YEAR ROUND ICE HOTEL CHILLED BY HOT SPRING WATER

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ABSTRACT

A double lift absorption chiller ("ThermoChiller") was installed in the Aurora Ice Museum at Chena Hot Springs, Alaska. The ThermoChiller runs on locally available 75.5°C hot spring water, and provides 4.26 kW of –28.8°C chilling. The ThermoChiller successfully kept the Ice Museum frozen year round, and thus allowed summer visitors to experience winter amenities at the resort. The ThermoChiller was custom designed to deliver very cold chilling from a low temperature heat source, by using a double lift ammonia absorption cycle. The Chena Ice Museum is the only such structure in the world to remain frozen year round.

BACKGOUND

Chena Hot Springs Resort is located seventy miles northeast of Fairbanks, Alaska, and is a year-round wilderness resort. The main attractions are the natural hot springs and the fantastic views of the Aurora Borealis. Chena assembled the first version of the Aurora Ice Hotel (now renamed the Aurora Ice Museum) in January 2004. The ice hotel is the first of its kind to be built in the United States, and one of just a handful worldwide. The museum features a great hall and lounge area with ice carvings created by 12 time world champion ice sculptor, Steve Brice. Long daylight hours, plus summer temperatures in the 30's melted the first Aurora Ice Hotel in July, 2004.

An ambitious plan to redesign the 2005 version of the Ice Museum so as to stay frozen year-round was formulated in late 2004. The limiting factor in using a traditional vapor compression chiller big enough to keep the hotel frozen is the cost of electricity at this remote site. Electricity at the resort is provided by diesel generators at a cost of 30¢ per kWh. In part because of the premium rate of electric power onsite, the owners have extensively developed the geothermal resource for direct use applications. Two geothermal wells producing 757 lpm to 2,650 lpm provide heating for 46 buildings onsite. In the interest of taking advantage of the geothermal resource to provide refrigeration for the Ice Hotel, the resort owners contacted Energy Concepts in December 2004 and ordered a custom built absorption chiller to keep the museum 'on ice' year round, without the high cost of generated electricity.

The ammonia-water absorption cycle can be driven by any heat source: hot water, steam, or exhaust gas. It requires cooling water for the condenser and absorber. Standard packaged units are available in capacities up to 57 kW[1]. However, like many other low-temperature heat driven applications, this Chena Hot Springs unit is so specialized that a custom unit is required. A similar custom unit was installed in Kotzebue, Alaska twelve years ago, which makes ice using 74°C engine jacket coolant as the heat source[2].

CYCLE

Energy Concepts designed a double lift ammonia water absorption cycle, using the hot spring water as the driving heat (322 lpm @ 73°C). Figure 1 is the cycle diagram, and Figure 2 depicts the design statepoints. The ammonia-water pair is uniquely suited to deliver this performance, since it can accept heat over a temperature glide, and deliver very low temperature chilling. Hot spring water is abundant at Chena, and cold river water (303 lpm @ 4.4°C) is available to cool the absorbers and condenser. Proprietary heat and mass exchangers are used throughout the cycle to give high thermal performance, in a compact, low cost package.

1. Erickson, D. C., Anand, G., Kyung, I., Makar, E., and Panchal, C. B., 2005. "Absorption Refrigeration and/or Power Cycles for Industrial Waste Heat Applications." ISHPC-003-2005, International Sorption Heat Pump Conference, June 22-24, Denver, CO., USA.
2. Erickson, D. C., 1995. "Waste-Heat Powered Icemaker for Isolated Fishing Villages." ASHRAE Transactions, CH-95-18-3, pp. 1185-1188.

The components which contact external fluids (hot spring water, river water, chill brine) are constructed of stainless steel. Other internal cycle components are carbon steel. The chill brine is a CaCl2 solution, to allow temperatures down to –45.5°C. The brine circulates through an air handler, which cools an annular space in the ice hotel between the ice walls and the external insulation. With 73^{o}C hot spring water (322 lpm), and 4.4^{o}C (303 lpm) river water, the brine is delivered at –28.9°C (208 lpm) and the temperature in the ice hotel is maintained at a constant –4.4^{o}C.

SYSTEM OVERVIEW

The overall system includes:

- 2 insulated air handling units, capable of delivering 226.5 m^3/min at –17.8°C
- 7,571 liter chill brine storage tank
- 45 meters of insulated 7.6 cm pipe (runs to a nearby stream for cooling water)
- 454 meters of insulated 7.6 cm pipe (runs to the geothermal well)
- backup vapor compression refrigeration system, which requires a portable 300 kW generator for startup and operation

The hot spring water is cooled to 63^{o}C in the absorption unit, and is subsequently used to heat a large greenhouse and an outdoor pool.

SYSTEM OPERATION

The system was installed in late February, 2005 and was initially operated as a two pressure system. After two months of nearly flawless operation, the system was reconfigured to operate in three pressure mode as originally designed, in order to meet the load requirements for summertime operation. While there have been some minor setbacks and unanticipated complications, the system has operated with about 95% availability since installation.

A few factors have contributed to decreased system performance at times, all of which are solvable. The system was designed for a cooling water supply temperature of 44^{o}C, however there is considerable diurnal variation in supply water temperature from the creek. Not surprisingly, the warmest creek temperatures (~7.2^{o}C) occur in mid-afternoon, simultaneous to the highest Ice Museum cooling load requirements. This results in a decrease in system efficiency. In the future, the owners of the resort plan to use a shallow cold water well for the cooling water supply, with a stable downhole temperature of 3.9^{o}C.

Another factor contributing to a decrease in system efficiency is the need for frequent defrost of the air handlers. An automated $CaCl_2$ drip system was installed, but never operated properly. As a consequence, a manual defrost has to be initiated several times per day. If the air handlers are not defrosted on a regular basis, the brine temperature drops to the point where the system crashes (around –34.4^{o}C). This problem is being addressed by building a bypass duct for each air handler, while simultaneously installing a low brine temperature automatic shutdown for the chiller to prevent a system crash.

SYSTEM ECONOMICS

While the absorption chiller per se uses only 1.84 kW to operate circulating pumps for the ammonia-water mixture, an additional 14.7 kW are required to operate the cold and geothermal supply pumps, 1.84 kW are required for the CaCl2 brine circulating pump, and 14.7 kW are required for the air handler. In total, the absorption system requires 32.4 kW, while the backup vapor compression system requires 108.9 kW to operate. This results in fuel cost savings alone of $360 per day, or more than $10,000 per month at current fuel prices ($0.57 per liter bulk diesel).

CONCLUSIONS

Chena Hot Springs, Alaska is now the site of a world class ice museum/hotel which is the first in the world to remain open year round. In addition, this project illuminates the path to a more energy-responsible future by using geothermal hot spring water as the motive power to provide useful energy products. The project relies on the unique ability of ammonia water absorption cycles to convert very low temperature heat to refrigeration.