

## CHAPTER/REGIONAL TECHNOLOGY AWARD - SHORT FORM

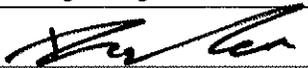
**1. Category (Check one and indicate New or Existing, if applicable)**

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|---|------------------------------|---|
| <input checked="" type="radio"/> Commercial Buildings       | <input type="radio"/> New or | <input checked="" type="radio"/> Existing |
| Institutional Buildings:                                    |                              |   |
| <input type="radio"/> Educational Facilities                | <input type="radio"/> New or | <input type="radio"/> Existing            |
| <input type="radio"/> Other Institutional                   | <input type="radio"/> New or | <input type="radio"/> Existing            |
| <input type="radio"/> Health Care Facilities                | <input type="radio"/> New or | <input type="radio"/> Existing            |
| <input type="radio"/> Industrial Facilities or Processes    | <input type="radio"/> New or | <input type="radio"/> Existing            |
| <input type="radio"/> Public Assembly                       | <input type="radio"/> New or | <input type="radio"/> Existing            |
| <input type="radio"/> Residential (Single and Multi-Family) |                              |   |

**2. Name of building or project:** Chase Tower Chiller Plant Upgrade  
City/State: Chicago, IL

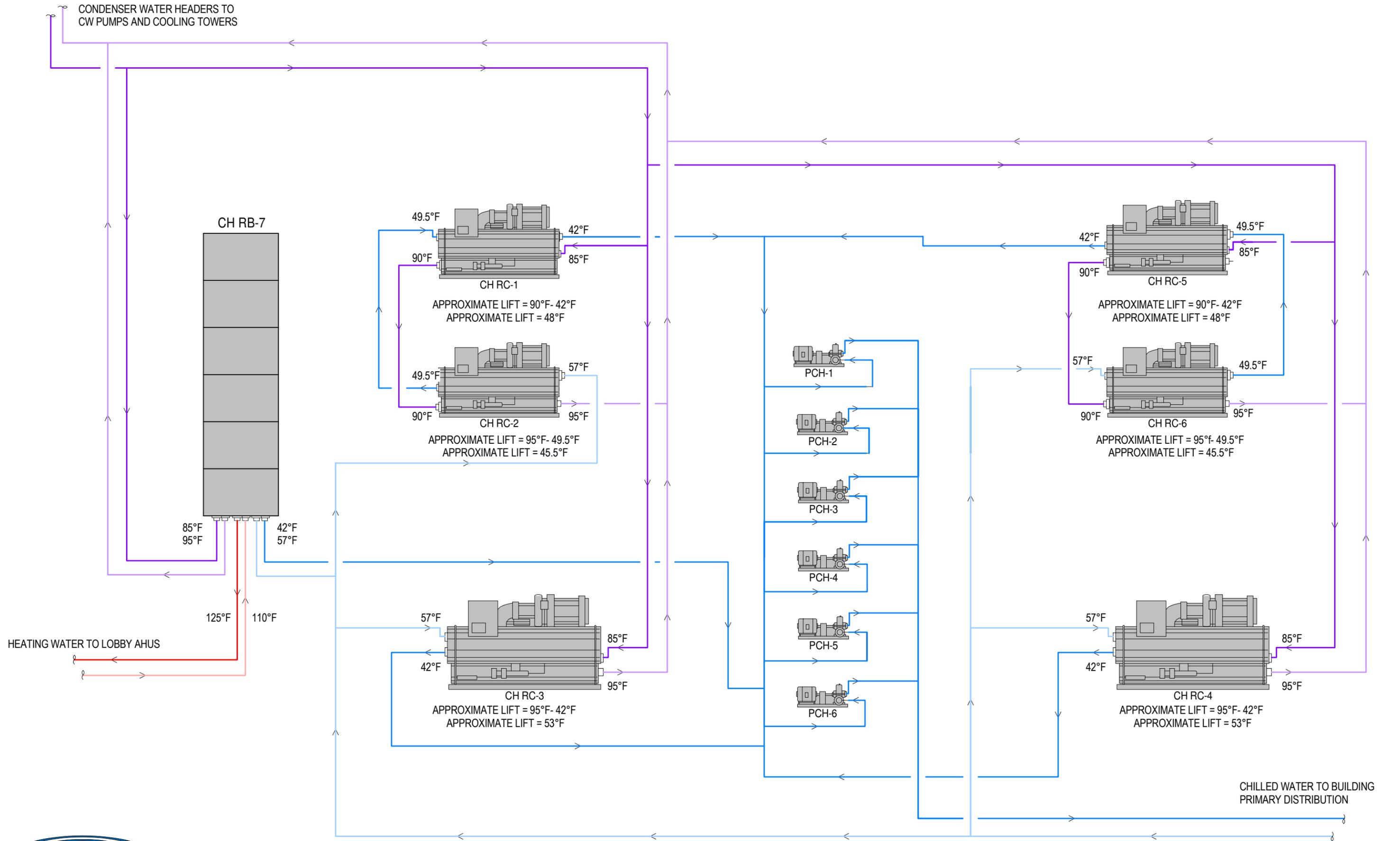
**3. Project Description:** Chiller plant upgrade of original plant. Series counterflow cooling chillers and heat recovery systems implemented  
Project Study/Design Period: 01/2012 to 07/2013  
Begin date (mm/yyyy) End date (mm/yyyy)  
Percent Occupancy at time of submission: 100%

**4. Entrant (ASHRAE member with significant role in project):**

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f. Member's Signature: 

**5. Engineer of Record:** James D. Johnson

By affixing my signature above, I certify that the information contained in this application is accurate to the best of my knowledge. In addition, I certify that I have discussed this entry with the owner and have received permission from the owner to submit this project to the ASHRAE Technology Awards Competition.



CHASE TOWER CHILLER PLANT UPGRADE  
SYSTEM SCHEMATIC

October 7, 2013



# ASHRAE 2013 Technology Award – Chase Tower Chiller Plant Upgrade

*Chase Tower*  
10 South Dearborn  
Chicago IL 60603

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October 7, 2013



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## **I. Project Description:**

Built in 1967, the 2.4 million square foot, 60 story Chase Tower has been undergoing numerous mechanical and electrical infrastructure upgrades since 2003. In 2003, Chase began upgrading the building mechanical infrastructure which included converting from dual duct, constant volume air systems to a variable volume air system, chiller renovation and other infrastructure upgrades meant to modernize the building and position it for another 40 years of efficient operation. To date the upgrades have already seen a significant energy savings.

In 2011 ESD began analysis on options for renovating the original 10,000 ton chiller plant located on the third floor of the building. The plant consisted of the following:

- Two 1,500 ton heat recovery chillers (RB-1 and RB-2)
- Two 3,500 ton R22 cooling only chillers, re-built in 2003 (RC-3 and RC-4)
- Variable primary chilled water pumping system
- Condenser water pump with VFDs used to match design flow of different chiller pairs

In order to evaluate options for the upgraded plant ESD built an energy model. More than 10 different detailed plant configurations were simulated using the energy model. The modeling results were combined with pricing developed with local contractors to develop returns on investment for the different designs. The designed and installed new chiller plant consists of six 85 ton modular Climacool heat recovery chillers and four 525 ton Carrier 23XRV cooling only chillers. The four Carrier 23XRV screw chillers were piped as two pairs in series counterflow which provides additional energy savings.

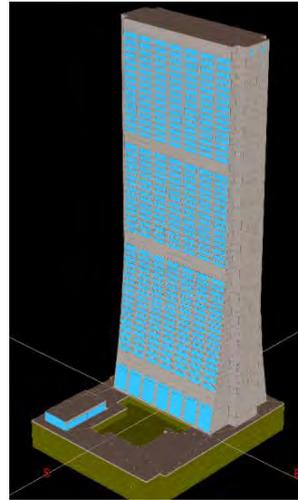
## **II. Energy Efficiency and Innovation:**

### **A. Energy Modeling**

The goal of the chiller plant study and renovation was to build a robust, reliable, and energy efficient chiller plant to serve Chase Tower for the next 50 years. The 10 different plant options were all simulated using a calibrated energy model built in eQuest v3.64. Because of the complicated building geometry a representative model was built in Autodesk Revit MEP and converted to eQuest for a detailed energy study. The entirety of the building geometry and envelope construction was defined using Revit, but all of the internal loads, occupancies, operating schedules, and HVAC systems were defined using detailed mode of eQuest. The ease of interoperability allowed for the combination of the model construction using the most streamlined, efficient, and accurate process. Figures 1 and 2 are images of the building geometry developed using Revit and translated to eQuest.



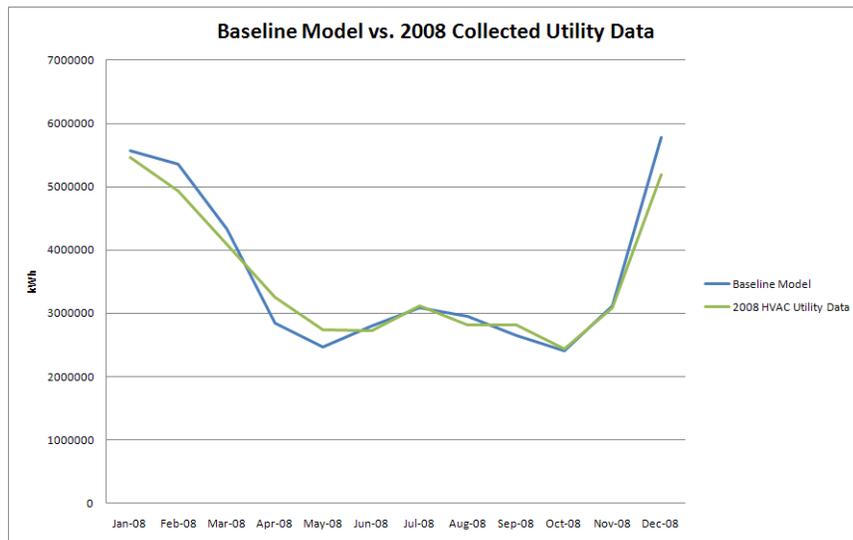
**Figure 2 Revit Model Screenshot**



**Figure 1 Revit Model translated to eQuest**

The final step in completing the energy model involved calibrating performance of the model with actual building utility data. Historical utility data was provided by the building operations staff and 2008 was chosen as the representative year for calibration. 2008 was a year with no major restacking or infrastructure projects and the building was fully occupied. Monthly kilowatt-hour [kWh] consumption of the building HVAC system was compared to the monthly model results. Historical weather data for 2008 was obtained from the National Climatic Data Center and input into the model.

The model was found to be within 1.6% of actual building operation over the year. Figure 3 illustrates the month by month energy comparison between the computer simulation and actual building energy consumption. Once the model was calibrated, the weather file was switched from 2008 specific data to typical year weather data. This model, with typical year data, was then used as the baseline for comparing various chiller optimization options.



**Figure 3 Comparison of Energy Consumption between Model and Actual**



## B. Option Evaluation

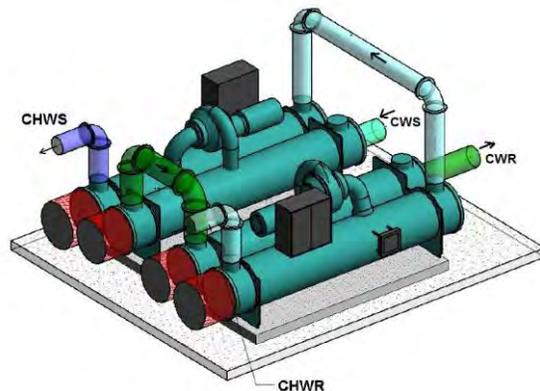
In parallel to developing the energy model more than 10 different chiller configurations were developed for analysis, these options are summarized in Table 1.

Option	Description
Option 1	Waterside Economizer Only
Option 2A	Hot Gas By-Pass Modification
Option 2B	Waterside Economizer Hot Gas By-Pass Modification
Option 2C	Waterside Economizer Hot Gas By-Pass Modification Refurbishment of RB-1
Option 3A	Waterside Economizer Additional 500 ton chiller
Option 3B	Waterside Economizer Additional 500 ton chiller Refurbishment of RB-1
Option 4	Waterside Economizer Cooling-Only Parallel Compressor Retrokit Refurbishment of RB-1
Option 5	Heat Recovery Parallel Compressor Retrokit Refurbishment of RB-1
Option 6	Single Compressor Retrokit Refurbishment of RB-1
Option 8	Replace RB-1 with two Carrier 30XW400 heat recovery chillers and one Carrier 23XRV Chiller
Option 9	Replace RB-1 with one set of six Climacool UCH modular chillers and two Carrier 23XRV chillers

**Table 1 Summary of Options**

In developing Option 9, the selected option, multiple comfort cooling chillers were analyzed. It was determined that a series counterflow arrangement of chiller sets provided the most efficient cooling plant.

The series counter flow arrangement consists of piping two chillers in series on both the evaporator and the condenser water side. These chillers are generally selected as single pass chillers so the overall pressure drop is the same as a typical two pass chiller. The advantage of this arrangement is that it reduces the lift on each chiller making the

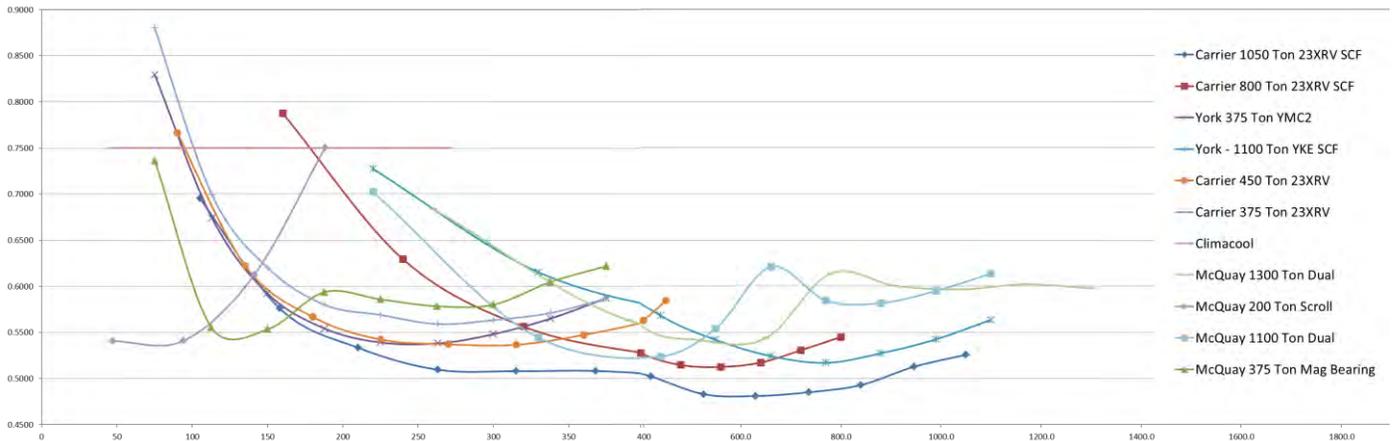


**Figure 4 Series Counter flow Arrangement**



combination more efficient. A sample arrangement is shown in Figure 4.

A comparison of chillers at constant entering condenser water temperature is shown in Figure 5. From this chart several conclusions can be drawn. Toward the lower end of the chart it is clear that the Carrier 23XRV have comparable efficiencies to the York YMC2 magnetic bearing chillers. There is also a difference that can be seen between the screw and centrifugal compressors. The screw machines have flatter performances through their part load ratios compared to the centrifugal chillers. The efficiency advantage from series counter flow can be seen by looking at the individual 450 ton 23XRV on comparison to the dual series counter flow 23XRVs (SCF). Toward the lower end, efficiencies are similar because only a single machine would be operating but as the load increases the series counter flow arrangements efficiency remains steady and better than a single chiller. The difference between the screw 23XRV and the centrifugal chiller is also clear from this chart. Similar operating characteristics are also noticeable with the series counter flow arrangement of centrifugal chillers with the steeper curve and more defined efficient point of operation compared to the screw compressor which is flatter and more efficient throughout the entire operating range.



**Figure 5 Chiller Comparison at Constant Entering Condenser Water Temperature**

The Carrier 23XRV piped in series counter flow was further studied along with the new York YMC2 magnetic bearing chiller. Data was gathered to evaluate turndown, part load efficiencies, and variable condenser water temperature effects. Figure 6 shows the chiller performance as a function of load and condenser water temperature. It can be seen that chiller efficiencies between 100 and 200 tons are very similar and there is a slight efficiency gain of the York YMC2 chiller at condenser water temperatures less than 70°F.

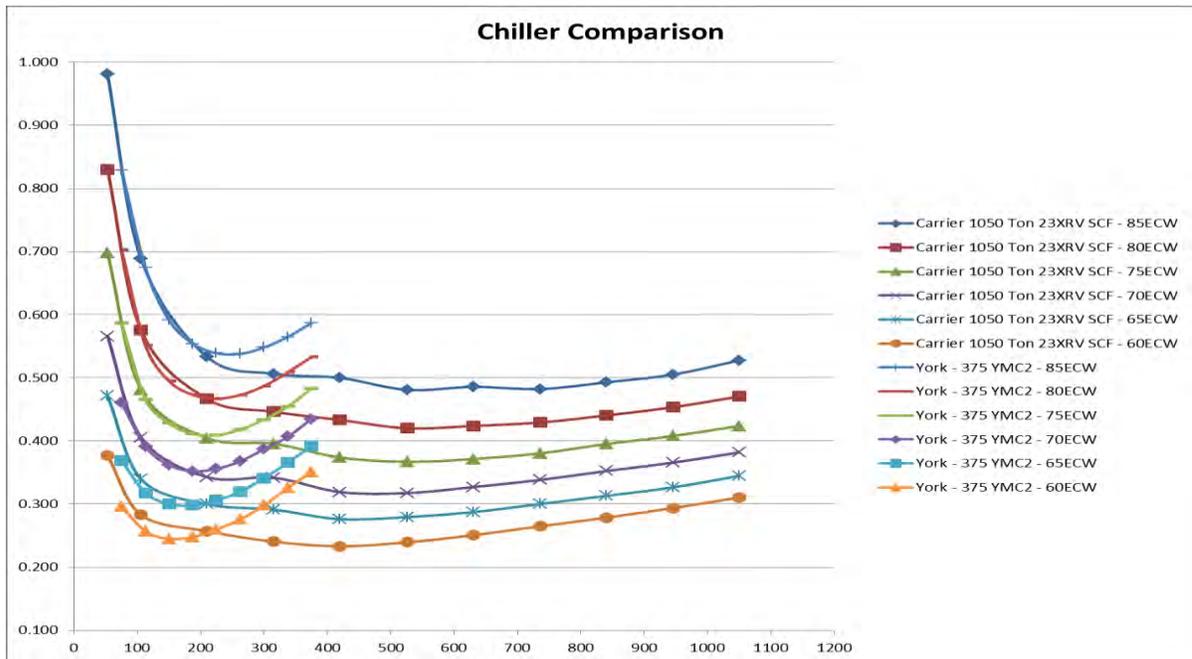


Figure 6 Chiller Comparison Chart with Variable ECW Temperatures

Performance data for each option were input into eQuest and simulated. Detailed chiller performance curves at part load, variable condenser and chilled water temperatures were provided for each option from the manufacturers.

The simulations compare the total kWh consumed by the building HVAC systems (chillers, cooling towers, main fan systems, pumps and other base building HVAC systems) to the existing system. Figure 7 indicates the savings for the different options as it was presented to Chase. The options were evaluated based on the existing operations remaining the same (ie. no change in occupancy, schedules, equipment, etc.). Similar studies were run to compare savings if the building increased in occupancy, hours of operation, and equipment density as was potentially planned at the time.

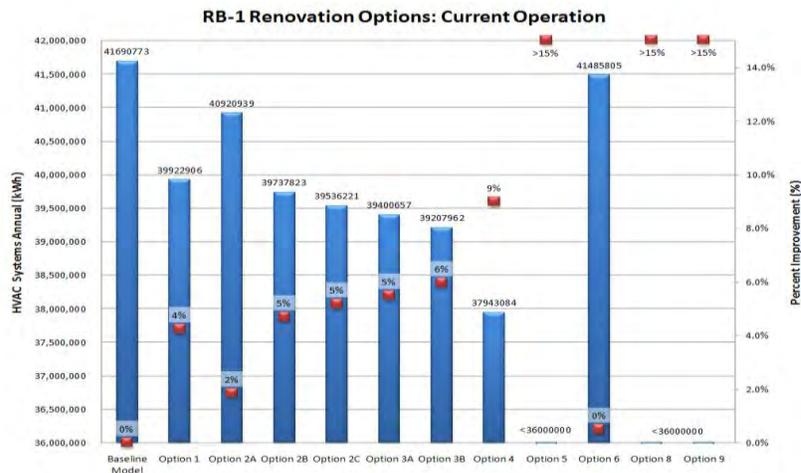


Figure 7 Comparison of Options for Current Operating Year



Results of the energy models show that system efficiency can be greatly improved with three of the nine options, 5, 8, and 9. These options all have several commonalities; heat recovery, turn down capability to meet low load conditions (100-200 Tons cooling), and high efficiency at low load. The 100 – 200 ton base load on the building chilled water system comes from the building data center and tenant IDF closets. These spaces are currently water cooled and had to remain on the same system.

Previously, water side economizer appeared to be an efficient solution for Chase Tower; however, after careful review it was not considered an appropriate solution. In analyzing the hourly reports and comparing the recovered heat to new data from Carrier and Climacool it was discovered that the simulations underestimated the amount of recovered heat. Research of this eQuest simulation shortcoming showed that other users around the world have had similar issues and that no resolution was available for proper simulation of heat recovery chillers in eQuest. As a result, ESD manipulated the hourly results and manually simulated the heat recovery chillers. To perform this manual calculation ESD generated and researched the necessary information from Climacool, Carrier and York to properly calculate the heat generated and additional chiller power consumption when operating in heat recovery mode.

With waterside economizer the buildings electric boilers must also run to produce all required heat. Electric boilers effectively have a coefficient of performance (COP) of 1 (1kw of power in means 1kw of heat out). Simple analysis below shows that heat recovery chillers can produce the necessary chilled water while efficiently producing hot water for the building. In heating mode a heat recovery chiller has COP ranging from approximately 3 to 5. A calculation showing energy use to produce 3750MBH of heat, the current average building hot water heating load, is shown below for both a heat recovery chiller and a boiler:

Heat Recovery Chiller:

150 Tons of cooling can produce 2340MBH of heat and uses 175kw; from heat recovery chiller selection

To produce 3750 MBH (Building peak lobby heating load):

$$175kw + \frac{(3750MBH - 2340MBH) \left(0.2928 \frac{kw}{MBH}\right)}{0.98 \text{ (Boiler efficiency)}} = 596.3kw$$

Boiler:

Using only boilers, the energy required to produce 3750MBH is:

$$\frac{(3750MBH) \left(0.2928 \frac{kw}{MBH}\right)}{0.98 \text{ (Boiler efficiency)}} = 1120.4kw$$

**Figure 8 Energy Comparison for Boilers versus Heat Recovery Chillers**

From this simple calculation, and shown using the energy model, it is clear that using heat recovery provides a significant energy reduction.

**C. Construction and Results**

Option 9, the (2) sets of series counterflow chillers and modular heat recovery chillers was recommended to Chase and constructed in two phases. The first phase included the heat recovery

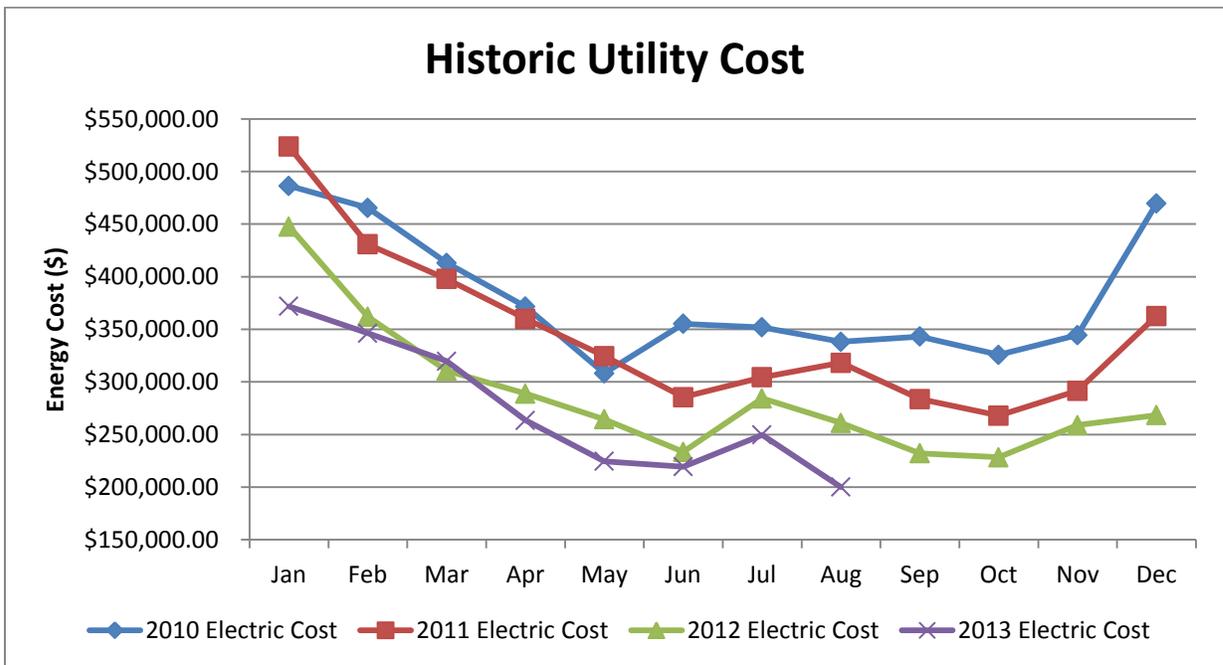


**Figure 9 Chiller being Hoisted through Building Louvers**

chillers and was installed in the summer of 2011. The second phase was completed in the spring/summer of 2013. The modular chillers utilized an existing pad and were brought up through the service elevator. New hot taps were made to connect the chillers to the existing headers. The series counterflow chiller sets were designed and coordinated to drop in using the existing header connections. The concrete pads were extended to fit the new chillers. Due to the size and weight of the chillers they were broken down into three pieces, condenser bundle, evaporator bundle, and compressor, and then hoisted into the third floor mechanical room.

The chiller installation was phased to provide continuity of operation throughout the installation. After the first set was installed it was connected to the BAS and commissioned so the next set could be installed. Once everything was complete commissioning of the entire plant took place over a weekend. The new plant has been fully operational since August.

Figure 10 indicates the drop in utility costs after the construction of these projects. The heat recovery efficiency can be seen in the winter of 2011 and 2012 months. Cooling energy savings from 2010 to 2012 are attributed to the building efforts to optimize the existing chillers performance. The 2013 summer cooling savings can begin to be seen in August, the final data point. September utility data is not yet available but similar cost savings are expected to be seen.



**Figure 10 Annual Utility Costs**

The building energy use has dropped by approximately 30% (almost \$900,000) compared to the 2010 operating costs. The operations team at Chase Tower carefully monitors trend data to find more

efficient ways of operating their plant. Additional energy saving operational strategies that are currently being implemented with the new systems include condenser water reset, staging of cooling towers, and night time chilled water loop sub cooling. In the past strategies such as night time chiller shut downs (fly wheel of building chilled water system mass), have been implemented to optimize the performance of their existing chillers. There was however a peak efficiency they could achieve with the equipment. Figure 11 indicates a comparison of the existing, optimized, chillers compared the new chillers. Performance indicated is an average for the month.

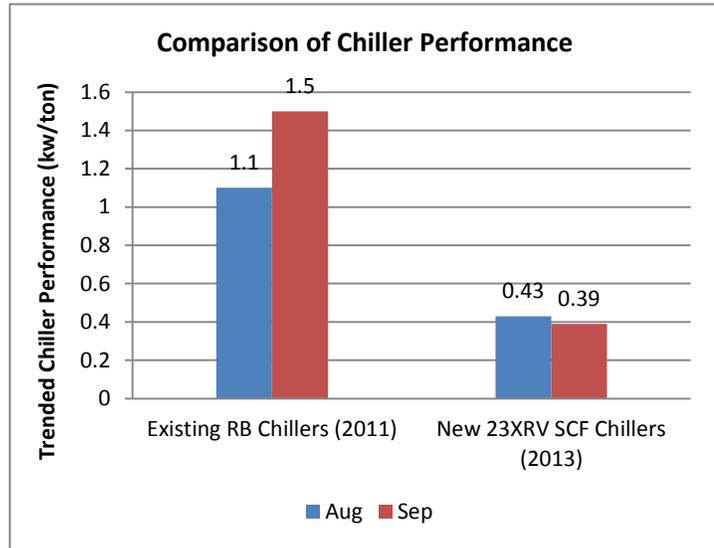


Figure 11 Comparison of Chiller Performance

### III. Operations and Maintenance:

The upgraded chiller plant design provides a great deal of redundancy by having modular heat recovery chillers in parallel with the other sets of series counterflow chillers. Should a set of chillers need to be taken down the modular chillers can supplement the load in a cooling only operation. If a heat recovery chiller needs service a module can be removed and replaced while the remaining five modules operate. In addition, the Carrier 23XRV chillers have industrial grade screw compressors that have a service life of 500,000 hours. Another advantage of the screw compressor is their stability, because they are positive displacement they cannot surge and can adjust quickly to changes in system temperatures and pressure changes. They have also reduced noise to levels less than most centrifugal chillers. The chillers were specified with marine water boxes, providing ease of access to the tube bundles for cleaning and tube replacement if necessary. An additional feature of the Carrier chillers is their ability to pump refrigerant to the condenser bundle or evaporator bundle. This allowed the building to demolish the existing refrigerant storage tanks freeing up much needed space in the mechanical room while eliminating storage tanks that required cleaning and maintenance.

### IV. Conclusions

The chiller systems serving Chase Tower had been functional for 40 years and saw decades of service without refurbishment. The goal of this project was to find an energy efficient option that would be able to serve the building for another 40 years of operation. Given the clear results of the energy model and recent utility bills it is clear that this fit for purpose design with modern high efficiency equipment is serving the building well and will continue to do so for another 40 years.