PRGI-2866-68 R0801

WHITE PAPER ICE RINK REFRIGERATION TECHNOLOGIES EVALUATION

Saguenay – Lac-Saint-Jean

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Table of Contents

1. Executive Summary

Renteknik Group Inc. ("Renteknik") performed an Evaluation on two Ice Rinks located in the region of Saguenay – Lac-Saint-Jean. These Rinks were selected because each utilizes a different Refrigeration Technology, as well as being within 100 km of each other.

Table 1 below provides the location as well as the refrigeration technology for each of the Rinks.

Table 1: Energy Consumption Results Over Monitoring Period

Arena Name	Address	Technology
Sports Center Jean Claude Tremblay Arena 2	1000 Rue Aimé Gravel, La Baie, QC G7B 2M4	Ammonia (NH_3)
Centre Marius Sauvageau	82 Rue de la Plaine, Chambord, QC G0W 1G0	Refrigerant (R513A)

The comparison evaluation between the Systems is based on data collected utilizing a proprietary ClimaCheck Performance Analyzer. The data herein analyzed and presented is for an operational period of 10 days during the month of March 2020.

Table 2 below details the Energy delivered by each System as well as Energy Recovered for Space Heating and Domestic Hot Water purposes.

Table 2: Energy Consumption Summary

Arena Name	Average Cooling Energy Delivered	Average Cooling Efficiency	Average Heating Energy Delivered	Average Heating Efficiency
Sports Center Jean Claude Tremblay Arena 2 – NH_3	93.16 Ton	0.74 kW/Ton	111.12 Ton	19.65 EER
Centre Marius Sauvageau – R513A	39.66 Ton	1.29 kW/Ton	53.22 Ton	12.54 EER

Table 3: Heat Recovery Ratio Summary

Arena Name	Space Heating	Domestic Hot Water	Waste
Sports Center Jean Claude Tremblay Arena 2 - NH_3	61.18 % (986.80 kWh)	8.89 % (143.44 kWh)	29.93 % (482.74 kWh)
Centre Marius Sauvageau – R513A	100% (810.45 kWh)	N/A	N/A

2. Background Information – Measuring Methodology

2.1 About ClimaCheck

The ClimaCheck Method is unique and based on thermodynamics. The ClimaCheck Method is based completely on physical data for the cooling medium and basic correlations and is applicable to any HVAC/R system. In a normal cooling process, the method is based on ten measuring points that are connected to collect key data. More complex systems can also be evaluated with the addition of data points. ClimaCheck analyses and evaluates this data immediately when connected and records the real-time performance. Users will quickly get a complete picture of how the equipment is working and what adjustments can be made to increase energy efficiency. ClimaCheck records and documents the performance of cooling processes independent of input from the system or component suppliers – and therefore completely neutral and unbiased.

The ClimaCheck technology is monitoring more than 1500 Systems in over 20 countries. These Systems include data centers, district heating/cooling, sports centers, but also manufacturing, the food and provisions industry, property owners, and contractors

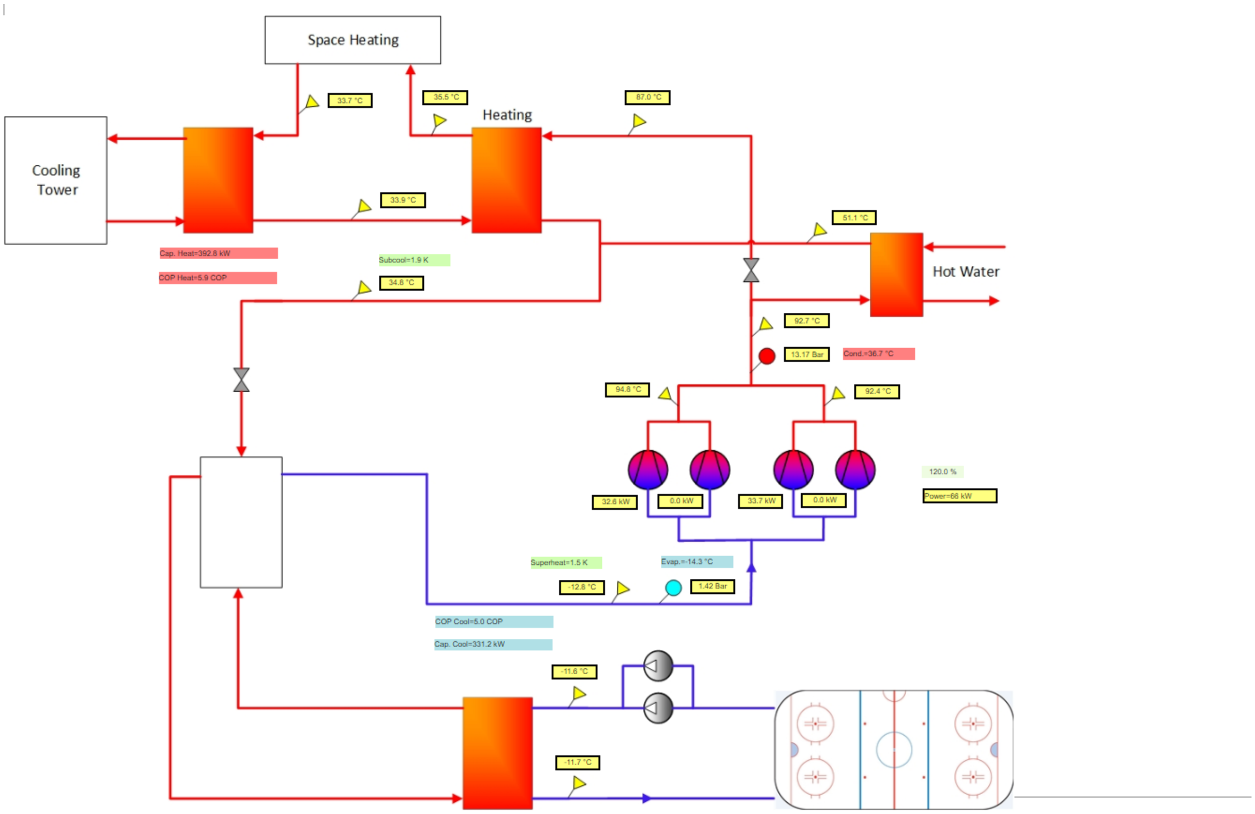
2.2 Systems Overview

The two (2) different Ice Plants at the Saguenay – Lac-Saint-Jean were monitored utilizing the ClimaCheck Performance Analyzer which allows for the real-time evaluation of the Thermodynamic Performance of the Refrigeration System. In order to model the Thermodynamic System, the following components were measured:

- Suction Pressure
- Suction Temperature
- Discharge Pressure
- Discharge Temperature
- Liquid Line Temperature
- Compressor Discharge Temperature
- Heat Reclaim Supply Temperature
- Heat Reclaim Return Temperature
- Power Consumption

Schematics 1 and 2 below detail the flow chart used to model the performance of each System.

Schematic 1: Sports Center Jean Claude Tremblay Arena 2, La Baie – NH_3



Schematic 2: Centre Marius Sauvageau, Chambord – R513A

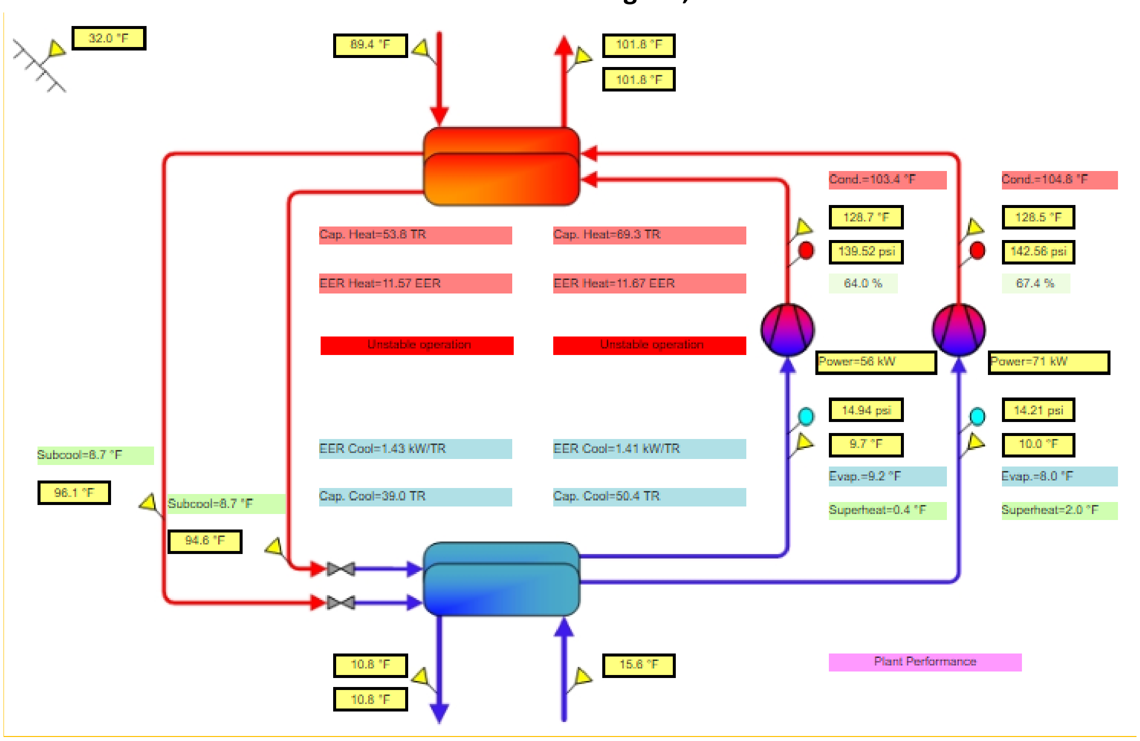


Table 4 below details the monitoring points for each System:

Table 4: Monitoring Points

Sports Center Jean Claude Tremblay Arena 2, La Baie – NH_3		
Measuring Point	**Sensor Type**	**Logging Interval**
Common discharge temperature	PT1000	1 minute
Compressors 1 and 2 common discharge temperature	PT1000	1 minute
Compressors 3 and 4 common discharge temperature	PT1000	1 minute
Common discharge pressure	(0-10Vdc) 35 Bar	1 minute
Hot water heat recovery return Temperature	PT1000	1 minute
Heating heat recovery ammonia supply temperature	PT1000	1 minute
Heating glycol supply temperature	PT1000	1 minute
Heating glycol return temperature (cooling tower supply)	PT100	1 minute
Cooling tower glycol return temperature	PT1000	1 minute
Liquid line temperature	PT1000	1 minute
Ice rink supply temperature	PT1000	1 minute
Ice rink return temperature	PT1000	1 minute
Common suction temperature	PT1000	1 minute
Common suction pressure	(0-10Vdc) 10 Bar	1 minute
Compressor 1 amperage	Split Core CT – 100 A	1 minute
Compressor 2 amperage	Split Core CT – 100 A	1 minute
Compressor 3 amperage	Split Core CT – 100 A	1 minute
Compressor 4 amperage	Split Core CT – 100 A	1 minute
System voltage	EM-24	1 minute
Centre Marius Sauvageau, Chambord – R513A		
Measuring Point	**Sensor Type**	**Logging Interval**
Circuit A discharge temperature	PT1000	1 minute
Circuit A discharge pressure	(0-10Vdc) 35 Bar	1 minute
Circuit A liquid line	PT1000	1 minute
Circuit A suction temperature	PT1000	1 minute
Circuit A suction pressure	(0-10Vdc) 10 Bar	1 minute
Circuit B discharge temperature	PT1000	1 minute
Circuit B discharge pressure	(0-10Vdc) 35 Bar	1 minute
Circuit B liquid line	PT1000	1 minute
Circuit B suction temperature	PT1000	1 minute
Circuit B suction pressure	(0-10Vdc) 10 Bar	1 minute
Circuit A heat recovery supply temperature	PT1000	1 minute
Circuit B heat recovery supply temperature	PT1000	1 minute
Common heat recovery return temperature	PT1000	1 minute
Circuit A ice rink supply temperature	PT1000	1 minute

Circuit B ice rink supply temperature	PT1000	1 minute
Common ice rink return temperature	PT1000	1 minute
Circuit A amperage	Split Core CT – 100 A	1 minute
Circuit B amperage	Split Core CT – 100 A	1 minute
System voltage	EM-24	1 minute

2.3 Monitoring Period

The Monitoring Period and Reporting Period used for the Evaluation Report are detailed in Table 5 below.

Table 5: Monitoring and Reporting Periods

Arena Name	Monitoring Period	Reporting Period
Sports Center Jean Claude Tremblay Arena 2 – NH_3	March 3rd to March 20th, 2020	March 3rd to March 13th, 2020
Centre Marius Sauvageau – R513A	March 3rd to March 20th, 2020	March 3rd to March 13th, 2020

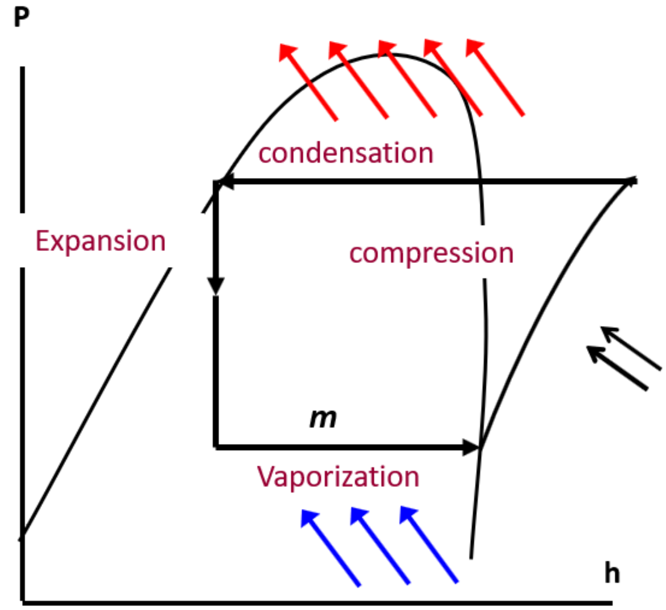
Note that the Reporting Period is up until Quebec declared the State of Emergency on March 13th, 2020 due to the COVID-19 Pandemic. All data post this State of Emergency date was analyzed and deemed irrelevant for the purpose of this Evaluation Report as the facilities were no longer operating normally.

2.4 Monitoring Methodology Overview

As detailed in Section 2.1 above a customized ClimaCheck Performance Analyzer was used to collect real time data on the Refrigeration Systems at each of the facilities. ClimaCheck/Renteknik Group utilizes a proprietary software that allows for the modeling and evaluation of any refrigeration System. This analysis is based on the thermodynamic principles that govern any refrigeration System from house-hold refrigerators to in this case Ice Rinks.

The ClimaCheck/Renteknik Group analysis is based on actual performance of the cooling processes and is independent of input from the System or component suppliers. The Recorded Data is therefore completely neutral and unbiased which allows for a true third-party evaluation of the System Performance. In order to perform the analysis the model uses the temperature and pressures detailed in Section 2.1 above to determine the Enthalpies at each stage of the Refrigeration Cycle, the enthalpies and thermodynamic data in conjunction with the short sampling period (1 minute) allows to accurately determine System performance.

Schematic 3: Basic Refrigeration Cycle



The ClimaCheck/Renteknik Group Model allows for the identification of the following operational parameters:

- Refrigeration Capacity
- Condenser/Heating Capacity
- Heat Reclaim Performance
- kW/ton and COP rating
- Refrigeration Cycle Isentropic Efficiency
- System Efficiency Index (SEI)

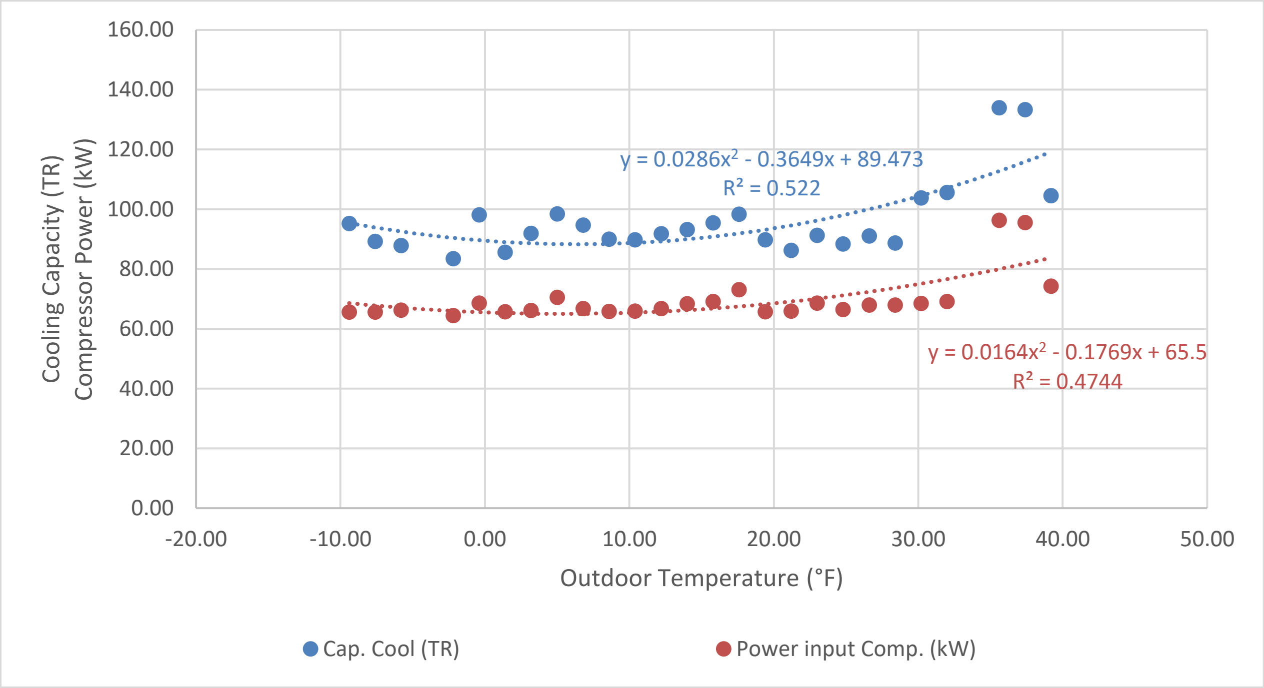
Sections below describe the results for each Refrigeration Plant during the Reporting Period.

3. Sports Centre Jean Claude Tremblay, Arena 2 – Evaluation (NH_3)

The Refrigeration System servicing the Arena 2 at the Sports Centre Jean Claude Tremblay utilizes a traditional ammonia (NH_3) refrigeration cycle. The System consists of four (4) compressors, two (2) heat recovery heat exchangers, servicing the space heating and the domestic hot water (DHW), as well as a cooling tower for when space heating within the building is not required or additional heat rejection is needed.

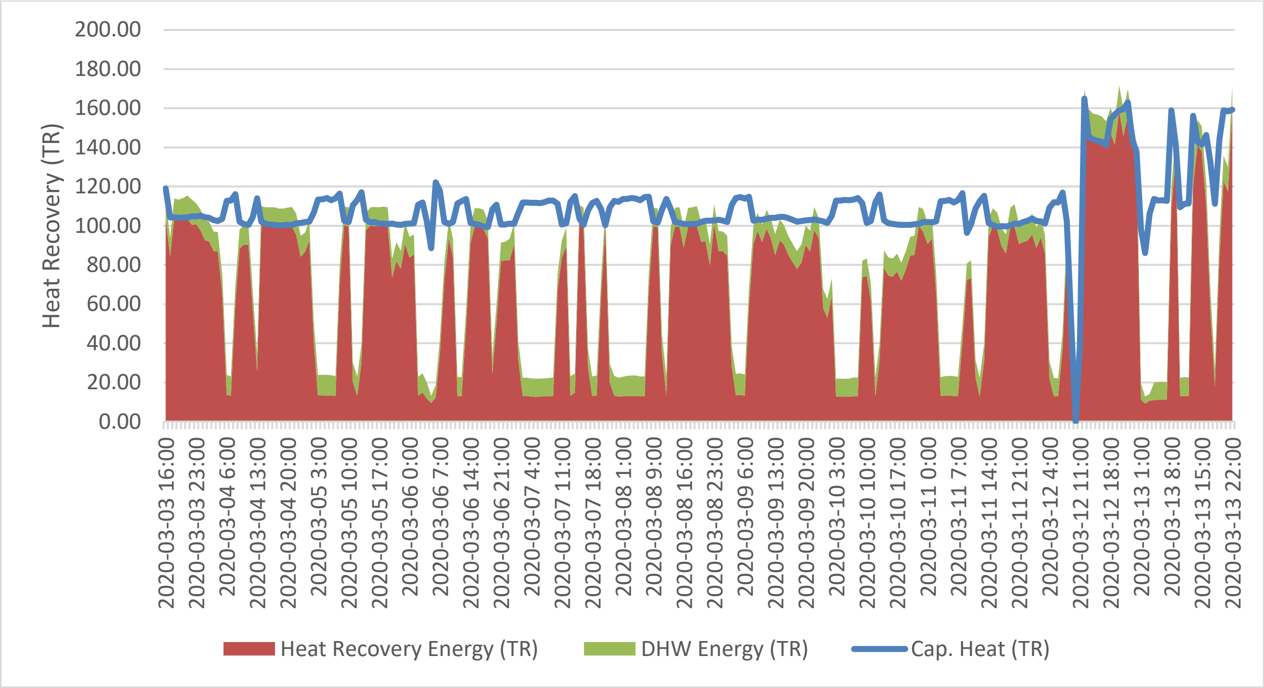
Graph 1 below details the Weather Normalized Cooling Capacity and Compressor Power delivered by the Ice Plant servicing the arena. As seen in Graph 1. the System delivers a stable capacity of approximately 93 Tons of Refrigeration (TR) whilst maintaining a stable Power Consumption of approximately 70 kW.

Graph 1: Compressor Power (kW) and Cooling Capacity (TR) vs Outdoor Temperature (°F)



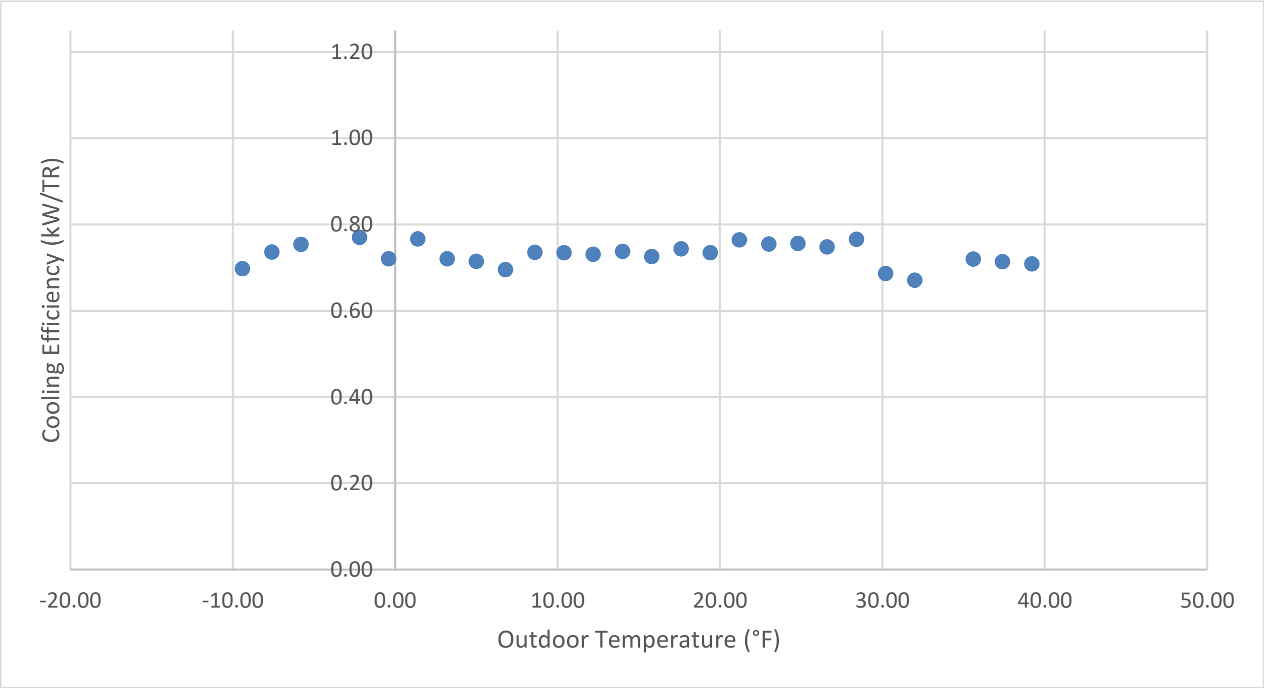
The NH_3 Ice Plant is used to supply Space Heating within the building as well as the production of Domestic Hot Water (DHW). The amount of heat recovered for Building Heating purposes and Domestic Hot Water can be seen in Graph 2, below. From Graph 2 it can be seen that heat is not being constantly recovered for Space Heating purposes however it is always being used for DHW purposes. During the Reporting Period (10 days), the Ice Plant generated approximately 1,612 kWh of thermal Energy of which 70% (986.8 kWh) was recovered and used for Space Heating (61%) and DHW (9%)

Graph 2: Hourly Heat Recovery - NH_3 Ice Plant during the Reporting Period



The average efficiency for this Ice Plant during the Reporting Period is detailed in Graph 3 below. As seen in Graph 3 the operation is stable at approximately 0.75 kW/ton over the range of ambient temperatures.

Graph 3: Ice Plant Efficiency (kW/TR) vs Outdoor Temperature (°F)



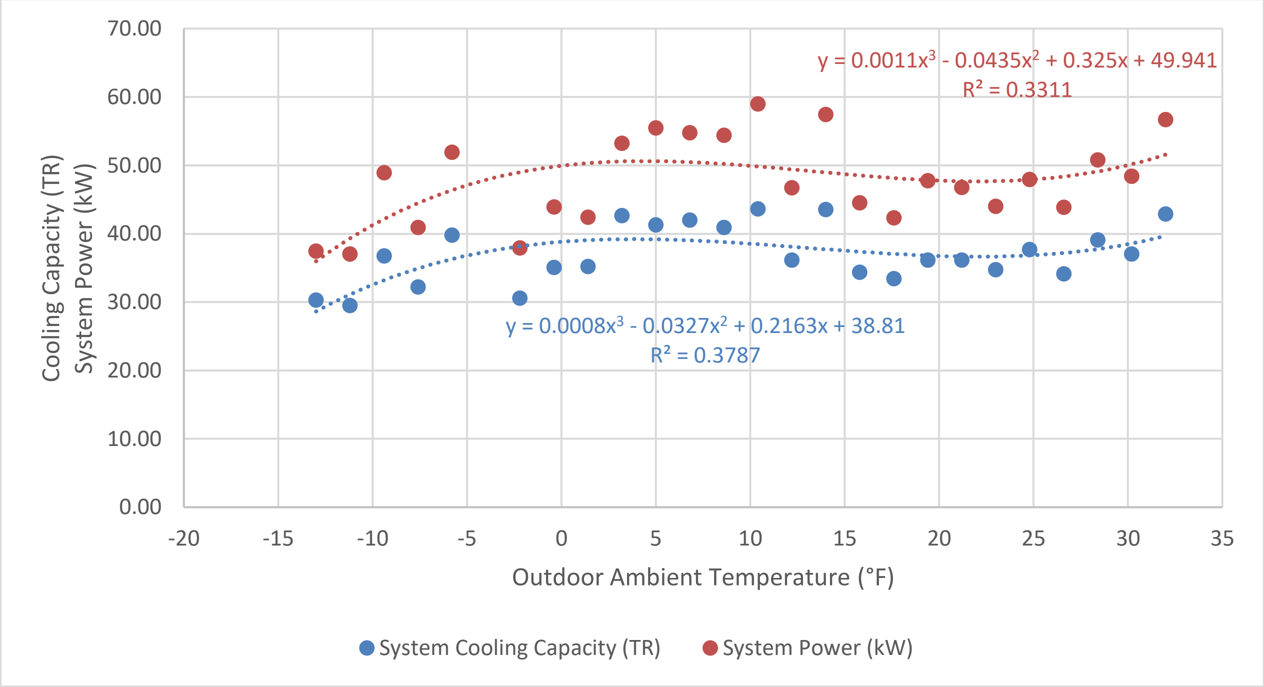
4. Centre Marius Sauvageau – Evaluation (R513A)

The Refrigeration System servicing the Centre Marius Sauvageau, utilizes a dual Circuit Chiller using R513A as the refrigerant. This Refrigeration Plant architecture is typical of a traditional refrigeration design seen in the majority of Ice Plants for Arenas. The R513A refrigerant allows for low evaporating temperatures and therefore is suitable for the making of the Ice.

The System utilizes two separate circuits with one Compressor per Circuit. On the Condenser side the heat is being used for Space Heating within the building therefore all generated heat is being used by the Glycol Heating Loop.

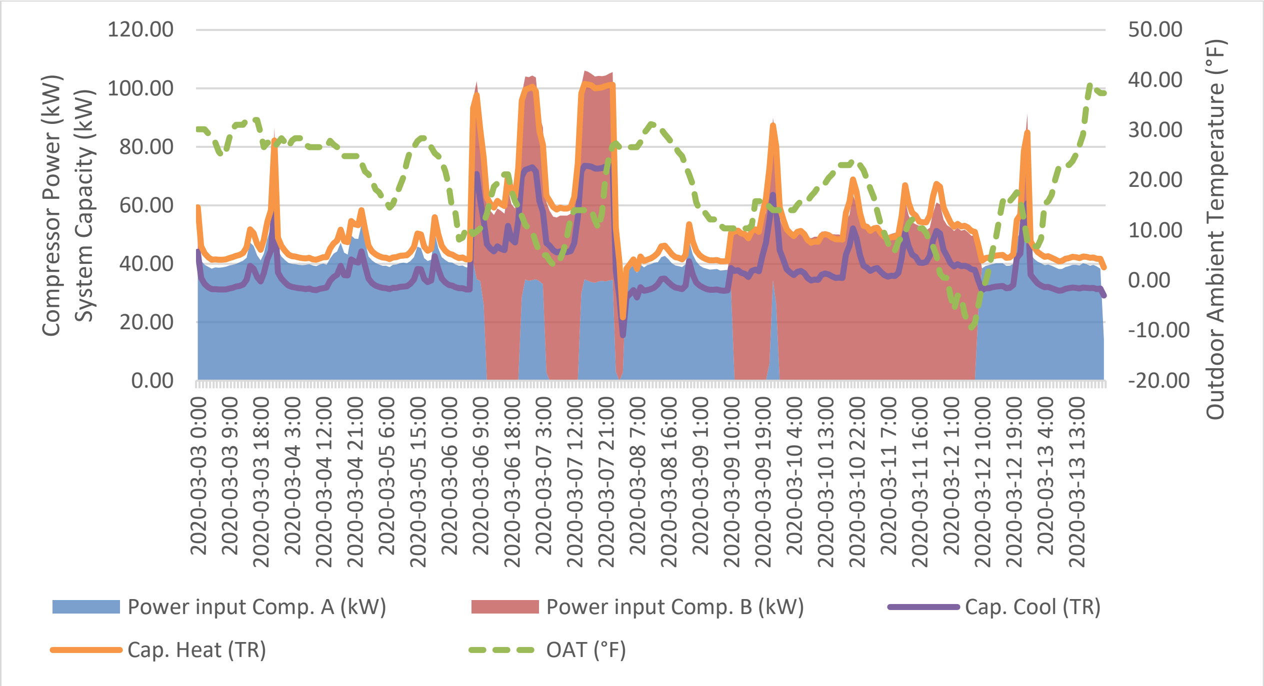
Graph 4 below details the Weather Normalized Compressor System Power (both compressors together due to the architecture) and the Total Cooling Capacity delivered by the Ice Plant servicing the arena. As seen in Graph 4, the System operates at a stable capacity of approximately 40 TR with an average System Power of 55 kW.

Graph 4: System Power and Cooling Capacity (TR) vs Outdoor Temperature (°F)



Given the configuration of this Ice Plant with two (2) separate circuits. The following Graph 5 details the operation of each of the Circuits. Note that for the majority of the Reporting Period the System operates with one (1) Compressor. There are few instances where the secondary circuit is energized, this allows the System to deliver additional cooling and/or heating capacity as seen in the Graph 5 below.

Graph 5: Individual Compressor Power, System Capacity and Outdoor Temperature (°F)



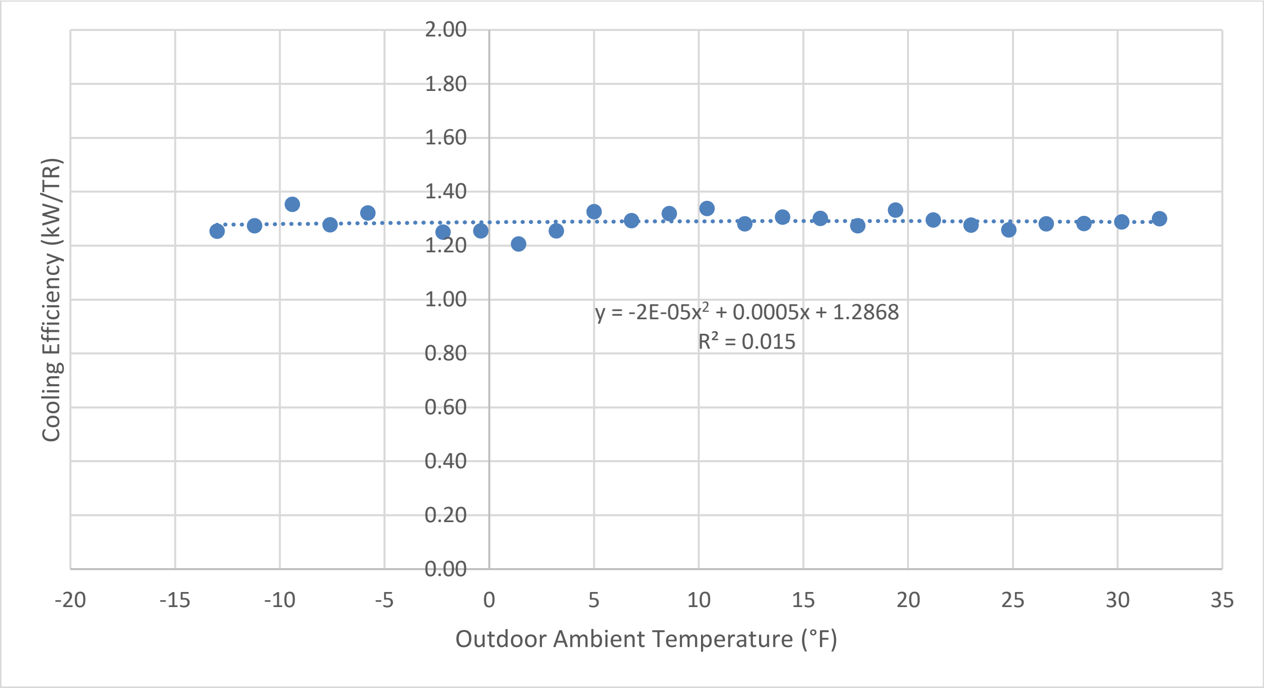
Note that given the configuration of this System, all heat being generated by the Refrigeration Cycle is being recovered by the Space Heating System. At the time of this Report it is not clear whether all this heat is being used within the building for Space Heating or if it is rejected to the atmosphere via a dry cooler and/or cooling tower.

Based on the data collected during the Reporting Period the average efficiency for this Ice Plant is shown in Graph 6 below. As seen in Graph 6, the operation is very stable at approximately 1.30 kW/ton.

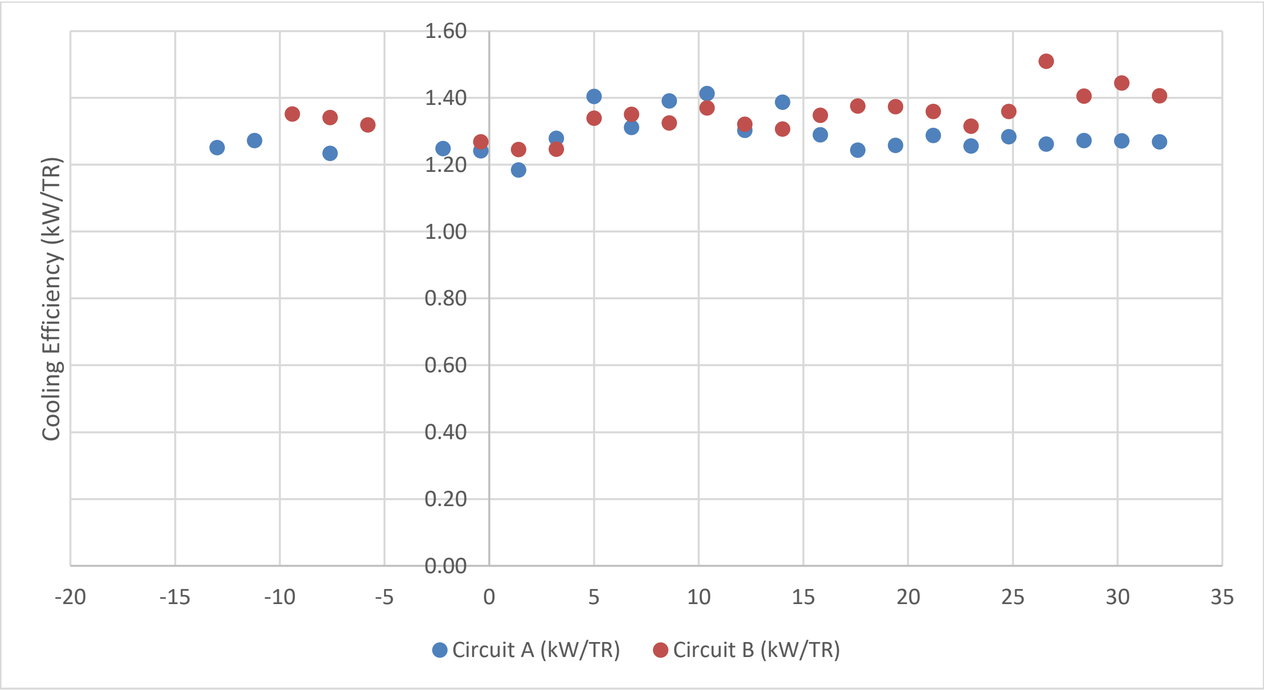
Given that the System can operate with independent Circuits, the individual Circuit Efficiency is evaluated on a kW/TR basis and shown in Graph 7 below. This analysis allows for the identification of the most efficient circuit and can assist with the scheduling and sequencing of compressors to ensure optimal efficiency is maintained.

For the case of this Ice Plant the Circuit A operates marginally more efficient than Circuit B, 1.29 kW/TR vs 1.35 kW/TR. This improved performance can also be seen in Graph 8 where Circuit A consistently consumes less Power than Circuit B.

Graph 6: Plant Efficiency (kW/TR) vs Outdoor Temperature (°F)



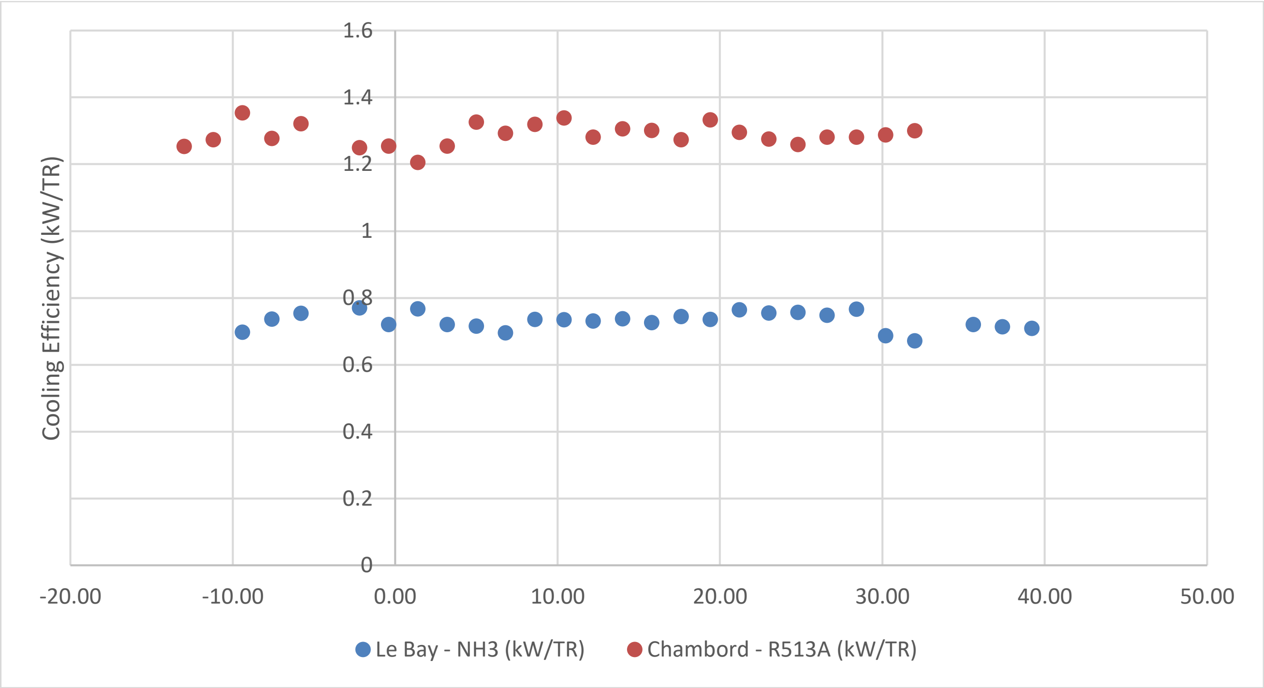
Graph 7: Circuit Efficiency (kW/TR) vs Outdoor Temperature (°F)



5. System Comparison (NH_3 vs R513A)

Based on the data collected the Systems can be compared based on Normalized profiles. Graph 8 below details the Cooling Efficiency for each System. It can be noted that the Le Bay System which operates on NH_3 is significantly more efficient than the Chambord System operating on R513A

Graph 8: Cooling Efficiency (kW/TR) Comparison



Another available tool to benchmark the rinks performance is the System Efficiency Index (SEI). The SEI methodology consist of creating a benchmark based on the maximum efficiency that the System can have within its operating envelope.

For these Ice Rinks the operational envelope chosen is defined by:

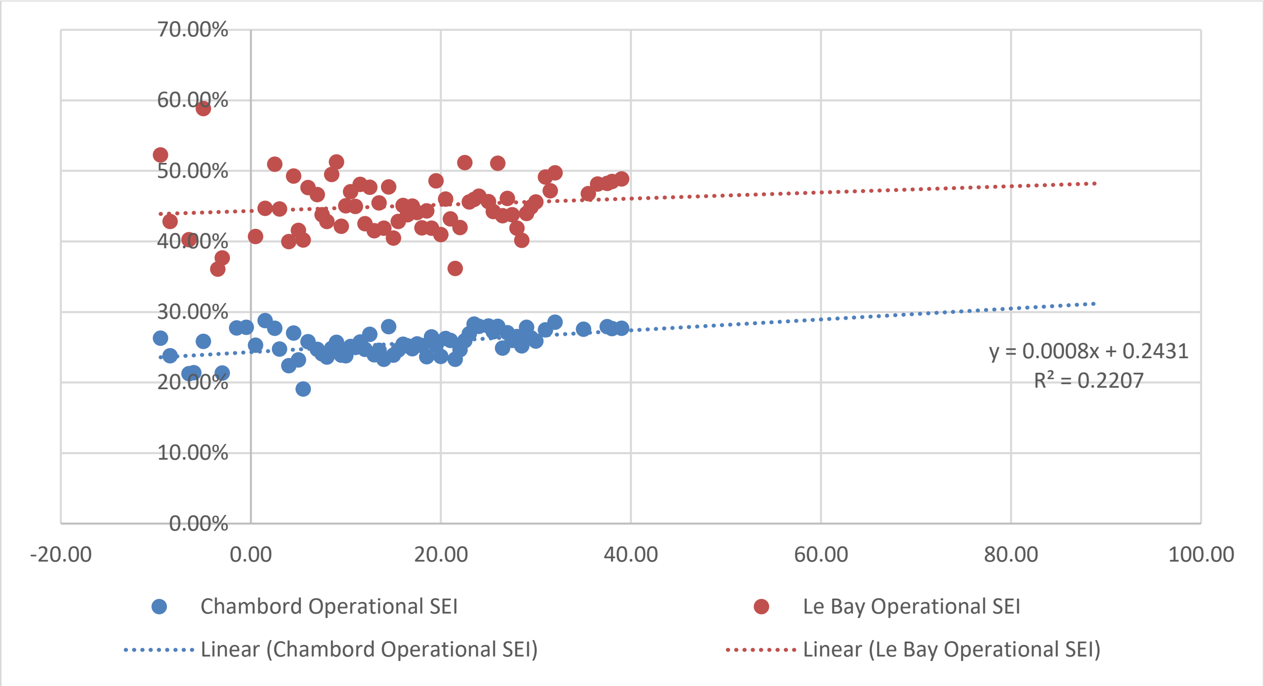
- Cold Temperature – Slab Temperature (19°F when occupied and 23°F when unoccupied)
- Hot Temperature – Indoor Space Temperature (71°F when occupied and 65°F when unoccupied)

Therefore, the Reference Maximum Operational COP is defined by the following equation;

$$Max\ Operational\ COP = \frac{Indoor\ Space\ Temperature}{Indoor\ Space\ Temperature - Slab\ Temperature}$$

Graph 9 below details the difference between the System Efficiency Index between the rinks at Le Bay and Chambord.

Graph 9: SEI comparison between NH_3 and R513A



6. Reporting Period Conclusion

Based on the data gathered during the Reporting Period it can be concluded that under the tested conditions the Ice Plant operating on Ammonia (NH_3) has far better performance than the Ice Plant operating on R513A.

Table 6 below details the average Performance Results based on the 10 day Reporting Period from March 3rd to March 13th, 2020

Table 6: Performance Results Based on Reporting Period

Arena Name	Average Cooling Energy Delivered	Average Cooling Efficiency	Average Heating Energy Delivered	Average Heating Efficiency
Sports Center Jean Claude Tremblay Arena 2 – NH_3	93.16 Ton	0.74 kW/Ton	111.12 Ton	19.65 EER
Centre Marius Sauvageau – R513A	39.66 Ton	1.29 kW/Ton	53.22 Ton	12.54 EER