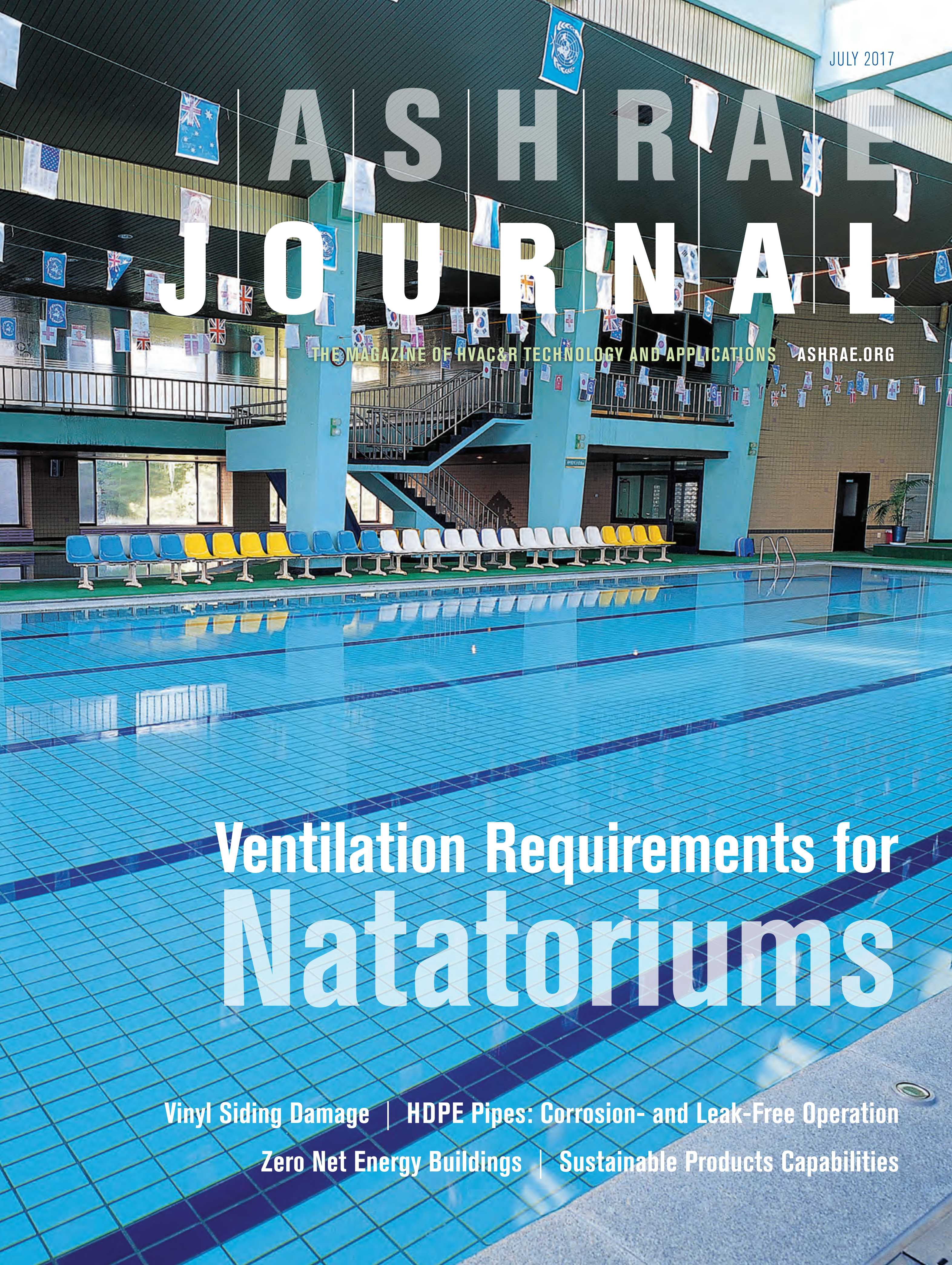

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COMMENTARY


Jay Scott

Getting Ventilation Right in Indoor Pools

Indoor pool environments pose the challenge of requiring a well-designed ventilation system with effective air distribution and enough outdoor and exhaust air to remove toxic and corrosive chloramines.

A technical feature this month describes the factors to consider when calculating outdoor air rates.

The factors include pool type, pool activity, ceiling height, supply and return airflow rates, and air-distribution complexity and effectiveness. The authors also present a methodology that augments ASHRAE Standard 62.1-2016's ventilation rates with minimum outdoor air multipliers to help designers when calculating outdoor air requirements.

MOST SWIMMING POOLS are treated with chlorine. Chlorine binds to contaminants in the water, resulting in chloramines that off-gas into pool air space, irritating skin and eyes and creating respiratory hazards for swimmers and spectators. The chloramines also corrode building materials.

These results are especially true if air-handling systems do not bring in enough fresh air and exhaust enough chloramine-polluted air.

The authors walk through issues that must be understood to design a system that provides a healthy, durable enclosure.

One of those issues is designing the supply air-distribution system. There are complexities in designing such a system because there are different microzones with specific needs for total and outdoor airflow.

First, there is directing supply air to the swimmer's breathing zone and up to 72 in. (1.8 m) above the deck to remove chloramines.

Second, some supply air must be directed to the deck and spectator seating areas and toward lower-level walls and windows to prevent condensation and corrosion.

Elevated areas also require supply air movement for comfort and enough supply air to deliver the ASHRAE Standard 62.1-2016 prescribed outdoor air to spectators.

FOR PUBLIC POOLS with greater activity and higher ceilings, the authors write that the minimum amount of outdoor air required to provide a healthy and noncorrosive environment can be significantly more than what ASHRAE prescribes. The *2015 ASHRAE Handbook—HVAC Applications* confirms that point.

The authors build upon ASHRAE's recommendations and provide a table on Page 23 to modify ASHRAE's pool and deck ventilation rates.

The authors conclude: "Designing with these multipliers and the air distribution guidelines presented in this article have proven effective for accurately calculating the outdoor air requirements of a variety of indoor aquatic facilities."

Enjoy the issue.

Mission Statement: ASHRAE Journal reviews current HVAC&R technology of broad interest through publication of application-oriented articles. ASHRAE Journal's editorial content ranges from back-to-basics features to reviews of emerging technologies, covering the entire spectrum of professional interest from design and construction practices to commissioning and the service life of HVAC&R environmental systems.

ASHRAE

Ventilation Requirements For Indoor Pools

BY GARY LOCHNER, MEMBER ASHRAE; LYNNE WASNER, ASSOCIATE MEMBER ASHRAE

Healthy and durable indoor pool environments require a well-designed ventilation system with effective air distribution and sufficient outdoor and exhaust air to remove toxic and corrosive chloramines from the space. A key question for system designers becomes: How much outdoor air is required?

This article describes factors to consider when calculating outdoor air rates, including pool type, pool activity, ceiling height, supply and return airflow rates, and air distribution complexity and effectiveness. We also explain why ASHRAE Standard 62.1-2016's minimum ventilation rates for swimming pool, deck, and spectator areas may not always produce a durable facility with acceptable air quality. We present a methodology that augments Standard 62.1-2016's ventilation rates with minimum outdoor air multipliers to help designers represent a variety of pool types, spaces, and activities when calculating outdoor air requirements.

Removing Chloramines Is the Goal

Most swimming pools are treated with chlorine. When chlorine binds to water contaminants, it forms chemicals such as dichloramine and trichloramine. These chloramines, which off-gas into pool space air, corrode building materials, irritate skin and eyes, and are a known respiratory health hazard for swimmers, lifeguards, and other pool occupants. A chlorine-type odor indicates chloramines are present in a space.

The Centers for Disease Control and Prevention says, "Chloramines can build up in the water, which means they can build up in the air if there is not enough fresh air surrounding pools and other places people swim in chlorinated water. This is particularly true for indoor aquatic facilities where air-handling systems are not bringing in enough fresh air and exhausting enough chloramine–polluted air, which is common during winter months when heating costs increase. Chloramines that off-gas from the water are heavier than air. This

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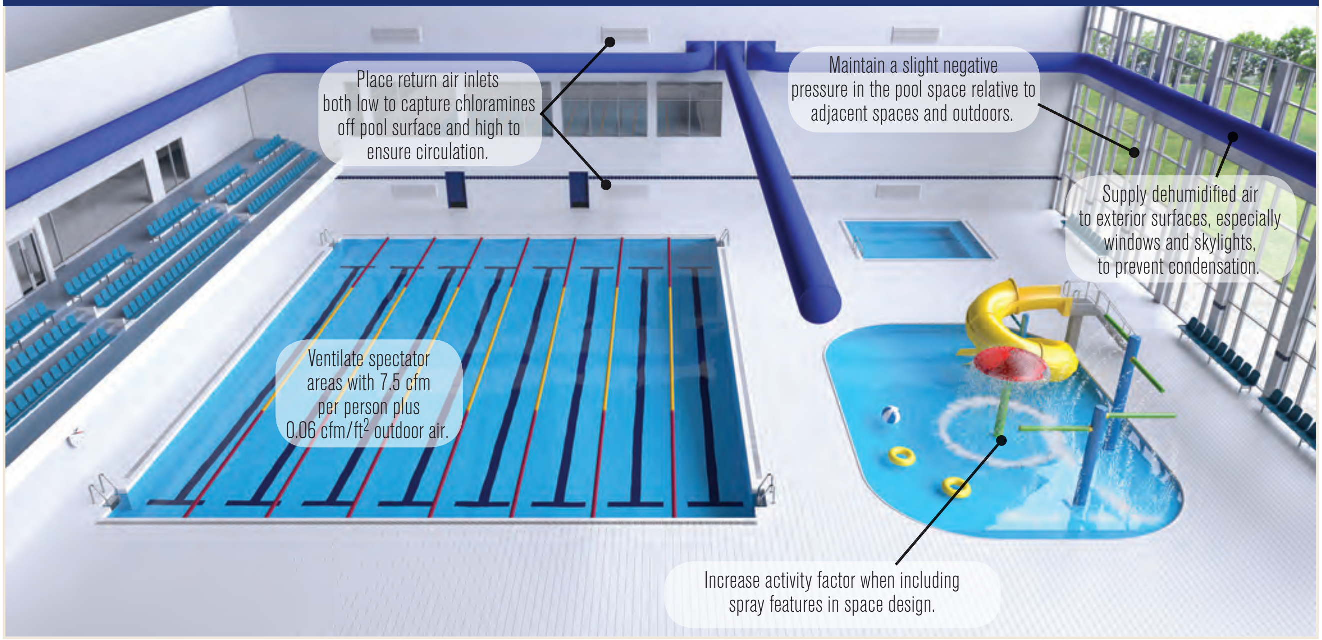
FIGURE 1 Creating a healthy space and protecting it from corrosion requires delivering sufficient outdoor air to all microzones including spectator areas, the breathing zones of swimmers and people on the deck, exterior surfaces, and upper levels of the space.



means they settle on top of the water's surface where they can cause negative health effects in swimmers and spectators."[1]

When chloramines concentrate above the water surface, it can be challenging to maintain proper water chemistry. Chloramine-polluted air is also acidic and corrodes stainless and carbon steel, which can cause structural deterioration. Effective water treatment supplemented with an ozone or UV system and limiting entry of biological contaminants into the pool (through showering, for example) can reduce chloramine production.

An understanding of the following issues is necessary to design a system that effectively and efficiently removes chloramines and provides a healthy, durable enclosure.

Air Distribution

Pool spaces are often very tall (from 15 ft to 50 ft [4.6 m to 15.2 m]) and require the air distribution system to provide good mixing throughout the space to prevent stratification and dead spots, which can lead to severe corrosion. Within these tall spaces, a typical indoor pool space has several microzones, including areas with swimmers, people on the deck, spectator areas, and exterior walls and roofs that require condensation and corrosion prevention.

Proper air distribution in an indoor aquatic facility:

- Prevents condensation, corrosion, and stratification;
- Removes airborne disinfectant by-products such as chloramines;
- Provides effective mixing throughout the space; and
- Delivers fresh air to the breathing zones of swimmers, people on the deck, and spectators.

Supply Air Distribution

The design of the supply air distribution system for an indoor pool is complex because it can have several microzones with specific needs for total and outdoor airflow.

Supply air to the breathing zone over the pool and up to 72 in. (1.8 m) above the deck. Some supply air must be directed toward the pool surface to move chloramines away from the swimmers' breathing zone just above the water surface. (Note that the *2015 ASHRAE Handbook—HVAC Applications* states "air movement over the pool water surface must not exceed 30 fpm [0.15 m/s]."[2]) Some supply air also must be directed toward deck areas (for swim teams, lifeguards, people on the deck), toward the spectator seating area (if at deck level and if a separate air-handling 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, roof, and spectators beyond 72 in. (1.8 m) above the deck. The pool enclosure must be designed with enough R-value and a thermal break to prevent surface condensation, and with a vapor barrier to stop moisture migration from the high vapor pressure of the pool space into and through walls. Supply air volume directed at exterior wall, roof, and glass surfaces must be sized to keep them above the space dew point to prevent condensation. This can be challenging for windows, glass walls, and skylights. To meet swimmer comfort and energy-efficiency requirements, 60% RH is the ideal pool space relative humidity, which results in a high dew point of typically 67°F to 70°F (19.4°C to 21.1 °C) and a high potential for condensation. In winter, the dry outdoor air introduced to improve indoor air quality forces the relative humidity down (typically to the 40% to 50% RH range), but the space dew point is still high at 55°F to 65°F (12.8°C to 18.3°C).

Elevated spectator areas require supply air movement for comfort and enough supply air to deliver the Standard 62.1-2016 prescribed outdoor air to spectators when present. It may be possible to use a common supply duct for the upper level supply requirements. For space heights of 35 ft to 50-plus ft (10.7 m to 15.2-plus m), using high volume, low speed fans may offer an economical solution to meet air distribution requirements at upper heights without including that air volume in the ducted distribution system.

Location of Return Air Inlets

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

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 and dedicated low-level deck exhaust ducts should, theoretically, remove a higher concentration of chloramines. The exhaust air can be incorporated into the pool air handler for a reasonable first-cost add. A low-level deck return (Strategy 1 above) 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. Systems with low-level deck return or low-level deck exhaust (Strategy 2) may be better for swimmer health because chloramines are displaced and moved away from where swimmers breathe.

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.

Determining the Supply Air Delivery Rate

The supply air delivery rate that meets the ventilation, air distribution, dehumidification, and heating and cooling requirements of pool spaces is defined by ASHRAE in air changes per hour (ach), which can be converted to cfm or L/s:

Supply air delivery rate =
(Room volume × Number of air changes/h)/60 min/h

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

Supply air delivery rate =
Outdoor air rate + Recirculated air rate

Start With a Supply Air Delivery Rate of Six Air Changes Per Hour

To meet air distribution requirements, ASHRAE recommends a supply air delivery rate of 4 ach to 6 ach for recreational pools and 6 ach to 8 ach for competition pools with spectators. Start with a supply air delivery rate of 6 ach, and if the designer is confident that all air distribution requirements can be met with less airflow, it may be acceptable to reduce this amount for recreational pools (minimum 4 ach) per the *2015 ASHRAE Handbook—HVAC Applications* (Chap. 5, Natatoriums section).

Adjust Supply Air Delivery Rate to Avoid Uncomfortable Supply Air Temperature

Enclosures with very high sensible loads (such as facilities with high solar loads due to large amounts of glass), or single-story spaces (such as many therapy pools) can require more air changes to provide a comfortable supply air temperature for swimmers. A practical minimum supply temperature is about 65°F (18.3°C).

Supply Air Delivery Rate to Spectator Areas

Spectator seating areas in competition pools are often elevated above the pool deck and located within the pool space.

For large competition pools, a good option is a dedicated air-handling unit for the spectator area that is incorporated into the total supply air 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. A dedicated unit also allows reducing outdoor air to spectator areas when unoccupied.

Due to budgetary concerns, the most common design for supplying air to spectator areas uses 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 ach, 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 62.1-2016.[3]

Return Airflow Rate

ASHRAE recommends keeping pool spaces at a negative pressure of 0.05 in. w.g. to 0.15 in. w.g. (12.4 Pa to 37.3 Pa) 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 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.

Return airflow rate = Supply air delivery rate + Excess exhaust air rate

Our experience shows that the average excess exhaust resulting from pressure control for a typical pool ranges from 2% to 10% of supply air volume after commissioning. Therefore, to be conservative the authors recommend designing the excess exhaust air rate at 10% of the supply air delivery rate.

Design for return airflow rate = 1.1 × Supply air delivery rate

Determining the Outdoor Air Portion of the Supply Air

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 it can absorb evaporated pool water and moisture from spectators and/or outdoor air on very humid days to maintain the space humidity setpoint. 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.

Use ASHRAE Standard 62.1-2016 as a Basis

ASHRAE minimum ventilation rate. Standard 62.1-2016 prescribes an amount of outdoor air that, per the *2015 ASHRAE Handbook—HVAC Applications* section on natatoriums,[2] is intended to provide acceptable air quality for an average pool using chlorine as the primary disinfectant (see *Table 1*). 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 (2.4 L/s·m^2) for swimming pool and deck areas. The breathing zone is the area 3 in. to 72 in. (76 mm to 1.8 m) above the floor.

Table 1's Note B defines the deck area as "the area surrounding the pool that is capable of being wetted during pool use or when the pool is occupied." Wetted deck areas and the pool itself can off-gas chloramines, which must be removed with ventilation. Any deck areas not capable of being wetted must be designated as another occupancy category (such as spectator area). Since deck areas for competition pools are not typically large, and the layout of most recreational pools has minimal possibility of dry surface, the conservative approach for the designer is to include all pool and deck areas in the calculation.

For spectator areas (and any deck area the designer determines is not capable of being wetted during pool use), 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). For spectator areas, this is 0.06 cfm/ft^2 (0.3 L/s·m^2) plus an additional 7.5 cfm/person (3.8 L/s·person) when spectators are present. *Table 1*'s Note A allows outdoor air to be reduced to zero in spectator areas when no people are present.

Regarding the minimum ventilation rates in *Table 1*, the *2015 ASHRAE Handbook—HVAC Applications* section 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."[2]

Since most public pools are intended to be high occupancy and used heavily, it follows that designing based on the Standard 62.1-2016 ventilation rates prescribed in *Table 1* may be inadequate at providing an owner a durable facility with acceptable air quality. 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:

TABLE 1 Minimum ventilation rates in breathing zone.[4]

Occupancy Category: Sports and Entertainment	People Outdoor Air Rate (cfm/person)	Area Outdoor Air Rate (cfm/ft^2)	Default Values	
			Occupant Density[c] (Occupants/1,000 ft^2)	Combined Outdoor Air Rate[d] (cfm/person)
Spectator Areas[a]	7.5	0.06	150	8
Swimming (Pool and Deck)[b]	–	0.48	–	

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

[b] Rate does not allow for humidity control. "Deck area" refers to the area surrounding the pool that is capable of being wetted during pool use or when the pool is occupied. Deck area that is not expected to be wetted shall be designated as an occupancy category.

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

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

- Facility type and associated swimmer activity level, water agitation, and water features; and
- Air distribution complexity, as discussed earlier in the Air Distribution 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 and a limited area of wetted deck.[2] For pools with more or less evaporation, activity factors have been defined that modify the estimated evaporation rate based on pool activity (*Table 2*).

TABLE 2 ASHRAE natatorium activity factors.[2]

Pool Type	Typical Activity Factor[a]
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)

[a] Activity factors are based on industry experience.

Pool water evaporation increases when water/air surface area increases with swimming, diving, splashing, and water features such as slides, sprays, and fountains. The off-gassing of chloramines also increases with 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 minimal agitation (like a therapy pool). Therefore, it is important to consider the activity factor when determining the minimum outdoor air required.

System ventilation efficiency and zone air distribution effectiveness. Standard 62.1-2016 includes concepts regarding the ability of an air distribution system to effectively deliver outdoor air. System ventilation efficiency is relevant for spaces with multiple zones served by the same air distribution system. Zone air distribution effectiveness is relevant for various configurations of supply and return points in the same space.[3] These two concepts describe the air distribution requirements of most indoor pools.

For example, Standard 62.1-2016 (*Table 1*) prescribes 0.48 cfm/ft^2 (2.4 L/s·m^2) outdoor air to be delivered to the breathing zone. But, if 50% of the supply airflow (and, therefore, 50% of the outdoor air) is required to be distributed/used 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, if 30% of the supply airflow is delivered to the spectator area, then 40% to 50% of the supply air might need to be outdoor air to deliver the required 7.5 cfm/spectator (3.8 L/s·spectator) of outdoor air. These situations might result in a system ventilation efficiency of 65% to 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%.

Adjust ASHRAE-Defined Ventilation Rates for Activity, Air Distribution Requirements

ASHRAE pool activity and air distribution concepts can be used to modify the minimum ventilation rates prescribed in *Table 1* to more accurately meet ventilation requirements of a variety of pool types and spaces.

TABLE 3 Minimum ventilation rate (outdoor air) multipliers to adjust for activity factor and air distribution complexity.

		POOL TYPE					
		THERAPY/ CONDO	HOTEL	PUBLIC/ SCHOOL	COMMUNITY RECREATION	RECREATION PLUS	SMALL HOTEL WATER PARK
		ACTIVITY FACTOR					
		0.65	0.80	1.00	1.25	1.5	2.0
		MINIMUM OUTDOOR AIR MULTIPLIERS					
POOL SPACE HEIGHT	15 ft	1.00	1.19	1.39	1.59	1.75	2.06
	20 ft	1.04	1.24	1.45	1.65	1.82	2.14
	25 ft	1.08	1.29	1.50	1.71	1.89	2.23
	30 ft	1.12	1.34	1.56	1.78	1.96	2.31
	35 ft	1.16	1.38	1.62	1.84	2.03	2.39
	40 ft	1.20	1.43	1.67	1.90	2.10	2.47
	45 ft	1.24	1.48	1.73	1.96	2.17	2.55
	50 ft	1.28	1.52	1.78	2.03	2.24	2.63

The minimum ventilation rate (outdoor air required) for indoor aquatic facility pool and deck areas = 0.48 cfm/ft^2 of pool and deck × Minimum outdoor air multiplier. The design minimum outdoor air amount shall not be below the applicable local code requirement, whether ASHRAE Standard 62.1 or a different standard is used.

Ventilation efficiency decreases as ceiling height increases 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 two air distribution concepts.

The ventilation rates in *Table 1* have proved successful for low-height pool spaces (15 ft [4.6 m]) with relatively low activity. For public pools with greater activity and higher ceilings, the minimum amount of outdoor air required to provide a healthy and noncorrosive environment can be significantly more than what ASHRAE prescribes in *Table 1*. This is in keeping with the *2015 ASHRAE Handbook—HVAC Applications*'s statement that the ventilation requirement prescribed in *Table 1* "may prove inadequate for high-occupancy public or water park installations."[2]

Building upon ASHRAE's recommendations and relying on direct experience gained from providing over 1,000 air handlers for a variety of indoor aquatic facility types, the minimum outdoor air multipliers in *Table 3* were created by the author's firm to modify ASHRAE's pool and deck ventilation rates to achieve a more accurate minimum outdoor air calculation.

Incorporating the minimum outdoor air multiplier from *Table 3*, the minimum ventilation rate calculation becomes (for pool and deck areas during normal operating mode, not during a swim meet):

$$\text{Minimum ventilation rate} = 0.48\ \text{cfm/ft}^2 \text{ of pool and deck} \times \text{Minimum outdoor air multiplier}$$

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 [3.8 L/s·spectator + 0.3 L/s·m^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.

Summary

The amount of outdoor air required to create a healthy and durable indoor pool environment varies depending on pool type, pool activity, and ceiling height. *Table 3*'s minimum outdoor air multipliers take these factors into account to modify ASHRAE's minimum ventilation rates. Designing with these multipliers and the air distribution guidance presented in this article have proven effective for accurately calculating the outdoor air requirements of a wide variety of indoor aquatic facilities.

References

1. CDC. 2016. "Chloramines and Pool Operation." Centers for Disease Control and Prevention. http://tinyurl.com/zbgp7ty.

2. *2015 ASHRAE Handbook—HVAC Applications,* Chap. 5, Places of Assembly; Section 6, Natatoriums.

3. *ANSI/ASHRAE Standard 62.1-2016, Ventilation for Acceptable Indoor Air Quality*.

4. *ANSI/ASHRAE Standard 62.1-2016, Ventilation for Acceptable Indoor Air Quality, Table 6.2.2.1.* ■