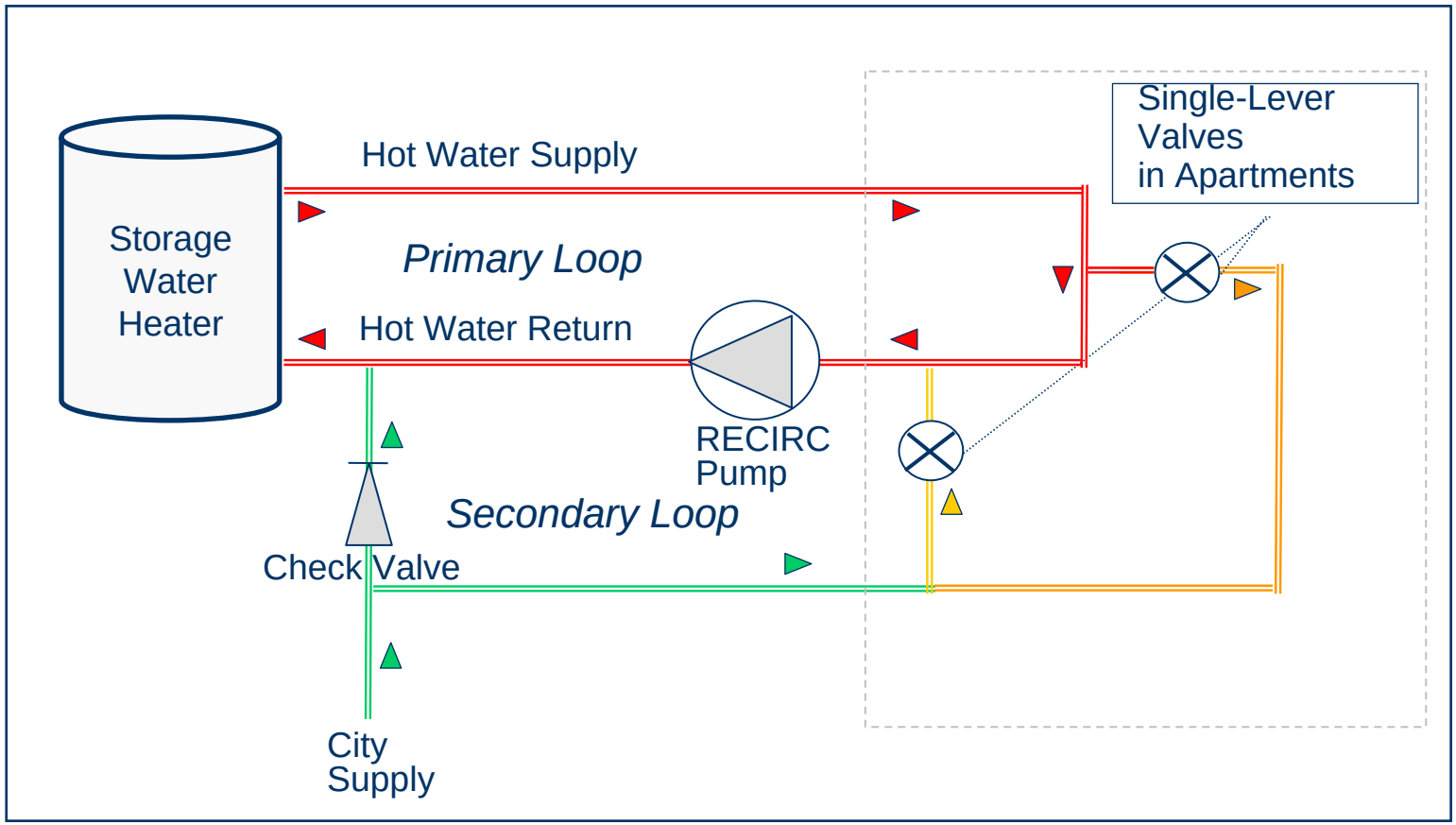
Building location	Oakland	St Helena
Base case	**Continuous**: Recirculation pump running 24hrs	**Continuous**: Recirculation pump running 24hrs
Regime #1	**Timeclock**: The recirc pump switches off from 1-4 a.m.	**Timeclock**: The recirc pump switches off from 11p.m-5a.m.
Regime #2	**Demand control**: recirc pump switches on if there is demand AND HWR temp falls to 104F (off again at 110F).	**Demand control**: recirc pump switches on if there is demand AND HWR temp falls to 100F (off again at 101F).
Regime #3	**Aquastat**: The recirc pump switches on when the HWR temp falls to 100F (off again at 106F).	**Temperature modulation**: Recirc pump runs 24hrs. Storage water setpoint varies hourly according to demand data from previous weeks*.

Findings: Crossover

- HWR is greater than HWS for most of the day, which indicates crossover

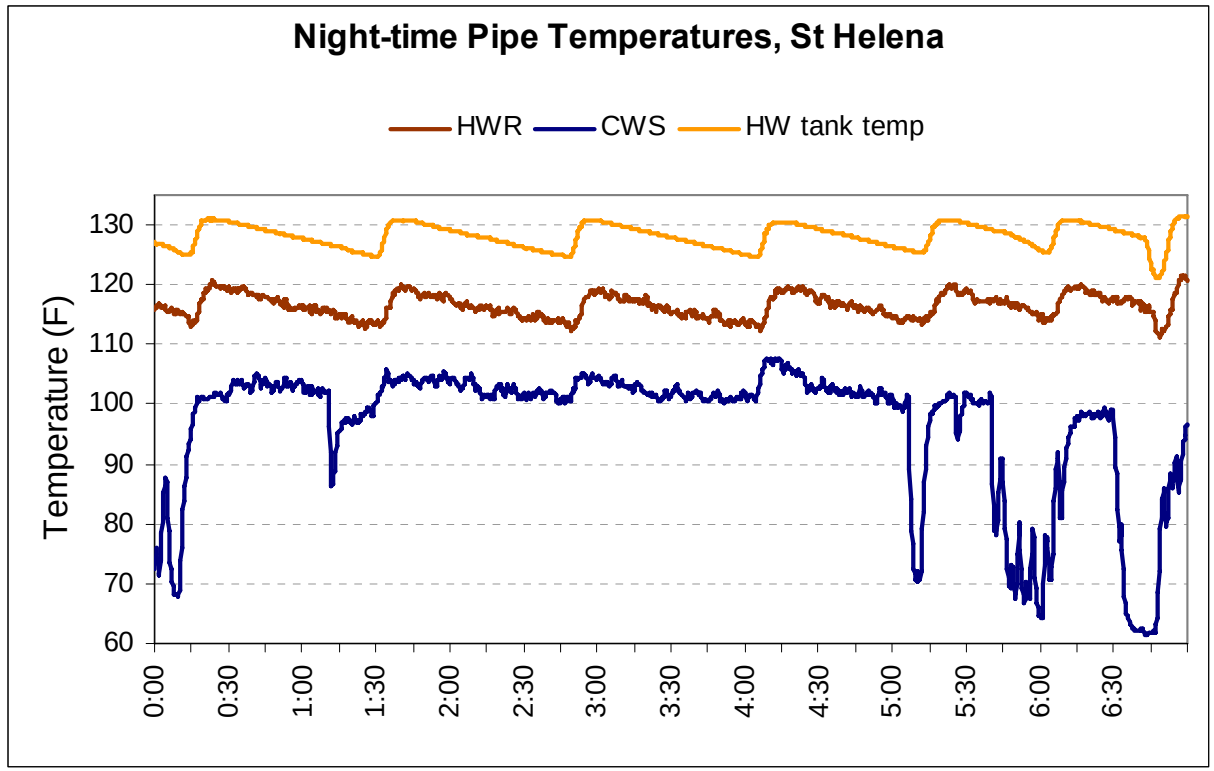


Findings: Crossover



Findings: Crossover

- Further evidence for crossover: CW make-up pipe temp is high and tracks (without time lag) except when there is demand for HW



Findings: Crossover

- Magnitude of crossover estimated at 1.3 gpm (St Helena) and 2.7 gpm (Oakland)
- There is likely to be additional undetected crossover flow that does not pass through the tank
- Approximate energy loss of 52 therms per year per apartment ($1230 n.p.v.)

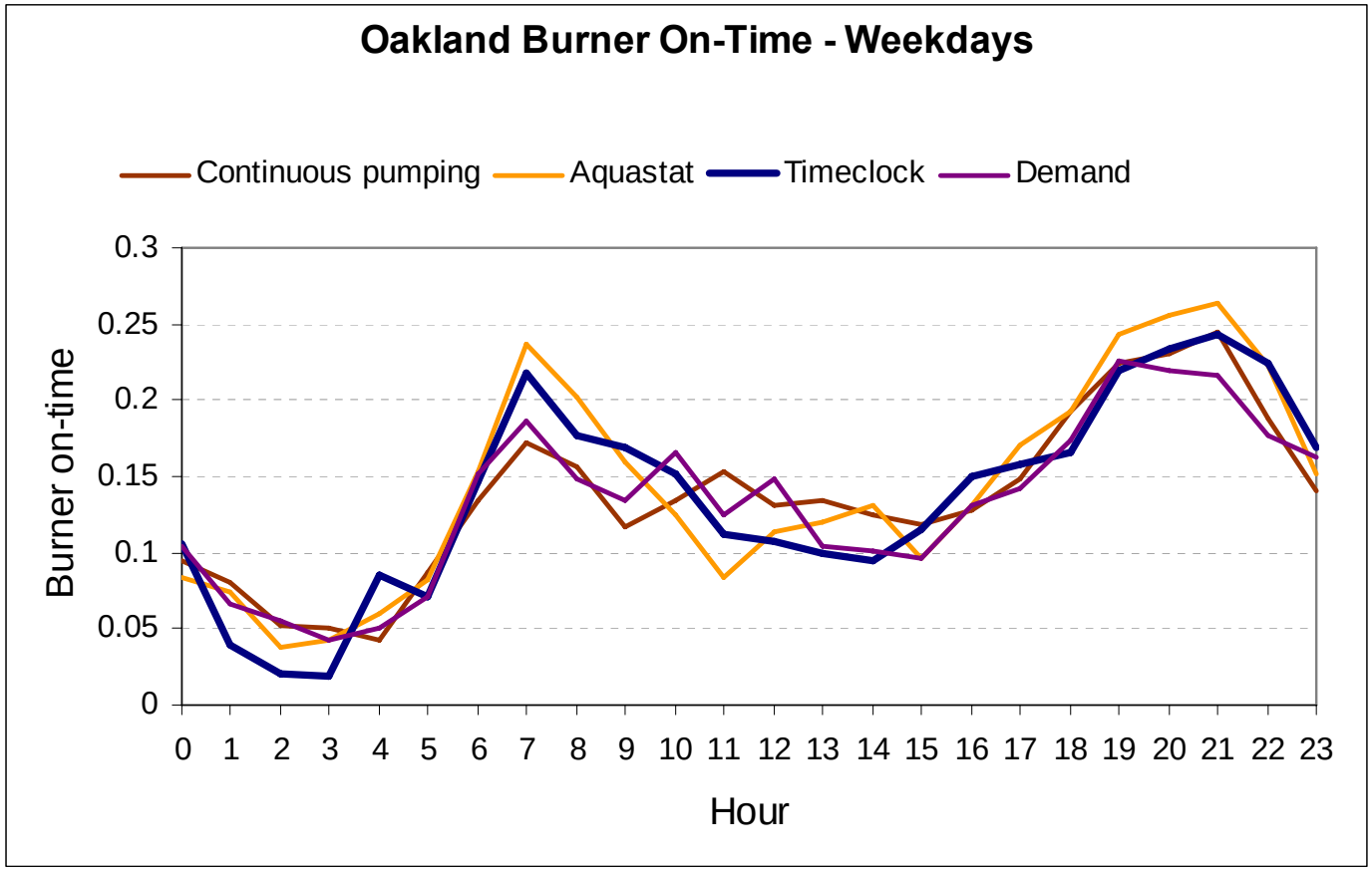
Findings: Pump Cavitation

- EDC data: 16 out of 36 failed systems had a failed pump. 12% of EDC installed systems are in failure at any given time, so around 5% of all CDHW systems are in pump failure.
- Air in the recirc loop is the most common form of pump failure.
- This estimate is conservative because EDC sends out notices to its clients to inform them of pump failures, and encourage them to repair the pump.
- A common response to pump failure is for maintenance staff to increase the HWS temperature by 15ºF on average, to reduce tenant complaints of excessive waiting time for hot water.
- 65 gal/day-unit multiplied by the temperature differential (15ºF) between the two conditions, results in 30 therms per year per apartment of wasted gas. N.p.v. is $710.

Findings: Effect of Controls (Oakland)

	Average week	Savings compared to continuous pumping	Annual savings/unit vs. Continuous (kBtu/unit/yr)
Continuous pumping	0.14	0%	N/A
Aquastat	0.14	-5%	-470
Timeclock	0.14	-1%	-10
Demand	0.13	5%	490

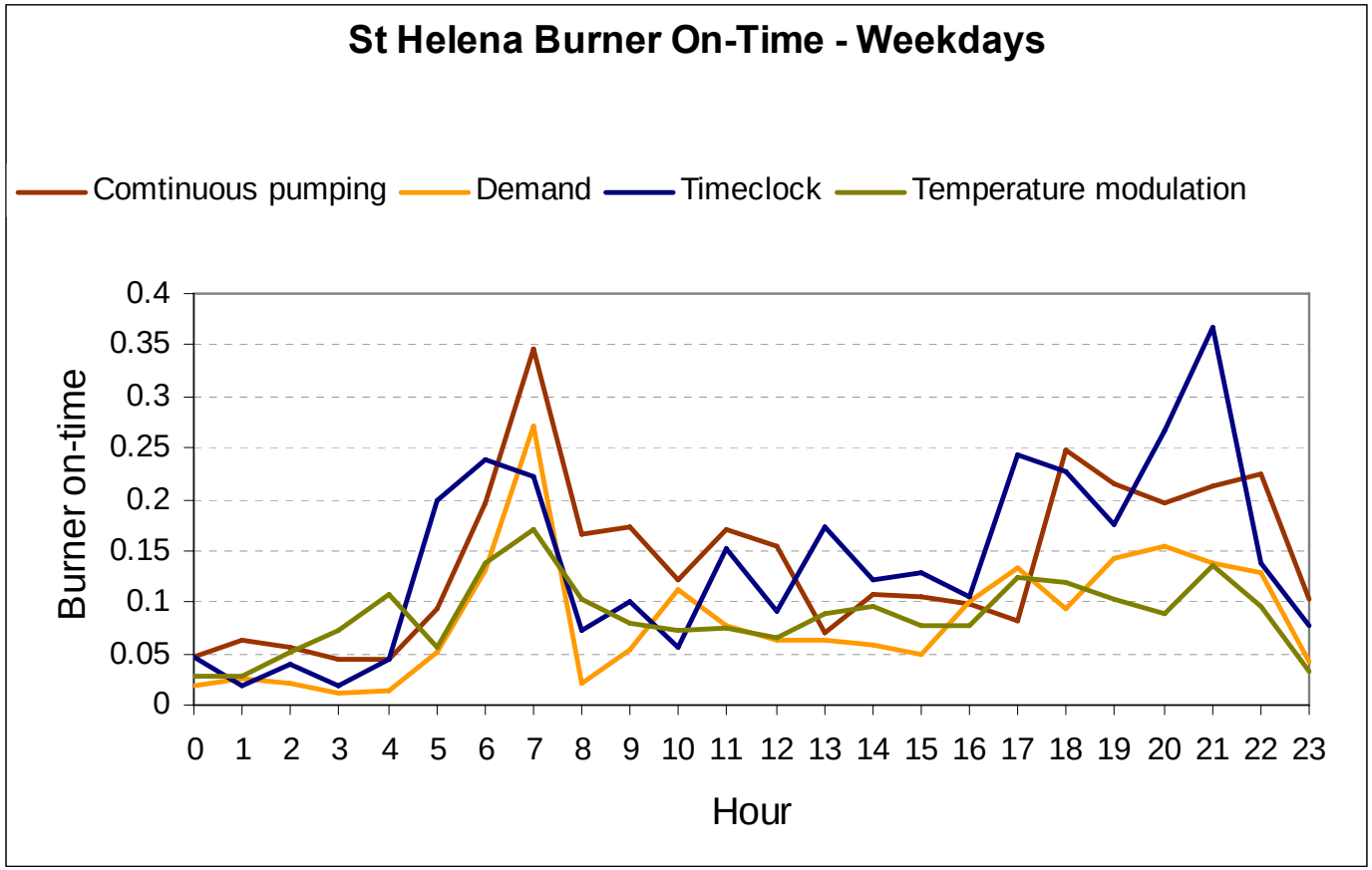
Findings: Effect of Controls (Oakland)



Findings: Effect of Controls (St Helena)

	Weekdays	Weekends	Average week	Savings compared to continuous pumping	Annual savings/unit vs. Continuous (kBtu/unit/yr)
Continuous pumping	0.14	0.14	0.14	0%	N/A
Temperature modulation	0.08	0.06	0.08	44%	9,150
Timeclock	0.14	0.13	0.14	1%	300
Demand	0.09	0.10	0.09	35%	7,260

Findings: Effect of Controls (St Helena)



Findings: Effect of Controls

Savings Estimate for Demand Controls and Temperature Modulation Controls			
Approx # of MF new const/yr		60,000	
Estimated percentage that have CDHW		40%	
Demand controls		**Temperature modulation controls**	
Lower bound of savings (Btu/unit)	490,000	Lower bound of savings (Btu/unit)	0
Upper bound of savings (Btu/unit)	9,150,000	Upper bound of savings (Btu/unit)	7,260,000
CA therms (lower bound)	58,800	CA therms (lower bound)	0
CA therms (upper bound)	1,098,000	CA therms (upper bound)	871,000
20 apts n.p.v. of savings.	$22,300	20 apts n.p.v. of savings	$17,790
system cost	$1,100	system cost	$2,100

Continuous Commissioning

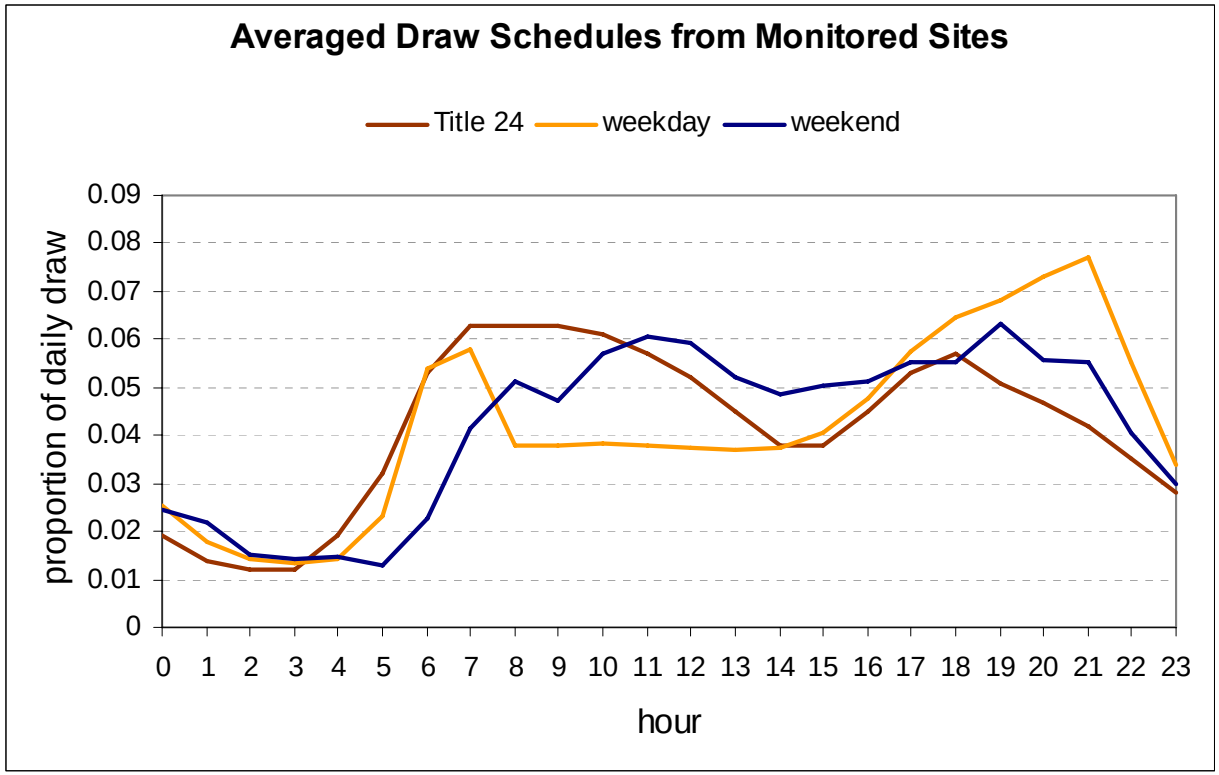
- EDC has many years of logged data on hundreds of MF buildings.
- They report frequent problems on-site, including failed pumps and crossover.
- Without monitoring and intervention, these problems are likely to result in override of controls by site staff, and loss of savings
- Controls failures common in other building fields (HVAC, lighting)

Continuous Commissioning

Continuously monitored site data

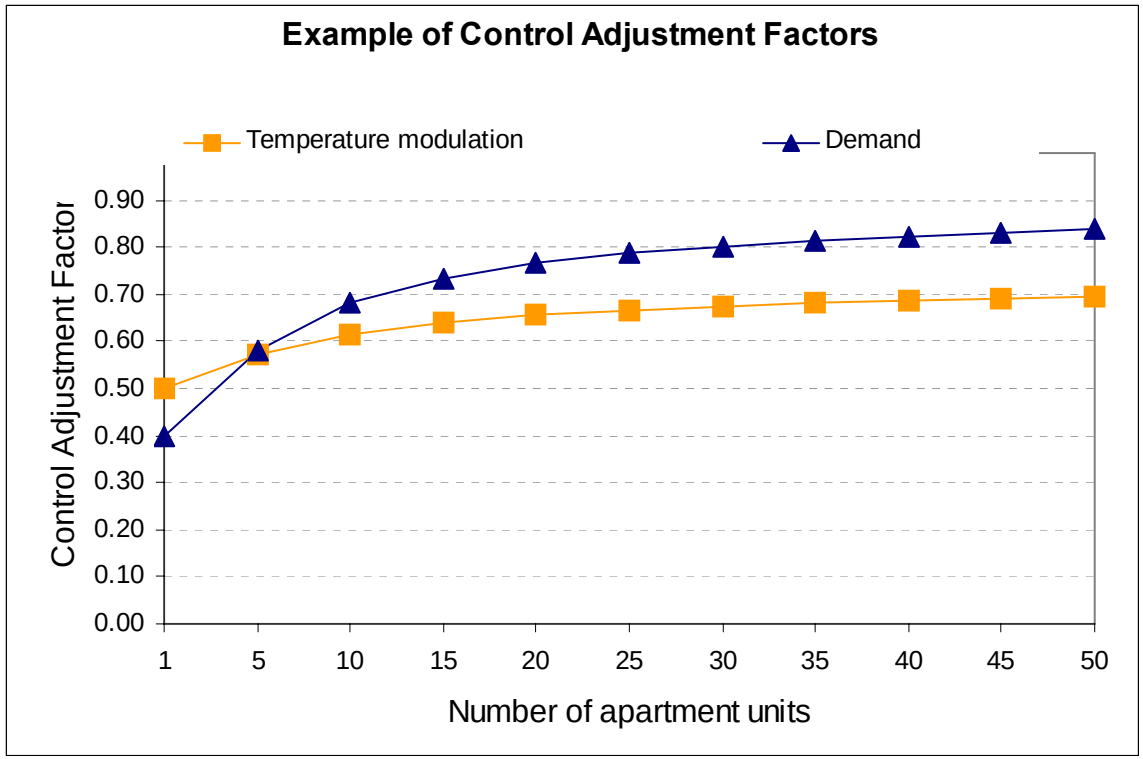
- Can remotely detect not only the *presence* of a failure but the *cause* of a failure.
- Is likely to significantly reduce failures when systems send alarms to facility managers
- Manufacturers have data on hundreds of systems over many years that could be mined for diagnostics.

MF Draw Schedule for Hot Water



Averaged data from all regimes at St Helena and Oakland

Energy savings – Example Factors



Based on savings from St Helena and Oakland

Possible Code Changes 2011

- Inspection
  - Check that air release valve is functioning
  - Check that vent dampers are working
- Commissioning of recirculation systems
  - Delta T in loop, depending on pipe diameter
  - HWR and HWS limits