Evaporative Cooling in a Hot-Dry Climate

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SWEEP Workshop

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Sponsors: Clarum Homes

California Energy Commission

U.S.Department of Energy

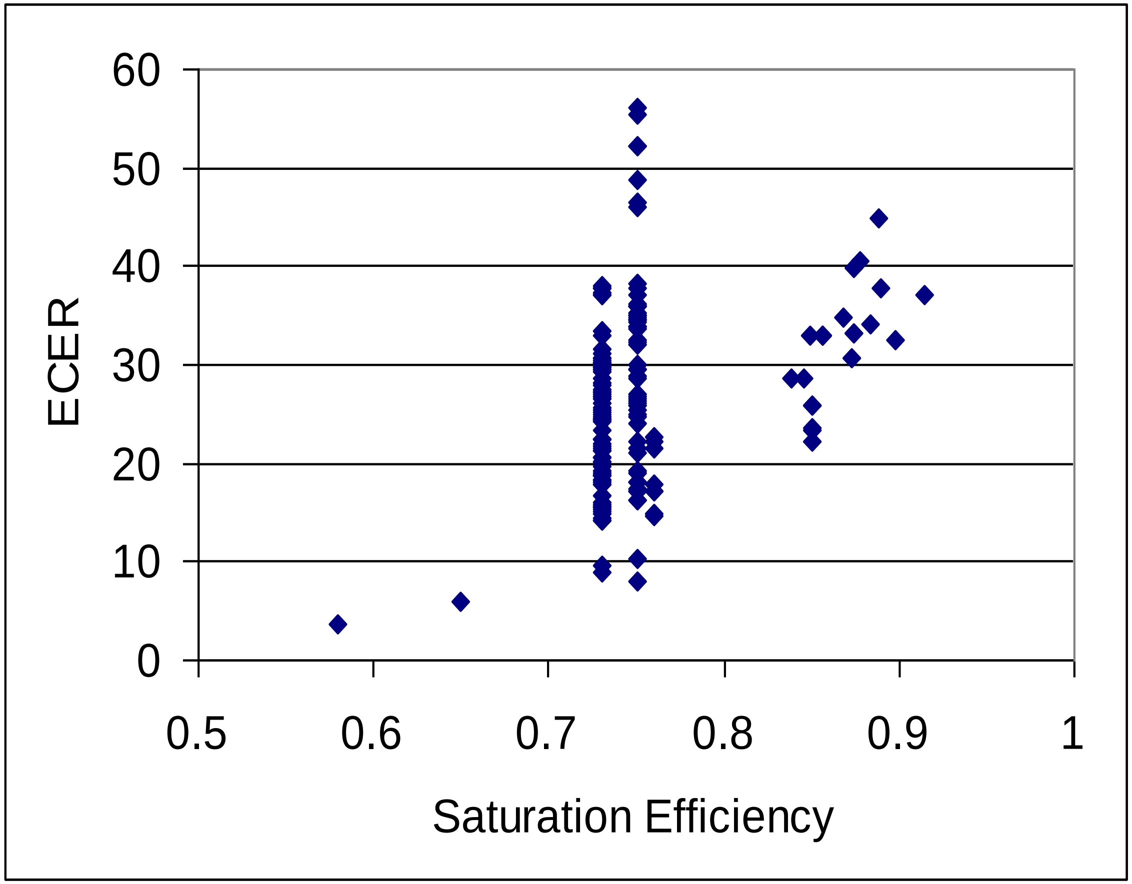
Issues for Discussion

- High Saturation Efficiency Evap Coolers
  - What comfort standards apply?
  - Under what climate conditions can they provide comfort?
  - What is their energy and peak load reduction potential?
  - How much water do they use?
  - Is their use to augment vapor compression cooling in extreme hot-dry climates warranted?
- Evaporative Condensers
  - How do they perform relative to conventional air conditioners?
  - How much water do they use?

EC Performance Ratings

- Test Standards
  - Direct & two stage: ANSI/ASHRAE 133-2001
  - Indirect: ANSI/ASHRAE 143-2001
- CEC Title 20 Evaporative Cooler Standards
  - Tested in accordance with ASHRAE standards
  - Conditions: 80°F indoor dry bulb (relief)
    91°F outdoor dry bulb
    69°F outdoor wet bulb
  - Ratings: Saturation effectiveness
    Total power
    Airflow rate
    Evaporative cooler efficiency ratio (ECER)

Current CEC Product Listings



ECER = 1.08 * (Tin – (Tdb – ε * (Tdb – Twb)) * Q / W

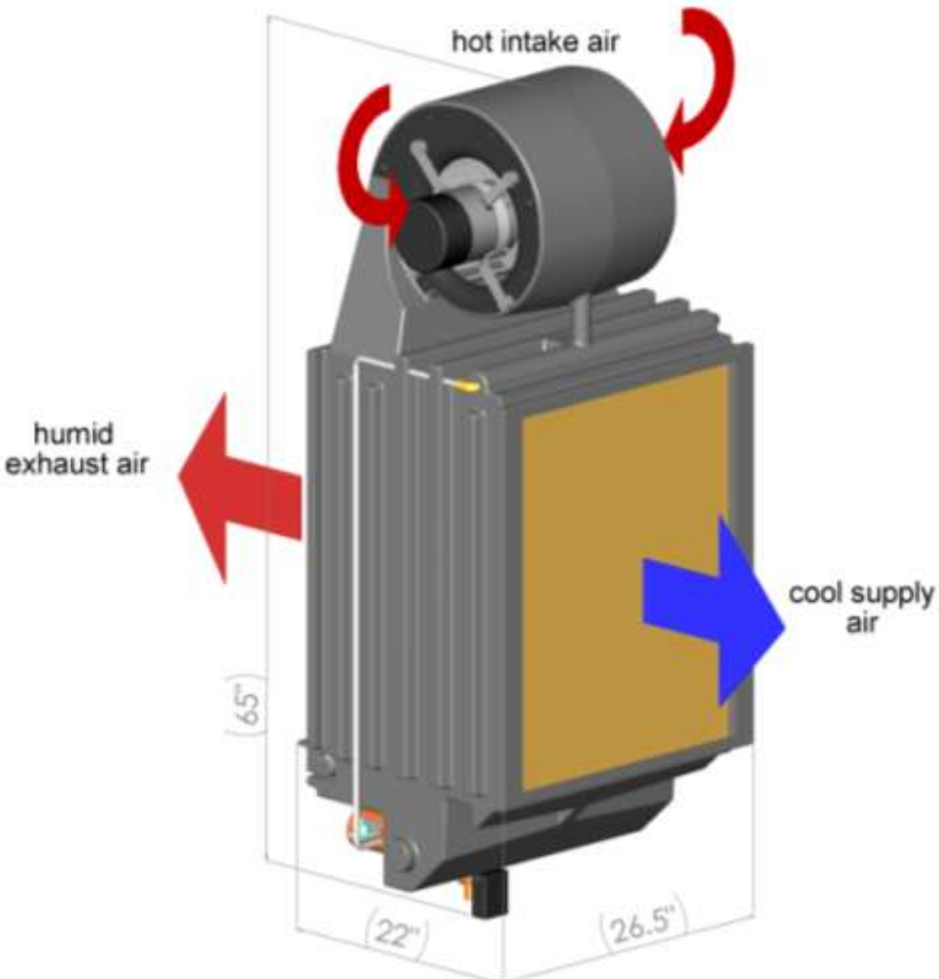
ASHRAE Standard 55-2004

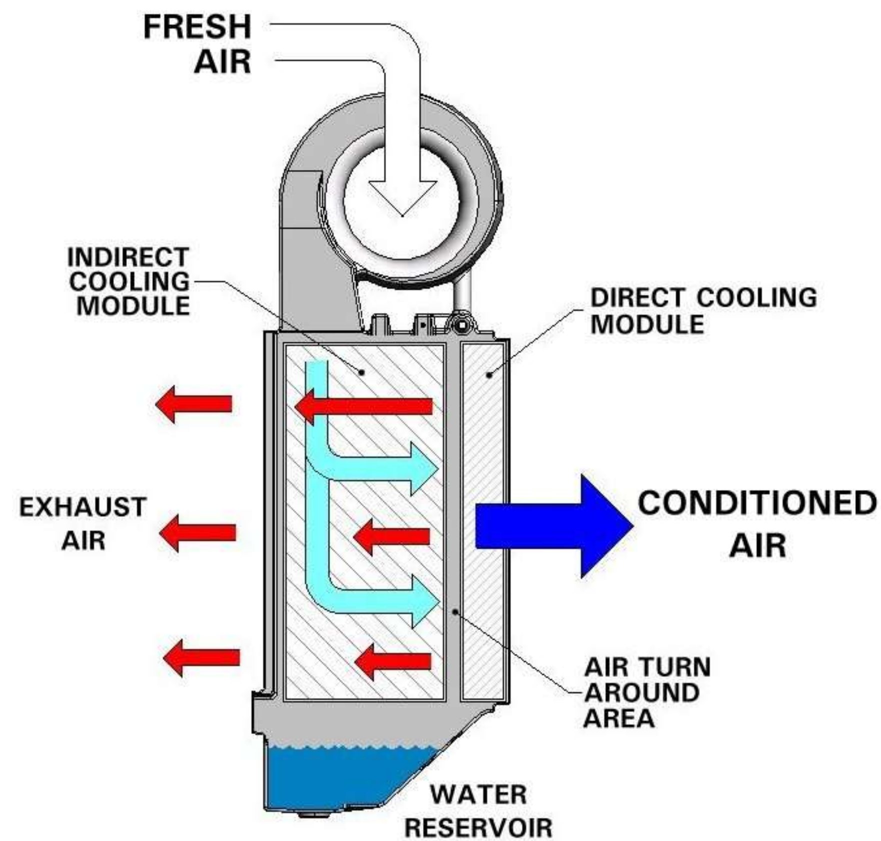
- Which method applies to EC's?
  - Section 5.2
    - Graphical method using "comfort zone"
    - Accounts for operative dry bulb temperature and relative humidity
  - Section 5.3
    - Optional method for naturally conditioned spaces
    - Assumes occupant use of windows to maintain comfort
    - No "mechanical cooling system (e.g. refrigerated air conditioning, radiant cooling, or desiccant cooling)"

Prototype Evaporative Cooler

- Saturation efficiency > 1
- Single variable speed blower
- Double pass plastic indirect heat exchanger
- Rigid cellulose evaporative media
- Airflow varies with thermostat temperature offset
- Controls regulate purge cycles as a function of cycles of concentration

Prototype Evaporative Cooler





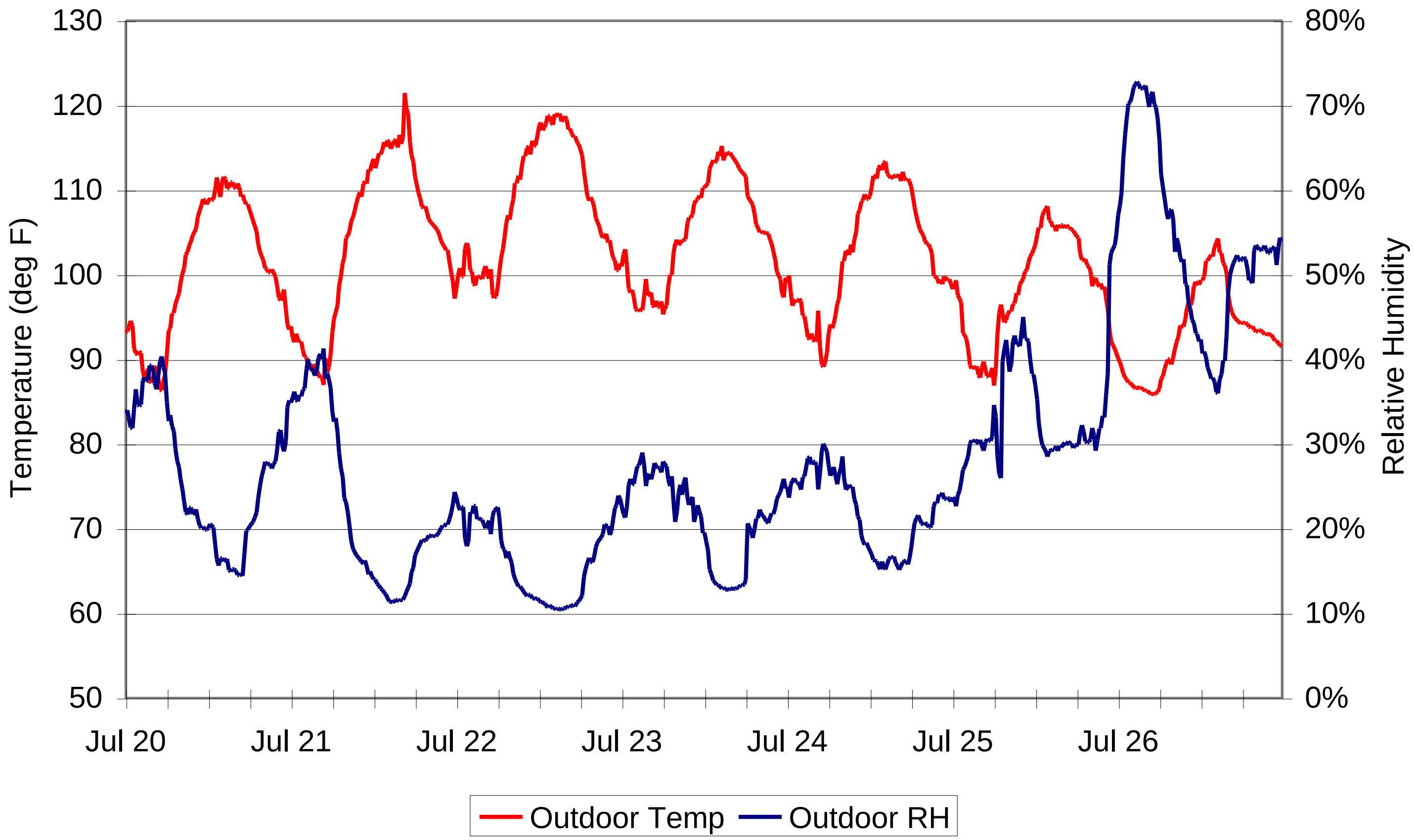
Borrego Springs Field Test

- Two 2000 ft^2 houses (“Arrow” & “Wagon”)
- Identical floor plans
- Different wall systems
  - Arrow: structural insulated panels (SIP)
  - Wagon: concrete-foam-concrete sandwich panel

Location


15
San Bernardino
10
Redlands
Riverside
Corona
Perris
Lake Elsinore
Hemet
Murrieta
Temecula
Fallbrook
5
Vista
San Marcos
Escondido
Ramona
Encinitas
Poway
Del Mar
Santee
163
Alpine
La Mesa
El Cajon
San Diego
Chula Vista
Yucca Valley
Twentynine Palms
Desert Hot Springs
Joshua Tree National Park
Palm Springs
Thousand Palms
Indio
Palm Desert
La Quinta
Mecca
10
86
Niland
Salton Sea
Anza-Borrego Desert State Park
78
Calipatria
Brawley
Imperial
Holtville
Pine Valley
8
El Centro
8
Calexico

Climate

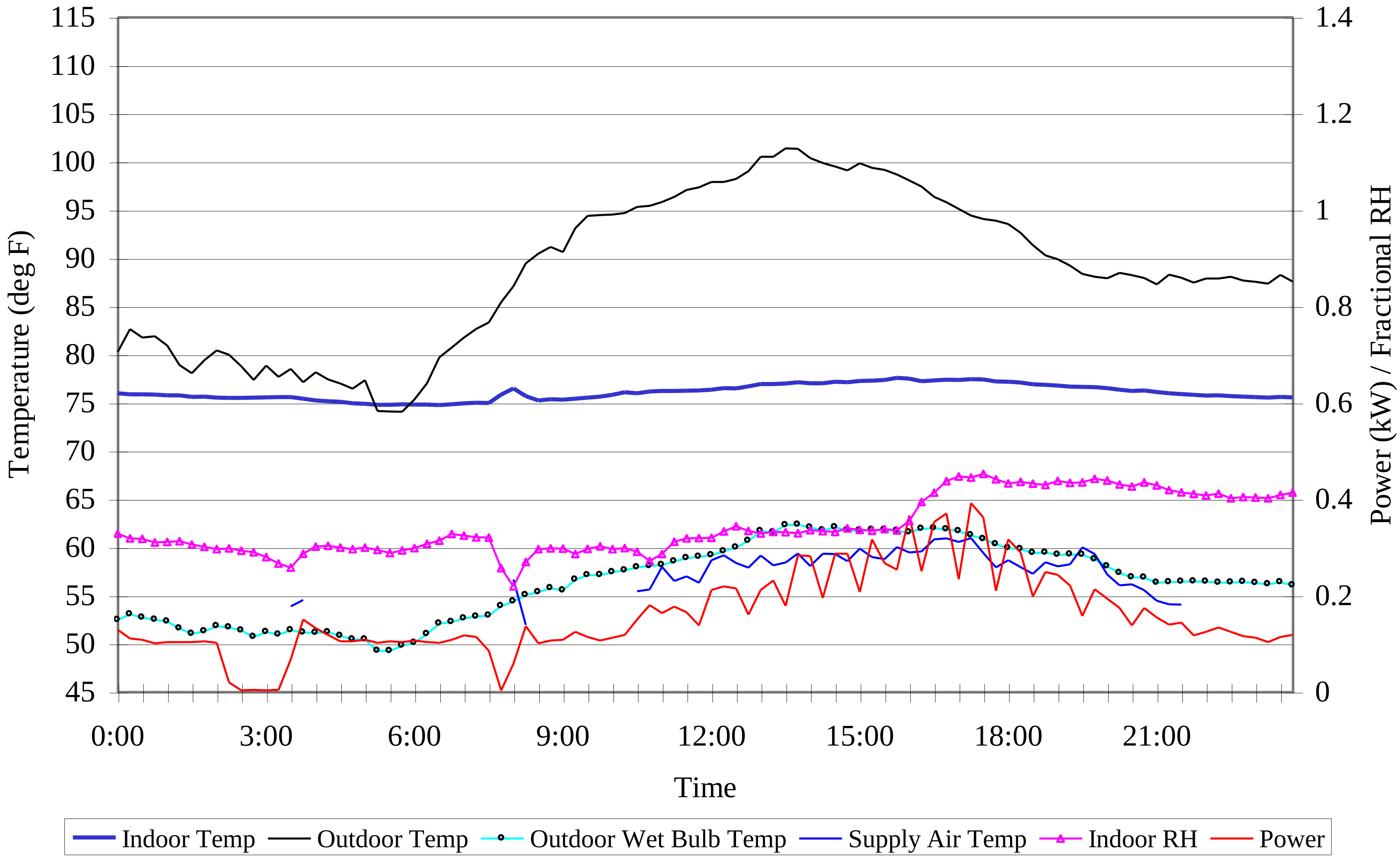


	July	December
Normal High	109°F	70°F
Normal Low	77°F	38°F
2006 Range of Highs	105-121°F	60-81°F
2006 Range of Lows	75-97°F	23-46°F

Mechanical Equipment

- ‘Wagon’
  - Minimal ducting
  - Forced air/radiant backup cooling
- ‘Arrow’
  - Full ducting shared with forced/air heating cooling
  - Motorized dampers to prevent back-drafting

“Mild” Day



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Temperature (deg F)
Power (kW) / Fractional RH
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3:00
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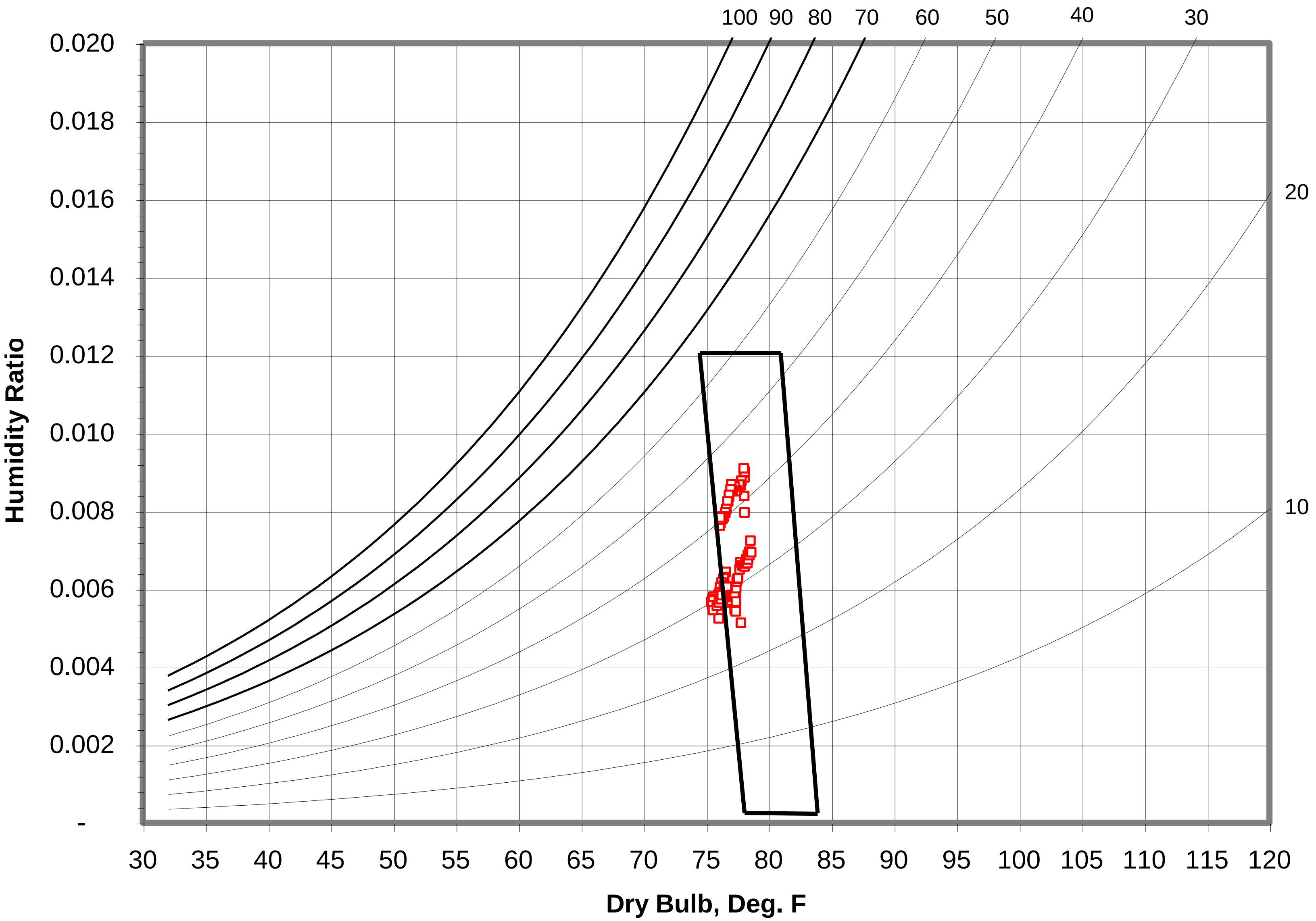
Time
Indoor Temp
Outdoor Temp
Outdoor Wet Bulb Temp
Supply Air Temp
Indoor RH
Power

“Mild” Day



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Humidity Ratio
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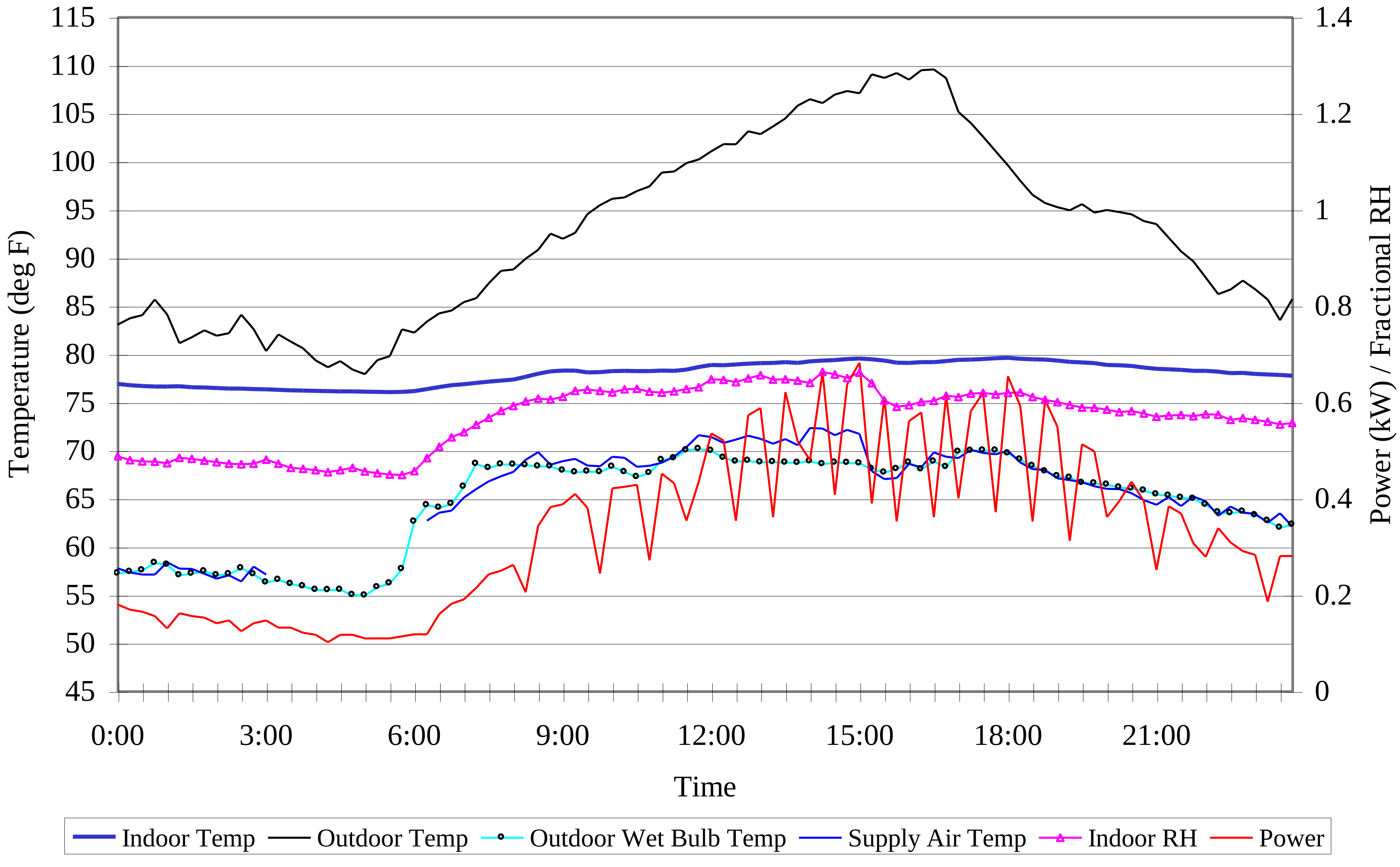
Dry Bulb, Deg. F

“Warm” Day



Temperature (deg F)
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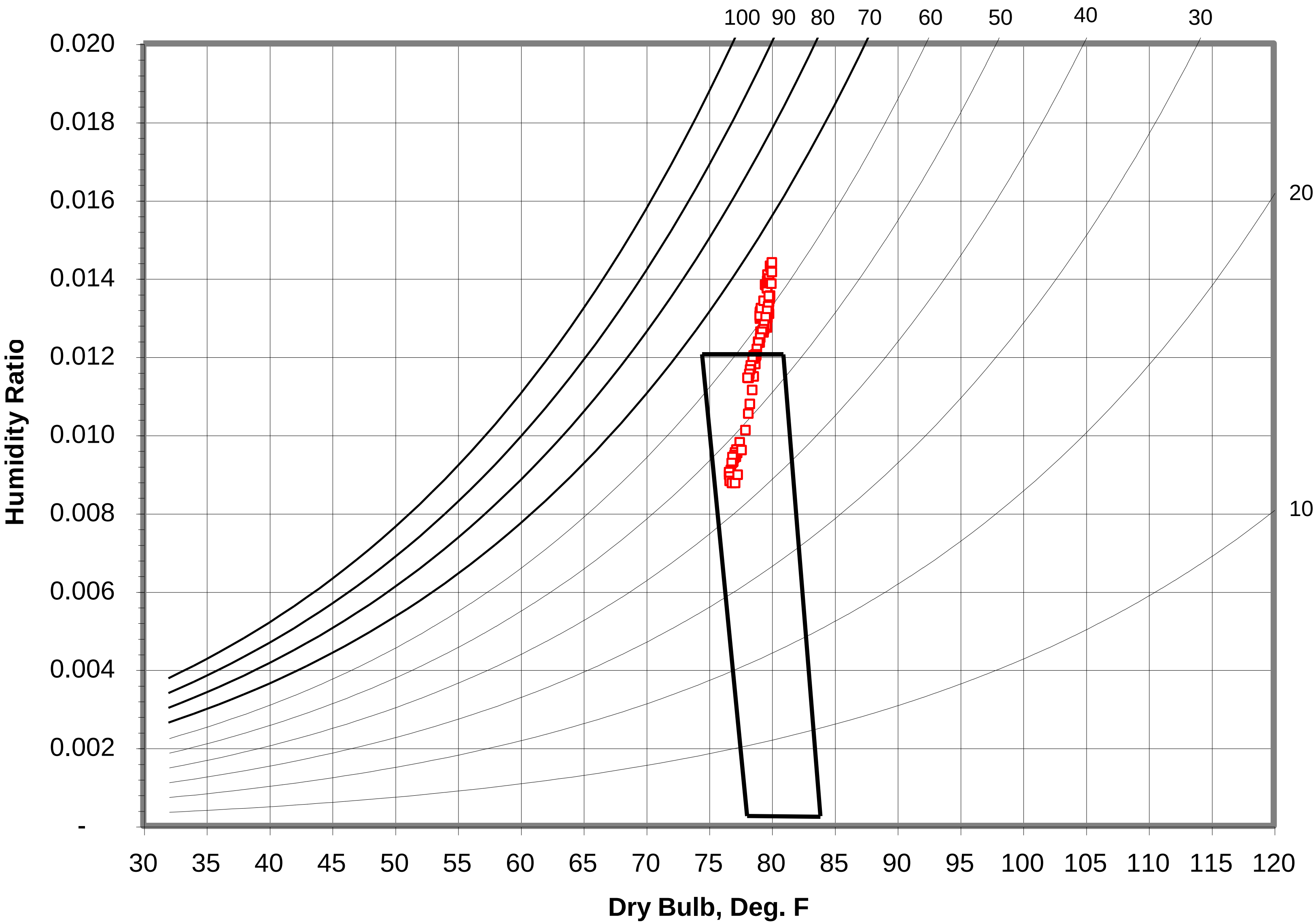

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Humidity Ratio
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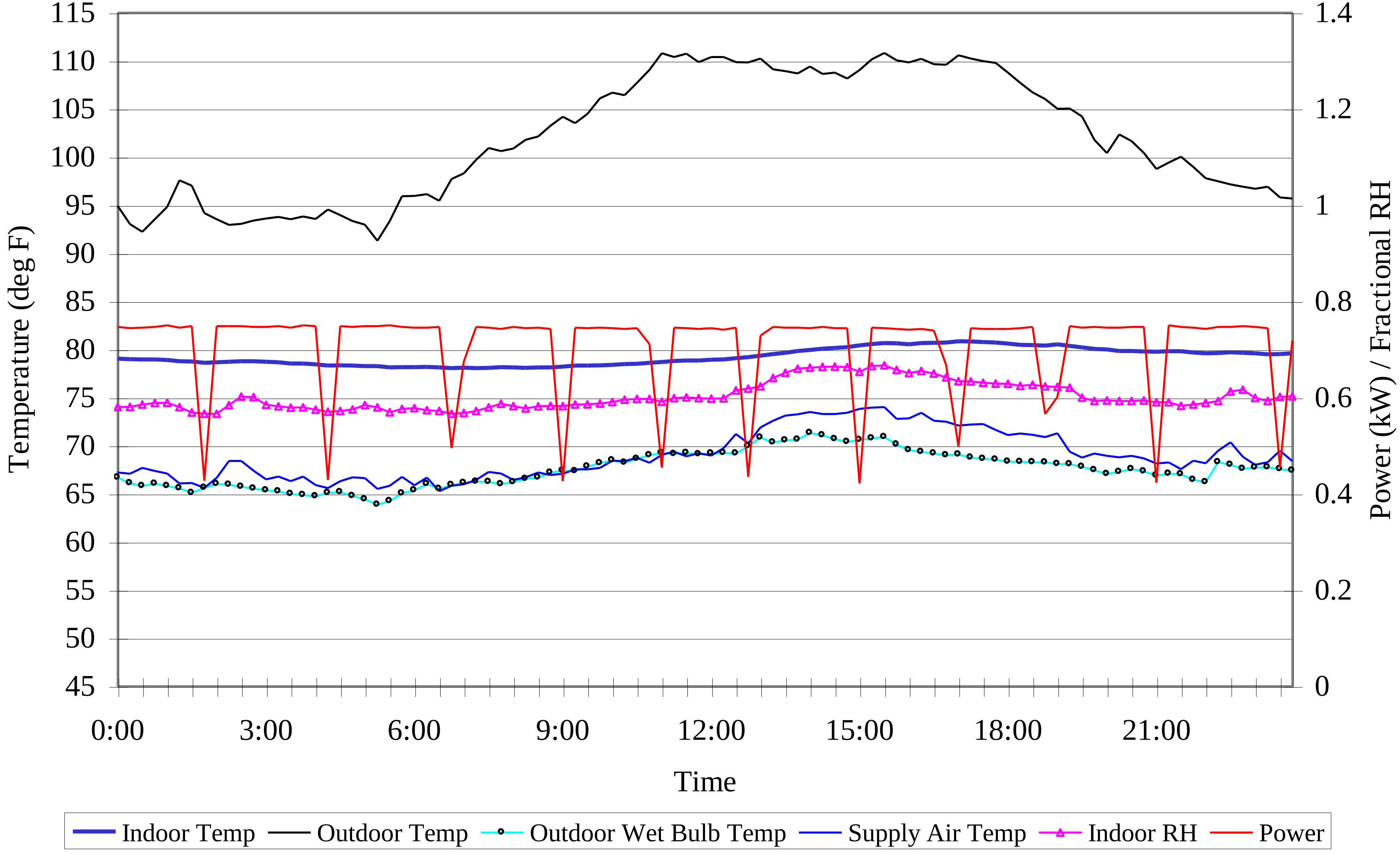
Dry Bulb, Deg. F

“Hot” Day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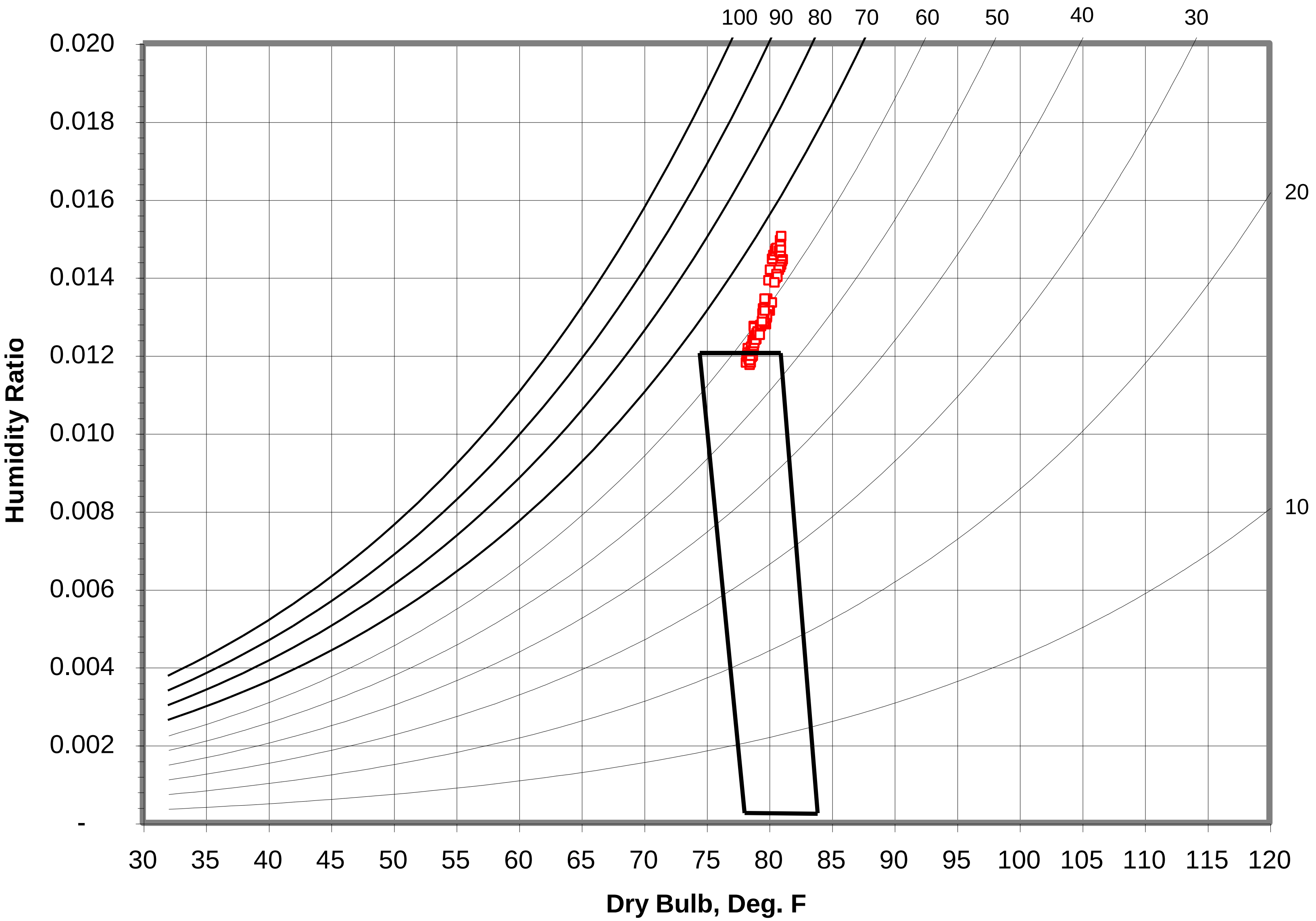
“Hot” Day



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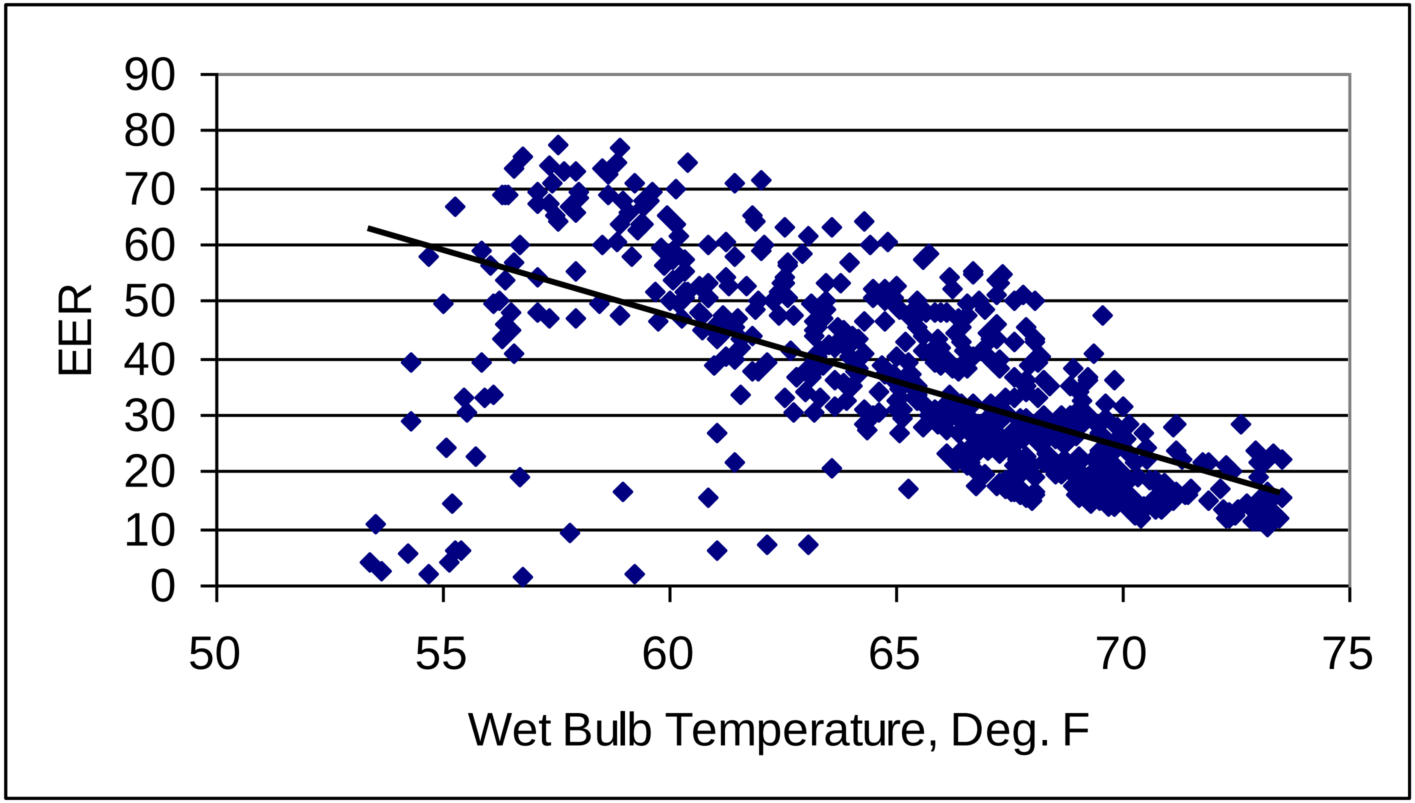
Dry Bulb, Deg. F

Energy & Water Use

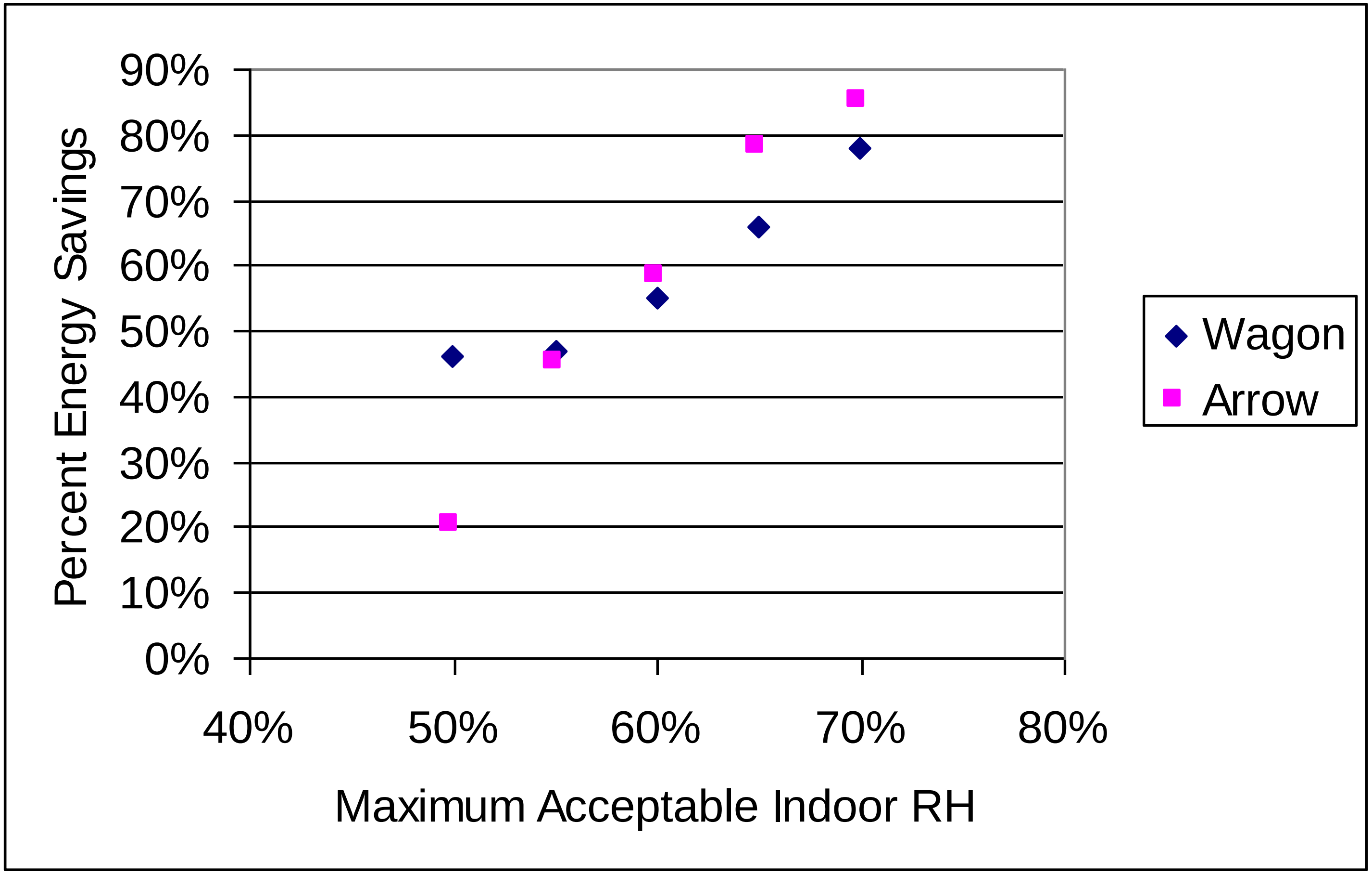
May 23 - July 3, 2007

Outdoor Conditions		
Max Outdoor Temp	113.8	ºF
Avg Outdoor Temp	88.2	ºF
Avg Outdoor Wet Bulb	59.1	ºF
Indoor Conditions		
Max Indoor Temp	79.6	ºF
Avg Indoor Temp	76.5	ºF
Max Indoor RH	66	%
Avg Indoor RH	45	%
Energy & Water		
kWh Saved	17.02	per day
% kWh Savings	79	%
Water Use	97.4	gal per day
Cooling Delivered	160.1	kBtu/day
Water Use/kBtu	0.61	gal/kBtu

Evaporative Cooler EER



Energy Savings vs. Indoor RH



Evap Cooler vs. AC Energy Demand

15 minute peak loads, Summer 2006

	AC	Evap
Wagon	3834 W	645 W
Arrow	4278 W	816 W

Evaporative Cooling Economics

- Assumptions
  - Neutral cash flow (incremental mortgage payments = energy savings)
  - 6.5%, 30 year mortgage
  - $0.14/kWh
- Results
  - At a maximum indoor RH of 60%, energy savings range from 55-58% and justify an incremental cost ranging from $4443 to $9282
  - Cash flow is more favorable when cooling load is higher

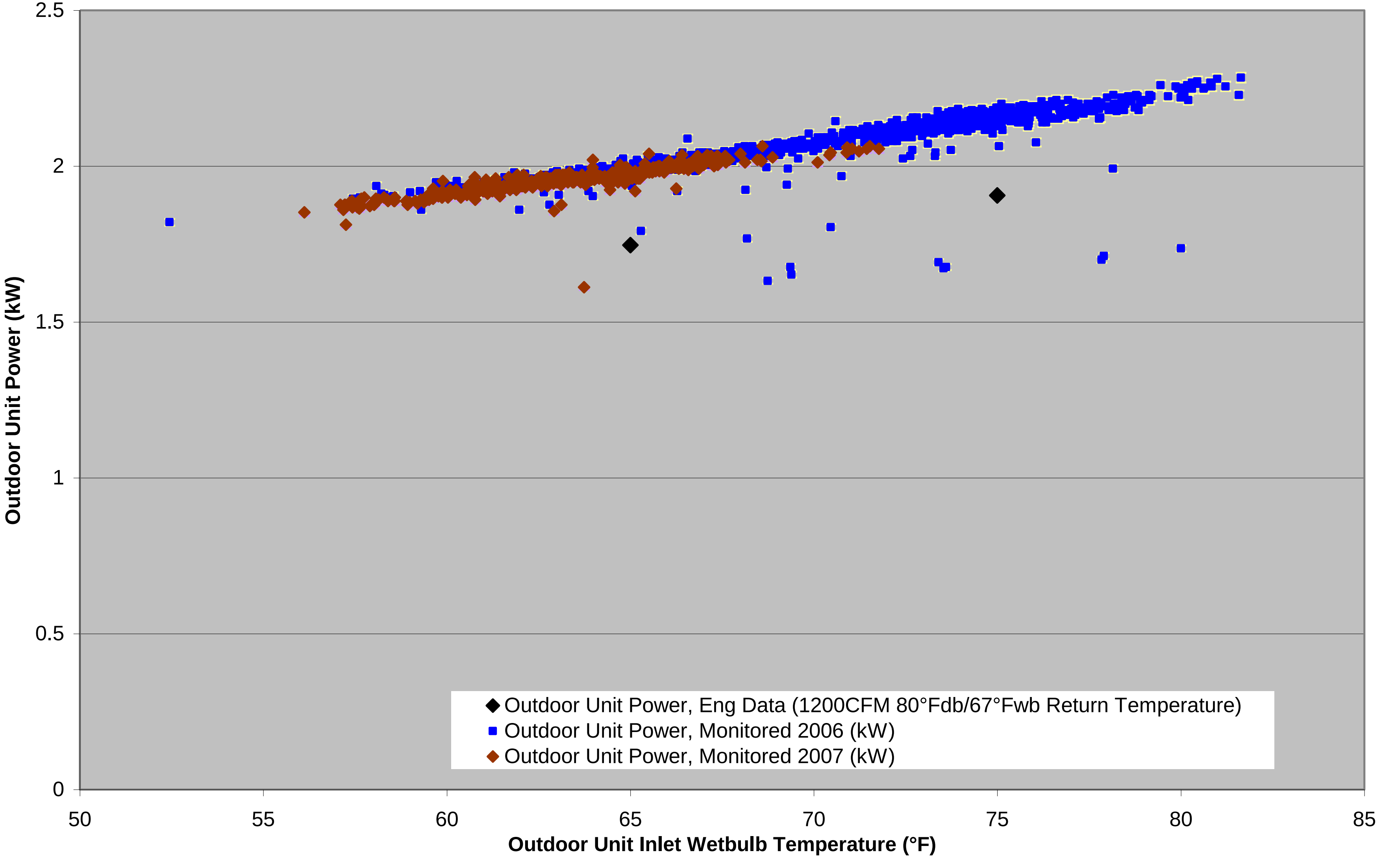
Evap Cooler Conclusions

- Evaporative cooling comfort criteria are subjective
- When used with air conditioning, energy savings can range from 40-60% while maintaining conditions that meet ASHRAE 55
- Peak load can be reduced by as much as 80%
- Houses in climates with extreme highs exceeding 105°F and coincident wet bulb temperatures exceeding 70°F should probably use vapor compression cooling
- High saturation efficiency evaporative coolers can be justified in hot climate homes equipped with conventional air conditioning

Freus Evap Condenser Performance

- 3 ton nominal outdoor unit capacity
- Nightbreeze air handler w/ Amana 5 ton indoor coil
- Evap sump water used for "floor cooling mode"
- Following results for AC mode only

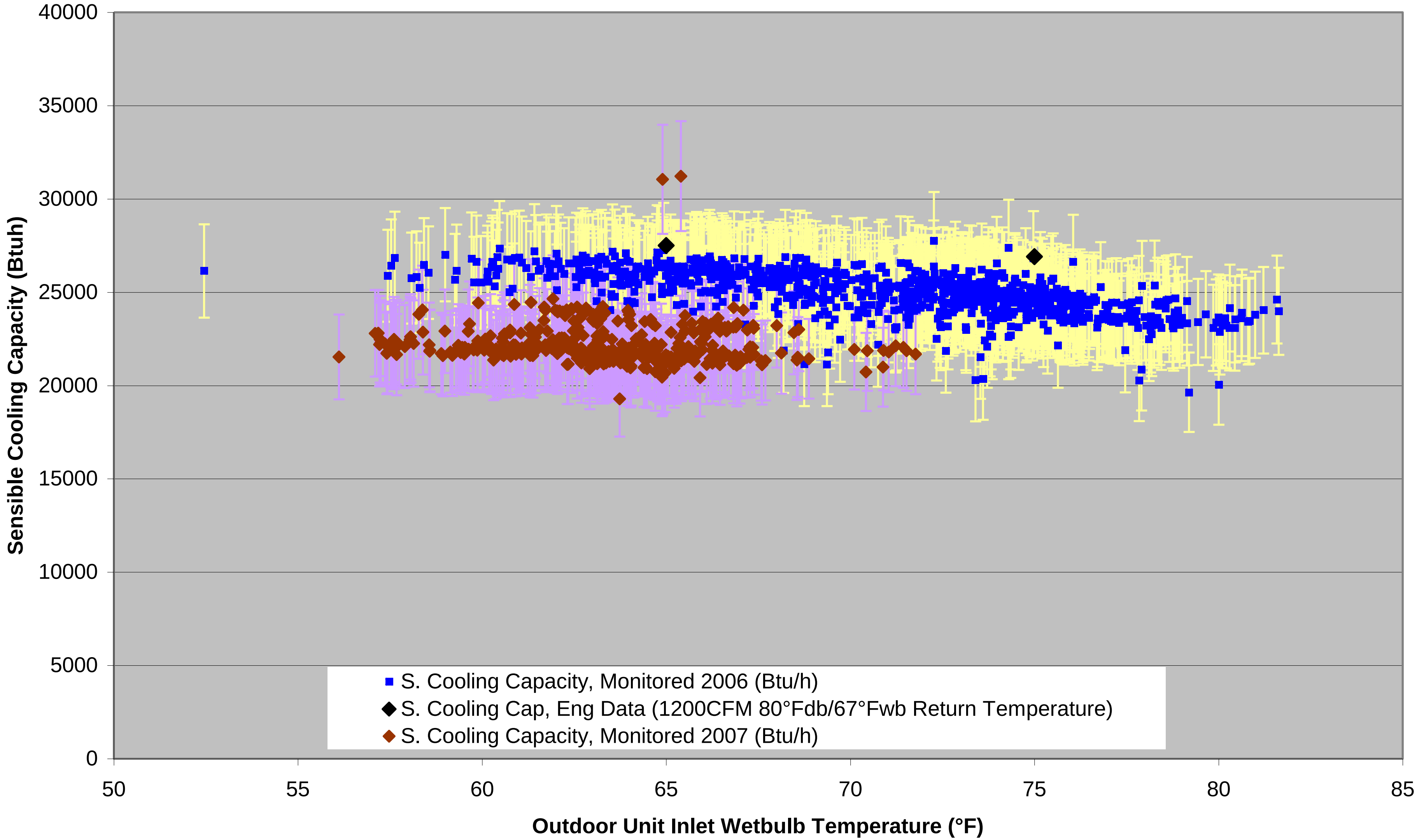
Comparison to Mfg. Power Data



Outdoor Unit Power Comparison

- Why is the outdoor unit power as measured in the field higher than Manufacturer’s data?
  - Non-standard condenser fan (276W, ~1500CFM) was installed. Standard condenser fan is ~100w, 1000CFM
  - Water pump power was found to be higher than expected (~90W vs 60W expected)
  - Manufacturer suspects that scale from condenser coils may have damaged the water pump, water pump inlet screen was improperly placed underneath coils allowing scale to fall into the water pump suction port

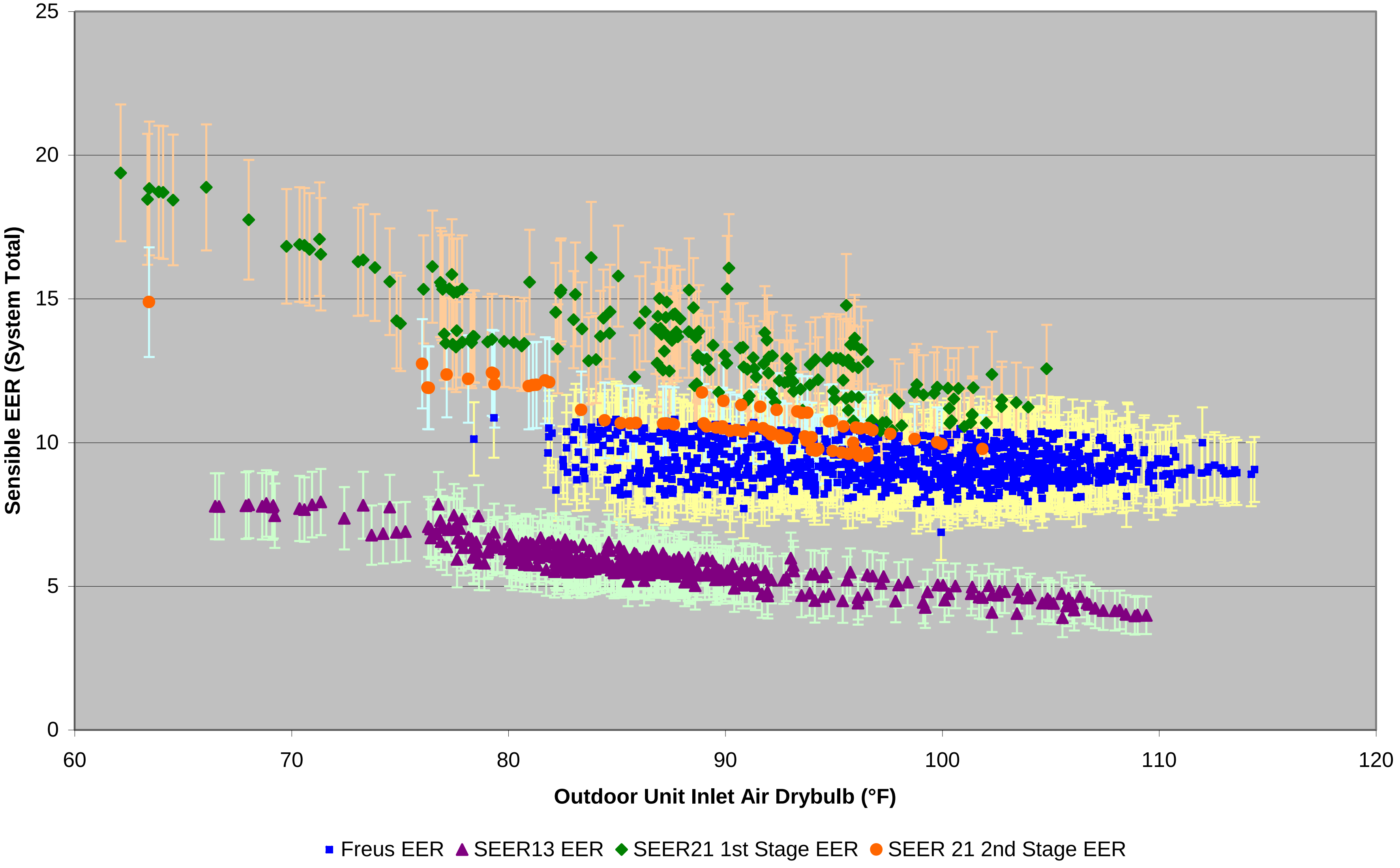
Comparison to Mfg. Capacity Data



Sensible Cooling Capacity Comparison

- Why is the sensible cooling capacity as measured in the field higher than Manufacturer's data?
  - Indoor fan power higher than expected, high external static pressure
  - 2006 data compares to Manufacturer's data within measurement uncertainty
  - 2007 data shows sensible capacity degradation, manufacturer suspects that evap media is not properly wetted due to scale from water pump inhibiting water distribution

Measured Sensible EER Comparison



Freus Performance Comparison to other Borrego Air Conditioners

- Freus sensible EER is relatively flat with outdoor drybulb temperature
- Freus sensible EER approaches SEER 21 performance at high drybulb temperatures
- Freus outperforms the SEER 13 air conditioner
- Caveats (2006 data)
  - Freus indoor fan has a higher power draw (~560W, ~400CFM/ton) than the SEER 21 unit (2 ton mode - ~125W, 3 ton mode ~360W, ~400CFM/ton) due to duct system & extra heating coil
  - Freus had higher condenser fan power and water pump power than expected
  - After reviewing field data and making a site visit Manufacturer is replacing the outdoor unit, new unit will have standard condenser fan and properly located pump inlet screen, swap to be completed 7/10/07. Monitoring will continue through summer ‘07