

# Reducing Maintenance-Water Consumption in Evaporative Cooling Equipment

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# Learning Objectives

- \* Explain why calcium and magnesium behave differently in the production of scale in evaporative cooling equipment
- \* Describe how proper maintenance of scale production can actually reduce water consumption
- \* Provide estimates of water use savings for different supply water characteristics

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# Acknowledgements

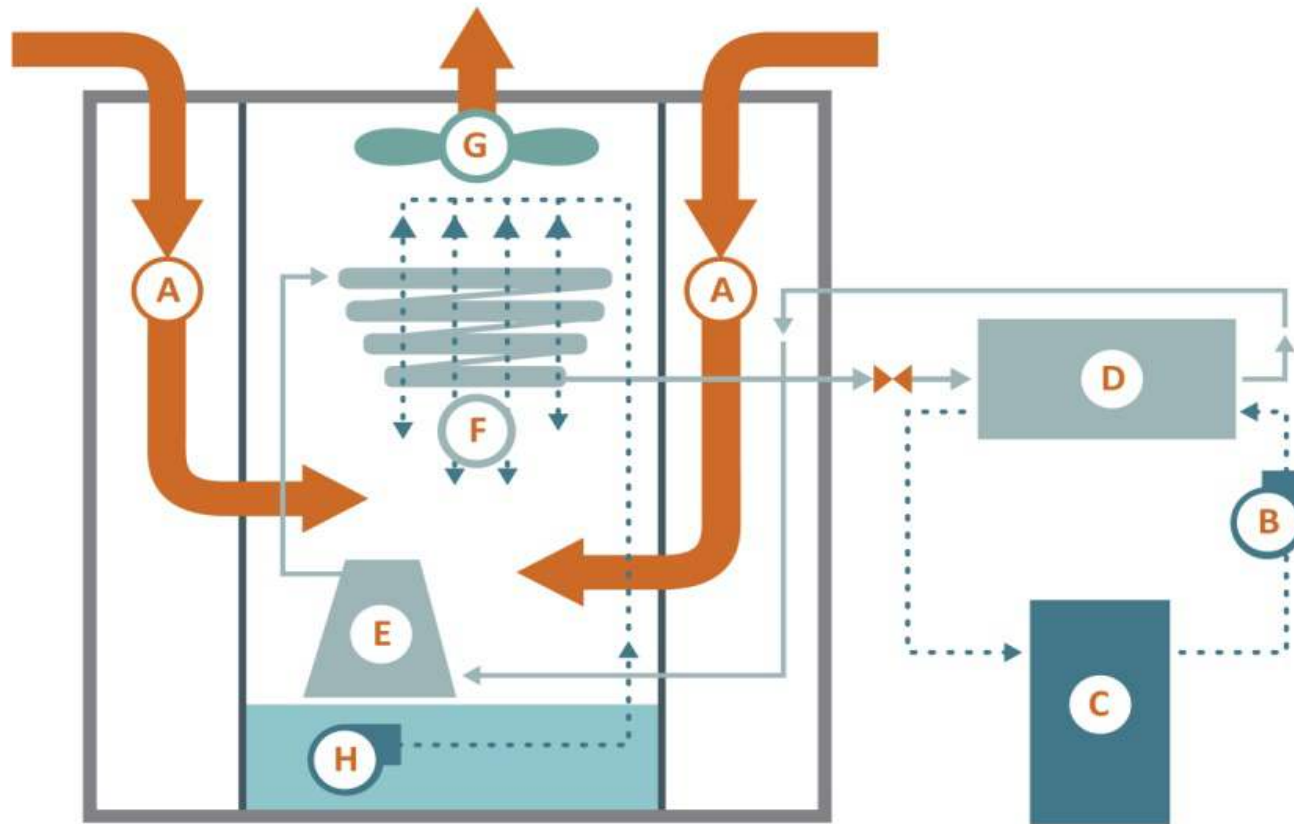
- \* WCEC Contributors include Theresa Pistochni, Erica R. McKenzie, Curtis Harrington and Peter Breyfogle
- \* Research funded by Southern California Edison under the Emerging Technologies Program

# Project Objectives

- \* Understand impact of water management and treatment strategies on longevity of residential evaporative condenser
- \* Develop optimized water management strategies (i.e. bleeds and/or treatment devices)



# Evaporative Condenser Schematic



**A** Plenums with 95°F airflow at neutral pressure

**B** Pump

**C** Water heater

**D** Water to refrigerant HX

**E** Compressor

**F** Condenser coil

**G** Exhaust blower

**H** Sump pump

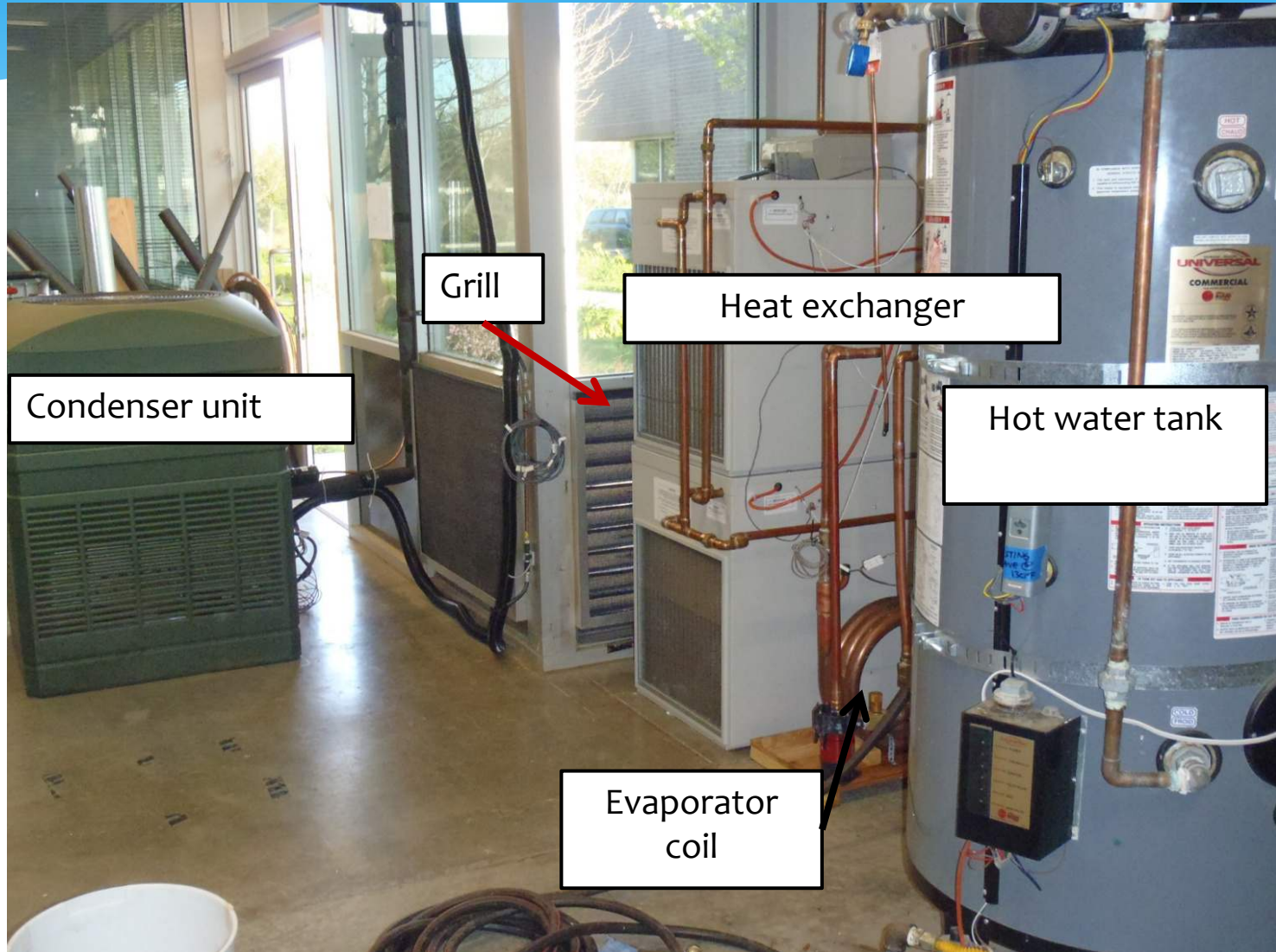
# Full Scale Experimental Design

## Measurement/Control

- \* Temperature and %RH of input air
  - \* Controlled to 95°F
- \* COP
  - \* Capacity of the system
    - \* Water-refrigerant heat exchanger
    - \* Water flow rate and  $\Delta T$
  - \* Total Power
- \* Bleed-water removal rate
- \* Make-up water supply rate and electrical conductivity
- \* Evaporation rate
  - \* Difference between supply and bleed
- \* Water conductivity in sump

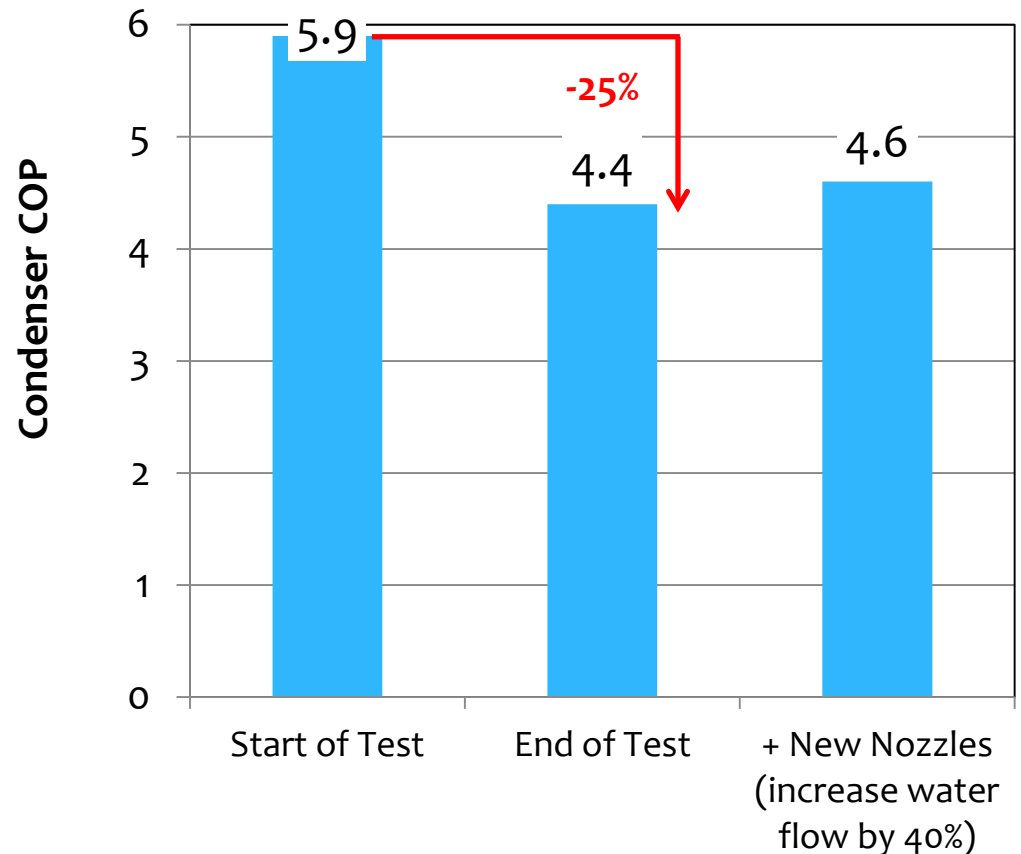


# Full Scale Experimental Design



# Full-Scale Evaporative Condenser Results

- \* 2075 hours of operation
- \* 11,000 gallons of water
- \* Maintenance Performed
  - \* Two pump failures
  - \* Cleaned filter basket



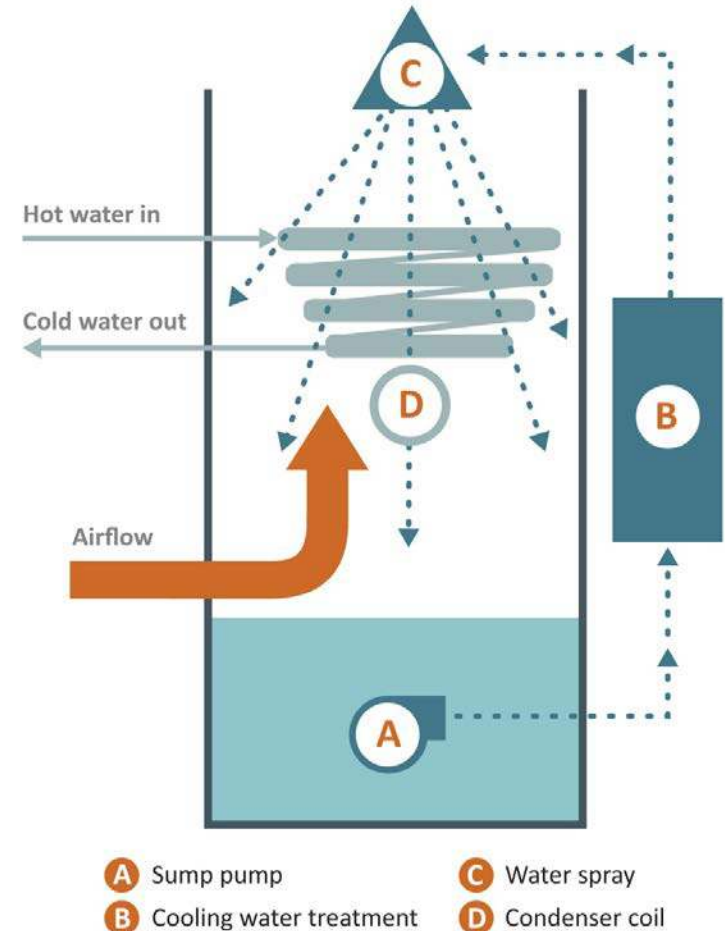
# Small Scale Experimental Design



# Small Scale Experimental Design

## Measurement/Control

- \* Temperature and %RH of input air
  - \* Controlled to 95°F
- \* Capacity of coils
  - \* Hot-water flow rate and  $\Delta T$
- \* Air pressure differential across coils
- \* Bleed-water removal rate
- \* Make-up water supply rate and electrical conductivity
- \* Evaporation rate
  - \* Difference between supply and bleed
- \* Water conductivity in sumps
- \* Periodic water analysis
- \* Deposit analysis



# Evaporative Condenser Impacts on Water

- \* **Concentration of mineral solutes**

- \* Scale-forming constituents (Ca and Mg)
- \* Salinity and carbonate concentrations

- \* **Increase in pH**

- \* High pH decreases solubility of Ca and Mg

- \* **Temperature changes that impact  $\text{CaCO}_3$  solubility**

- \* Solubility is lower at higher temperatures

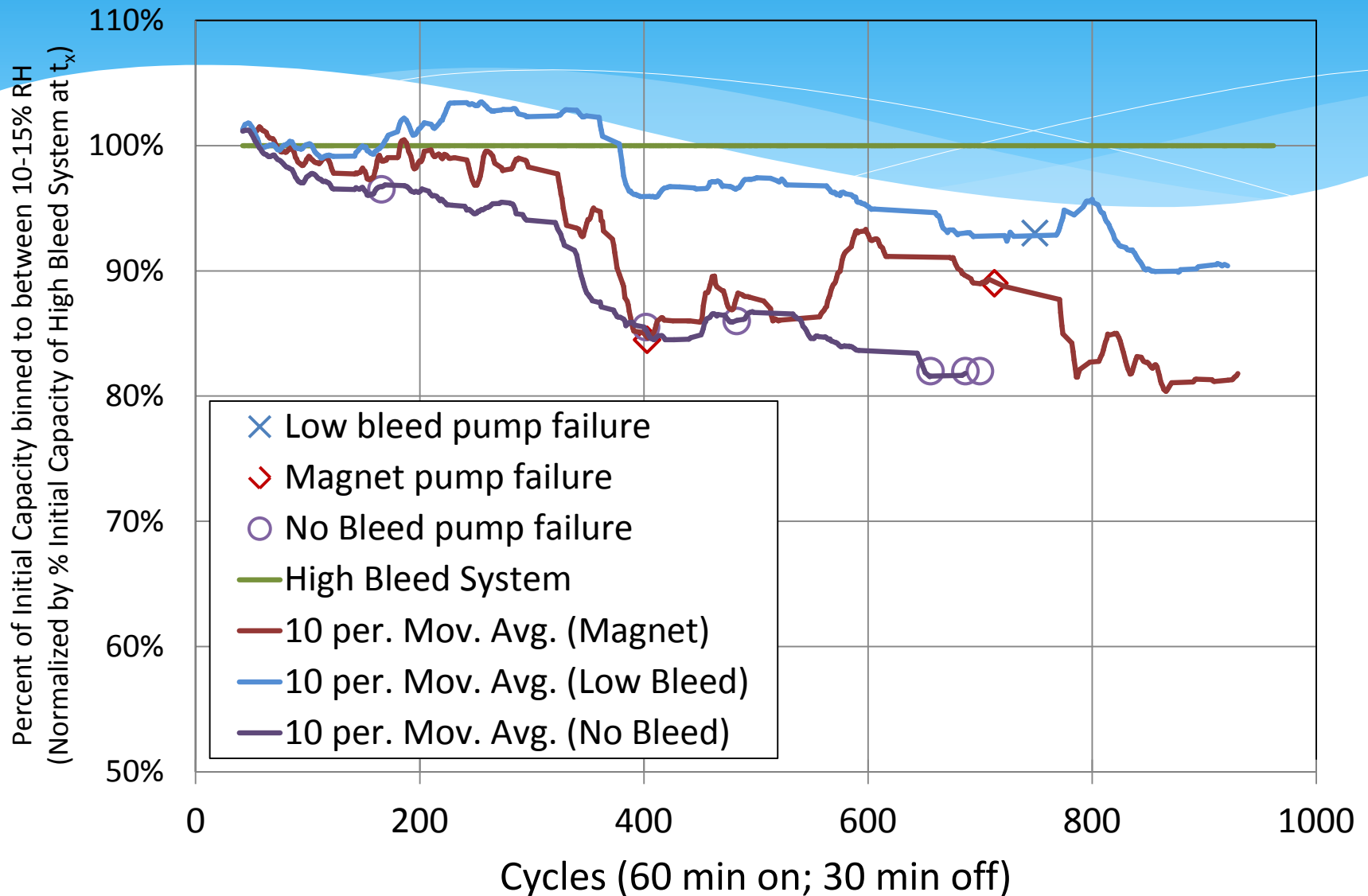


# Small-Scale Test Results – Round 1

- \* Chamber 1 – Low Bleed (+8% water use)
- \* Chamber 2 – Permanent magnets
- \* Chamber 3 – High Bleed (+40% water use)
- \* Chamber 4 – Baseline



# Small-Scale Results – Round 1



# Small-Scale Tests: Water Chemistry

SYSTEM	PH	CALCIUM			MAGNESIUM			Coil scale mass/cycle (g)
		Sump (mM)	Precipitated		Sump (mM)	Precipitated		
			(mols)	(%)		(mols)	(%)	
Influent (tap)	8.11	0.85	-	-	1.97	-	-	-
Control - no bleed	9.46	0	1.13	100	11.04	2.57	98.4	0.22
Magnets - no bleed	9.56	0	1.13	100	8.73	2.58	98.7	0.22
Low bleed +8% water	9.19	0.40	1.17	95.4	14.41	1.23	43.4	0.13
High bleed +40% water	8.99	0.21	1.29	81.1	7.64	0.00	0.0	0.11

\* Primary finding – **increased bleed rate**

⇒ significantly **decreased magnesium precipitation**

⇒ somewhat **increased calcium precipitation**

# Water Chemistry: Dissolved Solid Solubility

- \* Preliminary results from small-scale tests at different bleed rates
- \* Calcium and Magnesium are not equivalent



⇒ calcite is less soluble than magnesite

# Follow-Up Full-Scale Test

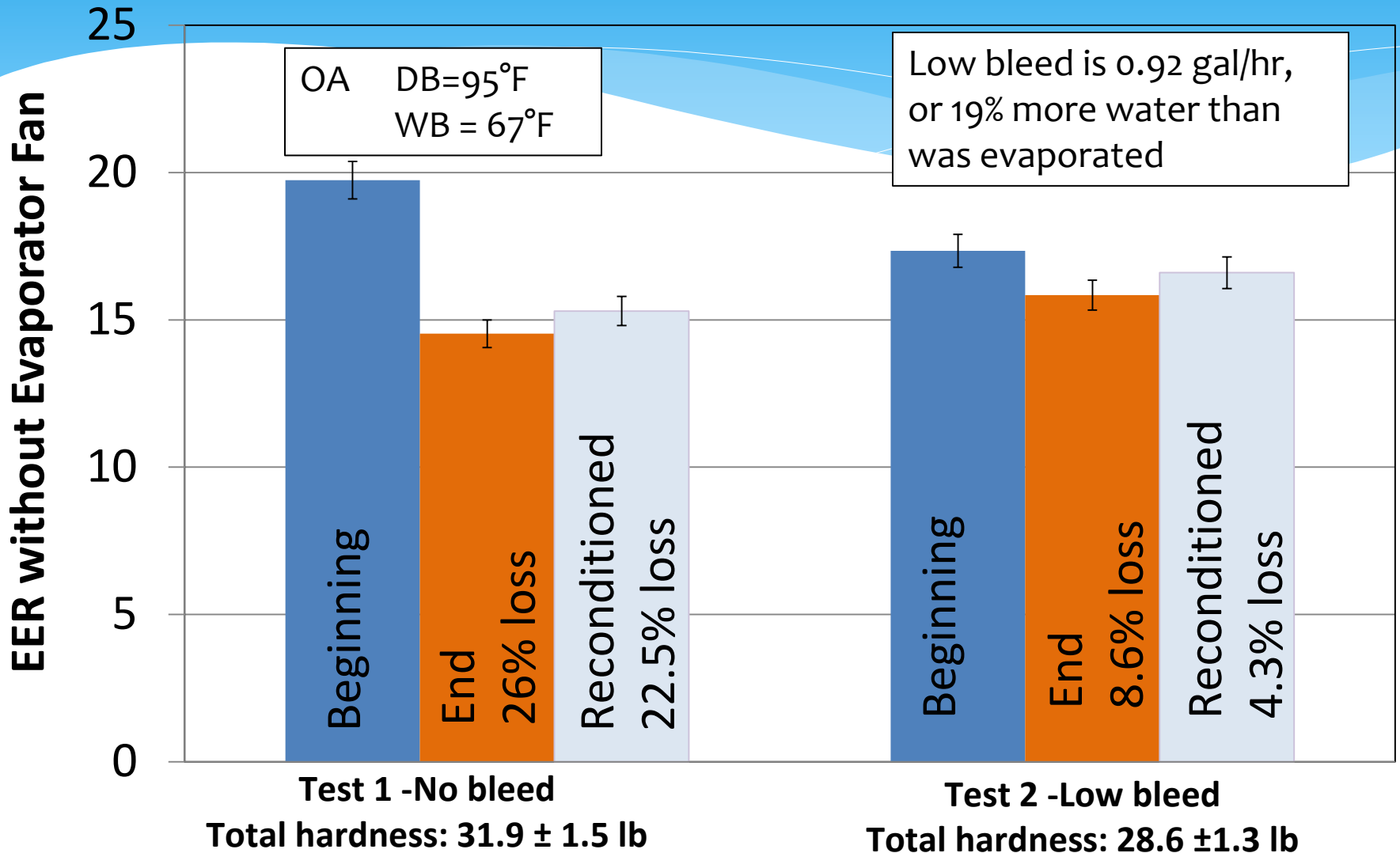
No Bleed



Low Bleed (+19%)



# Follow-Up Full-Scale Results



# Follow-Up Full Scale Results

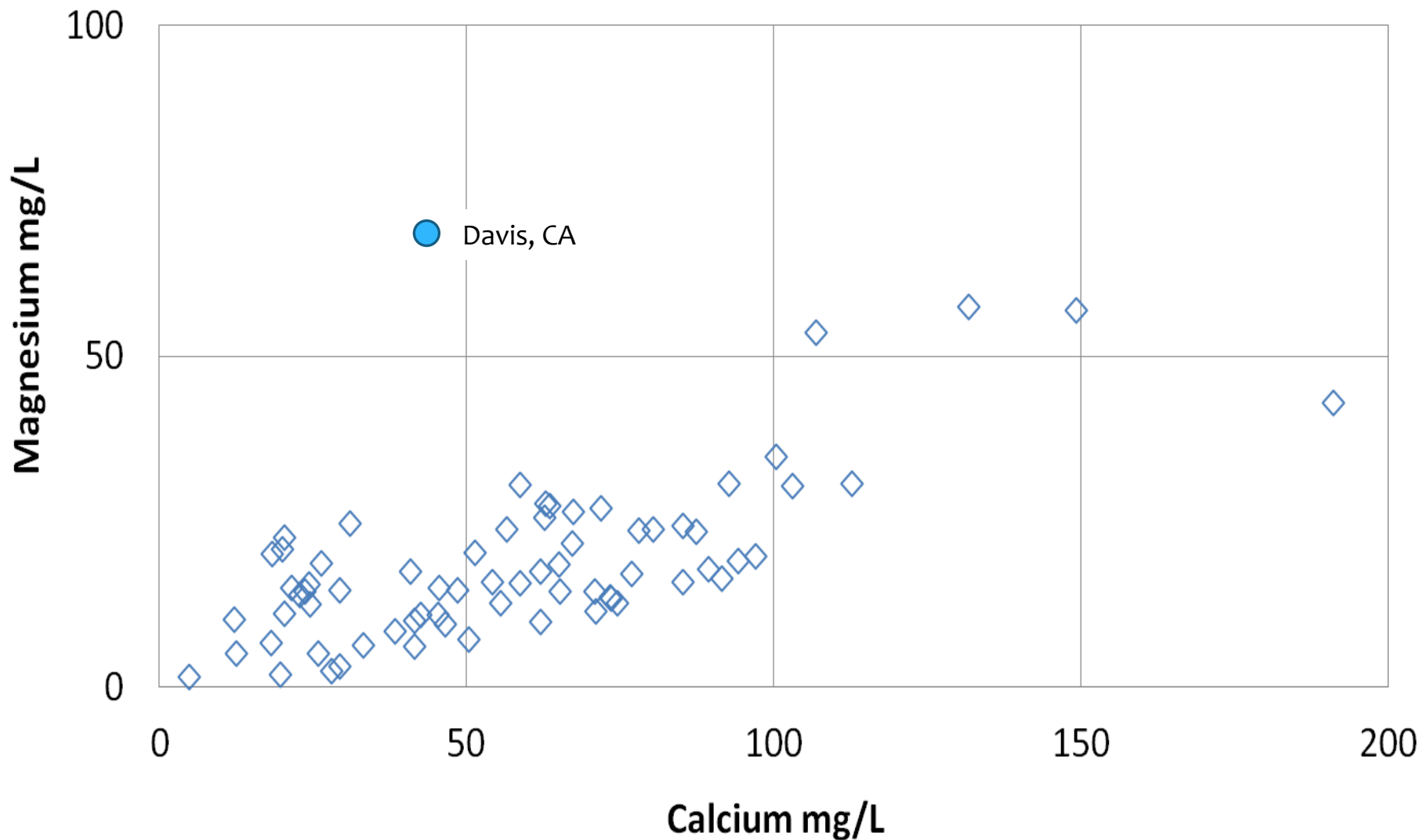
## \* **No Bleed Test**

- \* ~362 ppm average hardness tap water
- \* 30% Reduction in water flow due to clogged nozzles
- \* ~30lb of scale on coil, and two failed pumps

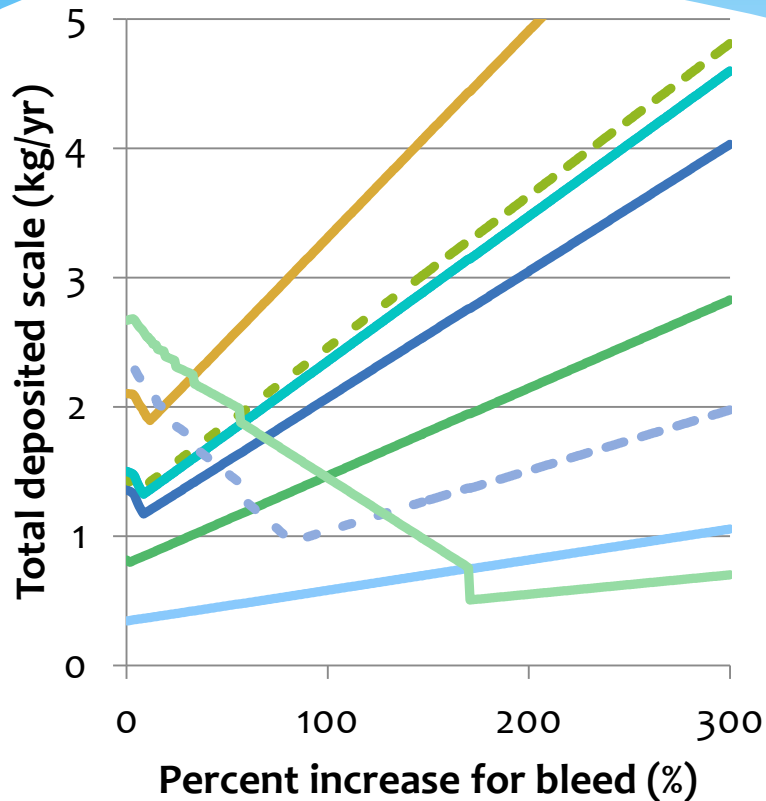
## \* **Low Bleed Test (+19% water)**

- \* ~254 ppm average hardness tap water (30% lower)
  - \* Same run hours, but only 10% less mineral introduction (due to minerals brought in by make-up for bleed water)
- \* Some nozzles blocked, negligible water flow reduction
- \* Negligible deposition on coil and no pump failures

# Calcium/Magnesium in CA Water



# (Semi) Optimized Bleed Rates



Location	Mg (mg/L)	Ca (mg/L)	Lifespan (yr)
Riverside	17	70	10
Eastern	17	62	12
Irvine	11	45	17
Santa Ana	14	73	10
Anaheim	20	97	7
Los Angeles	17	70	10
Long Beach	2	20	39
Davis	53	33	14
Hypothetical	70	15	27

\* % increase for bleed =  $V_{\text{bleed}}/V_{\text{evaporation}} * 100\%$

\* Use bleed to eliminate magnesium precipitation

# Conclusions

- \* **Thermal degradation is modest**
  - \* System performance robust even with scale build-up
  - \* Pumps appear to fail before significant thermal degradation
- \* **Bleed rate affects many water quality parameters**
  - \* Ca and Mg concentrations, pH, Salinity
- \* **Calcium and Magnesium behave differently**
  - \* Different solubility limits
  - \* Need to consider local water conditions
  - \* Lower bleed rates should be considered, and could improve performance in some circumstances
- \* **Manufacturer Specifications**
  - \* Often inconsistent with these research results