

HUMIDITY CONTROL AND THE BUILDING THERMAL ENVELOPE IN NATATORIUMS



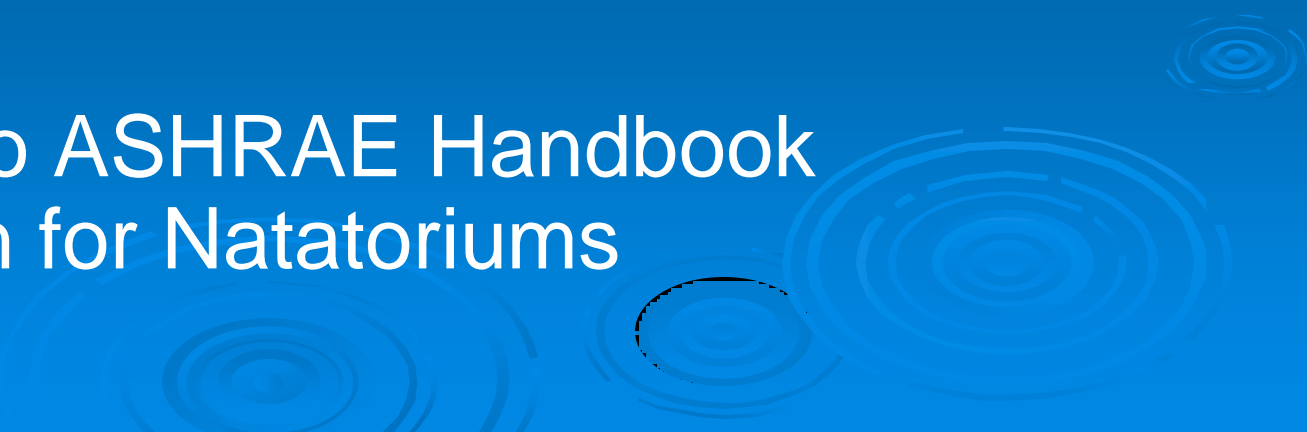
(What you don't see might hurt you)

Natatoriums



Photo © BigStockPhoto/Liang Zhang

Purpose/Topics

- Understand Pool Evaporation and the Beneficial Effect of Outside Air
 - Stack Effect, and its Impact on the Building Thermal Envelope
 - Basics of Vapor Retarders/Air Barriers
 - Changes to ASHRAE Handbook information for Natatoriums
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GOALS

- Control Pool Surface Evaporation



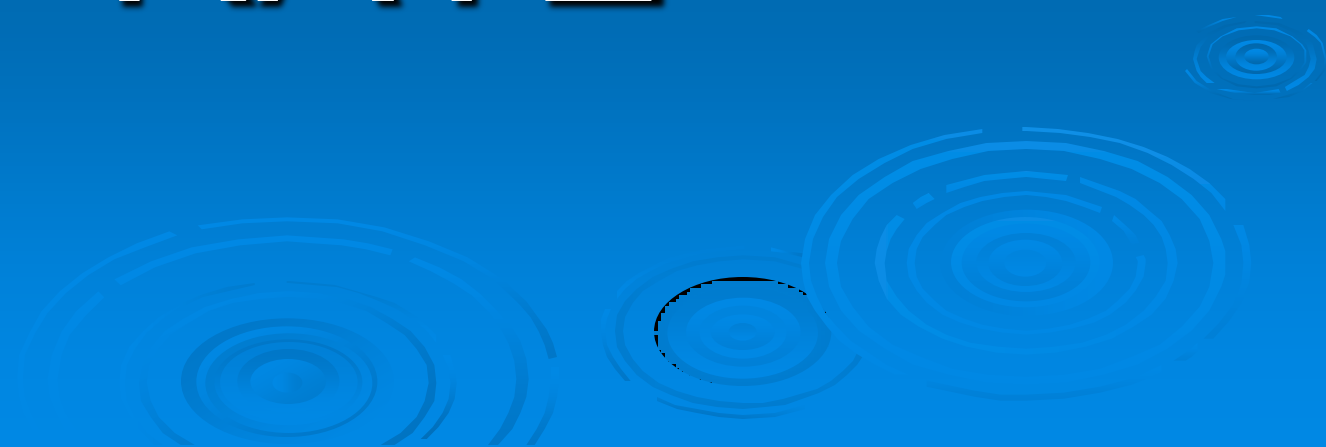
GOALS

- Minimize Movement of Water Vapor into the Thermal Envelope



<http://contractingbusiness.com/iaq-amp-ventilation/dive-indoor-pool-dehumidification>

EVAPORATION RATE



Willis Carrier – 1876-1950

- Father of “Air Conditioning”
- “Apparatus for Treating Air”
- Wrote “Magna Carta of Psychrometrics”

- Equation for calculating the evaporation rate from a wet surface



RECOMMENDED READING:
“Father of Air Conditioning” by
Margaret Ingels

Willis Carrier – 1918

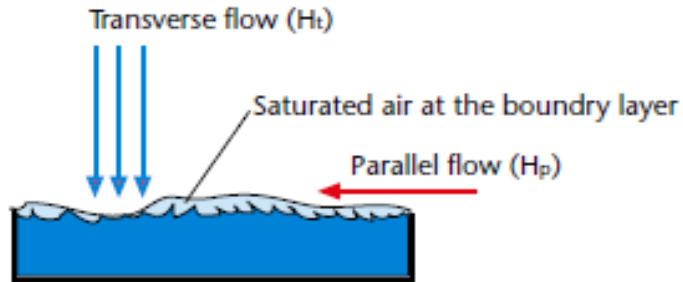


FIGURE 5.11

Wet surfaces

Moisture evaporates from wet surfaces quite slowly, even when the surrounding air is very dry. The rate increases dramatically when high velocity air is blown at the surface perpendicularly, and when the wet surface water is warm.

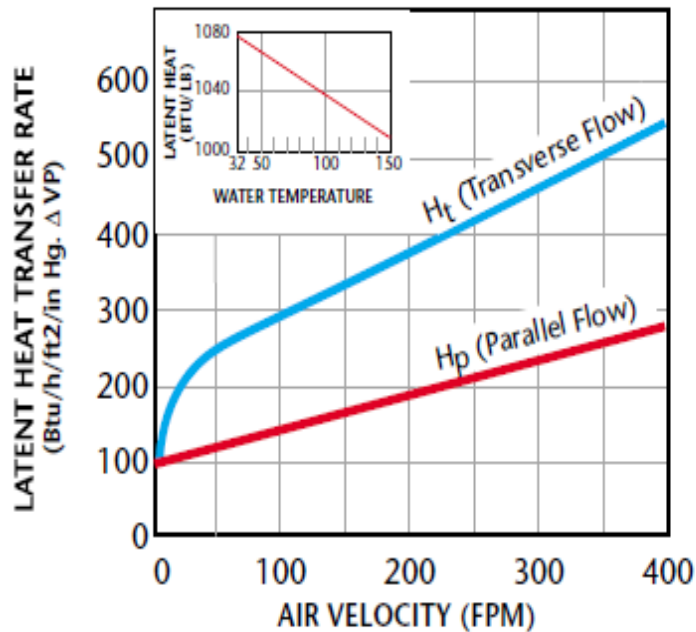


From [The Dehumidification Handbook](#) by Munters Corporation
Lewis G. Harriman III, Editor, 1989, 2002

<http://www.matsakis.gr/Munters%20DH%20Handbook.pdf>

$$E = H \times A \times (VP_s - VP_a)$$

FIGURE 5.10



Where:

E = Evaporation rate (btuh)

H = Latent Heat Transfer Rate (Figure 5.10)

A = area (sq.ft.)

VP_s = Vapor Pressure of surface

VP_a = Vapor Pressure of air

From *The Dehumidification Handbook* by Munters Corporation
Lewis G. Harriman III, Editor, 1989, 2002

<http://www.matsakis.gr/Munters%20DH%20Handbook.pdf>

$$E = A(VPs - VP_a)(95 + 0.425V)$$

[Related Commercial Resources](#)

CHAPTER 5

PLACES OF ASSEMBLY

General Criteria	5.1	Convention and Exhibition Centers	5.5
Houses of Worship	5.2	Natatoriums	5.6
Auditoriums	5.3	Fairs and Other Temporary Exhibits	5.8
Arenas and Stadiums	5.4	Atriums	5.9

ASSEMBLY rooms are generally large, have relatively high ceilings, and are few in number for any given facility. They usually have a periodically high density of occupancy per unit floor area, as compared to other buildings, and thus have a relatively low design sensible heat ratio.

This chapter summarizes some of the design concerns for enclosed assembly buildings. ([Chapter 3](#), which covers general criteria for commercial and public buildings, also includes information that applies to public assembly buildings.)

1. GENERAL CRITERIA

Energy conservation codes and standards must be considered because they have a major impact on design and performance.

a suitably low level of light during performances, with much higher lighting levels during cleanup, when the house is nearly empty. The designer should ascertain the light levels associated with maximum occupancies, not only for economy but also to determine the proper room sensible heat ratio.

Indoor Air Conditions

Indoor air temperature and humidity should follow ASHRAE comfort recommendations in Chapter 9 of the 2013 *ASHRAE Handbook—Fundamentals* and ASHRAE *Standard 55*. In addition, the following should be considered:

- In arenas, stadiums, gymnasiums, and movie theaters, people generally dress informally. Summer indoor conditions may favor the

$$E = A(VPs - VP_a)(95 + 0.425V)$$

$$w_p = 0.1A(p_w - p_a)F_a \quad (2)$$

The following activity factors should be applied to the areas of specific features, and not to the entire wetted area:

Type of Pool	Typical Activity Factor (F_a)
Baseline (pool unoccupied)	0.5
Residential pool	0.5
Condominium	0.65
Therapy	0.65
Hotel	0.8
Public, schools	1.0
Whirlpools, spas	1.0
Wavepools, water slides	1.5 (minimum)

Evaporation - Psychrometrics

Denver, Colorado

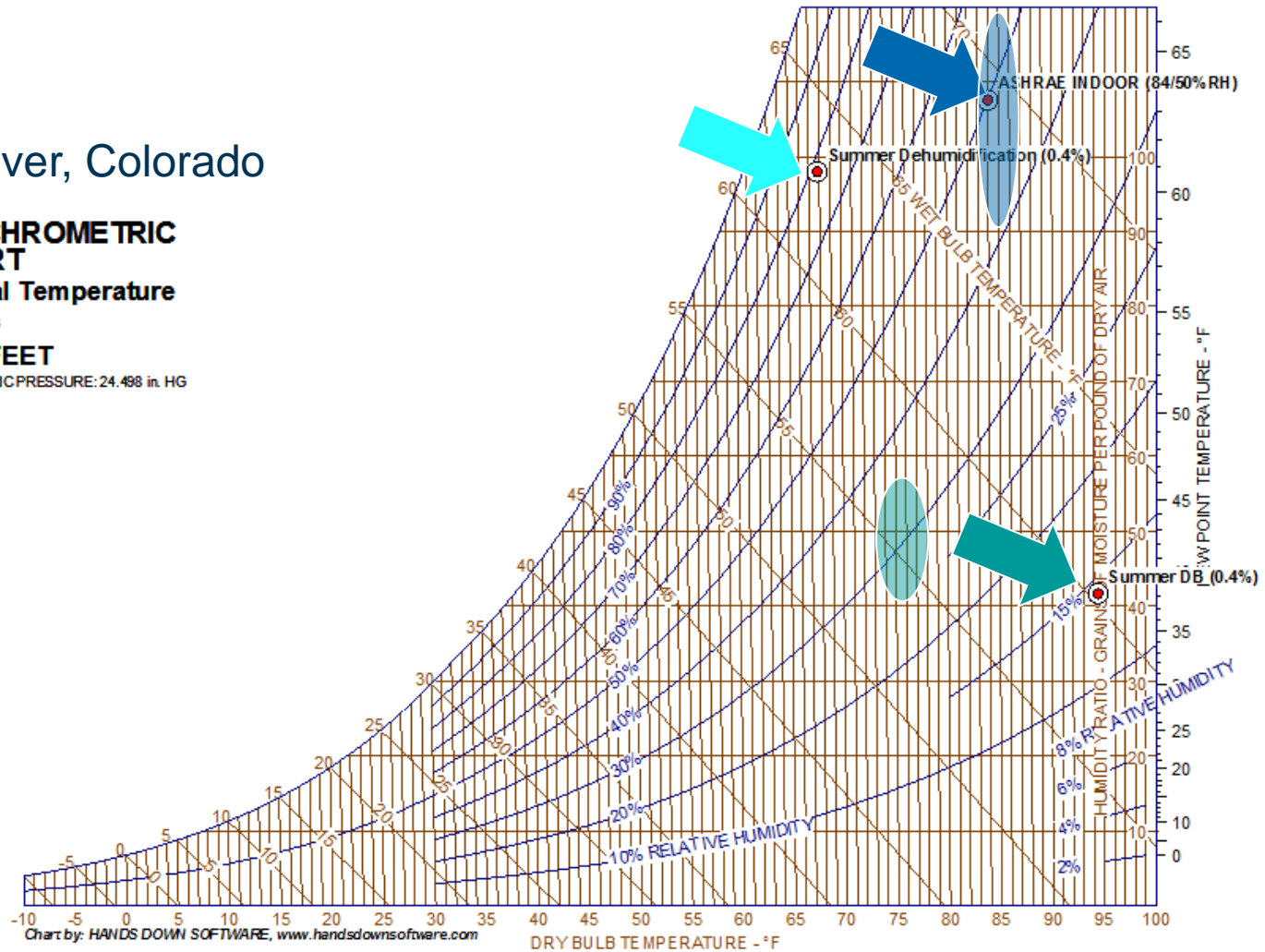
PSYCHROMETRIC CHART

Normal Temperature

I-P Units

5430 FEET

BAROMETRIC PRESSURE: 24.498 in. HG



Evaporation - Psychrometrics

Denver, Colorado

PSYCHROMETRIC CHART

Normal Temperature

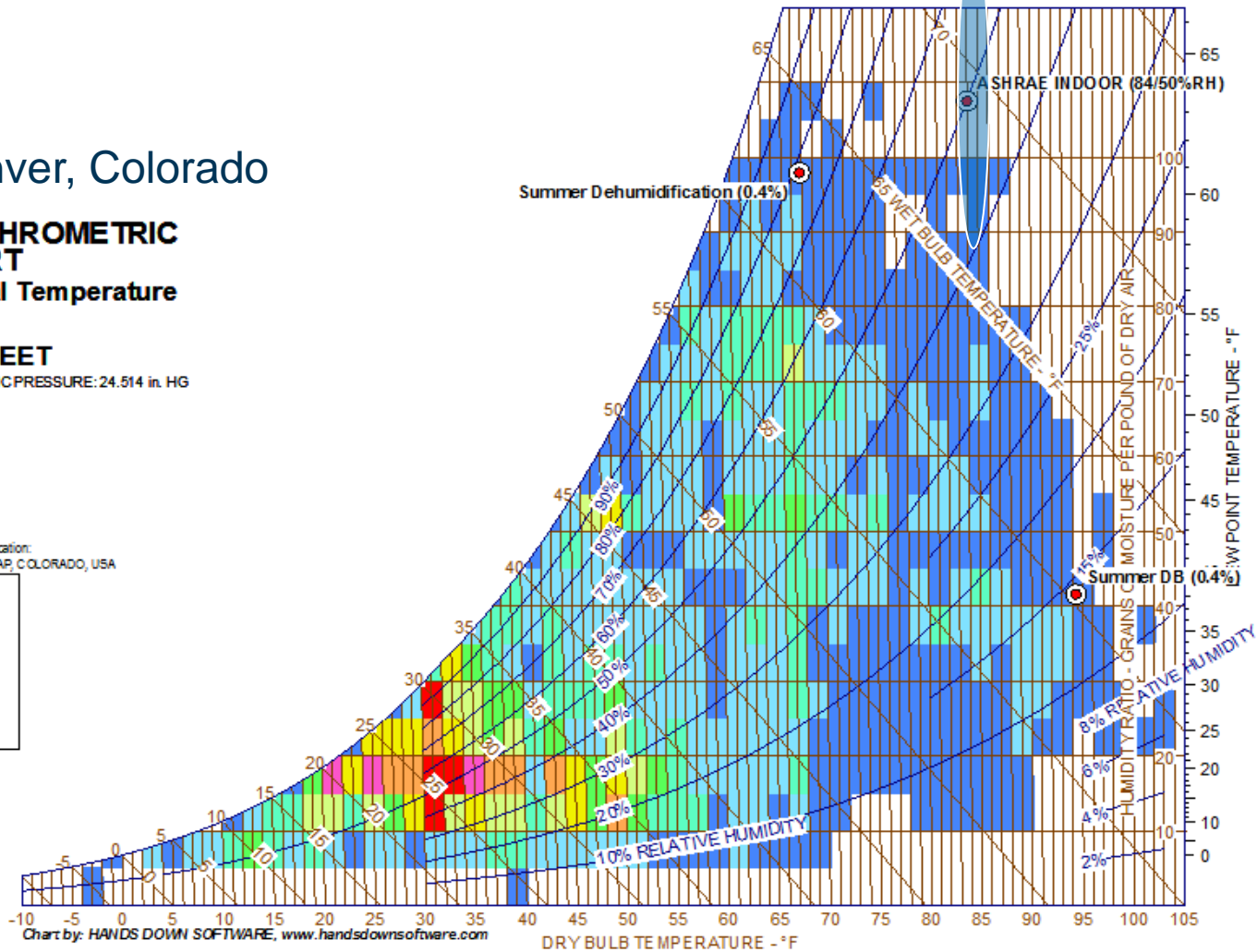
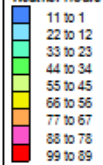
I-P Units

5413 FEET

BAROMETRIC PRESSURE: 24.514 in. HG

Weather Data Location:
DENVER_INTL_AR, COLORADO, USA

Weather Hours



Evaporation - Psychrometrics

Denver, Colorado

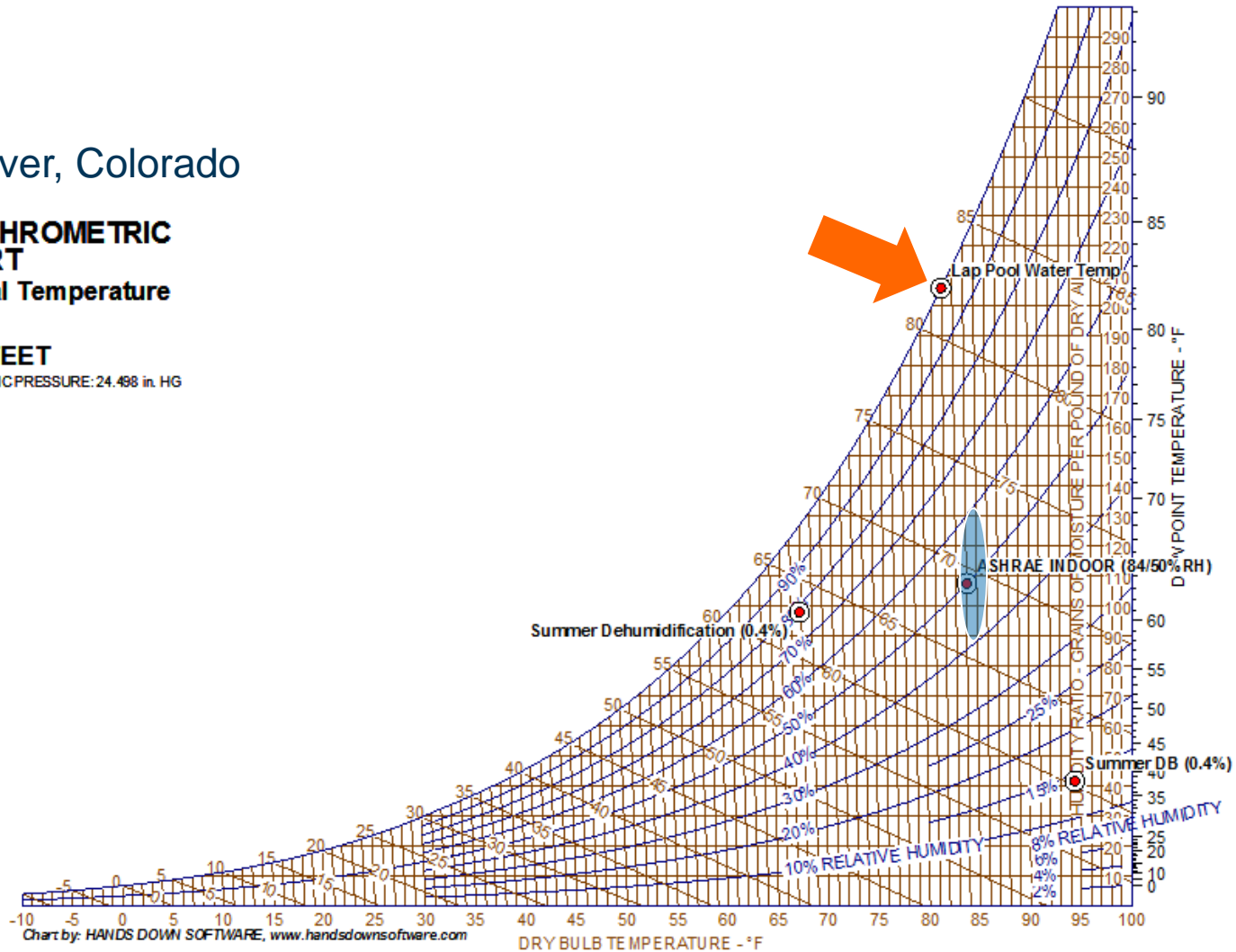
PSYCHROMETRIC CHART

Normal Temperature

I-P Units

5430 FEET

BAROMETRIC PRESSURE: 24.468 in. HG



Evaporation - Psychrometrics

Denver, Colorado

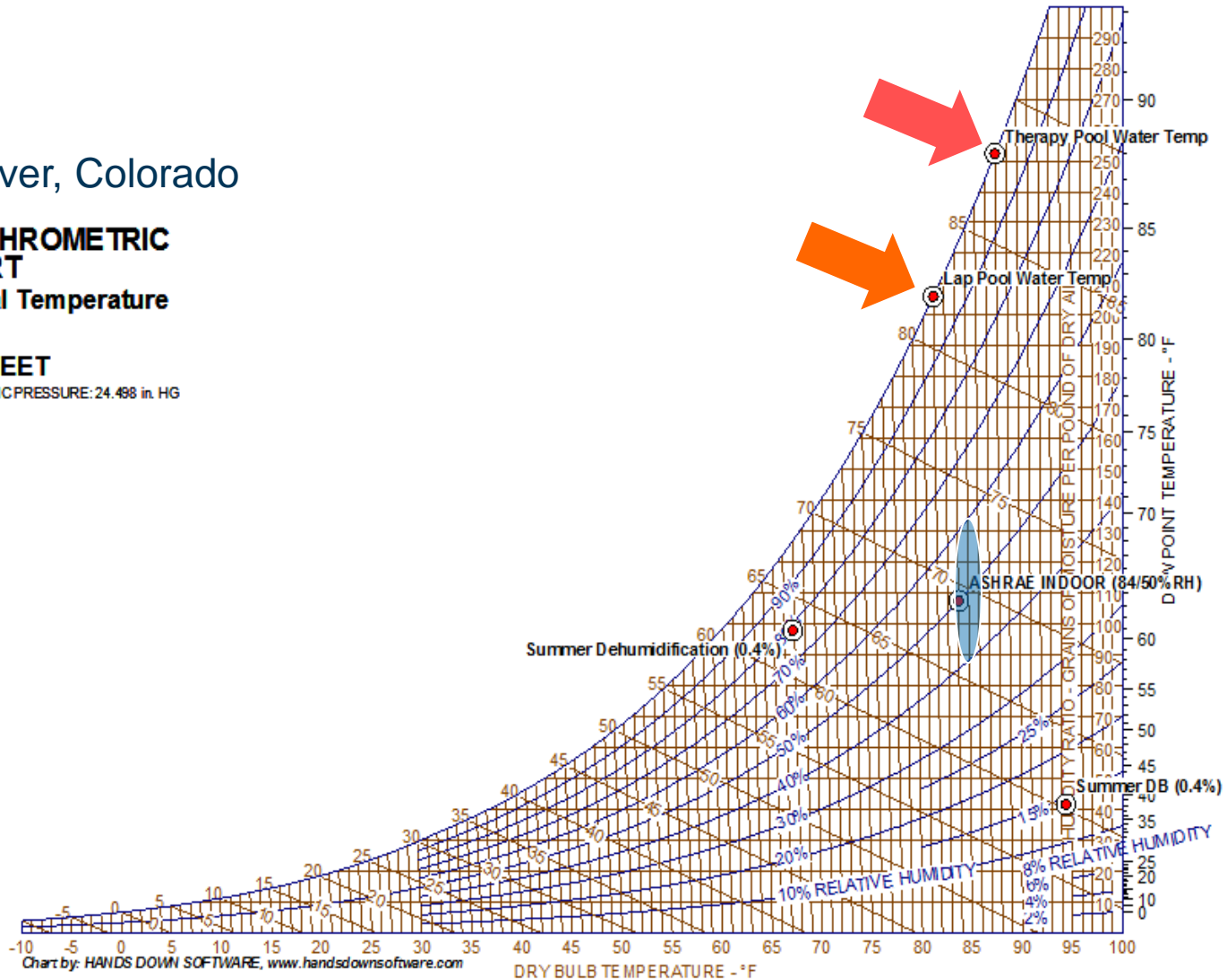
PSYCHROMETRIC CHART

Normal Temperature

IP Units

5430 FEET

BAROMETRIC PRESSURE: 24.498 in. HG



Evaporation Rate as a function of Vapor Pressure



“Typical Large Natatorium”

- Lap Pool: 3900 sq.ft. /82°
- Therapy/Play Pool: 3100 sq.ft. /89°
- Hot Tub: 80 sq.ft. /104°
- Slides, Bubblers, Water Jets, etc.
- Wetted Deck Area: 10,000 sq.ft.

Pollutants

- Primarily Trichloramine vapor
- Causes “chlorine smell”
- Several times heavier than air
- Ventilation air should be introduced at deck level
- Consider gutter exhaust systems or “Evacuators”

STACK EFFECT



Natatoriums “Suck”

SCHEMATIC REPRESENTATION OF “STACK EFFECT”

Upper Part of building

Magnitude of air pressure causing EXFILTRATION from top of building

Neutral Plane

Magnitude of air pressure causing INFILTRATION into building

Lower Part of building

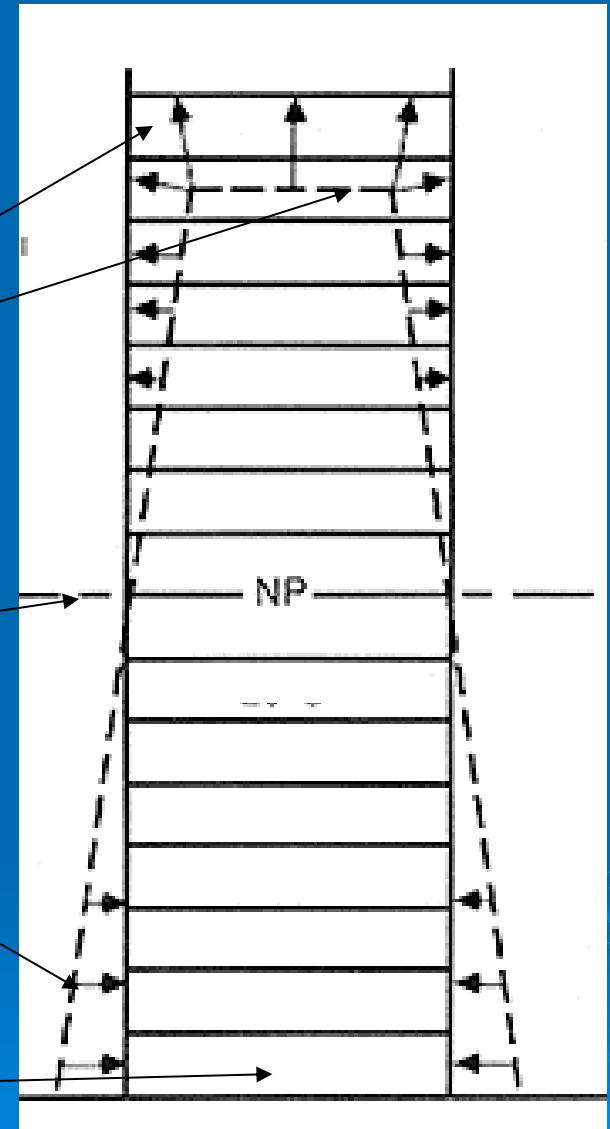


Illustration of typical no-wind stack effect pressurization in a high-rise building. (From “The Air Barrier Defined”, National Research Council Canada, <http://www.nrc-cnrc.gc.ca/eng/ibp/irc/bsi/86-air-barrier.html>)

Wind Effects

SCHEMATIC REPRESENTATION OF “STACK EFFECT & WIND”

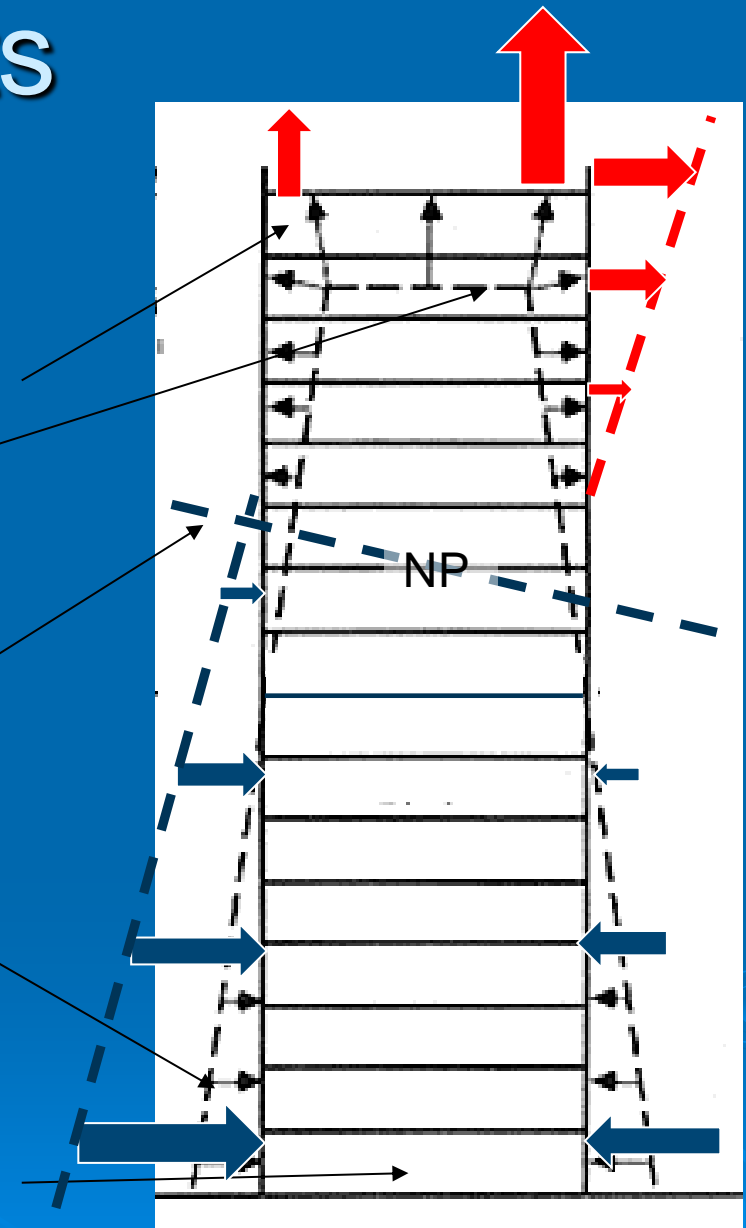
Upper Part of building

Magnitude of air
pressure causing
EXFILTRATION from
building

Neutral Plane

Magnitude of air
pressure causing
INFILTRATION into
building

Lower Part of building



GOAL: Offset Stack Effect

SCHEMATIC REPRESENTATION OF “STACK EFFECT & WIND”

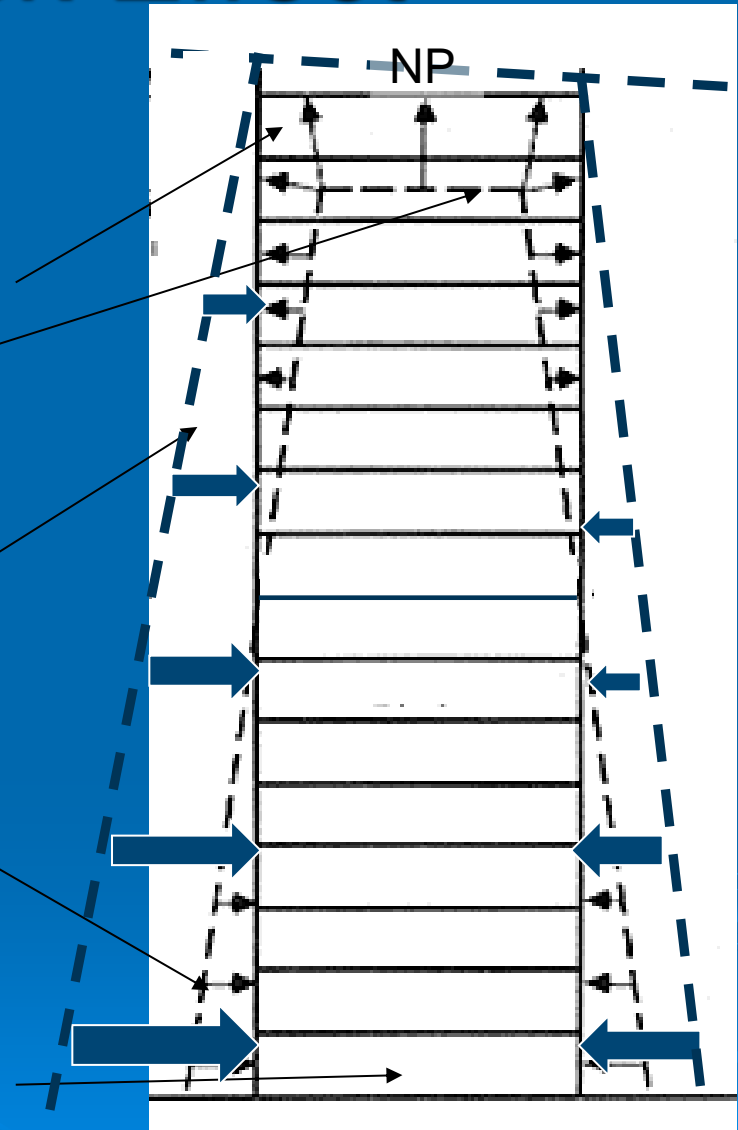
Upper Part of building

Magnitude of air
pressure causing
EXFILTRATION from
building

Neutral Plane

Magnitude of air
pressure causing
INFILTRATION into
building

Lower Part of building



Natatorium Pressure

- Equation found in Chapter 4 of Applications Handbook
- Function of building height and temperature difference
- Each foot of elevation = 0.0024”w.c.

Natatorium Pressure

- Each foot of elevation = 0.0024”w.c.
- At 42-ft high = 0.11”w.c.
- Control the HVAC system: The pressure near the roof MUST be slightly negative
- When properly pressurized, the deck pressure will be -0.10”w.c.,

HVAC System Considerations



Basic HVAC System Goals

- The HVAC system is primarily a de-humidifier and de-pressurizer
- Sensible cooling may not be necessary
- Space heating should be provided as low as possible
 - Consider the use of radiant heating
- **CONSIDER THE USE OF 100% OUTSIDE AIR**

Vapor Pressure Comparison

- Indoor Air at 84°/40% RH = 0.413 (“Hg)
- Indoor Air at 86/60% RH = 0.752
- Lap Pool at 82° = 1.103
- Therapy Pool at 89° = 1.379
- Hot Tub at 104° = 2.180

- Outdoor Air at 30°/60° (DB/WB) = 0.099
- Outdoor Air at 69°/60° (DB/WB) = 0.443
- Outdoor Air at 95°/60° (DB/WB) = 0.231

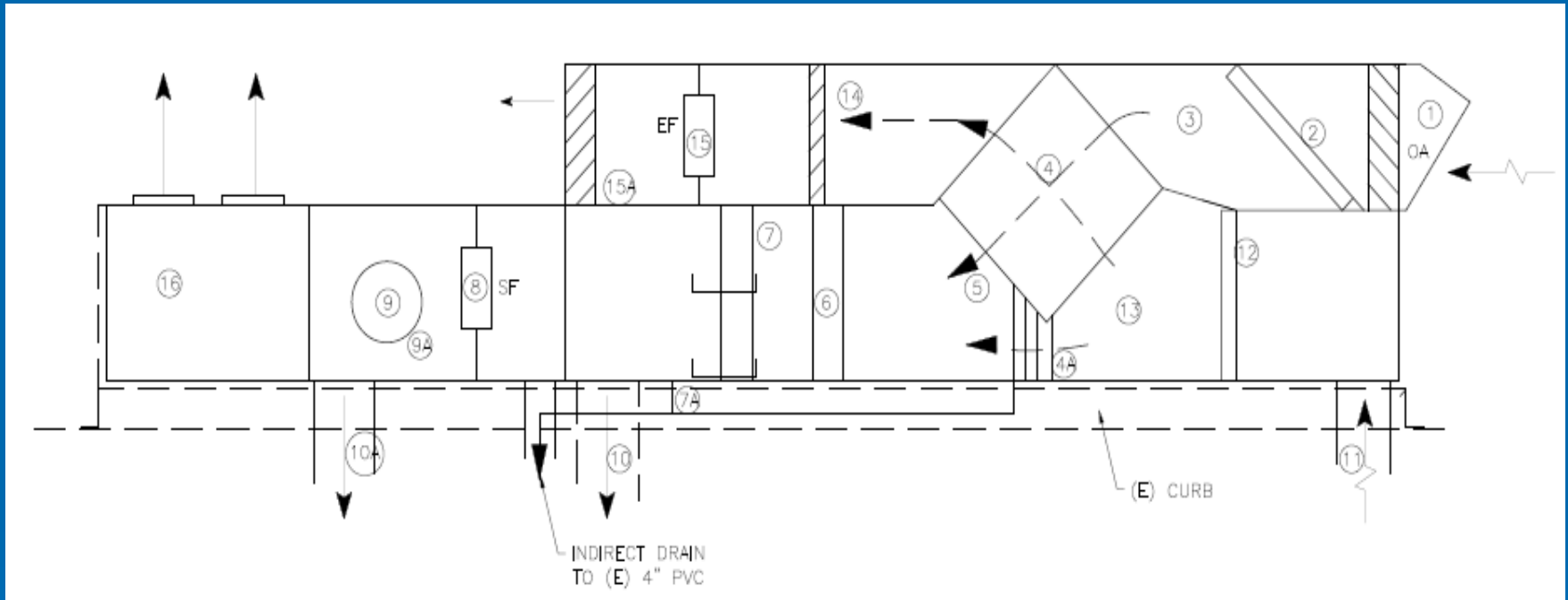
Calculated Evaporation Rate

- Indoor conditions of 84°/45% RH (winter) and 86°/60% RH (summer)
- At SAME ACTIVITY LEVELS:
 - WINTER: 590 LBS/HR
 - SUMMER: 412 LBS/HR

Calculated Outside Air

- Outdoor conditions of 30°/60% RH (winter) and 68°/78% RH (summer design)
- At SAME ACTIVITY LEVELS:
 - WINTER: 590 LBS/HR
 - SUMMER: 412 LBS/HR
- RESULTANT OUTSIDE AIRFLOW:
 - WINTER: 14,000 CFM
 - SUMMER: 22,000 CFM

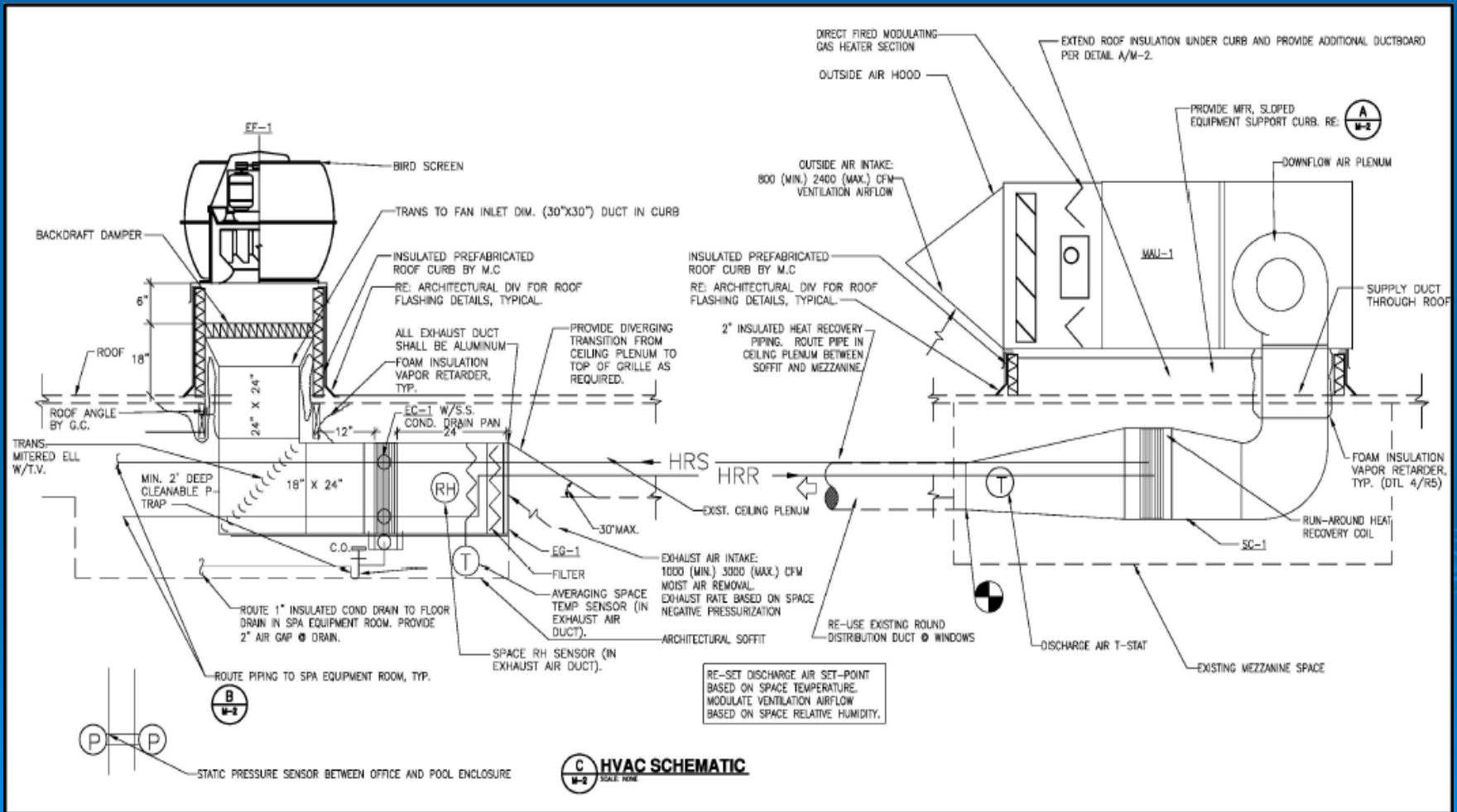
Typical Large Natatorium



1 = OA INTAKE
2 = OA PRE-FILTER
3 = FILTERED OA TUNNEL
4 = SENS. ONLY QXΔER
5 = TEMPERED OA
6 = MIXED AIR FILTER

7,14 = DX COIL/CU
8 = SUPPLY FAN
9 = INDIRECT GAS-FIRED HEAT
10A = RELOCATED SA OUTLET
14 = RA BY-PASS
15 = MODULATING EXHAUST FAN

Typical Small Natatorium



BUILDING THERMAL ENVELOPE CONCERNS



Why?

- Architects don't always get it
- As HVAC professionals, we should help



POOR DESIGN

- Failure to include design features to protect the thermal envelope can cause:
 - Roof failure



Failure to Protect

- Failure to include design features to protect the thermal envelope can cause:
 - Roof failure



Failure to Protect

- Failure to include design features to protect the thermal envelope can cause:
 - Roof Failure

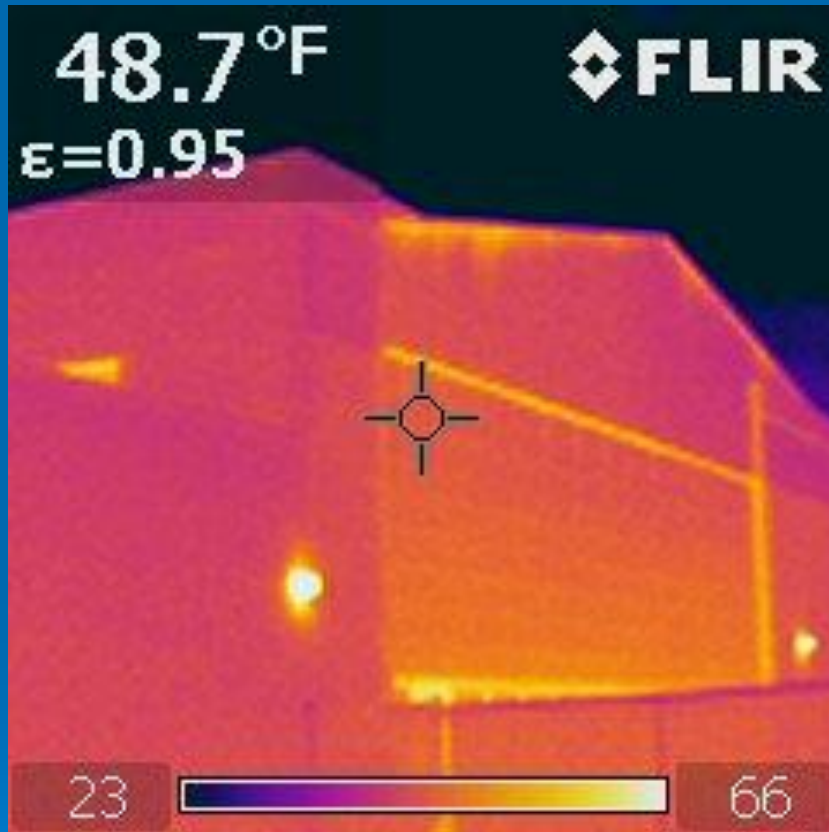


Failure to Protect

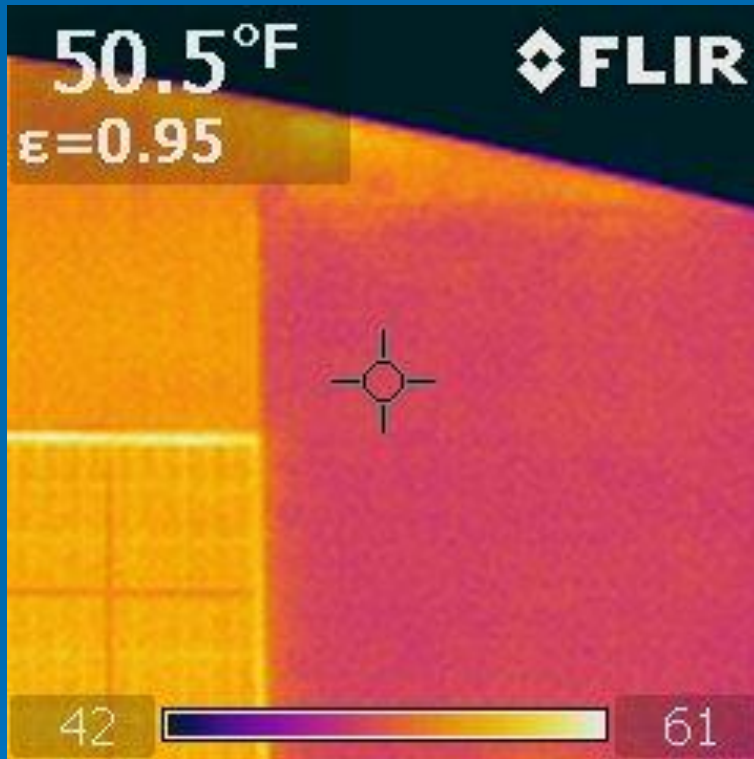
- Failure to include design features to protect the thermal envelope can cause:
 - Which can lead to Structural Failure



Stack Effect



Stack Effect



Stack Effect



What the Architect Should Do

-

“Belt and Suspenders”

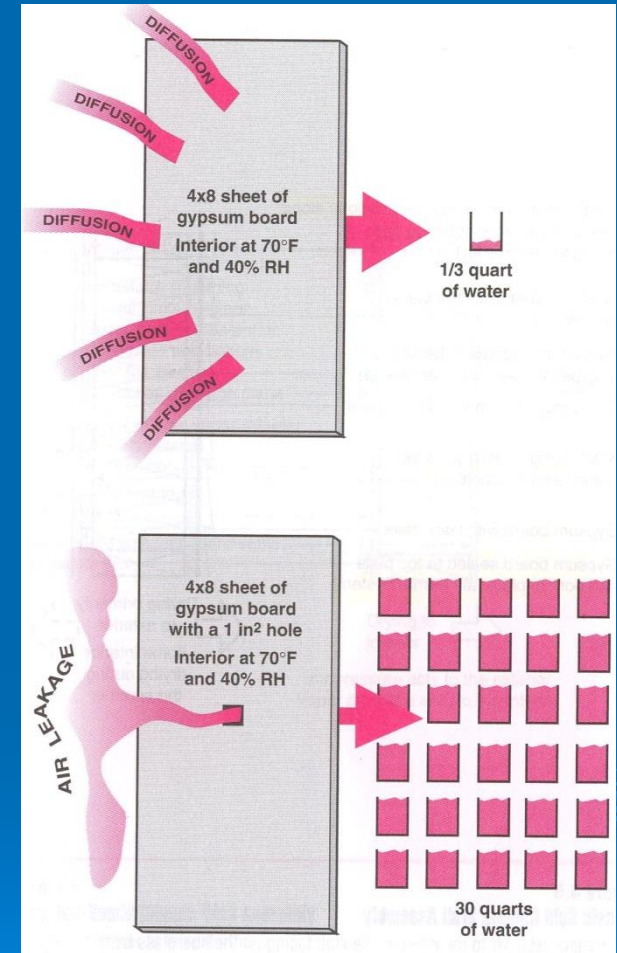
The background of the slide is a solid blue color. In the lower half, there are several decorative elements consisting of concentric circles, resembling ripples in water or a target pattern. These circles are rendered in a lighter shade of blue and are scattered across the bottom portion of the slide.

Why install an Air and Vapor Retarder?

- Failure to properly install an appropriate air and vapor retarder can result in
 - Structural damage
 - Mold
 - Undesirable odors
 - Decreased building component life

Why install an Air and Vapor Retarder?

- Air flow can carry a much greater amount of water vapor into a cavity than diffusion through most construction materials
- Therefore, continuity of the air retarder is of extreme importance



From Builder's Guide to Cold Climates
by Joseph Lstiburek, 2004

<http://www.buildingscience.com/>

Considerations for Mountain Jobs

➤ **Outside air is drier**

- Vapor pressure is lower
- Vapor diffusion is driven by vapor pressure

➤ **Surfaces are Colder**

- Colder condensing surfaces



TWO Wetting Mechanism

- Water Vapor Diffusion:
Moves vapor from areas with higher vapor pressure to lower vapor pressure
- Air Transport:
Moves air, but carries moisture through the building thermal envelope



Vapor Retarders

➤ Vapor Retarders

- ASTM defines a vapor retarder as a material or construction that *adequately* impedes the transmission of water vapor under special conditions
- To some extent, all materials used in an assembly retard the passage of water vapor

➤ ASTM no longer uses the term vapor barrier

Air BARRIERS

- The effectiveness of a vapor retarder is of no consequence unless air movement through the thermal envelope is minimized
- ASTM defines an air barrier as a material or construction that is *designed and installed* to reduce air leakage
- Air permeance is measured by ASTM E 2178
 - Cfm/sq.ft. @ 1/2" w.c. = cm³/m² @ 125 Pa

AIR BARRIERS

- Air Barrier: sheet membrane or material that you can't blow through, usually installed near interior
- This is separate from the current-code mandated outside air barrier.
- Best Practice: install inside and outside Air Barrier
- The outside barrier must not also be a Vapor Retarder

SUMMARY

▶ Figure 1 Comparison of Air and Vapor Retarders



	VAPOR RETARDER	AIR BARRIER
Purpose	Control of water vapor flow via diffusion through building materials	Control of water vapor and heat flow <u>via moving air</u>
Requirements for continuity	Does not need to be completely continuous; can contain small gaps, holes, or unsealed laps without significant performance loss	<u>Must be continuous to be effective</u> ; even small discontinuities will significantly affect performance
Location	Typically <u>installed on 'warm-in-winter' side of insulation</u> (some exceptions may apply depending on climate); improper location can exacerbate condensation problems	Can be installed anywhere in the building enclosure when vapor-permeable, otherwise follow guidelines for vapor retarder TWO AB RECOMMENDED!
Structural support	No structural support necessary	Must be continuously supported and be capable of resisting forces from wind, mechanical pressurization, and stack effect
Detailing	Minimal detailing required to achieve design intent	<u>Careful detailing of transitions and changes in material are necessary</u> to support proper system installation and meet the air barrier system's design intent

From [Avoiding Problems in Aquatics Facilities: Atypical design for atypical buildings](#)
<http://www.constructionspecifier.com>

Natatorium

ASHRAE Handbook

Chapter Update



Natatorium Handbook Chapter

- Under ASHRAE TC 9.8 - Large Building Air-Conditioning Applications
- New Chapter officially approved
- Part of on-line Handbooks as of 2017
- Issued with 2019 Applications Handbook

Current Handbook Information

➤ **Places of Assembly - 2015 ASHRAE Handbook (HVAC Applications)**

- Load estimation (for water heating and dehumidification)
- Recommended pool water and Natatorium air conditions
- Ventilation Requirements (for human occupancy)
- Air distribution considerations
- Energy considerations and
- Envelope design considerations

Places of Assembly - 2015 ASHRAE Handbook HVAC Applications

...“Pool and spa areas should be maintained at a negative pressure of 0.05 to 0.15 in. of water relative to the outdoors and adjacent areas of the building to prevent chloramine odor migration. Active methods of pressure control may prove more effective than static balancing and may be necessary where outdoor air is used as a part of an active humidity control strategy. Openings from the pool to other areas should be minimized and controlled. Passageways should be equipped with doors with automatic closers and sweeps to inhibit migration of moisture and air.”...

Places of Assembly - 2015 ASHRAE Handbook HVAC Applications

“...Openings from the pool to other areas should be minimized and controlled. Passageways should be equipped with doors with automatic closers and sweeps to inhibit migration of moisture and air.” ...



What to do for your first Natatorium Project

- Understand Psychrometrics (Chapter 1 of Fundamentals Handbook)
 - Understand Chapters 15, 24, 25, 26 and 27 of the Fundamentals Handbook
 - Read (and understand) the ASHRAE Humidity Control Design Guide
 - Understand Chapter 4 and 5 of the Applications Handbook
 - Understand Chapters 23, 25 and 26 of the Systems and Equipment Handbook
- OR
- For Future You: Read the Natatorium Chapter in the Applications Handbook

Table of Contents - Summary

- 1. Introduction – Overview
- 2. Air Quality & Chlorine Chemistry
- 3. Building Envelope Design
- 4. Environmental Control
- 5. Load Calculation
- 6. Energy Consumption Considerations
- 7. Dehumidification methods and equipment.
- 8. Best Practice System Design
- 9. Operation and Maintenance
- 10. Applicable Standards, Codes and Reference Materials
- 11. References

Thank you

Rocky Mountain ASHRAE

March 2, 2016