Thermal Energy Storage &
Low Temperature Air Distribution

Senior Thesis Final Report
Spring 2006

Bronx School for Law Government & Justice

Bronx, NY

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Architectural Engineering
Mechanical Option

Bronx School for Law, Government & Justice

Yulien Wong - Mechanical Option

Project Overview

Location: Bronx, NY
6 stories plus 1 mechanical penthouse & 1 floor below grade
Approx. Size: 114,000 SF
Construction Dates: June '01 – Sept. '04
Estimated Cost: 65 million
Project Delivery: Design-Bid-Build

Features

School is one of the first "specialized" high schools in NYC. Specialized spaces include forensic labs, tri-facial labs, distance learning court rooms, and crime labs.

Project Team

Owner: New York School Construction Authority
Architect: The Hillier Group Architecture
Structural Engineer: Ysrael A Seinuk, P.C.
MEP/Telecom: Joseph R. Loring & Associates, Inc
Civil Engineer: Langan Engineering
Lighting: Lighting Design Collaborative
Contractor: Silverite Construction

Mechanical

Cooling: (2) 200 Ton reciprocation type chillers
Heating: (3) 85 BHP low pressure steam boilers
Heating Distribution: Duct mounted heating coils & fin tube radiation
Ventilation: (7) constant volume AHUS & (3) VAV AHUS
Fire Protection: Fully sprinkled wet type & smoke exhaust system

Structural

Foundation: Column Footings
Superstructure: Steel frame
Floor: Concrete on metal deck
Roof: Parapet roof with slab construction

Electrical

Service: 6000 amp, 208/120 volt, 3 phase, 4 wire
Generator: 300kW, 480 volt, 3 phase, 4 wire

http://www.arche.psu.edu/thesis/eportfolio/current/portfolios/yzw103

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1.0 EXECUTIVE SUMMARY

Bronx School for Law Government & Justice is a school located in Bronx, NY. The following analysis utilizes this building as a basis for a complete overhaul of its mechanical systems. Specifically, the mechanical redesign explored the possibility of ice thermal storage with cold air distribution.

One of ice thermal storage's main focuses is to eliminate high demand cost during on peak times and "shift" it to off peak times, when the rate is cheaper. As will be discussed, there are a few ways to operate thermal storage in either full or partial storage. Full storage transfers all of the peak loads to off peak times and part load, as the name suggests, transfers part of the load to off peak time with the remaining load being met by the chiller. It will be shown that it is often more economical to operate with the partial storage strategy because often, equipment sizes are smaller than conventional systems and less storage capacity is required as compared to full storage.

Cold air distribution takes advantage of the cooler than average water from ice thermal storage and supplies low temperature air to the spaces. Cold air distribution has many advantages including lowering first cost due to the reduction of fans, ductwork and pumps.

Also in this analysis, the impact of thermal storage and cold air distribution on other systems namely, structural and electrical will be evaluated.

2.0 ACKNOWLEDGEMENTS

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Dr. William P. Bahnfleth
Dr. James D. Freihaut
Jae-Weon "JJ" Jeong
Dr. Stanley A. Mumma

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Thank you for helping me out throughout the entire process and having the patience to teach me all summer. I'll always remember you as the human library.

Charles Johnson, Loring Engineers
Even though you were always busy you went out of your way to sit down and help me out. Thanks for everything.

The rest of the Loring Staff, thanks for everything last summer I really learned a lot and met a lot of good people. I wish you all the best.

Fellow Students

To my fellow graduating AE's it has been an incredible ride these past years. We all have had our share of ups and downs, from the good times in Chicago to writing this thesis. I liked to specially thank Jess for putting up with my antics these past years, Evan for always making me shake my head and laugh, Jenny for always being compelled to argue with me, DRH for always letting me throw food at him, Jayme for always telling me I'm an idiot, Dave and Justin for being my brothers in Chicago and everyone else that I didn't mention, I'm sorry it's the end of another all-nighter and I'm tired. Thank you all and I wish you the best.

3.0 INTRODUCTION

Bronx School for Law Government & Justice is a grades 7-12 middle/high school located in Bronx, NY. It is one of the first "specialized" high schools constructed in New York City and as the name suggests it caters to students seeking careers in the criminal justice system. The school has a capacity for about 1000 students and equipped with the latest of technologies. The school is approximately 110,000 square feet with six floors of occupied space. The school's primary mechanical systems are located on top of the sixth floor in a specially designed mechanical penthouse. The building's final cost was approximately 75 million dollars and was completed in September 2004.

Figure 1: Construction Phase of Bronx School for Law Government & Justice

4.0 PROJECT TEAM

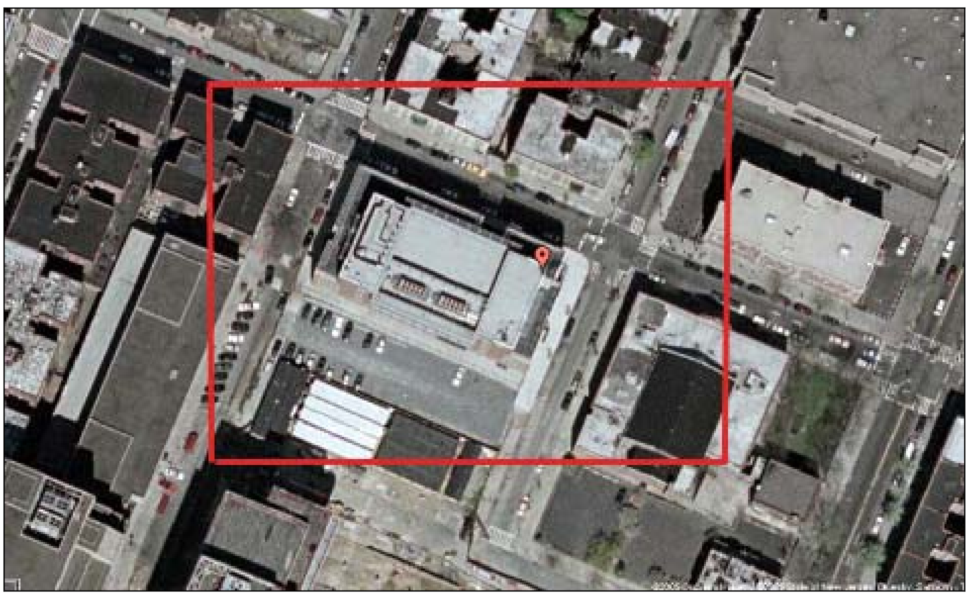
Owner:	New York School Construction Authority
Architect:	The Hillier Group Architecture
Structural Engineer:	Ysrael A Seinuk, P.C
MEP/Telecom Engineer:	Joseph R. Loring & Associates, Inc
Civil Engineer:	Langan Engineering & Environmental Services
Lighting Consultant:	Lighting Design Collaborative

Figure 2: Entrance to Bronx School for Law Government & Justice

5.0 SITE & ARCHITECTURE

The Bronx School for Law is located at the Bronx Civic Center, the borough's main law, government and justice district. The school is situated between Sherman Avenue and Grant Avenue on 163rd Street, as shown in Figures 3. The students of the school participate in studies of the criminal justice system which allow them to be able to take advantage of the new Bronx Criminal Court Complex built on the adjacent site to the south. The Building is an architectural transition in scale from the court buildings to the south to the residential areas to the north, east and west. One feature of the building is that it relates to the surrounding neighborhood and still displays its own unique architectural elements.

Figure 3: Aerial View of Bronx School for Law



The school caters to students seeking careers in the legal profession; therefore it includes spaces that complement their learning. The school contains forensic labs, tri-facial labs, integrated learning court rooms, crime labs, an art studio, library, multipurpose rooms and kitchen /dining areas. The capacity of the school is for approximately 1,000 students, and has a total of 25 classrooms in addition to the specialty rooms listed above.

The structure consists of steel frame and concrete on metal deck. The lateral system consists of moment frames and concentric braces. The gym, which is located at the top of the building, is supported by an isolated floor over the structural floor, which eliminates all vibrations to the floors below.

6.0 MECHANCAL DEPTH: EXISTING CONDITONS

Waterside of Existing Mechanical System:

The existing waterside system for the Bronx School for Law consists of two 250 ton air cooled DX chillers that provide chilled water for the ten air handling units. The total capacity needed by the air handlers at peak load is only 320 tons therefore; the extra capacity of the chiller is used for redundancy or for future cooling loads. Each chiller uses R-22 refrigerant and was designed for an entering and leaving temperatures of 55˚F and 44˚F. Once the chilled water is supplied to the air handlers it is returned by three end suction pumps that pump the return chilled water back to the chillers. An expansion tank is connected to the chilled water system on the inlet (suction) side of the distribution pumps by a branch line. The chiller process can be shown in Figure 4 and 5.

Figure 4: Existing Condenser Water System Schematic

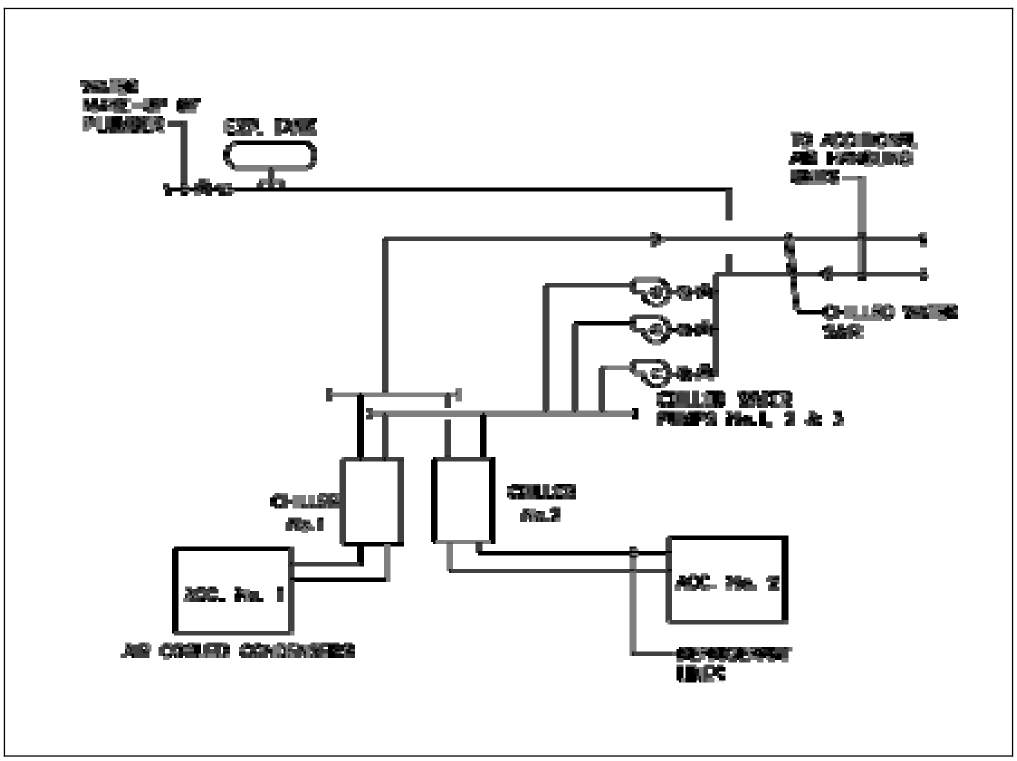
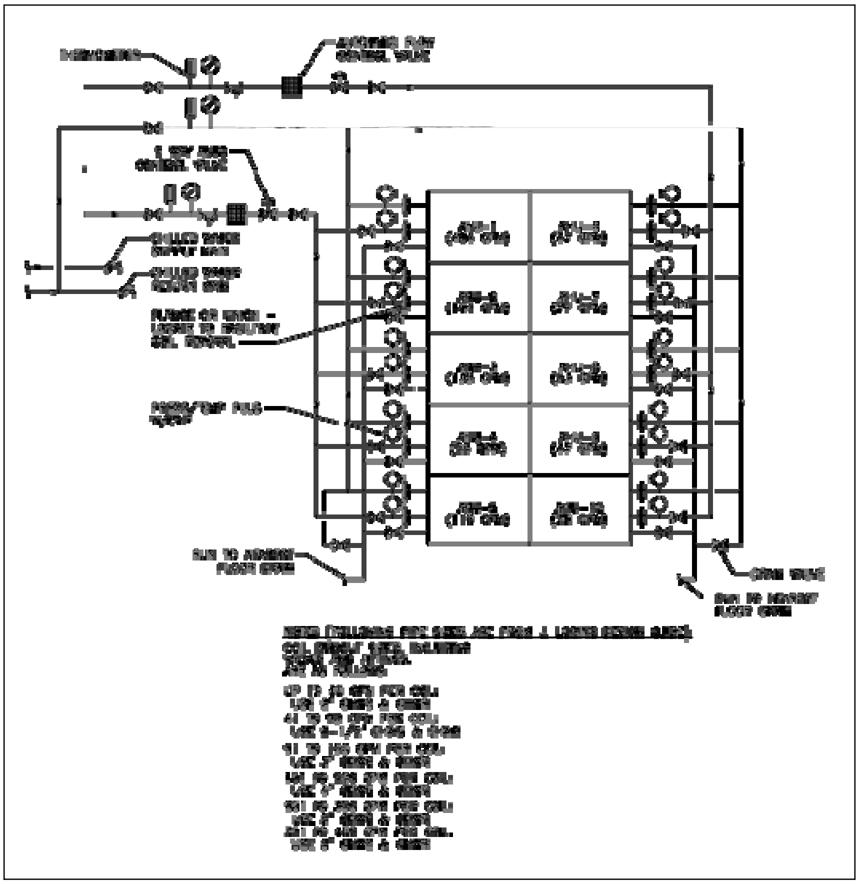


Figure 5: Existing Chilled Water Supply and Return



Airside of Existing Mechanical System:

All of the air handling units came pre-packaged and each equipped with steam heating coils. However, the primary heating in the building comes from steam fin tube radiators while the heating coils inside the air handling units act as the secondary or back-up heat source. There are a total of ten air handlers serving all of the major spaces within the school. Bronx High School of Law utilizes both variable air volume (VAV) and constant air volume (CAV) systems. The CAV system is used primarily for either single zone spaces or zones that are not temperature sensitive such as storage spaces. The VAV system was used for the multi-zone spaces such as the classrooms and offices. The VAV allows for better temperature and humidity control throughout the variety of spaces. Figure 6 represents a typical VAV detail from the original design documents.

Figure 6: VAV Detail Schematic

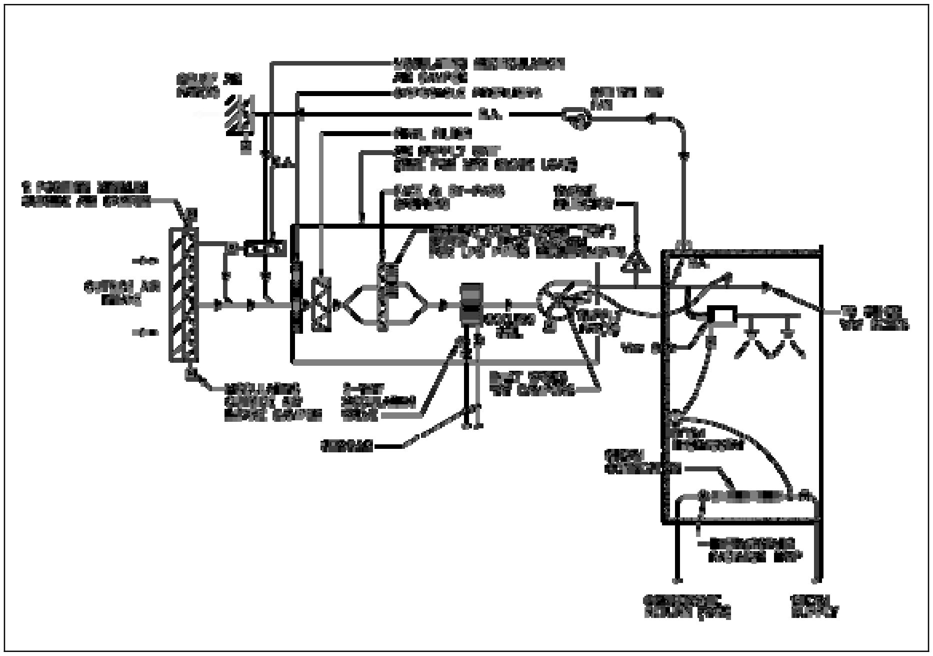


*Figure 6 Detail Schematic from Joseph R. Loring & Associates

A pneumatic automatic temperature system was installed. Air compressors, pneumatic lines, thermostats, freeze stats, etc. are installed to provide a control system. A local control panel was provided for each of the HVAC and mechanical systems. Individual room thermostats in classrooms and offices sequence the room VAV box control damper with each room's respective perimeter steam heating convector's valve. Space thermostats in assembly areas (auditorium, gymnasium, cafeteria, kitchen, etc.) control the operation of their respective constant volume air handling units and perimeter heating.

As with any building supplying fresh outdoor to the building was an important issue. The Bronx School for Law's site falls within the boundaries of the New York City Energy Code. The NYC energy code requires a greater percentage of fresh outdoor delivered through the building, which is ideal because of the population density within the city. Table 1, on the following page, represents the ten scheduled air handlers, area served, type and scheduled supply ventilation and fresh outdoor air.

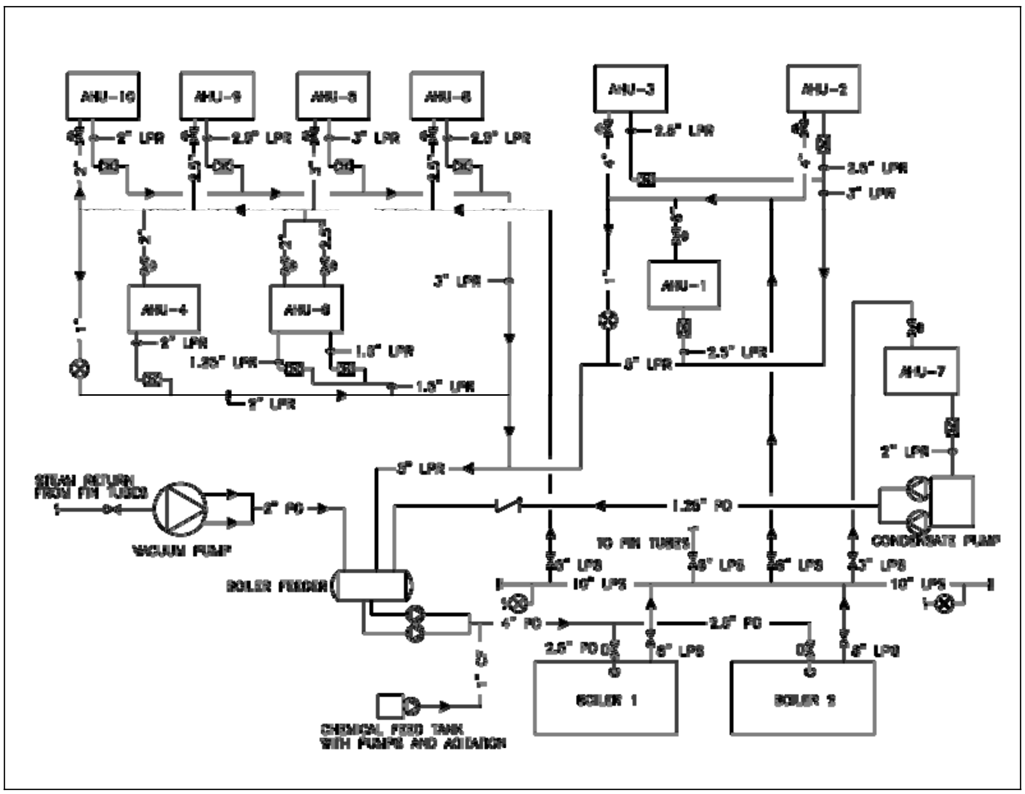
Heating System:

The primary heat source comes from two duel-fired boilers that produce steam for all of the fin tube radiators and packaged air handling units. The boilers use natural gas as the primary fuel source with fuel oil as the back-up. The duel source boiler was chosen in case the incoming natural gas was not accessible. Both boilers send steam to a main distribution steam pipe in which, the respective loads branch off this main pipe. All the steam return is pumped into a boiler feeder tank and then is re-pumped to both boilers at a rated temperature of 212°F. A separate condensate pump is provided for return steam which is then pumped into the feeder tank. Figure 7 illustrates the heating system for Bronx School for Law.

Table 1: Air Handler Schedule

Air Handling Units (AHU)	Type	Total [CFM]	Min. Outdoor Air [CFM]	OA %
AHU 1 [Classrooms & misc.]	VAV	48000	26000	54.2
AHU 2 [Classrooms & misc.]	VAV	19000	9000	47.4
AHU 3 [Gymnasium]	CAV	18500	7500	40.5
AHU 4 [Library]	CAV	3400	1020	30.0
AHU 5 [Lobby & Corridor]	CAV	12000	6900	57.5
AHU 6 [Kitchen]	CAV	5200/2600	5200/2600	100/100
AHU 7 [Administration]	VAV	12000	3800	31.7
AHU 8 [Dining]	CAV	6000	3360	56.0
AHU 9 [Plant Operations]	CAV	7200	2200	30.6
AHU-10 [Orchestra]	CAV	3100	1050	33.9
TOTAL		133440	66030	49.1

Figure 7: Steam Heating System



6.1 MECHANCAL DEPTH: REDESIGN

The mechanical redesign of the Bronx School for Law Government & Justice consisted of two parts, involving both the waterside and airside. The waterside redesign involved implementing an ice thermal storage system. There were many benefits from using ice thermal storage as stated by ASHRAE's *Design Guide for Cool Thermal Storage*. In this instance, there were two main benefits that made ice thermal storage an applicable system to investigate, which were the maximum cooling load of the facility is significantly higher than the average load and the electric utility rate structure included a high demand charge.

As previously stated, the building is a middle/high school, therefore, the majority of the cooling required occurs when the school is in session and when school is in not in session minimal cooling is needed. This scenario translates to a high peak cooling load versus a rather low average or base load. The result, in this case, has a peak load almost 16 times greater than the average load. This outcome leans favorably towards enabling the use of ice thermal storage. The other major advantage of incorporating thermal storage is because of New York City's high demand cost. The demand cost is based on the highest or "peak" use of electricity for any 15-30 minute gap within the on-peak period in a given month. Therefore, the use of thermal storage would allow "shifting" or moving the peak load and distributing it completely or partially to off-peak times.

Ice thermal storage produces water at lower temperatures with the aid of a secondary coolant typically glycol, either ethylene or propylene. The below average chilled water produced, 36-39°F, adds to another benefit of thermal storage by incorporating cold air distribution. The airside analysis took advantage of the lower temperature water from the ice thermal storage and delivered low temperature air, 44-47°F, throughout the spaces within the building. One of main advantages of incorporating cold air distribution with thermal storage is that it has the ability to reduce the first cost in mechanical systems. Generally, the addition of thermal storage adds a significant first cost with the added addition of storage tanks, pumps and controls. However, cold air distribution reduces the required supply air quantity. Correspondingly, the size of fans and ductwork is reduced, which saves on first cost as well as, operating cost. Also the addition of cold air distribution has the potential to offset the cost of the thermal storage system allowing the owner to not only benefit from operating cost savings from thermal storage but also pay less initially compared to a nonstorage system.

Although not specifically analyzed in this report, other applicable benefits of cold air distribution include: possible decrease in floor-to-floor height requirements and improve comfort with lower space relative humidity. The decrease in duct size, can lead to reduction in floor-to-floor height, which transcribes to potential savings in structural, envelope and other building systems costs. There have been studies that the lower space relative humidity maintained by cold-air distribution systems provides improved comfort and indoor air quality (Kirkpatrick & Elleson, 1996).

6.2 MECHANCAL DEPTH: DESIGN GOALS

The ice thermal storage with cold air distribution system was designed with the idea of the following goals:

- Reduce high demand costs
- Downsize the needed chiller capacity
- Increase chiller efficiency
- Reduce energy consumption
- Minimize first cost

\- Reduce high demand costs

Typically, the main reason for adding thermal storage is to avoid or reduce high demand costs. In this case, it is also true, because of the location of the building, high demand charges are present. The use of thermal storage allowed for savings in demand costs by shifting the peak loads to off-peaks times.

\- Downsize the needed chiller capacity and increase chiller efficiency

A common design standard in designing conventional systems is design for the peak load on design day. This often leads to oversized mechanical equipment and forces the equipment to operate more often at part load conditions which may occur only 1-2% of the year. This causes many systems to perform with less efficiency and thus, exceedingly waste energy. In providing thermal storage the chillers would be able to operate more often at the full rated capacity which would be the optimal efficiency and reduce wasting energy.

\- Reduce Energy Consumption

As stated previously, incorporating cold air distribution would reduce the amount of air delivered to the spaces which would lead to smaller fans required. The reduction in fans is an example of how energy can be reduced. By having smaller fans less energy is needed which would save considerably in operating costs each year.

\- Minimize first cost

In today's world many new building projects are "first cost" driven. Meaning owner's priority lies with saving money initially rather than annually with savings in operating costs. Therefore, in this design, first cost had to be taken into account. The addition of cold air distribution aided tremendously in minimizing and even reducing the first cost compared to a nonstorage system.

6.3 MECHANCAL DEPTH: INITIAL DESIGN CRITERIA

In designing any new system for a building the first step is typically defining the initial conditions or design criteria. This was also the approach taken in the redesign of Bronx School for Law Government & Justice. The first and most important information needed for this analysis was finding the most accurate utility rates. Since the feasibility of ice thermal storage relies heavily on the utility rate structure, it had to be determined and analyzed to determine if thermal storage could be cost effectively utilized. Table 2 displays the peak demand, on-peak and off-peak cost for electricity provided by Con Edison, the sites provider of electricity. The electricity rates came from the *New York State Energy Research and Power Authority* which had a typical average bill for commercial buildings for the month of January 2006.

Table 2: Con Edison Electric Utility Rate for January 2006

On-Peak Demand Charge	$12.17 per kW
On-Peak	$0.183 per kWh
Off-Peak	$0.147 per kWh

*http://www.dps.state.ny.us/typical_bills/util_elec_comm_bills_Jan_2006.pdf

The utility rates do not have a significant difference between on-peak and off-peak times, approximately 20%. However, there is a rather high demand charge which favors the use of thermal storage. A demand charge that is over $10/kW/month makes thermal storage a viable option (Dorgan & Elleson 1993). Unfortunately, no rebates or other incentive programs could be found to aid in the cost savings. However, thermal storage can still be cost effectively justified with rebates or incentive programs. Another important factor about the rate structure that needed to be known was the times for on-peak and off-peak. According to a design engineer, the on-peak period ranges from 8 AM to 5 PM. This large on-peak time, 11 hours, had an impact on the redesign because there were fewer hours to shift the load to off-peak times. However, since the difference between the on-peak and off-peak times were not significant the important issue was reducing or avoiding the demand cost.

Another important design parameter was determining the indoor and outdoor design conditions and knowing the thermal properties of the building. This information was compiled from the original design which derived from the *2001 ASHRAE Fundamentals Handbook.* As stated previously, the fresh outdoor air requirements were taken from the New York City building codes which also meet ASHRAE Standard 62.1. The initial design parameters are listed as follows:

WINTER/SUMMER DESIGN PARAMETERS

A. Winter

1. Outdoor air requirements for ventilation: A minimum of 15 cfm per occupant (number of occupants based on NYC Building code, Table 6-2).

2. Inside ambient design temperature:72°F DB.

3. Outside ambient design temperature: 5°F DB (based on wind at 15 mph).

B. Summer

1. Outdoor air requirements for ventilation: A minimum of 15 cfm per occupant (number of occupants based on Board of Education Program Space Requirements).

2. Inside ambient design temperature:78°F DB, 50% RH.

3. Outside ambient design temperature: 89°F DB, 73°F WB.

C. Thermal Properties of Building

1. Overall transmission coefficient for walls: U_W = 0.08

2. Overall transmission coefficient for roof: U_R = 0.05

3. Overall transmission coefficient for windows: U_W = 0.63

4. Overall transmission coefficient for walls below grade walls and floors: U_B = 0.08

5. Glass factor 0.45

6.4 MECHANCAL DEPTH: DESIGN PROCEDURE

Dorgan and Elleson's (1993) *Design Guide for Cool Thermal Storage* and Kirkpatrick and Elleson's (1996) *Cold Air Distribution System Design Guide* provided a basis on the design procedure needed to evaluate the mechanical redesign. The procedure included the following steps:

- ❖ Screening initial economics
- ❖ Calculating load profiles
- ❖ Selecting storage type
- ❖ Selecting operating strategy
- ❖ Sizing cooling plant and storage
- ❖ Determining chiller and equipment parameters
- ❖ Sizing cooling coils for cold-air distribution
- ❖ Laying schematics
- ❖ Evaluating economics both first and life cycle cost
- ❖ Finalizing design

- Screening initial economics

The initial economics was already explored in the previous section to identify if thermal storage was applicable. Since it was determined that thermal storage would be a viable option the proceeding step was to determine the building's load profile. Determining the load profiles first, required the design weather conditions and thermal properties of the building, found in the previous step. Additionally, the building occupancy needed to be known. The building is primarily occupied between the hours of 6 a. m. and 5 p.m., Monday through Friday. There are numerous summer school activities which makes the need for cooling all year round.

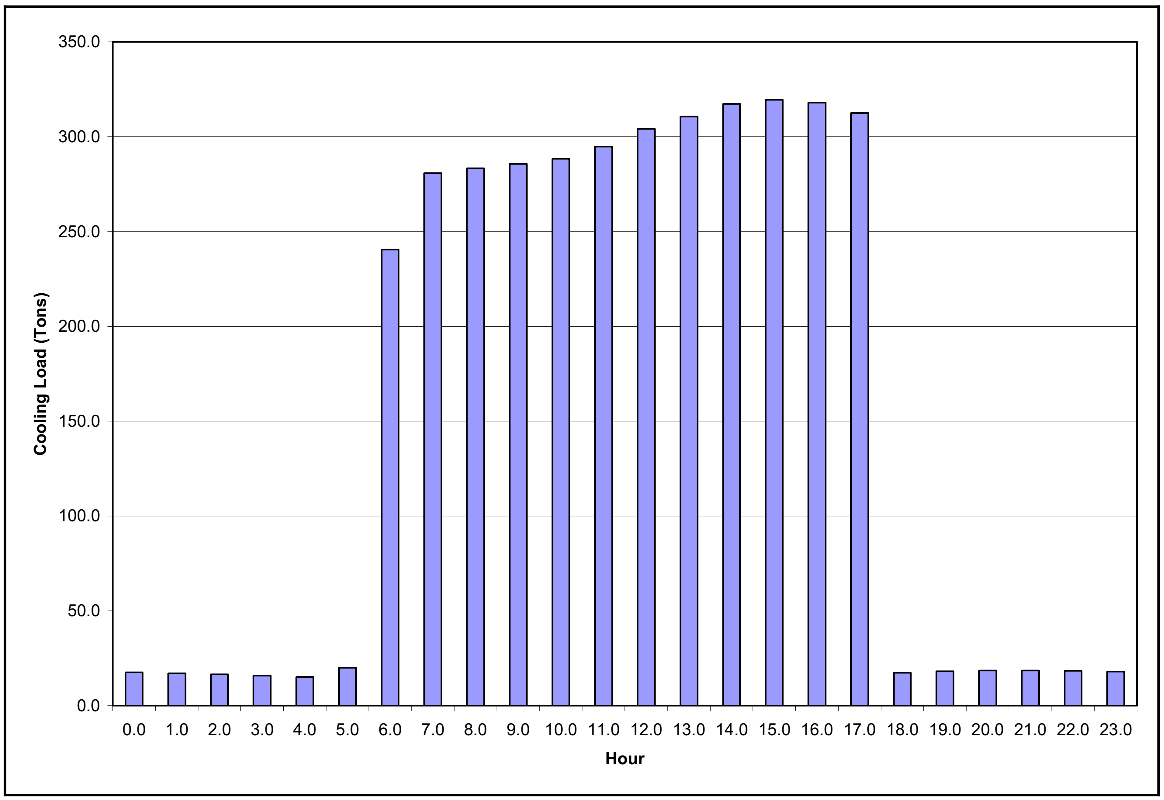
- Calculating load profiles

Then with the aid of a computer energy analysis program, in this case, Carrier's Hourly Analysis Program (HAP) version 4.20, an 8760-hour load profile was obtained. In order to determine the size of the system, HAP was able to generate a 24-hour load profile for the design day (in this case July 23), which is the day with the greatest cooling load, shown, on the following page, in Figure 8. The figure illustrates that there is a relatively low base load compared to the peak load. As stated previously, this scenario favors thermal storage as the peak load can be shifted completely or partially to off peak hours.

- Selecting storage type

After determining the 24-hour load profile the next step was to determine the storage type. Typically, in thermal storage there are two storage types either chilled water or ice. Chilled water storage uses the sensible heat capacity of water, 1 Btu per pound per °F, to store cooling. Meanwhile, ice thermal storage uses the latent heat of water, 144 Btu/lb. One of the major differences between the two is the tank size needed for storage. Since chilled water storage is stored at a warmer temperature, between 39 and 42 °F, versus ice storage, between 22 and 26 °F, the tank size needed is also greater. Tank volume size for a chilled water storage system can range from 11 to 21 ft^3/ton-hr where ice tank volume sizes range from 2.4 to 2.8 ft^3/ton-hr (Dorgan and Elleson, 1993). The size of tanks needed for chilled water is at least four times greater than that of ice storage. Another factor to why ice was chosen was space. As stated previously, the building's site is in the heart of the criminal justice section in Bronx, NY which led to limited space for storage tanks. Considering both first cost and available space, ice was chosen as the storage media.

Figure 8: Nonstorage System Design Day Load Profile



However, the storage type selection is still incomplete. There are three main types of ice thermal storage that was considered including: ice harvesting, external melt and internal melt ice-on-coil. The ice harvesting refrigeration plant generates and releases sheets or tubes of ice with a specially designed evaporator section. Water is pumped out of the storage tank and is distributed over the evaporator surfaces and is either chilled or frozen. The ice harvesting plant is capable of operating as both an ice maker and as a water chiller. Unfortunately, because this chiller has to be specially designed the first cost is extremely high, around $1000 to $2000 per ice making ton (Dorgan and Elleson, 1993). The first cost for an ice harvesting system relative to the size of project could not be cost justified.

An external melt ice-on-coil storage system builds and stores ice on the exterior surfaces of a heat exchange coil submerged in a non-pressurized water tank. In order to charge the storage system, typically a secondary coolant, such as a glycol solution, is circulated inside the heat exchange tubes, causing ice to form on the outside of the tubes. Discharging the stored cooling, the ice on the tubes is melted by warm return water which circulates through the tank. The leaving water is chilled and used to meet the building load. External melt ice storage systems normally build ice to a thickness of 1.5 to 2.5 inches on the pipe. The greater the thickness requires lower charging temperatures around 10-15°F. This means the chiller capacity has to be increased significantly to be able to produce that low of temperature water. This is due to the chiller efficiency dropping for every temperature degree below its rated leaving water temperature, because it requires more energy to lower the temperature (Dorgan and Elleson, 1993). This chiller becomes "de-rated" meaning the actual capacity of the chiller is significantly less than the rated nominal capacity. For example, if a 100-ton chiller is de-rated 30 percent than the chiller actually only produces 70 tons and not the full 100. Also external melt systems require a separate charge and discharge circuit which would add to first cost in piping and in pumps.

Internal melt ice systems work similarly to the external system except instead of using a separate discharging circuit it uses the same circuit for both charging and discharging. In discharge mode, warm coolant flows through the tubes, melting the ice from the inside out and reducing the coolant temperature for use in meeting the cooling load. Building ice, works exactly like same way as external melt only the coolant temperature is warmer, 22-26°F. When comparing between internal and external melt systems the chillers for internal are generally smaller because of the warmer water meaning the chiller is less de-rated as compared to external melt. Another advantage is internal melt only require one circuit for charging and discharging whereas, external requires two separate lines. Therefore, on these principles the internal melt system was chosen.

- Selecting Operating Strategy

The next step after determining the storage type was to decide on the operating strategy either: partial or full storage. Both partial and full storage systems have their distinct advantages. A partial storage system is able to meet a portion of the on-peak cooling load from storage, with the remainder of the load met by the operating chiller equipment. Typically, in a partial storage system the chiller is smaller than compared to a nominal chiller. Partial storage systems can be operated in two control strategies: load-leveling and demand-limiting operation. A load-leveling system generally operates at full capacity continuously throughout the day, charging during off-peak and directly cooling during on-peak, while a demand-limiting system operates at a reduced capacity during on-peak hours. Although, a full storage system shifts the entire on-peak cooling load to off-peak periods. The downfall with full and demand-limiting storage strategies is that they require more storage capacity and larger chiller sizes as compared to the load-leveling strategy (Dorgan and Elleson, 1993). This analysis explored the options of both load-leveling partial storage and full storage. The same 24-hour load profile that was generated for the nonstorage system was used to determine the required storage capacity needed for both full and partial storage, shown in Figures 9 and 10. The *Design Guide for Cool Thermal Storage* was again used to determine the chiller and storage capacities needed.

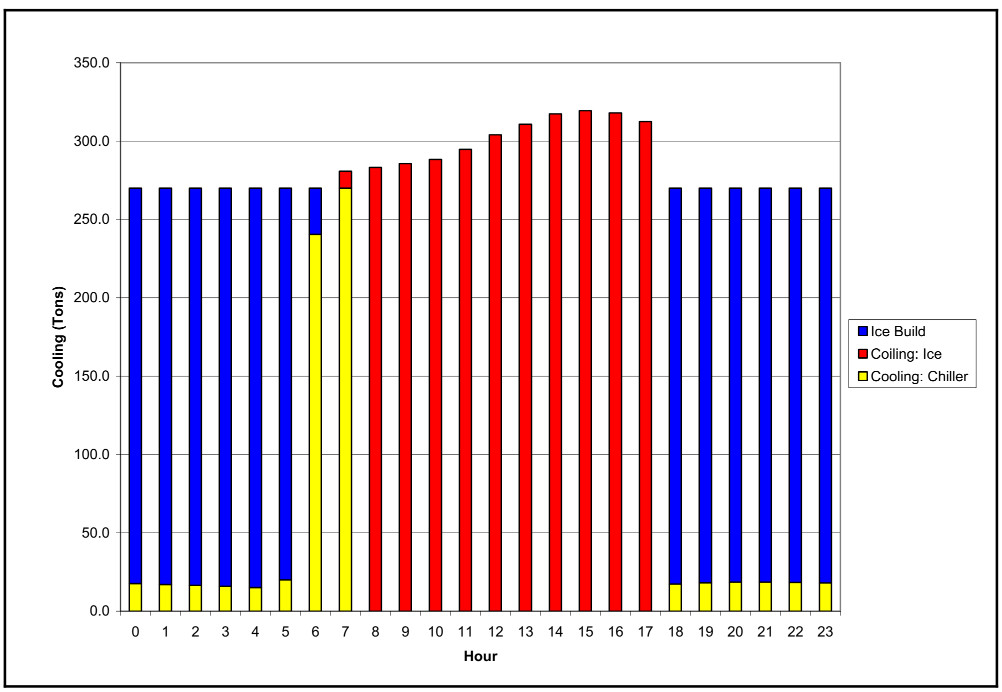
- Sizing cooling plant and storage

From Figures 9 and 10, it was originally calculated for chillers sizes for full storage to be 270 tons and partial storage to be 160 tons. However because the leaving water temperature is between 22-26°F the chiller capacity is reduced approximately 33 percent. Therefore, a larger capacity chiller needed to be selected to meet the required loads. The following components was selected and sized:

- Full Storage

  - ❖ (2) 410 ton propylene glycol chillers
  - ❖ (2) 1400 gpm cooling towers
  - ❖ (6) 486 ton-hour ice storage tanks
  - ❖ (1) 162 ton-hour ice storage tanks

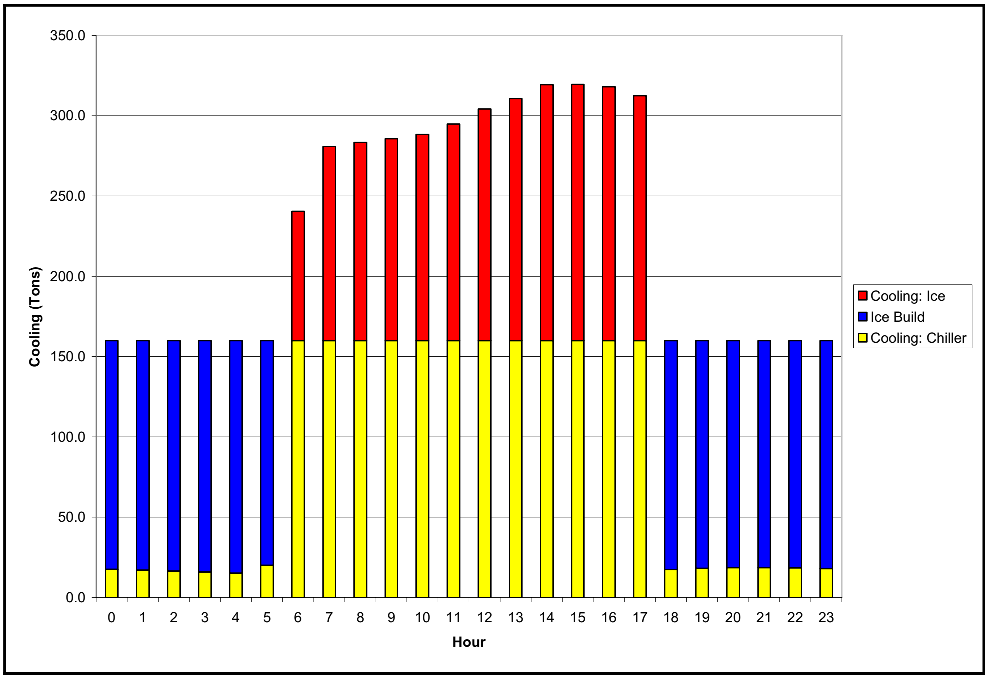
Figure 9: Full Storage System Design Day Load Profile



- Partial Storage

  - ❖ (2) 240 ton propylene glycol chillers
  - ❖ (2) 800 gpm cooling towers
  - ❖ (3) 486 ton-hour ice storage tanks
  - ❖ (2) 162 ton-hour ice storage tanks

Figure 10: Partial Storage System Design Day Load Profile



- Determining chiller and equipment parameters

The chillers were selected for peak load conditions and designed with the "n+1" rule of thumb. The n+1 rule of thumb is designing one chiller or a combination of chillers and adding one of equal capacity. This is done for redundancy, incase a chiller would fail or is in need of maintenance the redundant chiller would be able to operate to serve the cooling load. Adding an "extra" chiller does add significant first cost but the tradeoff is that it also provides a fail-safe and flexibility to the system.

Another option during the process of chiller selection was to incorporate a "base" chiller. A base load chiller is used to serve the average load during off-peak times. A base load chiller can be advantageous when the average load during off-peak hours remains constant. In this case, the base load does remain relatively constant however; the average load was only around 20 tons. The option of installing a 20 ton base chiller was explored however; was not implemented. There were several reasons as to why a base chiller was not selected. Having a chiller with an extremely small capacity compared to the capacity needed for the peak loads was not economically cost effective. Aside from the actual chiller having a high first cost additional pumps and controls would need to be added which also increase first cost. To meet the demands of the off-peak loads, the resolution was to add a three-way valve and additional piping and during the charging mode a portion of the cold water, 26°F, would be diverted and mixed with the return, 51°F, to meet the required cooling coil entering water temperature at 39°F.

Selecting the type of chiller was another issue that had to be addressed. Centrifugal, reciprocating and screw chillers are all capable of producing the necessary chilled water for ice storage. However, the problem with centrifugal chillers selections must be made specific for designed operating conditions while reciprocating and screw chillers are more adaptable to a wider range of leaving temperatures. The YORK® MaxE™ water-cooled screw chillers were selected to provide the necessary chilled water. The technical specifications for these chillers can be seen in Appendix A.

Figure 11: YORK® MaxE™ water-cooled screw chillers

As stated earlier, the original mechanical systems were air cooled DX condensers. The redesign required water cooled chillers which means that cooling towers needed to be added to the system. After selecting the chillers the required condenser flow rates were obtained and Marley's NC Class cooling towers were selected. The technical specifications for these cooling towers can be seen in Appendix A.

Figure 12: Marley NC Class Cooling Towers

The other major equipment that needed to be selected was the ice storage tanks themselves. Calmac's IceBank ice storage tanks were selected as the storage containers. The IceBank model 1190C has the capacity for 162 ton-hrs of storage and the model 1190C, which simply are three model 1190C tanks piped together. Evaluating the tank capacities and capacities needed for cooling, six model 1500C and one model 1190C tanks, totaling 19 tanks and 3078 ton-hrs of cooling, were selected for full storage and three model 1500C and two model 1190C tanks, totaling 11 tanks and 1782 ton-hrs of cooling, were selected for partial storage. More information can be found in Appendix A.

Figure 13: Calmac IceBank Storage Tanks

- Sizing cooling coils for cold-air distribution

Taking advantage of the colder water being supplied from the ice thermal energy system cold air distribution was also applied. An advantage of using cold air distribution was that it would reduce the required airflow. Equation (1) was used to determine the reduced amount of airflow required and still meet the capacity needed for the load. One of the main components that needed to be changed was the cooling coils inside the packaged air handlers. The current cooling coils were sized for entering and leaving water temperatures of 44 and 55°F, with entering and leaving air at 85 and 55°F. In order to handle the new entering and leaving water temperature of 39 and 51°F, and entering and leaving air at 85 and 44°F, the cooling coils needed resized. Obtaining the new cooling coils Carrier's AHUBuilder v. 5.42 was used. Knowing the sensible load required, the new airflow and the new enter and leaving water temperature, AHUBuilder was able to specify the new cooling coils. Table 3 represents the original designed air handler's airflow, flow rate and cooling capacity and Table 4 represents the resized air handlers. The calculated cooling coil data from AHUBuilder can be seen in Appendix A.

Equation 1: $Q_s = 1.08*(CFM)*\Delta T$

Q_s = Required Sensible Load
CFM = Required airflow
ΔT = Change in entering and leaving air temperature

Table 3: Original Design Data

	CFM	GPM	Sensible	Total
AHU-1	48000	404	1614.0	2440.0
AHU-2	19000	164	612.4	903.5
AHU-3	18500	138	578.7	848.3
AHU-4	3400	25	101.3	152.1
AHU-5	12000	119	479.3	728.1
AHU-6	5200	47	178.6	287.5
AHU-7	12000	77	333.3	471.6
AHU-8	6000	53	207.3	323.0
AHU-9	7200	47	202.4	284.9
AHU-10	3100	22	91.0	134.1
Totals:	134400	1096	4398.3	6573.1

Table 4: Redesigned Data

	CFM	GPM	Sensible	Total
AHU-1	37500	336.6	1656.3	2442.8
AHU-2	14500	120.2	621.9	875.3
AHU-3	13500	112.3	580.4	817.6
AHU-4	2400	19.3	103.4	140.6
AHU-5	11200	92.8	480.4	675.6
AHU-6	4200	35.8	183.4	260.9
AHU-7	8000	64.3	335.4	468.2
AHU-8	4800	40.7	208.4	296.0
AHU-9	4800	40.7	208.4	296.0
AHU-10	2400	17.7	95.1	128.9
Totals:	103300	880.4	4473.1	6401.9

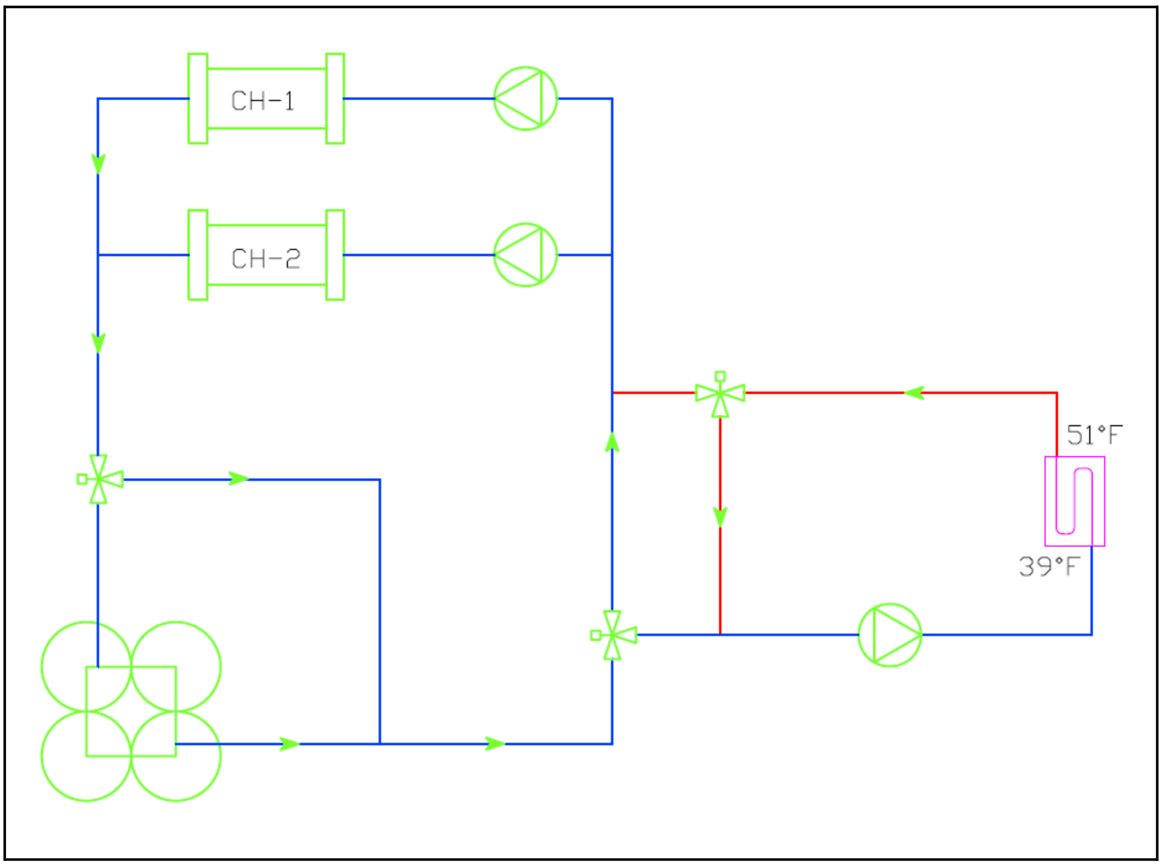
The biggest concern with cold air distribution involves concerns with condensation both through the ductwork and off the supply diffusers. Although not specifically studied in the analysis there are ways to overcome these problems. The easiest way of solving the ductwork issue is assure that all the ducts are properly insulated; improperly insulating the ductwork can lead to condensation problems with any system not just cold air distribution systems. There are two ways to solve to the supply diffuser issue involving either switch the conventional supply diffusers to linear slot diffusers or use fan-powered VAV boxes to blend a portion of the return air with the supply air and typical 55°F air will be delivered to the spaces. The linear diffusers have a higher momentum (mass flow rate × velocity) of cold air increases the throw. This is important because the air will mix faster and will then be able to satisfy thermal comfort. A slight downside to the fan-powered box option is that it will increase fan energy slightly because of the need to operate continuously during use. However, both options are viable and will solve the problem of condensation on the diffusers.

- Ice storage system schematic

As previously analyzed, in both full and partial storage there will be two chillers specified. The schematic layout for both would be identical with the exception of the size of the equipment. Again as stated previously, there will not be a base load chiller therefore; the load during off-peak times will be met by the chiller directly. The important aspect with this design is the controlling sequence. It is imperative that when cooling directly from the chiller during ice build mode that the water be mixed with the return, enough to warm the water to the rated 39°F. This is important because sending 26°F water directly to the cooling coil may freeze the coil and cause major problems. To assure that the water is mixed properly three-way temperature and diverting valves were added. The valves will modulate to mix the proper flow to obtain the rated temperature to meet the loads. Another control strategy that had to be determined was for partial storage. Figure 13 is the schematic for the new redesigned thermal energy storage system.

During partial storage there were two options to operate either chiller priority or storage priority. Chiller priority results in higher chiller use during on peak times while storage priority more of the on peak cooling is done by the storage. Like most decisions there is a trade-off, chiller priority operates the chiller with better efficiency but cost more during on-peak hours while storage priority is the opposite the chiller operates less efficiency but cost less during on peak times. Also storage priority requires more storage capacity which again adds to the first cost and because the difference between on and off peak rates were not significant chiller priority was selected.

Figure 13: Ice Storage Schematic



- Evaluating first cost

One of the main goals of the entire redesign process was to minimize the first cost. In addition to the cost concerns stated earlier the following must also be taken into account: chilled water pumps, condenser pumps, additional secondary pump, additional valves, piping and glycol.

- Chilled Water Pumps

  The addition of thermal storage and cold air distribution reduced the size of chillers which would also reduce the chilled water flow and correspondingly reduce the chilled water pumps needed.

- Condenser Water Pumps

  Since the original chillers were air cooled packaged chillers there were no condenser pumps. However, in the redesign cooling towers were added to reject the heat from the chillers. This required the addition of condenser pumps to be added to the system.

- Additional Secondary Pump

  Originally, the chilled water was pumped directly to the air handling units in a primary loop system. The addition of a secondary loop required also an additional pump.

- Additional Valves

  Three-way mixing valves that were not needed in the original design was now required. The additions of these valves were needed to properly control the temperature and flow throughout the system.

- Piping

  There was a need for additional piping in the system because of the change from a primary system to a primary/secondary system. However, because the flow is less the pipe sizes were able to be reduced.

- Glycol

  The original system was a fresh water system and did not require the use of glycol. However, to achieve the low temperature required a 25% by volume glycol system was needed. Propylene glycol was selected because it was less toxic compared to its ethylene counterpart.

Results

The first cost, operating cost, life cycle cost, and simple payback period were determined and analyzed for the conventional, partial storage and full storage systems.

Table 5 represents a summary of the first cost comparison; the entire first cost analysis can be seen in APPENDIX B. The first cost analysis used the *2006 RS Means Mechanical Cost Data.*

Table 5: First Cost Comparison

	Conventional		Partial Storage		Full Storage	
	Material	Labor	Material	Labor	Material	Labor
Chillers	$314,000.00	$34,080.00	$378,103.00	$47,003.00	$614,103.00	$52,936.00
Pumps	$9,525.00	$1,695.00	$22,100.00	$1,365.00	$22,100.00	$1,365.00
Air Handling Units	$187,050.00	$13,185.00	$154,750.00	$11,985.00	$154,750.00	$11,985.00
Cooling Coils	$23,828.00	$12,638.00	$27,315.00	$14,537.00	$27,315.00	$14,537.00
Fans	$59,985.00	$16,140.00	$41,135.00	$12,225.00	$41,135.00	$12,225.00
Air Distribution	$396,525.00	$836,663.00	$375,875.00	$740,544.00	$375,875.00	$740,544.00
Pipe	$128,765.00	$157,613.00	$103,012.00	$126,090.00	$103,012.00	$126,090.00
Pipe Insulations	$38,585.00	$29,960.00	$30,868.00	$23,984.00	$30,868.00	$23,984.00
Subtotal	$1,158,263.00	$1,101,974.00	$1,133,158.00	$977,733.00	$1,369,158.00	$983,666.00
Grand Total	$2,260,237.00		$2,110,891.00		$2,352,824.00	

Determining the operating cost required a few steps. First the energy model needed to be created to see the yearly cooling required. Carrier's HAP was once again used to simulate the 8760-hour energy model. Although thermal storage could not be simulated directly from HAP it was however, able to take into account the cold air distribution savings. The two energy models have been recreated in Microsoft's Excel sheets and are included in Appendix B. Table 6 represents the peak loads on design day for each month.

Table 6: Peak Loads Design Day

	PEAK TON		PEAK TON
JAN	110.7	JUL	319.5
FEB	134.7	AUG	317.5
MAR	188.5	SEP	289.9
APR	227.2	OCT	245.3
MAY	277.5	NOV	190.1
JUN	301.8	DEC	132.1

To determine the annual operating cost the energy models that were created and the initial utility rates were needed. Then knowing the on-peak and off-peak kWh use the operating cost for the conventional and full storage systems could be calculated. However, it is more difficult to determine the annual energy cost for partial storage because of the fluctuation of on-peak loads. Therefore, equation (2) from Pacific Gas & Electric's article *Thermal Energy Storage Strategies for Commercial HVAC Systems* was used to estimate the operating cost. Chiller efficiency had to be factored into the estimations as well. Producing ice is less efficient than producing regular chilled water. Dorgan and Elleson's (1993) *Design Guide for Cool Thermal Storage* had the ice chillers around 1.1 kW/ton and 0.7 kW/ton was used for the conventional chillers. The Table 7 breaks down the estimated annual energy costs.

Equation (2):

$$kWh_{shifted} = \#\ tons_{shifted} \times (kW/ton)_{chiller\ performance} \times \text{on-peak hours} \times \text{load shape factor}$$

"The load shape factor is a needed multiplier because peak cooling load typically is not constant. This factor, used in the above equation, is for the on-peak period only (the time when cooling load will be shifted) and for the peak cooling load for that day. Typical load shape factors are in the range of 60 to 90 percent for a variety of building types and climates." – PG&E

Table 7: Estimated Annual Energy Cost

	Conventional System	Partial Storage	Full Storage
Demand Cost (kW)	26626.01	22318.81	0.00
Operating Cost (kWh)	49140.21	40079.48	55800.05
Total Annual Cost	75766.22	62398.29	55800.05

The Life Cycle cost was estimated at a 25-year period, beginning in 2003 when the actual building was occupied. Electricity escalation factors were found for electricity using the *Energy Price Indices and Discount Factors for Life-Cycle Cos Analysis – April 2006*. Table 8 represents the estimated life-cycle cost.

Table 8: Estimated Life Cycle Cost

	Conventional	Partial Storage	Full Storage
First Cost	2260237.00	2110891.00	2352824.00
25 yr LC Cost	2533622.49	2086598.70	1865953.67
LLC	4793859.49	4197489.70	4218777.67

Finally, the payback period for both partial and full storage were calculated and shown in the Table 9.

Table 9: Simple Payback Period

	Partial Storage	Full Storage
Payback (yrs)	-1.9	10.5

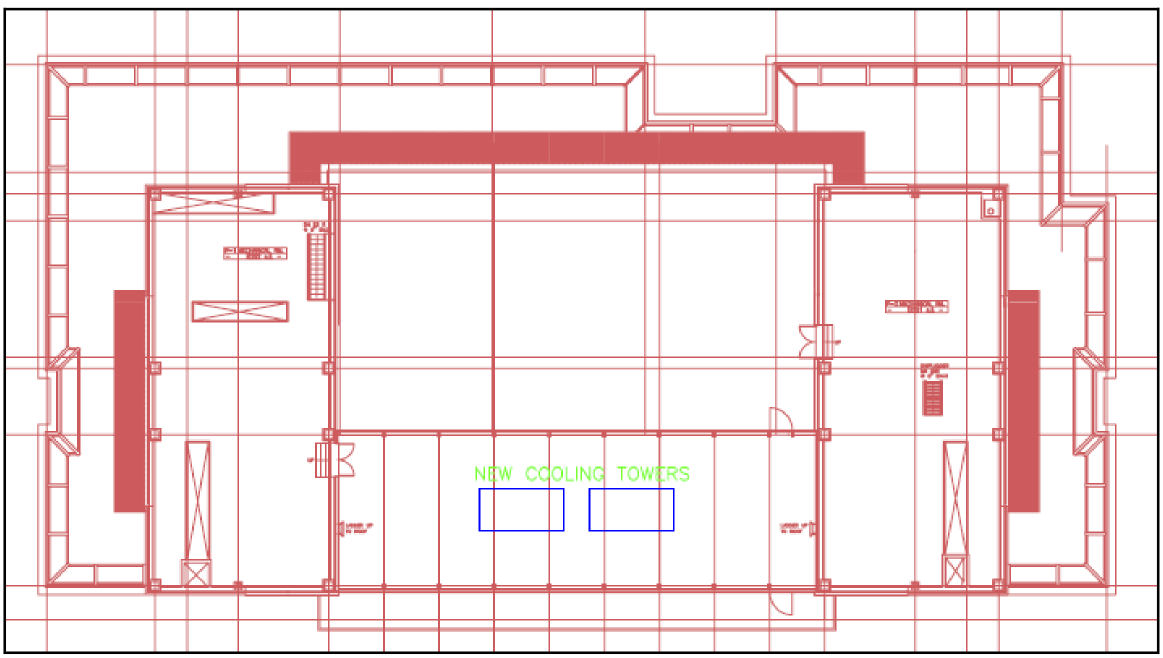
- Finalizing Design

There are many factors involved when considering the feasibility of implementing any new system. Typically, first cost is the main factor as to whether a system is implemented or not regardless of energy optimization. Owners want a quick payback to their investments and disregard the other issues. In analyzing thermal energy storage alone the first cost was significantly more than a conventional system. By adding cold air distribution allowed the first cost for partial storage to be cheaper than that of the conventional system. In deciding between the two operating strategies partial storage seemed the most cost effective and overall the most optimal chose. Space was another issue as to why partial storage was more applicable, full storage required larger chillers, cooling towers and storage capacity. Space is at a premium in New York City therefore, more space needed to be devoted to occupancy use than for building life systems. Considering both first cost and space partial storage was chosen over full storage. As far as comparing thermal storage with the conventional system, not only is the cost of thermal storage with cold air distribution cheaper but it also reduces the energy consumption through the mechanical systems. By not only saving on demand charges but reducing energy consumption and smaller equipment makes thermal storage an applicable solution.

7.0 STRUCTURAL ANALYSIS

In analyzing any new system the impact on other building systems has to be evaluated. In this analysis of thermal storage cooling towers had to be added to the roof. The original design specified air cool condensing units on the roof. However, by adding thermal storage the air cooled units would no longer be needed and the space could be used for the cooling towers. Figure 14 illustrates the cooling tower location. The only problem was that the cooling towers operating weight was greater than the air cooled condensing units. Therefore, an analysis was completed to determine if the current beams, HSS 10 x 6 x 3/8, would be able to support the additional weight, 1000 lbs. per tower. The complete set of calculations can be seen in Appendix C. It was determined that the current HSS beams did indeed have enough capacity to hold the new cooling towers.

Figure 14: New Location for Cooling Towers



Another analysis that was considered was the placement of the ice thermal storage tanks. There were a few options including placing the tanks on top of the roof. However, after some preliminary analysis it was determined that the majority of the roof system would have had to been redesigned to accommodate the weight of the storage tanks. The conclusion for the location of the storage tanks was to take a portion of the small parking lot behind the building. The drawback to this approach was that the chillers were located up in the mechanical penthouse and the chilled water pipes would then have to run from the top building to the bottom to store ice and the storage tanks would then have to pump the water back up to the mechanical penthouse to serve the cooling coils, also located in the mechanical penthouse. However, based on the economics purchasing extra piping was cheaper than purchasing larger beams.

Another structural element that was not explored but considered was because the addition of cold air distribution the duct sizes became smaller. Reducing the duct sizes may have allowed the floor-to-floor height to be reduced. However, because the building is only six stories tall the overall reduction may have been minimal but in large high-rise building the cost savings could have been greater.

8.0 ELECTRICAL ANALYSIS

Whenever changing any equipment the first system that is usually affected is the electrical system. The addition of thermal storage and cold air distribution had an impact on the electrical system. The redesign was able to downsize numerous pieces of equipment including chillers, air handling units, fans, and pumps. Most of the equipment that is motor driven is powered through motor control centers. This allows for all the motors in the building to be controlled by in one central location. There are a total of two – 1200A and one 600 A motor control centers located to serve the majority of HVAC equipment in the building. Figure 15 illustrates one of the 1200 A motor control centers within the building.

Figure 15: 1200 A Motor Control Center

'MCC-6A'	–									
1200A, 480V 3ø, 3W + GND (6TH FL. WEST MER)	1	ACC-1	318 KW	–	800	700	3	2 SETS (3-350KCMIL & 1#1/0 GND-2 1/2"C)		DISCONNECT SWITCH ONLY
	2	AHU-4	5	1	30	15	3	3#12 & 1#12GND-3/4"C		
	3	AHU-5	20	2	60	45	3	3#6 & 1#10GND-1"C		
	4	AHU-6	7 1/2	1	30	15	3	6#12 & 1#12GND-1"C		2 SPEED 1 WINDING
	5	AHU-8	10	2	30	20	3	3#12 & 1#12GND-3/4"C		
	6	AHU-9	15	2	60	35	3	3#8 & 1#02GND-3/4"C		
	7	AHU-10	7 1/2	1	30	15	3	3#12 & 1#12GND-3/4"C		
	8	RF-4	1 1/2	1	30	6	3	3#12 & 1#12GND-3/4"C		
	9	RF-5	5	1	30	10	3	3#12 & 1#12GND-3/4"C		
	10	RF-8	1 1/2	1	30	6	3	3#12 & 1#12GND-3/4"C		
	11	RF-9	3	1	30	10	3	3#12 & 1#12GND-3/4"C		
	12	RF-10	1 1/2	1	30	6	3	3#12 & 1#12GND-3/4"C		
	13	EF-3	3	1	30	10	3	3#12 & 1#12GND-3/4"C		
	14	HEF-1	1 1/2	1	30	6	3	3#12 & 1#12GND-3/4"C		
	15	HEF-2	1 1/2	1	30	6	3	3#12 & 1#12GND-3/4"C		
	16	HEF-3	1 1/2	1	30	6	3	3#12 & 1#12GND-3/4"C		
	17	HEF-4	1 1/2	1	30	6	3	3#12 & 1#12GND-3/4"C		
	18	HEF-5	1 1/2	1	30	6	3	3#12 & 1#12GND-3/4"C		
	19	SPARE	–	1	30	–	3	–		
	20	KX-1	5	1	30	10	3	3#12 & 1#12GND-3/4"C		
	21	TX-1	2	1	30	6	3	3#12 & 1#12GND-3/4"C		
	22	UH-A1	30KW	2	60	50	3	3#6 & 1#10GND-1"C		DISCONNECT SWITCH ONLY
	23	UH-A2	30KW	2	60	50	3	3#6 & 1#10GND-1"C		DISCONNECT SWITCH ONLY
	24	SPARE	–	1	30	–	3	–		
	25	SPARE	–	1	30	–	3	–		
	26	SPARE	–	1	30	–	3	–		
	27	SPARE	–	–	30	–	3	–		DISCONNECT SWITCH ONLY
	28	SPARE	–	–	30	–	3	–		DISCONNECT SWITCH ONLY
	29	SPARE	–	1	60	–	3	–		
	30	SPARE	–	2	60	–	3	–		
	31	SPARE	–	2	60	–	3	–		
	32	SPARE	–	2	60	–	3	–		

This particular motor control center (MCC) serves six of the ten air handling units serving the school. However, because of the cold air distribution, the air handling units and fans were all able to be downsized. An analysis was completed to determine whether the downsizing of the equipment would be able to reduce the size of the motor control centers. In order to perform this analysis the new feeder ampacity was needed for each downsized equipment. Table 10 compares the original and the new equipment.

Table 10: Comparison of Ampacity Between Original and New Equipment

	Original	New
AHU-4	15	10
AHU-5	45	35
AHU-6	15	10
AHU-7	20	15
AHU-8	35	25
AHU-9	15	10
AHU-10	10	10
RF-4	6	6
RF-5	10	10
RF-8	6	6
RF-9	10	10
RF-10	6	6
Unchanged Loads	846	846
Total	1039	999
Difference	40	

From Table 10, there was only a 40A difference between the original and new equipment selected. A 1000A MCC could be selected and would meet the necessary load however, the MCC would not be able to take on future expansions. The current 1200A MCC would still allow for future additions of equipment. Although, direct electrical first cost savings could not be found other savings could be found by smaller wire and conduit sizes.

9.0 FINAL THOUGHT

In designing any new mechanical system it is imperative to set initial goals. Then it is important throughout the design process to keep in mind those goals and at the end determine if those goals were met. In this analysis the technologies of ice thermal storage and cold air distribution were explored, dissected and analyzed. Thermal storage is not a "new" technology but often not utilized because of cost, space, unfavorable electricity rates, etc. However, with the proper circumstances and optimum design thermal storage can be a very cost and energy saving technology. The same holds true for cold air distribution it too is not a "new" technology and if utilized properly can be beneficial. However, like every system, these technologies do not apply to every building. Every system has their strengths and weaknesses it is the designer's job to identify the strengths of a system for a specific application. Then analyze whether the strengths outweigh the weaknesses. Every building is different which means every system is different in some capacity or another. That is why setting initial goals and sticking to them is the basis of any design.

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APPENDIX A

Mechanical Equipment Sheets:

York Chiller
Marley Cooling Towers
Calmac IceBank Storage Tanks
Low Temp Air Cooling Coils

FORM 201.24-EG3 (1201)

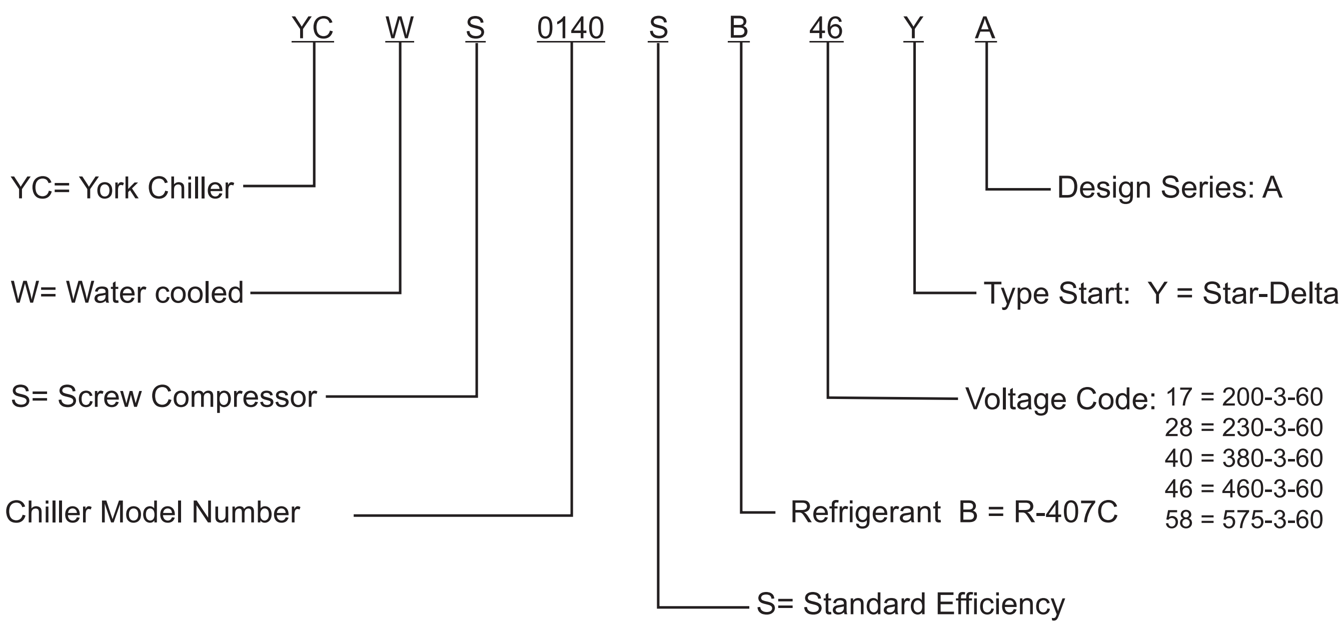
YCWS
WATER COOLED LIQUID CHILLER

HFC-407C

89 TONS THROUGH 209 TONS
313 kW THROUGH 735 kW
60Hz
STYLE A

Table of Contents

Nomenclature



Introduction

York YCWS Water Cooled Screw Chillers

*YORK **YCWS** Water-Cooled models provide chilled water for all **HFC** air conditioning applications that use central station air handling or terminal units. They are completely self-contained and are designed for indoor (new or retrofit) installation. Each unit includes accessible semi-hermetic screw compressors, a liquid cooler, water cooled condenser, and a user-friendly, diagnostic Microcomputer Control Center all mounted on a rugged steel base. The units are produced at an ISO 9001 registered facility. The YCWS chillers have certified ratings in accordance with ARI Standard 550/590.*

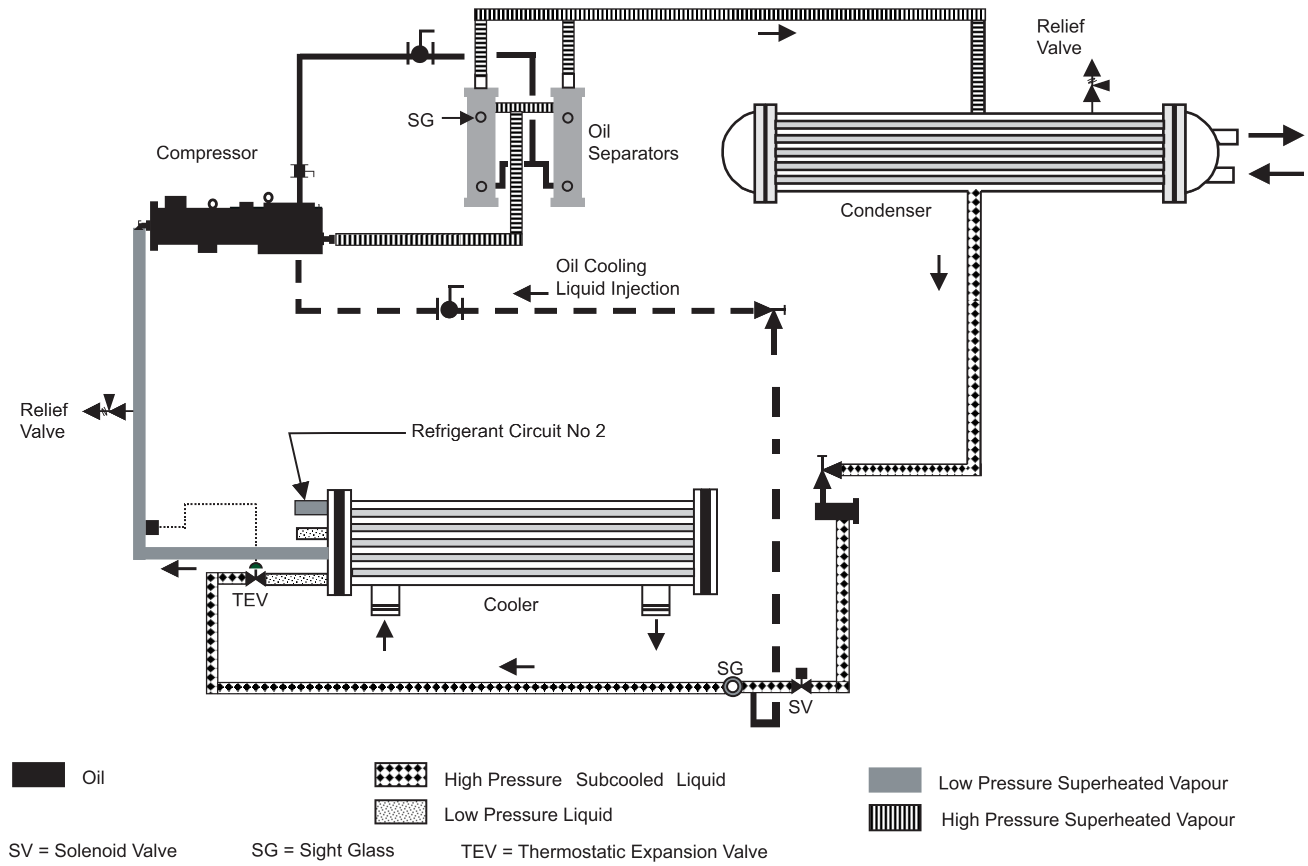
Design Parameters

English

YCWS	0100SB	0120SB	0140SB	0180SB	0200SB	0220SB	0240SB
Min. Cooler Water Flow - GPM	200	200	200	260	260	300	300
Max. Cooler Water Flow - GPM	506	506	506	695	695	830	830
Min. Cond. Water Flow - GPM	193	193	193	330	330	330	330
Max. Cond. Water Flow - GPM	645	645	645	1050	1050	1050	1050
Min. Lvg. Liquid Temp. - °F	40	40	40	40	40	40	40
Max. Lvg. Liquid Temp. - °F	50	50	50	50	50	50	50
Min. Ent. Cond. Water Temp - °F	75	75	75	75	75	75	75
Max. Ent. Cond. Water Temp - °F	95	95	95	95	95	95	95
Min. Equipment Room Temp. - °F	40	40	40	40	40	40	40
Max. Equipment Room Temp. - °F	115	115	115	115	115	115	115

SI

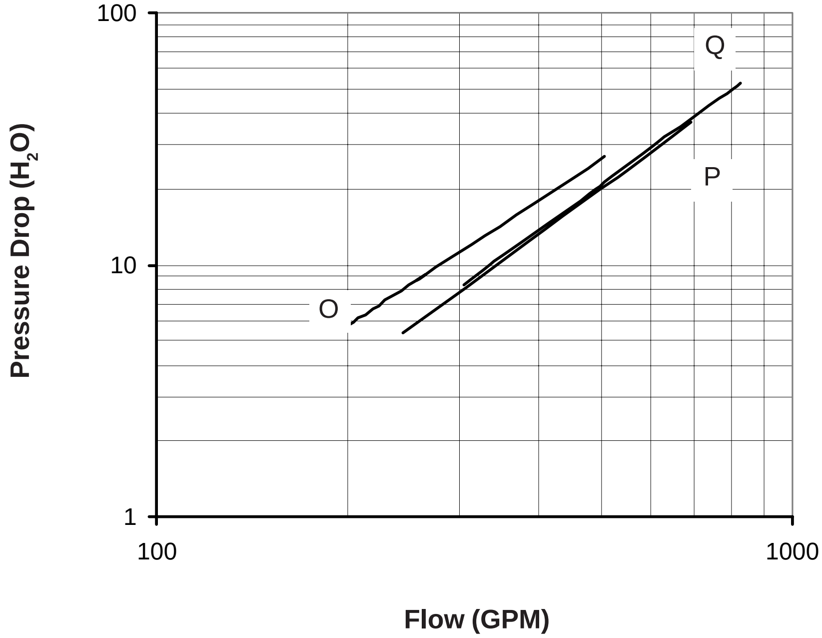
YCWS	0100SB	0120SB	0140SB	0180SB	0200SB	0220SB	0240SB
Min. Cooler Water Flow - l/sec	12.6	12.6	12.6	16.4	16.4	18.9	18.9
Max. Cooler Water Flow - l/sec	31.9	31.9	31.9	43.8	43.8	52.4	52.4
Min. Cond. Water Flow - l/sec	12.2	12.2	12.2	20.8	20.8	20.8	20.8
Max. Cond. Water Flow - l/sec	40.7	40.7	40.7	66.2	66.2	66.2	66.2
Min. Lvg. Liquid Temp. - °C	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Max. Lvg. Liquid Temp. - °C	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Min. Ent. Cond. Water Temp - °C	23.8	23.8	23.8	23.8	23.8	23.8	23.8
Max. Ent. Cond. Water Temp - °C	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Min. Equipment Room Temp. - °C	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Max. Equipment Room Temp. - °C	46.1	46.1	46.1	46.1	46.1	46.1	46.1



Low-pressure liquid refrigerant enters the cooler tubes and is evaporated and superheated by the heat energy absorbed from the chilled liquid passing through the cooler shell. Low-pressure vapor enters the compressor where pressure and superheat are increased. High-pressure vapor is passed through the oil separator where heat is rejected to the condenser water passing through the tubes. The fully condensed and subcooled liquid leaves the condenser and enters the expansion valve, where pressure reduction and further cooling take place. The low pressure liquid refrigerant then returns to the cooler. Each refrigerant circuit utilizes liquid injection, maintaining efficient oil temperature operation within the compressor.

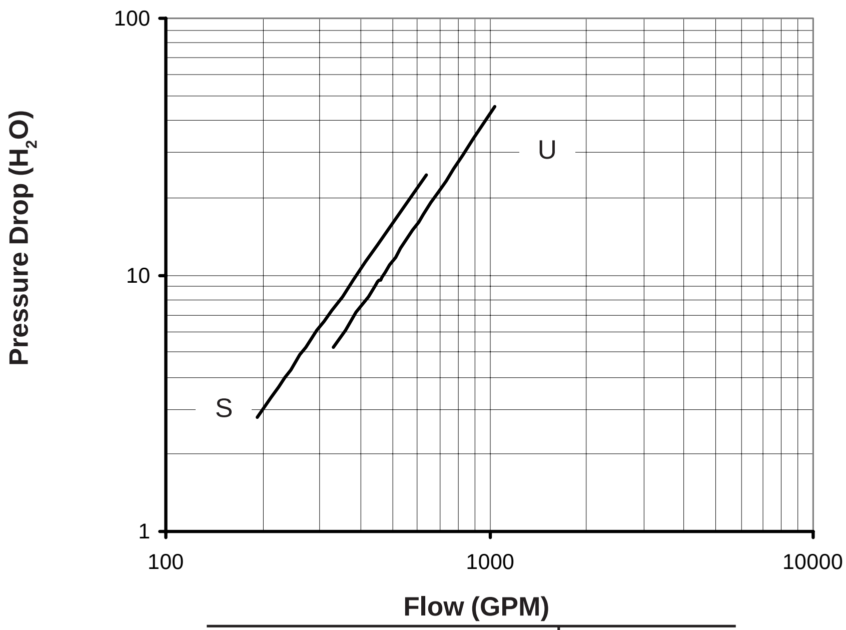
Pressure Drops

FIGURE 1 - COOLER WATER PRESSURE DROP CURVES (ENGLISH)



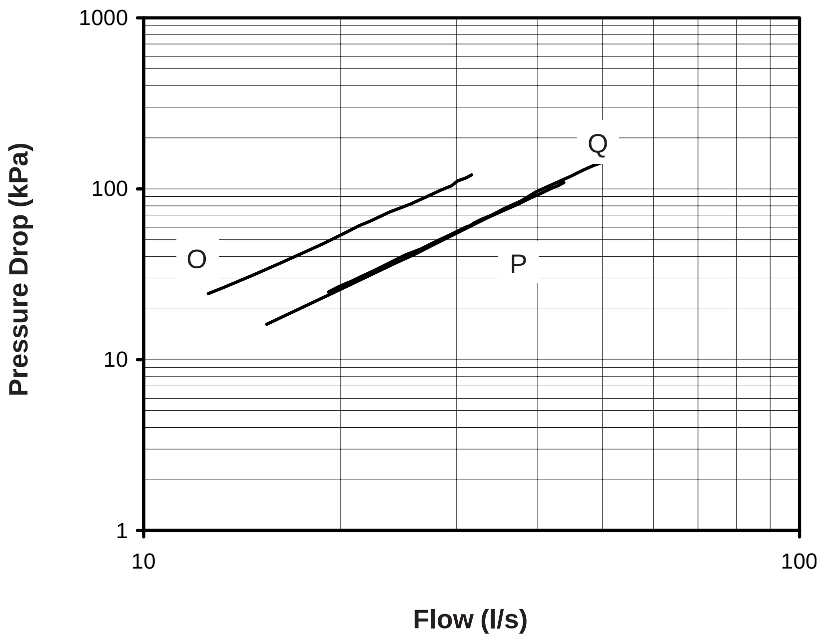
YCWS Model Number	Cooler
0100SB, 0120SB, 0140SB	O
0180SB, 0200SB	P
0220SB, 0240SB	Q

FIGURE 3 - CONDENSER WATER PRESSURE DROP CURVES (ENGLISH)



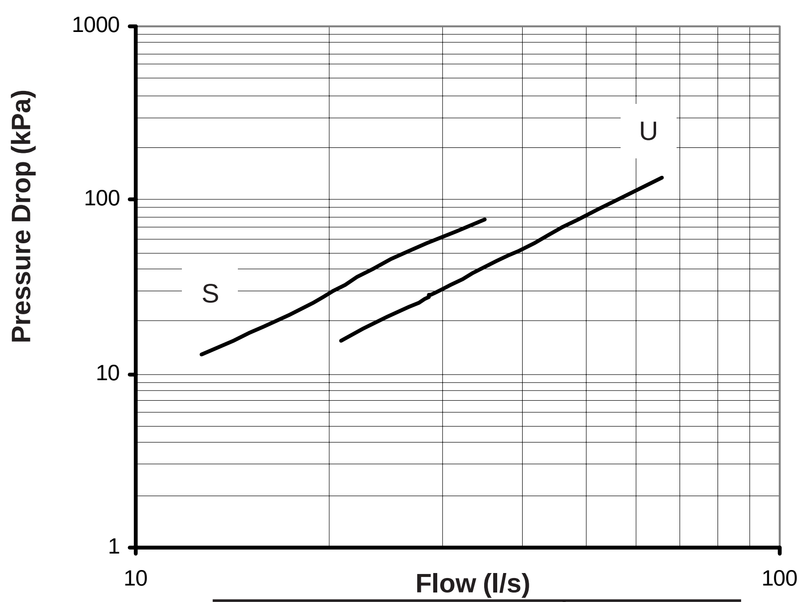
YCWS Model Number	Cooler
0100SB, 0120SB, 0140SB	S
0180SB, 0200SB 0220SB, 0240SB	U

FIGURE 2 - COOLER WATER PRESSURE DROP CURVES (SI)



YCWS Model Number	Cooler
0100SB, 0120SB, 0140SB	O
0180SB, 0200SB	P
0220SB, 0240SB	Q

FIGURE 4 - CONDENSER WATER PRESSURE DROP CURVES (SI)



0100SB, 0120SB, 0140SB	S
0180SB, 0200SB 0220SB, 0240SB	U

Selection Data

GUIDE TO SELECTION

Complete water chilling capacity ratings for YORK YCWS chillers are shown on the following pages to cover the majority of job requirements. For any application beyond the scope of this Engineering Guide, consult your nearest YORK Office.

SELECTION RULES

1. RATINGS - YCWS 200, 230 380, 460 & 575-3-60 rating are certified in accordance with ARI standard 550/590, at the ARI standard condition. Rating not at standard ARI conditions are rated in accordance with ARI rating procedures. These ratings may be interpolated but should not be extrapolated.

2. COOLING WATER QUANTITY - Ratings are based on 10ºF chilled water range. Use the chilled water correction factors (below) for other ranges except as limited by water pressure drop, minimum or maximum water flows for the cooler.

3. CONDENSER WATER QUANTITY – Rating are applicable from 2 to 4 gpm/ton as limited by water pressure drop or minimum or maximum water flows for the condenser. Using the tabulated MBH, the Cond. GPM is calculated as follows:

$$\text{Cond. GPM} = \frac{\text{MBH x 2}}{\text{Cond. Water Range (ºF)}}$$

4. FOULING FACTORS – Rating are based on 0.0001 evaporator and 0.00025 condenser fouling factor. For other fouling factors, consult the table below or contact your YORK representative.

EVAP FOULING FACTORS

Temp Split	0.0001 Tons	0.0001 Compr kW	x	0.00025 Tons	0.00025 Compr kW
6	0.9692	1.0015		0.9972	1.0001
8	0.9849	1.0008		0.9980	1.0001
10	1.0000	1.0000		0.9982	1.0001
12	1.0133	0.9993		0.9978	1.0001
14	1.0248	0.9986		0.9979	1.0001

Note: Temperature split factors @ 44ºF Leaving Chilled Liquid Temp (LCLT)

COND FOULING FACTORS

Temp Split	0.00025 Tons	0.00025 Compr kW	x	0.0005 Tons	0.0005 Compr kW
8	0.9998	1.0004		0.9957	1.0072
10	1.0000	1.0000		0.9959	1.0068
12	1.0001	0.9998		0.9961	1.0065
14	1.0001	0.9998		0.9965	1.0060

Note: Temperature split factors @ 95ºF Leaving Condenser Water Temp (LCWT).

METHOD OF SELECTION

If the duty requires a 10ºF range on both the cooler and condenser, see "Ratings". For water ranges other than 10ºF, use the following procedure.

1. Determine capacity required from the following formula

$$\text{Capacity (tons)} = \frac{\text{GPM x Chilled Water Range (ºF)}}{24}$$

2. After applying any fouling factor corrections, the actual condenser heat rejection may be determined as follows:

Heat Rejection (Btuh) = (Tons x 12,000) + (kW x 3415)

$$\text{Heat Rejection (MBH)} = \frac{\text{Heat Rejection (Btuh)}}{1000}$$

= (Tons x 12) = (kW x 3.415)

3. Determine condensing water requirements for water cooled models as follows:

$$\text{Condenser Tons} = \frac{\text{Heat Rejection (MBH) x 1000}}{15{,}000}$$

$$\text{Cond. Water GPM} = \frac{\text{Condenser Tons x 30}}{\text{Condenser Water Range (ºF)}}$$

Or combine the two formulas:

$$\text{Cond. Water GPM} = \frac{\text{MBH x 2}}{\text{Condenser Water Range (ºF)}}$$

SAMPLE SELECTION

Water Cooled Condenser (YCWS)

GIVEN – Chill 200 GPM of water from 56ºF to 44ºF and 0.0001 evaporator fouling factor with 85ºF to 95ºF condensing water available. Fouling factor of 0.0005 special field for the condenser.

FIND – The required unit size capacity, kW, EER, and water pressure drop.

SOLUTION:

1. Chilled water range = 56ºF - 44ºF = 12ºF and correction factors are 1.0133 for Tons and 0.9993 for kW for the cooler.

2. Capacity (tons) = $\frac{\text{GPM x Chilled Water Range}}{24}$

$$= \frac{200 \times 12}{24} = 100\text{TR}$$

2. From the rating, a model YCWS0120SB has a capacity range required. For the cooler leaving water temperature of 44ºF and a condenser leaving water temperature of 95ºF, the unit capacity rating table indicates:

Tons = 106.2
KW = 96.7
EER = 13.2

Correcting for the 12ºF chilled water range and the 0.0005 condenser-fouling factor:

Tons = 106.2 x 1.0133 x 0.9961 = 107.2TR
KW = 96.7 x 0.9993 x 1.0065 = 97.3

<u>The unit is suitable</u>.

3. Determine the average full load kW and EER at 95.0 Tons

$$\frac{95.0}{107.2} \text{ X } (97.3) = 86.2\text{KW}$$

$$\text{EER} = \frac{\text{Tons x 12}}{\text{Kw}} = \frac{95.0 \text{ X } 12}{86.2} = 13.2$$

4. Determine the cond. Heat rejection as follows:

Heat Rejection (MBH) = (Tons x 12) + (kW x 3.415)
= (95.0 x 12) + (86.2 x 3.415)
= 1140 + 294
= 1434

5. Determine GPM condensing water as follows:

$$\text{GPM Condenser Water} = \frac{\text{MBH x 2}}{\text{Cond Water Range}}$$

6. From curves on pages 10 and 11, the pressure drops with 200GPM through the cooler and 288 through the condenser of the Model YCWS120SB

Cooler Pressure Drop at 200 GPM = 2.9ft
Condenser Pressure Drop at 288 GPM = 5.5ft

Ratings *(HFC-407C English)*

LCWT	LEAVING CONDENSER WATER TEMPERATURE (°F)															
	85.0				95.0				100.0				105.0			
(°F)	TONS	KW	MBH	EER	TONS	KW	MBH	EER	TONS	KW	MBH	EER	TONS	KW	MBH	EER
YCWS0100SB																IPLV = 16.4
40.0	89.4	70.7	1314.0	15.2	81.2	80.4	1248.0	12.1	77.4	86.0	1222.0	10.8	73.7	92.2	1199.0	9.6
42.0	93.3	70.1	1359.0	16.0	84.8	79.7	1289.0	12.8	80.9	85.3	1261.0	11.4	77.1	91.4	1237.0	10.1
44.0	97.3	69.5	1405.0	16.8	88.5	79.0	1331.0	13.4	84.4	84.6	1301.0	12.0	80.5	90.6	1275.0	10.7
45.0	99.4	69.2	1428.0	17.2	90.4	78.7	1353.0	13.8	86.2	84.2	1321.0	12.3	82.2	90.2	1294.0	10.9
46.0	101.4	68.8	1451.0	17.7	92.3	78.3	1374.0	14.1	88.0	83.8	1342.0	12.6	84.0	89.7	1314.0	11.2
48.0	105.6	68.1	1499.0	18.6	96.1	77.6	1418.0	14.9	91.7	83.0	1384.0	13.3	87.6	88.9	1354.0	11.8
50.0	109.8	67.3	1547.0	19.6	100.1	76.8	1463.0	15.6	95.5	82.2	1427.0	13.9	91.2	88.1	1395.0	12.4
YCWS0120SB																IPLV = 15.7
40.0	107.3	85.4	1578.0	15.1	97.6	97.4	1503.0	12.0	93.1	104.3	1472.0	10.7	88.8	111.7	1446.0	9.5
42.0	111.9	85.1	1633.0	15.8	101.9	97.1	1553.0	12.6	97.2	103.9	1520.0	11.2	92.7	111.3	1492.0	10.0
44.0	116.7	84.8	1689.0	16.5	106.2	96.7	1605.0	13.2	101.4	103.5	1570.0	11.8	96.8	110.8	1539.0	10.5
45.0	119.1	84.6	1717.0	16.9	108.5	96.5	1631.0	13.5	103.5	103.3	1595.0	12.0	98.8	110.6	1563.0	10.7
46.0	121.5	84.4	1746.0	17.3	110.7	96.3	1657.0	13.8	105.7	103.0	1620.0	12.3	100.9	110.3	1588.0	11.0
48.0	126.4	84.0	1803.0	18.1	115.3	95.8	1710.0	14.4	110.1	102.5	1671.0	12.9	105.2	109.8	1637.0	11.5
50.0	131.4	83.4	1862.0	18.9	119.9	95.3	1764.0	15.1	114.6	102.0	1723.0	13.5	109.5	109.2	1687.0	12.0
YCWS0140SB																IPLV = 16.6
40.0	126.8	100.0	1863.0	15.2	115.4	114.4	1775.0	12.1	110.2	122.5	1740.0	10.8	105.1	131.3	1709.0	9.6
42.0	132.2	100.1	1928.0	15.8	120.5	114.4	1836.0	12.6	115.0	122.5	1798.0	11.3	109.8	131.3	1765.0	10.0
44.0	137.8	100.1	1994.0	16.5	125.6	114.4	1897.0	13.2	119.9	122.4	1857.0	11.8	114.5	131.1	1822.0	10.5
45.0	140.6	100.0	2028.0	16.9	128.2	114.3	1928.0	13.5	122.4	122.4	1887.0	12.0	117.0	131.0	1851.0	10.7
46.0	143.4	100.0	2062.0	17.2	130.9	114.2	1960.0	13.7	125.0	122.3	1917.0	12.3	119.4	130.9	1880.0	10.9
48.0	149.2	99.7	2130.0	17.9	136.2	114.0	2023.0	14.3	130.2	122.0	1978.0	12.8	124.4	130.6	1938.0	11.4
50.0	155.0	99.4	2199.0	18.7	141.7	113.7	2088.0	15.0	135.4	121.7	2040.0	13.4	129.5	130.3	1998.0	11.9
YCWS0180SB																IPLV = 17.8
40.0	156.7	110.2	2257.0	17.1	142.2	126.1	2137.0	13.5	134.8	135.1	2079.0	12.0	129.1	144.9	2044.0	10.7
42.0	163.7	110.1	2339.0	17.8	148.5	126.0	2212.0	14.2	141.6	135.0	2159.0	12.6	134.4	144.7	2107.0	11.2
44.0	170.7	109.9	2423.0	18.6	155.1	125.7	2290.0	14.8	147.8	134.7	2233.0	13.2	141.0	144.4	2184.0	11.7
45.0	174.2	109.7	2465.0	19.1	158.4	125.5	2329.0	15.1	151.0	134.5	2271.0	13.5	144.0	144.2	2220.0	12.0
46.0	177.9	109.5	2509.0	19.5	161.7	125.4	2368.0	15.5	154.2	134.3	2309.0	13.8	147.1	143.9	2256.0	12.3
48.0	185.3	109.0	2595.0	20.4	168.5	124.9	2448.0	16.2	160.8	133.8	2386.0	14.4	153.4	143.4	2330.0	12.8
50.0	192.8	108.4	2684.0	21.4	175.5	124.3	2530.0	16.9	167.4	133.2	2464.0	15.1	159.8	142.9	2405.0	13.4

NOTES:
1. Tons = Unit Cooling Capacity Output
2. kW = Compressor Input Power
3. MBH = Condenser heat rejection
4. EER = Chiller Energy Efficiency Ratio (Capacity [Tons x 12] ÷ kW)
5. LCWT = Leaving Chilled Water Temperature
6. Ratings based on 2.4 GPM cooler water per ton
7. Ratings certified in accordance with ARI Standard 550/590-98 up to 200 tons.

LCWT	LEAVING CONDENSER WATER TEMPERATURE (°F)															
	85.0				95.0				100.0				105.0			
(°F)	TONS	KW	MBH	EER	TONS	KW	MBH	EER	TONS	KW	MBH	EER	TONS	KW	MBH	EER

YCWS0200SB

IPLV = 18.5

LCWT (°F)	85.0 TONS	85.0 KW	85.0 MBH	85.0 EER	95.0 TONS	95.0 KW	95.0 MBH	95.0 EER	100.0 TONS	100.0 KW	100.0 MBH	100.0 EER	105.0 TONS	105.0 KW	105.0 MBH	105.0 EER
40.0	177.4	124.7	2554.0	17.1	161.0	142.7	2419.0	13.5	153.4	152.9	2363.0	12.0	146.2	163.9	2313.0	10.7
42.0	185.2	124.6	2648.0	17.8	168.2	142.6	2505.0	14.2	160.3	152.7	2445.0	12.6	152.8	163.7	2392.0	11.2
44.0	193.2	124.4	2743.0	18.6	175.6	142.3	2593.0	14.8	167.4	152.5	2529.0	13.2	159.6	163.4	2473.0	11.7
45.0	197.3	124.2	2791.0	19.1	179.3	142.2	2637.0	15.1	171.0	152.3	2572.0	13.5	163.1	163.2	2514.0	12.0
46.0	201.4	124.0	2839.0	19.5	183.1	142.0	2682.0	15.5	174.6	152.1	2615.0	13.8	166.6	163.0	2555.0	12.3
48.0	209.7	123.5	2937.0	20.4	190.8	141.5	2772.0	16.2	182.0	151.6	2702.0	14.4	173.7	162.4	2639.0	12.8
50.0	218.1	122.8	3037.0	21.3	198.7	140.8	2865.0	16.9	189.6	150.9	2790.0	15.1	181.0	161.8	2724.0	13.4

YCWS0220SB

IPLV = 17.6

LCWT (°F)	85.0 TONS	85.0 KW	85.0 MBH	85.0 EER	95.0 TONS	95.0 KW	95.0 MBH	95.0 EER	100.0 TONS	100.0 KW	100.0 MBH	100.0 EER	105.0 TONS	105.0 KW	105.0 MBH	105.0 EER
40.0	193.0	138.0	2787.0	16.8	175.3	157.9	2642.0	13.3	167.1	169.1	2582.0	11.9	159.2	181.3	2529.0	10.5
42.0	201.5	138.0	2889.0	17.5	183.0	157.8	2735.0	13.9	174.5	169.0	2671.0	12.4	166.4	181.1	2615.0	11.0
44.0	210.1	137.7	2992.0	18.3	191.0	157.5	2830.0	14.6	182.1	168.7	2761.0	13.0	173.8	180.8	2702.0	11.5
45.0	214.5	137.6	3044.0	18.7	195.1	157.4	2878.0	14.9	186.1	168.5	2808.0	13.2	177.5	180.6	2746.0	11.8
46.0	219.0	137.4	3096.0	19.1	199.2	157.2	2927.0	15.2	190.0	168.3	2855.0	13.5	181.2	180.4	2790.0	12.1
48.0	228.0	136.8	3202.0	20.0	207.6	156.6	3025.0	15.9	198.1	167.8	2949.0	14.2	189.0	179.8	2882.0	12.6
50.0	237.2	136.1	3311.0	20.9	216.1	156.0	3125.0	16.6	206.3	167.2	3046.0	14.8	196.9	179.2	2974.0	13.2

YCWS0240SB

IPLV = 18.1

LCWT (°F)	85.0 TONS	85.0 KW	85.0 MBH	85.0 EER	95.0 TONS	95.0 KW	95.0 MBH	95.0 EER	100.0 TONS	100.0 KW	100.0 MBH	100.0 EER	105.0 TONS	105.0 KW	105.0 MBH	105.0 EER
40.0	210.9	151.5	3048.0	16.7	191.6	173.3	2891.0	13.3	182.6	185.6	2825.0	11.8	174.1	199.0	2768.0	10.5
42.0	220.2	151.5	3159.0	17.4	200.1	173.2	2992.0	13.9	190.8	185.5	2923.0	12.3	182.0	198.8	2862.0	11.0
44.0	229.6	151.3	3271.0	18.2	208.8	173.0	3096.0	14.5	199.2	185.2	3022.0	12.9	190.0	198.5	2957.0	11.5
45.0	234.3	151.1	3327.0	18.6	213.3	172.8	3149.0	14.8	203.4	185.1	3073.0	13.2	194.1	198.3	3006.0	11.7
46.0	239.1	150.9	3384.0	19.0	217.7	172.6	3202.0	15.1	207.7	184.8	3124.0	13.5	198.2	198.0	3055.0	12.0
48.0	248.9	150.3	3500.0	19.9	226.8	172.1	3309.0	15.8	216.5	184.3	3227.0	14.1	206.7	197.5	3154.0	12.6
50.0	258.9	149.6	3618.0	20.8	236.1	171.4	3418.0	16.5	225.5	183.7	3332.0	14.7	215.3	196.8	3255.0	13.1

NOTES:
1. Tons = Unit Cooling Capacity Output
2. kW = Compressor Input Power
3. MBH = Condenser heat rejection
4. EER = Chiller Energy Efficiency Ratio (Capacity [Tons x 12] ÷ kW)
5. LCWT = Leaving Chilled Water Temperature
6. Ratings based on 2.4 GPM cooler water per ton
7. Ratings certified in accordance with ARI Standard 550/590-98 up to 200 tons.

Ratings *(HFC-407C SI)*

LCWT	LEAVING CONDENSER WATER TEMPERATURE (°C)															
	30.0				35.0				40.0				45.0			
(°C)	KW*o*	KW*i*	KW	COP	KW*o*	KW*i*	KW	COP	KW*o*	KW*i*	KW	COP	TONS	KW	MBH	EER
YCWS0100SB																IPLV= 4.8 COP
5.0	314.9	71.5	386.0	4.4	288.7	80.3	369.0	3.6	264.7	90.9	355.0	2.9	242.8	103.1	346.0	2.4
6.0	327.3	70.9	398.0	4.6	300.2	79.7	380.0	3.8	275.4	90.1	365.0	3.1	252.8	102.2	355.0	2.5
7.0	340.0	70.4	410.0	4.8	312.0	79.1	391.0	4.0	286.4	89.4	375.0	3.2	263.1	101.3	364.0	2.6
8.0	352.8	69.8	422.0	5.1	324.0	78.4	402.0	4.1	297.6	88.7	386.0	3.4	273.5	100.5	374.0	2.7
9.0	365.9	69.1	435.0	5.3	336.2	77.8	414.0	4.3	309.0	87.9	396.0	3.5	284.2	99.6	383.0	2.9
10.0	379.3	68.4	447.0	5.5	348.6	77.1	425.0	4.5	320.6	87.2	407.0	3.7	295.0	98.8	393.0	3.0
YCWS0120SB																IPLV= 4.6 COP
5.0	378.1	86.5	464.0	4.4	347.1	97.4	444.0	3.6	318.6	110.3	428.0	2.9	292.6	125.0	417.0	2.3
6.0	392.7	86.3	479.0	4.6	360.8	97.2	458.0	3.7	331.4	109.9	441.0	3.0	304.6	124.5	429.0	2.5
7.0	407.7	86.0	493.0	4.7	374.7	96.8	471.0	3.9	344.5	109.5	454.0	3.2	316.8	124.0	440.0	2.6
8.0	422.9	85.6	508.0	4.9	388.9	96.4	485.0	4.0	357.7	109.0	466.0	3.3	329.3	123.4	452.0	2.7
9.0	438.5	85.2	523.0	5.2	403.4	96.0	499.0	4.2	371.2	108.5	479.0	3.4	341.9	122.8	464.0	2.8
10.0	454.2	84.7	539.0	5.4	418.2	95.5	513.0	4.4	385.0	108.0	493.0	3.6	354.8	122.2	477.0	2.9
YCWS0140SB																IPLV= 4.9 COP
5.0	447.1	101.5	548.0	4.4	410.8	114.6	525.0	3.6	377.5	129.7	507.0	2.9	347.0	147.0	494.0	2.4
6.0	464.2	101.6	565.0	4.6	426.8	114.6	541.0	3.7	392.5	129.6	522.0	3.0	361.1	146.8	508.0	2.5
7.0	481.7	101.5	583.0	4.7	443.2	114.5	557.0	3.9	407.8	129.5	537.0	3.2	375.4	146.6	522.0	2.6
8.0	499.5	101.4	601.0	4.9	459.8	114.4	574.0	4.0	423.4	129.3	552.0	3.3	390.0	146.3	536.0	2.7
9.0	517.7	101.2	618.0	5.1	476.7	114.2	590.0	4.2	439.2	129.1	568.0	3.4	404.9	146.0	551.0	2.8
10.0	536.2	100.9	637.0	5.3	494.1	113.9	608.0	4.3	455.4	128.8	584.0	3.5	420.1	145.7	565.0	2.9
YCWS0180SB																IPLV= 5.2 COP
5.0	551.0	111.9	662.0	4.9	504.8	126.3	631.0	4.0	462.6	143.1	605.0	3.2	424.4	162.4	586.0	2.6
6.0	572.8	111.8	684.0	5.1	525.0	126.2	651.0	4.2	481.3	142.9	624.0	3.4	441.9	162.1	604.0	2.7
7.0	595.0	111.5	706.0	5.3	545.6	126.0	671.0	4.3	500.5	142.7	643.0	3.5	459.6	161.7	621.0	2.8
8.0	617.7	111.2	728.0	5.6	566.7	125.6	692.0	4.5	520.2	142.3	662.0	3.7	477.8	161.3	639.0	3.0
9.0	640.6	110.8	751.0	5.8	588.2	125.2	713.0	4.7	540.1	141.9	682.0	3.8	496.5	160.8	657.0	3.1
10.0	664.3	110.2	774.0	6.0	610.1	124.7	734.0	4.9	560.3	141.4	701.0	4.0	515.6	160.2	675.0	3.2

NOTES:
1. KWo = Unit kW Cooling Capacity Output
2. KWi = Compressor kW Input
3. COP = Coefficient of Performance
4. LCWT= Leaving Chilled Water Temperature
5. Ratings based on 0.047 l/s cooler water per kW.

LCWT	LEAVING CONDENSER WATER TEMPERATURE (°C)															
	30.0				35.0				40.0				45.0			
(°C)	KWo	KWi	KW	COP	KWo	KWi	KW	COP	KWo	KWi	KW	COP	TONS	KW	MBH	EER

YCWS0200SB

IPLV= 5.4 COP

5.0	623.8	126.6	750.0	4.9	571.6	142.9	714.0	4.0	524.3	161.9	686.0	3.2	481.2	183.7	664.0	2.6
6.0	648.4	126.5	775.0	5.1	594.5	142.8	737.0	4.2	545.2	161.7	707.0	3.4	500.9	183.3	684.0	2.7
7.0	673.5	126.3	799.0	5.3	617.9	142.6	760.0	4.3	567.0	161.5	728.0	3.5	520.9	183.0	703.0	2.9
8.0	699.1	125.9	825.0	5.6	641.6	142.3	783.0	4.5	589.2	161.1	750.0	3.7	541.4	182.5	724.0	3.0
9.0	725.2	125.5	850.0	5.8	666.0	141.8	807.0	4.7	611.8	160.6	772.0	3.8	562.5	182.0	744.0	3.1
10.0	751.9	124.9	876.0	6.0	690.7	141.3	832.0	4.9	634.9	160.1	795.0	4.0	584.1	181.4	765.0	3.2

YCWS0220SB

IPLV= 5.1 COP

5.0	678.5	140.1	818.0	4.8	622.2	158.2	780.0	3.9	570.1	179.2	749.0	3.2	523.8	203.2	727.0	2.6
6.0	705.3	140.1	845.0	5.0	647.0	158.1	805.0	4.1	593.6	179.0	772.0	3.3	545.2	202.8	748.0	2.7
7.0	732.5	139.8	872.0	5.2	672.0	157.9	829.0	4.3	617.2	178.7	796.0	3.5	566.8	202.4	769.0	2.8
8.0	760.3	139.5	899.0	5.5	697.9	157.5	855.0	4.4	641.2	178.3	819.0	3.6	589.5	201.9	791.0	2.9
9.0	788.6	139.0	927.0	5.7	724.4	157.1	881.0	4.6	665.5	177.8	843.0	3.7	612.4	201.4	813.0	3.0
10.0	817.4	138.4	955.0	5.9	751.3	156.5	907.0	4.8	690.7	177.3	868.0	3.9	635.8	200.8	836.0	3.2

YCWS0240SB

IPLV= 5.3 COP

5.0	741.7	153.8	895.0	4.8	680.3	173.6	854.0	3.9	623.8	196.6	820.0	3.2	573.1	222.9	796.0	2.6
6.0	770.8	153.8	924.0	5.0	707.3	173.5	880.0	4.1	649.2	196.5	845.0	3.3	596.3	222.6	819.0	2.7
7.0	800.4	153.6	954.0	5.2	734.9	173.3	908.0	4.2	674.9	196.2	871.0	3.4	620.0	222.2	842.0	2.8
8.0	830.7	153.2	984.0	5.4	763.0	173.0	936.0	4.4	701.2	195.8	897.0	3.6	644.8	221.7	866.0	2.9
9.0	861.5	152.7	1014.0	5.6	791.8	172.5	964.0	4.6	727.9	195.3	923.0	3.7	669.8	221.1	891.0	3.0
10.0	892.7	152.1	1044.0	5.9	821.1	172.0	993.0	4.8	755.2	194.7	950.0	3.9	695.4	220.4	915.0	3.2

NOTES:
1. KWo = Unit kW Cooling Capacity Output
2. KWi= Compressor kW Input
3. COP = Coefficient of Performance
4. LCWT= Leaving Chilled Water Temperature
5. Ratings based on 0.047 l/s cooler water per kW.

Ratings- Brine (30 % Ethylene Glycol) (R-22 English)

LCWT	LEAVING CONDENSER WATER TEMPERATURE (°F)											
	85.0				95.0				105.0			
(°F)	TONS	KW	MBH	EER	TONS	KW	MBH	EER	TONS	KW	MBH	EER

YCWS0100SC

16.0	43.1	69.0	753.0	7.5	38.9	82.2	746.0	5.7	34.9	98.4	755.0	4.3
20.0	48.7	70.6	825.0	8.3	43.9	82.8	809.0	6.4	39.5	98.0	808.0	4.8
24.0	55.0	71.5	904.0	9.2	49.7	83.1	880.0	7.2	44.9	97.3	870.0	5.5
28.0	62.5	72.0	995.0	10.4	56.5	82.9	961.0	8.2	51.1	96.4	942.0	6.4
32.0	71.3	72.0	1101.0	11.9	64.6	82.4	1056.0	9.4	58.5	95.2	1026.0	7.4
36.0	81.0	71.6	1216.0	13.6	73.5	81.6	1161.0	10.8	66.7	93.9	1121.0	8.5
40.0	88.5	70.8	1303.0	15.0	80.5	80.5	1240.0	12.0	73.1	92.4	1193.0	9.5

YCWS0120SC

16.0	52.0	77.9	890.0	8.0	47.0	92.6	879.0	6.1	42.3	110.4	884.0	4.6
20.0	58.7	80.6	979.0	8.7	53.0	94.6	958.0	6.7	47.8	111.6	954.0	5.1
24.0	66.3	82.6	1077.0	9.6	60.0	96.0	1047.0	7.5	54.2	112.3	1033.0	5.8
28.0	75.1	84.0	1188.0	10.7	68.0	96.9	1147.0	8.4	61.6	112.6	1123.0	6.6
32.0	85.5	85.0	1316.0	12.1	77.7	97.5	1264.0	9.6	70.4	112.7	1229.0	7.5
36.0	97.1	85.5	1456.0	13.6	88.3	97.7	1392.0	10.8	80.2	112.5	1346.0	8.6
40.0	106.0	85.4	1563.0	14.9	96.5	97.4	1490.0	11.9	87.8	111.8	1435.0	9.4

YCWS0140SC

16.0	61.8	87.0	1038.0	8.5	55.8	103.3	1021.0	6.5	50.2	122.8	1021.0	4.9
20.0	69.6	90.7	1144.0	9.2	62.7	106.4	1116.0	7.1	56.8	125.4	1109.0	5.4
24.0	78.5	93.7	1262.0	10.1	71.1	109.1	1225.0	7.8	64.3	127.4	1206.0	6.1
28.0	88.9	96.1	1395.0	11.1	80.6	111.1	1346.0	8.7	73.0	129.0	1317.0	6.8
32.0	101.2	98.0	1548.0	12.4	91.9	112.7	1487.0	9.8	83.4	130.2	1445.0	7.7
36.0	114.7	99.3	1715.0	13.9	104.4	113.8	1641.0	11.0	94.9	131.1	1586.0	8.7
40.0	125.1	100.0	1842.0	15.0	114.0	114.3	1758.0	12.0	103.9	131.3	1694.0	9.5

YCWS0180SC

16.0	75.7	97.6	1241.0	9.3	70.5	116.5	1243.0	7.3	61.4	137.0	1205.0	5.4
20.0	85.5	101.5	1372.0	10.1	77.1	118.9	1331.0	7.8	69.5	139.7	1311.0	6.0
24.0	96.0	104.5	1508.0	11.0	87.3	121.5	1462.0	8.6	78.8	141.8	1429.0	6.7
28.0	109.8	107.1	1683.0	12.3	100.0	123.7	1622.0	9.7	89.4	143.3	1562.0	7.5
32.0	125.3	108.8	1874.0	13.8	113.5	125.0	1788.0	10.9	102.7	144.4	1725.0	8.5
36.0	142.6	109.9	2086.0	15.6	129.2	125.9	1980.0	12.3	117.2	145.0	1901.0	9.7
40.0	155.9	110.2	2246.0	17.0	141.5	126.1	2128.0	13.5	128.4	144.9	2036.0	10.6

NOTES:
1. Tons = Unit Cooling Capacity Output
2. kW = Compressor Input Power
3. MBH = Condenser heat rejection
4. EER = Chiller Energy Efficiency Ratio (Capacity [Tons x 12] ÷ kW)
5. LCWT = Leaving Chilled Water Temperature
6. Ratings based on 2.4 GPM cooler water per ton.
7. Rated in accordance with ARI Standard 550/590-98 up to 200 tons.
8. For ratings other than 30% glycol, refer to the Design 03 dxchill program.

LCWT (°F)	LEAVING CONDENSER WATER TEMPERATURE (°F) 85.0				95.0				105.0			
	TONS	KW	MBH	EER	TONS	KW	MBH	EER	TONS	KW	MBH	EER

YCWS0200SC

16.0	85.8	110.1	1406.0	9.4	77.4	130.4	1374.0	7.1	69.6	154.8	1364.0	5.4
20.0	96.7	114.5	1551.0	10.1	87.4	134.2	1507.0	7.8	78.8	157.9	1484.0	6.0
24.0	109.0	118.0	1710.0	11.1	98.9	137.3	1655.0	8.6	89.3	160.3	1618.0	6.7
28.0	124.4	121.0	1905.0	12.3	112.6	139.7	1827.0	9.7	101.5	162.0	1770.0	7.5
32.0	142.0	123.0	2123.0	13.8	128.5	141.3	2025.0	10.9	115.9	163.2	1948.0	8.5
36.0	161.4	124.3	2361.0	15.6	146.4	142.4	2243.0	12.3	132.8	164.0	2153.0	9.7
40.0	176.4	124.7	2542.0	17.0	160.2	142.7	2410.0	13.5	145.5	163.9	2306.0	10.7

YCWS0220SC

16.0	93.6	121.6	1538.0	9.2	84.4	144.0	1504.0	7.0	75.9	170.9	1494.0	5.3
20.0	105.7	126.7	1701.0	10.0	95.3	148.3	1649.0	7.7	85.9	174.3	1625.0	5.9
24.0	119.4	130.6	1878.0	11.0	107.8	151.7	1811.0	8.5	97.3	177.0	1772.0	6.6
28.0	135.4	133.7	2081.0	12.2	121.9	154.2	1989.0	9.5	110.6	179.0	1938.0	7.4
32.0	154.6	136.0	2319.0	13.6	139.9	156.3	2212.0	10.7	126.8	180.5	2137.0	8.4
36.0	175.7	137.5	2577.0	15.3	159.4	157.5	2450.0	12.1	144.6	181.3	2353.0	9.6
40.0	192.0	138.0	2774.0	16.7	174.4	157.9	2631.0	13.3	157.8	181.3	2513.0	10.4

YCWS0240SC

16.0	102.4	133.2	1683.0	9.2	92.3	157.7	1646.0	7.0	83.1	187.3	1636.0	5.3
20.0	114.9	138.4	1851.0	10.0	104.3	162.5	1806.0	7.7	94.0	191.0	1780.0	5.9
24.0	130.6	143.1	2055.0	10.9	117.8	166.2	1980.0	8.5	106.5	194.0	1940.0	6.6
28.0	148.1	146.6	2278.0	12.1	134.0	169.2	2185.0	9.5	121.1	196.3	2123.0	7.4
32.0	169.0	149.1	2536.0	13.6	153.1	171.4	2422.0	10.7	138.7	197.9	2340.0	8.4
36.0	191.9	150.8	2818.0	15.3	174.3	172.8	2681.0	12.1	158.1	198.9	2576.0	9.5
40.0	209.6	151.5	3032.0	16.6	190.6	173.3	2878.0	13.2	173.3	199.0	2758.0	10.4

NOTES:
1. Tons = Unit Cooling Capacity Output
2. kW = Compressor Input Power
3. MBH = Condenser heat rejection
4. EER = Chiller Energy Efficiency Ratio (Capacity [Tons x 12] ÷ kW)
5. LCWT = Leaving Chilled Water Temperature
6. Ratings based on 2.4 GPM cooler water per ton
7. Rated in accordance with ARI Standard 550/590-98 up to 200 tons.
8. For ratings other than 30% glycol, refer to the Design 03 dxchill program.

Ratings- Brine (30 % Ethylene Glycol) (R-22 SI)

LCWT	LEAVING CONDENSER WATER TEMPERATURE (°C)											
	30.0				35.0				40.0			
(°C)	KWo	KWi	KW	COP	KWo	KWi	KW	COP	KWo	KWi	KW	COP

YCWS0100SC

-8.0	157.5	70.9	228.0	2.2	143.4	82.5	225.0	1.7	130.4	96.6	227.0	1.4
-6.0	175.7	72.0	247.0	2.4	160.3	83.0	243.0	1.9	145.9	96.2	242.0	1.5
-4.0	196.5	72.7	269.0	2.7	179.4	83.0	262.0	2.2	163.6	95.6	259.0	1.7
-2.0	220.4	72.9	293.0	3.0	201.4	82.8	284.0	2.4	183.9	94.8	278.0	1.9
0.0	248.2	72.9	321.0	3.4	227.2	82.4	309.0	2.8	207.8	93.8	301.0	2.2
2.0	279.6	72.6	352.0	3.9	256.2	81.7	338.0	3.1	234.8	92.8	327.0	2.5
4.0	303.0	71.8	374.0	4.2	278.0	80.7	358.0	3.4	255.0	91.4	346.0	2.8

YCWS0120SC

-8.0	190.0	80.4	270.0	2.4	173.3	93.5	266.0	1.9	157.8	109.1	266.0	1.5
-6.0	211.8	82.5	294.0	2.6	193.3	95.0	288.0	2.0	176.3	110.0	286.0	1.6
-4.0	236.5	84.1	320.0	2.8	216.1	96.2	312.0	2.3	197.4	110.6	308.0	1.8
-2.0	264.9	85.3	350.0	3.1	242.4	97.0	339.0	2.5	221.7	111.0	332.0	2.0
0.0	297.9	86.1	384.0	3.5	273.1	97.5	370.0	2.8	250.1	111.0	361.0	2.3
2.0	335.2	86.6	421.0	3.9	307.6	97.7	405.0	3.2	282.2	110.9	393.0	2.5
4.0	362.9	86.5	449.0	4.2	333.4	97.5	430.0	3.4	306.2	110.4	416.0	2.8

YCWS0140SC

-8.0	225.5	90.0	315.0	2.5	205.8	104.6	310.0	2.0	187.4	121.8	309.0	1.5
-6.0	251.1	93.1	344.0	2.7	229.4	107.3	336.0	2.1	209.3	124.0	333.0	1.7
-4.0	280.1	95.6	375.0	2.9	256.3	109.5	365.0	2.3	234.2	125.8	360.0	1.9
-2.0	313.6	97.7	411.0	3.2	287.1	111.3	398.0	2.6	262.8	127.3	390.0	2.1
0.0	352.3	99.3	451.0	3.6	323.2	112.7	435.0	2.9	296.2	128.4	424.0	2.3
2.0	395.9	100.6	496.0	3.9	363.7	113.8	477.0	3.2	333.9	129.2	463.0	2.6
4.0	428.4	101.2	529.0	4.2	393.9	114.3	508.0	3.5	362.2	129.5	491.0	2.8

YCWS0180SC

-8.0	276.6	100.8	377.0	2.7	252.0	116.9	368.0	2.2	229.4	135.9	365.0	1.7
-6.0	308.6	104.1	412.0	3.0	281.7	119.8	401.0	2.4	256.3	138.2	394.0	1.9
-4.0	343.1	106.6	449.0	3.2	314.8	122.0	436.0	2.6	287.1	140.0	427.0	2.1
-2.0	386.9	108.8	495.0	3.6	354.4	123.8	478.0	2.9	322.7	141.4	464.0	2.3
0.0	436.3	110.3	546.0	4.0	398.9	125.0	524.0	3.2	364.7	142.3	507.0	2.6
2.0	492.0	111.3	603.0	4.4	450.2	125.9	576.0	3.6	412.3	142.9	555.0	2.9
4.0	533.4	111.7	645.0	4.8	488.6	126.1	614.0	3.9	447.9	142.9	590.0	3.1

NOTES:
1. KWo = Unit kW Cooling Capacity Output
2. KWi = Compressor kW Input
3. COP = Coefficient of Performance
4. LCWT= Leaving Chilled Water Temperature
5. Ratings based on 0.047 l/s cooler water per kW.
6. For ratings other than 30% glycol, refer to the Design 03 dxchill program.

LCWT (°C)	30.0 KWo	30.0 KWi	30.0 KW	30.0 COP	35.0 KWo	35.0 KWi	35.0 KW	35.0 COP	40.0 KWo	40.0 KWi	40.0 KW	40.0 COP
YCWS0200SC												
-8.0	313.6	113.8	427.0	2.8	285.6	132.0	417.0	2.2	259.9	153.5	413.0	1.7
-6.0	349.7	117.5	467.0	3.0	319.0	135.2	454.0	2.4	290.5	156.1	446.0	1.9
-4.0	387.5	120.3	507.0	3.2	356.5	137.8	494.0	2.6	325.5	158.2	483.0	2.1
-2.0	438.6	122.9	561.0	3.6	400.0	139.8	539.0	2.9	365.1	159.7	524.0	2.3
0.0	494.3	124.7	619.0	4.0	451.9	141.3	593.0	3.2	412.7	160.9	573.0	2.6
2.0	557.1	125.9	683.0	4.4	510.1	142.4	652.0	3.6	467.3	161.6	629.0	2.9
4.0	603.7	126.3	730.0	4.8	553.5	142.7	696.0	3.9	507.4	161.7	669.0	3.1
YCWS0220SC												
-8.0	341.6	125.7	467.0	2.7	311.4	145.8	457.0	2.1	283.4	169.5	453.0	1.7
-6.0	381.1	129.9	511.0	2.9	347.6	149.4	497.0	2.3	316.6	172.4	489.0	1.8
-4.0	424.2	133.1	557.0	3.2	387.9	152.2	540.0	2.6	354.6	174.8	529.0	2.0
-2.0	477.6	135.9	613.0	3.5	436.4	154.6	591.0	2.8	395.4	176.4	572.0	2.2
0.0	533.9	137.7	671.0	3.9	489.6	156.2	645.0	3.1	450.6	177.9	628.0	2.5
2.0	606.2	139.3	745.0	4.4	555.3	157.5	712.0	3.5	508.6	178.7	687.0	2.9
4.0	657.0	139.8	796.0	4.7	602.4	157.9	760.0	3.8	552.5	178.9	731.0	3.1
YCWS0240SC												
-8.0	373.8	137.7	511.0	2.7	340.8	159.7	500.0	2.1	310.2	185.7	496.0	1.7
-6.0	415.7	142.1	557.0	2.9	380.2	163.7	543.0	2.3	346.6	189.0	535.0	1.8
-4.0	466.0	146.0	612.0	3.2	425.4	166.9	592.0	2.6	387.9	191.5	579.0	2.0
-2.0	522.4	148.9	671.0	3.5	477.4	169.4	646.0	2.8	436.2	193.6	629.0	2.3
0.0	588.4	151.2	739.0	3.9	538.3	171.4	709.0	3.1	492.5	195.0	687.0	2.5
2.0	662.5	152.8	815.0	4.3	607.2	172.7	780.0	3.5	556.3	196.1	752.0	2.8
4.0	717.5	153.4	871.0	4.7	658.5	173.2	831.0	3.8	604.2	196.3	800.0	3.1

LEAVING CONDENSER WATER TEMPERATURE (°C)

NOTES:
1. KWo = Unit kW Cooling Capacity Output
2. KWi= Compressor kW Input
3. COP = Coefficient of Performance
4. LCWT= Leaving Chilled Water Temperature
5. Ratings based on 0.047 l/s cooler water per kW.
6. For ratings other than 30% glycol, refer to the Design 03 dxchill program.

Ratings- Brine (30 % Propylene Glycol) (R-22 English)

LCWT	LEAVING CONDENSER WATER TEMPERATURE (°F)											
	85.0				95.0				105.0			
(°F)	TONS	KW	MBH	EER	TONS	KW	MBH	EER	TONS	KW	MBH	EER

YCWS0100SC

16.0	42.9	68.9	750.0	7.5	38.7	82.1	744.0	5.6	34.8	98.4	753.0	4.2
20.0	48.4	70.5	821.0	8.2	43.7	82.8	807.0	6.3	39.4	98.0	807.0	4.8
24.0	54.7	71.5	900.0	9.2	49.5	83.1	877.0	7.1	44.7	97.4	868.0	5.5
28.0	62.1	71.9	990.0	10.4	56.2	82.9	957.0	8.1	50.8	96.4	939.0	6.3
32.0	70.8	72.0	1095.0	11.8	64.2	82.4	1052.0	9.3	58.2	95.3	1023.0	7.3
36.0	80.5	71.6	1210.0	13.5	73.1	81.7	1156.0	10.7	66.4	94.0	1117.0	8.5
40.0	87.9	70.8	1297.0	14.9	80.0	80.6	1234.0	11.9	72.7	92.5	1188.0	9.4

YCWS0120SC

16.0	42.9	68.9	750.0	7.5	38.7	82.1	744.0	5.6	34.8	98.4	753.0	4.2
20.0	48.4	70.5	821.0	8.2	43.7	82.8	807.0	6.3	39.4	98.0	807.0	4.8
24.0	54.7	71.5	900.0	9.2	49.5	83.1	877.0	7.1	44.7	97.4	868.0	5.5
28.0	62.1	71.9	990.0	10.4	56.2	82.9	957.0	8.1	50.8	96.4	939.0	6.3
32.0	70.8	72.0	1095.0	11.8	64.2	82.4	1052.0	9.3	58.2	95.3	1023.0	7.3
36.0	80.5	71.6	1210.0	13.5	73.1	81.7	1156.0	10.7	66.4	94.0	1117.0	8.5
40.0	87.9	70.8	1297.0	14.9	80.0	80.6	1234.0	11.9	72.7	92.5	1188.0	9.4

YCWS0140SC

16.0	61.3	86.7	1031.0	8.5	55.4	103.0	1016.0	6.4	49.9	122.6	1017.0	4.9
20.0	69.0	90.4	1136.0	9.2	62.4	106.2	1111.0	7.0	56.4	125.2	1104.0	5.4
24.0	77.9	93.5	1253.0	10.0	70.5	108.9	1218.0	7.8	63.8	127.3	1200.0	6.0
28.0	88.1	95.9	1384.0	11.0	80.0	111.0	1338.0	8.6	72.5	128.9	1310.0	6.7
32.0	100.2	97.8	1537.0	12.3	91.1	112.6	1478.0	9.7	82.8	130.2	1438.0	7.6
36.0	113.7	99.2	1702.0	13.7	103.5	113.8	1630.0	10.9	94.2	131.0	1577.0	8.6
40.0	124.1	99.9	1829.0	14.9	113.1	114.3	1747.0	11.9	103.1	131.3	1685.0	9.4

YCWS0180SC

16.0	75.4	97.4	1237.0	9.3	68.0	115.3	1209.0	7.1	61.1	136.9	1200.0	5.4
20.0	85.1	101.4	1368.0	10.1	77.0	118.8	1329.0	7.8	69.2	139.7	1307.0	5.9
24.0	96.3	104.6	1513.0	11.1	87.0	121.5	1458.0	8.6	78.5	141.8	1425.0	6.6
28.0	109.4	107.0	1678.0	12.3	98.9	123.5	1608.0	9.6	89.4	143.3	1562.0	7.5
32.0	124.9	108.8	1870.0	13.8	113.1	125.0	1783.0	10.9	102.3	144.4	1721.0	8.5
36.0	142.1	109.9	2080.0	15.5	128.8	125.9	1975.0	12.3	116.7	145.0	1895.0	9.7
40.0	155.3	110.2	2240.0	16.9	141.0	126.1	2123.0	13.4	127.8	144.9	2028.0	10.6

NOTES:

1. Tons = Unit Cooling Capacity Output
2. kW = Compressor Input Power
3. MBH = Condenser heat rejection
4. EER = Chiller Energy Efficiency Ratio (Capacity [Tons x 12] ÷ kW)
5. LCWT = Leaving Chilled Water Temperature
6. Ratings based on 2.4 GPM cooler water per ton
7. Rated in accordance with ARI Standard 550/590-98 up to 200 tons.
8. For ratings other than 30% glycol, refer to the Design 03 dxchill program.

LCWT	LEAVING CONDENSER WATER TEMPERATURE (°F)											
	85.0				95.0				105.0			
(°F)	TONS	KW	MBH	EER	TONS	KW	MBH	EER	TONS	KW	MBH	EER

YCWS0200SC

16.0	85.5	109.9	1401.0	9.3	77.0	130.2	1368.0	7.1	69.3	154.7	1359.0	5.4
20.0	96.7	114.5	1551.0	10.1	87.0	134.1	1502.0	7.8	78.5	157.8	1481.0	6.0
24.0	109.2	118.1	1713.0	11.1	98.6	137.2	1651.0	8.6	89.0	160.2	1614.0	6.7
28.0	123.9	120.9	1900.0	12.3	112.1	139.6	1821.0	9.6	101.3	162.0	1768.0	7.5
32.0	141.4	122.9	2116.0	13.8	128.1	141.3	2020.0	10.9	116.0	163.2	1949.0	8.5
36.0	160.8	124.3	2353.0	15.5	145.9	142.4	2237.0	12.3	132.4	164.0	2148.0	9.7
40.0	175.6	124.7	2533.0	16.9	159.7	142.7	2403.0	13.4	145.1	163.9	2300.0	10.6

YCWS0220SC

16.0	93.2	121.4	1532.0	9.2	84.0	143.8	1498.0	7.0	75.6	170.7	1489.0	5.3
20.0	105.2	126.5	1693.0	10.0	94.2	147.9	1635.0	7.6	85.5	174.2	1621.0	5.9
24.0	118.9	130.5	1873.0	10.9	107.4	151.6	1806.0	8.5	97.0	176.9	1767.0	6.6
28.0	135.0	133.6	2076.0	12.1	122.1	154.3	1991.0	9.5	110.4	179.0	1935.0	7.4
32.0	154.0	136.0	2312.0	13.6	139.5	156.2	2207.0	10.7	126.4	180.4	2132.0	8.4
36.0	175.0	137.5	2569.0	15.3	158.9	157.5	2444.0	12.1	144.2	181.3	2349.0	9.5
40.0	191.2	138.0	2765.0	16.6	173.8	157.9	2624.0	13.2	158.0	181.3	2514.0	10.5

YCWS0240SC

16.0	102.0	133.0	1678.0	9.2	91.9	157.5	1641.0	7.0	82.7	187.1	1631.0	5.3
20.0	115.1	138.5	1854.0	10.0	103.9	162.3	1801.0	7.7	93.6	190.9	1774.0	5.9
24.0	130.1	143.0	2049.0	10.9	117.5	166.1	1977.0	8.5	106.1	193.9	1935.0	6.6
28.0	147.6	146.5	2271.0	12.1	133.6	169.1	2180.0	9.5	120.4	196.2	2115.0	7.4
32.0	168.3	149.1	2528.0	13.5	152.6	171.3	2415.0	10.7	138.3	197.9	2334.0	8.4
36.0	191.1	150.8	2807.0	15.2	173.6	172.8	2673.0	12.1	157.6	198.9	2570.0	9.5
40.0	208.6	151.5	3020.0	16.5	189.8	173.2	2869.0	13.1	172.7	199.0	2751.0	10.4

NOTES:
1. Tons = Unit Cooling Capacity Output
2. kW = Compressor Input Power
3. MBH = Condenser heat rejection
4. EER = Chiller Energy Efficiency Ratio (Capacity [Tons x 12] ÷ kW)
5. LCWT = Leaving Chilled Water Temperature
6. Ratings based on 2.4 GPM cooler water per ton
7. Rated in accordance with ARI Standard 550/590-98 up to 200 tons.
8. For ratings other than 30% glycol, refer to the Design 03 dxchill program.

Ratings- Brine (30 % Propylene Glycol) (R-22 SI)

LCWT (°C)	LEAVING CONDENSER WATER TEMPERATURE (°C) 30.0				35.0				40.0			
	KW*o*	KW*i*	KW	COP	KW*o*	KW*i*	KW	COP	KW*o*	KW*i*	KW	COP
YCWS0100SC												
-8.0	156.6	70.8	227.0	2.2	142.8	82.5	225.0	1.7	129.8	96.6	226.0	1.3
-6.0	174.8	71.9	246.0	2.4	159.4	82.9	242.0	1.9	145.2	96.2	241.0	1.5
-4.0	195.3	72.6	268.0	2.7	178.4	83.1	261.0	2.2	162.8	95.7	258.0	1.7
-2.0	219.0	72.9	291.0	3.0	200.2	82.9	283.0	2.4	183.0	94.9	277.0	1.9
0.0	246.6	72.9	319.0	3.4	225.8	82.4	308.0	2.7	206.7	93.9	300.0	2.2
2.0	277.8	72.6	350.0	3.8	254.7	81.8	336.0	3.1	233.4	92.8	326.0	2.5
4.0	301.0	71.9	372.0	4.2	276.3	80.8	357.0	3.4	253.6	91.5	345.0	2.8
YCWS0120SC												
-8.0	188.7	80.2	268.0	2.4	172.1	93.3	265.0	1.8	156.7	109.0	265.0	1.4
-6.0	210.2	82.3	292.0	2.6	192.0	94.9	287.0	2.0	175.1	109.9	285.0	1.6
-4.0	234.7	84.0	318.0	2.8	214.6	96.1	310.0	2.2	196.1	110.6	306.0	1.8
-2.0	262.8	85.2	348.0	3.1	240.6	97.0	337.0	2.5	220.2	110.9	331.0	2.0
0.0	295.6	86.0	381.0	3.4	271.0	97.5	368.0	2.8	248.3	111.0	359.0	2.2
2.0	332.5	86.5	419.0	3.8	305.2	97.7	403.0	3.1	280.2	110.9	391.0	2.5
4.0	360.1	86.5	446.0	4.2	330.9	97.5	428.0	3.4	304.1	110.4	414.0	2.8
YCWS0140SC												
-8.0	223.6	89.7	313.0	2.5	204.2	104.4	308.0	2.0	186.1	121.7	307.0	1.5
-6.0	249.0	92.8	341.0	2.7	227.6	107.1	334.0	2.1	207.8	123.9	331.0	1.7
-4.0	277.8	95.4	373.0	2.9	254.2	109.3	363.0	2.3	232.4	125.7	358.0	1.9
-2.0	310.8	97.5	408.0	3.2	284.8	111.2	396.0	2.6	260.8	127.2	388.0	2.1
0.0	349.2	99.2	448.0	3.5	320.4	112.6	433.0	2.9	293.9	128.3	422.0	2.3
2.0	392.4	100.5	492.0	3.9	360.6	113.7	474.0	3.2	331.3	129.1	460.0	2.6
4.0	424.8	101.1	526.0	4.2	390.7	114.2	505.0	3.4	359.4	129.4	488.0	2.8
YCWS0180SC												
-8.0	275.5	100.7	376.0	2.7	250.9	116.8	367.0	2.2	228.2	135.8	364.0	1.7
-6.0	307.5	104.0	411.0	3.0	280.2	119.6	399.0	2.3	255.2	138.1	393.0	1.9
-4.0	343.8	106.7	450.0	3.2	313.7	121.9	435.0	2.6	286.1	139.9	426.0	2.0
-2.0	386.2	108.8	495.0	3.6	352.2	123.7	476.0	2.9	321.7	141.3	463.0	2.3
0.0	434.8	110.3	545.0	3.9	397.6	125.0	522.0	3.2	363.4	142.3	505.0	2.6
2.0	490.2	111.3	601.0	4.4	448.9	125.9	574.0	3.6	410.9	142.9	553.0	2.9
4.0	531.5	111.7	643.0	4.8	487.2	126.1	613.0	3.9	446.5	142.9	589.0	3.1

NOTES:
1. KWo = Unit kW Cooling Capacity Output
2. KWi = Compressor kW Input
3. COP = Coefficient of Performance
4. LCWT= Leaving Chilled Water Temperature
5. Ratings based on 0.047 l/s cooler water per kW.
6. For ratings other than 30% glycol, refer to the Design 03 dxchill program.

LCWT (°C)	LEAVING CONDENSER WATER TEMPERATURE (°C) 30.0 KWo	30.0 KWi	30.0 KW	30.0 COP	35.0 KWo	35.0 KWi	35.0 KW	35.0 COP	40.0 KWo	40.0 KWi	40.0 KW	40.0 COP
YCWS0200SC												
-8.0	312.2	113.7	425.0	2.8	284.3	131.8	416.0	2.2	258.6	153.4	412.0	1.7
-6.0	348.5	117.4	465.0	3.0	317.8	135.1	453.0	2.4	289.2	156.0	445.0	1.9
-4.0	389.6	120.5	510.0	3.2	355.5	137.7	493.0	2.6	324.2	158.1	482.0	2.1
-2.0	437.1	122.8	560.0	3.6	400.5	139.8	540.0	2.9	364.6	159.7	524.0	2.3
0.0	492.4	124.6	617.0	4.0	450.5	141.3	591.0	3.2	412.0	160.9	572.0	2.6
2.0	554.8	125.8	680.0	4.4	508.3	142.3	650.0	3.6	465.5	161.6	627.0	2.9
4.0	601.2	126.3	727.0	4.8	551.5	142.7	694.0	3.9	505.8	161.7	667.0	3.1
YCWS0220SC												
-8.0	340.3	125.5	465.0	2.7	310.4	145.7	456.0	2.1	282.1	169.4	451.0	1.7
-6.0	379.6	129.7	509.0	2.9	346.2	149.2	495.0	2.3	315.3	172.3	487.0	1.8
-4.0	424.5	133.1	557.0	3.2	387.4	152.2	539.0	2.6	353.4	174.7	528.0	2.0
-2.0	476.0	135.8	611.0	3.5	435.0	154.5	589.0	2.8	396.6	176.5	573.0	2.3
0.0	536.2	137.8	674.0	3.9	490.5	156.2	646.0	3.1	448.2	177.8	626.0	2.5
2.0	603.9	139.2	743.0	4.3	553.5	157.4	711.0	3.5	507.1	178.7	685.0	2.8
4.0	654.3	139.8	794.0	4.7	600.4	157.9	758.0	3.8	550.7	178.9	729.0	3.1
YCWS0240SC												
-8.0	373.2	137.6	510.0	2.7	339.4	159.5	499.0	2.1	308.7	185.6	494.0	1.7
-6.0	415.5	142.1	557.0	2.9	379.2	163.6	542.0	2.3	345.2	188.8	534.0	1.8
-4.0	464.4	145.9	610.0	3.2	423.9	166.8	590.0	2.5	386.3	191.4	577.0	2.0
-2.0	520.5	148.8	669.0	3.5	475.9	169.4	645.0	2.8	434.9	193.5	628.0	2.3
0.0	586.0	151.1	737.0	3.9	536.5	171.3	707.0	3.1	491.0	195.0	686.0	2.5
2.0	659.5	152.7	812.0	4.3	604.9	172.7	777.0	3.5	554.5	196.0	750.0	2.8
4.0	714.2	153.4	867.0	4.7	655.9	173.2	829.0	3.8	602.1	196.3	798.0	3.1

NOTES:
1. KWo = Unit kW Cooling Capacity Output
2. KWi= Compressor kW Input
3. COP = Coefficient of Performance
4. LCWT= Leaving Chilled Water Temperature
5. Ratings based on 0.047 l/s cooler water per kW.
8. For ratings other than 30% glycol, refer to the Design 03 dxchill program.

Brine Correction Factors

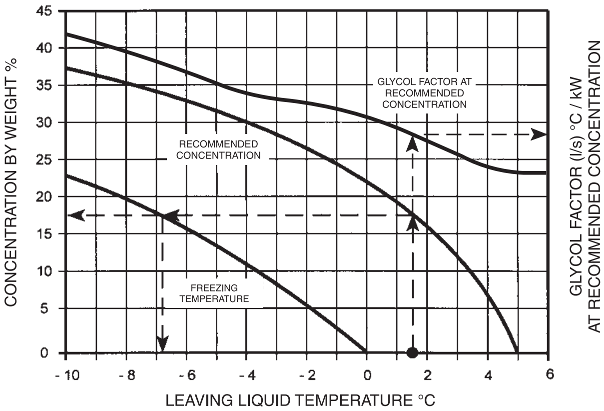


FIGURE 3 - RECOMMENDED CONCENTRATIONS FOR ETHYLENE GLYCOL SOLUTIONS

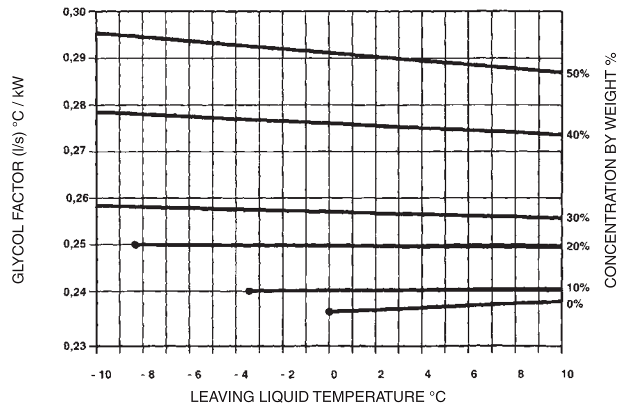


FIGURE 4 - FACTORS AT OTHER CONCENTRATIONS FOR ETHYLENE GLYCOL SOLUTIONS

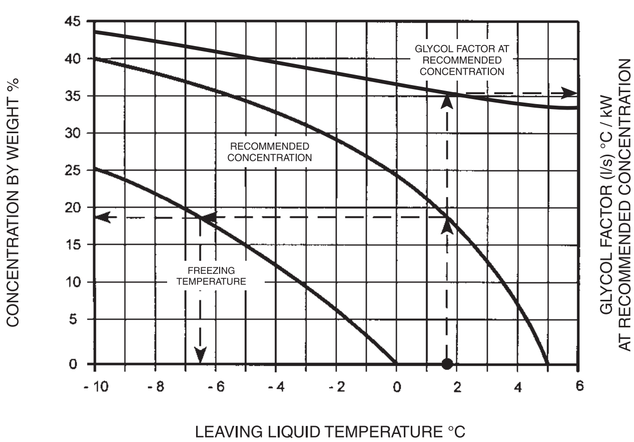


FIGURE 5 - RECOMMENDED CONCENTRATIONS FOR PROPYLENE GLYCOL SOLUTIONS

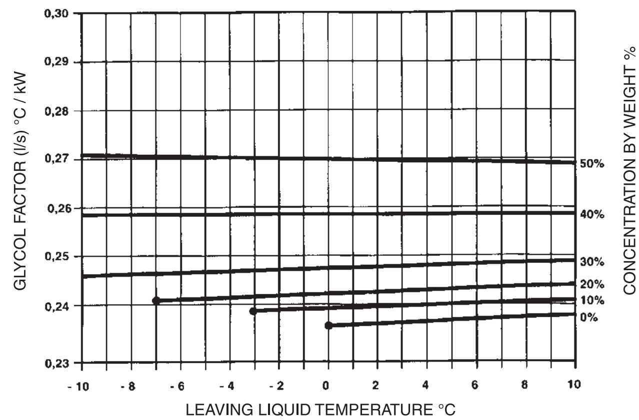
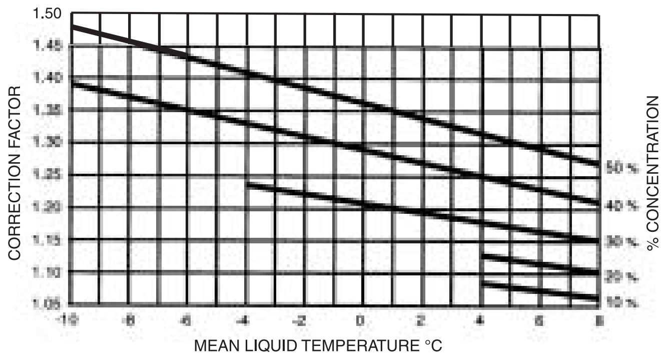


FIGURE 6 - FACTORS AT OTHER CONCENTRATIONS FOR PROPYLENE GLYCOL SOLUTIONS



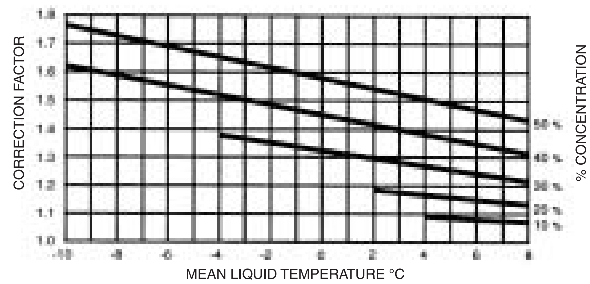


FIGURE 7 - PRESSURE DROP CORRECTION FACTORS FOR ETHYLENE GLYCOL SOLUTIONS

FIGURE 8 - PRESSURE DROP CORRECTION FACTORS FOR PROPYLENE GLYCOL SOLUTIONS

TABLE 1 - CORRECTION FACTORS

% By Weight	Ethylene Glycol (pgs 20 - 23)		Propylene Glycol (pgs 24 - 27)	
	Capacity Factor	*Comp. Input Factor (kW)*	*Capacity Factor*	*Comp. Input Factor (kW)*
10	**1.009**	**1.003**	**1.011**	**1.004**
20	**1.004**	**1.002**	**1.006**	**1.003**
30	**1.000**	**1.000**	**1.000**	**1.000**
40	**0.995**	**0.998**	**0.988**	**0.996**
50	**0.988**	**0.996**	**0.975**	**0.992**

Part Load Ratings

English

YCWS0100SB			
Load	Tons	kW	EER
100%	88.5	79.0	13.4
75%	66.4	55.5	14.4
50%	44.3	27.5	19.3
25%	22.1	21.2	12.5
IPLV: 16.4 EER			

YCWS0200SB			
Load	Tons	kW	EER
100%	175.6	142.3	14.8
75%	131.7	99.1	16.0
50%	87.8	48.1	22.0
25%	44.0	36.4	14.5
IPLV: 18.5 EER			

YCWS0120SB			
Load	Tons	kW	EER
100%	106.3	96.7	13.2
75%	79.7	67.1	14.3
50%	53.2	35.1	18.2
25%	26.6	27.6	11.5
IPLV: 15.7 EER			

YCWS0220SB			
Load	Tons	kW	EER
100%	191.0	157.5	14.6
75%	143.3	109.4	15.7
50%	95.5	56.0	20.5
25%	47.8	43.2	13.3
IPLV: 17.6 EER			

YCWS0140SB			
Load	Tons	kW	EER
100%	125.6	114.4	13.2
75%	94.2	78.5	14.4
50%	62.8	38.2	19.7
25%	31.4	28.5	13.2
IPLV: 16.6 EER			

YCWS0240SB			
Load	Tons	kW	EER
100%	208.8	173.0	14.5
75%	156.6	119.8	15.7
50%	104.4	58.2	21.5
25%	52.2	44.0	14.3
IPLV: 18.1 EER			

YCWS0180SB			
Load	Tons	kW	EER
100%	155.1	125.7	14.8
75%	116.3	87.7	15.9
50%	77.5	45.0	20.7
25%	38.8	34.2	13.6
IPLV: 17.8 EER			

Rated in accordance with ARI Standard 550/590

SI

YCWS0100SB			
Load	kWo	kWi	COP
100%	312.0	79.1	3.95
75%	233.5	55.5	4.21
50%	155.8	27.5	5.67
25%	77.7	21.2	3.67
IPLV:4.8 COP			

YCWS0200SB			
Load	kWo	kWi	COP
100%	617.9	142.6	4.33
75%	463.2	99.1	4.67
50%	308.8	48.1	6.42
25%	154.7	36.4	4.25
IPLV: 5.4 COP			

YCWS0120SB			
Load	kWo	kWi	COP
100%	374.7	96.8	3.87
75%	280.3	67.1	4.18
50%	187.1	35.1	5.33
25%	93.6	27.6	3.39
IPLV: 4.6 COP			

YCWS0220SB			
Load	kWo	kWi	COP
100%	672.0	157.9	4.26
75%	504.0	109.4	4.61
50%	335.9	56.0	6.00
25%	168.1	43.2	3.89
IPLV: 5.1 COP			

YCWS0140SB			
Load	kWo	kWi	COP
100%	443.2	114.5	3.87
75%	331.3	78.5	4.22
50%	220.9	38.2	5.78
25%	110.4	28.5	3.87
IPLV: 4.9 COP			

YCWS0240SB			
Load	kWo	kWi	COP
100%	734.9	173.3	4.24
75%	550.8	119.8	4.60
50%	367.2	58.2	6.31
25%	183.6	44.0	4.17
IPLV: 5.3 COP			

YCWS0180SB			
Load	kWo	kWi	COP
100%	545.6	126.0	4.33
75%	409.0	87.7	4.66
50%	272.6	45.0	6.06
25%	136.5	34.2	3.99
IPLV: 5.2 COP			

Rated in accordance with ARI Standard 550/590

Marley UPDATE™ Version 4.7.0
Product Data: 3/22/2006

4/1/2006 5:25:23 PM

Job Information

HS LAW

Selected By

Penn State
104 Engineering Unit A
University Park, PA
wpb5@psu.edu

PSUAE
Tel 814-863-2076

SPX Cooling Technologies Contact

H & H Associates, Inc.
4510 Westport Drive
Mechanicsburg, PA 17055
frank@hhassociates.com

Tel 717-796-2401
Fax 717-796-9717

Cooling Tower Definition

Manufacturer	Marley	Fan Motor Speed	1800 rpm
Product	NC Class	Fan Motor Capacity per cell	20.00 BHp
Model	NC8303G1	Fan Motor Output per cell	20.00 BHp
Cells	1	Fan Motor Output total	20.00 BHp
CTI Certified	Yes	Air Flow per cell	96690 cfm
Fan	7.000 ft, 6 Blades	Air Flow total	96690 cfm
Fan Speed	434 rpm, 9544.2 fpm	ASHRAE 90.1 Performance	52.0 gpm/Hp
Fans per cell	1		

Sound Pressure Level 80 dBA/Cell, 5.000 ft from Air Inlet Face. See sound report for details.

Conditions

Tower Water Flow	800.0 gpm	Air Density In	0.07094 lb/ft³
Hot Water Temperature	95.00 °F	Air Density Out	0.07136 lb/ft³
Range	10.00 °F	Humidity Ratio In	0.01712
Cold Water Temperature	85.00 °F	Humidity Ratio Out	0.02821
Approach	7.00 °F	Wet-Bulb Temp. Out	86.97 °F
Wet-Bulb Temperature	78.00 °F	Estimated Evaporation	8.9 gpm
Relative Humidity	50 %	Total Heat Rejection	3986000 Btu/h

- This selection meets your design conditions.

Weights & Dimensions

	Per Cell	Total
Shipping Weight	5900 lb	5900 lb
Max Operating Weight	12160 lb	12160 lb
Width	15.500 ft	15.500 ft
Length	7.896 ft	7.896 ft
Height	11.937 ft	
Static Lift	11.151 ft	

Minimum Enclosure Clearance

Clearance required on air inlet sides of tower without altering performance. Assumes no air from below tower.

Solid Wall	5.949 ft
50 % Open Wall	4.588 ft

Weights and dimensions do not include options; refer to sales drawings. For CAD layouts refer to file NC8303.dxf

Cold Weather Operation

Heater Sizing (to prevent freezing in the collection basin during periods of shutdown)

Heater kW/Cell	12.0	9.0	7.5	6.0	4.5	3.0
Ambient Temperature °F	-21.75	-5.25	3.00	11.25	19.50	27.75

Marley UPDATE™ Version 4.7.0
Product Data: 3/22/2006

3/31/2006 11:13:02 PM

Job Information

HS LAW

Selected By

Penn State
104 Engineering Unit A
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Tel 814-863-2076

SPX Cooling Technologies Contact

H & H Associates, Inc.
4510 Westport Drive
Mechanicsburg, PA 17055
frank@hhassociates.com

Tel 717-796-2401
Fax 717-796-9717

Cooling Tower Definition

Manufacturer	Marley	Fan Motor Speed	1800 rpm
Product	NC Class	Fan Motor Capacity per cell	30.00 BHp
Model	NC8305H1	Fan Motor Output per cell	30.00 BHp
Cells	1	Fan Motor Output total	30.00 BHp
CTI Certified	Yes	Air Flow per cell	133600 cfm
Fan	8.000 ft, 6 Blades	Air Flow total	133600 cfm
Fan Speed	434 rpm, 10908 fpm	ASHRAE 90.1 Performance	55.7 gpm/Hp
Fans per cell	1		

Sound Pressure Level 83 dBA/Cell, 5.000 ft from Air Inlet Face. See sound report for details.

Conditions

Tower Water Flow	1355 gpm	Air Density In	0.07094 lb/ft³
Hot Water Temperature	95.00 °F	Air Density Out	0.07106 lb/ft³
Range	10.00 °F	Humidity Ratio In	0.01712
Cold Water Temperature	85.00 °F	Humidity Ratio Out	0.02998
Approach	7.00 °F	Wet-Bulb Temp. Out	88.81 °F
Wet-Bulb Temperature	78.00 °F	Estimated Evaporation	14 gpm
Relative Humidity	50 %	Total Heat Rejection	6751300 Btu/h

- This selection meets your design conditions.

Weights & Dimensions

	Per Cell	Total
Shipping Weight	8850 lb	8850 lb
Max Operating Weight	19150 lb	19150 lb
Width	18.750 ft	18.750 ft
Length	10.896 ft	10.896 ft
Height	12.979 ft	
Static Lift	12.234 ft	

Minimum Enclosure Clearance

Clearance required on air inlet sides of tower without altering performance. Assumes no air from below tower.

Solid Wall	7.284 ft
50 % Open Wall	5.534 ft

Weights and dimensions do not include options; refer to sales drawings. For CAD layouts refer to file NC8305.dxf

Cold Weather Operation

Heater Sizing (to prevent freezing in the collection basin during periods of shutdown)

Heater kW/Cell	18.0	15.0	12.0	9.0	7.5	6.0	4.5
Ambient Temperature °F	-16.14	-6.05	4.04	14.13	19.17	24.22	29.26

TANK MODELS	1082C	1098C	1190C	1320C	1500C
Drawings	View drawings: 1082C 2F 1082C 3F 1082C 4F,U4F	View drawings: 1098C2F 1098C3F 1098C4F	View drawings: 1190C2F 1190C3F 1190C4F	View drawings: 1320CRF 1320CSF	View drawings: 1500CRF 1500CSF
	Download CAD drawings: 1082C2F 1082C3F 1082C4F 1082CU4F	Download CAD drawings: 1098C	Download CAD drawings: 1190C	Download CAD drawings: 1320CRF 1320CSF	Download CAD drawings: 1500CRF 1500CSF
Net-Usable Capacity Ton-Hr (i)	82	98	162	324	486
With Mix Air	--	92	156	312	469
Max. Operating Temp.,ºF	100	100	100	100	100
Factory Tested Pres., PSI	250	250	250	250	250
Max. Operating Pres., PSI (ii)	100	90	90	90	90
Dimensions (ODxH), in.	--	--	--	--	--
Dimensions (WxLxH), in.	74.5x75x84.5(2F) 74x76.5x84.5(3F) 74x76.5x84.5(4F)	89x91x69.5(2F) 89x93x69.5(3F) 89x93x69.5(4F)	89x91x102(2F) 89x93x102(3F) 89x93x102(4F)	89x183x102(RF) 89x181x102(SF)	89x273x102(RF) 89x271x102(SF)
Shipping Weight, lb (iii)	1,095	1,275	2,000	4,000	6,000
Weight, Filled, lb	8,580	10,235	16,890	33,730	50,600

Floor Loading, lb/Sq Ft	286	237	391	391	391
Volume Of Water/Ice, Gal	820	980	1,655	3,310	4,965
Vol. Solution in HX, Gal	86	99	157	315	470
With Mix Air	--	85	152	304	434
Type of connection	4" Flange	4" Flange	4" Flange	4" Flange	4" Flange
Total Burial Drawing	Full Burial Models 1190XC (2F, 3F, 4F); 1320XC & 1500XC (RF & SF); and 1098XC (2F, 3F, 4F).				
i. Typical value, actual varies with conditions ii. Consult factory for higher ratings iii. Shipping weight may vary slightly because of differences in volumes of residual water from hydrostatic test					

Partial Burial

Return to Top

AHU Selection Program Performance Summary (Chilled Water)

Project Name: THESIS HS-LAW LOW TEMP — **3/31/2006 4:49:03 PM**

Air Handler Unit: 39RN
Tag Name: AHU-1

Cooling Application's Balance Criteria: Leaving Air DB

Coil Model	**39RN**
Unit Size	**85**
Row / FPI / Circ	**8 / 10 / FL**
Face Area Type	**Large**
Coil Face Area	**85.30** sqft
Face Velocity	**439.6** fpm
Fin/Tube Material	**Al-Galv.**
Tube Wall Thickness	**0.020** in
Site Airflow Rate	**37500** CFM
Site Altitude	**0** ft
Total Cooling Capacity	**2442.77** MBH
Sensible Cooling Capacity	**1656.31** MBH
Fluid Flow Rate	**336.6** gpm
Fluid Pressure Drop	**38.1** ft wg
Fluid Velocity	**5.9** ft/s
Entering Fluid Temperature	**36.00** °F
Leaving Fluid Temperature	**51.00** °F
Fluid Temperature Rise	**15.0** °F
Cv Rating	**82.7**
Entering Air Dry Bulb	**85.00** °F
Entering Air Wet Bulb	**67.00** °F
Entering Air Enthalpy	**31.40** Btu/lb
Leaving Air Dry Bulb	**44.29** °F
Leaving Air Wet Bulb	**43.98** °F
Leaving Air Enthalpy	**17.1** Btu/lb
Air Friction	**0.90** in wg
Brine	**PG**
Brine Concentration	**25** %

AHU Selection Program Performance Summary (Chilled Water)

Project Name: THESIS HS-LAW LOW TEMP **3/31/2006**
4:50:18 PM

Air Handler Unit: 39M
Tag Name: AHU-2

Cooling Application's Balance Criteria: Leaving Air DB

Coil Model	**MC**
Unit Size	**30**
Row / FPI / Circ	**8 / 11 / FL**
Face Area Type	**Large**
Coil Face Area	**30.35** sqft
Face Velocity	**477.8** fpm
Fin-Casing Material	**Al-St. Stl.**
Tube Wall Thickness	**0.016** in
Site Airflow Rate	**14500** CFM
Site Altitude	**0** ft
Total Cooling Capacity	**875.28** MBH
Sensible Cooling Capacity	**621.92** MBH
Fluid Flow Rate	**120.2** gpm
Fluid Pressure Drop	**36.2** ft wg
Fluid Velocity	**5.4** ft/s
Entering Fluid Temperature	**36.00** °F
Leaving Fluid Temperature	**51.00** °F
Fluid Temperature Rise	**15.0** °F
Cv Rating	**30.3**
Entering Air Dry Bulb	**85.00** °F
Entering Air Wet Bulb	**67.00** °F
Entering Air Enthalpy	**31.40** Btu/lb
Leaving Air Dry Bulb	**45.78** °F
Leaving Air Wet Bulb	**45.73** °F
Leaving Air Enthalpy	**18.0** Btu/lb
Air Friction	**1.15** in wg
Brine	**PG**
Brine Concentration	**25** %

AHU Selection Program Performance Summary (Chilled Water)

Project Name: THESIS HS-LAW LOW TEMP **3/31/2006 4:50:18 PM**

Air Handler Unit: 39M
Tag Name: AHU-2

Cooling Application's Balance Criteria: Leaving Air DB

Coil Model	**MC**
Unit Size	**30**
Row / FPI / Circ	**8 / 11 / FL**
Face Area Type	**Large**
Coil Face Area	**30.35** sqft
Face Velocity	**477.8** fpm
Fin-Casing Material	**Al-St. Stl.**
Tube Wall Thickness	**0.016** in
Site Airflow Rate	**14500** CFM
Site Altitude	**0** ft
Total Cooling Capacity	**875.28** MBH
Sensible Cooling Capacity	**621.92** MBH
Fluid Flow Rate	**120.2** gpm
Fluid Pressure Drop	**36.2** ft wg
Fluid Velocity	**5.4** ft/s
Entering Fluid Temperature	**36.00** °F
Leaving Fluid Temperature	**51.00** °F
Fluid Temperature Rise	**15.0** °F
Cv Rating	**30.3**
Entering Air Dry Bulb	**85.00** °F
Entering Air Wet Bulb	**67.00** °F
Entering Air Enthalpy	**31.40** Btu/lb
Leaving Air Dry Bulb	**45.78** °F
Leaving Air Wet Bulb	**45.73** °F
Leaving Air Enthalpy	**18.0** Btu/lb
Air Friction	**1.15** in wg
Brine	**PG**
Brine Concentration	**25** %

AHU Selection Program Performance Summary (Chilled Water)

Project Name: THESIS HS-LAW LOW TEMP — **3/31/2006 6:13:40 PM**

Air Handler Unit: 39M
Tag Name: AHU-4

Cooling Application's Balance Criteria: Leaving Air WB

Coil Model	**MC**
Unit Size	**10**
Row / FPI / Circ	**8 / 8 / HF**
Face Area Type	**Large**
Coil Face Area	**9.93** sqft
Face Velocity	**261.8** fpm
Fin-Casing Material	**Al-St. Stl.**
Tube Wall Thickness	**0.016** in
Site Airflow Rate	**2600** CFM
Site Altitude	**0** ft
Total Cooling Capacity	**140.56** MBH
Sensible Cooling Capacity	**103.43** MBH
Fluid Flow Rate	**19.3** gpm
Fluid Pressure Drop	**14.0** ft wg
Fluid Velocity	**3.0** ft/s
Entering Fluid Temperature	**36.00** °F
Leaving Fluid Temperature	**51.00** °F
Fluid Temperature Rise	**15.0** °F
Cv Rating	**7.8**
Entering Air Dry Bulb	**85.00** °F
Entering Air Wet Bulb	**67.00** °F
Entering Air Enthalpy	**31.40** Btu/lb
Leaving Air Dry Bulb	**48.62** °F
Leaving Air Wet Bulb	**48.40** °F
Leaving Air Enthalpy	**19.4** Btu/lb
Air Friction	**0.34** in wg
Brine	**PG**
Brine Concentration	**25** %

AHU Selection Program Performance Summary (Chilled Water)

Project Name: THESIS HS-LAW LOW TEMP — **3/31/2006 5:23:55 PM**

Air Handler Unit: 39M
Tag Name: AHU-5

Cooling Application's Balance Criteria: Leaving Air DB

Coil Model	**MC**	
Unit Size	**30**	
Row / FPI / Circ	**8 / 11 / FL**	
Face Area Type	**Large**	
Coil Face Area	**30.35**	sqft
Face Velocity	**369.0**	fpm
Fin-Casing Material	**Al-St. Stl.**	
Tube Wall Thickness	**0.016**	in
Site Airflow Rate	**11200**	CFM
Site Altitude	**0**	ft
Total Cooling Capacity	**675.63**	MBH
Sensible Cooling Capacity	**480.42**	MBH
Fluid Flow Rate	**92.8**	gpm
Fluid Pressure Drop	**22.8**	ft wg
Fluid Velocity	**4.2**	ft/s
Entering Fluid Temperature	**36.00**	°F
Leaving Fluid Temperature	**51.00**	°F
Fluid Temperature Rise	**15.0**	°F
Cv Rating	**29.5**	
Entering Air Dry Bulb	**85.00**	°F
Entering Air Wet Bulb	**67.00**	°F
Entering Air Enthalpy	**31.40**	Btu/lb
Leaving Air Dry Bulb	**45.77**	°F
Leaving Air Wet Bulb	**45.75**	°F
Leaving Air Enthalpy	**18.0**	Btu/lb
Air Friction	**0.76**	in wg
Brine	**PG**	
Brine Concentration	**25**	%

AHU Selection Program Performance Summary (Chilled Water)

Project Name: THESIS HS-LAW LOW TEMP **3/31/2006**
5:24:17 PM

Air Handler Unit: 39M
Tag Name: AHU-6

Cooling Application's Balance Criteria: Leaving Air DB

Coil Model	**MC**
Unit Size	**12**
Row / FPI / Circ	**10 / 8 / HF**
Face Area Type	**Large**
Coil Face Area	**12.64** sqft
Face Velocity	**332.3** fpm
Fin-Casing Material	**Al-St. Stl.**
Tube Wall Thickness	**0.016** in
Site Airflow Rate	**4200** CFM
Site Altitude	**0** ft
Total Cooling Capacity	**260.89** MBH
Sensible Cooling Capacity	**183.40** MBH
Fluid Flow Rate	**35.8** gpm
Fluid Pressure Drop	**31.8** ft wg
Fluid Velocity	**4.4** ft/s
Entering Fluid Temperature	**36.00** °F
Leaving Fluid Temperature	**51.00** °F
Fluid Temperature Rise	**15.0** °F
Cv Rating	**9.6**
Entering Air Dry Bulb	**85.00** °F
Entering Air Wet Bulb	**67.00** °F
Entering Air Enthalpy	**31.40** Btu/lb
Leaving Air Dry Bulb	**45.07** °F
Leaving Air Wet Bulb	**44.97** °F
Leaving Air Enthalpy	**17.6** Btu/lb
Air Friction	**0.65** in wg
Brine	**PG**
Brine Concentration	**25** %

AHU Selection Program Performance Summary (Chilled Water)

Project Name: THESIS HS-LAW LOW TEMP — **3/31/2006 5:24:39 PM**

Air Handler Unit: 39M

Tag Name: AHU-7

Cooling Application's Balance Criteria: Leaving Air DB

Coil Model	**MC**
Unit Size	**21**
Row / FPI / Circ	**6 / 11 / HF**
Face Area Type	**Large**
Coil Face Area	**21.44** sqft
Face Velocity	**373.1** fpm
Fin-Casing Material	**Al-St. Stl.**
Tube Wall Thickness	**0.016** in
Site Airflow Rate	**8000** CFM
Site Altitude	**0** ft
Total Cooling Capacity	**468.18** MBH
Sensible Cooling Capacity	**335.39** MBH
Fluid Flow Rate	**64.3** gpm
Fluid Pressure Drop	**40.6** ft wg
Fluid Velocity	**5.8** ft/s
Entering Fluid Temperature	**36.00** °F
Leaving Fluid Temperature	**51.00** °F
Fluid Temperature Rise	**15.0** °F
Cv Rating	**15.3**
Entering Air Dry Bulb	**85.00** °F
Entering Air Wet Bulb	**67.00** °F
Entering Air Enthalpy	**31.40** Btu/lb
Leaving Air Dry Bulb	**46.66** °F
Leaving Air Wet Bulb	**46.53** °F
Leaving Air Enthalpy	**18.4** Btu/lb
Air Friction	**0.58** in wg
Brine	**PG**
Brine Concentration	**25** %

AHU Selection Program Performance Summary (Chilled Water)

Project Name: THESIS HS-LAW LOW TEMP **3/31/2006**
5:24:39 PM

Air Handler Unit: 39M
Tag Name: AHU-7

Cooling Application's Balance Criteria: Leaving Air DB

Coil Model	**MC**
Unit Size	**21**
Row / FPI / Circ	**6 / 11 / HF**
Face Area Type	**Large**
Coil Face Area	**21.44** sqft
Face Velocity	**373.1** fpm
Fin-Casing Material	**Al-St. Stl.**
Tube Wall Thickness	**0.016** in
Site Airflow Rate	**8000** CFM
Site Altitude	**0** ft
Total Cooling Capacity	**468.18** MBH
Sensible Cooling Capacity	**335.39** MBH
Fluid Flow Rate	**64.3** gpm
Fluid Pressure Drop	**40.6** ft wg
Fluid Velocity	**5.8** ft/s
Entering Fluid Temperature	**36.00** °F
Leaving Fluid Temperature	**51.00** °F
Fluid Temperature Rise	**15.0** °F
Cv Rating	**15.3**
Entering Air Dry Bulb	**85.00** °F
Entering Air Wet Bulb	**67.00** °F
Entering Air Enthalpy	**31.40** Btu/lb
Leaving Air Dry Bulb	**46.66** °F
Leaving Air Wet Bulb	**46.53** °F
Leaving Air Enthalpy	**18.4** Btu/lb
Air Friction	**0.58** in wg
Brine	**PG**
Brine Concentration	**25** %

AHU Selection Program Performance Summary (Chilled Water)

Project Name: THESIS HS-LAW LOW TEMP — **3/31/2006 5:25:57 PM**

Air Handler Unit: 39M
Tag Name: AHU-9

Cooling Application's Balance Criteria: Leaving Air DB

Coil Model	**MC**
Unit Size	**12**
Row / FPI / Circ	**10 / 8 / HF**
Face Area Type	**Large**
Coil Face Area	**12.64** sqft
Face Velocity	**379.7** fpm
Fin-Casing Material	**Al-St. Stl.**
Tube Wall Thickness	**0.016** in
Site Airflow Rate	**4800** CFM
Site Altitude	**0** ft
Total Cooling Capacity	**296.02** MBH
Sensible Cooling Capacity	**208.43** MBH
Fluid Flow Rate	**40.7** gpm
Fluid Pressure Drop	**39.7** ft wg
Fluid Velocity	**4.9** ft/s
Entering Fluid Temperature	**36.00** °F
Leaving Fluid Temperature	**51.00** °F
Fluid Temperature Rise	**15.0** °F
Cv Rating	**9.8**
Entering Air Dry Bulb	**85.00** °F
Entering Air Wet Bulb	**67.00** °F
Entering Air Enthalpy	**31.40** Btu/lb
Leaving Air Dry Bulb	**45.29** °F
Leaving Air Wet Bulb	**45.16** °F
Leaving Air Enthalpy	**17.7** Btu/lb
Air Friction	**0.81** in wg
Brine	**PG**
Brine Concentration	**25** %

AHU Selection Program Performance Summary (Chilled Water)

Project Name: THESIS HS-LAW LOW TEMP **3/31/2006 5:26:25 PM**

Air Handler Unit: 39M
Tag Name: AHU-10

Cooling Application's Balance Criteria: Leaving Air WB

Coil Model	**MC**
Unit Size	**10**
Row / FPI / Circ	**8 / 8 / HF**
Face Area Type	**Large**
Coil Face Area	**9.93** sqft
Face Velocity	**241.7** fpm
Fin-Casing Material	**Al-St. Stl.**
Tube Wall Thickness	**0.016** in
Site Airflow Rate	**2400** CFM
Site Altitude	**0** ft
Total Cooling Capacity	**128.85** MBH
Sensible Cooling Capacity	**95.13** MBH
Fluid Flow Rate	**17.7** gpm
Fluid Pressure Drop	**12.0** ft wg
Fluid Velocity	**2.7** ft/s
Entering Fluid Temperature	**36.00** °F
Leaving Fluid Temperature	**51.00** °F
Fluid Temperature Rise	**15.0** °F
Cv Rating	**7.8**
Entering Air Dry Bulb	**85.00** °F
Entering Air Wet Bulb	**67.00** °F
Entering Air Enthalpy	**31.40** Btu/lb
Leaving Air Dry Bulb	**48.75** °F
Leaving Air Wet Bulb	**48.56** °F
Leaving Air Enthalpy	**19.5** Btu/lb
Air Friction	**0.30** in wg
Brine	**PG**
Brine Concentration	**25** %

APPENDIX B

Cost Estimates:

First Cost
Energy Consumption
Operating Cost
Life Cycle Cost

PROJECT: BRONX HIGH SCHOOL FOR LAW, GOVERNMENT & JUSTICE
CONVETIONAL SYSTEM

DESCRIPTION OF WORK	UNIT		MATERIAL		LABOR		TOTAL COST
	QNTY	UNIT MEAS	UNIT COST	TOTAL	UNIT COST	TOTAL	
CHILLERS - AIR COOLED							
320 T.R., CHILLED WATER, REFRIG. 134A	2	EA	148,500.00	297,000	11,300.00	22,600	319,600
DX PIPING W/ INSULATION - LIQ & GAS	800	LF	21.25	17,000	14.35	11,480	28,480
Total:				314,000		34,080	348,080
PUMPS - W/ LOCAL PIPING/VALVING							
CHILLED WATER PUMPS	3	EA	3,175.00	9,525	565.00	1,695	11,220
Total:				9,525		1,695	11,220
AIR HANDLING UNITS: W/ FILTERS, MOTOR & DRIVE							
AHU-1: 48,000 CFM	1	EA	58,500.00	58,500	4,825.00	4,825	63,325
AHU-2: 19,000 CFM	1	EA	26,600.00	26,600	1,375.00	1,375	27,975
AHU-3: 17,500 CFM	1	EA	25,400.00	25,400	1,290.00	1,290	26,690
AHU-4: 3,200 CFM	1	EA	4,850.00	4,850	635.00	635	5,485
AHU-5: 14,500 CFM	1	EA	21,200.00	21,200	1,200.00	1,200	22,400
AHU-6: 5,200 CFM	1	EA	7,975.00	7,975	710.00	710	8,685
AHU-7: 12,000 CFM	1	EA	16,100.00	16,100	985.00	985	17,085
AHU-8: 6,000 CFM	1	EA	10,100.00	10,100	740.00	740	10,840
AHU-9: 7,200 CFM	1	EA	11,600.00	11,600	805.00	805	12,405
AHU-10: 3,100 CFM	1	EA	4,725.00	4,725	620.00	620	5,345
Total:				187,050		13,185	200,235
COOLING COILS							
AHU-1	1	EA	8,496.00	8,496	4,470.00	4,470	12,966
AHU-2	1	EA	3,365.00	3,365	1,769.00	1,769	5,134
AHU-3	1	EA	3,099.00	3,099	1,630.00	1,630	4,729
AHU-4	1	EA	567.00	567	298.00	298	865
AHU-5	1	EA	2,368.00	2,368	1,350.00	1,350	3,718
AHU-6	1	EA	921.00	921	484.00	484	1,405
AHU-7	1	EA	2,125.00	2,125	1,118.00	1,118	3,243
AHU-8	1	EA	1,063.00	1,063	559.00	559	1,622
AHU-9	1	EA	1,275.00	1,275	671.00	671	1,946
AHU-10	1	EA	549.00	549	289.00	289	838
Total:				23,828		12,638	36,466
FANS							
RF-1: 38,400 CFM	1	EA	12,750.00	12,750	3,250.00	3,250	16,000
RF-2: 15,200 CFM	1	EA	7,100.00	7,100	1,750.00	1,750	8,850
RF-3: 14,000 CFM	1	EA	7,100.00	7,100	1,750.00	1,750	8,850
RF-4: 2,560 CFM	1	EA	1,950.00	1,950	1,040.00	1,040	2,990
RF-5: 14,500 CFM	1	EA	7,100.00	7,100	1,750.00	1,750	8,850
RF-6: 4160 CFM	1	EA	3,985.00	3,985	1,350.00	1,350	5,335
RF-7: 9,600 CFM	1	EA	5,100.00	5,100	1,500.00	1,500	6,600
RF-8: 4,800 CFM	1	EA	4,400.00	4,400	1,500.00	1,500	5,900
RF-9: 5,750 CFM	1	EA	2,750.00	2,750	1,500.00	1,500	4,250
RF-10: 2,480 CFM	1	EA	1,750.00	1,750	750.00	750	2,500
Total:				53,985		16,140	70,125
AIR DISTRIBUTION							
GALVANIZED IRON DUCTWORK	155,000	LBS	1.06	164,300	4.02	623,100	787,400
DUCT INSULATION	80,000	SF	1.76	140,800	2.40	192,000	332,800
DIFFUSERS	575	EA	159.00	91,425	37.50	21,563	112,988
Total:				396,525		836,663	1,233,188

PROJECT: BRONX HIGH SCHOOL FOR LAW, GOVERNMENT & JUSTICE
CONVETIONAL SYSTEM

DESCRIPTION OF WORK	UNIT		MATERIAL		LABOR		TOTAL COST
	QNTY	UNIT MEAS	UNIT COST	TOTAL	UNIT COST	TOTAL	
PIPE							
8" PIPE/ FITTINGS/ SUPPORTS	500	LF	30.00	15,000	60.00	30,000	45,000
6" PIPE/ FITTINGS/ SUPPORTS	550	LF	29.00	15,950	39.50	21,725	37,675
5" PIPE/ FITTINGS/ SUPPORTS	650	LF	26.50	17,225	34.25	22,263	39,488
4" PIPE/ FITTINGS/ SUPPORTS	750	LF	19.50	14,625	21.50	16,125	30,750
3" PIPE/ FITTINGS/ SUPPORTS	900	LF	17.50	15,750	17.50	15,750	31,500
2 1/2" PIPE/ FITTINGS/ SUPPORTS	800	LF	13.25	10,600	13.25	10,600	21,200
2" PIPE/ FITTINGS/ SUPPORTS	700	LF	11.25	7,875	9.50	6,650	14,525
1 1/2" PIPE/ FITTINGS/ SUPPORTS	1,000	LF	9.20	9,200	9.25	9,250	18,450
1 1/4" PIPE/ FITTINGS/ SUPPORTS	1,200	LF	8.20	9,840	8.75	10,500	20,340
1" PIPE/ FITTINGS/ SUPPORTS	900	LF	7.10	6,390	8.25	7,425	13,815
3/4" PIPE/ FITTINGS/ SUPPORTS	500	LF	7.10	3,550	8.25	4,125	7,675
1/2" PIPE/ FITTINGS/ SUPPORTS	400	LF	6.90	2,760	8.00	3,200	5,960
Total:				128,765		157,613	286,378
PIPE INSULATION							
8" PIPE SIZE	500	LF	10.40	5,200	7.90	3,950	9,150
6" PIPE SIZE	550	LF	9.50	5,225	7.40	4,070	9,295
5" PIPE SIZE	650	LF	9.50	6,175	7.40	4,810	10,985
4" PIPE SIZE	750	LF	4.20	3,150	3.30	2,475	5,625
3" PIPE SIZE	900	LF	4.10	3,690	3.20	2,880	6,570
2 1/2" PIPE SIZE	800	LF	4.10	3,280	3.20	2,560	5,840
2" PIPE SIZE	700	LF	4.00	2,800	3.10	2,170	4,970
1 1/2" PIPE SIZE	1,000	LF	2.30	2,300	1.80	1,800	4,100
1 1/4" PIPE SIZE	1,200	LF	2.30	2,760	1.80	2,160	4,920
1" PIPE SIZE	900	LF	2.30	2,070	1.80	1,620	3,690
3/4" PIPE SIZE	500	LF	2.15	1,075	1.65	825	1,900
1/2" PIPE SIZE	400	LF	2.15	860	1.65	660	1,520
Total:				38,585		29,980	68,565
GRAND TOTAL				**1,152,263**		**1,101,993**	**$ 2,254,256**

PROJECT: BRONX HIGH SCHOOL FOR LAW, GOVERNMENT & JUSTICE
FULL STORAGE WITH LOW TEMPERATURE AIR DISTRIBUTION

DESCRIPTION OF WORK	UNIT QNTY	UNIT MEAS	MATERIAL UNIT COST	MATERIAL TOTAL	LABOR UNIT COST	LABOR TOTAL	TOTAL COST
CHILLERS							
410 T.R., CHILLED WATER, REFRIG. 407C	2	EA	135,500.00	271,000	11,600.00	23,200	294,200
600 TON COOLING TOWER	2	EA	46,400.00	92,800	4,425.00	8,850	101,650
PROPYLENE GLYCOL	220	GAL	8.65	1,903	12.65	2,783	4,686
DX PIPING W/ INSULATION - LIQ & GAS	1,200	LF	21.25	25,500	14.35	17,220	42,720
TEMPERATURE SENSOR	3	EA	305.00	915	34.45	103	1,018
GLOBE VALVES	3	EA	2,175.00	6,525	80.00	240	6,765
ICE THERMAL STORAGE TANKS	3,078	TON-HR	70.00	215,460	0.00	-	215,460
Total:				614,103		52,396	666,499
PUMPS - W/ LOCAL PIPING/VALVING							
CHILLED WATER PUMPS	3	EA	2,775.00	8,325	455.00	1,365	9,690
CONDENSOR PUMP	2	EA	3,175.00	6,350	685.00	1,370	7,720
SECONDARY VARIABLE SPEED PUMP	1	EA	7,425.00	7,425	2,300.00	2,300	9,725
Total:				22,100		1,365	27,135
AIR HANDLING UNITS: W/ FILTERS, MOTOR & DRIVE							
AHU-1: 37,500 CFM	1	EA	57,800.00	57,800	4,725.00	4,725	62,525
AHU-2: 14,500 CFM	1	EA	20,100.00	20,100	1,100.00	1,100	21,200
AHU-3: 13,500 CFM	1	EA	18,100.00	18,100	1,075.00	1,075	19,175
AHU-4: 2,400 CFM	1	EA	4,125.00	4,125	580.00	580	4,705
AHU-5: 11,200 CFM	1	EA	15,800.00	15,800	965.00	965	16,765
AHU-6: 4,200 CFM	1	EA	6,250.00	6,250	655.00	655	6,905
AHU-7: 8,000 CFM	1	EA	12,900.00	12,900	925.00	925	13,825
AHU-8: 4,800 CFM	1	EA	7,775.00	7,775	690.00	690	8,465
AHU-9: 4,800 CFM	1	EA	7,775.00	7,775	690.00	690	8,465
AHU-10: 2,400 CFM	1	EA	4,125.00	4,125	580.00	580	4,705
Total:				154,750		11,985	166,735
COOLING COILS							
AHU-1	1	EA	9,770.00	9,770	5,140.00	5,140	14,910
AHU-2	1	EA	3,870.00	3,870	2,035.00	2,035	5,905
AHU-3	1	EA	3,560.00	3,560	1,875.00	1,875	5,435
AHU-4	1	EA	350.00	350	345.00	345	695
AHU-5	1	EA	2,950.00	2,950	1,550.00	1,550	4,500
AHU-6	1	EA	1,060.00	1,060	560.00	560	1,620
AHU-7	1	EA	2,445.00	2,445	1,285.00	1,285	3,730
AHU-8	1	EA	1,220.00	1,220	645.00	645	1,865
AHU-9	1	EA	1,460.00	1,460	770.00	770	2,230
AHU-10	1	EA	630.00	630	332.00	332	962
Total:				27,315		14,537	41,852
FANS							
RF-1: 30000 CFM	1	EA	9,960.00	9,960	2,540.00	2,540	12,500
RF-2: 11600 CFM	1	EA	5,420.00	5,420	1,335.00	1,335	6,755
RF-3: 10800 CFM	1	EA	5,480.00	5,480	1,350.00	1,350	6,830
RF-4: 1920 CFM	1	EA	1,460.00	1,460	780.00	780	2,240
RF-5: 8960 CFM	1	EA	5,485.00	5,485	1,350.00	1,350	6,835
RF-6: 3360 CFM	1	EA	3,220.00	3,220	1,090.00	1,090	4,310
RF-7: 6400 CFM	1	EA	3,400.00	3,400	1,000.00	1,000	4,400
RF-8: 3840 CFM	1	EA	3,520.00	3,520	1,200.00	1,200	4,720
RF-9: 3840 CFM	1	EA	1,835.00	1,835	1,000.00	1,000	2,835
RF-10: 1920 CFM	1	EA	1,355.00	1,355	580.00	580	1,935
Total:				41,135		12,225	53,360
AIR DISTRIBUTION							
GALVANIZED IRON DUCTWORK	135,000	LBS	1.06	143,100	4.02	542,700	685,800
DUCT INSULATION	65,000	SF	1.98	128,700	2.67	173,550	302,250
DIFFUSERS	575	EA	181.00	104,075	42.25	24,294	128,369
Total:				375,875		740,544	1,116,419

PROJECT: BRONX HIGH SCHOOL FOR LAW, GOVERNMENT & JUSTICE
FULL STORAGE WITH LOW TEMPERATURE AIR DISTRIBUTION

DESCRIPTION OF WORK	UNIT		MATERIAL		LABOR		TOTAL COST
	QNTY	UNIT MEAS	UNIT COST	TOTAL	UNIT COST	TOTAL	
PIPE							
8" PIPE/ FITTINGS/ SUPPORTS	400	LF	30.00	12,000	60.00	24,000	36,000
6" PIPE/ FITTINGS/ SUPPORTS	440	LF	29.00	12,760	39.50	17,380	30,140
5" PIPE/ FITTINGS/ SUPPORTS	520	LF	26.50	13,780	34.25	17,810	31,590
4" PIPE/ FITTINGS/ SUPPORTS	600	LF	19.50	11,700	21.50	12,900	24,600
3" PIPE/ FITTINGS/ SUPPORTS	720	LF	17.50	12,600	17.50	12,600	25,200
2 1/2" PIPE/ FITTINGS/ SUPPORTS	640	LF	13.25	8,480	13.25	8,480	16,960
2" PIPE/ FITTINGS/ SUPPORTS	560	LF	11.25	6,300	9.50	5,320	11,620
1 1/2" PIPE/ FITTINGS/ SUPPORTS	800	LF	9.20	7,360	9.25	7,400	14,760
1 1/4" PIPE/ FITTINGS/ SUPPORTS	960	LF	8.20	7,872	8.75	8,400	16,272
1" PIPE/ FITTINGS/ SUPPORTS	720	LF	7.10	5,112	8.25	5,940	11,052
3/4" PIPE/ FITTINGS/ SUPPORTS	400	LF	7.10	2,840	8.25	3,300	6,140
1/2" PIPE/ FITTINGS/ SUPPORTS	320	LF	6.90	2,208	8.00	2,560	4,768
Total:				103,012		126,090	229,102
PIPE INSULATION							
8" PIPE SIZE	400	LF	10.40	4,160	7.90	3,160	7,320
6" PIPE SIZE	440	LF	9.50	4,180	7.40	3,256	7,436
5" PIPE SIZE	520	LF	9.50	4,940	7.40	3,848	8,788
4" PIPE SIZE	600	LF	4.20	2,520	3.30	1,980	4,500
3" PIPE SIZE	720	LF	4.10	2,952	3.20	2,304	5,256
2 1/2" PIPE SIZE	640	LF	4.10	2,624	3.20	2,048	4,672
2" PIPE SIZE	560	LF	4.00	2,240	3.10	1,736	3,976
1 1/2" PIPE SIZE	800	LF	2.30	1,840	1.80	1,440	3,280
1 1/4" PIPE SIZE	960	LF	2.30	2,208	1.80	1,728	3,936
1" PIPE SIZE	720	LF	2.30	1,656	1.80	1,296	2,952
3/4" PIPE SIZE	400	LF	2.15	860	1.65	660	1,520
1/2" PIPE SIZE	320	LF	2.15	688	1.65	528	1,216
Total:				30,868		23,984	54,852
GRAND TOTAL				**1,369,158**		**983,126**	**$ 2,355,954**

PROJECT: BRONX HIGH SCHOOL FOR LAW, GOVERNMENT & JUSTICE
PARTIAL STORAGE WITH LOW TEMPERATURE AIR DISTRIBUTION

DESCRIPTION OF WORK	UNIT		MATERIAL		LABOR		TOTAL COST
	QNTY	UNIT MEAS	UNIT COST	TOTAL	UNIT COST	TOTAL	
CHILLERS							
240 T.R., CHILLED WATER, REFRIG. 407C	2	EA	77,000.00	154,000	10,700.00	21,400	175,400
350 TON COOLING TOWER	2	EA	32,300.00	64,600	2,800.00	5,600	70,200
PROPYLENE GLYCOL	220	GAL	8.65	1,903	12.65	2,783	4,686
DX PIPING W/ INSULATION	1,200	LF	21.25	25,500	14.35	17,220	42,720
TEMPERATURE SENSOR	3	EA	305.00	915	34.45	103	1,018
GLOBE VALVES	3	EA	2,175.00	6,525	80.00	240	6,765
ICE THERMAL STORAGE TANKS	1,782	TON-HR	70.00	124,740	0.00	-	124,740
Total:				378,183		47,003	425,529
PUMPS - W/ LOCAL PIPING/VALVING							
CHILLED WATER PUMPS	3	EA	2,775.00	8,325	455.00	1,365	9,690
CONDENSOR PUMP	2	EA	3,175.00	6,350	685.00	1,370	7,720
SECONDARY VARIABLE SPEED PUMP	1	EA	7,425.00	7,425	2,300.00	2,300	9,725
Total:				22,100		1,365	27,135
AIR HANDLING UNITS: W/ FILTERS, MOTOR & DRIVE							
AHU-1: 37,500 CFM	1	EA	57,800.00	57,800	4,725.00	4,725	62,525
AHU-2: 14,500 CFM	1	EA	20,100.00	20,100	1,100.00	1,100	21,200
AHU-3: 13,500 CFM	1	EA	18,100.00	18,100	1,075.00	1,075	19,175
AHU-4: 2,400 CFM	1	EA	4,125.00	4,125	580.00	580	4,705
AHU-5: 11,200 CFM	1	EA	15,800.00	15,800	965.00	965	16,765
AHU-6: 4,200 CFM	1	EA	6,250.00	6,250	655.00	655	6,905
AHU-7: 8,000 CFM	1	EA	12,900.00	12,900	925.00	925	13,825
AHU-8: 4,800 CFM	1	EA	7,775.00	7,775	690.00	690	8,465
AHU-9: 4,800 CFM	1	EA	7,775.00	7,775	690.00	690	8,465
AHU-10: 2,400 CFM	1	EA	4,125.00	4,125	580.00	580	4,705
Total:				154,750		11,985	166,735
COOLING COILS							
AHU-1	1	EA	9,770.00	9,770	5,140.00	5,140	14,910
AHU-2	1	EA	3,870.00	3,870	2,035.00	2,035	5,905
AHU-3	1	EA	3,560.00	3,560	1,875.00	1,875	5,435
AHU-4	1	EA	350.00	350	345.00	345	695
AHU-5	1	EA	2,950.00	2,950	1,550.00	1,550	4,500
AHU-6	1	EA	1,060.00	1,060	560.00	560	1,620
AHU-7	1	EA	2,445.00	2,445	1,285.00	1,285	3,730
AHU-8	1	EA	1,220.00	1,220	645.00	645	1,865
AHU-9	1	EA	1,460.00	1,460	770.00	770	2,230
AHU-10	1	EA	630.00	630	332.00	332	962
Total:				27,315		14,537	41,852
FANS							
RF-1: 30000 CFM	1	EA	9,960.00	9,960	2,540.00	2,540	12,500
RF-2: 11600 CFM	1	EA	5,420.00	5,420	1,335.00	1,335	6,755
RF-3: 10800 CFM	1	EA	5,480.00	5,480	1,350.00	1,350	6,830
RF-4: 1920 CFM	1	EA	1,460.00	1,460	780.00	780	2,240
RF-5: 8960 CFM	1	EA	5,485.00	5,485	1,350.00	1,350	6,835
RF-6: 3360 CFM	1	EA	3,220.00	3,220	1,090.00	1,090	4,310
RF-7: 6400 CFM	1	EA	3,400.00	3,400	1,000.00	1,000	4,400
RF-8: 3840 CFM	1	EA	3,520.00	3,520	1,200.00	1,200	4,720
RF-9: 3840 CFM	1	EA	1,835.00	1,835	1,000.00	1,000	2,835
RF-10: 1920 CFM	1	EA	1,355.00	1,355	580.00	580	1,935
Total:				41,135		12,225	53,360
AIR DISTRIBUTION							
GALVANIZED IRON DUCTWORK	135,000	LBS	1.06	143,100	4.02	542,700	685,800
DUCT INSULATION	65,000	SF	1.98	128,700	2.67	173,550	302,250
DIFFUSERS	575	EA	181.00	104,075	42.25	24,294	128,369
Total:				375,875		740,544	1,116,419

PROJECT: BRONX HIGH SCHOOL FOR LAW, GOVERNMENT & JUSTICE
PARTIAL STORAGE WITH LOW TEMPERATURE AIR DISTRIBUTION

DESCRIPTION OF WORK	UNIT		MATERIAL		LABOR		TOTAL COST
	QNTY	UNIT MEAS	UNIT COST	TOTAL	UNIT COST	TOTAL	
PIPE							
8" PIPE/ FITTINGS/ SUPPORTS	400	LF	30.00	12,000	60.00	24,000	36,000
6" PIPE/ FITTINGS/ SUPPORTS	440	LF	29.00	12,760	39.50	17,380	30,140
5" PIPE/ FITTINGS/ SUPPORTS	520	LF	26.50	13,780	34.25	17,810	31,590
4" PIPE/ FITTINGS/ SUPPORTS	600	LF	19.50	11,700	21.50	12,900	24,600
3" PIPE/ FITTINGS/ SUPPORTS	720	LF	17.50	12,600	17.50	12,600	25,200
2 1/2" PIPE/ FITTINGS/ SUPPORTS	640	LF	13.25	8,480	13.25	8,480	16,960
2" PIPE/ FITTINGS/ SUPPORTS	560	LF	11.25	6,300	9.50	5,320	11,620
1 1/2" PIPE/ FITTINGS/ SUPPORTS	800	LF	9.20	7,360	9.25	7,400	14,760
1 1/4" PIPE/ FITTINGS/ SUPPORTS	960	LF	8.20	7,872	8.75	8,400	16,272
1" PIPE/ FITTINGS/ SUPPORTS	720	LF	7.10	5,112	8.25	5,940	11,052
3/4" PIPE/ FITTINGS/ SUPPORTS	400	LF	7.10	2,840	8.25	3,300	6,140
1/2" PIPE/ FITTINGS/ SUPPORTS	320	LF	6.90	2,208	8.00	2,560	4,768
Total:				103,012		126,090	229,102
PIPE INSULATION							
8" PIPE SIZE	400	LF	10.40	4,160	7.90	3,160	7,320
6" PIPE SIZE	440	LF	9.50	4,180	7.40	3,256	7,436
5" PIPE SIZE	520	LF	9.50	4,940	7.40	3,848	8,788
4" PIPE SIZE	600	LF	4.20	2,520	3.30	1,980	4,500
3" PIPE SIZE	720	LF	4.10	2,952	3.20	2,304	5,256
2 1/2" PIPE SIZE	640	LF	4.10	2,624	3.20	2,048	4,672
2" PIPE SIZE	560	LF	4.00	2,240	3.10	1,736	3,976
1 1/2" PIPE SIZE	800	LF	2.30	1,840	1.80	1,440	3,280
1 1/4" PIPE SIZE	960	LF	2.30	2,208	1.80	1,728	3,936
1" PIPE SIZE	720	LF	2.30	1,656	1.80	1,296	2,952
3/4" PIPE SIZE	400	LF	2.15	860	1.65	660	1,520
1/2" PIPE SIZE	320	LF	2.15	688	1.65	528	1,216
Total:				30,868		23,984	54,852
GRAND TOTAL				**1,133,238**		**977,733**	**$ 2,114,984**

Energy Consumption for Conventional System

HOUR	January		Febuary		March		April	
	MBH	TONS	MBH	TONS	MBH	TONS	MBH	TONS
0.0	2036	170	1764	147	1334	111	619	52
1.0	2095	175	1820	152	1416	118	578	48
2.0	2162	180	1886	157	1479	123	548	46
3.0	2240	187	1951	163	1544	129	529	44
4.0	2327	194	2036	170	1613	134	514	43
5.0	2413	201	2112	176	1676	140	506	42
6.0	7435	620	6243	520	8190	682	14973	1248
7.0	9527	794	8015	668	10843	904	19949	1662
8.0	9809	817	8426	702	11561	963	20797	1733
9.0	10288	857	8970	747	12388	1032	22056	1838
10.0	10874	906	9568	797	13395	1116	23483	1957
11.0	11432	953	10229	852	14418	1202	24823	2069
12.0	11995	1000	10846	904	15252	1271	25899	2158
13.0	12507	1042	11241	937	15850	1321	27149	2262
14.0	12842	1070	11614	968	16246	1354	27770	2314
15.0	12853	1071	11702	975	16293	1358	27631	2303
16.0	12651	1054	11511	959	15748	1312	27297	2275
17.0	12417	1035	11138	928	14867	1239	26522	2210
18.0	1769	147	1427	119	897	75	838	70
19.0	1838	153	1476	123	970	81	829	69
20.0	1888	157	1518	127	1027	86	774	65
21.0	1914	159	1577	131	1093	91	735	61
22.0	1948	162	1620	135	1165	97	685	57
23.0	1987	166	1700	142	1238	103	660	55
	159246	13271	140391	11699	180502	15042	296163	24680

HOUR	May		June		July		August	
	MBH	TONS	MBH	TONS	MBH	TONS	MBH	TONS
0.0	929	77	1070.6	89	2118.6	177	2004.4	167
1.0	853	71	939.6	78	1929.3	161	1835.5	153
2.0	798	66	875	73	1727.6	144	1664.2	139
3.0	721	60	797.4	66	1519.7	127	1509.3	126
4.0	672	56	756.3	63	1329.2	111	1373.8	114
5.0	660	55	815.2	68	1416.5	118	1292.4	108
6.0	23607	1967	34631.2	2886	46056.8	3838	45959.3	3830
7.0	30303	2525	44042.7	3670	56899.9	4742	55929.8	4661
8.0	31176	2598	45632.5	3803	58215.7	4851	57238.4	4770
9.0	32075	2673	47699.5	3975	59584.2	4965	58408.7	4867
10.0	33216	2768	49783.9	4149	61015.9	5085	59614.1	4968
11.0	34437	2870	51050.9	4254	62266.9	5189	60964.7	5080
12.0	35555	2963	52162.3	4347	63518.8	5293	62459.4	5205
13.0	36786	3065	53902.5	4492	64589.3	5382	63748.4	5312
14.0	37252	3104	54738	4562	65221	5435	64022.4	5335
15.0	36854	3071	54193.6	4516	65407.5	5451	63382.8	5282
16.0	36219	3018	52790.7	4399	64905.1	5409	62019.6	5168
17.0	35114	2926	50930.1	4244	63473.4	5289	59823.5	4985
18.0	1413	118	2053.8	171	3130.1	261	3076.6	256
19.0	1345	112	1925.4	160	3027.3	252	3010.6	251
20.0	1256	105	1753.6	146	2856.9	238	2808.7	234
21.0	1174	98	1578.3	132	2678	223	2613.8	218
22.0	1082	90	1417.1	118	2500.4	208	2420.6	202
23.0	998	83	1291.3	108	2332	194	2251.4	188
	414495	34541	606831.5	50569	757720.1	63143	739432.4	61619

HOUR	September		October		November		December	
	MBH	TONS	MBH	TONS	MBH	TONS	MBH	TONS
0.0	1244.9	104	734	61	823.2	69	1367.6	114
1.0	1125	94	668	56	865	72	1445.1	120
2.0	1040.5	87	591	49	906.9	76	1491	124
3.0	974.2	81	566	47	934.3	78	1554.1	130
4.0	891.8	74	535	45	956.8	80	1645	137
5.0	800	67	513	43	990.8	83	1743.6	145
6.0	30234.8	2520	19978	1665	11180.6	932	7573.7	631
7.0	38337.5	3195	26715	2226	14244	1187	9815.7	818
8.0	39511.5	3293	28066	2339	14387.5	1199	10107.8	842
9.0	40658.8	3388	29763	2480	14794.8	1233	10696.8	891
10.0	42248.5	3521	31597	2633	15423.4	1285	11403.3	950
11.0	44214.1	3685	33099	2758	16135.4	1345	12083.9	1007
12.0	46200.2	3850	34606	2884	16835.3	1403	12655.3	1055
13.0	47613.3	3968	35987	2999	17503.4	1459	13237	1103
14.0	48675.7	4056	36722	3060	17747.7	1479	13724.5	1144
15.0	48775	4065	36842	3070	17472.5	1456	13785.5	1149
16.0	47515	3960	36175	3015	17269.3	1439	13639.3	1137
17.0	45907.8	3826	34656	2888	17050.1	1421	13420.3	1118
18.0	1632.1	136	1003	84	718.9	60	1105.6	92
19.0	1605.2	134	997	83	751.6	63	1135.2	95
20.0	1501.9	125	949	79	773.8	64	1158.1	97
21.0	1406	117	882	73	793.9	66	1191.4	99
22.0	1304.9	109	829	69	825.4	69	1217.5	101
23.0	1206.8	101	784	65	865.1	72	1240.1	103
	534625.5	44552	393257	32771	200249.7	16687	158437.4	13203

Energy Consumption for Ice Thermal Storage

HOUR	January		Febuary		March		April	
	MBH	TONS	MBH	TONS	MBH	TONS	MBH	TONS
0.0	1833	153	1587	132	1201	100	557	46
1.0	1886	157	1638	137	1274	106	520	43
2.0	1946	162	1697	141	1331	111	493	41
3.0	2016	168	1756	146	1390	116	476	40
4.0	2095	175	1833	153	1451	121	463	39
5.0	2172	181	1901	158	1508	126	456	38
6.0	6692	558	5619	468	7371	614	13476	1123
7.0	8574	714	7214	601	9759	813	17954	1496
8.0	8828	736	7583	632	10405	867	18717	1560
9.0	9260	772	8073	673	11149	929	19850	1654
10.0	9787	816	8611	718	12055	1005	21134	1761
11.0	10289	857	9206	767	12976	1081	22340	1862
12.0	10796	900	9761	813	13727	1144	23309	1942
13.0	11256	938	10117	843	14265	1189	24434	2036
14.0	11557	963	10452	871	14621	1218	24993	2083
15.0	11567	964	10532	878	14664	1222	24868	2072
16.0	11386	949	10360	863	14173	1181	24567	2047
17.0	11175	931	10024	835	13380	1115	23870	1989
18.0	1592	133	1285	107	807	67	754	63
19.0	1654	138	1328	111	873	73	746	62
20.0	1699	142	1367	114	924	77	697	58
21.0	1722	144	1420	118	984	82	662	55
22.0	1753	146	1458	121	1049	87	616	51
23.0	1788	149	1530	127	1114	93	594	50
	143321	11943	126352	10529	162452	13538	266547	22212

HOUR	May		June		July		August	
	MBH	TONS	MBH	TONS	MBH	TONS	MBH	TONS
0.0	836	70	963.54	80	1906.74	159	1803.96	150
1.0	767	64	845.64	70	1736.37	145	1651.95	138
2.0	718	60	787.5	66	1554.84	130	1497.78	125
3.0	649	54	717.66	60	1367.73	114	1358.37	113
4.0	605	50	680.67	57	1196.28	100	1236.42	103
5.0	594	49	733.68	61	1274.85	106	1163.16	97
6.0	21247	1771	31168.08	2597	41451.12	3454	41363.37	3447
7.0	27273	2273	39638.43	3303	51209.91	4267	50336.82	4195
8.0	28058	2338	41069.25	3422	52394.13	4366	51514.56	4293
9.0	28868	2406	42929.55	3577	53625.78	4469	52567.83	4381
10.0	29894	2491	44805.51	3734	54914.31	4576	53652.69	4471
11.0	30993	2583	45945.81	3829	56040.21	4670	54868.23	4572
12.0	32000	2667	46946.07	3912	57166.92	4764	56213.46	4684
13.0	33107	2759	48512.25	4043	58130.37	4844	57373.56	4781
14.0	33527	2794	49264.2	4105	58698.9	4892	57620.16	4802
15.0	33169	2764	48774.24	4065	58866.75	4906	57044.52	4754
16.0	32597	2716	47511.63	3959	58414.59	4868	55817.64	4651
17.0	31602	2634	45837.09	3820	57126.06	4761	53841.15	4487
18.0	1272	106	1848.42	154	2817.09	235	2768.94	231
19.0	1210	101	1732.86	144	2724.57	227	2709.54	226
20.0	1130	94	1578.24	132	2571.21	214	2527.83	211
21.0	1057	88	1420.47	118	2410.2	201	2352.42	196
22.0	974	81	1275.39	106	2250.36	188	2178.54	182
23.0	898	75	1162.17	97	2098.8	175	2026.26	169
	373045	31087	546148.4	45512	681948.1	56829	665489.2	55457

HOUR	September		October		November		December	
	MBH	TONS	MBH	TONS	MBH	TONS	MBH	TONS
0.0	1120.41	93	661	55	740.88	62	1230.84	103
1.0	1012.5	84	601	50	778.5	65	1300.59	108
2.0	936.45	78	532	44	816.21	68	1341.9	112
3.0	876.78	73	510	42	840.87	70	1398.69	117
4.0	802.62	67	482	40	861.12	72	1480.5	123
5.0	720	60	461	38	891.72	74	1569.24	131
6.0	27211.32	2268	17980	1498	10062.54	839	6816.33	568
7.0	34503.75	2875	24044	2004	12819.6	1068	8834.13	736
8.0	35560.35	2963	25260	2105	12948.75	1079	9097.02	758
9.0	36592.92	3049	26786	2232	13315.32	1110	9627.12	802
10.0	38023.65	3169	28437	2370	13881.06	1157	10262.97	855
11.0	39792.69	3316	29789	2482	14521.86	1210	10875.51	906
12.0	41580.18	3465	31145	2595	15151.77	1263	11389.77	949
13.0	42851.97	3571	32388	2699	15753.06	1313	11913.3	993
14.0	43808.13	3651	33050	2754	15972.93	1331	12352.05	1029
15.0	43897.5	3658	33158	2763	15725.25	1310	12406.95	1034
16.0	42763.5	3564	32558	2713	15542.37	1295	12275.37	1023
17.0	41317.02	3443	31191	2599	15345.09	1279	12078.27	1007
18.0	1468.89	122	902	75	647.01	54	995.04	83
19.0	1444.68	120	897	75	676.44	56	1021.68	85
20.0	1351.71	113	854	71	696.42	58	1042.29	87
21.0	1265.4	105	794	66	714.51	60	1072.26	89
22.0	1174.41	98	746	62	742.86	62	1095.75	91
23.0	1086.12	91	705	59	778.59	65	1116.09	93
	481163	40097	353931	29494	180224.7	15019	142593.7	11883

Detail Operating Cost

	Peak kW			Demand Cost (kW)		
	Conventional	Full	Partial	Conventional	Full	Partial
JAN	88.6	0	0	1077.78	0.00	0.00
FEB	107.8	0	0	1311.44	0.00	0.00
MAR	150.8	0	0	1835.24	0.00	0.00
APR	181.8	0	250	2212.02	0.00	3041.53
MAY	222.0	0	264	2701.74	0.00	3212.88
JUN	241.4	0	264	2938.32	0.00	3212.88
JUL	255.6	0	264	3110.65	0.00	3212.88
AUG	254.0	0	264	3091.18	0.00	3212.88
SEP	231.9	0	264	2822.47	0.00	3212.88
OCT	196.2	0	264	2388.24	0.00	3212.88
NOV	152.1	0	0	1850.81	0.00	0.00
DEC	105.7	0	0	1286.13	0.00	0.00
Total	2188	0	1833.92	26626.01	0.00	22318.81

	Operating Cost (kWh)			Total Operating Cost		
	Conventional	Full	Partial	Conventional	Full	Partial
JAN	1701.84	2294.94	1999.94	2779.62	2294.94	1999.94
FEB	1504.67	1902.79	1602.79	2816.11	1902.79	1602.79
MAR	1965.35	2060.73	2060.73	3800.59	2060.73	2060.73
APR	3264.50	3781.20	2709.54	5476.52	3781.20	5751.07
MAY	4551.58	4951.58	3413.69	7253.32	4951.58	6626.57
JUN	6670.54	7227.99	4802.79	9608.86	7227.99	8015.67
JUL	8294.05	8850.64	6884.06	11404.70	8850.64	10096.94
AUG	8089.98	8741.85	5662.99	11181.16	8741.85	8875.87
SEP	5161.97	6803.64	3768.24	7984.44	6803.64	6981.12
OCT	4337.61	4489.68	3079.70	6725.85	4489.68	6292.58
NOV	1882.83	2886.18	2286.18	3733.64	2886.18	2286.18
DEC	1715.29	1808.83	1808.83	3001.42	1808.83	1808.83
Total	49140.21	55800.05	40079.48	75766.22	55800.05	62398.29

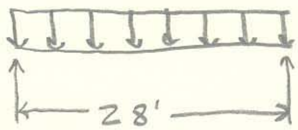
Life Cycle Cost

Date	Electricity Escalation 4% Inflation	Conventional	Partial Storage	Full Storage
2003	0.95	71977.91	59278.37	53010.05
2004	0.95	71977.91	59278.37	53010.05
2005	0.95	71977.91	59278.37	53010.05
2006	0.95	71977.91	59278.37	53010.05
2007	0.95	71977.91	59278.37	53010.05
2008	0.92	69704.92	57406.42	51336.05
2009	0.92	69704.92	57406.42	51336.05
2010	0.92	69704.92	57406.42	51336.05
2011	0.93	70462.59	58030.41	51894.05
2012	0.96	72735.57	59902.35	53568.05
2013	1.02	77281.55	63646.25	56916.05
2014	1.06	80312.20	66142.18	59148.05
2015	1.09	82585.18	68014.13	60822.05
2016	1.14	86373.49	71134.05	63612.06
2017	1.2	90919.47	74877.94	66960.06
2018	1.26	95465.44	78621.84	70308.06
2019	1.33	100769.08	82989.72	74214.07
2020	1.37	103799.73	85485.65	76446.07
2021	1.44	109103.36	89853.53	80352.07
2022	1.51	114407.00	94221.41	84258.08
2023	1.58	119710.63	98589.29	88164.08
2024	1.65	125014.27	102957.17	92070.08
2025	1.73	131075.57	107949.04	96534.09
2026	1.81	137136.86	112940.90	100998.09
2027	1.89	143198.16	117932.76	105462.09
2028	1.96	148501.80	122300.64	109368.10
		2533622.49	2086598.70	1865953.67

APPENDIX C

Structural Calculations:

STRUCTURAL CALCULATIONS: ADDING COOLING TOWER



$M = \frac{wl^2}{8}$

BEAM

DEAD LOAD:

40 PSF [FROM UNITED STEEL DECK

LIVE LOAD:

20 PSF [ASCE 705]

$w = 1.2 \times (40) + 1.6(20)$

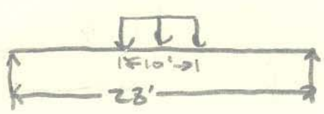
$= 80\ PSF\ (10.22)$

$= 818\ PLF$

$M = \frac{818(28)^2}{8}$

$M_U = 80.14^{ft \cdot K}$

NEW COOLING TOWER



$M = R_1\left(a + \frac{R_1}{2w}\right)$

$= 3.648\left(10' + \frac{3.648}{2(924)}\right)$

$M_U = 36.15$

DEAD

$12160/2 = 6080/7.896'$

$= 770\ PLF$

$W_U = 1.2(770)$

$= 924\ PLF$

$R_1 = \frac{924(7.896)}{2}$

$R_1 = 3648\ P$

BEAM + COOLING TOWER

$M_{U\,TOTAL} = 80.14 + 36.5 = \underline{116.63^{ft \cdot K}}$

CHECK HSS $10 \times 6 \times 3/8$

$\lambda = b/t = 14.2$

$\lambda = h/t = 25.7$

SECTION 16.2-4

$\lambda_p = 3.76 \sqrt{E/F_y} \sim \frac{29000 \text{ KSI}}{46 \text{ KSI}} = 94.4$

$\lambda_r = 5.7 \sqrt{E/F_y} = 5.7 \times 25.1 = 143.07$

CABON A500 GR. B, $F_y = 46$ $F_u = 58$

FOLLOWING EQN FROM LRFD PG 16.2-7

DESIGN SPEC FOR STEEL HOLLOW STRUCTURE

$M = F_y Z = 48 \times 33.8 \text{ in}^3 = 1622.4 \text{ K·IN} = 135.2 \text{ K·FT}$

$135.2 \text{ K·FT} > 116.63 \text{ K·FT}$

SO BEAM OK FOR NEW COOLING TOWERS

APPENDIX D

Electrical MCC Resizing:

MOTOR CONTROL CENTER SCHEDULE																							
					PROTECTIVE DEVICE				FEEDER					DEVICES IN COVER						LOAD			
DESIGNATION MAIN BUS CAPACITY VOLTAGE ARRANGEMENT	CIRCUIT NUMBER	SERVICE	HORSE POWER (HP)	STARTER SIZE (NEMA)	TYPE	SWITCH RATING (AMP)	POLES	FUSE SIZE (AMP)	FEEDER DESIGNATION	POWER	GROUND	CONTROL	CONDUIT SIZE	S/P P.B. W/ PILOT LT.	HOA SEL SW. W/ PILOT LT.	RESET P.B.		INTERLOCK WITH UNIT	ELEMENTARY DIAGRAM	CONNECTED LOAD (A)	CONNECTED LOAD (KVA)	DEMAND FACTOR	DEMAND CONNECTED LOAD (KVA)
MCC-	1	Ahu-4	5		FU/SW	50	3	15	F1	12	12									7.60	6.31104	80%	5.0488
100 A BUS	2	Ahu-5	15		FU/SW	60	3	45	F2	6	10									9.50	7.8888	80%	6.311
60 A MSW	3	Ahu-6	5		FU/SW	50	3	15	F3	12	12									7.60	6.31104	80%	5.0488
60 A FUSE	4	Ahu-7	7.5		FU/SW	50	3	15	F4	12	12									7.80	6.47712	80%	5.1817
480/277 V	5	Ahu-8	7.5		FU/SW	50	3	15	F5	12	12									7.80	6.47712	80%	5.1817
3 PHASE, 4W	6	Ahu- 9	10		FU/SW	50	3	15	F6	12	12									7.60	6.31104	80%	5.0488
W/GROUND BUS	7	Ahu-10	7.5		FU/SW	50	3	6	F7	12	12									4.00	3.3216	80%	2.6573
12 POLE	8	RF-4	1.5		FU/SW	50	3	6	F8	12	12									3.00	2.4912	80%	1.993
	9	RF-5	5		FU/SW	50	3	15	F9	12	12									7.60	6.31104	80%	5.0488
	10	RF-8	1.5		FU/SW	50	3	6	F10	12	12									3.00	2.4912	80%	1.993
FLOOR MOUNTED	11	RF-9	3		FU/SW	50	3	10	F11	12	12									4.80	3.98592	80%	3.1887
	12	RF-10	1.5		FU/SW	50	3	6	F12	12	12									3.00	2.4912	80%	1.993

FEEDER SIZE: 3#4+1#8GND-1-1/4"C

TOTAL CONNECTED LOAD:		48.69 **KVA**
COINCIDENTAL DEMAND:	0.8	
DEMAND LOAD:		38.96 **KVA**
SPARE CAPACITY AT	1.25	48.69 **KVA**
POWER FACTOR:	0.8	38.96 **KW**
TOTAL CONNECTED AMPERAGE AT	480 **V**	34.66 **A**
WITH STARTING AMPERAGE OF LARGER MOTOR		39.66 **A**