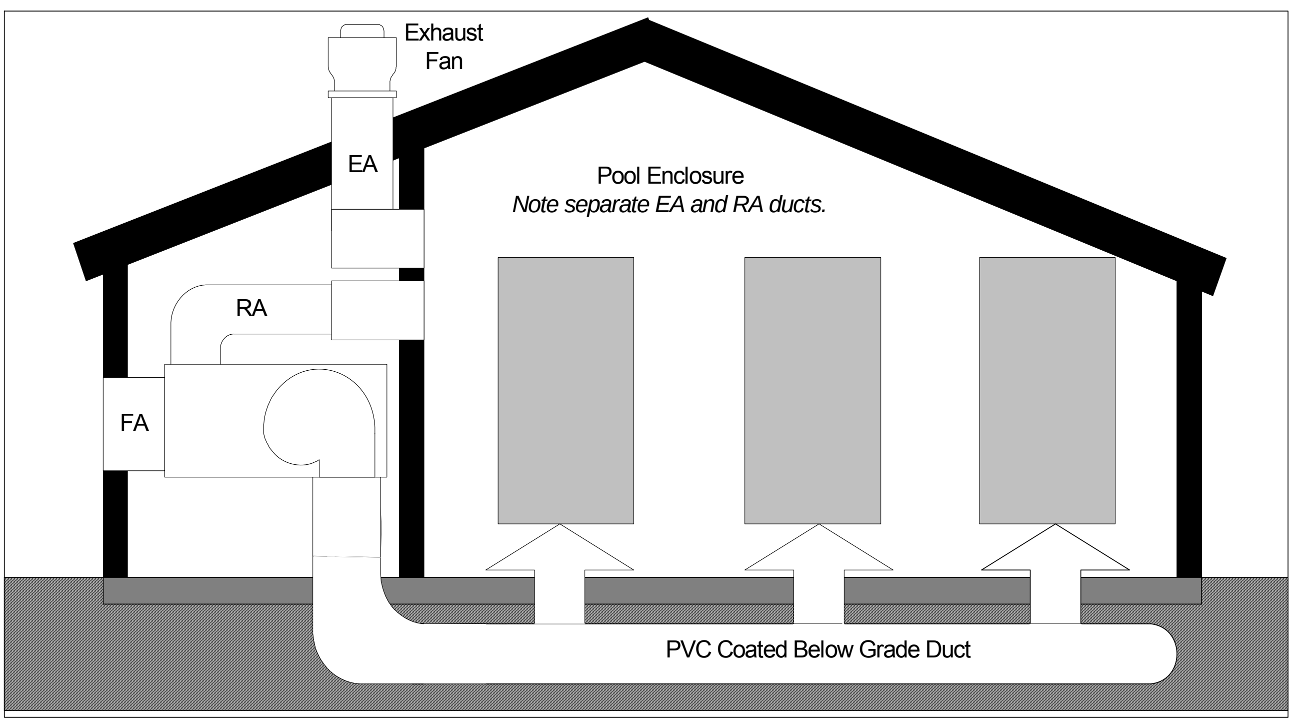
American Society of Heating, Refrigeration and
Air Conditioning Engineers (ASHRAE)
Design Guidelines

1. *"Natatoriums are characterized by high latent loads that should be controlled to minimize corrosion and condensation on the building structure. Outdoor air of low moisture content may be used for this purpose." "Ventilation of the pool enclosure helps control corrosion and condensation."*

During much of the year in cooler climates, outside air moisture content is low and once it is heated, this warmed air has a low relative humidity. Titan's AR/80™ pool package control system takes advantage of this low relative humidity air to purge a pool area of unwanted corrosive moisture. Titan's AR/80™ is capable of modulating the supply air from 100% outside air down to a low of 20% outside air. During cooler months, only 20% outside air is typically needed and the remaining 80% of the supply air is recirculated from the pool area without passing across the burner.

As tempered dry air is introduced, a nearly equal amount of humid air is exhausted. If humidity level rises, more fresh air is introduced and more humid air is exhausted.



2. *“The pool area should be isolated from adjacent building areas, if possible, by creating a negative pressure in the pool area.”*

Titan’s control scheme for swimming pool applications includes a variable frequency drive (VFD) to change the speed of the exhaust fan. A pressure differential sensor is employed to determine the pressure differential between pool area and lobby area (in the case of a hotel). The signal from the pressure differential sensor is wired to a controller that adjusts exhaust fan speed to maintain a slight negative pressure in the pool area as compared to an immediately adjacent section of the building.

3. *“All components of the pool heating, air handling and air distribution systems that are exposed directly or indirectly to the moist, corrosive pool atmosphere should be protected against the corrosiveness.”*

Proper design of the equipment will include a phenolic coated interior. Heresite, Titan’s phenolic coating of choice, is impervious to chlorine or bromine laden air common in a swimming pool application.

ADDITIONAL FACTORS AFFECTING EQUIPMENT PERFORMANCE

Delivering tempered dry air to a pool enclosure is only part of a good pool de-humidification and ventilation system. Proper air distribution is essential to prevent condensation on windows and other building components. Air distribution also plays a large role in the volume of water evaporated from a pool surface. Along with proper air distribution, the control system (temperature, humidity and pressure) must be wired, set up and operating properly. Vapor barriers on interior surfaces of pool areas play an important role in keeping moist corrosive air from damaging insulation and other building materials.
Titan strongly recommends installing pool heating/ventilation equipment in a mechanical room adjacent to the pool area and providing suitable room for proper service and maintenance work. Outdoor mounted equipment **SHOULD NOT** be placed directly over the pool with a discharge duct arrangement that also terminates over the pool. Such arrangements typically result in excessive air velocity over the water surface and can create difficulties restarting the equipment after a shutdown. Additional installation and operational restrictions will apply to outdoor mounted equipment.

DUCTWORK, REGISTERS AND WINDOWS

Ducts and registers must be designed to deliver an adequate supply air to the entire surface area of each exposed window. If the inner surface temperature of a window drops below room air dew point temperature, condensation will occur (see chart 1). The aesthetic appeal of numerous windows (especially those high on the side wall and near a spa or hot tub) should be weighed against the required increased air volume and duct work to prevent condensation. Per ASHRAE’S guidelines, *“the use of glass on pool exposures complicates the design problem and adds cost, especially in colder climates. Cold drafts and condensation are difficult and expensive to eliminate if glass walls or exposures are used”.*
Premium multi-pane energy efficient windows themselves should feature a top quality, non-metallic thermal break to help keep inner surface temperatures above room air dewpoint temperature even in cold weather.

Chart 1

Temperature at which condensation will take place on interior surfaces							
% Relative Humidity	Pool area Temperatures (degrees F)						
	74	76	78	80	82	84	84
40	48	50	52	54	55	57	59
50	54	56	58	60	61	63	65
60	59	61	63	65	67	68	70

Air velocity over water surface(s) should be kept at a minimum to reduce water evaporation. Supply air should be directed up or down along perimeter windows and/or walls. Separate return air and exhaust inlets should be located as high as possible to minimize air velocity over the water surface. Lower evaporation rates reduce costs associated with ventilation air heating and water heating. Some air movement over water surfaces is needed for proper air quality, but avoiding excessive air movement over water surfaces will reduce operating costs.

Outdoor air intake hood or louver should be sized and located to prevent snow and rain from being drawn in. Mechanical room layout should facilitate proper installation of the unit, and proper configuration of supply, return and exhaust ductwork, filter sections, etc.

CONTROLS, START-UP AND MAINTENANCE

There are three key parameters to consider in a swimming pool enclosure application. Humidity, temperature and building pressure controls must be properly designed and integrated to ensure all three are optimized efficiently. Titan has selected sensors that are well adapted to the corrosive atmosphere associated with this application. The pool area temperature and humidity sensor is wired to a programmable controller located in the airhandler. Preferred location for the pool area temperature and humidity sensor is in the exhaust duct immediately behind the grille where it is drawn from the space. Other locations are possible given an understanding of common sensor placement issues. Proper sensing of average space temperature and humidity is critical. Building pressure sensor is typically located in the airhandler (for an indoor unit) or in a remote panel intended to be placed in the building but not in the pool area for an outdoor unit. The programmable controller that receives all sensor inputs is typically located in the airhandler. Associated user interface display module can be mounted on airhandler for an indoor unit, but many customers prefer to have this module shipped loose so they can install it in a more convenient monitoring location such as near a front desk or in an office.

Factory checkout cannot duplicate conditions the equipment will see when installed. A thorough check out of the system must be performed at job site. In addition to job site start-up, detailed operator training should be given to building staff. A qualified technician should perform a complete start-up procedure every six months to ensure all sensors and controls are functioning properly and all safety controls are operational. Filter, bearing and belt maintenance inspections should be more frequent.

DESIGN CRITERIA

An indoor swimming pool environment can be one of the more difficult environments to control. When designing a pool area heating and ventilation system there are several factors that must be taken into account.

1. People Comfort - both in and out of pool. Chart 2 shows ASHRAE recommended design conditions for a pool area.
2. Air Movement - Air movement at outside perimeter and across water surface(s).
3. Humidity Level - Keep humidity in a zone that will provide comfort and building protection.
4. Negative Pressure - Pool area should be kept at a negative pressure as compared to rest of facility to minimize the amount of destructive, chlorine laden, air that migrates into building structure or other areas of building.

Chlorine laden moisture can have devastating effects on most building materials. Studies have proven the optimum RH level for human comfort is 50 % to 60% (see chart 2).

Chart 2

DESIGN Conditions for Pool Areas	
Indoor Air	
Pleasure Swimming	75 to 85^o F ; 50 to 60% RH
Therapeutic	80 to 85^o F ; 50 to 60% RH
Pool Water	
Pleasure Swimming	75 to 85 ^{o} F
Therapeutic	85 to 95 ^{o} F
Whirlpool/Spa	97 to 102^o F

From ASHRAE Application Handbook

Evaporation of water, in a pool area, is the source for high levels of humidity. Of the methods of controlling humidity in a swimming pool environment, dry fresh air is the most effective method. The introduction of fresh air and exhausting of an equal volume of pool air will purge the area of moisture, thereby lowering relative humidity. Even in summer months when fresh air can have a relatively high moisture content, introduction of a higher percentage of fresh air while exhausting a higher volume of corrosive, chlorine/bromine laden air minimizes potential for damaging the building structure and provides fresh air for occupants.

CALCULATING REQUIRED FRESH AIR FOR MOISTURE REMOVAL

In order to calculate the volume of fresh air required to remove moisture from a pool area, the evaporation rate must first be found. Several aids will be required to complete calculations. The information in the following charts is taken from ASHRAE Psychrometric Chart. This information is required to calculate needed fresh air to remove undesired humidity in pool area.

Formula for calculating evaporation rate (from ASHRAE):

$$Wp = 0.1\ A\ (\ Pw - Pa\ )$$

Where:
Wp = Evaporation rate of water: #'s / Hr
A = Area of water surface: Ft^2
Pa* = Saturation (vapor) pressure at room air Dew Point Temp: "Hg (chart 3)
Pw* = Saturation pressure at water surface temp: "Hg. (chart 3)

(see chart 4 for Dew Point Temps at various room air temps and humidity levels)

Chart 3

DEW POINT V.S. VAPOR PRESSURE					
Dew Point Temp	Vapor Pressure	Dew Point Temp	Vapor Pressure	Dew Point Temp	Vapor Pressure
105	2.200	90	1.421	75	.875
104	2.178	89	1.377	74	.846
103	2.115	88	1.335	73	.818
102	2.053	87	1.293	72	.791
101	1.992	86	1.252	71	.764
100	1.993	85	1.213	70	.739
99	1.875	84	1.175	69	.714
98	1.819	83	1.137	68	.690
97	1.765	82	1.101	67	.666
96	1.712	81	1.066	66	.644
95	1.660	80	1.032	65	.622
94	1.610	79	.998	64	.600
93	1.561	78	.966	63	.580
92	1.513	77	.935	62	.559
91	1.467	76	.904	61	.540

* NOTE: Saturation Pressure and Saturation Vapor Pressure are slightly different. However, the difference is so slight we will use the vapor pressure chart (chart # 3) for both factors Use dew point temperature for water surface temperature for selection of saturation pressure.

Chart 4

Room Air Temps		Dew Point Temps @ Humidity Levels		
		50%	55%	60%
75		55.08	57.71	60.15
76		56	58.64	61.09
77		56.91	59.57	62.03
78		57.83	60.5	62.97
79		58.75	61.43	63.91
80		59.67	62.36	64.85
81		60.59	63.29	65.79
82		61.51	64.22	66.73
83		62.42	65.15	67.67
84		63.34	66.08	68.61
85		64.26	67.01	69.56

Chart 5

Room Air Temps		Humidity Ratios @ Humidity Levels		
		50%	55%	60%
75		0.00994	0.01096	0.01197
76		0.01029	0.01133	0.01239
77		0.01064	0.01172	0.01281
78		0.011	0.01213	0.01325
79		0.01138	0.01254	0.0137
80		0.01177	0.01297	0.01417
81		0.01216	0.01341	0.01465
82		0.01257	0.01386	0.01515
83		0.013	0.01432	0.01566
84		0.01343	0.0148	0.01619
85		0.01388	0.0153	0.01673

Chart 6

Humidity Ratios (@ 60% RH) at Various OA Temperatures					
OA Temps		OA Temps		OA Temps	
- 30	.00009	-2	.00046	18	.00127
-25	.00013	-1	.00048	19	.00133
-20	.00017	0	.00051	20	.00139
-19	.00018	1	.00054	21	.00146
-18	.00019	2	.00057	22	.00154
-17	.0002	3	.0006	23	.00161
-16	.00021	4	.00063	24	.00169
-15	.00023	5	.00066	25	.00177
-14	.00024	6	.0007	26	.00186
-13	.00025	7	.00073	27	.00195
-12	.00027	8	.00077	28	.00204
-11	.00028	9	.00081	29	.00214
-10	.0003	10	.00085	30	.00224
-9	.00031	11	.0009	31	.00234
-8	.00033	12	.00094	32	.00243
-7	.00035	13	.00099	33	.00253
-6	.00037	14	.00104	34	.00263
-5	.00039	15	.00109	35	.00274
-4	.00041	16	.00115	36	.00285
-3	.00043	17	.00121	37	.00297

Once the water evaporation rate is known the required volume of ventilation air can be calculated with the following formula: (From ASHRAE)

$$Q = ((Wp / C) \div (q (Wi - Wo)))$$

Where:

Q = Minimum ventilation rate: CFM
Wp = Evaporation rate of water: #'s / Hr
C = Units conversion: 60 min / H
q = Standard air density: .075 #'s / Ft^3
Wi = Humidity ratio of pool air: #'s moisture / # air (see Chart 5)
Wo = Humidity ratio of outside air: #'s moisture / # air (see Chart 6)

One may find the calculated ventilation air flow, to remove evaporated moisture on a cold day, is somewhat low. In fact, it may be less than one air change. ASHRAE has set up minimum air changes (chart 7) for a swimming pool area. We have found this to be a good practice as the additional air aids in wiping exposed windows & walls with warm air keeping their inner surface temps above the room dew point temperature. In this case, ventilation air flow (outside air volume) is not the same as air change rate. Air volume, above that required for moisture removal, will be recirculated through the Titan unit. The unit has the capabilities to modulate its fresh air volume between 20% and 100% of total air volume to the space. There may be times when the system will run to 100% fresh air to remove moisture. This condition should exist only in cases of high pool activity and during warmer outside air conditions.

Chart 7

Type of pool area	Air Changes/Hr.
Pools w/o Spectator Facilities	4 to 6
Spectator Facilities	6 to 8
Therapeutic Pools	4 to 6

ASHRAE recomended air changes

EXAMPLE CALCULATIONS

Pool area is to be kept at 80°F and 55% RH
Pool water to be maintained at 80°F
Pool surface is 20' x 30'
Outdoor air design is 20°F at 60% RH

The first step is to find design indoor air temperature and design indoor RH on chart 4, cross reference to dew point temperature.

The second step will to be cross reference dew point temperatures found on Chart 4 to find saturation (vapor) pressure of the pool air on chart 3.

Third step is to find vapor pressure at water surface by selecting vapor pressure associated with water temperature on chart 3

Insert these numbers into the following formula.

$$Wp = (.1 \times (20' \times 30')) \times (1.032'' \text{ Hg}_{(\text{from chart 3})} - .559'' \text{ Hg}_{(\text{from chart 3})}) = \mathbf{28.38\ \#'s / Hr.}$$

We now know that with pool water at 80°F and 80°F air temperature the evaporation rate is 28.38 #'s per hour.

The minimum volume of fresh air required can now be determined. The humidity ratio of the room air and humidity ratio of incoming air will have to be found. Humidity ratios of indoor air can be found on chart 5 and humidity ratio of outdoor design air temperatures can be found on chart 6.

$$Q = ((28.38\#/Hr \div 60\ Min/Hr) \div ((.075\#/Ft^3) \times (.01297\#/\# - .00139\#/\#))) = 5\mathbf{44.61\ CFM}$$

Since 560 CFM will be the minimum out door air to control humidity level in pool area, divide this volume by 20% to find total air volume the unit must handle.

$$\text{Unit CFM} = 545\ CFM \div (20/100) = \mathbf{2725\ CFM}$$

If there is a Hot Tub or Spa in the same area as the pool it will require additional, minimum outside air to dissipate the humidity produced by evaporation from the Spa or Hot Tub.
If the Hot Tub or Spa is ten feet in diameter with the water at 104°F the additional minimum outside air requirement will be:

$$A = \pi 5^2 = 78.5\ Sq.\ Ft.$$

$$78.5\ Sq.\ Ft.\ X\ .1\ X\ (2.1786 - .559) = \mathbf{12.71\ \#/Hr}$$

$$(12.71\ \#/Hr / 60\ Min/Hr) \div ((.075\ \#/Ft^3) \times (.01297\#/\# - .00139\#/\#)) = \mathbf{248.8CFM}$$

Add this air volume to the volume required for the pool and the new required outside air is 794 CFM. Total unit volume will be 3970 CFM.

$$794\ CFM \div (20/100_{\text{(min OA volume of unit)}}) = \mathbf{3970\ CFM}$$

Note that this is an example calculation and does not include any additions for optional pool area features such as water slides or other accessories that would increase water evaporation rates.

OPERATION WHEN HEAT IS NOT REQUIRED

Using tempered (heated) outside air as the primary means to ventilate a pool enclosure is obviously targeted primarily at regions with cooler climates. Even in these climates, customers may be concerned with how the system operates during the summer. In general, units that do not have an active cooling means will switch over to modulate outside air percentage based on space temperature when heating is not required. During warmer weather, condensation on exposed windows and walls is no longer a concern. At mild OA conditions, varying the outside air percentage can effectively cool the space given that the space cooling setpoint is likely to be at or above 80°F and the unit can supply full outside if necessary while exhausting slightly more air to maintain a slightly negative building relative pressure. The use of outside air for "free cooling" in mild weather conditions is achieved using a control strategy commonly known as an economizer. A dry bulb based economizer is standard for use with or without active mechanical cooling and an enthalpy based economizer is available as an option that should only be used with active mechanical cooling.

During hot summer weather, space temperature can climb even in cooler climates. Many customers prefer to simply accept this condition and avoid the initial cost and maintenance requirements associated with active mechanical cooling equipment. At mid-day, pool area can get quite warm during hot summer weather, but so would conditions around an outdoor pool which leads many customers to simply accept this condition.

If desired, a cooling coil can be added to the airhandler or can be field installed in discharge ductwork. When active cooling capability is included, Titan recommends incorporating a means to enhance moisture removal and avoid supplying saturated air through the discharge ductwork and registers. A wrap-around heat pipe is an energy efficient and simple means of increasing moisture removal capacity while providing slight reheat of the supply air. Another more complicated method is through use of a refrigerant reheat coil placed immediately downstream of the cooling coil. Note that some customers have successfully incorporated mechanical cooling without including any means to provide enhanced moisture removal and slight reheat of the supply air.

Simple two stage cooling control based on space temperature is provided as a standard feature on Titan's pool package control system so that cooling can be field added even if not ordered initially. In all cases, selection of proper materials and coatings is critical for coils exposed to corrosive air recirculated from the pool area.