Term Paper

Energy Recovery at the UBC Winter Sports Center

CHBE 484 – Green Engineering

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TABLE OF CONTENTS

1.0 ACKNOWLEDGEMENTS

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- Wayne Borrowman, CIMCO Refrigeration
- Hadi Dowlatabadi, UBC
- Brenda Sawada, UBC SEEDs
- James Tansey, UBC

1.1 Site Visit

We have been in contact with UBC Properties, UBC SEEDs and CIMCO Refrigeration to gain an understanding of and gather information on energy recovery at a rink facility. We met with the BC Chapter of the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) for a tour of the UBC Winter Sports Center on March 14th, 2007. This gave us the opportunity to see the progress of the facility particularly the ECO Chill heat recovery system. At the time of the tour, the practice rink and Father Bauer rink were under construction and renovations, respectively. The Olympic facility is to commence construction later this year.

2.0 INTRODUCTION

This is a proposal for a green engineering project at the UBC Winter Sports Center. The proposal includes the background of the project, the green engineering approach adopted, and the significance of the work proposed. Specifically, we looked at energy recovery from the refrigeration condenser and possible uses within the facility and on the UBC campus.

2.1 Background

The UBC Winter Sports Center will be the venue for the 2010 Olympics women's ice hockey games and for the 2010 Paralympics sledge hockey games. Following 2010, the three rinks will carry an Olympic legacy and be used for UBC and Vancouver athletics.

The UBC Winter Sport Center began as a 37 million dollar project to construct two ice rinks for the 2010 Winter Olympics, a practice rink and an Olympic rink venue. The Vancouver Olympic Committee (VANOC) funded the project. Before construction it was decided that one of the existing rinks would be salvaged and renovated adding another 12 million dollars to the project. This extra funding came from UBC and private donors. Reconstruction of the center began in April 2006 and it to be completed in spring of 2008.

The three ice rinks in the Winter Sport Center will be:

1. New practice rink (spectator rink);
2. New Olympic rink venue (main rink); and
3. Renovated Father Bauer rink (leisure rink).

The main stadium will seat 5,000 people and the leisure rink will seat 1,000. Dressing rooms line one side of the rinks and a cafeteria overlooks the spectator rink.

2.2 Green Engineering Problem

The refrigeration system for ice rinks generates excess heat. In the UBC Winter Sports Center there will be 36 BTU of heat generated by the refrigeration process and available for use. This heat can be used for conventional and non-conventional uses within the facility and on the UBC campus.

2.3 Approach to be Adopted

The UBC Winter Sports Center will install an ECO Chill system which will convert recovered heat from the condenser into usable energy. The rinks will use this recovered energy for conventional uses such as:

- Snow melt;
- Water heating for resurfacing; and
- Frost prevention under ice floor.

The conventional uses utilize 20-30 % of the total available heat. The UBC Winter Sports Center will recover over 70 % of the available heat and use this energy for non-conventional uses such as:

- Heat pumps;
- Fan coils;
- Force flow heaters;
- In-floor heating in dressing rooms; and
- Hot water pre-heating.

The total recovered heat usage is estimated to be 1,262 kW (4,302,867 BTU/h), which is 70-75 % of the total available heat. as this is the efficiency of the ECO Chill system.

3.0 DESCRIPTION OF PROCESS

3.1 Refrigeration Process

The refrigeration process is used to cool and maintain ice on the rink surface. The refrigeration cycle is facilitated by a heat pump mechanism and consists of 4 stages: condensation, evaporation, expansion and compression. As shown in Figure 1, the refrigeration cycle is controlled by changes in temperature, pressure and entropy.

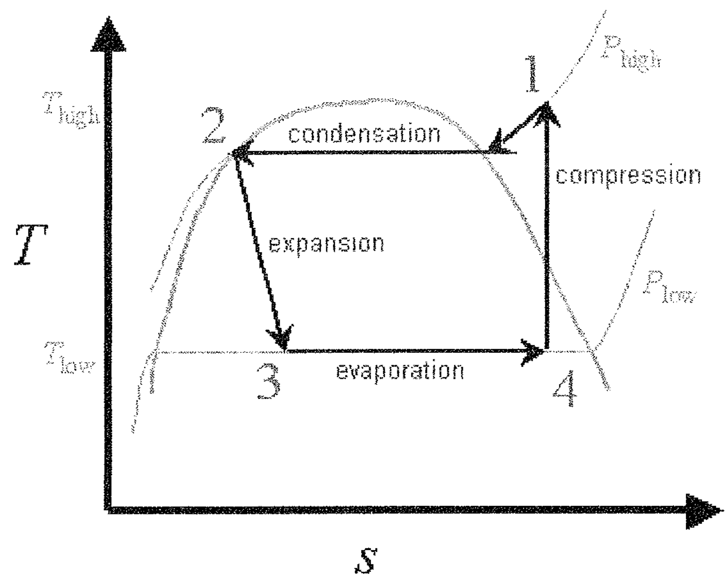

Figure 1: Refrigeration Cycle – Temperature vs. Entropy
Source: http://www.qrg.northwestern.edu

From stage 1 to 2, the superheated vapour passes through a condenser, which removes the superheat and condenses the vapour to saturated liquid at constant pressure. From stage 2 to 3, most of the saturated liquid ammonia undergoes adiabatic flash evaporation by passing through an expansion valve and decreasing in pressure and temperature. From stage 3 to 4, the cold liquid and vapour passes through an evaporator where it is totally vapourized by warm air at constant pressure. The evaporator is where the ice rink brine is cooled. The saturated vapour ammonia enters the compressor at stage 4. The vapour is isentropically compressed from points 4 to 1 and becomes a superheated vapour to continue the thermodynamic cycle.

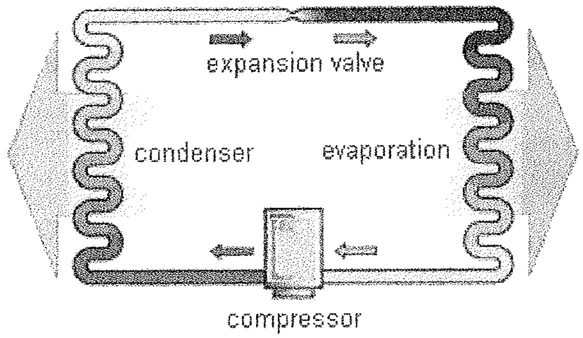

Figure 2: Heat Pump Refrigeration Cycle Diagram
Source: http://en.wikipedia.org/wiki/Heat_pump

In the refrigeration cycle, a condenser is used to condense ammonia vapour to saturated liquid. The condenser is a heat sink; it releases the net heat from the movement of thermal energy from the cold source (evaporator) to the hot sink (condenser). Figure 2 shows the temperature distribution in the heat pump refrigeration cycle.

3.2 EcoChill Process

The CIMCO ECO Chill is a system that recovers the heat from the condenser and then converts the heat to usable energy for use in the facility. Heat recovery and conversion is performed with a thermal equalizer and plate and frame condenser as shown in Figure 3 below.

The ECO Chill consists of a plate and frame condenser, which act as a heat exchanger with ammonia and water. Ammonia is considered the hot stream and water is considered the cold stream. The water is then cycled to the thermal equalizer, which acts as a heat source for water distribution and as a recovery unit for returning cooled water after heat dissipation.

Water or glycol act as the medium of heat transfer. Water will be used at the UBC Winter Sports Center; glycol can be used in place of water depending on the conditions of the application.

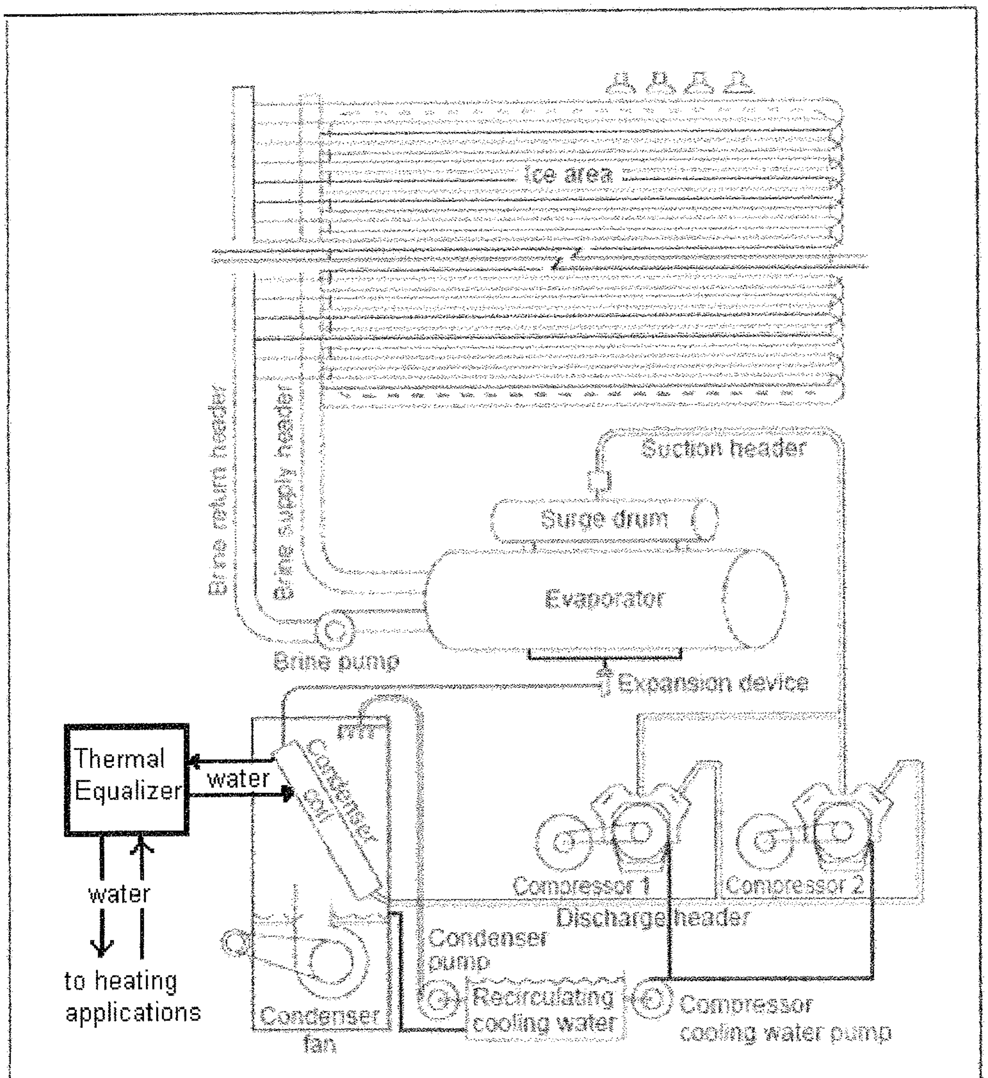

Figure 3: Schematic of Ice Rink Refrigeration System with Heat Recovery
Source: http://oee.nrcan.gc.ca

4.0 LIFE CYCLE ANALYSIS

4.1 Energy Savings

In order to calculate the amount of energy removed from the three ice rinks, a number of parameters have been investigated. The amount of potential heat recovered has been calculated based on the required temperature of the ice, the surface area of the ice, the thickness of the ice and the heat energy losses to the environment throughout the process.

There are a number of potential heat energy losses in the system. These include heat lost through the piping and joints, heat loss through the building and heat loss due to temperature variations in the ice. In order to minimize heat losses, the mechanical component of the process incorporates thick-walled cast iron piping, which significantly reduces the amount of heat loss to the environment.

During the operation of the UBC Winter Sports Centre, the ice temperature will be maintained at -12°C. However, the temperature of the main rink will change for the Olympics. The following temperatures and heat duties are required during the process of the refrigeration of the ice.

Table 4: Temperature and Heat Duty For Each Rink

	Temperature (°C)	Heat Duty (kW)
Olympic Ice Rink	-21	844
Legacy (All 3 Rinks)	-12	1358

As you can see, during the operation of the Olympic sized rink, a much larger heat duty will be produced as the temperature of the ice is required to be -21°C. This generates more available heat during the low temperature operation. However, an extensive energy analysis conducted by CIMCO based its calculations only at a temperature of -12°C for all three of the rinks: the Olympic sized main rink, the spectator rink and leisure rink at NHL size.

The surface area of the rink and the thickness of the ice are also considered when calculating the amount of potential heat recovery. The main rink has a width of 30m and a length of 60m, and the other two rinks have a width of 26m and a length of 60m. The following table outlines the dimensions of all three rinks.

Table 5: UBC Winter Sports Center Rink Dimensions

Rink	Width (m)	Length (m)	Surface Area (m)	Thickness of the Ice (m)
Main	30	60	1800	0.025
Spectator	26	60	1560	0.025
Leisure	26	60	1560	0.025

The energy analysis of the three rinks conducted by CIMCO calculated the potential recoverable heat energy to be 11.34 gigawatts per year for a 5000 hour run time. The process designed by CIMCO allows for 70-75% efficiency of heat recovery resulting in a net heat recovery of 8.27 gigawatts per year (7,834,995 Btu/hr) with heat losses of 3.07 gigawatts per year. Based on the amount of net heat recovered and the amount of heat required for operation, CIMCO has divided the heat recovery utilization into the following applications as shown in Table 6 below.

Table 6: Recovered Heat Energy Applications

Application	kW
Heat Pumps	136.20
Fan Coils	160.18
Force Flow Heaters	45.66
Unit Heaters	246.99
Snow Melt Pits	175.75
In Floor Heating	78.18
Future Heating	161.10
Hot Water Preheat	124.49
Under Floor Heating	131.81

The applications above are used continuously and non-continuously. The heat energy required for the snow melt pit was estimated based on 144,000 Btu/h of energy per flood for 2 melt pits and 14 floods per day. The under floor heating energy required was based on 16, 666 Btu/hr per rink. The zamboni water heating requirement was based on 100 gallons per flood with 14 floods a day and a temperature increase of 30°F.

As you can see in Table 6, there is also approximately 161.1 kW allocated for future heating. This indicates that there is an excess of heat recovered that can be used for additional applications in the future. Based on the value of excess heat recovered, the actual amount of heat being used is 5.37 gigawatts per year, leaving about 35% of the heat recovery energy unused.

4.2 Economic Savings

Due to the application of the heat recovery system, there will be large reduction in energy costs. The cost of energy is expected to be reduced by 70-75% as this amount of heat energy will be recovered and recycled at the facility.

CIMCO conducted a cost estimation which accounts for variations in the heat recovered and in the value of the heat recovered. The cost estimation showed that the value of the recovered heat was equivalent to $114,715 per year of electricity. This was based on the cost of electricity from BC Hydro at $0.05 /kWh. CIMCO also estimated the value of the heat recovered based on the use of natural gas for heating. The recoverable energy equivalent to using natural gas for heating was found to be $104,859 based on a cost of natural gas of $0.013 /MBH. The following table shows a breakdown of the anticipated amount of heat required for each month of the year and its associated costs.

Table 7: Monthly Heat Requirements and Costs

Month	Days	Heat Required MBH	Heat Available MBH	Total/Day MBH	Total/Month MBH	Cost/Month if Gas, $	Cost/Month if Electric, $	300 TR Hrs/Day for Heat
January	31	43,452		43,452	1,347,012	18,027	18,722	12.0
February	28	43,452		43,452	1,216,656	16,293	17,818	12.0
March	31	43,452		43,452	1,347,912	18,027	18,722	12.0
April	30	3,280		3,280	98,400	1,317	1,441	6.0
May	31	3,280		3,280	101,680	1,361	1,459	6.0
June	30	3,280		3,280	98,400	1,317	1,441	6.0
July	31	3,280		3,280	101,680	1,361	1,489	6.0
August	31	3,280		3,280	101,680	1,361	1,489	6.0
September	30	3,280		3,280	98,400	1,317	1,441	6.0
October	31	21,729		21,729	673,599	9,014	9,861	6.0
November	30	43,452		43,452	1,303,560	17,446	18,088	12.0
December	31	43,452		43,452	1,347,012	18,027	18,722	12.0
Total/year:		0		0	7,634,993	$104,858	$114,715	

The costs of the CIMCO refrigeration system include mechanical additions and the ECO Chill process. The following table summarizes the cost analysis of the ECO Chill heat recovery system.

Table 8: Economical Analysis

Net Heat Recoverable	8.266 GW/year
Value of Heat Recoverable (NG)	$104, 859
Cost of Eco Chill	$150,000
Mechanical Cost	$235,000
Total Heat Recovery System Cost	$385,000
Pay Back Period	**3.7 years**

As there are significant savings with respect to energy costs and there is a pay back period of only 3.7 years. This is a favourable payback period which will benefit UBC with a savings of $104, 859 per year after four years of service.

4.3 Reduction in Emissions

As there has been a reduction in the amount of energy required at the UBC Winter Sports Center, a significant amount of emissions will be reduced. The greenhouse gas emissions for electricity and natural gas were found from Natural Resources Canada's, Office of Energy Efficiency. Based on 2004 emission values, approximately 6.22E-06 tonnes of CO_2 equivalent are emitted per kilowatt of energy produced by electricity, and for natural gas approximately 4.98E-06 tonnes of CO_2 equivalent are emitted per kilowatt of energy produced. Using these values and the amount of heat energy recovered (8.27 gigawatts per year) there would be a reduction of approximately 514 tonnes of CO2 equivalent if electricity is used for energy and if natural gas is used for energy, there would be a reduction of approximately 412 tonnes of CO_2 equivalent. This is a significant reduction of green house gases and it would be beneficial for other ice rinks to incorporate a heat recovery system in their chilling process to achieve the same emission reductions.

5.0 ENERGY CONSERVATION

In addition to energy recovery and reuse, there are energy conservation strategies that enhance energy savings in rink facilities. The building materials of construction, process instruments, and operation methods contribute to energy wastes. The following energy conservation strategies are suitable for the UBC Winter Sports Center and should be considered in the facility design and operation. The percent reductions in refrigeration costs were estimated by Energy Ice (Lenko, 2001).

5.1 Low Emission Ceilings

Ceilings carry heavy heat loads as they have a large surface area and are exposed to a range of temperature gradients. Low emission ceilings reduce heat transmission through the ceilings and can reduce refrigeration costs in the rink from 20-35 %. The pay back on low emission ceilings is often around 3 years.

5.2 Ice Temperature Controls

Ice temperature controls allow the ice to rise in temperature when the ice is not in use ie. overnight, and then lower the temperature when the ice is in use. This can save over 6 % of refrigeration costs.

5.3 Ice Maintenance

Ice maintenance primarily refers to ice thickness. Thicker ice requires more energy to refrigerate, so maintaining thin (1 inch) ice is best when considering energy conservation.

5.4 Dehumidification

Dry air is easier to cool, so having a dehumidifier in the rink to dry the air can save in the energy required for cooling.

5.5 Air Circulation

The circulation of air has a significant effect on ice refrigeration. Air blown onto this ice causes the ice to warm and more energy is required for refrigeration. Air circulation in the facility should be designed with energy conservation in mind and should be inspected throughout the facilities' operation.

5.6 Flood Water Purification

The water used to flood the ice should be purified to remove contaminants in the water. Contaminants change the chemistry of the water and the freezing properties change as a result. Purified water can reduce refrigeration costs by up to 10 %.

6.0 CONCLUSION

Ice rinks are one of the most energy intensive recreation facilities making energy recovery logical for both the environment and economics. The UBC Winter Sports Center will recover energy and use it in the facility for heating rooms, under ice frost thawing and heating water. The amount of energy and cost saving from energy recovery and reuse yields a rewarding pay-back of approximately 4 years. The energy recovery also reduces carbon dioxide emissions, which complies with the Kyoto protocol to reduce overall energy consumption to achieve lower greenhouse gas emissions.

The UBC Winter Sports Center will be a state of the art facility broadcasted to a worldwide audience during the 2010 Olympics. The implementation of energy recovery and reuse in the facility demonstrates environmental awareness and action. The proposal for energy conservation strategies at the facility should be considered and implemented where appropriate as they too demonstrate environmental awareness and innovation as well as deliver reduced energy costs and greenhouse gas emissions.

7.0 REFERENCES

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APPENDIX A: SAMPLE CALCULATIONS

Energy Savings Calculations

It was provided by CIMCO that the net amount of heat energy recovered using the ECO Chill process is 7,834,995 MBH. When converted to kilowatts, that comes to 8.266E+06 kW/yr. The following conversion was used.

$$kWh = MBH * 1000Btu * \frac{1.055kW}{Btu} \tag{1}$$

The amount of time the rinks are operating was given by CIMCO as 5000 hours per year. The potential energy was found by multiplying 1.3 times the net energy based on an efficiency of 70-75%.

The future heating was given as a value of 161.1 kW by CIMCO. The future heating per year was calculated using the following equation:

$$FutureHeating(kW / yr) = 161.1kW * \frac{3600s}{hr} * \frac{5000hr}{yr} \tag{2}$$

$$= \underline{2.9E{+}09 \text{ kW/yr}}$$

The percent valve of future heating was found using the following equation:

$$\%ValueFutureHeating = \frac{2.9E^{+}09}{8.67E^{+}09} * 100\% \tag{3}$$

$$= \underline{35.1\%}$$