Swimming Pool Load Calculations

INTRODUCTION

This application note highlights the source of moisture loads in pool room enclosures and its potential harmful effects if left uncontrolled.

SOURCES OF MOISTURE LOAD

Indoor pools have three main sources of moisture:

1. **Evaporation from pool water surfaces**
2. **Outdoor ventilation air**
3. **People**

The vapor pressure difference between pool water and the air causes continuous evaporation. The vapor pressure of both water and air will change based upon each one's temperature and the differences in their temperatures. The evaporation rate increases the higher the water temperature is in relationship to the air temperature. The activity level at the water surface will also either increase or decrease the evaporation rate. Activity factors as defined by the ASHRAE Applications Handbook are shown in Table 2 of this bulletin.

During the summer months, outdoor ventilation air that is being introduced into the space to meet local code requirements may also be contributing to the moisture load of the space depending on the climate location.

The presence of spectators also adds to the moisture load of the space. This load is typically minimal in residential pools but can be fairly substantial when bleacher spectator areas are present.

PROBLEMS WITH HUMIDITY

Air is a gas. Like most gases, it expands in volume when heated and contracts in volume when cooled. This expansion or contraction that occurs with changing temperatures increases or decreases the percentage of moisture that the air can hold. In other words, as air expands, its ability to hold moisture increases. For a given moisture content, the percentage of moisture to air volume (relative humidity) is reduced when air is heated.

CONDENSATION

Condensation is one of the major enemies to an indoor pool environment. When condensation develops on surfaces, it can damage the material it forms on and also provides food for fungi and bacteria to grow.

Visible condensation will appear when the surface temperature is below the indoor dew point of the space. (See Figure 1.) In most pool environments, this dew point is in the range of 58° F to 66° F. The surface temperature can be calculated using the formula:

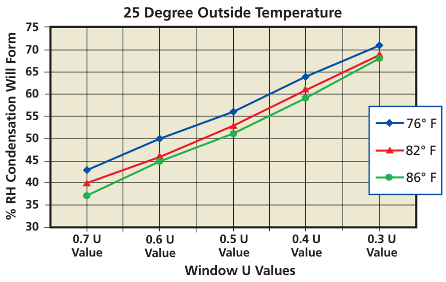
$$Ts = Ti - (K \times (1/R) \times (Ti - To))$$

Ts = Surface Temperature
Ti = Indoor Temperature
K = Constant of 0.68 for Vertical Surface
R = R Value of Structural Panel
To = Outdoor Temperature

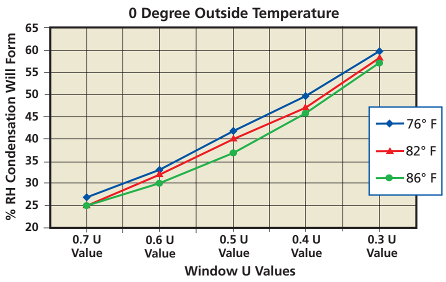
Since windows are the major contributor to condensation in this environment, we will only look at this building component. However, the same process can be used for any building component. Windows typically do not have an R value but are rated with U values. The U value is the reciprocal of the R value, R = 1/U.

The U values published for windows are for the entire window assembly and do not reflect the U value for each component of the window. For this reason we recommend that you add 5° F to the actual calculated surface temperature and use this value for your dew point. This would mean that all surfaces in an indoor pool environment should be kept above 63° F to 71° F to prevent visible condensation.

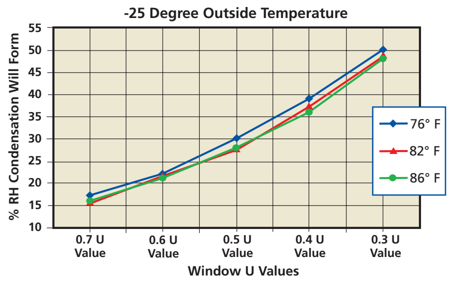
If you're more comfortable referencing percent relative humidity, Graph's 1, 2 and 3 show what percent relative humidity that surface condensation will appear for different U values at indoor space temperatures of 76° F, 82° F and 86° F with outdoor temperatures of 25° F, 0° F, and -25° F.



Graph 1 - % RH for Various U Values at 25° F OA



Graph 2 - % RH for Various U Values at 0° F OA



Graph 3 - % RH for Various U Values at -25° F OA

HUMIDITY RANGE

The American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) recommends that you maintain between 50% and 60% relative humidity in an indoor pool environment. Relative humidity above 60% will be uncomfortable to the occupants of the space, promotes the growth of certain fungi and bacteria and makes it more difficult to prevent visible condensation. A relative humidity below 50% will cause evaporative cooling on swimmers' skin as they exit the water, giving them a chilling effect. Lower humidity levels will also cause more water evaporation, requiring more make-up water and more chemical usage, therefore requiring larger equipment and an increase in operating costs.

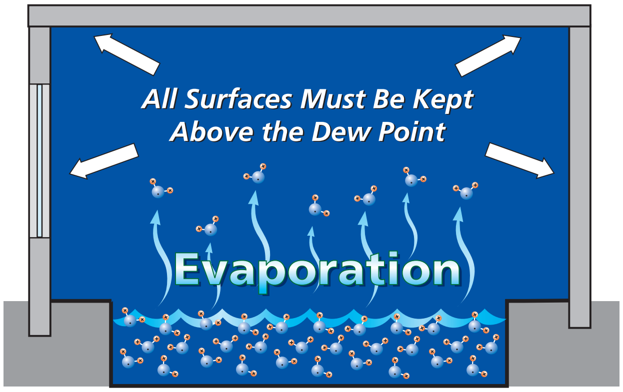


Figure 1 - Proper Dew Point of Pool Room Surfaces

METHODS OF HUMIDITY CONTROL

Several different techniques can be used to reduce humidity in an indoor pool environment. One of the oldest and most common practices in years past was to use a make-up air / exhaust method. Warm moist air is exhausted to the outdoors and new outdoor air is introduced into the building. (See Figure 2.) During the winter months, this air needs to be heated to the room temperature before entering the space. A high operating cost is associated with this process. During the spring, summer and fall in certain parts of the country, the outdoor air actually may have more moisture in it than the indoor environment. This will cause the indoor humidity to rise and potentially cause building damage.

In some parts of the country, the outdoor air may be dryer than the indoor environment. At first glance, it appears that this solves all humidity problems. As long as the indoor humidity is below 60% RH, there shouldn't be a problem. However, considering today's high energy costs, we also must add operating costs into the equation. If we take a 75 foot by 25 foot pool that has an average depth of 6 feet, we find that this contains 84,000 gallons of water. Let's assume that the space is maintained using outdoor air and we are in a dry climate, say constantly below 30% relative humidity.

This pool is evaporating 85.3 pounds of moisture per hour or 10.3 gallons per hour. This means in 340 days the pool is empty. If we maintain 50% relative humidity in the space, the evaporation rate decreases to 52 lbs/hr or 6.24 gallons per hour. In the same 340 days, we have saved the cost of over 50,000 gallons of make-up water. Also associated with this savings is the energy to reheat this water and the chemical costs to treat it. We have reduced the make-up water and chemical costs by about 40%.

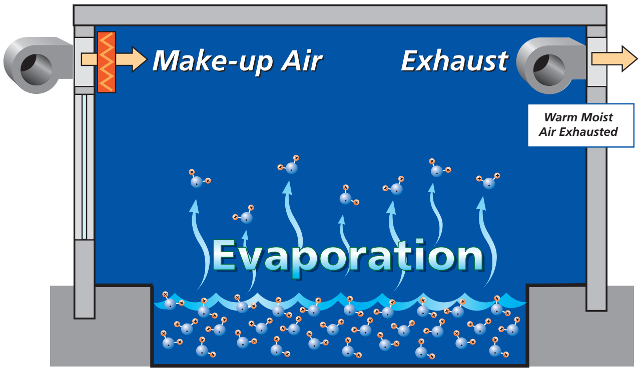


Figure 2 - Make-Up Air / Exhaust Method

The most effective method of maintaining appropriate relative humidity levels and achieving these types of savings is to use a refrigeration-based dehumidification system. (See Figure 3.)

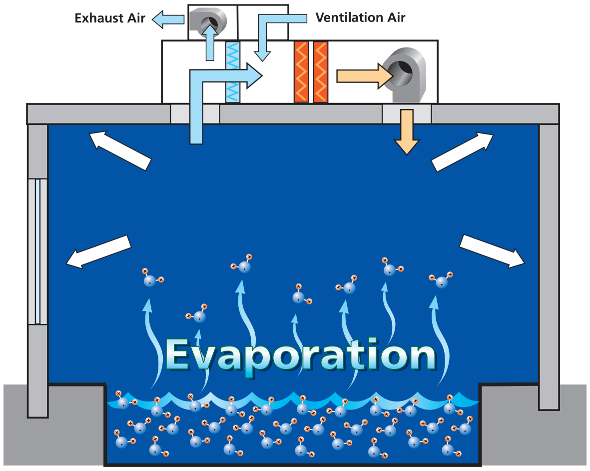


Figure 3 - Refrigeration-Based Dehumidification System

CALCULATION OF MOISTURE LOAD

Table 1 provides ASHRAE's recommended design temperatures for indoor pools. The table indicates a maximum of 90° F air temperature (Elderly Swimmers). While not shown in the table, ASHRAE also suggests that the air temperature should not exceed 86° F which would be above the comfort threshold. Also, most refrigeration circuits are only designed for a maximum of 90° F.

Type of Facility	Air Temperature	Water Temperature
Recreational	75° F to 85° F	75° F to 85° F
Therapeutic	80° F to 85° F	85° F to 95° F
Competition	78° F to 85° F	76° F to 82° F
Diving	80° F to 85° F	80° F to 90° F
Elderly Swimmers	84° F to 90° F	85° F to 90° F
Hotel	82° F to 85° F	92° F to 86° F
Whirlpool / Spa	80° F to 85° F	97° F to 104° F

Table 1 - ASHRAE Recommended Air and Water Design Temperatures

Type of Pool	Activity Factor
Baseline (Unoccupied Pool)	0.5
Residential Pool	0.5
Condominium	0.65
Therapy	0.65
Hotel	0.8
Public, School, YMCA	1.0
Whirlpool, Spas	1.0 to 1.5
Wavepools, Water Slides	1.5 or more

Table 2 - Activities Factor Table from ASHRAE Applications Handbook 2007

Discussion of the evaporation formula is beyond the scope of this application note. Desert Aire uses the latest information from the ASHRAE Applications Handbook. ASHRAE's formula uses the vapor differential method of determining the evaporation rate from the water surface. This formula is used to develop the factors listed in Table 1. The values listed in Table 3 are based on 25 FPM of air movement across the surface of the water. Variations of this formula are available to account for an increase in air movement over the water surface.

All values in Table 3 are based on an activity factor of one (1) and are for the occupied times of operation. Table 2 lists different activity factors that can be applied to your end results based on the type of pool you are designing.

Please note that all unoccupied hours of operation should apply the activity factor of 0.5 to determine the evaporation rate.

VENTILATION AIR

The amount of ventilation air required is generally accepted to be the amount as recommended by ASHRAE Standard 62.1. Most codes are based on this method but always check with your local code authority for the proper method of calculating this amount. The 2007 version of this standard recommends that this be based on the square footage of water surface at a rate of 0.48 cfm per square foot, while the square footage of the deck / floor area be calculated at some other rate, generally at 0.06 cfm per square foot. If the space includes a spectator area, which means a place where people can sit and watch, than you must also include 7.5 cfm per person plus 0.06 cfm per square foot of bleacher area.

This standard also suggests that when calculating the moisture of the ventilation air being introduced into the space that you use the ASHRAE Dehumidification Weather Data. Desert Aire recommends using the 1% weather conditions. A selection of cities and values across the United States and Canada are listed in Table 5.

EVAPORATION RATE IN LB./HR. PER SQUARE FOOT OF WATER SURFACE

Water Temp	Air Temperature °F															
	74° F		76° F		78° F		80° F		82° F		84° F		86° F		88° F	
	50% RH	60% RH	50% RH	60%RH	50% RH	60% RH	50% RH	60% RH	50% RH	60% RH	50% RH	60% RH	50% RH	60% RH	50% RH	60% RH
76° F	0.048	0.0395	0.0451	0.036	0.042	0.0323	0.0387	0.0284	0.0352	0.0243	0.0316	0.0199	0.0277	0.0152	0.0236	0.0103
78° F	0.0541	0.0457	0.0512	0.0422	0.0481	0.0385	0.0449	0.0346	0.0414	0.0304	0.0377	0.026	0.0339	0.0214	0.0298	0.0165
80° F	0.0607	0.0522	0.0578	0.0488	0.0547	0.045	0.0514	0.0411	0.0479	0.037	0.0443	0.0326	0.0404	0.0279	0.0363	0.023
82° F	0.0676	0.0592	0.0647	0.0557	0.0616	0.052	0.0583	0.048	0.0549	0.0439	0.0512	0.0395	0.0473	0.0348	0.0432	0.0299
84° F	0.0749	0.0665	0.072	0.063	0.0689	0.0593	0.0656	0.0554	0.0622	0.0512	0.0585	0.0468	0.0546	0.0422	0.0506	0.0373
86° F	0.0827	0.0742	0.0798	0.0707	0.0767	0.067	0.0734	0.0631	0.0699	0.059	0.0663	0.0546	0.0624	0.0499	0.0583	0.045
88° F	0.0909	0.0824	0.0879	0.0789	0.0848	0.0752	0.0816	0.0713	0.0781	0.0671	0.0745	0.0627	0.0706	0.0581	0.0665	0.0532
90° F	0.0995	0.0911	0.0966	0.0876	0.0943	0.0839	0.0902	0.0799	0.0868	0.0758	0.0831	0.0714	0.0792	0.0667	0.0751	0.0618
92° F	0.1086	0.1002	0.1057	0.0967	0.1026	0.093	0.0994	0.091	0.0959	0.0849	0.0922	0.0805	0.0884	0.0759	0.0843	0.071
94° F	0.1183	0.1098	0.1154	0.1063	0.1123	0.1023	0.109	0.0987	0.1055	0.0946	0.1019	0.0902	0.098	0.0855	0.0939	0.0806
96° F	0.1284	0.12	0.1255	0.1165	0.1224	0.1128	0.1192	0.1089	0.1157	0.1047	0.112	0.1003	0.1082	0.0957	0.1041	0.0908
98° F	0.1392	0.1307	0.1362	0.1272	0.1332	0.1235	0.1299	0.1196	0.1264	0.1155	0.1228	0.1111	0.1189	0.1064	0.1148	0.1015
100° F	0.1505	0.142	0.1475	0.1385	0.1445	0.1348	0.1412	0.1309	0.1377	0.1268	0.1341	0.1224	0.1302	0.1177	0.1261	0.1128
102° F	0.1624	0.1539	0.1595	0.1504	0.1564	0.1467	0.1531	0.1428	0.1496	0.1387	0.146	0.1343	0.1421	0.1296	0.138	0.1247
104° F	0.1749	0.1665	0.172	0.163	0.1689	0.1593	0.1656	0.1553	0.1622	0.1512	0.1585	0.1468	0.1546	0.1421	0.1505	0.1372

Table 3 - Evaporation Rates of Still Water at Sea Level (Using ASHRAE Fundamentals Method)

The following formula is used to determine the amount of moisture in the ventilation air.

Moisture in lbs/hr = cfm x ∆grains / 1,555

∆grains = value from Table 5 – value from Table 4

Indoor Air Moisture Content		
Inside Temperature	**grains / lb**	
	50% RH	**60% RH**
74° F	62	75
76° F	68	81
78° F	72	86
80° F	77	92
82° F	82	96
84° F	88	106
86° F	93	113
88° F	100	120

Table 4 - Moisture Content Guidelines (All Values Are at Sea Level)

HUMAN IMPACT ON MOISTURE

Moisture contributed by people is normally only accounted for when spectator or bleacher areas are part of the space design. Most design manuals will list the latent moisture per person in the values of btu/h. The values these manuals list are usually for indoor conditions below 80° F. Most indoor pools are above 80° F so 20% more latent must be added to the listed values in most design books. Desert Aire recommends a value of 190 btu/h per person. If you had 100 people, this would give you 19,000 btu/h of moisture. To convert this value to lbs/hr of moisture, use a factor of 1,061 btu/h per lb. Therefore, 19,000 btu/h is equal to 17.9 lbs/hr or about the same as the evaporation from a 400 square foot pool surface that is running at 82° F within the space, 80° F water and 55% RH.

CONCLUSION

Commercial pool enclosures must consider all three humidity load calculations – air, water and people – to determine the total moisture load. A design professional must still perform a sensible heating and cooling load to ensure that the selected equipment can maintain the space temperature during the entire year. This application note is only intended to give you a general understanding of what is involved in the calculation process. Please contact your nearest Desert Aire Representative for assistance with the design of your pool facility and dehumidification system.

OUTDOOR AIR MOISTURE CONTENT @ ASHRAE 1% DEHUMIDIFICATION WEATHER DATA

State	City	GR lbs	State	City	GR lbs	State	City	GR lbs	State	City	GR lbs	State	City	GR lbs
AK	Anchorage	59	GA	Atlanta	123	MT	Billings	70	PA	Philadelphia	124	WA	Seattle	71
AK	Annette	65	GA	Augusta	128	NC	Cape Hatteras	142	PA	Pittsburgh	116	WA	Spokane	61
AK	Kodiak Island	60	HI	Honolulu	117	NC	Charlotte	122	PA	Scranton	114	WA	Yakima	63
AK	Yakutat	65	IA	Des Moines	122	NC	Raleigh	126	RI	Providence	114	WI	Green Bay	117
AL	Birmingham	126	ID	Boise	59	ND	Fargo	109	SC	Charleston	136	WI	Madison	115
AL	Mobile	137	IL	Chicago	118	NE	Omaha	125	SC	Columbia	122	WI	Milwaukee	115
AR	Little Rock	102	IL	Rockford	119	NH	Concord	109	SD	Sioux Falls	119	WV	Charleston	120
AZ	Phoenix	102	IN	Fort Wayne	121	NJ	Atlantic City	123	TN	Bristol	118			
CA	Long Beach	91	IN	Indianapolis	130	NJ	Newark	121	TN	Chattanooga	126		**CANADA**	
CA	Los Angeles	96	KS	Wichita	120	NM	Albuquerque	80	TN	Knoxville	124			
CA	Sacramento	72	KY	Louisville	125	NV	Las Vegas	82	TN	Memphis	132	AL	Calgary	69
CA	San Diego	103	LA	Baton Rouge	136	NV	Reno	59	TN	Nashville	126	BC	Vancouver	76
CA	San Francisco	67	LA	New Orleans	143	NY	Albany	109	TX	Brownsville	136	MN	Winnipeg	97
CA	Santa Barbara	85	LA	Shreveport	134	NY	Buffalo	108	TX	Corpus Christi	141	NB	Saint John	87
CO	Stockton	75	MA	Boston	112	NY	New York	121	TX	Dallas / Ft. Worth	121	NF	St. John's	89
CO	Denver	78	MD	Baltimore	120	NY	Rochester	116	TX	El Paso	99	NS	Halifax	100
CT	Hartford	111	ME	Portland	106	NY	Syracuse	110	TX	Houston	135	ON	Ottawa	101
DC	Washington	129	MI	Detroit	114	OH	Cincinnati	120	TX	Lubbock	111	ON	Sudbury	93
DE	Wilmington	121	MI	Flint	117	OH	Cleveland	116	TX	San Antonio	128	ON	Thunder Bay	91
FL	Daytona Beach	137	MI	Grand Rapids	116	OH	Columbus	119	UT	Salt Lake City	76	ON	Toronto	108
FL	Jacksonville	134	MN	St. Paul	114	OK	Oklahoma City	125	VA	Norfolk	124	ON	Windsor	115
FL	Miami	137	MO	Kansas City	126	OR	Eugene	73	VA	Richmond	130	QC	Montreal	106
FL	Tallahassee	136	MO	St. Louis	132	OR	Portland	72	VA	Roanoke	113	QC	Quebec	100
FL	Tampa	136	MS	Jackson	136	PA	Erie	114	VT	Burlington	105	SK	Regina	80

Table 5 - Geographic Outdoor Design Criteria (ASHRAE Fundamentals 1%)

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