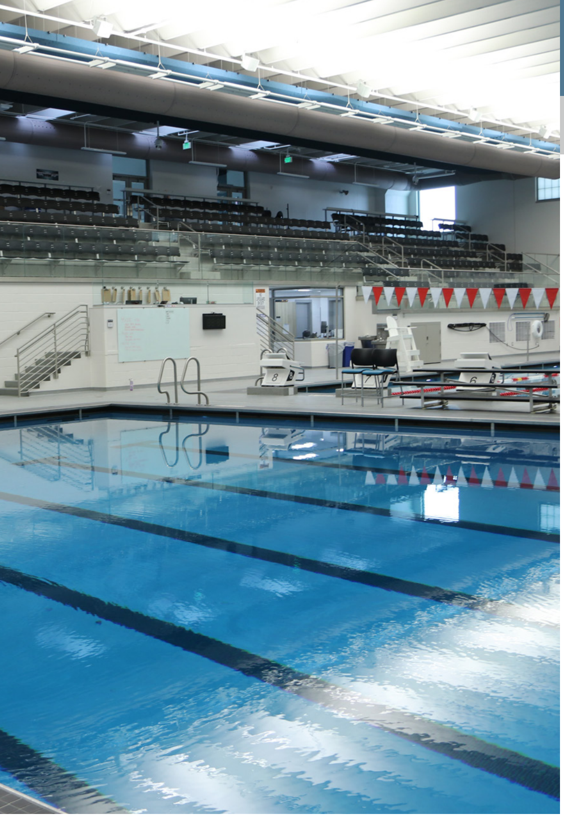


Natatorium HVAC Design

by Innovent

This guide provides recommendations for using HVAC system design to dehumidify, heat and cool, and provide outdoor air to indoor aquatic facilities. Topics include ventilation, air distribution, and energy efficiency.

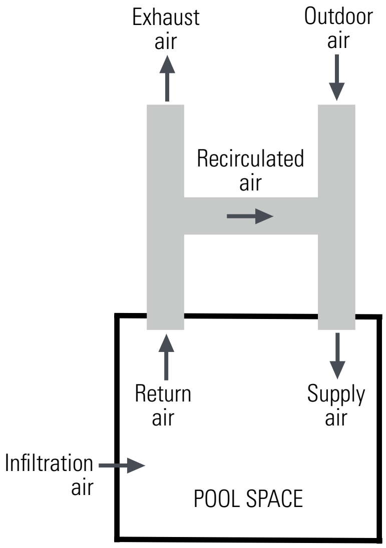
POOL VENTILATION OVERVIEW

Healthy and durable pool spaces require proper air distribution to all space micro-zones. Zones shown here include swimming, deck, and elevated spectator areas, and exterior-facing glass, wall, and roof areas.

Indoor aquatic facilities (also known as natatoriums) are distinctive places for recreation, competition, relaxation, therapy, and exercise. But for HVAC engineers, natatoriums pose challenges of air quality, temperature, humidity, and contaminant removal that differ from those in typical comfort-cooling applications. Contaminants binding to chlorine-treated water form chloramines, which off-gas acidic air that corrodes steel and irritates swimmers' eyes just above the water surface. Humidity from evaporated pool water must be controlled through dehumidification while managing energy costs. Additionally, both pool water and surrounding air temperatures need to be comfortable for swimmers year-round.

This guide outlines methods for solving these challenges while optimizing outdoor air with energy recovery devices. Outdoor air is important for dehumidification and exhausting chloramines, as well as minimizing the unpleasant chlorine odor from the pool. Through thoughtful design, indoor aquatic facilities can be healthy, well-ventilated, and energy-efficient spaces.

Definitions



Supply air: Total airflow delivered to the pool space. Includes outdoor air and recirculated air.

Outdoor air: Ventilation air; also called fresh air before it is treated.

Return air: Air delivered to the air handling equipment through return ducts from the pool space. Includes both air to be recirculated and exhausted.

Air changes per hour (ACH): Describes the number of times the total volume of air in the space is replaced. Includes outdoor air and recirculated air when discussing indoor pools.

Exhaust air: Air removed from the pool space and exhausted to the atmosphere.

Infiltration air: Outdoor air or conditioned air entering the pool space through the pool space enclosure due to pressure differential.

Dehumidification Methods

The high humidity of natatoriums requires continuous dehumidification. Which dehumidification technology you choose has a major effect on energy usage. There are three common strategies for dehumidifying air:

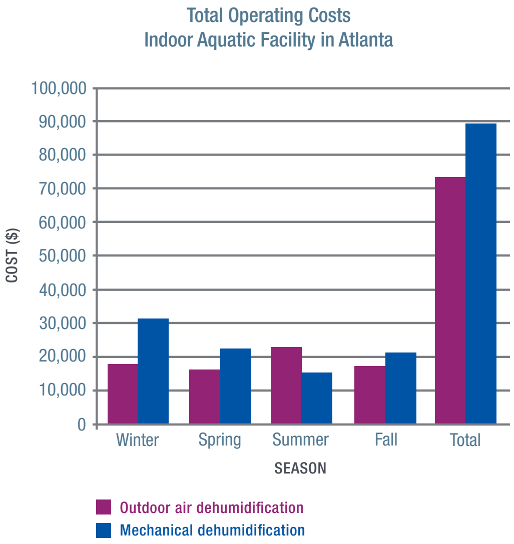
- **Chemical dehumidification:** These systems dehumidify with desiccants, typically requiring post cooling. However, chemical dehumidification systems are generally not economical at the high dew points of pool spaces, and desiccants deteriorate when exposed to chlorine.
- **Mechanical dehumidification:** These systems use direct expansion (DX) cooling, typically with reheat, to extract moisture from indoor air. Complex options include multiple condensers and pumped glycol overlays to recapture energy from compressor operation. For a small hotel pool, these types of systems are ideal. For larger facilities such as recreation centers and school natatoriums, they are less economical than outdoor air dehumidification because of their higher energy cost.
- **Outdoor air dehumidification:** These systems replace moist indoor air with dry outdoor air. Note that systems using only outdoor air cannot provide humidity control on humid summer days in most climates. Introducing low-humidity outdoor air to humid indoor aquatic facilities, even when that air needs to be heated, can be the most economical way to dehumidify these spaces, especially since fresh air is already being delivered to dilute the above-average level of indoor air contaminants (see Figure 1). When outdoor air cannot meet the dehumidification load economically, typically in summer, hybrid systems use mechanical dehumidification (often a cooling coil with reheat) to meet the dehumidification load.

Figure 1: Total Operating Costs, Indoor Aquatic Facilities, in Climate Zones 3–7
The chart below describes the total operating costs of an indoor aquatic facility located in Atlanta, GA, and includes costs for air heating, pool water heating, dehumidification, and fan motors. The text describes total operating costs for the same type of aquatic facility when located in Climate Zones 3 through 7.

$ HOW MUCH CAN YOU SAVE?

A 6,300-square-foot competition pool in a 300,000-cubic-foot indoor aquatic facility maintained at 82 °F and 60% RH can have the following operational cost reductions when using outdoor air dehumidification for most of the year instead of using year-round mechanical dehumidification:

- 50% in Denver (ASHRAE Climate Zone 7)
- 40% in Minneapolis, Portland, and Boston (ASHRAE Climate Zones 4, 5 & 6)
- 30% in Washington DC and Kansas City (ASHRAE Climate Zone 4)
- 25% in Los Angeles (ASHRAE Climate Zone 3)
- 20% in Atlanta, shown in graph at right (ASHRAE Climate Zone 3)
- 15% in Dallas (ASHRAE Climate Zone 3)



Enclosures with very high sensible loads, or single-story spaces with high dehumidification loads or air volume (such as therapy pools), can require more air changes to provide an acceptable supply air temperature.

POOL LOADS AND ENERGY USE

Indoor aquatic facilities consume energy primarily in four categories:

- Air heating and cooling (sensible loads)
- Dehumidification (latent loads)
- Air distribution (fan motor operating cost)
- Pool water heating

Table 1:
Component energy costs by percentage, indoor aquatic facility, 82 °F air / 60% RH*

Component	All Climates, Average % of total	Atlanta % of total	Chicago % of total
Fans	40	41	37
Envelope and ventilation	25	18	34
Pool water heating	20	22	19
Compressors	15	19	10

Note
* These are projected annual energy costs of an indoor aquatic facility before dehumidification system selection, using gas heat, no energy recovery, occupied 16 hrs/day, and ventilating with minimum outdoor air as defined by ASHRAE 62.

Table 1: Indoor aquatic facility energy cost baseline
This provides a general overview of indoor aquatic facility energy costs. As climate moves from south to north more energy is used for envelope and ventilation (heating) and less is used for compressors (dehumidification and cooling). Fan energy costs are high because these environments require high-volume constant air movement.

Air Heating and Cooling Sensible Loads

Occupied indoor aquatic facility air temperatures usually range from 82–86 °F. This means that the pool space is in heating mode for much more of the year than a typical comfort environment.

The primary air heating and cooling sensible loads are:

- Building envelope
- Outdoor air
- Infiltration
- Lighting
- Fan motors

Building envelope

BEST PRACTICE TIP

Envelope loads are typically among the largest heating loads and can be the largest cooling load if there is significant solar exposure. When utilizing building modeling software to calculate heating and cooling design sensible loads, be sure to use the design space temperature, which can be as high as 86 °F, and not the normal default temperature, typically 75 °F.

Thoughtful window orientation and sizing can reduce solar gain, summer cooling load, winter heating load, and total air change rate. As exterior glass increases, so does the amount of warm air required at windows to reduce fogging and condensation. Skylights can be problematic because it is difficult to effectively wash their surfaces with warm supply air in high-humidity spaces, as well as to keep them maintained in what can be corrosive environments.

It is especially important in these warm, moist environments to construct walls with a high R-value and proper vapor barrier. This prevents energy loss and condensation and protects the pool enclosure and adjacent spaces from corrosion, fascia discoloration, and undesirable organism growth. Chloramines cause pool environment air to be acidic and corrosive to stainless and carbon steel. Whenever possible use building materials, such as aluminum, that will endure in this environment.

Outdoor air

As indoor pools maintain relatively warm temperatures (82–86 °F), in many climates there are significant hours where sensible heating is required to maintain space conditions. This is true not only for pools which use outdoor air for dehumidification, but also for mechanical dehumidifiers operating at the minimal outdoor air requirement prescribed by ASHRAE.

Several energy recovery methods are available to recapture the sensible heat normally rejected to the atmosphere in the form of exhaust air.

- **Aluminum flat plate heat exchanger:** In addition to offering high levels of sensible efficiency (65–75%), this method of energy recovery is also very simple, without any moving parts, refrigerants, or pumps.
- **Heat pipe**: Sensible heat transfer between two adjacent airstreams using a closed refrigeration loop with slightly lower sensible efficiencies (45–55%). Requires an industrial coating for corrosion resistance and full refrigeration charge to operate.
- **Runaround coil system:** Hydronic coil system to transfer energy between two or more airstreams at slightly lower sensible efficiencies (45–55%). Commonly used when outdoor air intakes and exhaust air outlets are not located near one another.

What are chloramines?

Chlorine is the predominant disinfectant used to sanitize pool water, and treats both water-borne pathogens and contaminants introduced by swimmers. Chloramines are gases that form as a disinfectant by-product of chlorination.

Chloramines are toxic to occupants and cause corrosion. The only reliable way to detect chloramines is with your nose. If you notice a chlorine-type smell, the air is probably contaminated with chloramines.

- **Exhaust air heat pump:** Refrigeration system used to move energy from the exhaust airstream to the supply airstream. Provides an effective way of moving energy throughout the system but adds significant complexity and additional electrical load.

Additionally, there are several energy recovery devices that are not recommended in pool applications.

- **Sensible wheels:** Although they only transfer sensible energy, these wheels will carry moisture from the return airstream to the outdoor airstream and frost regularly in winter.
- **Enthalpy wheels:** In addition to posing a frosting risk, these devices will transfer unwanted moisture back into the outdoor air.
- **Enthalpic plates:** Like an enthalpy wheel, these devices will transfer moisture back into the outdoor air.

Infiltration

Infiltration air is outdoor air or conditioned air entering the indoor aquatic facility through its enclosure due to pressure differential. It is desirable to maintain a slight negative pressure in the pool space to keep chloramines from entering adjacent spaces. This can be accomplished in an energy efficient manner and on a real-time basis by controlling the difference between the exhaust airflow and the outdoor airflow through the pool dehumidification unit.

Lighting

Typical practice regarding lighting and fan sensible heat loads is to include them in the sensible cooling load calculation and ignore them when calculating sensible heating load, to be conservative when determining the design heating capability required.

Lighting loads can be reduced by incorporating natural lighting into the envelope design and by using efficient lighting options. However, note that the addition of windows will require air distribution modifications to prevent condensation.

Fan Motor Heat

Fan motor heat loads can be reduced by selecting efficient fans such as direct drive airfoil blade plenum fans. Use of forward curved fans, propeller fans, and belt drive fans should be avoided due to their low fan efficiency, sheave corrosion, belt losses, and extra maintenance costs.

Air Heating and Cooling Latent Loads

Indoor aquatic facilities have the following latent loads:

- Pool evaporation
- Outdoor air
- Infiltration
- Spectators (in a competition pool setting)

Pool Evaporation

A large, heated body of water continuously evaporates moisture into the air. The evaporation rate depends on vapor pressure at the water surface, which increases when water temperature increases, and vapor pressure of the air, which decreases when the air dew point decreases. Pool activities also affect the evaporation rate. The more activity in a pool, the more evaporation.

BEST PRACTICE TIP

The pool water evaporation rate is the largest component of the space latent load, and can be controlled by making the following design choices:

1. **Keep pool air temperature 2 °F above the water temperature.** Pool operators often choose to lower space temperature or raise water temperature in a well-intentioned but misguided attempt to reduce energy costs or make swimmers or other occupants more comfortable. However, this practice tends to have the opposite effect. It greatly increases evaporation rate and total energy costs and causes swimmers exiting the pool to feel cold.
2. **Control the space relative humidity (RH) to 60% whenever possible.** When using outdoor air to dehumidify, it is acceptable to drop below 60% when ambient conditions allow. Evaporation increases 30% for every 10% drop in pool space RH (see Figure 2). In colder months, a lower RH naturally occurs from introducing outdoor air to improve indoor air quality. This is often desirable because it prevents condensation on exterior surfaces without the need to operate cooling coils for mechanical dehumidification during winter. To learn more, see “Choosing the best RH design set point” on the next page.
3. **Use a pool cover at night, if feasible.** A pool cover nearly eliminates evaporation during unoccupied operation. It also stops pool chemical migration to the air and may allow reduction in outdoor air amounts. However, pool covers do not always match pool geometry. They also can take up space when spooled, and operators often find them cumbersome to deploy manually or expensive to deploy automatically.

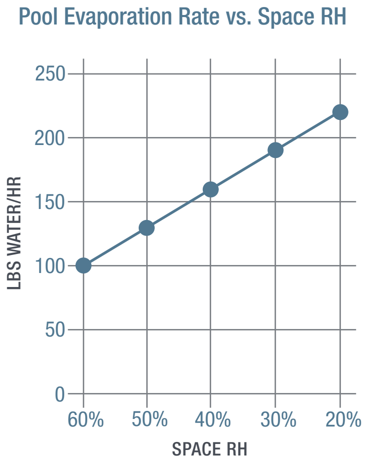


Figure 2:
Pool Evaporation Rate and RH
The pool evaporation rate is the largest component of the space latent load. This graph shows that the evaporation rate increases 30% for each 10% decrease in space relative humidity.

Choosing the best RH design set point

The higher the RH design set point, the lower the dehumidification load. ASHRAE recommends maintaining RH between 40–60% to prevent undesirable organism growth, and between 50–60% RH for swimmer comfort.

BEST PRACTICE TIP

Using 60% RH as your design set point will conserve the most energy and reduce equipment first costs. Designing for 50% RH instead of 60% RH can double required cooling capacity and increase operating costs by 50% (see Figure 3).

Table 2 shows how component energy costs change when RH changes. These costs are percentages of total operating costs, which increase by a factor of 1.5 when RH decreases from 60% to 50% (Figure 3). For example (see shaded cells in Table 2), if total operating costs at 60% RH are $100,000, compressor energy cost is $15,000 (15%). However, at 50% RH, total operating costs increase to $150,000, and compressor energy cost is $52,500 (35%).

When space design temperature is at the higher end of the recommended range (86 °F), consider designing for 55% RH to have dehumidification capacity available to make the environment more comfortable when clothed and dry spectators are present. Also, it may be desirable to reduce to as low as 40% RH at night during cold months to prevent condensation in indoor aquatic facilities with exterior walls. This can often be achieved with the low-humidity outdoor air already being introduced to remove air contaminants.

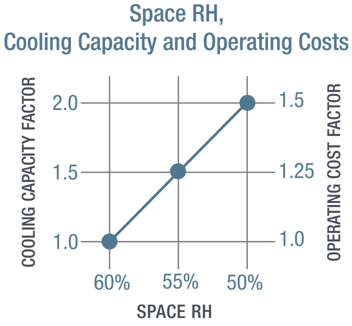


Figure 3: RH, Capacity, and Costs
Using a 60% RH design set point instead of 50% reduces first and operating costs.

Table 2:
Component energy costs by percentage, indoor aquatic facility, 82 °F air temperature*

Component	All Climates, Average % of total		Atlanta % of total		Chicago % of total	
	60% RH	50% RH	60% RH	50% RH	60% RH	50% RH
Fans	40	25	41	27	37	26
Envelope and ventilation	25	15	18	12	34	24
Pool water heating	20	20	22	19	19	18
Compressors	15	35	19	42	10	32

Note
* These are projected annual energy costs of an indoor aquatic facility before dehumidification system selection, using gas heat, no energy recovery, occupied 16 hrs/day, and ventilating with minimum outdoor air as defined by ASHRAE 62.

Two strategies for dehumidifying aquatic facilities

Mechanical pool dehumidification systems use cooling coils year-round to extract moisture from indoor air.

Outdoor air dehumidification systems replace moist indoor air with dry outdoor air for most of the year, and use cooling coils when outdoor air moisture content is high in summer.

Outdoor Air

Entering outdoor air has a latent load, either positive (as with moist summer air), or negative (as with dry winter air). During many months of the year the lack of humidity in outdoor air either completely cancels out the pool water evaporation load (winter) or greatly reduces it (spring and fall) resulting in minimal to no net dehumidification load to the space. Using outdoor air as a dehumidifying source when it is cost-effective, rather than using a mechanical dehumidification system, can greatly reduce total operating costs, provide better indoor air quality, and improve system reliability.

Infiltration

Infiltration air entering from an adjacent space or from outdoors will likely reduce the latent load since the pool space is generally warmer and more humid than other spaces. The (usually drier) infiltration air coming in through leaky joints and cracked or open doors will displace the moist pool area air. This infiltration can be controlled by actively controlling the pressure differential as discussed above. Refer to the *2021 ASHRAE Handbook: Fundamentals*[1] for more information.

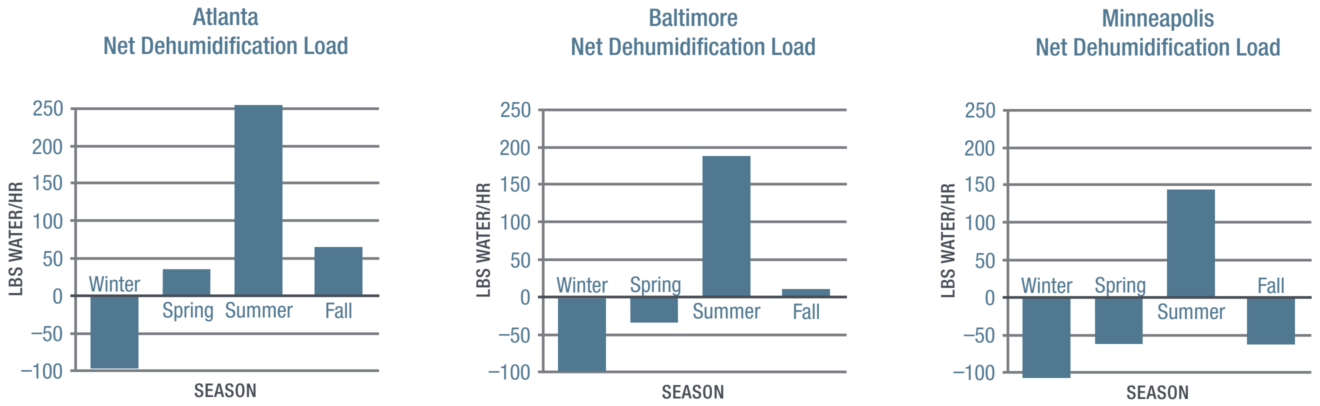
It is important to make a distinction between displacement of water vapor by air movement through gaps such as doors and cracks (infiltration) and moisture diffusion through the building materials of the enclosure due to vapor pressure gradients (exfiltration). If an intact vapor barrier is not provided, moisture will migrate from the high vapor pressure of the pool through the walls to the lower pressures of outdoor ambient air or the adjacent space, regardless of the pool air pressure differential to surrounding spaces or outdoor ambient air.

Spectators

Spectators observing events add to the space dehumidification load. Using ASHRAE guidelines for people seated at an event and modifying for the temperature and humidity of a pool space, the spectator latent load can be estimated at 0.16 lbs/hr per spectator.

Seasonal Effect on Dehumidification

The sum of the latent loads is greatly influenced on a seasonal basis by the outdoor air load and the pool evaporation rate. It is not an even load over the course of the year; in fact, the only time the seasonal averaged loads exceed 25% of the design load is during summer. See Figure 4 on the next page.



Data based on minimum 25% outdoor air, occupied mode

Figure 4: Net Dehumidification Load Profiles by Season and City When Dehumidifying with Minimum 25% Outdoor Air
In an indoor aquatic facility, the net dehumidification load varies by season and climate and derives primarily from the outdoor air latent load (positive or negative) and pool evaporation rate.

POOL VENTILATION DESIGN

Supply Air Delivery Rate

The supply air delivery rate that provides the ventilation, air distribution, dehumidification, and heating and cooling requirements of these spaces is defined by ASHRAE in air changes per hour (ACH), which can also be converted to cubic feet per minute (cfm).

In very tall pool spaces, consider using HVLS fans to provide mixing and prevent stratification and corrosion rather than sizing the air handler and duct system for air changes based on total space volume.

$$SA\ Delivery\ Rate\ [cfm] = \frac{Space\ Volume\ [ft^3] \times QTY\ Air\ Changes\ \left[\frac{changes}{hour}\right]}{60\ \left[\frac{minutes}{hour}\right]}$$

The total amount of supply air delivered to a pool space includes outdoor air and recirculated air.

Start With Six (6) Air Changes

To meet air distribution requirements, ASHRAE recommends a supply air delivery rate of 4–6 ACH for recreational pools and 6–8 ACH for competition pools with spectators. Innovent recommends starting with a supply air delivery rate of 6 ACH. If you are confident that the air distribution requirements can be met with less than 6 ACH, this amount can be reduced to a minimum of 4 ACH for recreational pools.

Adjust Air Changes to Meet Temperature Requirements

Enclosures with very high sensible loads such as facilities with large amounts of glass in the enclosure, or single-story spaces with high dehumidification loads or air volume (such as therapy pools) can require more air changes to provide an acceptable supply air temperature. This is especially important for occupants wearing wet bathing suits who could become chilled when out of the water. Therapy pool water temperatures are often above 90 °F, which normally requires a high space temperature (max. 86 °F) to keep swimmers comfortable and reduce water heating and chemical treatment costs. However, there are often clothed occupants in pool therapy spaces that would be too warm in an 86 °F space. A compromise is designing for a space temperature of 84 °F with a higher air change rate to help keep clothed occupants more comfortable.

Tall Spaces and Supply Air Delivery Rate

Some recreation centers with water slides, and aquatic centers designed for large competitions, have very high ceilings (35–50+ ft). However, other than a water slide, no people or water can usually be found at the upper heights in these facilities. It may be more economical to use high-volume low-speed (HVLS) fans to provide mixing and prevent stratification and corrosion at the upper heights while designing the ducted air system for 6 ACH based on a 30–35 ft pool space height, rather than size the air handler and duct system for air changes based on the total space volume. This can provide significant savings in duct and fan motor costs. It is important to provide safe maintenance access to HVLS fans if they are used in the design.

Spectators and Supply Air Delivery Rate

Spectator seating areas in competition pools are often elevated, beginning about 10–15 ft above the pool deck. The best practice for providing maximum comfort in spectator areas is to physically separate them from pool areas with glass and use a dedicated air handling unit to deliver conditioned air and proper ventilation to that area. However, this method often proves too costly, and spectator areas are often located within the pool space.

Air returned from a pool space to air handling equipment is contaminated with chloramines. Before resupplying to the space, the air handling unit must introduce enough outdoor air to create a healthy space and durable enclosure.

For large competition pools, a good option is to have a dedicated air handling unit for the spectator area that is incorporated into the total supply delivery rate of the pool air distribution system. This provides the capability of meeting spectator area ventilation and air distribution requirements while providing a slightly more comfortable supply air temperature. Due to budgetary concerns, the most common design for supplying air to spectator areas utilizes the main pool air handler to ventilate and condition both pool and spectator areas. In this case, the air volume of spectator areas must be included when sizing the main pool air handler and the minimum supply air delivery rate must be 6 air changes per hour, as recommended by ASHRAE. This strategy usually requires a higher percentage of outdoor air to meet system ventilation efficiency requirements.

For more information about system ventilation efficiency requirements, see ASHRAE Standard 62.1-2022.[2]

Return Air Rate

ASHRAE recommends keeping pool spaces at a negative pressure of 0.05 to 0.15 inches of water relative to the outdoors and adjacent areas of the building to keep humidity, chemicals, and odors confined to the pool space. To maintain negative pressure in the pool space, the exhaust air rate must exceed the outdoor air supply rate by a margin defined as the excess exhaust air rate. The excess exhaust air rate accounts for infiltration air due to pressure control, which will vary depending on enclosure tightness and doors opening. Because of this variability, negative pressure should be actively controlled, if possible.

Innovent recommends designing the excess exhaust air rate at 10% of the supply air delivery rate. When systems are commissioned, we've found that the average excess exhaust resulting from pressure control for a typical pool ranges from 2–10% of supply air volume.

$$Design\ Return\ Airflow\ Rate\ [cfm] = 1.1\ \times Supply\ Air\ Delivery\ Rate\ [cfm]$$

Supply air volume directed at exterior wall and roof surfaces must be sized to wash the surfaces with enough air to prevent condensation, especially on glass surfaces.

AIR DISTRIBUTION

Now that the total supply and return air volume to be ducted is determined, the air distribution system can be designed. Proper air distribution in an indoor aquatic facility:

- Prevents condensation
- Prevents corrosion
- Prevents temperature and humidity stratification
- Removes airborne disinfectant by-products such as chloramines
- Provides effective mixing throughout the space
- Delivers fresh, outdoor air to the swimmers' breathing zone (right above the water), to people on the deck, and to spectators.
- Helps maintain the pool space at a slight negative pressure relative to adjacent spaces in the building and outdoor ambient pressure. This prevents exfiltration of chloramines and moisture through openings and leaks in the enclosure.

Air Distribution System Construction

Coated steel can be used successfully if the coating is intact, but any scratches or poorly coated areas will result in corrosion from chloramines that can reduce the useful life of the pool enclosure, air distribution, and air handling equipment and, in the extreme case, cause structural failure.

Aluminum is the preferred material for ducting if metal duct is desired. Fabric duct is also commonly used. Air handler interior walls, floors (including drain pans), and components such as dampers, fan wheels, and heat exchangers should be made of aluminum, and coils should be completely coated with an elastic baked epoxy or phenolic coating. Components that must be made of steel for strength, such as fan isolation bases, should have an epoxy or phenolic coating. Use of coated steel inner walls and floors in air handlers should be avoided because the coatings are easily scratched during servicing no matter what type of coating process is used, and the underlying steel corrodes, shortening the life of the unit.

Supply Air Distribution

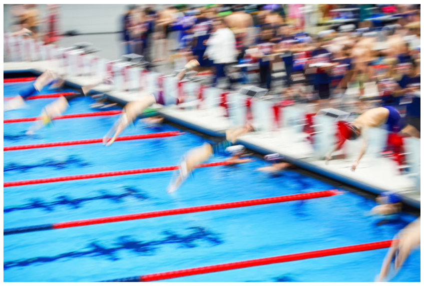
The design of the supply air distribution system for an indoor pool is complex because a typical space has several micro-zones with specific needs for total and outdoor airflow.

Supply air to the breathing zone over pool and up to 72" above the deck

Some supply air must be directed toward the pool surface to move chloramines away from the swimmer's breathing zone just above the water surface. ASHRAE recommends limiting air velocity at the pool surface to 30 fpm. Some supply air also must be directed toward deck areas (for

Air movement over pool surfaces

In the past, HVAC designers limited air movement over pool surfaces to reduce pool water evaporation and the corresponding costs of heating and adding chemicals to pool water. Return air grilles were only placed high in the space, away from the water. This practice resulted in poor removal of chloramines, supply air short-circuiting, and an unhealthy space with a shortened useful life. Since 1999, ASHRAE has recommended directing a portion of the supply air across the pool surface to displace and direct chloramines to a lower-level return/exhaust point.



Depending on climate, the outdoor air introduced to improve indoor air quality, which is drier than the warm humid return/exhaust air it replaces for most of the year, can reduce or completely eliminate the dehumidification load.

swim teams, lifeguards, and people on the deck), toward the spectator seating area (if a separate unit is not provided for this area), and toward the lower-level exterior-facing walls and windows to prevent condensation and corrosion. It may be possible to use a common supply duct with directed nozzles or diffusers for the lower-level supply requirements (air to the pool surface, air to the deck breathing zone, and lower level condensation prevention).

Supply air to exterior glass, walls, and roof

Supply air volume directed at exterior wall and roof surfaces must be sized to wash the surfaces with enough air to prevent condensation, especially on glass surfaces. To meet swimmer comfort and energy efficiency requirements, the ideal pool space RH is 60%, which results in a high dew point of typically 67–70 °F and a high potential for condensation. In winter, the dry outdoor air introduced to improve indoor air quality forces the RH down (typically to the 40–50% RH range), but the space dew point typically remains high at 55–65 °F. Interior surfaces should be kept 5 °F above the space dew point by washing entire surfaces with supply air to prevent condensation.

Supply air to spectator areas

If the spectator area is located within the pool space, supply air directed to this area must deliver the design minimum outdoor air amount for a swim meet (7.5 cfm/spectator + 0.06 cfm/ft^2 of area, as described in Table 3).

Depending on the amount of supply airflow needed for spectator areas and enclosure condensation and corrosion prevention above the breathing zone, the ratio of air delivered high in the space vs. low in the space may vary from 30% high/70% low for a lower-height facility with few windows, to 60% high/40% low for a tall facility with a large spectator space and significant potential for condensation on the exterior surfaces.

Table 3: Minimum Ventilation Rates in Breathing Zone[1]

	People Outdoor Air Rate		Area Outdoor Air Rate			Default Values			
						Occupant Density (see Note 4)	**Combined Outdoor Air Rate** (see Note 5)		
Occupancy Category: Sports and Entertainment	cfm/person	L/s•person	cfm/ft^2	L/s•m^2	**Notes**	#/1000 ft^2 or #/100 m^2	cfm/person	L/s•person	Air Class
Spectator areas	7.5	3.8	0.06	0.3	H	150	8	4.0	1
Swimming (pool & deck)	—	—	0.48	2.4	C	—			2

Notes

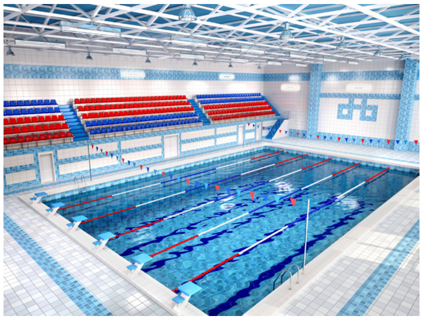
1 From TABLE 6.2.2.1, *ANSI/ASHRAE Standard 62.1-2022. Ventilation for Acceptable Indoor Air Quality.*

4 Default occupant density: The default occupant density shall be used where the actual occupant density is not known.

5 Default combined outdoor air rate (per person): Rate is based on the default occupant density.

C Rate does not allow for humidity control.

H Ventilation air for this occupancy category shall be permitted to be reduced to zero when the space is in occupied-standby mode.



The chlorides in chloramines attack building materials exposed to pool air (especially carbon steel and stainless steel), causing corrosion and early component failure.

The effectiveness of the supply distribution required to meet the ventilation requirements of each zone will have an impact on the amount of outdoor air required to be included in the supply air delivery rate.

It may be possible to use a common supply duct, with properly sized and directed nozzles or diffusers, to deliver air to spectators and upper-level areas requiring condensation prevention and mixing, with exhaust air collection at a high return point.

Return Air Inlets

A combination of low and high return air grilles promotes chloramine removal and good mixing throughout the space, as well as preventing stratification and corrosion.

Low-level return

At the low return level there are three strategies for removing chloramines that concentrate over the pool:

1. **Low-level deck return,** with grille(s) located a few feet above deck level that mix with upper-level return air prior to the air handling unit.
2. **Low-level deck exhaust,** with grille(s) located a few feet above deck level connected to a dedicated exhaust duct to avoid mixing with return air.
3. **Source capture,** a system that has multiple exhaust points in the water level pool gutter that are manifolded into one exhaust duct.

Source capture systems are most effective at removing chloramines when water is undisturbed or unoccupied. Systems with low-level deck return or exhaust may be better for swimmer health because chloramines are displaced and moved away from where swimmers breathe. Source capture systems and dedicated low-level deck exhaust ducts should theoretically remove a higher concentration of chloramines. They often can be incorporated into the pool air handler for additional first cost. A low-level deck return that mixes with upper-level return air before connection to the air handling unit has the lowest first cost of these three strategies and is very effective at chloramine removal when combined with proper ventilation air.

High-level return

At the high return level, locate the return point(s) to promote mixing by capturing air supplied to spectator areas and to the upper level for preventing condensation and corrosion. Care must be taken to avoid locating the return point(s) immediately adjacent to supply diffusers to prevent short-circuiting of the supply air.

Outdoor Air Requirement

Air returned from a pool space to air handling equipment is contaminated with chloramines. Before resupplying to the space, the air handling unit must replace enough of the return air with outdoor air to create a healthy space and durable enclosure.

The moisture level of the return air must also be reduced before resupplying the space so that it can absorb evaporated pool water and other moisture from spectators or outdoor air on very humid summer days to maintain the space humidity set point. Depending on climate, the outdoor air introduced to improve indoor air quality, which is drier than the warm humid return/exhaust air it replaces for most of the year, can reduce or eliminate the dehumidification load.

Note: Outdoor air is not a replacement for proper water treatment. The sizing recommendations made in this guide assume an effective water treatment system.

ASHRAE Guidelines

ASHRAE minimum ventilation rate

ASHRAE Standard 62.1 prescribes an amount of outdoor air that, according to the *ASHRAE Applications Handbook* section on natatoriums, is intended to provide acceptable air quality for an average pool using chlorine as the primary disinfectant[3] (see Table 3). Based on this table, the minimum ventilation rate required to be delivered to the breathing zone (minimum amount of outdoor air) is 0.48 cfm/ft^2 for swimming pool and deck areas. The breathing zone is the area between 3 inches and 72 inches above the floor.

The whole surface area of the space, including both deck and pool, is calculated at 0.48 cfm/ft^2. For spectator areas, the minimum ventilation rate is calculated using both the “Area Outdoor Air Rate” and “People Outdoor Air Rate” for the applicable occupancy category (other areas might include hotel recreation spaces).

This is 0.06 cfm/ft^2 plus an additional 7.5 cfm/person when spectators are present. Table 3’s Note H allows outdoor air to be reduced to zero in spectator areas when no people are present. Regarding the minimum ventilation rates in Table 3, the *ASHRAE Applications Handbook* on natatoriums states: “The ventilation requirement may be excessive for private pools and installations with low use and may also prove inadequate for high-occupancy public or water park installations.”[3]

Table 4:
ASHRAE natatorium activity factors[1]

Type of Pool	Typical Activity Factor
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)

Notes
1 From "Places of Assembly: Natatoriums," *2023 ASHRAE Handbook: Applications.* ASHRAE.

Pool water evaporation increases with swimming, diving, and splashing. Activity factors modify the estimated evaporation rate based on pool activity.

Since most public pools are intended to be high occupancy and used heavily, it follows that designing based on the ASHRAE 62.1 ventilation rates prescribed in Table 3 may be inadequate at providing an owner a healthy facility with acceptable air quality. In fact, this has proven to be the case in many installations across the country over the last 20 years. Innovent's experience has supported the conclusion that one ventilation rate cannot meet the requirements of a wide variety of pool types and spaces.

The following affects the amount of outdoor air needed in pool spaces:

1. Facility type and associated swimmer activity level, water agitation, and water features.
2. Air distribution complexity, as discussed in the previous section, and the effectiveness of air distribution at providing outdoor air to each microclimate within the space.

ASHRAE activity factors

ASHRAE defines a pool evaporation rate equation that is valid for pools at normal activity levels, allowing for splashing.[2] For pools with more or less evaporation, activity factors have been defined that modify the estimated evaporation rate based on pool activity (Table 4).

Pool water evaporation increases when water/air surface area increases with swimming, diving, splashing, and water features such as slides, sprays, fountains, dump buckets, etc. The off-gassing of chloramines also increases with the increased surface area, and more water treatment is necessary with higher activity and agitation. A community recreation center with some water features may have two to three times more evaporation than a hotel pool, and a public school pool may have 50% more evaporation than a pool with little agitation like a therapy pool.

System Ventilation Efficiency and Zone Air Distribution Effectiveness

ASHRAE 62.1 describes two concepts regarding the ability of an air distribution system to effectively provide outdoor air to spaces with multiple zones served by the same air distribution system (System Ventilation Efficiency) and with various configurations of supply and return points in the same space (Zone Air Distribution Effectiveness).[2] These two concepts describe the air distribution requirements of most indoor pools.

For example, if ASHRAE 62.1 (Table 3) requires 0.48 cfm/ft^2 outdoor air to be delivered to the breathing zone, but 50% of the supply airflow (and therefore 50% of the outdoor air) is required to be distributed above the breathing zone to provide proper mixing, prevent condensation and corrosion, and provide fresh air for spectators, then the minimum outdoor air in the supply air from the air handling unit would need to be doubled. In another example,

Innovent's minimum outdoor air multipliers (Table 5 on page 19) account for pool activity and ceiling height and therefore achieve more accurate outdoor air calculations.

if 30% of the supply airflow is delivered to the spectator area, then 40–50% of the supply air might need to be outdoor air to deliver the required 7.5 cfm/spectator of outdoor air. These situations might result in a System Ventilation Efficiency of 65–85%. In addition, the Zone Air Distribution Effectiveness for an air distribution configuration that has supply air points on the opposite side of a room from exhaust/return air points, which is often the case in pools, is 80%.

Adjustments Based on Activity Factors and Distribution Requirements

ASHRAE pool activity factors (Table 4) and air distribution factors can be used to modify the minimum ventilation rates prescribed in Table 3 to meet the ventilation requirements of a variety of pool types and spaces more accurately.

Ventilation efficiency decreases as ceiling height and the distance of the supply points from the deck increases. Air distribution requirements to prevent condensation on walls, roofs, and skylights; to supply spectator areas; and to provide good mixing to prevent corrosion and stratification dictate that a significant amount of the supply air (and therefore outdoor air) be delivered to areas above the breathing zone. As a result, the space height may be used as a reasonable proxy for the air distribution factor. Innovent’s experience has shown that the formula in Table 3 provides successful results for low-height pool spaces (15 ft) with relatively low activity.

For pools with greater activity and higher ceilings, the minimum outdoor air rate needs to be increased. This means that for most public pool spaces the minimum amount of outdoor air required to provide a healthy and non-corrosive environment can be significantly more than what ASHRAE prescribes. This is in keeping with the *ASHRAE Applications Handbook*’s statement that the ventilation requirement prescribed in Table 3 “may prove inadequate for high-occupancy public or water park installations.”[3]

Building upon ASHRAE's recommendations and statements and relying on experience gained from designing over 1,500 HVAC systems for a variety of indoor aquatic facility types, Innovent has created minimum outdoor air multipliers that modify ASHRAE's swimming pool and deck ventilation rates to achieve a more accurate minimum outdoor air calculation based on pool activity and ceiling height. See Table 5 on the next page.

Incorporating the minimum outdoor air multiplier from Table 5, the minimum ventilation rate calculation becomes (for pool and deck areas during normal operating mode, not during a swim meet):

$$Minimum\ Ventilation\ Rate\ [cfm] = 0.48\left[\frac{cfm}{ft^2}\right] \times Pool\ \&\ Deck\ Area\ \left[ft^2\right] \times Minimum\ OA\ Multiplier$$

TABLE 5:
Minimum ventilation rate (outdoor air amount) multipliers for indoor aquatic facility pool and deck areas

Pool type	Residential	Therapy/condo	Hotel	Public/school	Community rec	Rec plus	Small hotel water park
Activity factor	0.50	0.65	0.80	1.00	1.25	1.5	2.0
Pool height	MINIMUM OUTDOOR AIR MULTIPLIER						
15 ft	0.85	1.00	1.19	1.39	1.59	1.75	2.06
20 ft	0.89	1.04	1.24	1.45	1.65	1.82	2.14
25 ft	0.92	1.08	1.29	1.50	1.71	1.89	2.23
30 ft	0.96	1.12	1.34	1.56	1.78	1.96	2.31
35 ft	0.99	1.16	1.38	1.62	1.84	2.03	2.39
40 ft	1.03	1.20	1.43	1.67	1.90	2.10	2.47
45 ft	1.07	1.24	1.48	1.73	1.96	2.17	2.55
50 ft	1.10	1.28	1.52	1.78	2.03	2.24	2.63

Note
Minimum ventilation rate (amount of outdoor air required) for an indoor aquatic facility pool and deck area = 0.48 cfm/ft^2 of pool and deck × minimum outdoor air multiplier.

Note: If the pool has a spectator space, the designer should verify that the outdoor air required for swim meet spectators (7.5 cfm/spectator + 0.06 cfm/ft^2) will be provided by the supply air directed at the spectator area. For example, if 30% of the supply air is directed at the spectator area, then multiply the minimum ventilation rate calculated above by 30% and verify that the result is greater than the outdoor air required for spectators, adjusting the minimum ventilation rate up as necessary.

In Innovent's experience, using the minimum outdoor air multiplier has proven very effective at creating healthy indoor pool environments. The great news for owners is that a pool air handling system designed to embrace the health and economic advantages of outdoor air can provide a healthier space at a lower total operating cost than a mechanical dehumidification system.

SUMMARY

Indoor aquatic facilities can benefit greatly from outdoor air and energy recovery. Outdoor air flushes toxic chloramines from the space, making it healthy for swimmers and spectators. Outdoor air is also drier than pool air for most of the year and becomes a natural and efficient way to dehumidify natatorium spaces that have high latent loads. Only in summer, when outdoor dew points are high, is there a need for more expensive mechanical dehumidification. In winter, efficient exhaust air heat recovery warms up entering outdoor air, reducing operating costs.

How much outdoor air is required? It varies depending on factors such as pool type, pool activity, ceiling height, and air distribution complexity and effectiveness. Innovent's outdoor air multiplier, described in Table 5, builds on the foundation of ASHRAE's minimum ventilation rates by taking these factors into account and providing a method to accurately calculate outdoor air requirements for a wide variety of natatoriums.

Other elements that make a difference are thoughtful decisions about space conditions and water temperature, as well as effective air distribution and an enclosure that conserves energy. For more information or assistance, please contact your Innovent representative.

LEARN MORE ABOUT INDOOR AQUATIC FACILITY DESIGN

www.innoventair.com/applications-expertise/natatoriums

Innovent's online resource for healthy and energy efficient indoor aquatic facilities

Design Guide

Special operating modes: Strategies for maintaining IAQ and saving energy when pools are unoccupied, superchlorinated, or hosting swim meets. Gary Lochner.

Chloramines & Pool Operation

Website from The Centers for Disease Control and Prevention

www.cdc.gov/healthywater/swimming/aquatics-professionals/chloramines.html

REFERENCES

1	*2021 ASHRAE Handbook: Fundamentals.* ASHRAE.
2	*ANSI/ASHRAE Standard 62.1-2022: Ventilation for Acceptable Indoor Air Quality.* ASHRAE.
3	*2023 ASHRAE Handbook: Applications.* ASHRAE.

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