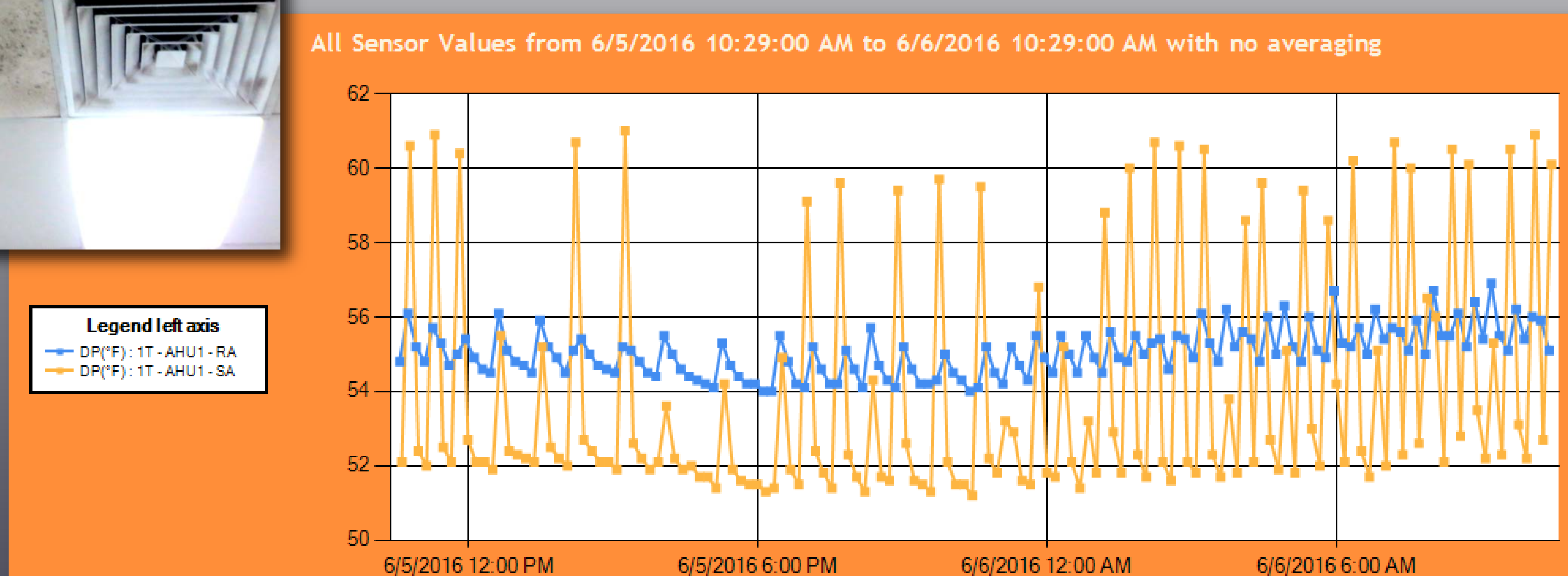
Humidity Control II

Real-World Problems and Solutions



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Learning Objectives

1. Understand that humidity control problems can only have three causes.

2. Know what steps can be taken, and in what order, to diagnose a humidity control problem.

3. Know what quantitative tools and techniques are used during each stage of troubleshooting a humidity control problem.

4. Understand what steps can be taken in design and building operation to avoid common humidity control problems.

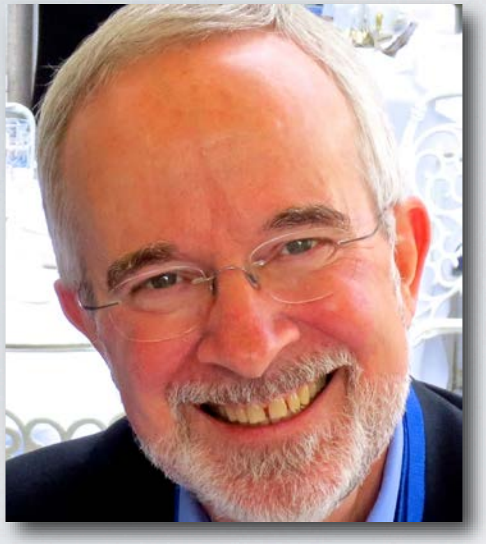
Workshop Outline

1. Introduction
2. Case histories—schools in Texas and Florida
3. Humidity troubleshooting sequence and procedures
4. Case history—community clinic in Southeast Asia
5. Troubleshooting the HVAC side of the problem
   - Hands-on: Calculate lb/hr removed from a room by dry supply air
6. Summary

Section 1 of 6

Introduction

Instructor



Lew Harriman, ASHRAE

Mason-Grant Consulting

- USAF: 1971–1976, Engineering and Services
- 40 years in humidity control, 10 years with dehumidification manufacturer, 30 years at Mason-Grant Consulting, humidity and moisture problems in buildings
- Lead author: ASHRAE *Humidity Control Design Guide*, *ASHRAE Guide for Buildings in Hot and Humid Climates*, and *The Dehumidification Handbook*
- ASHRAE Fellow and Distinguished Lecturer
- Past Chair and Vice Chair: ASHRAE Technical Committee 1.12 Moisture Management in Buildings

Introduction—Attendees

- **Your humidity control experiences?**
  - Responsible for **design**? *or*
  - Responsible for **finding and fixing problems**?
  - What answers do **you** want before the end of the session?

Great Building; **Great** HVAC System!
So Why Did It Grow Mold Three Times in Five Years?

The Building and Its HVAC Are a Single System

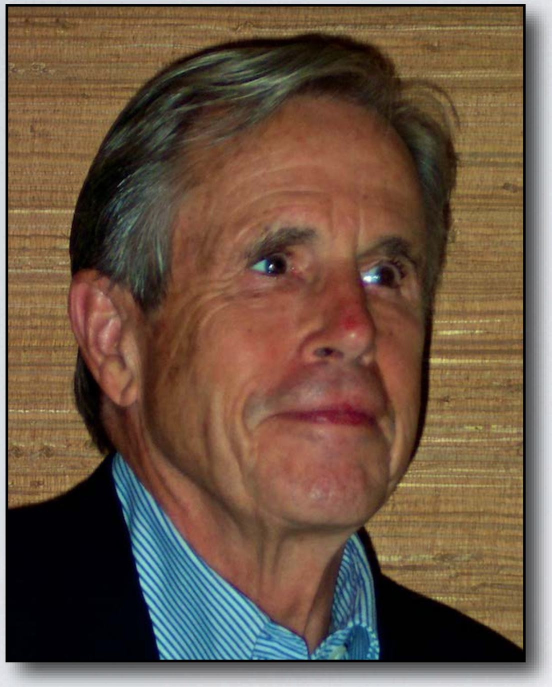
- **Cannot understand one without understanding the other.**

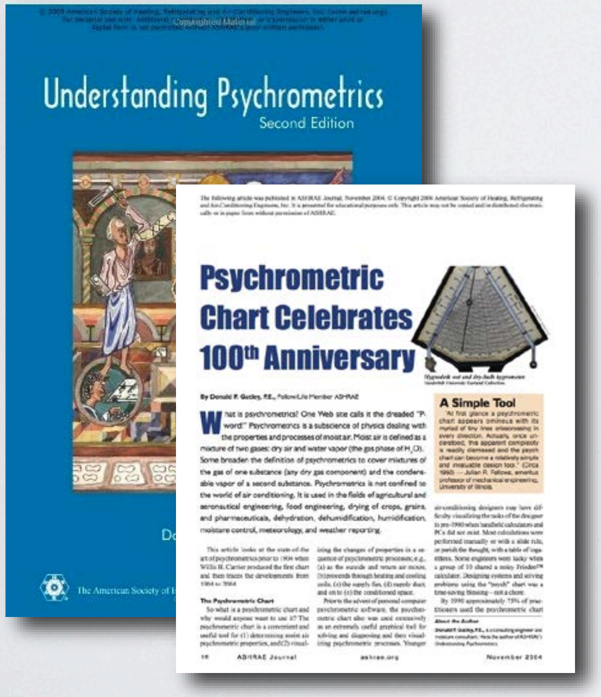
- **The HVAC system and the building enclosure interact in strange—and important—ways.**

- **Successful humidity control troubleshooting demands an *integrated* investigation…**

- ***Not* separate investigations for building and HVAC!**

The voice of experience…
Don Gatley, PE, Life Member and ASHRAE Fellow





79 moisture investigations in 25 years

- 40% hotel and nursing homes
- 40% apartments, condos, and houses
- 20% other

<u>*All*</u>, except four, were caused by <u>*building suction*</u> and/or <u>*excess humidity in ventilation and makeup air*</u>:

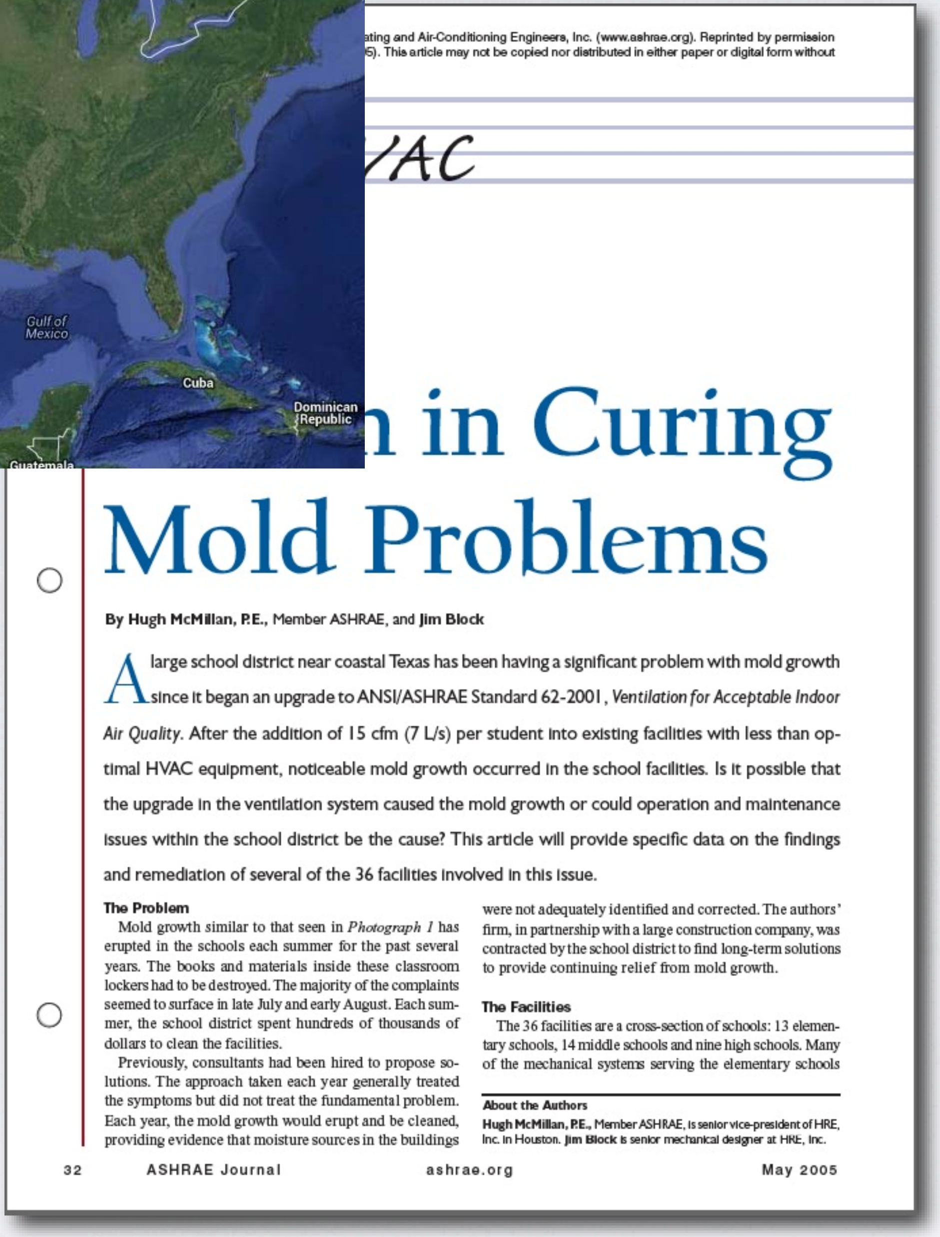
- Too much exhaust (<u>*not enough*</u> dry makeup air)
- Not enough <u>*drying*</u> of the makeup/ventilation air

Don's advice: <u>*Most humidity problems are simple*</u>! Don't overcomplicate humidity troubleshooting. Make sure the building does not suck, and make sure the ventilation air and makeup air are dry.

Section 2 of 6

Schools
in Texas and Florida

36 School Facilities Near Houston, TX



...VAC

...n in Curing Mold Problems

By Hugh McMillan, P.E., Member ASHRAE, and **Jim Block**

A large school district near coastal Texas has been having a significant problem with mold growth since it began an upgrade to ANSI/ASHRAE Standard 62-2001, *Ventilation for Acceptable Indoor Air Quality*. After the addition of 15 cfm (7 L/s) per student into existing facilities with less than optimal HVAC equipment, noticeable mold growth occurred in the school facilities. Is it possible that the upgrade in the ventilation system caused the mold growth or could operation and maintenance issues within the school district be the cause? This article will provide specific data on the findings and remediation of several of the 36 facilities involved in this issue.

The Problem

Mold growth similar to that seen in *Photograph 1* has erupted in the schools each summer for the past several years. The books and materials inside these classroom lockers had to be destroyed. The majority of the complaints seemed to surface in late July and early August. Each summer, the school district spent hundreds of thousands of dollars to clean the facilities.

Previously, consultants had been hired to propose solutions. The approach taken each year generally treated the symptoms but did not treat the fundamental problem. Each year, the mold growth would erupt and be cleaned, providing evidence that moisture sources in the buildings were not adequately identified and corrected. The authors' firm, in partnership with a large construction company, was contracted by the school district to find long-term solutions to provide continuing relief from mold growth.

The Facilities

The 36 facilities are a cross-section of schools: 13 elementary schools, 14 middle schools and nine high schools. Many of the mechanical systems serving the elementary schools

About the Authors

Hugh McMillan, P.E., Member ASHRAE, is senior vice-president of HRE, Inc. in Houston. **Jim Block** is senior mechanical designer at HRE, Inc.

Photograph 1: Mold growth on classroom wall after 72 hours.

consisted of multiple air-cooled water chillers, gas-fired heating hot water boilers and classroom two-pipe system unit ventilators operating as fan coil units (no ventilation cycle providing free cooling). School configurations range from classrooms with doors that open to the outside to those with doors that open to a conditioned corridor.

Many of the schools were renovated from 1985 to 1990. The renovations included replacement of the water chilling equipment, boilers and unit ventilators. The control systems were renovated to direct digital control (DDC) systems within the last five years.

The airside systems in these schools include various configurations of fan coil units, unit ventilators, and traditional air-handling units. *Photograph 2* is typical of how the additional outside air was added to existing facilities. Notice the lack of any volume or control damper. The only control damper is the 72 in. long by 4 in. wide (182 cm by 10 cm), two-position damper inside the fan coil unit. This damper has no seals and, due to its great length, has significant leakage.

Dedicated precooling air- handling units are not part of the facilities. Heat transfer is accomplished via chilled water/hot water delivered through two-pipe changeover and four-pipe systems. *Photograph 3* indicates how many HVAC systems were added long after the original construction of the buildings. Piping was added and routed through areas providing the most cost-effective solution.

The typical system in the middle schools and high schools was basically the same with the exception that water-cooled centrifugal and/or screw compressor chillers and cooling towers were used rather than air-cooled water chillers. Administration areas for a majority of facilities have been provided with direct-expansion stand-alone systems intended for after-hours operations.

Control systems include DDC with and without humidity control. The basic classroom unit ventilators are controlled with a DDC sequence that energizes the units on a programmed schedule, modulates the control valve to maintain the space temperature setpoint and changes the action of the control signal based on the temperature of the water in the piping system (for two-pipe systems). To conserve energy, the units are scheduled to operate during occupied hours only. The same happens with the water chilling plants that are de-energized at night and on weekends.

Methodology

Sampling criteria for selecting the areas to be monitored was based on direct observation of real-time conditions and past history of mold remediation. A meeting with maintenance personnel was conducted in early May to educate staff on the new district initiative to ensure that summer mold growth did not recur.

Inexpensive humidity monitors were provided to school custodians to locate potential problem areas as early as possible. School custodians were instructed to call area supervisors

Hugh McMillan and Jim Black - *ASHRAE Journal* - May 2005

School Problems

- Suburban school district—36 facilities
  - 13 elementary schools
  - 14 middle schools
  - 9 high schools
- Widespread mold problems (after adequate ventilation)
- $100k+ in cleaning and replacement of books and furnishings every year
- Repeated HVAC renovations from 1985–2000, but no effect on problems
- Problems most apparent during late July and August

HVAC/Envelope Interaction: Mold Growth on Walls

Photograph 1: Mold growth on classroom wall after 72 hours.

Relevant Facts

- Schools added ventilation to comply with ASHRAE Std 62.1-1989 (15 cfm per occupant versus less than 5 cfm per occupant)
  - No change in HVAC configuration—just added cooling tonnage
  - Ventilation air volume was random: no dampers or fixed-position dampers full open or closed
  - Ventilation airflow constant, even during unoccupied hours
  - No ventilation air dehumidification: "…4-row fan coil in each room will remove humidity…"
  - Chilled-water pipe insulation ineffective: CW temperature higher than expected at fan coils
- Thermostat setting raised to 80°F during unoccupied hours and vacations (to reduce energy costs)
- Neither monitoring nor control of humidity

Humid Ventilation Air Ducted to Fan-Coil Units

Photograph 1: Mold growth on classroom wall after 72 hours.

Problem Sequence

- Students leave and room thermostats reset to 80°F.
- Custodians scrub floors and wash walls; indoor dew point skyrockets.
- Fan coils run continuously: they pull in humid outdoor air, keeping the indoor dew point very high during all unoccupied hours.
- Periodically, fan-coil valves open and units chill the walls; then cooling (and dehumidification) stops after room falls below 80°F.
- High indoor dew point + cool walls = near condensation + moisture absorption + mold growth on interior surfaces

Retrofit Solution

- Measured and reset correct ventilation airflows for each room.
- Stopped constant supply fan operation when building unoccupied (overnight, weekends, and vacations).
- Installed automatic dampers which shut off ventilation air when supply fan turns off.
- Reduced chilled-water temperature to keep the supply air dew point down to 50°F—53°F.
- Replaced chilled water line insulation to keep CW cold enough to ensure supply air is dried to 50°F—53°F dew point.

San Carlos Park Elementary School, Florida

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"Until the building science engineer evolves as a separate discipline, primary responsibility for addressing building leakage will probably fall to the HVAC engineer."

journey in reasonable comfort, and lose no more air than can be replaced by the pump at hand. Although appearing airtight, the tire eventually will go flat. We should expect the same performance from the air barriers that help to form a building's pressure envelope.

So how much leakage is acceptable? The author suggests as a modest goal that buildings should leak no more than the air that must be introduced for acceptable indoor air quality.

The amount of outside air (OA) mandated by ANSI/ASHRAE Standard 62, *Ventilation for Acceptable Indoor Air Quality*, is enough of a burden to the owner in terms of capital equipment cost and energy consumption. The owner should not need to provide even more OA to gain control of the indoor/outdoor pressure relationship.

Building Pressurization

Building air pressure with respect to outdoors should be neutral so that doors open and flue-gas vents function properly. However, should buildings be slightly positive or slightly negative? Most building scientists and mold remediation professionals now believe that wall and roof constructs should be pressurized from the cooler, dryer side. Dry air (with respect to the negative side) migrating through the wall absorbs moisture and tends to dry out the interstitial construction. Conversely, if hot, humid air is allowed to migrate through the construct, it can cool below its dew point and create condensation in the interstitial space, damaging building materials and allowing mold to grow.

With this principle in mind, buildings experiencing hot, humid weather should be positive with respect to the outside, and buildings in cold climates can be slightly negative. Experience has shown that designing for a very small pressure differential, (less than 0.01 in. w.c. [2.5 Pa] works well in hot, humid climates.

Wind currents will override pressurization this small. However, as wind shifts direction, it tends to cancel out its effects upon pressurization. This does not hold where one strong, wind direction prevails, such as by the sea. Cold climates will require a greater pressure differential, primarily due to stack effect.

"Leakage" is the natural, unplanned and uncontrolled flow of air into (infiltration) and out of (exfiltration) buildings. The artificial, intentional, controlled (hopefully) flow of air into buildings is called ventilation or outside air; the corresponding outward flow is exhaust. These intentional flows must work in concert with natural leakage.

The relationship between OA, exhaust, and leakage can be expressed with simple arithmetic:

Building Positive, Hot, Humid Climate:

Outside Air = Exhaust + Leakage (Exfiltration)

Building Negative, Cold Climate:

Outside Air = Exhaust – Leakage (Infiltration)

HVAC engineers can readily calculate how much outside air is required for acceptable ventilation as prescribed in Standard 62, and how much exhaust is required for toilets, showers, hoods, etc.

Building leakage is a bit more elusive. The goal of this article is to discuss the methods for measuring and expressing leakage, and to report the results of a case study, San Carlos Park Elementary School, in Ft. Myers, Fla.

Quantifying and Expressing Leakage

Perhaps the oldest (and worst) method for estimating building leakage was the "crackage" method, where the width of cracks around windows and doors was estimated, a cfm per linear foot of crack allowance assumed, and infiltration estimated by extending these computations.

A better (and certainly much easier) method is to begin by computing the volume of a building in ft^3 and then divide that number by 60 as an expression of the cfm airflow required to "change" the air in an hour's time (ACH):

1.0 ACH cfm = V/60

Then, based upon the practitioner's experience, estimate an infiltration rate in terms of a fraction of ACH. The author, for example, has allowed between 0.50 and 1.0 ACH for "infiltration" throughout his career with reasonable success. Post-1973 buildings built to ANSI/ASHRAE/IESNA Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, requirements might be as tight as 0.25 ACH. Antiquated factory buildings on the other hand could experience 2 or more ACH.

Why did I use between 0.50 and 1 ACH? Because my HVAC professor at Iowa State told me to in 1962. All I had to go on was his direction, *Manual J*, and one tattered ASHRAE Handbook shared by the entire class. I had no need to question my assumption until 25 years later, when I was unable to heat a factory in Fargo, N.D., which had fenestration that had not been fixed for the past 55 years — its air apparently changed three times each hour. A few years later, I found that I couldn't dehumidify buildings in southwest Florida. I suspected there had to be better ways to estimate building leakage. There were.

Air change rates (ACH) continue to be a good way to express building leakage, but coupled with a pressure differential, normally 0.20 in. w.c. (50 Pa). A building would never operate (intentionally) at this pressure, but they can be more accurately tested at this high pressure (for the same reason that a damper or valve must experience a high-pressure differential before it can provide close control). The ACH rate at 0.20 in. w.c. (50 Pa) is interpolated to the actual building pressure desired (say 0.01 in. w.g. [2.5 Pa]) to determine how much air will be required for pressurization. The astute HVAC engineer should begin to see a relationship that looks like a constant mechanical duct system whose behavior can be predicted by

About the Author
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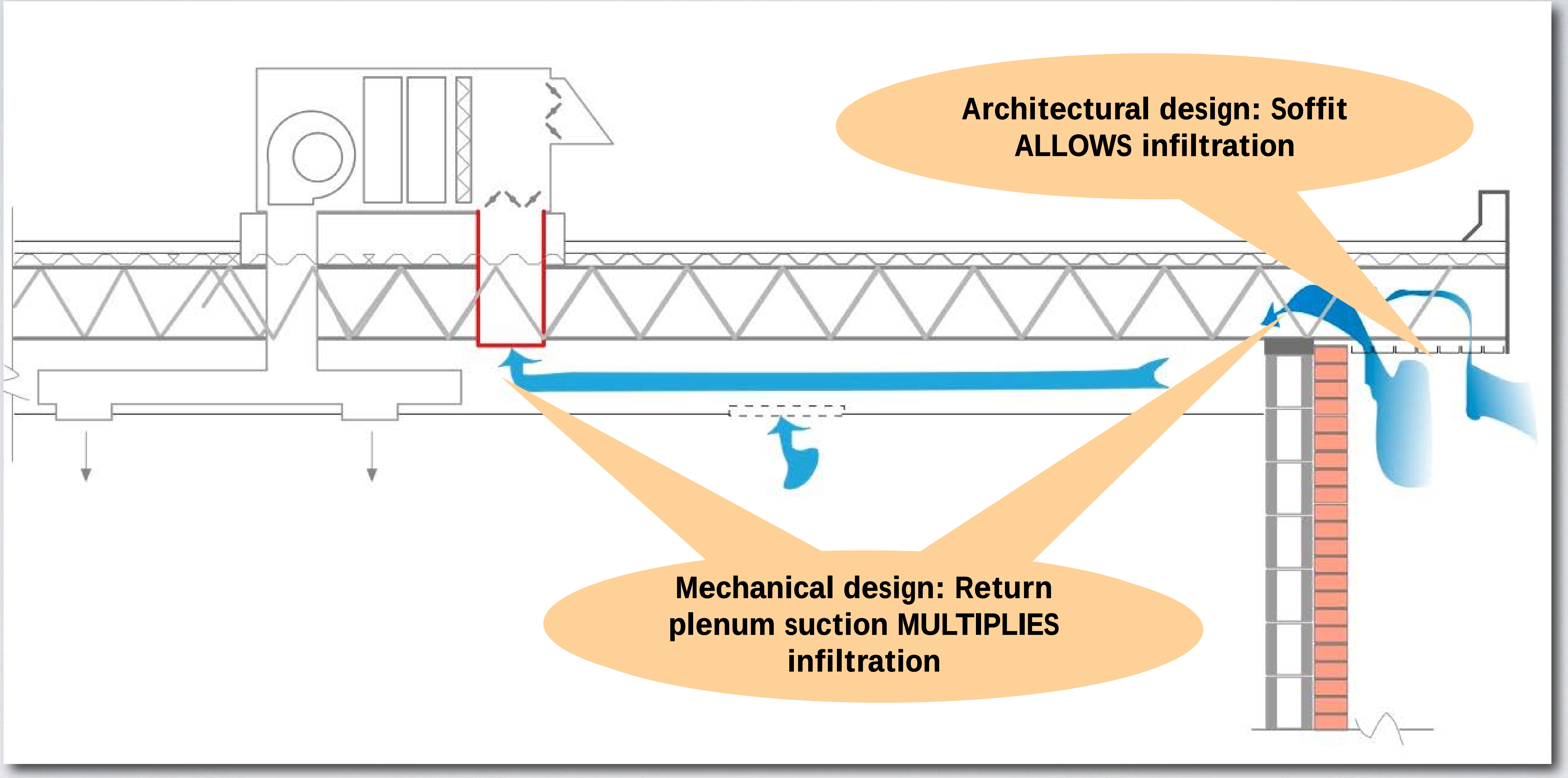
November 2003 ASHRAE Journal 29

Andy Åsk - *ASHRAE Journal* - November 2003

Problems

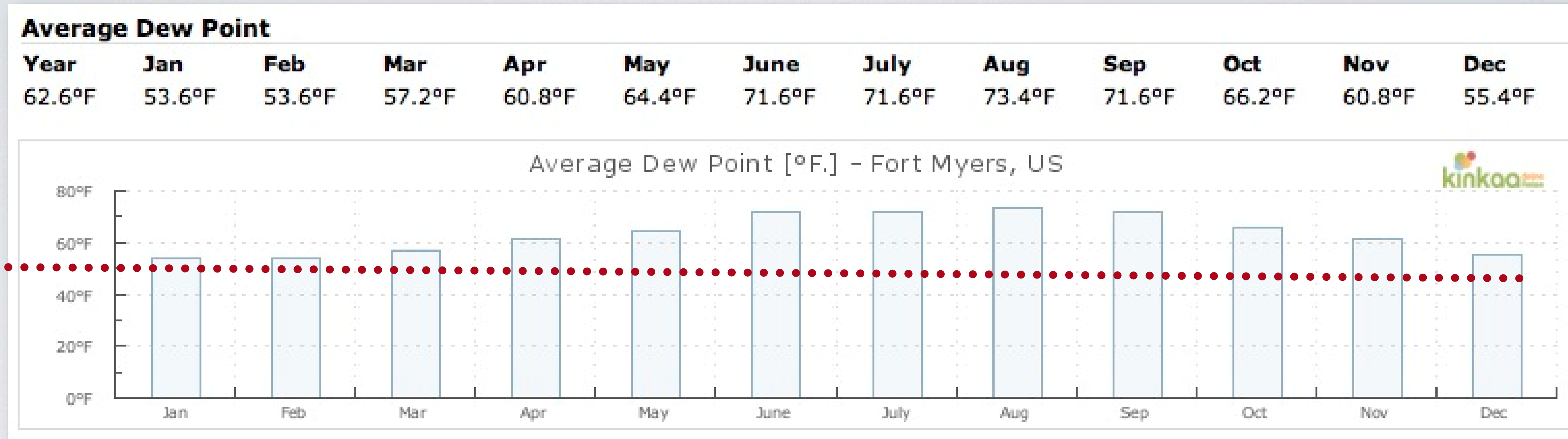
- Poor indoor air quality (moldy odors)
- Comfort complaints—damp and muggy
- AC system can't maintain temperatures
- High energy costs

Low-Cost HVAC Design—Return Air Plenums



Air Infiltration and Humidity Load

55°F (12.8°C) dew point



Average Dew Point

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
62.6°F	53.6°F	53.6°F	57.2°F	60.8°F	64.4°F	71.6°F	71.6°F	73.4°F	71.6°F	66.2°F	60.8°F	55.4°F

$$\frac{\text{cfm} \times 4.5 \times (\text{osa gr/lb} - \text{indoor air gr/lb})}{7000} = \text{lb/hr}$$

$$\frac{\text{l/s} \times 4.32 \times (\text{osa g/Kg} - \text{indoor air g/kg})}{1000} = \text{kg/hr}$$

Architectural and HVAC Shortcomings Combine to Cause Big Problems

Architectural design: Soffit ALLOWS infiltration

HVAC design: Return plenum DRIVES infiltration

Leakage	"System off" pressure = 3 Pa	"System off" humidity load (lb/h)	"System on" pressure = 50 Pa	"System on" humidity load (lb/h)
Before Remediation	7,268 cfm	425	42,715 cfm	2,455

Typical HVAC design assumes ZERO load when the systems are off. Obviously, that's a bad assumption

Note the SIZE of the unexpected load when systems ARE operating!

Architectural and HVAC Shortcomings Combine to Cause Big Problems

Architectural design: Soffit ALLOWS infiltration

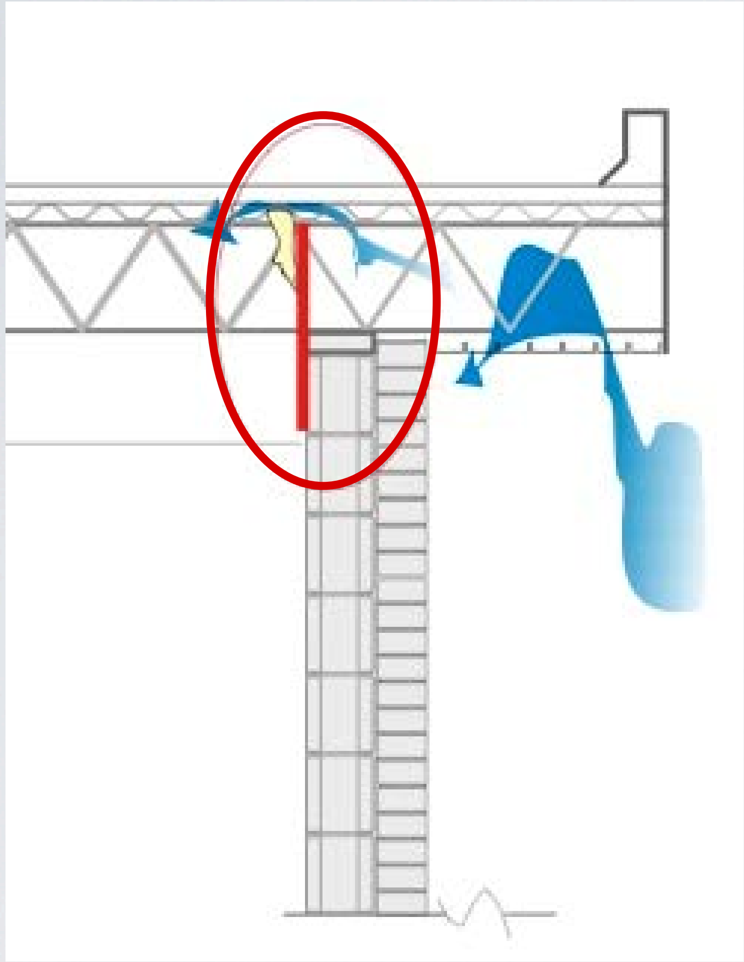
HVAC design: Return plenum DRIVES infiltration

Leakage	"System off" pressure = 3 Pa	"System off" humidity load (Kg/h)	"System on" pressure = 50 Pa	"System on" humidity load (Kg/h)
Before Remediation	3430 l/s	193	20,160 l/s	1,114.76 736

Typical HVAC design assumes ZERO load when the systems are off.
Obviously, that's a bad assumption

Note the SIZE of the unexpected load when systems ARE operating!

Retrofit Solution



- Added gypsum board between the wall and roof deck
- Sealed the gypsum board to the roof deck with spray foam to avoid labor-intensive cutting and fitting
- Protected spray foam with a layer of spray-on intumescent, fire-rated sealant
- Net result: 55% reduction in passive (system off) air infiltration

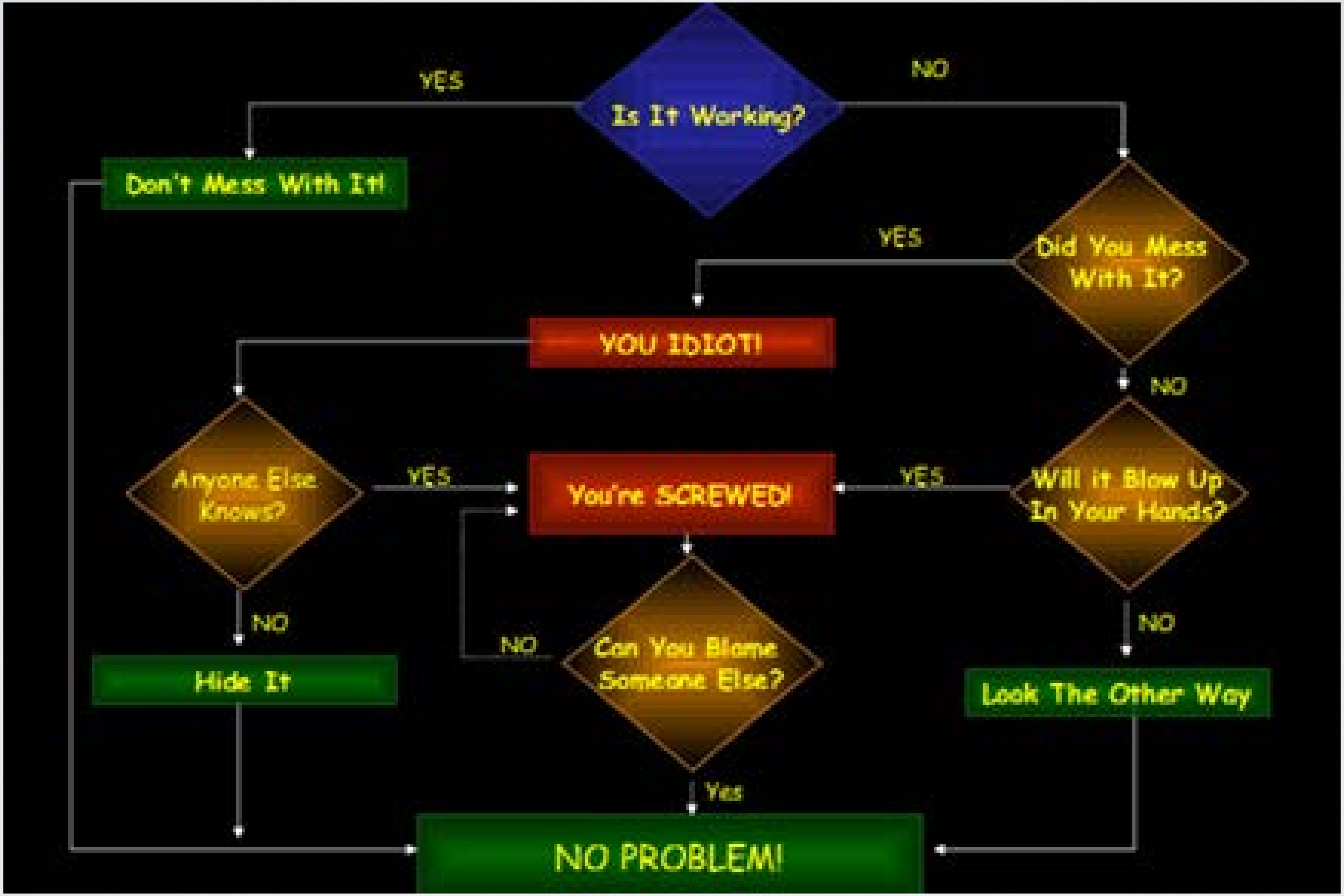
Section 3 of 6

Troubleshooting Sequence and Procedures

Troubleshooting Sequence and Procedures

1. Traditional troubleshooting procedures
2. The essence of humidity control troubleshooting—loads versus DH capacity
3. Troubleshooting sequence and procedures
   a. Investigate and understand the problems
   b. Measure the loads
   c. Measure the DH capacity
   d. Understand the controls
   e. Plan the solution

1. Traditional Troubleshooting Procedures



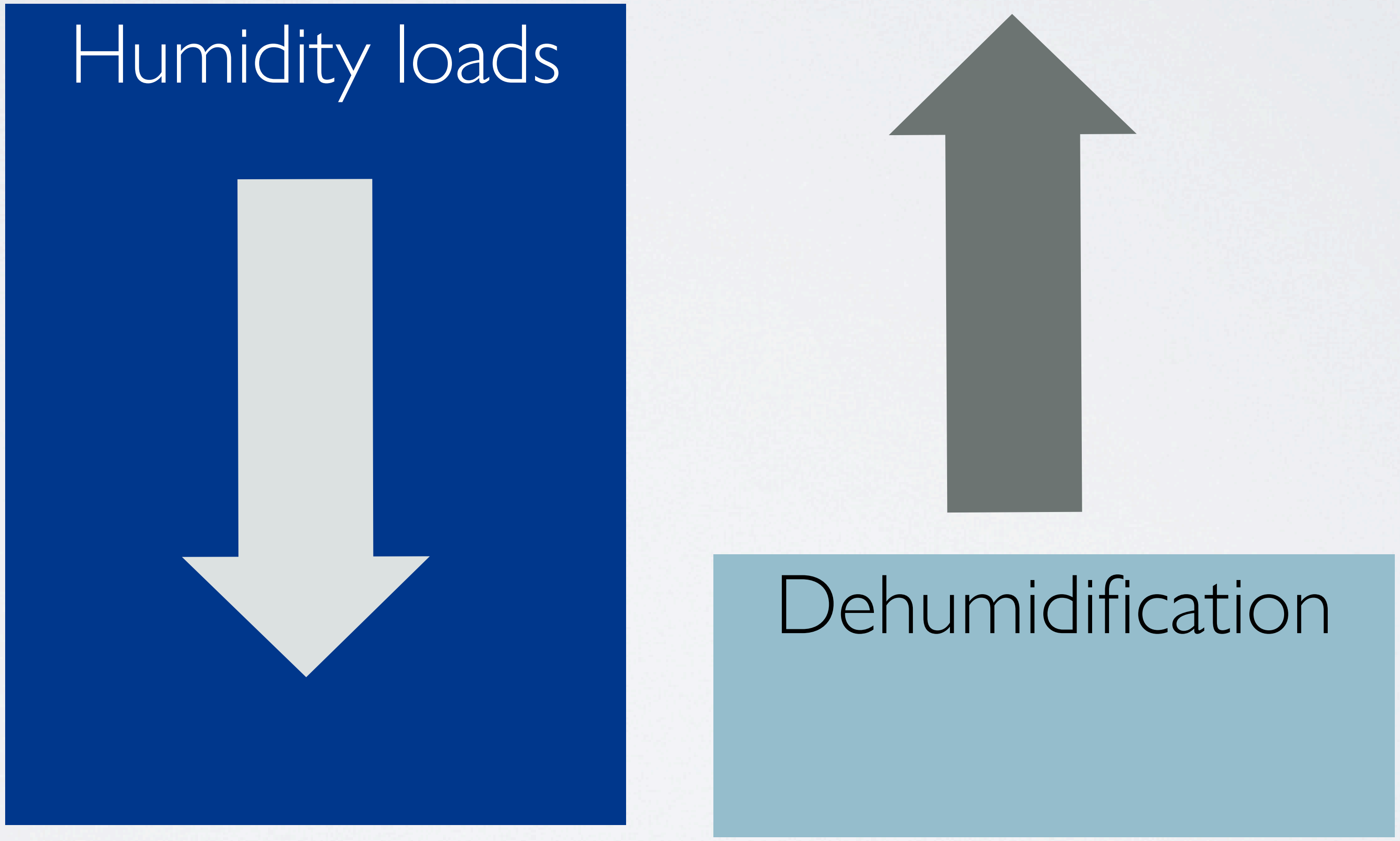
The Essence of Humidity Control Troubleshooting

When humidity is too high, it is because humidity loads > dehumidification

How to Solve Humidity Control Problems

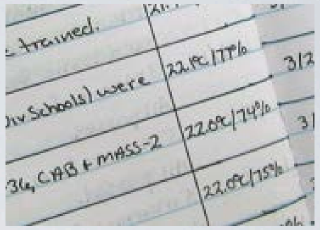
To solve the problem

- **reduce the loads,**
- **increase dehumidification, or**
- **do both**

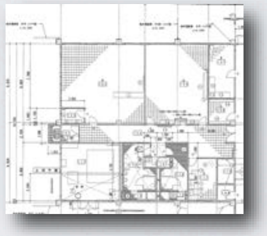


Troubleshooting Sequence

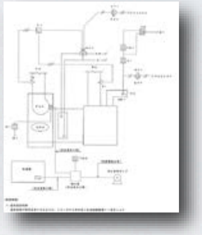
1. **Listen and understand the problems**

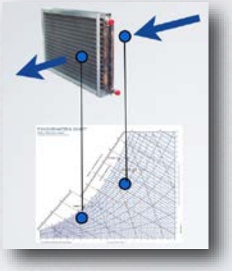
2. **Look at drawings, then walk through and understand the *building***



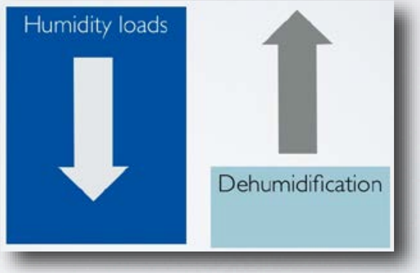

3. **Look at drawings, then walk through and understand the *HVAC system***



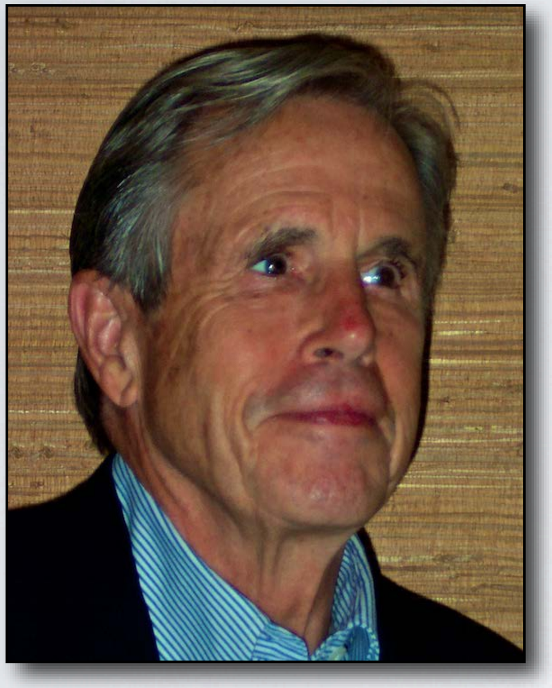

4. **Measure the key variables:**
   - **Loads**
   - **Dehumidification**

5. **Diagnose the problems; plan solutions**



Keep in Mind Don Gatley's Voice of Experience



79 moisture investigations in 25 years

All, **except four, were caused by** ***building suction*** **and/or** ***excess humidity in ventilation and makeup air*****:**

- Too much exhaust (*not enough* dry makeup air)
- Not enough *drying* of the makeup/ventilation air

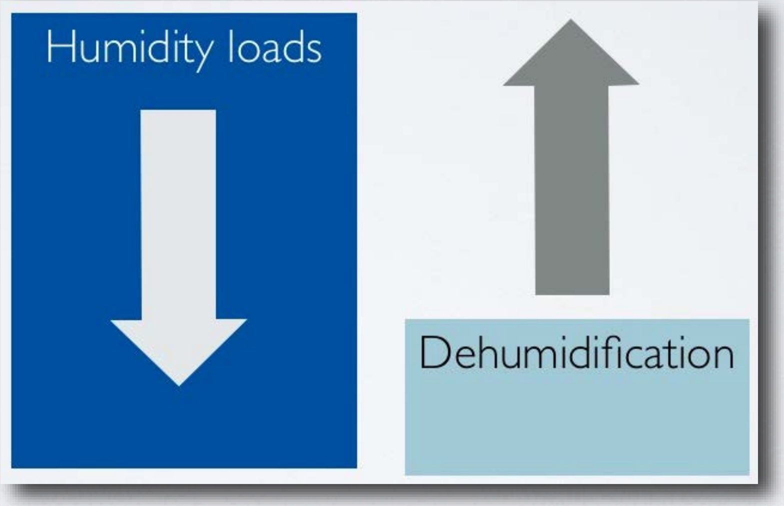
Don't overcomplicate humidity troubleshooting:

- Make sure the building does not suck, and
- Make sure the ventilation and makeup air is *dry all the time*.

Part 1—Finding and Understanding Problems

1. **Interview the building occupants (in person)**
   a. **What is the nature of the problems? Dripping? Stickiness? Machine failure? General discomfort?**
   b. **When do they happen, where do they happen, and how long do they last?**
   c. **When do they *not* happen?**
2. **Review the building drawings. Then walk through the building and around it to understand the enclosure.**
3. **Review the HVAC drawings, equipment schedules, and controls, then walk around to understand the DH capacity.**

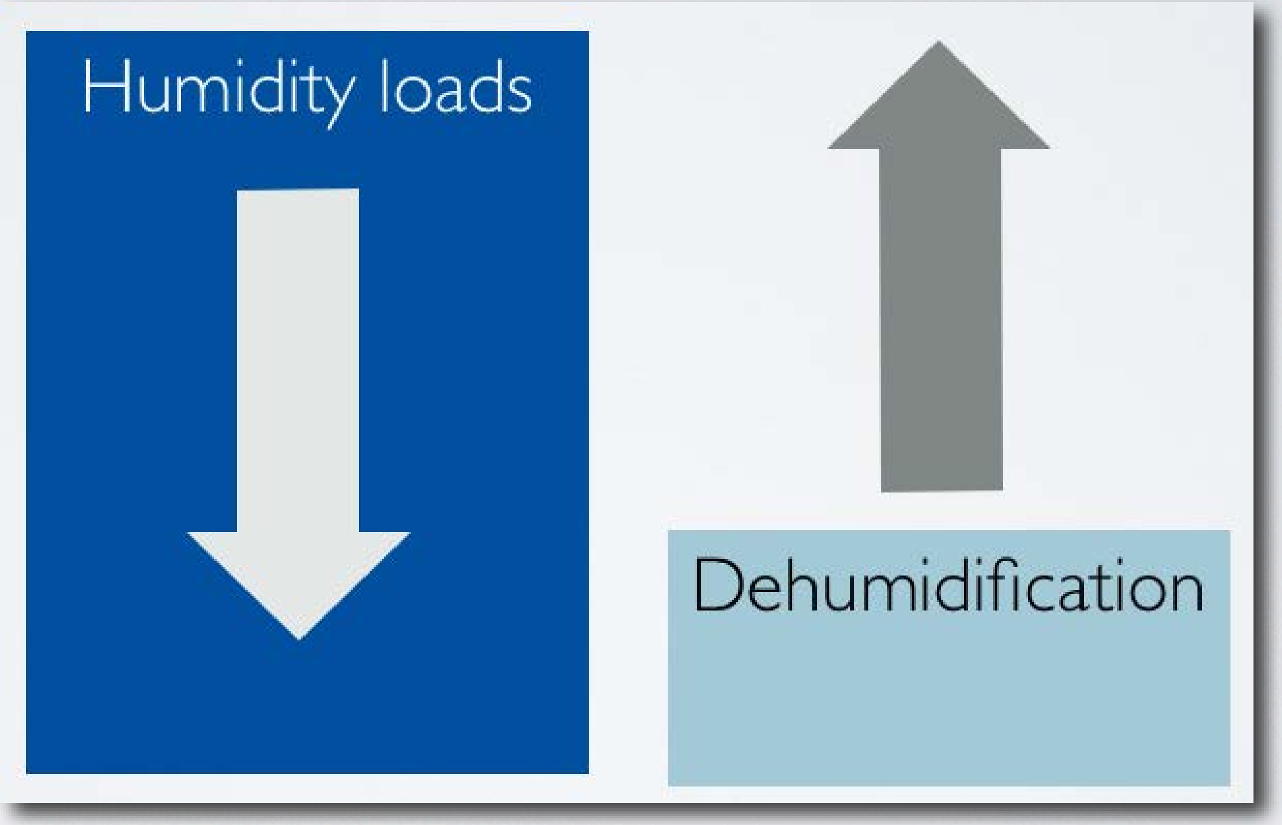
Then, Start Thinking about the Problems



1. **Why could the problems be happening?**
2. **When they happen, what is the sequence of events that leads to the problems?**
3. **If you are correct, how can those problems be solved?**

The Building Versus the HVAC System

To reduce the **loads**, look at the **building and its occupancy**



To increase the DH, look at the **HVAC components and controls**

Next, ***Measure*** **Loads**…
..and ***Measure*** the **Dehumidification**

Humidity Loads

- Exhaust airflow
- Incoming outdoor air
- Building air leakage
- Number of people
- Wet surfaces

Dehumidification

- Humidity removal
- Dry airflow
- Controls

Measuring Humidity Loads—Exhaust Airflow

Humidity Loads

- **Exhaust airflow**
- Incoming outdoor air
- Building air leakage
- Number of people
- Wet surfaces

How to measure?

Flow Hood

Measuring Humidity Loads—Incoming Outdoor Air

Humidity Loads

- Exhaust airflow
- **Incoming outdoor air**
- Building air leakage
- Number of people
- Wet surfaces

How to measure?

Flow Hood

Or

Pitot Tube

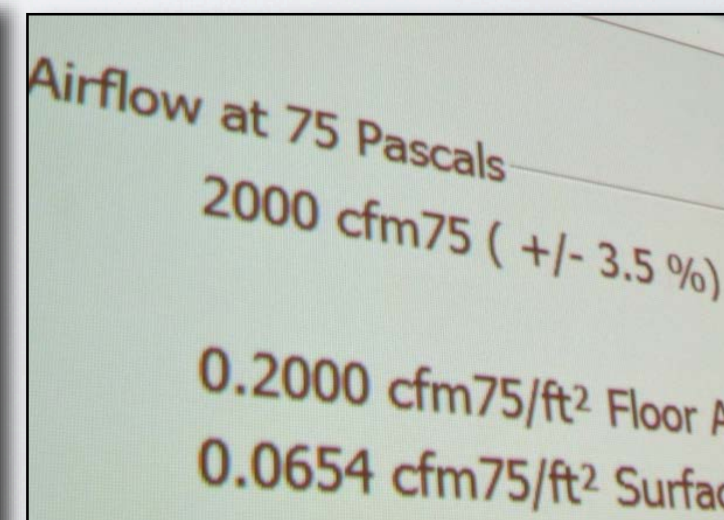
Measuring Humidity Loads—Building Air Leakage

Humidity Loads

- Exhaust airflow
- Incoming outdoor air
- **Building air leakage**
- Number of people
- Wet surfaces

How to measure?

Blower door



Measuring Humidity Loads—Number of People

Humidity Loads

- Exhaust airflow
- Incoming outdoor air
- Building air leakage
- **Number of people**
- Wet surfaces

How to measure?

Find out the fire-rated maximum occupancy, then observe!

Measuring Humidity Loads—Wet Surfaces

Humidity loads

- Exhaust airflow
- Incoming outdoor air
- Building air leakage
- Number of people
- Wet surfaces

How to measure?

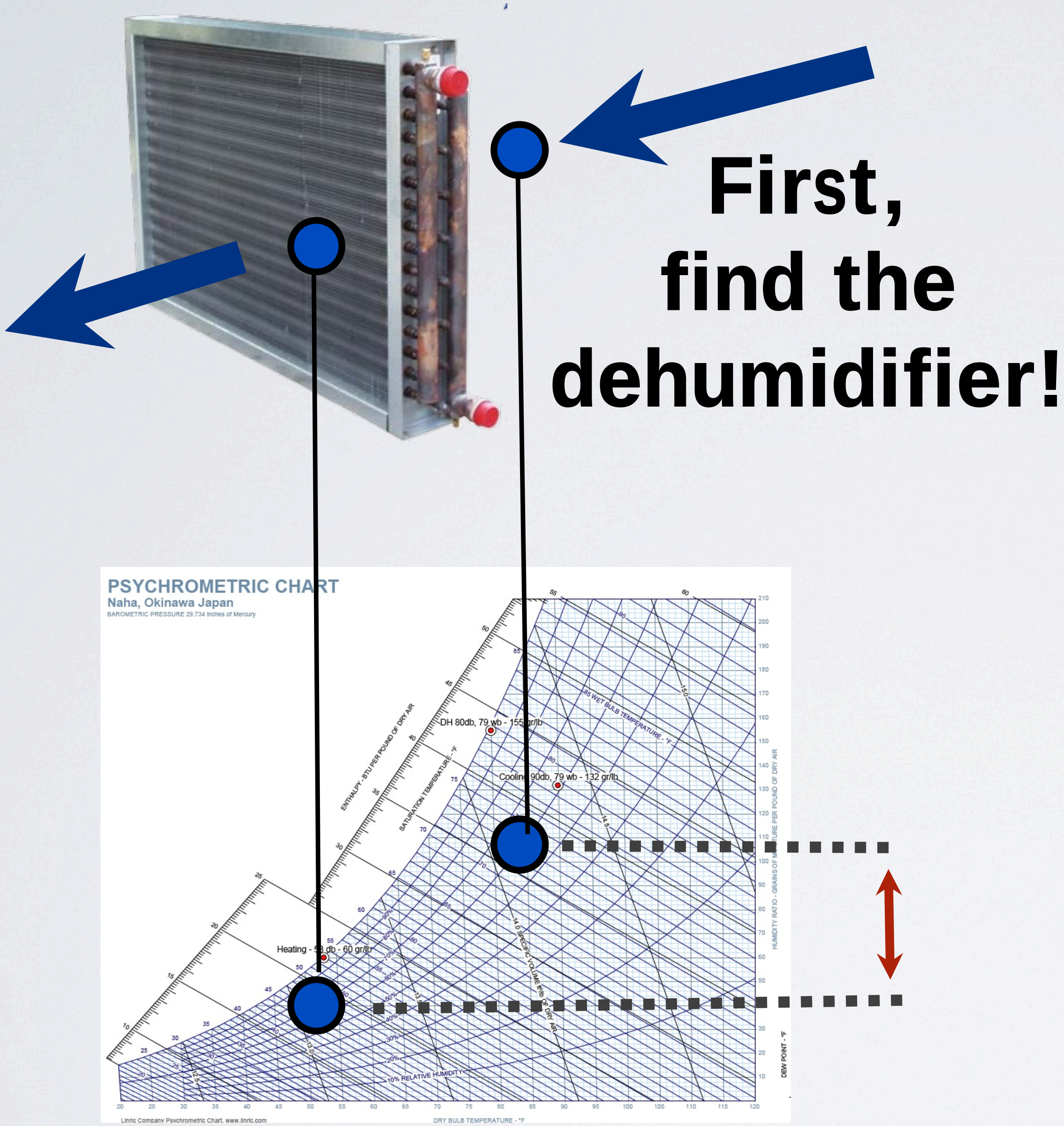
Interview, then observe!

After Measuring Loads… *Measure* Dehumidification

Dehumidification

- Humidity removal
- Dry airflow
- Controls

Measuring Dehumidification—Humidity Removal



Dehumidification

- **Humidity removal**
- Dry airflow
- Controls

How to measure?

Humidity ratios (gr/lb) before and after the coil

Dehumidification Accomplished by the Cooling Coil

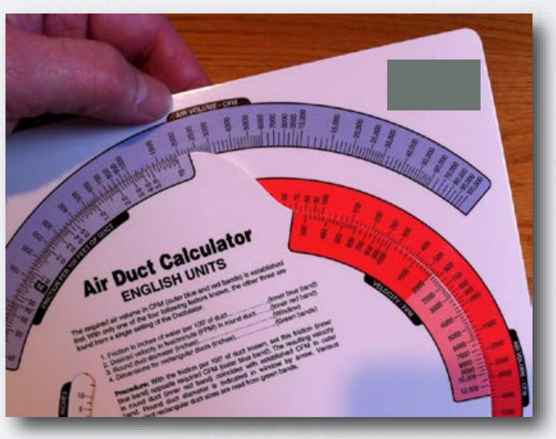
$$\frac{\text{cfm} \times 4.5 \times (\text{entering gr/lb} - \text{leaving air gr/lb})}{7000} = \text{lb/hr}$$

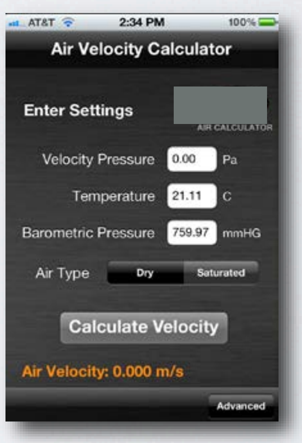
$$\frac{\text{l/s} \times 4.32 \times (\text{entering g/kg} - \text{leaving air g/kg})}{1000} = \text{kg/hr}$$

Measuring Dehumidification—Dry Airflow

Dehumidification

- Humidity removal
- **Dry airflow**
- Controls

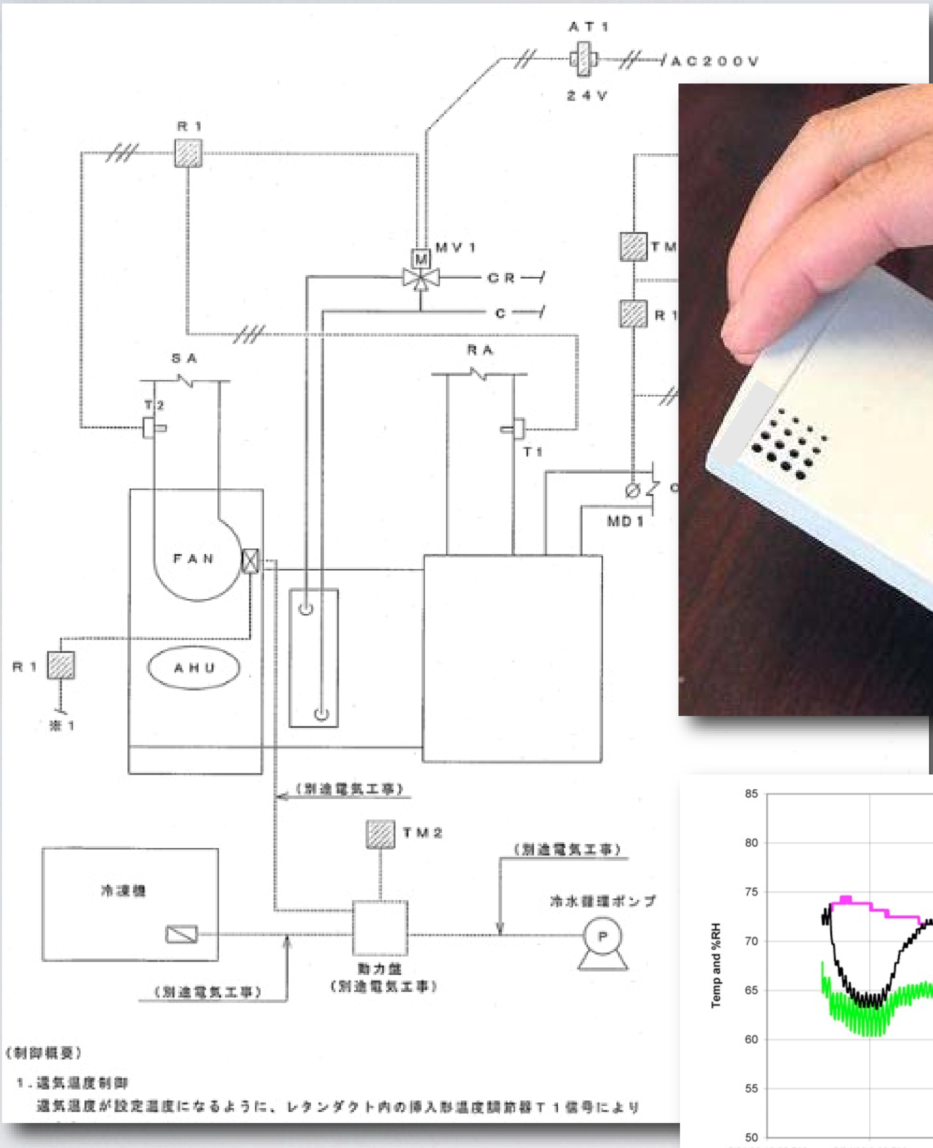


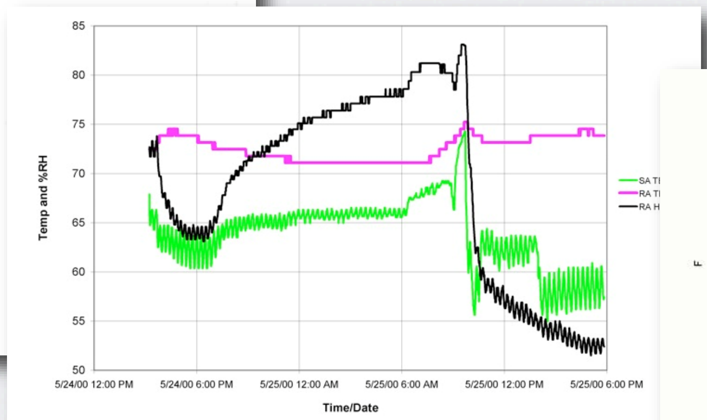


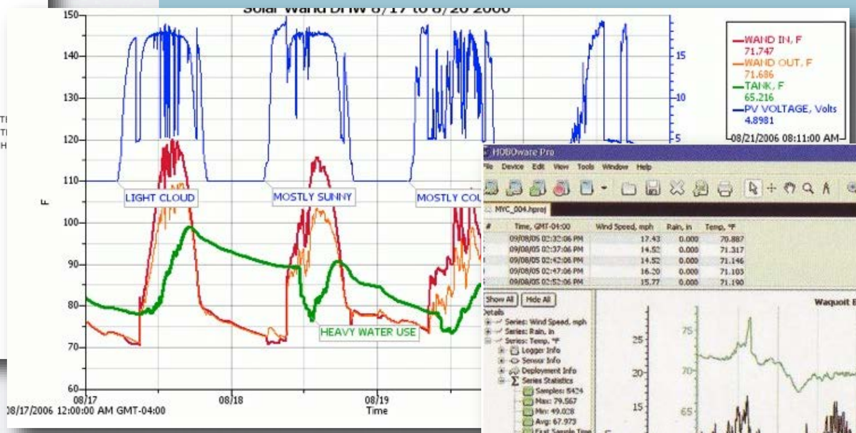
How to measure?

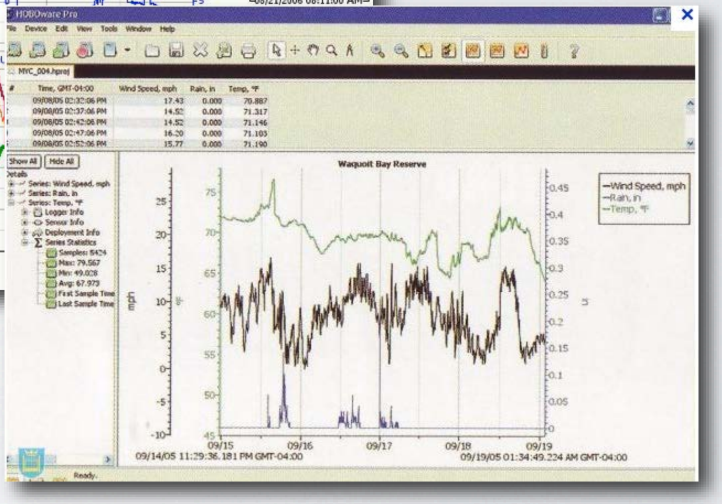
Flow Hood, or Pitot Tube and Calculator

Measuring Dehumidification *Over Time*—Controls









Dehumidification

Humidity removal

Dry airflow

Controls

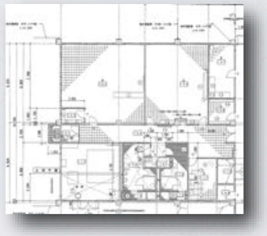
Do they really work?

Review diagrams, place data loggers, then compare to the real world

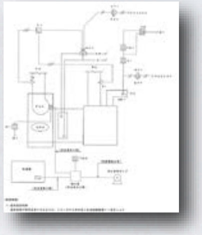
Logical Sequence—Summary

1. **Listen and understand the problems**

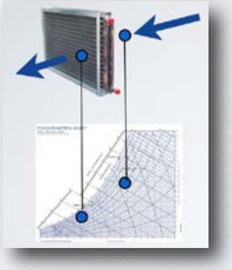
2. **Look at drawings, then walk through and understand the building**



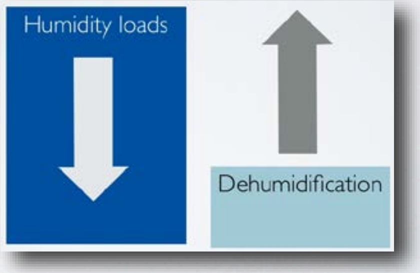
3. **Look at drawings, then walk through and understand the HVAC system**



4. **Measure the key variables**
   - **Loads**
   - **Dehumidification**



5. **Diagnose the problems, plan solutions**



Section 4 of 6

Community Health Clinic Malaysia

Community Health Clinic

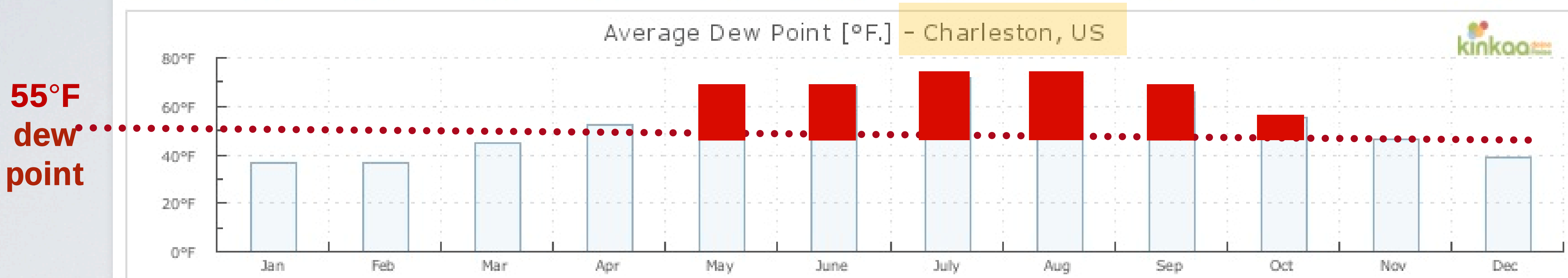
Background

- New government-owned and -operated community clinic
- Mold problems (almost immediately after opening in 2003)
- Constant comfort complaints: "Too cold!" "Too Hot!"
- Repeated HVAC adjustment; no improvement in either problem
- Bad publicity forced closure and mold remediation in 2008
- Engineering firm had contract to remediate mold and re-adjust HVAC yet again. Wanted to get to the root of the ongoing problems and solve them ***permanently***.

Outdoor Humidity in Malaysia

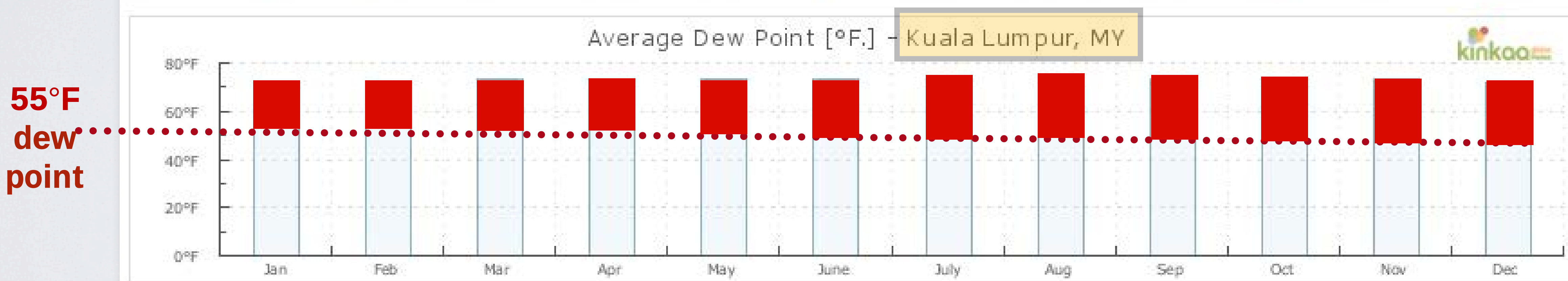
Average Dew Point

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
53.6°F	37.4°F	37.4°F	44.6°F	51.8°F	60.8°F	68°F	71.6°F	71.6°F	66.2°F	55.4°F	46.4°F	39.2°F



Average Dew Point

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
73.4°F	71.6°F	71.6°F	73.4°F	73.4°F	73.4°F	73.4°F	73.4°F	71.6°F	73.4°F	73.4°F	73.4°F	71.6°F




WAKTU OPERASI
ISNIN – KHAMIS
8.00 pg – 1.00 ptg
2.00 ptg –5 .00 ptg
JUMAAT
8.00 pg – 12.15 tgh
245 ptg –5 .00 ptg
TUTUP
SABTU
AHAD
PASAN AM
PADA WAKTU REHAT
POLIKLINIK KOMUNITI
AYER KEROH, MELAKA


KKM/PKMT/KKAK/LOBI/1/080515
HAK KERAJAAN MALAYSIA
POLIKLINIK KOMUNITI AYER KEROH
RUANG MAINAN KANAK-KANAK
PENDAFTARAN UTAMA
KAFETERIA
SHUTTLE
ANDA BERADA DISINI
LIFT
FARMASI (Bilik No 12)
TANDAS AWAM
KAWALAN & SEKURITI
KEMUDAHAN UMUM KAKI-TANGAN
UNIT PENGIMEJAN
BILIK REHABILITASI
SURAU
DEWAN SEMINAR
PENTADBIRAN
TELEFON AWAM
ARAS BAWAH
JABATAN PESAKIT LUAR
KLINIK IBU MENGANDUNG & KANAK-KANAK
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KEMUDAHAN UMUM KAKI-TANGAN
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HOSE REEL
TELEFON AWAM
POLIKLINIK KOMUNITI

[redacted]
User Screen 2
Mar 23, 2009
23.5 °C
DP 12.0 °C
Pocket A[redacted]
PEMERIKSAAN MATA :
• VISION TEST
• FUNDUS CAMERA
SILA KE BILIK A
JIKA TIADA STAFF


RUANG MAINAN KANAK KANAK
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TANDAS AWAM
KEMUDAHAN UMUM KAKI-TANGAN
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DEWAN SEMINAR
TANDAS AWAM


LIFT
ANDA BERADA DISINI
FARMASI
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KEMUDAHAN UMUM KAKI-TANGAN
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PENTADBIRAN
DEWAN SEMINAR
TANDAS AWAM


5
KEMUDAHAN UMUM KAKI-TANGAN
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FARMASI
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BILIK
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FARMASI (Bilik No 12)
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KEMUDAHAN UMUM KAKI-TANGAN
TANDAS AWAM
PENTADBIRAN
DEWAN SEMINAR


24
KELUAR
KEMUDAHAN UMUM KAKI-TANGAN
LIFT
TANDAS AWAM
FARMASI
(Bilik No 12)
ANDA BERADA DISINI
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PENDAFTARAN UTAMA
DEWAN SEMINAR
PENTADBIRAN
SURAU
LIFT
TANDAS AWAM


Bilik Perancang Keluarga
23


LIFT
ANDA BERADA DISINI
FARMASI
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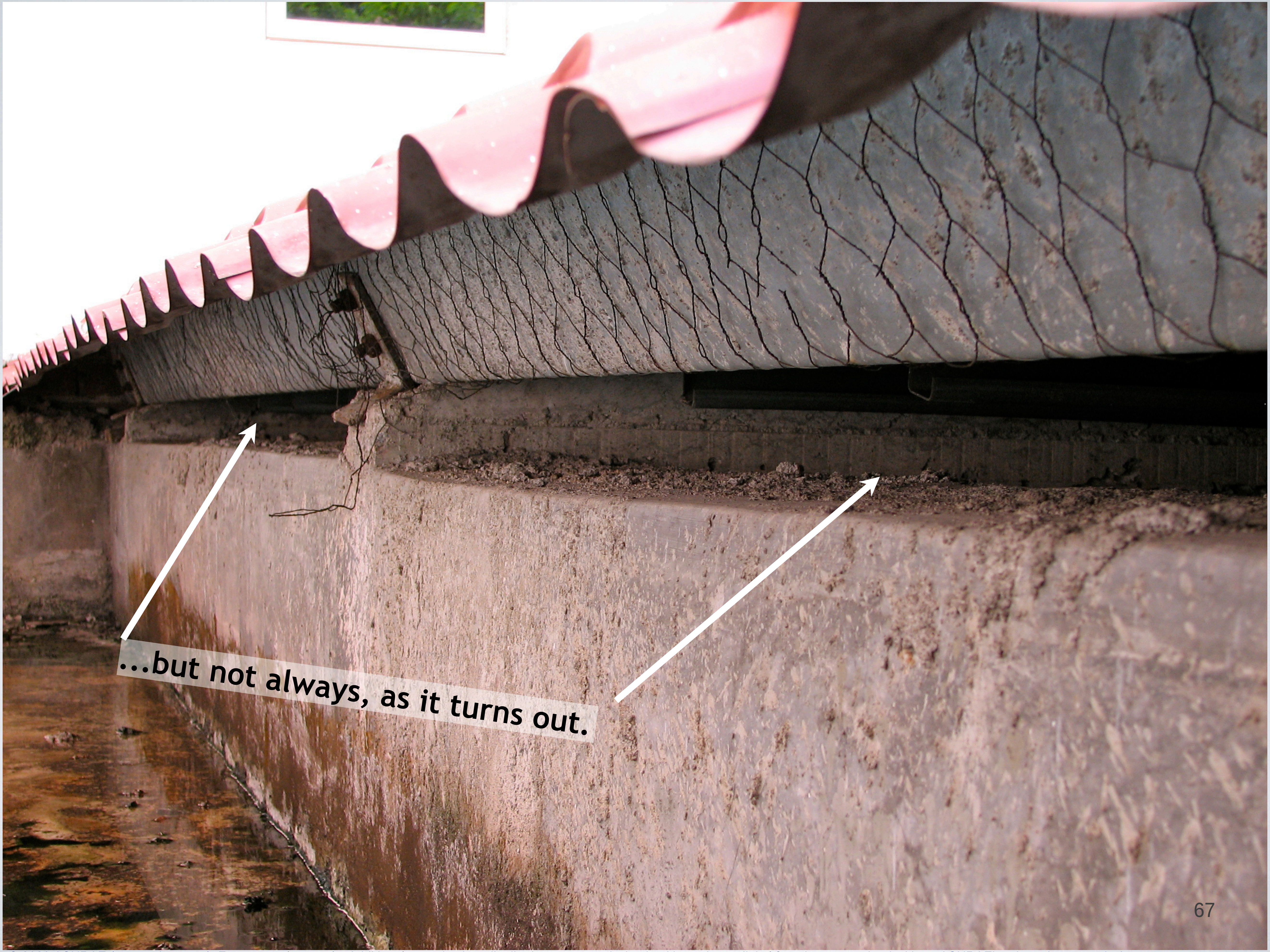
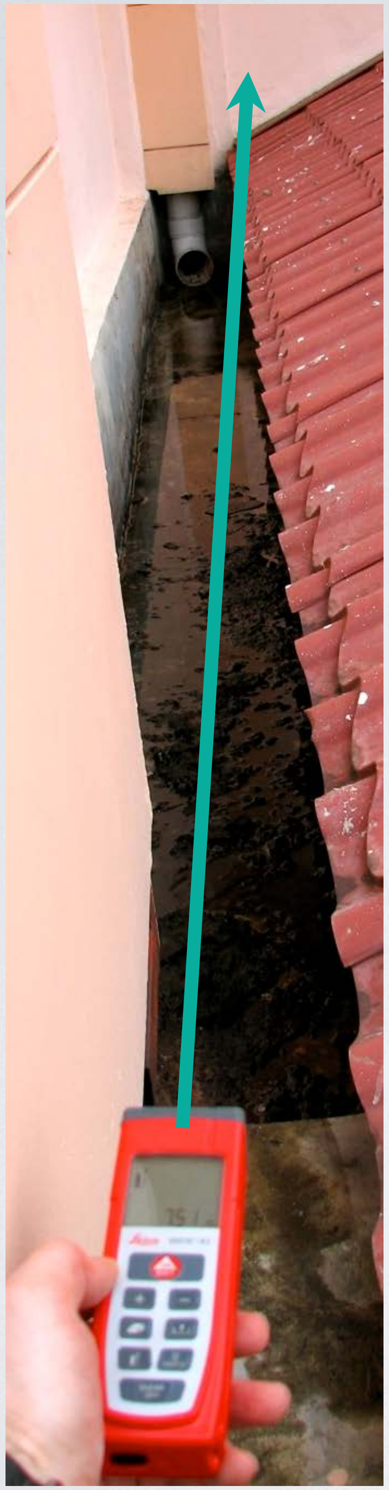
FARMASI (Bilik No 12)
TANDAS AWAM
SHUTTLE
KEMUDAHAN UMUM KAKI-TANGAN
PENTADBIRAN
TELEFON AWAM
SURAU
DEWAN SEMINAR


Sheet metal covers joint


…but not always, as it turns out.


ACESA
HERRAMIENTAS
2m.
Ref. 350o
This particular opening is 5 cm high by...



…7.5 meters long (15 ft).

So, this particular gap measures 2.5 ft^2 of open area.


…But that’s not the only gap. Here’s another one, same size.


Another 2.5 ft² opening in the building.


Big gaps *all* around the building at the roof/wall joint.


Big gaps *all* around the building at the roof/wall joint.

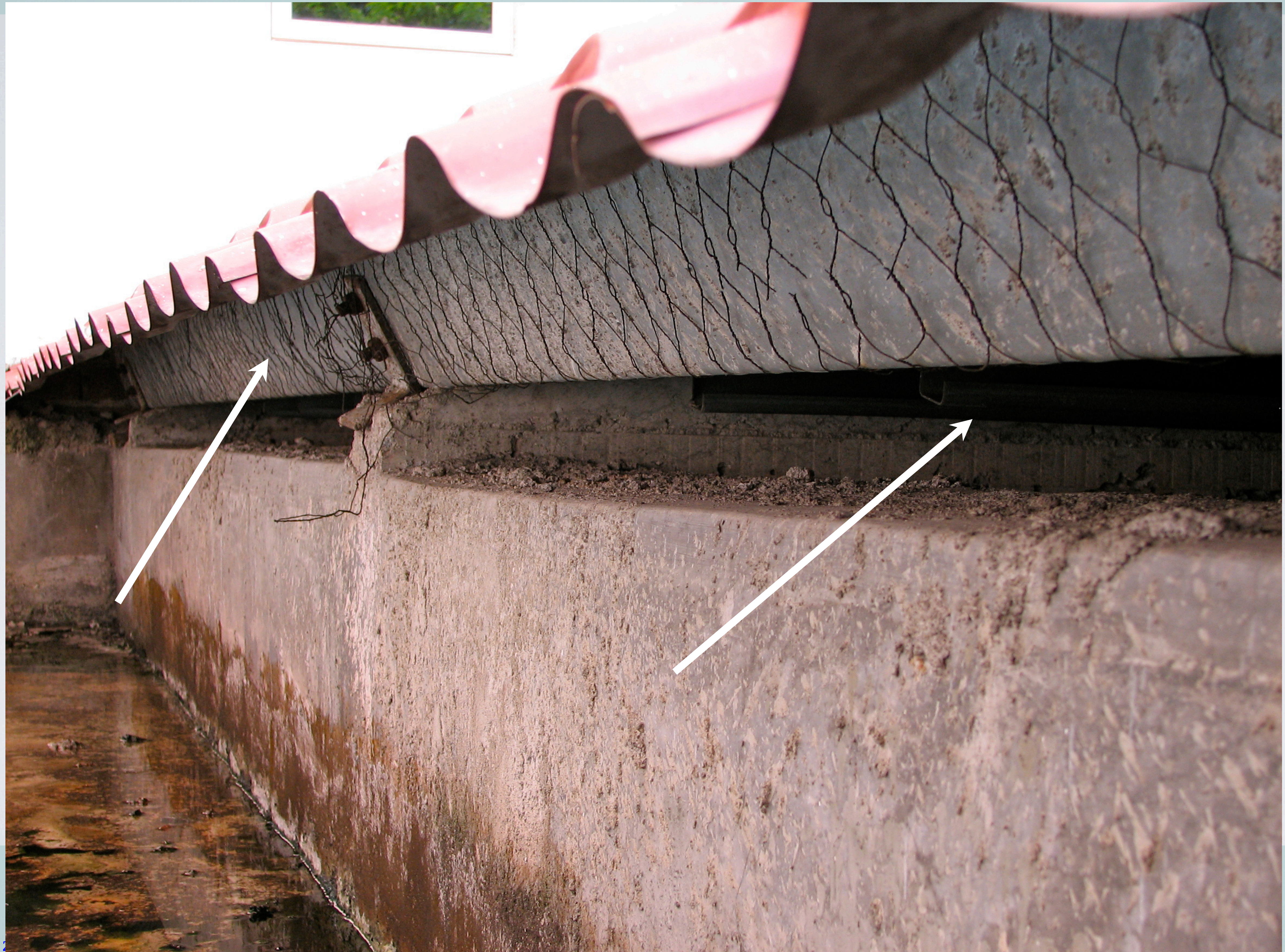

G AWX 400
Jangan Hidupkan Suis Aircond
Please Don't Switch On


WCP KUK 1 - AWX 300
SESALUR UDARA BALIK DARI TINGKAT SATU
SESALUR UDARA BEKAL KE TINGKAT SATU

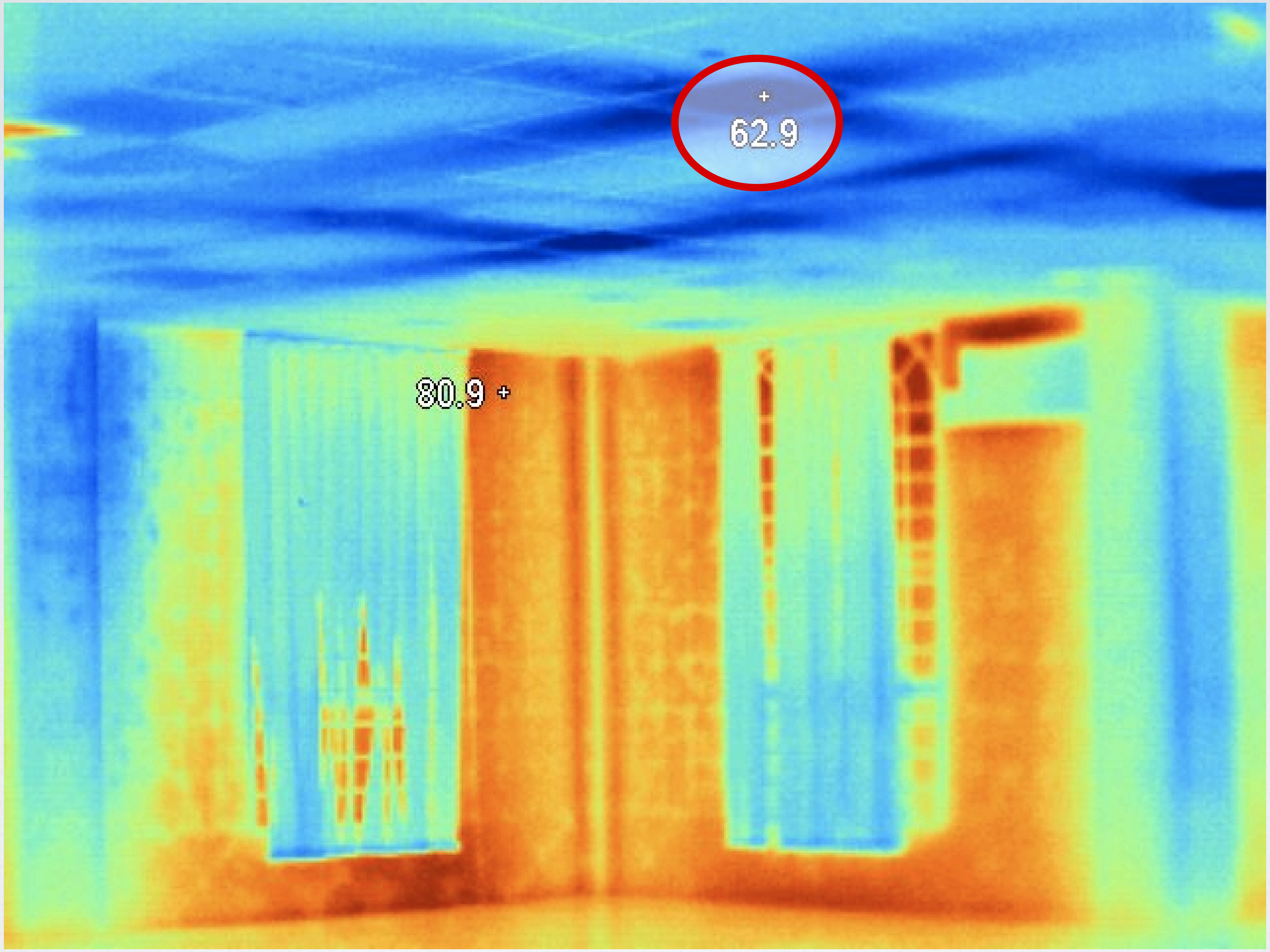

User Screen 2
Mar 23, 2009
23.5 °C
DP 12.0 °C
[redacted]
Pocket [redacted]
PEMERIKSAAN MATA :
• VISION TEST
• FUNDUS CAMERA
SILA KE BILIK A
JIKA TIADA STAFF

...so mold grows on
the cool, damp surface.
The RH *in the air*
is only 54%, however,...
The RH *at the surface* is
over 95%
...and the *surface* is
cold (66°F)...
...the *dew point* is
high (64°F).
OMEGASCOPE
E 86
°C
19
FUNC
LOCK
[redacted]
User Screen 1
28.4 °C
53.6 %
18.1 °C

Humid Air Floods into the Building...



And Contacts Cool Surfaces, which Absorb the Humidity, Allowing Mold Growth

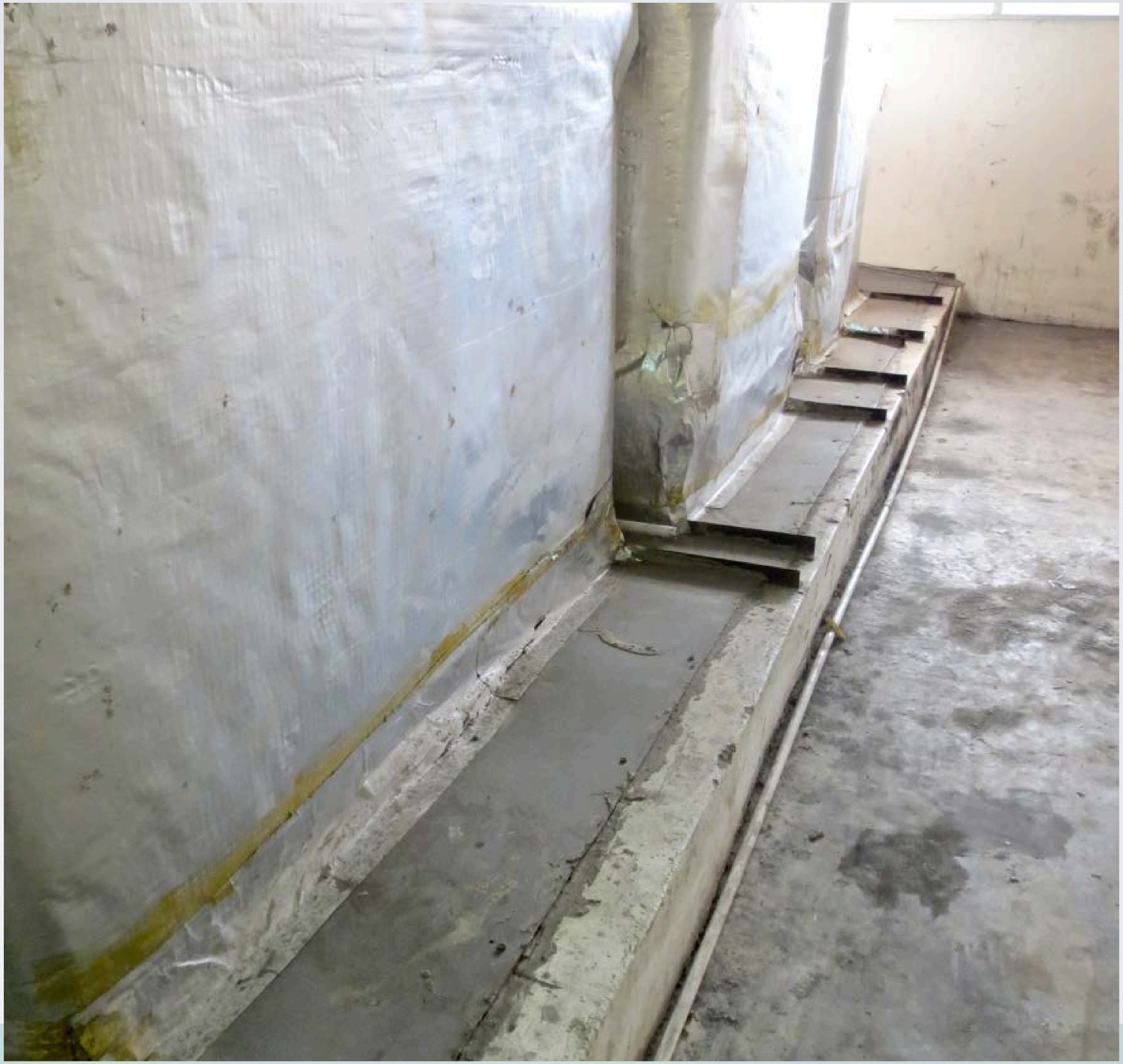


Solution

- Measured and reset correct supply airflows for each room.
- Sealed gaps between the roof and walls with sheet metal and spray foam (working from inside).
- Sealed the gaps between ducts and duct chase openings with sheet metal and spray foam.
- Installed desiccant DH unit which operates after AC units turn off at 5:00 p.m. DH keeps indoor air near or below 55°F dew point.
- No more comfort problems. Nearly no mold problems. There is a cost to operate the desiccant DH but much less than operating cooling units.

Before and After Air Sealing

Air Sealing the Duct Chases



Air Sealing Open Chase to First Floor

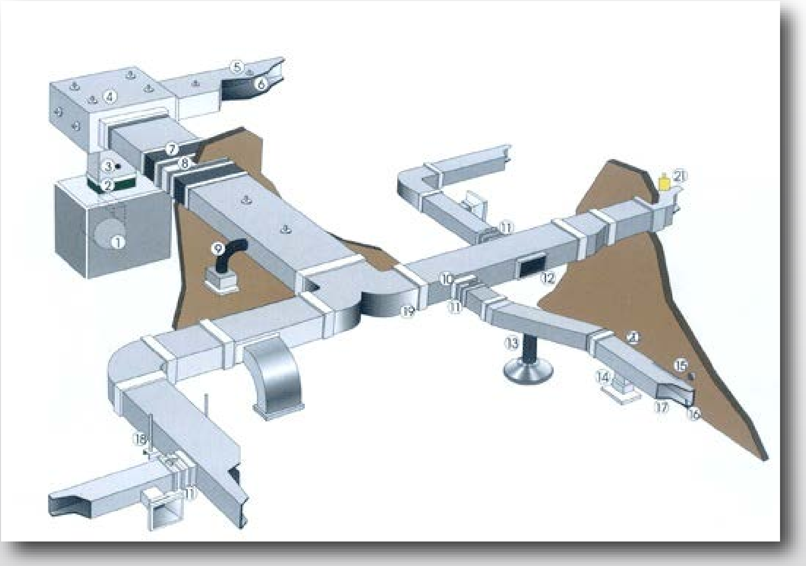
Desiccant Dehumidifier

Before and After (Air Sealing Alone—No DH)

Air Sealing + Desiccant during Unoccupied Hours

With Perfect Hindsight

- Excellent rain water management in Malaysian buildings (roofs, perimeter drains, foundation drains, etc.)
- Typical reaction of HVAC designers to high humidity loads = *more tonnage*! (Catastrophically wrong reaction.)
- Probably nobody told the architectural designer that airtightness is *critical* in an air-conditioned building.
- A focus on *controlling dew point* would have provided quick clues to surface condensation and mold growth problems



Part 5 of 6

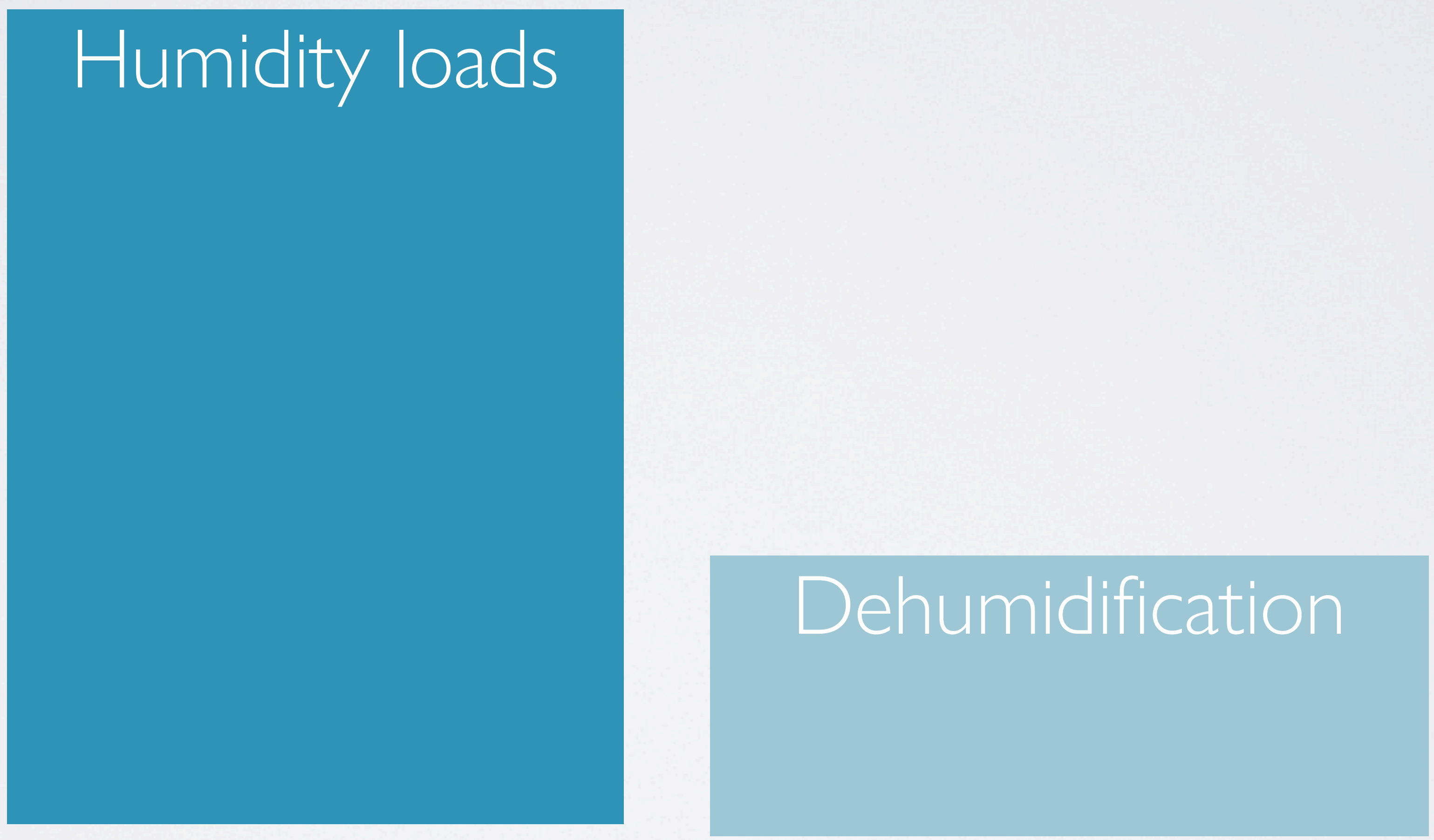
Troubleshooting the HVAC Side of the Problem

AC Systems and Humidity Control

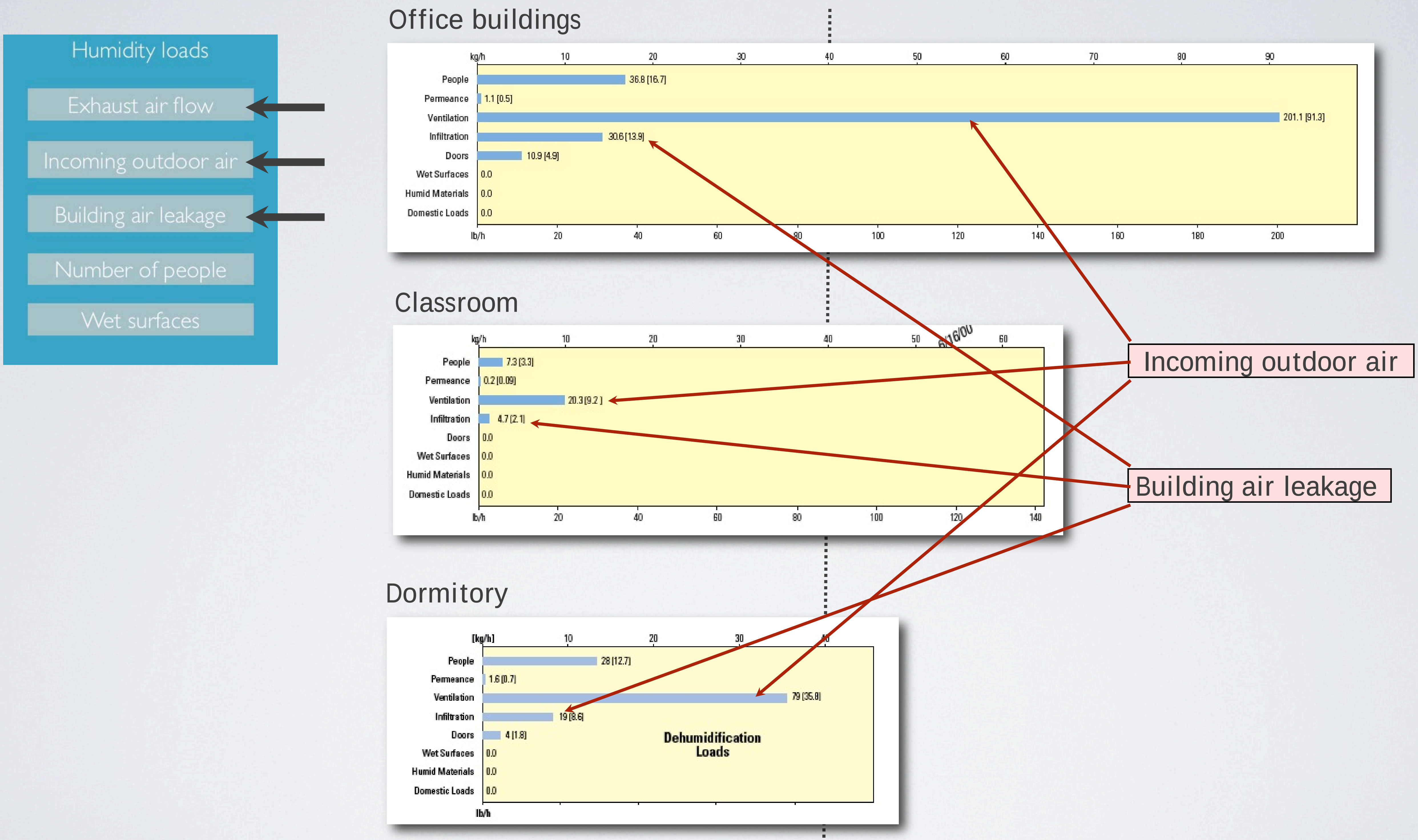
- Typical humidity load profiles
- DH equipment and performance
- Cooling systems—DH problems and solutions
- Overall HVAC system design and installation—DH problems and solutions
- Unoccupied hours—DH problems and solutions

Understanding Humidity Load Profiles

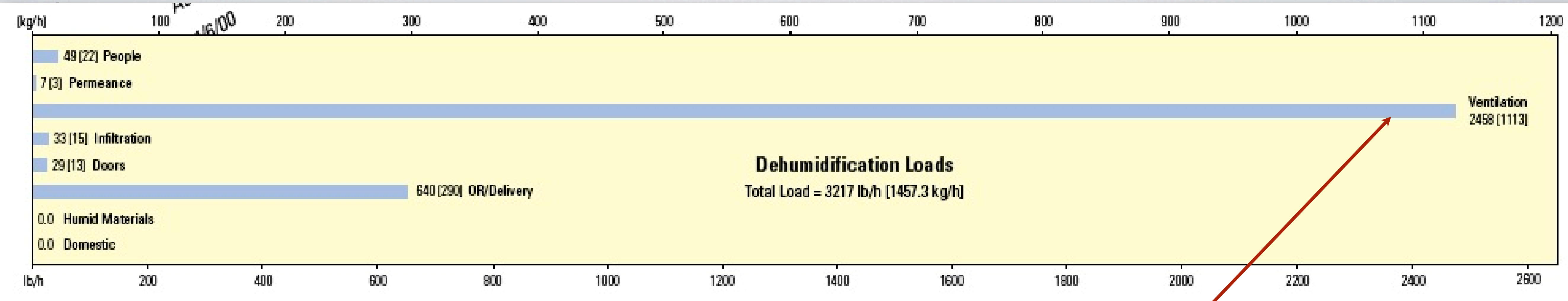
1. When humidity is too high it is because humidity loads > dehumidification

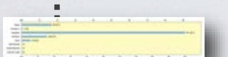


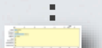
The Big Loads Are Almost Always *Ventilation/Makeup Air* and *Building Air Leakage*



Hospitals—Same Loads but *Much* Bigger



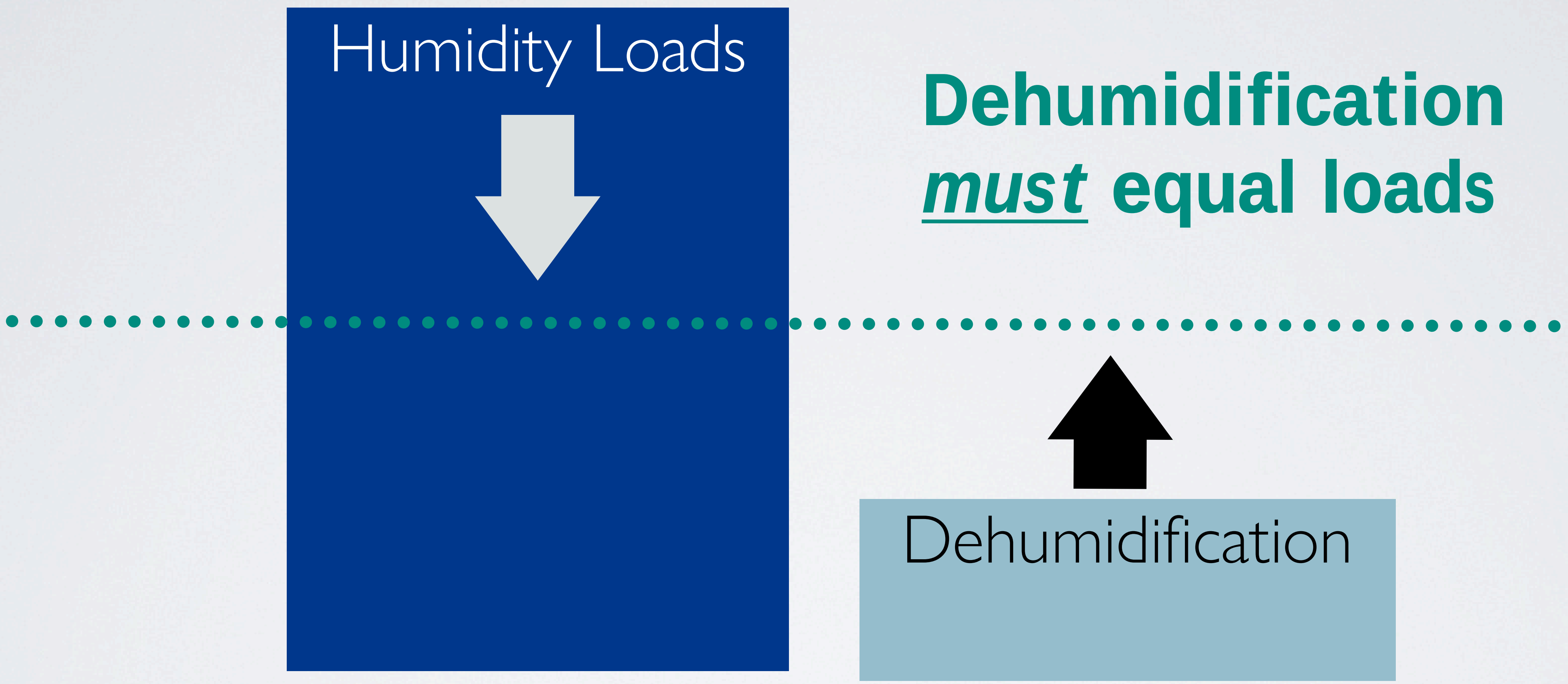

Office building


Classroom


Dormitory

Incoming outdoor air

For HVAC Troubleshooting—Look for High Loads or Reduced DH Capacity

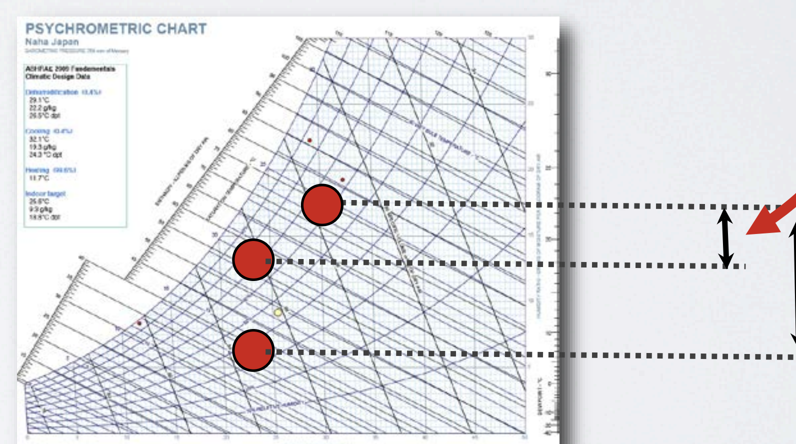


Dehumidification _must_ equal loads

DH Equipment Capacity Problems? Only Two Causes

$$\text{Humidity removal (lb/h)} = \frac{\text{cfm} \times 4.5 \times (\text{Inlet gr/lb} - \text{Outlet gr/lb})}{7000}$$

- **Not enough air, or...**
- **The air is not *dry* enough**



Calculating the Ventilation DH load

1. What you know:
   - Incoming ventilation airflow (1000 cfm)
   - Outdoor air humidity ratio (114 gr/lb)
   - Room humidity ratio (65 gr/lb)

- Calculate the ventilation DH load:

$$\text{Dehumidification load (lb/h)} = \frac{\text{cfm} \times 4.5 \times (\text{Outdoor gr/lb} - \text{Indoor gr/lb})}{7000}$$

Measuring **Ventilation Load** Versus Dehumidification Accomplished by **Cooling Just the Return Air**

	DH Load from Outdoors
Ventilation airflow (cfm)	1000
Outdoor air humidity (gr/lb)	114
Room air humidity (gr/lb)	65
Totals (lb/hr)	31.5

Calculating Dehumidification by Cooling the Return Air

1. What you know:
   - Total supply airflow (10,000 cfm)
   - Mixed outdoor + return air humidity ratio (70 gr/lb)
   - Air temperature leaving the cooling coil: 56°F
   - Therefore coil-leaving humidity ratio is 67 gr/lb

- Calculate the DH accomplished by the coil:

$$\text{Dehumidification load (lb/h)} = \frac{\text{cfm} \times 4.5 \times (\text{Return air gr/lb} - \text{Supply air gr/lb})}{7000}$$

Measuring **Ventilation Load** Versus Dehumidification Accomplished by **Cooling Just the Return Air**

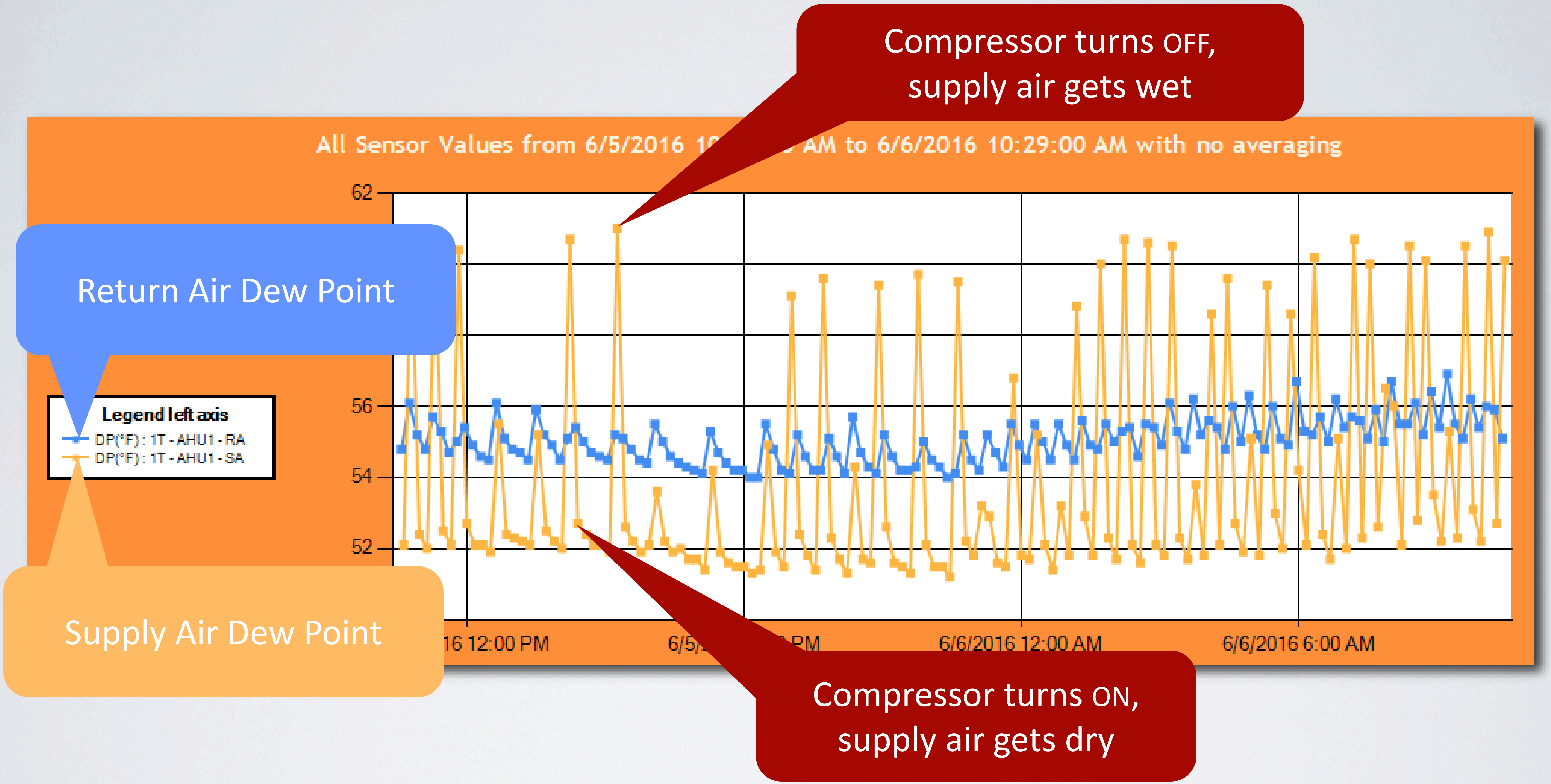
	DH Load from Outdoors	Dehumidification of Return Air
Ventilation airflow (CFM)	1,000	10,000
Entering air humidity (gr/lb)	114	70
Leaving air humidity (gr/lb)	65	67
Totals (lb/hr)	31.5	19.2

Cooling Systems—DH Problems and Solutions

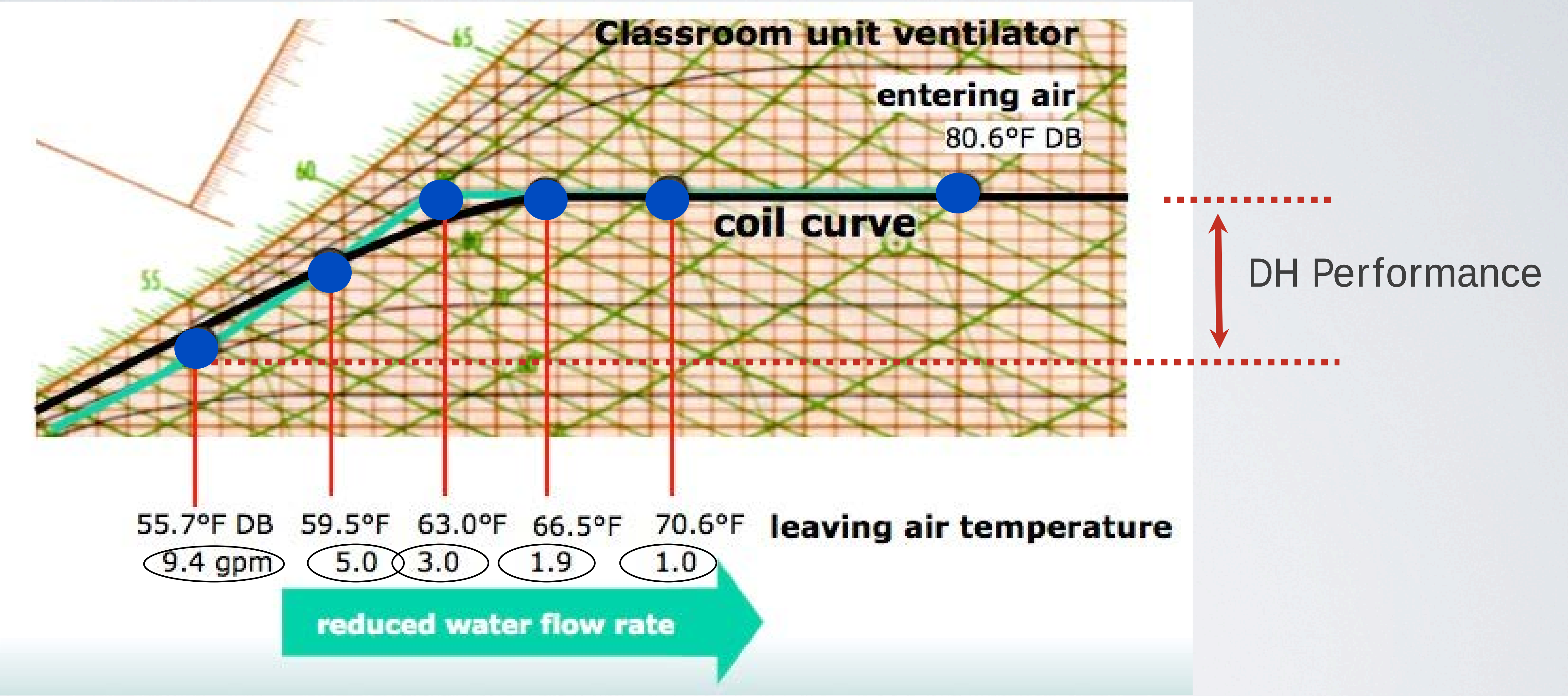
Constant-volume DX
cooling systems

Chilled-water
cooling coil
and air handler

Constant-Volume DX Cooling Equipment Dehumidification ***Varies Radically*** Over Time



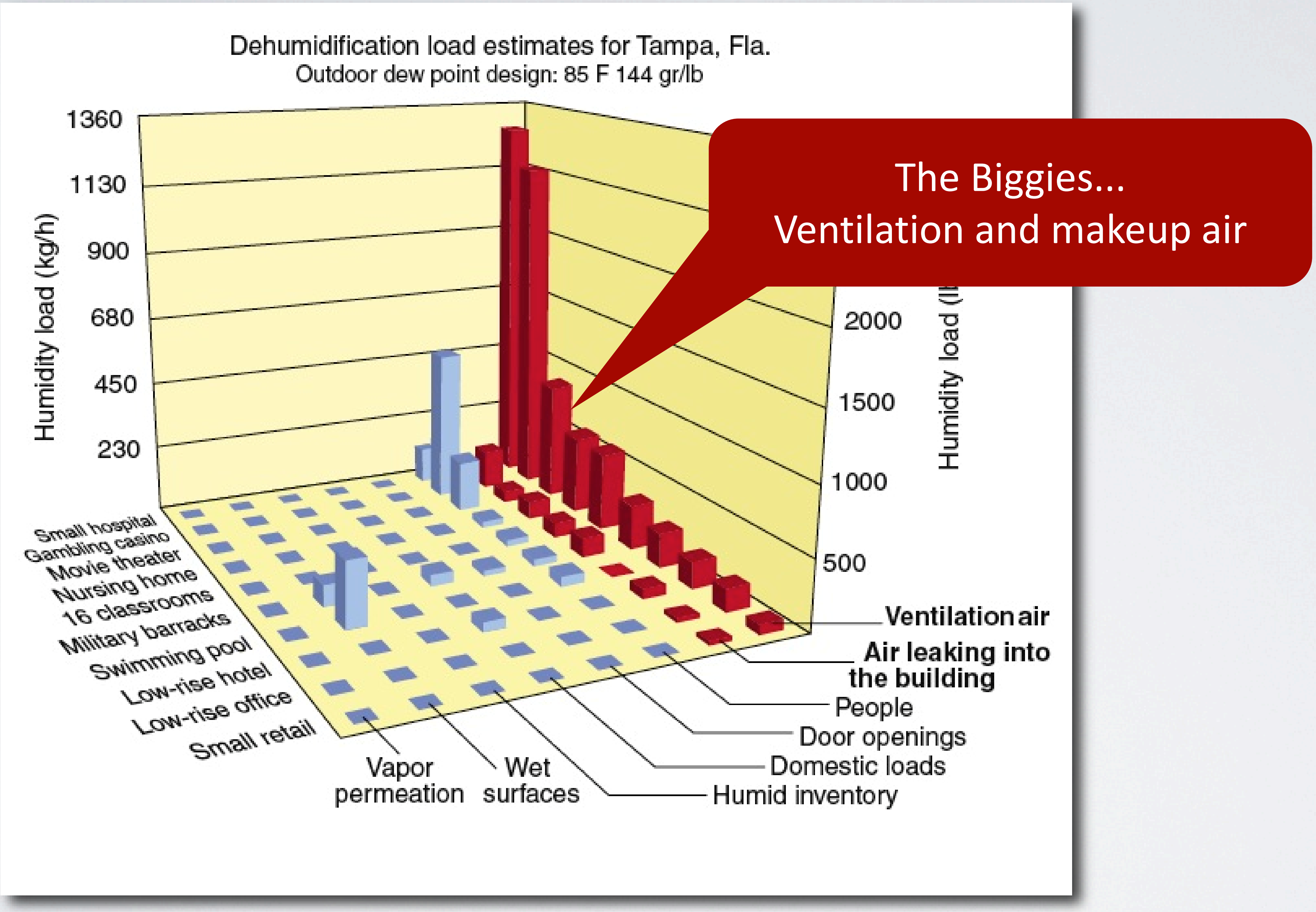
Chilled-Water Cooling Systems:
DH Performance Goes to Zero at about 30% Flow



Chilled Water: Classic DH Problems and Solutions

- **Coil surface clogged—Not enough air**
  - Short term—Clean the coil and install clean filters
  - Long term—UV lamps to break down and prevent biofilm
- **Chilled-water temperature too high; Coil cannot dry the supply air**
  - Short term—Reduce chilled-water temperature (and airflow)
  - Long term—Replace with two coils (stacked above one another); top one (big) modulates water flow to control temperature, while the lower one (small) runs constantly at low temperature to remove humidity
- **Modulating water valve—Coil temperature too high**
  - Short term—Reduce supply airflow
  - Long term—Replace with two coils (stacked above one another); top one (big) modulates water flow to control temperature, while the lower one (small) runs constantly at low temperature to remove humidity

BIG HVAC humidity loads - Ventilation + makeup air



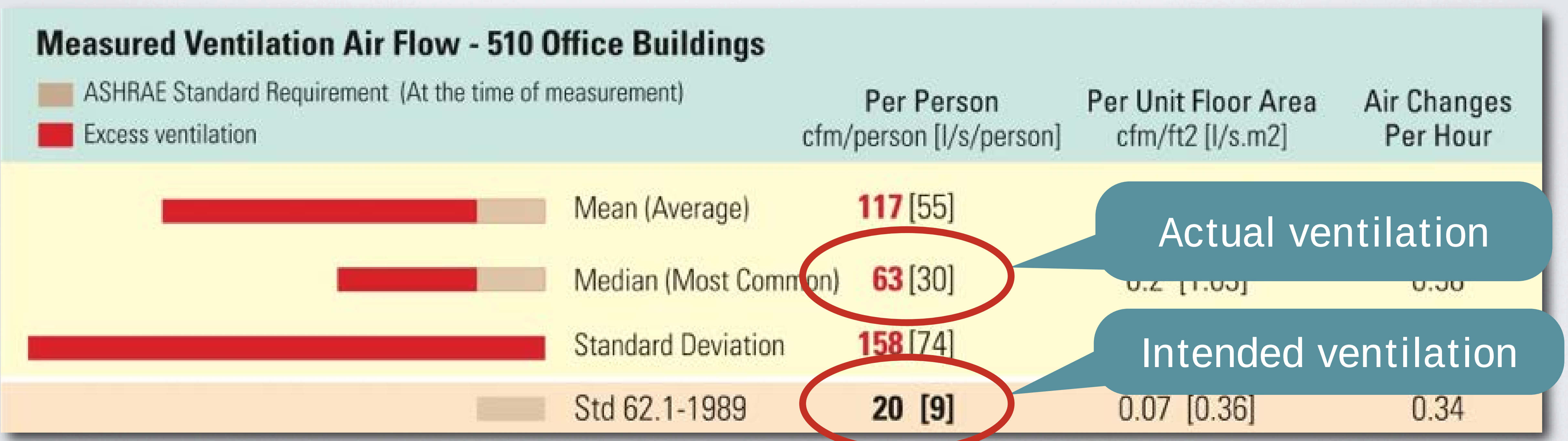
Important Questions about HVAC Humidity Loads

1. Do you really *need* the current amount of ventilation and makeup air?
   - Ventilation: How many people are really in the building?
   - Makeup air: Do all of those exhaust fans really need to be on?

2. Is the ventilation and makeup air *dry*?
   - Ventilation: **Can** the HVAC system dry the ventilation air? Does it **in fact** dry the air?
   - Makeup air: Can the **makeup air go direct to the exhaust** without going through the conditioned space?

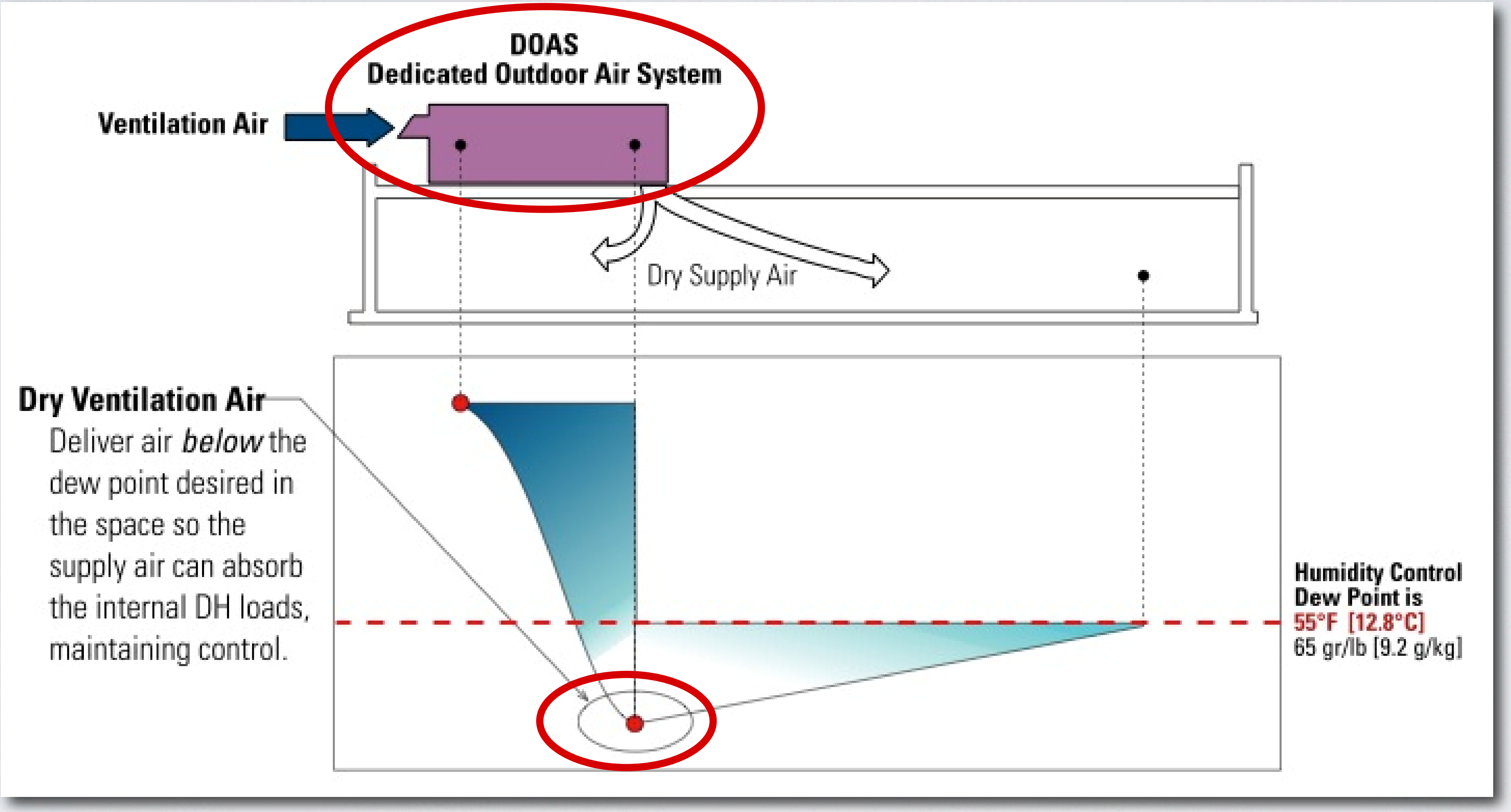
Do You Really Need the Current Volume of Ventilation Air?

- **Ventilation air often not controlled (Excess humid ventilation air overloads the DH component)**
  - Short term: Measure and reset the ventilation airflow to the actual current requirement
  - Long term: Add controls to modulate ventilation air in response to CO_2 sensor (demand-controlled ventilation [DCV])

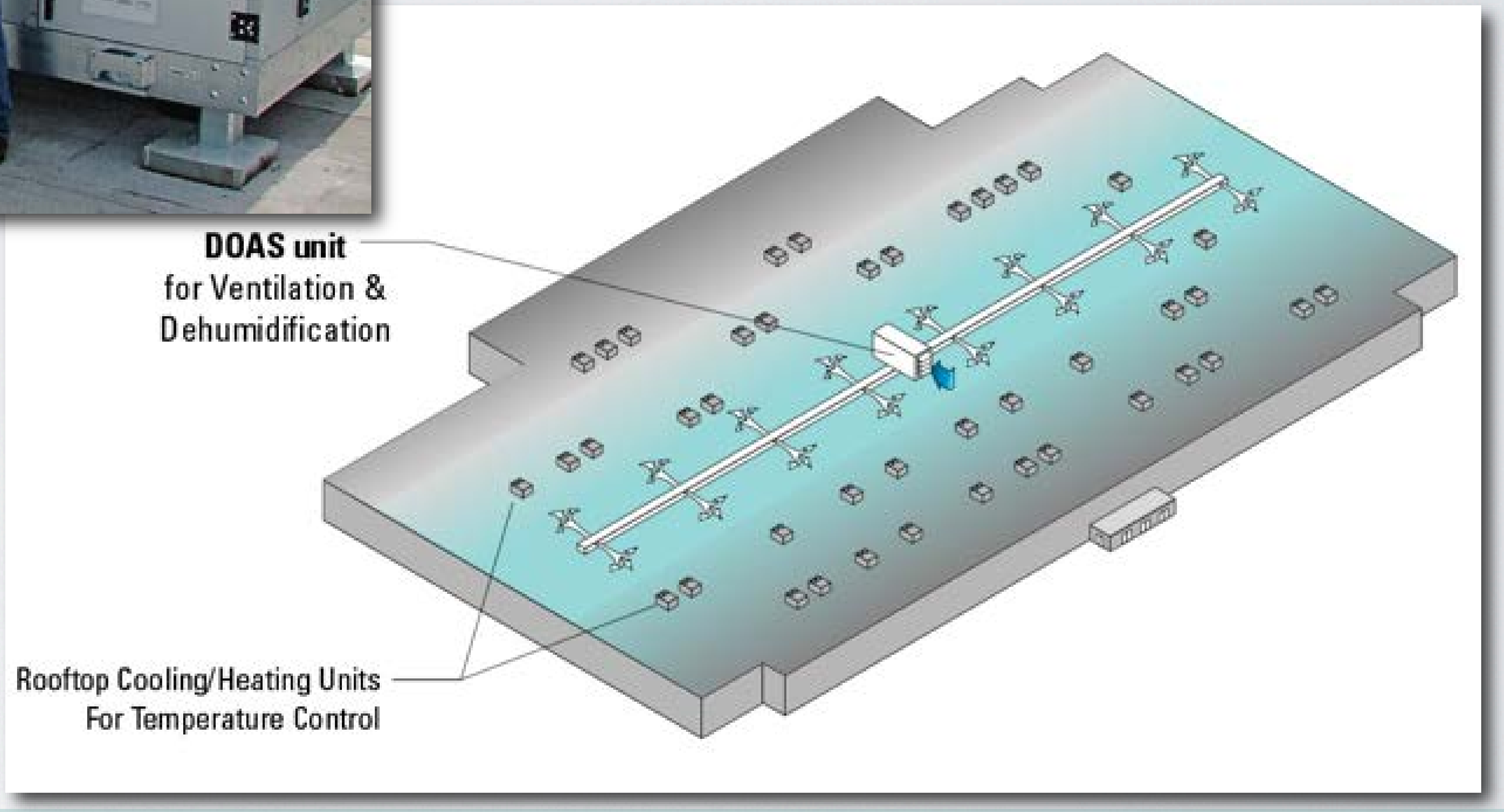


Andrew Persily (NIST) "Ventilation demand and performance in U.S. office buildings" *ASHRAE Journal*

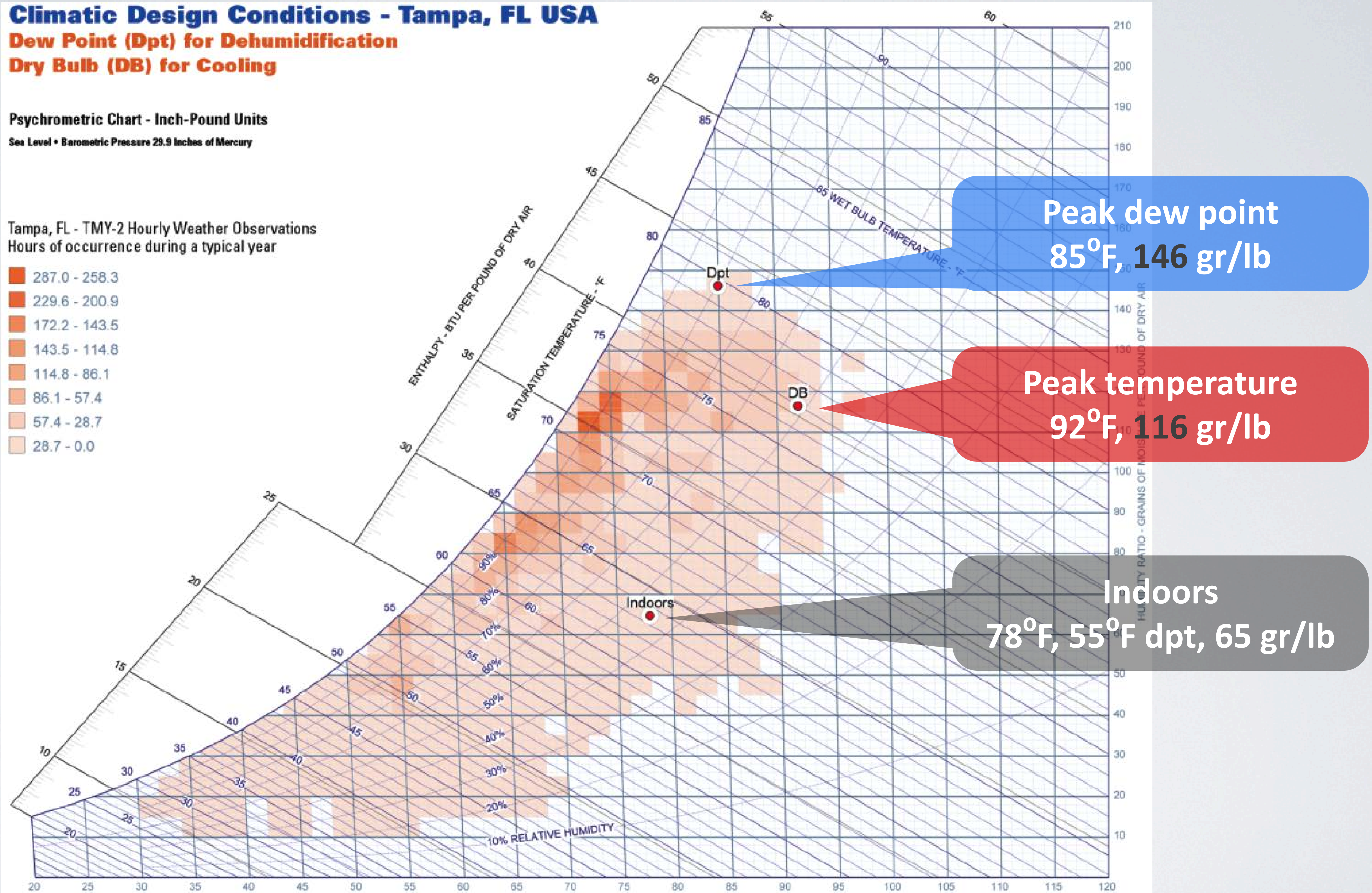
Keep the Ventilation Air Dry: Dedicated Outdoor Air Systems (DOAS) for Ventilation



Dedicated Outdoor Air System (Retail Store)



DOAS Equipment—Design for *Peak Dew Point*



Differences between Peak DB and Peak DPT

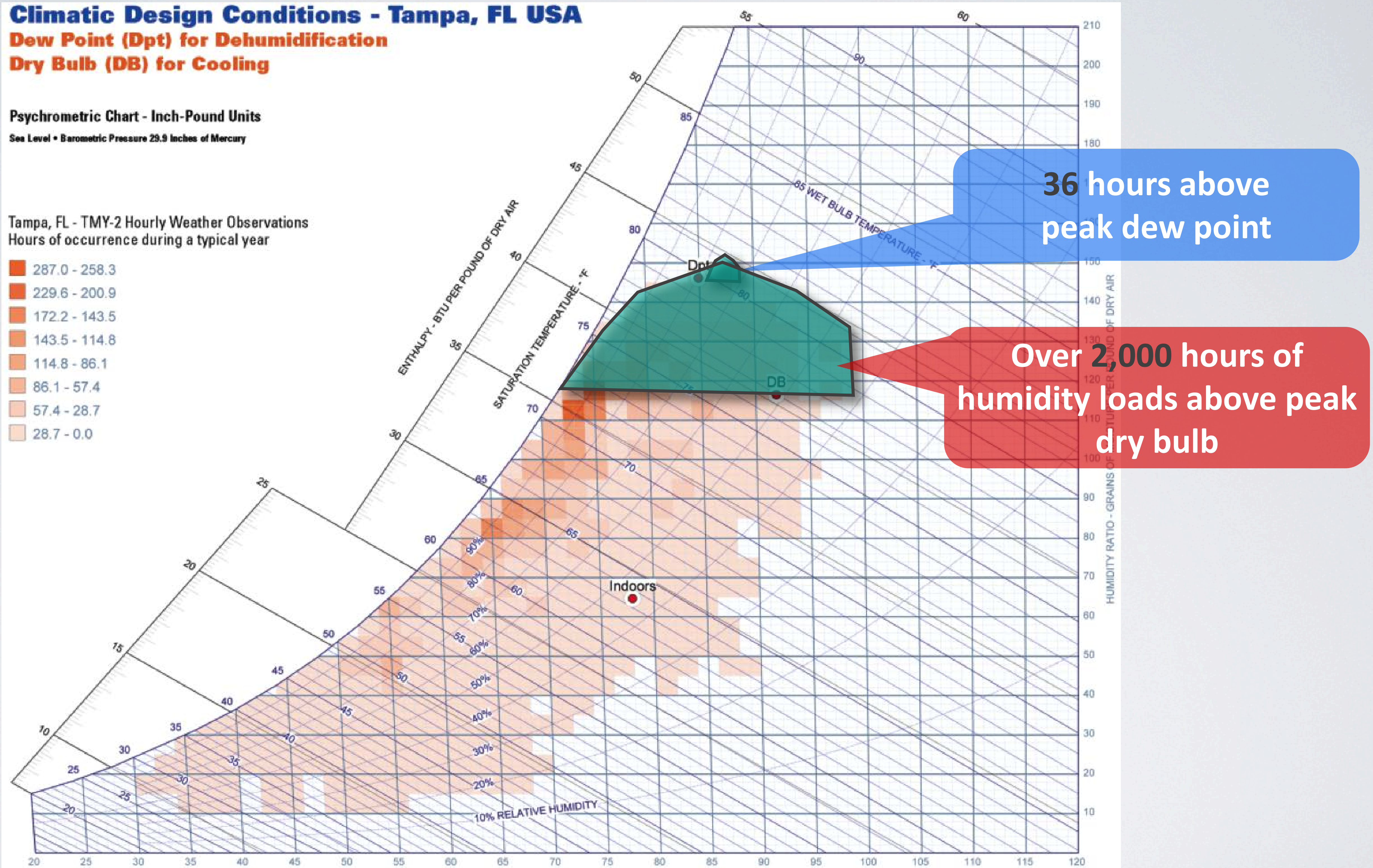
Dayton, OH

0.4% Dry Bulb	0.4% Dew Point	**Difference at peak dew point**
90° DB 74° MCWB	**81°**DB 74°MCWB	**-9°F DB**
98 gr/lb	128 gr/lb	**+30 gr/lb**

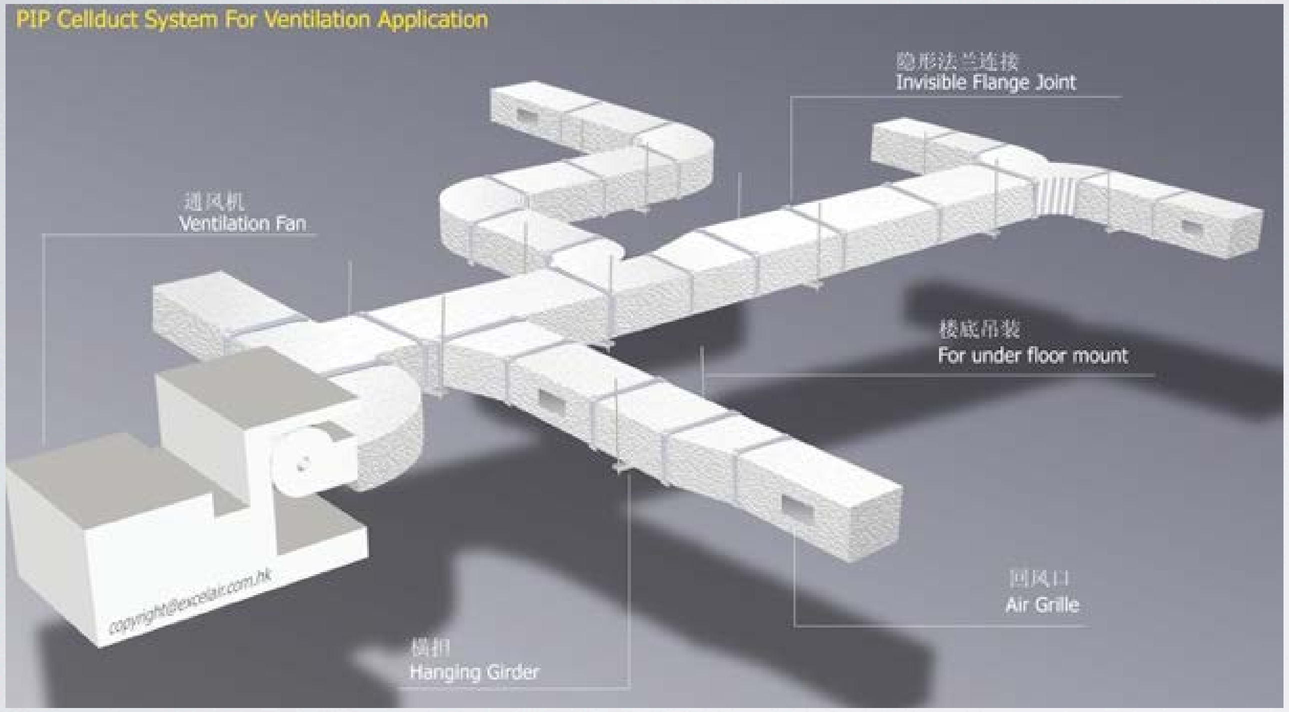
Phoenix, AZ

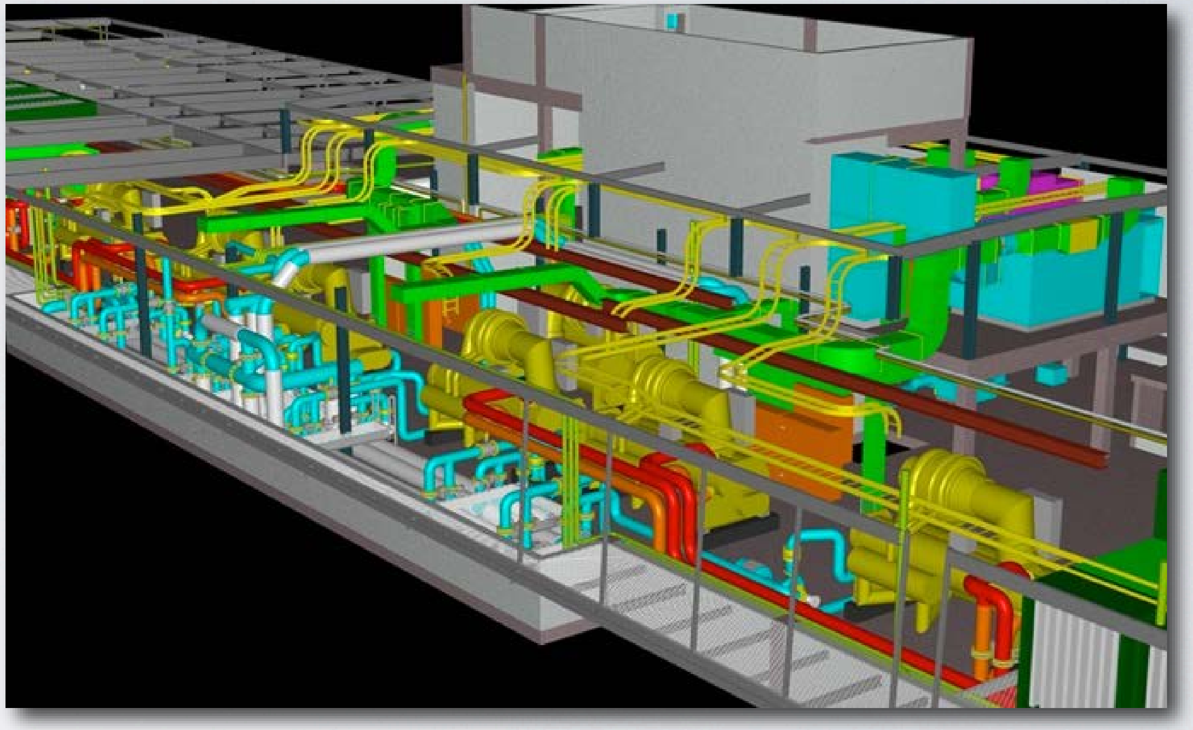
0.4% Dry Bulb	0.4% Dew Point	Difference at peak dew point
110° DB 69.6° MCWB	**82°**DB 75°MCWB	-28°F DB
44 gr/lb	120 gr/lb	**+76 gr/lb**

36 hr of Higher Load Risk Versus 2000 hr



Overall HVAC Design and Installation Problems





Overall HVAC Design and Installation Problems

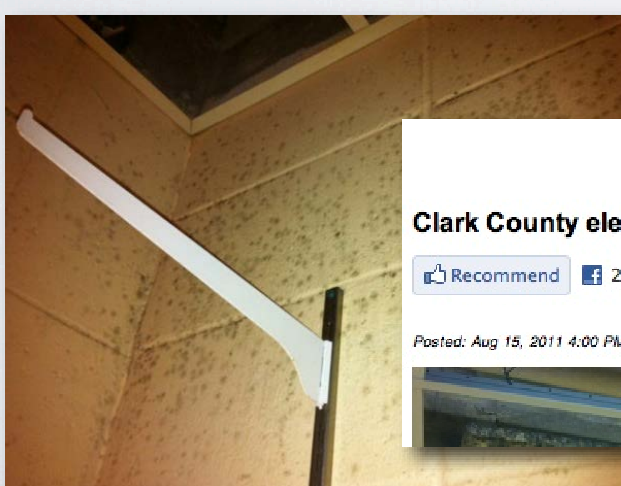
- **Air-side economizer control—Floods the building with humid air**
  - Short term: *Reduce economizer set point temperature* so it cannot bring in outdoor air with a dry-bulb temperature above the desired indoor dew point temperature (reset to 55°F).
  - Long term: Reconsider whether air-side economizer ever actually saves energy in humid climates.
  - Long term: Replace controls with dew-point control; monitor outdoor air dew point. Set a dew point limit on the outdoor air economizer (no extra outdoor air above a 55°F dew point.

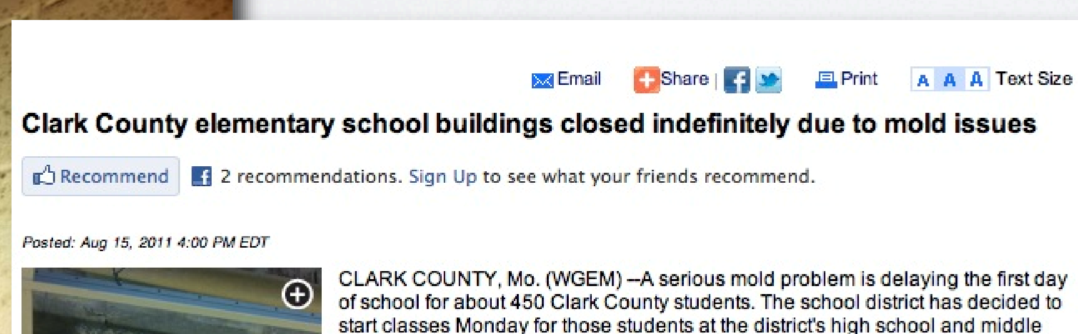
- **Chilled-water temperature reset—Coil no longer cold enough to dehumidify**
  - Short term: Reduce chilled-water temperature and also reduce airflow.
  - Long term: Replace single coil with two stacked coils. One dries air all the time; the other responds to indoor temperature set point.

Overall HVAC Design and Installation Problems

- **Air leaks in return air plenums and underfloor air supply plenums**
  - Short term: Seal up duct leaks, and reconnect ducts that have become detached from air handlers and other ducts.
  - Long term: *Replace* plenums with tightly sealed duct work. Plenums always waste energy because they always leak and they always cool parts of the building that do not need to be cooled.
- **Air leaks at exhaust duct joints**
  - Short term: Seal up duct joints that are accessible, using mastic.
  - Long term: *Replace* large central exhaust systems with many small, locally controlled exhaust and supply systems equipped with energy recovery devices.

Unoccupied Hours—Problems and Solutions





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Clark County elementary school buildings closed indefinitely due to mold issues

Recommend 2 recommendations. Sign Up to see what your friends recommend.

Posted: Aug 15, 2011 4:00 PM EDT

CLARK COUNTY, Mo. (WGEM) --A serious mold problem is delaying the first day of school for about 450 Clark County students. The school district has decided to start classes Monday for those students at the district's high school and middle school.

Problems during Unoccupied Hours

- **Temperature set point is raised. Indoor dew point also rises. Then intermittent cooling chills surfaces and grows mold.**
  - Short term: Make sure exhaust fans and ventilation air are *off entirely* during unoccupied hours.
  - Long unoccupied periods (vacations, etc.): Turn off AC systems. Install temporary desiccant dehumidifiers with "layflat" clear plastic supply ducting. Dehumidifiers operate when RH is above 50%.
  - Long term: Higher cost—Install dedicated outdoor air system with a return air connection. Dries ventilation air when the building is occupied and recirculates dry air when building is not occupied.
- **Exhaust Air Continues when AC Systems are Off**
  - Short term: Time clock for exhaust fan control or interlock with AC systems.

Problems during Unoccupied Hours

- **Ventilation air continues when indoor temperature set point is raised, flooding building with humid air**
  - Short term: Install motorized dampers to close off ventilation air when building is unoccupied.
  - Long term: Higher cost—Install dedicated outdoor air system with a return air connection. Dries ventilation air when the building is occupied and recirculates dry air when building is not occupied.

- **Building is partly occupied. A few rooms are cooled; most are not. Mold grows on cold surfaces.**
  - Short term: Operate cooling systems based on maximum dew point in unoccupied rooms, not on room temperature.
  - Long term: Higher cost—Install dedicated outdoor air system with a return air connection. Dries ventilation air when the building is occupied and recirculates dry air when building is not occupied.

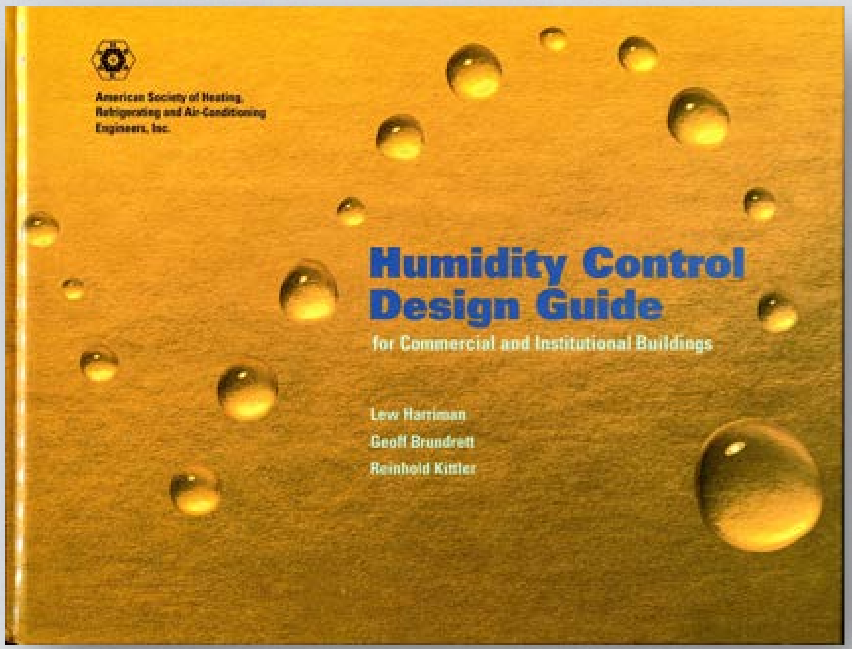
Summary

- **To solve humidity control problems:**
  - Reduce the loads or
  - Increase dehumidification (DH) capacity

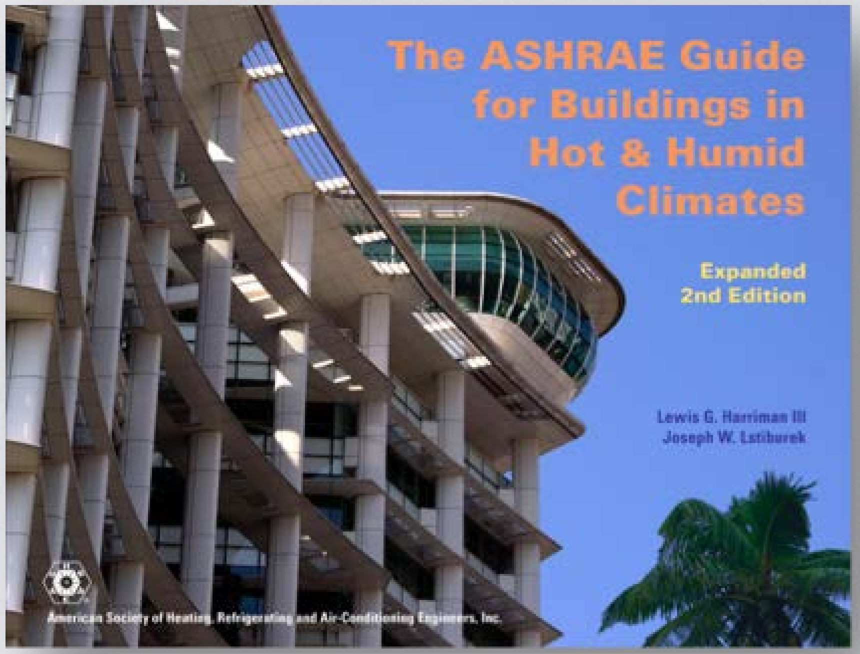
- **To reduce the loads:**
  - Make sure the HVAC system is not *creating* extra loads such as excess ventilation, plenum and duct leaks that pull humid air into the building, exhaust fans that do not turn off when AC systems turn off, etc.

- **To increase DH capacity:**
  - Make sure the DH components are actually removing humidity. If they are not, fix them so they will do so:
    - Adequate airflow
    - Adequate dew point reduction

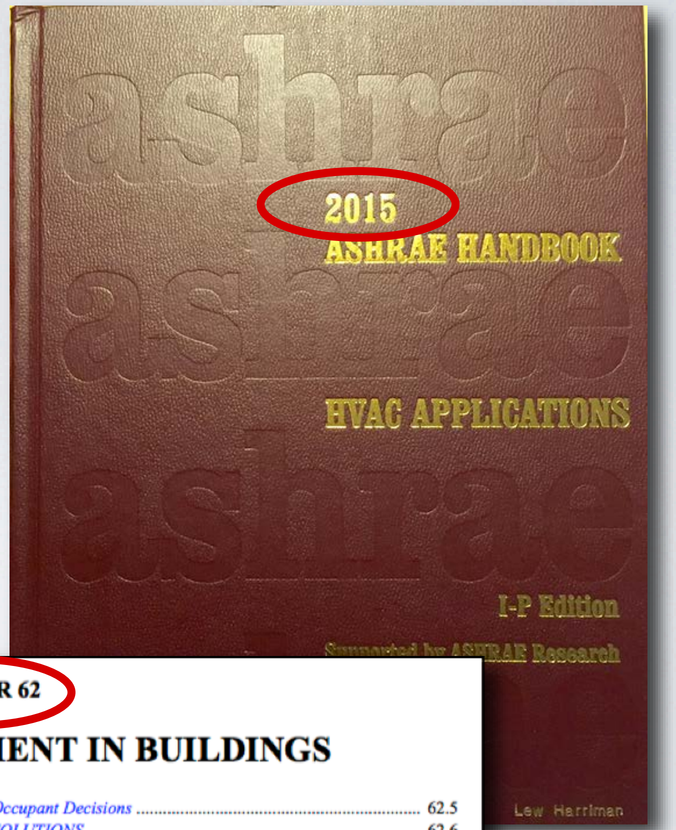
More detailed advice from ASHRAE



Humidity Control Design Guide



The ASHRAE Guide for Buildings in Hot & Humid Climates



Japanese Edition

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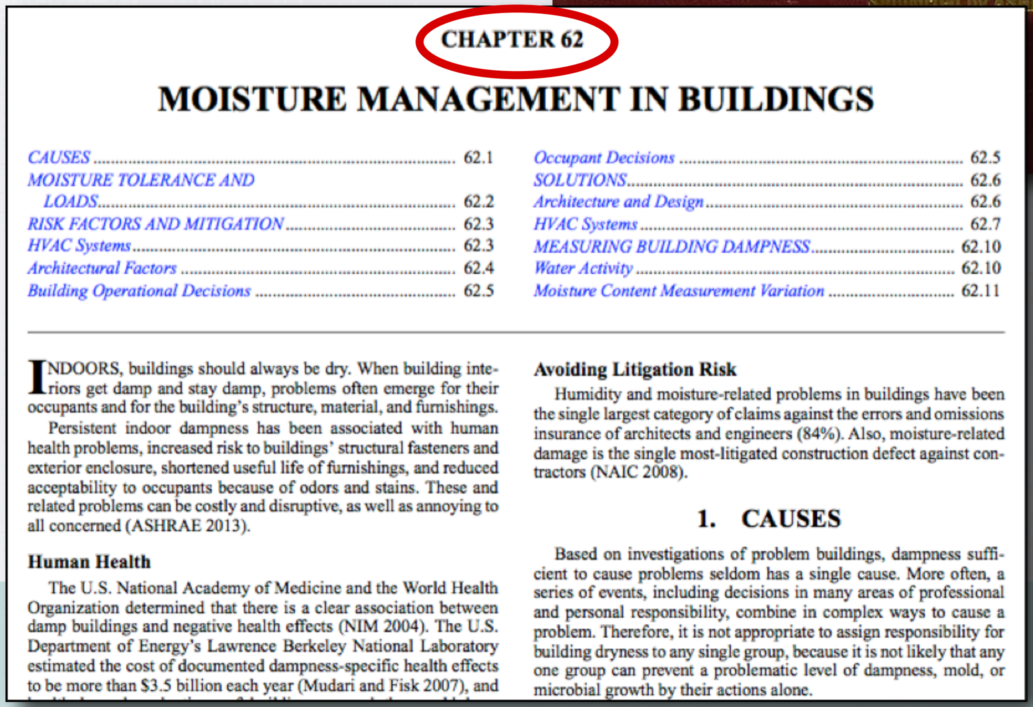

CHAPTER 62

MOISTURE MANAGEMENT IN BUILDINGS

INDOORS, buildings should always be dry. When building interiors get damp and stay damp, problems often emerge for their occupants and for the building's structure, material, and furnishings.

Persistent indoor dampness has been associated with human health problems, increased risk to buildings' structural fasteners and exterior enclosure, shortened useful life of furnishings, and reduced acceptability to occupants because of odors and stains. These and related problems can be costly and disruptive, as well as annoying to all concerned (ASHRAE 2013).

Human Health

The U.S. National Academy of Medicine and the World Health Organization determined that there is a clear association between damp buildings and negative health effects (NIM 2004). The U.S. Department of Energy's Lawrence Berkeley National Laboratory estimated the cost of documented dampness-specific health effects to be more than $3.5 billion each year (Mudari and Fisk 2007), and

Avoiding Litigation Risk

Humidity and moisture-related problems in buildings have been the single largest category of claims against the errors and omissions insurance of architects and engineers (84%). Also, moisture-related damage is the single most-litigated construction defect against contractors (NAIC 2008).

1. CAUSES

Based on investigations of problem buildings, dampness sufficient to cause problems seldom has a single cause. More often, a series of events, including decisions in many areas of professional and personal responsibility, combine in complex ways to cause a problem. Therefore, it is not appropriate to assign responsibility for building dryness to any single group, because it is not likely that any one group can prevent a problematic level of dampness, mold, or microbial growth by their actions alone.

Questions?

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