ABSORPTION CHILLER FOR THE CHENA HOT SPRINGS AURORA ICE MUSEUM

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INTRODUCTION

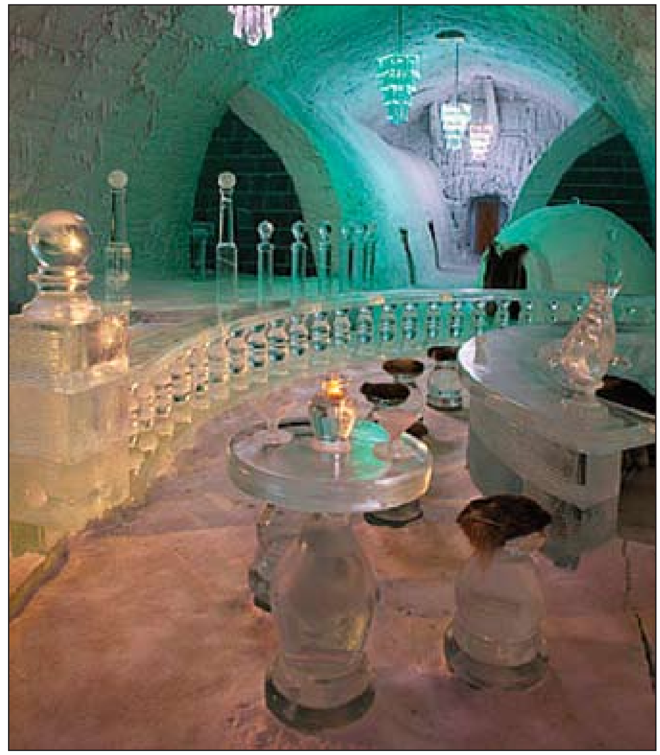
Absorption chilling uses a refrigeration cycle that requires little or no electric input, because it does not employ a mechanical compressor. Instead, the refrigeration effect is produced through heating and cooling a circulating absorbent liquid. When a moderate temperature heat source is available and/or local electric costs are high, absorption refrigeration can be quite economical. The type of absorption chiller most familiar to the general public is the 'propane refrigerator', which is found in RV's or at remote homesteads. In fact, absorption chilling is not a new concept. The first simple ammonia/water absorption chiller was built by Ferdinand Carre in 1846 and marketed as an ice-making machine.

Moderate temperature geothermal resources have long been recognized as promising heat sources to drive an absorption cycle, but the 230ºF minimum temperature classically considered necessary to make an air-cooled system cost effective encroached on temperature ranges which could similarly be used for power generation. For this reason, and because of increased maintenance issues when working with unique systems, no absorption chillers were in operation on geothermal sites between 1989 and 2004. Prior to 1989, the Oregon Institute of Technology used a lithium bromide/water absorption chiller for air conditioning buildings on campus.

THE AURORA ICE MUSEUM

In 2003, Chena Hot Springs Resort built the first Ice Museum in the United States. Chena is located 60 miles (100km) northeast of Fairbanks, Alaska, which is the traditional world capital of ice art. The Aurora Ice Museum was from its inception intended to be a year-round structure, something which had never before been attempted. Unfortunately, due to a number of reasons, the initial version of the Museum did not survive an unseasonably warm spring in 2004.

One of the primary problems was immediately identified as the cost of refrigeration for the structure. A standard 200-ton (700kW) Trane air-conditioning unit reprogrammed to circulate 300 gpm (19 l/s) of glycol was originally planned, but the cost of operating the unit was quickly deemed too high. Chena Hot Springs is located 30 miles (50km) from the nearest utility grid. Prior to the installation of a geothermal power plant in 2006, the cost of power generated onsite from a 200kW diesel generator was calculated to be 30¢ per kWh. The onsite generator was not large enough to power the 200-ton (700kW) Trane unit, and so a separate 500kW generator needed to be installed to start and operate it. The fuel cost alone for operating the Trane unit was over $500 per day.



Interior view of the Aurora Ice Museum.

ENERGY CONCEPTS COMPANY

Once the first Aurora Ice Museum melted, it was clear that in order to justify rebuilding the structure an alternative refrigeration system would be needed. The geothermal resource at Chena Hot Springs is 165ºF (74ºC), substantially lower than the minimum threshold generally considered for absorption systems. Fortunately, the owners of Chena were familiar with an absorption chiller operating in Kotzebue on the northwestern coast of Alaska, to make ice for the local fishing fleet. The Kotzebue chiller was powered by 165ºF (74ºC) jacket water from a diesel generator (coincidentally the identical temperature as the Chena geothermal resource). The system uses a three pressure ammonia/water absorption cycle, and had been in operation for 10 years. Chena contacted Energy Concepts Company, the manufacturer of the Kotzebue system, in late 2004, to order a similar unit for the Aurora Ice Museum. The order was placed in early January 2005, and installation was required by the end of March. This meant that there was no time for a shop test of the unit before shipping. It also meant that the unit had to be air shipped to meet the schedule, and hence compactness was at a premium.

CHENA ABSORPTION CHILLER

Chena Hot Springs required significantly more refrigeration capacity than Kotzebue, and so Energy Concepts designed a unique three pressure system for the Ice Museum, using an ammonia-water absorption cycle. One significant advantage Chena had over other sites was a supply of readily available cold river water to cool the absorbers and condenser. Special heat exchangers are used throughout the system to give high performance in a very compact package. The components which contact external fluids (hot spring water, river water, chilled brine) are constructed of stainless steel. Other internal cycle components are carbon steel. The chilled brine which transfers heat out of the Ice Museum is a $CaCl_2$ solution, concentrated to allow temperatures as low as -50ºF (-46ºC) (typical for winter temperatures at Chena). The brine circulates behind the Ice Museum and through an air handler, which cools an annular space in the Ice Museum between a thin inner wall and the external insulated wall. With 165ºF (74ºC) hot spring water (85 gpm (5.4 l/s)), and 40ºF (4ºC) (80 gpm (5.0 l/s)) river water, the brine is delivered at -20ºF (-29ºC) (55 gpm (3.5 l/s)) and the temperature in the ice hotel is maintained at a constant 24ºF (-4ºC).

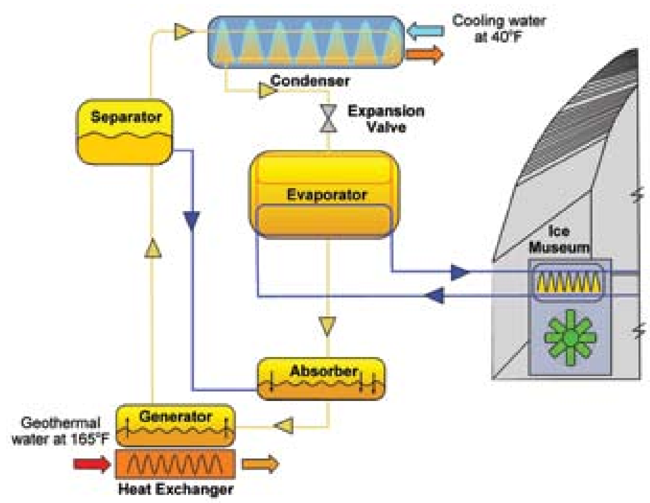
An additional system component is a 2000 gallon (7.56m^3) brine storage tank, which acts as a giant 'fly wheel' in the system. If the brine in the tank is kept below freezing, it can continue to provide cooling to the Ice Museum for one hour during shutdown of the absorption chiller for any reason. Additionally, defrost of the air handlers has not been perfected and is accomplished using hot water sprayed onto the coils. This heat can unbalance the absorption chiller, and therefore the tank allows the brine to circulate freely while allowing the air handlers to be cut out of the loop.

SYSTEM ECONOMICS

While the absorption chiller uses only two 1/2hp (0.37kW) pumps to circulate the ammonia-water mixture, an additional 20hp (15kW) are required to operate the cold and geothermal supply pumps, 3hp (2kW) are required for the CaCl2 brine circulating pump, and 20hp (15kW) are required for the air handler. In total, the absorption system requires 44hp (33kW), while the backup vapor compression system requires 148hp (110kW) to operate. This results in fuel cost savings alone of $400 per day, or more than $12,000 per month at current diesel fuel prices ($2.47 per gallon ($0.65/liter) for bulk diesel).

The Chena absorption chiller plant ("Thermochiller") has now operated through two warm seasons, keeping the Aurora Ice Museum frozen year-round. It demonstrates that absorption refrigeration is possible with very low driving temperatures, and in very compact packages. The Chena Thermochiller displaces both the conventional mechanical compressor chiller plant, and also 100 hp (75 kW) of otherwise required power plant capacity. The capital cost of the Thermochiller is substantially less than the capital cost of those two displaced components. Therefore, even with the installation of the 2 x 200kW geothermal power plant at Chena, the absorption chiller will remain in operation as the most economical cooling option for the Ice Museum because the upfront installation costs have already been covered.

Absorption Chiller prior to installation.



Chena Hot Springs Absorption Refrigeration System.

[1]The geothermal supply pump is operated regardless of absorption chiller operation as it is used for onsite district heating system.