First Place: Industrial Facilities or Processes, Existing

Arena Marcel Dutil, Les Coteaux, QC, Canada, is the first ice rink in the world to use a CO_2-based refrigeration system.

Ice Rink Uses CO_2 System

By Luc Simard, Associate Member ASHRAE

The Marcel Dutil Arena in the municipality of Saint-Gédéon-de-Beauce boasts the world's first 100% CO_2-based refrigeration system used in an ice rink. Saint-Gédéon-de-Beauce is in the Quebec province, about 20 miles north of the Maine border. The more than two-year-old ice rink was renovated in the summer of 2010. The existing R-22 chiller was removed, as well as the ice mat. The concrete slab was retrofitted to install the new system.

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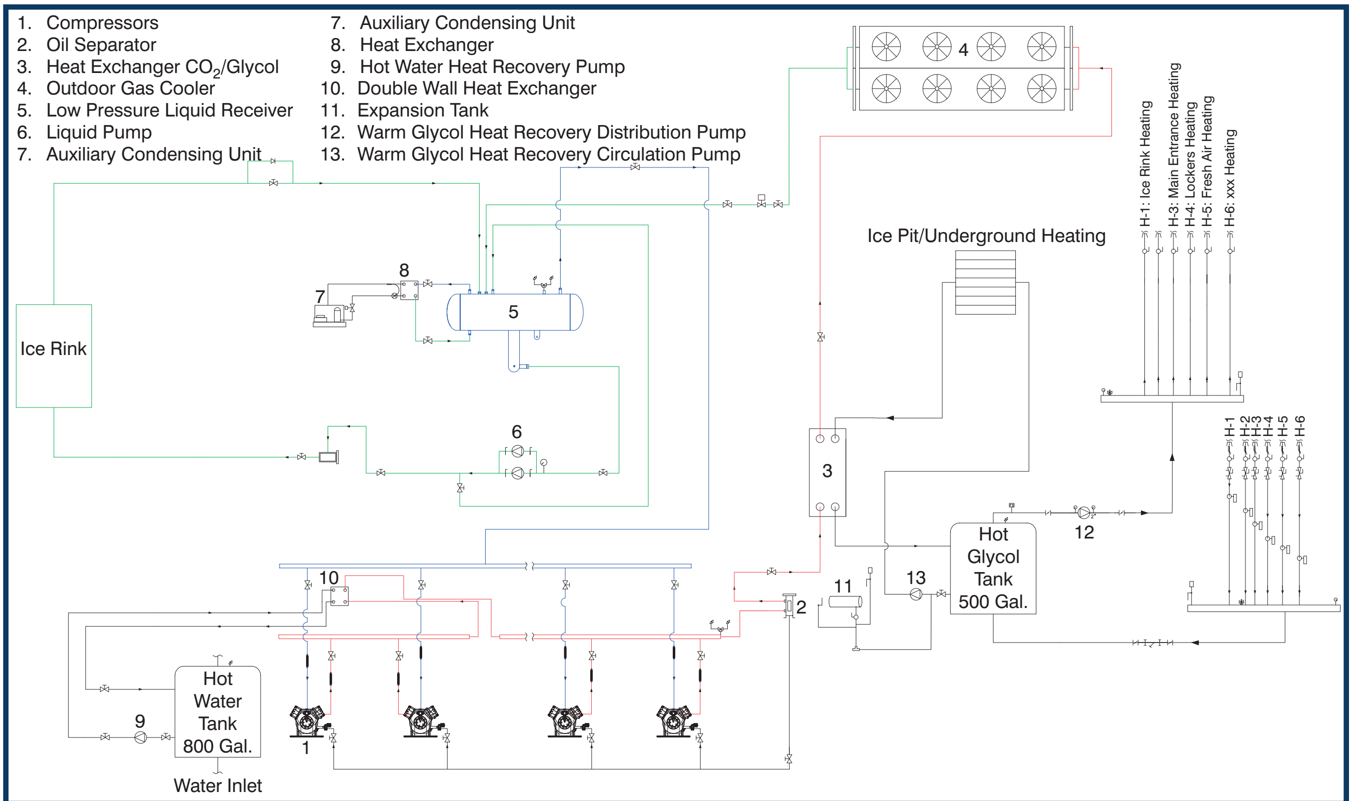

Figure 1: Schematic of CO_2 refrigeration system that does not use any secondary fluid to cool the concrete slab.

The 100% CO_2-based refrigeration system for ice rinks that was developed in this project is a unique refrigeration system that uses the natural refrigerant R-744 (carbon dioxide) as primary and secondary working fluid (this system has Canadian patents with U.S. patents pending) (*Figure 1*). The R-744 is a natural, non-toxic, non-corrosive and highly efficient refrigerant. As opposed to the traditional solutions that use ammonia or Freon chillers, and glycol or brine as secondary fluids, this 100% CO_2-based refrigeration system does not use any secondary fluid to cool the concrete slab.

In this case, carbon dioxide is pumped from a low pressure receiver directly into a tubing network installed in the concrete slab. In addition, since there is no secondary fluid, the evaporating temperature of CO_2 can be set at 19°F (–7°C) while keeping the ice sheet at 23°F (–5°C). The result is an evaporating temperature higher than all other standard ice rink refrigeration systems. The tubing network is made of a specially designed plastic-coated soft copper tube.

The design recirculation ratio of liquid CO_2 in the tubing network is 1.5. Since the phase change of liquid CO_2 is not completed in the copper tubing network located in the concrete slab, no superheat is created. The tube network configuration (number of passes) does not affect ice quality because inlet and outlet temperatures of liquid CO_2 are the same. So, the temperature of the concrete slab is the same over the entire surface.

By comparison, the nominal flow rate of a 90 ton (317 kW) ice rink chiller using 100% CO_2 technology would be 30 gpm (1.9 L/s) compare to 500 to 600 gpm (32 L/s to 38 L/s) in secondary fluid applications. Pumping power is reduced up to 90% compared to traditional secondary fluid pump power.

The tube network configuration in the concrete slab is only limited by pressure drop. Fortunately, CO_2 liquid viscosity is low even at a low temperature. For this reason, the increase in pressure of the circulating pump is small, and a design ΔP of 1 to 2 bar (100 kPa to 200 kPa) is common.

The tubing network is made with ½ in. OD plastic-coated copper tubing. The tube spacing is 4 in. (102 mm) center to center. The tubes are normally installed on the longest side (200 ft [61 m] for NHL size rinks) with a return bend installed at the end (two-pass configuration).

In this configuration, each pass has a length of approximately 400 ft. (122 m). The distribution manifolds are located

Building at a Glance

Marcel Dutil Arena

Location: Saint-Gédéon-de-Beauce, QC

Owner: Municipalite St-Gédéon-de-Beauce

Principal Use: Ice Rink

Gross Square Footage: 25,000

Substantial Completion/Occupancy: 2010

Photo 1: Concrete poured over new copper tube network.

Photo 2: CO_2 ice rink chiller package.

on the shortest side. Insulated copper manifold are made with heavy wall 2 1/8 in. OD.

The Marcel Dutil Arena project retrofitted an existing ice mat, and the trench for the distribution manifolds was on the longest side of the rink.

For this reason, a four-pass tubing configuration with tubes installed on the shortest side was done. The distribution manifolds were installed in reversed return configuration with no balancing valves on the longest side of the rink. This is the first time this configuration has been used in a CO_2 application.

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St-Gédéon (CO_2) 2010–2011 Season				Reference NH_2/Brine 2010–2011 Season			
	kW/h	Cost ($)	Backup Cost ($)		kW/h	Cost ($)	Backup Cost ($)
Sept. 10	61,560	6,103.15	–	Sept. 10	93,780	8,101.00	48.08
Oct. 10	83,160	7,040.23	–	Oct. 10	97,020	8,157.86	1,063.11
Nov. 10	89,280	7,197.65	1,399.95	Nov. 10	10,3140	8,742.18	367.30
Dec. 10	82,080	6,661.33	1,965.90	Dec. 10	130,320	10,947.84	1,144.69
Jan. 11	84,240	6,874.00	2,026.46	Jan. 11	115,560	8,667.94	1,850.10
Feb. 11	61,920	5,997.25	1,745.96	Feb. 11	113,220	9,918.45	374.43
Mar. 11	96,480	7,658.28	1,550.77	Mar. 11	93,960	8,380.71	1,956.06
Apr. 11	52,560	5,909.00	–	Apr. 11	39,600	4,669.27	1,844.48
	611,280	**53,440.89**	**8,689.04**		**786,600**	**67,615.25**	**8,648.25**

Table 1: Comparative energy cost for the first year of operation.

Because the concrete slab already existed, we poured 2 in. (51 mm) of new concrete over it to install the new copper tube network (*Photo 1*, Page 40).

The new refrigeration package was built in the factory and delivered on site (*Photo 2*, Page 40).

The main feature of this project is the energy consumption reduction when compared to similar projects using standard ice rink chiller/secondary fluid technologies. Because the system uses a part of the total heat reclaim, it covers all hot water needs for the facility at no additional cost. The hot water storage tank delivers 167°F (75°C) water at a constant temperature to the building. During the last season, the facility never ran out of hot water, and it never used back-up heating.

The 100% CO_2 refrigeration system for the ice rink is also connected to a warm glycol loop through another heat reclaim heat exchanger to recover the rest of the energy output. The

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glycol loop outlet temperature to the building is maintained between 113°F and 131°F (45°C and 55°C). This heat is transferred via standard fan coils to the main entrance, locker rooms and central air unit.

The glycol loop return temperature is between 86°F and 95°F (30°C and 35°C) and goes back to a storage tank. This design is very efficient for transcritical CO_2 heating application, and the total energy recovered by the heat exchangers is close to 100%.

The coefficient of performance (COP) in refrigeration of the compressors is also good when compared to standard chiller/secondary fluid technology. The annual COP in refrigeration is 3.35, an equivalent EER of 11.43, which was achieved using a higher saturated suction temperature: 18°F versus 5°F (–8°C versus –15°C).

This high saturated suction temperature is possible because there is no secondary fluid loss in heat exchangers. When compared to leading standard chiller/secondary fluid technology, which has a COP of 3.2, the improvement is 4.6% on an annual basis and reaches 11.2% in winter.

Photo 3: Computerized control system.

Finally, the last energy improvement occurs in the pump power reduction. The 100% CO_2 refrigeration system has a 3 kW variable-speed CO_2 pump that reduces the power needed for circulating the cold fluid by 90% compare to secondary fluid installations. For a typical single ice rink facility, the savings can be up to 125,000 kWh per year.

The Marcel Dutil Arena energy consumption was compared to similar projects located in the same area, with same attendance (55 to 58 hours/weeks) and using the reference ice rink chiller technology. The result is a reduction of 25% in total energy costs. *Table 1*, Page 42, shows the results for the first season of operation.

The total energy cost of the Marcel Dutil Arena before the renovation with the R-22 chiller/methanol system was $52,590.94 in electricity and $18,798.14 in backup fuel (propane). ■

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