The Impact of Part Load Air Conditioner Operation on Dehumidifier Performance: *Validating a Latent Capacity Degradation Model*

Hugh I. Henderson, Jr.
CDH Energy Corp.
Cazenovia, NY

hugh@cdhenergy.com
www.cdhenergy.com

Overview

- Background
  - there is degradation of latent capacity with constant fan operation (Khattar et al 1985)
  - a simple model has been developed to predict this degradation as a function of part load parameters (Henderson & Rengarajan 1996)
- The purpose of this paper
  - use relatively simple field measurements to verify the model
- Discuss what else needs to be done?

Why is Part Load Dehumidification Performance Important?

- Effects space humidity levels at part load conditions….where most operation occurs.
  – levels above 60% RH negatively impact human health and comfort (i.e., IAQ)
- Current building simulation models do not consider this impact.
  – so they do not properly predict space humidity levels or potential IAQ problems
  – do not accurately predict the loads imposed on dehumidification systems

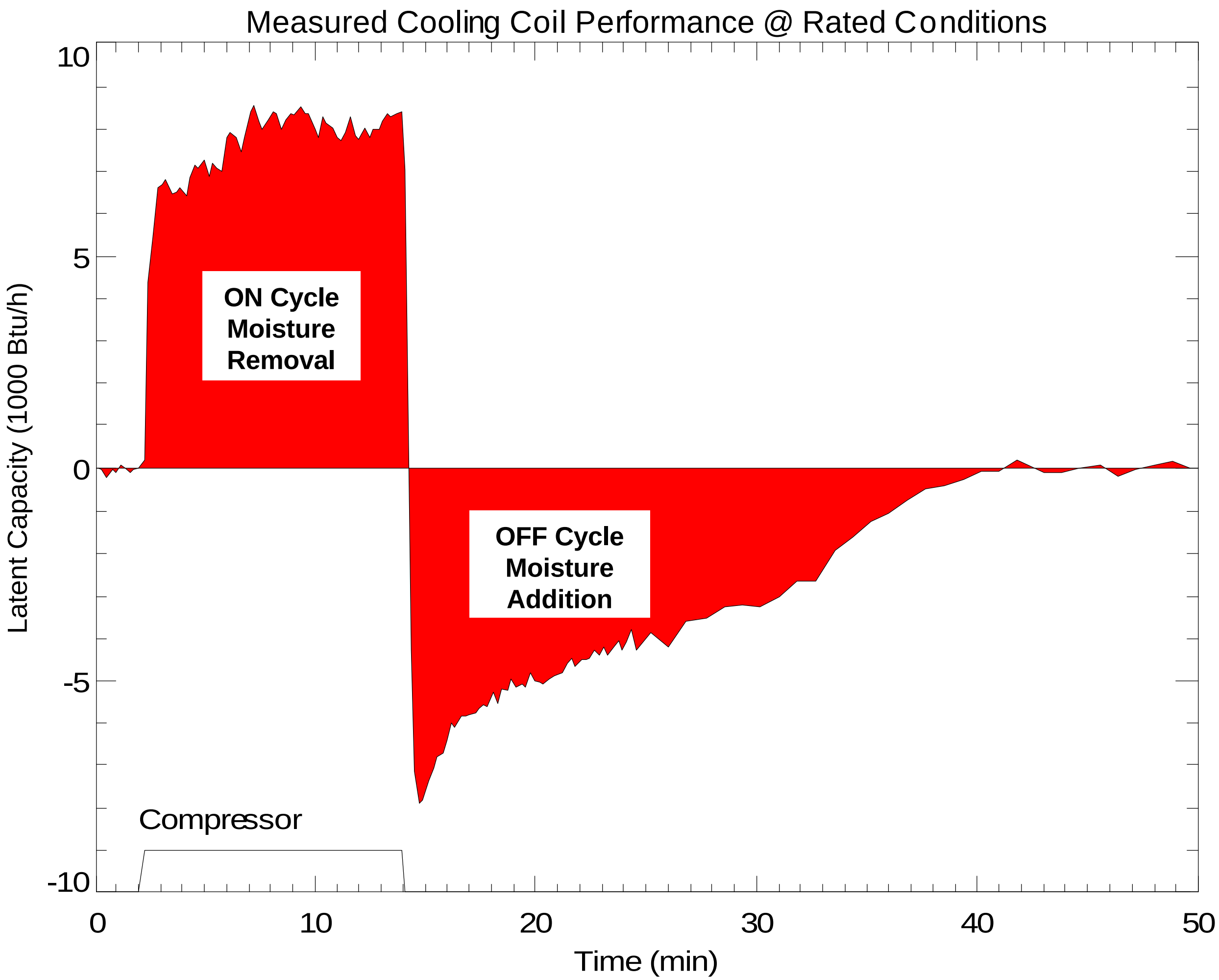
Magnitude of Latent Degradation

- Latent capacity degradation model has been incorporated into the detailed building simulation model FSEC 2.0 by Shirey and Rengarajan (1996)
  – considered this phenomenon in a small office building in Miami
  – it ***increased*** predicted space humidity levels by nearly10% RH during early morning hours on a summer day

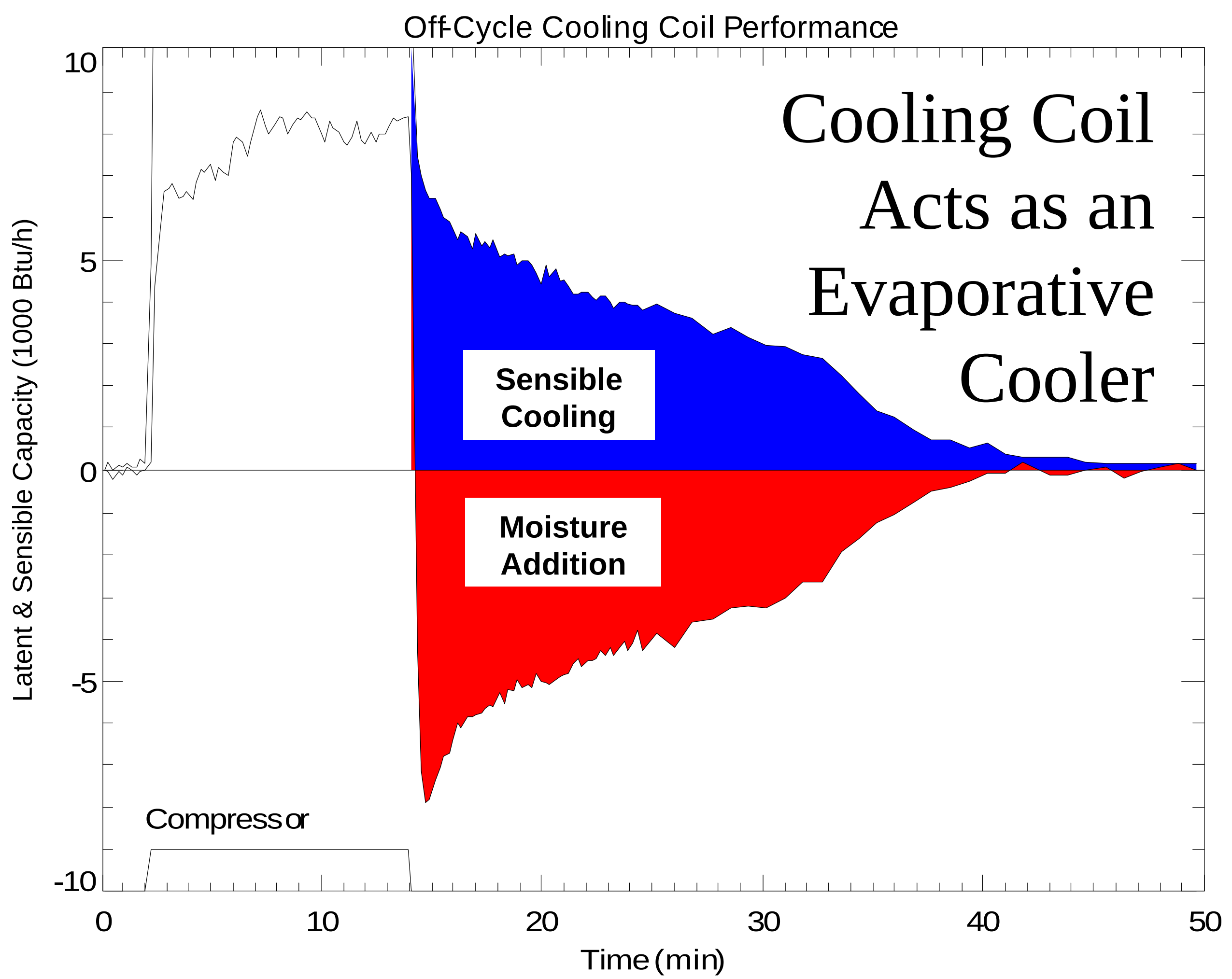
How is Latent Capacity Degraded?

- Moisture condenses on cooling coil surfaces during cooling operation
- When coil (or compressor) is deactivated wet surfaces are exposed to the air stream
- Moisture evaporates back into air stream
- Net effect: less moisture removal & higher space humidity levels

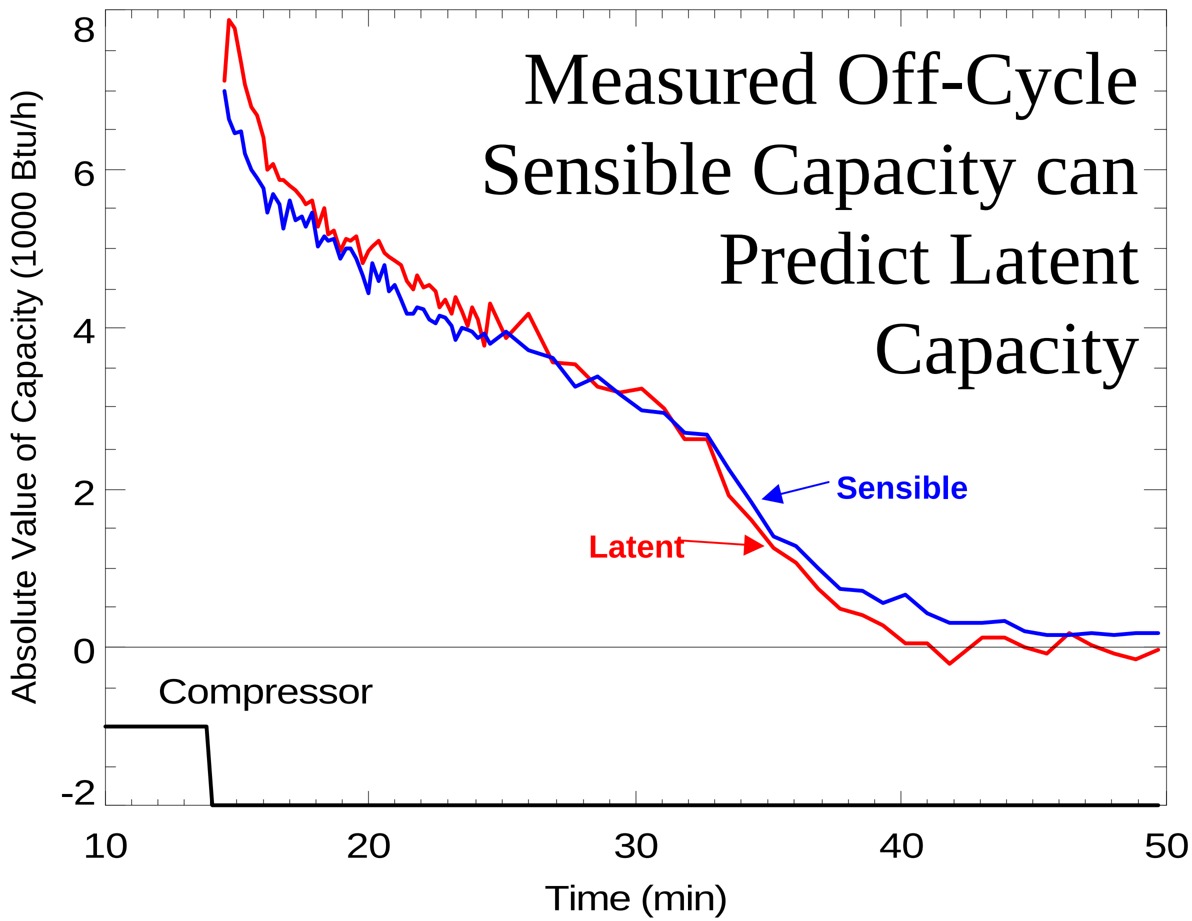
Typical Moisture Removal & Addition Cycle



Off-Cycle Coil Performance



Off-Cycle Sensible & Latent Capacity are Equivalent

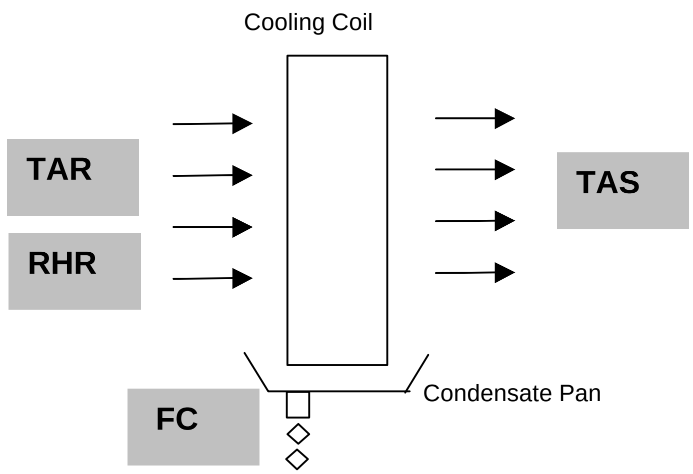


Summary & Implications of Lab Results

- Summary:
  - detailed laboratory measurements show that off-cycle sensible and latent capacity are equivalent (i.e., coil acts as an evaporative cooler)
- Implication:
  - relatively-simple temperature measurements can be used to predict off-cycle latent performance.

Field Data from Water-to-Air HP

- Monitored a 3 ton water-to-air heat pump in a North Carolina home
- Collected data at 30-second intervals for 4 days late in season
- Collected 15-minute data over the summer



Instrumentation:

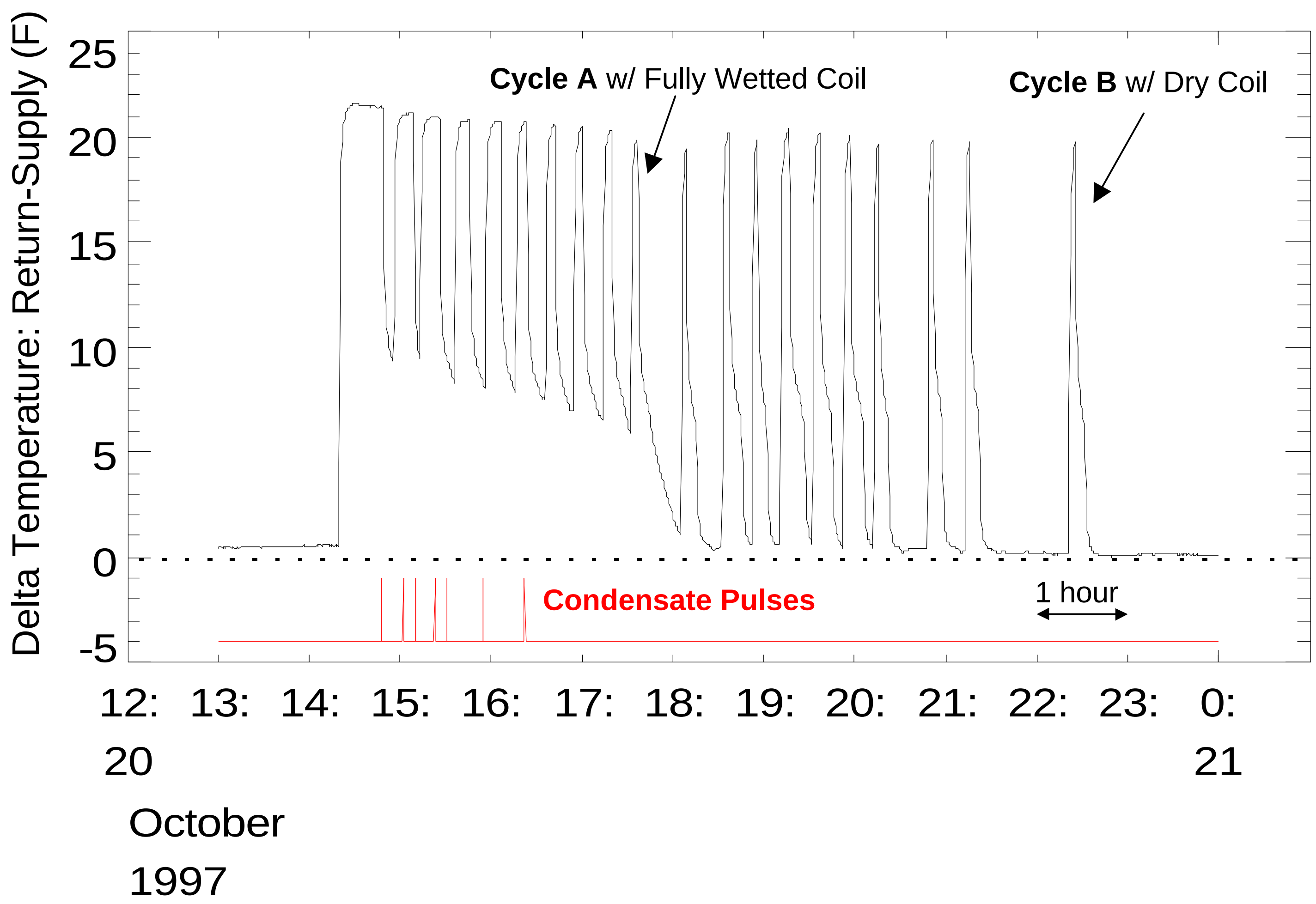
• low-mass type-T TCs

•bulk polymer RH (±2%)

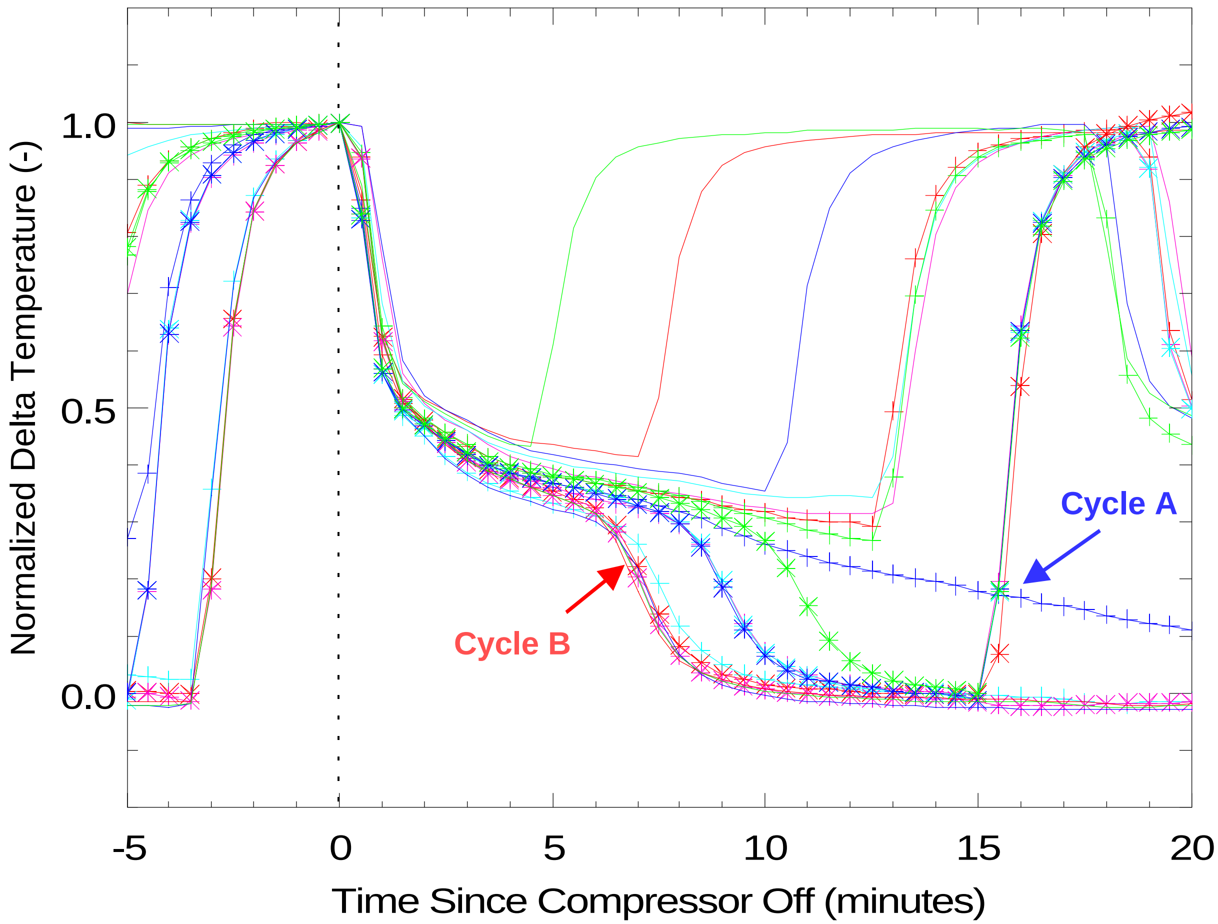
•calibrated condensate pump

•one-time measurement of air flow with hot-wire probe

Measured Sensible Cooling



Superimposed Off-Cycles



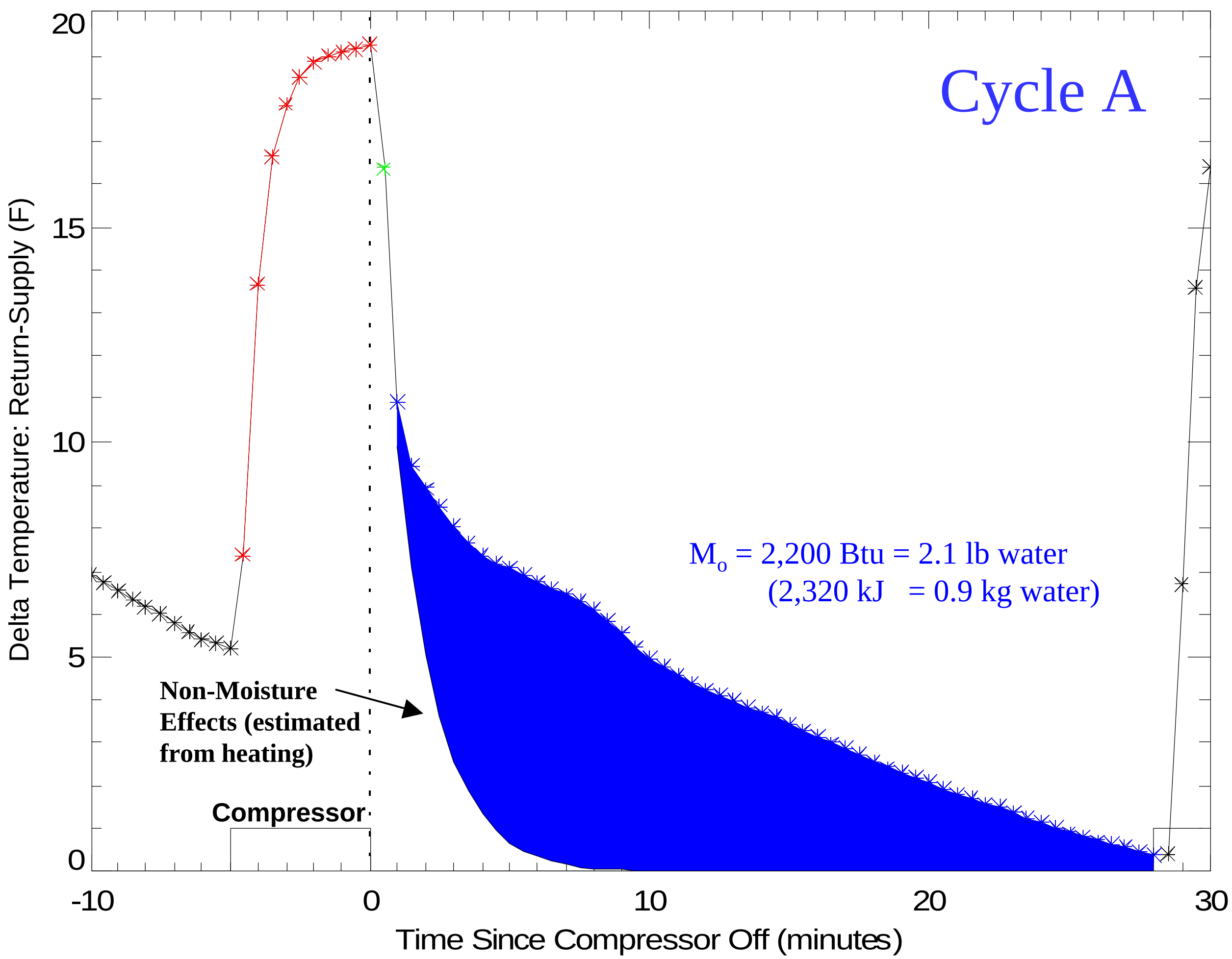
Latent Degradation Model

- Predicts degradation of latent heat ratio (LHR) as a function of runtime fraction and entering conditions (T & RH)
- Model is based on:
  - theory behind part load efficiency/capacity models (N_{max} & τ)
  - assumptions about how moisture evaporates from a coil (t_{wet} & γ)
- Described in Henderson & Rengarajan (1996)

Degradation Model Parameters

t_{wet}	The nominal time after cooling startup when moisture starts to drain from the condensate pan. Defined as the maximum moisture holding capacity of the cooling coil (M_o) divided by the steady-state latent removal capacity (Q_L): $t_{wet} = M_o/Q_L$.
γ	The ratio of the initial off-cycle evaporation rate (Q_e) and the steady-state latent removal capacity (Q_L): $\gamma = Q_e/Q_L$.
N_{max}	The maximum thermostat cycling rate. Typically 3 cycles per hour for most cooling systems.
τ	Time constant of latent capacity at startup. Typically 30 to 90 seconds.

Moisture Stored on Coil



Estimating Model Parameters

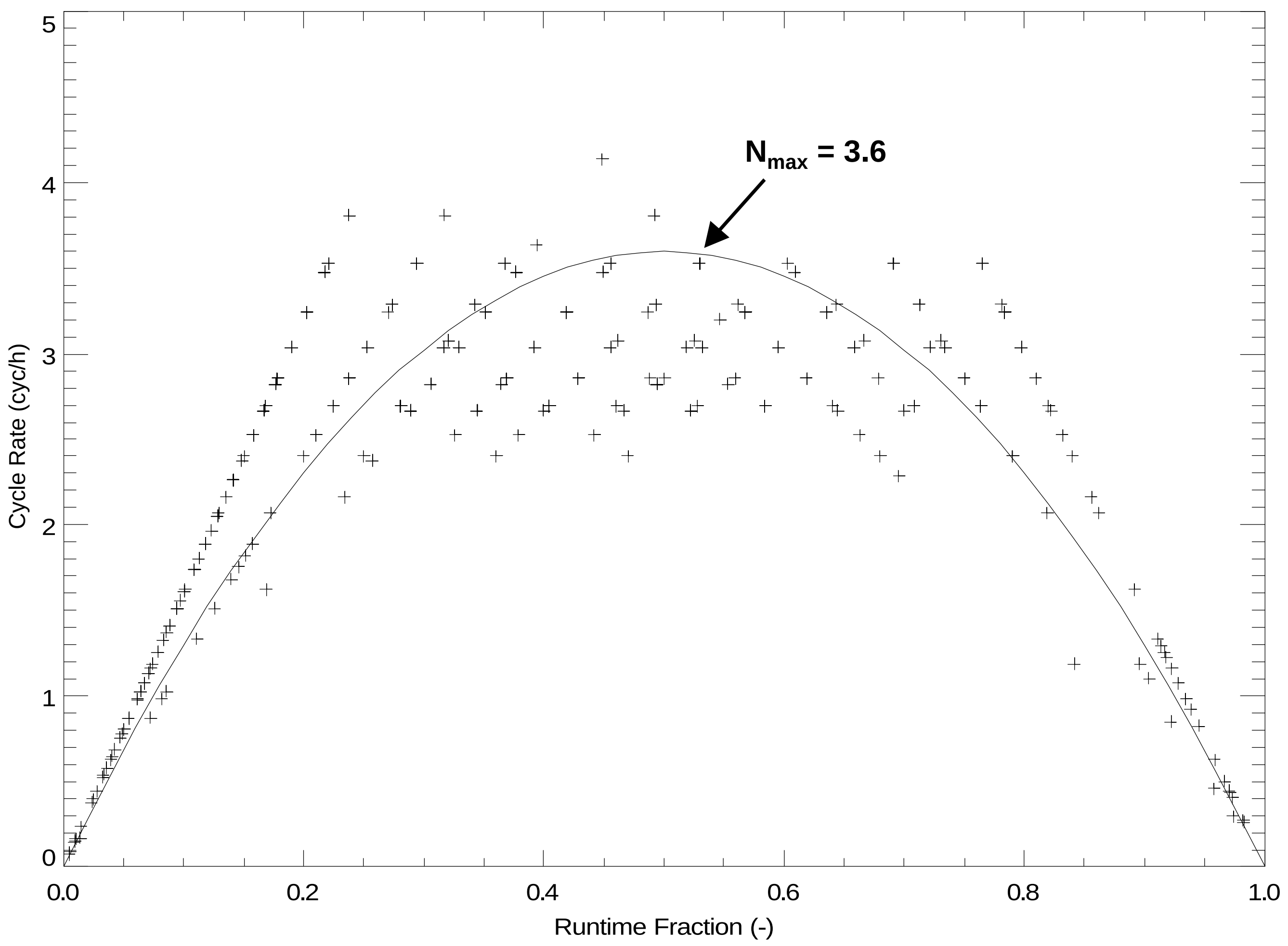
$$t_{wet} = \frac{M_o}{Q_L} = \frac{2{,}200 \text{ Btu}}{11{,}000 \text{ Btu/h}} = \mathbf{720\ seconds}$$

$$\gamma = \frac{Q_e}{Q_L} = \frac{11{,}800 \text{ Btu/h}}{11{,}000 \text{ Btu/h}} = \mathbf{1.07}$$

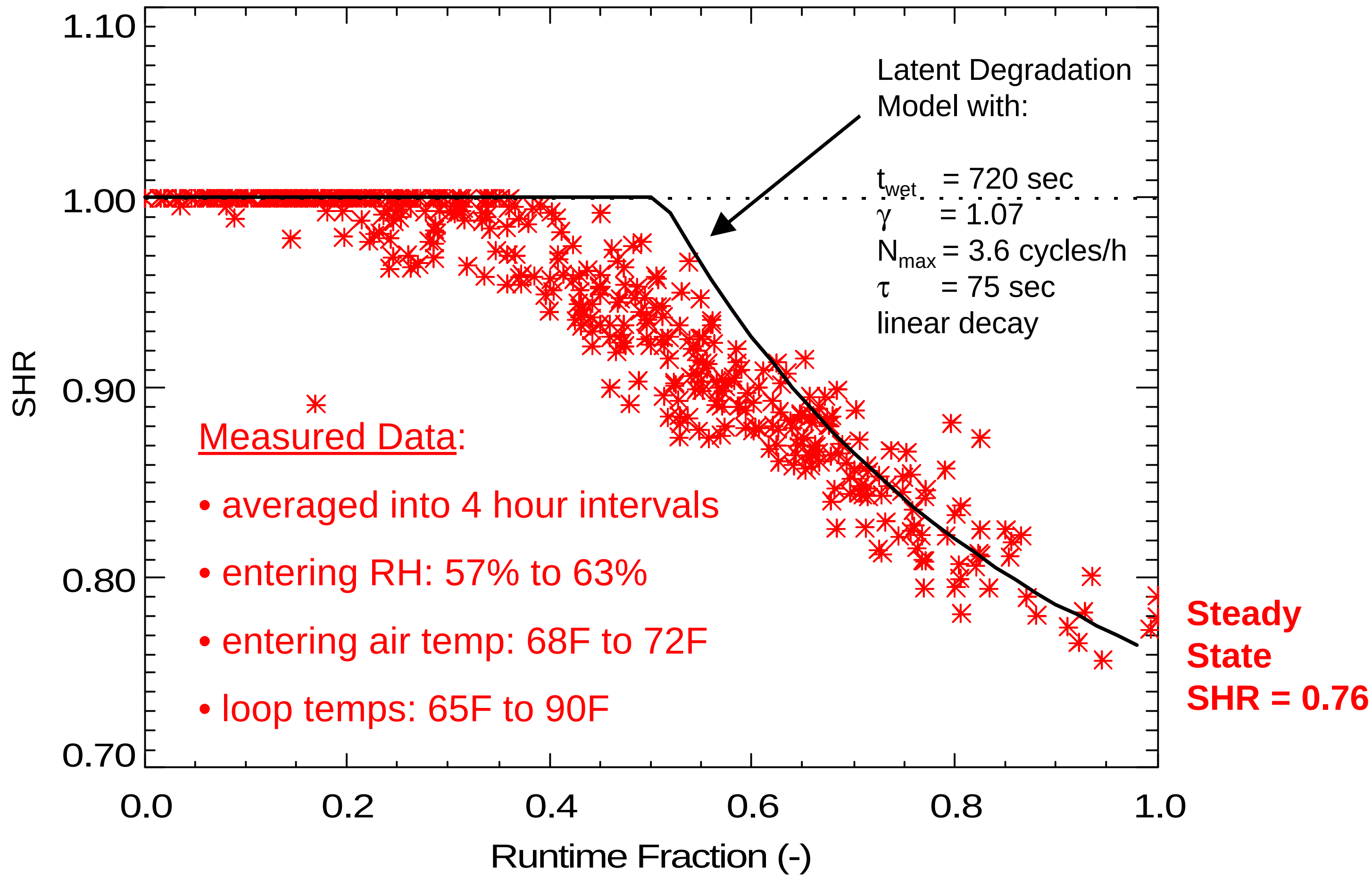
N_{max} = **3.6 cycles/h** (from measured data)

τ = **75 seconds** (inferred from sensible capacity)

Measured T'stat Cycling Rate



Comparing Model & Data



Observations

- Model predicts latent capacity degradation trends overall
- Agreement is poorest in mid-range
  - may be due to electronic thermostat….does not follow standard thermostat curve in 0.2 to 0.8 range of runtime fractions

Future Research Needs

- Latent Degradation Model has been "verified" with two data sets:
  - data from Khattar et al (1985)
  - data presented here
- Need to better understand:
  - mode of transient moisture evaporation
  - impact coil geometry on evaporation & moisture holding capacity
  - impact of fan cycling on degradation phenomena

Summary

- Latent capacity degradation is important
  - how many indoor air quality problems could be caused by this phenomena?
  - current mainstream building simulation models and calculation procedures do not consider it
- This latent degradation model predicts these effects
- Model has been initially verified. More work is needed.