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Carbon Dioxide in Ice Refrigeration

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Two important aspects of refrigeration systems are environmental perspective and energy cost. Some traditional refrigerants known as harmful to environment has been excluded from the market, the second generation represented by natural refrigerants, such as NH3 which has been developed over 50 years with many advantages. However, it still presents some disadvantages in term of safety and efficiency of the system. The risk of NH3 leakage is the main reason for indirect designs which NH3 is restricted as much as possible in the system, so it requires another liquid in the distribution cycle. Consequently, energy consumption of the indirect NH3/brine system is higher than a direct system because of heat exchange between different working fluids in the system. CO2 has been discovered as another candidate of natural refrigerant which is promising to solve the problem. The first concept for CO2 application in ice rink was in 1999 in Austria (GEA2011), CO2 is used in the second cycle with 80% decrease in secondary pump power (Rogstam2007). Then, with the successful story of CO2 application in supermarket, the second concept of CO2 is used for the whole cycle was applied in one ice rink in Quebec, Canada in 2011 what makes the results very positive. There has not been many research work of CO2 application in ice rink, and this study is to give a general picture of CO2 application in ice rink refrigeration system and a base study of evaluation of CO2 system in ice rink.

CO2 has been known as a popular natural refrigerant from 1850 due to its safe properties in comparison with ammonia or sulphur dioxide. Until 1930, CO2 was stop using because of the entry of artificial synthetic chemical refrigerants. With high cooling capacity at high ambient temperature and the ability to work at lower pressure than CO2 that is an advantage for artificial synthetic chemical refrigerants to develop low cost and light heat exchanger components. However, till 1990, when CFC and HCFC present the ozone depleting ability, CO2 was introduced again as one of alternatives. In a system using CO2 as a refrigerant, if ambient temperature is higher than 30o C, the heat rejection process will operate at supercritical condition as shown in figure 5. Operation in this cycle creates a loss in cooling capacity and higher power consumption in compressor so a loss of COP will happen. As the results, the COP of system is changing to the ambient temperature, a higher COP can be achieved with a lower outside temperature. Also, when condensing temperature closes to the critical point, the cycle is jumped to operate in transcritical also and reject heat above the critical point, the systems suffered loss in cooling capacity and efficiency. Figure 6 shows COP2d of a basic cycle of CO2 in comparison with NH3 at -10o C evaporating temperature, COP2d of CO2 cycle is lower then NH3 in all of condensing temperature. However, the CO2 discharge gas is warmer and stores higher energy density due to higher pressure and higher volumetric refrigeration effect, so the heat of CO2 vapor can be recovered better than other refrigerants. This can improve the performance of system if the heat recovery is utilized properly.

The average energy consumption of one ice rink is around 1000MWh/year, which approximately 69% is occupied by the refrigeration unit and heating demand. With the aim of decreasing the energy consumption, a new concept of refrigeration system with CO2 as a refrigerant has been developed and it is promising to become a high potential next generation for refrigeration system in ice rink. This thesis is to evaluate a new refrigerant application in ice rink refrigeration system under three different aspects; energy performance, heat recovery potential and economic efficiency. In order to make this evaluation, three main tasks are executed. Firstly, literature review and market statistic are processed to give a general picture of the CO2 development as a refrigerant. Secondly, a software Pack Calculation II is used for the simulations of CO2 refrigeration system and traditional ice rink refrigeration system. Älta ice rink located in Sweden, is chosen as a reference case for simulation’s input data. The simulation results is to compare these system in terms of energy performance and heat recovery potential. Finally, life cycle cost of these systems is calculated to investigate the economic benefits from this new application.

Results from this study show good benefits of the new CO_2 application in ice rink. From the market statistics, CO_2 has become a successful refrigerant in supermarket food and beverage industry with 1331 CO_2 refrigeration system installed until 2011 in Europe (Shecco2012). In ice rink industry, 24 ice rinks have been applied CO_2 in the second cycle of refrigeration system; one ice rink in Canada applied a refrigeration system with only CO_2 in the first cycle and the distribution system.

From the simulation's result, CO_2 full system has been proven as the most efficiency system with the lowest energy consumption (30% lower than NH_3/Brine system and 46% lower than CO_2/Brine system) and the highest COP (6.4 in comparison with 4.9 of NH_3/Brine system and 4.37 of CO_2/Brine system). Regarding heat recovery potential, CO_2 full system has highest energy saving in comparison with the other two systems. In ice rink refrigeration system, the pump in the distribution system or it calls secondary pump that also makes an effect to the compressor power consumption. Heating from the secondary pump that spreads to the around environment creates a heat loss in the fluid, then it requires more cooling load that makes compressor consume more power. The heat loss gets higher if the secondary pump. power is higher and it calls secondary effect in this part. A trial is made in the software, for the same simulation with different secondary pump power to investigate whether the compressor power consumes more energy in case of higher secondary pump power. The results shows that there is no change in compressor power consumption if the secondary pump power is changing.