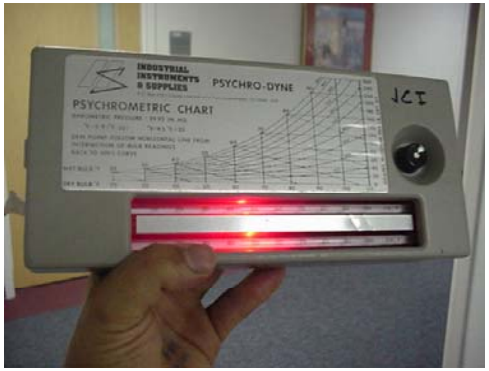
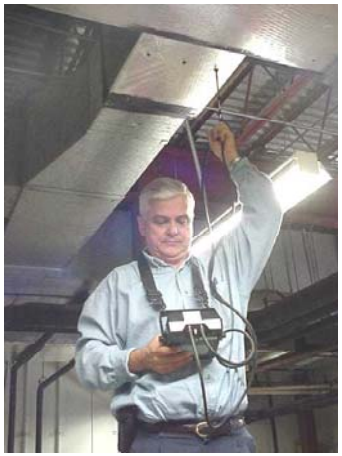
Indoor Air Quality (IAQ) in Schools





Scott Forsyth, PE, CEM, CIAQP

Johnson Controls Inc., Florida Team

Why Consider Indoor Air Quality?

- **Good IAQ in Schools**
  - Enhances student learning
  - Promotes occupant health, reduces absenteeism and reduces Workman's Comp costs
  - Promotes comfort and productivity of all school occupants
  - Reduces re-mediation and litigation costs
  - Minimizes life cycle costs (consider all costs, typical school budget: people-55% and energy-1.5%)

Indoor Air Quality Benefit Documentation

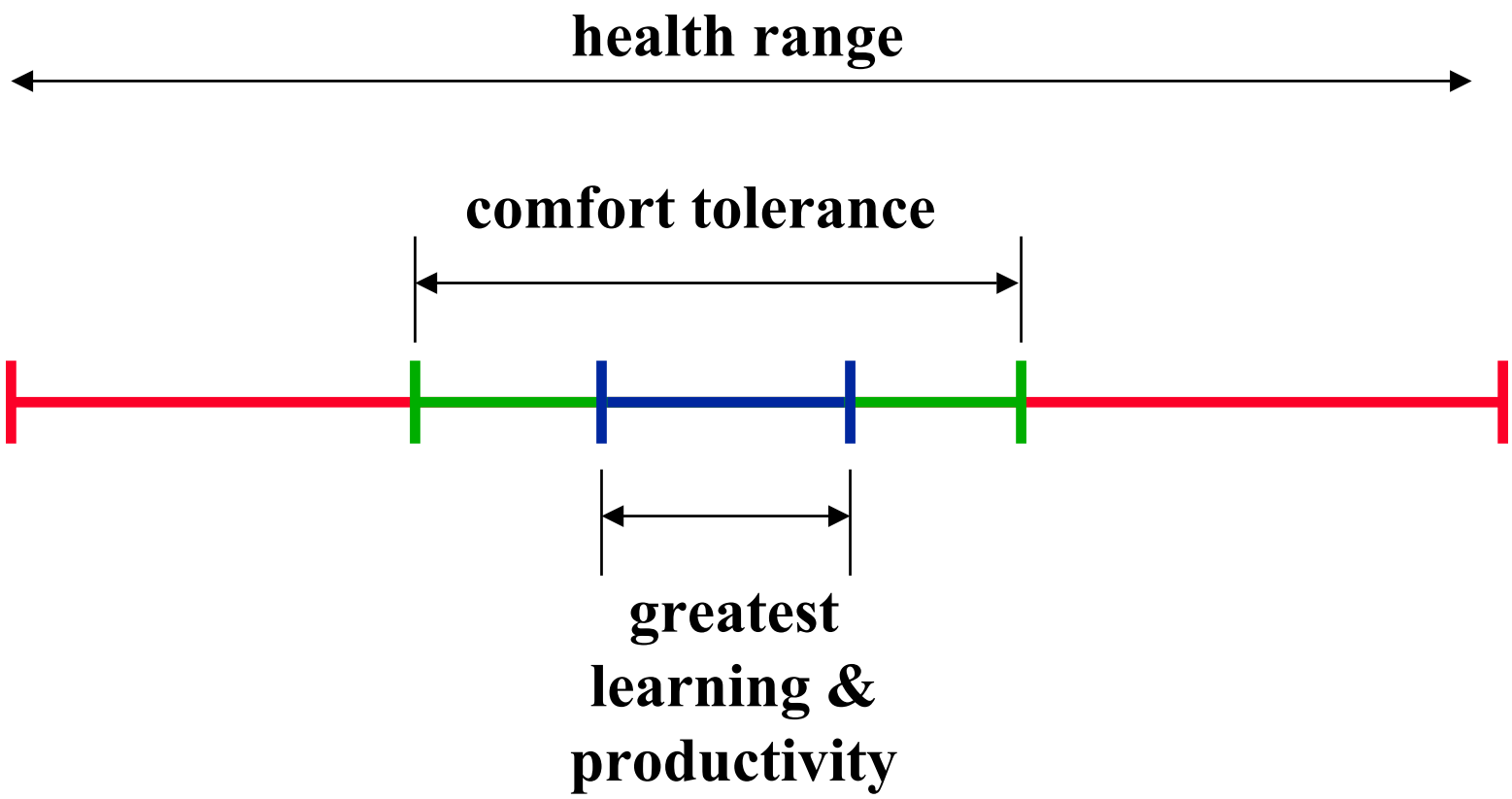
Recent ASHRAE Journal Articles Include:

- How IEQ Affects Health and Productivity, May 02
- Day-lighting and Human Performance, June 02
- IEQ and the Impact on Employee Sick Leave, July 02
- Ventilation Rates and Health, August 02
- HVAC Characteristics and Occupant Health, Sept. 02

Thermal Effect on Learning & Productivity Studies Include:

- Lofstedt,, Ryd and Wyon, 1969, How classroom temperatures affect performance of school work
- Wyon 1974; thermal effects on routine office work
- Mackie et al. '74 / Norin & Wyon '92; thermal effects on driver performance
- Wyon et al. 1980, thermal effects on manual dexterity and typing
- Kroner et al. 1992, individual control of worker's environment and productivity

Thermal Effects on Learning and Productivity



ASHRAE Standard 62-2001: Ventilation for Acceptable IAQ

- Compliance Methods
  - Ventilation Rate Procedure (Prescriptive)
  - IAQ Procedure (Theoretical, can't just use CO2 level)
- Proposed Addendum 62N Ventilation Rates

Space Use	Resulting Outdoor Air Intake CFM/person 62	62N	62N CFM/person	62N CFM/ft^2
Office Areas	20	18.2	6	.06
Classrooms	15	11.1	6	.1

Common Indoor Contaminants, Symptoms and Sources

- Molds, bacteria, virus and other microbes
  - Allergic reactions
  - Respiratory problems
  - Odors
  - Sinus problems
  - Legionnaire's Disease
- Formaldehyde
  - Eye and skin irritation
  - Suspected carcinogen
- Volatile Organic Compounds
  - Odor
  - Headache
  - Eye and respiratory irritation

Sources

Mold, mildew, leaks and water damaged surfaces, HVAC system coils and drip pans, people, cooling towers, outdoor air

Particleboard, plywood, furniture, cleaners, glues/resins

Solvents, paints, adhesives, building materials, waxes/polishes, pesticides, binders, copiers & printers

Common Indoor Contaminants, Symptoms and Sources

Sources

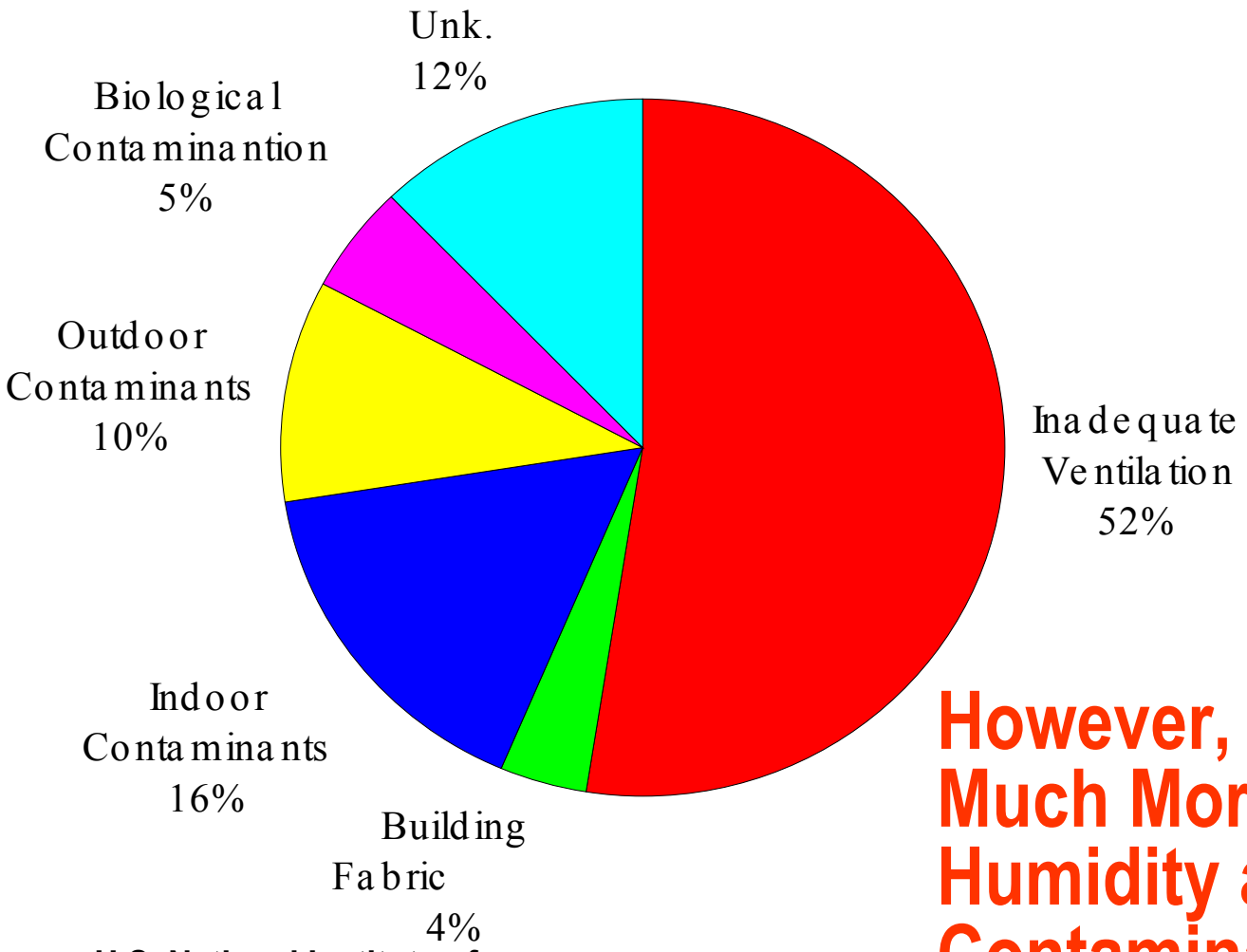
- Particulates
  - Eye and Skin Irritation
  - Respiratory Problems
  - Sinus Problems

  Foot Traffic, Carpet, Copiers, Printers, Infiltration Air, Inadequate Filtration

- Thermal Conditions
  - Discomfort
  - Sleepiness and Fatigue

  Improper Temp. or RH, Drafts, Direct Solar Heat

Nationwide Documented Causes of Poor IAQ



Source: U.S. National Institute of Occupational Safety and Health

However, Florida Has Much More Moisture, Humidity and Mold Contaminant Problems!!

Major Factors in Delivering Good IAQ and Avoiding Sick Building Syndrome

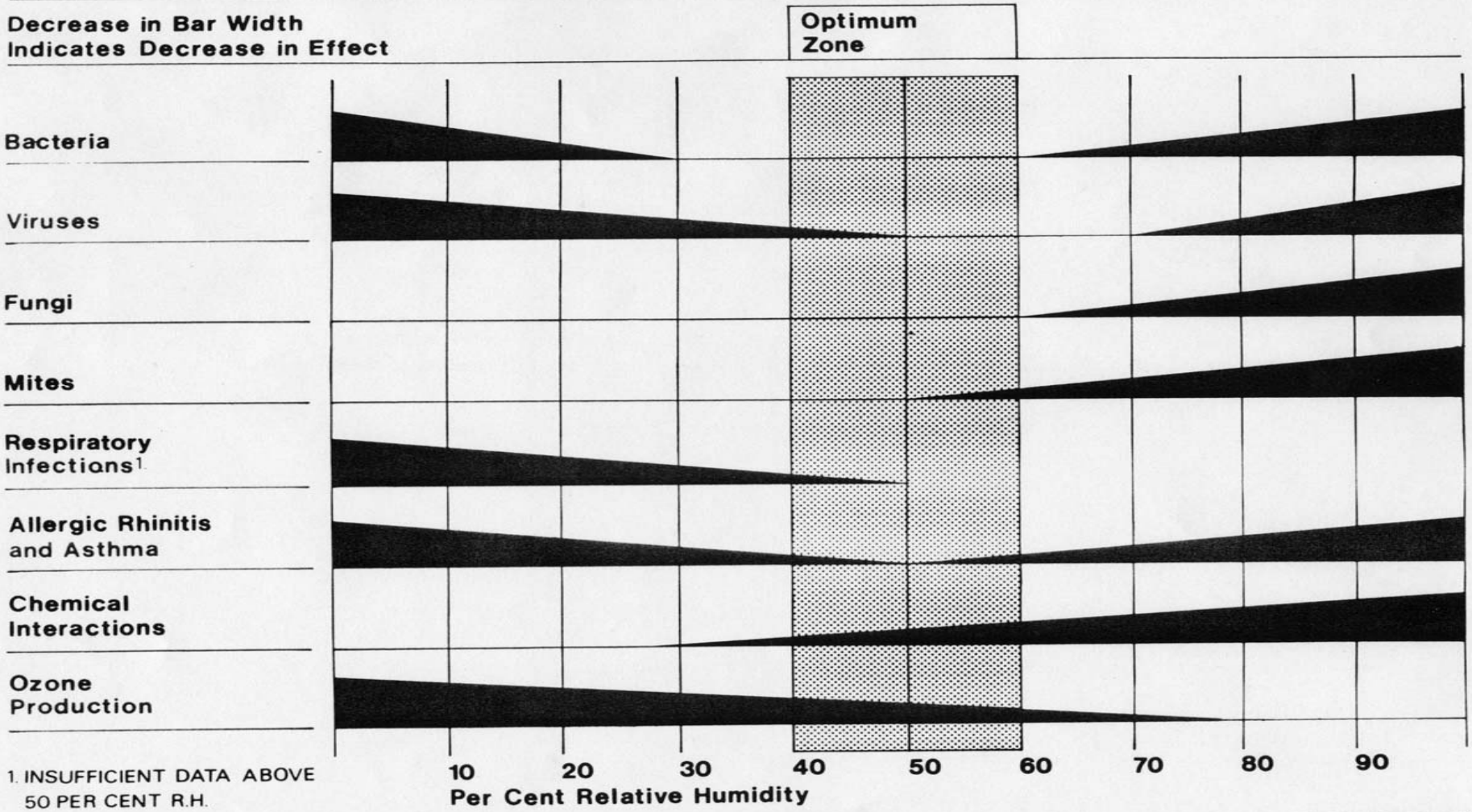
- Maintenance - written tasks, procedures and documentation when complete
- Moisture and leaks (roof, wall, piping, etc. leaks)
- Building pressurization (outdoor air exceeds exhaust)
- Relative humidity levels - AC dehumidifies well
- Ventilation - outdoor air qty. preferably to ASHRAE
- Occupant Comfort - ASHRAE stds., occupant control
- Filtration - minimum 20 % dust spot (pleated)

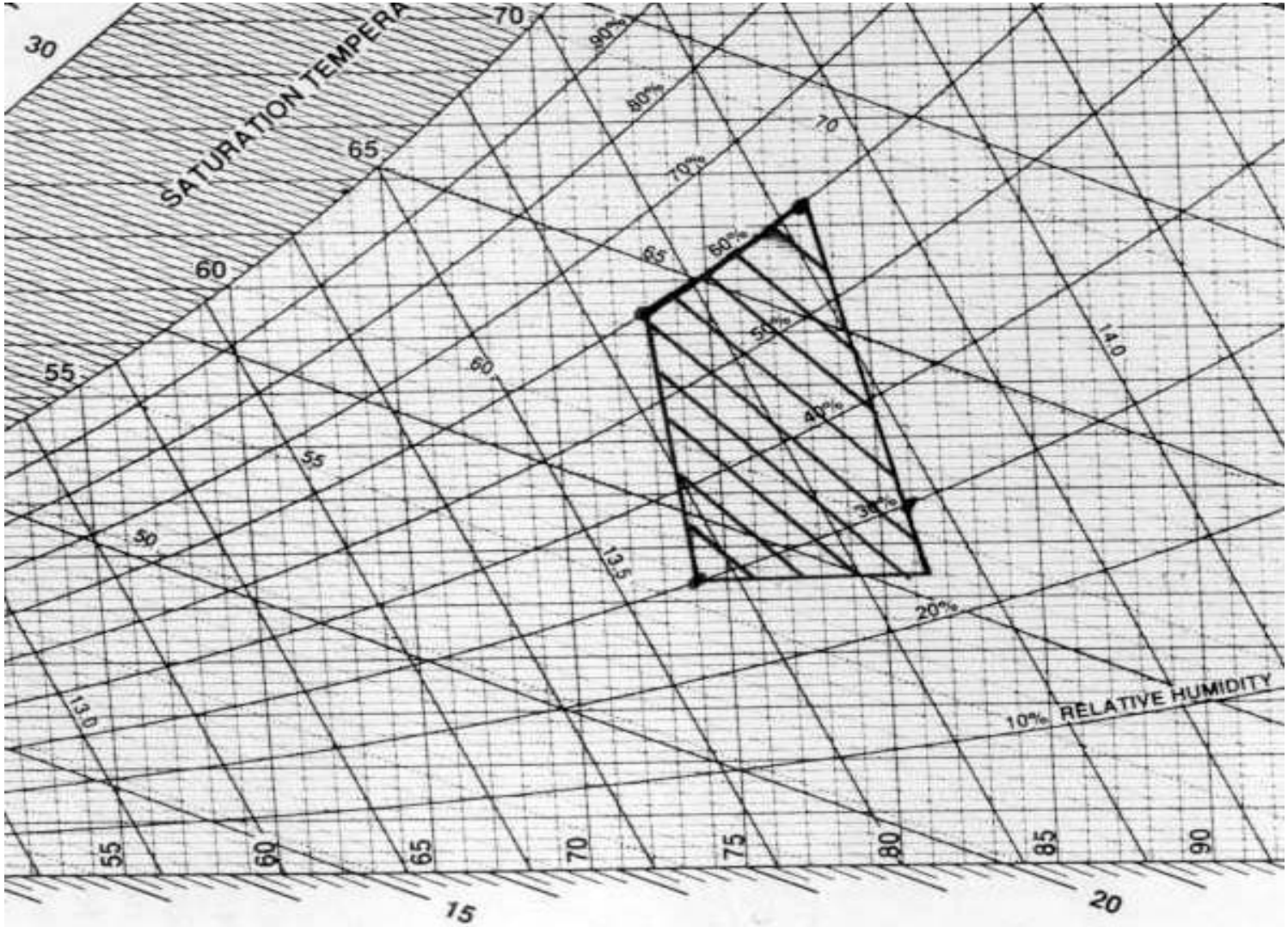
Moisture, Humidity and Microbial (Particularly Mold) Contamination: A Very Common and Significant Cause of Sick Building Syndrome in Florida Schools

- Mold, mildew and yeast are fungi, a microbial contaminant
- Can cause health problems including asthmatic and allergic reactions, fungal lung infections (aspergillus, for example) and with chronic exposure can lead to hypersensitive pneumonitis
- ASHRAE Standard 62: "RH...should be maintained between 30 and 60% to minimize growth of allergenic and pathogenic organisms."
- Fungi thrive on organic but can grow on inorganic surfaces
- Will grow in building materials or on surfaces if they have a high RH even though the space RH may be low

Relative Humidity and Health Related Factors

Source: ASHRAE Transactions 1984





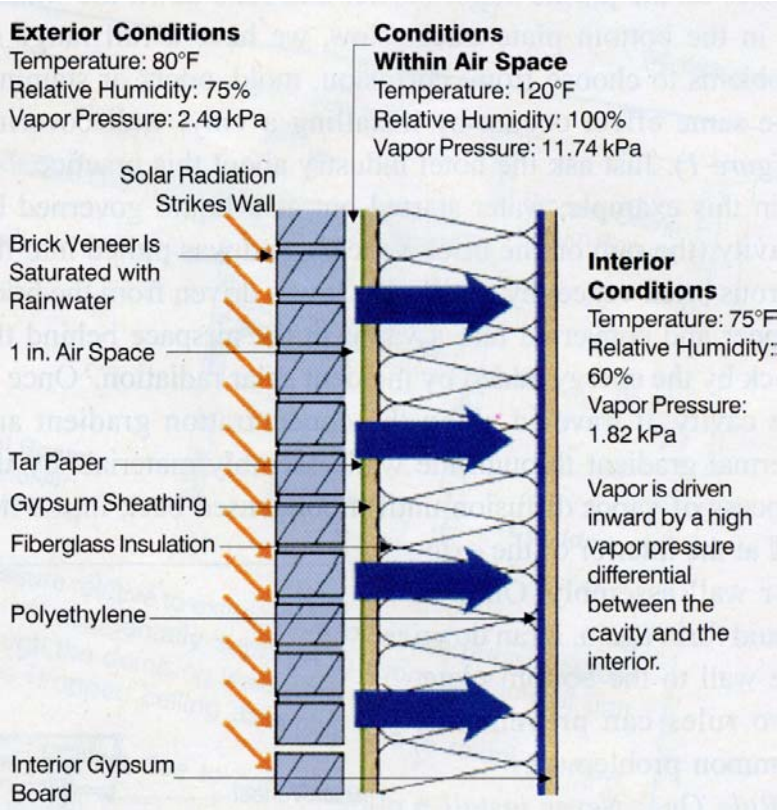
ASHRAE COMFORT RANGE

Three Basic Types of High RH and Modes of Mold Growth in Buildings

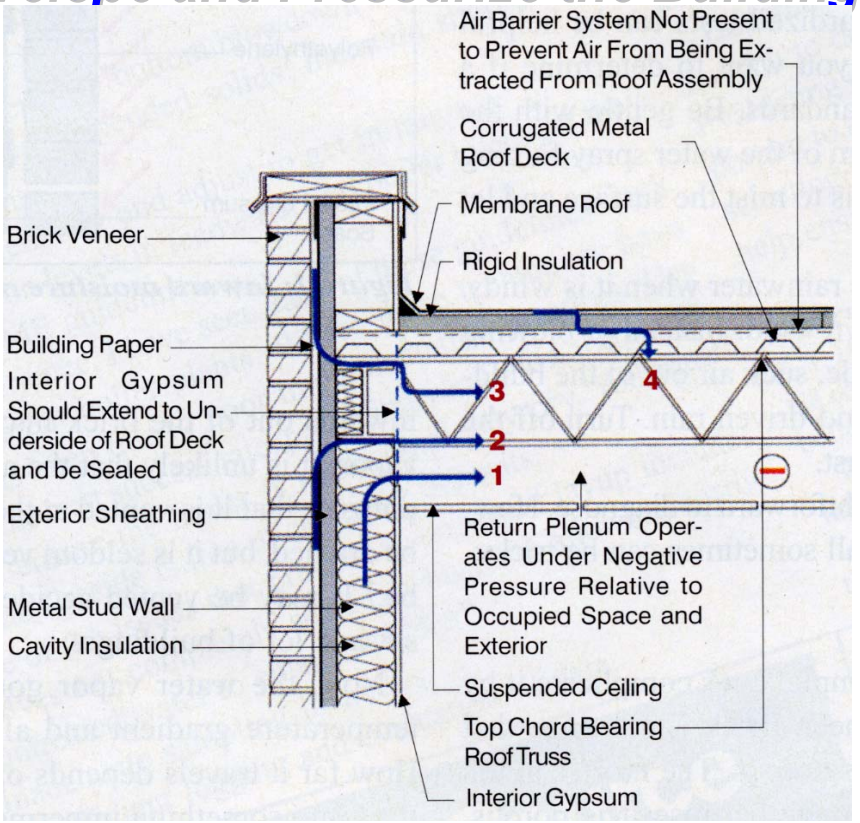
- High space RH allowing growth on a number of different surfaces (mold growth on books, supplies and furnishings for example)
- High RH or moisture in or on building materials or furnishings from moisture sources (roof, wall or AC leaks on ceiling tiles for example)
- High RH or moisture in or on building materials caused by differences in temperature. A common SBS related problem in Florida is high RH behind vinyl wall coverings on the inside surface of exterior walls. To eliminate:
  - Install an effective vapor barrier on the exterior side of the insulation (humid climate solution is opposite of northern)
  - Do not install impermeable finishes on the inside surface!

Common Problem: Moisture/Air Intrusion through Envelope

Solution: Construct a Tight Building Envelope and Pressurize the Building!



Moisture (Steam) Migration through Exterior Walls



Air / Moisture Infiltration into Negative Pressure Return Plenums

*Mold, Mildew and Moisture, Building Science Corp., 1992
*Preventing IAQ Problems in Hot, Humid Climates, Disney and CH2MHill, 1996
*Investigating and Diagnosing Moisture Problems, ASHRAE Journal, 12 / 2002, p. 36-41

What can be done to deliver good IAQ?

- Provide quality design, construction, commissioning and O&M Services to written standards
- Select professional services, contractors and building systems and components based upon quality, experience and value, NOT first cost.
- Good communication between all project team members including owner

What can be done to deliver good IAQ?

- Provide Quality Professional Design Services
  - To ASHRAE, IES, AIA and other industry standards as a minimum
  - Develop supplemental design written standards (example: all AHUs and FCUs shall be located in mechanical rooms with sloped floors to drains)
- Design for good part load system performance (particularly dehumidification)
- Design to facilitate ease of O&M
- Provide life cycle cost analysis for system selection
- Compensate design professionals adequately for basic and additional services

What can be done to deliver good IAQ?

- Provide "Fresh" Outdoor Air Distributed by a "Clean" HVAC System
  - **Positive building pressurization (outdoor air introduced exceeds exhaust air)**
  - **Locate outdoor air intakes away from potential contaminant sources**
    - **plumbing and exhaust vents**
    - **standing water**
    - **birds nests and droppings**
    - **loading dock vehicle exhaust**

What can be done to deliver good IAQ?

- Provide "Fresh" Outdoor Air Distributed by a "Clean" HVAC System
  - HVAC system components may be contaminant, particularly microbial, amplification sites

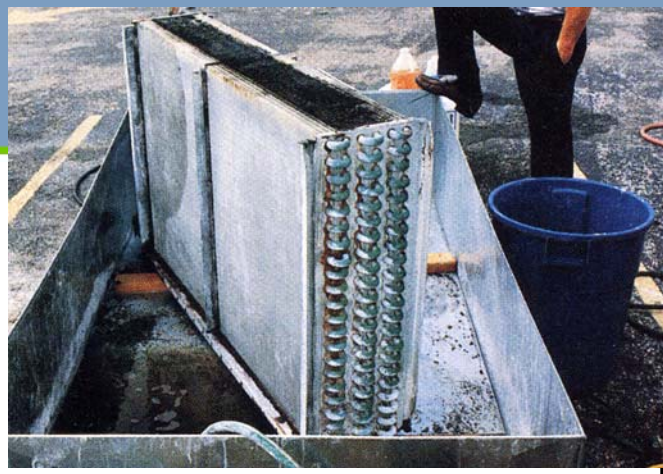
- Coils
- Drain pans - positive slope and drain?
- Inside surfaces of AHUs and ducts
- Are components accessible and clean-able?

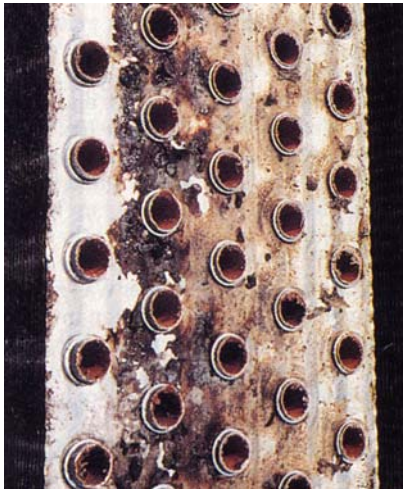
What can be done to deliver good IAQ?

- Provide Good Filtration To Remove Particulate Contaminants
  - Help keep coils, drain pans and ducts clean to reduce microbial food source
    - ASHRAE 62 Add. S requires minimum Filter MERV (Std. 52.2) of 6 (Approx. 20% Dust Spot)
    - Requires pleated filters, not flat panel type
    - Maintain good fit to eliminate/reduce bypass

Coil Cleaning

- Coils that are "deeply soiled" can't be physically cleaned, even after soaking and blasting with 180 ^{o}F water
- Coils may appear clean but have significant soiling within
- The only way to determine a coil's soiled condition is to measure CFM and the pressure drop across the coil and compare to original specs
- Use fan law to adjust for non-design CFM measured (press. drop across a coil varies as the square of the flow)
- Utilize good filtration maintenance to keep from having to replace coils pre-maturely





What can be done to deliver good IAQ?

- Provide Design and Installation which Facilitates HVAC System Maintenance
  - HVAC equipment which is relatively inaccessible will not be frequently accessed for service
    - Do not locate units with cooling coils above ceilings
    - Provide adequate access to roof mounted equipment
  - Locate equipment outside of occupied spaces, preferably in appropriately sized equipment rooms with sloped floors to drains

What can be done to deliver good IAQ?

- Project Team and Building Owner Should Communicate to Establish:
  - Space Occupancy ~ Ventilation Rates
  - Space Usage ~ Ventilation Rates
  - Occupancy Schedules
    - Zoning of HVAC Equipment
    - Interlocking of Exhaust Fans
    - Control of Zone and Building Space Pressurization
  - Contaminant Generating Equipment
    - Attempt to Isolate from Occupants (central printer and copier room for example)
    - Local Exhaust Source Control

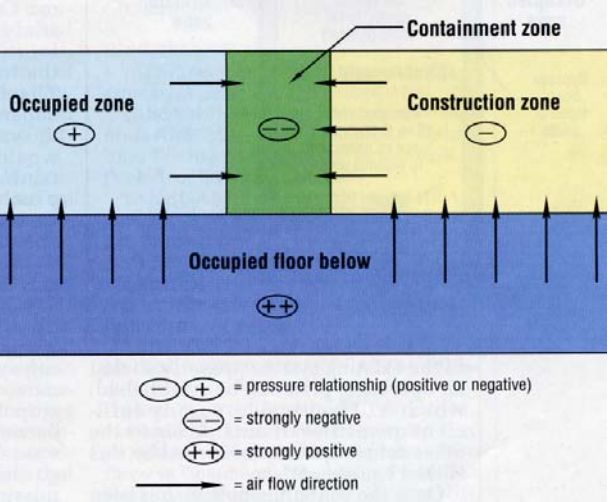
What can be done to deliver good IAQ?

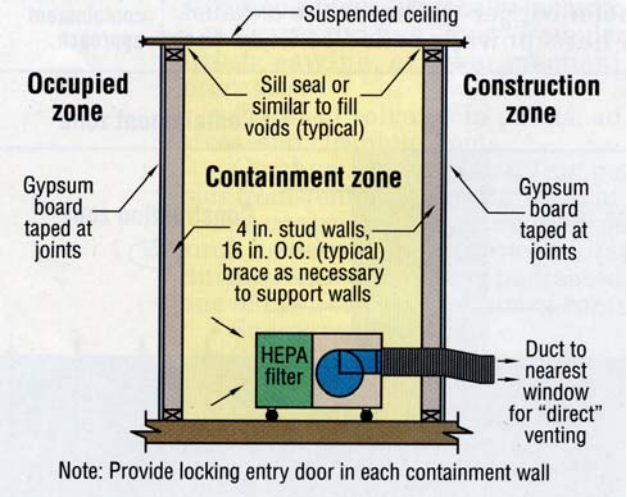
- Select Components to Be Placed in the Building Which are IAQ Friendly
  - Construction Materials (paint, carpet, ceiling tile, etc.)
  - Furnishings (partitions, desks, chairs, etc.)
  - Equipment and Machines (copiers, printers, etc.)
- Growing independent testing lab industry using high tech environmental chambers to determine type and quantity of VOCs, particulates, ozone, etc. emitted.
- Specification criteria and standards are growing (examples include Carpet and Rug Institute IAQ Guidelines, EPA LEED Program, criteria form State of Washington, State of Alaska, EPA Headquarters, etc.)

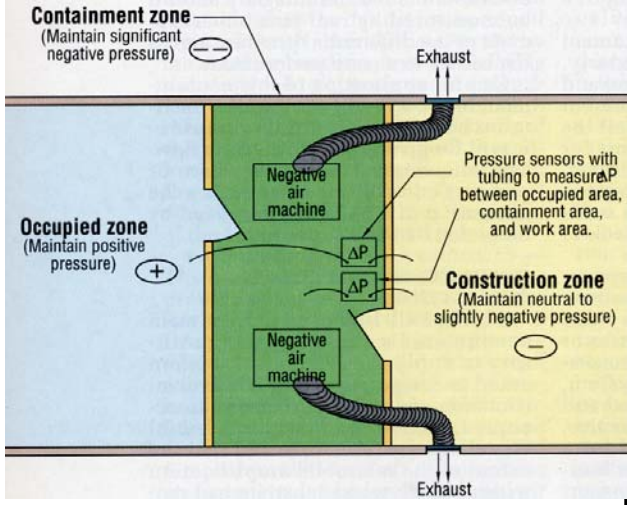
What can be done to deliver good IAQ?

- Provide Building Commissioning and HVAC Test and Balance (TAB)
  - Perform Initial Building Commissioning and HVAC System Test and Balance (TAB)
    - TAB required by ASHRAE 62 addendum L
    - TAB by certified firm (NEBB)
  - Limited Re-Commissioning and TAB ~ every 5 years or as needed due to:
    - Changes in Occupancy, Use, Schedule, Equipment
    - Equipment Wear and Tear
    - New Pollutant Sources Introduced

Avoiding IAQ Contamination During Construction, Maintenance and Mold Remediation Projects







Resources:

- IAQ Guidelines for Occupied Buildings Under Construction, SMACNA, 1995.
- Ventilation Practices & Systems for Existing Buildings, HPAC Supplement, Spring 1999, p. 16-19.
- Mold Remediation in Schools and Commercial Buildings, EPA, (available at www.epa.gov/iaq/molds)

Operation and Maintenance for Good IAQ

- ASHRAE Std. 62 Add. M Addresses Operation and Maintenance
  - Building Documentation Readily Available
    - Plans
    - O&M Manuals
    - Commissioning and TAB Reports
    - Control System Schematics and Sequences
  - Operation and Maintenance Procedures
    - Written Program of all Tasks and Schedules
    - Proactive and Reactive as Appropriate
    - Task Completion Documentation
    - Occupant Communication System
      - Empowers Occupants with Insight, Information and Influence
      - Complaint and Action Log

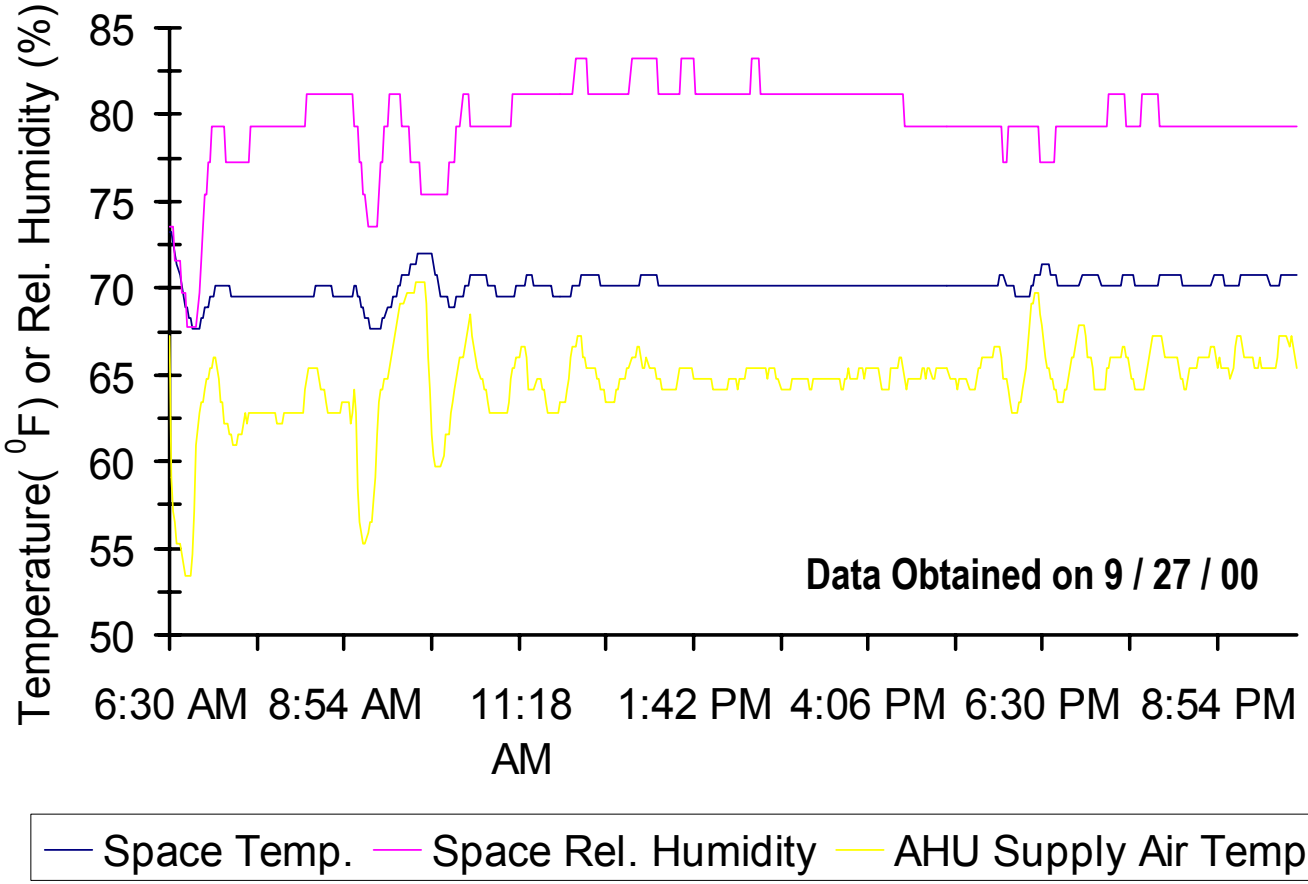
Select Operational Settings that Promote Good IAQ

- Lower AHU supply air temperatures to improve dehumidification performance
- Lower chilled water supply temperatures to improve dehumidification performance
- Operate HVAC systems as necessary to insure positive building pressurization during full and partial occupancy periods
- Operate HVAC systems as necessary to prevent excessive RH levels

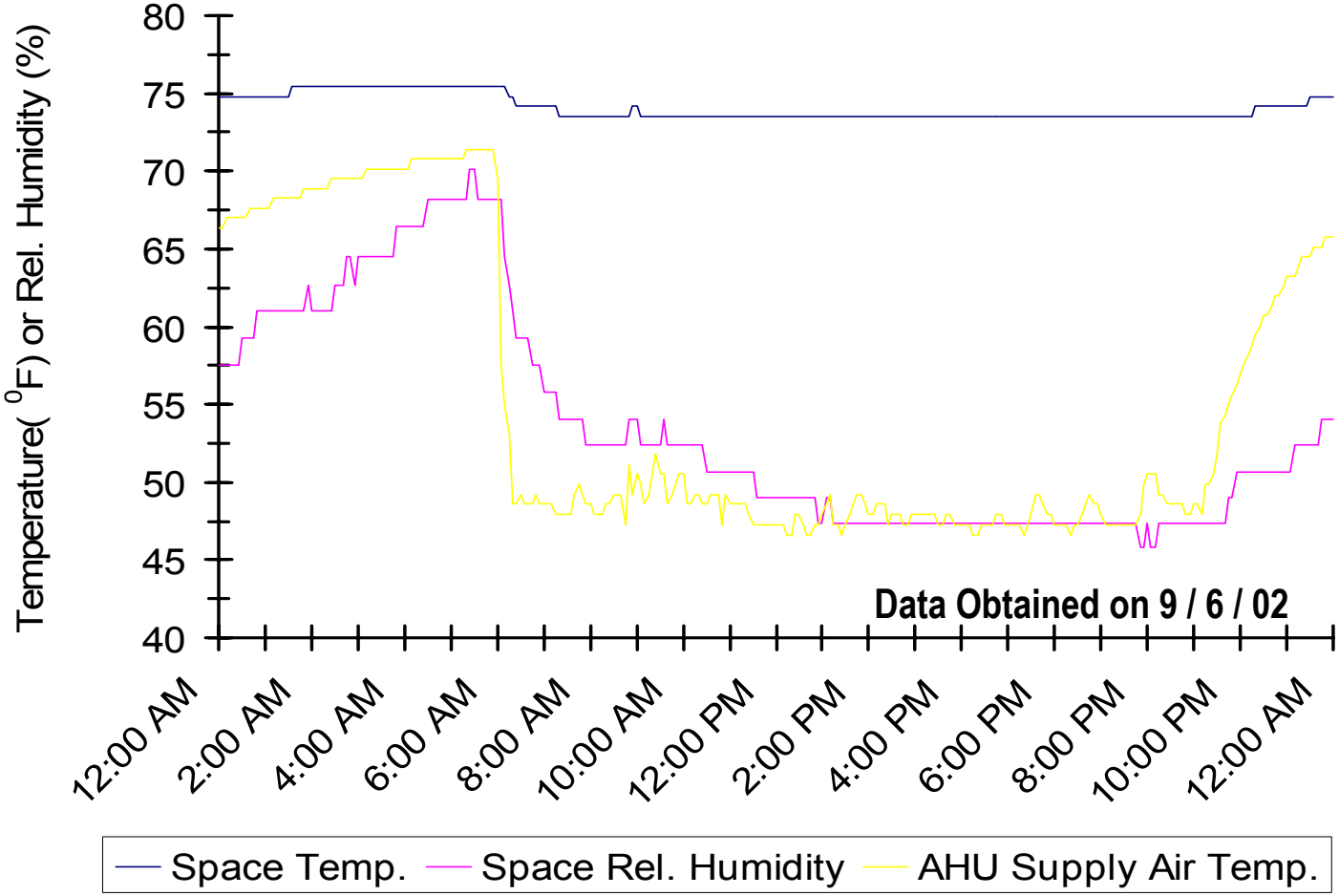
Select Operational Sequences that Provide Good Dehumidification

- Constant Air Volume Chilled Water AHUs and FCUs
  - Eliminate space temperature control sequences which dehumidify poorly such as:
    - Cycling the cooling coil "On" and "Off"
    - Resetting the cooling coil discharge air temperature above 55°F as load decreases
  - Consider changing sequence to:
    - face and bypass damper control
    - single zone variable air volume (VSDs or discharge air dampers)

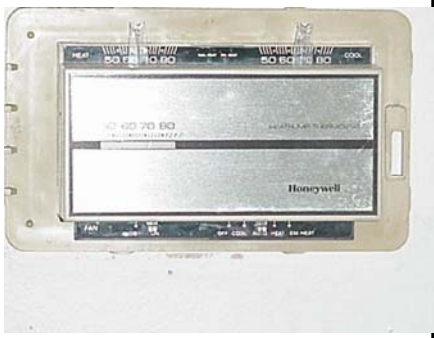
Case Study: School Auditorium Served by Constant Air Volume ChW AHU with Supply Air Reset for Temp Control Resulted in Severe Mold Growth



School Auditorium Case Study Solution: Convert to Variable Air Volume AHU by Installing Automatic Discharge Damper in Supply Duct

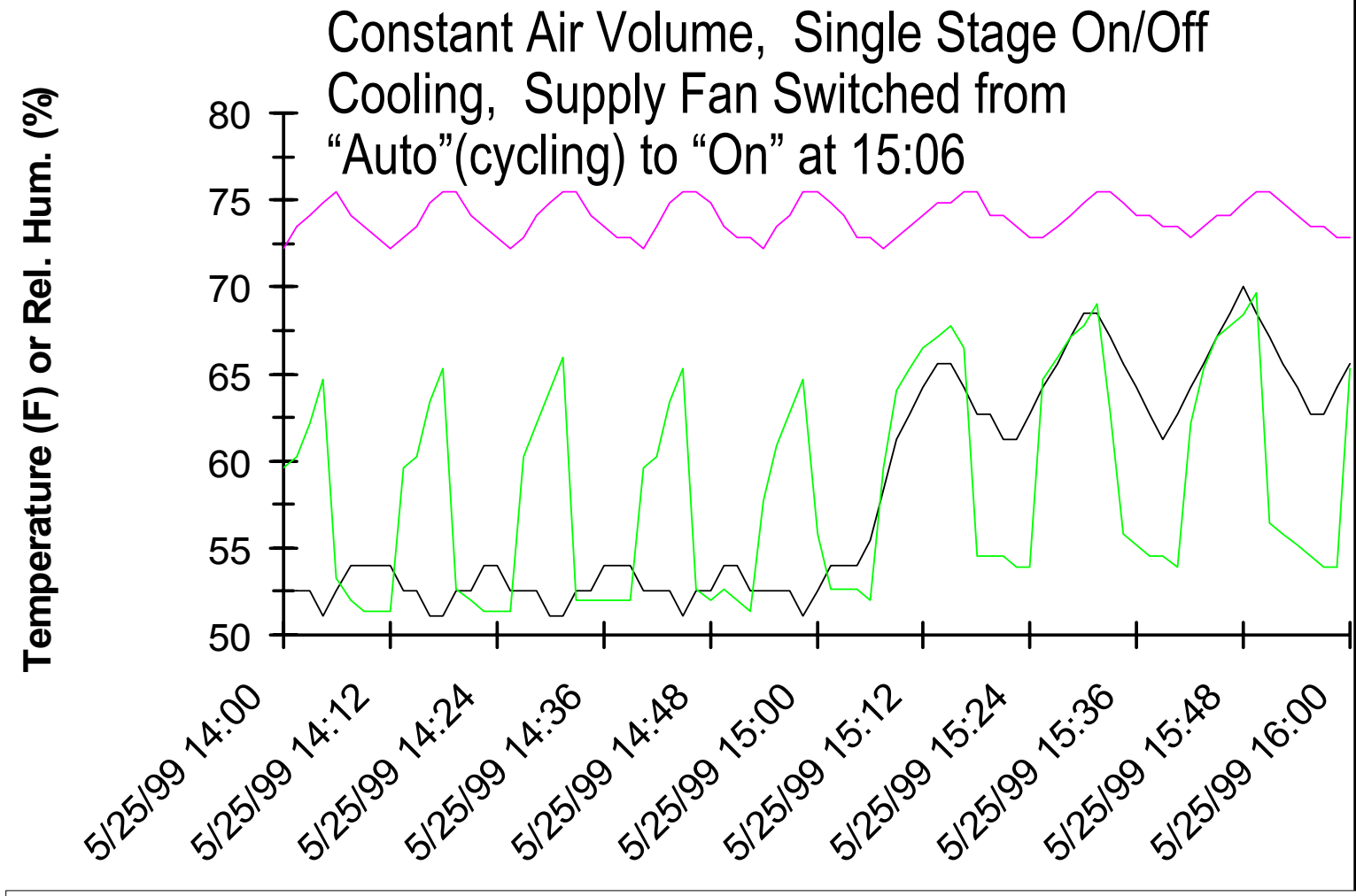


Select Operational Sequences that Provide Good Dehumidification



- On and Off (Cycling) Cooling Coil Control
  - Common in Florida Schools
  - Common on small ChW and Direct Expansion (DX) Equipment (Packaged and Split Systems)
- Often has a thermostat fan switch, “auto” or “on”
- Ventilation is continuous only if fan switch is “on”
- Dehumidification can be very poor if fan is set to “on”, when compressor cycles off:
  - Outdoor air which is introduced is not dehumidified
  - Moisture which has accumulated on the coil is subsequently evaporated and blown back in to the space

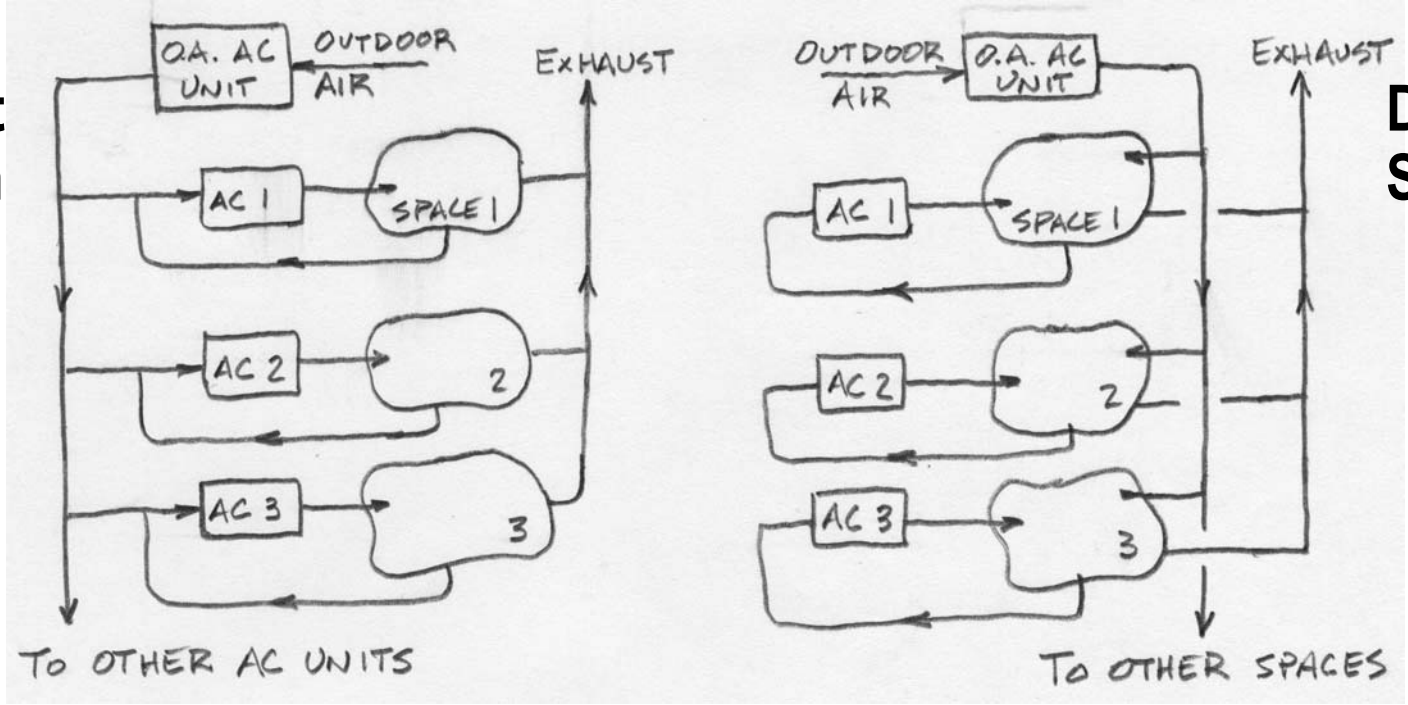
Actual Classroom DX Unit Performance



On / Off (Cycling) Unit Solutions Include:

- Multiple staged face split (stacked) evaporator coils with CAV
- Variable speed compressors / fans
- Preconditioned outdoor air units to continuously dehumidify OA
  - Indirect systems require space AC systems to operate for ventilation
  - Direct systems are better for independent ventilation and pressurization

Indirect System



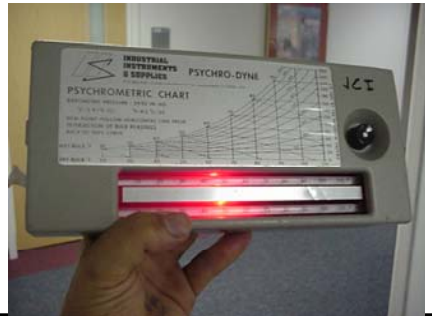
Direct System

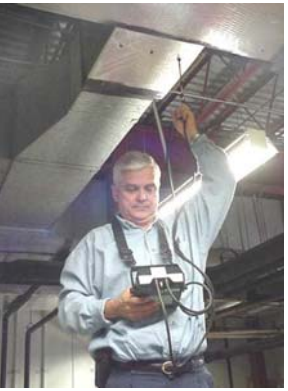
Preconditioned Outdoor Air Units

- Wide variety currently available that are well designed
  - Conventional cooling using DX or chilled water coils
  - Desiccant based dehumidification systems using heat
  - Combination cooling and desiccant systems
- Many options available to enhance performance
  - Heat wheels transfer heat between exhaust and outdoor air
    - Can reduce cooling and heating loads up to approximately 75 %
    - Require exhaust air be available at OA unit
  - Pre-cool and re-heat heat exchangers
    - Typically pre-cool the outdoor air and reheat the supply air for free
    - Available in several forms:
      - Heat pipe heat exchangers
      - Flat plate heat exchangers
      - Sensible heat wheels

IAQ Investigative Tools & IAQ Triangle: Occupants, Contaminants and Transport Mechanisms

- The Basics
  - Multi-discipline / Inter-department teaming
  - Investigators eyes, nose, ears
  - Occupant and staff interviews (non leading)
  - Review of building plans and documentation
  - Smoke stick or puffer for air flow visualization
  - Accurate thermometer and relative humidity meter (sling or battery powered psychrometer)





IAQ Investigative Tools Advanced

- Micro-manometer for measuring pressures
- Instrument for measuring air velocities
- Instrument for measuring air flow (hood)
- Carbon dioxide and carbon monoxide meter
- Moisture content meter (construction materials)
- Loggers for T, RH, CO2, pressurization, air flow
- Particle counter for measuring particulate levels
- Air, bulk and dust sampling such as air sampler for collecting culturable mold and bacteria

Some Publications and Resources

- ***ASHRAE Standards and Publications***
  - (800)-5-ASHRAE
  - www.ashrae.org
- ***IAQ Tools for Schools Action Kit***
  - US EPA Indoor Air Division, www.epa.gov/iaq
- ***IAQ Guidelines for Occupied Buildings Under Construction -*** SMACNA (703) 803-2989
- ***"Basics of High Humidity IAQ Problems and Practical Solutions" manual presented at 1999 FSPMA Conference*** *- Scott Forsyth, PE, CEM, CIAQP*
  - *Johnson Controls, (904) 732-5440 scott.r.forsyth@jci.com*