DESIGN CONSIDERATIONS FOR POOLS AND SPAS (NATATORIUMS)

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SWIMMING POOLS

According to ASHRAE (1999a), the desirable temperature for swimming pools is 27ºC, however, this will vary from culture to culture by as much as 5ºC. If the geothermal water is higher in temperature, then some sort of mixing or cooling by aeration or in a holding pond is required to lower the temperature. If the geothermal water is used directly in the pool, then a flow through process is necessary to replace the "used" water on a regular basis. In many cases, the pool water must be treated with chlorine, thus it is more economical to use a closed loop for the treated water and have the geothermal water provide heat through a heat exchanger. The water heating system in this case, is installed on the return line to the pool. Acceptable circulation rates vary from six to eight hours for a complete change of water. Heat exchangers must be designed to resist the corrosive effects of the chlorine in the pool water and scaling or corrosion from the geothermal water. This often requires, in the case of plate heat exchangers, using titanium plates.

Sizing of the system for temperature and flow rates depends on four considerations (ASHRAE, 1999a), which are also discussed in more detail in achapter on Aquaculture Design by Rafferty (1998). These are:

1. Conduction through the pool walls,
2. Convection from the pool surface,
3. Radiation from the pool surface, and
4. Evaporation from the pool surface.

Of these, conduction is generally the least significant unless the pool is above ground or in contact with cold groundwater. Convection losses depend on the temperature difference between the pool water and the surrounding air, and the wind speed. This is substantially reduced for indoor pools and ones with wind breaks. Radiation losses are greater at night, again especially for outdoor pools, however during the daytime there will be solar gains which may offset each other. A floating pool cover can reduce both radiation and evaporation losses. Evaporation losses constitute the greatest heat loss from pools--50 to 60% in most cases (ASHRAE, 1999a). The rate at which evaporation occurs is a function of air velocity and pressure difference between the pool water and the water vapor in the air (vapor pressure difference). As the temperature of the pool water is increased or the relative humidity of the air is decreased, evaporation rate increases. An enclosure can reduce this loss substantially, and a floating pool cover can practically eliminate the loss. Swimming and other pool uses causing waves and splashing will increase the surface area and thus the evaporation rate.

The required geothermal heating output q_t can be determined by the following two equations (ASHRAE, 1999a):

$$q_1 = \ ?\ c_p\ V\ (t_f - t_i)/? \qquad [1]$$

where

q_1	= pool heat-up rate, kJ/h
?	= density of water = 1,000 kg/m^3
c_p	= specific heat of water = 4.184 kJ/kg ºC
V	= pool volume, m^3
t_f	= desired temperature (usually 27ºC)
t_i	= initial temperature of pool, ºC
?	= pool heat-up time (usually 24 hours)

and

$$q_2 = U\ A\ (t_p - t_a) \qquad [2]$$

where

q_2	=	heat loss from pool surface, kJ/h
U	=	surface heat transfer coefficient = 214.4 kJ/(h m^2 ºC)
A	=	pool surface area, m^2
t_p	=	pool temperature, ºC
t_a	=	ambient temperature, ºC

then

$$q_t = q_1 + q_2 \qquad [3]$$

If there is no heat-up time, which is typical for geothermal pools, then equation [1] will be zero and only equation [2] will apply. Heat loss equation [2] assume a wind velocity of 5 to 8 km/h. For sheltered pools, and average wind velocity of less than 5 km/h, the second equation (q_2) can be reduced to 75%. For wind velocity of 8 km/h, multiply by 1.25; and for wind velocity of 16 km/h, multiply by 2.0 (ASHRAE, 1999a).

SPAS (NATATORIUMS)

Spas or natatoriums require year-round humidity levels between 40 and 60% for comfort, energy consumption, and building protection (ASHRAE, 1999b). Any design must consider all of the following variables: humidity control, ventilation requirements for air quality (outdoor and exhaust air), air distribution, duct design, pool water chemistry, and evaporation rates.

According to ASHRAE (1999b):

> "Humans are very sensitive to relative humidity. Fluctuations in relative humidity outside the 40 to 60% range can increase levels of bacteria, viruses, fungi and other factors that reduce air quality. For swimmers, 50 to 60% relative humidity is most comfortable. High relative humidity levels are destructive to building components. Mold and mildew can attack wall, floor, and ceiling coverings; and condensation can degrade many building materials. In the worst case, the roof could collapse due to corrosion from water condensing on the structure."

Heat loads for a spa include building heat gains and losses from outdoor air, lighting, walls, roof, and glass, with internal latent heat loads coming generally from people and evaporation. The evaporation loads are large compared to other factors and are dependent on the pool characteristics such as the surface area of the pool, wet decks, water temperature and the activity level in the pool.

The evaporation rate (w_p in kg/s) can be estimated for pools of normal activity levels, allowing for splashing and a limited area of wetted deck (Smith, et al., 1993) (ASHRAE, 1995).

$$w_p = A\,(p_w - p_a)\,(0.089 + 0.0782\,V) / Y \qquad [4]$$

where

A	=	area of pool surface, m^2
p_w	=	saturation vapor pressure taken at surface water temperature, kPa
p_a	=	saturation pressure at room air dew point, kPa
V	=	air velocity over water surface, m/s
Y	=	latent heat required to change water to vapor at surface water temperature, kJ/kg

For Y values of about 2330 kJ/kg and V value of 0.10 m/s, and multiplying by an activity factor Fa to alter the estimate of evaporation rate based on the level of activity supported, equation [4] can be reduced to:

$$w_p = 4.16 \times 10^{-5} \times A\,(p_w - p_a)\,F_a \qquad [5]$$

If p_w and p_a are given in bar absolute, then equation [5] becomes:

$$w_p = 4.16 \times 10^{-3} \times A\,(p_w - p_a)\,F_a \qquad [6]$$

And, if w_p is given in kg/hr, then equation [6] becomes;

$$w_p = 15.0 \times A\,(p_w - p_a)\,F_a \qquad [7]$$

Table 1. Common Values for p_w

For p_w:
- at 15ºC water, p_w = 0.0170 bar (1.70 kPa)
- at 20ºC water, p_w = 0.0234 bar (2.34 kPa)
- at 25ºC water, p_w = 0.0317 bar (3.17 kPa)
- at 30ºC water, p_w = 0.0425 bar (4.25 kPa)
- at 35ºC water, p_w = 0.0563 bar (5.63 kPa)
- at 40ºC water, p_w = 0.0738 bar (7.38 kPa)

For outdoor locations with a design dry bulb air temperature below 0ºC, p_a can be taken as 0.0061 bar (0.61 kPa). For indoor locations with a design from 40 and 60% humidity, the following values of p_a can be use:

Table 2. Common Values for pa

Temperature ºC	40% relative humidity bar (kPa)	50% relative humidity bar (kPa)	60% relative humidity bar (kPa)
20	0.0094 (0.94)	0.0117 (1.17)	0.0140 (1.40)
25	0.0127 (1.27)	0.0158 (1.58)	0.0190 (1.90)
30	0.0170 (1.70)	0.0212 (2.12)	0.0255 (2.55)

The following activity factors should be applied to the area of specific features, and not to the entire wetted area (ASHRAE, 1999b):

Type of Pool	Typical Activity Factor (F_a)
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)

It is important to apply the correct activity factor for the estimation of the water evaporation rate, as for example, the difference in peak evaporation rates between private pools (residential) and active public pools of the same size may be more than 100%.

ASHRAE (1999b) recommends operating temperatures and relative humidity conditions for design, and suggests that higher operating temperatures are preferred by the elderly. Air temperatures in public and institutional pools should be maintained 1 to 2ºC above the water temperatures (but not above the comfort threshold of 30ºC) to reduce the evaporation rate and avoid chill effects on swimmers. The maximum water temperature that can be tolerated by the human body (for short periods of time) is 43ºC. The recommendations are as follows:

Table 3. Typical Natatorium Design Conditions

Type of Pool	Air Temperature °C	Water Temperature °C	Relative Humidity %
Recreational	24 to 29	24 to 29	50 to 60
Therapeutic	27 to 29	29 to 35	50 to 60
Competition	26 to 29	24 to 28	50 to 60
Diving	27 to 29	27 to 32	50 to 60
Whirlpool/spa	27 to 29	36 to 40	50 to 60

Relative humidities should not be maintained below recommended levels because of the evaporated cooling effect on a person emerging from the pool and because of the increased rate of evaporation from the pool, which increases pool heating requirements. Humidities higher than recommended encourage corrosion and condensation problems as well as occupant discomfort. Air velocities should not exceed 0.13 m/s at a point 2.4 m above the walking deck of the pool (ASHRAE, 1995).

Ventilation is important, especially if chlorine is used to treat the pool water. Ventilation is also used to prevent temperature stratification in areas with high ceilings. Since exhaust air will have chloramine from the chlorine treatment and also have high moisture contents, care must be exercised to vent this air outside and not into changing rooms, toilets and showers. In addition, pool areas should have a light negative pressure and automatic door closers to prevent the contaminated air (laden with moisture and chloramine) from migrating into adjacent areas of the building. ASHRAE (1999b) states that most codes require a minimum of six air changes per hour, except where mechanical cooling is used. With mechanical cooling, the recommended rate is four to six air changes per hour for therapeutic pools.

Natatoriums can be a major energy burden on a facility, thus energy conservation should be considered. This includes evaluating the primary heating and cooling systems, fan motors, backup water heaters (in the case of geothermal energy use) and pumps. Natatoriums with fixed outdoor air ventilation rates without dehumidification generally have seasonally fluctuating space temperature and humidity level. Since these systems usually cannot maintain constant humidity conditions, they may facilitate mold and mildew growth and poor indoor air quality. In addition, varying activity level will also cause the humidity level to vary and thus change the demand on ventilation air.

The minimum air quantity to remove the evaporated water can be calculated from the following expression (ASHRAE, 1995):

$$Q = w_p/[?\ (W_i - W_o)]$$

where:

Q = quantity of air (m^3/s)
? = standard air density = 1.204 kg/m^3
W_i = humidity ratio of pool air at design criteria (kg/kg)(from psychrometric chart)
W_o = humidity ratio of outside air at design criteria (kg/kg)(from psychrometric chart).

The number of air changes per hour (ACH) to remove the quantity of moist air (Q) is:

$$ACH = (V/Q)/3600$$

where:

V = volume of the building in m^3

Normally, the air changes per hour calculated from the above expression is less than the minimum recommended of four to six per hour.

REFERENCES

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