The Impact of HVAC Control Improvements on Supermarket Humidity Levels

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Premise

- Minor HVAC system control changes can greatly improve dehumidification performance and system efficiency
- Key HVAC operating issues:
  - supply air flow (cfm/ton & cfm/ft^2)
  - evaporator temperature control
  - staging and part load control
  - supply fan control

Two Test Supermarkets

- Full direct digital control (DDC) systems installed to monitor performance and implement control improvements
  - instrumentation installed to measure HVAC and refrigeration system performance
- Both stores typical
  - packaged unitary cooling equipment
  - refrigeration heat reclaim for space heating

Test Store Characteristics

Characteristics	Store A	Store B
Location	Minneapolis, MN	Indianapolis, IN
Gross Floor Area	33,400 ft^2	50,000 ft^2
Sales Area (% of gross area)	77%	73%
Operating Schedule	24 hours per day	24 hours per day

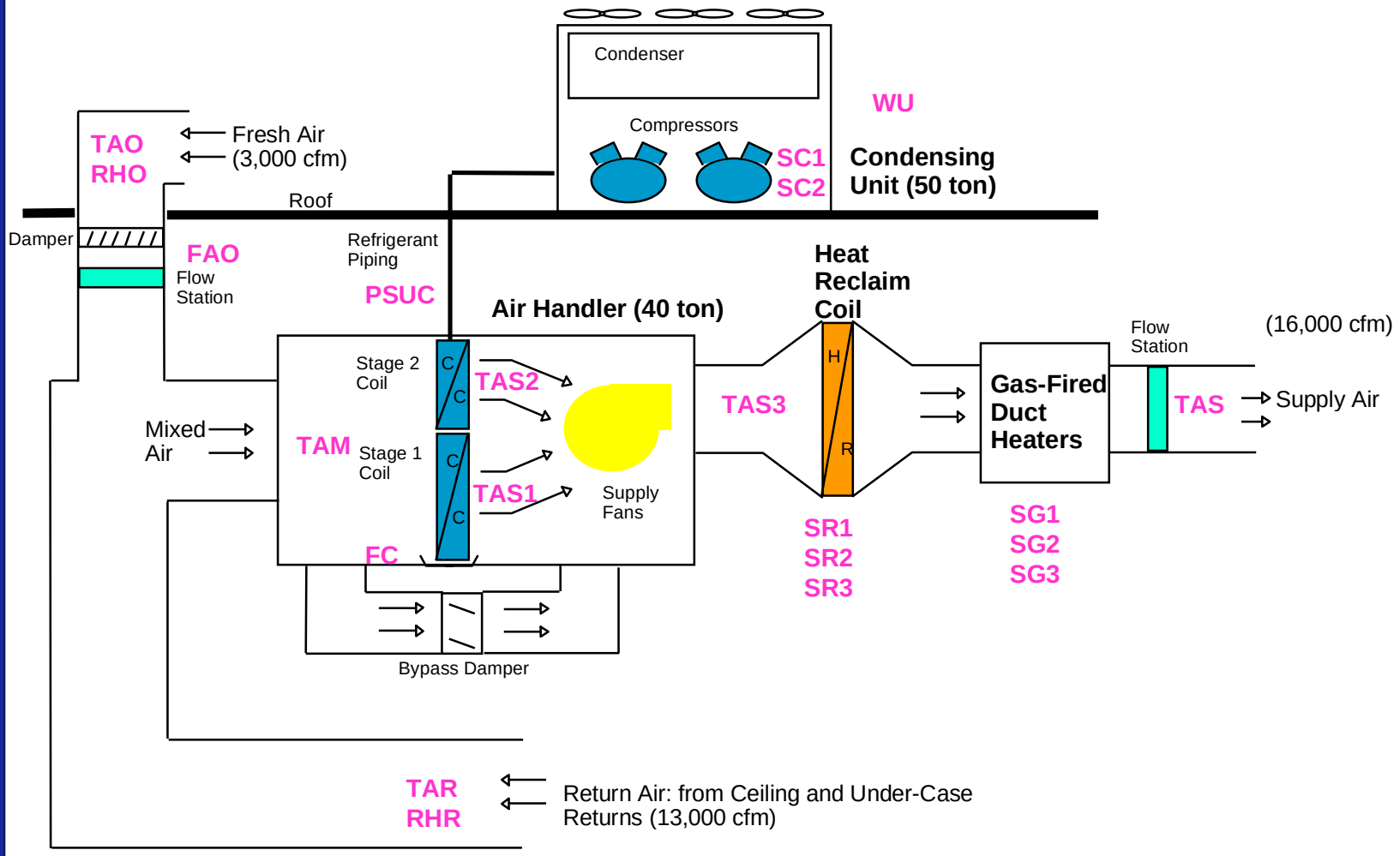
HVAC Systems

Characteristics	Store A	Store B
Type of System	**Spilt system** 50 ton condensing unit, 40 ton air handler	**Three Rooftop units** 60 ton with heat pipes, 30 ton, & 8 ton, two-speed fans
Total Installed Capacity	**50 tons** (668 ft^2/ton)	**98 tons** (510 ft^2/ton)
Supply Air Flow –High Speed - Low Speed	**16,000 cfm** (0.6 cfm/ft^2) na	**41,000 cfm** (0.8 cfm/ft^2) **24,000 cfm** (0.6 cfm/ft^2)
Nominal Ventilation Air	**3,000 cfm** (17 cfm/person)	**5,000 cfm** (20 cfm/person)
Heating	**Heat Reclaim** w/ Natural Gas Backup	**Heat Reclaim** w/ Electric Resistance Backup

Original HVAC Controls

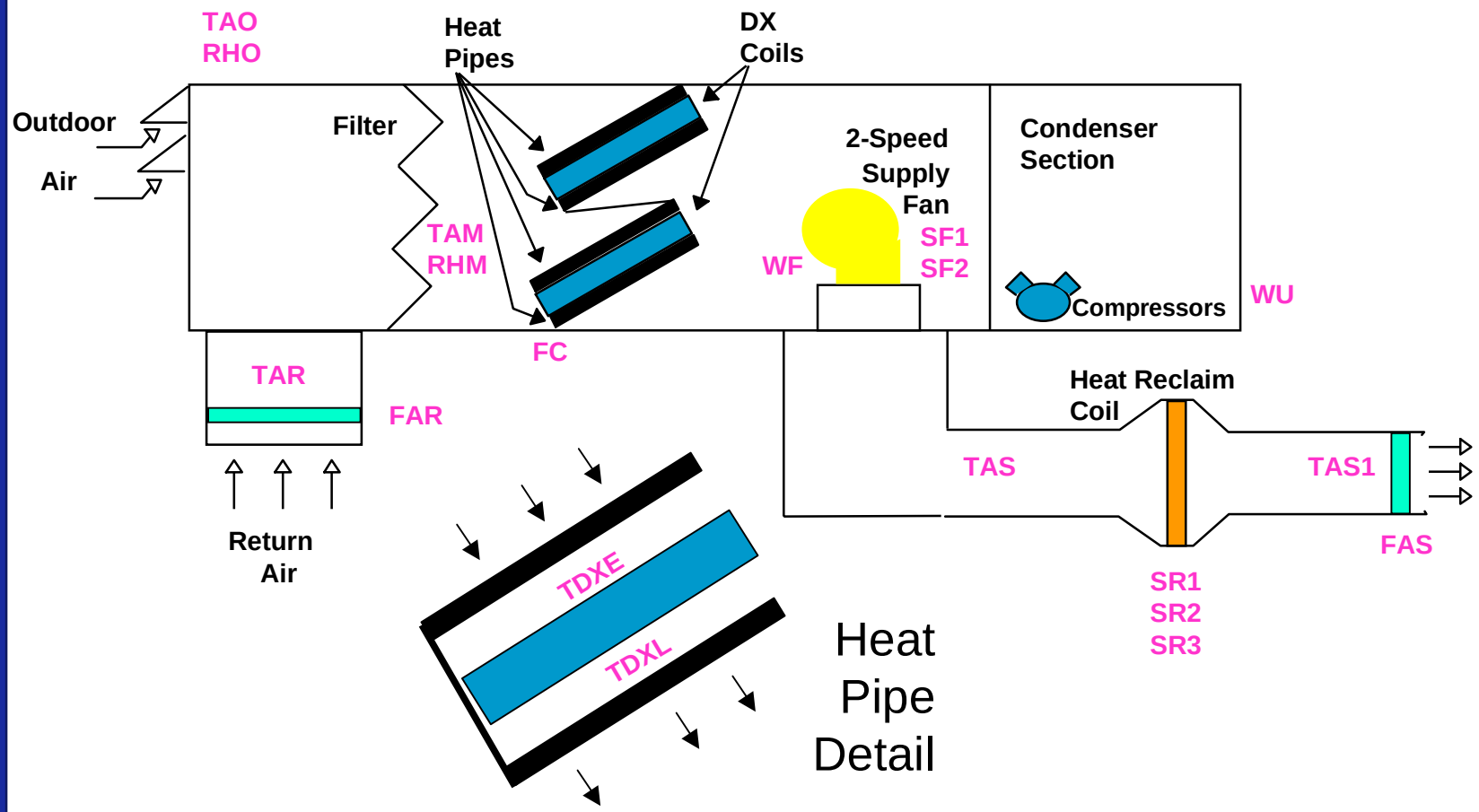
	Store A	**Store B**
Overall Controls	Two stages of cooling, 5 stages of heating.	Two stages of cooling, 5 stages of heating.
Cooling Controls	Thermostat activates 2 cooling coil sections (bottom & top section of face split coil) with LLSV. Both compressors controlled to maintain suction pressure.	1st stage thermostat activates one compressor in RTU#1 (60 ton) and RTU#2 (30 ton). 2nd stage thermostat activates remaining compressors. Inter-twined coils.
Dehumidification Controls	Humidistat activates 1st stage cooling.	Humidistat activates 1st stage of cooling (on 60 and 30 ton units).
Fan Control	na	Supply fan jumps to high speed when any cooling or heating is required

HVAC System - Store A



HVAC System - Store B

RTU#1 - 60 ton unit w/ heat pipes



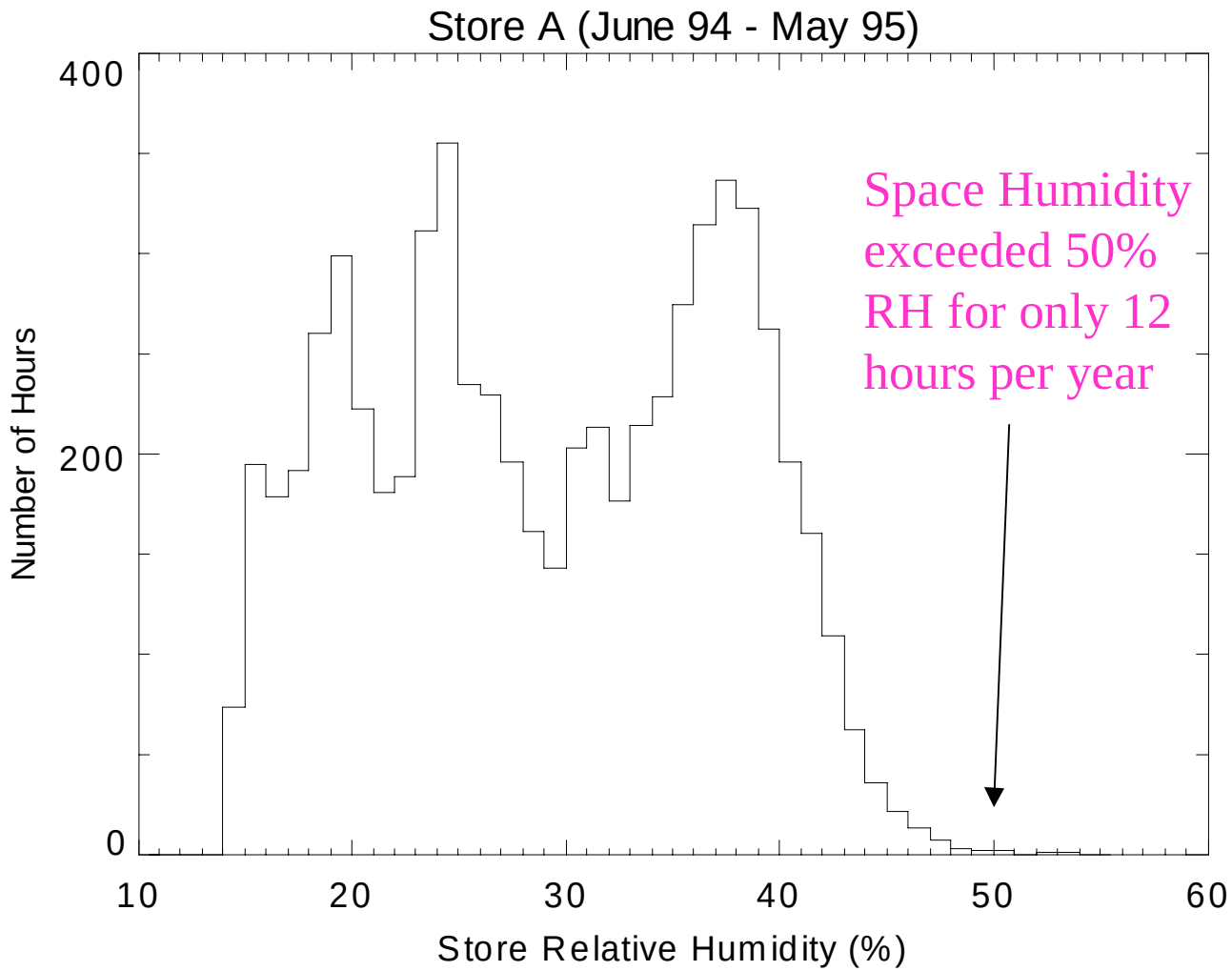
Store A - Test Schedule

- Store monitored “as is” from June 1994 to May 1995
- Control improvements implemented in June 1995, monitoring continued through September 1995
- Compared performance of two periods

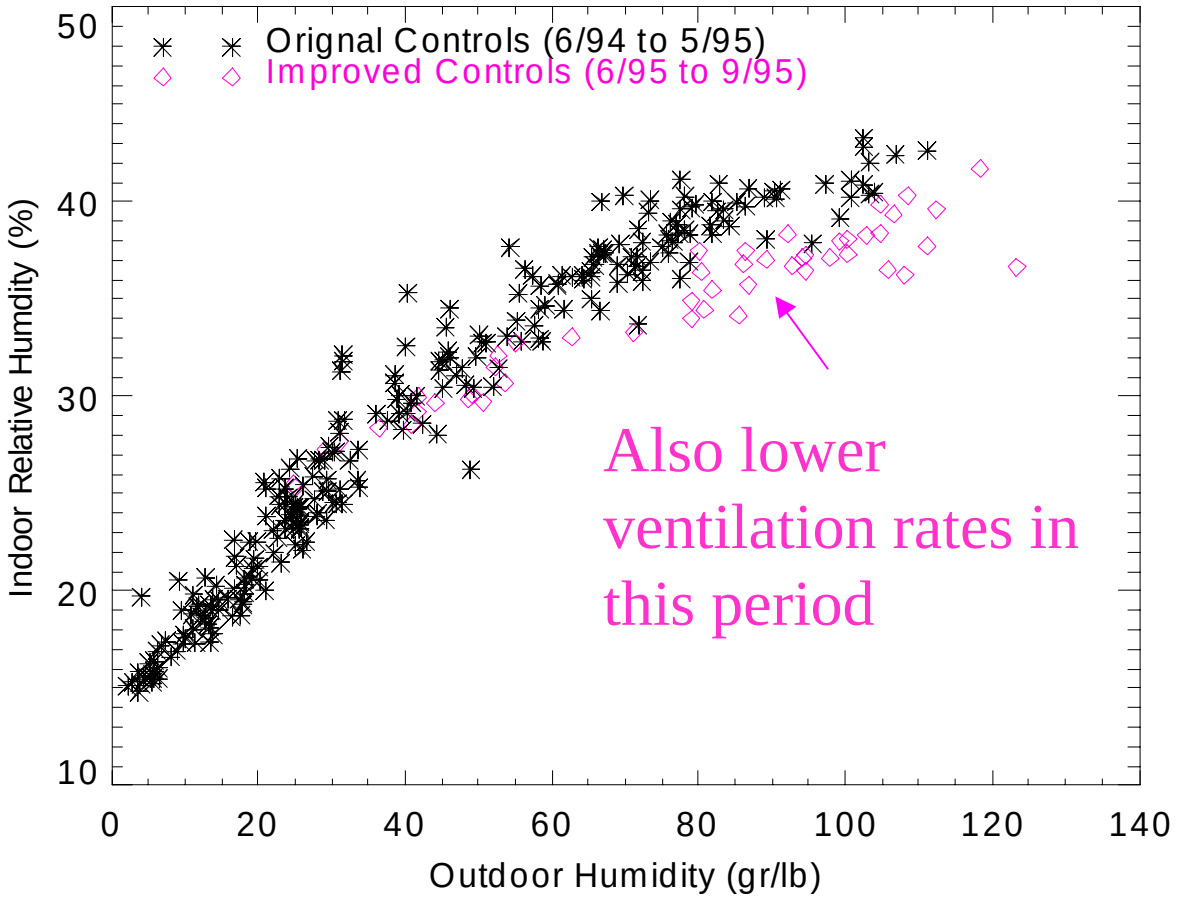
Control Improvements - Store A

- Closer control of evaporator temperature through DDC control (instead of mechanical suction pressure control).
- Reduction of coil temperatures in dehumidification mode.
- Lower supply air flow rates at night.
- Tighter control of store temperatures in the dehumidification mode (by raising the heating set point when reheat is required to limit overcooling).

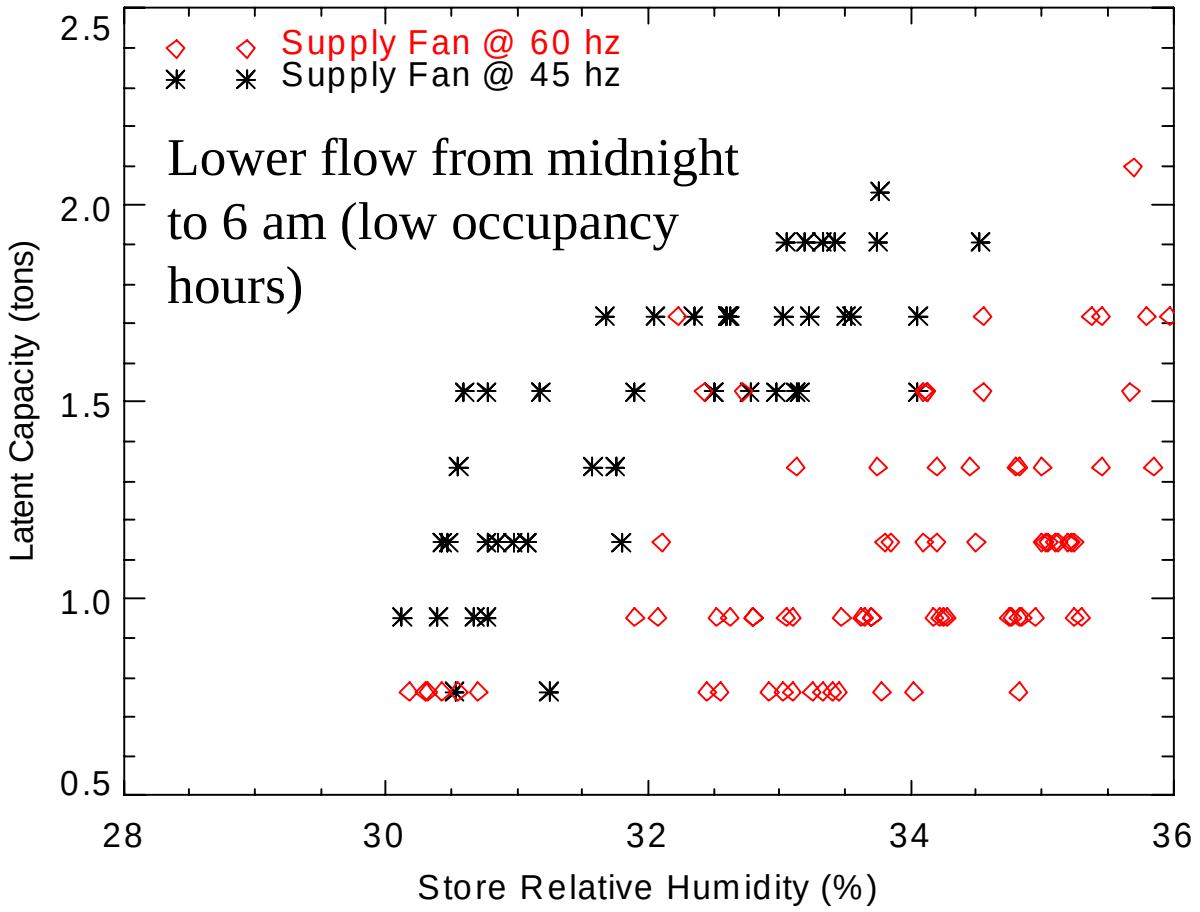
Space Humidity - Store A



Impact on Conditions - Store A



Impact of Lower Airflow at Night



Store A - Results

- Control improvements had little impact on store humidity levels because original system already provided good control:
  - low supply air flow rate: 0.6 cfm per ft^2
  - independent suction pressure control and coil staging consistently maintained cold suction temperatures
- Several “problems” with the original system controls actually improved dehumidification

Store B - Test Schedule

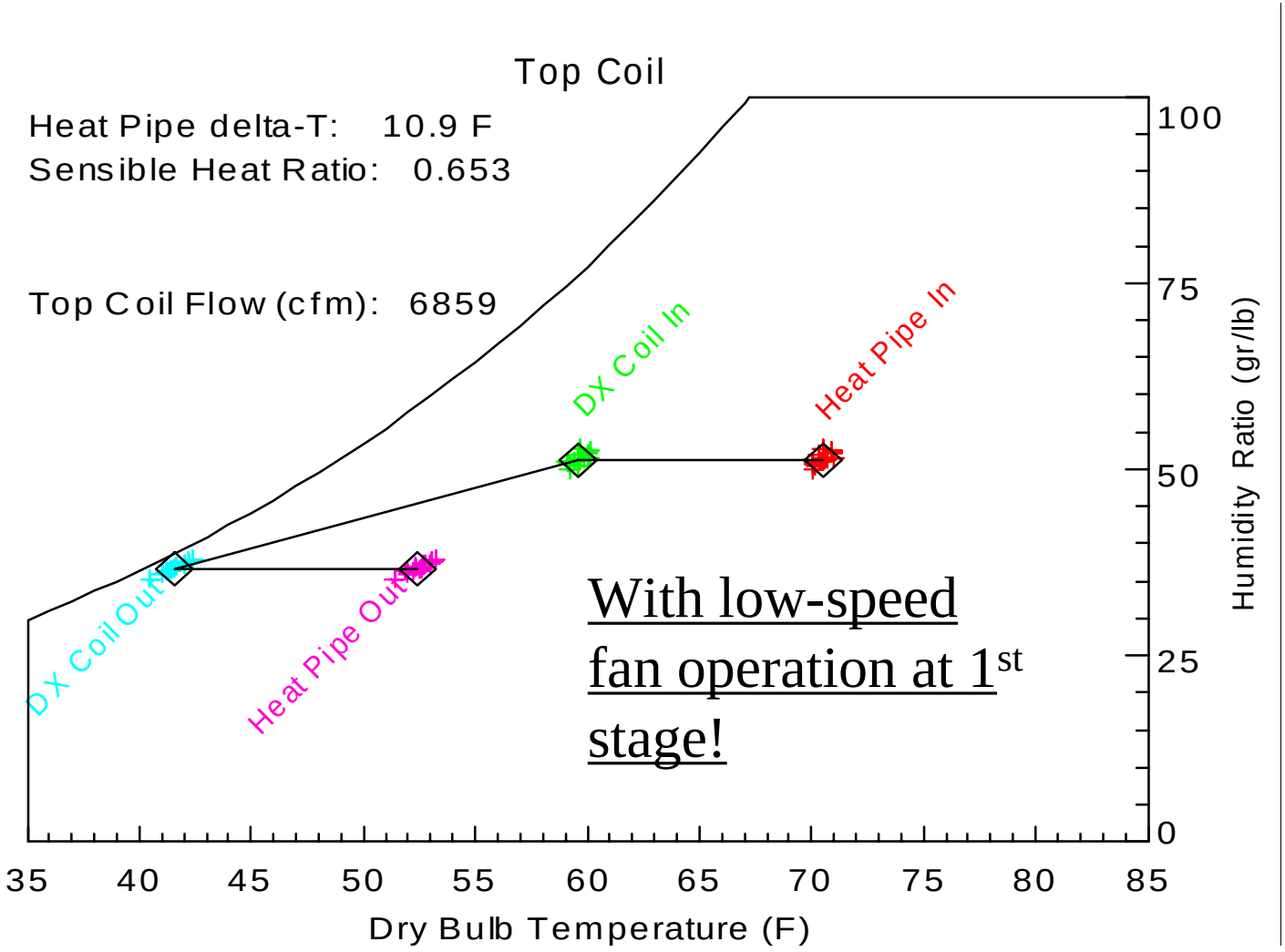
- Monitored original system starting in May 1995
- Implemented improved controls in mid-August 1995
- Continued monitoring into 1996

Control Improvements - Store B

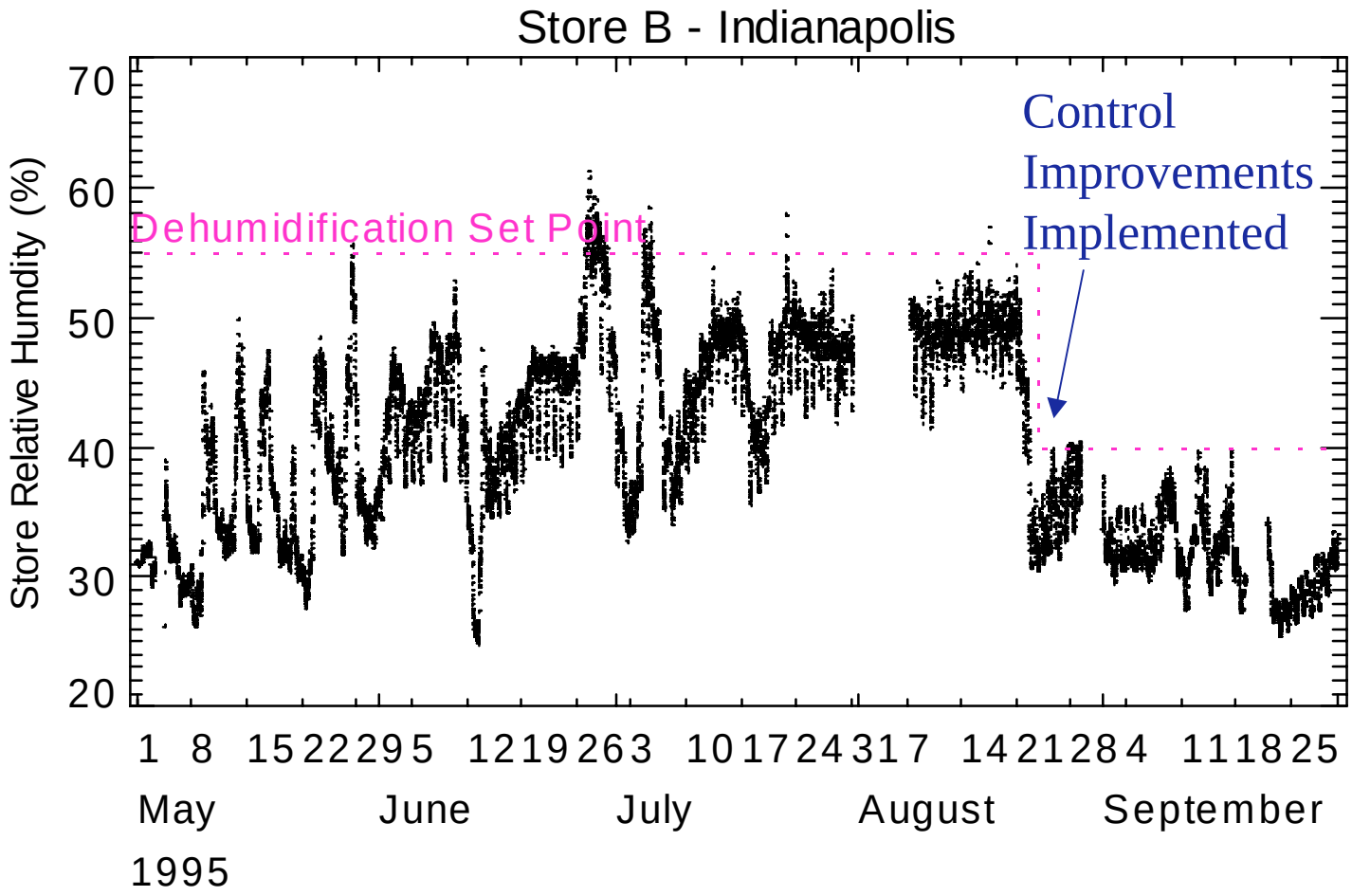
- Operate supply fans at low speed (instead of high speed) for first stage cooling.
- Decouple operation of the two main RTUs….. Operate heat pipe assisted RTU for first stage of cooling and for dehumidification.
- Tighter control of store temperatures in the dehumidification mode (by raising the heating set point when reheat is required to limit overcooling).

Same as Store A

Heat Pipe Performance



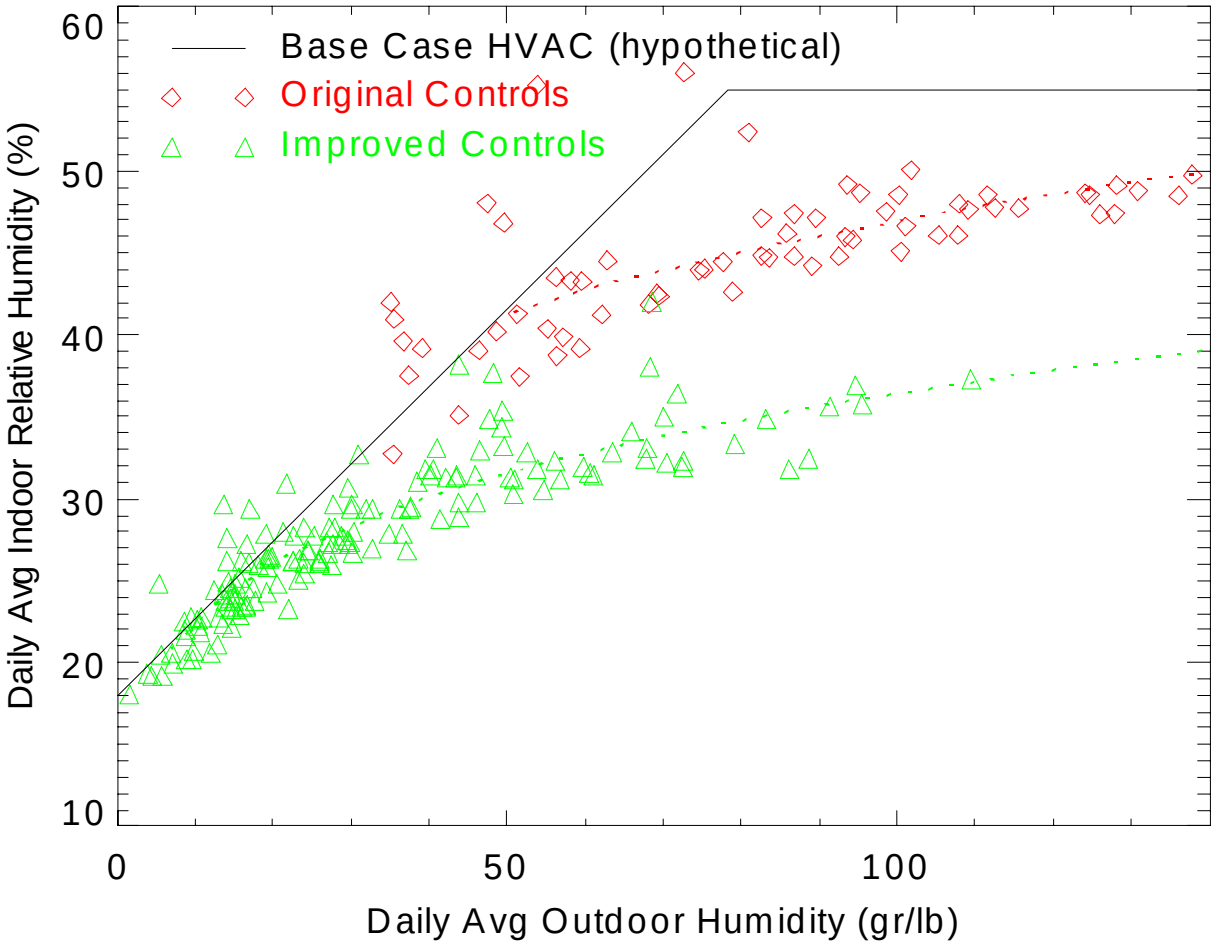
Impact of Improvements -Store B



Store B - Results

- Low speed fan operation with first stage cooling dramatically improved dehumidification performance
  - allowed heat pipes to work effectively on intertwined DX coils
- Putting cooling priority on heat pipe RTU increased “passive” dehumidification
- Active dehumidification improvements (i.e., reheat control) were not ever required

Comparing Performance



Net Impact of Heat Pipe AC

- Heat Pipes (with Improved Controls) reduced space humidity….. And decreased refrigeration energy use by 33,000 kWh/yr
- Penalty of 3,000 kWh/yr due to extra latent load and increased fan power
- NET IMPACT: 30,000 kWh/yr, or $1,000 per year

Key Improvements

- Low Supply Air Flow (cfm/ft^2 & cfm/ton)
  - lowering first stage air flow (from 700 to 420 cfm per ton) greatly improved dehumidification performance at Store B
  - low air flow in Store A (0.6 cfm/ft^2) helped to provide good dehumidification performance
- Continuously maintain low suction temperatures
  - independently control suction pressure and coil staging

Key Improvements (cont.)

- Put priority on enhanced dehumidification equipment
  - used heat-pipe-assisted unit as base cooling unit as fist stage cooling in Store B
- “Face-Split” cooling coil ensured that full dehumidification was provided at part load conditions

Conclusions

- Seemly minor control improvements can have a big impact
- Controls “tuning” can make a “simple” HVAC system very effective
- Enhanced technologies (such as heat pipe AC) can also benefit from controls tuning
- Proper supply air flow is the single most important factor