

Laboratory Testing of Add-on Evaporative Cooling Systems for Rooftop Units

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Session 7: Evaporative cooling and pre-cooling technology advancements – are we ready for prime-time?

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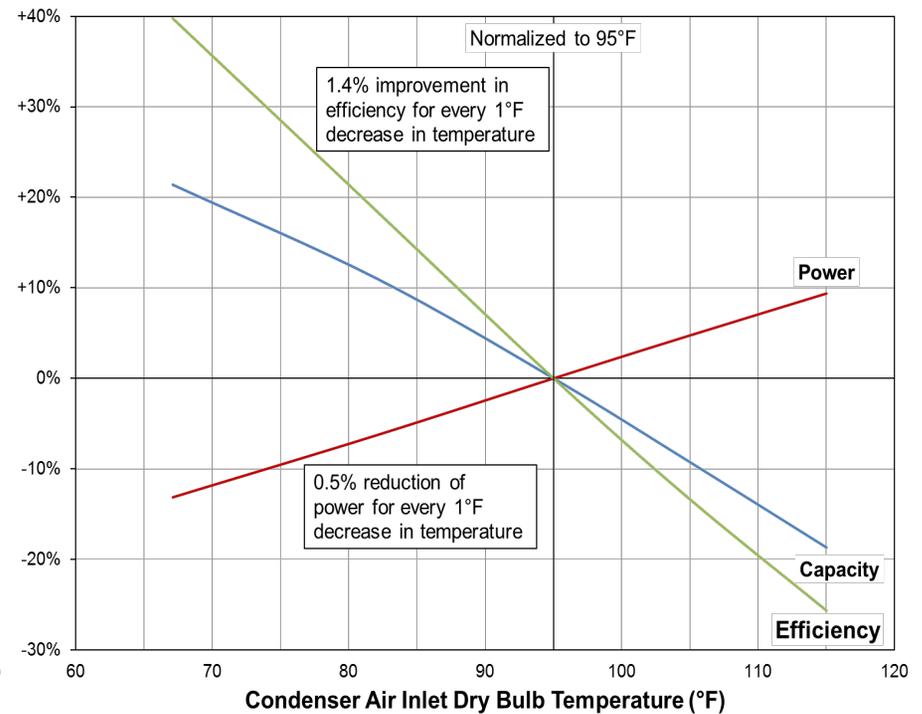
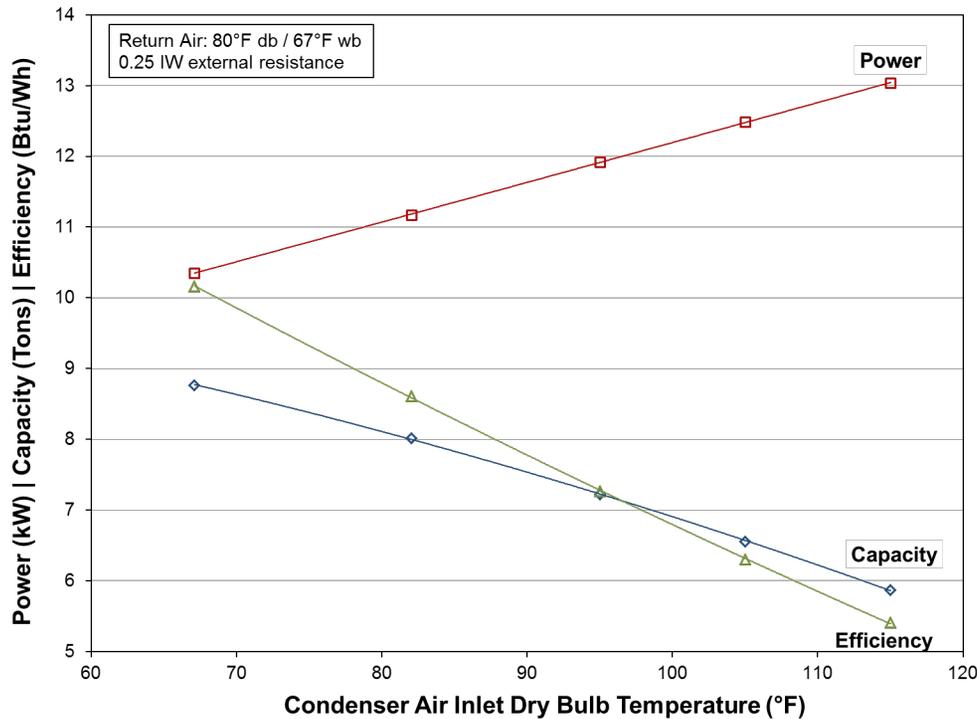
PG&E Applied Technology Services

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Air Conditioner Performance Map



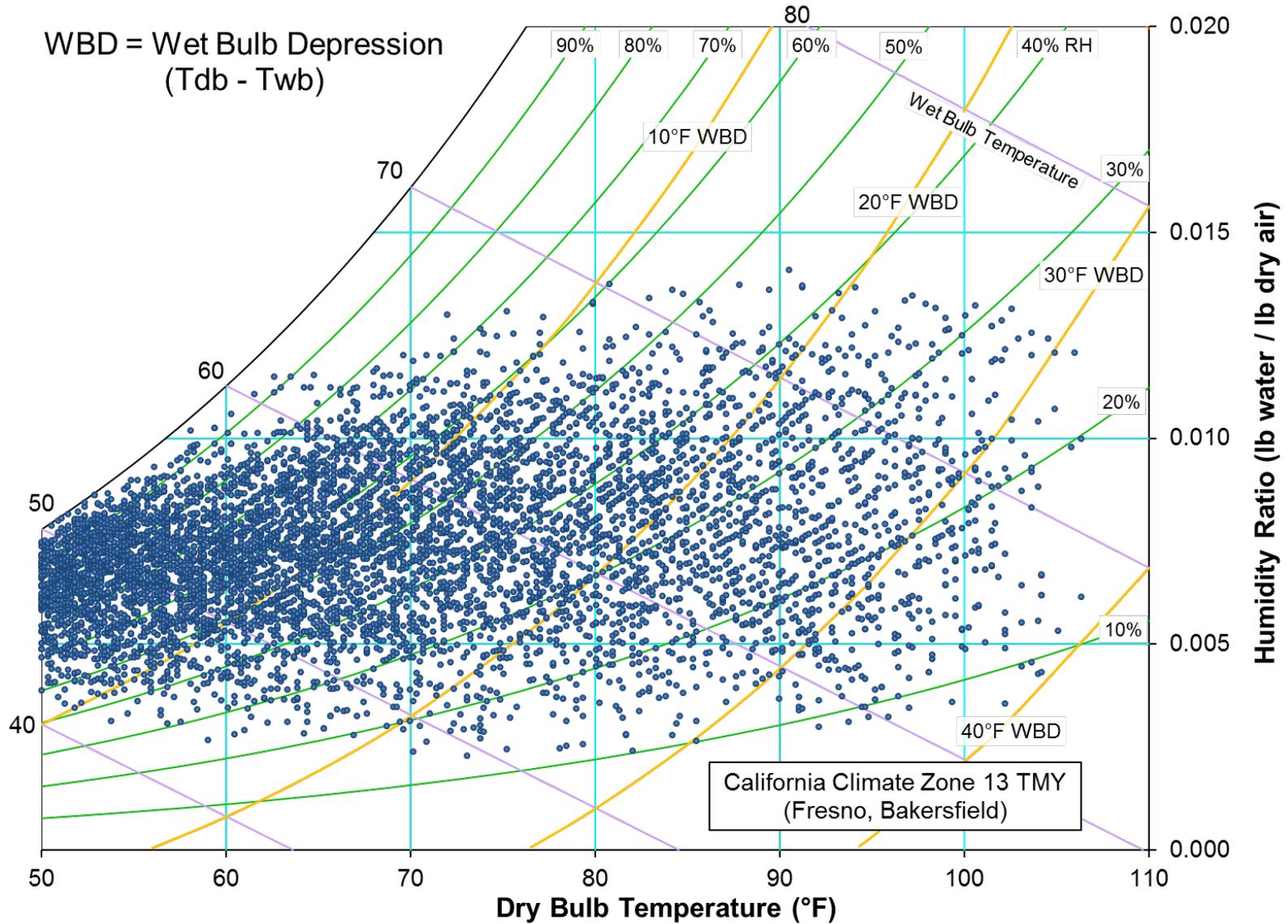
Test Unit

- Carrier 48DJD009
- ~22 years old
- R-22
- Nominal 8½-ton capacity
- 2 compressor stages
- 1½-hp indoor blower, ¾-hp condenser fan

- Rated airflows
 - 3,000 CFM Supply (0.25 IW External Resistance)
 - 6,500 CFM Condensing
- Exhaust static pressure held to zero
- Economizer OA damper closed and sealed
- All tests done with return air at 80°Fdb / 67°Fwb



But it's a dry heat!



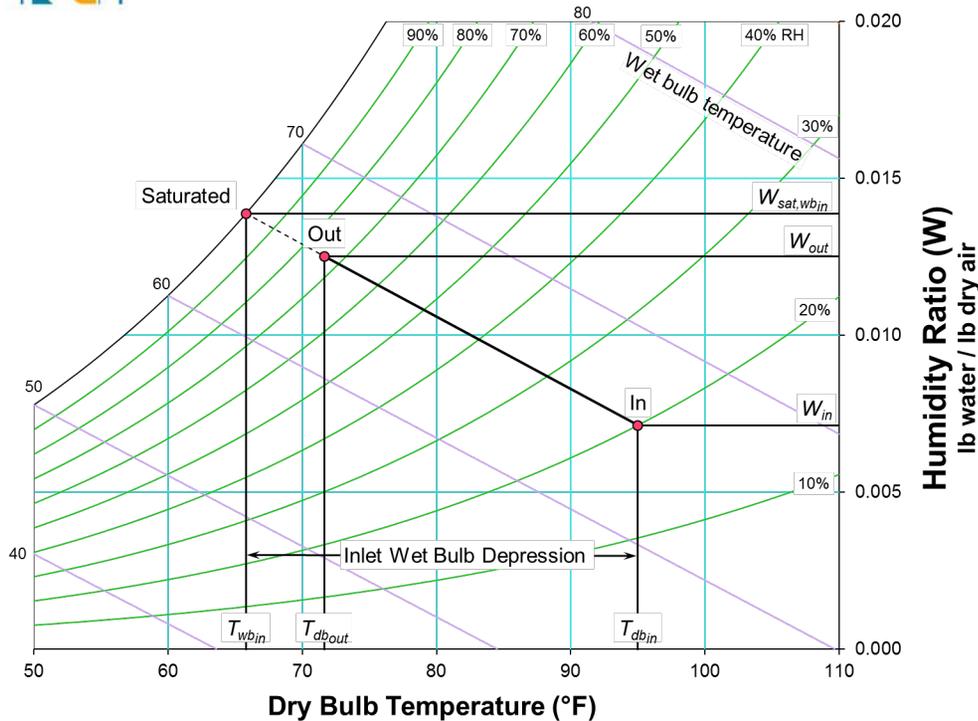


Evaporative Pre-Cooler Lab Testing Challenges

- Treatment of humidified air
 - Condense it out
 - Desiccant drying
 - *Exhausting*
- Difficult to accurately measure air properties between pre-cooler and condenser coil
 - Little air mixing
 - Uneven wetting
 - Carry-over spray
 - Radiant effects from coil
- Water treatment
 - Continuous versus intermittent flows
 - Quality (dissolved solids)



Evaporative Effectiveness Metrics



Temperature Effectiveness

$$EE = \frac{T_{db\,in} - T_{db\,out}}{T_{db\,in} - T_{wb\,in}}$$

Humidity Ratio Effectiveness

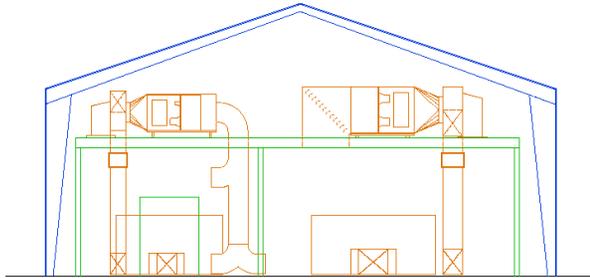
$$EE^* = \frac{W_{out} - W_{in}}{W_{sat,wb\,in} - W_{in}}$$

Water Consumption for Evaporation:

$$\begin{aligned}
 GPH &= 60 \times (W_{out} - W_{in}) \times CFM \times 0.075 \text{ lbA/ft}^3 / 8.33 \text{ lb H}_2\text{O/gal} \\
 &\approx (W_{out} - W_{in}) \times CFM / 2 \\
 &\approx (T_{db\,in} - T_{db\,out}) \times CFM / 8600 \\
 &\approx EE \times WBD \times CFM / 8600
 \end{aligned}$$



PG&E Laboratory San Ramon



Two independently conditioned rooms

15'H × 15'W × 16'7"L (small "indoor room" on left), and
15'H × 15'W × 23'9"L (large "outdoor room" on right)

Airflow measurement with nozzle boxes ("Code Testers") on roof

- 65 – 5,500 CFM indoor
- 500 – 13,500 CFM outdoor
- Variable speed booster fans to compensate for nozzle and duct pressure loss

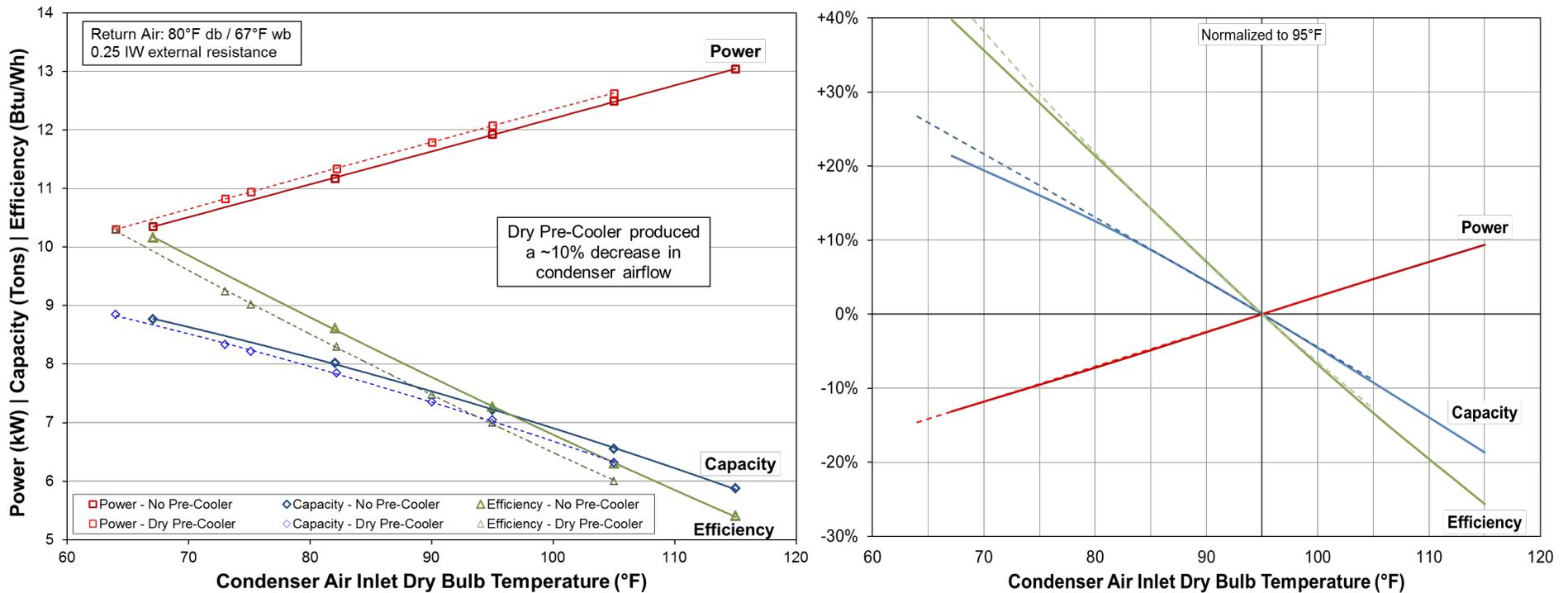
Separate space conditioning systems for each room

- Variable capacity heat pumps with supplemental resistance heat
- Fully functional outside air intakes for flushing humidified air



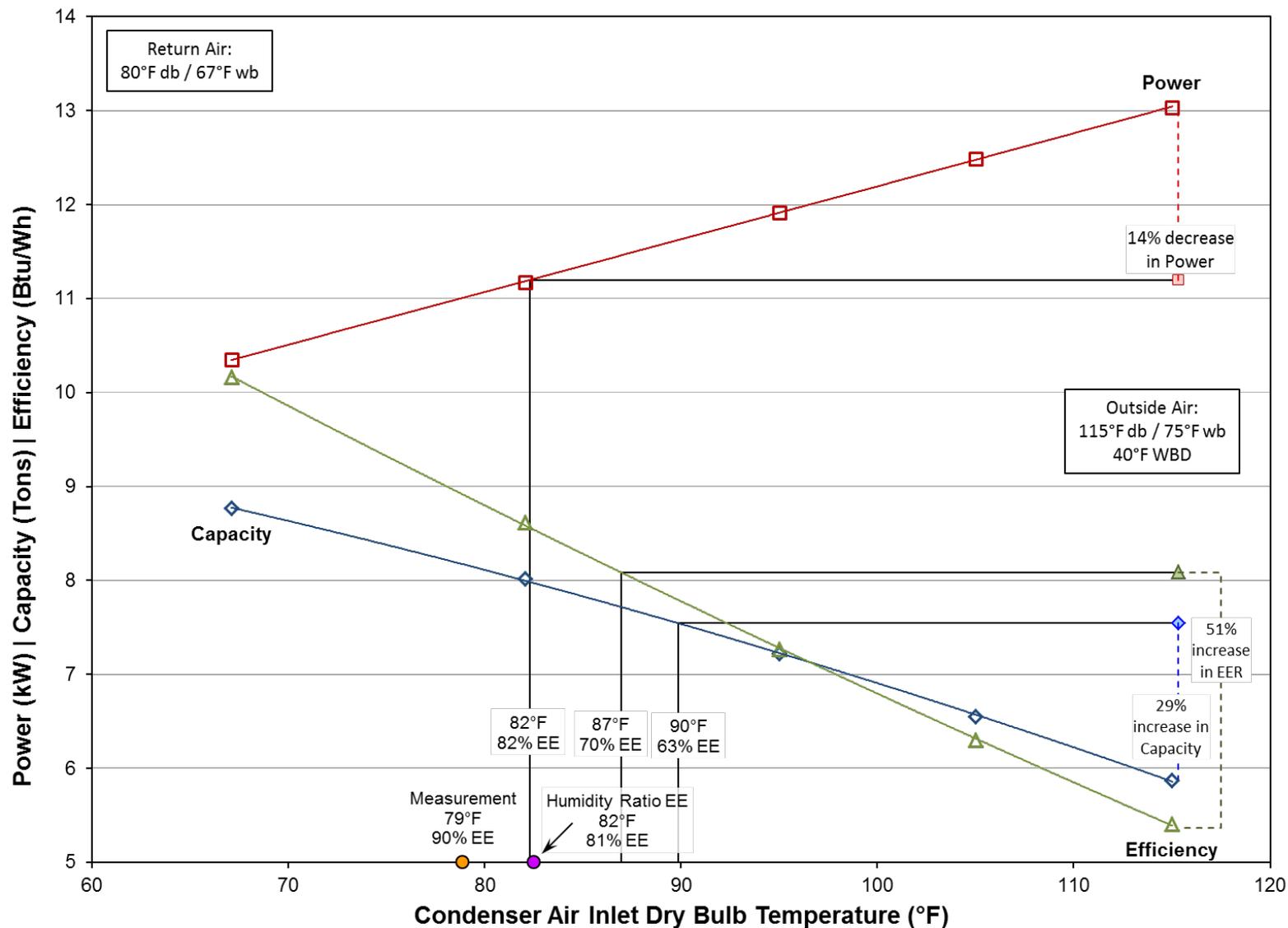
Addition of Dry Pre-Cooler

Creates extra resistance to condenser airflow





Calculating Evaporative Effectiveness from the Performance Map





Condenser Air Evaporative Pre-Cooling

Four systems tested of different configurations and approaches



Pre-Cooler
Face
Velocity

← 3.1 fps

4.2 fps →



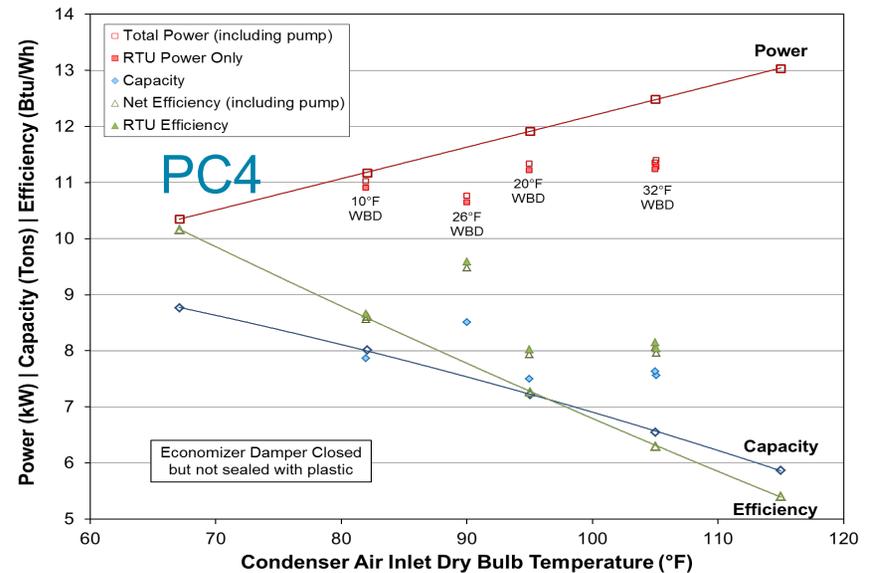
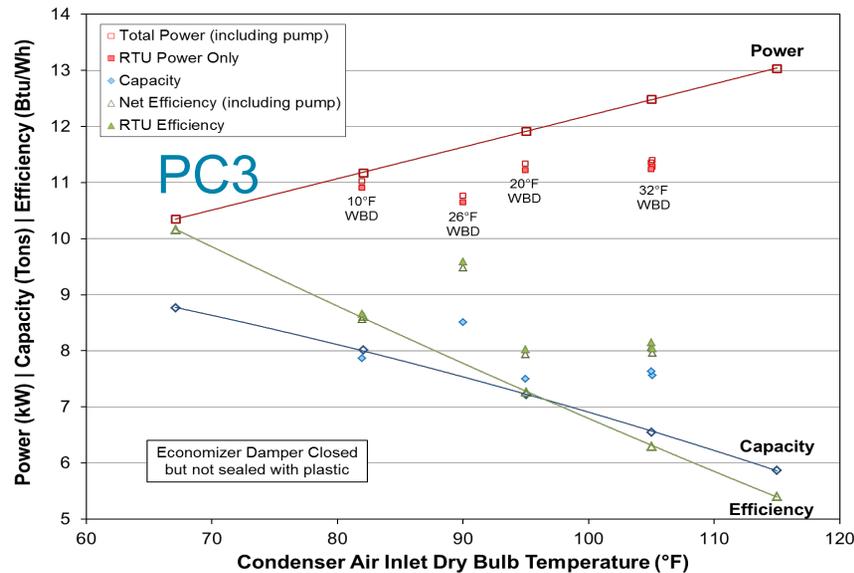
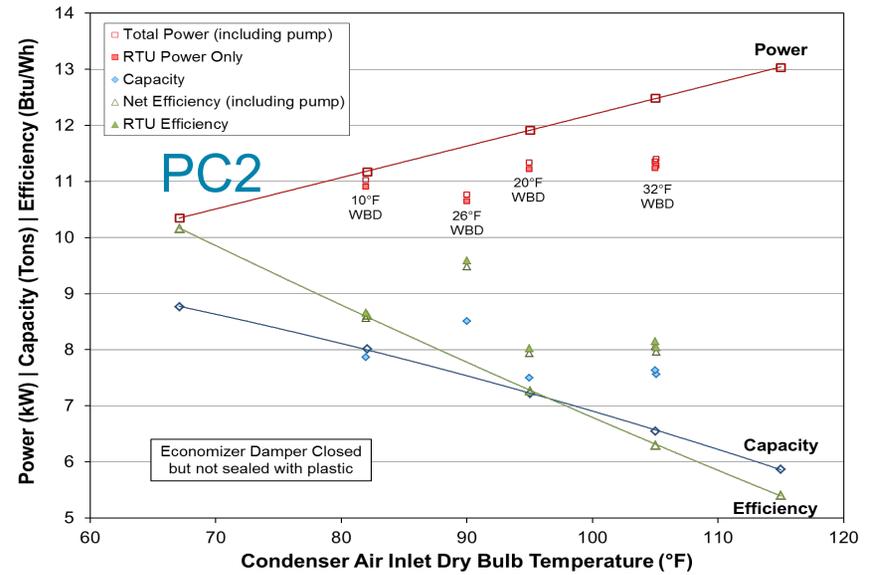
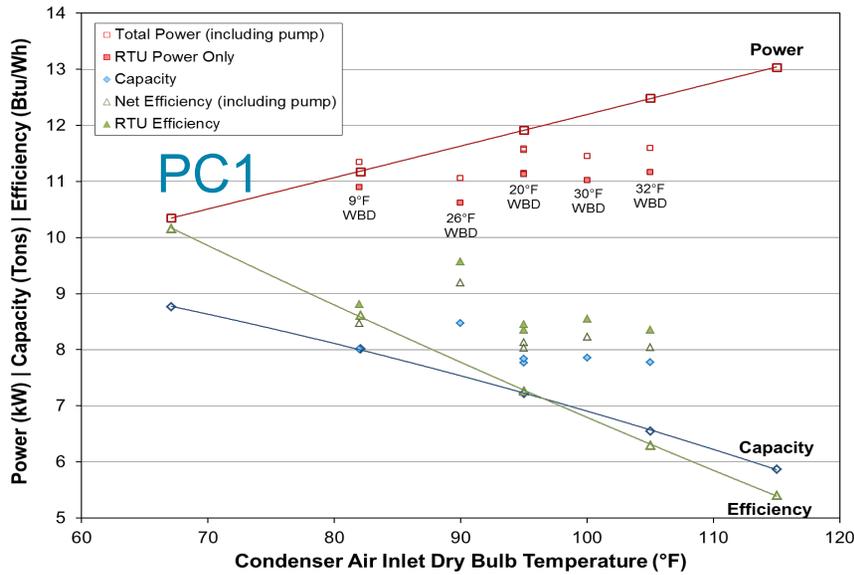
← 5.2 fps

4.9 fps →





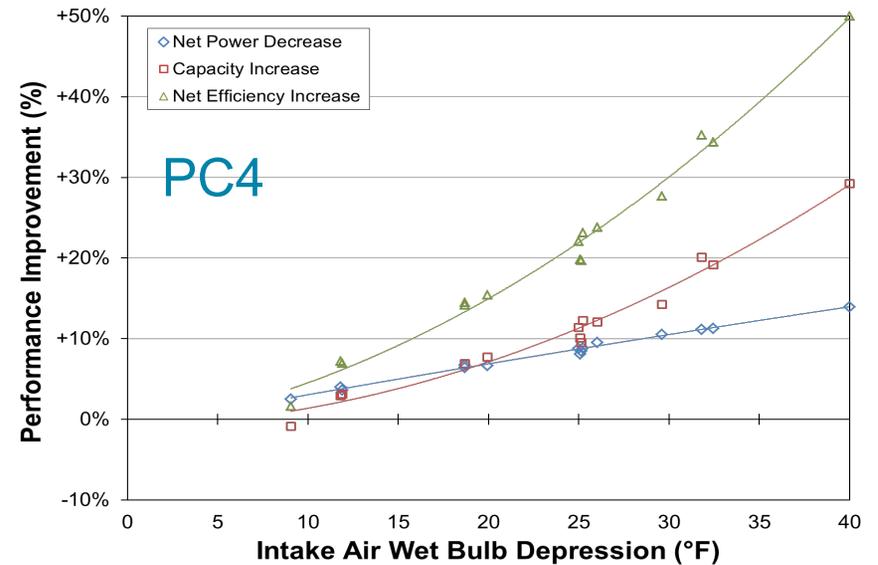
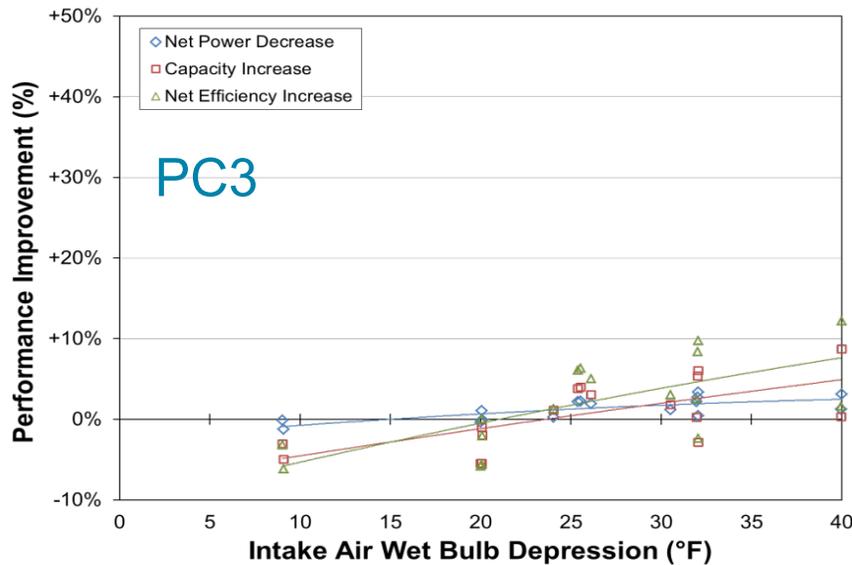
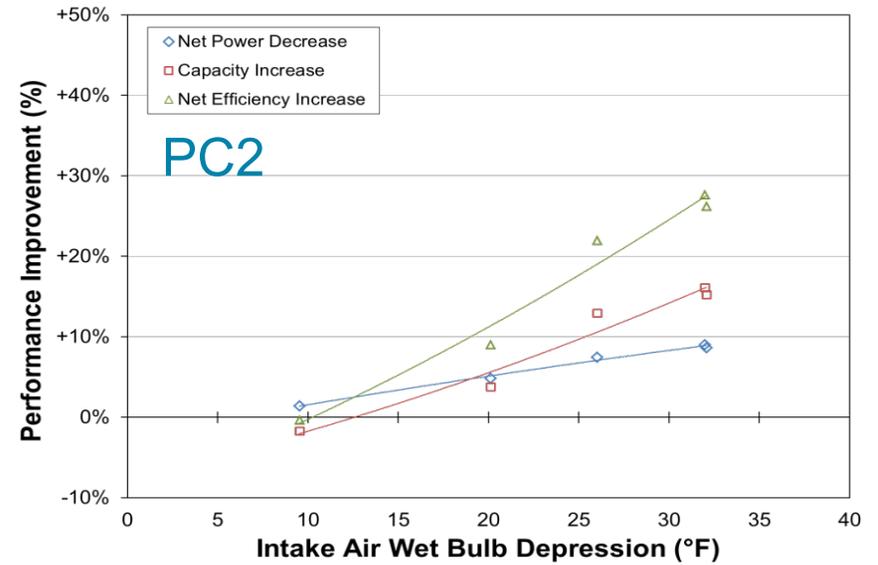
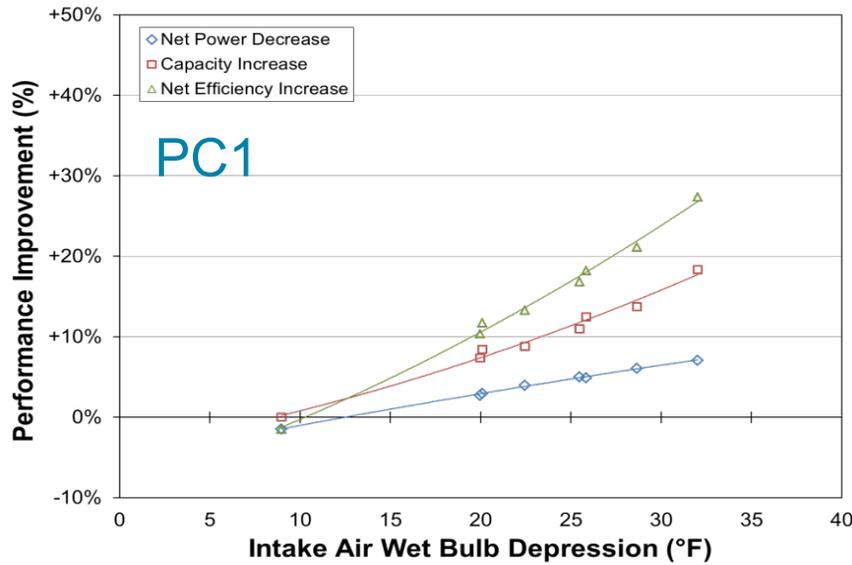
RTU Performance with Wet Pre-Cooler





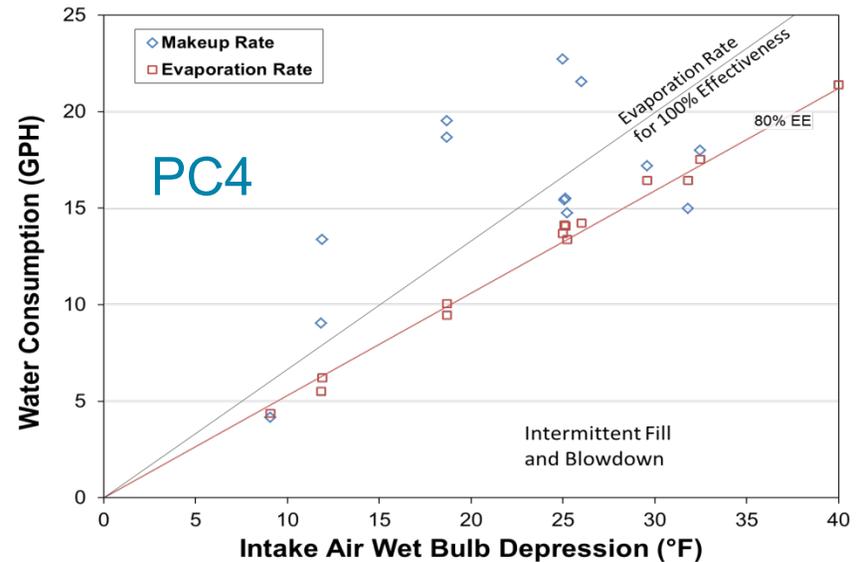
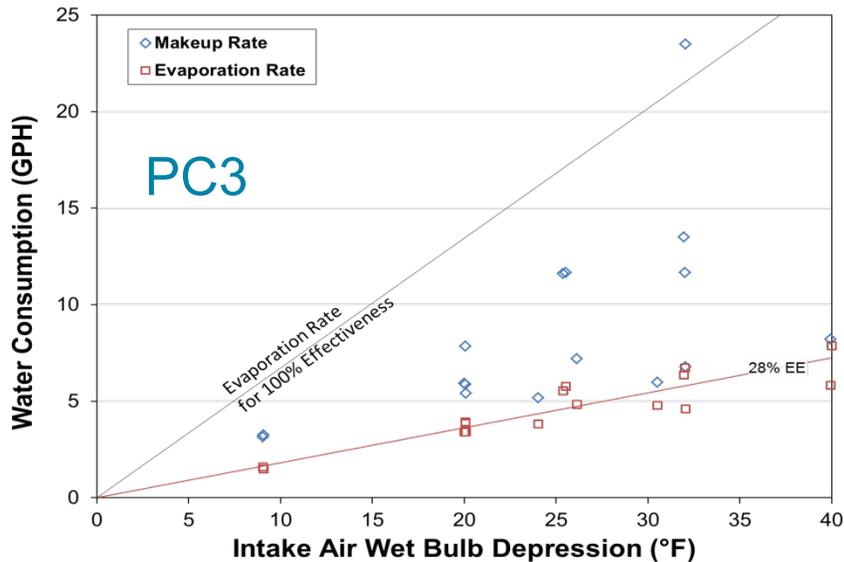
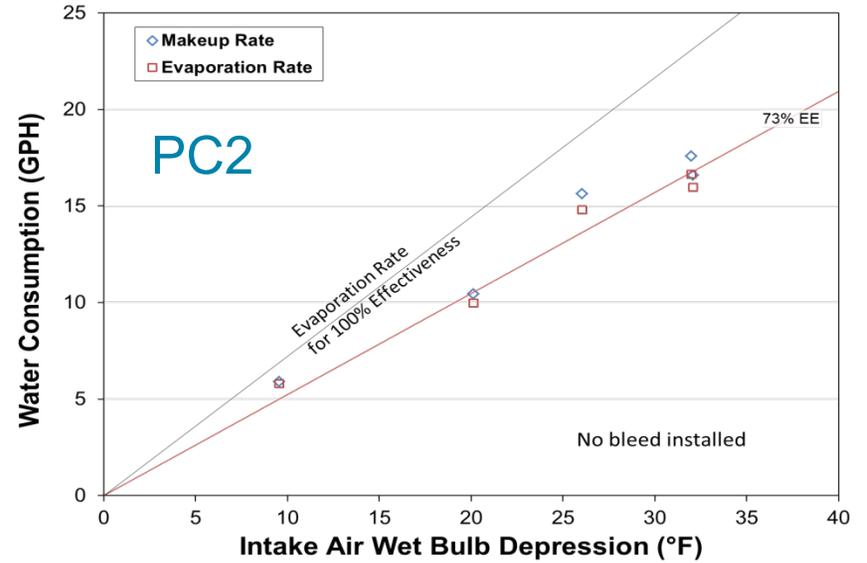
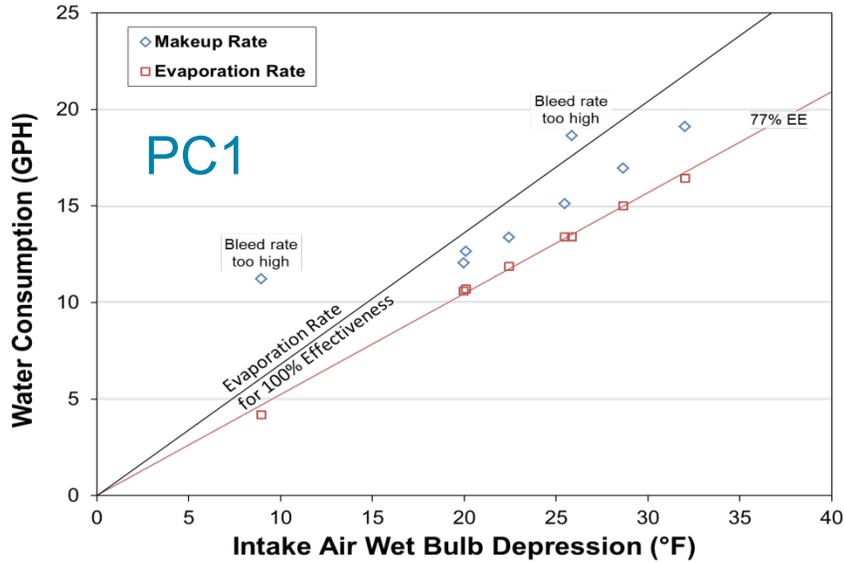
Relative Performance Improvements

“Net” means including added pump power





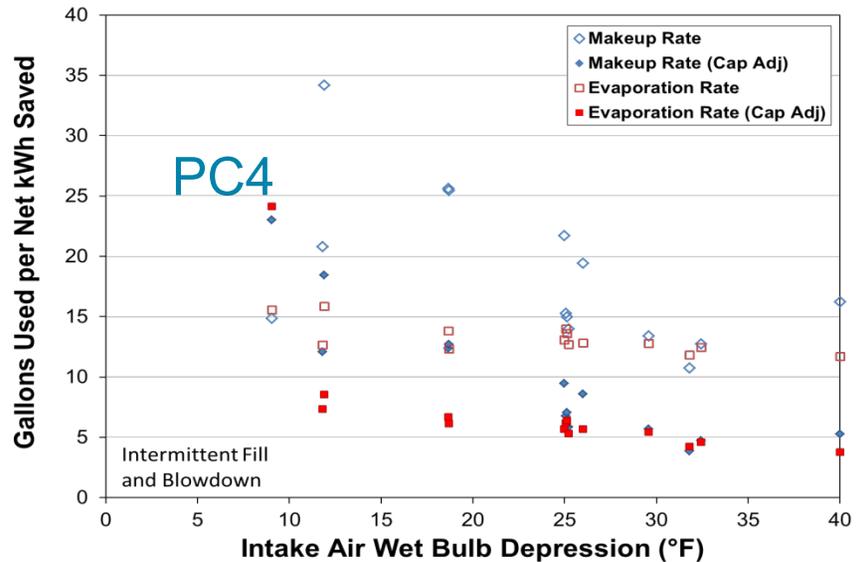
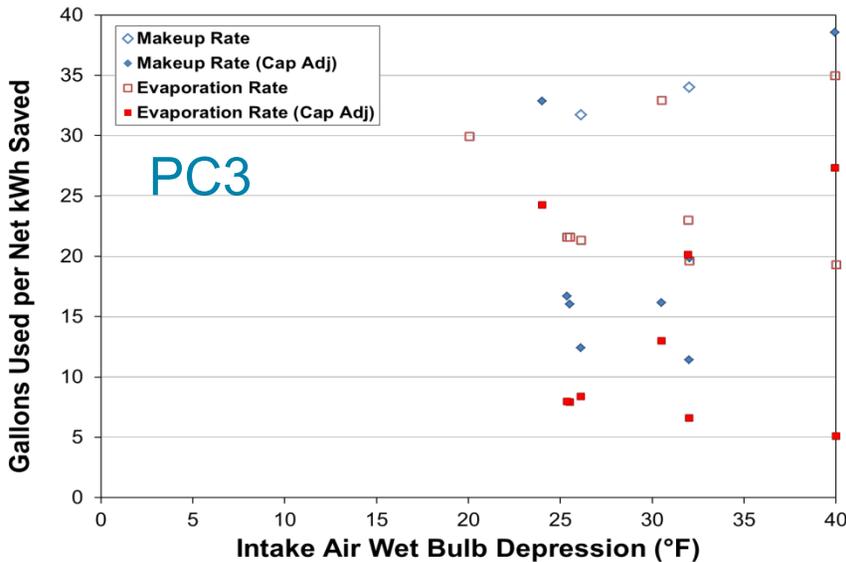
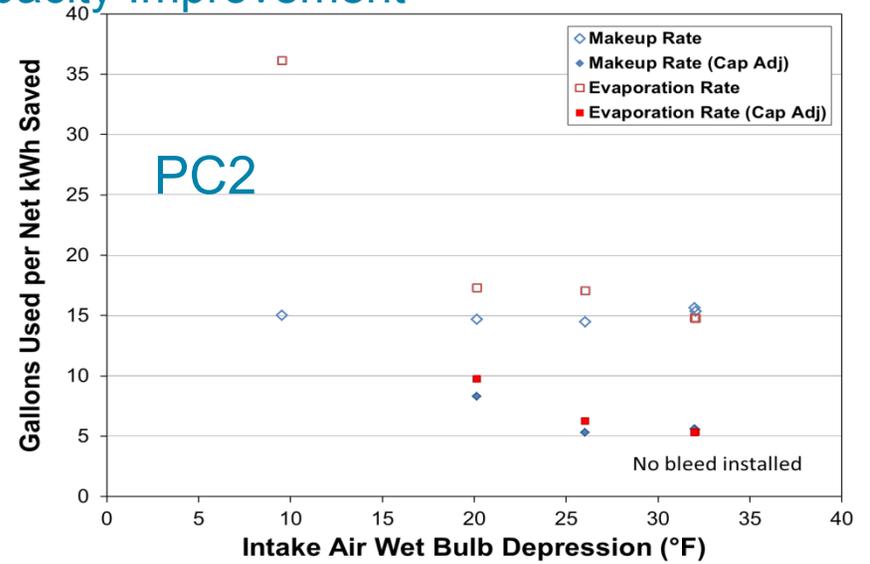
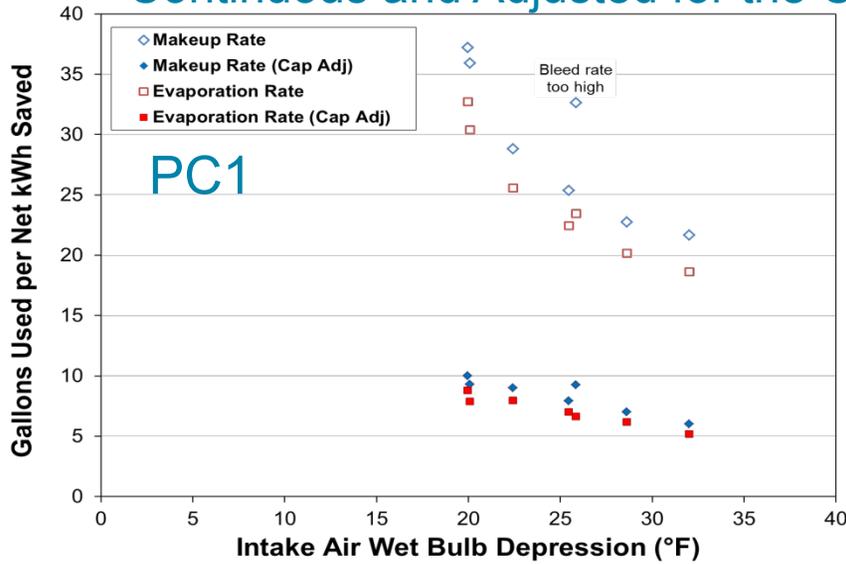
Water Consumption





Water Use per Unit of Energy Saved

Continuous and Adjusted for the Capacity Improvement





Conclusions

- Many systems can produce a significant improvement in RTU performance
 - Up to 14% Demand Reduction (maximum observed)
 - Up to 29% Capacity Improvement (maximum observed)
 - May allow system to operate less frequently
- Impact is greater at higher wet bulb depressions
- Appears to affect power and capacity differently
 - May be related to airflow restriction
- Results representative of only one test RTU and Pre-cooler samples
 - R-410a systems likely to be more responsive
 - “Your mileage may vary”

Thank You

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