INTRODUCTION

The purpose of this manual is to assist the reader in understanding pool enclosures, the importance of the initial design of the structure and the engineering/design of a mechanical dehumidification system for an indoor swimming pool. The booklet will also explain why this method of dehumidifying a pool enclosure is far superior to other means, including waste ventilation (exhaust fan) type systems.

Some of the information presented here comes from other technical references dealing with: dehumidification, swimming pools, air handling, and mechanical system design.

Humidity control in an indoor pool enclosure is a complex endeavor involving many parties and many disciplines. To ensure a successful application of the dehumidification system, it is crucial that each of the involved parties (architect, engineer, mechanical contractors, owners, builders, etc.) is aware of the objectives of the system and its requirements. It is also important that the various disciplines involved in the work are coordinated.

HISTORY

Prior to 1980 environmental and humidity control in North American indoor pools was ignored or attempted by applying 100% waste ventilation systems (exhaust fans) to the pool enclosure. Through the 1980's usage of pools increased or diversified and environmental control became a more serious concern. Buildings were showing signs of early deterioration, rust, mold, rot, mildew and in some severe cases, complete destruction of the enclosure, due to no dehumidification and waste systems.

Greater use of pools gave rise to increased year round use of the facilities, and new uses for pools required both new materials and greater control over humidity and condensation than was afforded by the traditional ventilation systems. With the advent of the energy crisis in the 1980's, the design concept of bringing in outside air at winter temperatures and heating it to 82 degrees F before introducing it into the pool space became cost prohibitive for most pool operators, and did not dehumidify the enclosure. Logic required that a way be found to recycle and dehumidify the air in the pool enclosure.

Early versions of the pool dehumidifying equipment were designed solely to provide dehumidified air to the pool enclosures. However, early analysis of the pool applications showed that the latent heat being extracted from the air by the dehumidifier was equal to the significant heat loss from the pool water. Pursuing that logic, the designers began to build units with the capability of rejecting this heat back to the pool water from where it was originally lost through evaporation.

If then became evident that in the majority of applications, the dehumidifier had enough recycled heat available to maintain the pool water temperature and room temperature at desired levels without the input of energy from any other source.

This represented significant further energy savings for the pool operators and indoor pool dehumidification systems with pool water heating circuits quickly became the standard mechanical air handling systems for indoor pools.

The energy efficiencies, the positive control of humidity and prevention of condensation available with these systems is well proven with literally thousands of new construction and retrofit installations throughout North America, Europe and elsewhere.

1. DESIGN OBJECTIVES

1.1. Prevention of Condensation

The prevention of condensation is perhaps the most important purpose of all for dehumidifying an indoor pool enclosure. If condensation forms in or on wood, plaster or other porous materials it can cause warping, rot, mold, mildew, rust or simply saturate the material until it loses it integrity.

Condensation, by nature, is aggressive and will attack many materials by leaching the minerals out of the surface it forms on. Condensation, if allowed to form on ferrous metals, will cause accelerated oxidation of the surface of the metal, creating unsightly rust stains as it drains. If left unchecked, condensation will ultimately compromise the structural integrity of the metal components leading to possible failure of that component.

The most common place for condensation to form in a building structure is on the inside surfaces of windows or skylights. Although most modern window structures and frames are not harmed by condensate, it is unsightly and it will cause damage to metal frame windows & skylights that are not thermally broken, to wall or roof sections surrounding the fenestration.

Condensation will form in and on any surface that reaches "Dew Point Temperature". The concept of Dew Point Temperature is dealt with in detail in Section Three of this manual. The design objective for designing mechanical air handling systems for pools is to ensure that no surface within the pool enclosure or within the structural members of the building will reach "Dew Point" and cause moisture to condense.

The dehumidifier helps to accomplish this objective by reducing the relative humidity in the pool enclosure and therefore effectively reducing the "Dew Point Temperature". Air distribution also plays a key role in preventing surfaces from reaching "Dew Point Temperature". There are surfaces, in particular, windows, that will reach dew point temperature even with the reduced humidity levels affected by the dehumidifier. For these surfaces, the objective is to completely blanket the area with warm dry air supplied by the dehumidifier, thereby increasing the surface temperature to a point above the temperature at which moisture will condense. Air distribution is dealt with in detail later in Section Five of this manual.

1.2 ENERGY EFFICIENCY

When compared with conventional ventilation systems, recycling and dehumidifying the pool enclosure air will save a considerable amount of energy. During the heating season, a ventilation system will be exhausting air at 82 degrees F and replacing it with air at the outside ambient temperature. This outdoor air must be heated up to 82 degrees F BEFORE being introduced into the pool enclosure. The energy requirement to heat this incoming air can be significantly reduced or eliminated by a recycling dehumidification system.

Heat inputs into the pool water and to compensate for structural heat loss are also lost with the exhaust air in a conventional system and must be replaced. A pool cover is highly recommended for additional energy and cost savings.

EVAPORATION RATE IN LB./HR. PER SQ. FT. OF SURFACE AREA																				
Temp (F) Water	76		78		80		82		84		86		88		90		102		104	
Air	50%	60%	50%	60%	50%	60%	50%	60%	50%	60%	50%	60%	50%	60%	50%	60%	50%	60%	50%	60%
72	.0341	.0288	.0383	.0330	.0427	.0374	.0474	.0421	.0523	.0470	.0574	.0521	.0630	.0577	.0688	.0635	.1112	.1059	.1196	.1143
74	.0323	.0266	.0364	.0307	.0408	.0352	.0455	.0399	.0504	.0448	.0556	.0499	.0611	.0555	.0670	.0613	.1093	.1036	.1178	.1121
76	.0303	.0242	.0345	.0284	.0389	.0328	.0436	.0375	.0485	.0424	.0536	.0476	.0592	.0531	.0650	.0590	.1074	.1013	.1158	.1097
78	0.0282	.0218	.0324	.0259	.0368	.0303	.0415	.0350	.0464	.0399	.0515	.0451	.0571	.0506	.0629	.0565	.1053	.0988	.1137	.1072
80	.0260	.0191	.0302	.0233	.0346	.0277	.0393	.0324	.0442	.0373	.0494	.0424	.0549	.0480	.0607	.0538	.1031	.0962	.1115	.1046
82	.0237	.0163	.0279	.0205	.0323	.0249	.0370	.0296	.0419	.0345	.0470	.0396	.0526	.0452	.0584	.0510	.1008	.0934	.1092	.1018
84	.0212	.0134	.0254	.0175	.0298	.0219	.0345	.0266	.0394	.0315	.0446	.0367	.0501	.0422	.0559	.0481	.0983	.0904	.1067	.0989
86	.0186	.0102	.0228	.0144	.0272	.0188	.0319	.0235	.0368	.0284	.0420	.0336	.0475	.0391	.0533	.0449	.0957	.0873	.1041	.0957
88	.0169	.0069	.0210	.0111	.0354	.0155	.0301	.0202	.0350	.0251	.0402	.0302	.0457	.0358	.0516	.0416	.0939	.0840	.1024	.0924
90	.0130	.0034	.0171	.0076	.0215	.0120	.0262	.0167	.0311	.0216	.0363	.0268	.0418	.0323	.0477	.0381	.0900	.0805	.0985	.0889
92	.0099	.0002	.0141	.0039	.0185	.0083	.0232	.0130	.0281	.0179	.0332	.0231	.0388	.0286	.0446	.0345	.0870	.0768	.0954	.0852

Table 3 - Evaporation Rates of Still Water at Sea Level (Using U.S. Department of Energy Simulation Method)

1.3 Occupant Health and Comfort

Unchecked humidity levels in a pool enclosure effect everyone in that enclosure. Bathers, spectators, staff, or competitive officials all experience discomfort with high humidity levels. Indoor swimming pools or "Natatoriums" are intended for the use, recreation and enjoyment of their patrons. A Natatorium with properly controlled conditions will be both used and enjoyed much more than one that is not.

Several studies have been conducted into the relationship between relative humidity and occupant health. The results of these studies show conclusively that for human occupancy, a relative humidity range of between 40% and 60% is ideal. The chart below which is excerpted from one such study conducted by Simon Fraser University shows what contaminant factors can be mitigated by maintaining appropriate relative humidity levels.

Study By: Ella M. Sterling, Director of Building and Research
Theodore Sterling Ltd., Vancouver, B.C.
A. Arundel Research Associates
T.D. Sterling, Professor Interdisciplinary Studies, Simon Fraser University, Burnaby, B.C.

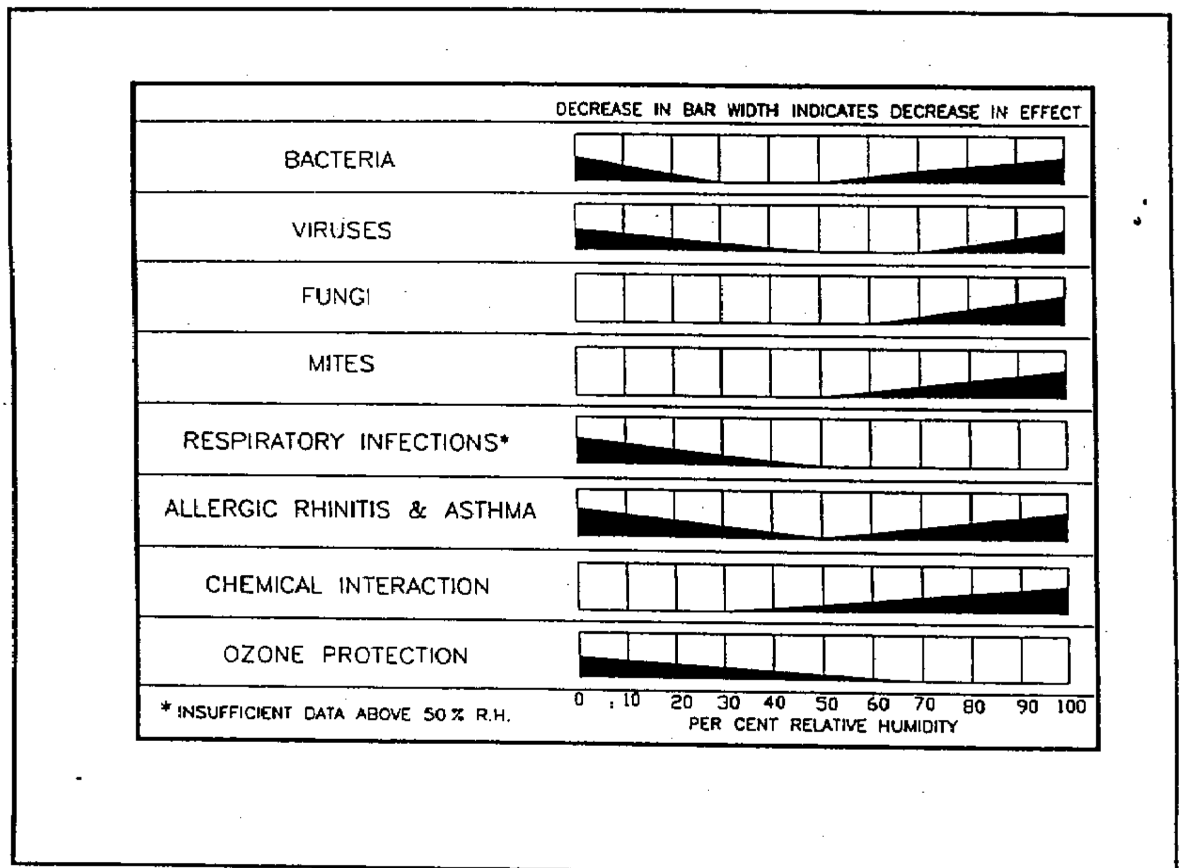


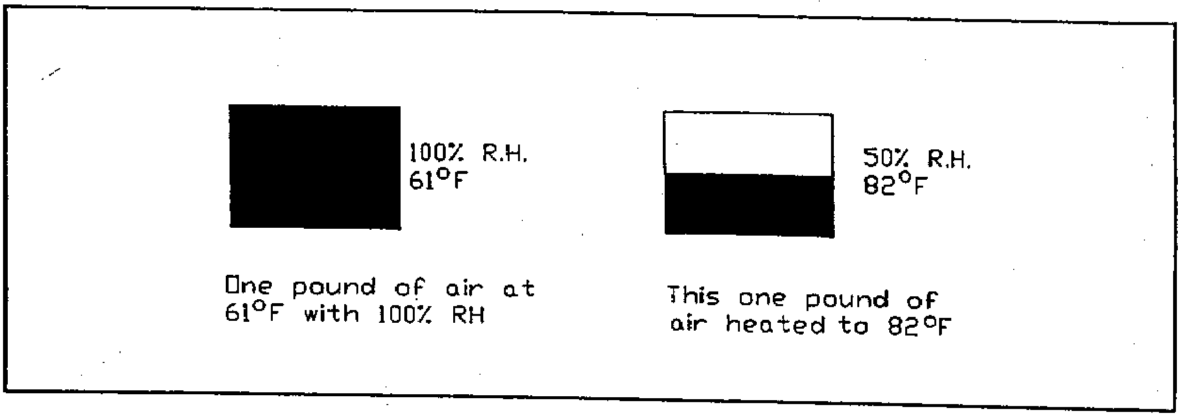
Diagram 1.3 Health vs Relative Humidity

2. RELATIVE HUMIDITY

The term "Relative Humidity" expresses the moisture content of the air as a percent of what this same air could hold if it was completely saturated.

The ability of air to hold moisture increases with a rise in temperature and decreases with a lowering of the air temperature. If you cool a volume of air sufficiently it will reach a point where the amount of moisture it can hold is equivalent to the amount of moisture that it actually contains. This is the point at which the air is saturated or is at 100% Relative Humidity. If you then increase the temperature of this air to a point where it can hold twice as much moisture as it actually contains, it is now at 50% Relative Humidity.

Illustration:



3. DEW POINT TEMPERATURE

As described previously, as you cool air, it cannot hold the same amount of moisture. At some point the air will become saturated and moisture will begin to condense out of the air onto any adjacent surface. This point is called the "Dew Point Temperature". The higher the relative humidity (or the greater percent of moisture in the air relative to its ability to hold moisture), the higher the "Dew Point Temperature". In other words, the lower the Relative Humidity, the cooler the air has to get before moisture will condense out of it.

4. DEW POINT TEMPERATURE TABLE

Conditions at which condensation will form:

Relative Humidity (%RH)		40	50	60	70	80
Air Temperature °F	74	48	54	59	63	67
	76	50	56	61	65	69
	78	52	58	63	67	71
	80	54	60	65	69	73
	82	55	61	67	71	75
	84	57	63	68	73	77
	86	59	65	71	75	79

Dew Point Temperatures (°F)

5. BUILDING CONSIDERATIONS

In order to ensure that the "Natatorium" is protected from the damage caused by excessive humidity and condensation, the building envelope must be designed and must perform to a much higher degree than structures intended for other uses. Because of the higher temperatures and higher relative humidity than found in other buildings, care must be taken right from the preliminary design

RELATIVE HUMIDITY AT WHICH MOISTURE WILL CONDENSE ON WINDOWS

Outside Temp (F)	Inside Building Temperature (F) 65		70		75		80	
	Single Pane	Double Pane	Single Pane	Double Pane	Single Pane	Double Pane	Single Pane	Double Pane
-20	-	46%	-	46%	-	44%	-	42%
-10	-	50%	-	49%	21%	48%	20%	46%
0	29%	55%	27%	55%	25%	52%	24%	50%
10	36%	60%	33%	59%	31%	57%	29%	54%
20	43%	66%	40%	63%	37%	62%	35%	59%
30	52%	73%	50%	71%	45%	68%	42%	65%
40	63%	80%	60%	79%	53%	74%	50%	71%

5.2 Fenestration

Windows and skylights are particular areas of concern with respect to the formation of condensation. Single glazed windows are to be avoided. Multi-pane windows such as "Thermopane" type or better should be used. All windows must have air distribution over them to keep them from reaching Dew Point Temperature. All metal frames must be thermally broken (insulated).

Skylights, if used, should be of the best quality available, and if at all possible, should be multi-layered with an insulating air space between the layers. Adequate air distribution over skylights is absolutely necessary. Recessed skylights must be addressed in the design stage as it is extremely difficult to get proper air distribution across recessed skylights. We recommend surface mounting skylights.

5.3 Doors and Other Openings

Any opening into the pool enclosure should be air tight, positive closing and be constructed with thermal breaks.

5.4 Exposed Structural Surfaces

Any structural members that are exposed to the outside of the structure or connected to an exterior member without a thermal break, must be blanketed with warm dry supply air from the dehumidification system.

6. VENTILATION

ASHRAE recommends a fresh air ventilation rate for indoor pools of 0.5 CFM per square foot of pool and deck area. This requirement is for indoor air quality considerations for commercial projects, and can be found listed in the ASHRAE Standard "62-1989". Ventilation rates should be kept to a minimum, but, some ventilation air is required during occupied periods and either the ASHRAE Standard or State and local codes should be adhered to. ASHRAE requirements for outside air must be met on all commercial projects.

VAPOR BARRIERS

As with all structures, the entire pool enclosure should be enveloped with a vapor barrier located on the inside of the insulation (warm side of the structure). Vapor Barriers must be continuous with all seams sealed and any perforations around openings or fixtures must be sealed and made air tight. Moisture migration through a perforation in the vapor barrier will result in condensation within exterior walls or roofing structures. The consequential damage caused by this condensation will be damaging at the least, and may in the worst cases, cause catastrophic failures of roof structures or exterior wall sections. More information on vapor barriers is included in this package.

Although this booklet provides a great deal of information, there are resources, publications, standards, national and local codes that should be reviewed prior to building this type of enclosure.

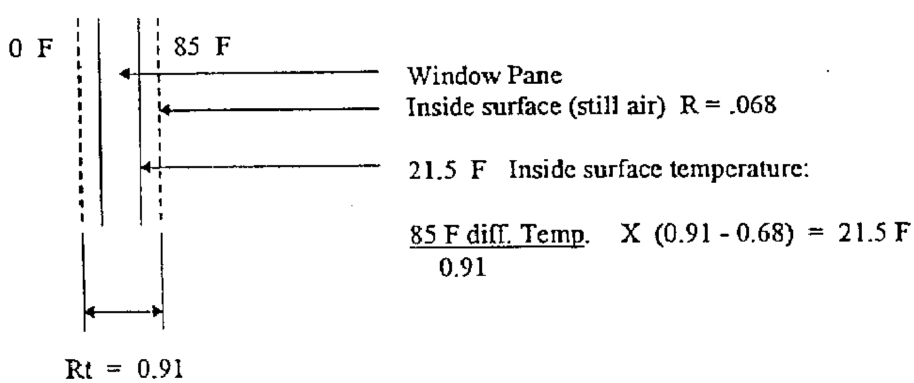
WINDOW INFORMATION FOR SWIMMING POOL ENCLOSURES

Figure 3 illustrates a method to determine the actual inside surface temperature of a window pane, based on a given indoor and outdoor temperature.

Based on the figure below, it can be seen that even a double pane window cannot prevent condensation, if the room dew point temperature is at 64.5 degrees F (see Figure 2) as the inside surface temperature is only 51.4 degrees F.

In order to prevent condensation, the inside surface temperature must be raised. This is normally done by installing most of the supply air outlets of the dehumidification system near the windows. The supply of warm dry air will then effectively prevent condensation.

In case a retrofit installation does not allow air distribution over the window surfaces, local blowers could be installed to raise the glass surface temperature.



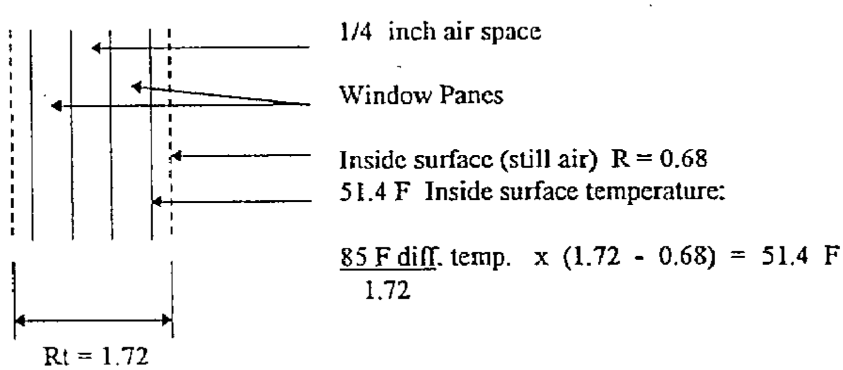


Figure 3

WALL CONSTRUCTION INFORMATION

POOL ENCLOSURE AT 85 DEGREES F DB, 50% RH, DEW POINT 54.5 F.

OUTSIDE WALL COMPOSITION		R
OUTSIDE SURFACE (15 MPH WIND)		0.17
FACE BRICK 4"		0.44
RIGID POLYSTYRENE 2"		10.00
VAPOR BARRIER		-------
CONCRETE BLOCK 8"		1.72
INSIDE SURFACE (STILL AIR)		0.68
	Rt =	13.01

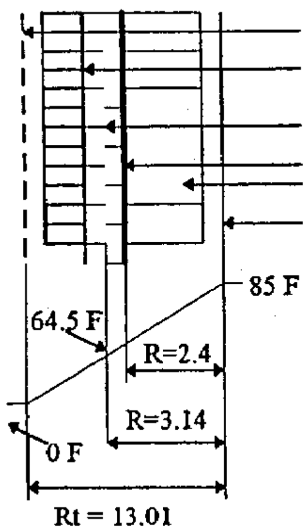


Figure 2

R AT 64.5 F DEW POINT:

$\frac{13.01}{85\text{ F differential temperature}} \times (85\text{ F db} - 64.5\text{ F dp}) = 3.14$

Figure 2 shows a cross section of a typical wall design with an outdoor temperature of 0 degrees F and indoor temperature of 85 degrees F. It can be assumed that somewhere in the wall is an area that is at the dew point temperature of 64.5 degrees F.

By using the formula in figure 2, it is found that 64.5 degrees F occurs at a partial resistance of R = 3.14, counting from the inside, for a total wall resistance of R =13.01, positioning the dew point of 64.5 degrees F on the cold side of the vapor barrier. This is a very important observation. If the 64.5 degrees F occurs on the warm side of the vapor barrier, condensation will form inside the wall, with all its consequential damages.

It is of the utmost importance to check the pool enclosure design for adequate insulation R factors and proper vapor barrier location.

Using the example in figure 2, more insulation would move the dew point temperature further away from the vapor barrier, hence reducing the risk of condensation, in case the outdoor temperature drops below design condition or the indoor conditions are changed to a higher dew point temperature.

With a recycling dehumidification system, these heat inputs are not exhausted and further energy savings are realized.

One more contribution to energy efficiency from the dehumidification system comes in the area of pool water heating.

With conventional air handling systems, some form of boiler must be used to maintain the pool water temperature. With a recycling dehumidification system, the evaporative heat loss from the pool water is captured by the dehumidifier and that heat is recycled back to the pool water by the water heating circuit of the unit.

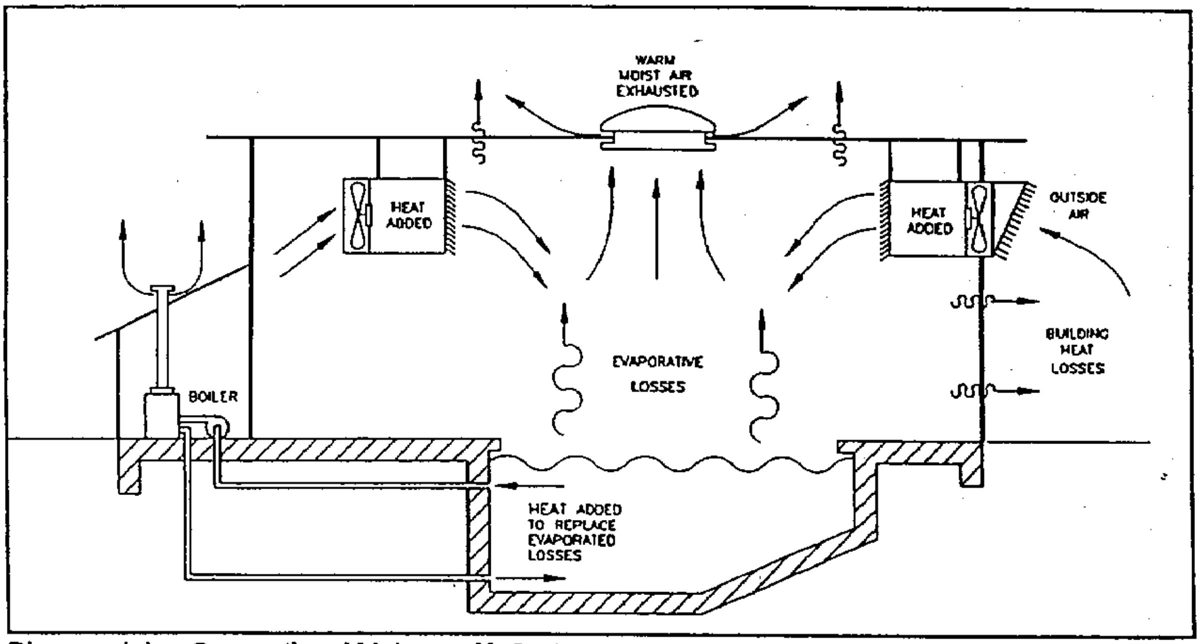


Diagram 1.1 Conventional Make-up Air System

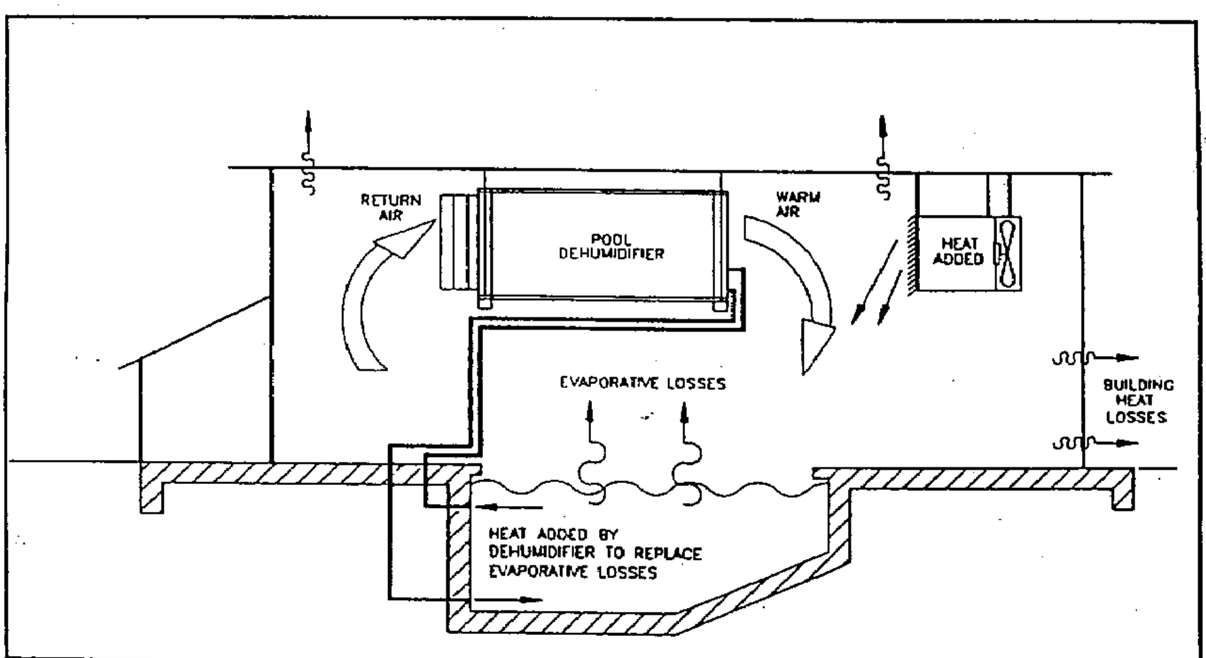
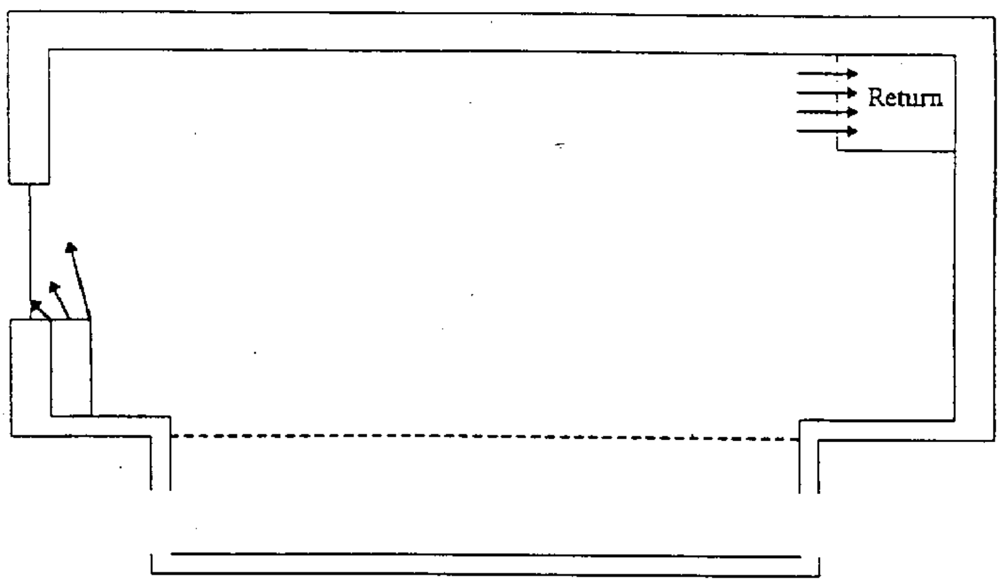


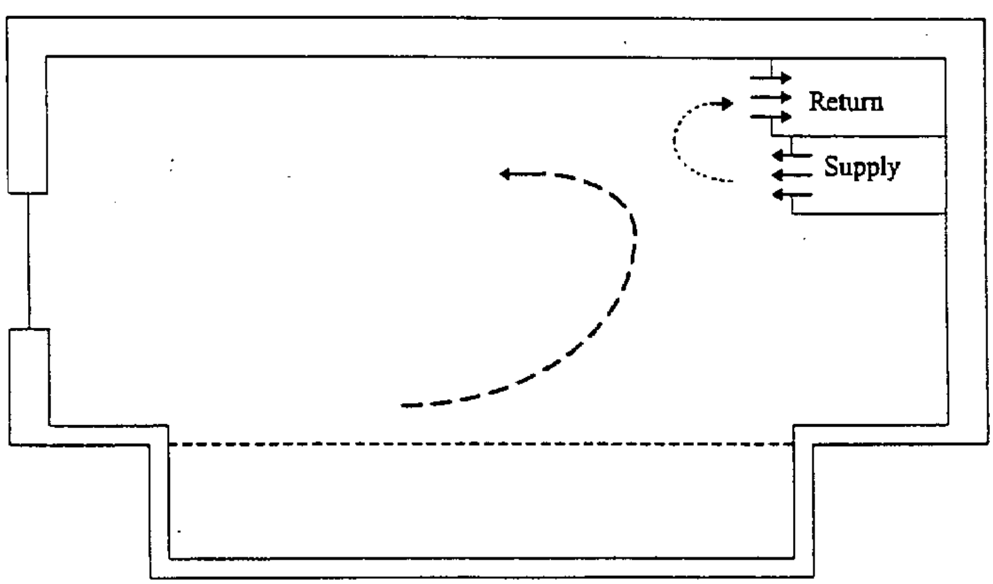
Diagram 1.2 Energy Recycling Dehumidification System

Note that with this duct arrangement as shown in figure 1, air movement over the water surface is prevented. Also, since moist air rises, the return air is at the highest point possible.



Recommended Air Circulation
Figure 1

Many systems are installed as per figure 2. The high supply air velocity, required to throw the air to the other side of the enclosure creates, in fact, a secondary airstream over the water surface which picks up moisture and increases the rate of evaporation. An efficient mechanical reclaim system turns into one with very high operating costs.



Not Recommended Air Distribution
Figure 2

Duct design standards for all DRY-AIR installations

Per ASHRAE Hand book, 1977 Fundamentals Chapter 31 or INDUSTRIAL VENTILATION (American Conference of Government Industrial Hygienists) Section 6