



# **A Guide to an Integrated HVAC System Design for the 21st Century Natatorium**



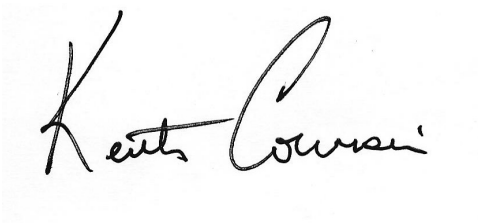
# Foreword

Desert Aire has written this document to provide owners, mechanical contractors and engineers with a helpful guide to designing or retrofitting an indoor pool facility.

Just in the past few years there has been a major breakthrough in understanding the complexity of maintaining the indoor air quality of a pool facility. This guide tries to tie together the many independent design elements of a very complex system, including HVAC, building structure, water loop, facility programming and energy consumption. For too long these elements were designed independently and rarely was an effort made to integrate them to create the best indoor pool for all stakeholders.

It is our expectation that this guide will assist in developing the dialog to solve problems in existing designs as well as serve as the benchmark for new construction. The guide will also refer to other documents or industry knowledge to support creation of final design specifications and the construction document.

This guide will be a living document so we welcome the opportunity to receive your feedback on innovations and innovative thinking that can help produce the highest quality indoor pool facility. Feel free to reach out to any Desert Aire sales representative or staff member with your feedback.



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# A Guide to an Integrated HVAC System Design for the 21st Century Natatorium

## Overview

### The Purpose of the Natatorium

The natatorium is a building that contains one or more aquatic venues and structures where the general public is exposed to water intended for recreational or therapeutic use.

Although we most often think of aquatic venues as indoor pool facilities for swimming and diving, they may not only contain standing water. The term can be used to describe indoor water parks where the public is exposed to water by contact or spraying, such as with waterslide landing pools and spray pads.

A natatorium can be housed in a dedicated building or non-dedicated building such as a school building or fitness club. The natatorium may also house locker rooms, lavatories and offices. Locker rooms, staff offices and storage rooms should not be part of the pool room mechanical HVAC system.

This design guide focuses on larger natatoriums and aquatic centers but many of the concepts would apply to smaller commercial and residential indoor pool facilities.

### The Goals of HVAC Design

The many ways people use buildings with enclosed pools for recreational, competitive and health purposes continue to evolve. These uses place demands on HVAC systems and on the buildings themselves that weren't present even a generation ago. Fortunately, there are advances in knowledge, understanding, strategies and technology that meet the challenges of today's natatorium.

Reflecting the depth and breadth of demands, the scope of HVAC design considerations for large natatoriums and aquatic centers has expanded in the 21st Century.

Objectives now include protecting the health of swimmers, divers, coaches and spectators; promoting the long-term structural integrity of the building and supporting systems; and conserving energy, water and water treatment resources.

But there is a guiding principle that applies to HVAC system design no matter the purpose, size and location of the natatorium: the HVAC system must work in harmony with systems that control water temperature and water quality.

For engineers who must translate these objectives into design goals an integrated, sustainable approach is required. These design goals must reconcile the intensive tasks of dehumidifying the space, heating and cooling the interior, heating pool water, and meeting outdoor air requirements.

Fortunately, today's design engineers have access to a range of problem-solving equipment technologies and strategies. These technologies and strategies complement resources made available by professional associations and engineering societies; and the goals manifest in building codes and standards. For example, the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) provides guidance and resources for pool room design.

The Model Aquatic Health Code (MAHC), published by the Centers for Disease Control and Prevention (CDC), is a more recent addition to the resources available to mechanical engineers.

First published in late 2014, the MAHC is a set of guidelines for public aquatic facilities. According to the CDC, the MAHC "brings together the latest knowledge based on science and best practices to help state and local government officials develop pool codes. Pool codes are specific rules that designers, builders, and managers of spas, pools, water parks, and interactive fountains must follow to keep the fun going and reduce injuries and illnesses."



The MAHC encompasses traditional aquatic venues such as those enclosing swimming pools and spas. The MAHC also covers contemporary water-containing structures including wave pools, surf pools, therapy pools and spray pads.

As part of bringing together the best knowledge and practices, the MAHC states the design, construction and installation of indoor aquatic facility air handling systems shall comply with local codes as well as the proven ANSI/ASHRAE standard 62.1- 2019, Ventilation for Acceptable Indoor Air Quality.

Together, this matrix of technologies and strategies provides mechanical engineers with essential tools for balancing diverse operating conditions, seasonal variations and special event needs with building codes and standards for the ongoing, critical concerns of indoor air quality and relative humidity.

## Heating, Cooling and Moisture Load Determination

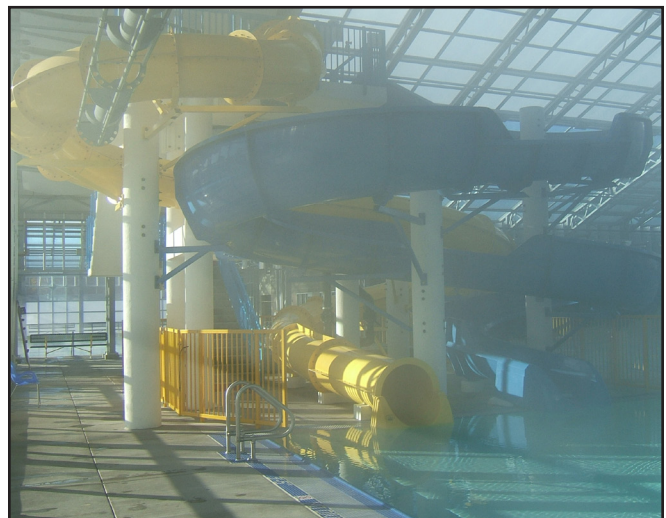
The heating, cooling and moisture loads of a natatorium are a product of seasonal variations in outdoor air temperature and humidity, solar gains and losses as well as the presence of spectators and bleacher areas.

- The heating load is the amount of heat energy that must be added to the natatorium to achieve or maintain a target temperature level. This is often considered the heat loss calculation and is a dominant factor due to the high internal design temperature of an indoor pool area.
- The cooling load is the amount of heat energy that needs to be removed to attain the target temperature. This is the heat gain calculation with solar gain and lighting heat being the most significant portions of this load.
- The moisture load is the amount of moisture that needs to be removed to attain a target relative humidity level. The moisture load has three components: evaporation from the water surface; moisture content from the ventilation air; and evaporation from spectators.

To calculate heating, cooling and moisture loads to specify and size HVAC equipment, these loads are expressed as sensible and latent. Sensible heat and loads are the heat swimmers and building users feel on their bodies and are temperatures that can be measured by a thermometer. Latent heat and loads are the energy and heat stored in humidity, a product of its change in state from liquid to gaseous. These two components when combined provide the total system rating that the HVAC equipment must be designed to remove.

The overarching goal in managing heating, cooling and moisture loads is sustainability: ensuring the natatorium can continue to fulfill the purposes for which it was built in a safe and cost-effective manner. Related HVAC design considerations, as stated earlier, are protecting the health of swimmers, divers, coaches and spectators; promoting the long-term structural integrity of the building and supporting systems; and conserving energy, water and water treatment resources.

The ASHRAE Applications Handbook provides formulas for calculating the natatorium moisture load. The factors that are used in those formulas include the air and water temperatures, relative humidity, airflow rate across the water, activity factor, spectator load, and the ventilation load. Each of those will be discussed below.



*Figure 1. A pool room with an overwhelmed HVAC system*

A pool room that does not maintain the proper temperature of its air and pool water along with setting the correct relative humidity range can quickly overwhelm even the best HVAC equipment.

## Air and Water Temperatures

There are many combinations of air and water temperatures being utilized in pool facilities and no one condition is more correct than the other. Therefore the owner must make a decision on what air and water set points they will use in their facility as this will be a key factor in dehumidifier selection. Changing design conditions after the HVAC systems are installed may not be possible.

ASHRAE recommends maintaining the natatorium air temperature at two to four degrees above the pool water temperature but not above the comfort threshold of 86°F. There are several reasons for this recommendation. This is an effort to create a design condition that seeks a balance in the overall dehumidifier sizing and the energy costs associated with maintaining the conditions in the space and pool water. In addition, the warmer air temperature will help make the swimmers not feel as cold when leaving a pool.

However, recent changes in the average water temperature of an indoor pool can make it difficult to maintain the air temperature higher than the pool water temperature. An analysis of commercial pools found that the average pool water temperature had increased from 82°F to 86°F between 2003 and 2013 due to the prevalence of swim lessons serving those 10-years-old and younger and vertical swim classes for senior citizens; both of these swimmer groups desire warmer water temperatures than recreational or competitive swimmers.

It is very important when designing a dehumidification system for a new or remodeled facility that the pool owner communicates to the engineer the desired operating set points. Similarly, it is important the engineer communicate to the pool operator the importance of maintaining conditions in the natatorium and adhering to design set points.

A 3,500 square foot natatorium, designed for 82°F pool water temperature and 84°F air temperature will have an evaporation rate of approximately 159 lbs/hr at 55% relative humidity. Raising the water temperature to 86°F and keeping all other factors the same will increase the evaporation rate by 33% to 211 lbs/hr. The dehumidification system designed for the lower water temperature will now be significantly undersized to handle the larger load of the warmer pool water. As mentioned earlier, communication between the engineer and the pool operator is essential when designing for a specific evaporative load.

## Relative Humidity

As the equipment centerpiece of natatorium HVAC systems, the dehumidifier controls humidity in pool enclosures to counter what is created by evaporation, regardless of outdoor conditions. This improves indoor air quality and the comfort of swimmers and occupants. Humidity control also protects building structural elements, furnishings, and support systems such as lighting.

ASHRAE recommends that the relative humidity in a natatorium be maintained between 50% to 60% relative humidity. Lower relative humidity increases operation costs due to increased evaporation and it can lead to swimmer discomfort due to evaporative cooling from their bodies when exiting the pool. Higher relative humidity increases the risk to the building structure.

## Airflow Across Water

One of the recent changes in natatorium design is moving away from designing ductwork to have grilles aimed at the pool water surface. It is now recommended that air be pulled across the pool water surface at less than 30 feet per minute. All of the air supply should be aimed at exterior walls and windows and not at the pool. The reasons for this are discussed in the Source Capture Solution section of this guide.

The ASHRAE formula for the evaporation load of a pool assumes that the air will not exceed 30 fpm. Using the same pool as mentioned above (3,500 sq. ft. at 82°F water and 84°F air) and increasing the airflow across the pool water from 30 fpm to 125 fpm will increase the evaporative load by 40%. If the design engineer for that pool uses the standard ASHRAE formula for computing the evaporative load but has air supplied directly across the pool surface, then the dehumidification equipment selected will most likely be substantially under designed.

## Activity Factor

Another factor in the formula for finding the natatorium evaporative load that an engineer needs to consider is the pool usage. The ASHRAE formula gives an activity factor based on the type of pool, ranging from an unoccupied baseline for any pool of 0.5 up to an activity factor of 2 or greater for a water park. Different activity factors are given for condominiums, therapy pools, hotels, public pools, spas, and water parks. Underestimating the activity factor can have substantial consequences. A public pool, school, or YMCA has an activity factor of 1. By adding water features such as a wavepool or waterslide the evaporative load for that pool can double. The activity factor is significantly higher with these added water features.

It is very important for the architect, engineer, and pool operator to discuss any water features that might be added to a public pool that is not considered to be a water park. Any remodeling of an existing pool must take into account the capacity of the present dehumidification equipment before adding water features.

## Spectator Load

Spectators are not the swimmers using the pool or the pool deck, but rather the fully clothed observers in a separate area. For spectator areas an additional amount of airflow needs to be introduced, when spectators are present. This will enhance spectator comfort and the quality of air around them. ASHRAE recommends an airflow rate of between 6 to 8 air changes per hour over the spectator area. The evaporative load of the spectators must also be taken into consideration when calculating the total load. Swimmers are not considered as part of the spectator load.

## Ventilation Load

The local building ventilation code protects public health and safety by providing minimum safeguards and standards for ventilation. Most codes have a set amount of outdoor air that must be brought into the pool area with factors based on the pool surface area, the swimmer drip area, and spectator areas.

Most local codes are based on ASHRAE Standard 62.1, the industry accepted ventilation code for indoor air quality, which defines the minimum volume of outdoor air to be introduced into the indoor pool enclosure. The standard exists to protect the health of natatorium users.

This volume is generally only a small percentage of the total air volume required by a dehumidification system to maintain the space humidity. Proper interpretation can also enhance energy conservation by reducing the volume of outdoor air required to the minimum required by code.

ASHRAE 62.1, table 6.1 provides the following levels of outdoor air to the breathing zones listed below.

- Pool and wet deck outdoor airflow  
 $\text{Pool and wet deck area (ft}^2\text{)} \times 0.48 \text{ (cfm)/(ft}^2\text{)}$
- Remaining floor area outdoor airflow  
 $\text{Room (ft}^2\text{)} - \text{Pool and wet deck (ft}^2\text{)}$   
 $- \text{Bleacher (ft}^2\text{)} \times 0.06 \text{ (cfm)/(ft}^2\text{)}$
- Spectator/Bleacher outdoor airflow  
 $\text{Spectator area (ft}^2\text{)} \times 0.06 \text{ (cfm)/(ft}^2\text{)}$   
 $+ (\text{\# of spectators}) \times 7.5 \text{ (cfm)}$

The interpretation of “wet deck” is sometimes difficult. ASHRAE defines the wet deck as the deck area that becomes wetted during a normal occupied condition. The accepted practice is to define the wet deck for a pool as a defined perimeter around the body of water. The width of this “wet deck” can vary from 2 to 5 feet.

Ventilation may be regulated based upon occupancy to establish an expanded range and sequence of operation that maintains acceptable indoor air quality. When the facility is unoccupied, outdoor airflow may be closed. During normal operation, outdoor airflow can be set to a minimum code-approved level. When a swim meet creates higher-than-normal occupancy an increased outdoor airflow may be engaged.

As a means of ensuring indoor air quality and providing for system accuracy and flexibility, a Volatile Organic Compound (VOC) sensor should be installed as part of the ventilation control system. In a short amount of time VOCs can build up in a pool room that has become busy for an extended period. The VOC sensor can override programmed set points that don't reflect current conditions and call for the ventilation system to increase outdoor and exhaust airflow.

## Condensation and Building Integrity

While the design of the building does not fall under the responsibility of the mechanical engineer, it is a key HVAC system component. The engineer and the architect must be in communication on construction materials that will influence the size and capacity of the HVAC system through the heat gain and heat loss of the structure; the location of the vapor barriers; the quality and quantity of the doors and windows in the natatorium; and, controlling humidity within the entire structure with proper vapor barriers. Nowhere is this communication more important than the area of condensation and building integrity.

We will be discussing in the duct design section the proper amount of airflow that is necessary to prevent condensation but it is important that all external areas be completely washed with airflow. In the photo on the following page (Figure 3) you can see that the lower areas of the windows did not receive adequate airflow and are fogged; while the upper areas did receive the proper airflow and they are clear. This was solely an issue of air distribution and not dehumidifier operation. This is an area where the engineer must communicate with the architect. Whenever there are large glass areas there must be adequate air distribution to keep these surfaces above dew point to prevent condensation in winter months.

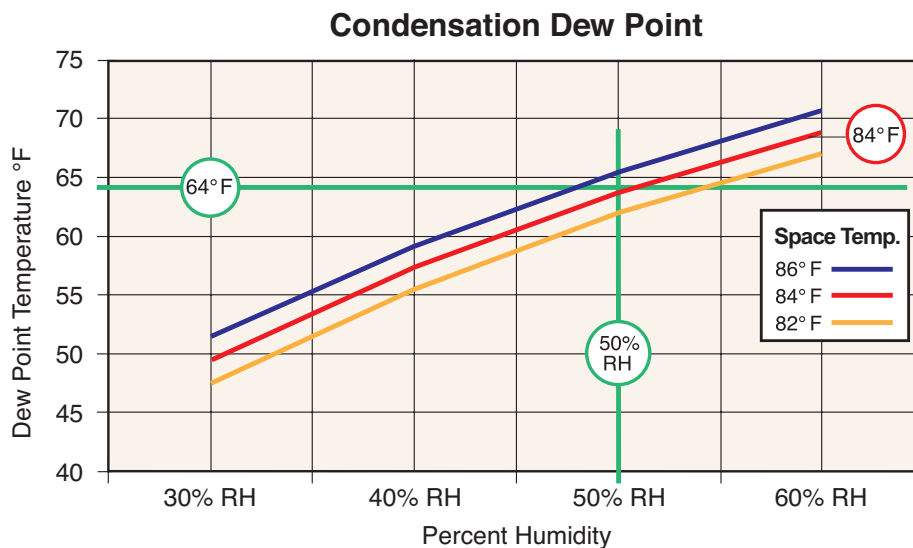


Figure 2. Condensation dew point for a natatorium

### Dew Point Control

All external walls, windows, and doors must be kept above the dew point in order to prevent condensation. Condensation control is essential to maintaining building integrity. As can be seen in the graph above (Figure 2), the dew point for a natatorium is fairly high. That means any surface that has a temperature below the natatorium dew point will see condensation form.

Over time, if condensation is allowed to form, the acidic content of the condensation can destroy key building features such as doors, windows, fixtures and, in the worst-case scenario, can destroy a building.





Figure 3. Examples of condensation and poor air distribution

### Vapor Barrier

A vapor barrier is a material or film that prevents moisture migration or penetration. Moisture will travel from high moisture content air to low moisture content air. In non-pool room building designs, the vapor barrier is located on the outside of the building's insulation. Location is dependent upon your geographical location but in general the vapor barrier should be placed on the side where the highest moisture is present. Because of the high moisture load inside a pool room, the vapor barrier is required to be on the inside of the structure in all North American locations.

Figure 4 shows white chalking on the outside of the brick building. The white chalking is caused by moisture from the pool room penetrating the brick, a result of having no vapor barrier installed on the inside of the wall structure.



Figure 4. Example of natatorium without vapor barrier showing white chalking on building exterior

If the facility is in a cold climate and the temperature outside is below freezing and a proper vapor barrier is not installed, moisture will condense inside the wall cavity. Once condensation occurs inside the wall cavity the remaining insulation value is lost and the problem will get worse. Condensation inside a wall cavity may also prompt decay or mold to the building structure.



Similarly, all windows and doors need to have a very tight seal to prevent moisture migration. The photo below (Figure 5) shows a facility that did not seal the wall to roof interface. Higher moisture content pool room air migrated to the roof and wall joint, condensed into water and then froze, forming icicles.

Moisture does not have to travel only to the outside of the building to cause damage. Adjacent interior rooms, such as offices, are typically maintained at 75°F and approximately 40% RH. Because this air has a lower moisture content, the moist air in the pool room will travel to these interior rooms. All pool room partitions need an appropriate vapor barrier or moisture damage will happen between the walls.

## Negative Pressure

According to ASHRAE, natatoriums should be maintained at a negative air pressure (0.05 to 0.15 in. of water) relative to the outdoors and adjacent areas of the building to prevent the forming of condensation in the wall and ceiling interstitial spaces; and to prevent the dispersal of chloramines, other noxious fumes and moisture to other occupied spaces in the building. The space pressurization scheme must be maintained during every hour of the year and for all possible operating conditions.



This may be installed in new or retrofit installations. VFDs and ECMs reduce or increase the speed of the fan to match the load and real-time needs of the natatorium's negative pressure requirements. They will speed up or slow down the exhaust air to maintain the desired negative pressure.

VFDs and ECMs also deliver pressure control benefits if installed as part of chloramine low exhaust systems. Because mechanical engineers must specify HVAC equipment and systems for worst-case scenarios, low exhaust systems may be oversized or running constantly if not modulated.

To maintain the favorable negative air pressure, HVAC systems use static and active methods of pressure control to provide the correct proportions of return air and outdoor air.

Static methods employ pressure sensors to measure airflows (differential pressure) across HVAC system components. For example, a dehumidifier's evaporator coil, exhaust blower and reheat coil. Dampers respond to the measurements through an automated control system, opening or closing to deliver the correct amount of air to the equipment or space.

One active method of pressure control that meshes well with automatic control systems, as well as energy efficiency objectives, is using either a Variable Frequency Drive (VFD) or an Electronically Commutated Motor (ECM) for the exhaust air stream.

*Figure 5. Example of natatorium with improper seals showing moisture migration and icicle formation*

On the other hand, if sensors measure an air pressure or air contaminant level that is not within the tolerances for proper indoor air quality, the VFDs can increase the exhaust volume in concert with dampers.

To promote the negative pressurization function of the HVAC system, the natatorium must be separated from adjacent spaces by effective partitions and air barriers. These include tightly gasketed doors and sealed cracks in the frames of doors and windows.

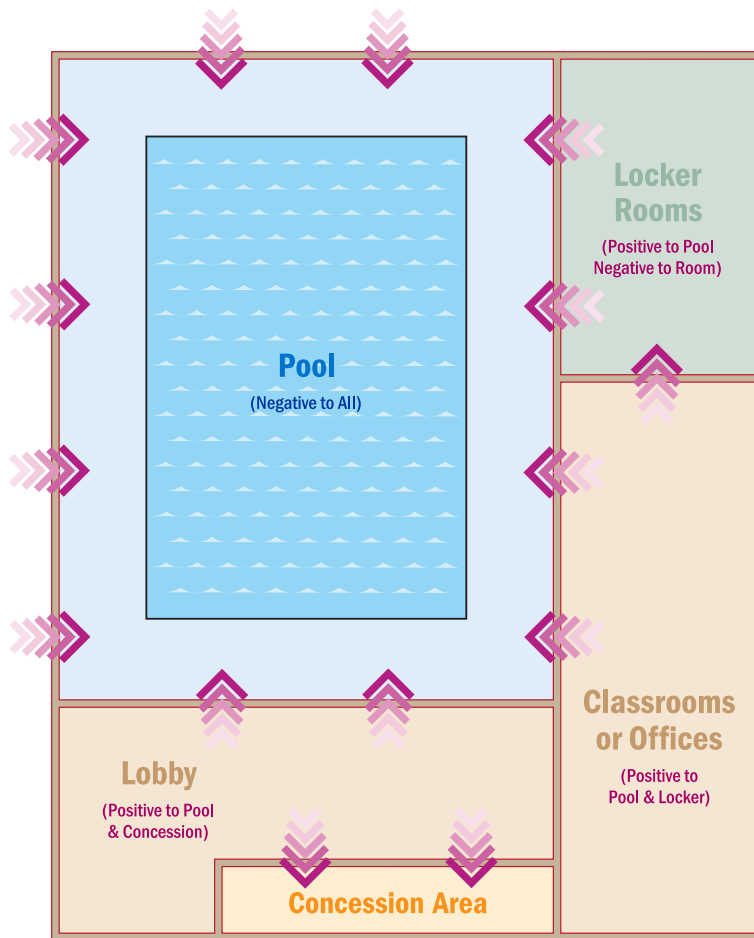


Figure 6. Building pressurization

Locker rooms, dressing rooms and food preparation spaces also need to be maintained at negative pressures with respect to their adjacent spaces, but they must be positive relative to the pool space. Chemical storage areas however, need to have negative pressures with respect to the pool space and all other spaces. Chemical storage areas must also have their own exhaust systems to prevent moisture and airborne chemicals from coming into contact with each other.

## Spectator Areas

Natatoriums and aquatic centers with spectator areas require multi-level strategies from mechanical engineers and their HVAC systems. Spectators may not be present at all times when the building is being used by swimmers. If a swim meet brings in spectators, loads increase. Spectators can impact the temperature of the space and create additional internal moisture through breathing and perspiration.

The ASHRAE 62.1 ventilation standard also requires that HVAC systems introduce additional outdoor air into the space during spectator events. As noted earlier, the standard requires a ventilation air volume of 0.06 cfm/ft<sup>2</sup> for the dedicated spectator area plus 7.5 cfm per spectator during times when spectators are present. This is in addition to the ventilation rate for the pool and wet deck.

In event modes, HVAC systems and equipment increase outdoor air volumes as a percentage of air supplied to the space. The dehumidifier's ventilation damper will open to a greater position to introduce the required amount of event air. The exhaust system will then respond to maintain the proper negative pressure set point. This is a higher rate than the occupied mode setting, providing the required volume for pool plus spectators. HVAC equipment such as dehumidifiers can increase the amount of fresh and exhaust air by re-balancing dampers and exhaust fans.

Because spectator occupancy is not constant in most facilities, the scheduling programs of building management systems can reduce the energy costs related to conditioning spectator areas.

To increase the comfort of fully clothed spectators many building owners and HVAC engineers choose to separate the spectator load by using dedicated outdoor air systems (DOAS) that flush spectators with clean, fresh air. These can be designed to supply an air temperature that is approximately two degrees less than air supplied to the pool space.

A DOAS allows for independent control of the temperature and a separate duct system for air delivery. This independence can reduce energy costs compared to HVAC systems that would serve combined pool and spectator areas. When spectators are not present, the DOAS recirculates air to provide dehumidification of air within spectator areas.

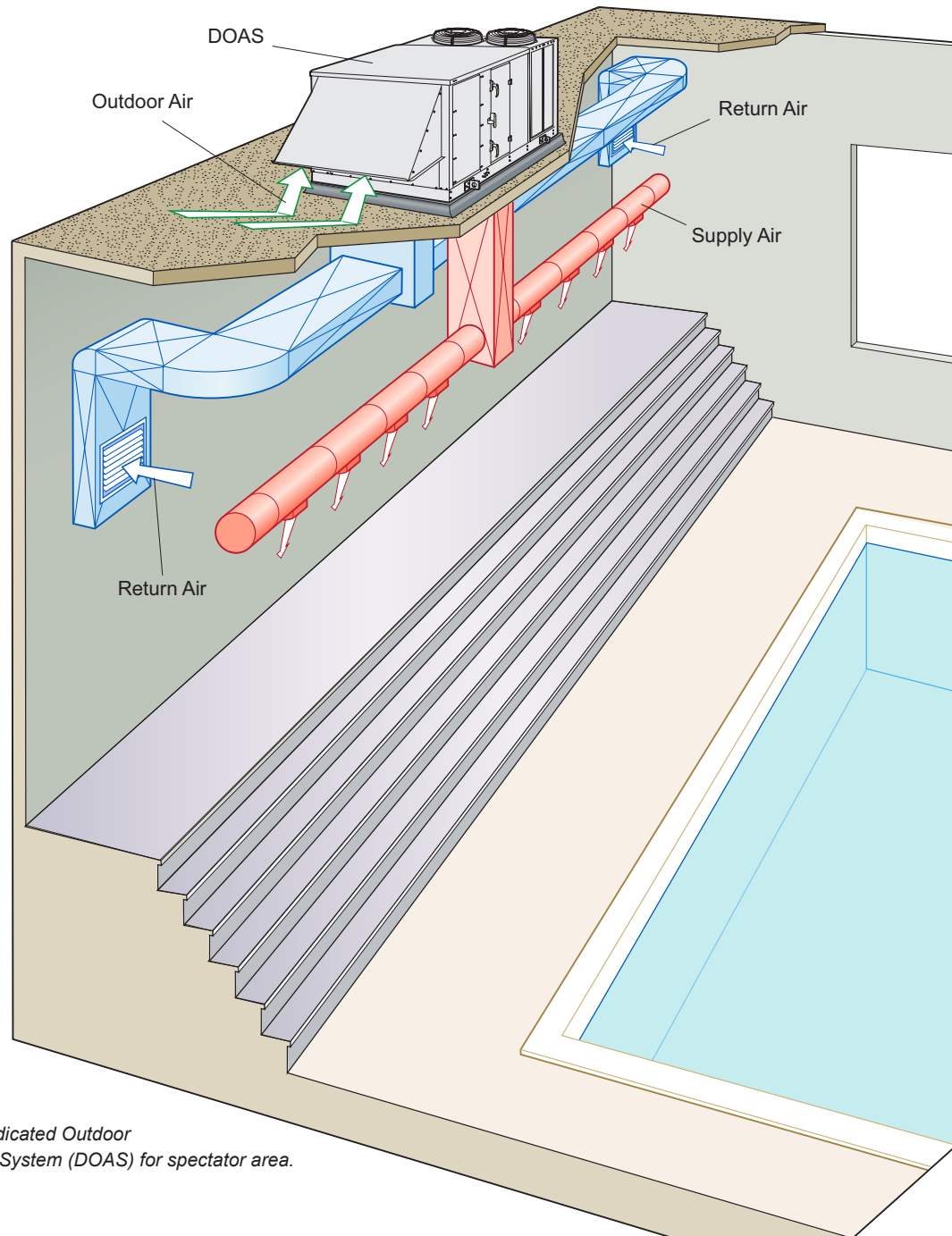


Figure 7. Dedicated Outdoor Air System (DOAS) for spectator area.

## Swimmer Health Concerns

### Toxic Air

In natatoriums, the presence of “pool smell” or chlorine odors is often confused with the use of chlorine disinfectants added to pool water to destroy germs that can give swimmers diarrhea, earaches and athlete’s foot. When the smell builds up and accumulates at the pool or deck level, it can irritate the eyes, lungs and skin of swimmers and occupants. The chemicals that are associated with these smells have a toxicity factor and should be removed in a manner that does not cause more

swimmer discomfort or a higher evaporative load.

In fact, the chemical smell results from the interaction of the chlorine disinfectants with perspiration, urine, oils and organic materials from swimmers. Chloramines are chemical compounds formed from the reaction of chlorine disinfectants with the ammonia in perspiration and urine. When there is a pool smell present or swimmers get reddened, bloodshot eyes, there is actually not enough chlorine present.



There are three chloramine by-products of the disinfection process. Monochloramines and dichloramines are predominately waterborne and can be removed by ultraviolet (UV) and other sanitation systems. Trichloramine, which is also known as nitrogen trichloride, becomes almost instantaneously airborne and does not stay in the water long enough to reach the UV or surge tank protection systems. Since it is approximately four times heavier than air it stays at the pool surface and is then inhaled by swimmers moving through the water.

## Most Common Airborne Contaminants

The top four airborne disinfection by-products are listed below.

- Nitrogen trichloride
- Cyanogen chloride
- Trihalomethane
- Hydrogen cyanide

The way these by-products move from the pool water to the air is through a process similar to evaporation. If the air has a lower concentration of the by-product than the water (lower partial pressure), then it migrates from the water to the air. As noted earlier, traditional chemical treatment systems do not remove these by-products from the water.

## Source Capture Solution

Source capture strategies and technologies have evolved to where they can assist in removing the by-products from the facility, improving the quality of the air and water. They should be used in any natatorium designed to hold a large number of swimmers or swimmers who will be in the water for long periods of time.

These source capture strategies employ bench, drain or wall-mounted systems positioned along the sides and decks of pools. They work in concert with code-mandated duct designs and ventilation standards that deliver supply air. The supply air is pulled over the water surface at a rate not to exceed 30 fpm so that contaminated air is moved toward a low exhaust point, in this case the source capture systems. The contaminated air is exhausted directly outdoors.

These low exhaust source capture strategies minimize and prevent the recirculation of chloramines and other airborne pollutants, helping maintain the quality of supply air to the breathing zone in the pool and deck area. The absence of chloramines and corrosive pollutants also helps protect natatorium equipment and other HVAC system components.

## Pool Chemical Usage

### A. Chlorine

The question is often asked as to why chlorine is used if the off-gassing is so bad for humans. The answer is simple: the good far outweighs the bad. Chlorine is put in the water to kill microorganisms and bacteria. If done properly, it does an excellent job. The chlorine in the pool water breaks down into hypochlorous acid and hypochlorite ions. Both will instantaneously attack and kill any microorganism or bacteria they come in contact with by attacking the lipids in their cell walls. This is the positive outcome of putting chlorine in pool water.

However, chlorine also reacts with sweat, skin cells, urine, and other organic compounds found in water to create the disinfectant by-products such as trichloramine and cyanogen chloride. It is these airborne by-products that can be hazardous to one's health if not removed properly.

### B. Chlorine Alternatives

There are alternatives to using chlorine as the primary sanitizer in a pool, if local codes allow. Bromine is the second most used disinfectant. Bromine can be as effective as chlorine in killing bacteria although the dosage has to be higher. In addition, bromine is a less powerful oxidizer than chlorine and thus is not as effective as chlorine in eliminating swimmer waste products. For this reason, oxidizers such as monopersulfate are often used in conjunction with bromine and can be more expensive in large pools.

### C. Salt Water Pools

Salt water pools have become popular among swimmers because of the softer feel of the water. It can be popular with pool operators because salt is safer to store than chlorine.

However, a common misperception is that this is a chlorine-free environment. The reality is that a salt water pool is also a chlorine pool. The salt system works by sending pool water through a salt cell with metal plates. These plates receive an electrical charge and the electrolysis produces chlorine. As the water returns to the pool it will now have chlorine and hypochlorous acid in it, the same as in a regular chlorinated pool although the concentrations may be less.

The design engineer and pool operator must use caution with a salt water pool since the salt in the water can conduct low level electrical current that can cause a galvanic reaction if separate metal components are not on the same earth ground connection.

If a pool water condenser is being specified for a dehumidifier serving a salt water pool then it should also be specified that the water condenser's inlet and outlet connections are wired back to the electrical box to connect to the common earth ground.

### Proper Airflow Design

The Overview section of this guide noted how natatoriums and aquatic centers create a challenging application environment for air handling systems. These systems must move significant volumes of air to control temperature, humidity and pressure. The speed of airflow created, location of ductwork that delivers the airflow, and nature of construction materials also play roles in providing acceptable indoor air quality for swimmers; and protecting the building and its equipment.

The designer can use either fabric duct or metal to meet the objectives of proper air distribution. Each has its own merits and comes down to personal preferences.

The American National Standards Institute (ANSI) has accredited the Sheet Metal and Air Conditioning Contractors National Association (SMACNA) as the lead standards-setting organization for HVAC duct design and construction.

The SMACNA standards for duct systems address duct construction and installation, indoor air quality and energy recovery. HVAC Duct Construction Standards - Metal and Flexible is the fourth and current edition recommended for use by design professionals as well as the HVAC Systems Duct Design, 4th edition.

### Duct Design

Supply air ductwork should form a "U" around three sides of the pool. This provides for airflow that travels across or "washes" windows and outside walls with dry supply air. The ductwork configuration also raises the temperature of the inside surface while flushing it with the lowest dew point air in the facility. The duct size and dimensions should follow the SMACNA design standards or the design guidelines provided by the fabric duct manufacturers.

As noted in the condensation section, proper airflow on exterior walls, windows, and doors eliminates or minimizes condensation that can be caused by the high humidity and high temperature levels of an indoor pool facility coming in contact with a cold surface. Depending on the window and wall surface area, the flow of dry supply air is set at 3 to 5 cfm per sq. ft.

HVAC engineers locate return air and exhaust air grilles on the fourth side or wall of natatoriums. High and medium height grill locations work best for the return air. The higher locations optimize the recovery of the higher temperature and humidity containing air since hot, humid air rises. This also keeps the air returns from being blocked by pool furniture and spectator stands. High returns should be as close to the ceiling as possible; medium returns 6 to 8 feet above the pool deck and spectator levels.

This combination of the "U" shaped supply air and fourth wall return air provides the best solution to utilize a source capture exhaust air technique (see Figures 8 and 9).

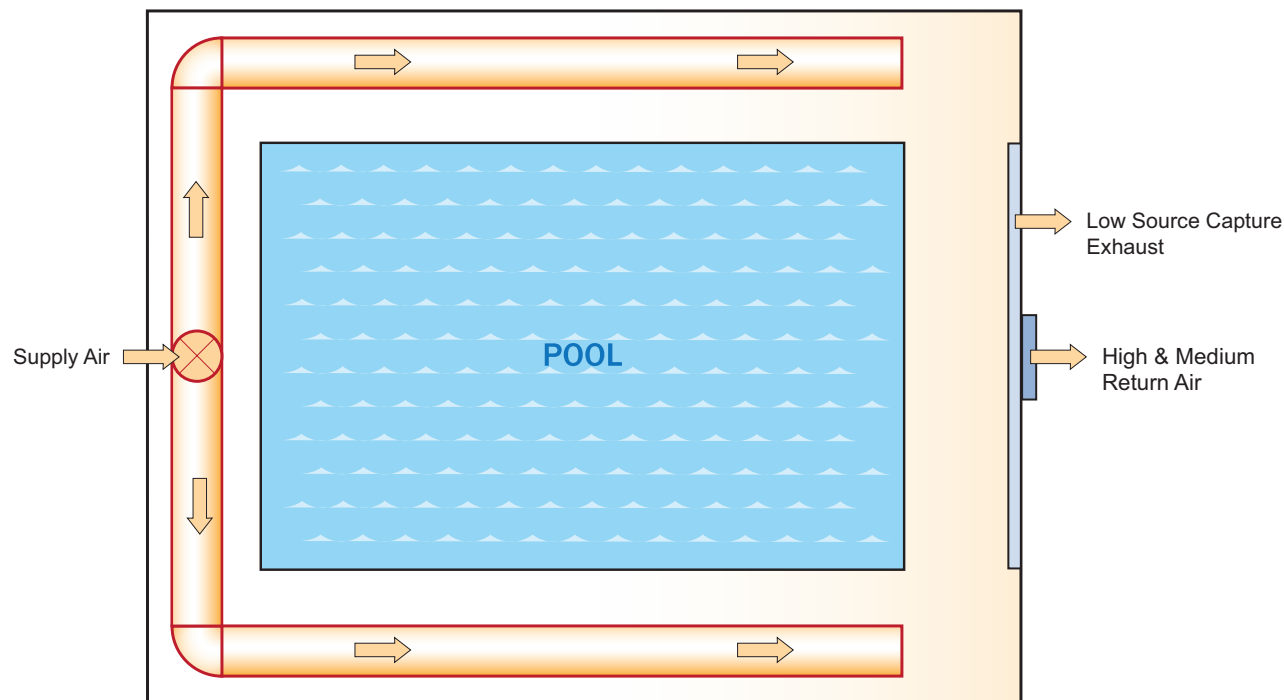


Figure 8. Top view of duct design

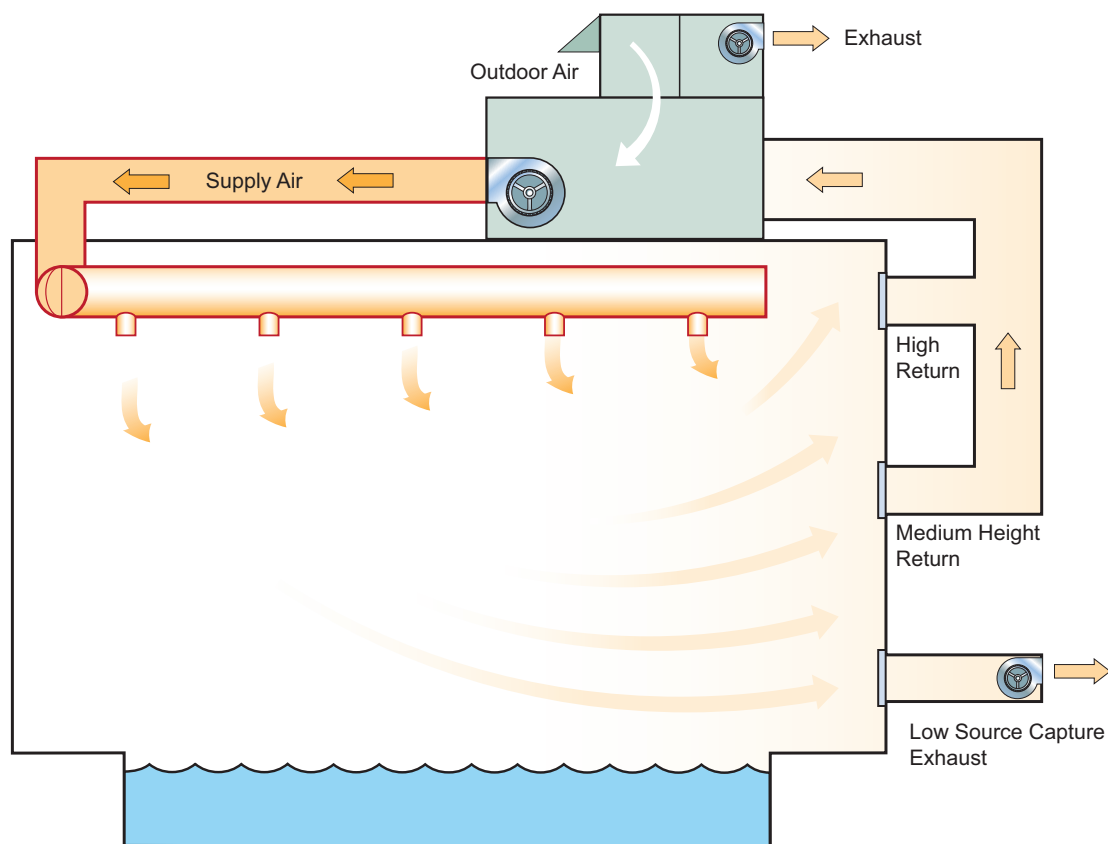


Figure 9. Plan view of duct design



Engineers and architects should choose duct materials and construction methods that are suitable for environments that are humid, wet and where airborne chemicals are present. Moisture and chemicals attack ducts, grilles, registers, diffusers and equipment enclosures. Fabric duct, galvanized steel or aluminum is used for above grade duct, PVC for below grade. Special epoxy paint is used to improve corrosion resistance on galvanized steel, aluminum ducts and 316 stainless steel. Aluminum or plastic is the material of choice for grilles, registers and diffusers.

### Supply Air Rate

Supply air should be delivered at a constant rate in order to continuously wash the walls, windows, and doors. The rate of supply air should not be lowered during unoccupied hours.

To provide sufficient air to flush the walls and windows, prevent stratification and deliver air down to the breathing zone, ASHRAE Applications Handbook 2019 recommends the air change rates listed below.

- 4 to 6 air changes per hour for pools with no spectator areas
- 6 to 8 air changes per hour for pools with spectator areas
- 4 to 6 air changes per hour for therapeutic pools

It should be noted that these are air changes within the room. The outdoor air ventilation rate is considered under a different formula as noted earlier in this guide.

Another strategy to address indoor air quality concerns are low velocity/high volume fans. These can be included in natatorium HVAC system designs to provide airflow to ceiling areas that would be difficult for the supply ductwork to reach. They should not be used in the down flow configuration as this can impact airflow across the pool surface.

## Dehumidification Equipment Design Considerations

### Dehumidifier System Components

At a minimum, the natatorium dehumidifier is an air handler sized to remove the moisture at a rate equal to the evaporation rate of the pool water plus (or minus) the summer ventilation air load.

Desert Aire SelectAire™ and SelectAire Plus™ dehumidifiers for natatoriums and aquatic centers go above and beyond the standard air handler definition. Desert Aire SelectAire™ and SelectAire Plus™ dehumidifiers meet the integrated requirements of natatoriums and their owners to protect the health of building users, maintain ideal temperature and humidity levels, promote the structural integrity of the building and its contents, and conserve energy.

Desert Aire SelectAire™ and SelectAire Plus™ dehumidifiers are refrigerant-type dehumidifiers providing closed loop systems that effectively transfer both latent and sensible heat from an indoor environment to a variety of alternate heat sinks.



Figure 10. SelectAire™ (top) and SelectAire Plus™ (bottom) dehumidifiers

An air reheat or condenser coil is present in all Desert Aire dehumidifiers and is the most common heat sink. The condenser or combination of condensers must be sized for the total heat of rejection (THR) of the system.

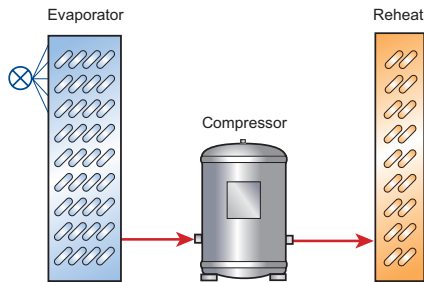


Figure 11. Refrigeration schematic without pool recovery

A water heater coil may be added as an additional heat sink. This component is generally a tube in tube heat exchanger that allows water to absorb the heat from the hot refrigerant. A diverting valve controls whether the refrigerant goes to the air reheat coil or the water heater coil. In most applications the air reheat coil has priority.

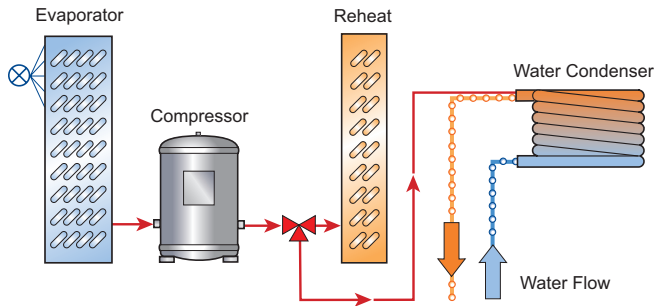


Figure 12. Refrigeration schematic with pool recovery

There are several potential water uses for this heat sink energy. Examples include pool water, spa water, potable water, and hydronic heat water. The actual water heater coil is selected to be compatible with the water source used. If the refrigerant to water heat exchanger is included it should not be replacing the primary pool water heating appliance. Desert Aire's pool water heating option will supplement the pool heating by using energy recovered energy, but it should not be used as the only pool heating method.

An air-cooled remote condenser may also be added to the dehumidifier. This would only be used when there are no other

uses for this energy. This becomes similar to a standard air conditioner by adding a condenser outside the conditioned space.

When all other heat sinks have satisfied the respective set points, then a valve diverts the hot refrigerant outside where the remote condenser dissipates the heat to the surrounding environment. This condenser must be sized to the dehumidifier to ensure proper charging and operation.

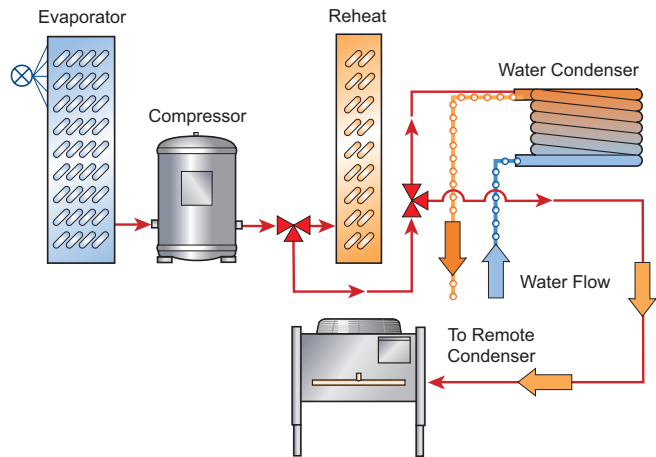


Figure 13. Refrigeration schematic with all modes

When the remote condenser is utilized, the cool air from the evaporator coil does not get reheated. The air leaving the dehumidifier is cooler than the entering air. The total air conditioning capability is a function of the latent and sensible load in the room.

For applications where an air-cooled remote condenser is not practical, such as a long line set, a refrigerant to water heat exchanger and a fluid cooler can be used to meet the space cooling needs.

## Dehumidifier Design Options

When planning a dehumidifier application there are several key specifications that must be considered.

First, how much moisture must be removed from the natatorium? This is generally calculated in pounds per hour of water. Once a size is selected, then a decision on what heat sinks are appropriate must be made. Answers to the heat sink question will then dictate whether an air-cooled or water-cooled unit is selected and if a remote condenser or fluid cooler is required.

Key features and benefits of the Desert Aire SelectAire™ and SelectAire Plus™ dehumidifiers include meeting ventilation codes; exhaust air recovery; ventilation air flexibility; pool water condenser capabilities; integration with a source capture system; and, latent and sensible energy recovery. Return of the condensate to the pool water system is also available where codes allow.

Desert Aire dehumidifiers integrate all ventilation air components through the dehumidifier to ensure the correct proportions of return air, supply air, exhaust air and outdoor air, and to maintain a negative pressure in the space.

Because conditioned air returning to the dehumidifier contains sensible energy in the form of heat and latent energy in the form of humidity, there is an opportunity to incur energy savings before conditioned air is exhausted from the HVAC system.

## Economizers

Building designers often ask mechanical engineers to include in their system designs HVAC equipment with energy efficiency features such as economizer functions. They want the new buildings to comply with ASHRAE 90.1, a standard that provides minimum requirements for energy efficient designs for buildings. HVAC equipment in this classification includes air conditioners, heat pumps, furnaces and boilers.

Including dehumidifiers in this classification is a common mistake. The code specifies that any air conditioner with a supply air volume greater than 5,000 cfm utilize an economizer in most weather zones.

Dehumidifiers are not in the same equipment classification as air conditioners, because they function mostly in the dehumidification and heating modes; not air conditioning modes. Therefore ASHRAE 90.1 does not directly apply to the pool room dehumidifier.

Nevertheless, to meet building owner requests and meet local codes, dehumidifiers with economizer features do exist and may theoretically be suitable for some climates under certain conditions. When certain weather and enthalpy conditions are present, outdoor air may be able to supply the cooling and dehumidification requirements for the pool facility.

Simulations typically show that an economizer-equipped dehumidifier for an indoor pool will not provide operational “economy”. This is due to the significant energy penalty of the full-sized blowers and their low Energy Efficiency Rating (EER) in the cooling and dehumidification modes. It will cost more money to operate the economizer-equipped dehumidifier compared to other dehumidifiers.

## Purge Mode

Many design engineers and pool operators require a purge mode. This allows the room to be quickly purged of indoor air and replaced with outdoor air. In all cases this purging occurs during unoccupied hours.

The Model Aquatic Health Code recommends the purge mode be set at a minimum of twice the code required outdoor air rate. The Desert Aire SelectAire™ and SelectAire Plus™ system can provide up to 50% of the total airflow when in the purge mode.

A common design mistake is to schedule 100% outdoor air for purge. The difference in time between a full purge of a natatorium space at 100% as compared to 50% is usually about 20 minutes or less. However, the backup space heater must be double the size to handle the full heating requirement of a 100% purge that happens on a design load winter day. This will add substantial equipment cost plus an increased structural load.



## Maximizing Energy Recovery

Desert Aire employs techniques and designs to maximize recovered energy. The dehumidifiers achieve energy efficiency without weighing down the equipment with fan systems and motors designed for introducing and exhausting 100% outdoor air. This system also saves substantial energy compared to an outdoor air system during non-occupied periods due to not having to exhaust all of the latent energy from the building while bringing in outdoor air that needs to be heated.

Desert Aire's SelectAire™ and SelectAire Plus™ systems have two exhaust air dampers. One is upstream of the evaporator coil and one is downstream. This special design feature allows SelectAire™ dehumidifiers to take advantage of two basic thermodynamic principles while not impacting the sensible cooling capacity of the units: exhaust air at its coldest point; and, exhaust air at its warmest point.

When the space requires heating, air is exhausted after the evaporator coil to recover the energy contained in the exhaust air prior to its discharge. In the cooling mode, air that is warm and humid is exhausted before the evaporator coil.

SelectAire™ and SelectAire Plus™ systems use the principle of a heat pump to recover energy in the heating mode by operating one of the two circuits in conjunction with exhaust air. As previously noted, exhaust air consists of two energy components: sensible and latent. The cold evaporator coil absorbs both of these components. In addition to this energy, the energy required to operate the compressors is returned in the form of heat. This option provides high coefficient of performance (COP) efficiency to the exhaust air recovery cycle.

This Desert Aire design is the most efficient method to recover the total energy of the exhaust air. Since the airflows and loads are maintained through the special airflow control sequence, the amount of recovery can be optimized.

Other systems that use passive heat exchangers cannot recover latent energy during the majority of the operation and the amount of sensible recovery is dependent on the outdoor temperature. In addition, their actual recovery effectiveness is variable as it changes based on the temperature differential. Passive heat exchangers require additional fan energy and cannot take full advantage of free outdoor air cooling unless bypass dampers and controls are installed.

SelectAire™ and SelectAire Plus™ systems have a constant rate of energy recovery when activated and are always controlled automatically based on the zone condition.

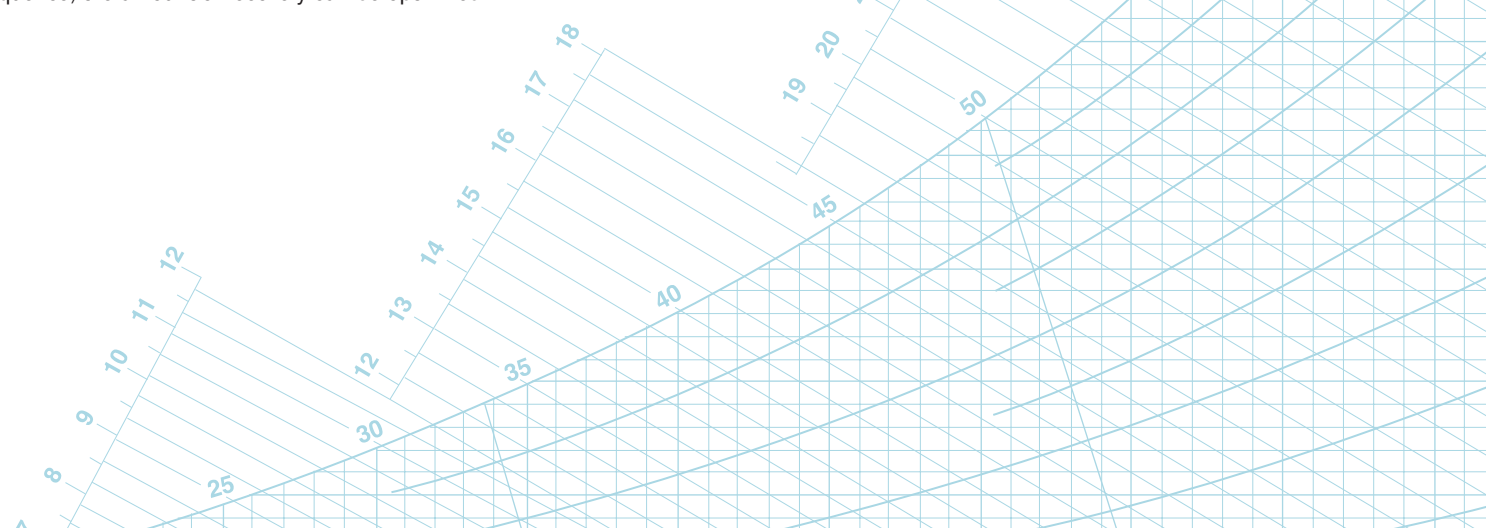
## Integrated With Source Capture

If natatorium HVAC designs include chloramine source capture evacuation systems such as the Evacuator®, Desert Aire dehumidifiers can provide all of the ventilation air, including what is required for operation of the Evacuator®.

Desert Aire's control system modulates the Evacuator® exhaust speed based on the required mode of operation. The Desert Aire dehumidifier can vary the volume of outdoor air and exhaust air based on the level of contaminants within the natatorium.

\*Evacuator® is a registered trademark of Paddock Industries.

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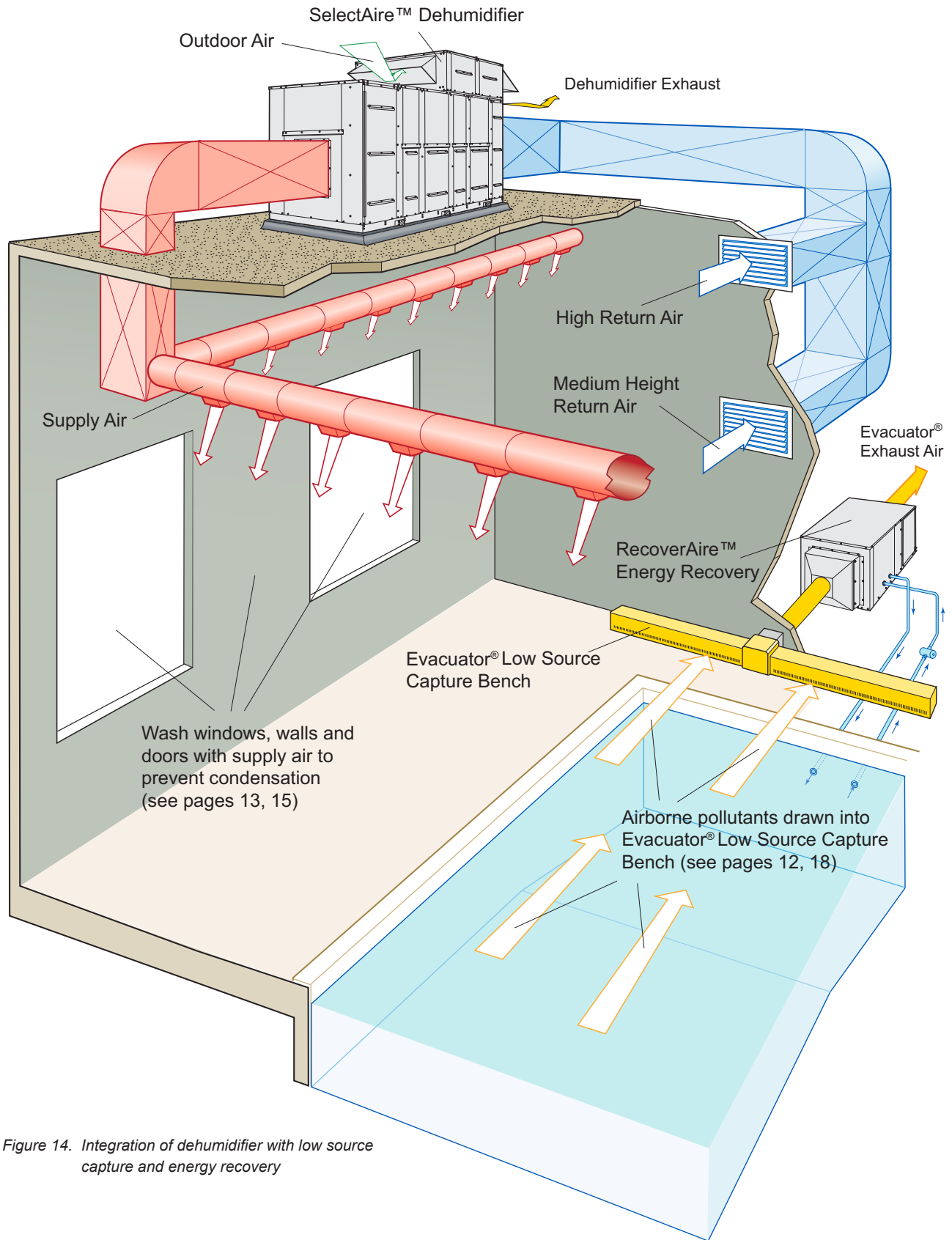


Figure 14. Integration of dehumidifier with low source capture and energy recovery

The key to this integration is the use of a VOC sensing element that can detect when interior levels of chemicals such as chloramines are present. This is similar to the use of CO<sub>2</sub> sensors in general ventilation applications but since the main source of contamination is a volatile organic compound, the VOC sensor is more appropriate for the pool environment.

This provides the ability to optimize the volume of exhaust air required with the energy cost of doing so and ensures a suitable pool environment for the occupants. If the VOC sensor is not included in the installation, the SelectAire™ and SelectAire Plus™ dehumidifiers will exhaust all air without optimizing its volume.

The following table (Figure 15) shows an example of the flexibility of the Desert Aire control system to meet the IAQ needs for pool rooms at various levels of occupancy.

	CFM			
Mode of Operation	Low Exhaust Air	Dehumidifier Exhaust Air	Total Exhaust Air	Total Outdoor Air
Unoccupied	2,200	0	2,200	1,800
Normal Occupancy	2,200	2,200	4,400	4,000
Event Occupancy	2,200	3,000	5,200	4,800
Maximum Occupancy	4,400	4,400	8,800	8,400
Purge (no cmpr)	4,400	6,600	11,000	10,600

Figure 15. Example of SelectAire™ dehumidifier airflow configuration

Low Exhaust Energy Recovery

A properly functioning system will not recirculate the air being removed from the low exhaust system; otherwise the system would reintroduce the highly concentrated chemicals back into the space. A perceived negative for this low exhaust is that it has a significant energy content that is bypassing the recovery capability of the SelectAire™ dehumidifier. To minimize this loss, a Desert Aire RecoverAire™ air to water heat pump recovery system should be installed in place of a basic exhaust air blower. By using a high coefficient of performance (COP) heat pump, the system can recover up to 75% of the heat loss of the pool.

Desert Aire’s RecoverAire™ system has been designed to meet the challenges of the low exhaust system and interfaces directly with the SelectAire™ system to allow easy field set-up and balancing. Exhausting too much air is an energy waste, but since every natatorium is different the SelectAire™/ RecoverAire™ tandem provides the end user with the control to optimize the volume of air in all 5 modes of operation. This capability balances the volume of outdoor air to ensure proper IAQ while minimizing the cost of treating this outdoor air.

Installation Considerations

SelectAire™ and SelectAire Plus™ dehumidifiers can be installed either indoors or outdoors. Units intended for outdoor installation are factory equipped with additional insulation, heavy-duty weather sealing and special rain hoods mounted on the outside air intake. When required they can also be installed on roof curbs that permit bottom return and supply air to meet HVAC design specifications.

Proper installation of the dehumidifier into the total HVAC system takes careful planning. All of the heat available from the dehumidification process is derived from the compressor and the conversion of latent energy through refrigeration technology.

With a seasonally fluctuating moisture load or maintenance condition, such as the draining of the natatorium pool, supplemental pool heaters must be added to compensate for the lack of heat from dehumidification. In the same manner, the dehumidifier should also include an auxiliary form of space heating. This can be in the form of an integral electric, hot water coil, or a gas heater downstream of the blower.



Figure 16. Desert Aire RecoverAire™ air to water heat pump recovery system

Another factor requiring attention is condensate removal from the dehumidifier. Some local codes state that condensate must be plumbed to a drain; but many allow the return of the condensate to the sump upstream of the filter and chemical feed system. The volume of recovered water can be significant and can equal the entire volume of the pool per year.

This should be a consideration on a natatorium designed to achieve high levels of recognition under the Leadership in Energy & Environmental Design (LEED) green building certification program. To recover the condensate water the dehumidifier employs a gravity drainage system. An unpressurized drain connection or a condensate pump then returns the condensate upstream of the sump.

Many older natatoriums with indoor mechanical rooms did not take into consideration that the dehumidification system would need to be replaced during the life of the facility. The removal of the failed system is the easiest part of the retrofit project while moving the new dehumidifier into the mechanical room can be quite challenging. Desert Aire offers a solution to this problem through the sectioning of our SelectAire™ Series dehumidifiers. Desert Aire works with the customer to determine the maximum size and weight of the largest section that can be moved into the mechanical room. This information is used by Desert Aire engineering to create a sectioned SelectAire™



Figure 17. The Desert Aire SelectAire Plus™

Series unit that meets the performance needs of the natatorium while taking into consideration the logistical problems caused by mechanical room access. Refer to Figure 18 for an example.

The key features of Desert Aire sectioned units include the following:

- Refrigeration valves provided when sectioning of refrigeration circuits is required
- Wiring harnesses with mating connectors and terminal strips to distribute power through the unit
- Flanged edges and gaskets for sealing sections



Figure 18. SelectAire™ sectioned unit ready for shipment



## Commissioning

A design process that includes an integrated approach to the natatorium's HVAC system should include commissioning. Commissioning encompasses a set of techniques and procedures to check, inspect and test each operational component of the system to confirm everything is working together as designed.

The system must be completely tested to verify airflow rates; negative pressurization; operation during all modes of occupied and unoccupied states; space heating and cooling; humidity control; water heating; and integration with the source capture system.

### Factory Certified Start-up

Due to the complexities of a natatorium's HVAC design, the start-up of a Desert Aire SelectAire™ or SelectAire Plus™ system should be done by either factory technicians or local technicians certified as having been factory-trained by Desert Aire.

### Facility Staff Training

The equipment start-up and commissioning process should include training of the natatorium maintenance staff. The maintenance staff should have a basic understanding of HVAC and pool dehumidification systems. This training should include the pool room design conditions, general overview of the sequence of operation, and navigation of the dehumidifier's operating control user interface. This training should also include the scheduling setup of Unoccupied, Occupied and Event modes.

Other natatorium personnel, such as aquatic directors and lifeguards, should be advised of the design conditions of the pool room and the importance of maintaining these conditions.

## Conclusions

The new ways people use natatoriums and indoor pool facilities place demands on HVAC systems and buildings that weren't present just a few years ago.

In addition to working in harmony with systems that control water temperature and water quality, the HVAC system for the 21st Century natatorium must protect the health of building users; promote the long-term structural integrity of the building and supporting systems; and conserve energy, water and water treatment resources.

Today there is a matrix of strategies, technologies and industry resources to provide building owners, mechanical contractors and engineers with solutions to these challenges.

As a key component of HVAC systems and their designs, Desert Aire SelectAire™ and SelectAire Plus™ dehumidifiers help meet the holistic needs of natatoriums and aquatic centers. A Desert Aire system properly removes humidity to promote greater comfort, protect structural integrity, improve indoor air quality and conserve resources.

For more information on meeting the HVAC design challenges of your 21st Century natatorium, contact Desert Aire at the address below.

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