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Improving Efficiency In Ice Hockey Arenas

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Municipal arenas in Canada are built mainly for hockey, but they also house other activities and special events. In most small municipalities, arenas are the public buildings that have the highest annual energy use and consumption.

Approximately 450 arenas operate throughout the province of Quebec. A general survey[1] of several arenas similar in size shows that for a standard ice arena, the energy use is 1,500,000 kWh/year. The most energy-efficient arenas use approximately 800,000 kWh/year, while less efficient ones consume nearly three times that much energy at 2,400,000 kWh/year.

To better understand the energy use of an arena, we must define what is meant by standard arena. For the purpose of this article, an arena is used for eight months per year with activities beginning in August (for hockey training) and generally ending in April. The main space is the amphitheatre with the ice sheet.

The average amphitheatre is 24,000 ft^2 (2230 m^2) (including stands for 500 people) with the ice sheet covering 16,327 ft^2 (1517 m^2) (standardized 85 ft × 200 ft [26 m × 61 m] National Hockey League ice rink). Other spaces consist of locker rooms, 2,800 ft^2 (260 m^2); mechanical and electrical rooms, 600 ft^2 (56 m^2); ice resurfacer machine room, 300 ft^2 (28 m^2); offices and meeting rooms, 2,500 ft^2 (232 m^2); canteen and kitchen area, 1,500 ft^2 (139 m^2); main entrance hall, 1,500 ft^2 (139 m^2); and service rooms 800 ft^2 (74 m^2). Overall, the total building area is approximately 34,000 ft^2 (3159 m^2).

Typically, arenas are used 18 hours per day on weekends and 12 hours per day during weekdays. A standard arena is

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used approximately 100 hours per week. The ice is resurfaced approximately 65 times per week.

The lighting of a nonefficient amphitheatre uses approximately 32 kW for most ice activities. Most of the lighting fixtures are installed above the ice rink (1.9 W/ft^2 [20.5 W/m^2]) and lower density lighting fixtures are installed above the stands (0.7 W/ft^2 [7.5 W/m^2]). Elsewhere in the building, the average lighting power is approximately (2 W/ft^2 [21.5 W/m^2]) for a total of 15 kW. Exterior lighting could amount to 2 kW.

The ventilation requirements of the amphitheater are approximately 10,000 cfm (4719 L/s), but the author's observations show that ventilation is not continuously used. Ventilation of an amphitheater is used for 15 minutes after each ice resurfacing to evacuate the pollution created by the propane gas combustion of the ice resurfacing machine. Several arenas use pollution detectors to monitor the ventilation use, which explains why the ventilation is not in continuous operation. Other ventilation systems with a total of fresh air of 7,000 cfm (3304 L/s) are used for the other spaces.

The refrigeration load of a standard arena, operating for eight months, is 70 tons (246 kW) of cooling using an average 110 hp (82 kW) for the refrigeration compressors. The brine pump (850 gpm [54 L/s]) generally uses a 25 hp (19 kW) motor. The refrigeration equipment is in use throughout the eight months of operation.

Heating is provided either by natural gas, propane gas, oil or electricity. In the province of Quebec, several arenas are heated with electricity, but most arenas use a dual source of energy (either gas and electricity or oil and electricity). Stands are heated in most municipal arenas. When heated, the stands are frequently kept to a comfort level with radiant gas units.

Typical municipal ice arenas consume 1500 MWh/year.

As an exercise for evaluating the energy savings measures, let's assume that we have a nonefficient arena with an annual energy use of 1,950,000 kWh. The total energy consumption could be divided into the following uses as shown in *Figure 1*.

Several energy-saving measures could be implemented in an existing building such as this one or when planning a new building.

Heat Recovery on Exhaust

In northern regions, the first energy saving measure to implement is usually the heat recovery of energy leaving the building in the exhausted air. This can be used for preheating the outside air being introduced for ventilation. This measure has a significant impact on the whole energy balance of the building. For instance, in this typical building, the energy savings with the use of a thermal wheel at 75% efficiency could reach 250,000 kWh. This savings will appear on the heating usage.

Subfloor Heating Using Heat Recovery

When an arena is used for more than seven months, it is important to eliminate the possibility of freezing the subsoil. In fact, the concrete slab under ice rinks had to be replaced in several arenas because of damages created by the formation of frost in the soil under the floor. To eliminate this problem, 4 in. (102 mm) of polystyrene insulation is installed under the concrete slab of the ice rink. Heating must be provided in the soil under the insulation to prevent freezing. The average heating requirement amounts to 20,500 Btu/h to 27,300 Btu/h (6 kW to 8 kW). It is used for the full eight months of operation. The heating of the subfloor could be provided by the heat rejection of the condenser of the refrigeration equipment.

As this is a low-temperature requirement, it could be provided at a condensing temperature that could be limited at 70°F (21°C) during winter months. The potential savings is equal to the total heat requirement of 35,000 kWh.

DHW and Surfacing Water Requirement

Domestic hot water and water used by the ice resurfacer require a higher temperature. The refrigeration gas superheat available at the outlet of the compressor offers an excellent opportunity for the heating of DHW. The problem with DHW and ice surfacing water is the wide variation of daily demand. Therefore, water storage is required. Successful preheating of domestic water is achieved with a 2,000 gallon (7571 L) water storage tank (often two tanks of 1,000 gallons (3785 L) each). With this amount of storage, it often happens that in the morning after heat recovery of the gas superheat, the 2,000 gallons (7571 L) may be at 170°F (77°C), ready for the daily operation. Monitoring of energy savings in some arenas show that the full DHW and surfacing water requirement could be provided with heat recovery on the gas superheat. The annual savings could amount to 130,000 kWh.

Brine Pump

Several tests were conducted in the Montreal area by modifying the distribution of the brine in the floor slab under the ice. The modified distribution used a four-pass arrangement instead of the conventional two-pass arrangement. This modification had a major impact on the energy use of the brine pump. It cut the energy requirement by 50%. Tests conducted showed the ice quality was the same and that no noticeable change in the activities carried out on the ice was reported during the test period. It was once reported that the four-pass distribution was better than the two-pass distribution. This specific comment was for a central refrigeration plant for two ice sheets, one being with the four-pass distribution and the other with the two-pass distribution. Because of a faulty installation (too much concrete over the plastic pipes), the operator had to lower the brine temperature when starting the two-pass ice sheet. The ice quality was good for the four-pass ice sheet with a higher temperature at 4°F (–16°C).

The thickness of concrete over the plastic pipes and the thickness of the ice over the slab have a major impact on the performance of heat exchanges. It is important that the concrete slab be leveled from within so that the ice thickness is limited to 1 in. (25 mm). The thickness of concrete over the plastic pipes should also be limited to 1 in. (25 mm). A 4 in. (102 mm) thickness of concrete means that the brine temperature must be lowered by 10°F (5.5°C).

Some questions remain on the brine velocity in the pipes. Should the brine flow be in the turbulent mode? Often, the heat transferred from the brine to the ice is low. A standard arena uses 53,000 ft (16 154 m) of plastic polyethylene pipes for the heat transfer with the ice. If we assume 70 tons (246 kW) for the refrigeration, it means that the heat transfer amounts to 16 Btu/ft (15 W/m) of pipe. This means that a brine flow in the laminar mode would have less impact on the heat transfer. The resistive film created by a laminar flow has more impact in a heat exchanger where the heat transfer is 1,000 Btu/ft (961 W/m) of pipe.

The four-pass arrangement generates an energy savings of 70,000 kWh on the pump's energy requirements and 20,000 kWh on the refrigeration equipment (lower heat generated by the brine pump). This represents annual savings of $6,000 for an arena in the Montreal area.

Heat Recovery for Heating

The refrigeration equipment of an arena could also act as a heat pump. All heat removed from the ice could be used for heating spaces and the outside air for ventilation purposes. Although heat is recovered from the exhaust, residual heating is still required for ventilation. It is easy to use rejected heat from the refrigeration equipment as it does not require high condensation temperature. Moreover, the heat recovery does not negatively impact on the performance of the refrigeration compressors.

Heat recovery condensers could be used for heating of space. Heating equipment would have to be selected for operation at low temperatures, so it does not require high condensation temperature (more than 100°F [38°C]).

When full heat recovery is achieved on the refrigeration equipment, almost all space heating, as well as ventilation heating, could be provided. This would represent annual savings of 475,000 kWh.

Low-e Ceiling

The refrigeration load of an ice arena is a complex mix of radiation and convection. Studies show that the radiation has a major impact on the refrigeration load. It is possible to lower the radiation exchange between the ice sheet and the ceiling with the use of a low-e ceiling by installing a high reflection (low-e) aluminized plastic sheet under the structural trusses of the ceiling. This addition will lower the radiation exchange with the ceiling, but it will increase the radiation exchange from the perimeter

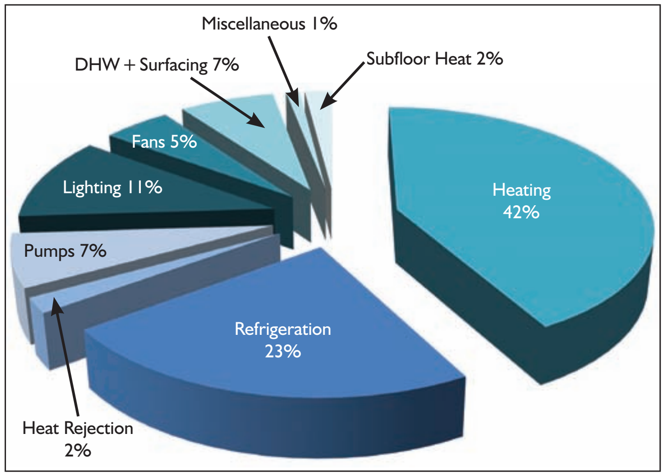

Figure 1: Inefficient arena (1,950,000 kWh).

stands because of the higher reflection. An ASHRAE research project is currently under way to help understand the radiation exchange process that occurs in an arena. Monitoring of the addition of a low-e ceiling shows a 15% savings on the refrigeration equipment, which translates into annual savings of 67,500 kWh.

Efficient Lighting System

Improvement in the lighting efficiency could be used to lower the energy use of an arena. Lighting fixtures have a large proportion of radiation components and, when installed over the ice sheet they generate a refrigeration load. Creative lighting systems could be used for arenas. Some experiences with T-5 or T-8 fluorescent lighting systems were successful as they create the possibility to modulate the lighting level according to the activities taking place on the ice. Lighting level can be adapted to the type of activity. It is easy to understand that a child below 10 years old won't shoot the puck at 100 mph (45 m/s) as a professional hockey player would. A high lighting level is not always needed. Efficient lighting level could generate annual savings of more than 50,000 kWh per year.

Efficient Refrigeration Equipment

Several energy-efficiency measures could be implemented on the refrigeration equipment such as: modulation of the condensing pressure, liquid subcooling, electronic expansion valves, flooded-type evaporator, variable frequency drive on compressor, thermal storage, etc. Simulation of the operation of the refrigeration equipment is the best tool to evaluate the advantages of its improvement. Lowering the energy requirement of the refrigeration equipment is often not possible when heat recovery is required for heating at a higher condensing pressure. Liquid subcooling is required with an alternative refrigerant such as R-410 or R-507. Lowering the condensing pressure will improve the refrigeration cycle, but a higher condensing pressure should be used if heat recovery is required.

It is always better to extract heat from the refrigeration equipment when heat is required than trying to improve the refrigeration cycle itself. Improving energy efficiency of an existing arena was achieved without lowering the condensing pressure.

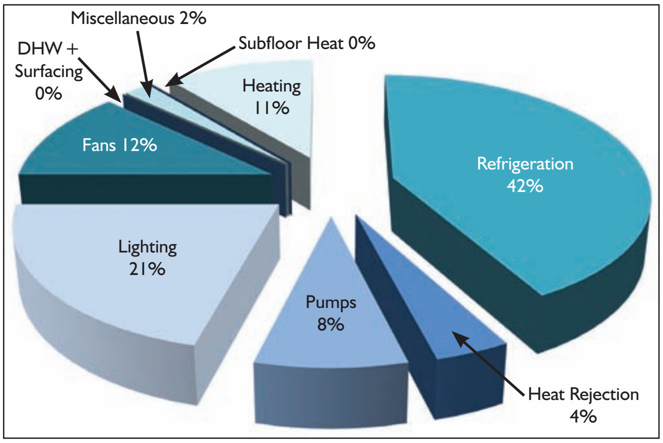

Figure 2: Modified arena (8,40,000 kWh).

The total energy was lowered by almost half of the energy use (from 1,600,000 kWh to 820,000 kWh) by heat recovery used for heating requirements. Improvement on the refrigeration equipment is possible but one should consider the building as a whole system and not focus only on the refrigeration.

Improved refrigeration could lower the energy use by 30%, which represents annual savings of 120,000 kWh. Energy-efficient refrigeration equipment is a must when the rejected heat is recovered by a water loop heat pump instead of a direct condenser heat recovery system.

Energy Savings

When all of the previously described energy efficiency improvement measures are implemented (with 20% improvement on the refrigeration), the standard arena uses less energy. An annual savings of 57% is achievable.

The total energy consumption of the improved arena (8,40,000 kWh) could be divided into the uses shown in *Figure 2*.

Conclusion

The analysis of energy efficiency for arenas should consider the building as a whole with all its mechanical systems and architectural systems. Because a refrigeration load exists for the ice rink along with other needs for heating, the refrigeration system should act as a heat pump to supplement the heating requirements. For many arenas, proper heat recovery could lead to a 50% annual energy savings.

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