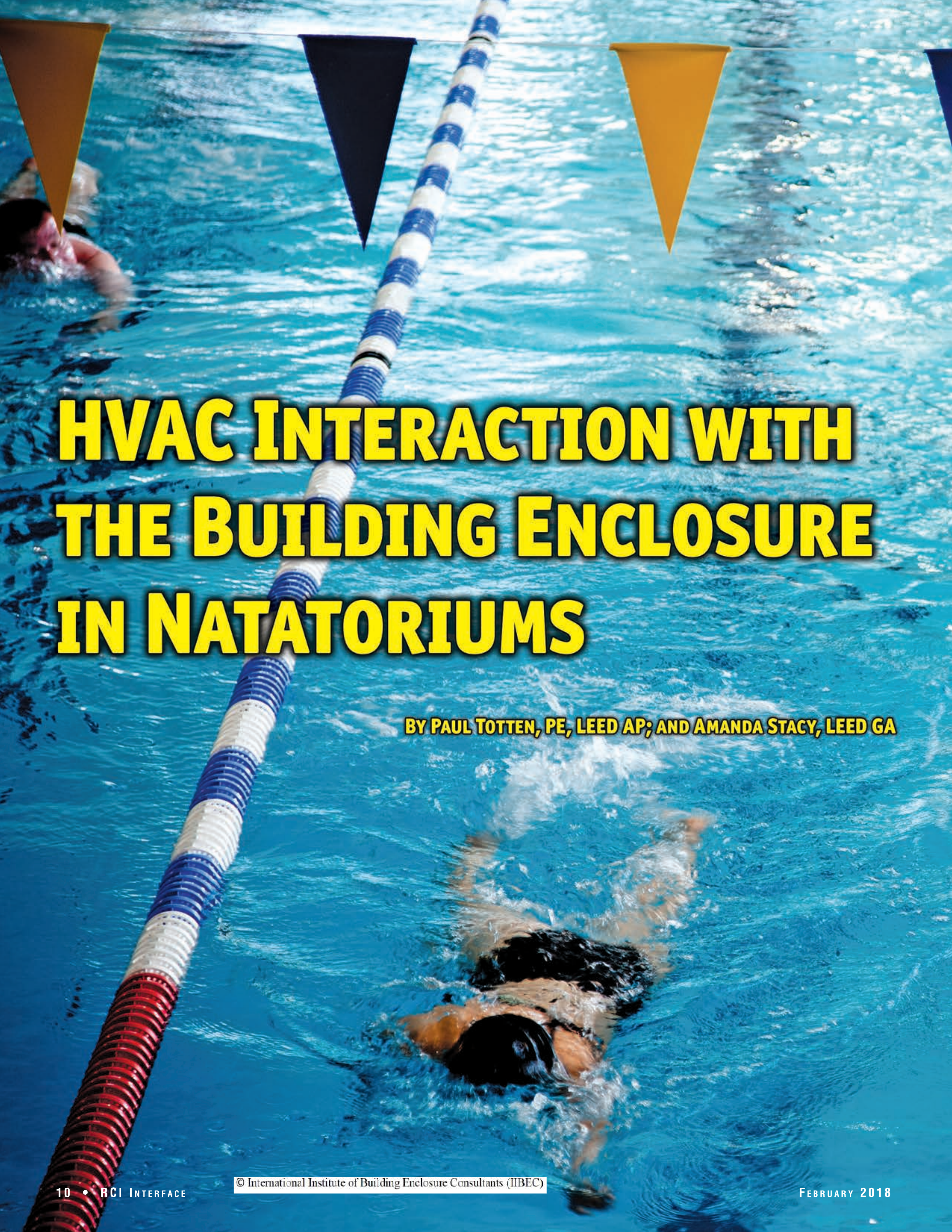

HVAC INTERACTION WITH THE BUILDING ENCLOSURE IN NATATORIUMS

BY PAUL TOTTEN, PE, LEED AP; AND AMANDA STACY, LEED GA

Natatoriums and similar buildings with a body of water set within an interior space have requirements that differ from most buildings as they pertain to the control of HVAC systems and considerations for building enclosure design and management. Natatorium operation must consider pool water depth and evaporation risk, indoor air quality, pool water quality, contaminant risk to occupants from pool chemicals, and the durability of finish surfaces and building enclosure materials. The architectural, mechanical, pool, and building enclosure teams must possess the knowledge to design for this unique building type. An understanding of building science is critical, as is the ability to control airflow, heat transfer, and moisture movement within the building enclosure assemblies. HVAC designers must understand how airflow contributes to occupant comfort, reduces condensation risk, properly ventilates the air, and interacts with the building enclosure. On top of this, individuals who utilize the natatorium impact how the space operates. This includes children and adults of all ages who may be observing, leisurely bathing, or performing highly athletic activities (in the case of competitive swimming and diving pools).

Natatoriums create a complex set of parameters to define the exterior building enclosure, how it integrates and interacts with the building enclosures of the interior natatorium and ancillary spaces, and the numerous HVAC systems that may be required to properly operate the space. (See *Figure 1*.)

AIRTIGHTNESS

Airtightness within an enclosure is critical to create a good boundary for air pressurization of any space. Interior spaces with a pool require airtightness and vapor control on all six sides of the space in its simplest configuration—the floor (pool deck and pool basin), the roof (including any clerestories or dormers), and all walls that intersect the roof (see *Figure 2*). When installing building components (i.e., mechanical, electrical, lighting, plumbing) within a pool environment, fixtures must be airtight, and components have to be durable and resilient to a pool environment. This may require epoxy or similar finishes for metal decks and some components of the walls. If material durability is compromised, it can negatively affect airtightness, in addition to leading to material failure over time.

Following are a few critical airtightness details to consider:

- Pool-deck-to-wall interface: May require concrete curbs that can be clad over, that extend above the pool deck, and are waterproofed 8 to 12 inches for improved watertightness.
- Wall-to-wall interface: If partition walls abut an adjacent interior space, this will require an airtightness detail that traverses the wall through the framing and is married into other air barrier components.
- Wall-to-roof deck interface: Requires redundant air sealing within the metal deck flutes and air barrier membrane integration at exterior walls for redundancy.
- At doors, fenestrations, and penetrations.

Design sets should include a series of sheets to illustrate airtightness details for the natatorium space; these details should also consider vapor drive risk and vapor permeance of systems. Hygrothermal analyses simulate temperature, bulk water, and vapor drive through an assembly over a period of time. These analyses can be helpful in understanding areas of condensation risk and when vapor barriers may need to be added, relocated, or have vapor permeance refined.

Figure 1 – Oulu Stadium. Photo by Nicola Evans. © WSP.

Figure 2 – Four Seasons Tianjin. © WSP.

Hygrothermal analysis can be a useful tool when coupled with working experience on these types of high-humidity projects.

BUILDING PERFORMANCE FOR DURABILITY

Materials used within a natatorium environment have to be very resilient to pool chemicals that become airborne, such as chloramines, and where components can be directly wetted by the pool water. High humidity, condensation, and direct wetting can break down and corrode building components. Pool chemicals that are airborne or within the water can more readily corrode metal components if not properly protected; this includes structural, mechanical, plumbing, fenestration, and finish materials. Air-resistance details, as discussed in the previous section, can prevent chloramine-laden air from reaching more vulnerable assembly materials.

Selecting higher-quality materials, which likely have a higher upfront cost, is prudent to reduce the number of maintenance cycles. More maintenance cycles equate to higher costs over the building life cycle. Moisture-sensitive products and finishes should not typically be installed. Products with higher moisture tolerance should be located closer to the pool deck, while less-tolerant products may be used farther away, as long as the coating applied over all portions of the wall is equally resilient. For example, cement board panels, as a tile backer for a wall, may be used closer to a pool deck surface since it is a more moisture-resistant assembly. Higher up on the wall, a moisture-resistant drywall with epoxy paint or other high-end coating can be utilized as long as the materials are intended for pool environments.

Metal light-gauge framing—and, in some cases (such as residential), wood framing—may be installed but must not be positioned at the pool deck surface. The framing should be installed on an 8- to 12-inch concrete curb or taller concrete knee wall that is anchored into the pool deck, waterproofed over, and integrated into the pool waterproofing system. Pool waterproofing systems should have several layers of protection. This may encompass the following: a concrete shell to set the pool liner shape, waterstops at all concrete cold joints, hot fluid-applied asphaltic waterproofing membrane or similar high-end waterproofing membrane with two layers of protection course over the concrete shell, a gunnite system for the pool liner, and an appropriate coating or tile finish over the gunnite.

In some cases, our projects have required additional measures to protect moisture-sensitive spaces below the pool. Thus, a sub-pool concrete shell was installed well below the pool, with access hatches, and included an additional waterproofing system and electronic leak detection (ELD) system tied to an alarm that would sound if water were detected.

Figure 3 – Toronto Pan Am Sports Centre Diving Towers. © Shai Gil.

The finishes at the ceiling/roof of a natatorium also require durability, such as a fully epoxy-coated metal deck. If an acoustic deck is used, care must be taken to ensure all metal perforations have been well coated to avoid holidays in the coating that, over time, may create a risk for corrosion.

Overall, the selection of durable building materials that may be exposed or hidden within an assembly is critical to the longevity of natatorium performance and the reduction in maintenance costs.

BUILDING PERFORMANCE FOR OCCUPANCY TYPES

The types of occupants accessing and utilizing a natatorium can vary greatly. Some individuals may use the pool for a leisurely swim or play, while competition pools accommodate individuals who race, and diving towers anticipate divers. Others may be in the natatorium space to teach, lifeguard, judge, and observe as coaches, parents, and other spectators.

Let's take the example of a competition pool that has a competitive dive pool in the same space. The swimmers and divers have different needs for optimum athlete performance (*Figure 3*). If interior air temperature and humidity conditions are inconsistent or do not meet recommended design conditions, divers may have concerns of muscle cramping that can inhibit strong dives. For instance, the calves are important for a good upward and outward launch off the platform or springboard, while the arm and upper back muscles are important if the diver is starting in a handstand or similar starting point on the platform. Airtightness of the building enclosure is essential for airflow control near the dive platform and for consistent air temperature stratification for the divers climbing the ladders/stairs, especially in platform diving. A well-planned natatorium should include review of stack effect (buoyancy of warmer air to rise and, in this environment, carrying moisture) and convection potential to assure good mixing of the air, which becomes critical for the layout of HVAC supply and returns. A well-planned diving area will promote increased diver performance by removing some of the outliers associated with diver comfort and cramping risk. Other outliers, such as lighting and how a diver sees the space, also need to be carefully evaluated.

Those racing as swimmers have a different need, especially for quick turnarounds between events. Excessive chloramines in the air space can impact lung performance and, similar to divers, muscle cramping can be a risk when entering and exiting the pool. Control of air quality and ventilation, pool chemical balance, and air temperature and

RH are essential for optimum swimming performance. Review of the airtightness boundary within the natatorium enclosure and how the HVAC system moves the air at the pool deck surface, across the water, and at the head height of the swimmers (where they breathe) is critical to providing good temperature stratification and better quality air, which may be the difference between not qualifying to move forward and winning an event. Airtightness detailing can be refined during the design process, reviewed during construction, and after installation, can be tested for functional performance to verify required air pressures can be maintained.

For all occupants using the space, airflow control can also enhance the transfer of acoustical paths to optimize the sound of cheering and the fan and competitor experience. If air is circulated such that sounds reflecting off the ceiling are combined with direct sound flow paths from the stands, the space will feel louder and as if occupied by more spectators, which will typically have a positive impact on the athletes. (See *Figure 4*.)

HVAC INTERACTION WITH THE ENCLOSURE AND PASSIVE CONDITIONING

The building enclosure boundary condition for air, vapor, and moisture control within a natatorium space should include:

- The underside of any ceiling or roof deck
- The pool deck and pool basin
- The inside surface of exterior walls and fenestration
- The inside surface of interior partitions, doors, and fenestration (observation windows or storefront)

The waterproofing in the pool assembly acts as a plane of airtightness, and the water in the pool creates a buffer zone before air can reach the waterproofing. HVAC flow should have good supply direction, velocity, and temperature—especially across fenestration systems to reduce the risk for condensation. HVAC flow should be continuous into and out of clerestory and dormer conditions to avoid the stagnation of air and moisture accumulation. Although it can be serviced by a single return louver,

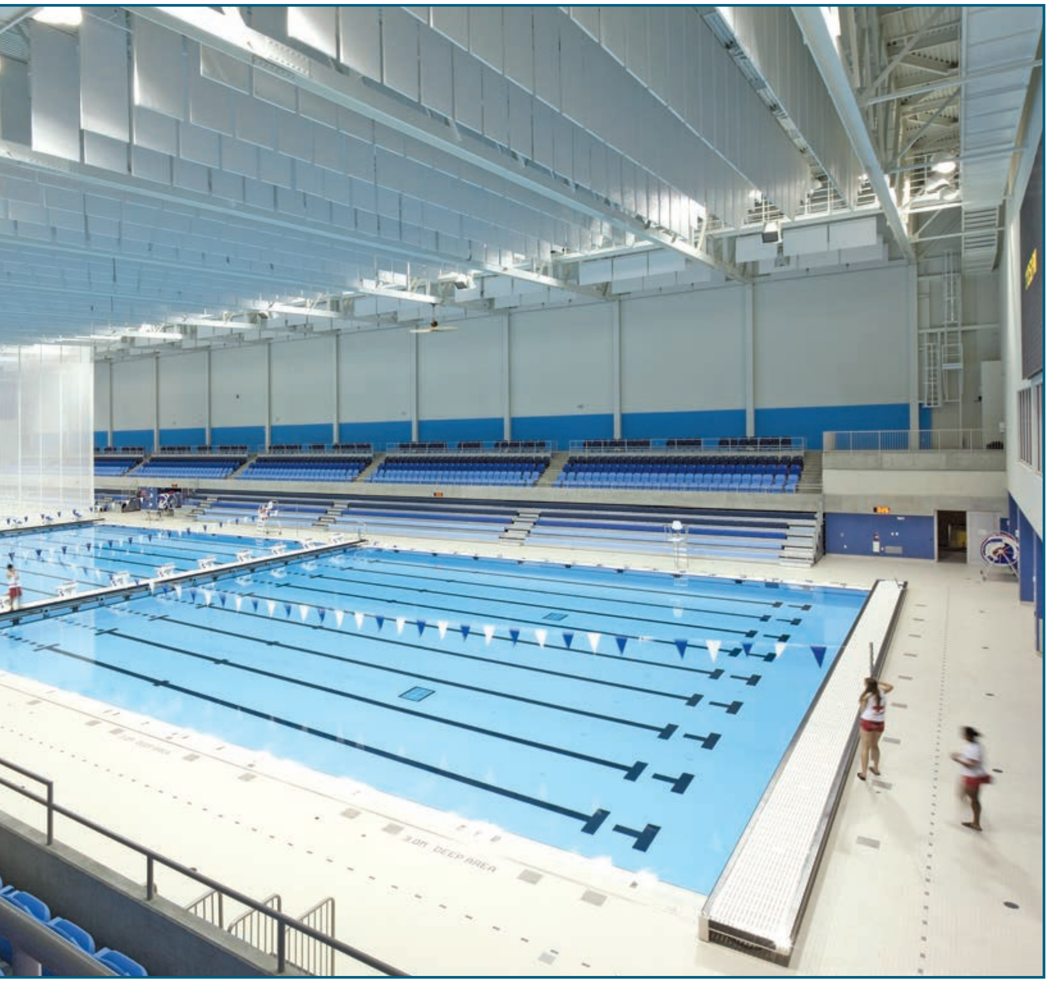

Figure 4 – Toronto Pan Am Sports Centre. © Lisa Logan Photography.

the return air system may need additional return ductwork for better HVAC flow paths and control to avoid limited mixing of air and one end of the pool potentially being driven by stack effect. The sensors and controls for the HVAC system require careful placement so the system has a good feedback loop so as to not over- or under-humidify the pool space.

During cooler seasons, an indoor natatorium is ideal for providing a comfortable environment for swimming. During the summer months, however, indoor natatorium spaces may be used infrequently if the facility also encompasses an outdoor swimming pool. By installing operable doors and windows within a typically enclosed natatorium space, there is an opportunity to provide an additional indoor/outdoor swimming pool space in the summer.

Indoor natatoriums are not typically designed for natural ventilation, because it is difficult to control the air temperature, RH, and ventilation strategy. Natatoriums have strict air temperature and RH requirements as they relate to the temperature of the pool water. These recommended design conditions encourage comfortable water conditions for bathers, reduce the evaporative cooling effect that can occur when bathers exit the pool, and facilitate adequate ventilation for occupants who may not be swimming. The air and water temperatures are close in degree to reduce pool water evaporation rates, which can increase energy loads required to maintain pool water temperatures.

When the doors and windows of an indoor natatorium are opened, the risk for condensation and occupant discomfort increases. If occupants are uncomfortable, they will not use the pool; if finish materials in the natatorium are corroding, building maintenance costs increase. Therefore, natural ventilation within a natatorium should be carefully considered and designed, and a thorough evaluation of the climate zone should be made.

The overall orientation of the natatorium building—in addition to door and window placement—should encourage natural airflow via direct wind flows or by creating

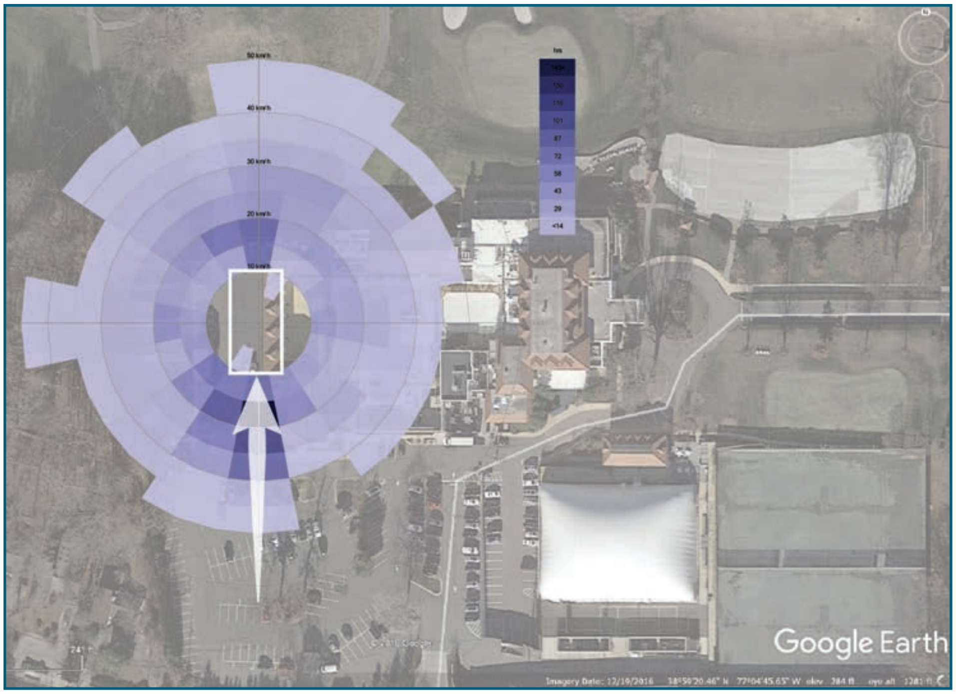

Figure 5 – Summer wind flow diagram for Washington, DC, metro area. Google Maps.

pressure differentials to pull air through the space. Wind flow diagrams can be helpful to understand the direction and velocity of wind flows during summer months, while computational fluid dynamics models can validate airflow performance. (See *Figure 5*.) The natural ventilation design should move air across the surface of the water to remove chloramines in the air, as well as to prevent stagnant air that may be uncomfortable to occupants. The air traversing the water must be at a higher temperature and heightened humidity load (85% RH or higher, and 85°F [29.4°C] or higher) to reduce the evaporation rate off the surface of the water. The HVAC systems typically need to be back-scaled, not shut down, to encourage airflow in areas where stagnant air and condensation are risks, such as at clerestory and dormer conditions.

In the morning when the natatorium doors and windows are opened, there is a risk for condensation if the interior surface temperatures are at or below the dew point temperature of the outside air. Therefore, the doors and windows should only be opened when outdoor conditions closely resemble recommended design conditions for the pool space and are also warm enough for bather comfort. Throughout the day, indoor air conditions and surface temperatures will equalize with outdoor conditions. Occupants will tend to have a larger comfort range under exterior air and RH conditions. In the late afternoon when the natatorium doors and windows are closed and the HVAC system is set to full performance, there is a risk for condensation if the interior surface temperatures are at or below the dew point temperature of the indoor supply air. Therefore, the doors and windows should be closed prior to the exterior temperature dropping below recommended design conditions.

We have seen success for natural ventilation in an indoor natatorium in a mixed-humid climate, such as the Washington, DC, metropolitan area. This cannot be accomplished in all climate conditions. Where climates drastically differ from natatorium recommended design conditions, there is an increased risk for condensation, occupant discomfort, and higher energy and HVAC loads. Weather events, such as rain and fog, can also increase the risk for condensation—even in a mixed-humid climate. Natural ventilation in an indoor natatorium can be challenging for the design team. We recommend establishing a schedule of operation for the doors and windows to reduce the risks while providing great benefits to the facility owner and occupants.

SUMMARY

Natatorium design must consider the relationship between HVAC systems and the building enclosure. The transfer of air, moisture, and heat are managed at the exterior of the building enclosure assemblies and at the interior of the natatorium.

Careful design of the HVAC systems can optimize building enclosure performance while also maintaining comfortable occupant conditions and creating efficiency in natatorium operations.

Design teams should specify durable materials that can withstand moisture and pool contaminant exposure via bulk water and vapor drive. Air and vapor control details within the building enclosure design promote proper air pressurization of the space in order to maintain recommended air temperatures and RH, while reducing the stratification of air temperatures. The interplay between the building enclosure and HVAC systems can enhance competitive swimmer or diver performance and the experience for spectators while leisure swimmers maintain comfort in and out of the water.

HVAC systems for natatorium spaces are designed to ventilate fresh air and exhaust humid, contaminant-laden air. Layout of the mechanical systems is crucial for maintaining recommended design conditions for pool operation and occupant comfort while reducing condensation risk. Natural ventilation within a natatorium can be beneficial to owner operations and occupant experience; the design team should reference recommended air temperature and RH design conditions, building orientation, operable fenestration locations and quantity, and summertime climate conditions for optimum performance.

Natatorium design and operation greatly differs from other building uses. A complex set of factors should be considered by the design team to create synergies between the building enclosure and the HVAC systems in order to successfully manage the space.

Amanda Stacy

Amanda Stacy joined the WSP DC office in 2014 after earning master's degrees in architecture and science in sustainable design. She focuses on optimizing building enclosure design through the utilization of sustainable design strategies and a methodology of building performance analytics. Stacy offers high-performance design and detailing solutions grounded in a thorough understanding of building science, construction technologies, and material performance. She is co-chair of the AIA|DC Technology Committee and a LEED Green Associate.

Paul E. Totten

Paul E. Totten is a vice president at WSP and leads the Building Enclosures Division. He has over 20 years of experience in the fields of structural engineering, building enclosure technology and commissioning, and building science. He has concentrated his expertise on the evaluation and analysis of heat, air, and moisture transfer, and the cumulative effect these elements have on building components and building operation.

IRMA'S CO$T ON FLORIDA

Hurricane Irma aftermath. Photo by Paul Brennan.

Costs to the state of Florida from the effects of Hurricane Irma are staggering:

- The insurance industry is facing $6.55 billion in property damage claims.
- Utility customers may be asked to pay more than $1 billion for power restoration.
- Agriculture officials estimate a $2.5 billion hit on crops and facilities.
- The Florida Division of Emergency Management says federal agencies have provided more than $2.49 billion to help cover losses.

Also impacting the state are costs from Hurricane Maria, which caused massive evacuations from Puerto Rico and the Virgin Islands to the state.

— News Service of Florida

JOBLESS RATE FALLS TO RECORD LOWS IN FIVE STATES

Unemployment rates dropped to record lows in Alabama, California, Hawaii, Mississippi, and Texas in November, according to the Bureau of Labor Statistics (BLS). Rates also fell in 19 other states over the previous 11 months. The national unemployment rate was 4.1% as of November, with 6.6 million people still looking for work. Hawaii has the lowest seasonally adjusted unemployment, at 2%, and unemployment was below 2.7% in Nebraska, New Hampshire, and North Dakota. The number of persons employed only part-time who would prefer full-time employment ("involuntary part-time workers") was 4.8 million, down by 858,000 over the year. Employment among specialty trade construction contractors increased 132,000 over the year.

— BLS and AP