Implications of GHP Fan Control Strategies on Humidity Control in Commercial Applications

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Fan Control Affects Latent Performance

- How is ventilation air supplied?
  - Provided directly to heat pump inlet
  - Provided directly to space

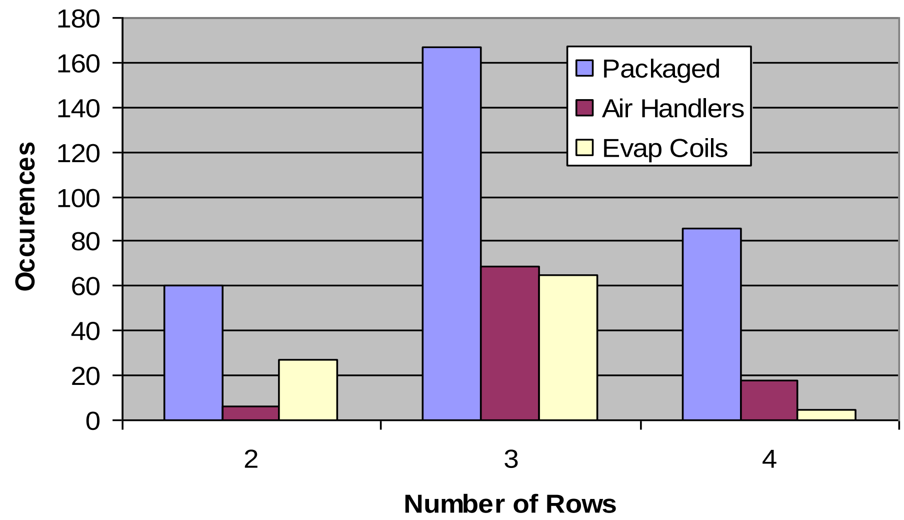
- If supply fan operates continuously, then latent capacity degrades at part load

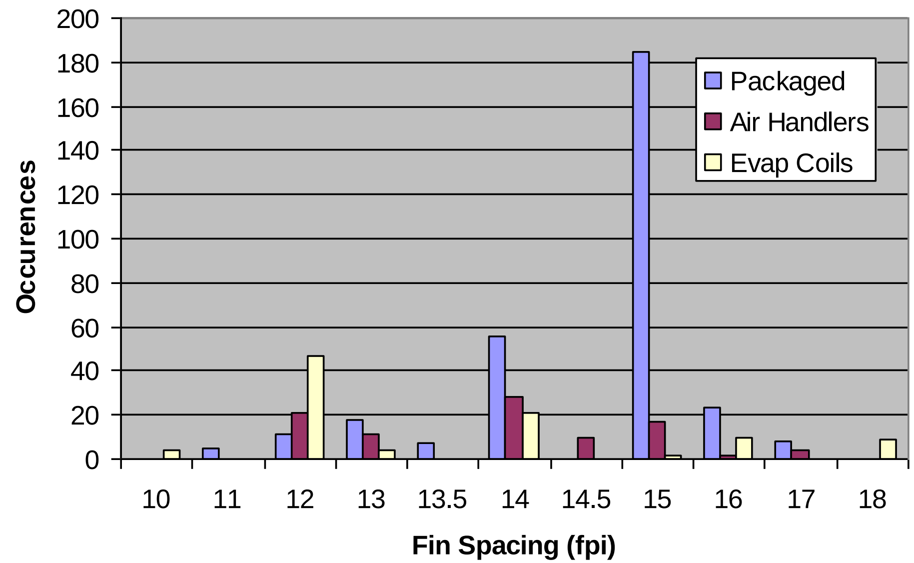
Steady-State Cooling Coil Performance

- AC coil performance is well understood at steady-state conditions
- GHP is similar to conventional AC
  - Coils provide both sensible cooling and moisture removal (latent cooling)
  - SHR: *sensible heat ratio*…..fraction of total cooling that is sensible
  - Colder coil surfaces remove more moisture
  - Reduced air flow provides more moisture removal (for DX coils)
  - Higher condenser temperatures increase SHR
    - i.e., high ground loop temperatures

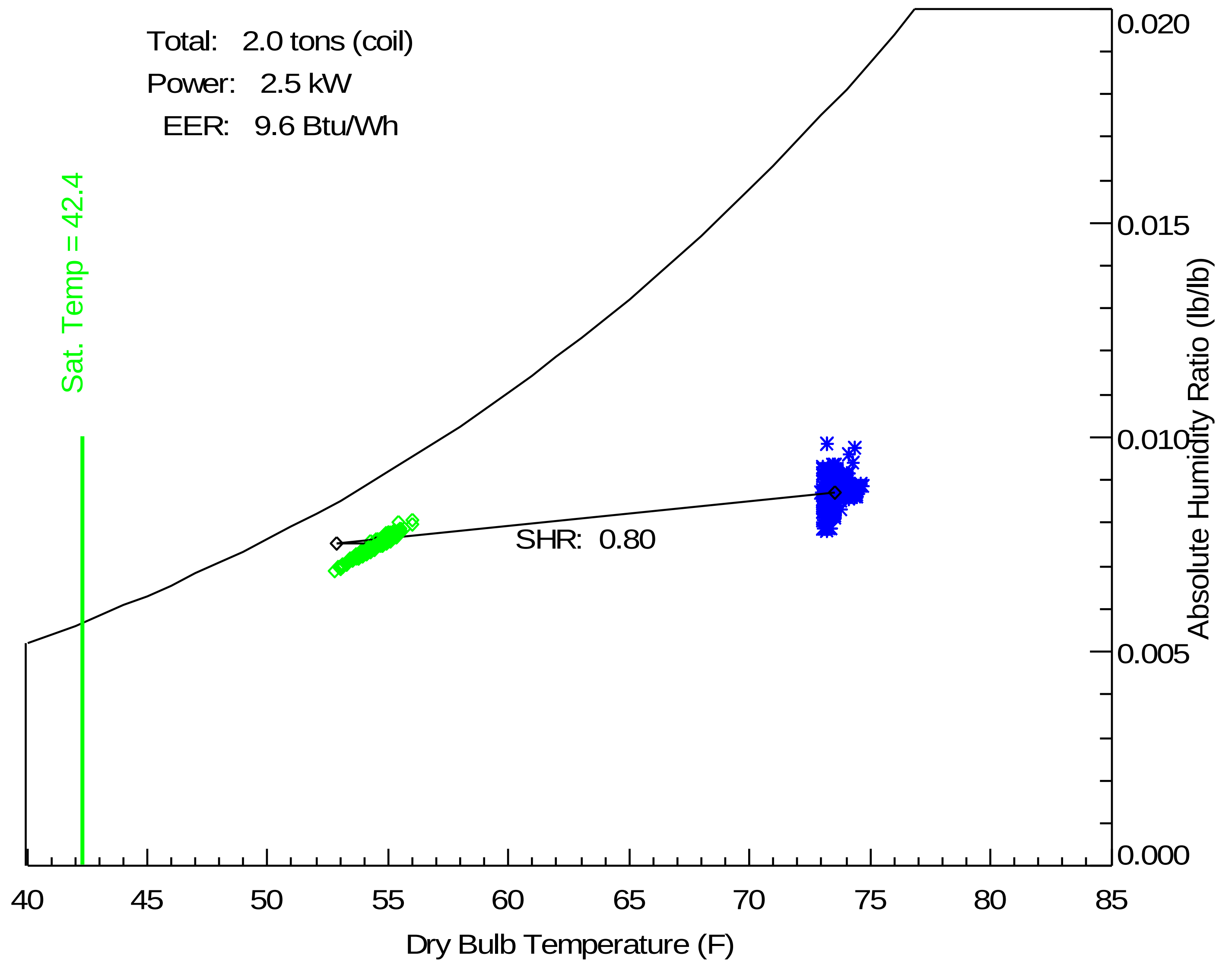
Equipment Survey

- Reviewed specifications for 500 commercial and residential AC units
- <u>Goal</u> was to determine
  - range of common coil geometries
  - Variation by equipment type
- <u>Typical DX AC coil is 3-rows, 1 fpi</u>





Typical AC Coil Performance



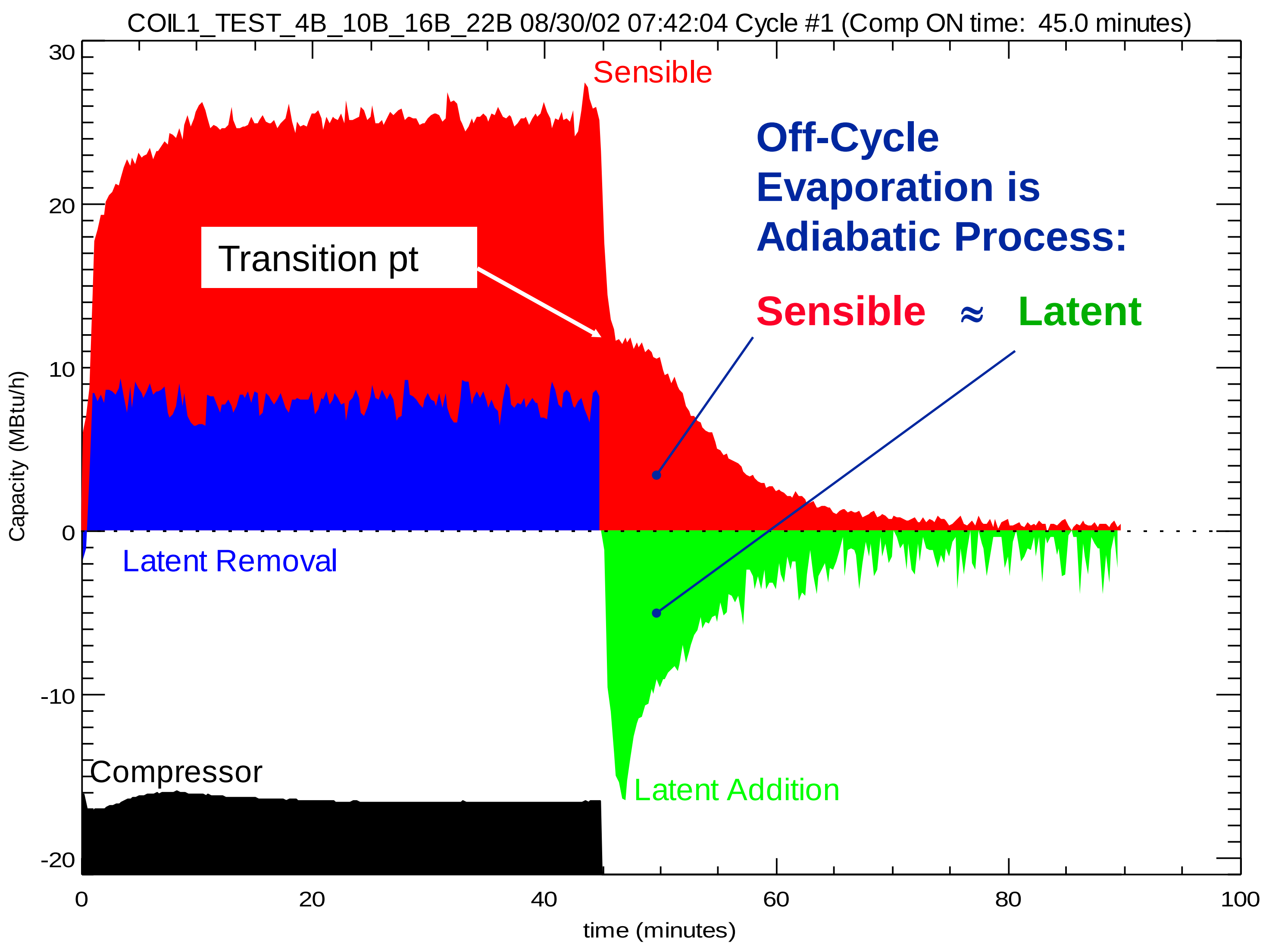
Part Load Performance

- GHP cycles compressor ON and OFF based on a space thermostat
- The portion of time the coil operates (i.e., the runtime fraction) is longer when cooling loads are greater

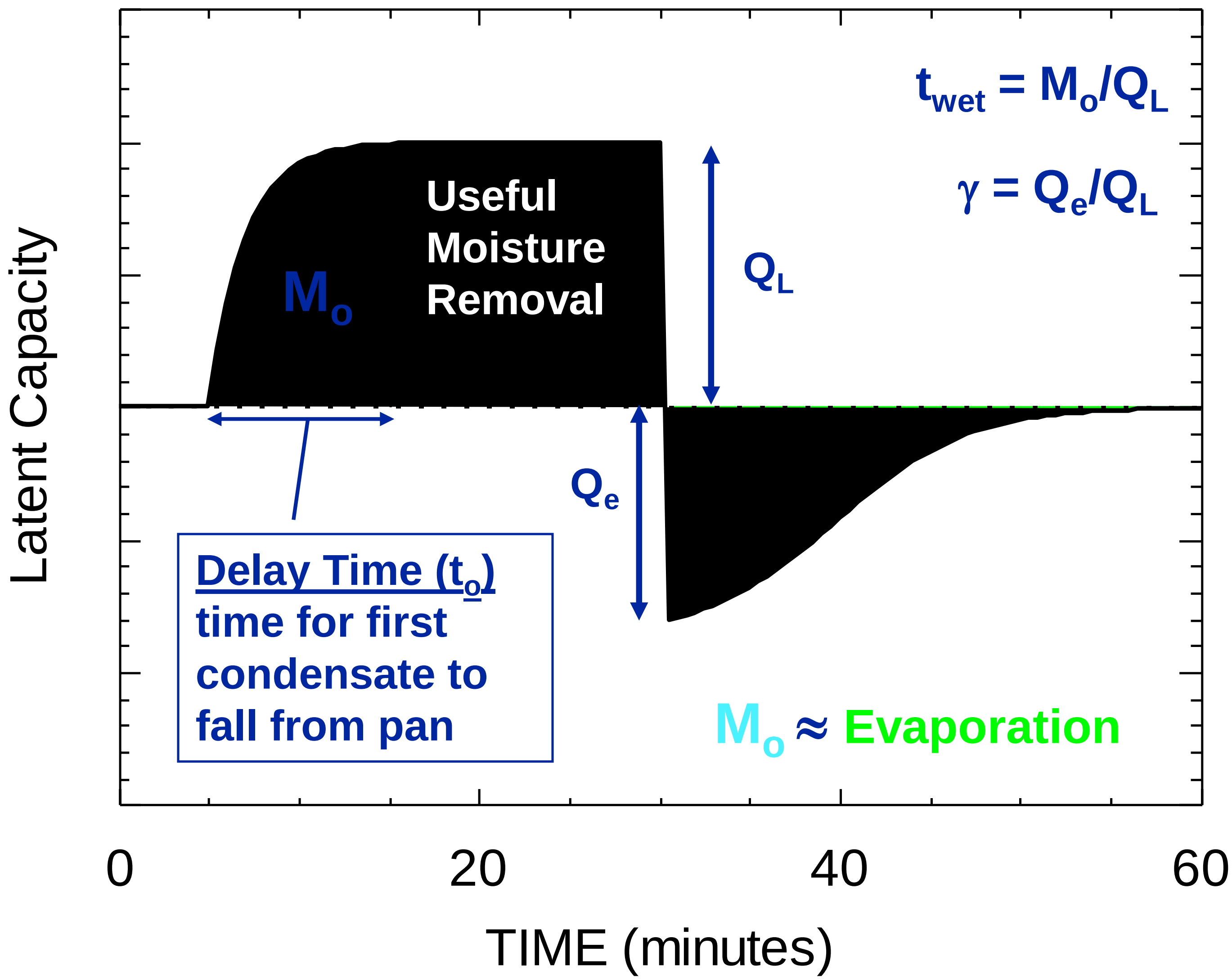
$$RTF = \frac{ON}{(ON + OFF)}$$

- How do sensible and latent capacity vary under cyclic conditions?

Sensible and Latent Capacity With Continuous Supply Air Fan Operation



Latent Degradation Concepts

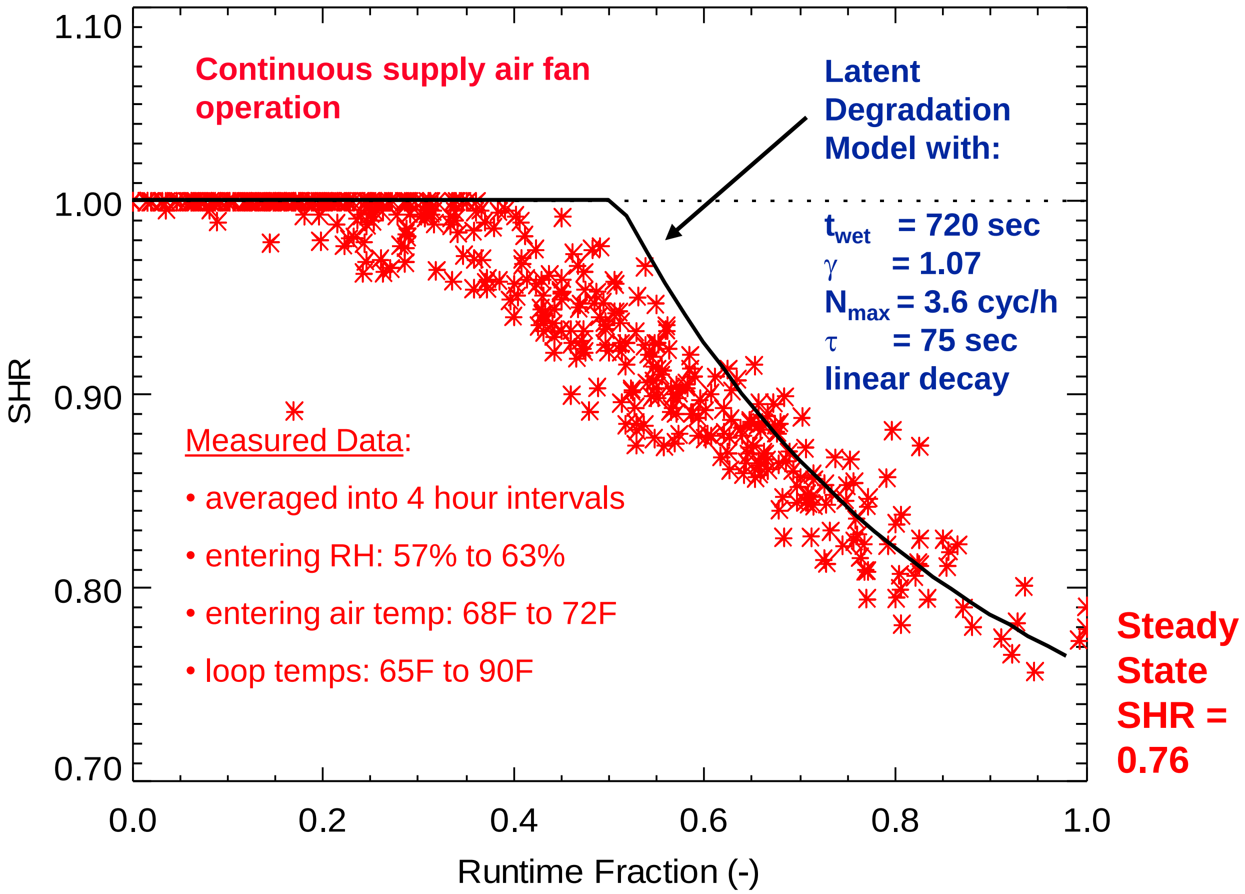


LHR Degradation Model

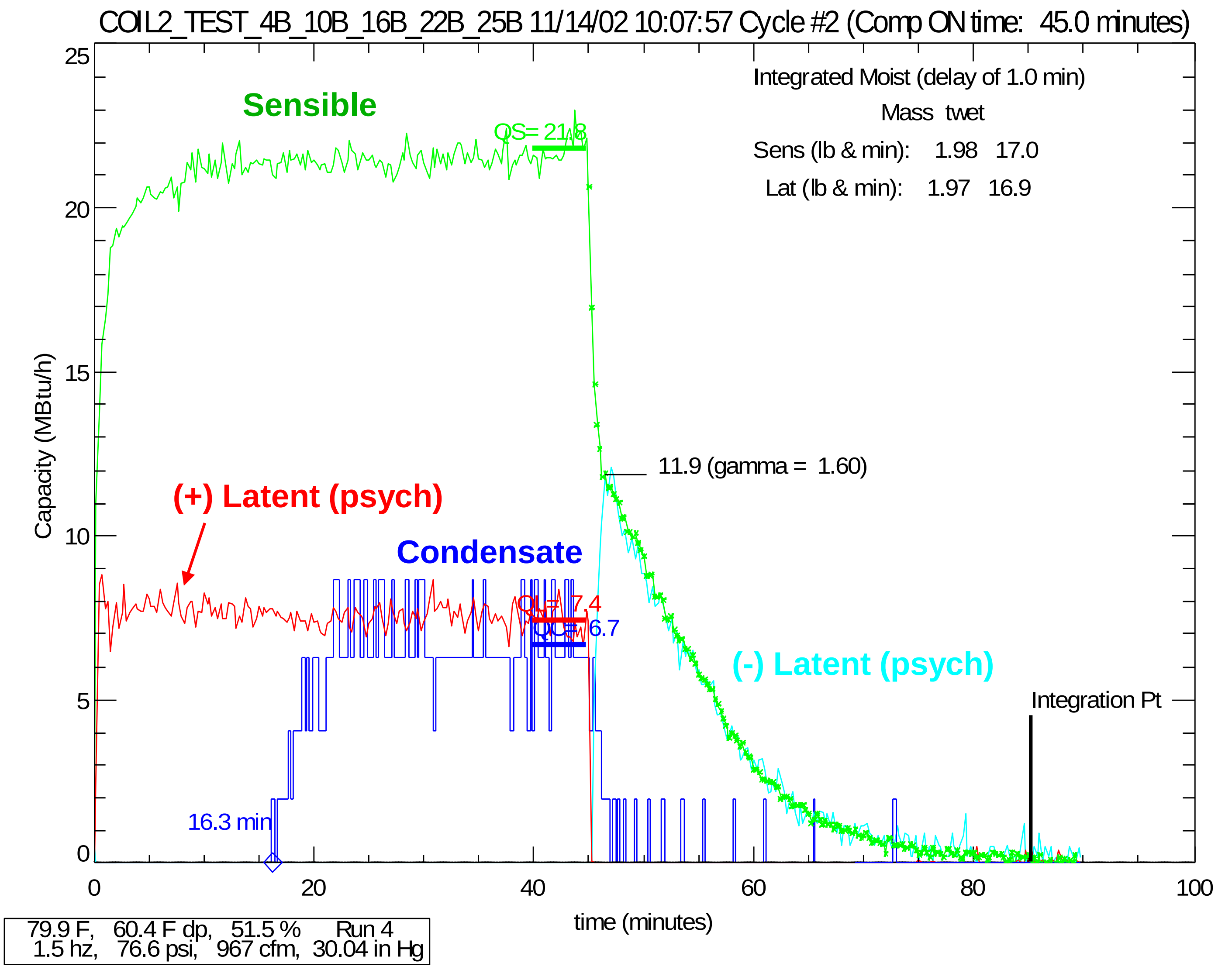
- Borrowed approaches used to develop part-load efficiency degradation function for SEER test procedure
- Used same part-load assumptions (C_d):
  - AC at startup described by a time constant
  - Cycling rate driven by thermostat curve
- Additional latent assumptions:
  - Coil surfaces hold a fixed amount of moisture (M_o)
  - Off-cycle coil is like an evaporative cooler

Comparing LHR Model to Field Tests

- Henderson (1998) compared the model results to field data collected on a 3-ton residential geothermal heat pump



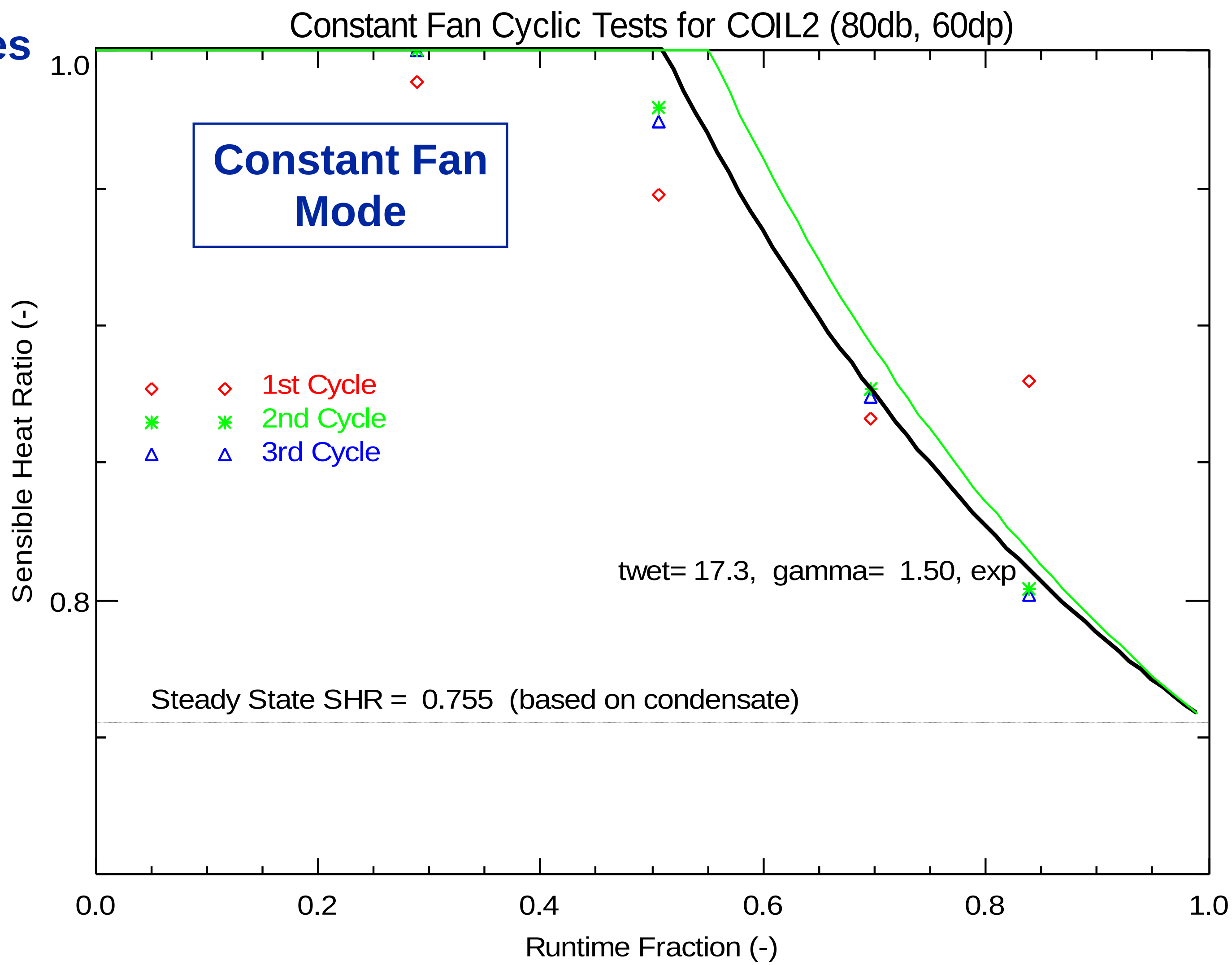
Actual Laboratory Results



Laboratory Testing – SHR Degradation

LHR Model matches measured data at nominal entering conditions

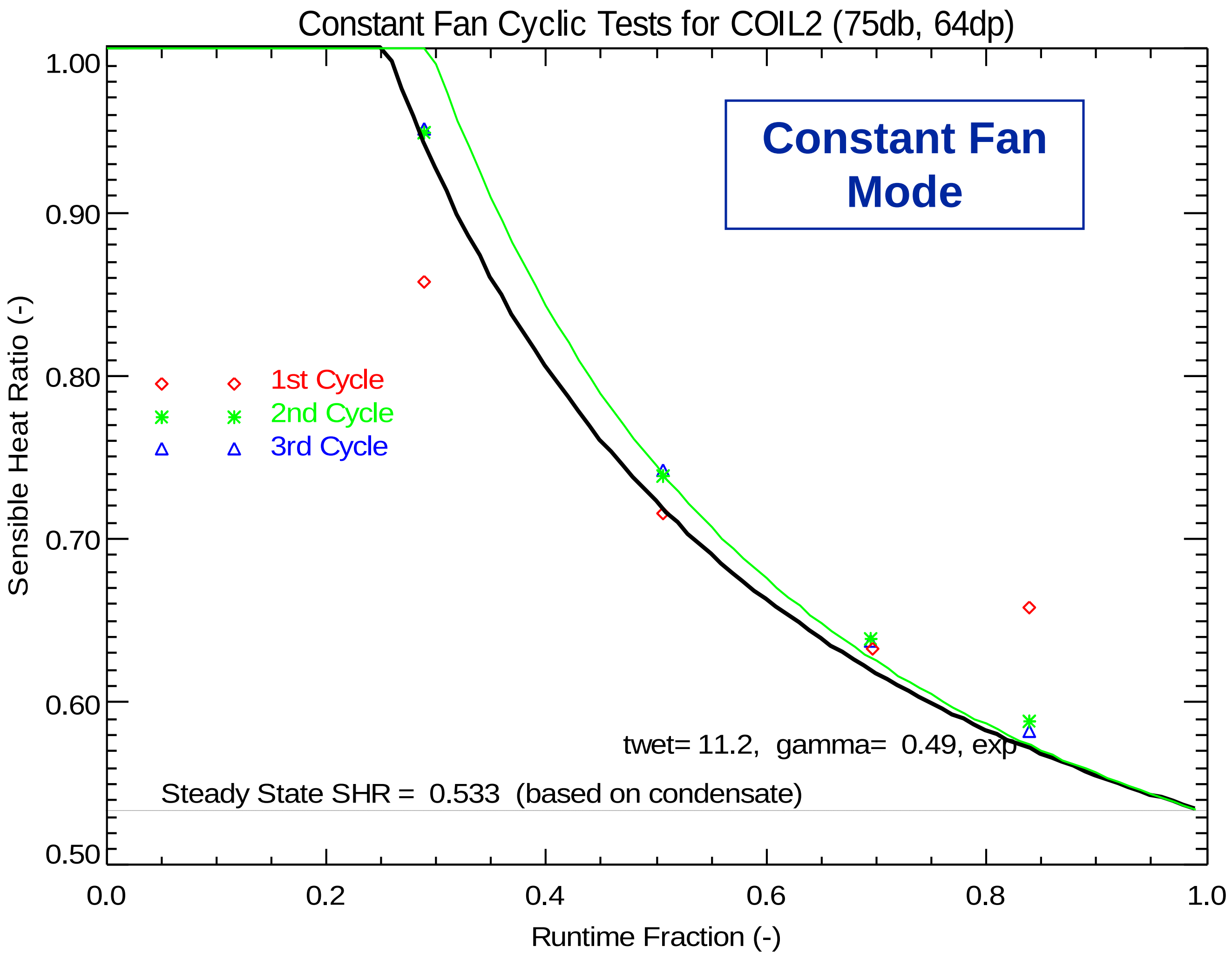
(80F db, 60.4F dp)



Laboratory Testing – SHR Degradation (cont.)

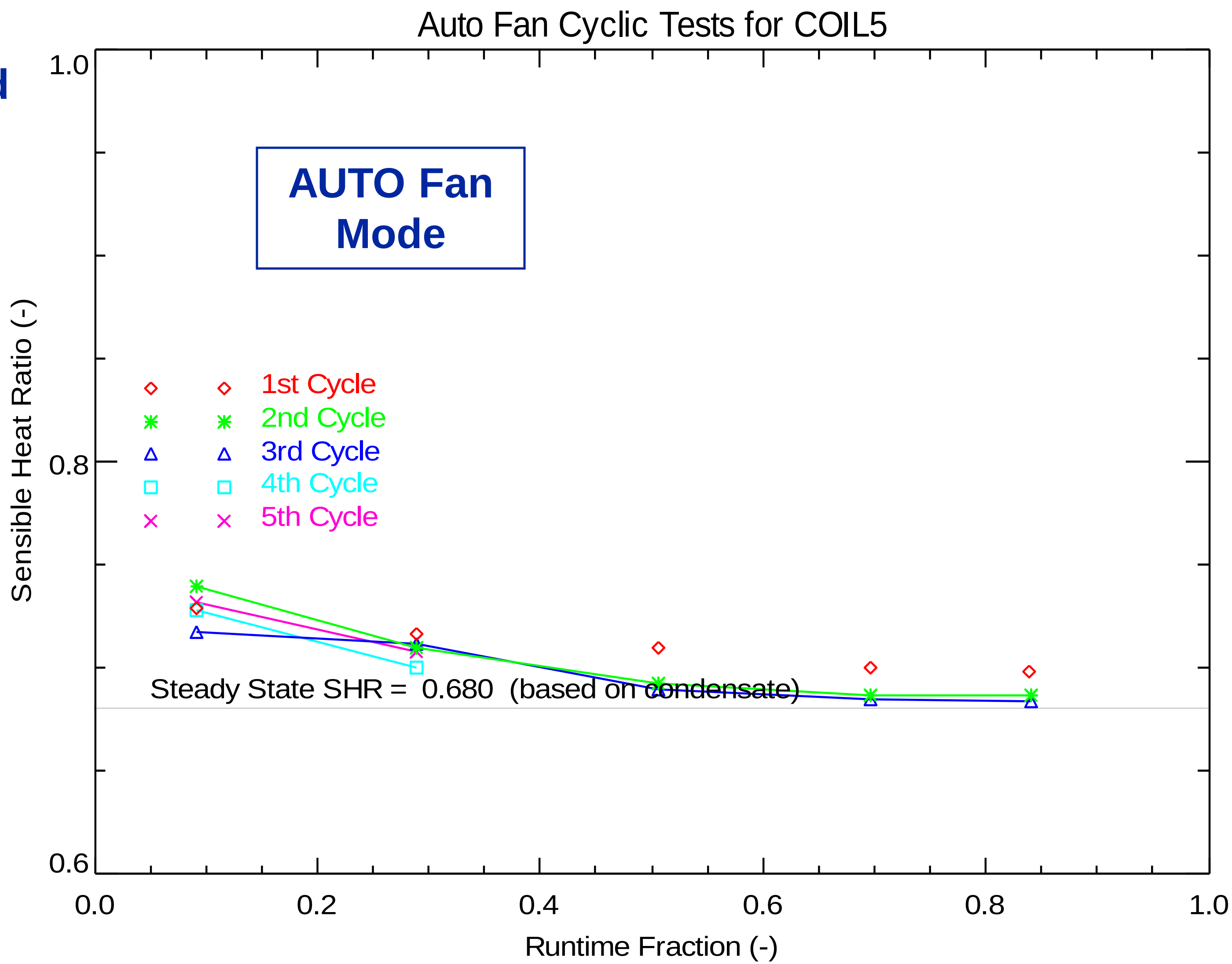
Model also matched measured data at other entering conditions!

(75F db, 64F dp)



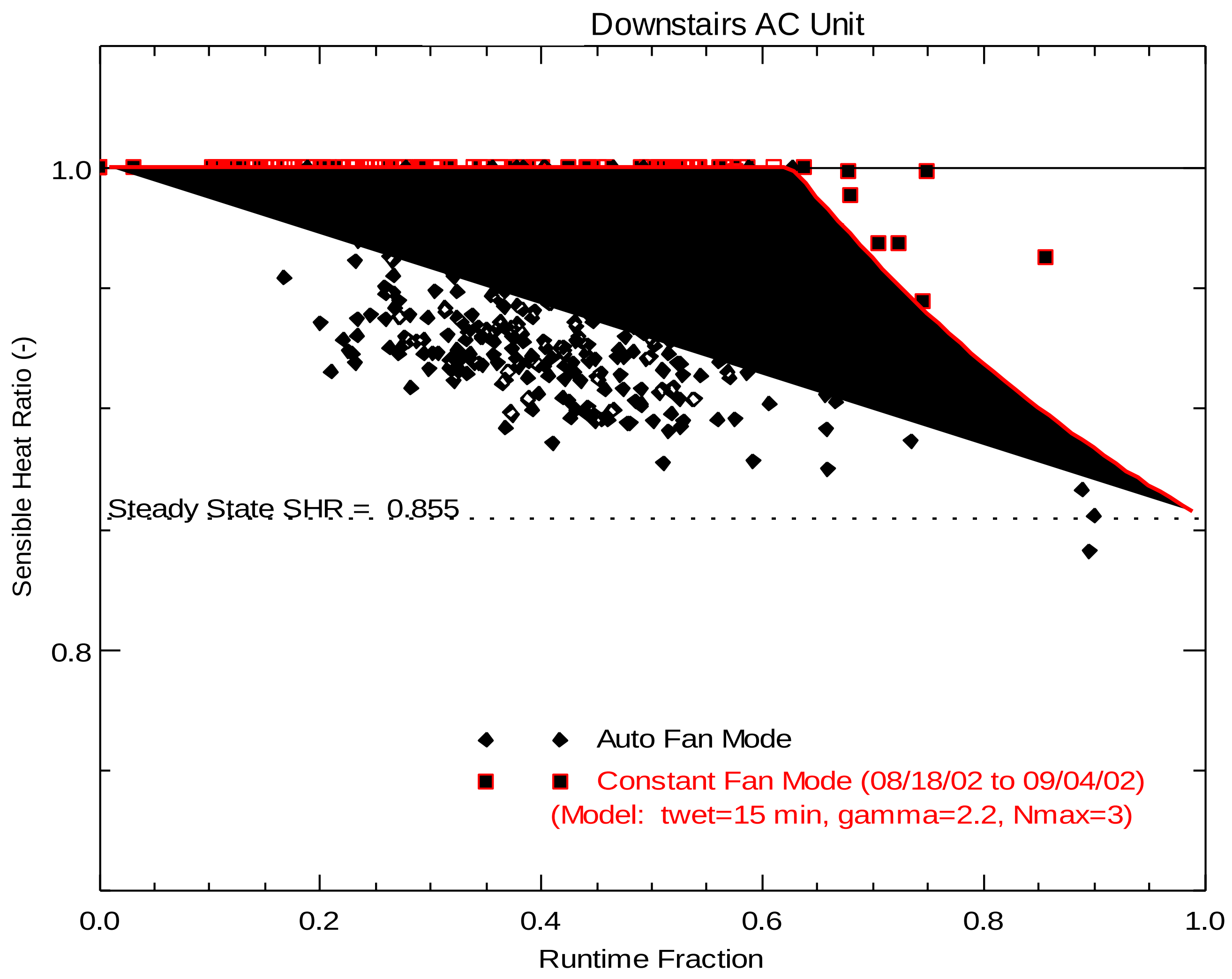
Laboratory Testing – SHR Degradation (cont.)

Coil 5 showed impact in AUTO Fan Mode!



Field Testing – SHR Degradation

Significant AUTO fan degradation!

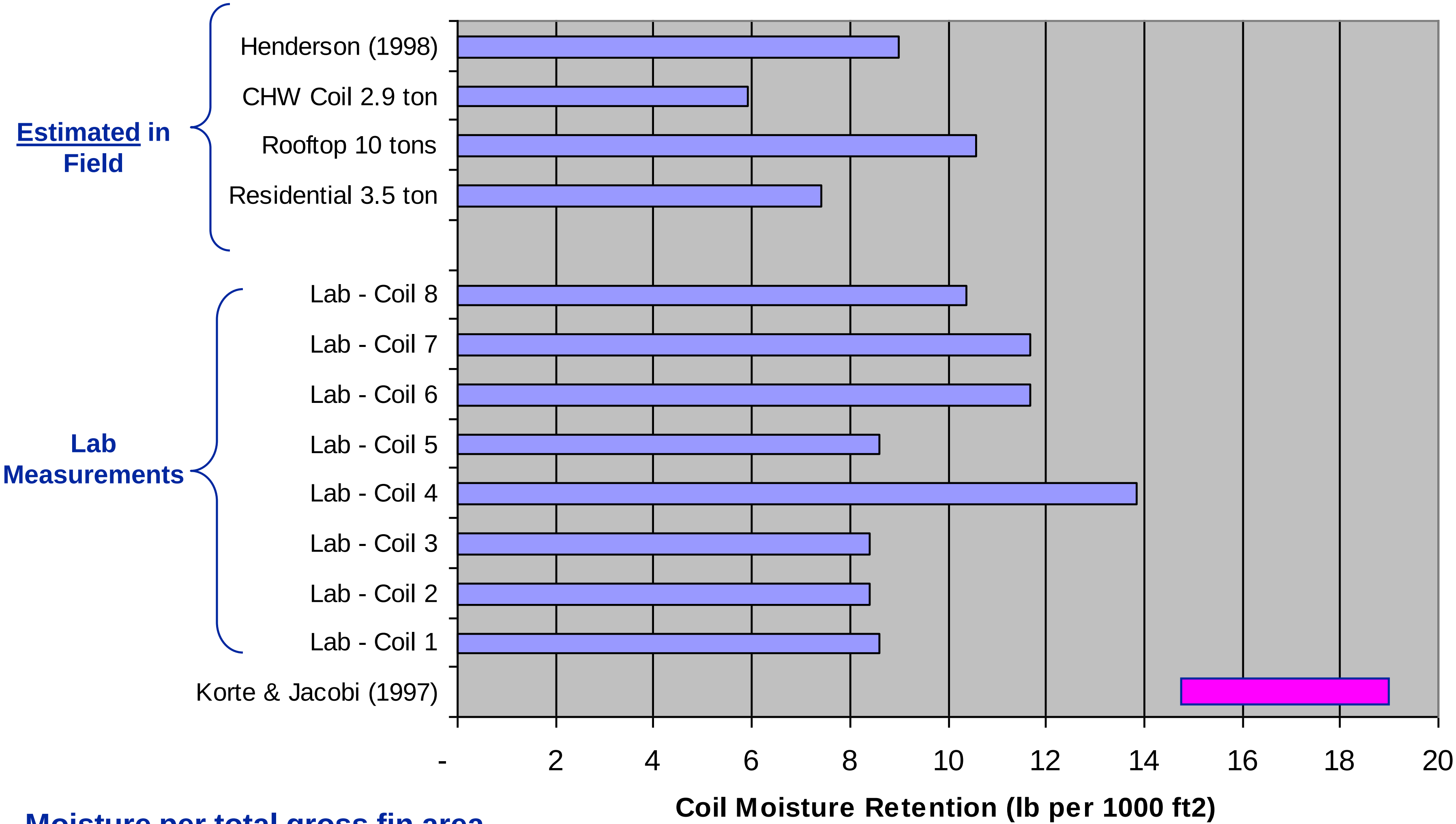


Measured Performance Parameters

	Size (tons)	Fin Surface Area (ft^2)	Retained Moisture Mass (lb)	Retained Moisture Mass (lb/kft^2)	Cond Delay Time (min)	t_{wet} (min)
Coil 1 (Slanted slab, 3 row, 13 fpi, plain fins, orifice)	2.9	243.8	2.1	8.6	13.5	16.5
Coil 2 – Normal Flow (A-coil, 3 rows, 15.5 fpi, lanced sine-wave fins, TXV)	2.4	237.8	2.0	8.4	16.3	17.0
Coil 2 – Low Flow (A-coil, 3 rows, 15.5 fpi, lanced sine-wave fins, TXV)	1.4	237.8	2.0	8.4	32.5	29.0
Coil 4 (vert. slab, 2 rows, 14 fpi, wavy fins, orifice)	1.8	137.4	1.9	13.8	23.5	18.5
Coil 5 (slanted slab, 4 rows, 12 fpi, wavy fins, orifice)	2.3	162.7	1.4	8.6	11.5	9.5
Coil 6 (A-coil, 3 rows, 13 fpi, wavy fins,TXV)	1.7	231.1	2.7	11.7	34.0	33.
Coil 6 – High Flow (A-coil, 3 rows, 13 fpi, wavy fins,TXV)	2.0	231.1	2.7	11.7	27.0	27.
Coil 8 – Chilled Water (vert. slab, 4 rows, 10 fpi, wavy fins,46°F CHW)	1.5	135.0	1.4	10.4	26.5	26.5

Notes:
1- Cooling capacity includes sensible and latent cooling at nominal conditions. Nominal conditions correspond to ASHRAE Test A test point.
2- Surface area is gross fin area (coil face area x coil depth x fin spacing x 2).
3- Condensate delay time and t_{wet} are at nominal conditions.

Lab + Field: Retained Moisture

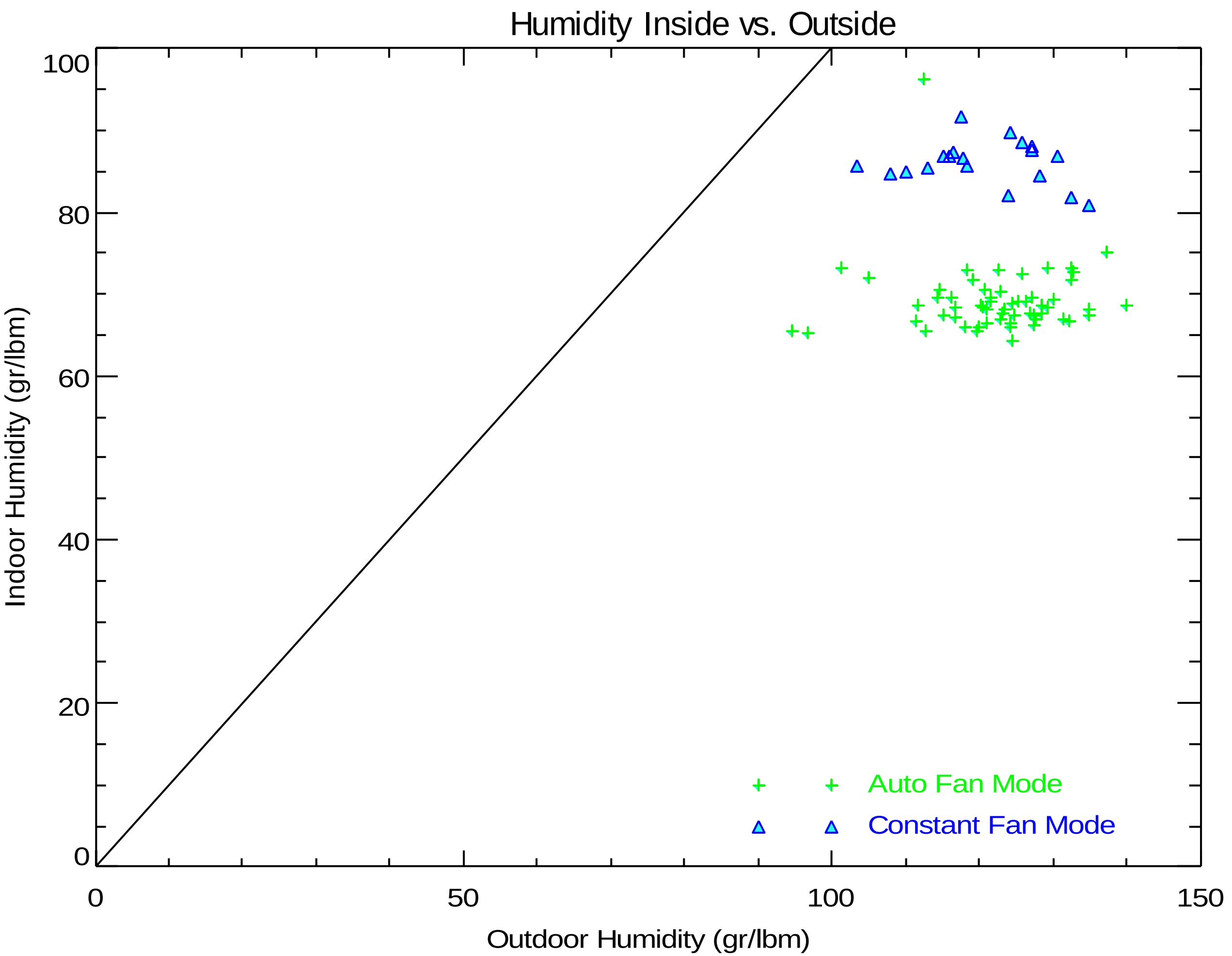


Moisture per total gross fin area
(gross area = face area x depth x fin spacing x 2)

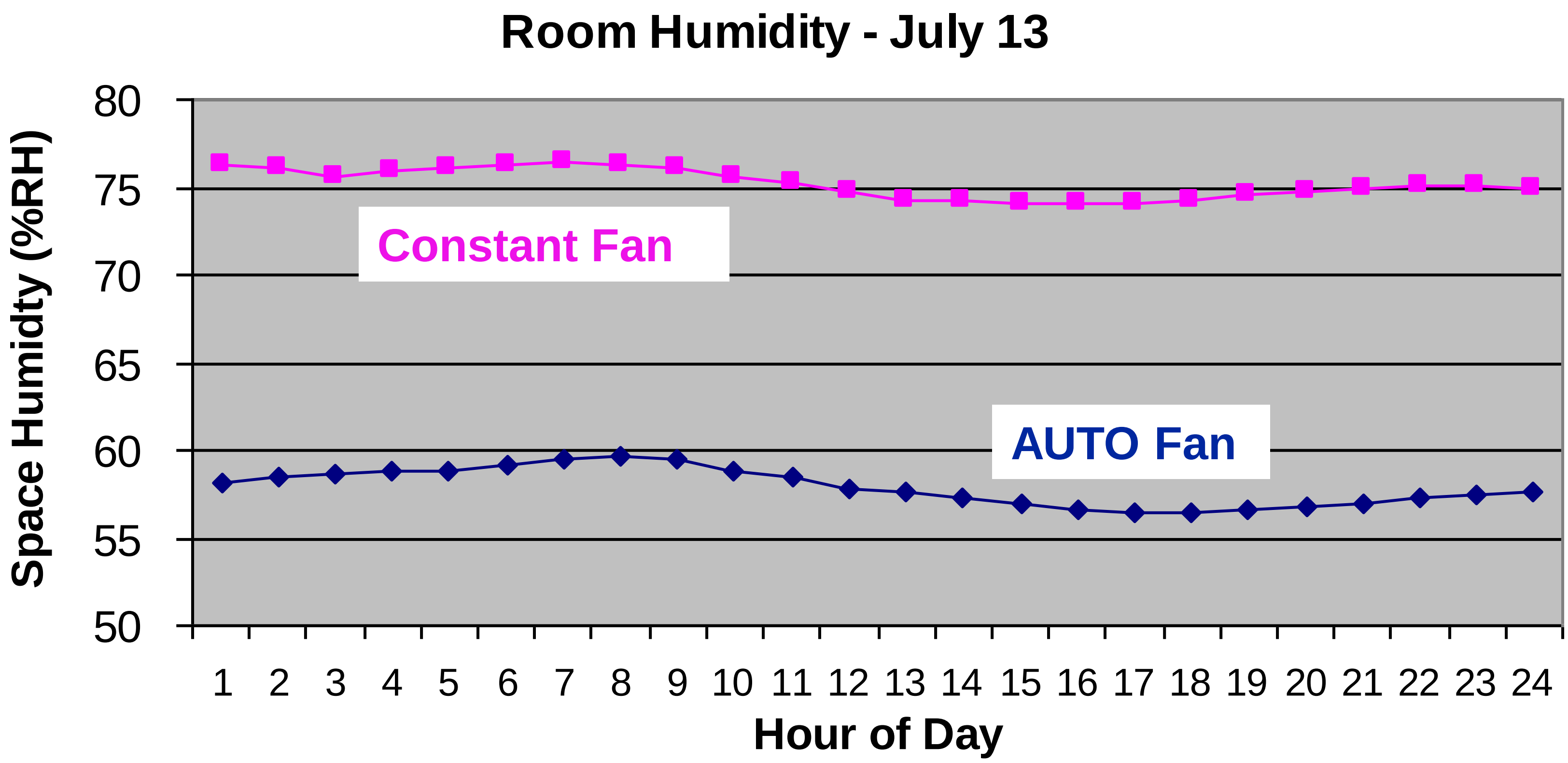
***Field Testing** – Impact of Constant Fan*

- Large penalty for constant fan operation

- Even for a dual-capacity AC unit



Impact on Space Humidity Levels



TRNSYS Model of Hotel Room in Hawaii

What Control Strategies Help?

Do fan delay strategies help?

- No…not until about a 10 minute delay

Two-speed or staged capacity heat pumps?

- Yes…increases runtime fraction (depends on coil split & fan control)

Reduced airflow during off cycle?

- Yes…would minimize off cycle evaporation

Cycle the fan with the compressor?

- Yes…whenever possible

Summary

- GHPs are like Air Conditioners, only they're geothermal
  - Follow same steady state latent/sensible trends as conventional DX coil
  - Subject to the same part load effects
- With constant fan, latent removal disappears below half load
- To maintain latent capacity
  - Cycle fan with the compressor (when possible)
  - Slow the fan down during off cycle
  - Add more capacity stages