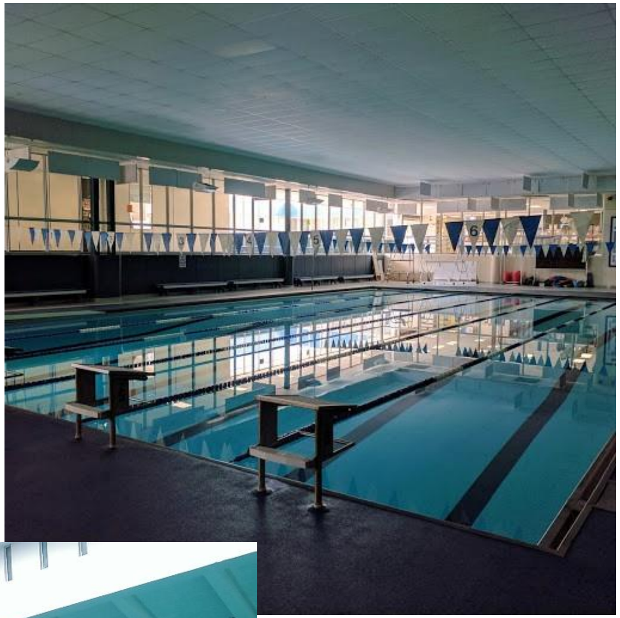
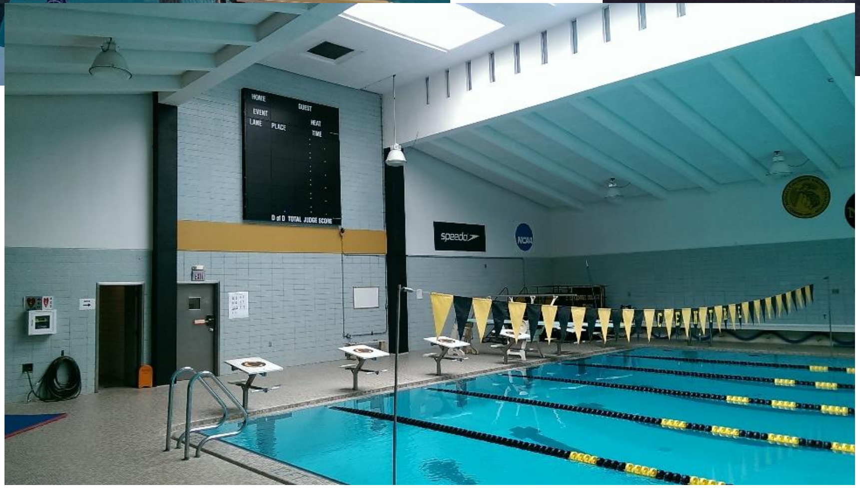
Indoor Pools
HVAC Overview





Est. 1978
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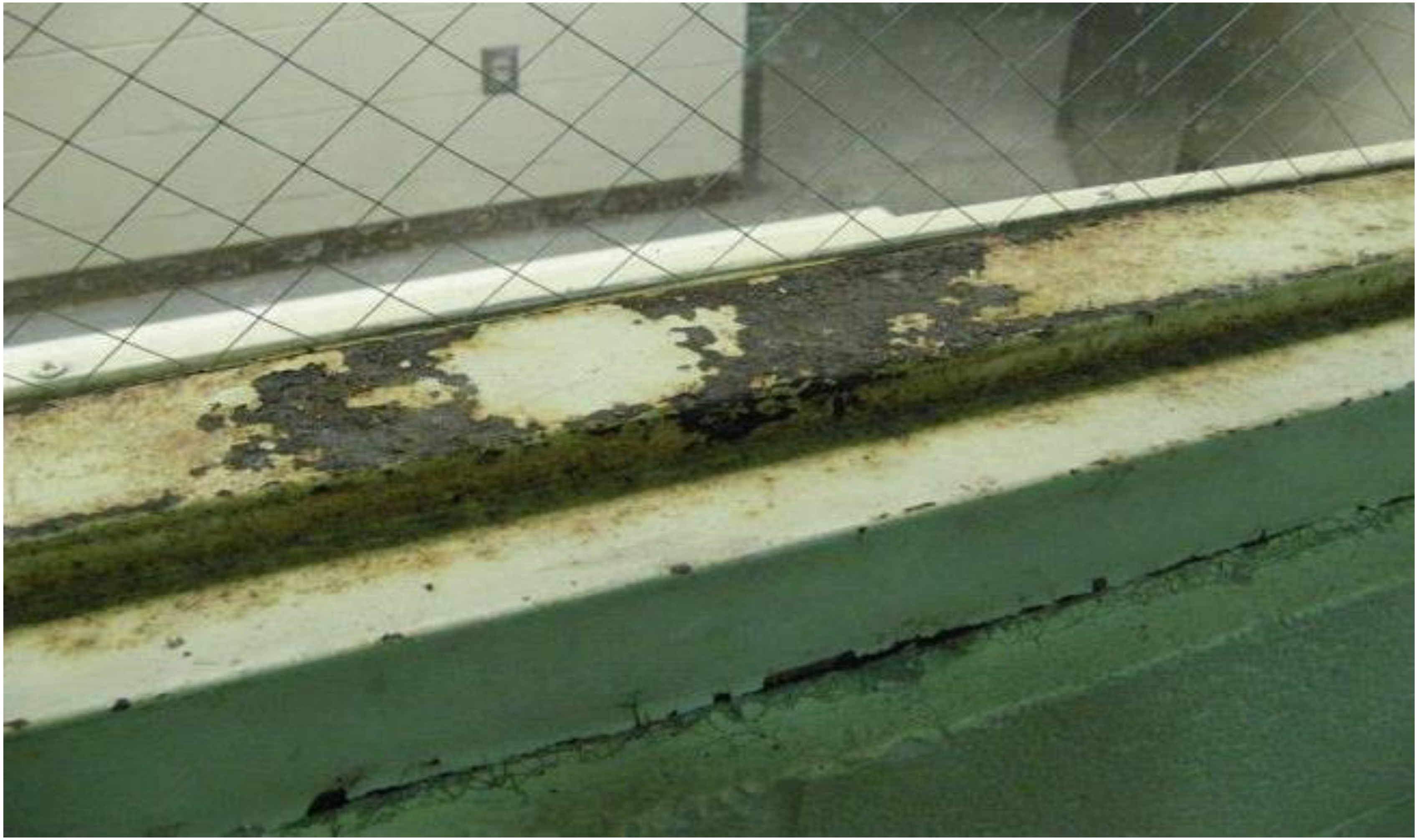
Agenda

- Importance of proper design
- HVAC design requirements
- Load calculation
- Airflow and source capture
- Checklist for a good design

Importance of Design

Importance of Design

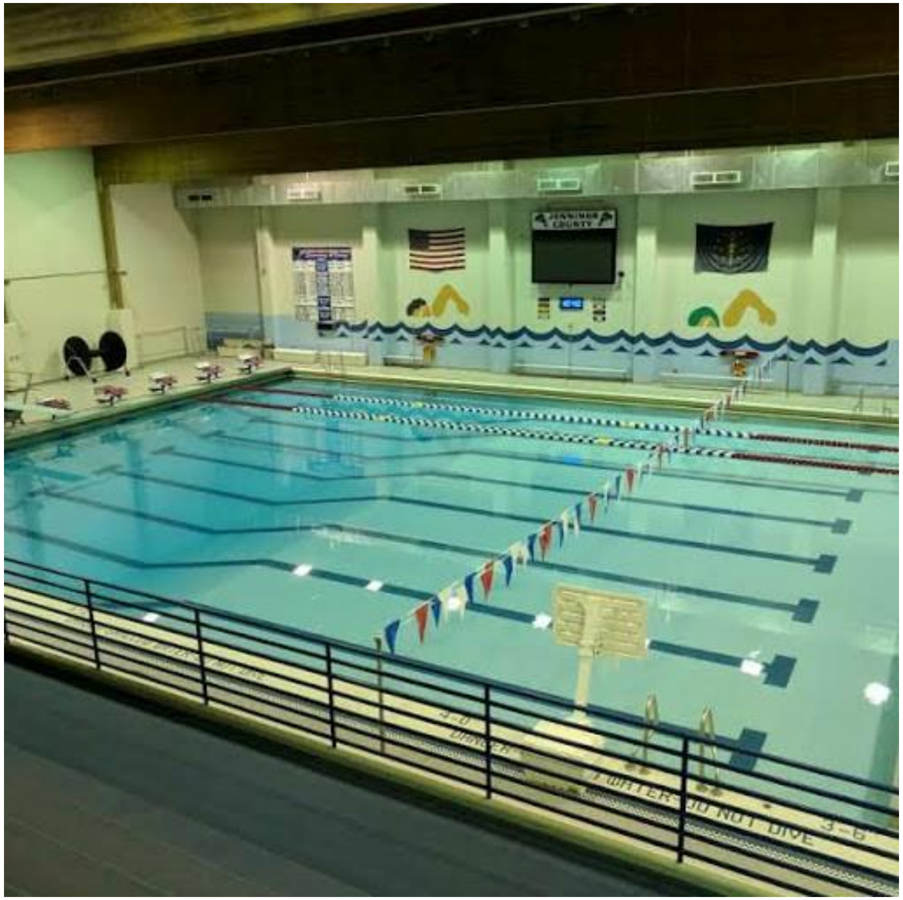


Importance of Design

Importance of Design

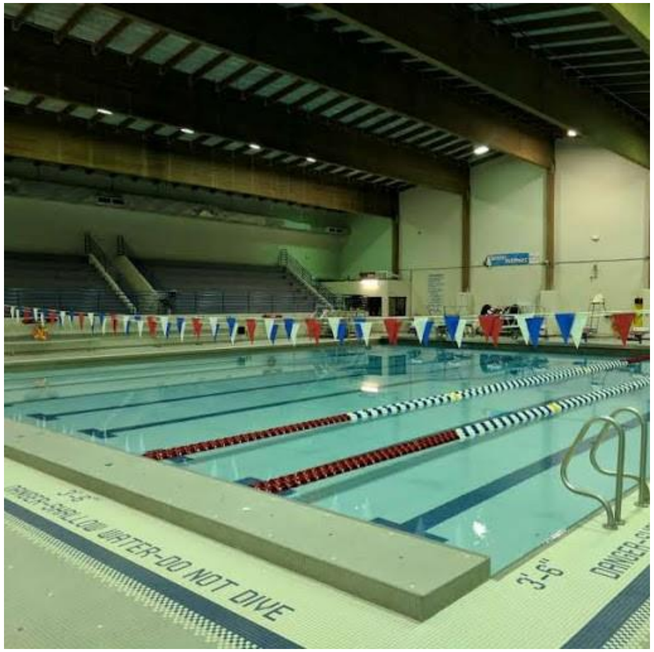
HVAC Design Requirements

- Humidity Control
- Temperature Control
- Air Turnover
- Ventilation Air
- Exhaust Air



Indoor Pool – Temp & Humidity

- Dehumidification is needed
  - Water Evaporates!
  - High humidity can contribute to Mold/Mildew & building decay
  - Occupant comfort impacted at >65%RH
- Pool Room Temperature
  - Impacts rate of evaporation
  - Balance swimmers need versus spectator need



Key Issue – Temperature & RH Levels

- Competing Objectives – Humidity
  - Reduce pool evaporation with higher RH
  - Preserve building with < 60%RH
  - Swimmer comfort affected at low RH
- Competing Objectives – Temperature
  - Swimmer comfort - high air temps
  - Non-Swimmer comfort – Lower air temps

What Causes Evaporation?

Key Issues

- Vapor Pressure drives evaporation
- ASHRAE recommends 50% - 60%RH
- ASHRAE recommendation:

"In order to minimize evaporation, the Air Temp should be maintained 2° to 4°F greater than water temp, up to a maximum Air Temp of 86°F."

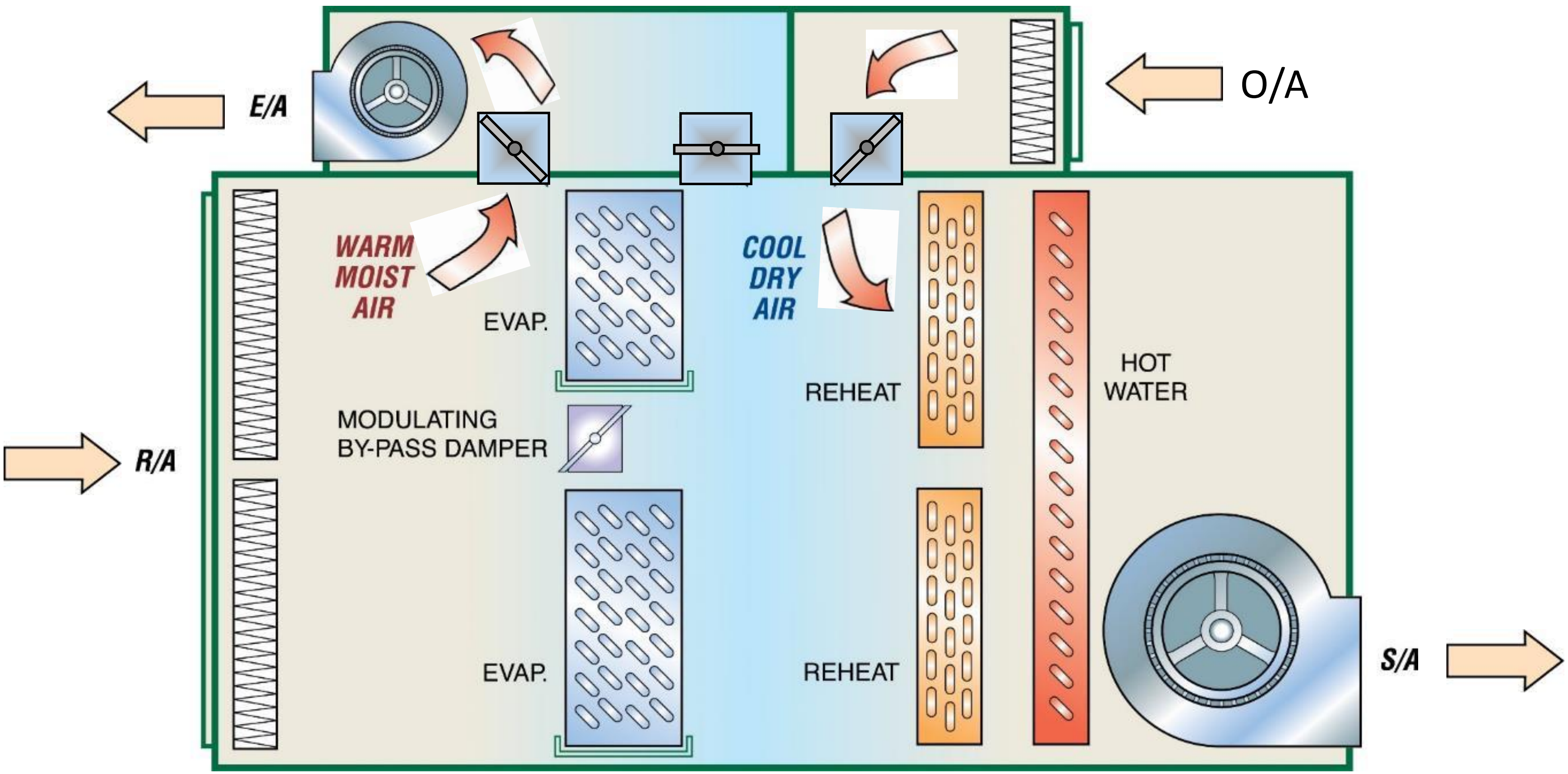
ASHRAE Handbook 2019: HVAC Applications, Chapter 6.2

Determining the Loads

- Pool evaporative losses
- Spectator load
- Ventilation air

Not Tons!
Pounds Per Hour

Specialty HVAC for Pool Rooms



Exhaust air energy recovery

ASHRAE Guidance

ASHRAE 2019 Handbook: HVAC Applications			
Table 2 Typical Natatorium Design Conditions			
Type of Pool	**Air Temperature, °F**	**Water Temperature, °F**	**Relative Humidity, %**
Recreational	75 to 85	75 to 85	50 to 60
Therapeutic	80 to 85	85 to 95	50 to 60
Competition	78 to 85	76 to 82	50 to 60
Diving	80 to 85	80 to 90	50 to 60
Elderly swimmers	84 to 90	85 to 90	50 to 60
Hotel	82 to 85	82 to 86	50 to 60
Whirlpool/spa	80 to 85	97 to 104	50 to 60

Air temperatures in public and institutional pools should be maintained 2°F to 4°F above the water temperature to reduce the evaporation rate and avoid chill effects on swimmers (<u>but not above the comfort threshold of 86°F</u>).

Evaporative Rate Formula

$$Wp = 0.1*A*(Pw - Pa)*Fa$$

Where:

Wp = evaporation of water in lb/hr

A = area of water surface

Pw = saturation pressure at water surface temperature in Hg

Pa = saturation pressure at room dew point temperature in Hg

Fa = activity factor

*Formula assumes air velocity is between <u>10 and 30 fpm</u> and latent heat of water of around 1,060 Btu/lb.

From ASHRAE 2019 Handbook: HVAC Applications Chapter 6.2

Activity Factors

Table 1 Typical Activity Factors for Various Pool Feature Types	
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)
ASHRAE 2019 Handbook: HVAC Applications Chapter 6.2 Table 1	

Pool Evaporative Load Example

- Wp = 0.1 x 3,750 (1.03298 - 0.60638 inHg) x 1

  = 160.0 lb/hr evaporation

  Where:

  - Pool surface = 3,750 sq ft
  - Space condition = 82°Fdb, 55% RH, 64.3°F dew point
  - Water = 80°F
  - Activity Factor = 1.0 Public Pool

Formula for Higher Air Movement Across Pool Surface

- Wp = A/Y x (pw – pa) x (95 + 0.425V)Fa

  Where:
  - Y = latent heat required to change water to vapor at surface water temperature
    - at 80°F it is 1048.1 Btu/lbm
  - Fa is the activity factor (1.0)
- If the air movement across the pool is changed from 30 fpm to 125 fpm, then the evaporation rate changes from 160.0 lbs/hr to 226.1 lbs/hr.

From ASHRAE 2019 Handbook: HVAC Applications Chapter 6.2

Impact of "*Minor*" Changes

- Water and air temperatures increased from 80ºF/82ºF to 84ºF/84ºF. Evaporation load = 201.3 lbs/hr

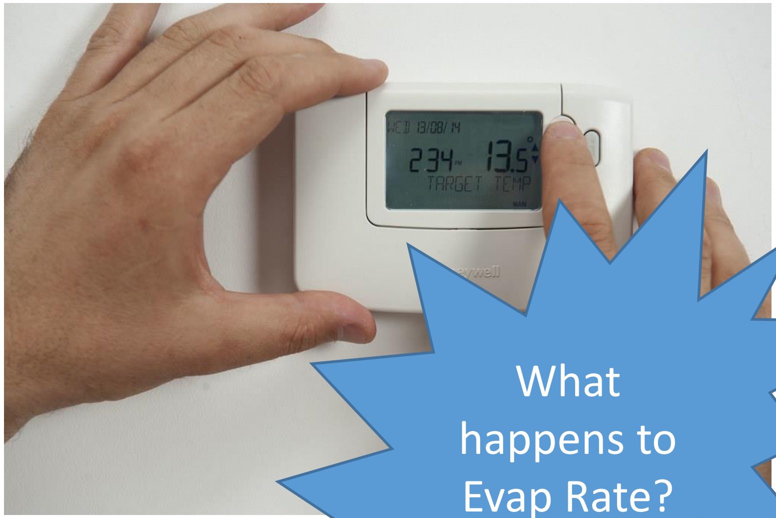
- Air flow increased to 125 fpm across pool. Evaporation rate increases 82.6 lbs/hr to 277.2 lbs/hr

- Addition of water toys and water features. Evaporation rate could increase to 451 lbs/hr

- Original design was 160.0 lbs/hr of evaporation

Unoccupied Mode

Quiz: Is it wise to Setback the Temp Setpoint in a Pool Room to save energy?



What happens to Evap Rate?

UnOccupied Mode will place the OA Damper in the Unoccupied position. This could be fully closed since no one will be in the pool room.

Unoccupied Mode

Quiz: What is the best way to save energy in a pool room during UnOccupied Mode?

Thermal Pool Cover

Image source: Spectrum Aquatics

Activity Type - Spectators

Activity Type	$Q_{Sen,Peo}$ [Btu/hr]	$Q_{Lat,Peo}$ [Btu/hr]
Seated at theater, matinee	225	105
Seated at theater, night	245	105
Seated, very light work	245	155
Moderately active office work	250	200
Standing light work, walking	250	200
Walking, standing	250	250
Sedentary work, eating	275	275
Light bench work	275	475
Moderate dancing	305	545
Walking 3 mph	375	625
Bowling alley	580	870
Heavy work	580	870
Heavy work, lifting	635	965
Athletics Gymnasium	710	109

Note: The table values are at 75°F room temperature. For 80°F the Qs goes down 20%, and Qt remains the same.

Adjusting People Load

Activity Type	$Q_{Sen,Peo}$ [Btu/hr]	$Q_{Lat,Peo}$ [Btu/hr]
Standing light work, walking	250	200

In a 75°F DB Room

What if the room is 82°F DB?

1. **Qt = 250+ 200 = 450 Btu/hr**
2. **Qs = 250 * (1 – (0.04 *(82-75))) = 180 Btu/hr**
3. **QL = 450 – 180 = 270 Btu/hr**

2017 ASHRAE Handbook – Fundamentals, Chapter 18 Table 1:Tabulated values are based on 75°F room dry-bulb temperature. For 80°F room dry bulb, total heat remains the same, but sensible heat values should be decreased by approximately 20%, and latent heat values increased accordingly.

Spectators Add a Latent Load

- Example
  - 400 spectators x 270 Btu/spectator or 108,000 Btu per hour of moisture being introduced into the space.
  - In this example we would have an additional 103.2 pounds of moisture per hour. (The spectator latent load divided by the latent heat of water at 82°F)

Hotel Pools – Spectators?

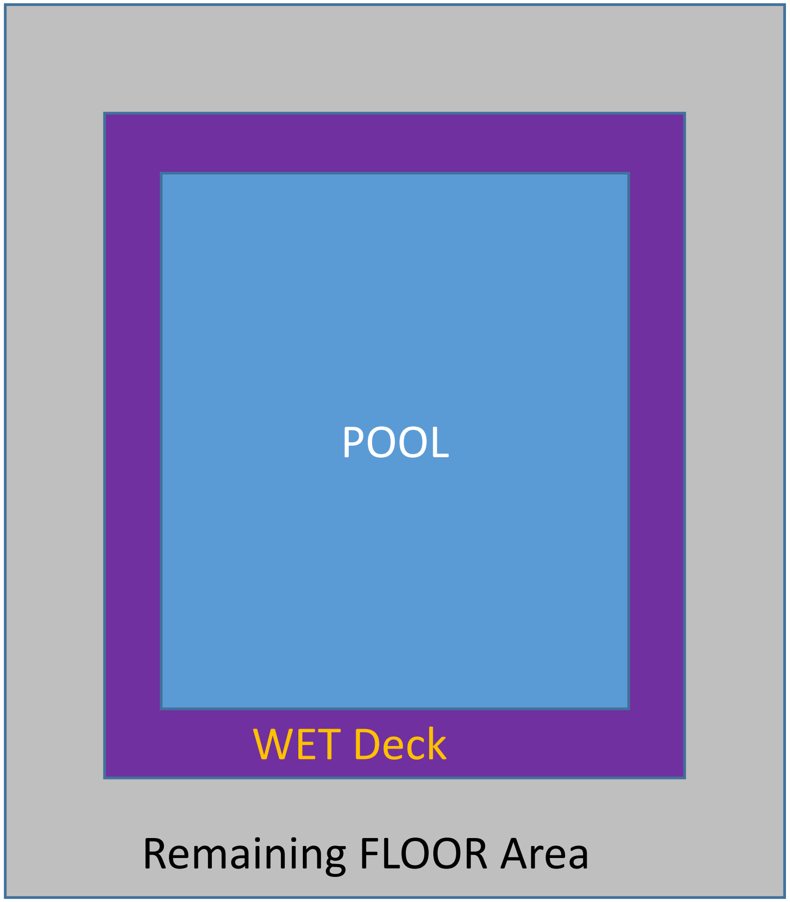
Do chairs in a Hotel pool constitute Spectators?

Code Ventilation

- ***Pool & wet deck***
  - Pool and wet deck area in ft^2 x 0.48 cfm/ ft^2
- ***Remaining floor area***
  - Room area – pool and wet deck area – bleacher area (ft^2) x 0.06 cfm/ft^2
- ***Spectator/Bleacher***
  - Spectator area (ft^2) x 0.06 cfm/ft^2 + (# of people x 7.5 cfm)

ASHRAE 62.1 – 2016 Ventilation for Acceptable Indoor Air Quality
Table 6.2.2.1 Minimum Ventilation Rates in Breathing Zone

Wet Deck Defined



ASHRAE: Wet Deck is defined as the surface area of pool deck that is wetted during a normal occupied condition.

Condensation Control

Surface Temperature Calculation

- Calculating the surface temperature of a structural component

$$Ts = Ti - (K \times (1/R) \times (Ti - To))$$

- Where:
  - Ts = Surface temperature
  - Ti = Indoor space temperature
  - To = Outdoor temperature
  - R = Total R-value of the structural component
  - K = Indoor air film coefficient =
    - 0.68 for vertical surface
    - 0.95 for horizontal roof or skylight
    - 0.76 for 45° roof or skylight

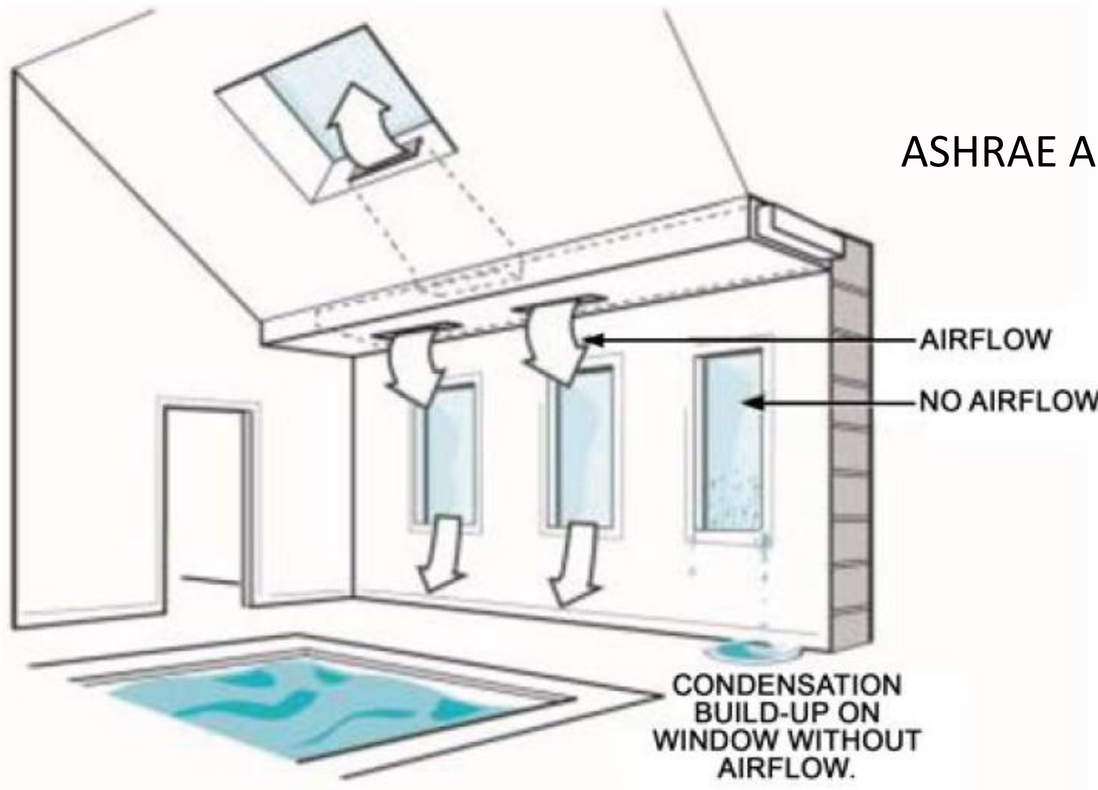
Dew point plus 5 degrees (safety factor)

Airflow Design – Critical Principles

- Keep all surfaces > dew point
- Provide 3 to 5 cfm/sq ft of air distribution on all cold surfaces
- Air Turnover
  - 4 to 6 air changes/hour (ACH) for pool room
  - 6 to 8 ACH for spectator area
- Negative Pressure
  - ASHRAE 2019 Handbook: HVAC Applications recommends 0.05” – 0.15” negative pressure

Focus on Windows

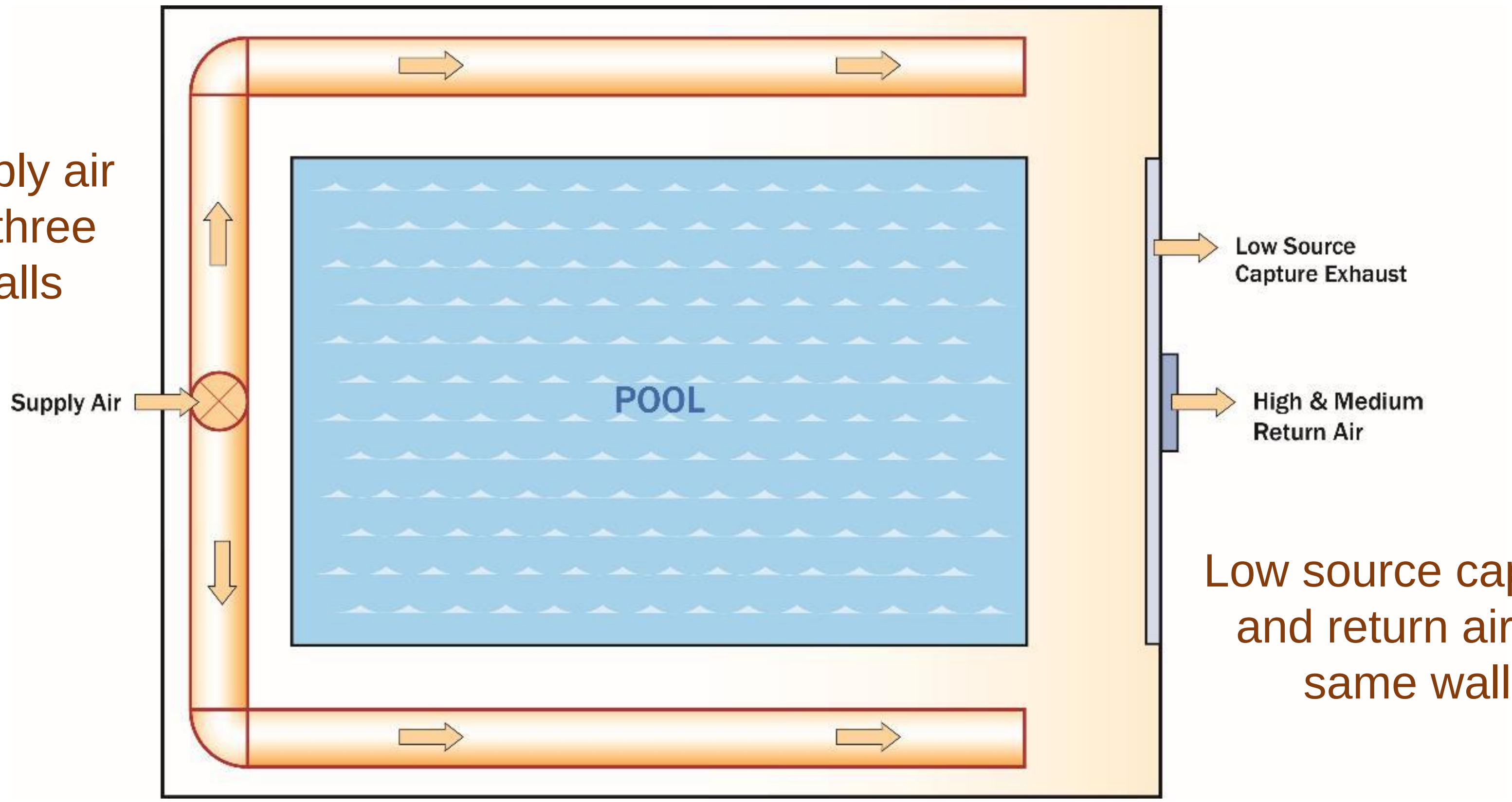
ASHRAE Applications -2019, Chapter 6



Supply Air Blanketing of Condensation-Prone Areas

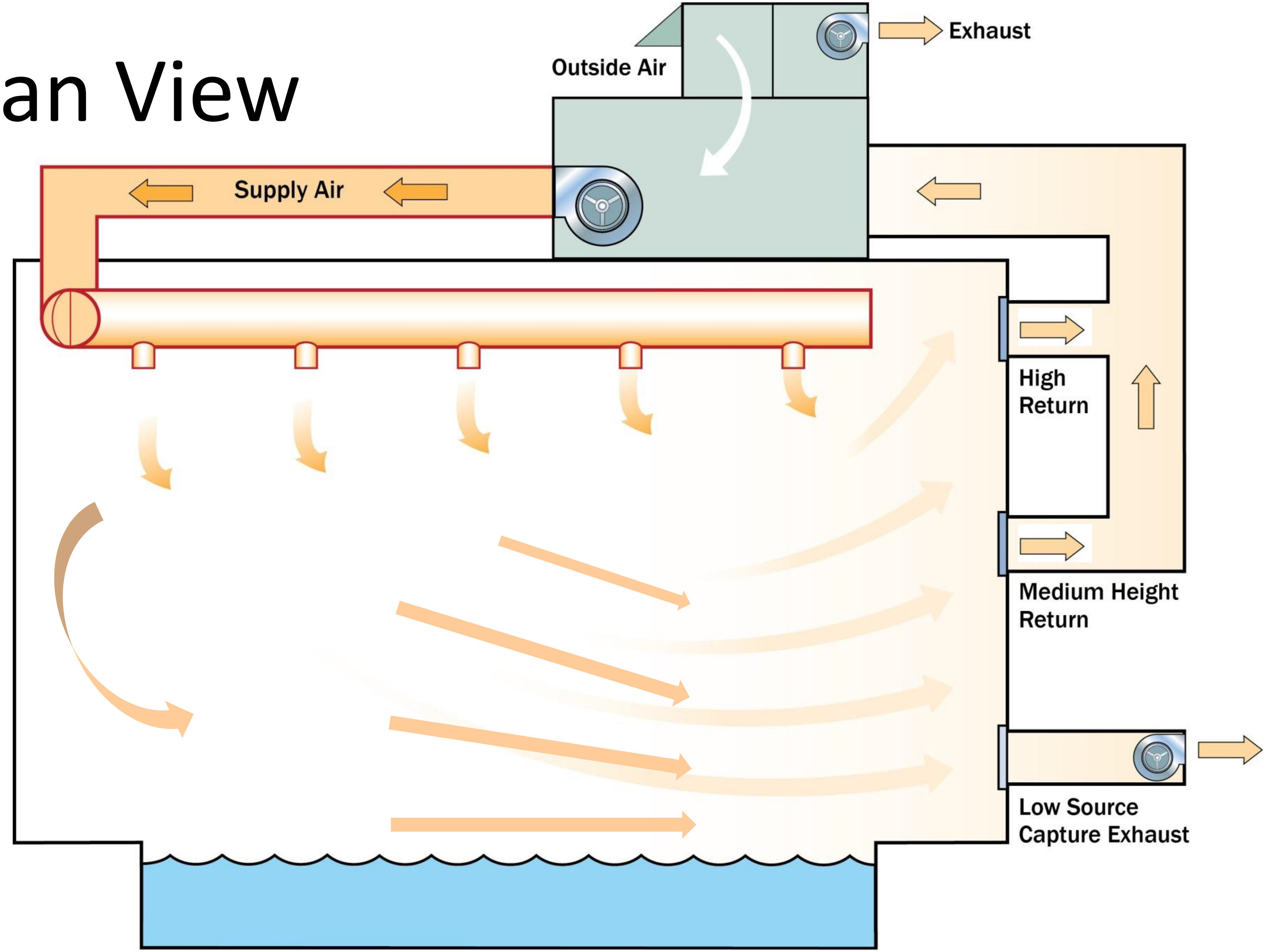
Top View

Supply air on three walls



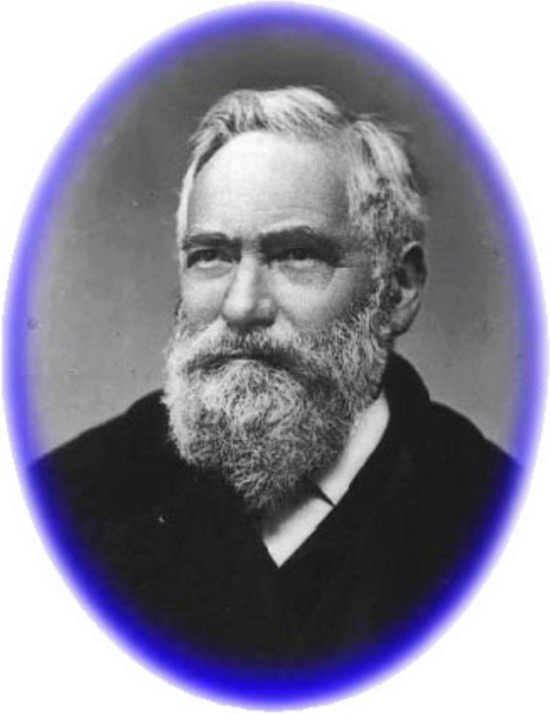
Low source capture and return air on same wall

Plan View


Outside Air
Exhaust
Supply Air
High
Return
Medium Height
Return
Low Source
Capture Exhaust

Famous Quote

“If there is a pile of manure in a space. Do not try to remove the odor by ventilation. Remove the pile of manure”



Max von Pettenkofer
Pioneer of Hygiene
1818-1901

What is our pile of manure in natatoriums?

Trichloramines

Source Capture Exhaust

Capture and remove unwanted odors at their source …..

Purdue University Study
You cannot spell Pool without P

Ernest R. Blatchley III, Ph.D., P.E., BCEE, F.ASCE

- Urine + Pool Water = Cyanogen chloride + Trichlormine

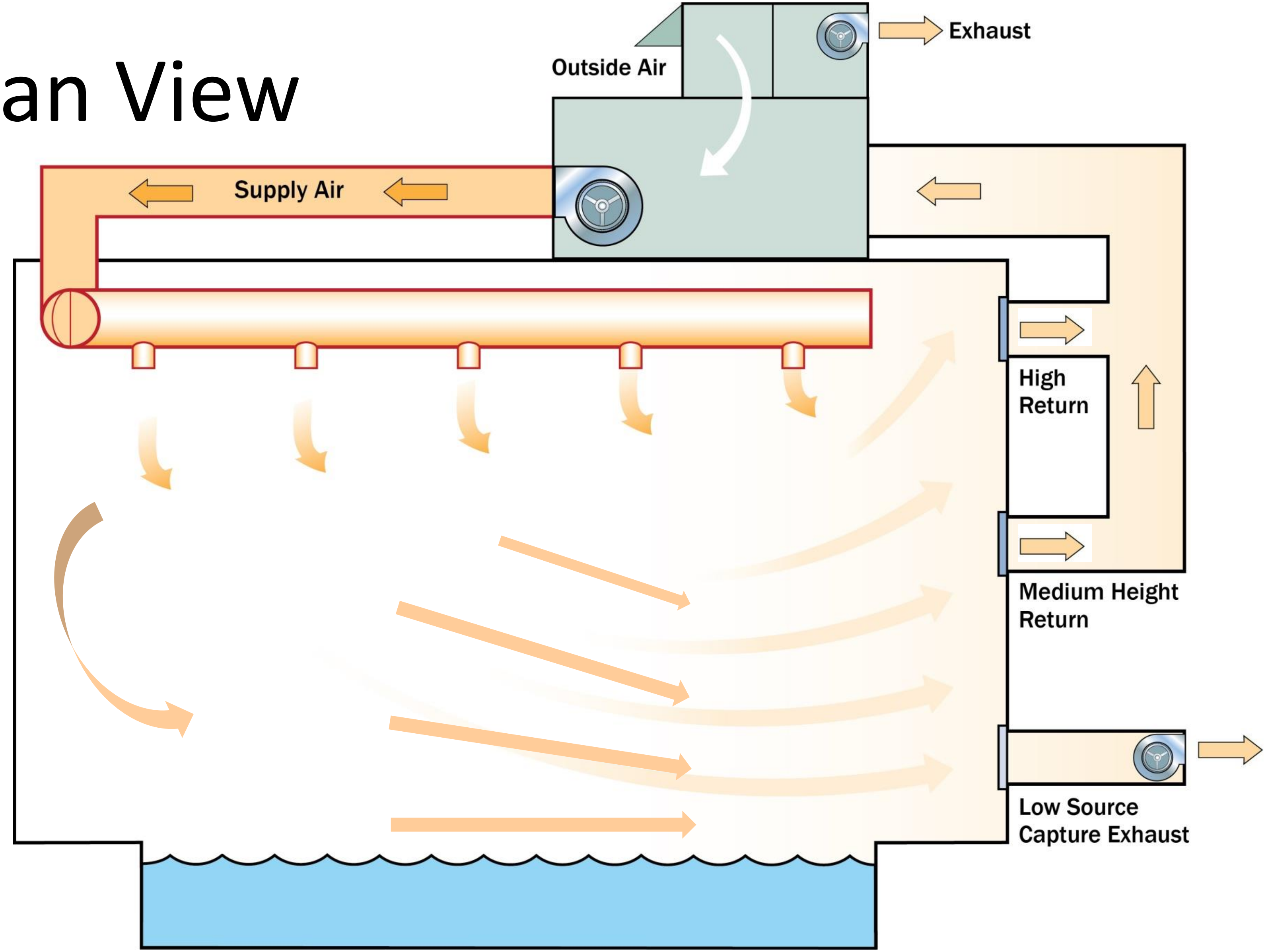
- Uric acid accounted for 24% to 68% (depending on temperature, water pH and chlorine condition) of the byproduct cyanogen chloride in pool water samples

Disinfection By-Products

Density of Air ~ 0.073 lb/ft^3

- Nitrogen trichloride
  - 102.4 lb/ft3
  - Severe eye and respiratory irritation
- Cyanogen chloride
  - 74.3 lb/ft3
  - Highly toxic blood agent that interferes with the body's ability to use oxygen
- Trihalomethane
  - 74.3 lb/ft3
  - Mainly four separate chemicals that are thought to be carcinogens (rectal, bladder and breast) and cause damage to the liver and brain
- Hydrogen cyanide
  - 42.9 lb/ft3
  - Extreme poison

Plan View



Outside Air
Exhaust
Supply Air
High
Return
Medium Height
Return
Low Source
Capture Exhaust

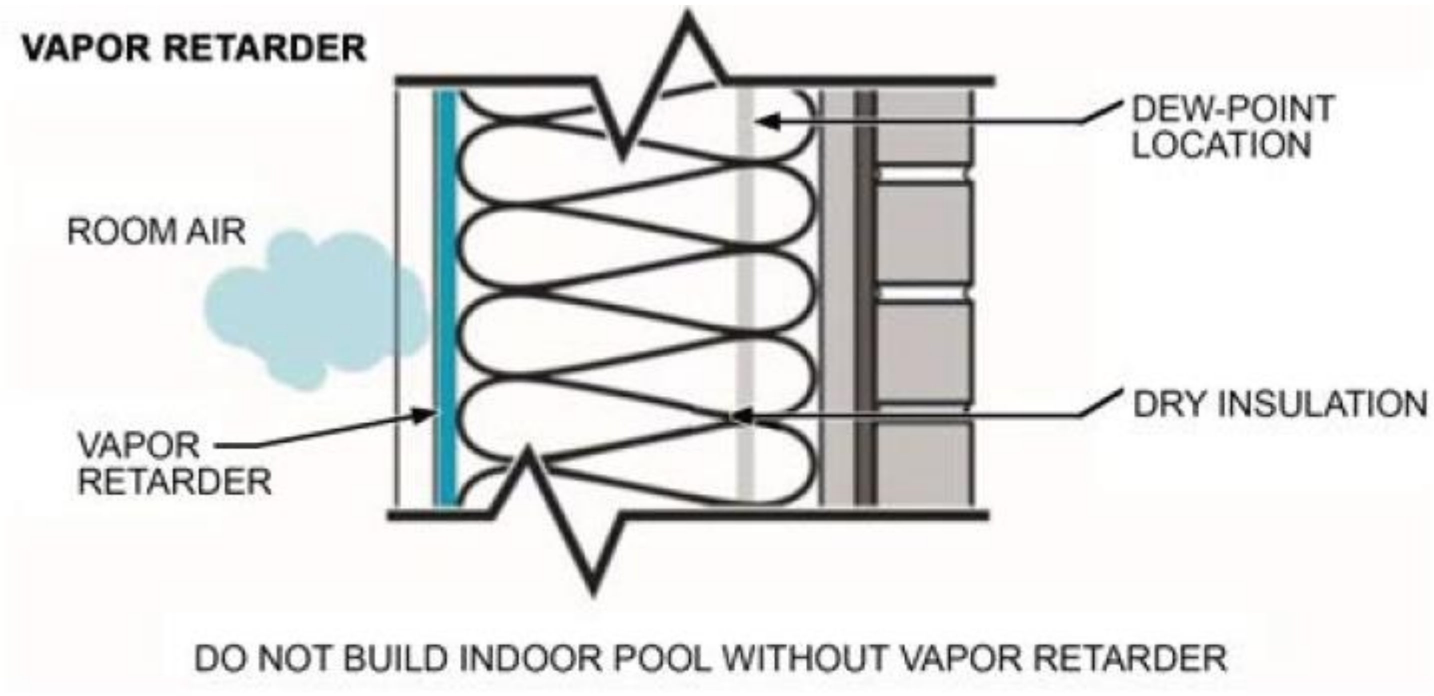
Retrofit of deck bench exhaust


GUARD
NO DIVING

Pool Room Construction

- Vapor barrier improves building integrity
- Impossible to keep the entire wall cavity above dew point.
- Placement of vapor barrier is critical!
  - Where should the vapor barrier be in a pool room?

Vapor Barrier (ASHRAE 2019)



Vapor Retarder Location for Indoor Pool

Checklist of a Good Design

- Define air & water temps
- Calculate moisture loads
- Provide at least 4-6 ACH in pool area
    - 6-8 ACH in spectator area
- Determine surface temps
    - keep all surfaces > space dew point
- Provide 3-5 cfm/ft^2 of air on all glass and cold surfaces

Checklist of a Good Design
(Continued)

- Maintain negative pressure in pool room
- Install a Vapor barrier ***ON INSIDE***!
- Aux Heat sized for Purge Mode
- Source capture exhaust…. ***Great for air quality!***
- Commission the total system

Checklist of a Good Design
(Continued)

- Equipment Schedule
  - Lbs/hr of moisture removal
  - Unit efficiency in MRE*
  - CFM range of outside air & supply air
  - Auxiliary heat requirement
  - Highlight pool water condenser on piping diagram

***MRE (moisture removal efficiency) is a dehumidifier term, while EER is an air conditioning term.**

Performance Ratings – AHRI 910

ANSI/AHRI Standard 910 (I-P)

2014 Standard for

Performance Rating of Indoor Pool Dehumidifiers

Approved American National Standard

Approved by ANSI on September 27, 2016

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Purge Mode

- Purge is used to ventilate the room after a superchlorination of the pool water. When does this occur?

Video

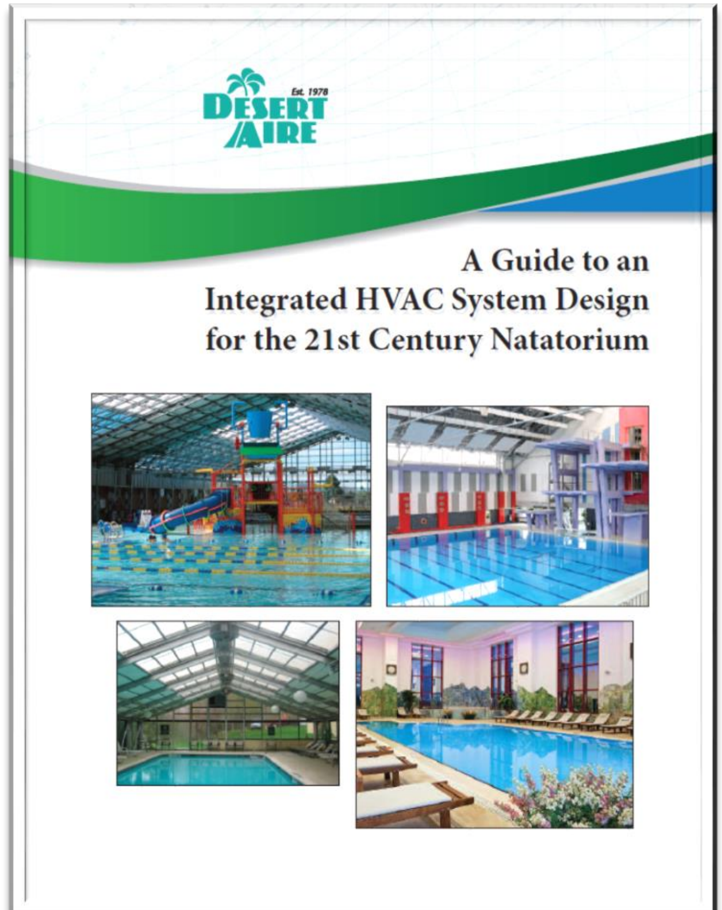
Key Dehumidifier Features

- High moisture removal effectiveness
- Energy recovery of pool evaporation
  - To the pool room air
  - To the pool water
- Reclaim of exhaust air’s high energy content
  - Reduce air heating costs
  - Reduce pool heating costs

21st Century Pool Design Guide

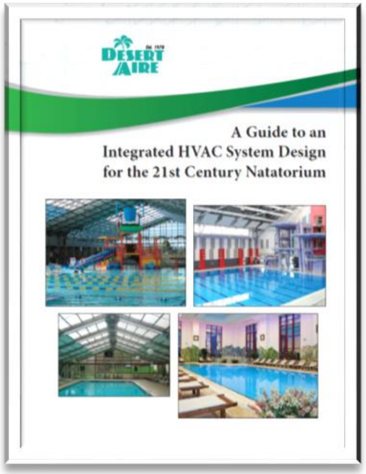
- Who is Guide For….
  - Architects
  - Engineers
  - Owners

Reviews the latest design factors for indoor aquatic facilities



21st Century Pool Design Guide

- Heating, cooling, and moisture load determination
- Condensation and building integrity
- Swimmers health concerns
- Proper airflow design
- Dehumidification equipment design
- Commissioning



Questions?

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Pool Dehumidification
DOAS

Optimizing solutions through superior dehumidification technology℠