Application Note 13

Est. 1978 DESERT AIRE

Indoor Ice Rink Dehumidification

INTRODUCTION

This application note will examine the sources of moisture found in indoor ice rinks or curling rinks. It will also provide formulas for estimating the amount of moisture which must be removed to ensure good quality ice, user comfort and structural integrity.

CAUSES OF HUMIDITY, CONDENSATION & FOG

Moisture is introduced into an ice skating facility through several sources:

- Flood water evaporation
- Skaters & spectators
- Code ventilation
- Infiltration
- Combustion (ice resurfacers and gas heaters)

Moisture follows a physical law of nature and migrates through the air from a higher concentration to a lower concentration due to a difference in vapor pressure. When the air is cooled it is unable to hold as much moisture. Moisture will condense on colder surfaces that have a lower temperature than the dew point temperature of the air. This moisture will be deposited on the cooler surfaces in the form of water droplets, leading to sweating, dripping and fogging above the ice surface.

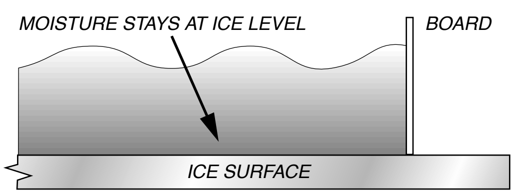

Figure 1 - Fogging at Ice Level

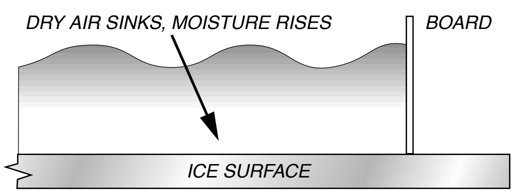

Figure 2 - Fogging Eliminated

This condition is intensified in indoor skating and curling rinks due to the large area of ice surface and the indoor air which has been cooled considerably below the outdoor ambient. Consequently, outdoor air will increase the inside relative humidity, and at this point, fog is formed above the ice surface. The cold ice surface at this time will in fact produce a dehumidification effect by having moisture condense and accumulate at its surface, known as "frosting." Frosting causes "slow" ice and an additional load on the ice making system.

RESURFACING

As skaters cut and chip the ice, another small layer of water must be applied to the surface of the ice to form a new, smooth layer. It is common practice to use hot water (140° to 180° F) when applying the new layer to melt part of the old and allow bonding between new and old ice as the water freezes. There have been many studies to find the optimum water temperature and in an effort to strike a balance between cost of energy and quality of ice, 140° to 160° F water generally chosen.

From a moisture perspective, the hotter the water, the more moisture that is released into the air. When the hot water is applied, the water gives up a substantial portion of its energy when it melts the top layer of ice. The rink refrigeration system then cools the water to reform ice. The very top layer remains in the liquid form for 5 to 8 minutes before finally freezing. During this time, the rate of evaporation diminishes to a very small amount.

The approximate formula is a vapor pressure differential equation which varies with the resurfacing water temperature and the inside design dew point of the facility. (180° F water releases up to 5 times the volume of water as 140° F water.) The lower the design dew point, the faster the evaporation rate and the more the ice tends to be brittle. Table 1 provides examples of the typical volumes of water released during the resurfacing process. Contact Desert Aire to run a customized analysis for other values.

Resurfacing Water Temp	140°F			
Inside Design	***60/70%***	***60/40%***	***55/70%***	***55/40%***
Hockey	6	25	12	31
4 Isle Curling	3	14	7	17
8 Isle Curling	6	27	13	33
Speed Skating	18	77	37	75

Table 1 - Selected Resurfacing Evaporation Amounts (lbs. of water per application)

Resurfacing Water Temp	160°F			
Inside Design	***60/70%***	***60/40%***	***55/70%***	***55/40%***
Hockey	36	58	43	65
4 Isle Curling	20	32	24	36
8 Isle Curling	39	64	48	72
Speed Skating	110	181	134	203

Table 1 - Selected Resurfacing Evaporation Amounts (lbs. of water per application)

Since resurfacing is done typically four to eight times a day, the load for the defogging dehumidifier is calculated by summing the moisture released for all of the resurfacing and dividing the total value by the number of hours the rink is operated per day. This allows the defogger to pull the moisture down over time and thereby minimizing capital costs while eliminating fog.

$$\text{Lb./Hr.} = \frac{\text{Resurfacing Load x Frequency}}{\text{Hours of Operation}}$$

PEOPLE LOAD

The ice rink facility has two different types of moisture load sources during occupied time periods: skaters and spectators.

The actual users of the rink will be generating significantly more moisture per person than the spectators, who are at rest. Table 2 provides the amount of moisture generated per person.

Type	LB/hr per person
Skaters	1.095
Spectators	0.100

Table 2 - Occupant Moisture Loads

The actual number of users is variable over time. The designing engineer should choose the hourly average to avoid oversizing the defoggers. During many times of the year, code ventilation can help with the dehumidification process.

$$\text{Hr. Avg.} = \frac{\text{Total Rink Users Per Day}}{\text{Hours of Operation}}$$

If the ice rink has a spectator gallery, then the designing engineer must add the additional moisture load generated by these people. The people load is calculated as follows:

Lb./Hr. 1 = User Hr. Avg. * 1.095 = ______________

Lb./Hr. 2 = Spectator Capacity * 0.100 = ______________

Total Lb./hr = ______________ add

CODE VENTILATION

ASHRAE 62 ventilation code has established a standard volume of outdoor air which must be introduced to the rink - during occupied times, 0.5 cfm per square foot of ice rink surface area or 15 cfm per person, whichever is greater. In most cases, the rink is designed for less than 500 people, so the ice surface area will dictate the amount of code ventilation. For typical rinks, the outdoor air volume is:

Rink Type	***Ice Area***	***Outdoor Air***
Hockey	16,300 sq. ft.	8,150 cfm
4 Isle Curling	9,000	4,500
8 Isle Curling	18,000	9,000
Speed Skating	50,730	25,365

Table 3 - Outdoor Air Requirements of Typical Facilities

With the advent of this new code, outdoor air ventilation creates the single largest moisture load source in the rink. Most design engineers use a pretreatment system to control the humidity from this source and to provide positive verification of complying with the building ventilation code. An additional control scheme to reduce energy costs would be to stage the pretreatment system based on the internal CO_2 levels.

The major factors in accounting for outdoor air loads are the geographic location and whether the rink will be year-round or seasonally used. If the facility will be used in the summer, then the ASHRAE summer design (ASHRAE Fundamentals) values should be used in the sizing of the outdoor air treatment system. If the facility is seasonal, estimate the worst case outdoor air values. Please refer to Desert Aire's *Technical Bulletin 5* for details on how to size this equipment and the ASHRAE Fundamental design values.

The pretreatment system should be designed to treat the air to a design condition of 50° to 60° F drybulb and 50° F dewpoint. If this is achieved, the outdoor air becomes "neutral" with respect to the rest of the building system (building structure, boards and HVAC system).

Depending on what internal space conditions are maintained, this outdoor air may still add to the design load of the defogging dehumidifiers. The equation to calculate this load is:

$$\text{LB/hr} = \frac{V \times 4.5 \times (Gr_0 - Gr_I)}{7000}$$

Where:
V = Volume of Outdoor Air, cfm
4.5 = The Conversion Factor
$Gr_0 - Gr_I$ = The grain difference between the outdoor air pretreatment system's leaving air condition and the inside design (refer to Table 4).

Inside Design		***Dew Point***	***Grain***
°F	RH%		
65	70	55.0	64
	60	50.8	55
	50	45.9	46
	40	40.2	37
60	70	50.2	54
	60	46.1	46
	50	41.4	38
	40	35.8	31
55	70	45.4	45
	60	41.4	39
	50	36.9	32
	40	31.4	26
50	70	40.7	37
	60	36.8	32
	50	32.4	27
	40	27.0	21

Table 4 - Inside Design Dew Points and Moisture Values @ Sea Level

CEILING CONDENSATION

The cold ice surface is directly opposite the ceiling and absorbs heat by radiation, literally drawing the heat out of the roof or ceiling structure. This radiation effect can be such that the ceiling is actually cooler than the air below it. If the ceiling inside surface temperature falls below the room air dew point temperature, then condensation will occur.

The design of the structure must take this radiation effect into account and at design conditions the ceiling inside surface temperature should be no cooler than 5° F below the room air temperature. The room air dew point temperature should not exceed this temperature if condensation is to be prevented. Low emissivity ceilings may be considered to raise the inside ceiling structure temperature.

The dehumidifier removes moisture from the air, reducing the relative humidity levels and lowering the room air dew point. In conjunction with proper building design, this helps to reduce condensation of ceiling structures.

During mild weather, particularly in early fall and late spring in the northern United States and Canada, condensation often drips from the ceiling and ceiling supports of rinks because they have insufficient internal heat loads. The condensation dropping on the ice ruins the surface and the fog obstructs the view. These conditions cannot be solved by ventilation because the introduction of outdoor air only aggravates the problem when the weather outdoor is mild and humid. Insulating the roof also aggravates drip during mild outdoor weather conditions. Low emissivity ceilings stay warmer and thus reduce condensation and drip.

A common misconception is that the more ceiling insulation installed, the better. However, unlike residential and commercial building, this practice in an ice rink does very little to save refrigeration energy/capacity and may actually create condensation and building integrity problems.

The more insulation that is added, the colder the ceiling surface temperature will be and the more likely the surface will be below dew point. In addition, too much insulation can also cause the dew point temperature to occur within the insulation itself, which would render the insulation practically useless. In fact, from a refrigeration standpoint, conductive heat transfer (i.e. effect of insulation) through the ceiling is not even considered a heat load source.

Therefore, insulating an ice rink ceiling to R30 or R40 will produce very little refrigeration energy related benefits and will actually create moisture problems. It makes much more sense to insulate the structural ceiling between R12 and R20 and install a separate low emissivity ceiling, just below the structural ceiling. In other words, a proper design for an ice rink ceiling would be one that keeps the ceiling as warm as possible (i.e. above the dew point), but radiates very little heat towards the ice (i.e. refrigeration savings). Low emissivity ceilings are specifically designed to accomplish this task.

CONCLUSION

Prior to the implementation of ASHRAE 62 code ventilation, the defogging dehumidifier was simply sized to match the resurfacing and people loads (the infiltration and combustion loads are considered insignificant and ignored). Now the new code creates a more complex decision which must consider:

- Year-round or seasonal operation
- Pretreatment of outdoor air or packaged system
- Pretreatment effectiveness

It is possible that seasonal rinks in the northern parts of the U.S. and Canada can ignore the impact of outdoor air since the worst case outdoor air moisture load is below the design dew point already.

Year round rinks will need to include the impact of outdoor air into the dehumidification system selection with two typical solutions being utilized.

For inside design conditions above 40° F dew point (refer to Table 4 for cross references), the typical system would include two refrigeration - based defogging dehumidifiers at ice level and a pretreatment outdoor air system(s) to reduce peak load moisture introduction. Refer to Figure 3 for a typical design.

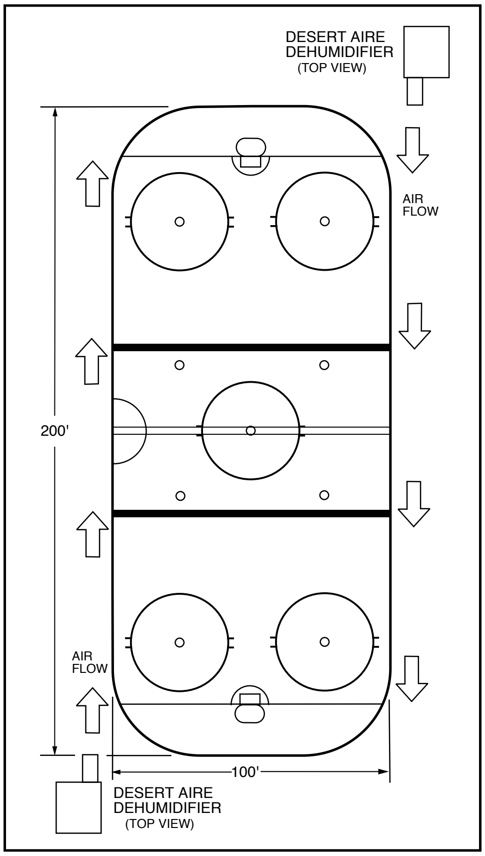

Figure 3 - Dehumidification System Spec

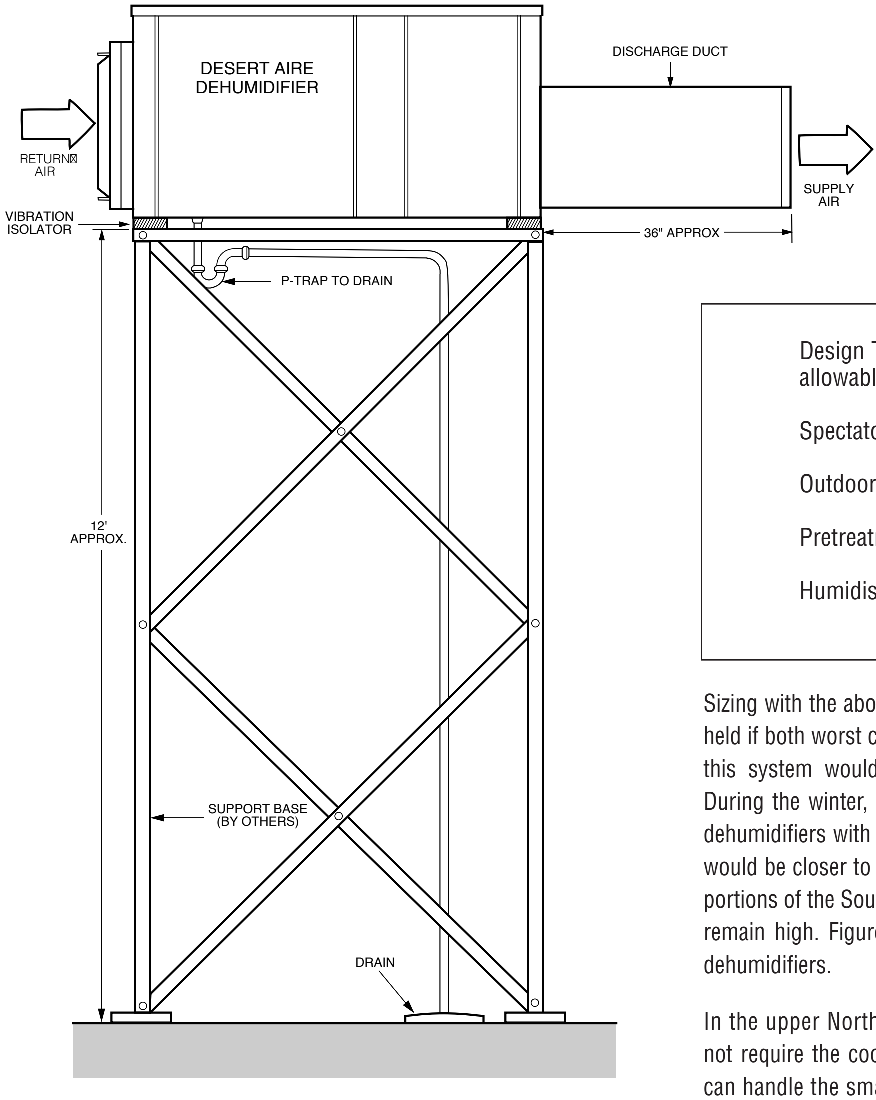

Figure 4 Dehumidification System Installation

To select the correct size dehumidifier(s), the designer must balance up-front equipment cost with the actual loads occurring. Two of the most significant dehumidification loads will be people (spectators) and summer outdoor air (code ventilation). Both of these loads are variable. The spectator design load occurs infrequently during major events while the summer design load will only occur 1% of the year or about four days. Understanding that these two peak loads rarely occur simultaneously, the designer can use the following assumptions with the knowledge that the resultant system will provide better results.

Design Temperature: 60° F/70% RH or maximum allowable worst case in summer.

Spectator: Design for maximum.

Outdoor Air Design: 1% ASHRAE Moisture Peaks

Pretreatment Design Setpoint: 55° F dew point

Humidistat Setpoint: 70%

Sizing with the above criteria, the summer worst case design would be held if both worst case loads happened simultaneously. At other times, this system would produce significantly lower humidity conditions. During the winter, spring and fall, the code outdoor air will assist the dehumidifiers with dryer air. With this system, winter inside conditions would be closer to 55° F/50% RH. The exception being in the southern portions of the Southeastern United States where winter humidity levels remain high. Figure 4 shows the typical installation of the defogging dehumidifiers.

In the upper North American areas, the defogging dehumidifiers do not require the cooling option because the rink's refrigeration system can handle the small amount of reheat energy produced. However, in the southern portions of the U.S., the building solar load may require the addition of an air handler to cool the space. In these situations, the remote condenser cooling option should be added to the defogging dehumidifiers.

For inside designs below 40° F dew point a packaged desiccant-based dehumidifier will be selected to treat the inside and outdoor moisture loads.

The refrigeration-based solution will have the lowest capital and operational costs but is limited to the internal design dew points achieved.

Optimizing Solutions Through Superior Dehumidification Technology

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