SOUTH CARIBOO RECREATION CENTRE
100 MILE HOUSE, BRITISH COLUMBIA, CANADA

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South Caribou Recreation Centre, 100 Mile House, BC

Interior BC Community eliminates greenhouse gas emissions and reduces energy costs in new recreation centre

INTRODUCTION

The recreation centre is the centre of activities in communities across Canada, and the hockey arena is the heart of most facilities. Rising energy prices over the last decade, however, has forced communities to look for energy efficient alternatives to industrial refrigeration plants that have been the norm for the last century.

At the turn of the century the community of 100 Mile House in the centre of British Columbia made a decision to replace their aging hockey arena that had served them for the last 50 years. The community began researching other new facilities that had been built recently. Two new facilities they visited in Chase and Kamloops, BC caught their attention. Both facilities had installed an integrated geothermal refrigeration, heating, ventilating and air conditioning (R/HVAC) system. The simplicity of operating the systems, low energy costs and low operating and maintenance costs, attracted their attention. The elimination of fossil fuels for heating the facilities also appealed to the growing concern for reducing greenhouse gas emissions.

THE BUILDING

Since the community is built around the forestry industry, it's only natural that wood is used for much of the structure. The building is well insulated (R20 walls, R30 ceiling). The ice arena is approximately 28,600 square feet (2,660 square meters), with approximately 700 spectator seats. The ice rink area and the concrete bleacher seating area is heated with a radiant floor heating system. The ice area is maintained at a comfortable 50°F (10°C). The ceiling is covered with wood for aesthetics. The wood surface on the ceiling, however, creates a much greater radiant heat load on the ice surface than a ceiling covered with a "low-emissivity" material.

There are six change rooms alongside the ice area, under the bleachers. The change rooms are maintained at approximately 70°F (21°C) with a radiant floor heat system. One and a half inches (39 mm) of high-density foam insulation was placed under the floor to prevent heat loss to the ground. The change rooms are well ventilated with a heat recovery ventilation system that exhausts air from the change rooms. Fresh, preheated air from the heat recovery system is ducted to the ice arena and then brought back to the change rooms through transfer grills from the ice area. The change rooms and mechanical rooms cover an area of approximately 8,200 square feet (760 square meters)

The lobby and viewing area overlooking the ice rink is approximately 5,900 square feet (550 square meters). Adjacent to the lobby is an office area of approximately 2,100 square feet (195 square meters). These areas are heated and cooled with several ground source heat pumps connected to the horizontal ground loop in the field behind the building.

The refrigeration system of the existing curling rink adjacent to the new arena has been connected to the geothermal system. The heating system of the lobby and lounge of the curling rink, however, has not been connected because of cost. There are plans to convert the heating system in the near future.

THE REFRIGERATION SYSTEM

A hockey arena is typically the most expensive building to operate (energy cost and operating and maintenance costs) in most small communities. The electrical costs associated with operating the compressors and pumps of the refrigeration system are high. The majority of the hockey arenas throughout Canada and much of the United States use ammonia as the primary refrigerant. Ammonia is a very efficient refrigerant, but the large refrigerant charge (1,000 to 1,200 pounds or 450 to 500 kg) requires constant monitoring and stringent safety procedures, including airlock entries to the refrigeration room, high capacity ventilation systems, eyewash stations and oxygen masks. Because of the potential danger, most jurisdictions require highly trained operators and the system operating pressures must be monitored regularly.

Ammonia does not transport oil through the system. It collects in the evaporator, or chiller barrel, and must be drained regularly, and treated as a hazardous waste product. Fresh oil must be added to the refrigerant system to ensure lubrication of the compressors. An average rink will drain and replace close to a barrel of oil annually, depending on how heavily the rink is used. This adds approximately $500 to $1,000 to the operating cost every year.

In this arena, eight large water to water heat pumps were used in place of a traditional ice plant (Figure 1). The heat pumps are designed to operate at source temperatures as low as 0°F (-18°C). They are designed to produce water to temperatures as high as 125°F (51°C). Each of the heat pumps contains approximately 12 pounds (5.5 kg) of HFC refrigerant R404A. The entire refrigeration system of eight units contains approximately 10% of the refrigerant of a traditional refrigeration system, and it is contained in eight independent units. Since this is a non-toxic refrigerant, there is no need for the same level of safety considerations.

The eight separate heat pumps are piped as four pairs. Each pair of heat pumps is piped with two pumps connected to the chilled fluid side and two pumps to the hot fluid side. The chilled fluid can be circulated either to the ice surface piping, the thermal storage buffer or the earth loop to pick up heat. The heated fluid can be circulated either to the building heating system or the earth loop, based on the temperatures in the building. This arrangement provides a high degree of redundancy

Figure 1. ***Eight low temperature water-to-water heat pumps provide approximately 84 tons of refrigeration at ice rink temperatures. The heat pumps reject heat either directly to a radiant floor heat system or to a horizontal earth loop.***

HUMIDITY AND TEMPERATURE CONTROL IN THE ICE AREA

Humidity control is important in an ice arena, especially if the ice surface will be used in warm weather. Condensation will form on the ice surface if the humidity is too high, creating a significant load on the refrigeration equipment. Each pound of water that condenses on the ice surface absorbs over 1,100 Btu (0.33 kW) of energy. Steel at the ceiling above the ice area radiates heat to the cold ice below it. Warm air at the ceiling will condense on the cold steel, eventually causing rusting and structural damage. It can also collect and drip onto the ice, creating bumps on the ice.

Figure 2. ***Dehumidification, air conditioning and heating are provided by a 20-ton heat pump in the ice area. The unit can cool and reheat 40-50°F (5-10°C) air. It can also cool or heat the arena by either rejecting or drawing heat from the horizontal earth loop.***

A heat pump designed specifically to provide dehumidification is installed in the ice area (Figure 2). The heat pump is designed to cool the air enough to condense the moisture from the air. Heat from the cooling process plus compressor heat reheats the air to provide warmer, drier air. The heat pump is also connected to the earth loop through a fluid to refrigerant heat exchanger. If the air temperature in the ice area is satisfied, the heat can be rejected to the earth loop, and the unit is used to provide approximately 16 tons (56 kW) of air conditioning. It can also be used when the facility is used for other activities, such as inline hockey or lacrosse during the summer.

The heat pump can also be used to extract heat from the earth loop if additional heat is needed in the ice rink area. It will provide approximately 200,000 to 250,000 Btu/h (59 to 73 kW), depending on the earth loop temperature.

The spectator stands are heated with radiant floor heat piping embedded in the precast concrete bleachers (Figure 3). The warmed seats provide heat where it is most needed. If snow is tracked into the seats, or a drink is spilled in the stands, it is melted and evaporates quickly, reducing cleanup time and potential liability from someone slipping on wet concrete.

Figure 3. ***Much of the building, including the spectator seating, is heated with a radiant floor heat system. The warm floor dries snow that is tracked from outside into the building and reduces the opportunity for mildew growth in the change rooms.***

BUILDING HEATING AND COOLING

The ice surface and the Thermal Storage Buffer[1] are the primary heat source for the low temperature water to water heat pumps. Only when both the ice and the buffer temperatures are satisfied, and the building still needs heat, do the heat pumps extract heat from the earth loop. The building radiant floor heat system, the domestic hot water and snow melt are the primary heat sink for the heat pumps. Only when the building temperature is satisfied do the heat pumps reject heat to the earth loop. Conventional ground source heat pumps are connected to the earth loop to provide heating and air conditioning to the office areas (Figure 4).

A large site allowed the construction of a horizontal earth loop. The loop is a secondary heat source and secondary heat sink for the main heat pump system, storing excess heat that can't be used. It is the primary heat source/heat sink for the conventional forced air heat pumps, domestic hot water heat pump and the dehumidification unit.

Domestic hot water is preheated using a double wall heat exchanger. When hot water is used in the building in showers or flooding the ice, make-up water is preheated to about 75 to 85°F (25-30°C). A water to water heat pump operating directly from the earth loop heats the water to 120°F (50°C) (Figure 5).

Figure 5. ***A 10-ton water-to-water heat pump draws heat from the earth loop to produce service hot water (showers and ice flooding) at 120°F (50°C)***

Heat removed from the ice is either used directly to provide space heating or domestic hot water, or is stored in the earth loop. This type of facility is very cooling dominant, and the earth loop becomes saturated with heat when the ice

1 US Patent #6,170,278, Canadian Patent #2,273,760

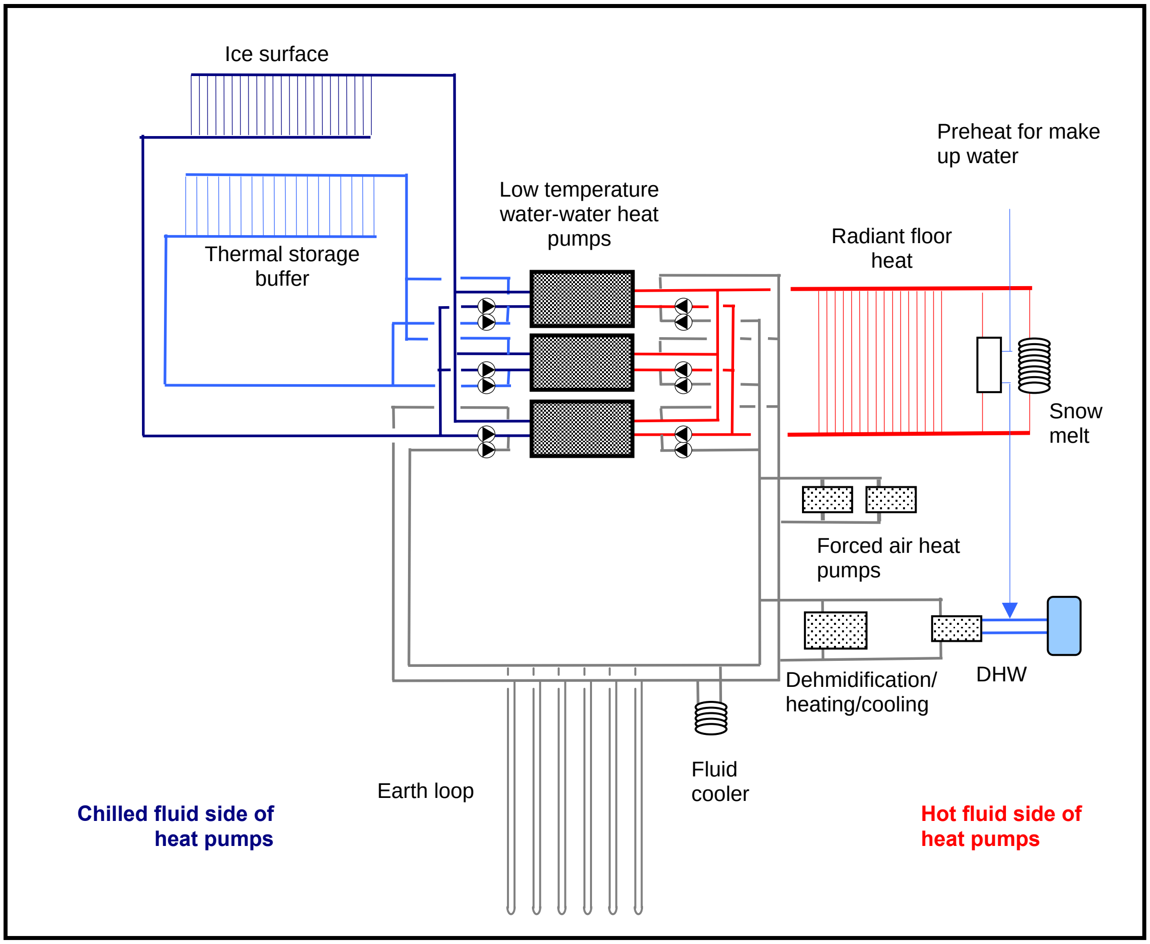

Figure 4.

is used in summer. A fluid cooler is used to prevent the earth loop from becoming overheated.

Air from the change rooms is continuously exhausted using a heat recovery ventilation (HRV) system. Fresh air from the HRV is introduced to the ice area. Air from the ice area is drawn into the change rooms through intake grills from the ice area.

THERMAL STORAGE

The patented rink floor design provides thermal cold storage directly beneath the ice surface. It provides several advantages over a conventional thin rink floor design:

- The large mass maintains a more consistent ice temperature than a floor with little storage. This is especially noticeable when the ice is being heavily used and resurfaced often.
- The large mass of the floor is "sub-cooled" several degrees lower than the ice surface when the ice is not being used. This is the heat source used for the heat pumps to heat the building, while simultaneously providing a significant amount of refrigeration for the ice when it is being heavily used.
- The sub-cooled buffer provides a significant portion of the refrigeration during peak use. Both the refrigeration capacity and the fluid circulation pumps required to maintain the ice surface during peak use can be reduced. A conventional system would require a 20 to 30-hp circulation pump for the ice surface and a 7.5 to 10-hp circulation pump for the curling rink. Four 3-hp circulation pumps provide the flow for both the ice surface and the curling rink. This reduces the refrigeration load created by friction losses in the rink
- surface pipe by 57 to 70% compared to a facility with a conventional thin floor.
- In the event of a power failure, the mass of the rink floor will maintain the ice for up to 3 days.

INTEGRATING SYSTEMS WITH AN EARTH LOOP

The integration of the entire system revolves around the earth loop. The facility is built on a large site that allows space for a horizontal earth loop (Figure 6). An area was excavated behind for the installation of the earth loop. All heat pumps in the system are connected to the earth loop. The large water-to-water refrigeration units use the earth loop as a secondary heat source when the ice temperature is satisfied, and a secondary heat sink when the building temperature is satisfied. The forced air heat pumps in the office spaces, the water-to-water heat pump that produces hot water for showers and flooding the ice, and the dehumidification/heating/air conditioning unit are all connected directly to the earth loop, and either pull heat from it, or reject heat into it as needed.

Figure 6. This photo shows the installation of the horizontal earth loop at 100 Mile House, BC. 50,000 feet (15,200 m) of 1 inch (25 mm) pipe was installed to a depth of 8 feet (2.4 m).

The primary benefit of integrating all the systems into a common earth loop takes advantage of the thermal storage capacity of the earth. In a building such as the South Caribou Recreation Centre, the water-to-water heat pumps used to make the ice either reject heat directly to the building radiant floor heat system, or to the earth loop. Since only a portion of the heat taken from the ice can be used in the building directly, even during a cold winter day, the earth loop is constantly being recharged by "waste heat" taken from the ice.

Heat pumps operate more efficiently and have higher heating capacity when the source temperature is higher. The heat pumps used for space heating and heating water typically operate with an earth loop of 55-70°F (13°C), and operate at a COP between 4.4 and 5.4.

In spring and fall when less heat is needed in the building, the earth loop temperature typically climbs to 80-90°F (27-32°C). To prevent the earth loop temperature from climbing even higher, an evaporative fluid cooler was installed. During peak use of the ice the fluid cooler works in parallel with the earth loop to reduce the load on the loop. More importantly, at night when the building is not being used, the fluid from the earth loop is circulated through the fluid cooler to take advantage of cooler night time temperatures to drop the loop temperature. This allows the loop to absorb heat more readily during peak use the following day.

SYSTEM ECONOMICS

The cost of installing a geothermal system is typically higher than the cost of installing a conventional system. This holds true with an integrated geothermal ice rink application as well. The building qualified for a Commercial Building Incentive Program (CBIP) from Natural Resources Canada (NRCan) of $60,000. The capital cost of the integrated system is compared to the estimated cost of installing a conventional refrigeration plant and heating system in Table 1. As is often the case, the difference in cost of the two systems is typically the approximate cost of the installation of the earth loop.

The additional cost of installing the integrated system is offset by lower energy costs as well as lower operating and maintenance costs. The energy costs of the facility are shown in Figure 6, along with a comparison of the energy costs of a typical conventional system. Annual energy cost savings are estimated at approximately $48,000 annually.

Operating and maintenance costs for a conventional refrigeration plant are typically much higher than the cost of maintaining other mechanical equipment. Ice rink owners and operators typically budget approximately $14,000 to $17,000 annually for maintenance costs.

Table 1.

	Integrated System	**Conventional System***
Refrigeration heat pumps, circulation pumps, rink floor	$575,000	$525,000
Horizontal loop	$105,000	---
Building heating, cooling, ventilation	$112,000	$96,000
Incentives (NRCan / CBIP)	($60,000)	---
Connecting Curling Arena Refrigeration	$30,000	---
Dehumidification	$72,000	$110,000
Domestic hot water	$34,000	$18,000
Total	**$868,000**	**$749,000**

** estimated cost of conventional system*

Some of the costs of operating a conventional ammonia ice plant include:

- Oil to lubricate the compressor (ammonia vapor does not transport oil from the evaporator (chiller barrel) back to the compressor – it must be drained regularly and replaced. Typical cost is approximately $500-1,200 annually. The waste oil must then be disposed of appropriately
- Compressor rebuilds. A conventional reciprocating ammonia compressor must be rebuilt after approximately 6,000 to 8,000 hours of runtime, at a typical cost of $6,000 to $12,000. With the schedule of this facility, one compressor would typically be rebuilt every year.
- In most jurisdictions it is required that an industrial refrigeration plant must be monitored regularly.

Typically a rink operator must check the operating pressures and flows of the system 4-6 times per day (1.5-3 hours per day) This time is taken away from other needs in the facility.

- Special circumstances. The integrated geothermal system is designed with a high level of system redundancy. The design includes eight independent water-to-water heat pumps designed to operate with four sets of circulation pumps. If a heat pump or circulation pump fails, the other heat pumps and circulation pumps simply carry on to maintain the ice. If the single circulation pump, or one of two or three large compressors fails, the system must be repaired immediately, often at emergency service rates.

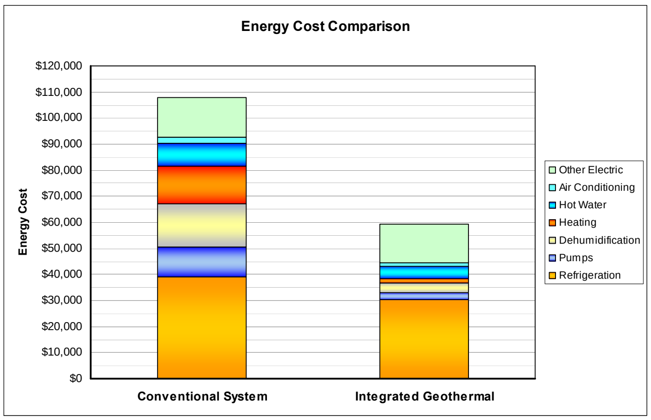

Figure 6. ***The actual energy cost of the facility in 2004 was slightly over $60,000. Energy consumption was 1,195,000 kWh, with a peak electrical demand of 257 kW. The total energy consumption of a comparable rink with a conventional refrigeration plant and gas fired heating system is estimated at approximately $107,000 annually. Heating, service hot water and dehumidification would typically be done with gas equipment. Gas costs for a conventional system in this building are estimated at approximately $40,000 annually.***

The water-to-water heat pumps do not require compressor rebuilds. Oil does not have to be drained from the system regularly. The size of the compressors of the water-to-water heat pumps and built in redundancy of the system eliminates the much of the daily operating cost of the system and reduces the cost of service. Similar ice rink facilities report operating and maintenance costs of $4,000 to $5,000 annually after several years of operation.

The simple payback of the system installed in 100 Mile House is estimated at approximately two years if the NRCan / CBIP incentive is included, and approximately three years if no incentive is considered.

OVERALL SUMMARY

Building Description:

- Occupancy: Hockey arena, curling arena, office space
- Location: 100 Mile House, BC
- Gross Floor Area: 56,400 square feet (5,241 square meters)
    - Arena: 28,600 square feet (2,498 square meters)
    - Offices, change rooms, lobby: 15,400 square feet (1,430 square meters)
    - Curling Arena: 9,000 square feet (836 square meters)
    - Curling Lobby & Lounge: 3,600 square feet (335 square meters)
- Construction
    - Hockey Arena: new construction, well insulated
    - Curling Arena: retrofit
- Completion Date: 2002
- Heating Degree Days (below 64.4°F / 18°C): 9,076 / 5,042

System Description:

- Refrigeration heat pumps (hockey and curling combined): 88 tons (310 kW)
- Hockey Arena climate control
    - Humidity control: 15 tons (52.8 kW)
    - Cooling: 15 tons (52.8 kW)
    - Heating: 230,000 Btu/h (68.6 kW)
- Heating / cooling (offices, change rooms, lobby etc.): 24 tons (84 kW)
- Fluid: Methanol 30%, & water
- Circulation pumps
    - Refrigeration heat pumps (Hockey and Curling Arenas)
        - 4 3-hp circulation pumps building heating system / earth loop
        - 4 3-hp circulation pumps for ice floor circulation / earth loop
    - Heating / cooling heat pumps
        - 1 3-hp circulation pump
- Earth Loop: Horizontal earth loop, buried to 8 feet (2.4 meters), 50 circuits of 1" (25 mm) HDPE SDR11 pipe, 1,000 feet (300 m) length

Special Features:

- Thermal storage buffer floor (patented) design to minimize peak refrigeration demand and maintain constant ice temperature
- Optimized rink pipe layout to reduce pumping power requirements
- Earth loop to store excess heat and provide additional heat as needed