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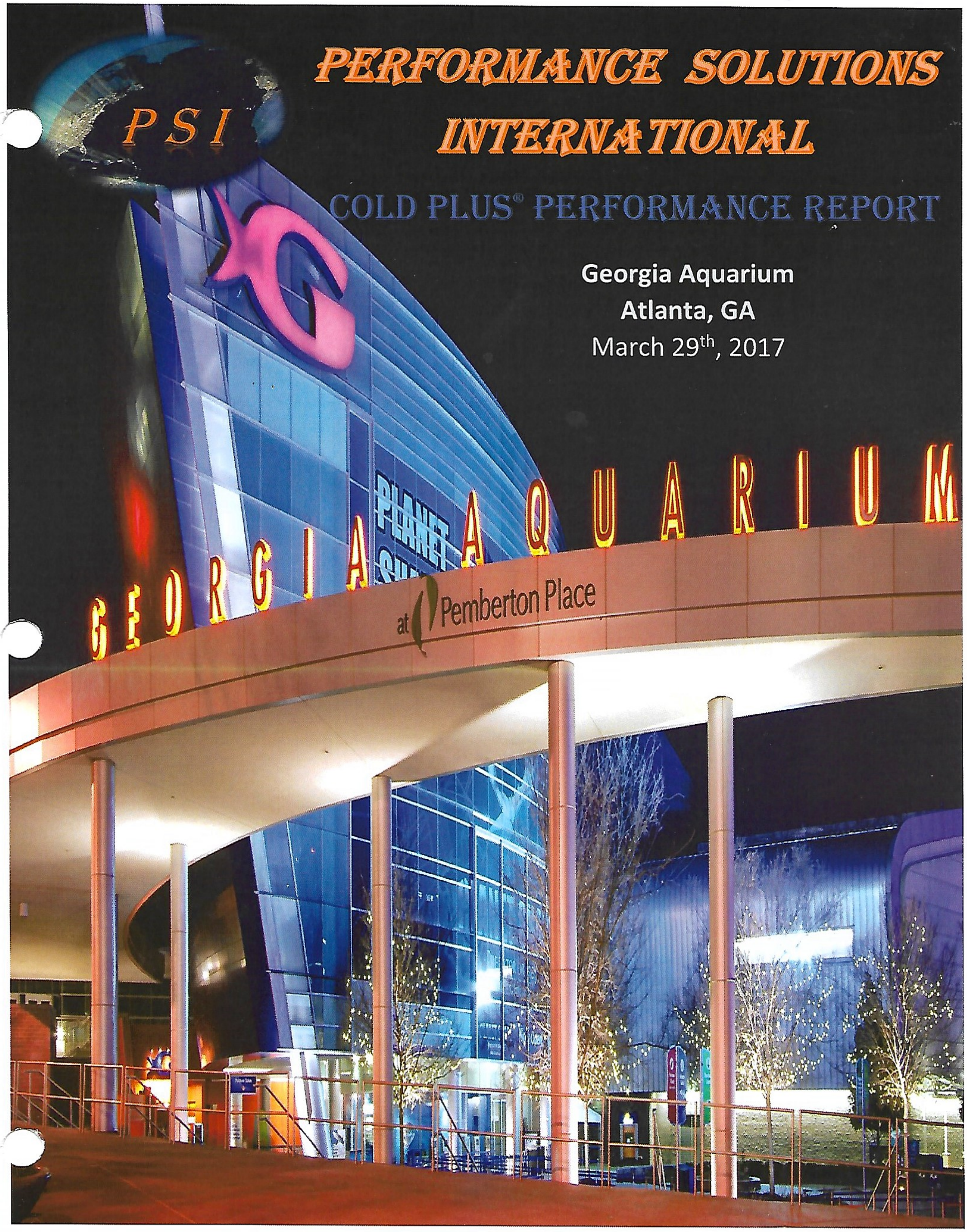
PERFORMANCE SOLUTIONS INTERNATIONAL

COLD PLUS® PERFORMANCE REPORT

Georgia Aquarium
Atlanta, GA
March 29th, 2017



Cold-Plus® Testing Analysis and Report of Findings
Georgia Aquarium, Atlanta GA
March 29th, 2017

Chiller 2 Only (Completed)

Project Executive Summary

The Purpose of the test was to demonstrate the results of installing Cold Plus® into one of the Trane CVHF 910 chillers that service the aquarium tanks that are required to maintain temperature within +/-.5°F. The results as demonstrated by the attached report compiled by Professor Peter Jenkins, Ph.D., P.E, define an 8.6% efficiency improvement.

In collaboration with the Georgia Aquarium, Patrick Starnes, Tim Denney, David Nash and the installation team from McKenney's, it was agreed that the following data would be collected from the Georgia Aquarium's own *Chiller Check* program and analyzed from chiller #2 located in Atlanta, GA.

The data compares energy efficiency expressed by comparing the energy consumed to produce a ton of cooling prior to and after the installation of Cold Plus®. Interval data was collected from the *Chiller Check* program one week prior to the installation of Cold Plus® and was compared to 4 consecutive days of interval data post installation and prior to the standard chiller rotational shutdown.

The onsite engineers provided the assumptions that due to redundancy and backup configurations each chiller only runs approximately 60% of the time on an annualized basis.

The conclusions provided in the report indicate an efficiency gain on Chiller 2 with a calculated ***8.6% improvement in electrical consumption*** per ton cooled that can be attributed to the installation of Cold Plus®. Once injected, Cold Plus® caused a more efficient flow of the refrigerant and more efficient transfer of the cooling through the cooling system. This in turn resulted in less compressor usage per degree of cooling produced and supports the manufacturer's claim of significant energy savings and extension of life of the equipment after the injection of Cold-Plus®.




Testing Procedure Overview:

1. Introduction & Project Overview:

Performance Solutions International project managed a performance test of the Cold Plus® product on Chiller #2 at the Georgia Aquarium. The goal was to determine the energy impact of installing 168 ounces of Cold Plus®.

- Trane 910 Ton Chiller Model CVHF 910

2. Equipment Used:

Performance Solutions International worked with McKenney's to gather the following data:

- Amps
- Evaporator Inlet Temperature
- Evaporator Outlet Temperature
- Evaporator Gallons Per Minute (GPM)
- ΔT (Temperature Differential) Across Evaporator
- Tons of Evaporative Cooling
- kW (Kilowatts)
- kW/Ton
- Condenser Flow Rate
- Condenser Inlet Temperature
- Condenser Outlet Temperature
- ΔT Across Condenser
- Tons of Condensing

3. Methodology:

- Baseline measurements of all sensors were recorded utilizing *Chiller Check* for 7 days prior to installing Cold Plus using continuous operation for 24 hours to maintain the +/-.5°F temperature 24/7/365.
- Raw Data results were analyzed
- Data was consolidated to four 24 hour like continuous periods
- Baseline electrical consumption required to produce a ton of cooling was compared prior to and after the installation of Cold Plus®

4. Results:

- The compiled results provided show an ***8.6% efficiency improvement*** of Chiller #2 based on the data collected and integrated into the attached report provided by, Professor Peter Jenkins, Ph.D., P.E.

DETAILED ENGINEERING REPORT PRODUCED

BY:

PROFESSOR PETER JENKINS, PH.D., PE

Peter E. Jenkins, Ph.D., P.E.
Professor, Mechanical Engineering Dept.
University of Colorado Denver
Denver, Colorado 80217

Work Address:
Mechanical Engineering Dept.
University of Colorado Denver
Denver, CO 80217
Phone: 303/556-2894
Email: peter.jenkins@ucdenver.edu

Summary

Extensive experience serving in administrative and management positions in both industry and academic institutions. Served as an officer of the University of Colorado Denver and of an advanced technology and manufacturing company with experience in administration, strategic and financial planning. Experience as senior contract officer dealing with U.S. and foreign industrial and government agencies. Academic and industry experience includes serving as Dean, Department Chair, Associate Department Chair, Executive Vice President, Chief Operating Officer, and Director of Engineering.

Successful experience dealing with government and industry institutions and have had success working and obtaining support from both political and industrial agencies. Enjoy outreach programs and working with the industrial and state political systems to obtain program support. Have extensive experience working with industry and government agencies to develop partnerships for technology transfer and for developing R&D programs.

Education

Ph.D.	Purdue University, W. Lafayette, IN, 1974
M.S.	Southern Methodist University, Dallas, TX, 1969
B.S.	University of Kansas, Lawrence, KS, 1965
I.E.M.	Harvard University, Cambridge, MA, 1994
M.B.A.	Pepperdine University, Malibu, CA, 1986

Military Experience

United States Marine Corps: 1958-1963

Academic Experience

United States Naval Academy, Annapolis, ME

- Visiting Professor, Mechanical Engineering Dept, July, 2007- August, 2008
- Director, ONR Fuels Research Group

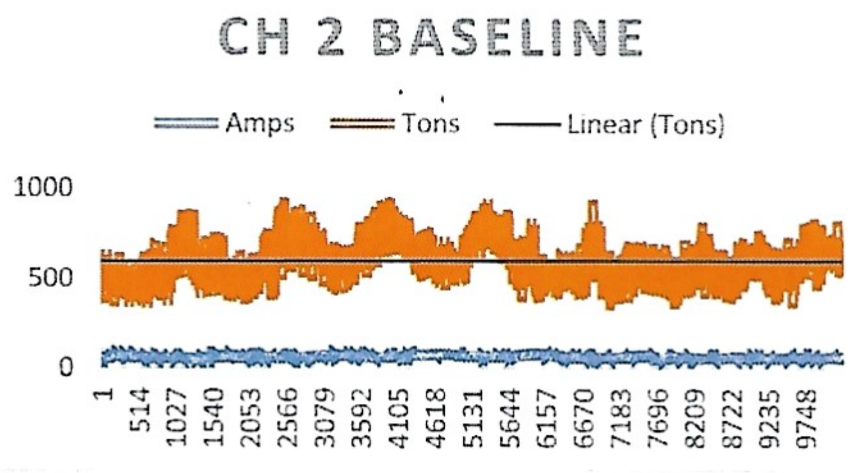
United States Air Force Academy, Colorado Springs, CO

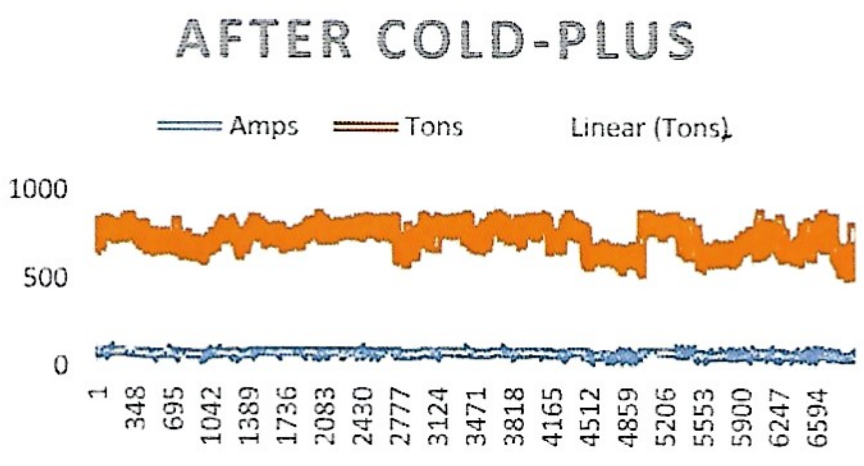
- Distinguished Visiting Professor, Engineering Mechanics Dept., July 2004-May, 2006
- Director, Energy Research Center
- Member of UAV Research Program

Georgia Aquarium Chiller 2

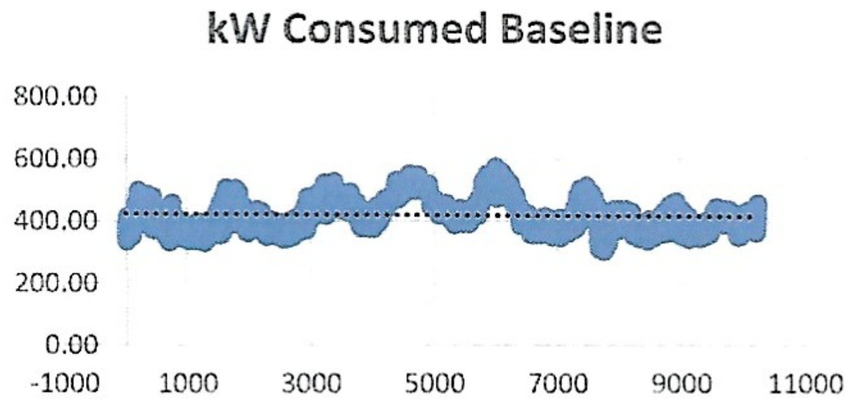
This is the comparison of the operational characteristics of Chiller 2 at the Georgia Aquarium before and after the installation of Cold-Plus™. The chiller is a Trane CVHF 910r, 23 which is part of the system providing water temperature control for the aquarium tanks. Temperature control of this water is within .5 F degrees. In order to achieve this control there is a heating component that works in conjunction with the chiller. Data was taken from the chiller management system to provide a baseline from November 21st thru 28th, 2016. The unit was injected with 168 fl.oz of Cold-Plus™ on December 14th, 2016 and operated until December 24th when the logging was started again and operated until December 29th, 2016 when the chiller was shut down as part of the normal chiller rotation.

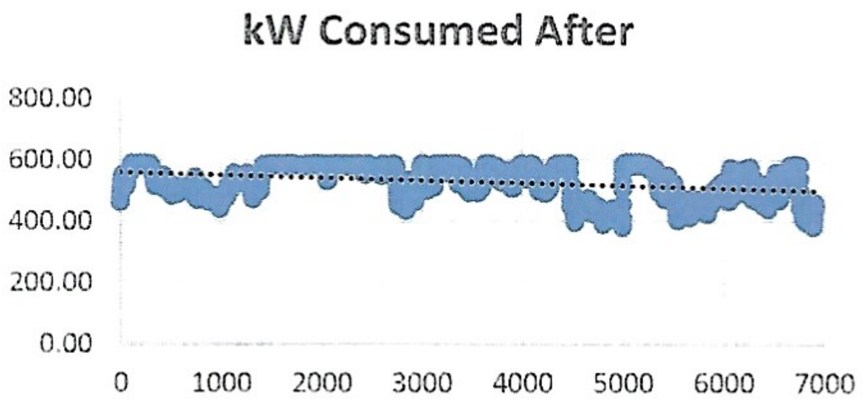
The best way to illustrate the results is graphically followed by data. We will begin by looking at all the data for before and after installation. The graphs are shown side by side showing baseline and after injection.





The numbers at the bottom of the chart show individual data points





Left axis is kW the unit is consuming.

What we see here is the tons produced is higher in the after data than the baseline. The kW consumed is also higher to produce the additional required tonnage. We also observe tighter operating band for the tons produced in the post data. Looking at the other data collected we see what was involved in the change.

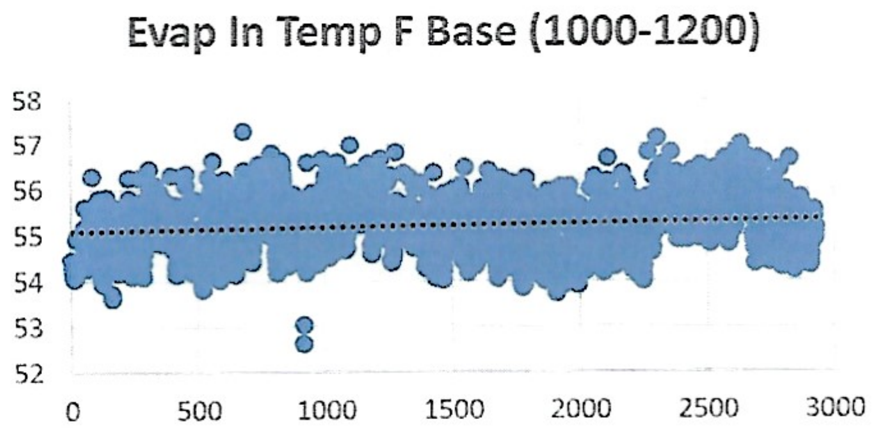
	Evap In Temp F	Evap Out Temp F	Evap Gal/Min	Δ	Tons Evap	kW	kW/Ton	Cond Flow Rate	Cond In F	Cond Out in F	Δ	Tons Cond
Base	55.17	43.18	1203.10	11.99	600.99	419.47	0.70	1749.59	80.31	90.09	9.79	713.57
Post	56.18	44.59	1479.89	11.59	711.27	530.23	0.71	1920.25	80.29	91.58	11.29	903.85
	-1.02	-1.42	-276.78	0.40	-110.28	-110.76	-0.02	-170.65	0.02	-1.49	-1.51	-190.28
	-1.8%	-3.3%	-23.0%	3.3%	-18.3%	-26.4%	-2.4%	-9.8%	0.0%	-1.6%	-15.4%	-26.7%

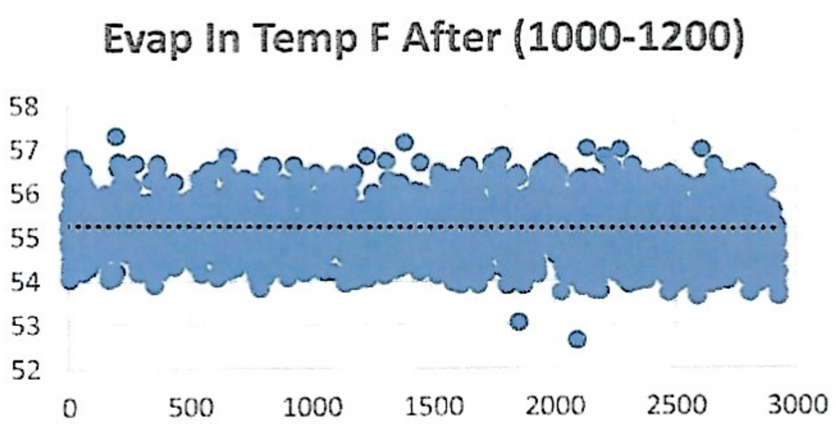
First of all the evaporator in temperature increases 1.8% while the evaporator out temperature increases 3.3%. This is due to additional load which is compensated for with increased coolant flow of 23%. This increases tons of evaporator output by 18.3% with an accompanying 26.4% increase in kW. The condenser flow rate increases by 9.8% to compensate for the additional heat produced.

As we look at these graphs we see two scenarios as far as heat load is concerned with significant variation in each data set. What is happening here is manual management of the chiller to meet the needs of temperature control in the tanks. The chiller is operating in a mode that allows for control at the heat exchangers to maintain the .5 degree tolerance as opposed to normal operation where there would be more temperature variance. This is perfectly understandable in this scenario.

There are common GPM flow rates in both data sets so we can look at them to see what is happening under similar conditions. The data will come from evaporator flow rate of 1000-1200 gpm, 1201-1400 gpm and 1401-1600 gpm.

Since there is considerable more data available in the baseline data we will limit the data in both sets to four 24 hour consecutive periods.

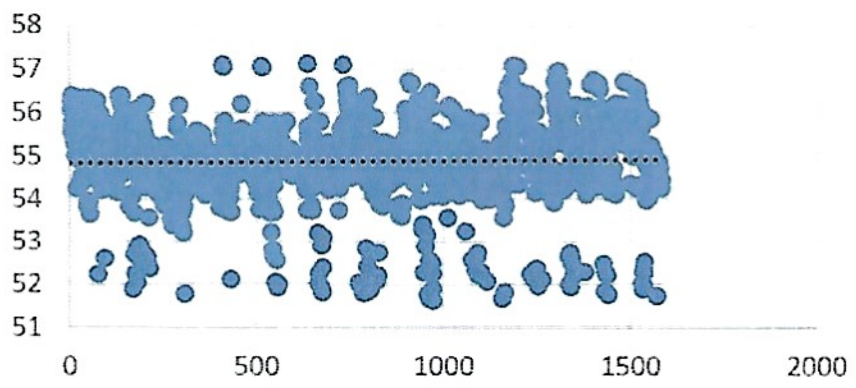




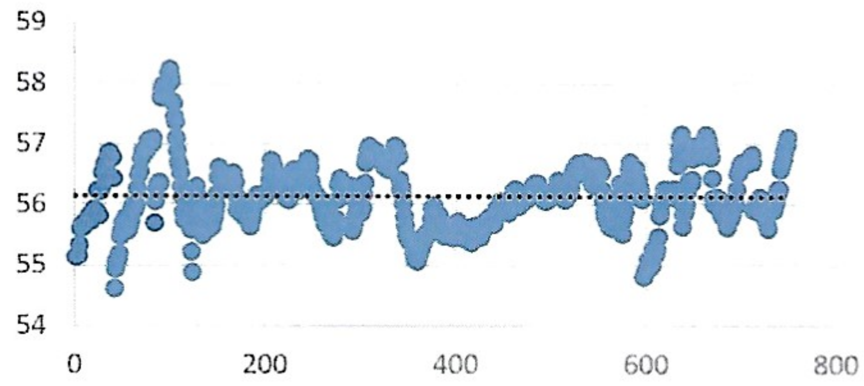
	Amps	Evap In Temp	Evap Out Temp	Evp Gal/Min	Δ	Tons Evap	kW	kW/Ton	Cond Flow Rate	Cond In	Cond Out	Δ	Tons Cond
1000-1200													
base	60.95	55.22	43.13	1098.25	12.09	552.90	417.21	0.76	1750.82	80.28	89.99	9.70	707.95
after	62.47	56.52	43.40	1151.70	13.12	628.70	427.57	0.68	1884.54	79.98	89.54	9.56	750.84
	-1.51	-1.30	-0.26	-53.46	-1.03	-75.80	-10.36	0.08	-133.72	0.30	0.45	0.14	-42.88
					-	-							
	-2.5%	-2.4%	-0.6%	-4.9%	8.6%	13.7%	-2.5%	10.9%	-7.6%	0.4%	0.5%	1.5%	-6.1%

Using kW/ton as the measurement this flow rate shows a 10.9% improvement over the base. The improvement in ΔT was 8.6%.

Evap In Temp F Base (1201-1400)



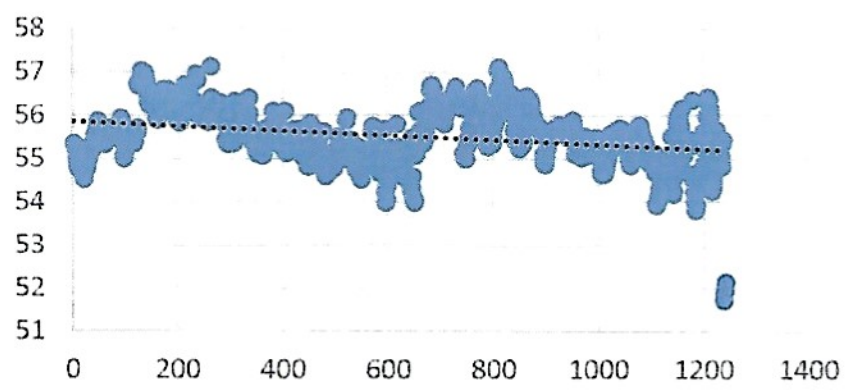
Evap In Temp F After(1201-1400)



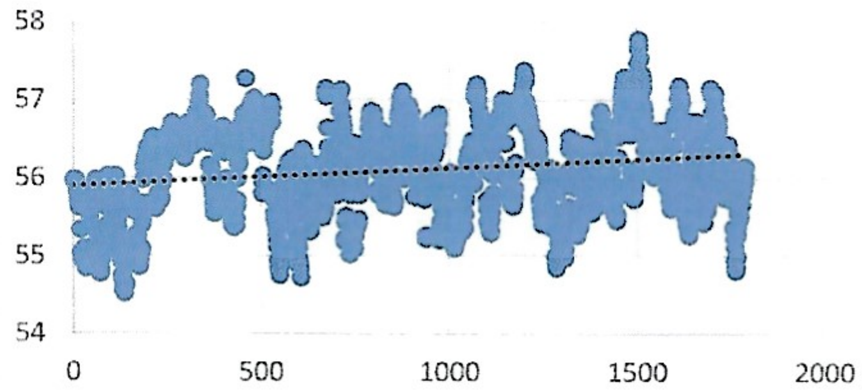
	Amps	Evap In Temp	Evap Out Temp	Evp Gal/Min	Δ	Tons Evap	kW	kW/Ton	Cond Flow Rate	Cond In	Cond Out	Δ	Tons Cond
1200-1400													
base	66.33	54.88	43.41	1295.76	11.47	620.15	454.01	0.74	1749.95	80.35	91.18	10.83	789.69
after	67.03	56.13	44.22	1327.73	11.91	658.53	459.37	0.70	1916.55	80.15	90.44	10.29	821.81
	-0.70	-1.25	-0.81	-31.97	-0.44	-38.38	-5.36	0.05	-166.60	0.20	0.74	0.54	-32.11
	-1.1%	-2.3%	-1.9%	-2.5%	-3.8%	-6.2%	-1.2%	6.2%	-9.5%	0.2%	0.8%	5.0%	-4.1%

Using kW/ton as the measurement this flow rate shows a 6.2% improvement over the base. The improvement in ΔT was 3.8%.

Evap In Temp F Base (1401-1600)



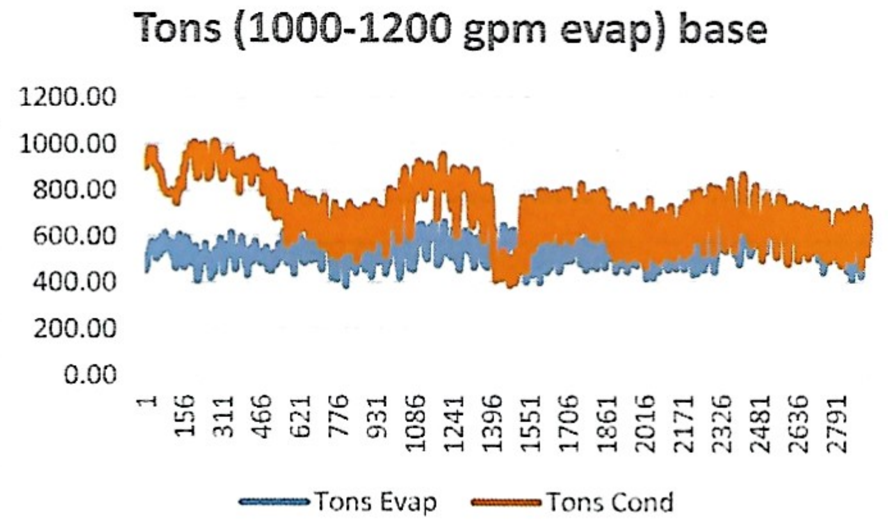
Evap In Temp F After (1401-1600)

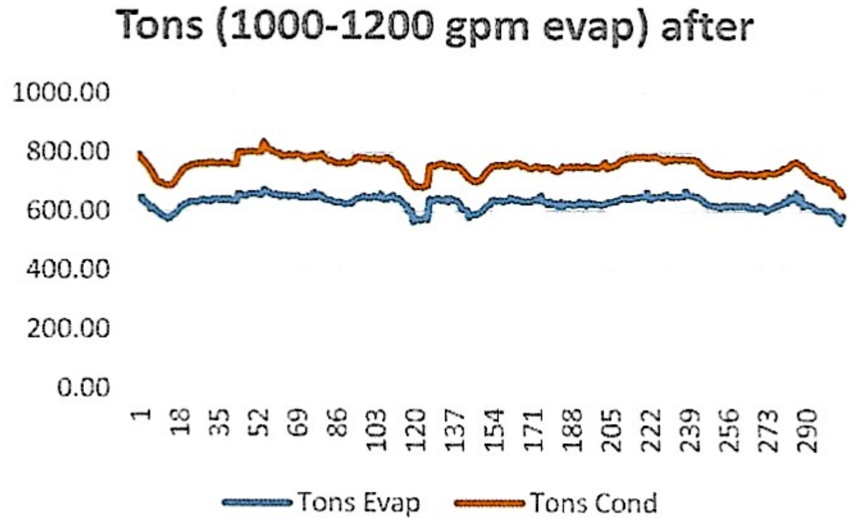


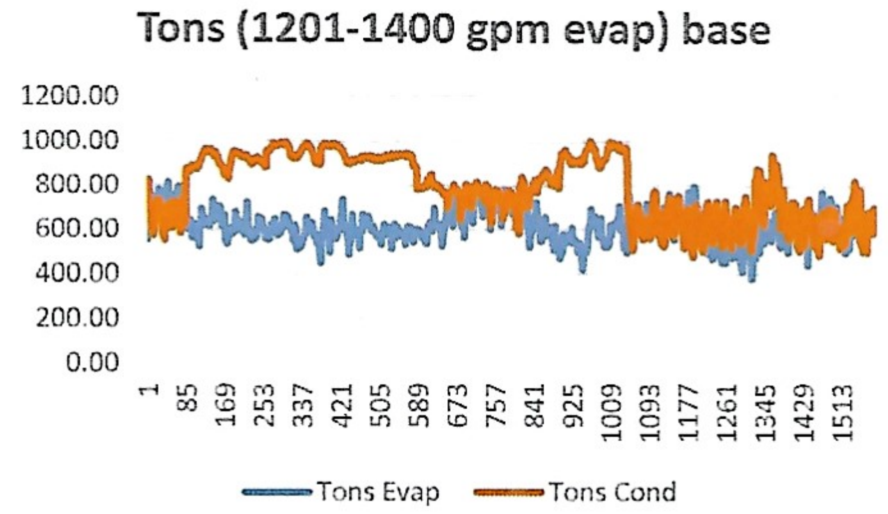
	Amps	Evap In Temp	Evap Out Temp	Evp Gal/Min	Δ	Tons Evap	kW	kW/Ton	Cond Flow Rate	Cond In	Cond Out	Δ	Tons Cond
1400-1600													
base	63.92	55.53	43.26	1476.97	12.26	755.04	437.54	0.59	1746.76	80.34	90.75	10.41	757.88
after	74.92	56.10	44.58	1516.06	11.52	728.27	512.38	0.70	1926.29	80.17	91.78	11.61	932.20
	-11.00	-0.57	-1.31	-39.09	0.74	26.77	-74.85	-0.12	-179.52	0.17	-1.04	-1.20	-174.33
	-17.2%	-1.0%	-3.0%	-2.6%	6.0%	3.5%	-17.1%	-20.3%	-10.3%	0.2%	-1.1%	-11.6%	-23.0%

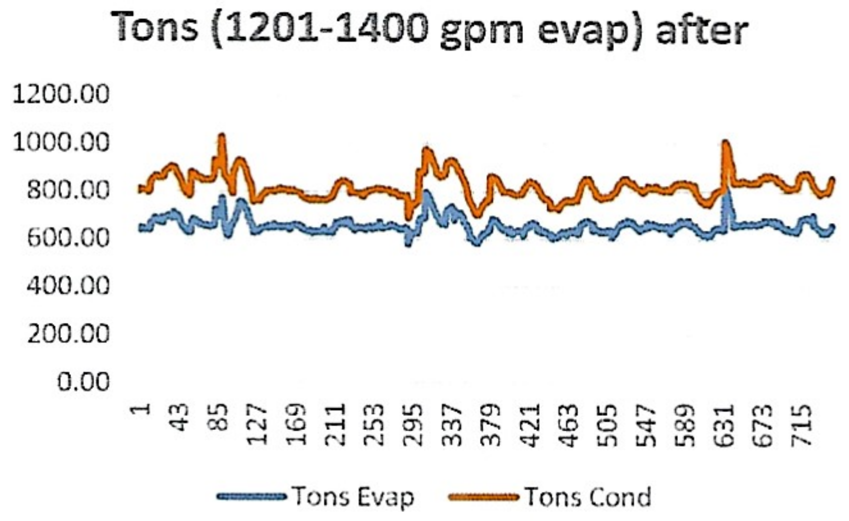
The data in the baseline is showing a kW/ton of .58 which is considerably lower than would be expected and the tons the evaporator is producing is equal to the tons the condenser is rejecting which is not possible.

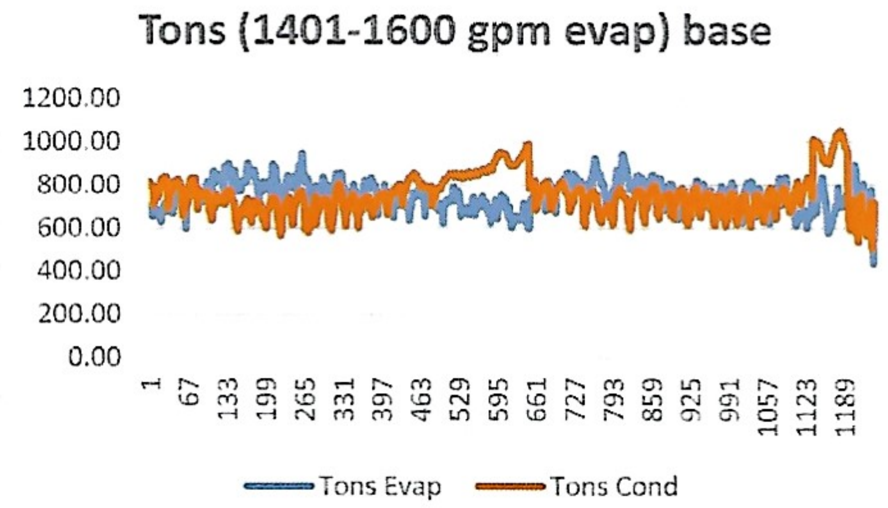
Now we will look at the tons of cooling and the and the condenser heat rejection.

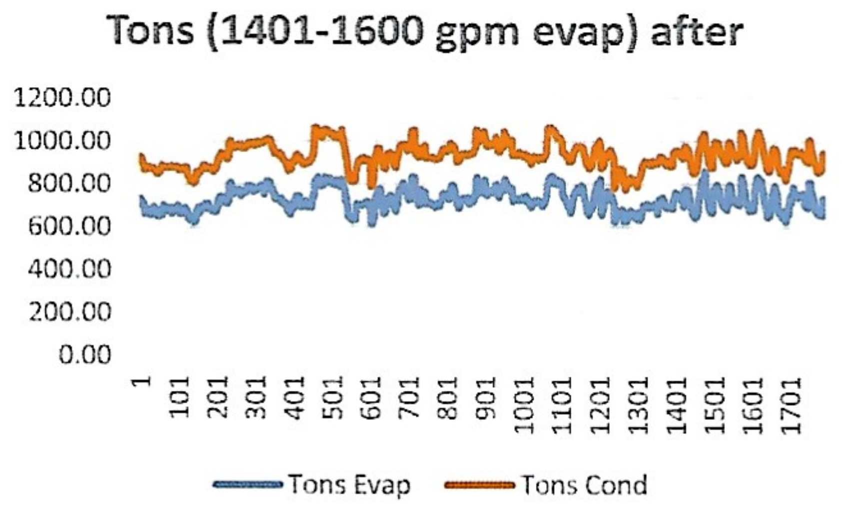

Tons (1000-1200 gpm evap) base


Tons (1000-1200 gpm evap) after


Tons (1201-1400 gpm evap) base


Tons (1201-1400 gpm evap) after


Tons (1401-1600 gpm evap) base


Tons (1401-1600 gpm evap) after

The base charts show a series in the 1401-1600 chart where the tons produced are greater than the condenser tons rejected which is not possible.

Conclusions

Because the chiller is operated to support the heat exchangers in their task of maintaining a .5 degree F tank water tolorance and a signoficant amount of manual intervention is required to do so you cannot use a total data approach to analyze this. The variable is primarily water flow thru the evaporator so we can make a comparison of water gpm ranges.

We have chosen 1000-1200 gpm, 1201-1400 gpm and 1401-1600 gpm for this comparison because there is sufficient data in both the baseline data and after treatment with Cold-Plus™.

A comparison of this data will show us the following:

	Amps	Evap In Temp	Evap Out Temp	Evap Gal/Min	Δ	Tons Evap	kW	kW/Ton	Cond Flow Rate	Cond In	Cond Out	Δ	Tons Cond
1000-1200													
base	60.95	55.22	43.13	1098.25	12.09	552.90	417.21	0.76	1750.82	80.28	89.99	9.70	707.95
after	62.47	56.52	43.40	1151.70	13.12	628.70	427.57	0.68	1884.54	79.98	89.54	9.56	750.84
	-1.51	-1.30	-0.26	-53.46	-1.03	-75.80	-10.36	0.08	-133.72	0.30	0.45	0.14	-42.88
	-2.5%	-2.4%	-0.6%	-4.9%	-8.6%	-13.7%	-2.5%	10.9%	-7.6%	0.4%	0.5%	1.5%	-6.1%

	Amps	Evap In Temp	Evap Out Temp	Evp Gal/Min	Δ	Tons Evap	kW	kW/Ton	Cond Flow Rate	Cond In	Cond Out	Δ	Tons Cond
1200-1400													
base	66.33	54.88	43.41	1295.76	11.47	620.15	454.01	0.74	1749.95	80.35	91.18	10.83	789.69
after	67.03	56.13	44.22	1327.73	11.91	658.53	459.37	0.70	1916.55	80.15	90.44	10.29	821.81
	-0.70	-1.25	-0.81	-31.97	-0.44	-38.38	-5.36	0.05	-166.60	0.20	0.74	0.54	-32.11
	-1.1%	-2.3%	-1.9%	-2.5%	-3.8%	-6.2%	-1.2%	6.2%	-9.5%	0.2%	0.8%	5.0%	-4.1%

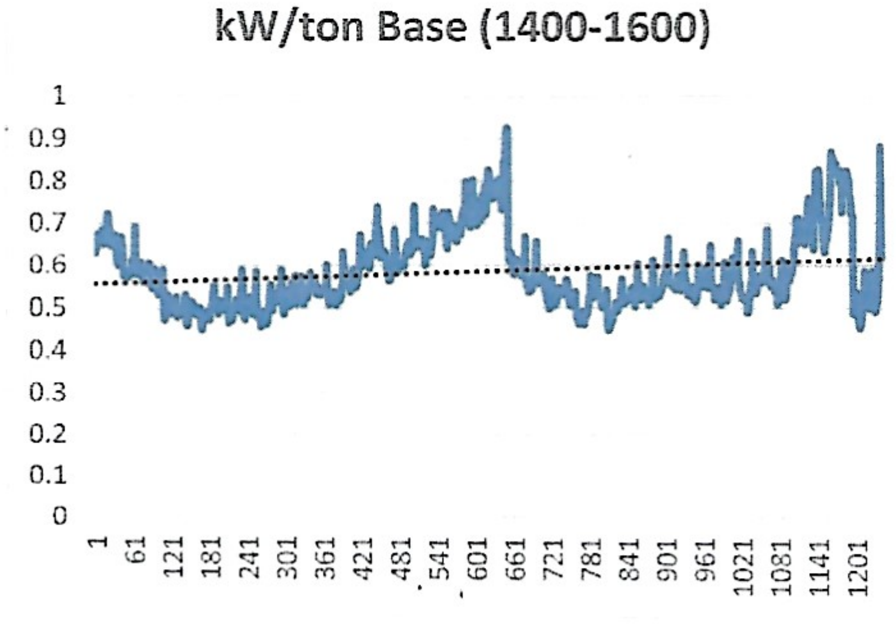
	Amps	Evap In Temp	Evap Out Temp	Evp Gal/Min	Δ	Tons Evap	kW	kW/Ton	Cond Flow Rate	Cond In	Cond Out	Δ	Tons Cond
1400-1600													
base	63.92	55.53	43.26	1476.97	12.26	755.04	437.54	0.59	1746.76	80.34	90.75	10.41	757.88
after	74.92	56.10	44.58	1516.06	11.52	728.27	512.38	0.70	1926.29	80.17	91.78	11.61	932.20
	-11.00	-0.57	-1.31	-39.09	0.74	26.77	-74.85	-0.12	-179.52	0.17	-1.04	-1.20	-174.33
	-17.2%	-1.0%	-3.0%	-2.6%	6.0%	3.5%	-17.1%	-20.3%	-10.3%	0.2%	-1.1%	-11.6%	-23.0%

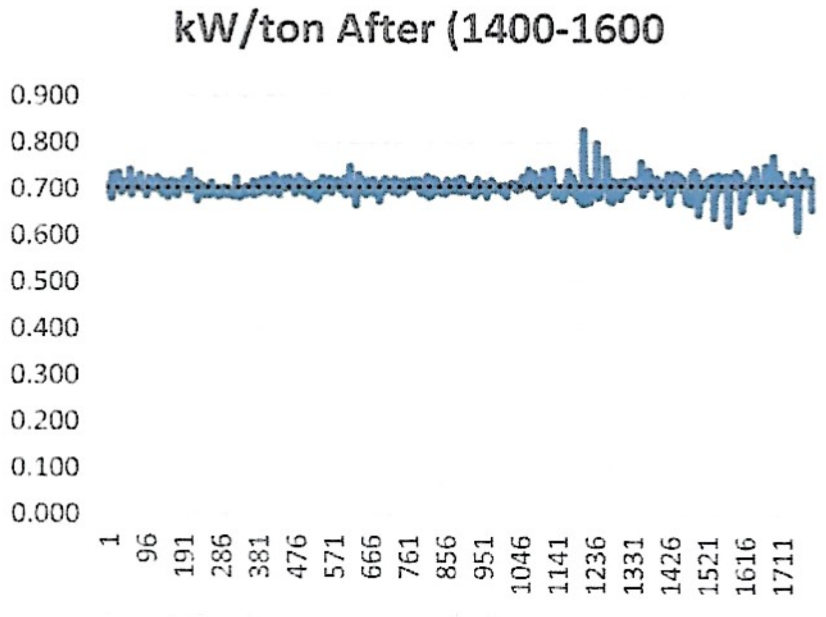
In the 1000-1200 gpm group the average in evaporator gpm varied only 4.9% and the efficiency as expressed in kW/ton improved by 10.9%.

In the 1201-1400 gpm data the evaporator gpm varied only 2.5% while showing a efficiency improvement of 6.2%.

In the 1401-1600 gpm data there is a problem with the baseline data. First of all it would be impossible to achieve a .59 kW/ton over the complete data group. Secondly The evaporator tons and condenser tons are almost identical.

Looking at this graphically you can see:





The graph on the right is what you would expect to see while the baseline graph shows extreme variation with values that would be technically impossible to achieve. For these reasons we will not use the 1401-1600 gpm data in the efficiency computation.

The computed efficiency change would be **8.6%** in this comparison methodology. The following shows the averages for each (1000-1400) data group.

	Amps	**Evap In F**	**Evap Out F**	**Evap gpm**	**Δ**	**Tons Evap**	**kW**	**kW/Ton**
Base	62.84	55.10	43.23	1167.54	11.87	576.49	430.12	0.76
After	65.71	56.24	43.98	1276.72	12.26	649.88	449.69	0.692
	-2.87	-1.14	-0.75	-109.18	-0.39	-73.39	-19.57	0.06
% to Base	-4.6%	-2.1%	-1.7%	-9.4%	-3.3%	-12.7%	-4.5%	**8.6%**

	Cond gpm	**Cond In**	**Cond Out**	**Δ**	**Tons Cond**	**Tons Evap**
Base	1750.51	80.31	90.40	10.10	736.63	576.49
After	1907.27	80.10	90.18	10.08	801.24	649.88
	-156.76	0.21	0.23	0.02	-64.61	-73.39
% to Base	-9.0%	0.3%	0.2%	0.2%	-8.8%	-12.7%