FINAL REPORT

Building Chiller Unit

Prepared by:
Hudson Technologies
Pearl River, NY 10965.
Phone: (845) 512 6000

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The operating performance of the CHILLER unit at a medium size commercial office space Building (Building) was evaluated and this report presents the summary and findings of that study. Secondly, this report describes some of the recommendations and next steps that the operations and management should investigate going further. It has to be noted that this analysis is done on a snap-shot basis and although the analysis is detailed, projections are made for year round operation and potential savings opportunities. Design and past operating data was provided by the Building Operations personnel. Current operating data was collected manually by Hudson personnel with assistance from Building Operations personnel.

Figure 1 represents the design conditions of CHILLER unit. Figure 2a represents the actual operating performance of the CHILLER unit from August 2007. This represents the case "before" Hudson's R-Side Services were performed on CHILLER unit. Figure 2b represents the summary of results for this operating data point. Figure 3a represents the actual operating performance of the CHILLER unit from August 2008. This represents the case "after" Hudson's R-Side Services were performed on CHILLER unit. Figure 3b represents the summary of results for this data.

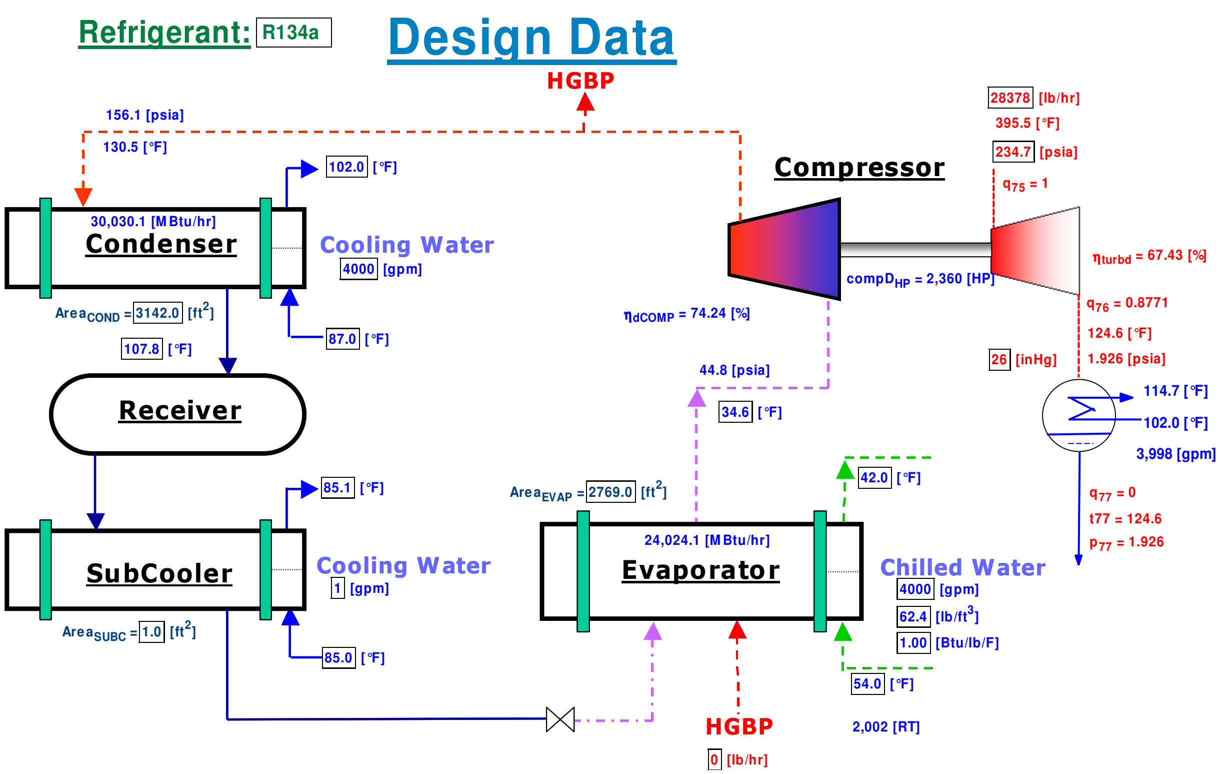

Figure 1: CHILLER Unit Design Model

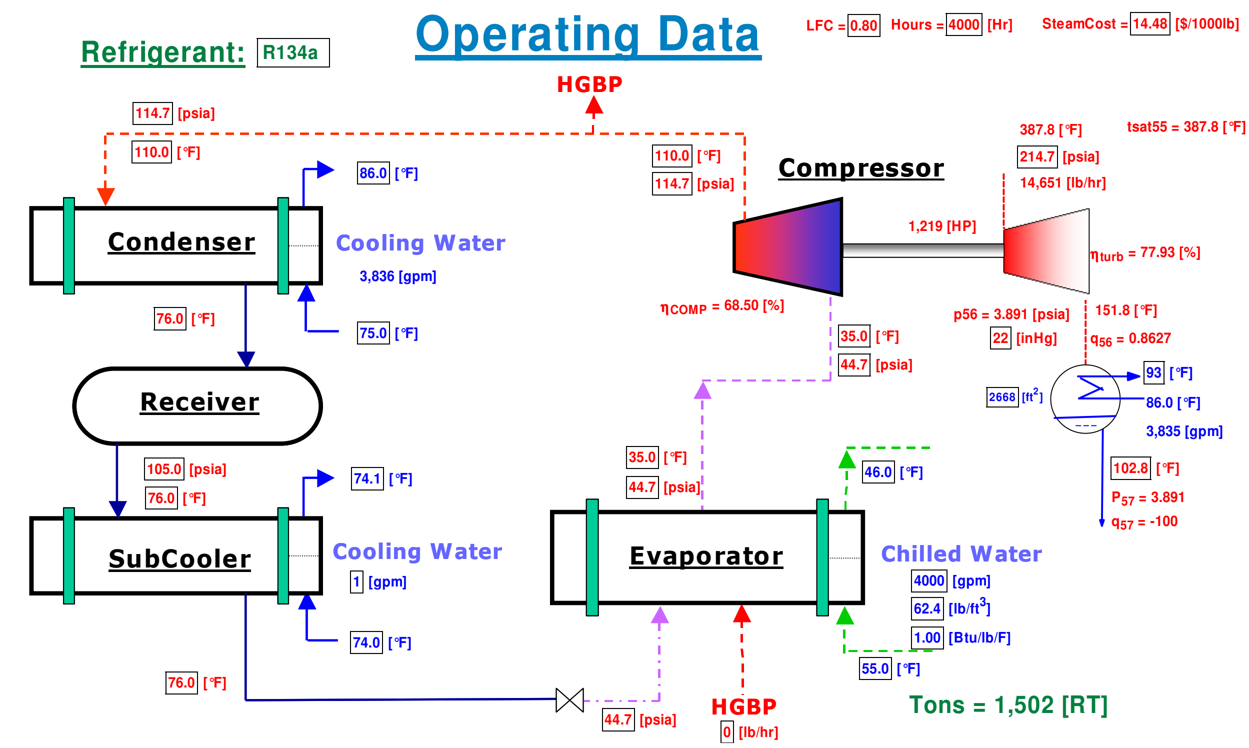

Figure 2a: Operating Performance of CHILLER Unit (August 2007)

SUMMARY of RESULTS & COST SAVINGS

Total System	Design P/L	Design F/L
Tons = 1,502 [RT]	1,502 [RT]	2,002 [RT]
compHP = 1,219 [HP]	1,503 [HP]	2,360 [HP]
HPTon = 0.81 [BHP/RT]	1.001 [HP/Ton]	1.18 [BHP/RT]
SteamRate = 12.02 [lb/hr-HP]		12.03 [lb/hr-HP]

NC% = 0.0 [%]

$Balance_{System}$ = 0.0 [%]

Component Balances

$Balance_{Evap}$ = 0.0 [%]

$Balance_{SubCooler}$ = ???? [%]

Annual Energy Costs

SteamCost = 14.48 [$/1000lb]

Hours = 4,000 [Hr]

LFC = 0.80 [kW/ton]

Cost ($)	NC Penalty ($)
678,871	0

Refrigerant

Design: R134a

Currently Used: R134a

Superheat Capacity Penalties

	Capacity Loss (RT)	%
Evaporator	2.8	0.1

Potential Savings Opportunities

Pressure Ratio (current): 2.6

	Evaporator	Condenser	System
New Ratio	2.3	2.6	2.3
Savings (%)	13.1	0.0	13.1

Figure 2b: Summary of Operating Results of CHILLER Unit (August 2007)

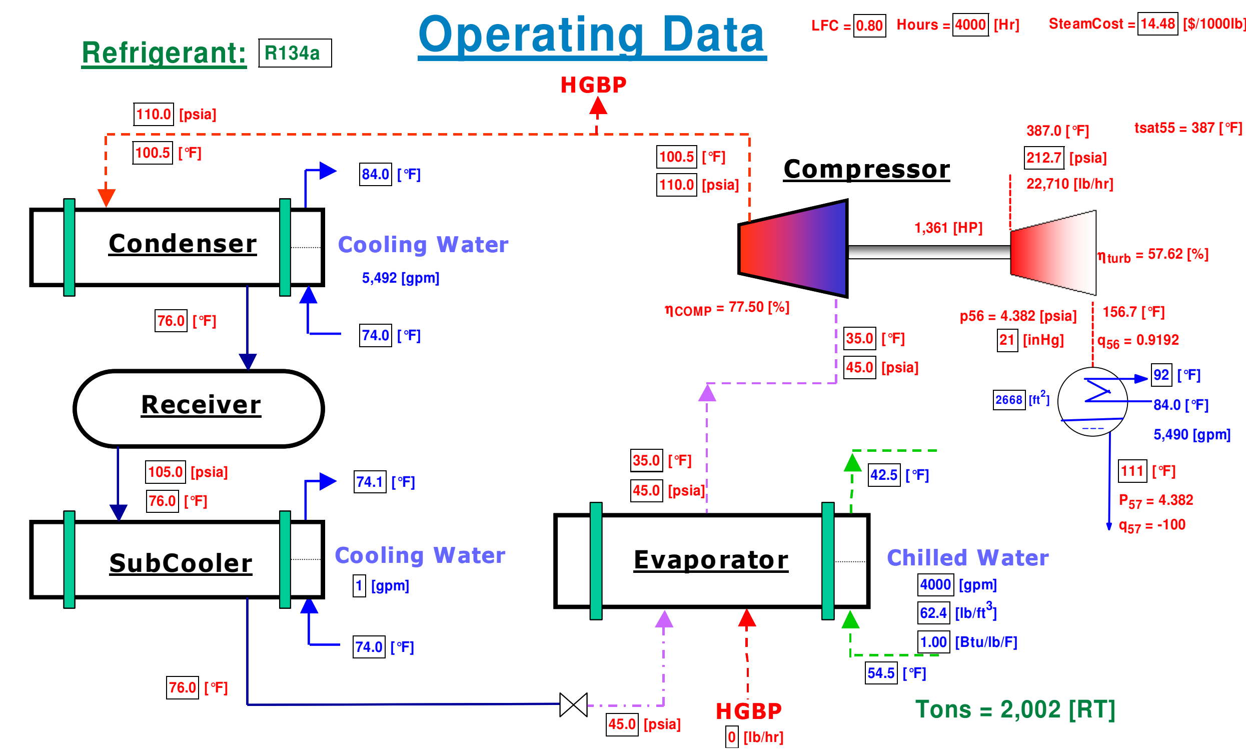

Figure 3a: Operating Performance of CHILLER Unit (August 2008)

SUMMARY of RESULTS & COST SAVINGS

Total System	Design P/L	Design F/L
Tons = 2,002 [RT]	2,002 [RT]	2,002 [RT]
compHP = 1,361 [HP]	1,921 [HP]	2,360 [HP]
HPTon = 0.68 [BHP/RT]	0.9596 [HP/Ton]	1.18 [BHP/RT]
SteamRate = 16.68 [lb/hr-HP]		12.03 [lb/hr-HP]

NC% = 0.0 [%]

$Balance_{System}$ = -0.0 [%]

Component Balances

$Balance_{Evap}$ = 0.0 [%]

$Balance_{SubCooler}$ = ???? [%]

Annual Energy Costs

SteamCost = 14.48 [$/1000lb]

Hours = 4,000 [Hr]

LFC = 0.80 [kW/ton]

Cost ($)	NC Penalty ($)
1,052,302	0

Refrigerant

Design: R134a

Currently Used: R134a

Superheat Capacity Penalties

	Capacity Loss (RT)	%
Evaporator	0.0	0.0

Potential Savings Opportunities

Pressure Ratio (current): 2.4

	Evaporator	Condenser	System
New Ratio	2.4	2.4	2.4
Savings (%)	0.6	0.0	0.6

Figure 3b: Summary of Operating Results of CHILLER Unit (August 2008)

Discussion of Results

As mentioned earlier, it has to be noted that this detailed analysis is done on a snap-shot basis rather than on a continuous annual performance. Hence, some of the conclusions may require additional due-diligence. Nevertheless, direct comparison between operating results from August 2007 and August 2008 indicate several different improvements. They include:

Efficiency improvement

From a chiller only perspective, August 2007 operation shows the chiller operating at 0.81 hp/RT (horsepower per ton). Operation in August 2008 indicates an efficiency improvement of 16% and the operating efficiency is 0.68 hp/RT.

Evaporator performance improvement

This is the main reason that resulted in the chiller efficiency improvement. August 2007 results showed fouling in the evaporator (implying a 13.1% potential savings), whereas August 2008 results indicated that there is no fouling (indicated by 0.6% potential savings). Oil, moisture and particulate seem to be the major impediments and since these are finned tubes, the nucleation sites are very concentrated and can trap oil and other impurities. Hence, a small amount of excess oil can have a large detrimental impact on the heat transfer coefficient, thereby leading to a lower suction pressure and a lower overall chiller efficiency.

Increase in capacity

Operation in August 2007 shows operation at 1,500 RT whereas operation in August 2008 is at 2,000 RT. This may be due to the demand requirement of that particular time (snap-shot) and hence, operators may have slowed down the chiller to provide for the system balance. Nevertheless, when comparing these cases individually to design operations, it should be noted that these cases represent part-load operations. This is because either the condenser cooling water is lower than the design temperature and/or the total load (refrigeration tons) is lower than the design load. Hence, a direct comparison to design conditions is not possible, but an attempt is made here in the analysis to try and compare the conditions.

Recommendations & Next Steps

The findings of the analysis and system operation have led Hudson's engineers to develop a list of recommendations and next steps to further optimize system operations. These recommendations take into account the complete system (boilers – chillers – cooling towers) and hence, will lead to an overall systems approach for plant personnel rather than just one component at a time. This section is divided into three parts.

Near-term Recommendations

1. The steam condenser pressure is at much higher levels than expected (21 inches Hg vacuum instead of 26-28 inches). A US Department of Energy BestPractices steam model was built for the system and it indicates an increase of ~4,000 lb/hr of steam required to offset the pressure penalty. At a marginal steam cost of $14.5 per klb of steam (based on $10 per MMBtu natural gas and boiler efficiency calculated from the data collected) and 2,000 annual operating hours, this equates to $116,000 of extra operating cost annually. Hence, evaluation of steam jet ejectors, PRV's, ambient valves, leaks should be done at the earliest possible.

2. Currently, operators manually record several parameters on an hourly basis. There are some additional parameters that should also be recorded to provide a good evaluation of the system in the future. They include:
   a. Compressor suction temperature
   b. Compressor discharge temperature
   c. Steam mass flow rate

3. Predictive maintenance can be done on each of the steam turbine driven chillers by implementing a ChillSMART™ program on a regular basis. This program would include sampling (refrigerant, oil and water) from each of the chillers and a performance evaluation of snapshot data from the chiller's operating conditions. Hudson recommends that this be done twice a year (Early spring and Late summer). The results from the ChillSMART program can be trended and will provide very valuable information on the health, reliability and operating efficiency of each of the chiller units.

4. Since operators collect daily data already, there is significant information available to undertake a quasi-real time optimization analysis. Hudson has already developed the models for evaluating the steam turbine driven chiller units and Hudson can take all the collected data and analyze it with the model on a periodic basis. It is recommended that daily average (or hourly) data on a periodic (preferably monthly) basis be collected and transferred in an excel type spreadsheet format to Hudson for evaluation and historical trending. This would allow the plant to really follow the day-to-day operations and make future just-in-time adjustments to maximize overall chiller plant efficiency.

5. While performing the detailed data analysis, it was found that certain instrumentation may be providing erroneous data. If calibration of the instrumentation is not done in the past 18-24 months, it is recommended

that the instrumentation be calibrated at the next shutdown. Some of this suspect instrumentation included:

a. Compressor discharge pressure
b. Steam mass flow rate

Medium-term Recommendations

1. There is a significant amount of instrumentation on the overall system. While the boilers and Air-Handlers are on the Data Acquisition System (DAS), the chillers are not. Operators would gain significant flexibility if the chillers were also incorporated on the DAS. This would allow for historian capability for critical parameters and make the system easy to operate and identify optimal operating conditions.

2. Implementing a simple algorithm that actually calculates a real-time operating cost including chiller performance efficiencies would be the next step to build on the DAS. This would allow operators to immediately modify operations to make the system improve its energy efficiency continuously. Additionally, an overall optimized routine could be implemented that could indicate to the operator a "lost opportunity cost" at any point of time and thereby allow the operator to make an informed decision about any change that he maybe planning to make.

3. Incorporate a "predictive maintenance" approach using the historian of the DAS for developing operating efficiency trends for the system and the individual components.

Long-term Recommendations

1. Although the overall system has been extremely well-designed, there is still room to implement certain infrastructure level modifications. One such example is fuel and tonnage flexibility. Since both the chillers are steam-turbine driven and each of them is 2,000 RT, there is limited operational flexibility. There are several times, especially during the shoulder season (when load is small – 1,000 RT or less) and also peak (when load is greater than 2,000 RT but less than 3,000 RT) where the current combination of chillers does not provide good system efficiency. This is because either one or both chillers are part loaded or boilers are part loaded or both. Also, the fuel is always natural gas and there is no way to hedge against high fuel prices unless you have got into a long-term contract. One option to solve both these issues is to consider an electric motor driven high-efficiency packaged centrifugal chiller (750 RT) that would be run at low load conditions and in conjunction with one steam turbine driven chiller at high loads. The electric chiller would

function as a swing machine and would be a very quick start-up for a fast response. It is recommended that along with this additional other options should be investigated also.