The Westhills Recreation Centre's outdoor rink offers an interesting energy balance opportunity in winter by providing additional rejected energy during the heating season. Even with the extensive use of energy, 60% of waste heat is pumped to a nearby housing development.

FIRST PLACE
PUBLIC ASSEMBLY, NEW

Energy Efficient *Ice Rink*

BY ART SUTHERLAND, MEMBER ASHRAE

BUILDING AT A GLANCE

Westhills Recreation Centre

Location: Langford, BC, Canada

Owner: City of Langford, BC, Canada

Principal Use: Recreation center

Includes: Ice skating, bowling, restaurant, commercial offices

Employees/Occupants: 50 employees and 1,200 maximum occupancy in all areas

Gross Square Footage: 75,000

Conditioned Space Square Footage: 75,000

Substantial Completion/Occupancy: September 2012

Occupancy: 100%

An extensive study conducted by Natural Resources Canada determined that a typical 40,000 ft^2 (3716 m^2) ice rink in Canada will consume an average of 1.5 million kWh of equivalent energy per year. The Westhills Recreation Centre in Langford, British Columbia, is nearly twice as big uses only 768,000 kWh. And, the refrigeration system for the ice surfaces produces so much waste heat that excess is shared with a nearby housing development.

The 75,000 ft^2 (6967 m^2) facility consists of an NHL size indoor ice rink, an outdoor ice rink and a skating trail joining the two rinks together. The facility also houses a 20 lane bowling alley, restaurant/lounge, party rooms and 10,000 ft^2 (929 m^2) of leased office space with multiple sport-related tenants. The total cost of construction was $13.5 million, with a $9 million grant from the Building Canada Fund.

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ABOVE Westhills Recreation Centre's NHL size indoor ice rink.

LEFT VFD-driven high efficient ammonia compressors provide refrigeration for the ice rinks in winter and building air conditioning in summer.

The outdoor ice rink was designed with embedded refrigeration piping for winter ice and water fixtures to convert it into a children's splash park in summer, making use of the same footprint for both summer and winter.

Eliminating Fossil Fuels

The city of Langford, located on Vancouver Island, has among the highest natural gas prices in North America. The project objective was to eliminate natural gas consumption for all heating, hot water and dehumidification loads while minimizing electrical consumption year-round. In fact, the building does not use fossil fuels at all except in the kitchen, which does use natural gas. And, it was determined during the preliminary design phase that the quantity of heat rejected from the refrigeration to service the three ice surfaces would be more than enough to satisfy all of the heating loads with extra heat that could be shared with a nearby housing community.

The challenge was to ensure that there was heat available between compressor run cycles and during the colder periods of the year when the refrigeration was running less. The outdoor ice rink offered an interesting energy balance opportunity in Langford's mild winter by providing additional waste heat during the peak heating season, just when it was needed most.

To ensure that there would be no periods between refrigeration run cycles without heat being available, two approaches where taken. The refrigeration compressors and brine pumps were equipped with variable speed drives. The variable speed drives, controlled by the computer control system, were programmed to operate the compressors at their lowest permissible speed while precisely maintaining the temperature setpoint.

This strategy provided a number of benefits. The compressors always operated at their maximum coefficient of performance (COP) due to the higher saturated suction temperatures and lower saturated condensing temperatures while running at low speeds. The centrifugal brine pumps were also modulating their speed and taking advantage of the Pump Affinity Law, resulting in reduced electrical consumption. The main objective of perpetuating the heating cycle was also met as the compressor run cycles were much longer throughout the day.

A system also had to be designed that would have heat available during colder periods and when the night set back control strategy would shut the compressors off. To achieve this, we required some form of thermal storage. A cost effective solution was to use the ice rink sub-floor heating system for thermal storage.

Traditionally, ice rink sub-floor heating systems would operate at 40°F (4.5°C) to prevent frost heaves caused by long-term refrigeration operation. To minimize any impact to the ice surface as a result of higher sub-floor temperatures, we installed 6 in. (150 mm) of R-5 insulation board between the ice pad and the heating floor, and around the outside walls. This enabled the temperature of the sub-floor to be increased to 75°F (24°C). This "geothermal system on steroids" was cost effective to construct because the civil work, piping mains, pumps and half the insulation would have been required anyway for a traditional sub-floor heating system.

During the winter, 100% of the refrigeration waste heat is harvested with an energy recovery condenser, which is able to provide 82°F (28°C) glycol temperature while maintaining 85°F (30°C) condensing temperature. The warm 82°F (28°C) glycol from the energy recovery condenser directly provides radiant heating throughout 19,000 ft^2 (1765 m^2) of public space.

The concrete floors are maintained at 72°F to 74°F (22°C to 24°C), which provides an excellent level of comfort. In mid-winter, an energy recovery heat pump will boost the glycol temperature from 95°F (35°C) to 105°F (40°C), as required, to maintain comfort in all areas.

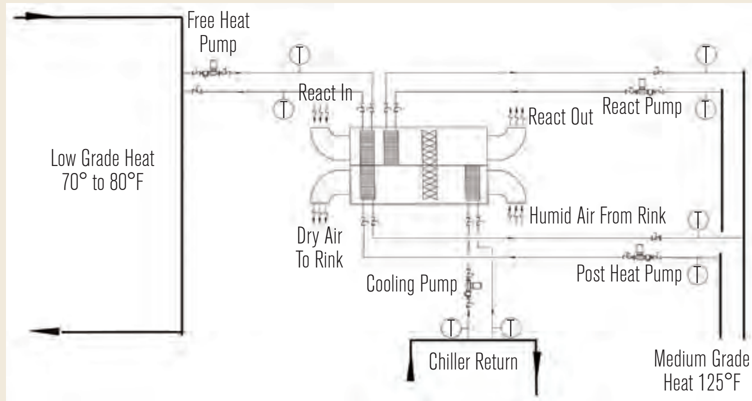
There are 15 HVAC units and two HRVs interspersed throughout the complex. All of the air handlers have large close-approach coils designed to provide heating with 95°F (35°C) glycol and cooling with 50°F (10°C) glycol. In very cold months, the heating glycol temperatures will automatically reset to provide sufficient heat.

With the combination of long compressor run times and thermal storage, the building heat pumps have an uninterrupted energy source of 75°F (24°C) and supply 95°F (35°C) heating glycol, while operating with an exceptional COP of 7.97 (7.49 adjusted for pump horsepower).

Domestic hot water for the facility is provided through two stages. The first stage is free heat from the ammonia desuperheating system and ranges from 100°F to 120°F (38°C to 49°C). The water is then brought up to 140°F (60°C) using a hot water heat pump that also uses the energy recovery loop as the heat source. During the winter, the hot water is produced at a COP of 4.28 (4.02 adjusted for pump horsepower).

The ice rink desiccant dehumidifier was custom designed for this facility (*Figure 1*). It uses a low temperature desiccant rotor that can be regenerated at 125°F (52°C), versus the traditional gas-fired rotors that require 275°F (135°C). The system uses two coils in

FIGURE 1 Energy recovery dehumidifier with cooling coil that services the ice rink.



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series to regenerate the desiccant wheel. The first coil is circuited for the 82°F (28°C) glycol that is directly harvested from the ammonia condenser and can temper the air up to 70°F (21°C). The second coil obtains its heat from an energy recovery heat pump, which also harvests heat from the ammonia system and produces 130°F (54°C) glycol to provide the finished temperature to regenerate the desiccant wheel.

On a typical 40°F (4°C) winter day the result of this two-step temperature lift is that the first 35% of the temperature lift is done using free heat and the second 65% by using a heat pump with a COP of 4.99 (4.68 adjusted for pump horsepower). The low temperature regeneration results in an air temperature entering the rink in the 85°F (29°C) range rather than the 115°F (29°C) range, which is typical of the gas-fired units.

A post-heating coil is installed that uses energy from the heat pumps to provide comfort heating above the ice rink bleachers, if required.

As a result of these initiatives, no fossil fuels are used in the facility other than the use of natural gas in the kitchen since the complex was commissioned in 2012.

Improving Electrical Energy Efficiency

Another challenge was keeping electrical consumption (electricity is provided by hydroelectricity) in check while using heat pumps in lieu of natural gas. The primary refrigerant is ammonia, which is inherently efficient. We used a new model of ultra-high efficient VFD-driven compressors that handle both the ice rink duty in winter and the air-conditioning duty in summer. The compressors have a cooling COP of 4.62 during the ice season and a summertime air conditioning COP of 15.1. The VFD uneven parallel compressors have a range of 30 to 60 tons (106 to 211 kW) for the small compressor and 60 to 90 tons (211 to 317 kW) for the large compressor, allowing them to exactly track the refrigeration load year-round. With 100% of the energy being recovered, the compressors have a combined heat/cool COP of 10.2 in winter. All of the loads in the complex including fans, pumps and compressors have a VFD controlled by the building automation system to minimize energy consumption.

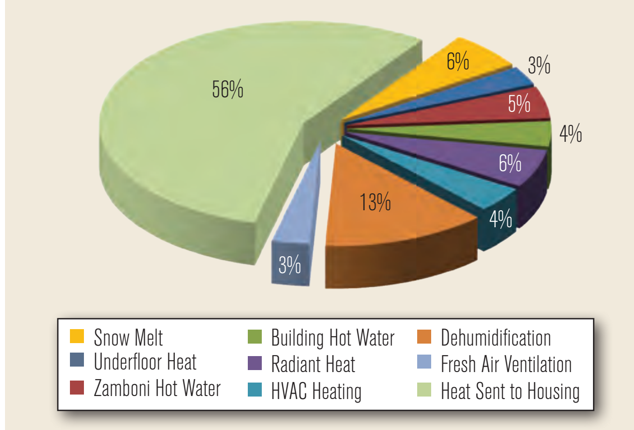
During the summer, the hot water heat pumps extract heat from the 19,000 ft^2 (1765 m^2) of radiant floors,

taking advantage of both sides of the heat pump cycle, which boosts the total heat pump COP to 7.6.

The ice rink will remove 8,000 pounds of snow per day during normal ice maintenance. When melted in the snow melt pit, this snow will provide 1,152,000 Btus (96 ton-hours) of useful cooling that helps shave the peak off the air conditioning requirement. A submersed enhanced surface coil is used to extract the energy during peak air conditioning hours. The coil has the ability to deliver 325,000 Btu/h (95 258 kW) of glycol at 45°F (7°C). This heat transfer can be sustained for three to four hours per day, depending on how much snow is in the pit.

Figure 2 shows where the harvested heat was used within the Westhills ice rink during a single 24 hour period in October 2012. The facility heating requirement was fairly low and the ice rink dehumidification was fairly high. The outdoor rink was not in operation so we were not at full waste energy production. The percentages were calculated from the run times on the three building heat pumps and run times on the various distribution pumps, along with the average supply and return temperatures. This was just a snapshot in time so the dynamic heating requirements for each load will change day to day with the various user groups, outdoor ambient temperature and humidity.

FIGURE 2 Ice rink energy use on a typical fall day.



Community Energy Sharing

Even with the extensive use of energy, only 40% of the waste energy is required within the complex. Therefore,

TABLE 1 Electrical consumption for the Westhills Recreation Complex.

MONTH	KILOWATT HOURS BILLED	COST
January 2014	111,070	$7,478.26
February 2014	104,304	$7,084.41
March 2014	91,074	$6,060.16
April 2014	94,609	$5,563.04
May 2014	75,168	$6,095.84
June 2014	62,157	$4,087.19
July 2014	56,600	$3,827.70
7 Month Total	594,982	$40,196.60
Actual Meter Reading Credit	146,850	$10,272.17
Actual Energy Consumed	448,132	$29,924.00
Monthly Average	64,016	$4,274.92
Extrapolated to 1 year	768,192 Annually	$51,294.04

TABLE 2 Payback for the energy efficiency features, including energy sharing.

Annual Reduction in Natural Gas Consumption	$46,928.96
BC Hydro's Calculated 259,751 kWh Annual Savings with VFDs	$15,585.00
Refrigeration and Air Conditioning Energy Efficiency Improvements	$5,718.00
Total On-Site Energy Savings	$68,231.96
Off-Site Energy Value Sent to Housing Development	$41,470.00
Total Energy Savings	$109,701.96
Net Cost Over Conventional System	$308,988.00
Payback on Energy Efficiency Components	2.81 Years

once the on-site geothermal field is satisfied and all of the zones are within their programed range, the remaining 60% of the heat is transferred via a VFD-driven pump to a growing housing development 400 yd (366 m) away as an energy source for the household heat pumps. The VFD is temperature controlled and programmed to maintain the ice rink energy loop at 80°F (27°C). A brazed plate heat exchanger provides a fluid separation between the housing development energy loop and the ice rink energy loop. There are just under 500 homes in the housing development, so the waste energy is only able to provide a portion of the required heating energy in winter. This results in absolutely every bit of waste energy being used from the two ice surfaces and skating path during the winter. This scenario is much easier to control in comparison to a situation where there is too much heat that must be diverted to an outdoor condenser. The average value of the approximately 830,000 kWh of energy sent to the housing development if it were natural gas would be $41,470.

The balance of heat in the housing development is supplied by two 180 ton (633 kW) VFD-driven ammonia heat pumps that use a geothermal field below a soccer field as the energy source.

The ammonia heat pumps are only required in the winter and operate at COPs ranging from 8 to 15. The heat pumps maintain the housing energy loop at a constant 60°F (16°C), which results in favorable COPs for the household heat pumps.

Water and Sewage Reduction

During the 8 months of the year that all of the energy is being used, the evaporative condenser is not used, which results in an annual water reduction of approximately 750,000 gallons (2.8 L) per year.

Electricity Use

Table 1 summarizes BC Hydro's electrical consumption for the Westhills Recreation Complex, including the refrigeration and air conditioning plant and all of the heat pumps, air handlers, energy distribution pumps and lighting. The ice rink refrigeration system provides all heating and cooling, dehumidification and hot water for the entire 75,000 ft^2 (6967 m^2) complex, including the ice rink, the 15,000 ft^2 (1394 m^2) of rented office space and shop area, the restaurant and the bowling alley.

Almost every ice rink in North America would have two energy sources being consumed simultaneously, including electrical for the ice plant, lighting, HVAC, etc., and fossil fuels for hot water, dehumidification, building heating, etc.

The electrical consumption for the Westhills ice rink is much lower than a typical single 40,000 ft^2 (3716 m^2) ice rink, and this modest amount of energy is serving an indoor and outdoor rink with a skating trail, in addition to providing all of the heating, air conditioning, hot water and dehumidification requirement for a 75,000 ft^2 facility (6967 m^2). ■