Conventional Ice Rink Refrigeration versus Geothermal Ice Rink Systems

By Mike Bryson, March 2007

Conventional ice rink refrigeration systems are designed solely to make ice. A well designed system with an appropriate control system, sized for the application, will do a good job of making and maintaining ice, but the “waste heat” from the system was, in the past, not typically used for other applications.

In typical refrigeration plants that are based on the vapor compression cycle, a compressor is used to create low pressure in a heat exchanger, causing liquid refrigerant to cool. The cold refrigerant chills liquid that is circulated through pipes in the ice rink floor to create ice. Energy absorbed from the ice by the chilled liquid is transferred to the cold refrigerant, warming it enough to evaporate the refrigerant and creating low temperature refrigerant gas.

The cold refrigerant gas is pulled into the compressor. As it is pressurized, the gas temperature rises. The hot gas is pumped through another heat exchanger, usually a cooling tower located outside the building, and the heat is dissipated to the outdoor air. After the gas is cooled by the outdoor air, it is drawn through the cycle again to transfer more energy from the ice.

In most ice rinks, electricity drives compressor motors, pumps and fans needed to transfer the energy from the ice surface to the outdoor air. Typically the amount of waste heat generated by operating the electric motors is significant in comparison to the amount of thermal energy that is taken from the ice, depending on the efficiency of the motors, the outdoor temperature and numerous other factors.

Most refrigerated ice rink floors are housed inside a temperature controlled building. The temperature and humidity of the arena and other areas of the building, such as the lobby, offices, locker rooms etc. are controlled by separate mechanical systems. A variety of systems are typically used to provide the space conditioning and service hot water, including gas or other fossil fuel furnaces, rooftop units, boilers, infra red heaters etc.

Humidity is typically controlled by condensing the moisture from the air using a vapor compression system, or by absorbing the moisture from the air using a desiccant and vaporizing it by heating the desiccant with natural gas or other fossil fuel.

Energy costs in the last few decades have driven suppliers of conventional refrigeration systems to look at methods of using some of the energy that is taken from the ice. The main problem encountered is the imbalance in the heating and refrigeration loads in the building. When the ice is used during the day and evening, occupants, lights and warmer outdoor temperatures reduce the need for heat in the building. When the building is unoccupied during the colder night time, the refrigeration plant operates much less but the need for heat is greater. With conventional thermal energy storage, only a portion of the waste heat can typically be reclaimed and the remainder is rejected to the environment through a cooling tower.

The approach taken in the design of a geothermal ice rink is completely different than the approach taken in the design of a conventional refrigeration system with waste heat reclaim. Heat pumps designed to extract heat from fluid as low as 0ºF (-18ºC) and as high as 80ºF (27ºC) are used to maintain the ice. At the same time, they produce warm water at a temperature ranging from 40 to 110ºF (4 to 43ºC). They operate on exactly the same principles as a conventional refrigeration plant.

Using heat pumps capable of operating at such large temperature ranges provides a great deal of design flexibility. They can be used to extract energy from ice like a conventional ice plant, but can also take energy from other sources. With an appropriately design heat distribution system, they can provide space heating and service hot water.

There are three other design features in a geothermal ice rink that differentiate it from a conventional ice rink system design. These are:
• A ground heat exchanger (GHX)
• Thermal energy storage
• Modular system design

A GHX provides a secondary energy source for the heat pumps as well as a medium to temporarily store thermal energy taken from the ice when it can't be used in the building. The same heat pumps can also extract energy from the GHX to provide heat for the building even when refrigeration is not needed. Additional heat pumps in other areas of the building, or even in another building, can be connected to the same GHX to provide space heating, service hot water or even swimming pool heating. They can also reject energy to the GHX and provide air conditioning in the buildings connected to the GHX.

Building a rink floor with a large amount of thermal mass (a floor 5 to 8 times thicker than a conventional rink floor) provides several benefits. Large amounts of energy can be extracted from the lower part of a thick rink floor without affecting the rink surface temperature immediately. This provides an additional energy source for the heat pumps when the ice temperature is satisfied. It can absorb large amounts of energy during peak use of the ice (i.e., when the ice is resurfaced several times during a hockey game). When the heat pumps are making ice or chilling the thermal storage buffer under the ice, while they are simultaneously providing heat for the building, the energy delivered to the building is free.

Using several independent heat pumps that can be controlled separately to take energy from different heat sources (the ice, the thermal storage buffer or the GHX), while they reject energy either to the building or the GHX provides a great deal of flexibility. It allows one heat pump to provide refrigeration directly to the ice, a second heat pump to sub-cool the thermal storage buffer for a hockey game later in the day, while a third heat pump can withdraw additional energy from the GHX to provide full heating capacity to the building if needed. Alternately, all of the heat pumps can chill the ice during peak use while only one of them provides the necessary heat to the building. The energy removed by the other heat pumps is stored in the GHX.