# The Impact of Desiccant Dehumidification on Classroom Humidity Levels

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# Overview

- Details of test school
- Instrumentation and test approach
- Field test results with desiccant system at a school
  - how well do conventional AC systems control humidity in classrooms?
  - can desiccant equipment lower space humidity levels and improve IAQ?
  - how do ventilation rates impact of humidity?
  - how do operating costs compare?

# Elementary School
# Olathe, Kansas (Kansas City)

- Elementary school built in 1988. New addition in 1995
- Water Loop Heat Pump (WLHP) System
- Good “side-by-side” test site in moderate climate

# Two Identical “Pods”

Base Case Pod

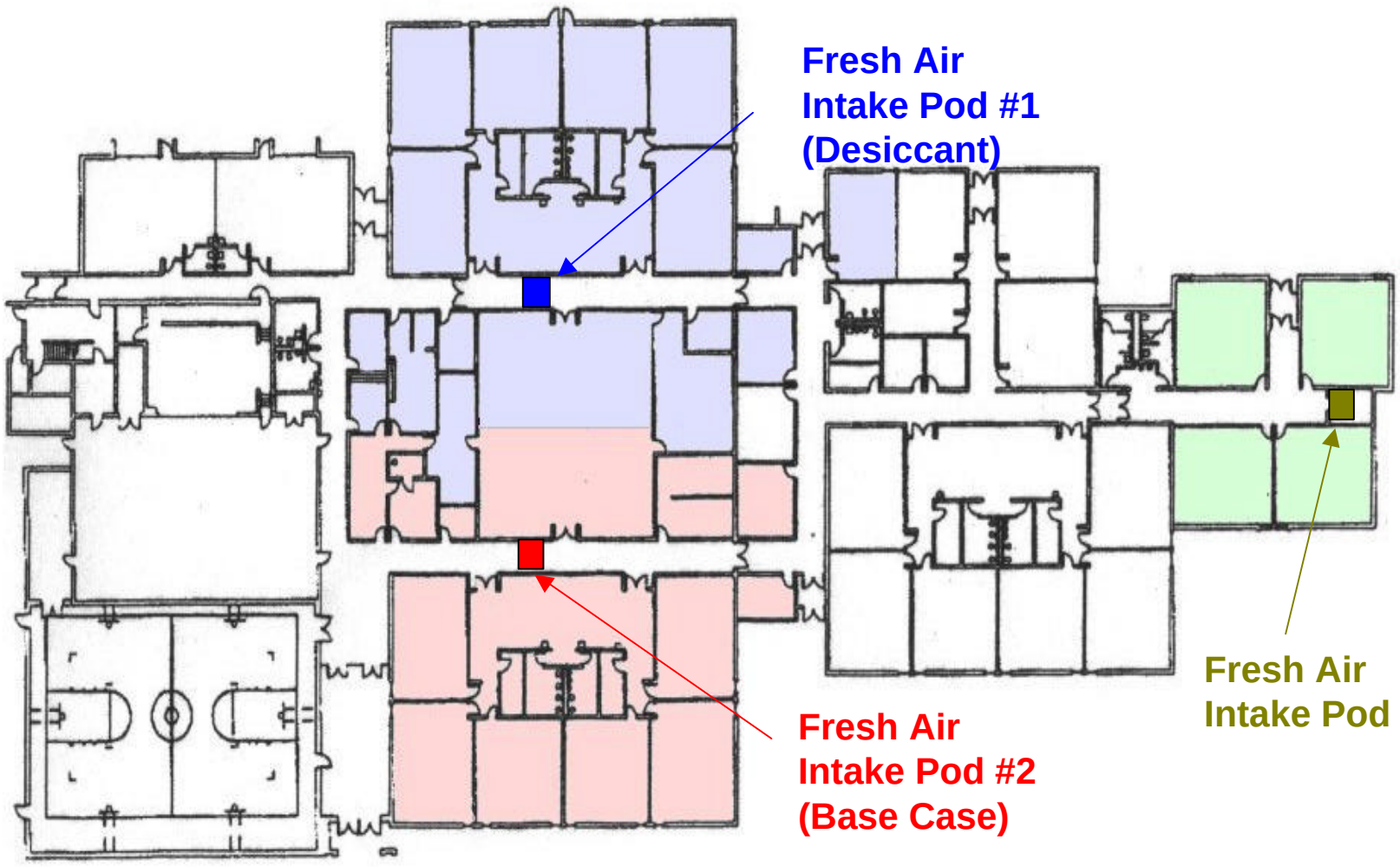
- separate fresh air intakes (ducted to WLHPs)
- 120 students nominal

- Both Pods Have:
- 6 classrooms & wet area
- same no. & type of WLHPS

Desiccant Pod

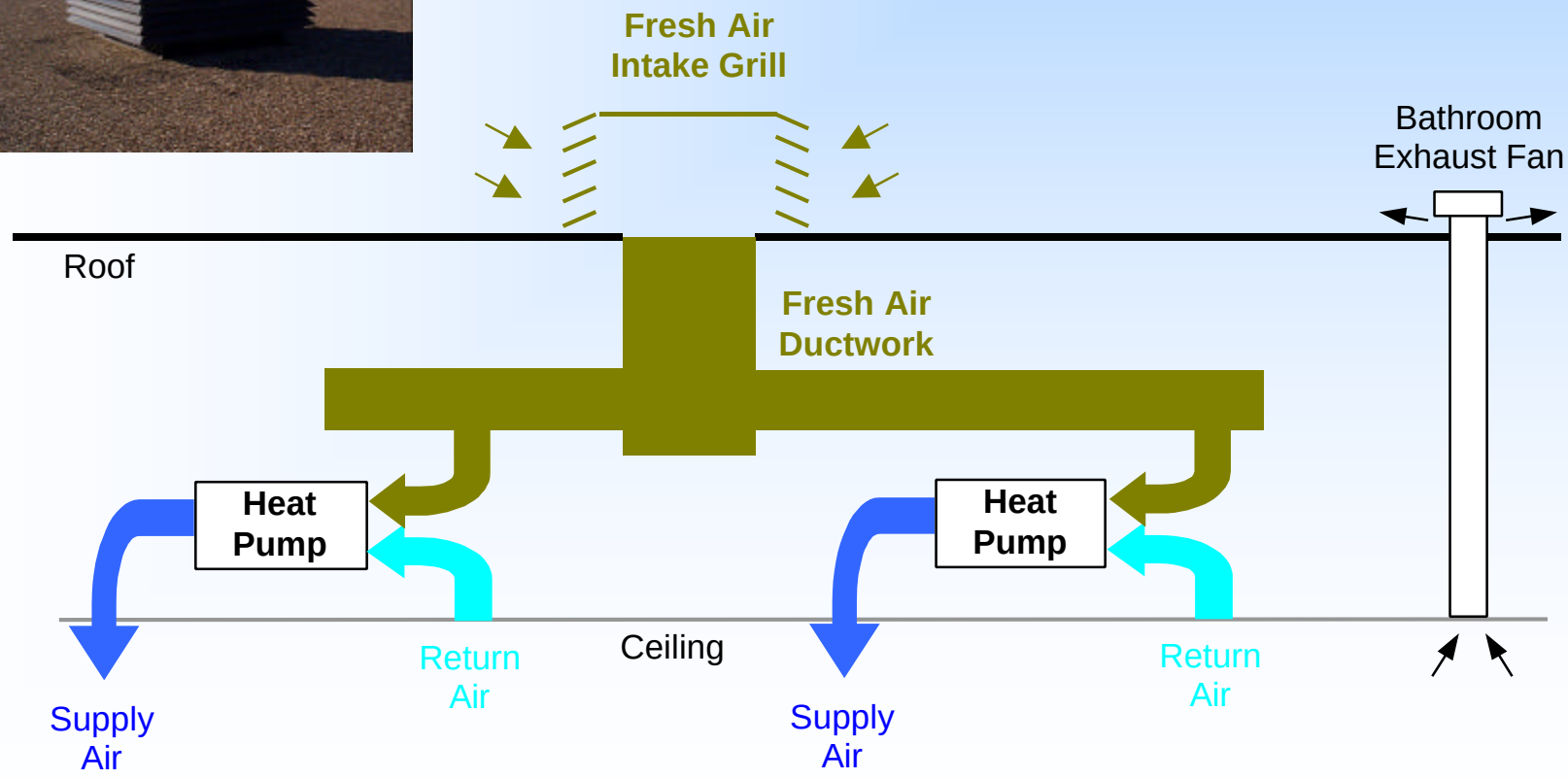
# School Layout

Fresh air intakes also serve other areas!



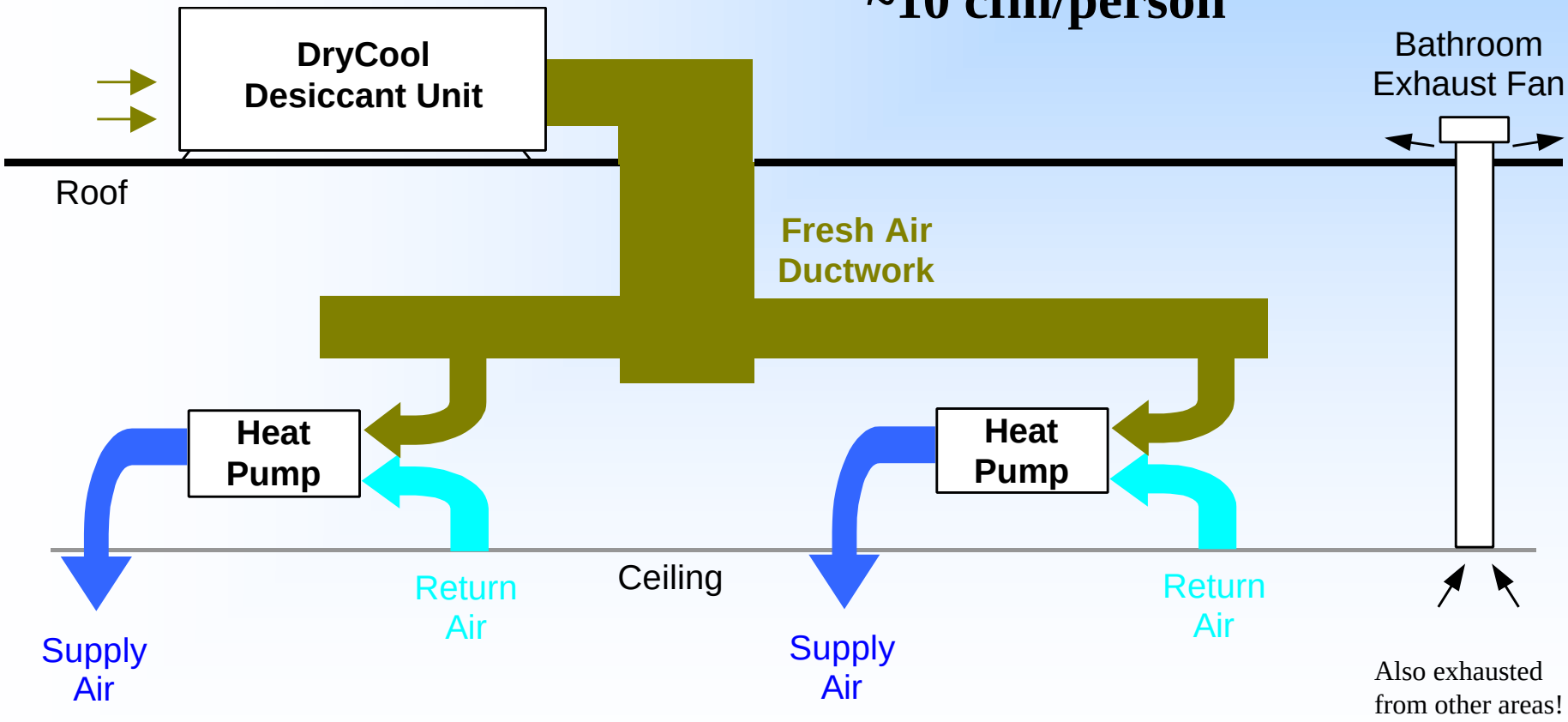
# Pod #2 - Current Fresh Air System

**Ventilation:**
**~4 cfm/person**



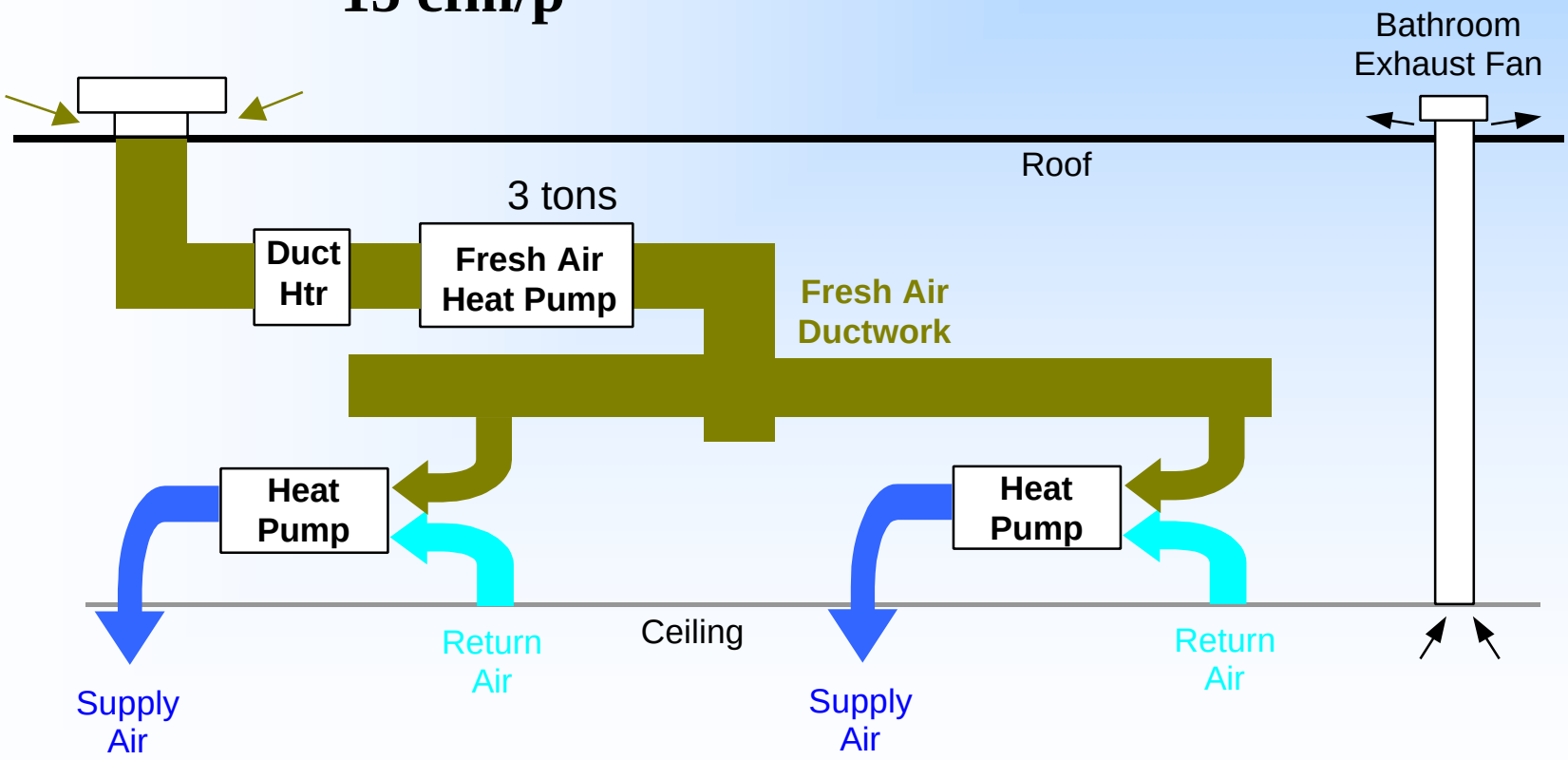
# Pod #1 - New Desiccant System

**Ventilation:**
**~10 cfm/person**

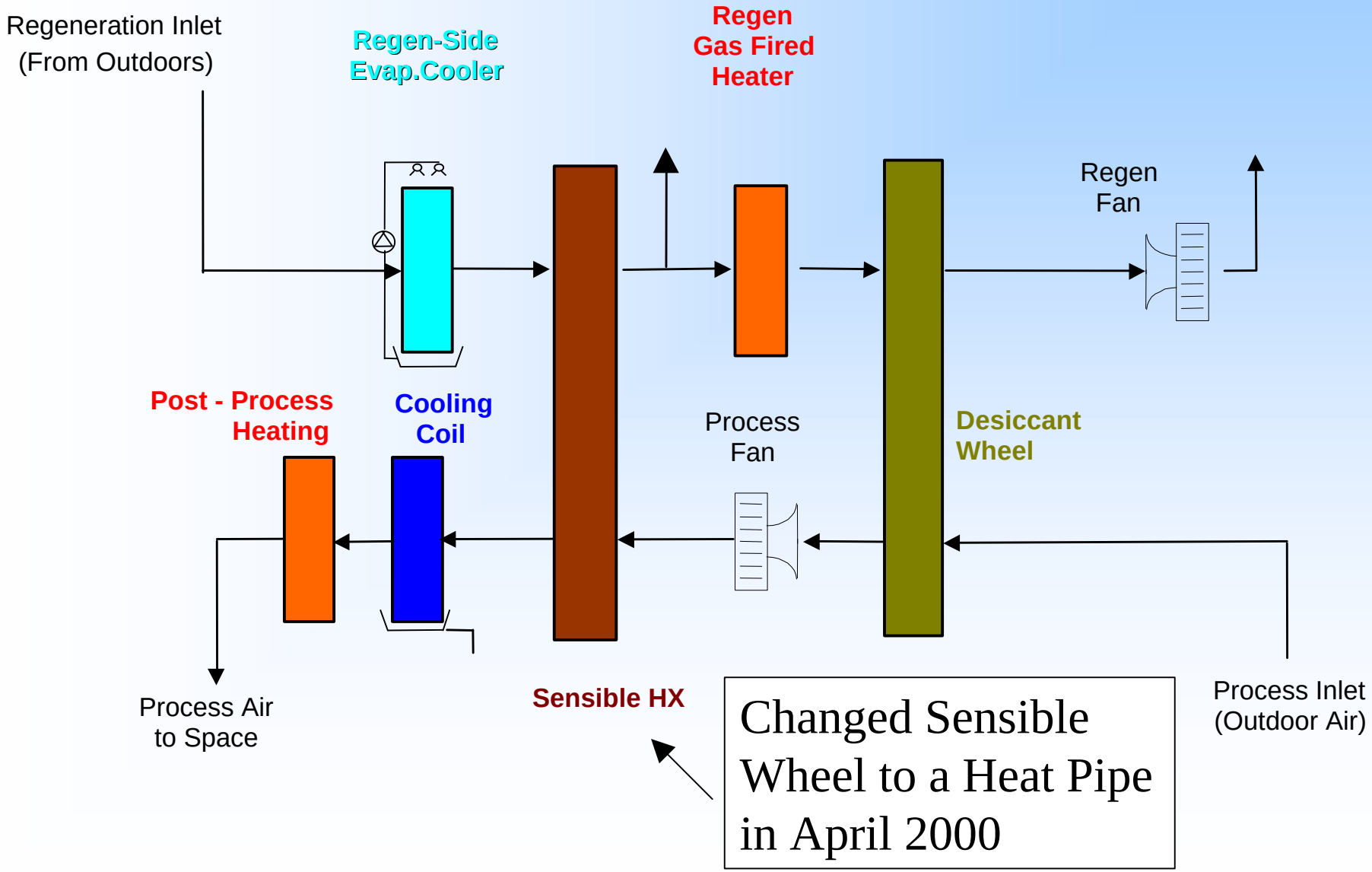


# Pod #4 - Fresh Air Heat Pump

**Ventilation:**
**15 cfm/p**



# Desiccant Unit Configuration




Changed Sensible Wheel to a Heat Pipe in April 2000

# Field Test Approach

- Monitor all three pods *and* fresh air systems
- Collect detailed data (Feb 1999 to Aug 2000)
  - fully monitor status, energy use, and performance of heat pumps in each Pod (sensible cooling system)
  - measure space T, RH, & $CO_2$ in each Pod
  - quantify *actual portion* of fresh air into each Pod with T&B readings & $CO_2$ concentrations
  - quantify desiccant unit and fresh air HP performance, status, and energy use

# Data Acquisition System

- Data Logger for Desiccant Unit (**A**)
- Data Logger for Pod Areas & Heat Pumps (**B**)
- Data Logger for Fresh Air HP & Pod #4 (**C**)
- Total of 106 data points logged every 5 minutes

Data Logger B - Pod Areas

# Initial Operating Issues

- Sensible heat wheel was found to be 65% effective “moisture exchanger” during 1999 season
  - tests of similar wheel at NREL confirmed oxidation changed sensible HX into “enthalpy wheel”
- Heat pipe HX installed in April 2000
  - approx 73% effective (slightly unbalanced)
- Desiccant system operated as expected with heat pipe installed

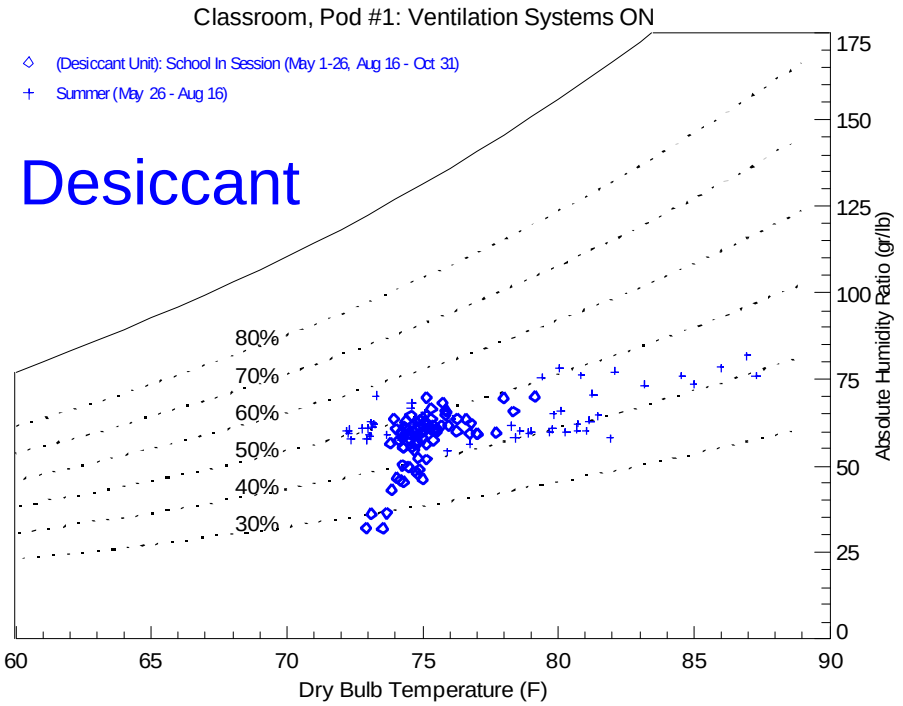
# Measured Ventilation Rates

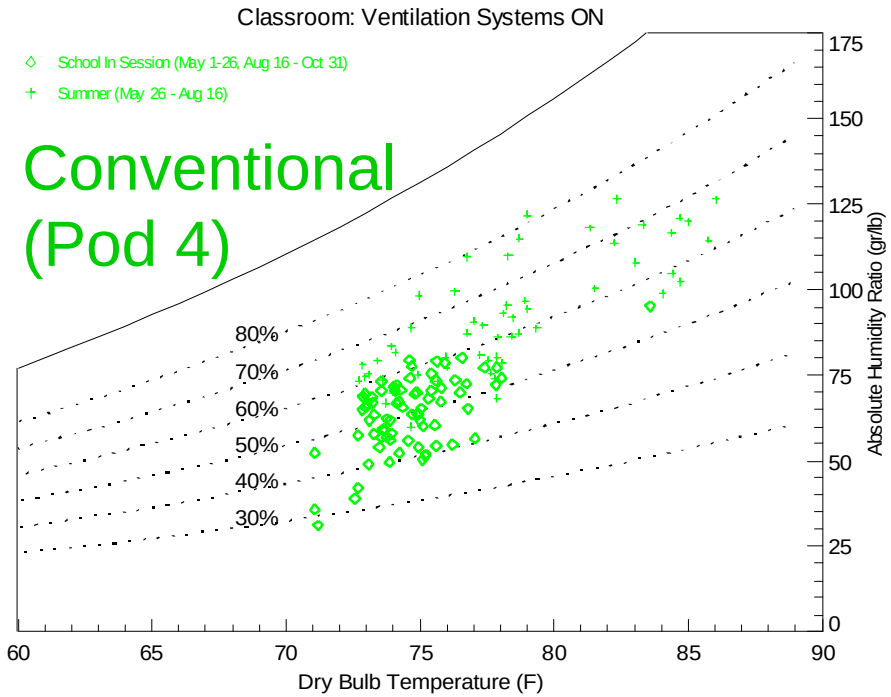
1) multiple-point velocity traverses in system ductwork,
2) energy balance calculations on systems in the heating mode,
3) tracer gas decay tests using artificially-introduced $CO_2$.

| | **Total SYSTEM Ventilation Airflow (scfm) [sl/s]** | **Ventilation Airflow into POD AREA (scfm) [sl/s]** | **Ventilation Provided per Student (scfm/p) [sl/s]** |
|---|---|---|---|
| Pod #1 - Desiccant Unit | ~2,000 [944] | 1,157 [546] | **9.6** [4.5] |
| Pod #2 – Base-Case | 1,062 [501] | 471 [222] | **3.9** [1.8] |
| Pod #4 - Fresh Air HP | 1,510 [713] | 1,510 [713] | **15.1** [7.1] |

Notes: Pod #1 and #2 occupancy averaged 120 students in six classrooms.
Pod #4 occupancy averaged 100 students in four classrooms.

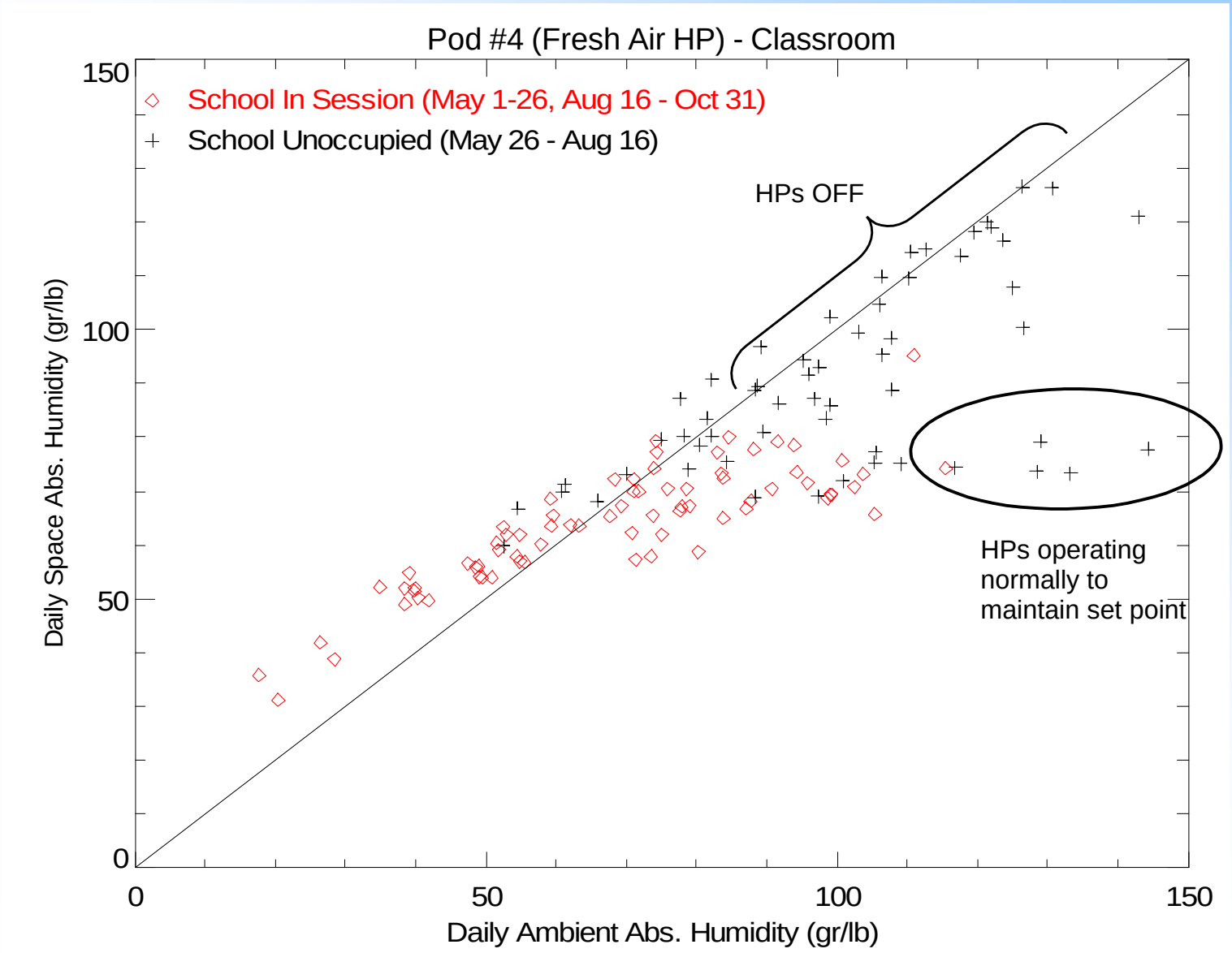
# Desiccants Clearly Provide Better Humidity Control



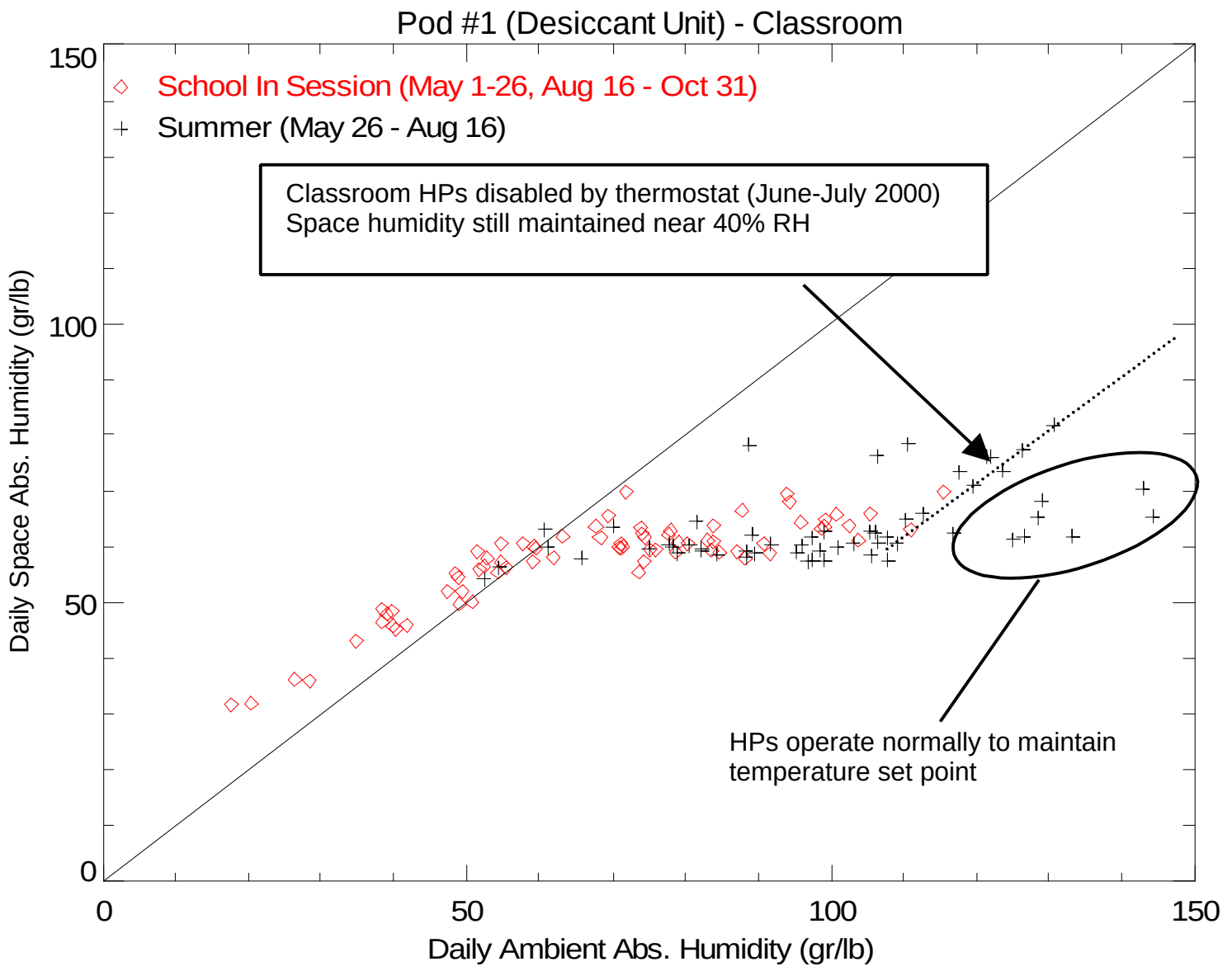




Maintained lower and more consistent humidity levels

# Conventional System (15 cfm/p)

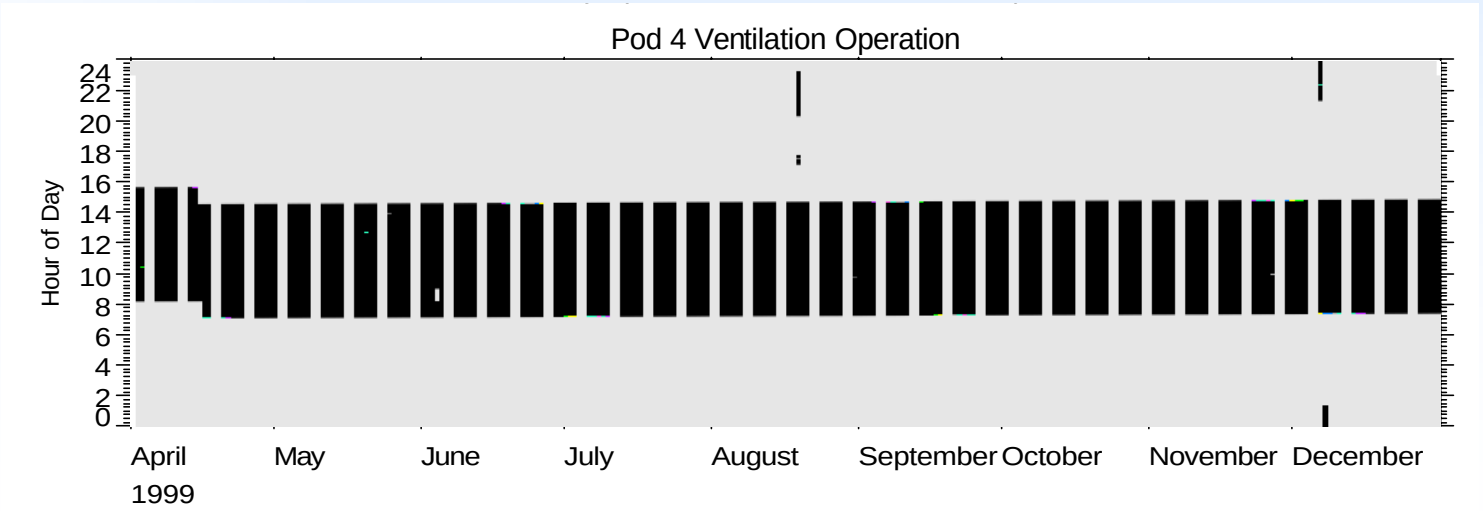


# Desiccant System (10 cfm/p)

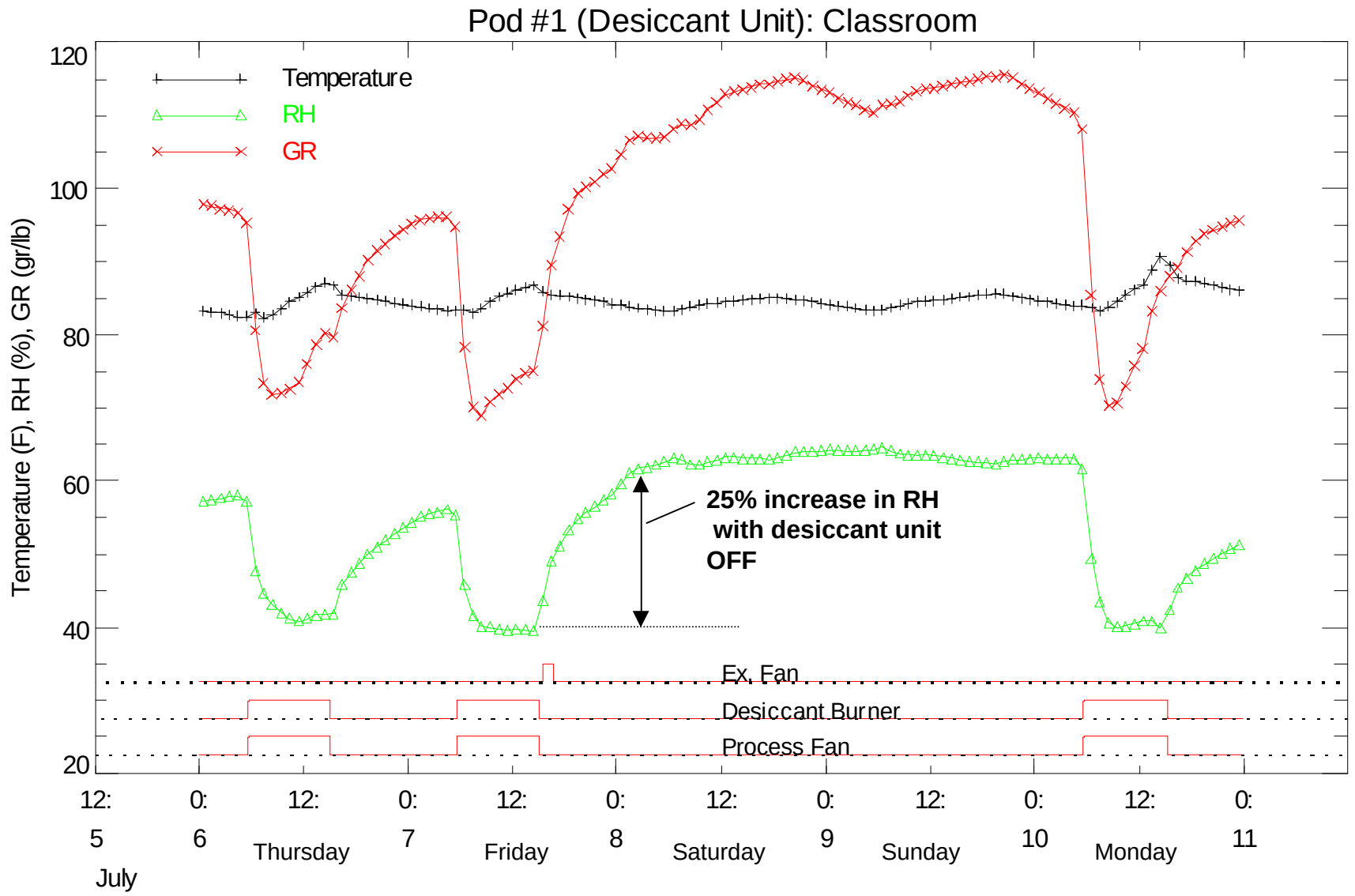


# Typical School Operating Patterns

- Space conditioning & ventilation provided from 7 am to 3 pm weekdays
  - most systems shut down in Summer from May 15 to August 15
- What happened to space conditions during unoccupied periods?



# What Happens on Weekends?

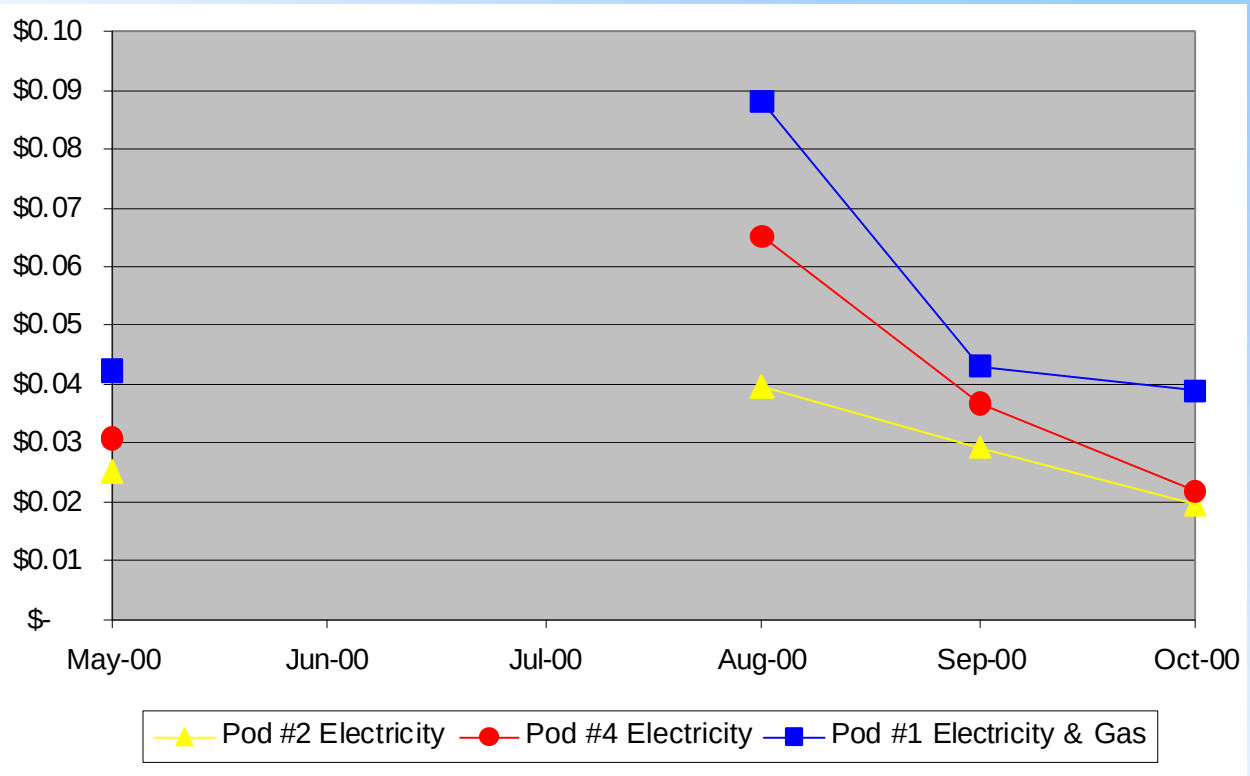


# Energy Use Breakdown

| | POD #1 Desiccant – 10 cfm/p | | | | POD#2 4 cfm/p | POD #4 Conventional – 15 cfm/p | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Month** | **Des Unit (therms)** | **Des Unit (kWh)** | **WLHPs (kWh)** | **Total (kWh)** | **WLHPs (kWh)** | **FAHP (kWh)** | **Duct Heater (kWh)** | **WLHPs (kWh)** | **Total (kWh)** |
| Nov-99 | 323 | 810 | 1,250 | 2,060 | 1,068 | 167 | 167 | 268 | 602 |
| Dec-99 | 371 | 847 | 738 | 1,585 | 545 | 175 | 909 | 360 | 1,445 |
| Jan-00 | 352 | 755 | 724 | 1,479 | 477 | 162 | 1,207 | 507 | 1,875 |
| Feb-00 | 208 | 708 | 489 | 1,197 | 512 | 160 | 581 | 341 | 1,082 |
| Mar-00 | 208 | 796 | 266 | 1,062 | 664 | 161 | 308 | 276 | 746 |
| Apr-00 | - | 806 | 434 | 1,240 | 935 | 209 | 133 | 466 | 808 |
| May-00 | 90 | 1,119 | 1,182 | 2,301 | 1,841 | 164 | - | 744 | 908 |
| Jun-00 | 152 | 1,355 | 782 | 2,137 | 597 | 162 | - | 155 | 317 |
| Jul-00 | 239 | 1,886 | 1,044 | 2,931 | 808 | 175 | - | 239 | 413 |
| Aug-00 | 227 | 2,008 | 2,448 | 4,457 | 2,899 | 210 | - | 1,703 | 1,913 |
| Sep-00 | 65 | 1,022 | 1,550 | 2,572 | 2,144 | 168 | 0 | 908 | 1,077 |
| Oct-00 | 102 | 966 | 983 | 1,948 | 1,435 | 158 | 19 | 463 | 640 |
| **Annual** | **2,337** | **13,078** | **11,890** | **24,968** | **13,923** | **2,070** | **3,324** | **6,430** | **11,824** |
| | | *(52%)* | *(48%)* | *(100%)* | *(100%)* | *(18%)* | *(28%)* | *(54%)* | *(100%)* |

Notes: Desiccant unit gas use includes dehumidification and vent pre-heating. Desiccant unit electric use includes ventilation/process fan, regeneration fan, and AC condensing unit for post-cooling coil. WLHPs – water loop heat pumps in each Pod. FAHP is fresh air heat pump in Pod #4.

# Comparing HVAC Operating Costs




**Energy Use Summary for the Three Pod Areas (May, August, September & October 2000)**

| System | Electric Costs ($/sq. ft.) | Gas Costs ($/sq. ft.) | Total Costs ($/sq. ft.) | Increased Energy Costs |
|---|---|---|---|---|
| Pod #2 Base-case - 4 cfm | 0.11 | - | 0.11 | - |
| Pod #4 Fresh air HP - 15 cfm | 0.15 | - | 0.15 | +36% |
| Pod #1 Desiccant - 10 cfm | 0.15 | 0.06 | 0.21 | +86% |

Notes: $0.08/kWh and $0.70/therms

# Why are Desiccant Operating Costs Higher?

- Meeting additional load
  - more moisture removal
  - meeting latent loads adds sensible loads to AC
- Desiccant unit fan power is 2-3 times a conventional rooftop unit (~1-2 Watts/cfm)
  - ventilation must be supplied through desiccant wheel for entire year
- Fan power is largest annual cost

# Summary

- Desiccant system provided better humidity control
  - space 10-15 gr/lb drier at peak conditions
  - more *consistent* than with conventional AC
- Schools need dehumidification independently of ventilation
  - long unoccupied periods during weekends and breaks (84% of year)
  - unoccupied dehumidification may be the most important aspect of providing good IAQ (i.e., controlling mold & mildew)

# Summary (cont.)

- Other desiccant system configurations may meet application needs and have lower operating costs
  - especially configurations that let conventional AC meet part of latent load
  - don’t treat the entire ventilation or supply air stream (allows for smaller equipment)
  - don’t pull all ventilation air through the desiccant system