Norman Disney & Young

Presentation to AIRAH

18th August 2010

VENTILATION OF INDOOR AQUATIC CENTRES

Presented by Jeff Dusting

INTRODUCTION

This presentation will cover

- Why ventilation and heating is so important
- Calculations and Formulas
- Design Conditions
- Sample Calculations / Rules of thumb
- Different Ventilation Configurations
- Different Heating Configurations
- Equipment selection and sizing

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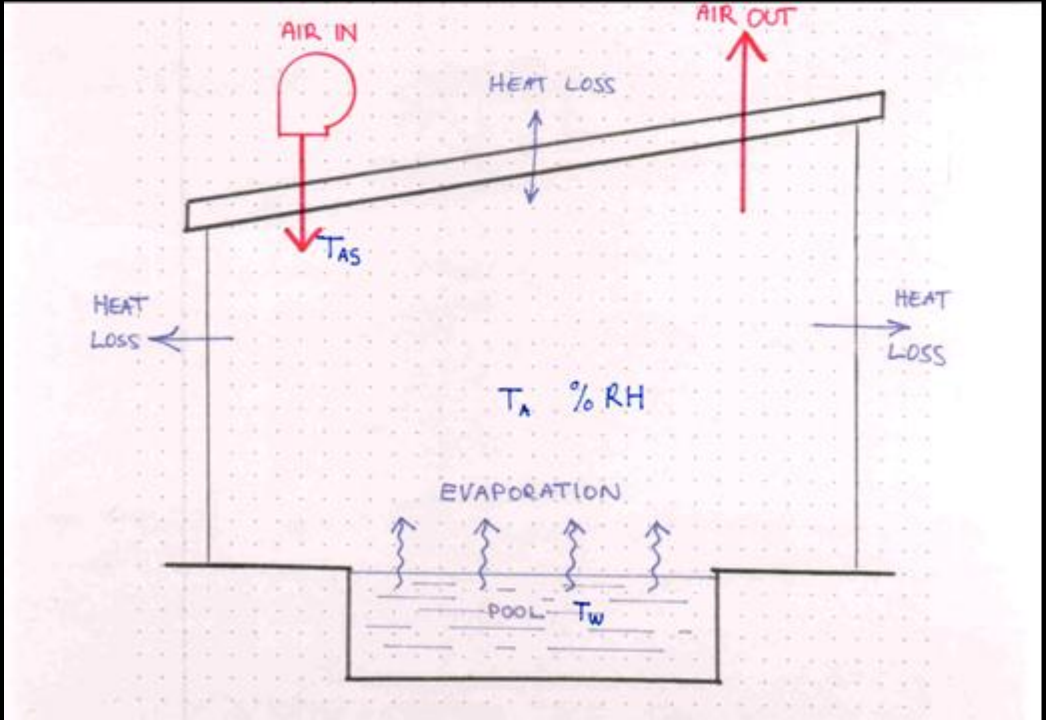
Why worry?

What Goes on in a Natatorium?

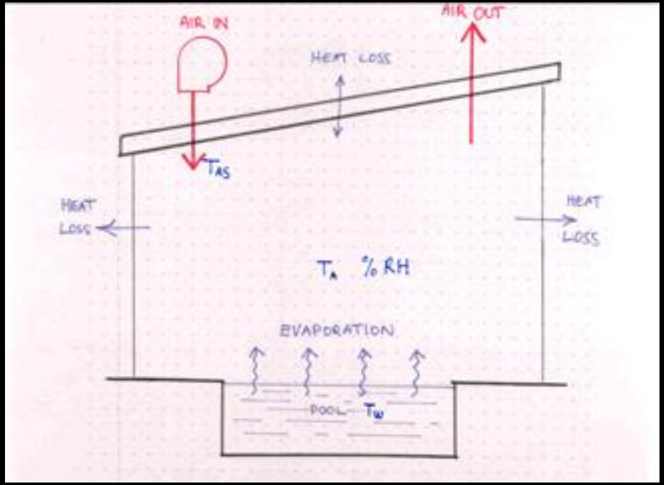


Why Worry?

- Occupant Comfort and Health

- Air Quality (chloramine levels)

- Condensation on cold surfaces



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CALCULATIONS

Mass / Heat Transfer Rates

Look Up in ASHRAE under Places of Assembly section 4.6 of the 2007 HVAC Applications Handbook

$$W_p = (A/Y)\ (p_w - p_a)(0.089 + 0.0782.V)\ F_a$$

p_w = water vapour pressure at T_w

p_a = partial water vapour pressure in the air

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CALCULATIONS

Mass / Heat Transfer Rates

Driving force for evaporation rates and water heat loss is

$$(p_w – p_a)$$

p_w = water vapour pressure at T_w

p_a = water vapour pressure at T_a x %RH

CALCULATIONS

Determining p_w and p_a

At 30°C p_w = 4.25 kPa

At 25°C p_w = 3.17 kPa

At 35°C p_w = 5.63 kPa

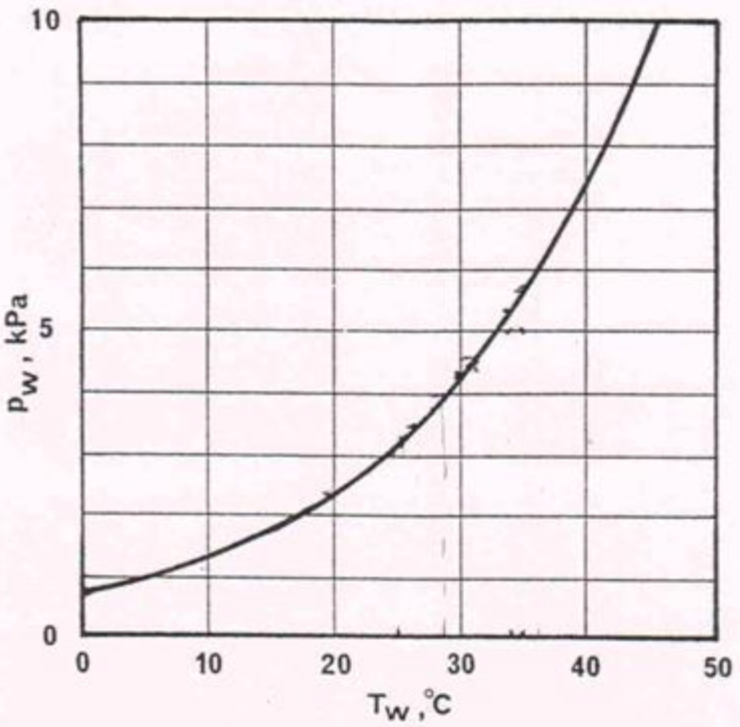

Fig. 1. Variation of the water vapour pressure p_w with the water temperature T_w.

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CALCULATIONS

Alternative formulae for Evaporation Rate:

- $W_p = (A/Y)(p_w - p_a)(0.089 + 0.0782.V)$ (kg/s)
- $W_p = 15\ A(p_w - p_a)F_a$ p_w in bar, W_p in kg/hr, F_a 0.5 to 1.5
- Heat Loss (W) = $16.3 \times (3.1 + 4.1\ V) \times (p_w - p_a)$, but activity factors higher – 0.8 to 2.0.

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CALCULATIONS

Ventilation Rates

AS 1668.2

- 3.5 m^2 per person and 10 L/s/person OR 2.86 $l/s/m^2$ for pool deck and pool area
- 1.5 m^2 per person and 10 L/s/person OR 6.66 $l/s/m^2$ for spectator areas

Humidity Control

- $Q = W_p / \rho (W_{ai} - W_{ao})$

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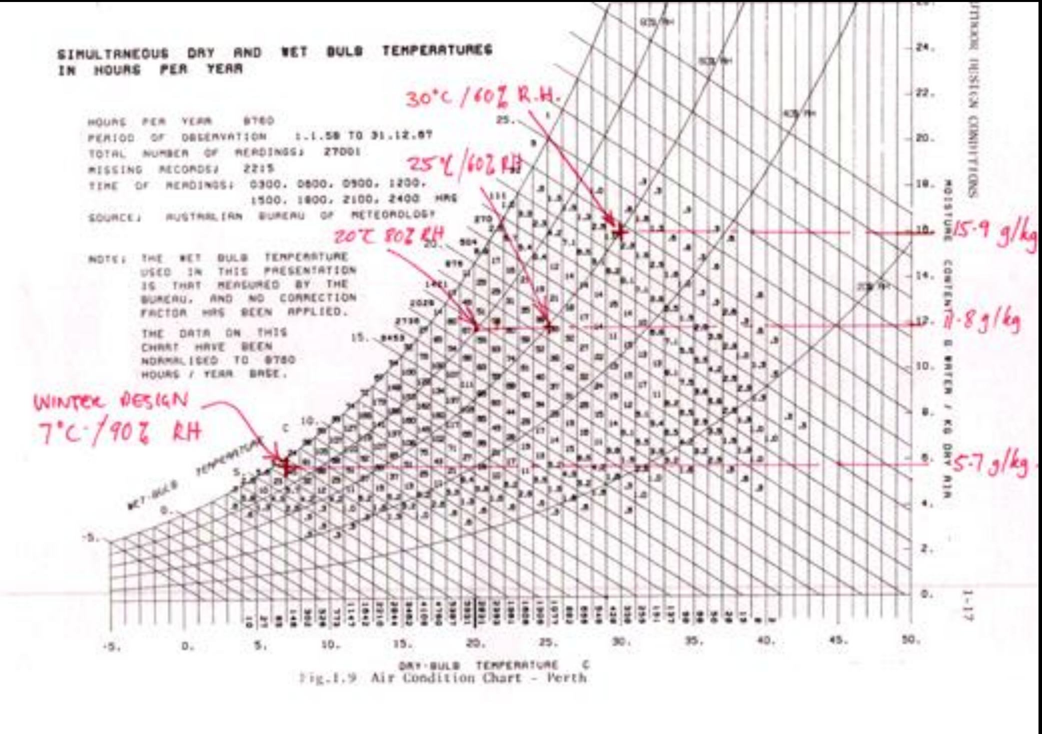
CALCULATIONS

Ventilation Rates – Determining W_{ai} and W_{ao}



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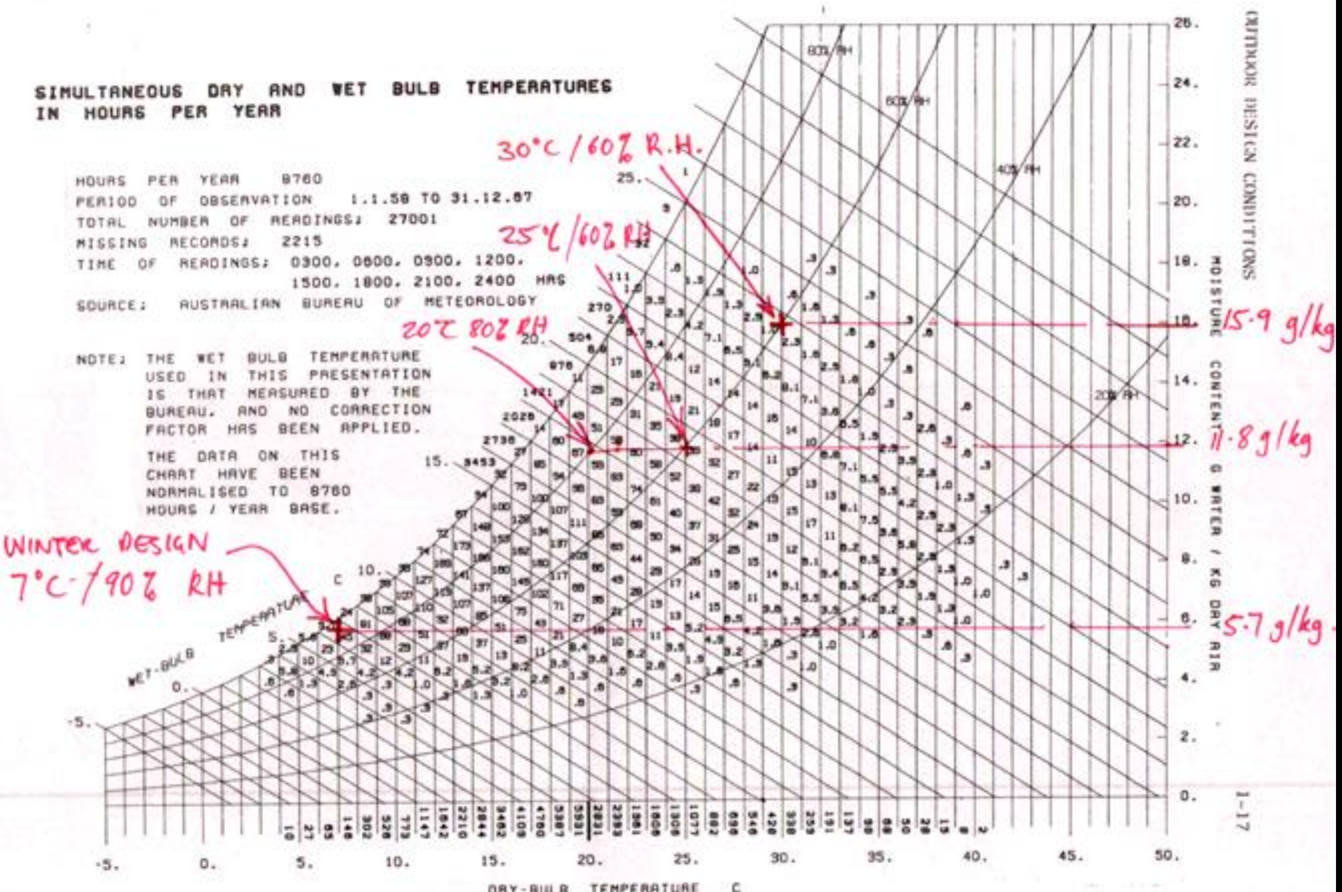

Fig.1.9 Air Condition Chart - Perth

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Design Criteria – Internal Air

Occupant Comfort / Health

- Bather comfort - 30 to 32 °C and 65 % RH
- Life Guard comfort - 26 to 28 °C and 50 % RH
- Spectators – 24 °C and 50% RH

Energy Use

- Higher the temperature the more air side heating required
- Higher the temperature the less water side heating required

Water Use

- Higher the temperature the less evaporation and less water use
- The higher the RH the less evaporation and less water use

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Design Criteria – Internal Air

Condensation

- The higher the air temperature the lower the condensation likelihood
- The higher the internal air temperature the greater the ability to control humidity with a given air change rate
- The lower the relative humidity the lower the condensation likelihood

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Design Criteria – Pool Water Temperature

Bather Comfort

• Competition Pool	24 to 26 °C
• Lap Pools	26 to 30 °C
• Diving Pools	27 to 32 °C
• Leisure Pools	28 to 32 °C
• Hydrotherapy Pools	32 to 36 °C
• Spa	36 to 40 °C

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Design Criteria – Pool Water Temperature

Impact on ventilation

An increase in pool temperature increases

- Evaporation Rate
- Water heat loss and hence energy use
- Need to increase ventilation rate to maintain RH

Design Criteria – External Temperature / %RH

- Primarily concerned with Heating so we consider 24 hour Winter Design conditions. This determines minimum outside air quantity / check against AS 1668 requirements.
- Review impact of Summer Design on Pool Hall Conditions. Absolute humidity in pool hall will have to be higher unless cooling is provided
- Check what external design conditions will allow internal design criteria to be met. Check that internal dew point is not too far below the external dry bulb

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Recommended Design Criteria

Indoor Temperature

- Within 1-2°C of water temperature
- Generally in the 28 to 30°C range – higher in Hydrotherapy areas if possible
- If lower bather comfort and ability to control RH and condensation deteriorate
- If higher then slightly higher heating energy required (the ratio of heat to water / air changes)

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Recommended Design Criteria

Indoor Humidity

- In the range 50 to 65% RH
- If lower, then evaporation rate increases and water heating requirement increases, bather comfort decreases, spectator comfort improves
- If higher, then risk of condensation on cold surfaces increases, and comfort for non bathing patrons becomes unpleasant

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Recommended Design Criteria

Ventilation Rates

- Minimum determined by internal and external winter design criteria as well as AS 1668.1 – typically aorund 2.5 to 3.0 air changes or 3.0 $l/s/m^2$
- Maximum between 5 and 8 air changes (rule of thumb is around 6)
- The minimum rate also depends on the quality of water treatment and extent of water features and associated evaporation rate

- If lower, condensation and poor air quality is likely
- The higher the better, but capital and energy costs obviously increase accordingly

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CONFUSED?

Some Examples:

Consider the Following

- Indoor Leisure Pool 25 x 15 m
- Pool Hall Size 30 x 25 x 5 m high
- Perth External Design Conditions
- Pool Temperature 30 °C
- Air Temperature 29 °C
- Air Humidity 60% RH

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30°C Pool Example

Pool   Area = 25 x 15 = 375 m2

Evaporation Rate? Use Activity Factor of 1.0 for leisure pool.

$W_p = (A/Y)\,(p_w - p_a)(0.089 + 0.0782.V)$

Take V as 0.15 m/s, Y = 2400 kJ/kg, p_w = 4.25 kPa,

$p_a = p_{Ta}$ x %RH = 4.10 x 0.60 = 2.46 kPa

W_p = 375 x 1.79 x 0.1 / 2400 = 0.028 kg /s or 1.7 L/min or

2,500 L/day Also equates to 67 kW heat loss from water

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30°C Pool Example

Determine Ventilation Rate

Pool Hall Volume is 30 x 25 x 5 = 3750 m3

Rule of Thumb gives 6 air changes = 3750 x 6 / 3.6 = 6250 L/s

AS 1668.1 regulation gives minimum of 30 x 25 / 3.5 x 10 = 2142 L/s

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30°C Pool Example

Check Ventilation rate for Humidity Control (Winter)

Use $Q = W_p / \rho \, (W_{ai} - W_{ao})$

$W_p = 0.028$ kg/s, $W_{ai} = 15.4$ g/kg for 29°C and 60 % RH (from psyc

$W_{ao} = 5.7$ g/kg for 7°C and 90 % RH (from psyc)

$Q = 0.028 / 1.2 \, (0.0154 - 0.0057) = 2.4 \, m^3/s = 2{,}400 \, l/s$

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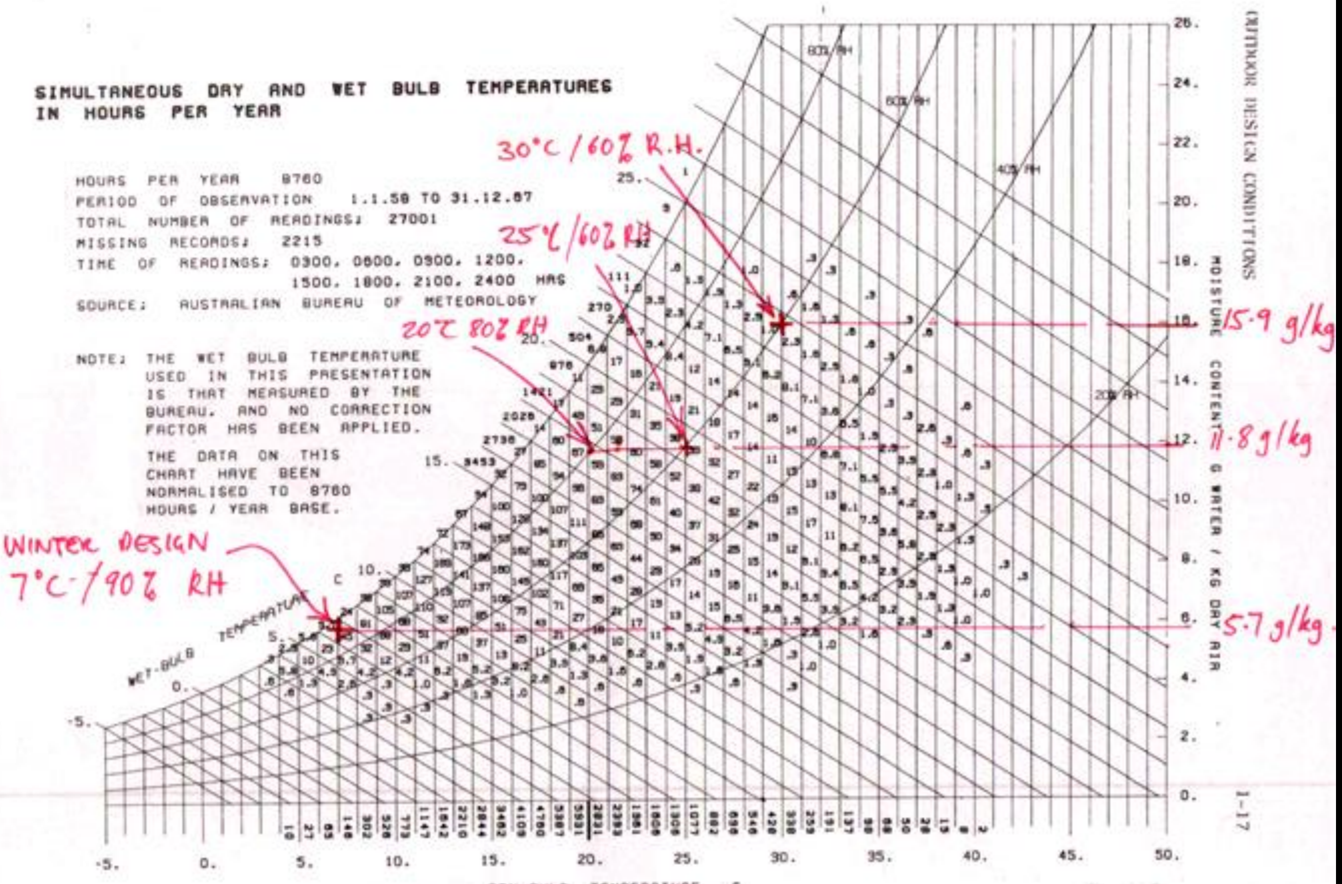

Fig.1.9 Air Condition Chart - Perth

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30°C Pool Example

Check Ventilation rate for Humidity Control (Mid Season Summer)

Use $Q = W_p / \rho \, (W_{ai} - W_{ao})$

$W_p = 0.028$ kg/s, $W_{ai} = 15.4$ g/kg for 29°C and 60 % RH (from psyc)

$W_{ao} = 11.8$ g/kg for 20.0°C and 80 % RH (from psyc)

$Q = 0.028 / 1.2 \, (0.0154 - 0.0118) = 6.48 \, m^3/s = 6{,}480$ l/s (a bit more than 6 air changes)

NOTE : RESULT IS SAME FOR 36.6/22.4 Ambient

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34°C Pool Example with Air at 26°C

Calculate Evaporation Rate

This time p_w = 5.40 kPa at water temp of 34°C instead of 4.25 kPa with water at 30.

And $p_a = p_{Ta}$ x %RH = 3.4 x 0.60 = 2.04 instead of 2.46 kPa

So $(p_w - p_a)$ = 3.36 instead of 1.79 kPa

W_p = 375 x 3.36 x 0.1 / 2400 = 0.0525 kg /s instead of 0.028 kg/s

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34°C Pool Example with Air at 26°C

Check Ventilation rate for Humidity Control (Winter)

Use $Q = W_p / \rho \, (W_{ai} - W_{ao})$

$W_p = 0.0525$ kg/s, $W_{ai} = 12.8$ g/kg for 26°C and 60 % RH (from psyc

$W_{ao} = 5.7$ g/kg for 7°C and 90 % RH (from psyc)

$Q = 0.0525 / 1.2 \, (0.0128 - 0.0057) = 6.162 \, m^3/s = 6{,}162$ l/s

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34°C Pool Example with Air at 26°C

Check Ventilation rate for Humidity Control (Mid Season / Summer)

Use $Q = W_p / \rho \, (W_{ai} - W_{ao})$

$W_p = 0.0525$ kg/s, W_{ai} = 12.8 g/kg for 26°C and 60 % RH (from psyc

W_{ao} = 11.8 g/kg for 25°C and 60 % RH (from psyc)

Q = 0.0525 / 1.2 (0.0128 – 0.0118) = 43.750m^3/s = 43,750 l/s (OR 42 airchanges!

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VENTILATION CONFIGURATIONS

Items to be Considered

- Humidity Control
  - VAV systems
  - Recirculation of air
  - Dehumidification cycles
- Air Distribution
  - Get warm air onto glass
  - Keep velocities across water and concourse low
  - Removal of heavy chloramines at point of generation
- Relationship to adjacent spaces
  - Pressure differential

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AIR DISTRIBUTION EXAMPLES

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HEATING CONFIGURATIONS

Natatoriums require heating as follows

- Pool Water
  - Loss to air
  - Evaporation Loss
  - Make Up Water
  - Radiant Loss to sky (if not indoor)
  - Skin loss (normally insignificant)
- Air
  - Where ambient is less than internal design criteria (outside air load)
  - Skin loss
  - Loss to water (if air warmer than water)

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POOL WATER HEAT LOSS

Loss to Air;

$$q_c = (3.1 + 4.1\,V)(T_W - T_A)$$

Evaporation Loss;

$$q_e = 16.3\,(3.1 + 4.1\,V)\,(p_w - p_a)$$ OR Use Evap rate.

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AIRSIDE HEAT LOSS

Outside Air Load

$$q = SAQ \times 1.213 \times (T_{oa} - T_{ia})$$

Skin Load

$$q = Area \times U\ factor \times (T_{oa} - T_{ia})$$

Loss to water (as per water calcs)

ENERGY SOURCES

- Hot Water Boiilers
  - Heat Exchangers to pool water
  - Heating coils to air

- Electric Resistance (EVIL!)

- Electric Heat Pumps
  - Packaged Units (Air and Water or combined)
  - Heat Reclaim units (Many different types)

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ENERGY SOURCES

- Geothermal
  - Water available at around 45°C at 800 m depth
  - Costly usually over ($1 M)
  - Risky
  - Water is Corrosive or fouls equipment
  - Don’t forget about pump energy use

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ENERGY SOURCES

- Solar
  - Reasonable for heating pool water – harder for air
  - Need space on roof
  - No Real impact in Winter

- Co – Generation
  - Depends on good gas price with respect to electricity
  - Beware of maintenance costs

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HEAT RECLAIM

HEAT PUMP HEAT RECOVERY

AIR TO AIR HEAT EXCHANGER

WATER COOLED HEAT RECLAIM UNITS

AIR HANDLING SIZING

Select air handlers to handle Supply air quantity from minimum ventilation rate to maximum (6 – 8 air changes)

Heating coils to suit full heating requirement (assume heat reclaim is not operational)

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AIR HANDLING EQUIPMENT SELECTION

- PACKAGED EQUIPMENT WITH WATER COILS
- PACKAGED EQUIPMENT WITH DX COILS
- BUILT UP AIR HANDLERS
- EXHAUST AIR SYSTEMS NEED TO HAVE CORROSION RESISTANCE (Bitumastic Paint or 2 pack polyesters or epoxies)
- FANS RUN CONTINUOUSLY - SO GOOD BEARINGS

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HEATING EQUIPMENT SELECTION

Boilers

- Comparatively Cheap First Cost
- Select for warm up load to get pool up to temperature at around 0.5 deg C / hr
- Can then usually provide both ongoing water and air heating requirements

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HEATING EQUIPMENT SELECTION

Air to Water Heat Pumps

- More Expensive than boilers - usually 6 – 10 year pay back depending on “spark gap”
- COP generally around 5
- COP drops to 2 to 3 during cold ambient unless heat rejection is to exhaust air
- Most efficient for water heating

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HEATING EQUIPMENT SELECTION

Water to Water Heat Pumps (Chillers)

- More Expensive than air cooled packages
- COP generally around 6
- Can provide Cooling of air space as well