Evaporative Condensers: Water Management and Chemistry

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Emerging Technologies

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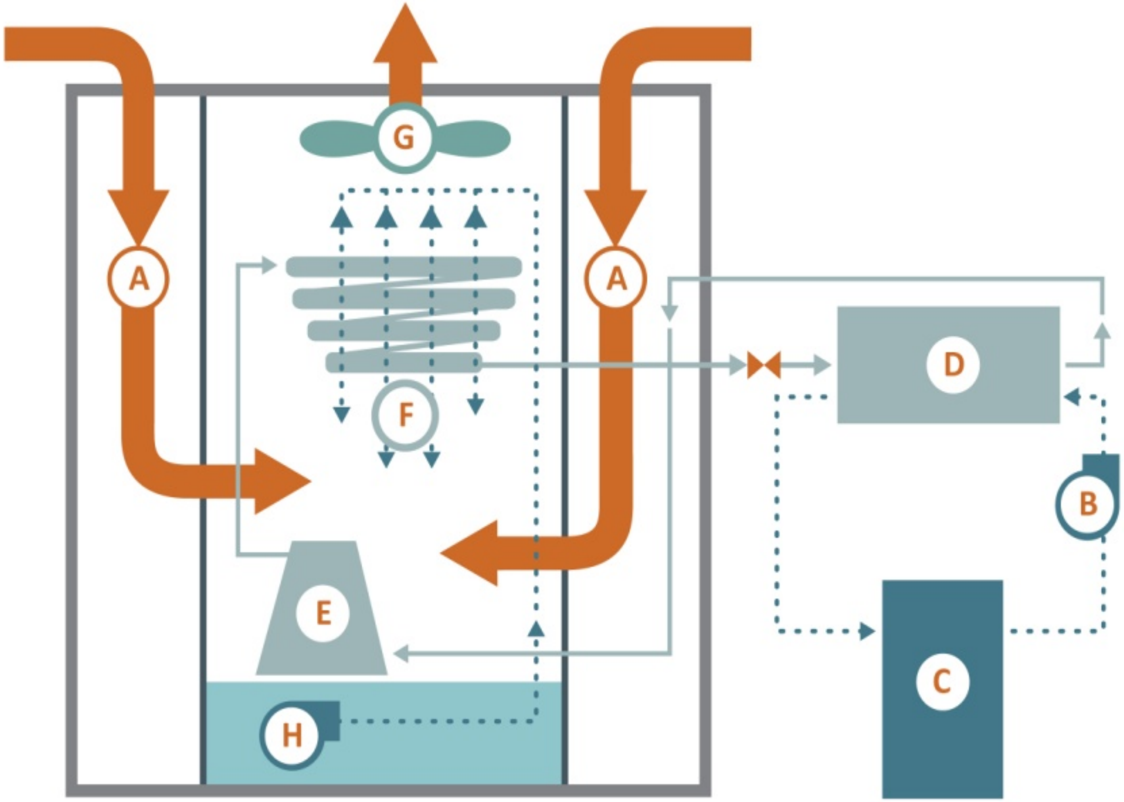
How Evaporative Condensers Work

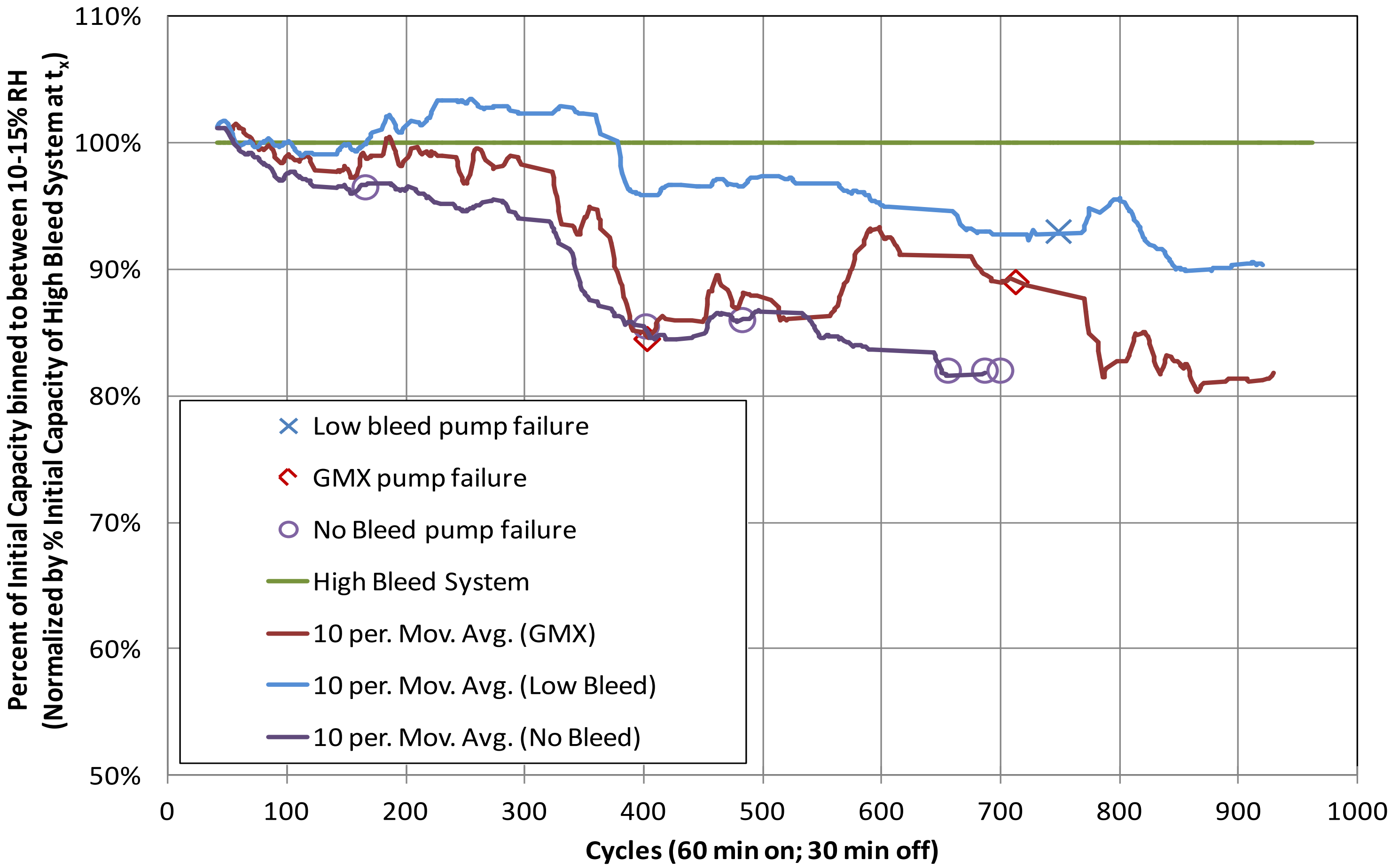


- **A** Plenums with 95°F airflow at neutral pressure
- **B** Pump
- **C** Water heater
- **D** Water to refrigerant HX
- **E** Compressor
- **F** Condenser coil
- **G** Exhaust blower
- **H** Sump pump

Evaporative Condenser Effects 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 $CaCO_3$ solubility constant

Small-Scale Results – Round 1



Carbonate System Solubility

- $MeCO_3$ (s) <==> $Me^{2+} + CO_3^{2-}$

$$K_{sp} \approx \left[Me^{2+}\right] \cdot \left[CO_3^{\ 2-}\right]$$

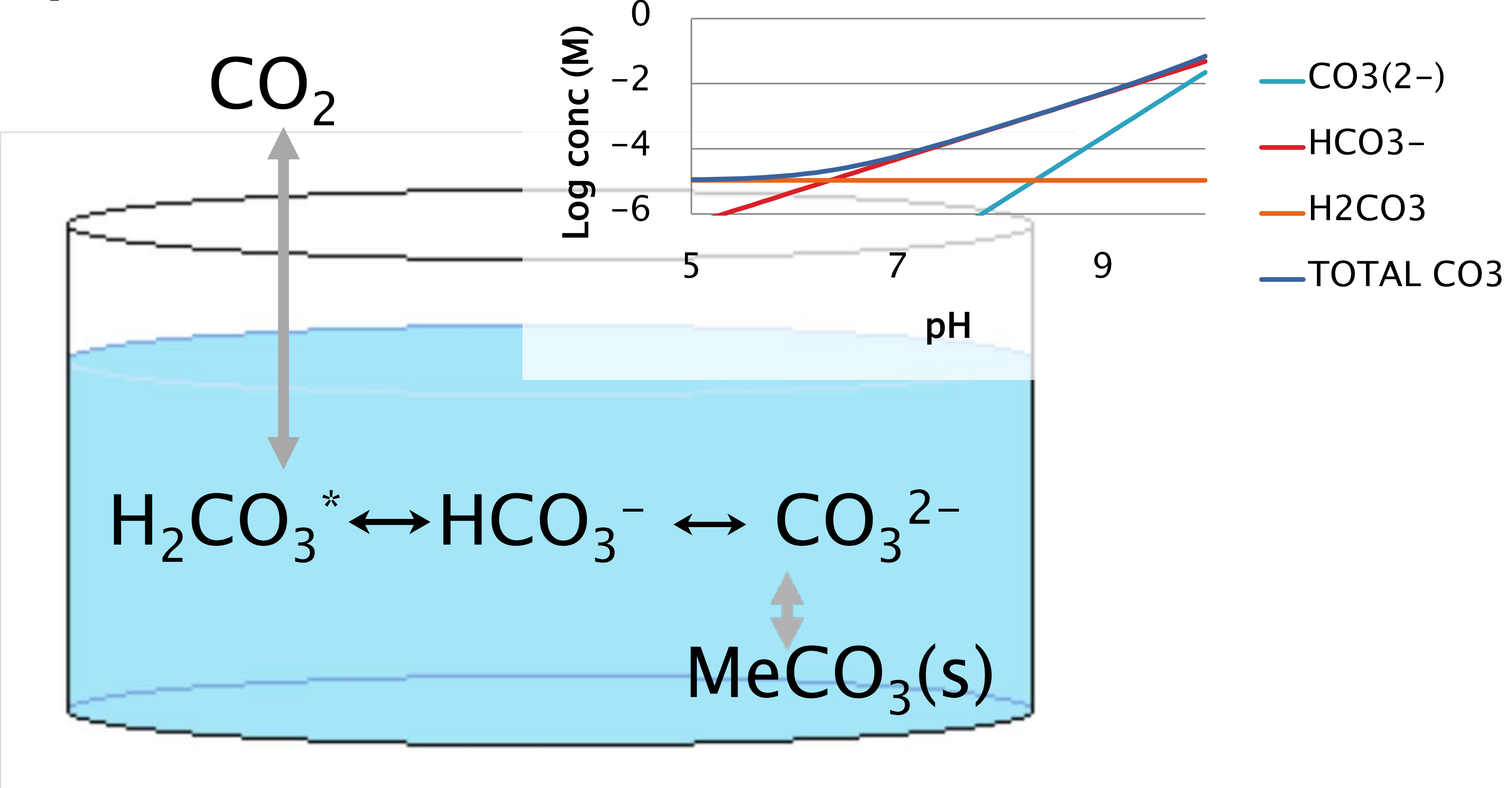
- Ca => $CaCO_3$ (calcite) K_{sp}=3.36e−9
- Mg => $MgCO_3$ (magnesite) K_{sp}=6.82e−6

⇨ calcite is less soluble than magnesite

- How quickly do the reactions occur?

The Carbonate System

$$K_{sp} \approx \left[Me^{2+}\right] \cdot \left[CO_3{}^{2-}\right]$$



Equilibrium with the atmosphere

CO_2

$H_2CO_3{}^{*} \leftrightarrow HCO_3{}^{-} \leftrightarrow CO_3{}^{2-}$

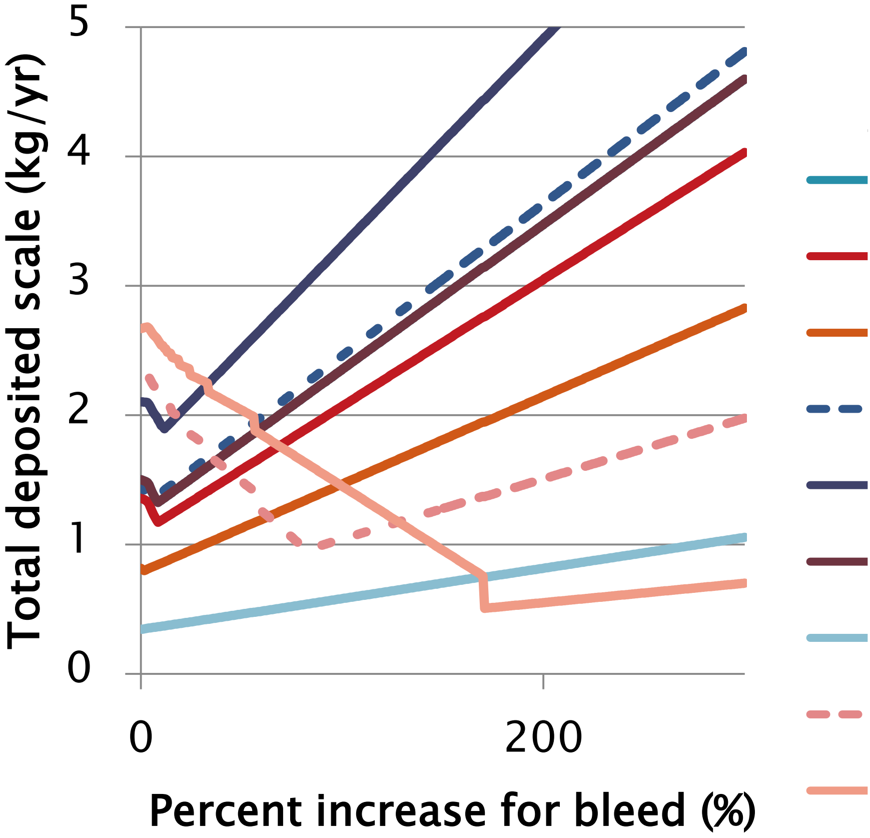
$MeCO_3(s)$

Small-Scale Water Chemistry

System	pH	Calcium			Magnesium			Coil scale mass/cycle (g)[d]
		Sump (mM)[a]	Precipitated		Sump (mM)[a]	Precipitated		
			(mols)[b]	(%)[c]		(mols)[b]	(%)[c]	
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

(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(bleed)/V(evaporation)*100%
- Use bleed to eliminate magnesium precipitation

Conclusions

- Thermal degradation is modest
  - 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
  - Solubility limits
  - Need to consider local water conditions
- Lower bleed rates should be considered, and could **improve** performance in some circumstances

Questions?