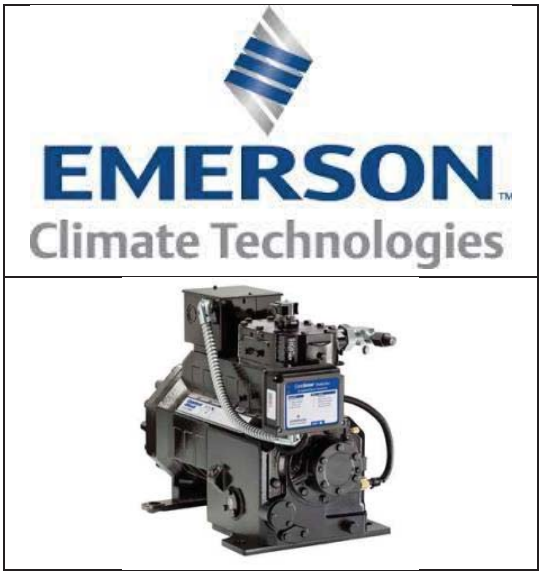
Variable Capacity Digital Discus Compressor Upgrade Measurement and Verification Report

Location
45,000 sq.ft. Grocery Store
Southwestern Ontario

Prepared for:

Andre Patenaude, Director of Marketing
Emerson Climate Technologies



Prepared by:

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Variable Capacity Compressor Upgrade M&V Report for a Refrigeration System at a 45,000 Sq.Ft Grocery Store in Southwestern Ontario

The following contains a complete Variable Capacity Compressor Upgrade Measurement and Verification Report including synopsis of the data obtained throughout the baseline and post implementation periods for the Project Phases for a Refrigeration System located at a 45,000 Sq.Ft Grocery Store in Southwestern Ontario. All information contained in this Report also meets the requirements of the saveONenergy Equipment Replacement Incentive Initiative (ERII) program for Refrigeration Systems in Ontario.

Background and work completed to date:

The analyzed Refrigeration System, which is over 20 years old, consists of a Medium and Low Temperature System (Total 164 HP) and operates with 10 Semi-Hermetic Copeland Compressors. The total cooling capacity of the Medium and Low Temperature System is approximately 1,000,000 BTU and historically consumed approximately 950,000 kWh of electricity per year prior to the enhanced recommissioning performed in February 2013. Through the enhanced recommissioning process a number of Energy Efficiency Measure (EEMs) have been implemented predominantly in the form of adjustments. These adjustments were intended to improve the System's stability while reducing energy use at the lowest possible cost within a short period of time. The implementation EEMs were considered to be no-cost/low-cost measures utilizing the existing Service and Maintenance Budget and produced an operational energy saving of approximately 173,000 kWh (approximately 18% energy savings). This reduced the annual operation to approximately 777,000 kWh of electricity per year. This operational condition formed the new optimized system baseline with which future capital based implementations would be measured. These EEMs were covered under previous Ontario Power Authority (OPA) ERII Incentive Applications and approximately twenty thousand ($20,000.00) dollars of incentives have already been received by the Grocery Store for this work.

Goal of this Demonstration Project:

The goal of this Demonstration Project was to analyze the Medium and Low Temperature Racks (hereafter the "Refrigeration System" or "System") at the Grocery Store in order to determine the impact of retrofitting each Rack by replacing one (1) 15 HP Semi-Hermetic Compressor with one (1) Semi-Hermetic Variable Capacity Copeland Digital Discus Compressor.

With the installation of the Variable Capacity Copeland Digital Discus Compressors in place (hereafter referred to as the Post-Implementation Period), the Refrigeration System operation consumed significantly less power at all outdoor temperatures and significant preliminary energy savings were achieved. The estimated yearly energy consumption of the Refrigeration System is now approximately 654,000 kWh which represents an energy saving of approximately 123,000kWh per year (approximately 16% energy saving)

TABLE 1: SUMMARY OF ENERGY SAVINGS, OPA INCENTIVES & ANNUAL OPERATIONAL SAVINGS

Item	Energy savings kWh/year	OPA Incentive	Annual savings
Rate		$0.10/kWh	$0.140/kWh
LT	47,390	$ 4,739	$ 6,635
MT	75,575	$ 7,558	$ 10,580
TOTAL	**122,965**	**$ 12,297**	**$ 17,215**

TABLE 2: SUMMARY OF PROJECT COSTS

Item	**Cost**
Compressor upgrade – LT **(Copeland Digital Discus) – full replacement**	$ 7,293
Compressor upgrade – MT **(Copeland Digital Discus) full replacement**	$ 6,532
Control Upgrade (Service and Maintenance Contractor)	$ 3,317
Engineering and M&V (Renteknik)	$ 7,450
Total Demonstration Project Cost	**$ 24,592**

The Business Case for a **"Standard Project"** and **"Simple Project"**, as defined later, are detailed below in the body of this document.

1. IMPLEMENTED ENERGY MEASURES:

The following EEMs were implemented on April 22nd, 2014 by the incumbent Service and Maintenance Contractor, under the review of Renteknik Group Inc. Table 3 and 4 below provide a summary of the EEMs on both the Low Temperature (LT) and Medium Temperature (MT) Racks.

TABLE 3: ENERGY EFFICIENCY MEASURES IMPLEMENTED ON LOW TEMPERATURE RACK

Energy Efficiency Measure	Compressor Information	Implementation #
1. Replacement of one (1) existing Semi-Hermetic Copeland Compressor with one (1) 22 HP Semi-Hermetic Digital Discus Compressor.	Compressor Model #: 4DT3F6KE-TSE-800 S/N 12A65048R	1

TABLE 4: ENERGY EFFICIENCY MEASURES IMPLEMENTED ON MEDIUM TEMPERATURE RACK

Energy Efficiency Measure	Compressor Information	Implementation #
1. Replacement of one (1) existing Semi-Hermetic Copeland Compressor with one (1) 15 HP Semi-Hermetic Digital Discus Compressor.	Compressor Model #: 3DS3R17ME-TFE-800 S/N 13K00809R	1

2. BASE CASE VS. ENERGY EFFICIENCY CASE (M&V)

The Savings estimated from the Variable Capacity Digital Discus retrofit were noted to be 122,965 kWh, representing approximately 16% savings and an Ontario Power Authority (OPA) incentive of $12,296.50 for the Project at a rate of $0.10/kWh. These values are determined using Pre-Implementation baseline data and Post-Implementation data collected by the *ClimaCheck* system that has been installed and logging data, including electricity consumption on a one minute interval since November 2012. This represents an annual operational saving of $17,215 based on a blended electricity rate of $0.140/kWh.

As part of the Measurement and Verification (M&V) process the permanently installed *ClimaCheck* Performance Analyzer System was used to log data, Pre Implementation (Base Case) and Post Implementation (Energy Efficiency Case) to validate the estimated annual kWh savings achieved through the implementation of these EEMs. The Base Case and Energy Efficiency Case Data for these periods with calculated Savings are included below.

TABLE 5: PRE- IMPLEMENTATION PERIOD

System	Pre-Implementation Period Energy Consumption*	Pre- Implementation Yearly kWh Consumption Estimate	Pre- Implementation Peak kW Demand
LT Rack	263,330	433,441	**64.5**
MT Rack	181,330	343,274	**62.6**
Total	444,660	786,715	

*Pre-Optimization Period is September 1st 2013 to April 22nd 2014 (223 days)

TABLE 6: POST- IMPLIMENTATION PERIOD

System	Post- Implementation Period Energy Consumption*	Post- Implementation Yearly kWh Consumption Estimate	Post- Implementation Peak kW Demand
LT Rack	74,988	386,051	**62.6**
MT Rack	55,344	267,699	**59.6**
Total	130,332	653,750	

*Post Optimization Period is April 23rd 2014 to June 30th 2014 (69 days)

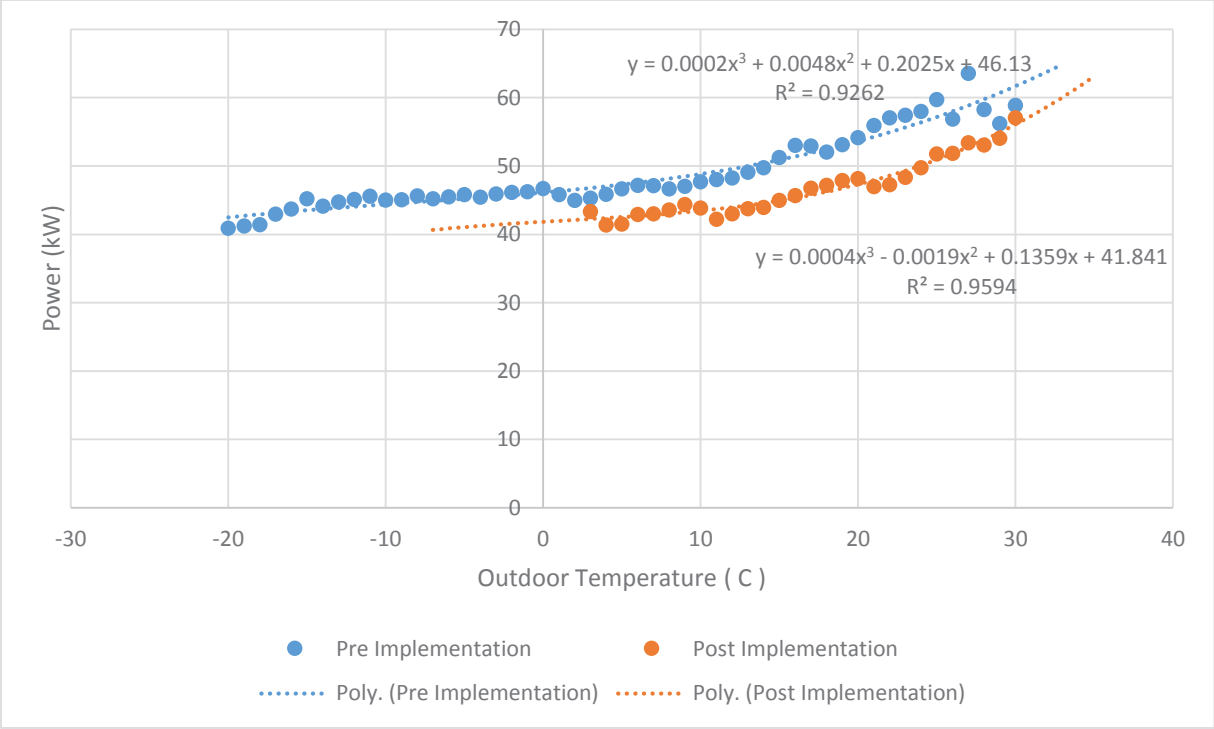
Energy Savings

LT Rack kW Demand Savings = 1.9kW
MT Rack kW Demand Savings = 3.0kW
LT Rack annual kWh Savings = 47,390kWh
MT Rack annual kWh Savings = 75,575kWh
Total annual kWh Savings = **122,965 kWh**

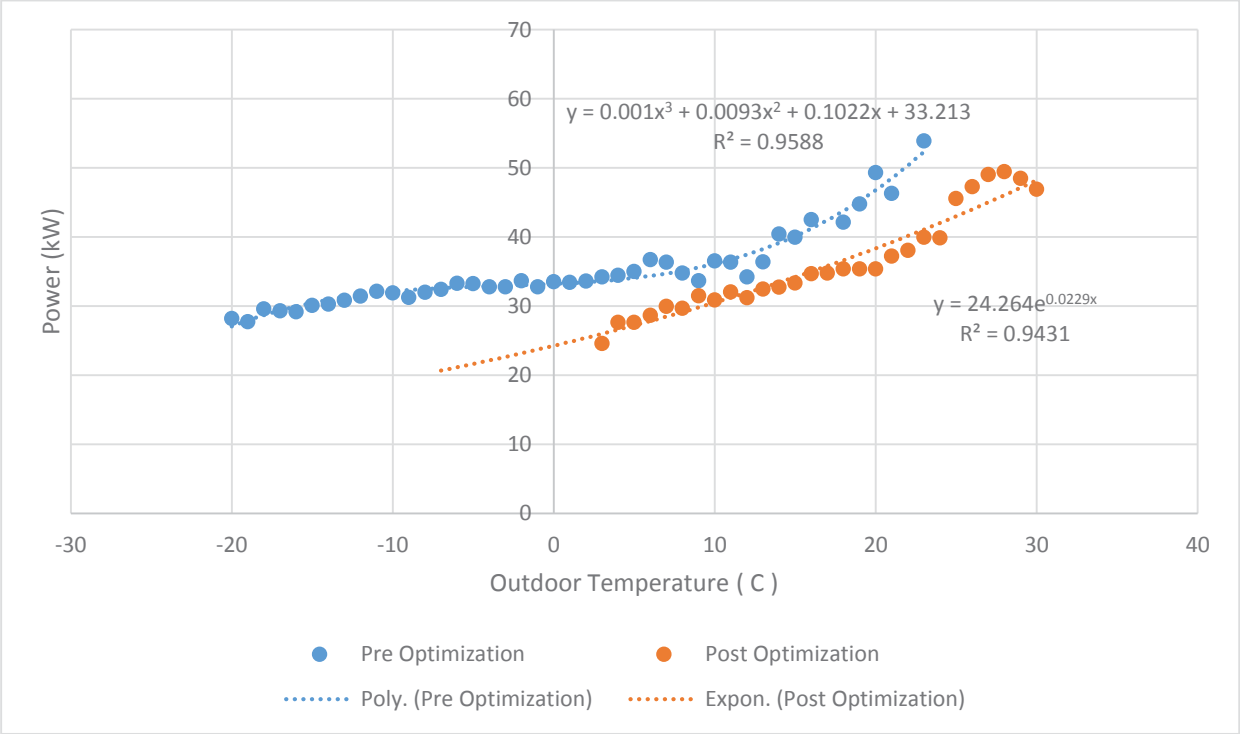
Pre-Implementation and Post-Implementation yearly kWh figures were calculated using annual temperature data and power profile equations derived from *ClimaCheck* data. Graphs 1 and 2 below show the power profile for the LT and MT Racks respectively, including the power profile equations used to generate the yearly energy consumption. All of these equations have R Squared values greater than 0.9, representing very high accuracy of the equations.

Although the *ClimaCheck* system was operating for the duration of 2013, recorded energy values do not give an accurate representation of the yearly energy consumption of the system, due to earlier implementations being made part way through the year. For this reason the baseline data for the Pre-Implementation power profile uses data from the period of September 1st 2013 to April 22nd 2014, the date of the compressor retrofit. Post-Implementation data is from the period of April 23rd 2014 to June 30th 2014.

Graph 1: LT Rack Power Profile

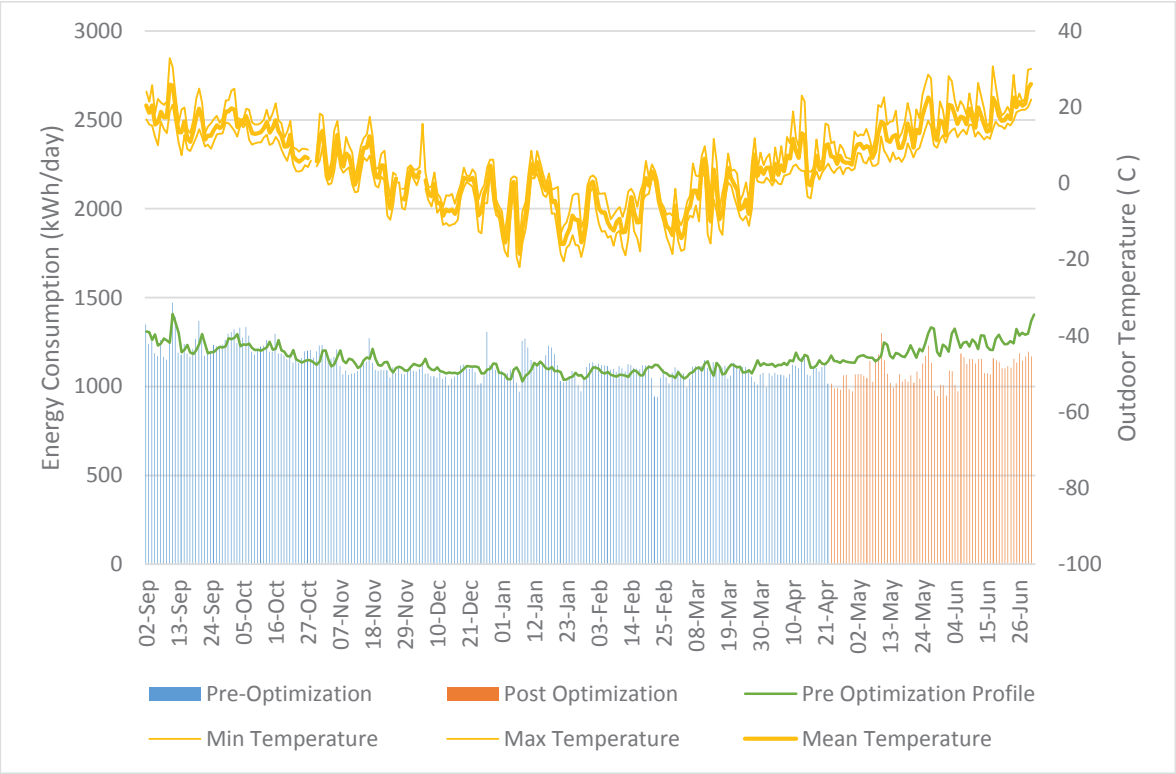


Graph 2: MT Rack Power Profile

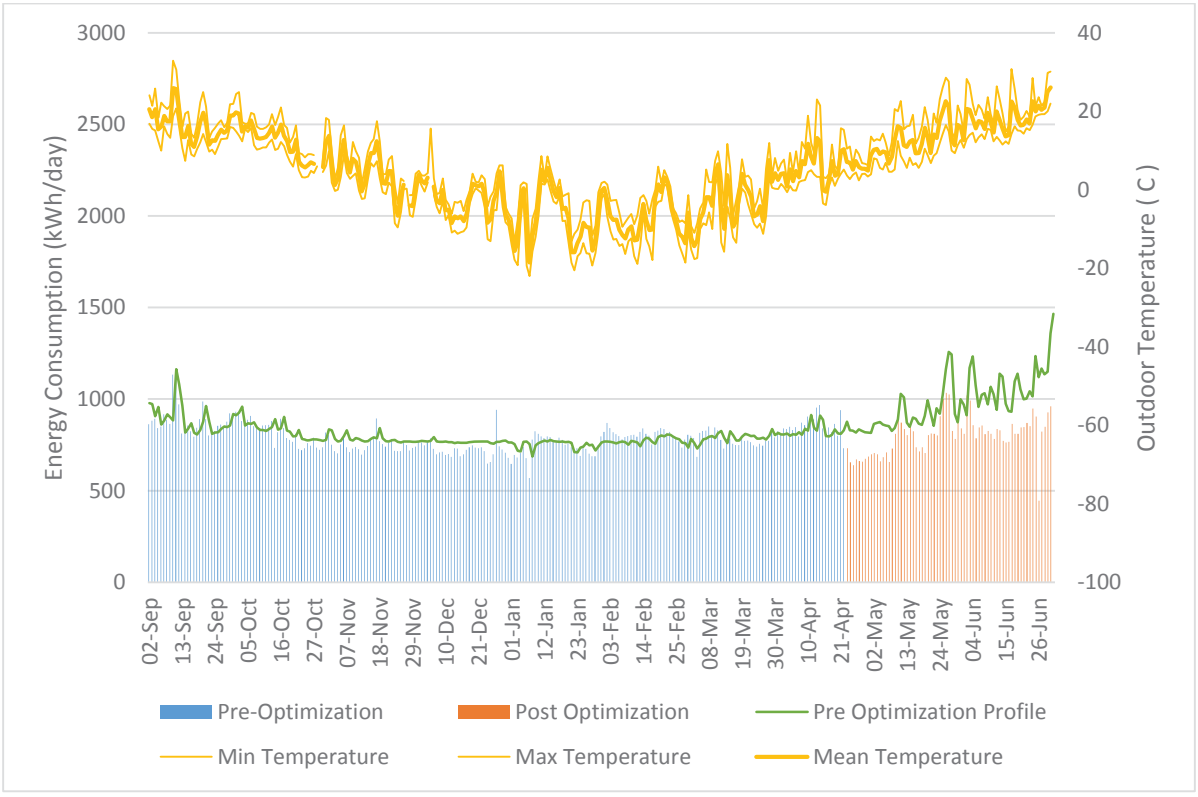


Graphs 4 and 5 below show the difference between the Pre-Implementation and Post-Implementation energy consumption over an extended period of time. The Graphs reinforce the long term benefits of the *ClimaCheck* ongoing monitoring and Continual Commissioning process to be able to evaluate the effects of future Non-Capital and Capital implementations on System performance and energy and cost savings. The Pre- Implementation Profile line shows the expected daily energy consumption based upon outdoor temperature. The profile follows the recorded daily energy consumption closely during the Pre-Implementation period as expected. Following the implementaion of the Variable Capacity Digital Discus Compressors, the actual daily energy consumption is seen to be much lower than the Pre- Implementation Profile, representing the energy savings.

Graph 4: LT Rack Daily Energy Consumption

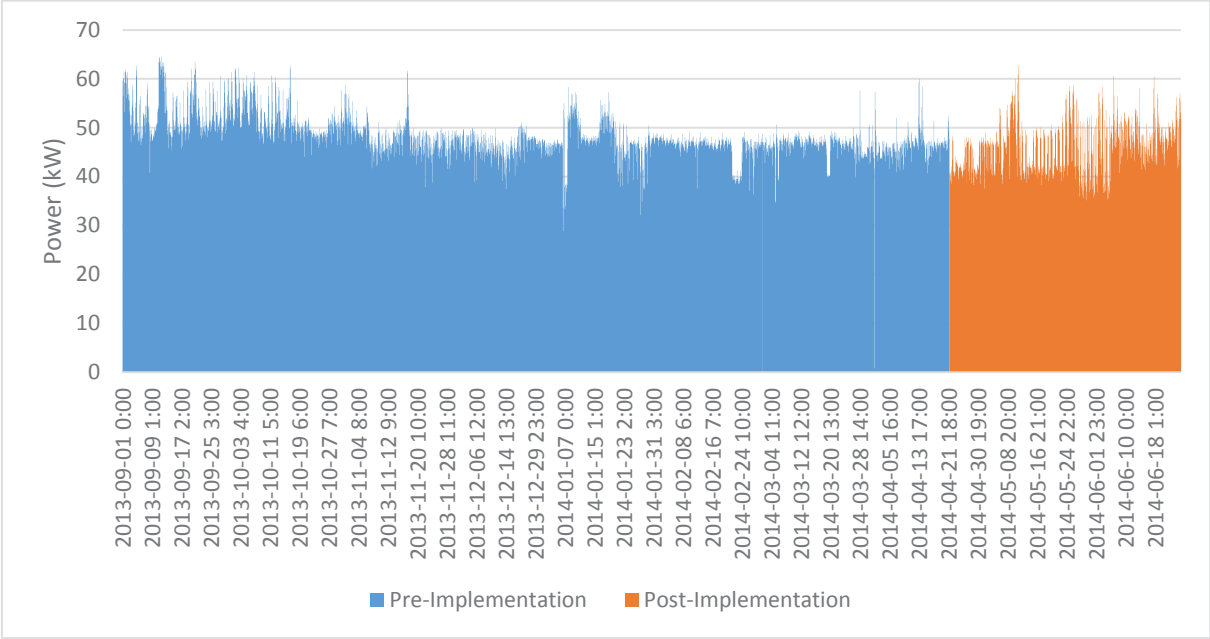


Graph 5: MT Rack Daily Energy Consumption

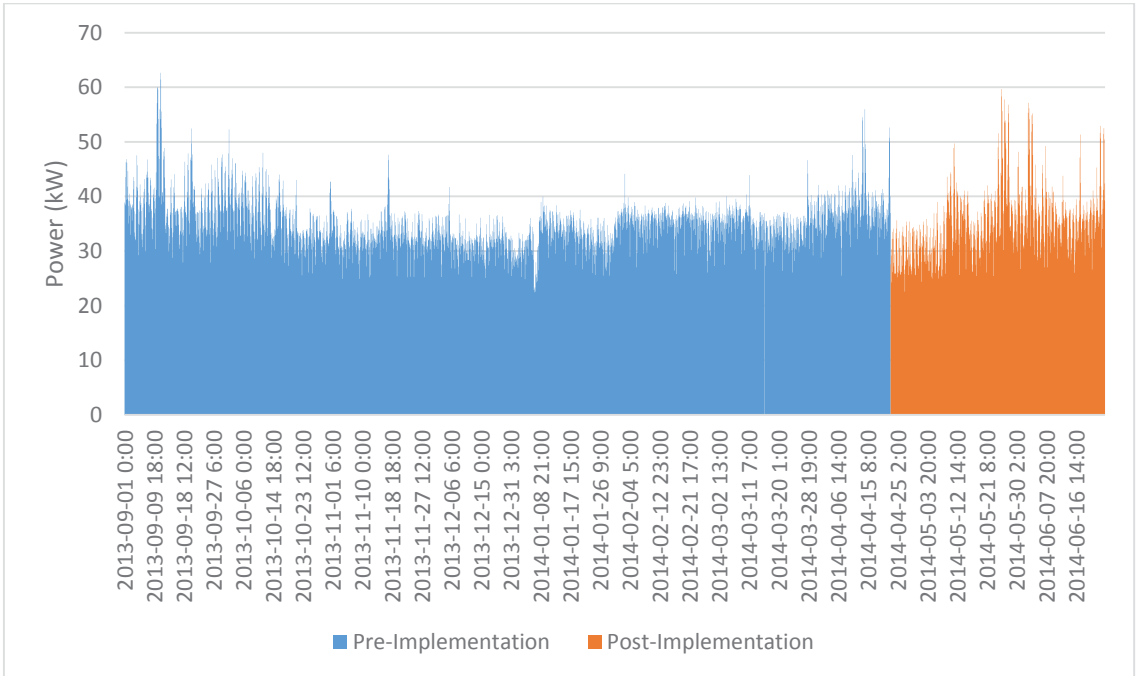


For the purpose of this Report the Peak kW consumption has been graphed. Graphs 6 and 7 below show the average hourly power demand in kW of the system. Since the replacement compressors have the same HP rating as the existing compressors, peak kW demand is not expected to decrease substantially when the system is operating at full load.

Graph 6: LT Rack Power Demand



Graph 7: MT Rack Power Demand



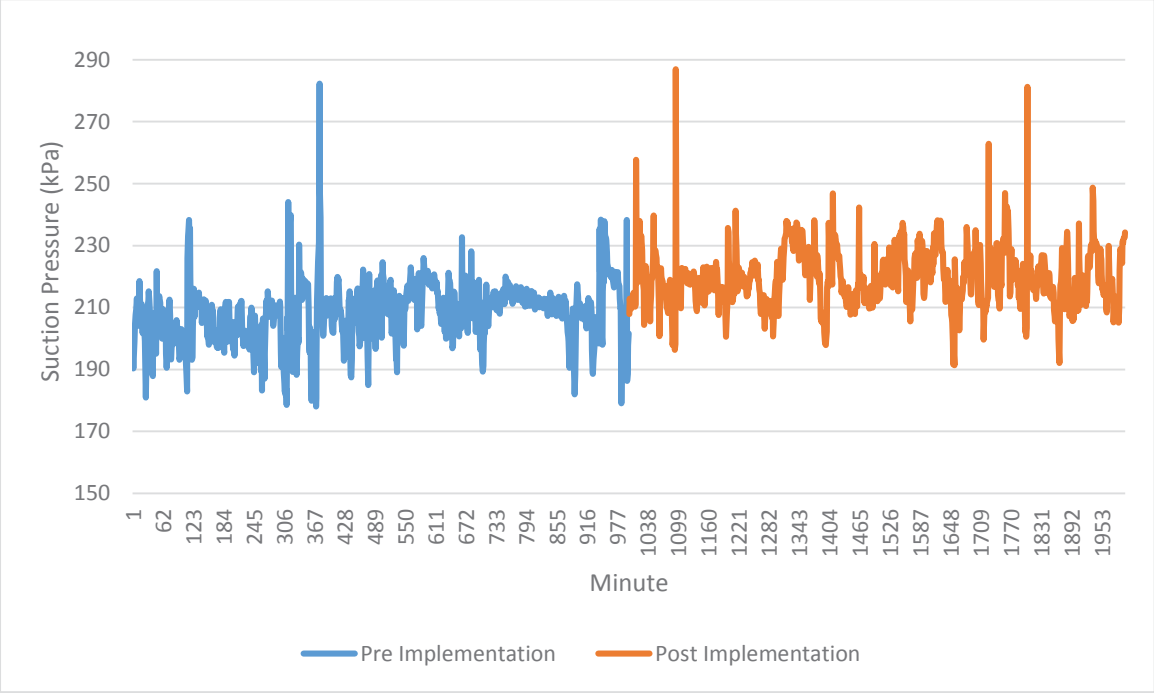
The Digital Compressors also provided improved control over suction pressure. Table 7 below shows the average suction pressure and standard deviation for both the LT and MT Racks Pre and Post Implementation. Graphs 8 and 9 below show the sucion pressure for both the LT and MT Racks Pre and Post Implementation over 1,000 minute samples. Standard Deviation on the LT Rack suction pressure improved by 39.8%. Standard Deviation on the MT Rack Suction Pressure Improved by 42.6%.

TABLE 7: SUCTION PRESSURE COMPARISON

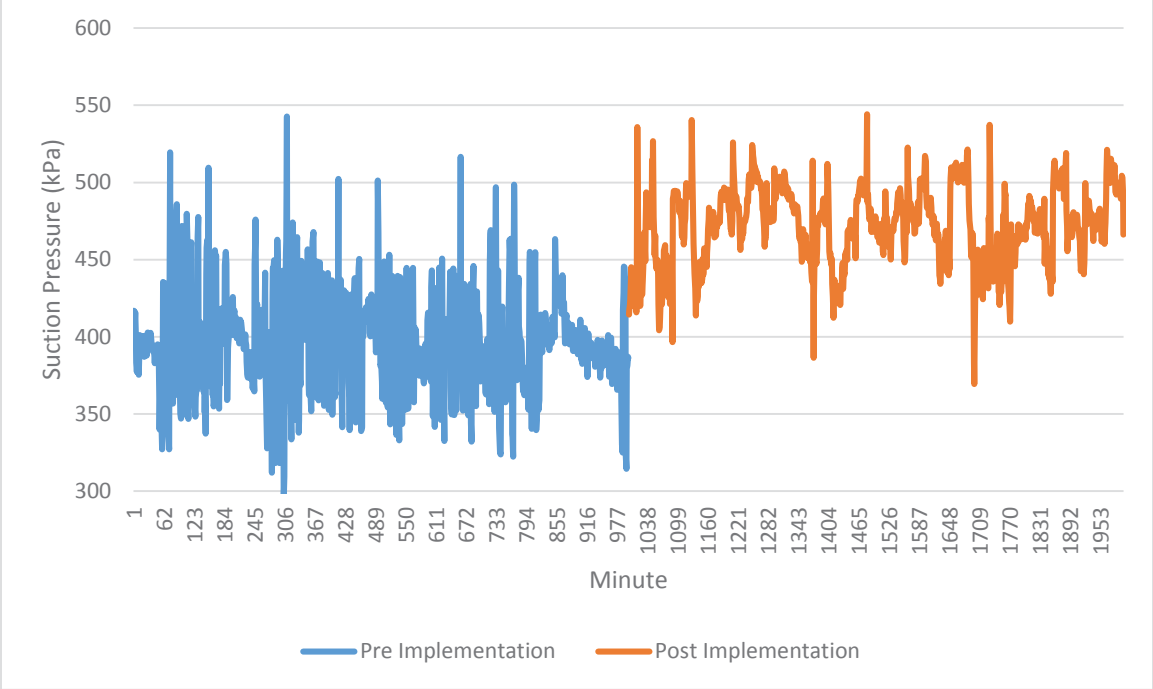
System	Pre Implementation Average Suction Pressure (kPa)*	Post Implementation Average Suction Pressure (kPa)**	Pre Implementation Suction Pressure Standard Deviation	Post Implementation Suction Pressure Standard Deviation
LT Rack	211.04	216.88	27.12	16.34
MT Rack	400.87	470.79	41.78	23.97

*Pre Implementation Period is February 1st 2014 to April 21st 2014 (89 days)
**Post Implementation Period is April 23rd 2014 to June 30th 2014 (69 days)

Graph 8: LT Rack Suction Pressure



Graph 9: MT Rack Suction Pressure



BUSINESS CASE EVALUATION:

1. DEMONSTRATION PROJECT ECONOMICS

The following Table 8 is the actual energy savings claimed for the Demonstration Project based on 223 days of baseline data reviewed against 69 days of post project data and then related to the incentives at $0.10/kWh and operational savings at $0.140/kWh.

TABLE 8: ACTUAL ENERGY SAVINGS

Item	Energy savings kWh/year	OPA Incentive	Annual savings
Rate		$0.10/kWh	$0.140/kWh
LT	47,390	$ 4,739	$ 6,635
MT	75,575	$ 7,558	$ 10,580
TOTAL	**122,965**	**$ 12,297**	**$ 17,215**

The following Table 9 is a summary of the actual costs for this Demonstration Project. The cost of the compressors includes for a new compressor with the Variable Capacity Digital Discus pre-installed because it had been previously identified through analysis of the *ClimaCheck* data that there was one (1) weak compressor in each rack in the original enhanced recommissioning and optimization reporting. The cost of replacing the compressor was paid to the Service and Maintenance Contractor by the facility owner and copies of the Invoices were reviewed and will form part of the OPA Incentive submission.

TABLE 9: ACTUAL DEMONSTRATION PROJECT COST

Item	Cost	Supplier/Contractor/Consultant
Compressor upgrade - LT	$ 7,293	Contractor - New Compressor with Digital Discus
Compressor upgrade - MT	$ 6,532	Contractor - New Compressor with Digital Discus
Control Upgrade	$ 3,317	Service and Maintenance Contractor
Engineering and M&V	$ 7,450	Renteknik
Total Proof of Concept Project Cost	**$ 24,592**	

The following Table 10 shows the Total Demonstration Project cost, the OPA Incentive, which is capped at 50% of project cost (Note: the maximum OPA Incentive based on the actual kWh savings would be $12,296.60 but the this cannot exceed 50% of the project costs) and the net Project Cost. The simple payback is calculated on the Net Project Costs with and also without Incentives.

TABLE 10: SUMMARY OF DEMONSTRATION PROJECT COSTS, OPA INCENTIVES, ANNUAL OPERATIONAL SAVINGS AND SIMPLE PAYBACK CALCULATIONS

Total Project Cost	$ 24,592
OPA Incentives (Max 50% of costs)	$ 12,296
Net Project Cost	$ 12,296
Estimated Annual savings	$ 17,215
Simple payback with Incentives	**0.7 years**
Simple payback without Incentives	**1.4 years**

Since not all future locations will require a compressor replacement a **'Simple Project'** was defined as one that only need to do a compressor head upgrade (Variable Capacity Digital Discus Upgrade Kit) as shown in the Simple Project example below. In addition, since this was a Demonstration Project, extra costs were incurred for the Measurement and Verification, Engineering and Reporting that would not be as detailed in future projects so a **'Standard Project'** was also defined as also shown below. The cost of the new PC and Control System Software upgrade can also be captured as a project cost since this is required to properly operate the Variable Capacity Digital Discus Compressors in both the Simple Project and the Standard Project. The last item is the Renteknik Costs for Engineering, OPA Incentive Application Filing, M&V and OPA reporting. **Please note that the foregoing assumes that there is a Permanent *ClimaCheck* System already installed as part of a full facility refrigeration enhanced recommissioning project.**

2. STANDARD PROJECT ECONOMICS

The following tables are a repeat of the tables shown above for the Demonstration Project Economics but modified for the Standard Project which includes one Variable Capacity Digital Discus Compressor replacement on each of the Low Temperature and Medium Temperature Racks together with the New PC and Control System upgrade and a reduced project cost for basic Engineering, OPA Incentive Application Filing, M&V and OPA reporting.

TABLE 11: ESTIMATED STANDARD PROJECT COSTS

Item	Cost	Comments
Compressor upgrade - LT	$ 7,500	New Compressor with Digital Discus
Compressor upgrade - MT	$ 7,000	New Compressor with Digital Discus
Control Upgrade	$ 4,000	Control Upgrade
Engineering and M&V	$ 4,500	Renteknik
Total	**$ 23,000**	

TABLE 12: SUMMARY OF STANDARD PROJECT COSTS, OPA INCENTIVES, ANNUAL OPERATIONAL SAVINGS AND SIMPLE PAYBACK CALCULATIONS

Total Project Cost	$ 23,000
OPA Incentives (Max 50% of costs)	$ 11,500
Net Project Cost	$ 11,500
Estimated Annual savings	$ 17,215
Simple payback with Incentives	**0.7 years**
Simple payback without Incentives	**1.3 years**

3. SIMPLE PROJECT ECONOMICS

The following tables are a repeat of the tables shown above for the Demonstration Project Economics and the Standard Project Economics but modified for the Simple Project which excludes the compressor replacement on each of the Low Temperature and Medium Temperature Racks and assumes that only the Digital Discus Upgrade Kit is installed onto existing compressors in each Rack. The Simple Project still includes the New PC and Control System upgrade and a reduced project cost for basic Engineering, OPA Incentive Application Filing, M&V and OPA reporting.

TABLE 13: ESTIMATED SIMPLE PROJECT COSTS

Item	Cost	Comments
Compressor upgrade - LT	$ 2,800	Digital Discuss Upgrade Kit
Compressor upgrade - MT	$ 2,800	Digital Discuss Upgrade Kit
Control Upgrade	$ 4,000	Control Upgrade
Engineering and M&V	$ 4,500	Renteknik
Total	**$ 14,100**	

TABLE 14: SUMMARY OF SIMPLE PROJECT COSTS, OPA INCENTIVES, ANNUAL OPERATIONAL SAVINGS AND SIMPLE PAYBACK CALCULATIONS

Total Project Cost	$ 14,100
OPA Incentives (Max 50% of costs)	$ 7,050
Net Project Cost	$ 7,050
Estimated Annual savings	$ 17,215
Simple payback with Incentives	**0.4 years**
Simple payback without Incentives	**0.8 years**

RECOMMENDATIONS FOR SIMILAR FACILITY LOCATIONS:

Based on the collected data, Measurement and Verification (M&V) Analysis and Business Case Evaluation performed it is our recommendation that the implementation of Variable Capacity Copeland Digital Discus Compressor Technology together with a Control System Upgrade should be performed at all Facility Owners locations with Medium and Low Temperature Refrigeration Racks as part of an overall *Enhanced Recommissioning and Optimization Project* that encompasses both no-cost/low-cost optimizations as well as capital projects. Ideally this should be performed in conjunction with the installation of Permanent *ClimaCheck* Systems to validate the energy savings achieved and to provide a Continual Commissioning tool that ensure that there is no degradation of the savings over time.

Without performing an *Enhanced Recommissioning and Optimization Project* it is still possible to achieve energy savings through the implementation of the Variable Capacity Copeland Digital Discus Compressors either through replacement or upgrade of an existing compressor however it will be more difficult to perform the required M&V to satisfy the requirements under the OPA Incentive program and without fully recommissioning the refrigeration system operation the fully potential of savings may not be realized.

It should also be noted that in both the Standard Project and Simple Project the anticipated energy saving of approximately 120,000 kWh per year from this EEM would provide for an incentive of approximately $12,000 (at a $01.0/kWh rate) however the incentive will be capped at 50% of the actual project cost. The net result is that if this project is done in isolation there will be incentive money available that cannot be collected. To fully benefit from the available incentives it would be beneficial to incorporate this EEM with other EEMs in order that the total cost of all measures together and the total energy saving allows for full utilization of available incentives.

Wherever possible it should also be the case that the weakest compressor in each rack is identified for full replacement rather than just a retrofit since this will also take full advantage of available incentives.

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Date Completed March 6th 2015	Date Reviewed: March 6th, 2015
Signature:	Signature: