4.6 2007 ASHRAE Handbook—HVAC Applications

NATATORIUMS   Environmental Control

A natatorium requires year-round humidity levels between 40 and 60% for comfort, energy consumption, and building protection.

The designer must address the following concerns: humidity control, ventilation requirements for air quality (outdoor and exhaust air), air distribution, duct design, pool water chemistry, and evaporation rates. A humidity control system will not provide satisfactory results if any of these items are overlooked.

See Chapter 47 of the 2004 *ASHRAE Handbook—HVAC Systems and Equipment* for additional dehumidifier application and design information.

Humidity Control

People 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% rh 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 because of corrosion from water condensing on the structure.

Load Estimation

Loads for a natatorium include heat gains and losses from outdoor air, lighting, walls, roof, and glass. Internal latent loads are generally from people and evaporation. Evaporation loads in pools and spas are significant relative to other load elements and may vary widely depending on pool features, areas of water and wet deck, water temperature, and activity level in the pool.

Evaporation.

The rate of evaporation can be estimated from empirical Equation

(1) This equation is valid for pools at normal activity levels, allowing for splashing and a limited area of wetted deck. Other pool uses may have more or less evaporation (Smith et al. 1993).

(1) *Where* wp = evaporation of water, lb/h

A = area of pool surface, ft2

Y = latent heat required to change water to vapor at surface water temperature, Btu/lb pw = saturation vapor pressure taken at surface water temperature, in. Hg pa = saturation pressure at room air dew point, in. Hg

V = air velocity over water surface, fpm The units for the constant 95 are Btu/(h·ft2·in. Hg). The units for the constant 0.425 are Btu·min/(h·ft3·in. Hg).

Equation (1) may be modified by multiplying it by an activity factor Fa to alter the estimate of evaporation rate based on the level of activity supported. For Y values of about 1000 Btu/lb and V values ranging from 10 to 30 fpm, Equation (1) can be reduced to $wp = 0.1A(pw - pa)Fa$ (2)

The following activity factors should be applied to the areas of specific features, and not to the entire wetted area:

The effectiveness of controlling the natatorium environment depends on correct estimation of water evaporation rates. Applying the correct activity factors is extremely important in determining water evaporation rates. The difference in peak evaporation rates between private pools and active public pools of comparable size may be more than 100%.

Actual operating temperatures and relative humidity conditions should be established before design. How the area will be used usually dictates design (Table 1).

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

Ventilation Requirements

Air Quality. Outdoor air ventilation rates prescribed by ASHRAE *Standard* 62.1 are intended to provide acceptable air quality conditions for the average pool using chlorine for primary disinfection. The ventilation requirement may be excessive for private pools and installations with low use, and may also prove inadequate for high-occupancy public or waterpark-type installations.

Air quality problems in pools and spas are often caused by water quality problems, so simply increasing ventilation rates may prove both expensive and ineffective. Water quality conditions are a direct function of pool use and the type and effectiveness of water disinfection used.

Because indoor pools usually have high ceilings, temperature stratification can have a detrimental effect on indoor air quality. Careful duct layout must ensure that the space receives proper air changes and homogeneous air quality throughout. Some air movement at the deck and pool water level is essential to ensure acceptable air quality. Complaints from swimmers indicate that the greatest chloramine (see the section on Pool Water Chemistry) concentrations occur at the water surface. Children are especially vulnerable to the ill effects of chloramines inhalation.

Exhaust air from pools is rich in moisture and may contain high levels of corrosive chloramine compounds. Although most codes allow pool air to be used as makeup for showers, toilets, and locker rooms, these spaces should be provided with separate ventilation and maintained at a positive pressure with respect to the pool.

Pool and spa areas should be maintained at a negative pressure of 0.05 to 0.15 in. of water relative to adjacent areas of the building to prevent chloramine odor migration. Active methods of pressure control may prove more effective than static balancing and may be necessary where outdoor air is used as a part of an active humidity control strategy. Openings from the pool to other areas should be minimized and controlled. Passageways should be equipped with doors with automatic closers to inhibit migration of moisture and air.

Exhaust air intake grilles should be located as close as possible to the warmest body of water in the facility. Warmer waters and those with high agitation levels off gas chemicals at higher rates compared to traditional pools. This also allows body oils to become airborne.

Ideally these pollutants should be removed from close to the source, before they have a chance to diffuse and negatively impact the air quality. Installations with intakes directly above whirlpools have resulted in the best air quality.

Table 1 Typical Natatorium Design Conditions

Type of Pool

Air Temperature, °F

Water Temperature, °F

Relative Humidity,%

Recreational 75 to 85 75 to 85 50 to 60RH

Therapeutic 80 to 85, 85 to 95, 50 to 60 RH

Competition 78 to 85, 76 to 82, 50 to 60RH

Diving 80 to 85, 80 to 90, 50 to 60RH

Elderly swimmers 84 to 90, 85 to 90, 50 to 60% RH

Hotel 82 to 85 82 to 86 50 to 60RH

Whirlpool/spa 80 to 85 97 to 104 50 to 60RH

$Wp\ A\ Y = ---(pw - pa)(95 + 0.425V)$

Type of Pool Typical Activity Factor (*Fa*)

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)

Places of Assembly 4.7

Air Delivery Rates. Most codes require a minimum of six air changes per hour, except where mechanical cooling is used. This rate may prove inadequate for some occupancy and use. Where mechanical dehumidification is provided, air delivery rates should be established to maintain appropriate conditions of temperature and humidity. The following rates are typically desired:

Pools with no spectator areas 4 to 6 air changes per hour

Spectator areas 6 to 8 air changes per hour

Therapeutic pools 4 to 6 air changes per hour

Outdoor air delivery rates may be constant or variable, depending on design. Minimum rates, however, must provide adequate dilution of contaminants generated by pool water and must maintain acceptable ventilation for occupancy.

Where a minimum outdoor air ventilation rate is established to protect against condensation in a building's structural elements, the rates are typically used for 100% outdoor air systems. These rates usually result in excessive humidity levels under most operating conditions and are generally not adequate to produce acceptable indoor air quality, especially in public facilities subject to heavy use.

Duct Design

As with any installation, proper duct design and installation is necessary for proper equipment performance. Poorly installed return duct connections, for example, can significantly reduce the performance of a dehumidifier. The following duct construction practices apply to natatoriums:

• Fiberglass duct liner should not be used. Where condensation may occur, the insulation must be applied to the duct exterior.

• Duct materials and hardware must be resistant to chemical corrosion from the pool atmosphere. Stainless steels, even the 316 series, are not recommended because they are readily attacked by chlorides and are prone to pitting. Galvanized steel, fabric (with adjustable grilles sewn in), or aluminum sheet metal may be used for exposed duct systems. Buried ductwork should be constructed from nonmetallic fiberglass-reinforced or PVC materials because of the more demanding environment.

• Grilles, registers, and diffusers should be constructed from aluminum. They should be selected for low static pressure loss and for appropriate throws for proper air distribution.

• Supply air should be directed against interior envelope surfaces prone to condensation (glass and doors). Some supply air should be directed over the water surface to move contaminated air toward an exhaust point and control chloramines released at the water surface.

However, air movement over the pool water surface must not exceed 30 fpm as per the evaporation rate *wp* in Equation (1)].

• Return air inlets should be located to recover warm, humid air and return it to the ventilation system for treatment, to prevent supply air from short-circuiting and to minimize recirculation of chloramines.

• Exhaust air inlets should be located to maximize capture effectiveness and minimize recirculation of chloramines. Exhausting from directly above whirlpools is also desirable. Exhaust air should be taken directly to the outside, through heat recovery devices where provided.

• Filtration should be selected to provide 45 to 65% efficiencies (as defined in ASHRAE *Standard* 52.1) and be installed in locations selected to prevent condensation in the filter bank. Filter media and support materials should be resistant to moisture degradation.

• Air systems may be designed for noise levels of NC 45 to 50; however, wall, floor, and ceiling surfaces should be evaluated for their attenuation effect.

Envelope Design

Glazing in exterior walls becomes susceptible to condensation when the outdoor temperature drops below the pool room dew point. The design goal is to maintain the surface temperature of the glass and the window frames a minimum of 5°F above the pool room dew point. Windows must allow unobstructed air movement on inside surfaces. Thermal break frames should be used. Avoid recessed windows and protruding window frames. Skylights are especially vulnerable, and require attention to control condensation.

Wall and roof vapor retarder designs should be carefully reviewed, especially at wall-to-wall and wall-to-roof junctures and at window, door, and duct penetrations. The pool enclosure must be suitable for year-round operation at 50 to 60% relative humidity. A vapor barrier analysis (as in Figure 2 in Chapter 23 of the 2005 *ASHRAE Handbook—Fundamentals*) should be prepared.

Failure to install an effective vapor retarder will result in condensation forming in the structure, and potentially serious

Pool Water Chemistry

Failure to maintain proper chemistry in the pool water causes serious air quality problems and deterioration of mechanical systems and building components. Water treatment equipment and chemicals should be located in a separate, dedicated, well ventilated space that is under negative pressure. Pool water treatment consists of primary disinfection, pH control, water filtration and purging, and water heating. For further information, refer to Kowalsky (1990).

Air quality problems are usually caused by the reaction of chlorine with biological wastes, and particularly with ammonia, which is a by-product of the breakdown of urine and perspiration. Chlorine reacts with these wastes, creating chloramines (monochloramine, dichloramine, and nitrogen trichloride) that are commonly measured as combined chlorine. Adding chemicals to pool water increases total contaminant levels. In high-occupancy pools, water contaminant levels can double in a single day of operation.

Chlorine's efficiency at reducing ammonia is affected by several factors, including water temperature, water pH, total chlorine concentration, and level of dissolved solids in the water. Because of their higher operating temperature and higher ratio of occupancy per unit water volume, spas produce greater quantities of air contaminants than pools.

The following measures have demonstrated a potential to reduce chloramine concentrations in the air and water:

• **Ozonation.** In low concentrations, ozone has substantially reduced the concentration of combined chlorine in the water. In high concentrations, ozone can replace chlorine as the primary disinfection process; however, ozone is unable to maintain sufficient residual levels in the water to maintain a latent biocidal effect. This necessitates maintenance of chlorine as a residual process at concentrations of 0.5 to 1.5 ppm.

• **Water Exchange Rates.** High concentrations of dissolved solids in water have been shown to directly contribute to high combined chlorine (chloramine) levels. Adequate water exchange rates are necessary to prevent the buildup of biological wastes and their oxidized components in pool and spa water. Conductivity measurement is an effective method to control the exchange rate of water in pools and spas to effectively maintain water quality and minimize water use. In high-occupancy pools, heat recovery may prove useful in reducing water heating energy requirements.

Energy Considerations

Natatoriums can be a major energy burden on facilities, so they represent a significant opportunity for energy conservation. Several design solutions are possible using both dehumidification and ventilation strategies. When evaluating a system, energy consumed by all elements should be considered, including primary heating and cooling systems, fan motors, water heaters, and pumps. Natatoriums with fixed outdoor air ventilation rates without dehumidification generally have seasonally fluctuating space temperature and humidity levels. Systems designed to provide minimum ventilation rates without dehumidification are unable to maintain relative humidity conditions within prescribed limits. These systems may facilitate mold and mildew growth and may be unable to provide acceptable indoor air quality. Peak dehumidification loads vary with activity levels and during the cooling season when ventilation air becomes an additional dehumidification load to the space.