Jäähallin kosteudenhallinta – Moisture control in ice rinks

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Abstract

This article is based on a research project in Sweden, which addresses sustainable and energy efficient moisture handling in ice rinks and has had access to numerous measurements in the field.

When the aim is to minimize moisture and heat loads into the arena room, focus should be put on eliminating air leakages (convection) through the building envelope. Diffusion is not a significant source for moisture loads but can still lead to damages if moisture gets trapped. An air barrier is therefore generally recommended to be used instead of a vapor barrier in the building envelope.

It is recommended that the ventilation function in the arena room is normally operated only by recirculation, i.e. fresh air is not brought in. As a result, the moisture load is reduced while fresh air still enters the ice rink through the building envelope as air leakage which is often enough to maintain appropriate CO2-levels.

Sorption type dehumidifiers are recommended to be used in ice rinks and to have a suitable design capacity, which in the case of a typical Nordic ice rink implies around 20 kg/hour. Regarding heat source for the dehumidifier reactivation, the most energy efficient way is to maximize the use of recovered heat from the refrigeration system. Today, recovered heat can cover up to 100% of the reactivation demand and after that electrical energy is only needed for the required fans. A “full heat recovery”-based solution can save ca 85% of the total dehumidifier energy consumption.

Furthermore, this article includes recommendations regarding the design capacity, distribution, and control strategy of the dehumidification function in a typical Nordic ice rink.

1. Introduction

This article is based on a research project conducted in Sweden called NERIS, which is an acronym for Nordicbuilt: Evaluation and Renovation of Ice halls and Swimming halls. NERIS has been led by the department of Civil Engineering at the Royal Institute of Technology (KTH) in Stockholm.

EKA is an expert in energy and refrigeration technology, with further specialization in the winter sports arena segment. The company's services are based on scientific research and impartiality, and therefore the company also cooperates closely with the academic world. EKA has been actively involved in ice rink projects in the Nordic countries, Europe, North America, and East Asia.

This article will review the main findings from a series of four NERIS-reports written be EKA, which together address moisture handling in ice rinks. The aim is to give requirements on how the structures of an ice rink and its dehumidification system should be designed and operated in order to have a well-functioning and energy efficient facility from the moisture perspective. The project has had access to numerous measurements carried out in Swedish ice rinks, which are used to illustrate the “actual operating conditions” in facilities of this type.

2. Moisture handling in ice rinks

A typical Nordic ice rink has an arena room indoor temperature of 5-10°C and a spectator capacity of ca 500 people. The main function of the building envelope is to separate the indoor climate from the alternating outdoor weather in a controlled manner. Support systems such as heating, ventilation and dehumidification should not have to work more than necessary in order to maintain the desired climate.

In the NERIS project the indoor air climate was analyzed in ice rinks near Stockholm during the season 2015/16 (around 8 months), as well as the dehumidification energy usage per season which is plotted in Figure 1. The variations that can be observed between the ice rinks may be dependent on factors such as the moisture load, the control strategy or the season length. By only analyzing this plot it is not possible to conclude what is the influence of each factor. However, these ice rinks are of similar size and made for similar purpose, with insulation, which indicates that the before-mentioned factors can significantly affect the energy-efficiency of an ice rink since the total dehumidification energy usage ranges between 55 to 158 MWh in these cases.

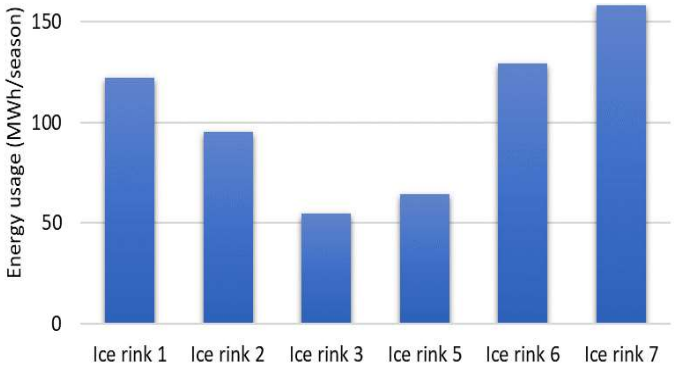

Figure 1. Dehumidification energy usage per season in analyzed Swedish ice rinks.

2.1 Minimization of moisture loads

So, where does the actual moisture load in an ice rink come from? Figure 2 illustrates the typical ones, but generally there are two main groups of moisture sources in an ice rink building:

- External – due to air leakages where humid ambient air by convection infiltrates into the ice rink, and moisture transfer by diffusion through the building envelope materials.
- Internal – due to skaters in activity, spectators, potentially ice resurfacing and melting pit water that evaporates.

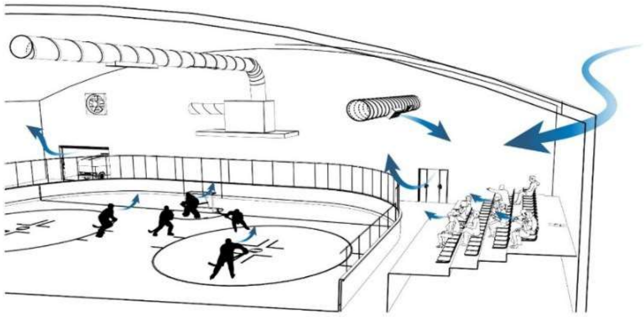

Figure 2. Sources for moisture loads in an ice rink.

The relation between the different moisture loads for a typical Nordic ice rink during peak use is summarized in Figure 3, where the external loads have been further divided into air leakages and diffusion. The results are based on theoretical calculations based on assumptions which have been verified by measured data. In this case it has been assumed that the indoor/outdoor temperature is 7/15 °C, that the air change rate (ACH) due do air leakages is 0.13/h which contributes to the external moisture load and that 500 spectators and 40 players are responsible for the internal loads. Diffusion through walls and ceilings accounts for a vanishingly small proportion, but it is included to put it all into perspective.

The total moisture load is then calculated to be just under 20 kg/hour, and this is when the internal loads are at their highest level of 5.4 kg/h. However, during most of the time of ice rink operation the internal loads will actually be around 0, which means that the main moisture load by far is the air leakage, in this case causing a moisture load of 13 kg/hour.

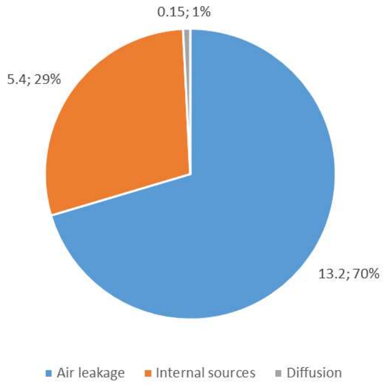

Figure 3. Relation between moisture loads in an ice rink, when the internal loads are maximized, in kg_{water}*/hour.*

Therefore, when the aim is to minimize moisture and heat loads into the arena room, focus should be put on eliminating air leakages (convection) through the building envelope. Diffusion is not a significant source for moisture loads but can still lead to moisture or mold damages in the building envelope if the vapor resistance is too high on the colder side of the structure. The use of vapor barrier is therefore generally seen as a potential risk factor with low benefits, and it is instead suggested that an air barrier with low vapor resistance should be placed in the envelope structure.

Furthermore, it is recommended that the ventilation/heating function in the arena room is normally operated only by recirculation, i.e. fresh air is not brought in. As a result, the moisture load is reduced while fresh air still enters the ice rink through the building envelope as air leakage which in most of the analyzed cases has been found to be enough to maintain appropriate CO2-levels, see Figure 4. Best practice would be to have the supply system controlled by a CO2-sensor, so that necessary fresh air would only be supplied on demand.

The information in Figure 4 can also be used to calculate the air change rate in an ice rink due to air leakages, where it in studied ice rinks in Sweden has been found to range between 0.05/h and 0.15/h. The CO2-concentration peak represents the end of occupancy after which air in the hall is exchanged gradually by air leakages and it happens during the night in this case. And exactly this decrease without other impacting factors can be used for calculations. The equation is as follows:

$$ACH = -\frac{3600}{t} \cdot \ln\left(\frac{C(t) - C_{ext}}{C_0 - C_{ext}}\right)$$

where ACH = Air change per hour (h-1)
t = Time interval (s)
$C(t) - CO2$ = concentration in the end of interval t (ppm)
$C_0 - CO2$ = concentration in the beginning of interval t (ppm)
C_{ext} = Mean outside CO2 concentration during the interval t (ppm)

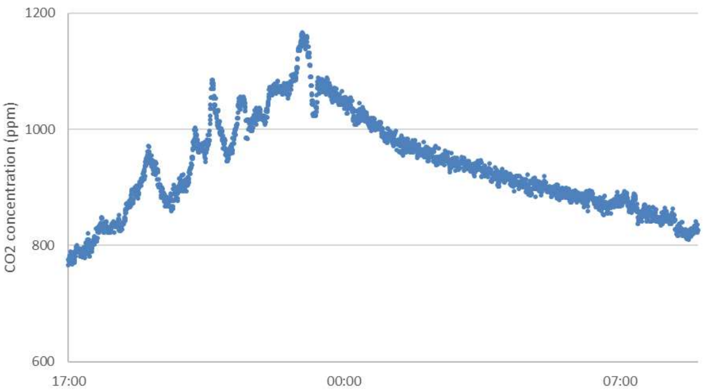

Figure 4. Measured CO2-levels in a typical Nordic ice rink operating on air recirculation only on a day of peak activity.

2.2 Correct control strategy and distribution

Correct control of humidity level is important to achieve good ice quality and healthy indoor climate in the most energy efficient manner. The NERIS-project has found a 30+ percent energy reduction when changing the control strategy from the typical relative humidity to dew point. The dehumidifier should be controlled to maintain a dew point between 0°C and ca 2°C in typical ice rinks, where indoor temperatures move between 5-10°C. If it's lower than 0°C it intensifies the moisture loads and if it is higher than 2°C there is an increased risk of problems related to condensation. Figure 5 illustrates the condensation risk zones and also shows over time how energy is saved by applying a control strategy based dew point instead of the traditional relative humidity, where the latter especially tends to "over dry" the arena room when there actually is no dehumidification demand.

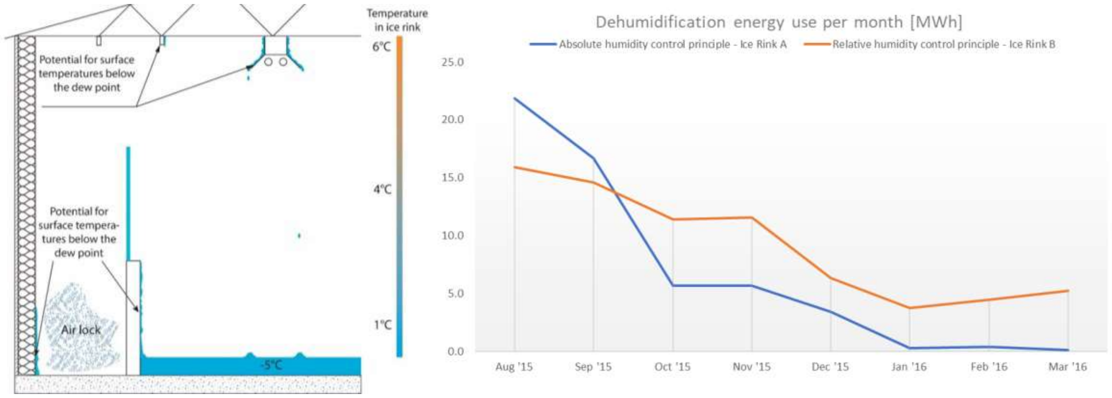

Figure 5. Comparison of energy use between control strategies based on relative humidity and dewpoint/absolute humidity in two ice rinks.

In order to further maximize the energy efficient climate control of an ice rink, the ventilation and dehumidification distribution systems should be separated in the arena room. Warm ventilation air should be blown towards the spectators where the real heat demand is located, while the dehumidification supply air should be distributed in a duct centered above the ice.

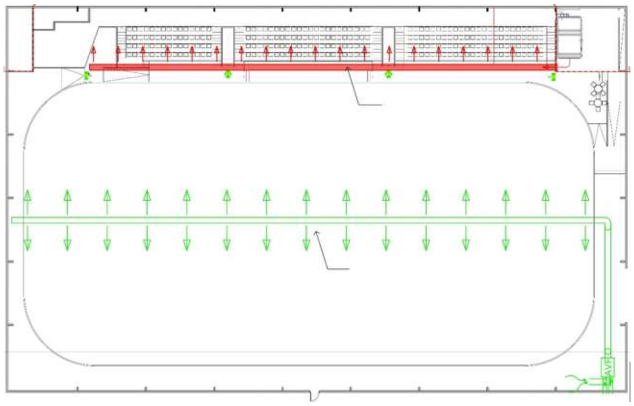

Figure 6. The ventilation and dehumidification distribution systems should be separated.

2.3 Dehumidifier design capacity for a typical Nordic ice rink

The evaluation method for the necessary dehumidification capacity in an ice rink in Sweden is based on using the range of data, where the dehumidifier with a capacity of 20 kg/h managed to maintain the indoor air dewpoint temperature at the appropriate level (below 2°C). By using the measured capacity values at this range, the trendline can be further extended, assuming similar moisture transport magnitude for the highest observed ambient humidity ratio of 12 g of H2O per kg of air. The resulting capacity requirement is around 28 kg/h for this particular ice rink. However, the desired indoor air dewpoint temperature was exceeded only 10 percent of the time during the season, meaning that most of the time the requirements were fulfilled. As a general recommendation for typical Nordic ice rinks it can therefore be concluded that the design capacity of the dehumidifier should be around 20 kg/h in order to maintain a suitable indoor climate.

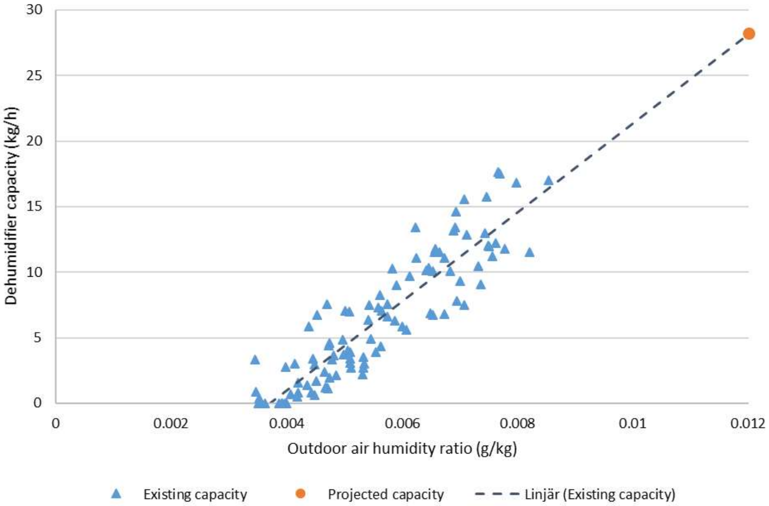

Figure 7. Calculation of dehumidifier design capacity.

2.4 Energy efficient dehumidifier

The sorption dehumidification method has proven to be the most suitable technology for ice rinks. It can remove moisture from air in the subzero dew point humidity range without performance issues, like frost formation, and it does not require as high air volumes as the refrigeration-based method. The majority of consumed energy in a sorption dehumidifier is used to heat the reactivation air, and that is where the highest saving potential also lies since it can be coupled with “free” heat released from the refrigeration system. The challenge however is achieving a sufficient amount of the high temperature level that is required for the reactivation process.

Successful application of refrigeration system heat recovery in the dehumidification process has been recorded in both Generation 1 and Generation 2 sorption dehumidifiers. Generation 1 dehumidifiers are more traditional, where the temperature requirement for the reactivation process is ca 110°C. In this application recovered heat covers the preheating-range that begins with the ambient air temperature and ends at around 60°C, subsequently followed by the electric heater which further raises the temperature from 60°C to 110°C. Generation 2 dehumidifiers have bigger sorption wheels, which lowers the temperature level requirement of the reactivation process down to 60°C. This in turn leads to a higher requirement in fan power, but the sacrifice is made in order to be able to cover the reactivation process heat demand with recovered heat only.

The performance of both a Generation 1 and a Generation 2 sorption dehumidifier is illustrated in Figure 8. The results show that in a Generation 1 dehumidifier almost 40 percent of the total energy use is saved in the operation thanks to the application of recovered heat that otherwise would have been rejected to the ambient air. For the Generation 2 dehumidifier it can be seen that even with a higher fan power requirement the reactivation process still requires by far most of the energy, with the additional observation that recovered heat now can cover up to 100% of the reactivation demand and after that electrical energy is only needed for the fans. A Generation 2 solution can therefore save ca 85% of the total dehumidifier energy consumption.

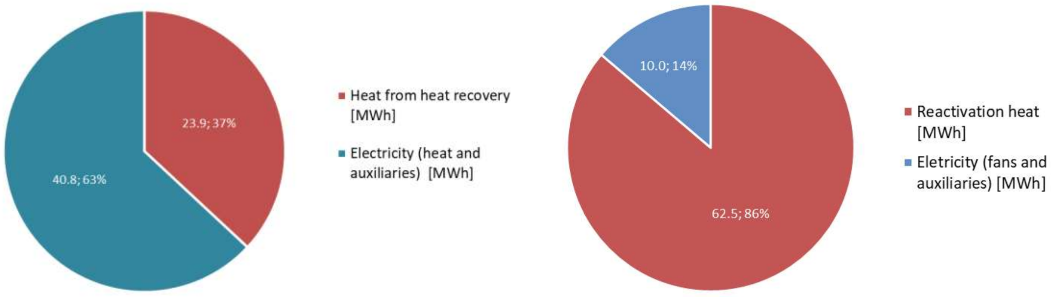

Figure 8. Application of recovered heat from a modern refrigeration system in the reactivation process leads to energy savings of ca 40% in Gen 1 and 85% in Gen 2 sorption dehumidifiers.

Sources

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[4] Rogstam, J., Pomerancevs, J., Bolteau, S., & Grönqvist, C. (2018b). NERIS del 4: Fuktsäkra ishallar – konstruktion och dimensionering. Stockholm.