Diagnosing and Fixing Humidity Control Problems
In Real-World Buildings

ASHRAE

Distinguished Lecture

Mason-Grant CONSULTING

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Portsmouth, NH
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Outline

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2. Understanding RH, dew point and mold growth

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6. Summary

Section 1 of 6

Examples of Real-world Humidity Problems

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School - Plenty of system capacity!... Why mold?

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

New training building and new HVAC equipment... Why mold and equipment failures?

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$6 Million new home, state-of-the-art HVAC... Why is humidity over 65% RH?

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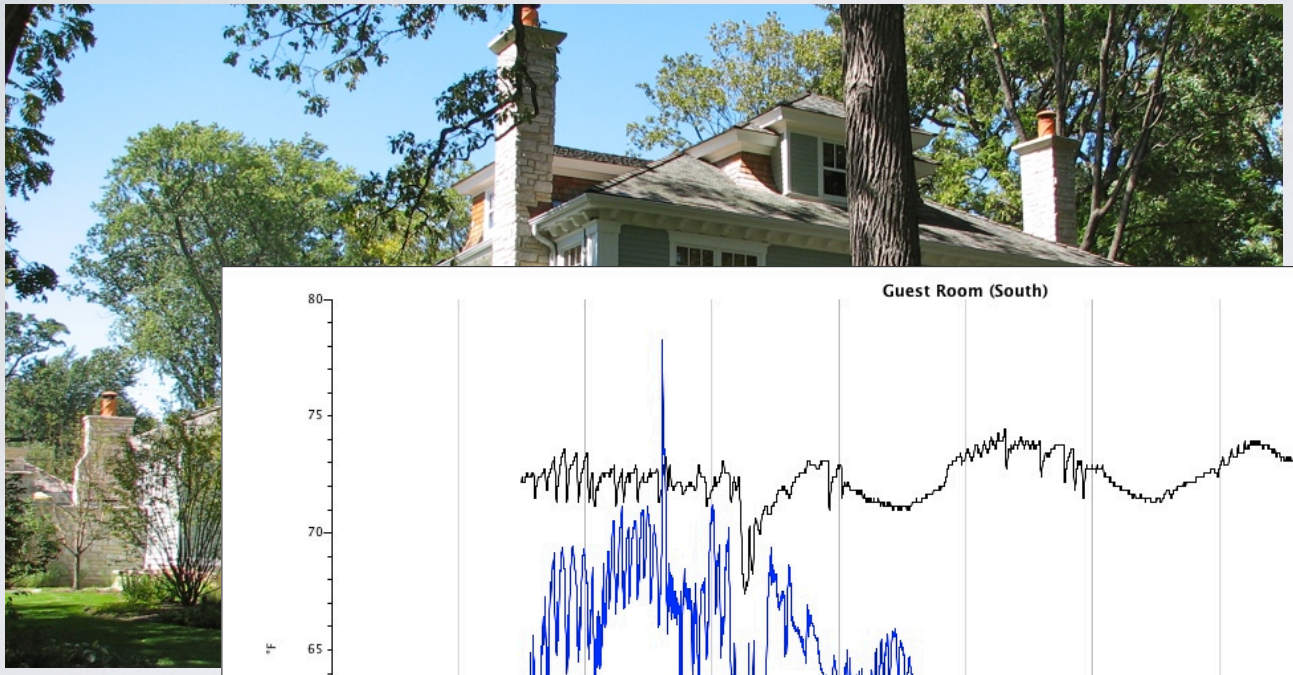

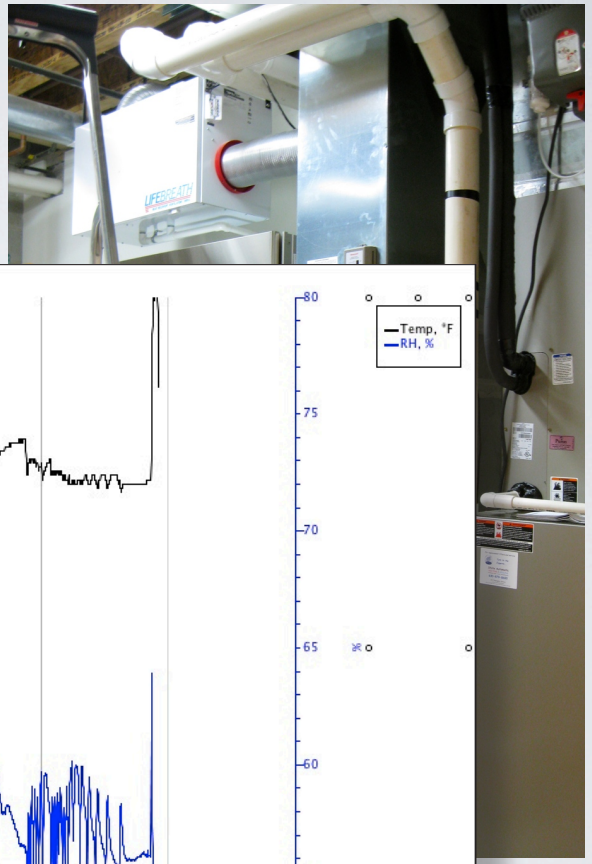

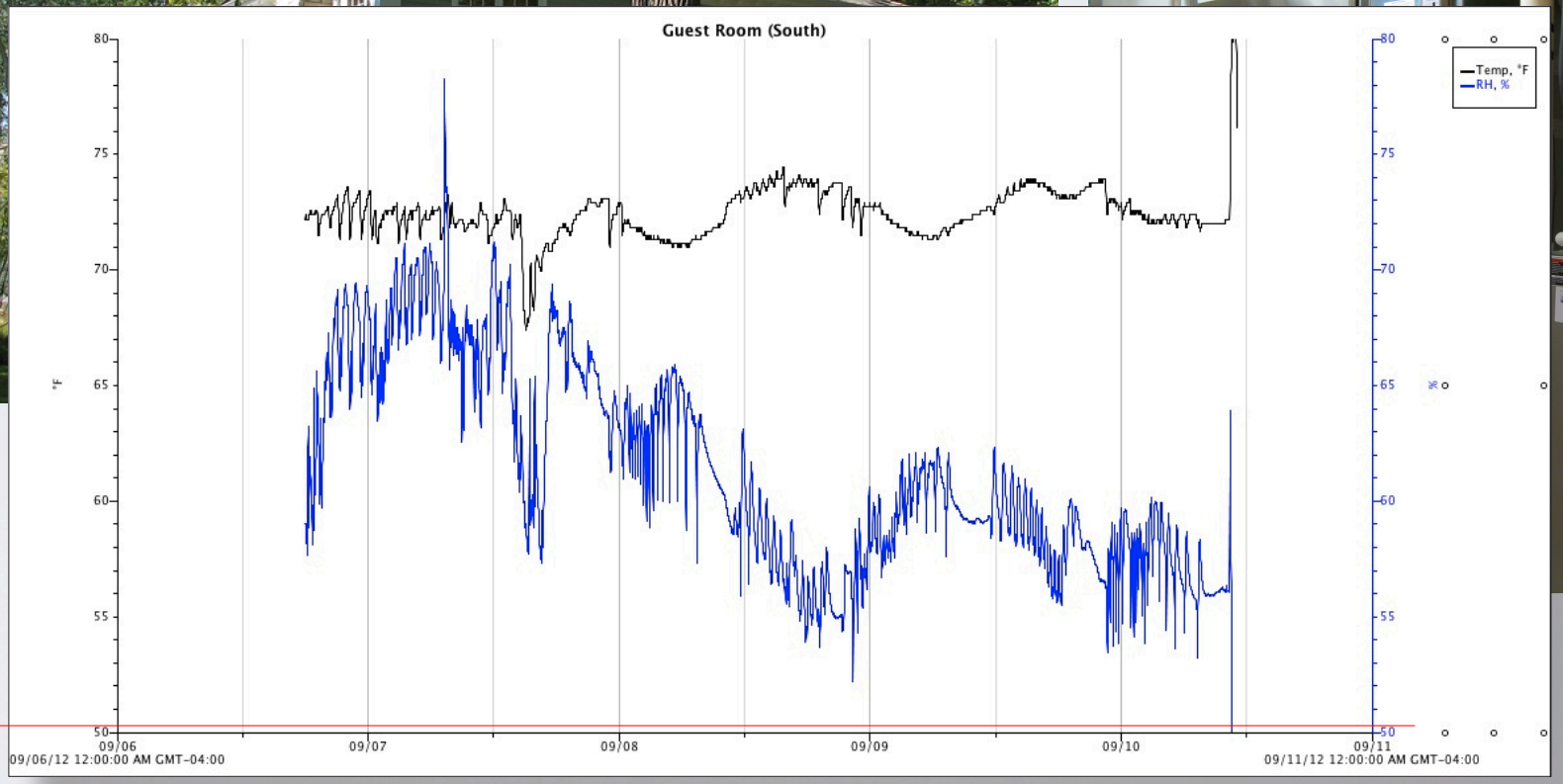

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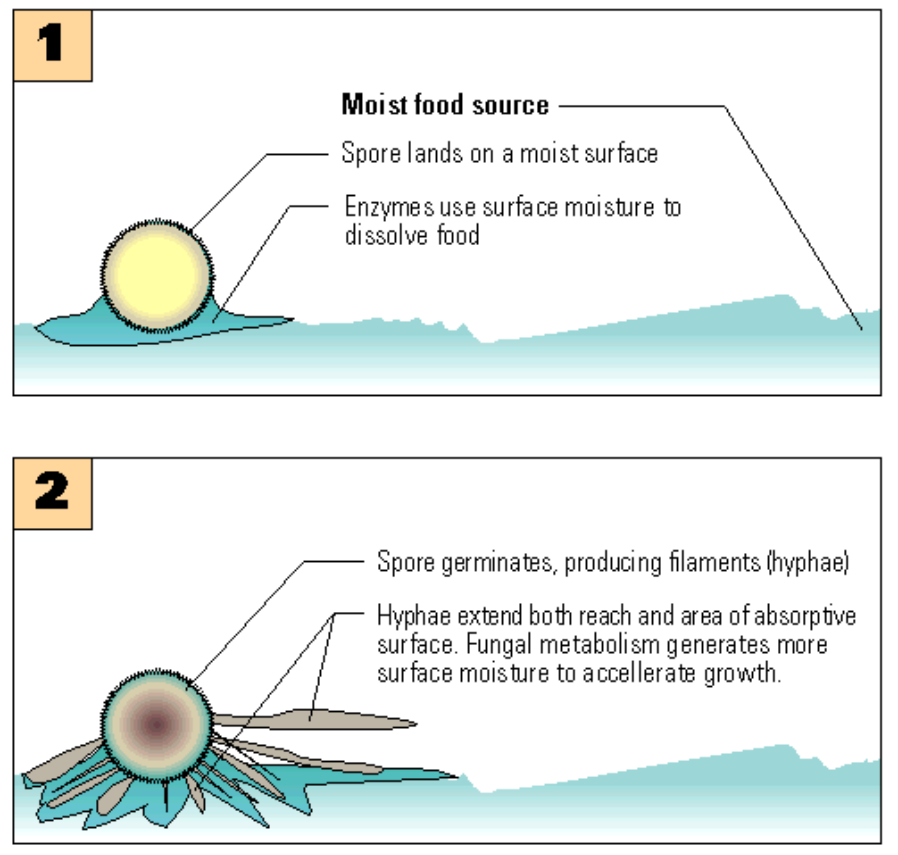
- Problems originate in UNOCCUPIED mode

Section 2 of 6

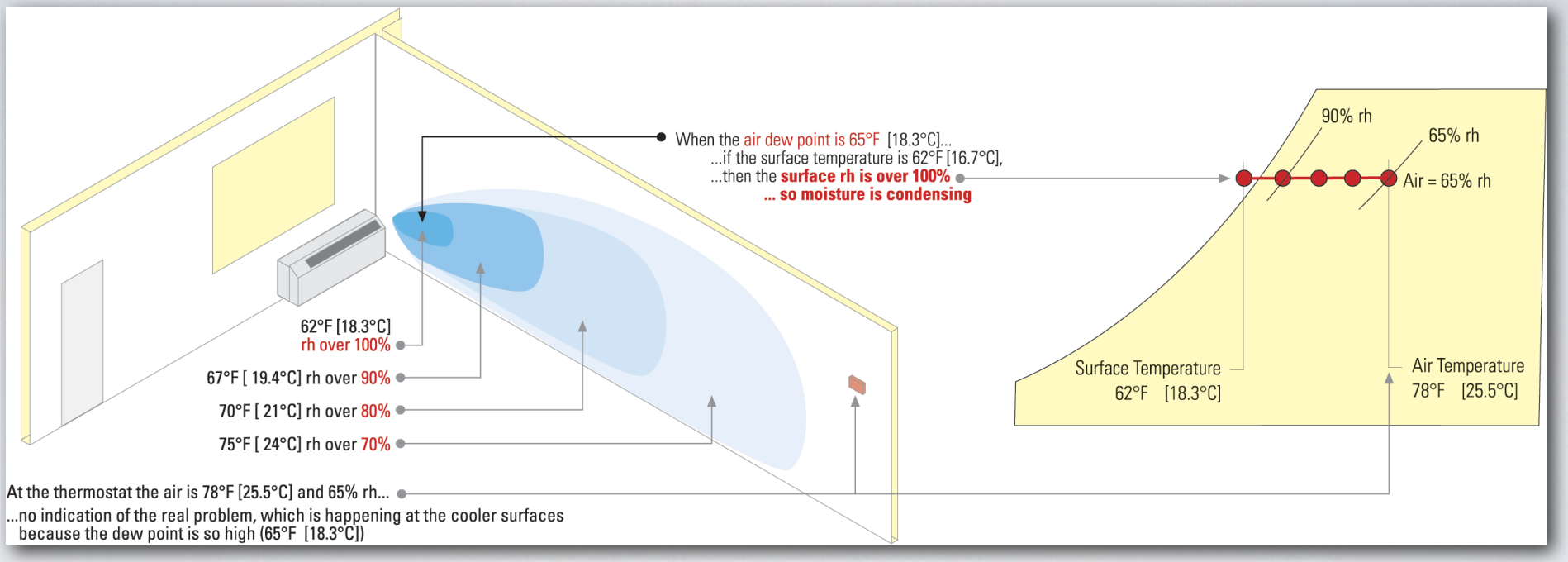
Understanding RH, dew point and mold growth

Understanding mold growth in buildings

Mold only cares about moisture in it's food - not RH



RH in the air.. vs. RH at the surface



Moldy building example

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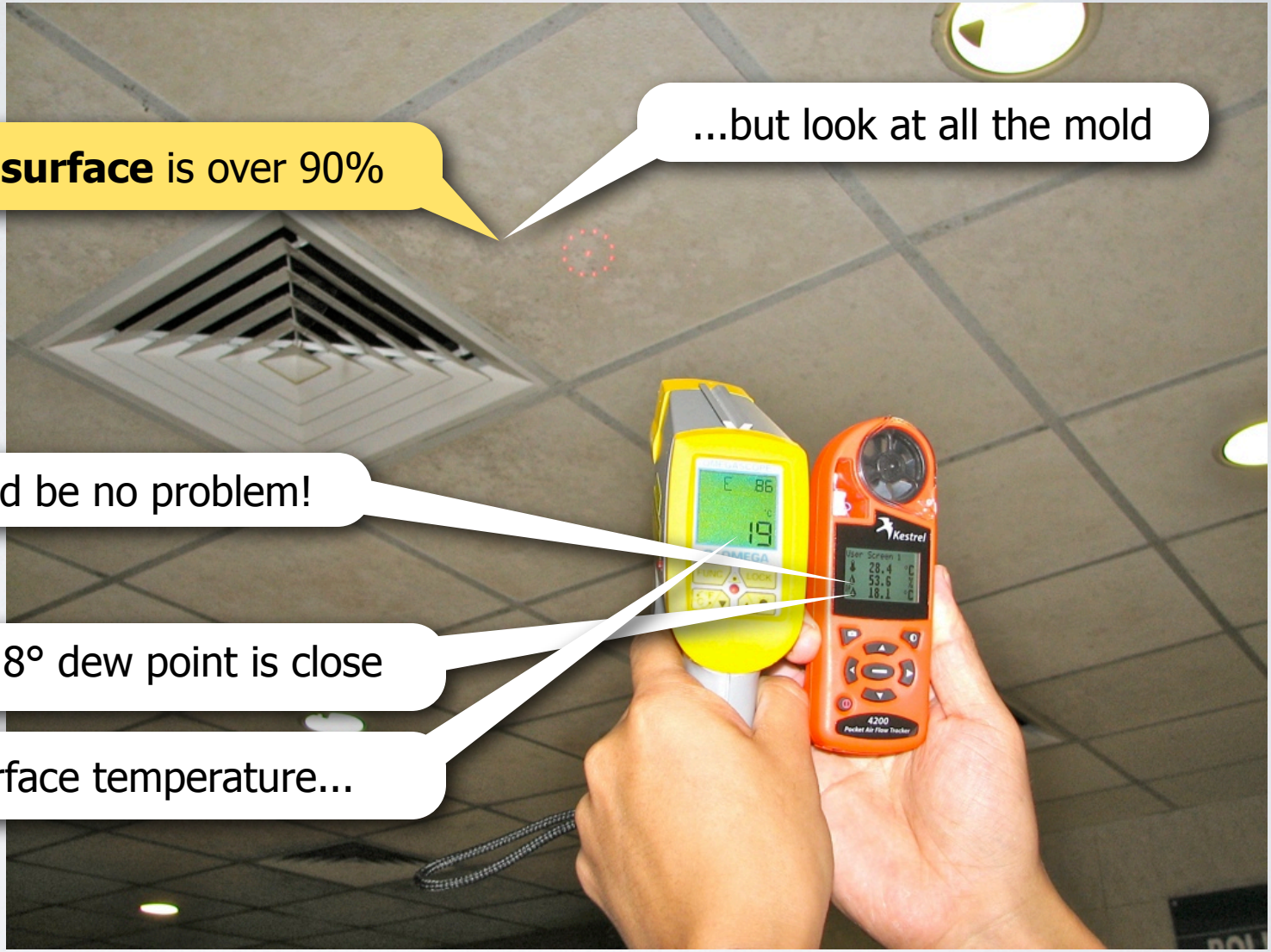

Mold growth is greatest on coldest surfaces

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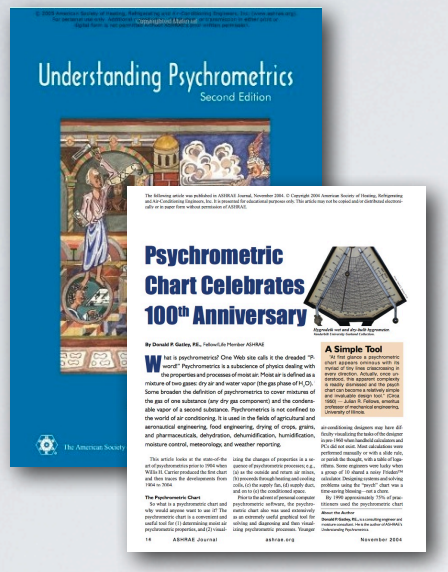
The building and it's HVAC are a single system

- 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 Fellow ASHRAE



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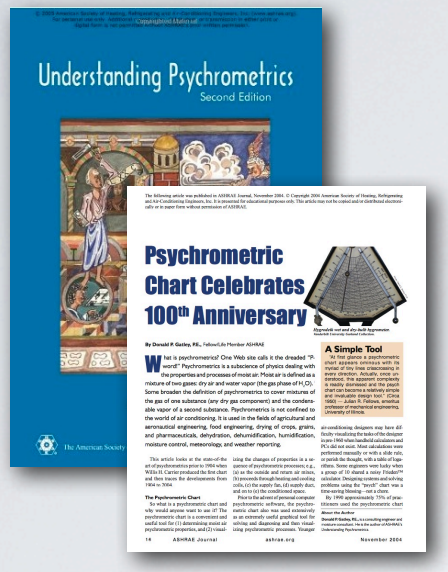

79 moisture investigations in 25 years

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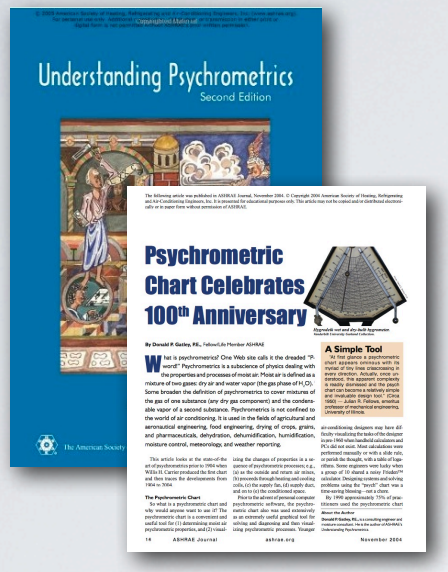

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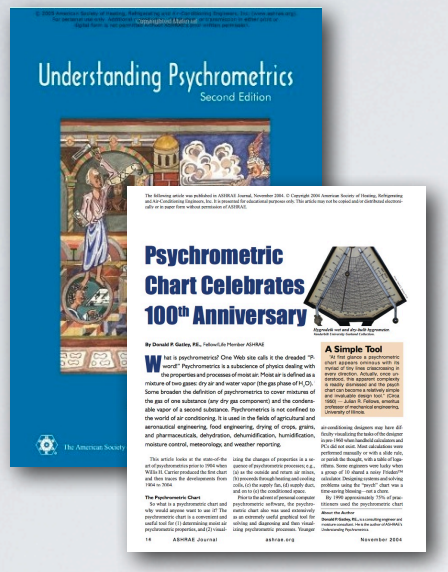

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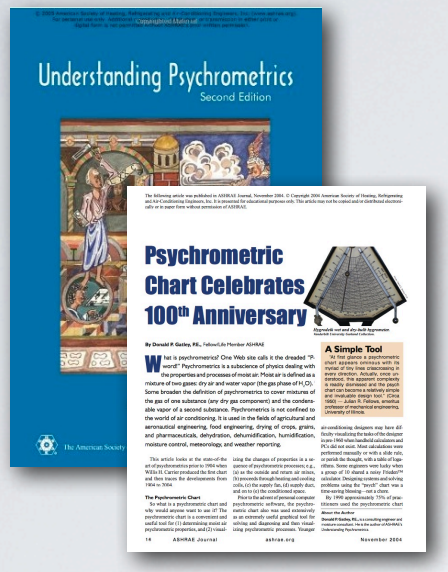

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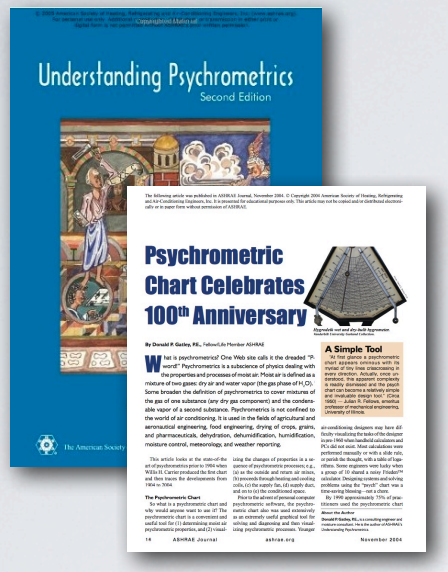

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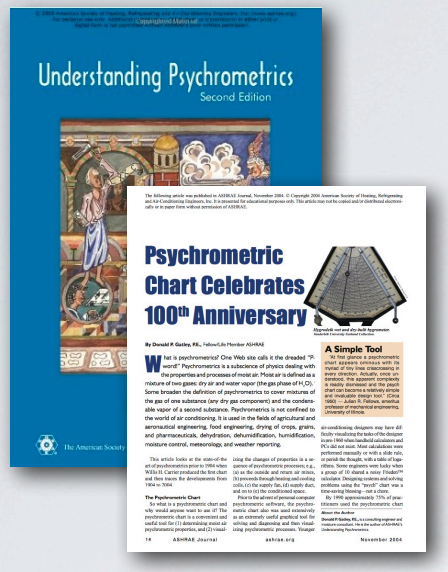

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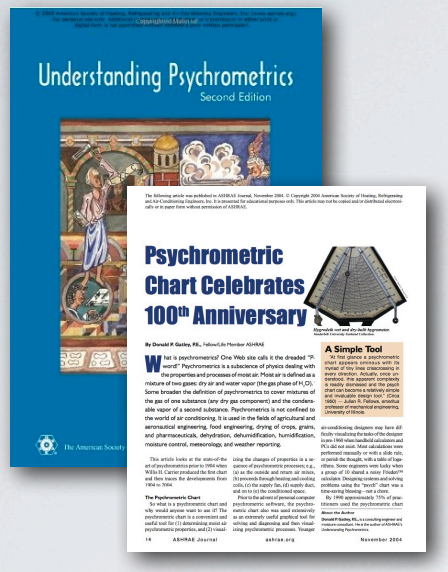

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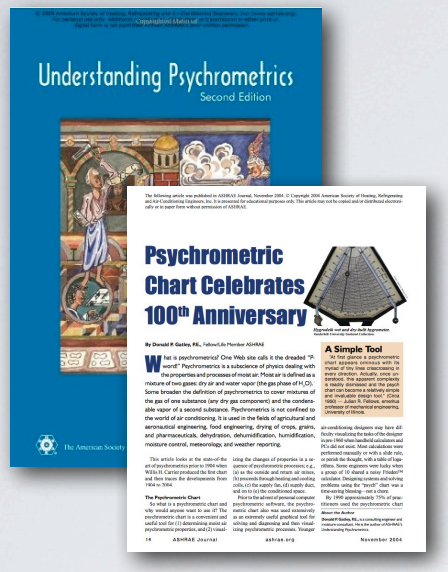

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Don's advice: MOST HUMIDITY PROBLEMS ARE SIMPLE! Don't overcomplicate humidity troubleshooting. Make sure the building does not suck, and make sure the ventilation and makeup air is dry.

Section 3 of 5

Schools in Texas

36 School facilities near Houston, TX

School HVAC

Lesson 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... No effect on problems
- Problems most apparent during late July + 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 62.1-1999 (15 cfm per occupant vs. 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 air flow 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

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- 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

Chilled walls + High Dew Point = Mold growth

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

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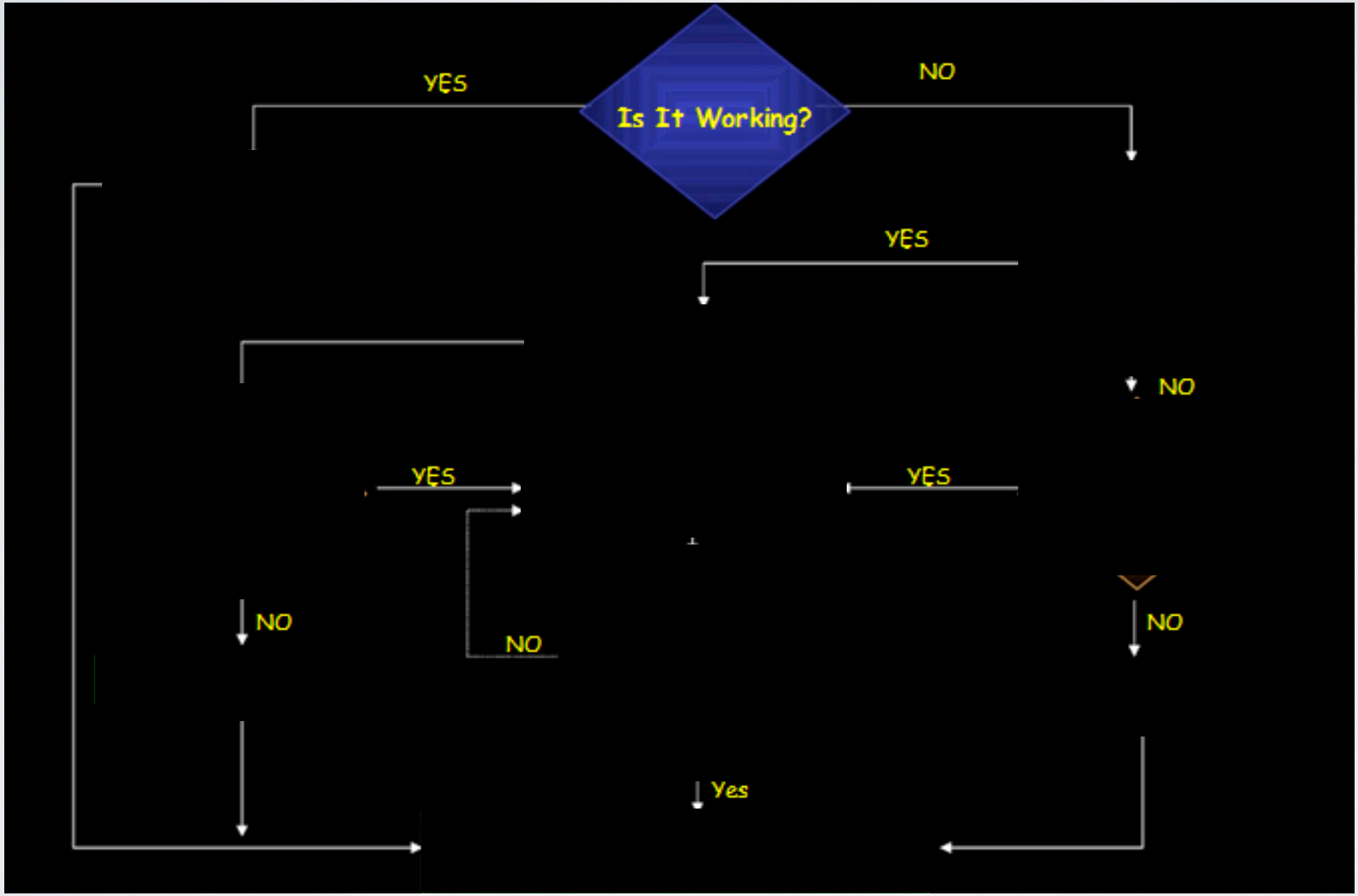
- Replaced chilled water line insulation to keep CW cold enough to ensure supply air is dried to 50 - 53°F dew point.

Section 4 of 6

Troubleshooting Sequence and Procedures

1. Traditional troubleshooting procedure...



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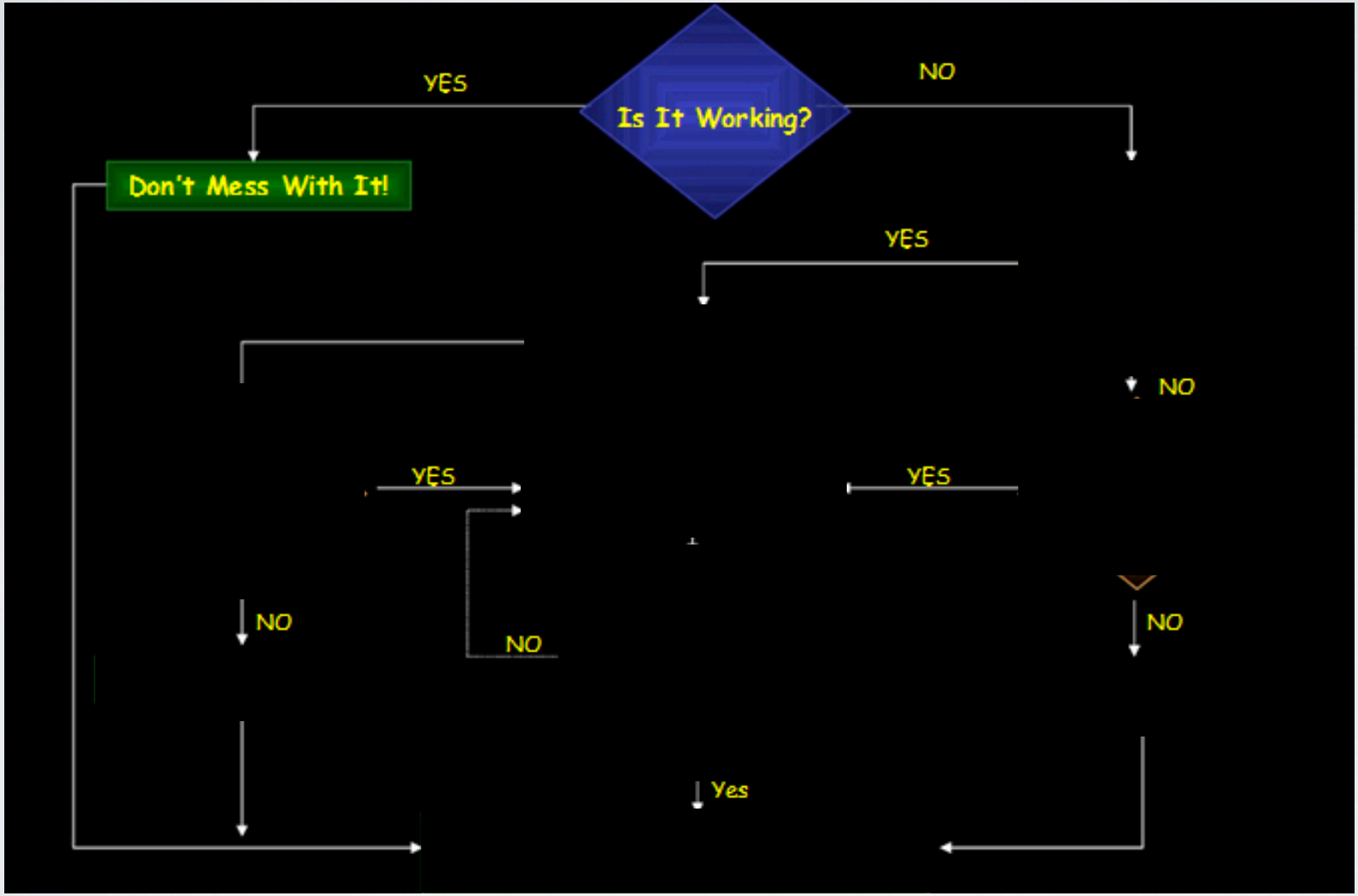

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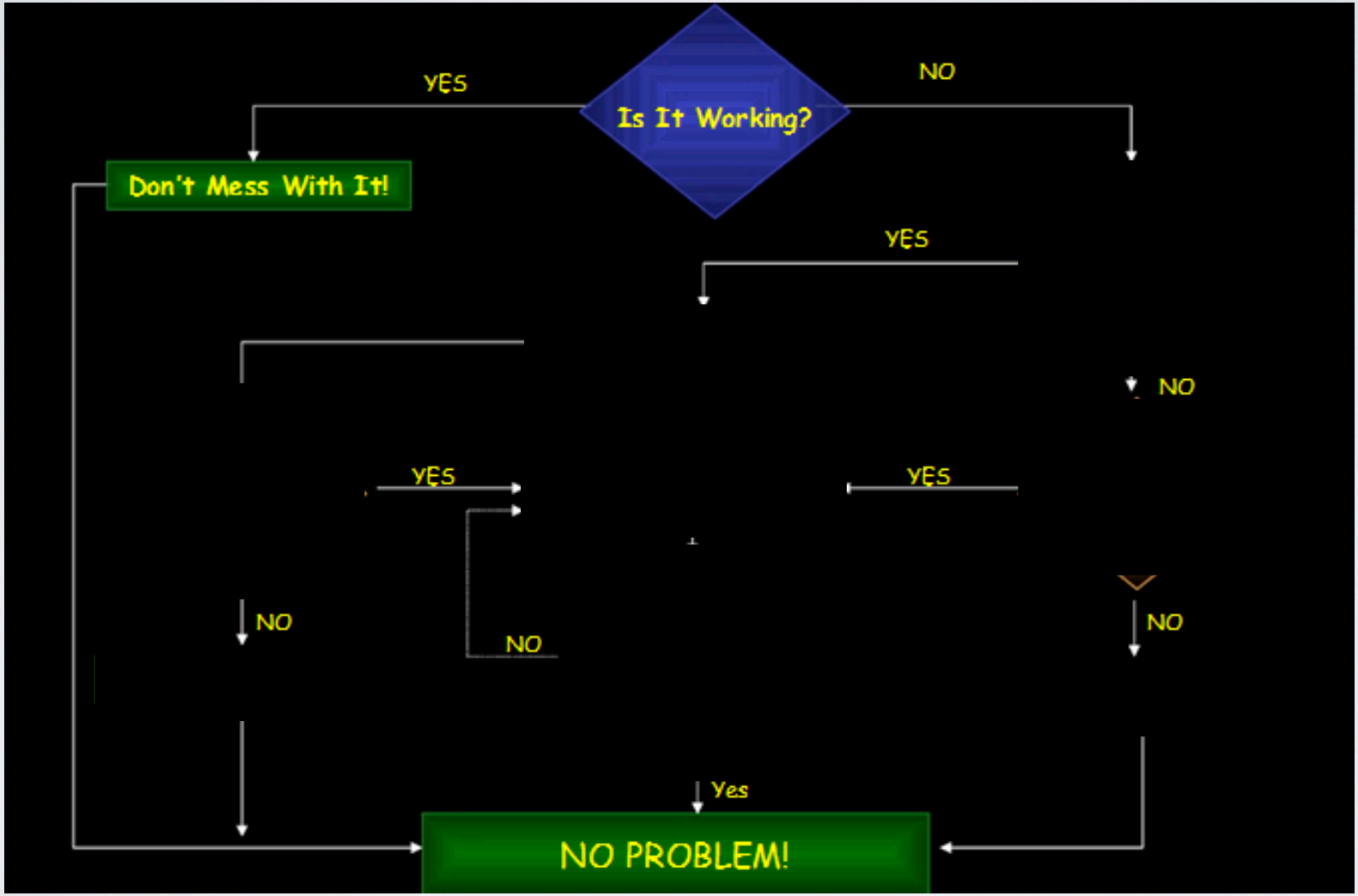

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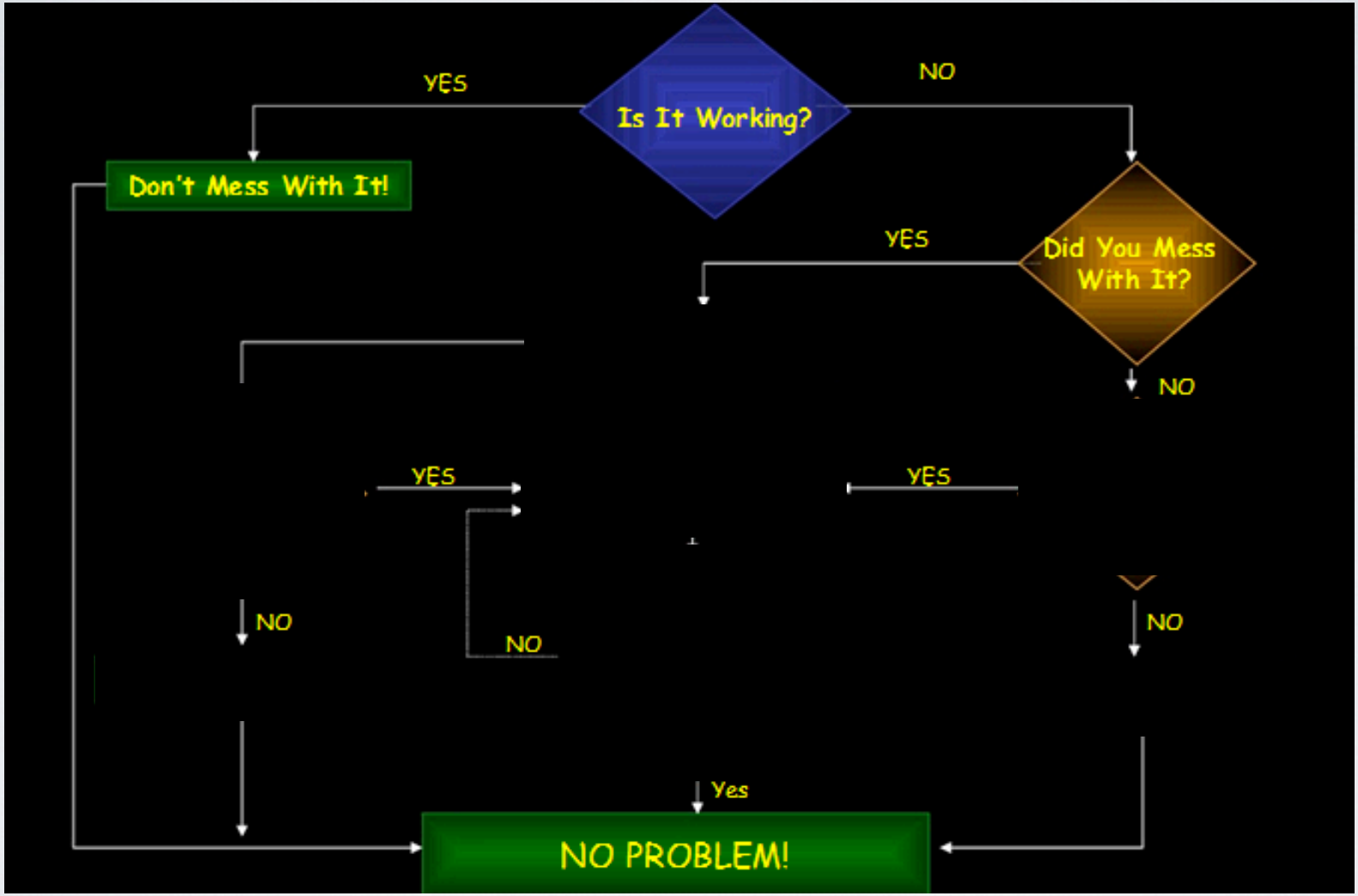

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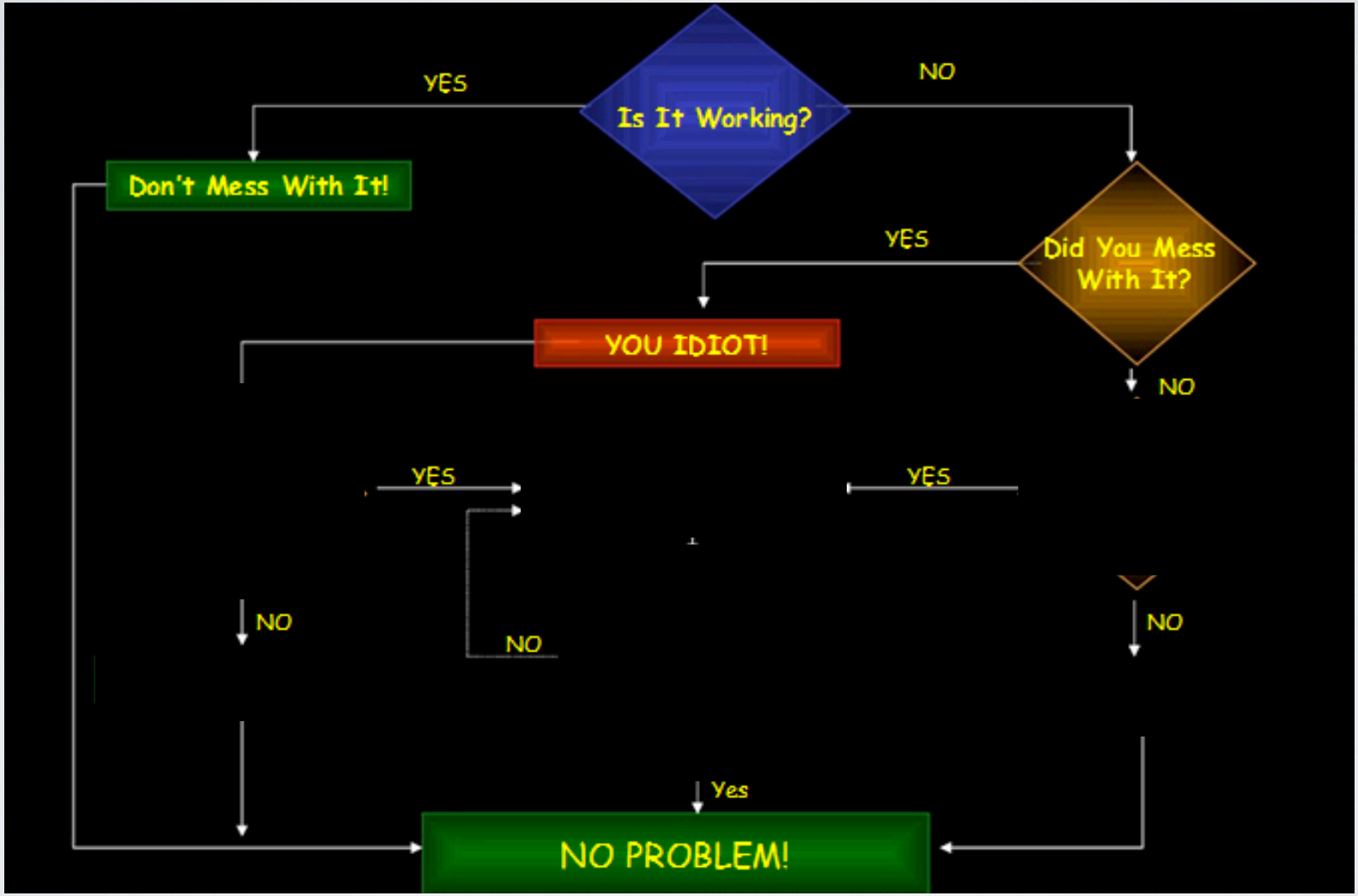

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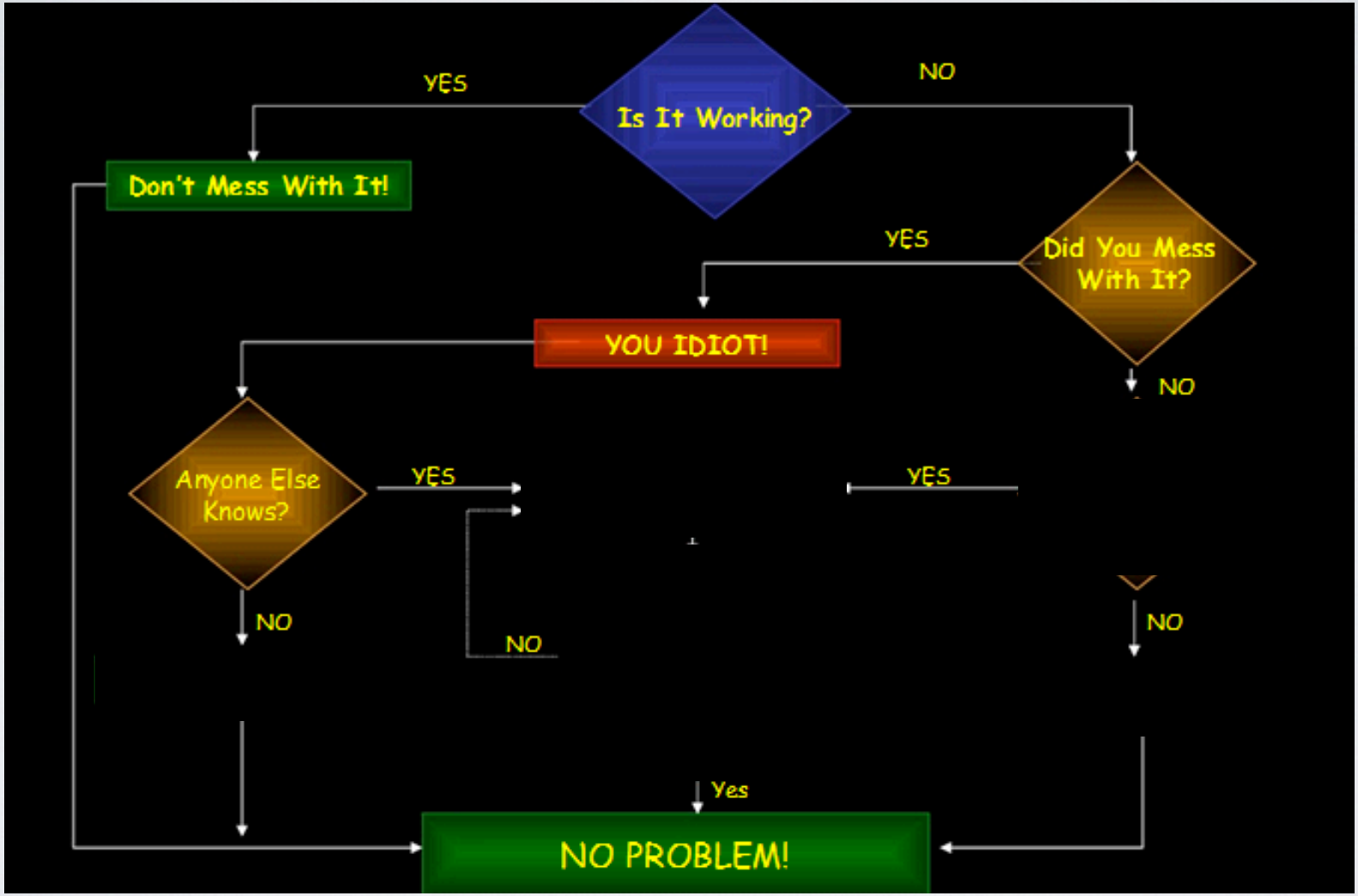

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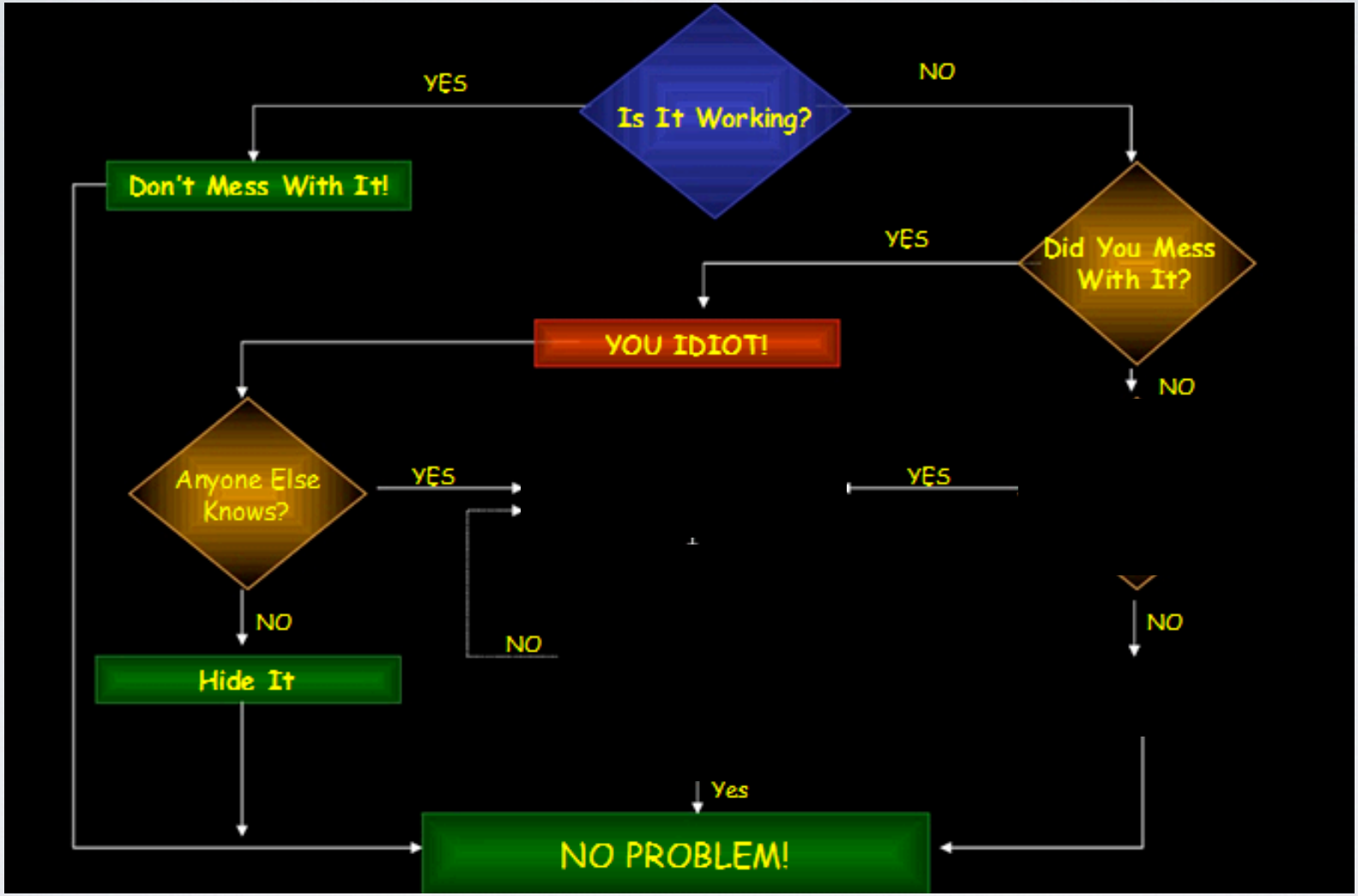

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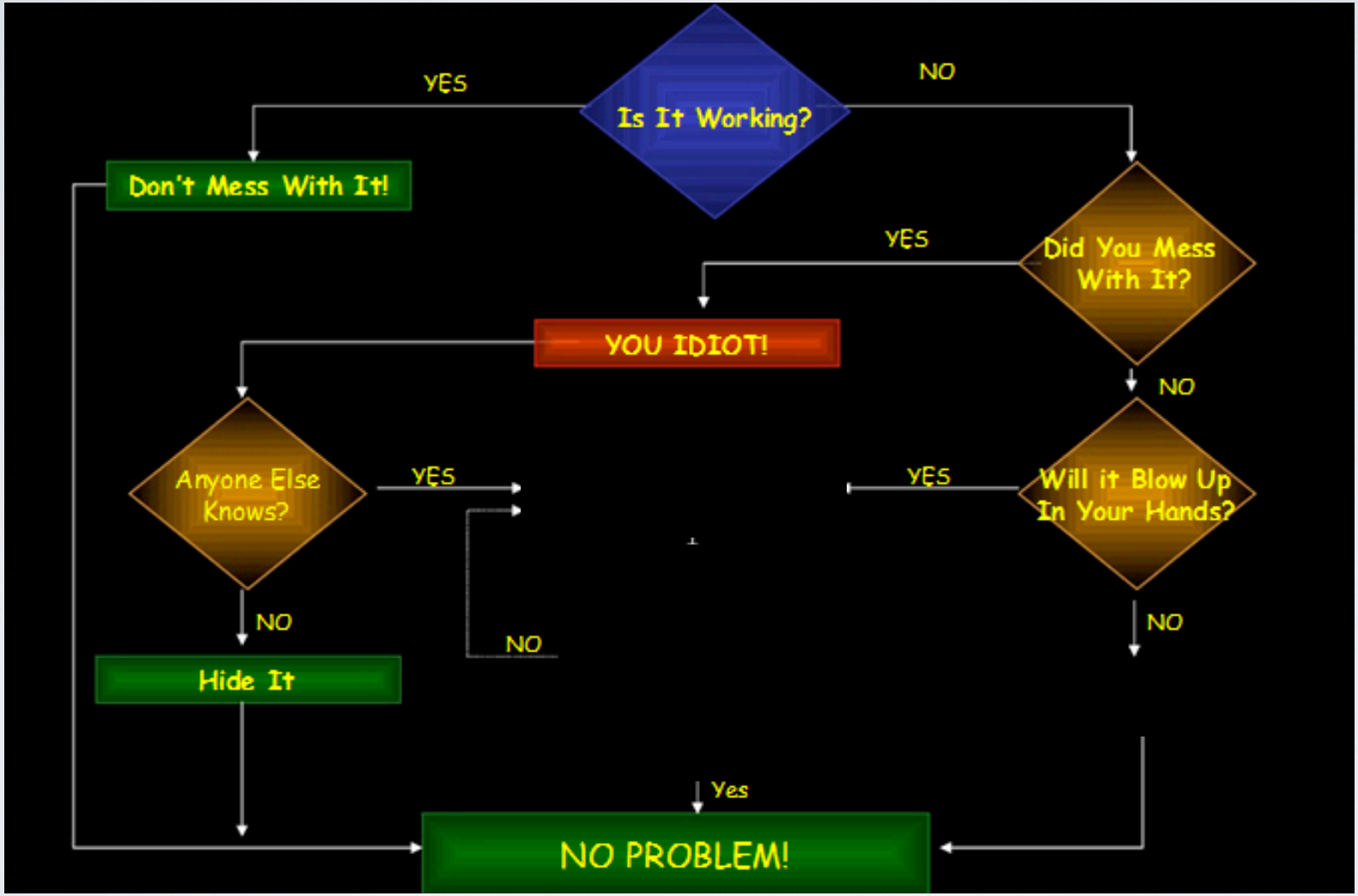

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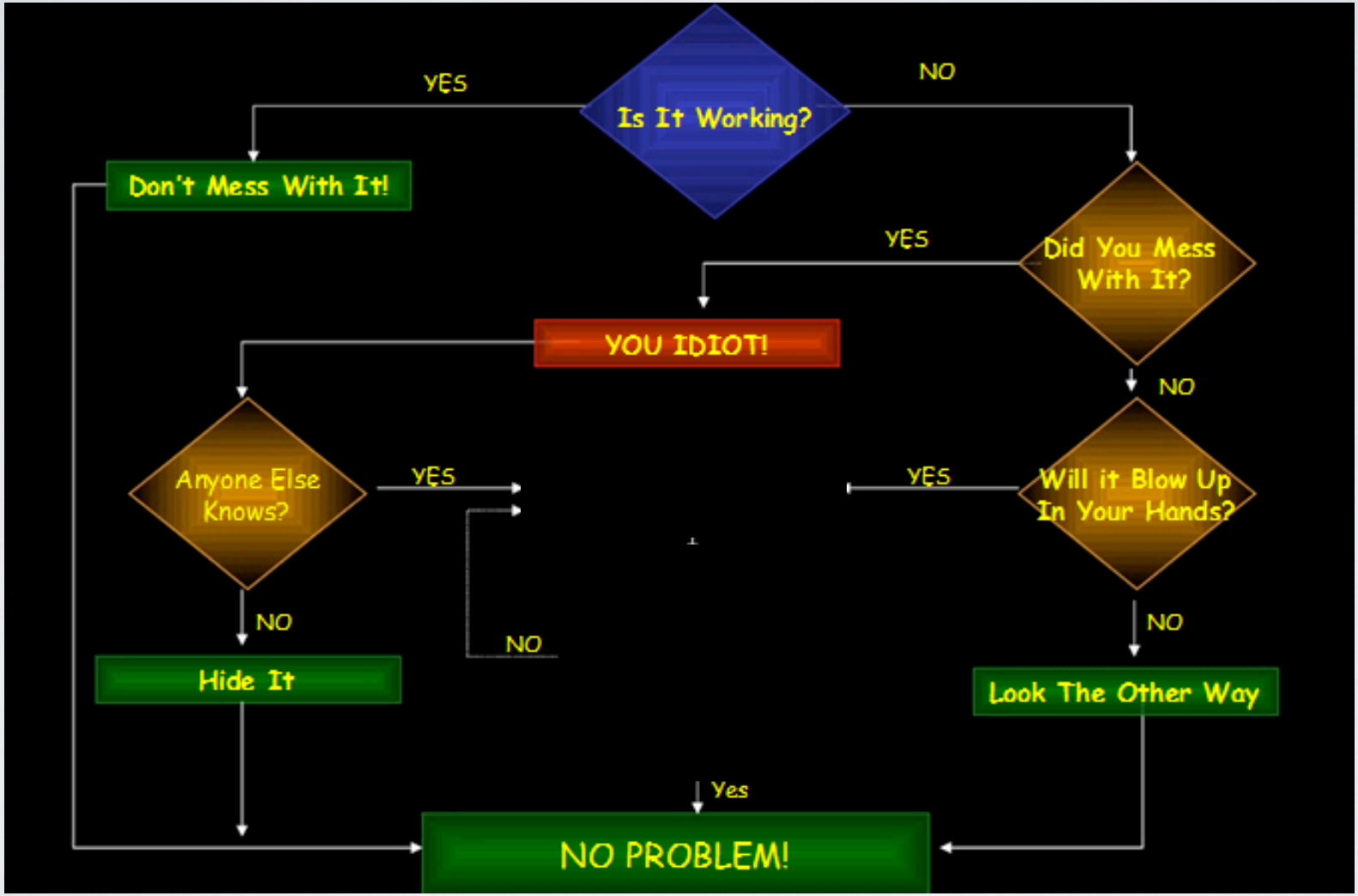

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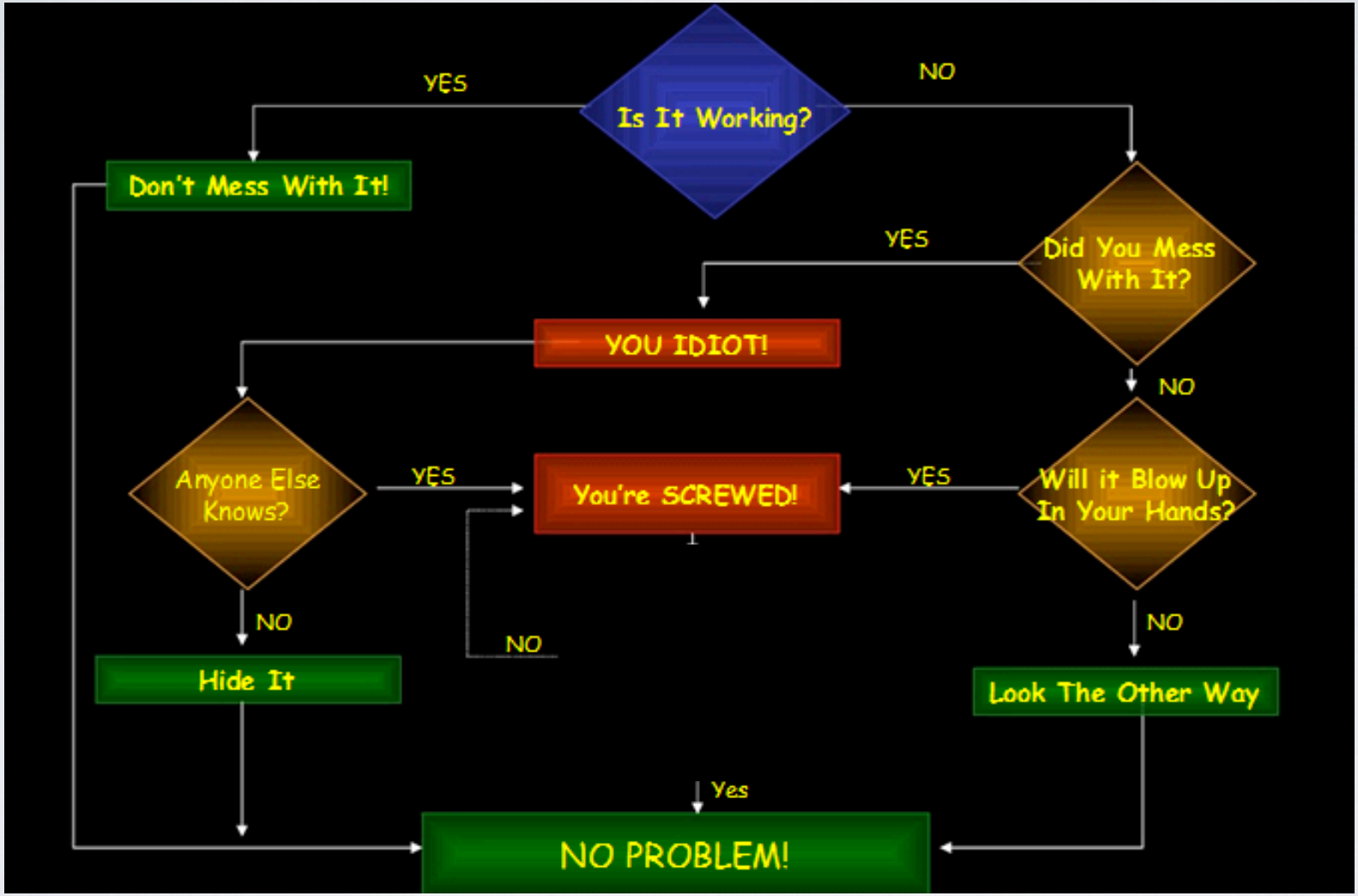

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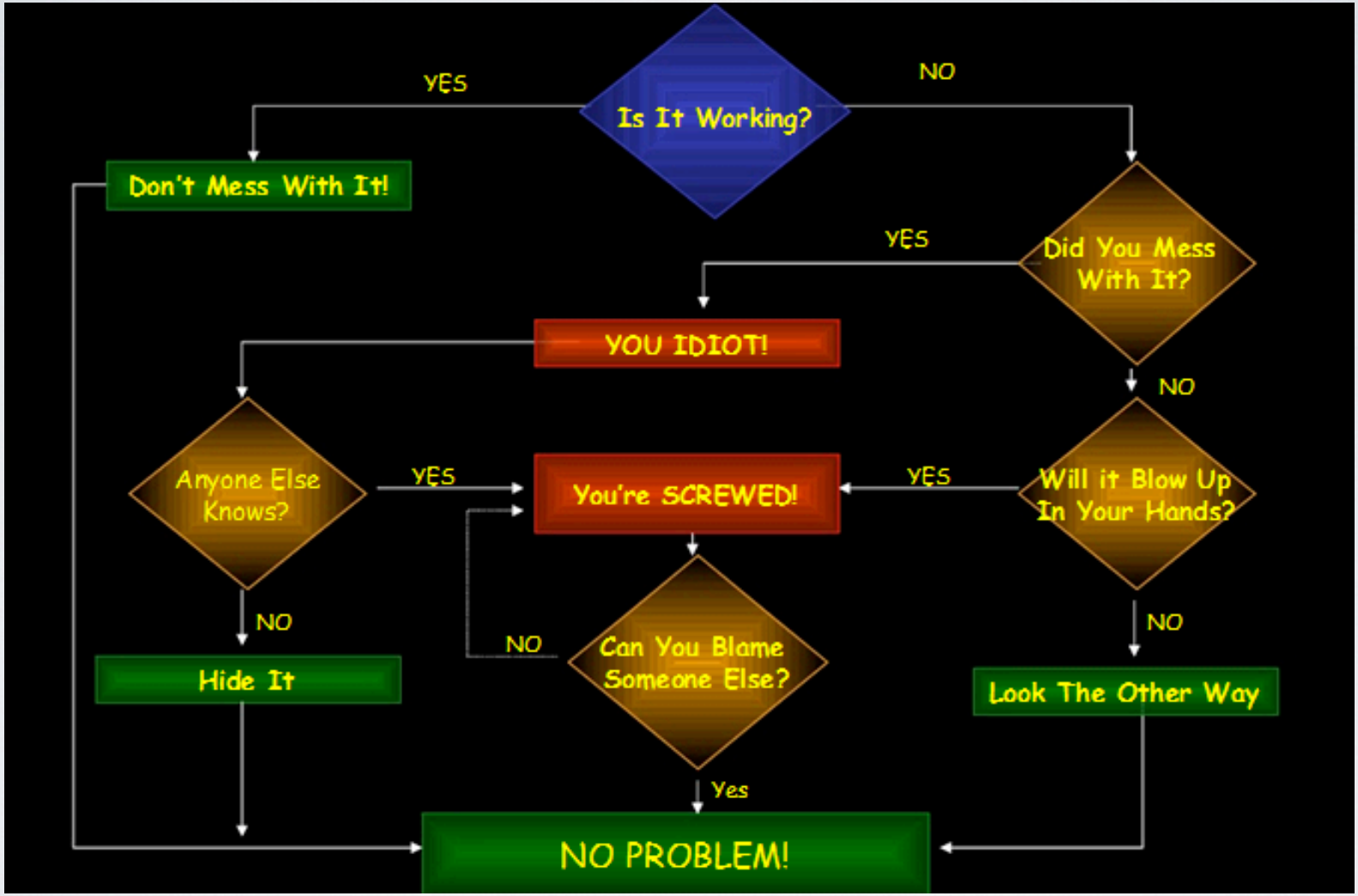

The essence of humidity control troubleshooting

When humidity is too high, it is because...

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Humidity loads

The essence of humidity control troubleshooting

When humidity is too high, it is because...

How to solve humidity control problems

How to solve humidity control problems

To solve the problem:

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To solve the problem:

a. reduce the loads or...

How to solve humidity control problems

To solve the problem:

a. **reduce the loads or...**
b. **increase dehumidification,**

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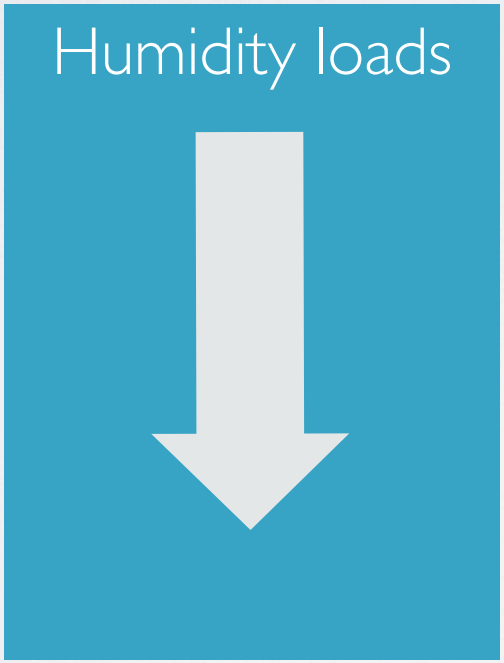

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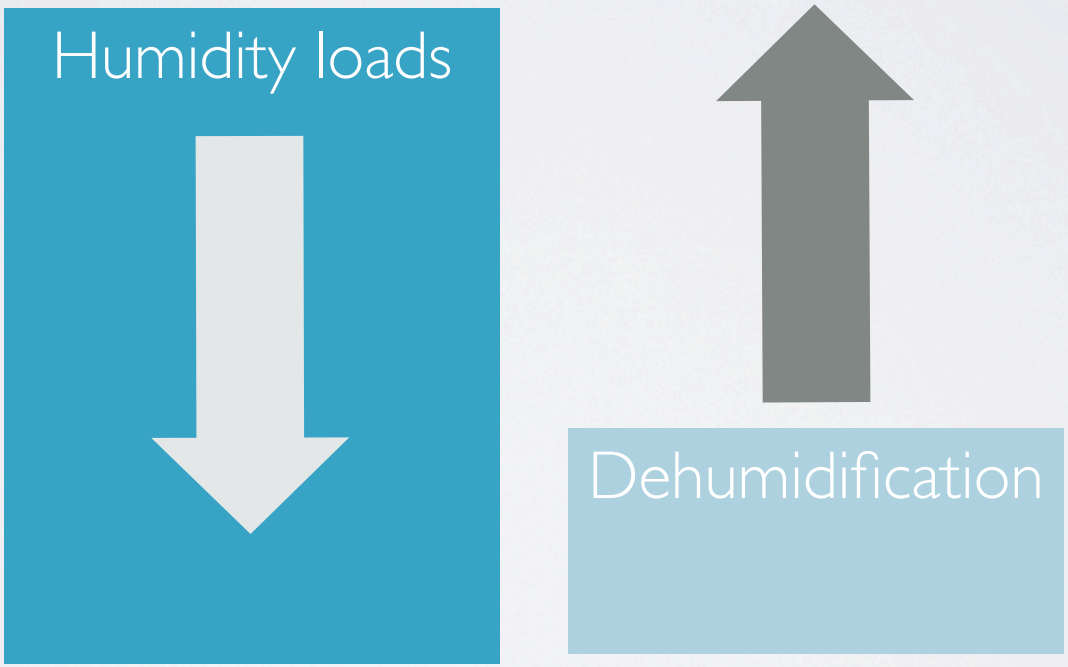
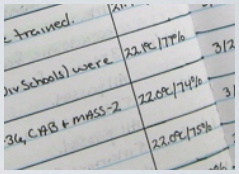


Troubleshooting sequence

1. Listen and understand the problems
2. Look at drawings, then walk though and understand the BUILDING
3. Look at drawings, then walk though and understand the HVAC SYSTEM
4. Measure the key variables
   a. The loads
   b. The dehumidification
5. Diagnose the problems... plan solutions

Troubleshooting sequence



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   b. The dehumidification
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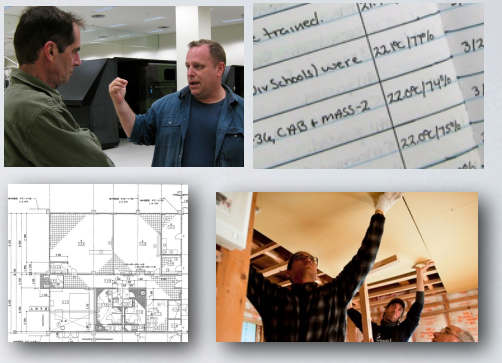

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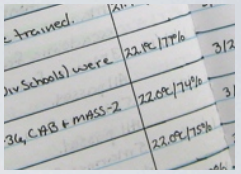
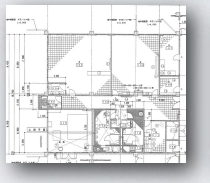

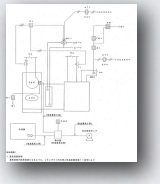


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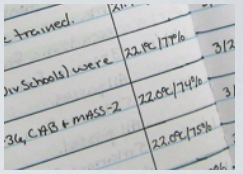
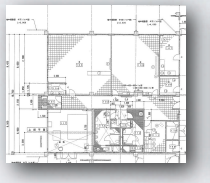

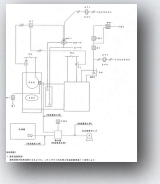


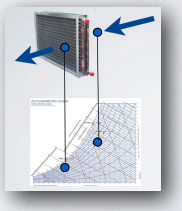

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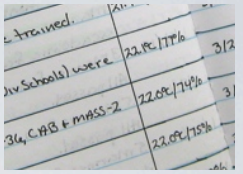

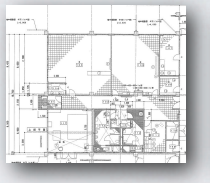

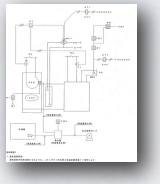


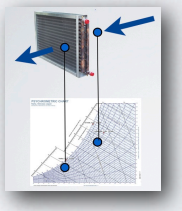
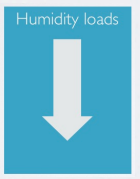

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Finding and understanding problems

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3. Review the HVAC drawings, equipment schedules and controls, then walk around, to understand the DH capacity.

Next, MEASURE **loads**...
..and MEASURE the **dehumidification**

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Humidity loads

- Exhaust air flow
- Incoming outdoor air
- Building air leakage
- Number of people
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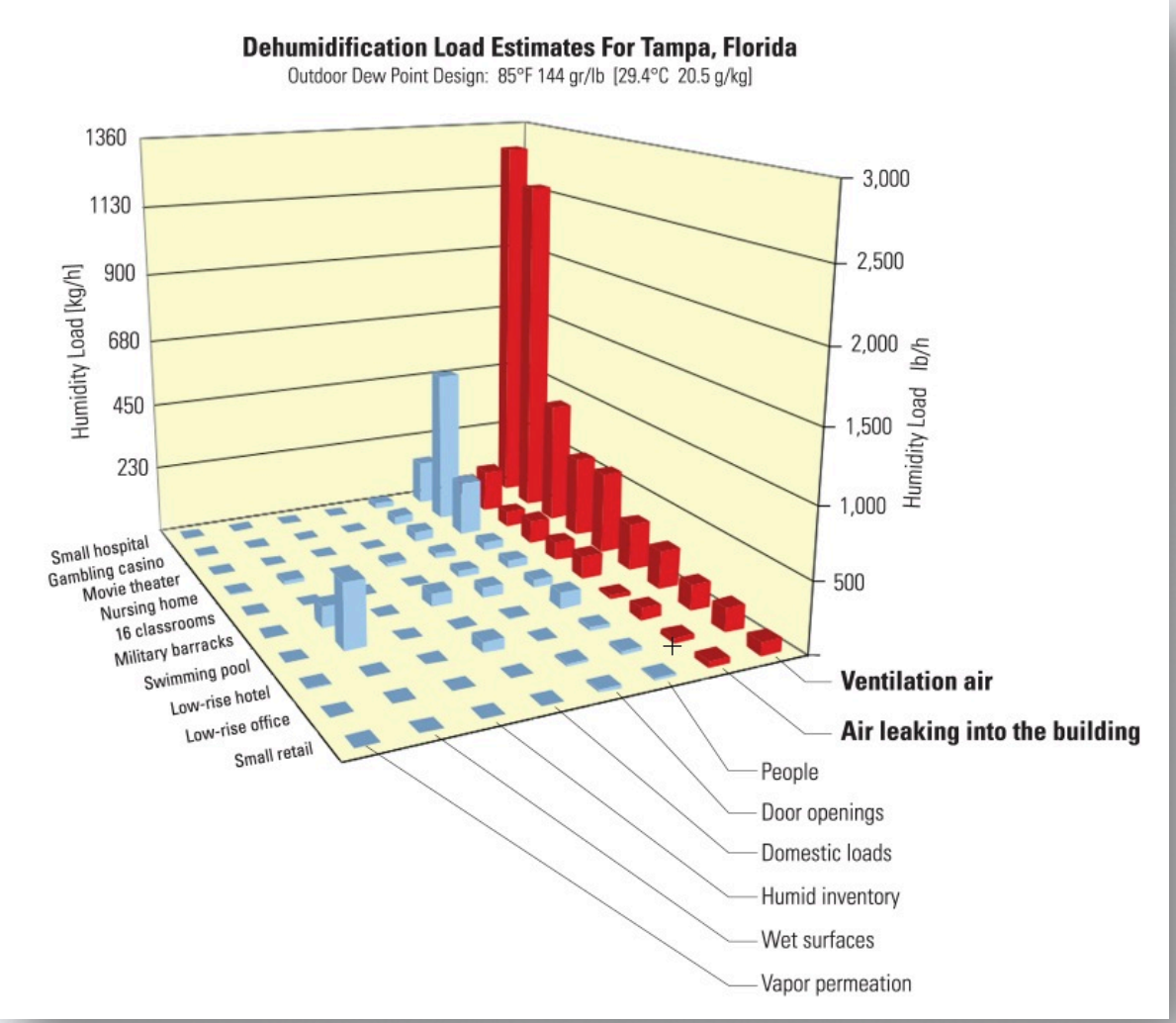
Dehumidification

- Humidity removal
- Dry air flow
- Controls

Section 4 of 6

The BIGGEST Humidity Load
Ventilation Air

For most commercial buildings the humidity biggest load is the ventilation and makeup air



To control humidity.. remove the humidity load

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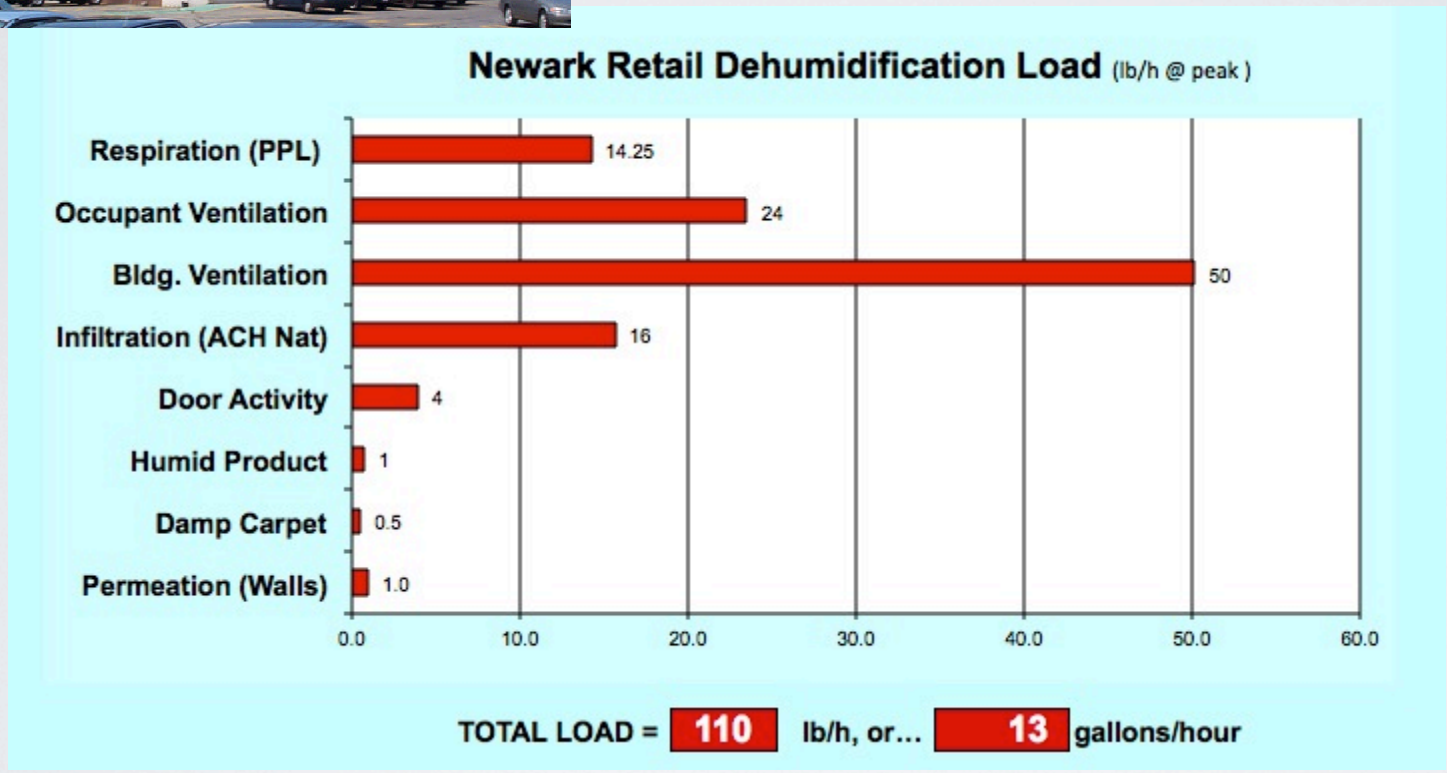

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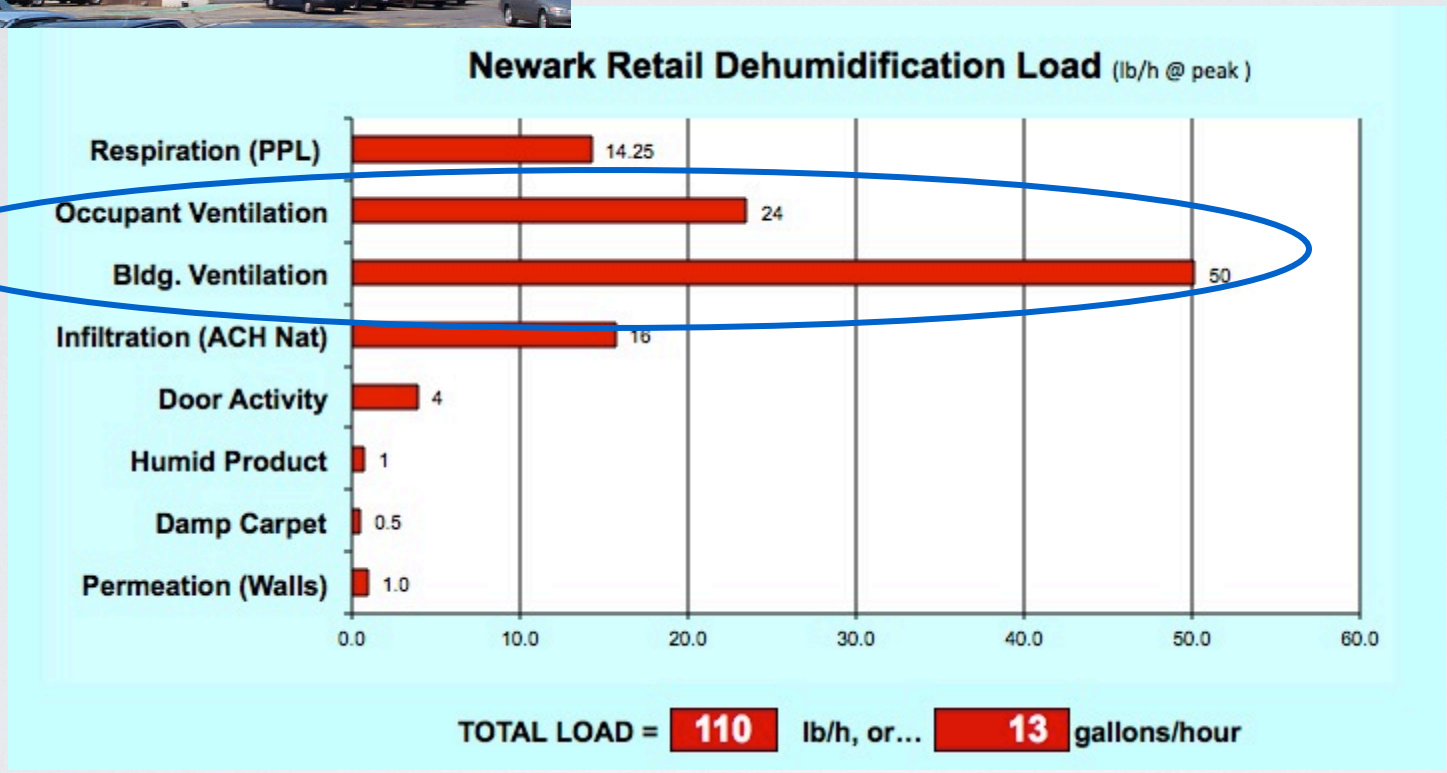
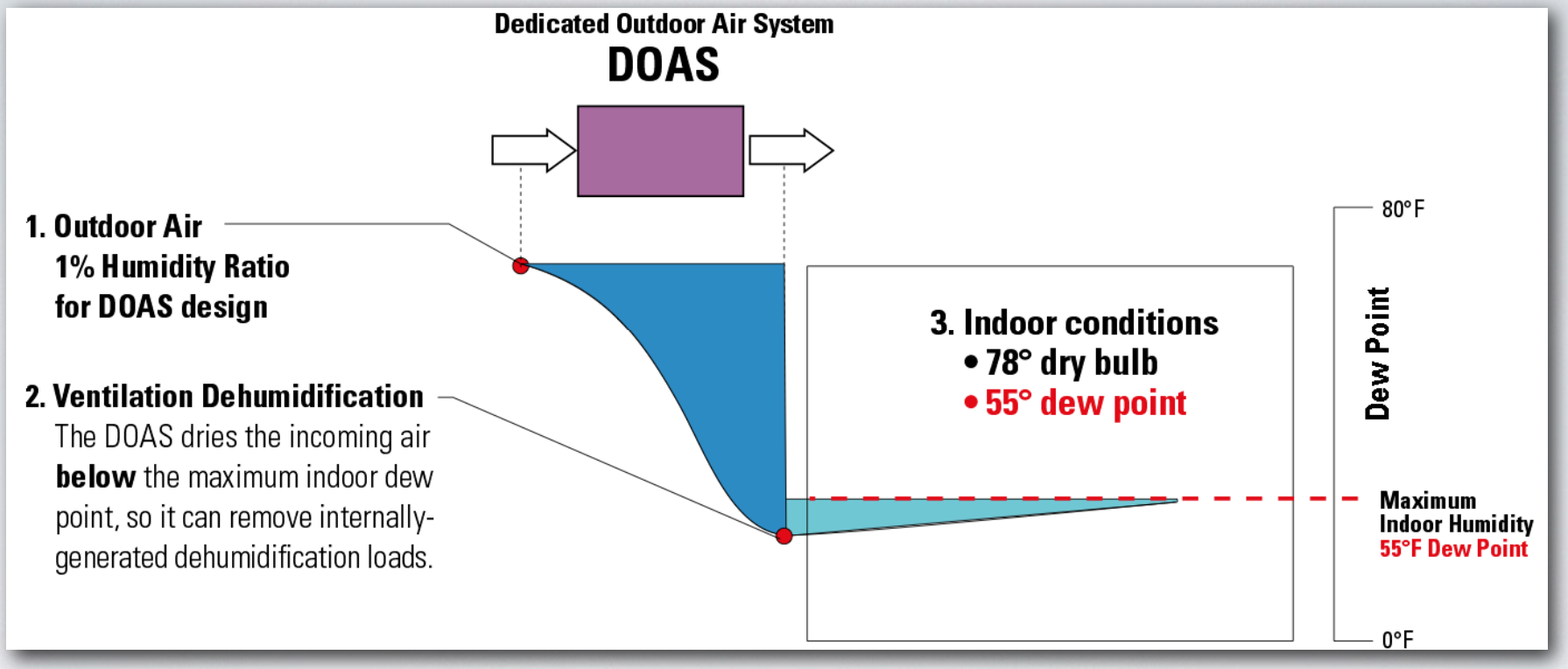


Dedicated outdoor air systems (DOAS)



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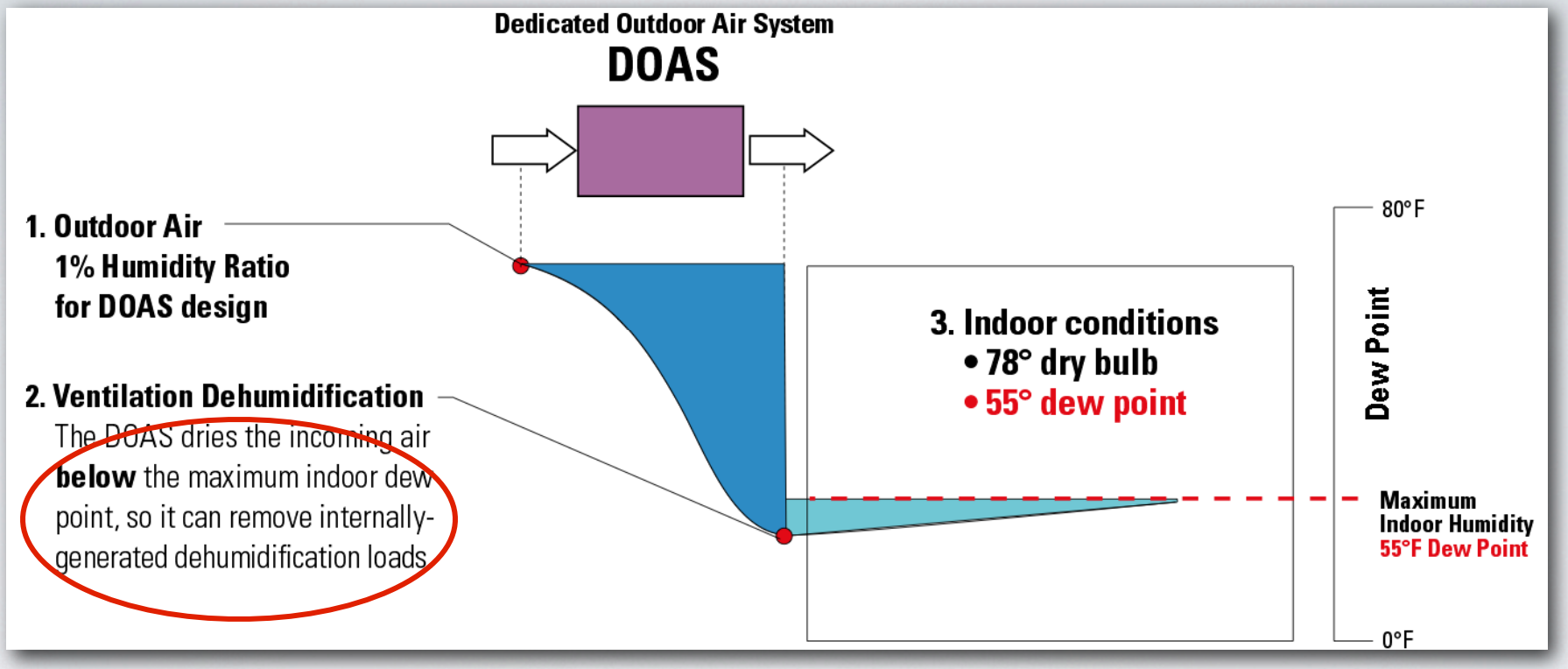
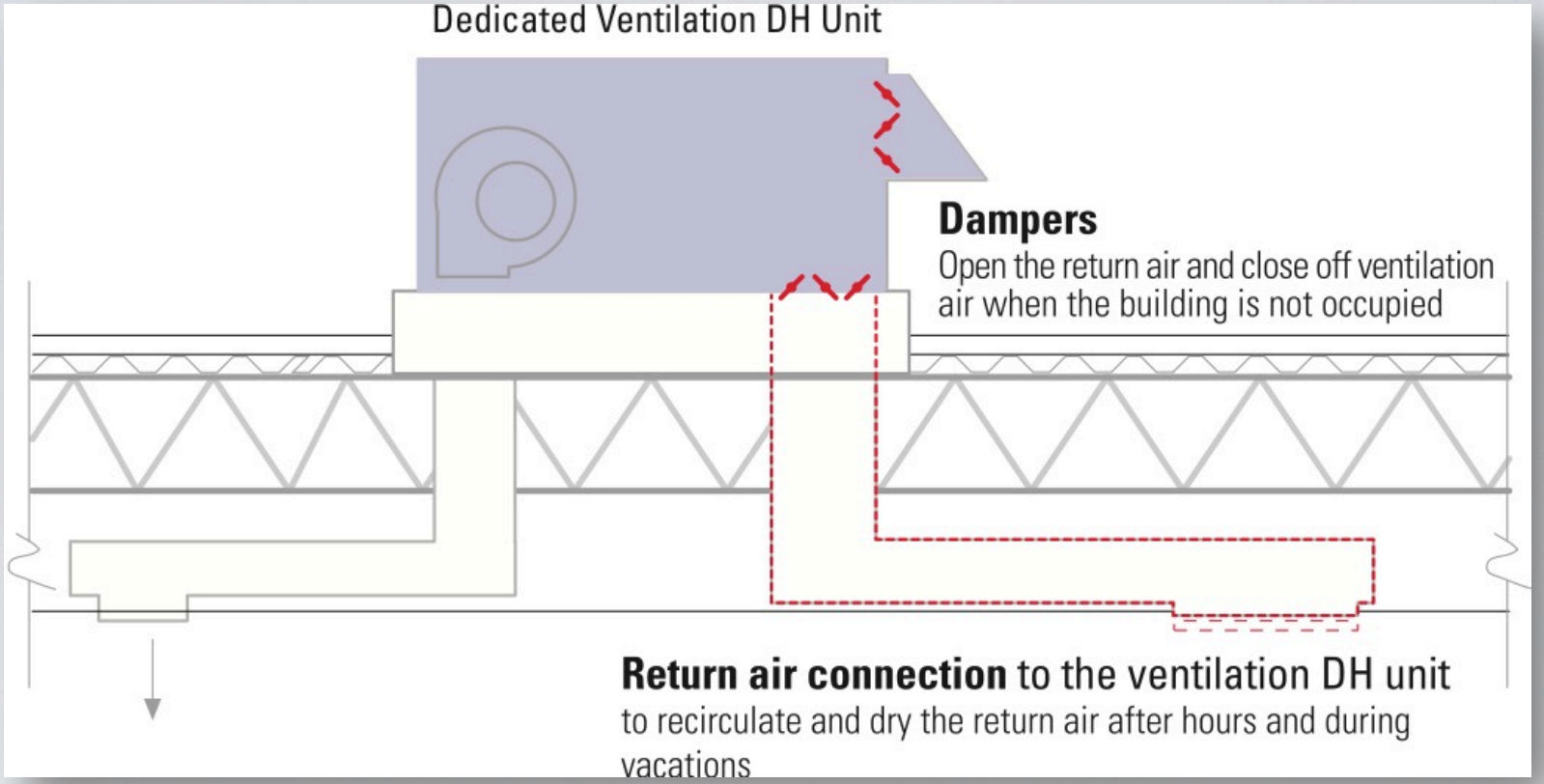


Add return air connection for humidity control during unoccupied hours and vacations



Source: ASHRAE Guide for Buildings in Hot & Humid Climates - 2009

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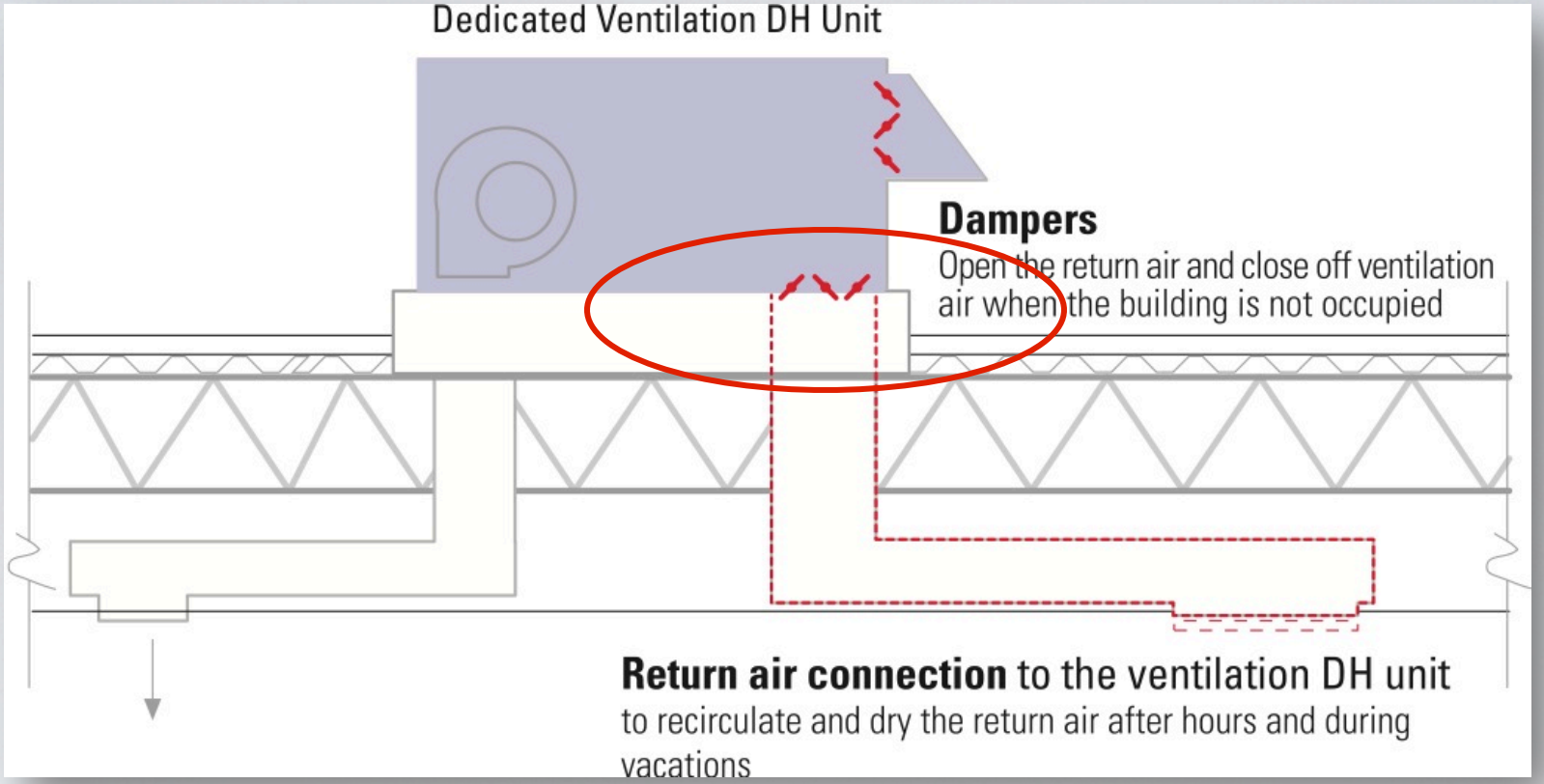

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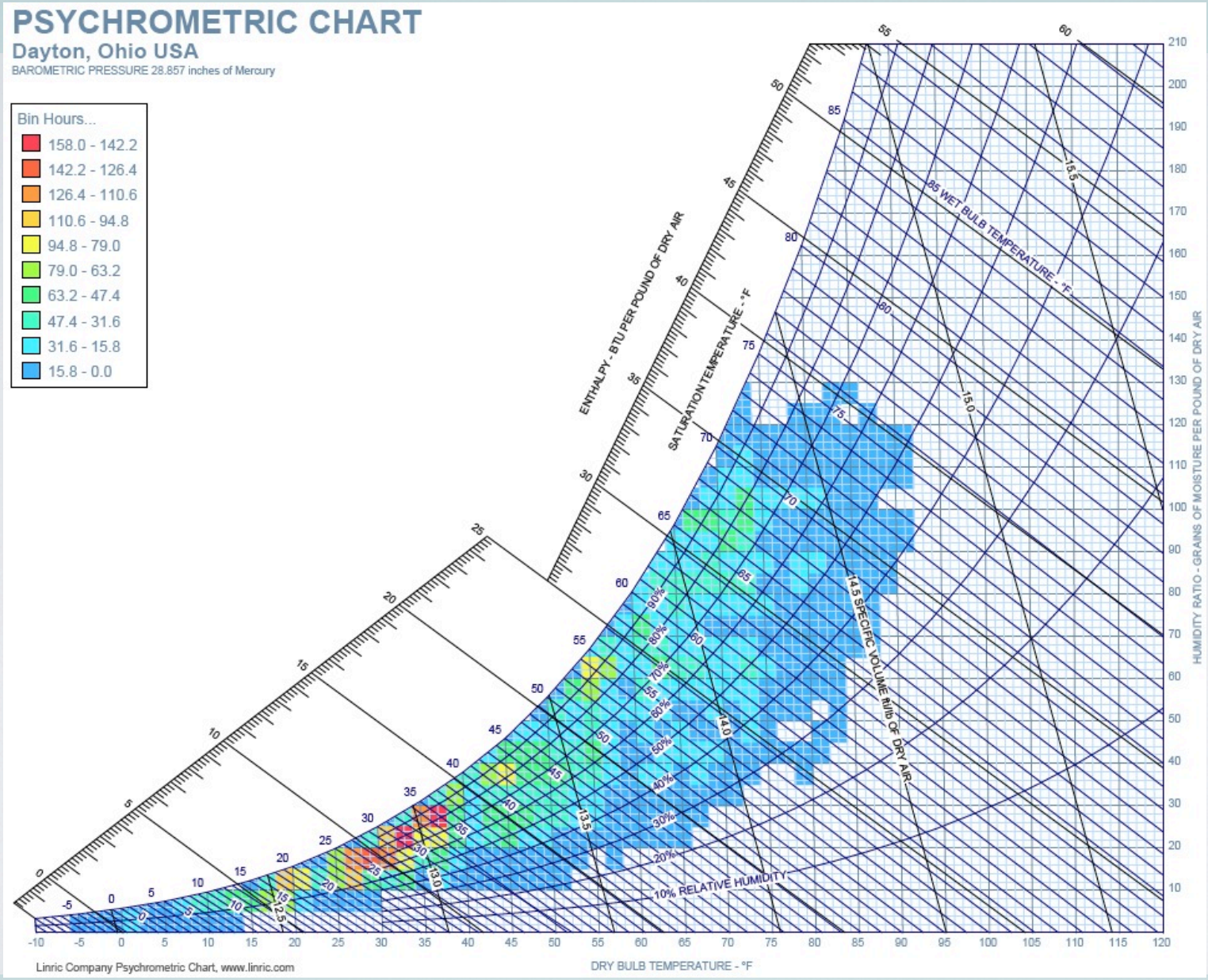
Use ASHRAE Peak Dew Point for DOAS design - Not peak DB



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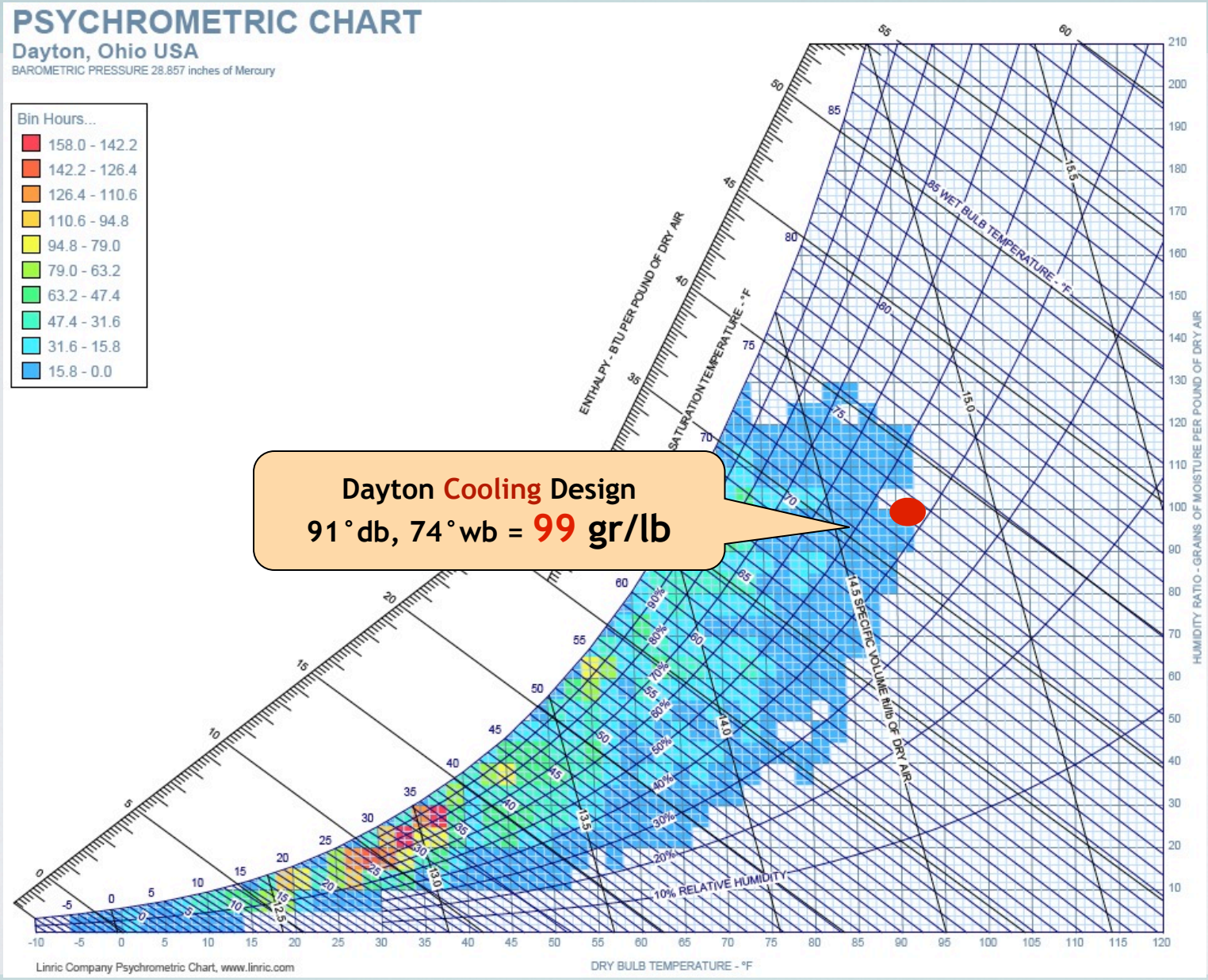

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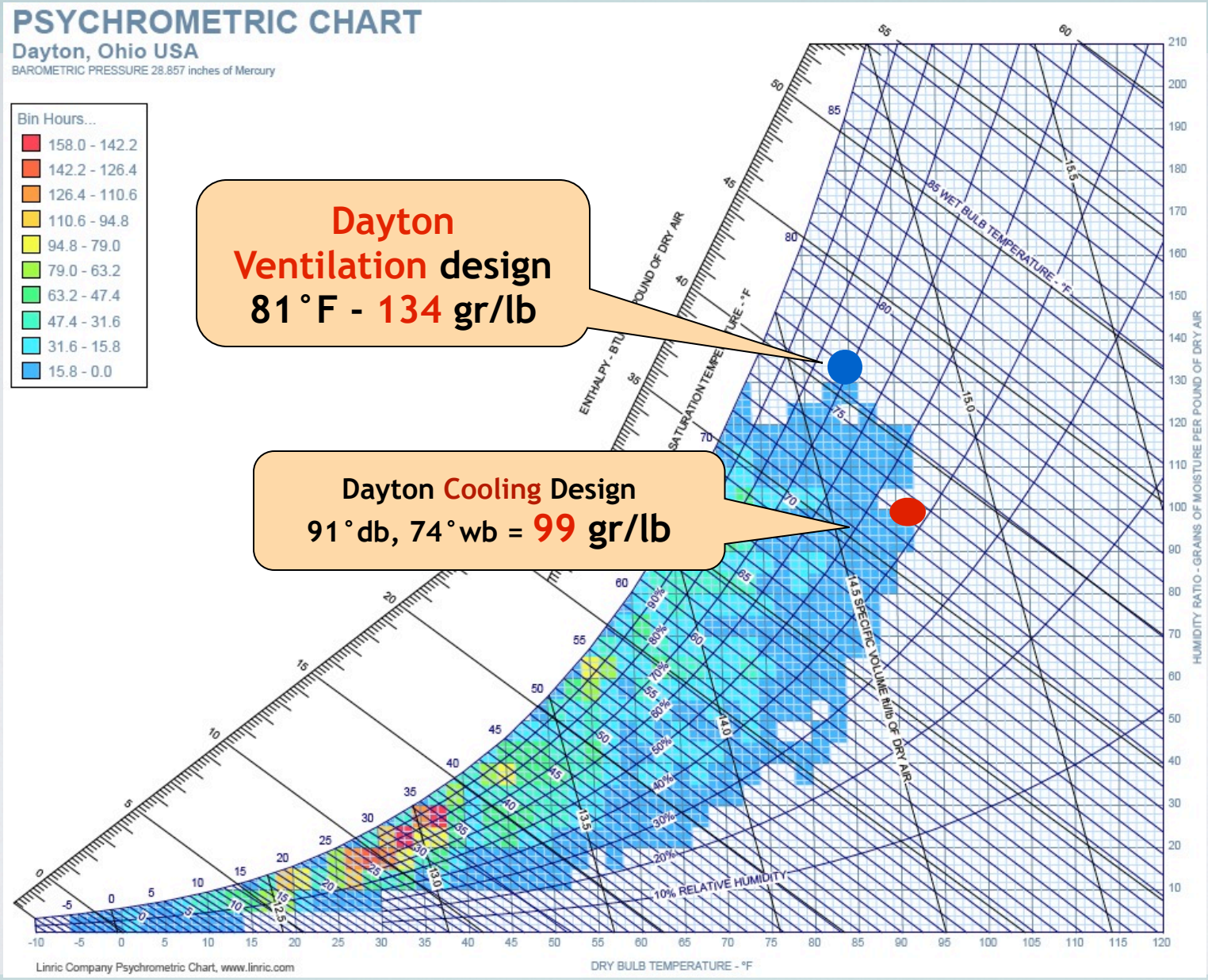
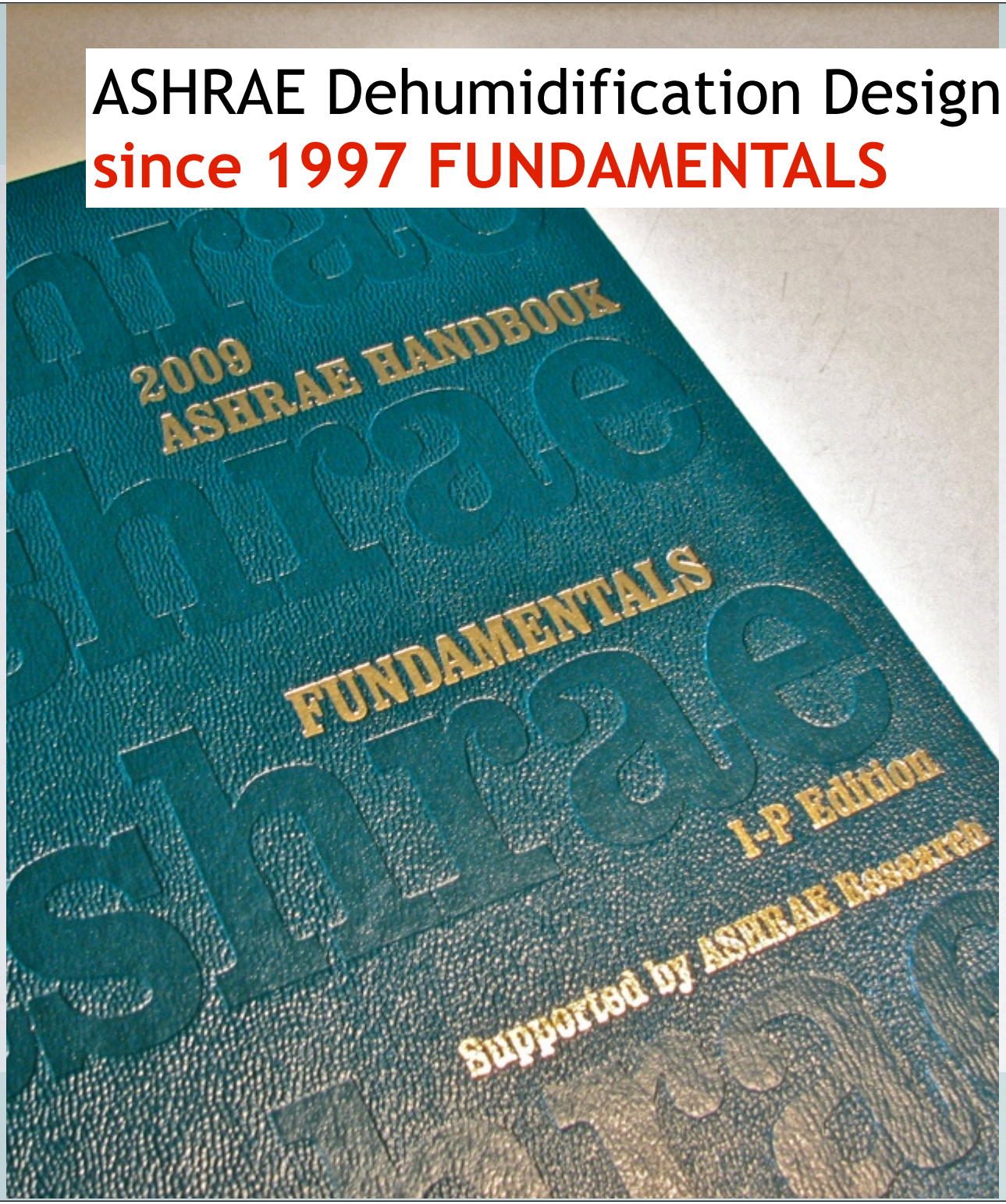


ASHRAE Dehumidification Design Values Available since 1997 FUNDAMENTALS



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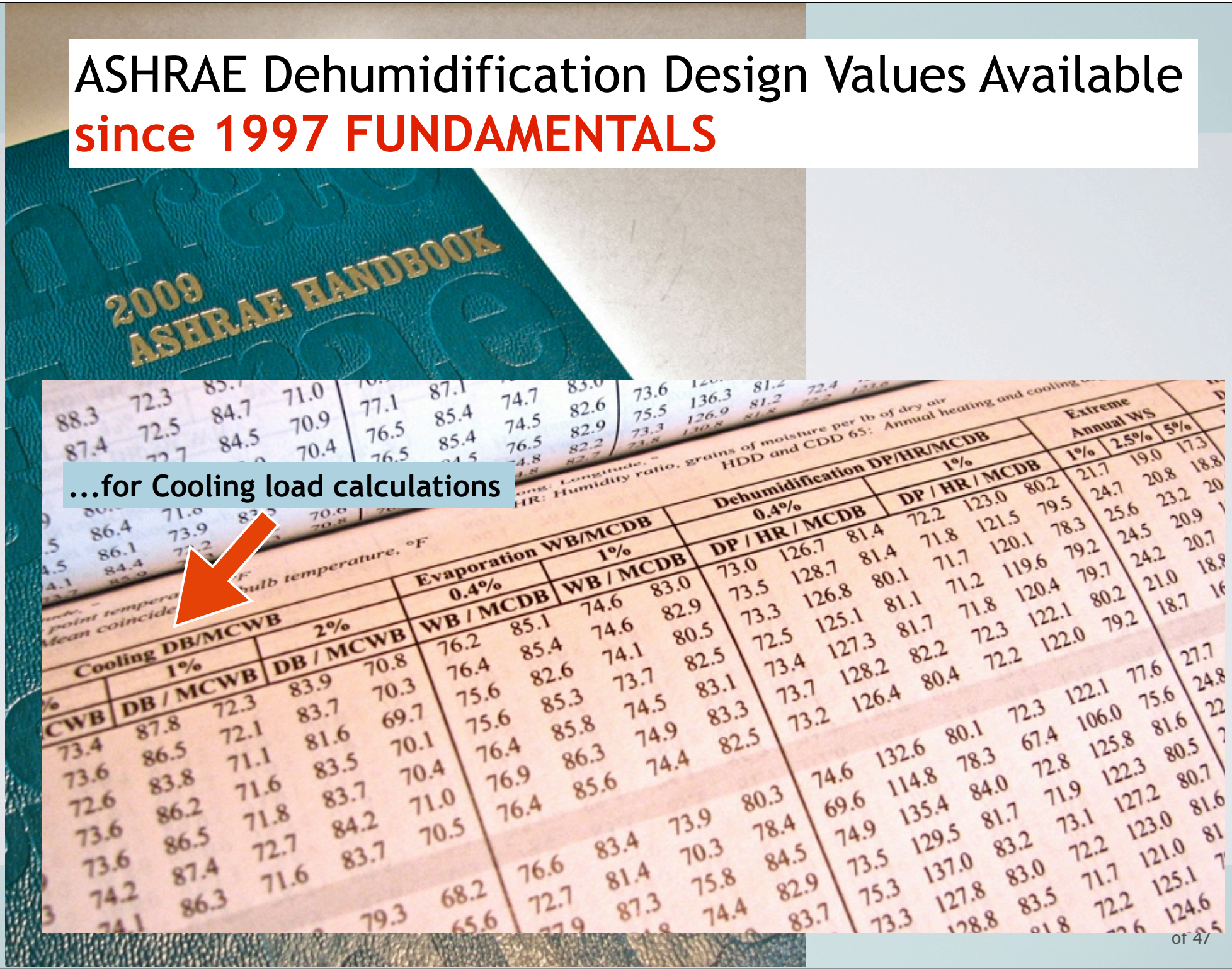

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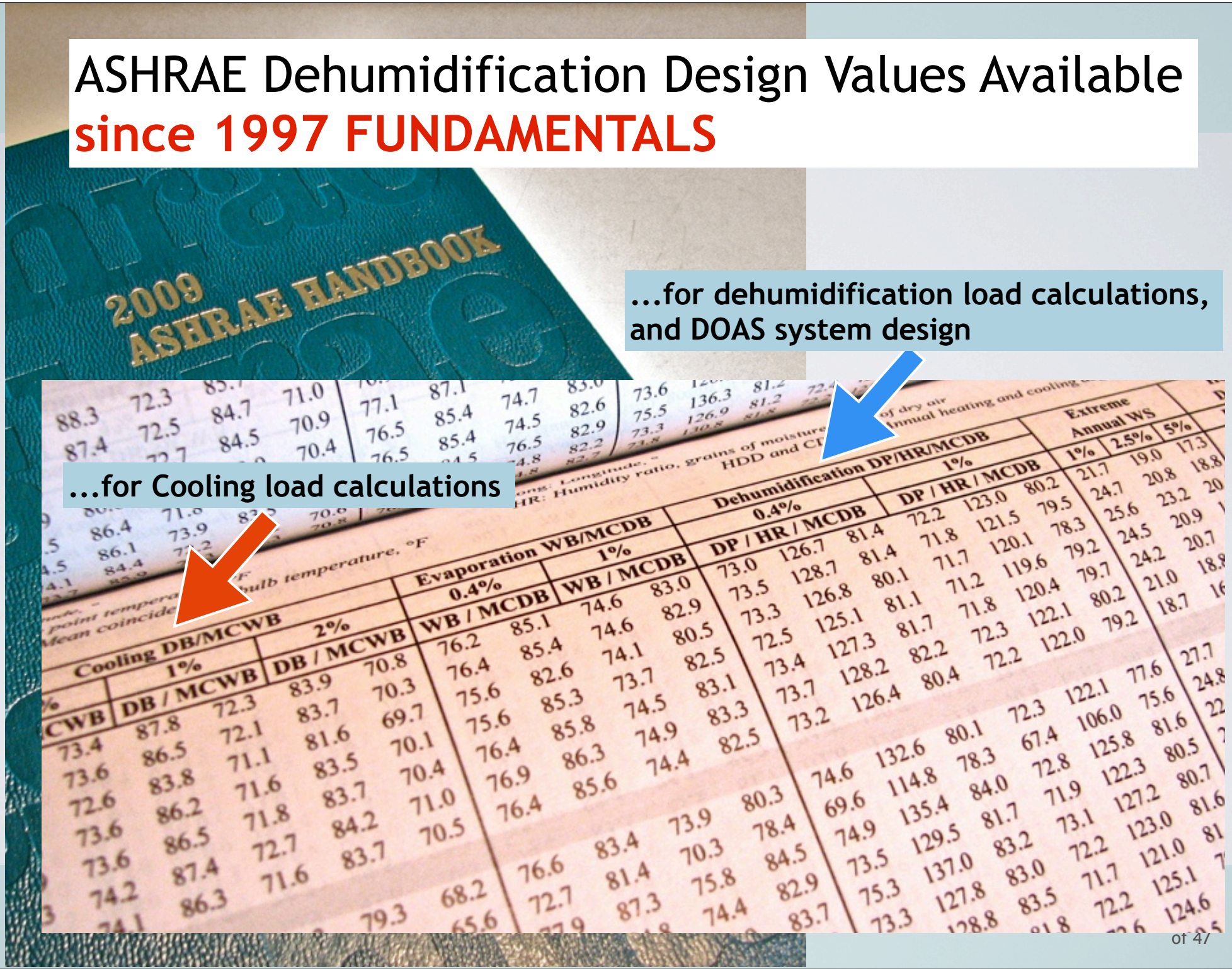

Dayton - ASHRAE humidity design conditions

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0.4% Dry Bulb
91° DB 74° MCWB
99 gr/lb

Dayton - ASHRAE humidity design conditions

0.4% Dry Bulb	0.4% Dew Point
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99 gr/lb	128 gr/lb

Dayton - ASHRAE humidity design conditions

0.4% Dry Bulb	0.4% Dew Point	**Difference at peak dew point**
91° DB 74° MCWB	**81°**DB 74°MCWB	**-10°F DB**
99 gr/lb	128 gr/lb	**+29 gr/lb**

Measuring Dehumidification - Humidity removal

Dehumidification

Humidity removal

Dry air flow

Controls

Measuring Dehumidification - Humidity removal

First..
Find the
Dehumidifier!

Dehumidification

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Measuring Dehumidification - Humidity removal

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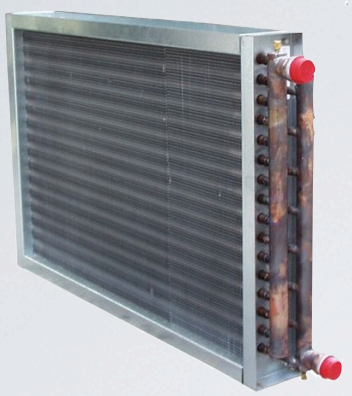

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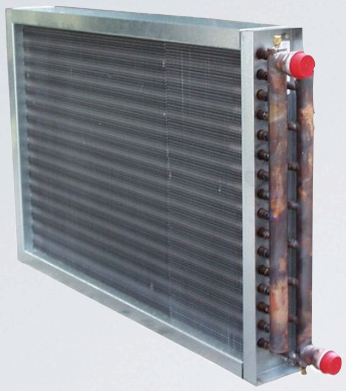
Measuring Dehumidification - Humidity removal



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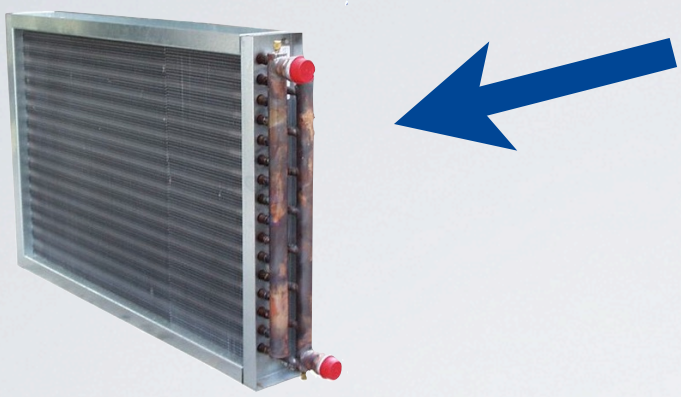
Measuring Dehumidification - Humidity removal



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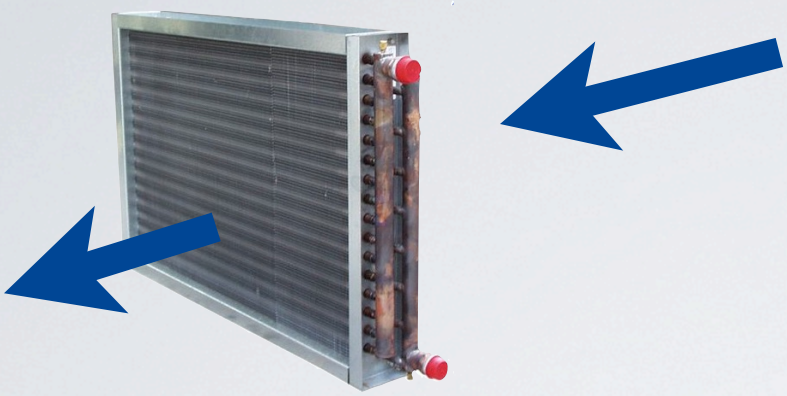

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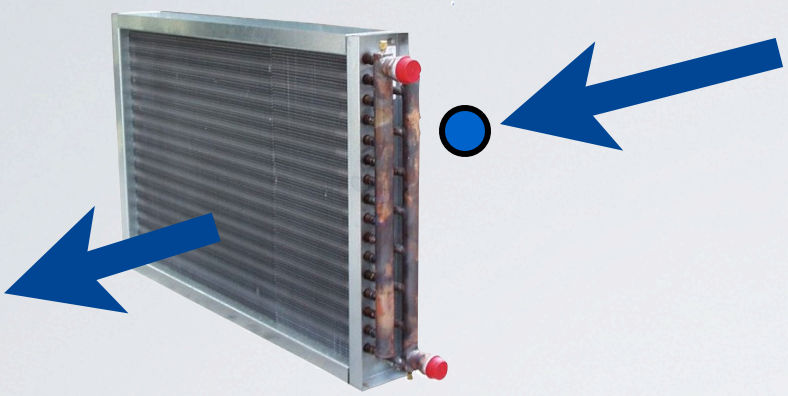

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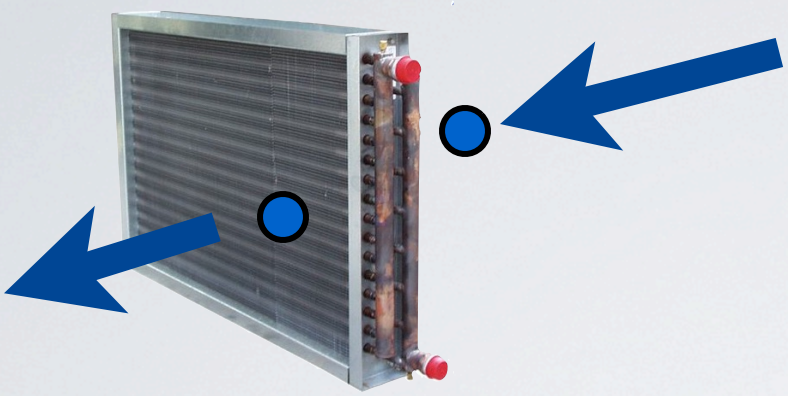

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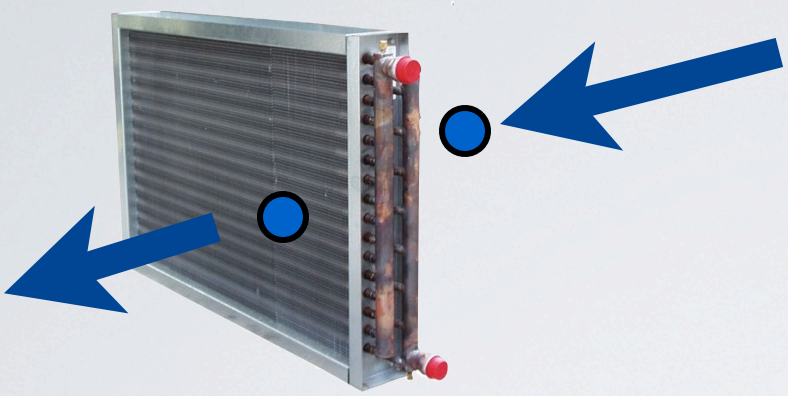

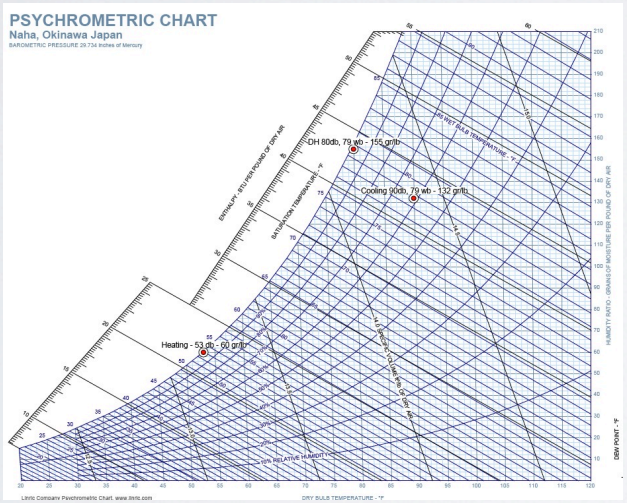

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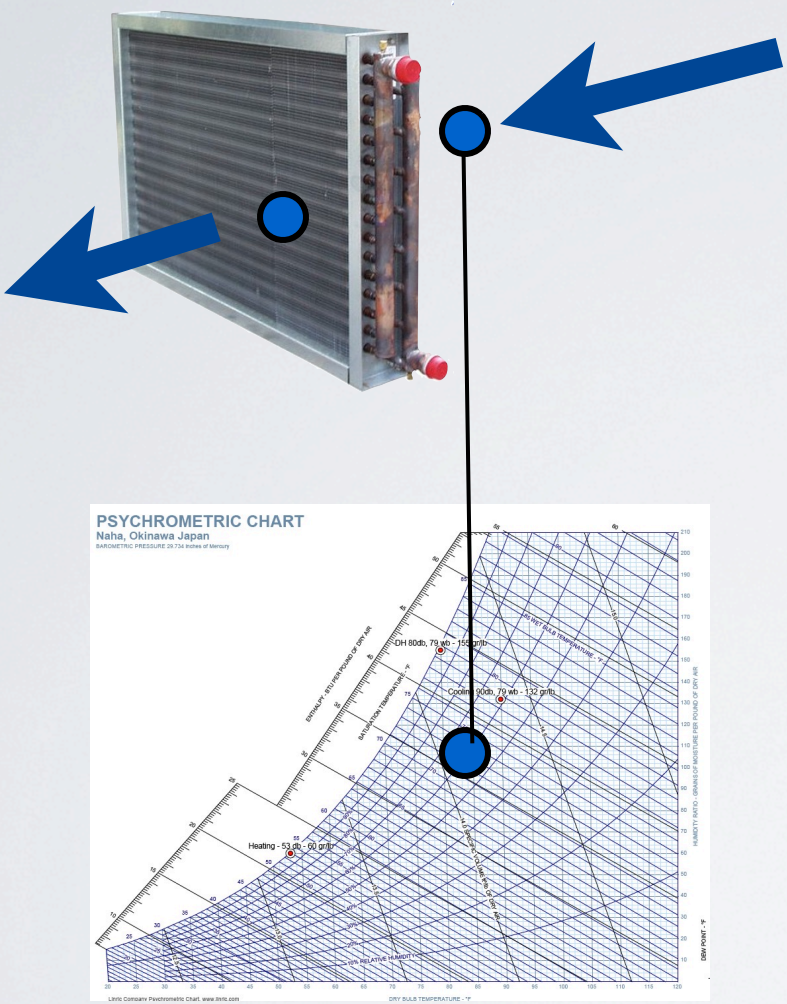

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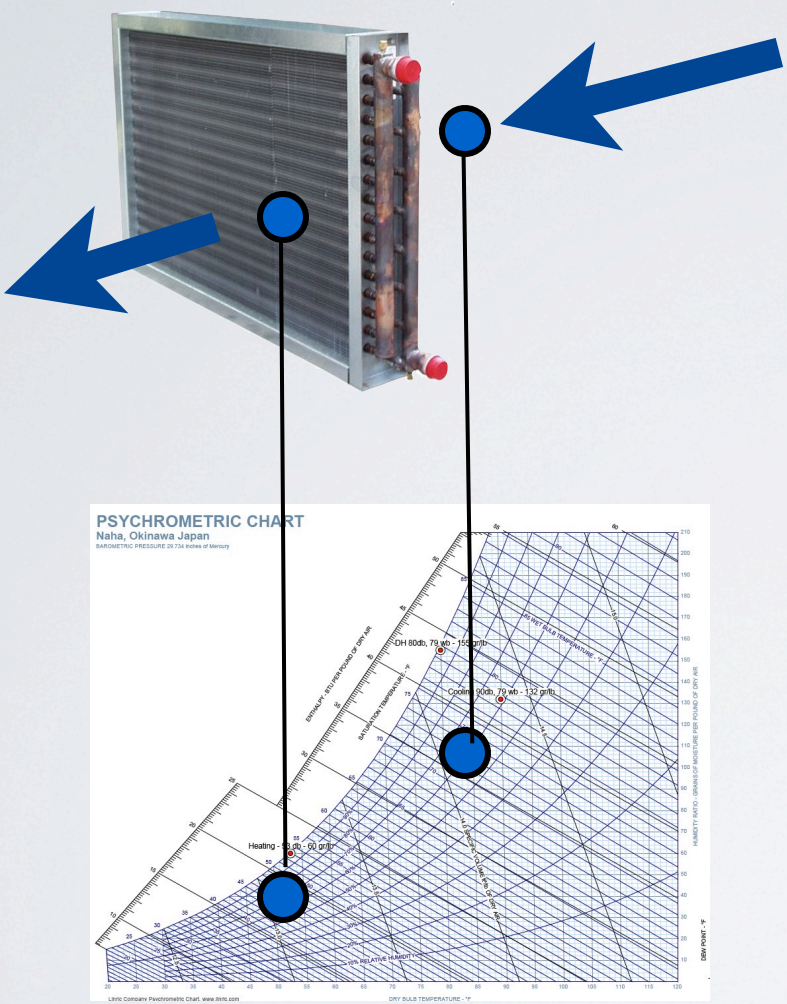

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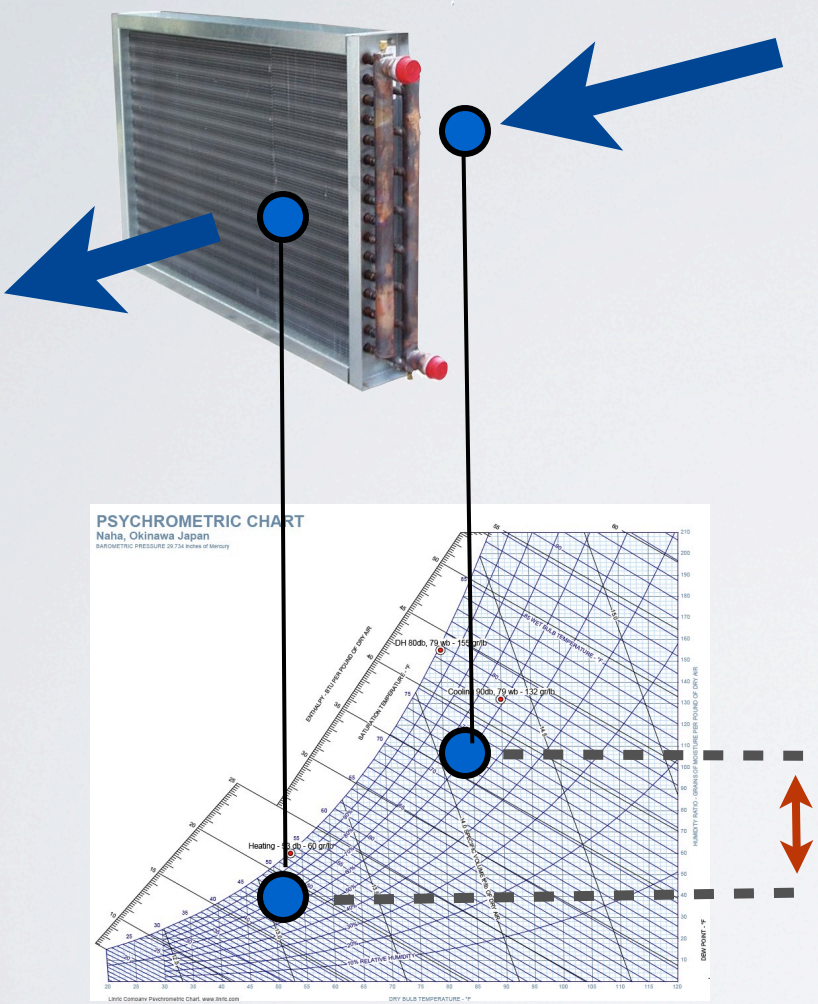

Dehumidification

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

Dehumidification accomplished by the cooling coil

$$\frac{\text{cfm} \times 4.5 \times (\text{Entering air gr/lb} - \text{Leaving gr/lb})}{7000}$$

$$= \text{lb/hr}$$

Measuring Dehumidification OVER TIME - Controls

Dehumidification

Humidity removal

Dry air flow

Controls

Measuring Dehumidification OVER TIME - Controls

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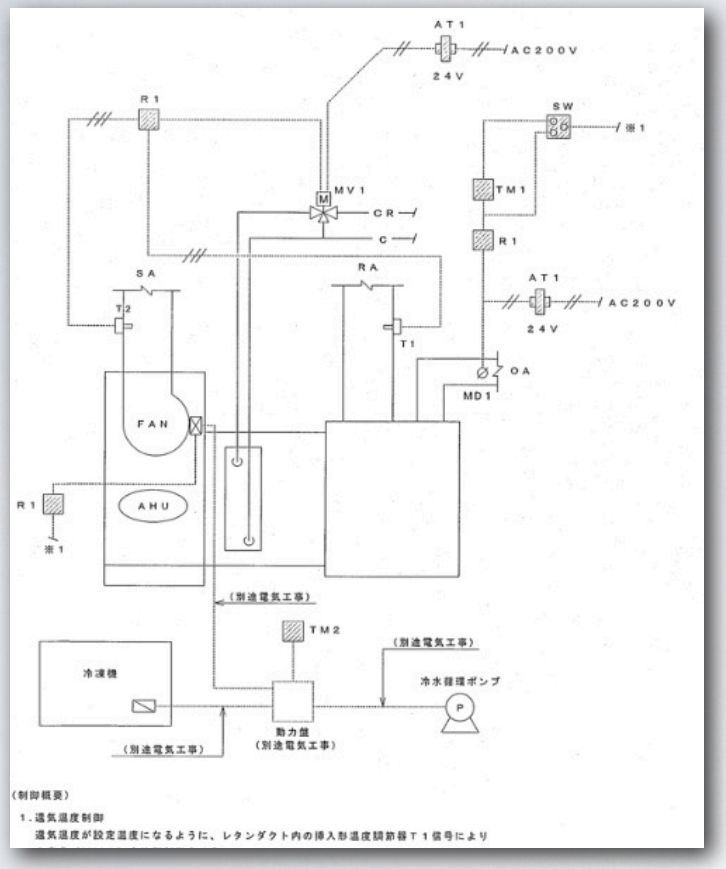
Do they really work?

Review diagrams, place dataloggers

..then compare to the real world

Measuring Dehumidification OVER TIME - Controls



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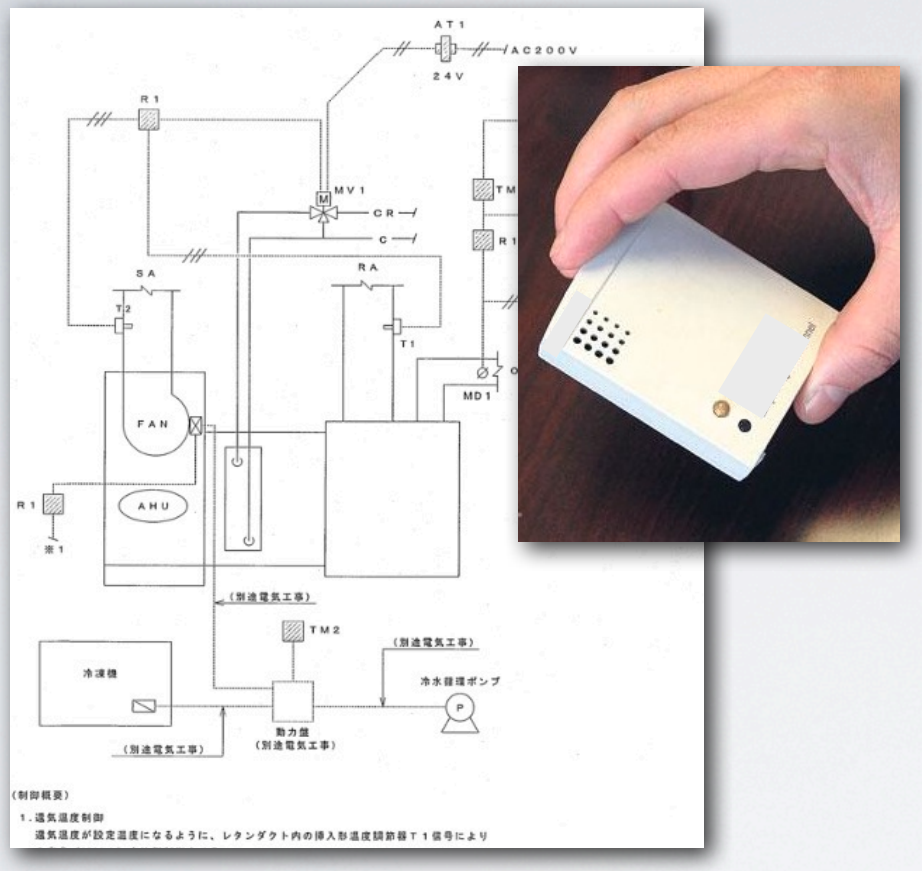

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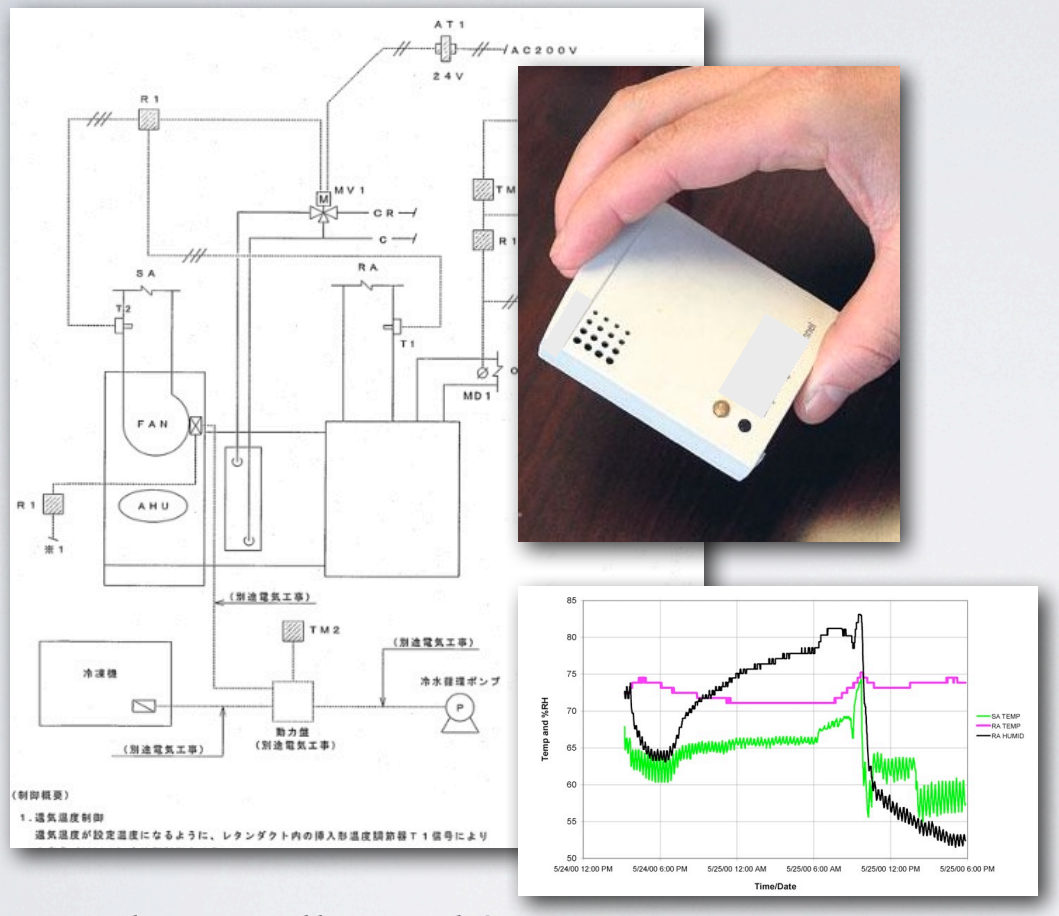

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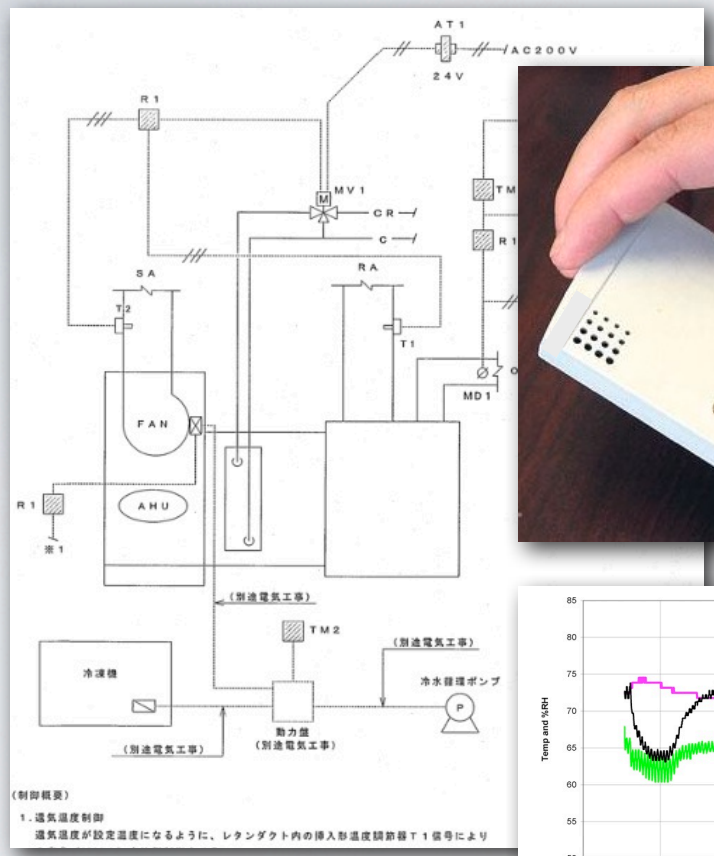

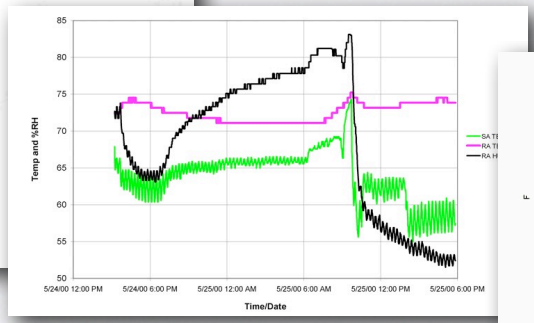

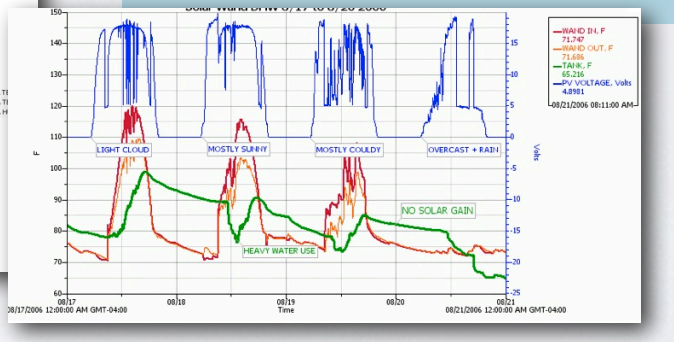

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Review diagrams, place dataloggers

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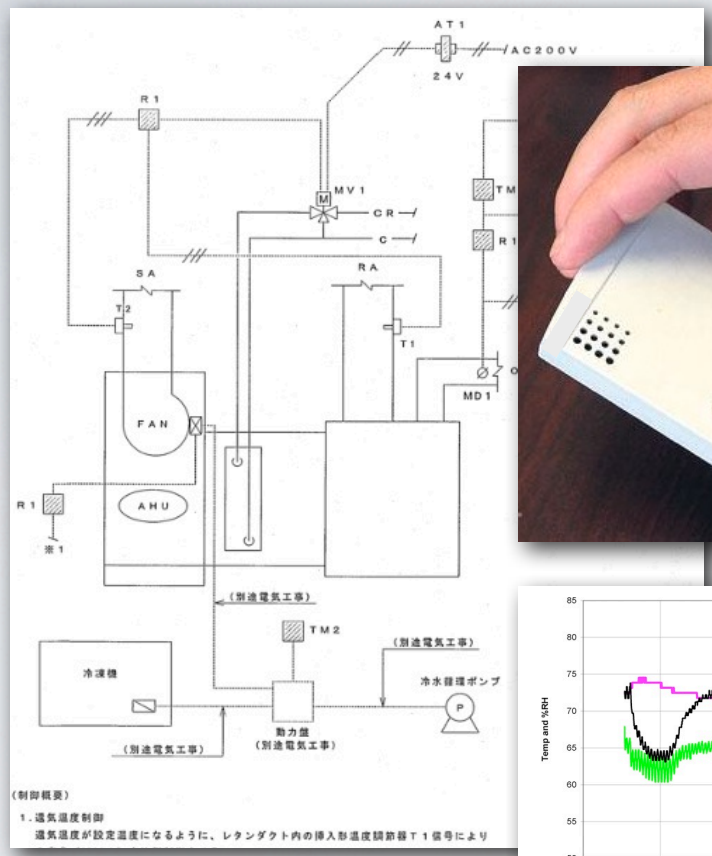
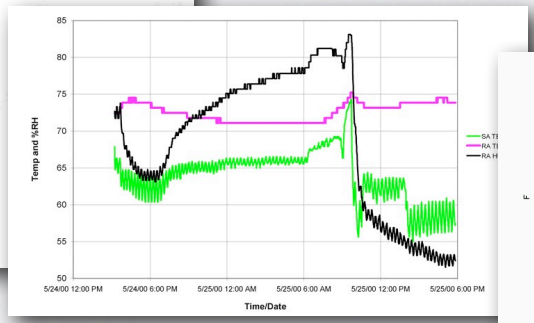
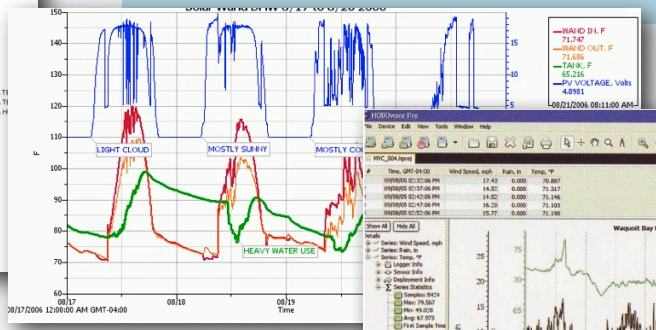
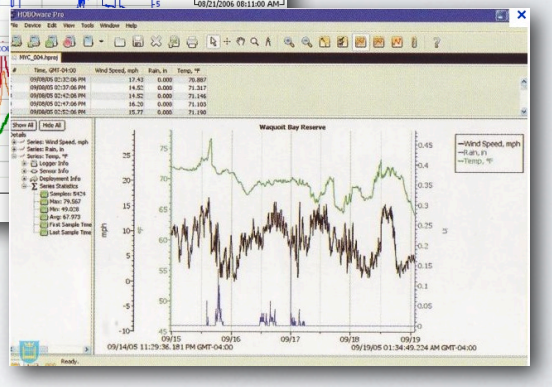
Measuring Dehumidification OVER TIME - Controls









Dehumidification

Humidity removal

Dry air flow

Controls

Do they really work?

Review diagrams, place dataloggers

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Logical sequence

1. Listen and understand the problems
2. Look at drawings, then walk though and understand the building
3. Look at drawings, then walk though and understand the HVAC system
4. Measure the key variables
   a. The loads
   b. The dehumidification
5. Diagnose the problems... plan solutions

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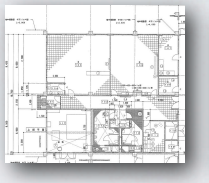

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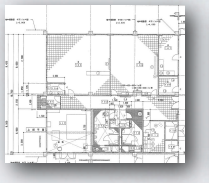

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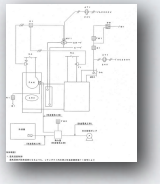

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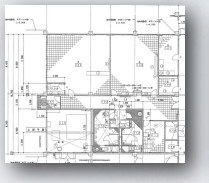

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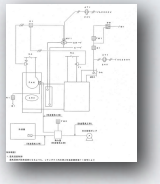

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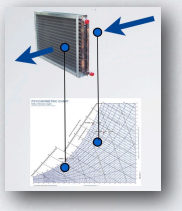

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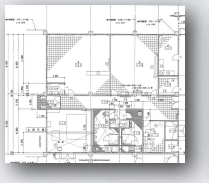

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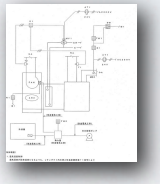

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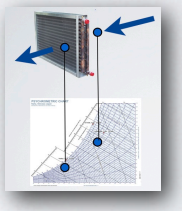

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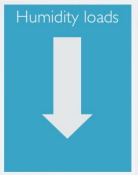
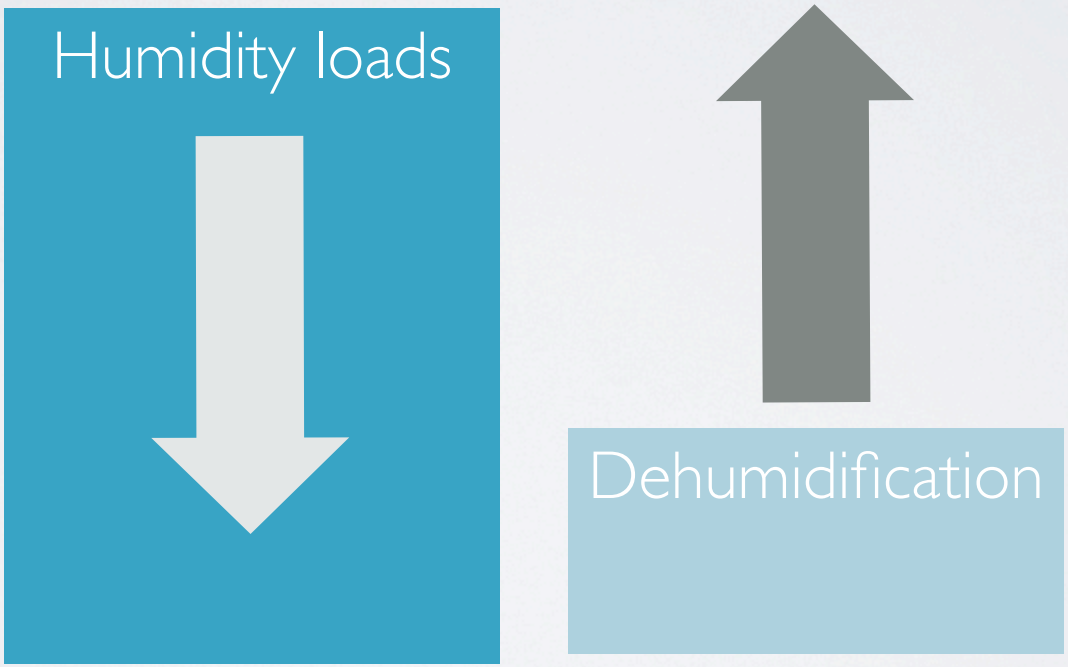


How to solve humidity control problems



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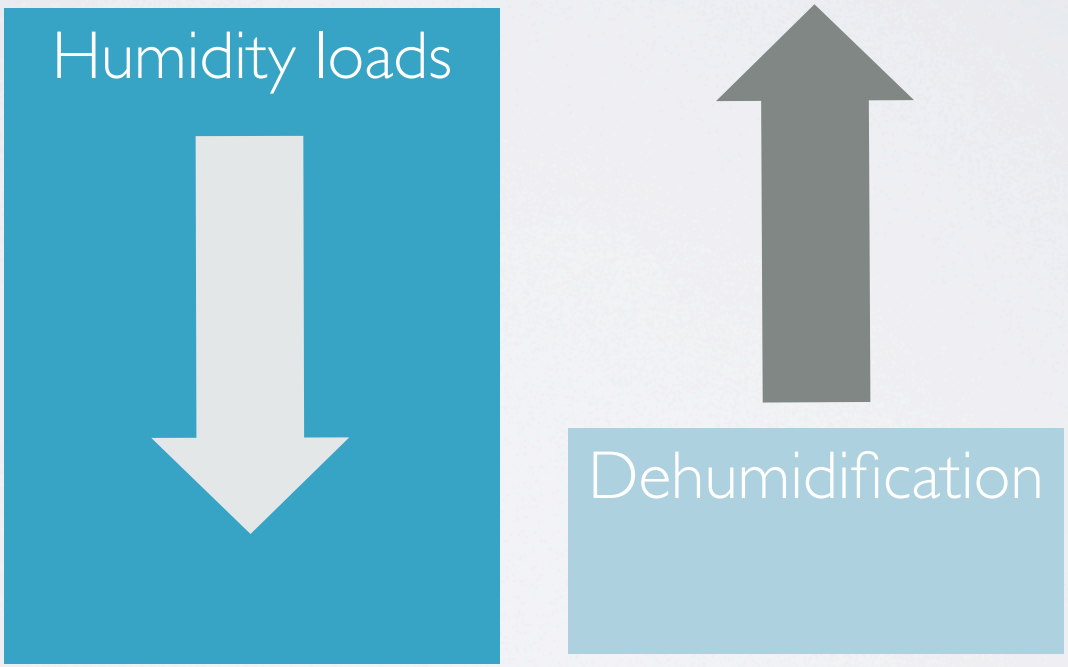

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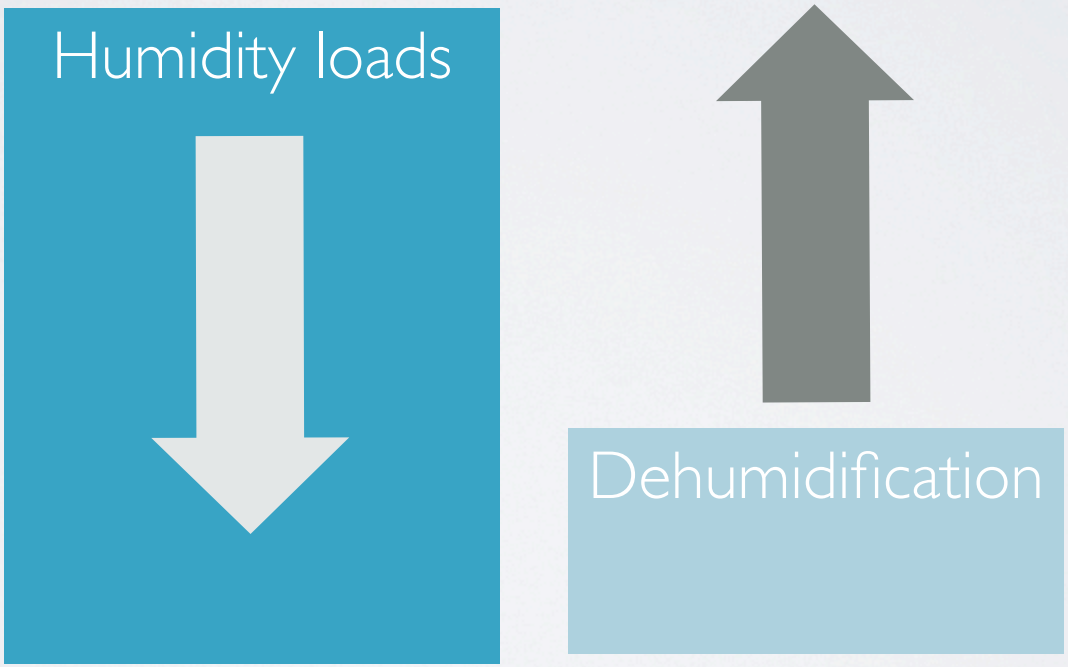

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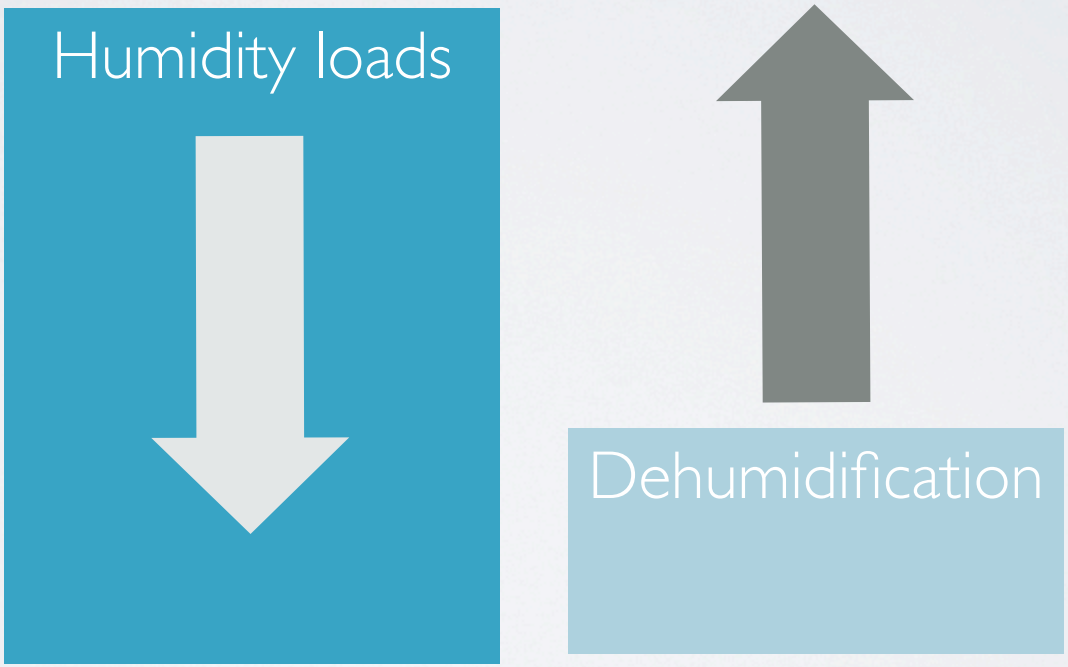

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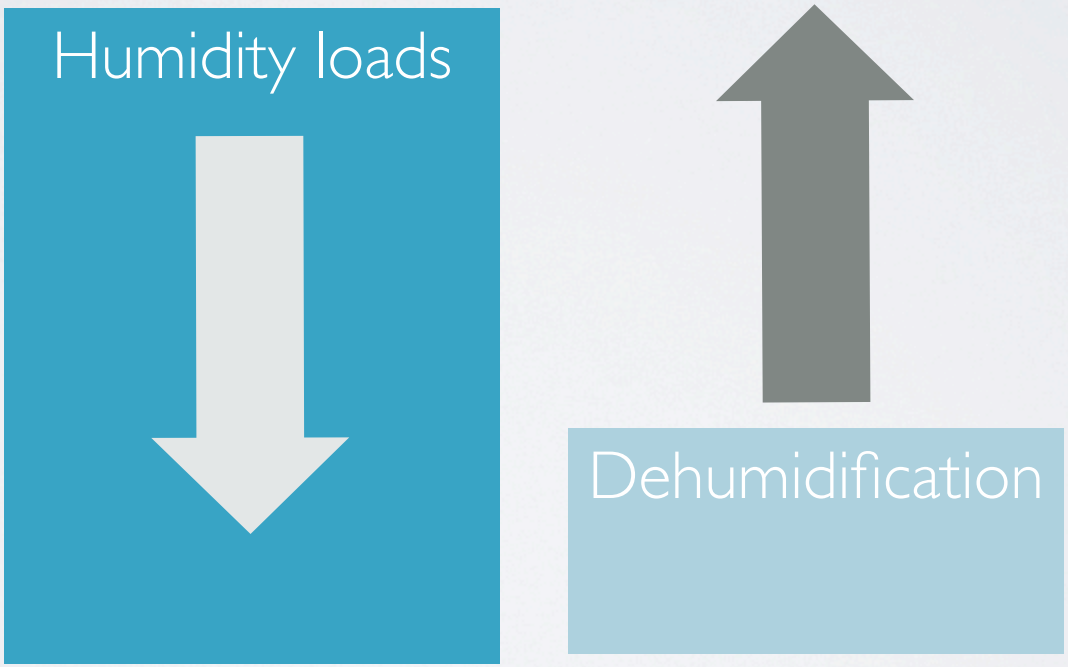

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Further ASHRAE Resources

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Humidity Control Design Guide

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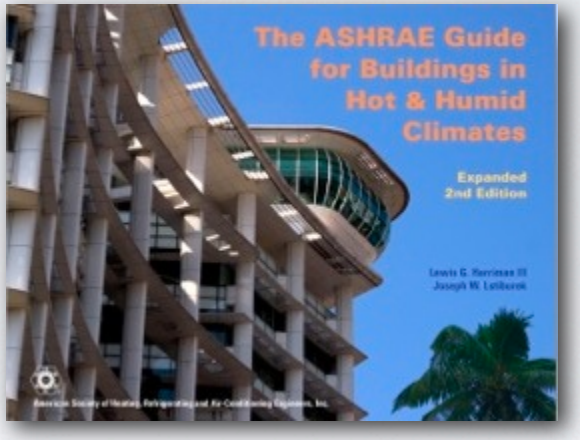

Guide for Buildings in Hot and Humid Climates

Further ASHRAE Resources

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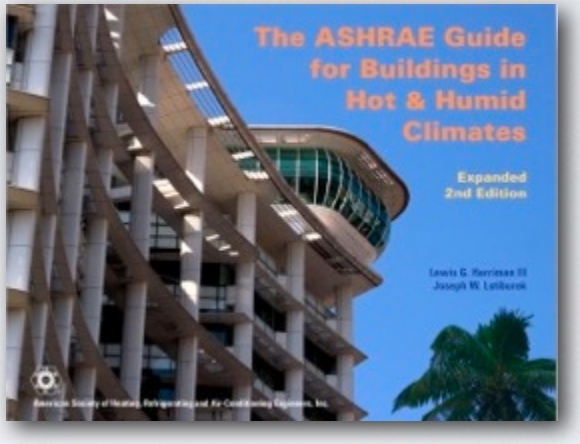

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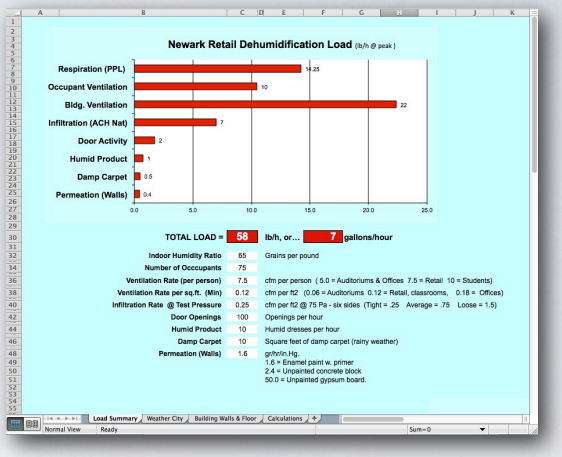

Load Estimator (Spreadsheet)

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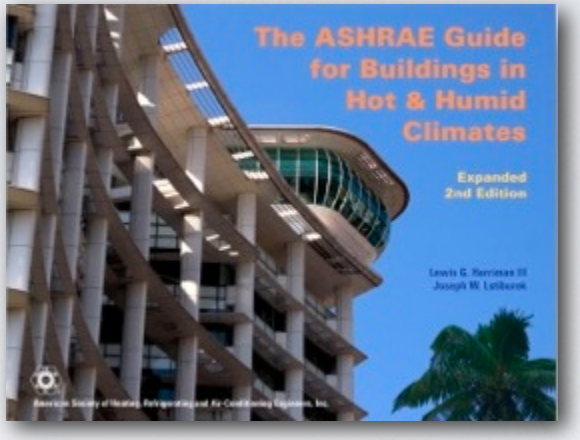

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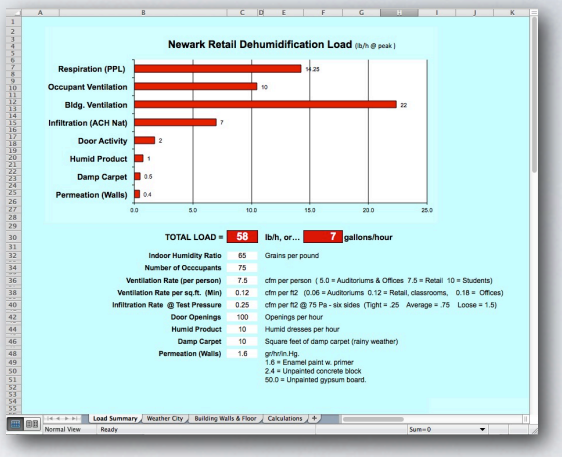

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2011-2013 Chair, ASHRAE TC 1.12
(603) 431-0635