Arena Mont-Royal benefited from the new four-pass brine system design.

New Brine System For Skating Rink

By Claude Dumas, eng.
Member ASHRAE

Montreal has 25 indoor skating rinks. Between 1989 and 1995, the rinks experienced recurring steel corrosion problems with brine header pipes. The city replaced six header systems due to pipe corrosion, which provided a unique opportunity to modify, redesign and cut energy consumption.

First, the design team updated the brine specification. Then, the team replaced the two-pass brine distribution systems with evaporators connected in parallel, as shown in *Figure 1,* with a four-pass brine distribution system with evaporators in series, as shown in *Figure 2*. Brine flow was reduced by 50% and pump horsepower by 40%, while maintaining sufficient fluid velocity in the heat exchangers.

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Energy Efficiency

The electricity bill for a skating rink is based on a combination of the demand for kilowatts and the consumption of kilowatt hours (kWh). *Table 1* shows the results achieved at three rinks where electrical consumption reduction exceeds the forecast and corroborates the order of magnitude of the savings.

The reduction of both flow and specific gravity of the brine enabled the team to replace the 25 hp (18.6 kW) pump motor with a smaller 15 hp (11.2 kW) high-efficiency motor. The use of a smaller motor resulted in savings of 10 hp (7.5 kW), thereby decreasing demand and consumption. The pump horsepower is decreased by 10 hp (7.5 kW), and consequently less heat dissipates into the brine. This means less heat to be removed by the compressor, while using 2 hp per ton (0.43 kW/kW), again decreasing demand and consumption. The condenser fan motors do not run as long and dissipate less heat, which also leads to decreased consumption.

Arranging the evaporators in series allows one chiller to operate more efficiently at a higher suction temperature than was possible in the parallel arrangement where both chillers were producing 15°F (–9.4°C) brine. Two out of six compressors are on permanent standby. Four compressors do the work of six, saving 50 hp (37.3 kW), once again lowering power demand.

The team's experiment using the four-pass brine system with evaporators in series has accumulated 23.4 seasons at five skating rinks, which is a cumulative energy savings of $200,000 (Canadian).

Innovation

The original slab system used 296, 1-in. (25 mm) polyethylene pipes spaced every 3.5 in. (89 mm), as shown in *Figure 1*. The brine header system was reversed return, using 8 in. (200 mm) Schedule 40 steel pipes. The chiller evaporators were piped in parallel. The brine was composed of calcium chloride with a specific gravity of 1.25 at 60°F (15.6°C) circulated by a single brine pump. The pump, driven by a 50 hp (37.3 kW), 1,800 rpm motor, had a capacity of 1,500 gpm (94.6 L/s) and a head of 43 psig (296 kPa). In most of the installations, two evaporators were piped for parallel flow, each evaporator using 750 gpm (47.3 L/s). In four installations, three evaporators were piped for parallel flow, each evaporator using 500 gpm (31.5 L/s).

From 1983 to 1986, the city modified all its ice systems to save energy. The original pumps' motors, 50 hp (37.3 kW) and 1,800 rpm, were rewound to produce 25 hp (18.6 kW) and 1,200 rpm. The brine flow was changed to 903 gpm (57 L/s)

About the Author

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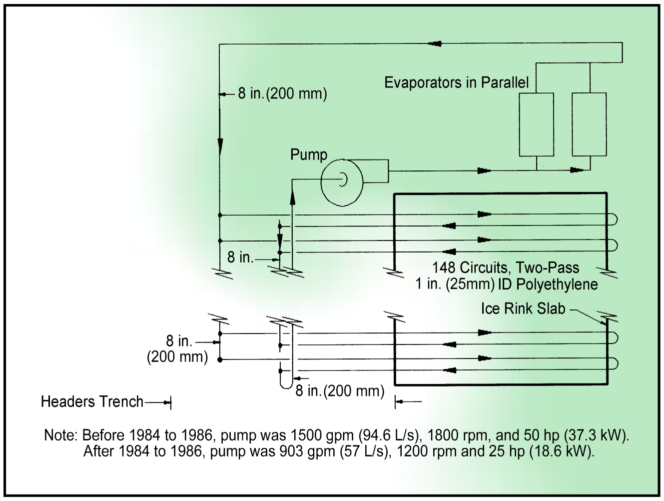


Figure 1: Two-pass system with evaporators in parallel.

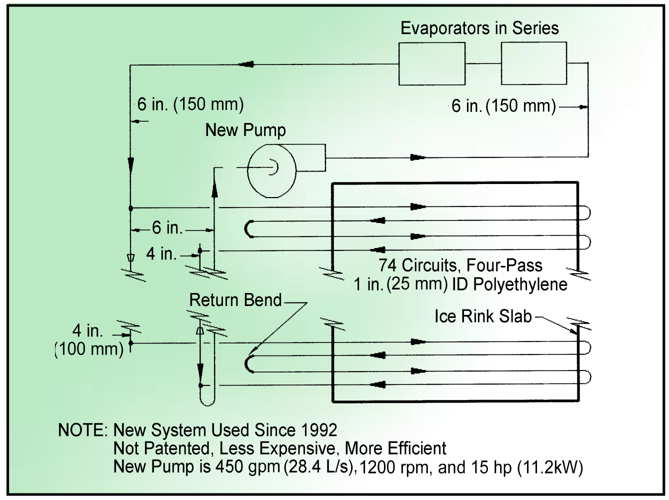
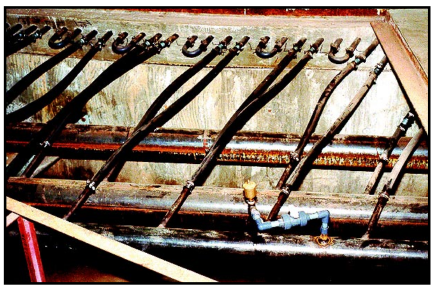


Figure 2: Four-pass system with evaporators in series.



The supplementary return bends and the skating rink's concrete slab are shown at the top of the photo.

Skating Rink	Heating System Type	Size of the Urban Park	Reduction of Electric Consumption	Energy Cool* MWh/8 months
Mont-Royal Arena	Electric	Small	16.7%	$98,500 1.33
Saint-Donat Arena	Natural Gas	Medium	14.0%	$89,025 1.18
Marcelin Wilson Arena	Natural Gas	Medium	14.1% (see Table 2)	$99,210 1.27

Table 1: The results achieved at three skating rinks.

(*Figure 1*). Timers were installed at each skating rink and the refrigeration systems (pump, compressors, condensers) were stopped for six to eight hours at night, to save energy during the unoccupied period.

At the end of 1991, budget restrictions on city energy consumption prompted the search for other possible modifications. It was decided to reduce the brine flow, decrease the specific gravity of the brine, and use a smaller high-efficiency motor on the brine pump. Such a major modification could not be financially justified based on its own energy savings potential. However, the team used the opportunity of the corrosion failure of a brine header to modify the design at no cost and cut energy consumption. The latest modifications of the slab pipe arrangements create a four-pass circuit, as shown in *Figure 2*, by adding a supplementary return bend to connect two two-pass circuits.

The original 8 in. (200 mm) brine header system is replaced with a 6 in. (150 mm) header because brine flow decreased from 903 gpm to 450 gpm (57 L/s to 28.4 L/s). The header stays reversed return, using 6 in. (150 mm). Schedule 40 steel pipe throughout the system, with the end section using 4 in. (100 mm) Schedule 80 pipe. All 148 nipples are ¾ in. (19 mm) Schedule 80 pipe. PVC pipe Schedule 80 can be used instead of steel pipe. The two (or three) evaporators in the systems are piped in series for a flow of 450 gpm (28.4 L/s) through. System brine flow can be reduced significantly if sufficient fluid velocity is maintained in the evaporator and in the slab heat exchanger. The brine is calcium chloride, adjusted for 1.18 specific gravity at 60°F (15.6°C). Brine is circulated by a single brine pump sized for 450 gpm (28.4 L/s) and 33 psig (228 kPa) of head, driven by a 15 hp (11.2 kW) high-efficiency motor rotating at 1,200 rpm.

At the rinks where three evaporators are used, they are piped in series, where one evaporator is valved off the brine circuit by leaving the bypass valve open. The brine pump head is underdesigned with the intent to circulate only two of the evaporators, have a foolproof system and save energy. Underdesign is a strong incentive to follow the energy guideline, operate with only four compressors and save on power demand.

The brine specifications originated in 1971. They were revised for three reasons. First, reducing the specific gravity from 1.25 to 1.18 automatically reduced the pump energy consumption. In the past, brine freezing temperature was set at –20°F (–28.9°C), whereas now, it is set at 0°F (–17.8°C). This is sufficient freeze protection, considering the low operating brine temperature of 15°F (–9.4°C).

Second, following a repair money is saved because less salt is required to top off the system. The calcium chloride used is as follows:

Calcium Chloride

- Canadian National Standard CAN/CGSB-15.1-92.

	Two-pass System			Change!	Four-pass System		
Year	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**For 1995 & 1996** Average
Month	kWh	kWh	kWh	kWh	kWh	kWh	kWh
1	200,609	198,919	173,871				
2	179,280	180,751	157,546	1		135,939	
3	174,717	181,152	142,763	155,712	150,606	111,766	131,186
4	74,470	98,803	77,704	71,498	82,846	68,876	75,861
5	49,107	44,477	45,534			41,565	
6							25,765
7		27,633	25,962		83,881		
8	144,538	113,423	128,541		162,242	114,330	138,286
9	222,544	196,680	190,820	134,766			155,755
10	220,274	231,270	215,609	150,609	136,434	196,973	
11	199,526	184,634	216,261			164,070	175,697
12	198,084	165,136	225,425		214,908	153,450	184,179
TOTAL kWh/12M	1,735,959	1,647,062	1,625,785	1,311,951	1,515,138	1,416,444	1,465,791 *$114,351
TOTAL kWh/8M	1,539,572	1,451,965	1,450,836	1,155,818	1,300,363	1,243,127	1,271,745
If the average kWh/8M (for 8 months/year) in 1995 and 1996 is compared with the average kWh/8M in 1991, 1992 and 1993, the savings are 14.1%. ! System changeover: Month 1, 2, 3 on two-pass, Months 8 to 12 on four-pass. *Using the kWh rate of 1996.							

Table 2: Energy consumption at Marcelin Wilson Arena operating for 8 months/year.

- Type S -(solid).
- Class 1-Minimal content of 77% calcium chloride for: Grade A—Flakes.
- This standard applies to commercial calcium chloride used for road applications (dust laying, stabilization, deicing), as admixtures for concrete (acceleration of set and curing), in refrigerating medium.

Third, environmental protection regulations prohibit the use of sodium chromate to inhibit corrosion. A biodegradable inhibitor is added directly to the brine system.

Operation and Maintenance

The evolution of a two-pass brine system into a four-pass system has no influence on the maintenance cost of a skating rink. It might be different when PVC pipes replace steel pipes. Frozen PVC is more fragile than steel but does not corrode. Only time will tell if the substitution is beneficial.

Replacement of the original pump with a different model is responsible for a decrease in maintenance and energy consumption. The previous system used a direct-drive, horizontal split-case, double-suction centrifugal pump. The replacement system uses a direct-drive, vertical in-line centrifugal pump. The replacement pump does not require annual alignment of shaft and couplings, required by the previous pump and it is more efficient.

Cost Effectiveness

The total modification cost between 1992 and 1994 was $77,000 per rink. (All amounts are in Canadian dollars and include taxes.) Energy savings resulting from a four-pass system with evaporators in series were estimated at $8,500 per year, or 8% to 9% of the energy cost. Replacement of a brine header using a four-pass system is less costly than a two-pass system, as smaller diameter pipes are used.

Table 1 shows a reduction of electrical consumption exceeding the forecast energy savings of a four-pass system. As of May 1998, the experiment using the four-pass brine system with evaporators in series has accumulated a run time of 23.4 seasons at five skating rinks, a cumulative energy savings of $200,000 (Canadian).

A new standard for skating rink design is being proposed to the industry. This system is not patented, is more efficient and costs less than the traditional two-pass design. *Table 2* shows historical kWh data for the Marcelin Wilson Arena. The ratio of kWh/8M (for 8 months/year) in 1995 and 1996 over the kWh/8M in 1991, 1992 and 1993 indicate savings of 14%. The same ratio for $/8M indicates a savings of 8.5%.

Conclusion

The four-pass brine system with evaporators in series design is recommended for replacing corroded headers, because in this particular situation payback can be immediate. The design team has tested the engineering principles supporting the design and it is sound. System brine flow can be reduced significantly if sufficient fluid velocity is maintained in the evaporator and in the slab heat exchanger, leading to good heat-transfer coefficient.

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