Learning Objectives

At the end of the presentation you should have a broader understanding of Swimming Pool Ventilation including:

1. Issues Attributed to Swimming Pool Halls
2. Legislation and Design Guides
3. Studies into Humidity/Evaporation
4. How to Calculate a Ventilation Rate
5. Air Flow Calculation (Working Example)
6. Energy Efficiency and Running Costs
7. Energy Saving Potential
8. System Design Considerations
9. Summary
Issues Attributed to Swimming Pools
Issues associated with indoor Swimming Pool environments

- Both water & air must be heated resulting in high energy usage & operational costs
- Evaporation must be controlled to prevent aggressive condensation from pool causing severe damage to building fabric
- Pool water must be continuously disinfected with chlorine, which leads to potentially harmful disinfectant by-products (DBPs)
- DBP’s in both the water & air cause poor experience for swimmers & potential health effects to both swimmers & pool staff alike
- High maintenance, particularly on the water side
- Storage & handling of hazardous chlorine on site
Issues Attributed to Swimming Pools

Corrosion & building fabric damage - All three elements are present for accelerated corrosion in a pool hall.

Moisture | Warmth | Chlorine

Water containing DBP’s is constantly evaporating from the warm pool water & is aggressive to the building fabric if allowed to condense on the fabric.
The Environmental Cost

Leisure Centres are one of the most energy intensive buildings to operate.

According to the Office of National Statistics, in 2012 the UK sports sector spent ~ £700m on energy.

Approximately 70% of these energy costs can be directly attributed to the swimming pool hall and adjoining changing areas.
Issues Attributed to Swimming Pools

Two thirds of energy is accounted for by Space heating and fans & pumps.

£470m a year
Increasing pool hall temperatures

Pool types & usage has changed over recent years with:

- An increase in leisure style pools
- Increase in the use of chlorine based disinfection
- Higher pool water temperatures. Typically these have increased by 1°C over the past 10 years:

<table>
<thead>
<tr>
<th>Pool Type</th>
<th>Original Temperature</th>
<th>Current Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competition Pools</td>
<td>27°C</td>
<td>28°C</td>
</tr>
<tr>
<td>Conventional Pools</td>
<td>28°C</td>
<td>29°C</td>
</tr>
<tr>
<td>Leisure Pools</td>
<td>29°C</td>
<td>30°C</td>
</tr>
<tr>
<td>Learner Pools</td>
<td>29°C</td>
<td>31°C</td>
</tr>
<tr>
<td>Hydrotherapy Pools</td>
<td>35°C</td>
<td>36°C</td>
</tr>
</tbody>
</table>
What does a swimming pool ventilation system need to do?

A swimming pool ventilation system needs to be designed to:

- Heat the air to maintain the pool hall temperature
- Provide sufficient fresh air for swimmers & staff
- Control the relative humidity to prevent aggressive condensate getting on & into the building fabric where it will cause damage
- Extract, treat or dilute DBP’s
Legislation and Design Guides
Legislation and Design Guides

There are numerous methods around to design pool ventilation systems.

But other than the building regulations, there is no specific legislation.

There are however numerous different design guides for pools available.............
Legislation and Design Guides

Sport England
Swimming Pools Updated Guidance for 2013

HSE Managing Health & Safety in Swimming Pools.
Published 2003 (Revised 2013)

Pool Water Treatment Advisory Group
Treatment and Quality Standard for Pools and Spas

Building Regulations Approved Document F
Table 6.3 refers to CIBSE Guide B2005

CIBSE Guide B2005
Section 2.3.21 (Table 2.27) - Sports Centre Ventilation Guide
Varying Design information

These offer a wide variety of somewhat differing advice;

- Ventilation rate of 4 to 10 air changes per hour – *a large difference*
- 10 l/s per the total floor area (m²) – *somewhat nonsensical?*
- 12 l/s of fresh air per person – *Correct, but likely to be a secondary factor*
- Minimum 30% fresh air if recirculation is used – *an arbitrary figure*
- Provide a slight negative pressure in the pool hall to prevent moisture ingress and permeation - *correct*
- Control over humidity and temperature - *correct*
- Air temperature to be ~1°C above pool water temperature – generally *correct*
- Pool ventilation system should be operational 24/7 - *correct*
- Air temperatures should generally not exceed 31°C with a relative humidity of between 55% and 65% - *correct*
Humidity and Evaporation & how to Calculate a Ventilation Rate
Humidity and Evaporation

How can we control humidity in a pool hall?

One method is to regulate the difference in absolute moisture content between outside air (fresh air) and the warm humid conditions found in a pool environment (pool air).

To do this we can use fresh air as it will _always_ be drier than pool air.

These properties can be illustrated on a Psychrometric chart...
Winter Condition: -4°C @ 100% RH
Summer Condition: 28°C @ 50% RH
Pool Hall Condition: 30°C @ 60% RH
How to Calculate Ventilation Rate

As mentioned, there are various methods. But the most reliable in our experience is the Biasin & Krumme formula.

Firstly we have to calculate the evaporation rate in kg/hr;
Evaporation Rate (m²) = 0.118 + (0.01995 x (40 - (42.40 x 0.6)))

Where;
0.118 is an empirical factor applied for the random shape of water
0.01995 is a factor applied relating to heat convection
40.0 is the vapour pressure of pool water at 29°C
42.4 is the vapour pressure of saturated air at 29°C
0.6 = 60%RH

So the above equation can be broken down as follows;
42.4 x 0.6 = 25.44
40 - 25.44 = 14.56
0.01995 x 14.56 = 0.2905
0.118 + 0.2905 = 0.4085 kg/hr/m²

continued/2
How to Calculate Ventilation Rate

Next calculate the Total Swimming Pool Evaporation Rate = E x U x A

Where:
E = Evaporation Rate
U = Activity Factor (detailed on the following page)
A = Area of swimming pool in m² (in this case we will use a pool with an area of 300m²)

So; E 0.4085 kg/hr/m² x U 0.4823 activity factor x A 300m² = 59.1 kg/hr
Activity factors are applied to the formula as increased disturbance of the water surface due to activity increases the rate of evaporation.

Typical factors are;

0.7947  Activated water such as a Jacuzzi, Flume, Wave Pool etc.

0.4823  Large public swimming pool

0.4329  School/Private swimming pools

0.2673  Unoccupied
How to Calculate Ventilation Rate

Having established the evaporation rate we can now calculate air volume:

\[ V = \frac{W \times 1000}{(X_i - X_o) \times 1.175 \times 3600} \]

- \( V \) = Ventilation rate (m\(^3\)/s)
- \( W \) = Evaporation rate from pool (kg/hr)
- \( X_i \) = Moisture content at design condition (g/kg of air at 30/60%RH)
- \( X_o \) = Moisture content of ambient air (g/kg of air at 28/50%RH)
- 1.175 is a constant for air density (kg/m\(^3\))
- 3600 to convert m\(^3\)/hr to m\(^3\)/s
Unusual Factors

Careful consideration should be given to unusual or additional factors such as:

Â If very large numbers of spectators are present
Â Very large water attractions in leisure pools such as flumes, slides & wave pools found in Center Parcs, Butlins, etc
Â Large or unusual building’s such as this old Victorian swimming baths
Calculating Air Flow
(Working Example)
The following example has been based on a typical modern swimming pool:

Internal pool hall volume of 2500 m³
Pool is 25m long with 8 lanes
Pool water temperature is 29°C
Winter temperature: -4°C @ 100% RH
Summer design condition: 28°C @ 50% RH
No pool cover
No additional activated water attractions
Calculating Airflow
(Working Example)

First calculate the maximum evaporation rate (kg/hr) when the pool is **occupied**.

**Evaporation Rate (W/m²) =**

\[ 0.118 + (0.01995 \times (40 - (42.40 \times 0.6))) \]

So; \(0.4085 \text{ kg/hr/m}² \times 0.4823 \text{ activity factor} \times 300\text{m}² = 59.1 \text{ kg/hr (maximum evaporation rate)}\)

40.0 is the vapour pressure of pool water at 29°C
42.4 is the vapour pressure of saturated air at 29°C
300 is the surface area of the pool
Calculating Airflow
(Working Example)

Then calculate the minimum evaporation rate (kg/hr) when the pool is unoccupied.

\[ W = (0.059 + 0.0105 \times 0.2673 \times (40.0 - 42.4 \times 0.6)) \times 300 \]

So the above equation can be broken down as follows;
42.4 \times 0.6 = 25.44
40 - 25.44 = 14.56
0.0105 \times 14.56 = 0.15288
0.059 + 0.15288 = 0.21188 \text{ kg/hr/m}^2 \times 300 \text{m}^2 = 63.56 \times 0.2673 \text{ calm activity factor}
= 17 \text{ kg/hr}

\[ W = 17 \text{ kg/hr (minimum evaporation rate)} \]

Pool water is assumed to be ‘calm’ therefore activity factor is 0.2673
Vapour pressure and relative humidity of pool water & air at 29°C is as when the pool is occupied.
0.059 and 0.0105 are reduced constants to take into account undisturbed water.
Calculating Airflow
(Working Example)

Then you can calculate the maximum and minimum air volume flow rates (m³/s) for when the pool is occupied and unoccupied.

\[ V = \frac{59.1 \times 1000}{(16.2 - 12.0) \times 1.175 \times 3600} \]

\[ V = 3.33 \text{ m}^3/\text{s} \text{ (maximum or occupied)} \]

\[ V = \frac{17 \times 1000}{(16.2 - 12.0) \times 1.175 \times 3600} \]

\[ V = 0.96 \text{ m}^3/\text{s} \text{ (minimum or unoccupied)} \]
Calculating Airflow
(Working Example)

Compare this calculation to other rule of thumb methods:

<table>
<thead>
<tr>
<th>Method</th>
<th>Flow Rate (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biasin &amp; Krumme</td>
<td>3.33 m³/s</td>
</tr>
<tr>
<td>4 AC/Hr</td>
<td>2.77 m³/s</td>
</tr>
<tr>
<td>10 l/s of total pool hall area</td>
<td>4.64 m³/s</td>
</tr>
<tr>
<td>10 AC/Hr</td>
<td>6.94 m³/s</td>
</tr>
<tr>
<td>15 l/s/m² of wetted area</td>
<td>4.5 m³/s</td>
</tr>
</tbody>
</table>
Calculating Airflow
(Working Example)

Cross-referencing this against a minimum fresh air requirement based on 12 l/s per person:

Å If you assume an occupancy of 50 people in the pool hall this would equate to 600 l/s or 0.6 m³/s.

Å If the maximum calculated air volume is 3.33 m³/s, 0.6 m³/s would equate less than 20% of fresh air.
Energy Efficiency & Running Costs
Energy Efficiency and Running Costs

What is the optimum heat recovery solution for a swimming pool hall?

- Run Around Coil
  - 45% Efficient
  - Too Low

- Thermal Wheel
  - 75% Efficient

- Plate Heat Exchanger
  - 70% Efficient
  - This we have found the optimum practical solution, particularly when combined with the ability to mix/return air from the pool hall
Optimum heat recovery

Using a plate heat exchanger combined with a mixing facility & accurately modulating the amount of fresh air, efficiencies well in excess of 80% can be attained.

If a pool cover is used this can be increased to over 90% during unoccupied periods using more recirculated air & the dwell time increases on the plate heat exchanger with a lower air volume.
Energy Saving Potential
Using data from the previous examples and typical annual energy costs and usage:

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupied Air Volume</td>
<td>3.33 m³/s</td>
</tr>
<tr>
<td>Unoccupied Air Volume</td>
<td>0.96 m³/s</td>
</tr>
<tr>
<td>Gas Energy Tariff*</td>
<td>3.5 pence per kW/hour</td>
</tr>
<tr>
<td>Electrical Energy Tariff*</td>
<td>10 pence per kW/hour</td>
</tr>
</tbody>
</table>

*Gas & Electric Tariffs based on a generic industry national averages

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Daily Temperature**</td>
<td>11 °C (across the year)</td>
</tr>
<tr>
<td>Pool in use</td>
<td>12 hours a day</td>
</tr>
</tbody>
</table>

**Average daily temperature based on Met Office data for London (2014)
Energy Saving Potential

Total annual saving of over 600,000 kW/h
Energy Saving Potential

- **Standard AHU NO Heat Recovery**
  - Year 1
  - Year 2
  - Year 3

- **Standard AHU 50% Heat Recovery**
  - Year 1
  - Year 2
  - Year 3

- **Pool AHU 80% Heat Recovery**
  - Year 1
  - Year 2
  - Year 3

Capital cost
- Year 1
- Year 2
- Year 3

Better air for the built environment
Importance of high energy efficiency

Why is PHX efficiency and correct air flow so important?

Every 1% decrease in PHX efficiency will have the effect of increasing running costs by over £500 per year.

Similarly, for every 0.1 m³/s above the required design air flow it will approximately cost an additional £240 per year to run.

* Based on data taken from previous example
System Design Considerations
System Design Considerations

Consideration should also be given to the maximum specific fan power (SFP) for an air handling unit serving a pool:

Source: Part L2 of the Building Regulations

<table>
<thead>
<tr>
<th></th>
<th>Existing</th>
<th>New Build</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Ventilation</td>
<td>1.8 W l/s</td>
<td>1.5 W l/s</td>
</tr>
<tr>
<td>PHX Heat Recovery</td>
<td>0.3 W l/s</td>
<td>0.3 W l/s</td>
</tr>
<tr>
<td>Return Air Filter</td>
<td>0.1 W l/s</td>
<td>0.1 W l/s</td>
</tr>
<tr>
<td><strong>Maximum SFP</strong></td>
<td><strong>2.2 W l/s</strong></td>
<td><strong>1.9 W l/s</strong></td>
</tr>
</tbody>
</table>

Because a pool is considered a process, it does not necessarily need to adhere to ErP 2016 regulations. But well designed systems would generally do so because of their high efficiencies.
System Design Considerations

What to look for when designing a pool ventilation system:

Å Selection of durable well protected equipment

Å Control options that can accurately maintain an optimum environment

Å High energy recovery particularly important during winter months

Å Systems that offer low energy use and a low maintenance regime

Å Effective air distribution
System Design Considerations

The use of a high grade paint finish inside and out will protect the AHU from aggressive chlorinated air.

Whereas the use of low grade materials will not.
System Design Considerations

Epoxy powder coated dampers.
IP66 damper actuator motors protect against moisture ingress.
System Design Considerations

Corrosion resistant plate heat exchanger that offer high transfer of energy (Anodised Aluminium or Virgin Plastic).
System Design Considerations

Controls are an important integral part of any pool ventilation system. A sophisticated control package that enables full control over temperature and humidity will dramatically improve energy efficiency.
To ensure the pool ventilation system runs at its optimum it is highly recommended to have the manufacturer undertake commissioning of the AHU and control systems.
System Design Considerations

Air distribution is very important & warm dry air should be distributed over cold surfaces to prevent condensation. Also distribution should be designed as best as possible to allow & even low velocity (as possible) distribution of air across the pool hall & back to the extract point.

Manchester Grammar school is a recent project where sock, fabric ductwork was retro-fitted to great effect. The extract points in the ceiling had to be re-used.
Summary

Â Air volume should be no more than absolutely necessary as this will be detrimental to running costs.

Â Pool halls should be maintained under a slight negative pressure to prevent pool air permeating other areas of the building and ingressing into the building fabric.

Â A minimum of 20% fresh air should be introduced to the pool hall to maintain satisfactory air quality.

Â Air temperature should be maintained approximately 1°C above pool water temperature to prevent unnecessary evaporation.
Summary

- Air temperatures should generally not exceed 31°C. Higher air temperatures can become uncomfortable for pool operators to work.

- Consideration for air distribution is very important & arm dry air should be distributed over cold surfaces to prevent condensation.
Thank you for your time

Better air for the built environment
Robust Case Construction
High Thermal & Acoustic Properties

Over 80% Heat Recovery
Durable Materials
Integrated Mixing

Energy Efficient
Zero Maintenance
Demand Responsive

Blue Sense Controls
Specific Pool Control Responds to Demand
VOC Option (New)

Better air for the built environment