Indoor Pools

HVAC Overview
Agenda

• Importance of proper design
• HVAC design requirements
• Load calculation
• Airflow and source capture
• Checklist for a good design
Importance of Design
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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
<table>
<thead>
<tr>
<th>Type of Pool</th>
<th>Air Temperature, °F</th>
<th>Water Temperature, °F</th>
<th>Relative Humidity, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recreational</td>
<td>75 to 85</td>
<td>75 to 85</td>
<td>50 to 60</td>
</tr>
<tr>
<td>Therapeutic</td>
<td>80 to 85</td>
<td>85 to 95</td>
<td>50 to 60</td>
</tr>
<tr>
<td>Competition</td>
<td>78 to 85</td>
<td>76 to 82</td>
<td>50 to 60</td>
</tr>
<tr>
<td>Diving</td>
<td>80 to 85</td>
<td>80 to 90</td>
<td>50 to 60</td>
</tr>
<tr>
<td>Elderly swimmers</td>
<td>84 to 90</td>
<td>85 to 90</td>
<td>50 to 60</td>
</tr>
<tr>
<td>Hotel</td>
<td>82 to 85</td>
<td>82 to 86</td>
<td>50 to 60</td>
</tr>
<tr>
<td>Whirlpool/spa</td>
<td>80 to 85</td>
<td>97 to 104</td>
<td>50 to 60</td>
</tr>
</tbody>
</table>

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 (but not above the comfort threshold of 86°F).
Evaporative Rate Formula

\[ W_p = 0.1 \times A \times (P_w - P_a) \times F_a \]

Where:
- \( W_p \): evaporation of water in lb/hr
- \( A \): area of water surface
- \( P_w \): saturation pressure at water surface temperature in Hg
- \( P_a \): saturation pressure at room dew point temperature in Hg
- \( F_a \): activity factor

*Formula assumes air velocity is between 10 and 30 fpm 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

<table>
<thead>
<tr>
<th>Type of Pool</th>
<th>Typical Activity Factor ($F_a$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline (pool unoccupied)</td>
<td>0.5</td>
</tr>
<tr>
<td>Residential pool</td>
<td>0.5</td>
</tr>
<tr>
<td>Condominium</td>
<td>0.65</td>
</tr>
<tr>
<td>Therapy</td>
<td>0.65</td>
</tr>
<tr>
<td>Hotel</td>
<td>0.8</td>
</tr>
<tr>
<td>Public, schools</td>
<td>1.0</td>
</tr>
<tr>
<td>Whirlpools, spas</td>
<td>1.0</td>
</tr>
<tr>
<td>Wavepools, water slides</td>
<td>1.5 (minimum)</td>
</tr>
</tbody>
</table>

*ASHRAE 2019 Handbook: HVAC Applications Chapter 6.2 Table 1*
Pool Evaporative Load Example

\[ W_p = 0.1 \times 3,750 \times (1.03298 - 0.60638 \text{ inHg}) \times 1 \]
\[ = 160.0 \text{ lb/hr evaporation} \]

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

• \( W_p = \frac{A}{Y} \times (p_w - p_a) \times (95 + 0.425V)F_a \)

Where:

• \( Y \) = latent heat required to change water to vapor at surface water temperature
  • at 80°F it is 1048.1 Btu/lbm
  • \( F_a \) 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 80°F/82°F to 84°F/84°F. 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?

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

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

**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

<table>
<thead>
<tr>
<th>Activity Type</th>
<th>$Q_{\text{Sen,Peo}}$</th>
<th>$Q_{\text{Lat,Peo}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing light work, walking</td>
<td>250</td>
<td>200</td>
</tr>
</tbody>
</table>

In a 75°F DB Room

What if the room is 82°F DB?

1. $Q_t = 250 + 200 = 450 \text{ Btu/hr}$
2. $Q_s = 250 \times (1 - (0.04 \times (82-75))) = 180 \text{ Btu/hr}$
3. $Q_L = 450 - 180 = 270 \text{ Btu/hr}$

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

\[ Ts = Ti - (K \times \frac{1}{R}) \times (Ti - To) \]

• 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

Supply Air Blanketing of Condensation-Prone Areas

ASHRAE Applications - 2019, Chapter 6
Top View

Supply air on three walls

Low source capture and return air on same wall
Plan View
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”

What is our pile of manure in natatoriums?

Trichloramines

Max von Pettenkofer
Pioneer of Hygiene
1818-1901
Source Capture Exhaust

Capture and remove unwanted odors at their source ….
Purdue University Study
You cannot spell Pool without P

- 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

- 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

Density of Air ~ 0.073 lb/ft³
Plan View
Retrofit of deck bench exhaust
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/ft² 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

2014 Standard for
Performance Rating
of Indoor Pool Dehumidifiers
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?

Pool Dehumidification
DOAS

Optimizing solutions through superior dehumidification technology℠