Andrew Rhodes

The Pennsylvania State University
Architectural Engineering – Mechanical

The Hilton Baltimore Convention Center Hotel

Depth: Chiller Plant Optimization Study
Breadths: Electrical, Construction Management

Faculty Advisor: Dr. William Bahnfleth
Spring 2007

The Hilton Baltimore Convention Center Hotel

Baltimore, MD



Project Overview
- Size: 850,000 square feet
- Cost: $250 million, $16 million mechanical
- Construction Dates: February 2006-August 2008
- Delivery Method: Design-Build
- Building Use: 750 hotel guest rooms, conference/ meeting rooms, restaurant, grand and junior ballrooms, swimming pool, and parking garage

Project Team

Owner: Baltimore Hotel Corp.

GC: Hensel Phelps

Architect: RTKL

Mechanical: Southland Industries

Structural: RTKL; Hope Furrer

Electrical: MC Dean

Civil: Whitney, Balley, Cox, and Magnani

Mechanical
- Comfort Link district chilled water with two 1,000 ton heat exchangers
- Trigen district steam at 150 psig
- 8 AHUs (274,000 cfm) serving VAV systems in public spaces and lower levels
- 4 MAUs (86,000 cfm) supply conditioned outdoor air to guest room towers
- 750 Guest rooms conditioned by 2-pipe vertical FCU's with electric resistance heat

Architecture
- Three story East Podium and 21 story West Podium with guest towers are connected by a walking bridge over Eutaw St.
- Lower levels are brick and glazed aluminum curtain wall, while guest room towers are silver metal wall panels with fixed aluminum windows
- Both podiums utilize a green roof system, and guest room towers have a traditional PVC membrane roof

Structural
- Steel encased concrete columns
- Two way flat concrete slab floor construction
- Exterior walls are non-load bearing
- Columns bear on drilled caissons or caisson cap
- Spread footings bear on reinforced soil
- Connecting bridges supported by steel beams

Electrical
- BGE service enters West Podium and splits three ways. 2000A 480/277 serves East Podium while two 4000A 480/277 serve West Podium
- 1100KW Emergency Generator
- Public spaces lit by recessed and surface mounted compact fluorescent lamps

Andrew Rhodes

Mechanical Option

http://www.arche.psu.edu/thesis/eportfolio/2007/portfolios/ARR171/

Acknowledgements

Thesis Building Sponsor

Southland Industries
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Dulles, VA 20166
www.southlandind.com

Special Thanks:

Scott Winkler, PE
Mike McLaughlin, PE
Andrew Tech, EIT

Pennsylvania State University Architectural Engineering Faculty

M. Kevin Parfitt – Faculty Director
Robert J. Holland – Faculty Director
Dr. William P. Bahnfleth – Thesis Advisor
Dr. James D. Freihaut – Mechanical Faculty

Special Thanks

To my family and friends…
Thanks for five years of unconditional love and support. You've been there through the ups and downs, and you mean more to me than you'll ever know.

To my fellow classmates…
It's been an amazing five years, and your help and understanding has allowed me to get to where I am today. I couldn't have done it without you.

Po and Shearer – It's incredible what a little teamwork and a few long nights can accomplish in five years… you deserve to have your names on my diploma, too.

Table of Contents

Andrew Rhodes

The Pennsylvania State University
Architectural Engineering – Mechanical

The Hilton Baltimore Convention Center Hotel

1.0 Executive Summary

The Hilton Baltimore Convention Center Hotel (HBCCH) is a multi-purpose hotel located in the heart of downtown Baltimore. The purpose of this report is creating a chiller plant optimization study on the plant used by the HBCCH. As originally designed, the HBCCH utilizes a district chilled water system and a district steam system. This report compares those original systems to four design alternatives: district chilled water with a backpressure steam turbine, on site centrifugal cooling, on site absorption cooling, and on site absorption cooling with a backpressure steam turbine. Both eQuest 3-6 and Microsoft Excel are used to model the energy usage of the HBCCH. The system comparison, based on an overall system life-cycle cost analysis which considers both first and yearly operating costs, shows that on site centrifugal cooling is the best design alternative. With a life-cycle cost of $13,291,220, this design alternative is $721,161 less expensive than the next best option.

Once the chiller plant optimization is completed, the electrical system of the HBCCH is upgraded. The equipment required for the best design alternative, two chillers, two primary pumps, two condenser water pumps, and a cooling tower with two cells, is powered and wires, conduits, and breakers are sized. A new panelboard is created and the original main distribution panel, Switchgear F, is resized.

The construction management breadth of this report involves the creation of a Short Interval Production Schedule (SIPS). SIPS are well-suited for construction projects which utilize repetitive tasks. The guest room towers of the HBCCH are perfectly suited for a SIPS since floors 4-19 have repetitive floor plans. Overall, the SIPS reduced the construction time of the guest room towers by four weeks.

Andrew Rhodes

The Pennsylvania State University
Architectural Engineering – Mechanical

The Hilton Baltimore Convention Center Hotel

2.0 What is Thesis?

The information in this section of the report was taken from The Pennsylvania State University Senior Thesis eStudio website.

> The course sequence of AE 481W and AE 482 comprise what is more commonly known as AE Senior Thesis. This year long capstone design project is one of the major highlights of the five year professional degree BAE program. It is required of all undergraduate students in the Department of Architectural Engineering at Penn State.
>
> Senior Thesis consists of obtaining an outside sponsor who provides the student with an actual building that will be used as the model for a variety of technical and management tasks throughout the year. Based on the building or project model, students will investigate the project, perform technical analysis, develop project criteria and eventually prepare a written proposal for more advanced design work. This is followed up by a semester of intense effort to complete the goals of the proposal. A formal written final report is required as is a verbal presentation to a faculty jury.
>
> A number of students, selected by the AE faculty from the first presentations, will represent their class and compete for numerous awards by presenting a second time. This second presentation will be to an invited jury of about 50 visiting practitioners from all over the country.
>
> It is important to note that students are required to include work in their primary discipline area of AE as well as to demonstrate breath capabilities in several other architectural engineering areas.

Andrew Rhodes

The Pennsylvania State University
Architectural Engineering – Mechanical

The Hilton Baltimore Convention Center Hotel

3.0 Building Overview

Project Information

The HBCCH is a full-service hotel located in the heart of downtown Baltimore. Immediately adjacent to both Oriole Park at Camden Yards and the Baltimore Convention Center, guests at the HBCCH will range from businessmen attending conferences to tourists looking to visit Inner Harbor and catch a Baltimore Orioles' game. The HBCCH is comprised of two separate buildings (East and West) connected by a two-story walking bridge that spans over Eutaw St.

Figure-1: Site Location

The East Building is a three story structure which houses a restaurant, Starbucks, junior ballroom, and numerous meeting/conference rooms. The second floor of the East Building also has a second walking bridge that spans Howard St. to allow patrons to access the Baltimore Convention Center.

The first three levels of the West Building hold the hotel lobby and lounge, large pre-function areas, grand ballroom, swimming pool and workout areas, and more meeting/conference rooms. The western side of these floors and also the two below-grade levels underneath house the 250,000 sq. ft. parking garage. The West Building also has two towers that rise up on its northern and eastern sides. The 758 hotel guest rooms are located on floors 4-19 of these towers. Floors 20 and 21 are for service use only.

Construction on the HBCCH began in February of 2006 and is set to be completed at the beginning of August 2008. At a cost of over $250 million, Hilton Hotels wants the HBCCH to be the centerpiece of Baltimore's downtown attractions.

Primary Project Team

Table-1: Project Team

Role	Company
Building Owner	Baltimore Hotel Corporation
General Contractor	Hensel Phelps
Architect	RTKL
Civil Engineer	Whitney, Bailey, Cox, and Magnani
Landscape Architect	Mahan Rykiel Associates
Structural Engineer	RTKL; Hope Furrer Associates
Electrical Engineer	M.C. Dean
Mechanical Engineer	Southland Industries
Fire Protection Engineer	National Fire Protection
Lighting Designer	Brandston Partnership
Food Service Designer	Clevenger Frable LaVallee
Restaurant Designer	Arnold Syrop Associates
Interior Designer	Daroff Design

Andrew Rhodes

The Pennsylvania State University
Architectural Engineering – Mechanical

The Hilton Baltimore Convention Center Hotel

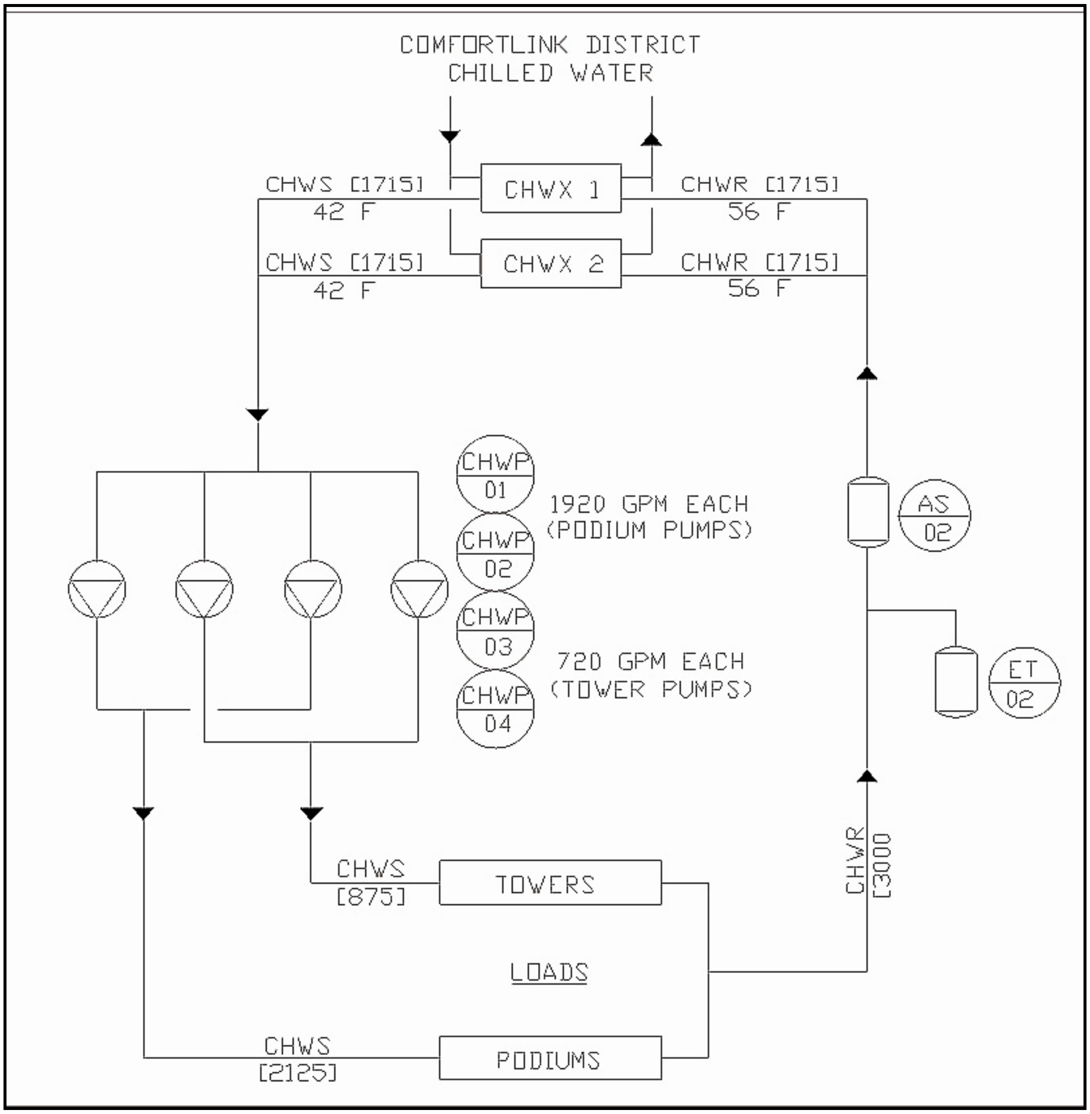
4.0 Existing Mechanical Conditions

Cooling

The HBCCH receives chilled water from the ComfortLink district chilled water system. Chilled water is supplied by two ComfortLink-owned plate and frame heat exchangers designated CHWX 1 and CHWX 2, seen in Figure-2 of this report. These heat exchangers are located in the mechanical room on the east podium mezzanine level. The capacity of each heat exchanger is roughly 1,000 tons. The district or primary side of both heat exchangers receive district chilled water from ComfortLink chilled water piping originating in the Baltimore Convention Center and running across the bridge spanning Howard Street to the mezzanine mechanical room in the east podium. This water is designed to have a seventeen degree change in temperature (37 F to 54 F).

Chilled water piping for the building systems of the HBCCH originates on the secondary or warm side of ComfortLink's heat exchangers. Chilled water is distributed in two main pumping zones; one zone is the guest room towers, and the second zone is for the east and west podium public areas. Two variable speed pumps are provided for each zone, each sized for 60% of the design flow rate. These pumps are designated CHWP 1, CHWP 2, CHWP 3, and CHWP 4 in Figure-2 of this report. CHWP 1 and CHWP 2 serve the podium zone while CHWP 3 and CHWP 4 serve the guest room towers. It's important to note that the pumps were selected such that should one pump fail, the other will be able to provide 100% of the total flow for the zone. Differential pressure sensors in the systems control the variable speed drives of the pumps to maintain the required flow and pressure. The chilled water system is designed for a fourteen degree temperature difference between the supply and return (42 F to 56 F).

Figure-2: Existing Chilled Water Schematic

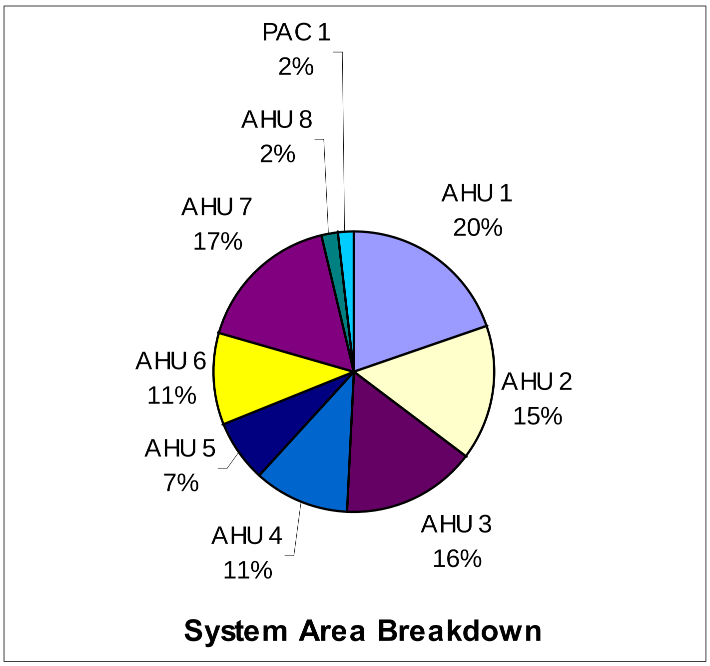


Air Handling

AHU 1: Located in the West Podium mezzanine level mechanical room, this AHU serves the ground and mezzanine levels of the West Podium. The unit is balanced to supply 31,000 cfm of air, with a minimum of 14,000 cfm of outdoor air. AHU 1 will be an indoor built-up variable volume unit with; an economizer section, filters, HW preheat coil, chilled water cooling coil, dual plenum supply fans, discharge plenum, and sound attenuators. Supply and relief fans will have variable frequency drives.

AHU 2: Located in the East Podium mezzanine level mechanical room, this AHU serves the ground level of the East Podium. The unit is balanced to supply 31,000 cfm of air, with a minimum of 24,000 cfm of outdoor air. AHU 2 will be an indoor variable volume unit with an economizer section, filters, HW preheat coil, chilled water cooling coil, plenum supply fan, discharge plenum, and sound attenuators. Supply and relief fans will have variable frequency drives.

Figure-3: System Area Breakdown



AHU 3: Located in the West Podium third level mechanical room, this AHU serves the second level of the West Podium. The unit is balanced to supply 38,000 cfm of air, with a minimum of 16,000 cfm of outdoor air. AHU 3 will be an indoor variable volume unit, with an economizer section, filters, HW preheat coil, chilled water cooling coil, plenum supply fan, discharge plenum, and sound attenuators. Supply and relief fans will have variable frequency drives.

AHU 4: Located on the roof of the East Podium second level, this AHU serves the second and third levels of the East Podium. The unit is balanced to supply 26,000 cfm of air, with a minimum of 11,000 cfm of outdoor air. AHU 4 will be an outdoor variable volume unit with; intake and relief louvers, economizer section with relief fan, filters, HW preheat coil, chilled water cooling coil, plenum supply fan, and discharge and return plenums. Supply and relief fans will have variable frequency drives.

AHU 5: Located on the roof of the East Podium second level, this AHU serves the second level and junior ballroom areas of the East Podium. The unit is balanced to supply 47,000 cfm of air, with a minimum of 25,000 cfm of outdoor air. AHU 5 will be an outdoor variable volume unit with; intake and relief louvers, economizer section with relief fan, filters, HW preheat coil, chilled water cooling coil, plenum supply fan, and discharge and return plenums. Supply and relief fans will have variable frequency drives.

AHU 6 and AHU 7: Located in the West Podium third level mechanical room, these units serve the grand ballroom and third level prefunction areas of the West Podium. The units are both balanced to supply 48,500 cfm of air, with a minimum of 28,000 cfm of outdoor air each. AHU 6 and 7 will be outdoor variable volume units with; intake and relief louvers, economizer section with relief fan, filters, HW preheat coil, chilled water cooling coil, plenum supply fan, and discharge and return plenums. Supply and relief fans will have variable frequency drives.

AHU 8: Located on the roof of the West Podium fourth level, this AHU serves the exercise areas on the fourth level of the West Podium. The unit is balanced to supply 4,000 cfm of air, with a minimum of 3,000 cfm of outdoor air. AHU 8 will be a constant volume unit, with an economizer section, filters, HW preheat coil, run-around hot water reheat coil, chilled water cooling coil, plenum supply fan, and discharge and return plenums.

PAC 1: Located in the pool equipment room on the fourth level of the West Podium, this unit serves the swimming pool and pool equipment room. The unit is balanced to supply 5,300 cfm of air, with a minimum of 4,300 cfm of outdoor air. PAC 1 will be an indoor packaged unit with ducted outdoor air, filter, refrigerant DX cooling coil, hot gas reheat coil, auxiliary heating coil and DX hot gas pool heater for heat reclaim.

The remainder of the spaces in the HBCCH receive outdoor air from four makeup air units.

MAU 1 and MAU 2: These units, located on the roof of the guest towers, provide conditioned outdoor air to the guest room bathrooms, corridors and elevator lobbies in the guest room towers. These units are 100% outdoor air units which keep the guest rooms properly ventilated. The remainder of the space load in the guest rooms is treated by fan coil units located in each room.

*MAU 3 and MAU 4***:** These units serve the large kitchen areas in the podiums. MAU 3 is located in the East Podium, and it serves the Multi-Purpose Restaurant Kitchen. MAU 4, located in the West Podium, serves the main kitchen area serving the grand ballroom. These units are 100% outdoor air units.

Guest Room FCUs: The fan coil units in the guest rooms are 2-pipe vertical stacked, (high-rise) fan coil units. Chilled water will be distributed using vertical risers located in chases. The units will be equipped with electric resistance heat. The FCUs will be non-ducted concealed type to be located in drywall enclosures at the outside walls of the guest rooms. Return air will be through a louvered access door on the fan coil unit enclosure.

Heating

Steam from the Trigen district steam system enters the HBCCH in the mechanical room located in the southeast corner of the west podium. This steam, initially at 150 psi, passes through a Trigen owned metering station before entering Pressure Reducing Station 1 (Figure-4). The steam, now at 50 psi, splits in order to serve two separate purposes. 2,250 lbs/hr of steam serve the kettles and dishwashers located in the east and west podium kitchens. The remainder of the steam is used in order to create heating hot water for the building systems located throughout the HBCCH.

Two shell and tube heat exchangers, HHWX 1 and HHWX 2 in Figure-4 and Figure-5 of this report, are used to convert the steam into heating hot water. These heat exchangers, designed for an inlet temperate of 140 F and outlet temperature of 180 F, are each sized for 810 gpm and 6,500 MBH.

Heating hot water is distributed throughout the HBCCH using three dedicated variable speed pumps. Each pump is designed for 50% of the total design flow. These pumps, designated HHWP 1, HHWP 2, and HHWP 3 in Figure-4 of this report, can each handle 750 gpm of flow. A differential pressure sensor in the system controls the variable speed drives of the pumps in order to maintain the required flow and pressure. Heating hot water serves preheat and reheat coils in AHU's and MAU's, VAV reheat coils, and domestic hot water generation.

Figure-4: Existing Steam Schematic

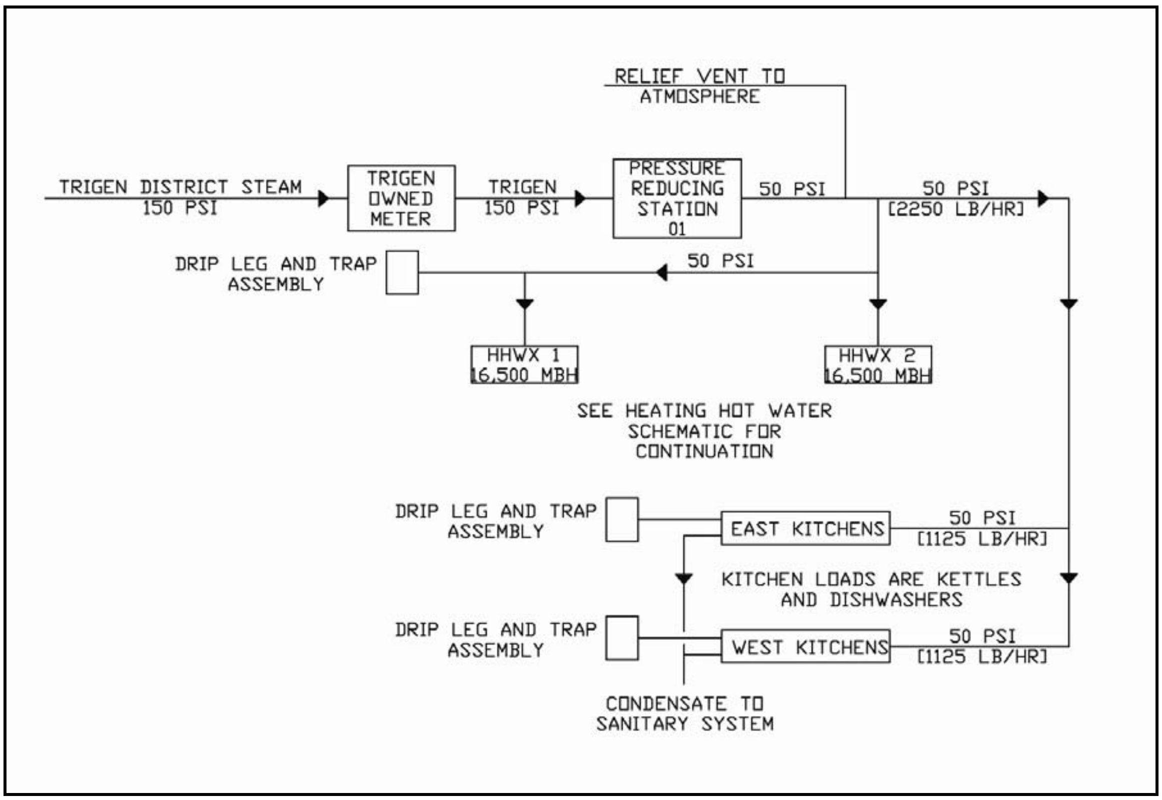
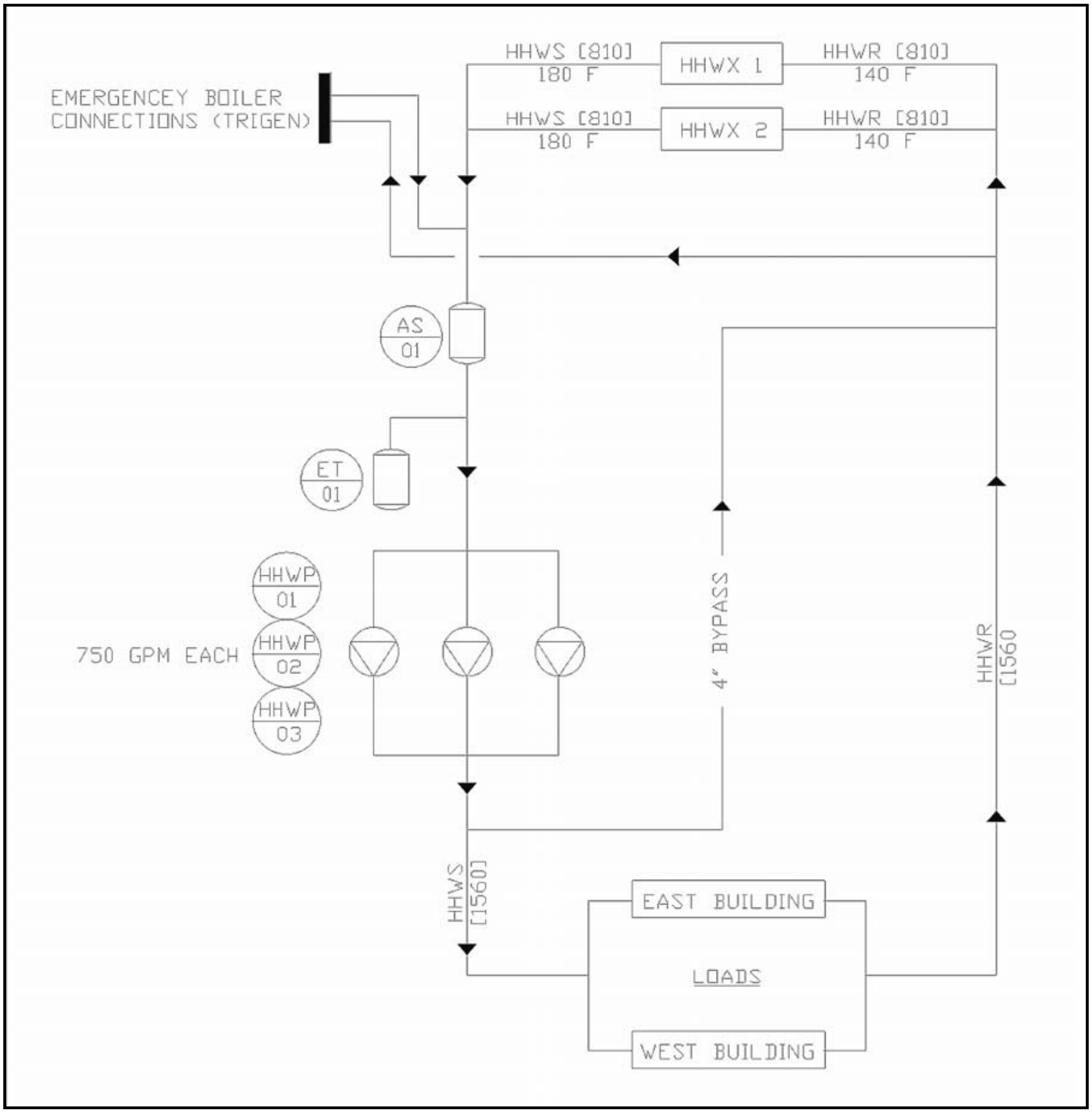


Figure-5: Existing Heating Hot Water Schematic



Andrew Rhodes

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The Hilton Baltimore Convention Center Hotel

5.0 Mechanical Depth

Purpose

The purpose of the Mechanical Depth is to perform a chiller plant optimization study. As described in Section 4.0 of this report, the HBCCH is currently designed to utilize both district chilled water and district steam. While studying these systems during the fall semester in order to complete Technical Reports 1, 2, and 3, numerous questions arose. Was the district approach really the most cost-effective? Would on site chilling (either electric or absorption) be a better design alternative? What about absorption cooling with combined heat and power? These questions brought to light the value of creating an in-depth chiller plant optimization study.

The primary goal of this study is to evaluate numerous design alternatives for the HBCCH in order to quantitatively prove which alternative is the most cost-effective. First and operating costs for each system will be calculated so that they may be used in the final life-cycle cost analysis. The most cost-effective system will be the design alternative with the lowest life-cycle cost. The original district system serves as the base case scenario.

Justification

Improved economics and helping the environment by using less energy are the primary areas of justification for the chiller plant optimization study. By optimizing the chiller plant, the owner of the HBCCH will pay less while still receiving quality results. Money will be saved by designing a chiller plant which uses less energy, which in turn also helps the environment. An emissions study is not in the scope of this report. In order to accurately justify lowering emissions, data from ComfortLink and Trigen would be needed. Neither of these district system providers was willing to share any emissions data.

Design Alternatives Considered

Option 1: District System with Backpressure Steam Turbine

Steam enters the HBCCH at a pressure of 150 psi, but steam at that pressure is not utilized throughout the building. Its pressure must first be reduced. The base case scenario design uses a pressure reducing valve (PRV) to lower the pressure of the steam. During this process, energy from the steam is lost which could be utilized in other processes.

A backpressure steam turbine can reduce the pressure of the steam while converting the steam energy that would be wasted into electrical energy. In a backpressure steam turbine, shaft power is produced when high-pressure steam is directed against the blades of the turbine's rotor. The rotor is attached to a shaft that is then coupled to an electrical generator. The electricity created in the generator can then be used to offset some of the yearly electric utility cost.

A diagram of a typical backpressure steam turbine can be seen in Figure-6 below, and an overall schematic of this design alternative can be seen in Figure-7 below. The base case scenario district chilled water system is not altered in this design alternative and is identical to the system shown in Figure-2 of Section 4.0 of this report.

Figure-6: Typical Backpressure Steam Turbine Diagram

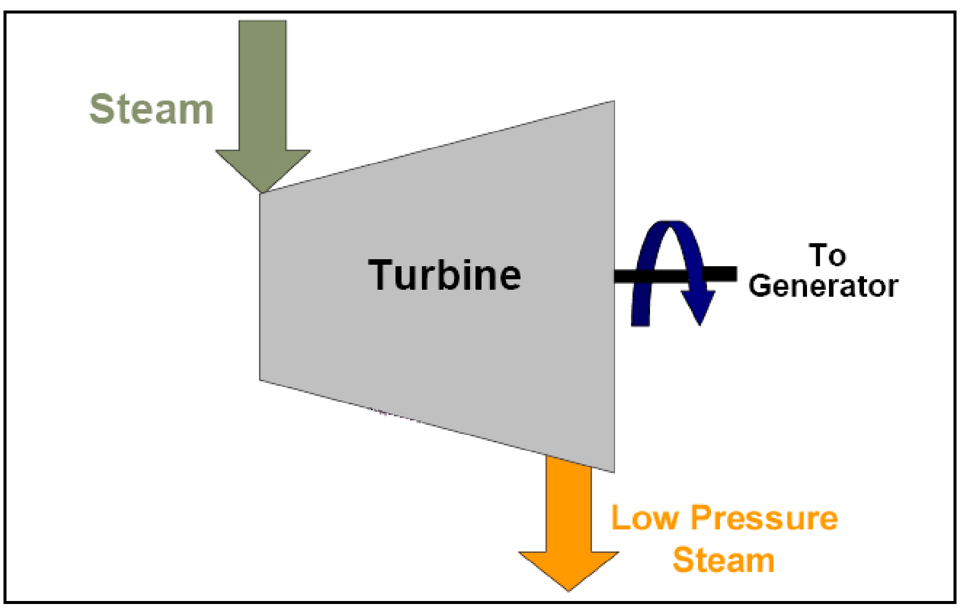
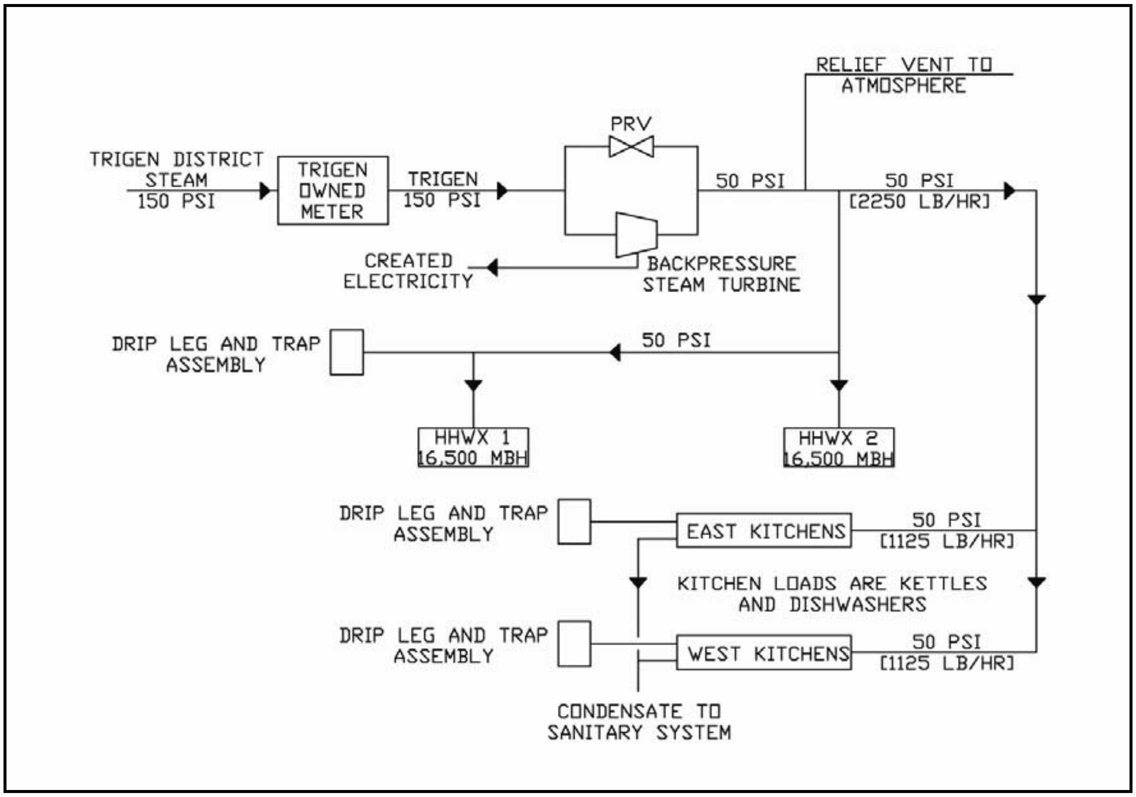


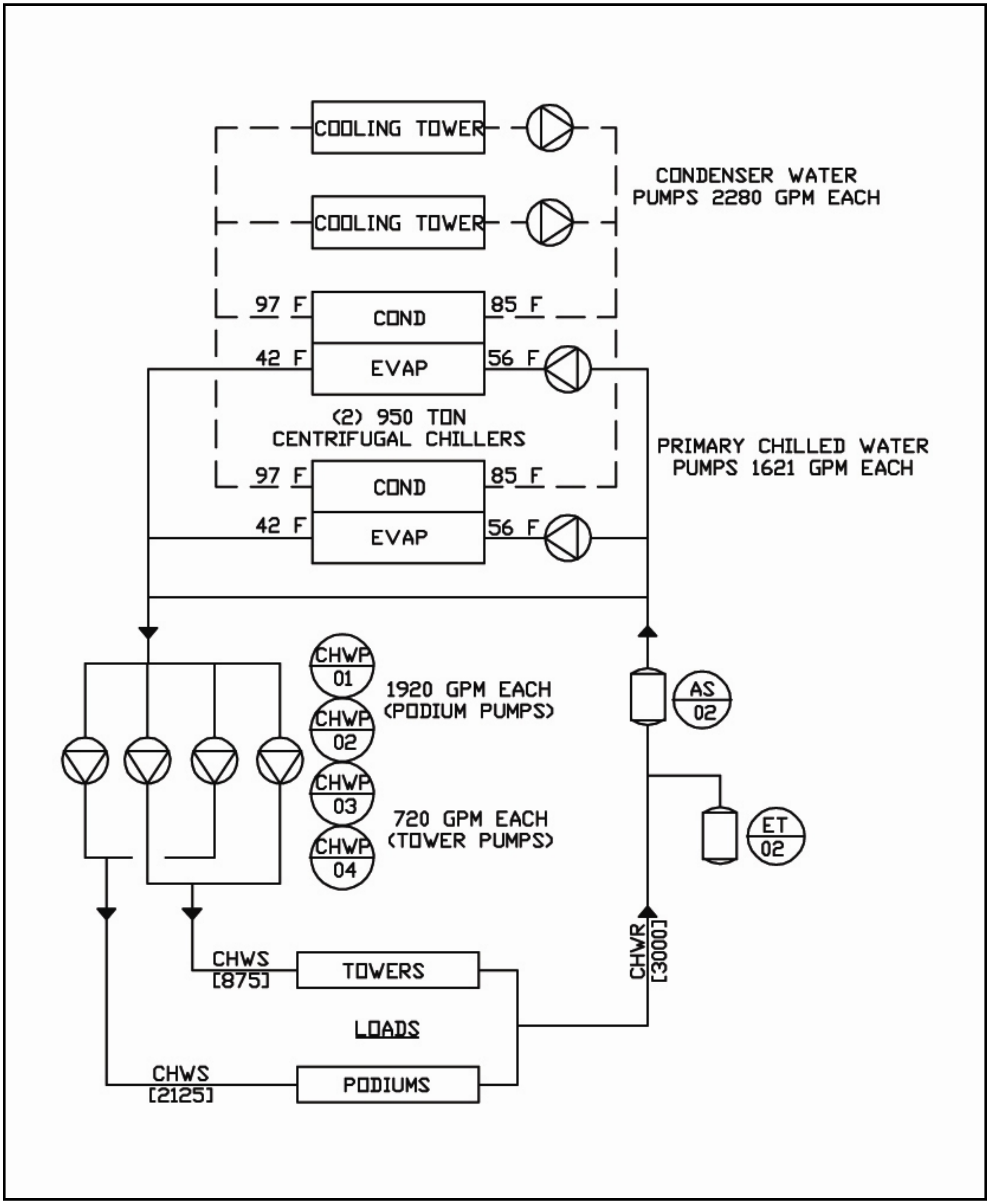
Figure-7: District System with BST Schematic



Option 2: On Site Centrifugal Chilling

For this design alternative, the district chilled water system is completely replaced with on site electric chilling. The building's cooling load is now handled by two 950 ton centrifugal chillers. Due to the fact that none previously existed with the district chilled water system, primary water pumps are also included in this alternative. Two pumps were selected, each of which can handle the full capacity of one of the chillers. No secondary pumps are needed since they are already included in the base case design. A two-celled cooling tower along with two condenser water pumps is also a necessity. Cut sheets of these equipment selections can be seen in Appendix-A of this report. A schematic of this design alternative can be seen in Figure-8 below. The base case scenario district steam system is not altered in this design alternative and is identical to the system shown in Figure-4 of Section 4.0 of this report.

Figure-8: On Site Centrifugal Chillers Schematic



Option 3: On Site Absorption Chilling

For this design alternative, the district chilled water system is completely replaced with on site absorption chilling. The building's cooling load is now handled by two 950 ton double-effect absorption chillers. These chillers use steam at 100 psi from the district steam system to power the generator in their "thermal compressors." Due to the fact that none previously existed with the district chilled water system, primary water pumps are also included in this alternative. Two pumps were selected, each of which can handle the full capacity of one of the chillers. No secondary pumps are needed since they are already included in the base case design. A two-celled cooling tower along with two condenser water pumps is also a necessity. A different cooling tower than the one used in Option 2 is required since the condenser water flow rates are not the same. Cut sheets of these equipment selections can be seen in Appendix-A of this report. Schematics of this design alternative can be seen in Figure-9 and Figure-10 below.

Figure-9: On Site Absorption Chillers Schematic

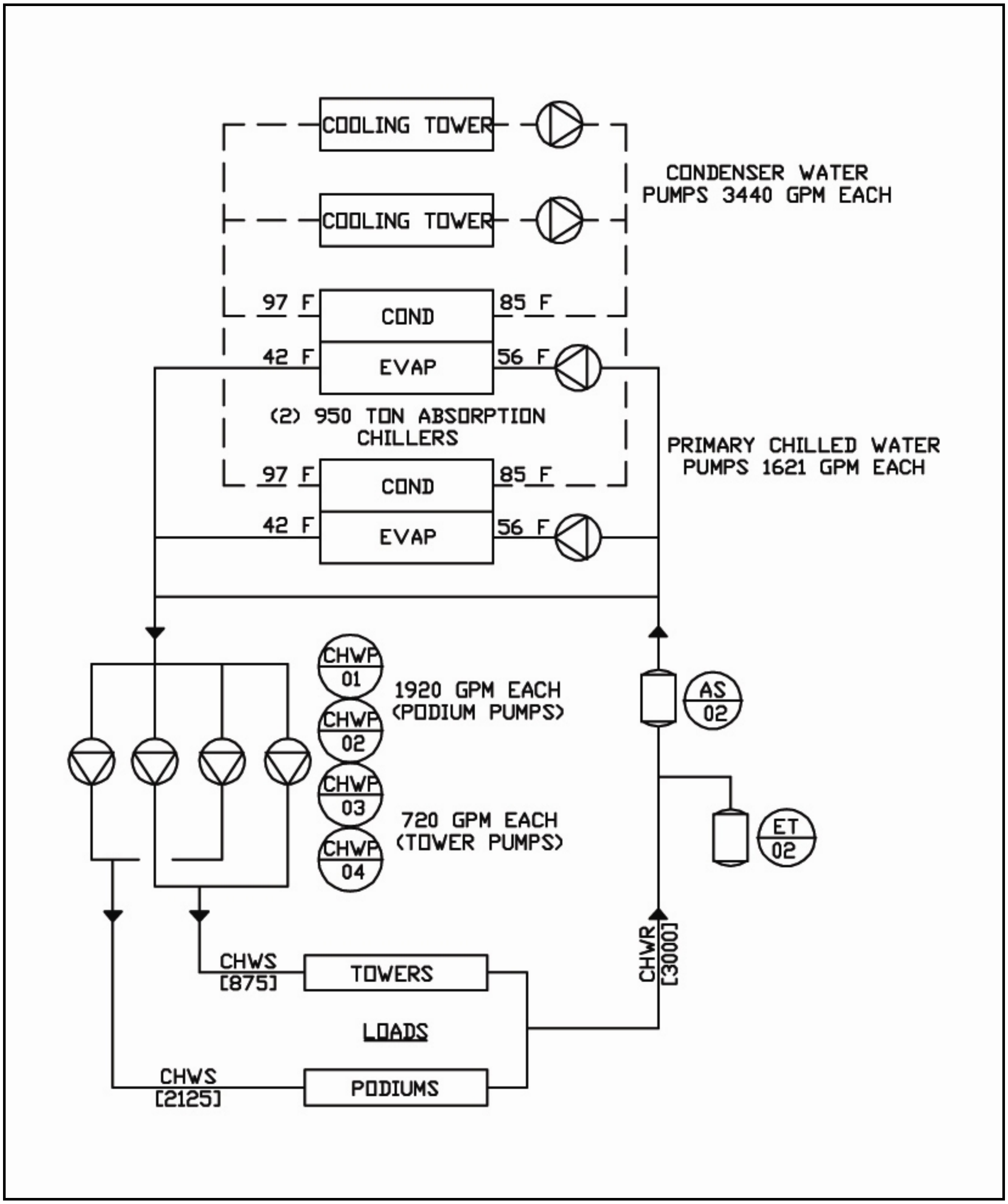
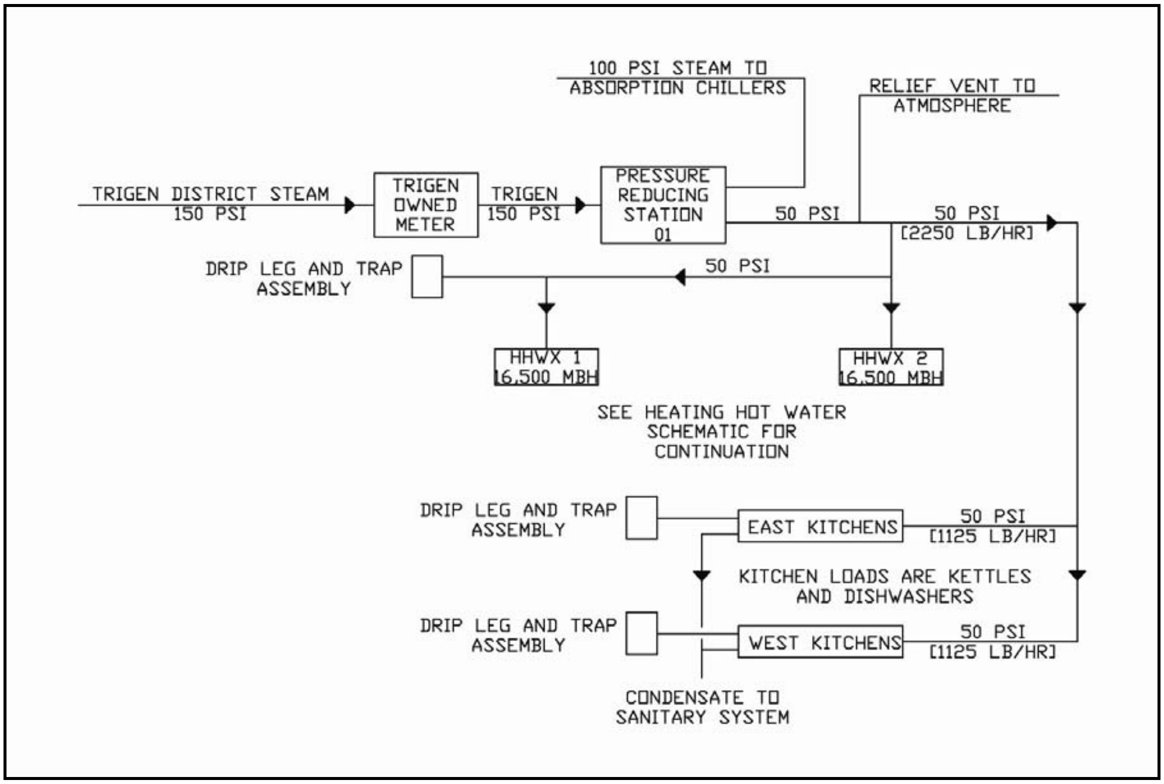


Figure-10: Absorption Chilling Steam Schematic



Option 4: On Site Absorption Chilling with Backpressure Steam Turbine

Once again, the district chilled water system is completely replaced with on site absorption chilling. The same chillers, cooling towers, and pumps are used as in Option 3. The only difference is that now a backpressure steam turbine (similar to the one added in Option 1) is added to the district steam system. Due to the fact that the absorption chillers require 100 psi steam while the rest of the HBCCH requires 50 psi steam, a slightly different type of backpressure steam turbine is needed. Called an extraction backpressure steam turbine, the turbine utilized in this design alternative can produce two different outlet steam pressures. The extraction turbine will lower the pressure of the district steam to 100 psi for the absorption chillers and to 50 psi for the remainder of the HBCCH. A diagram of a typical extraction backpressure steam turbine can be seen in Figure-11 below, and an overall schematic of this design alternative can be seen in Figure-12 below. The cooling schematic for this alternative matches that seen in Figure-9 above.

Figure-11: Typical Extraction Backpressure Steam Turbine Diagram

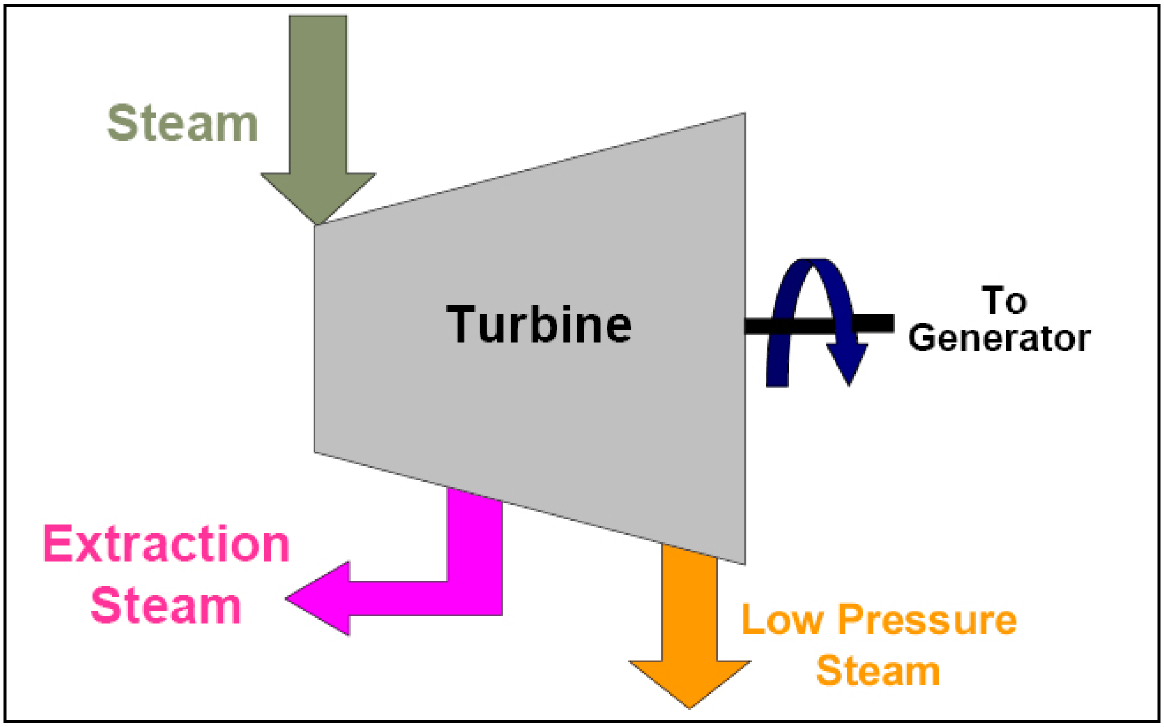
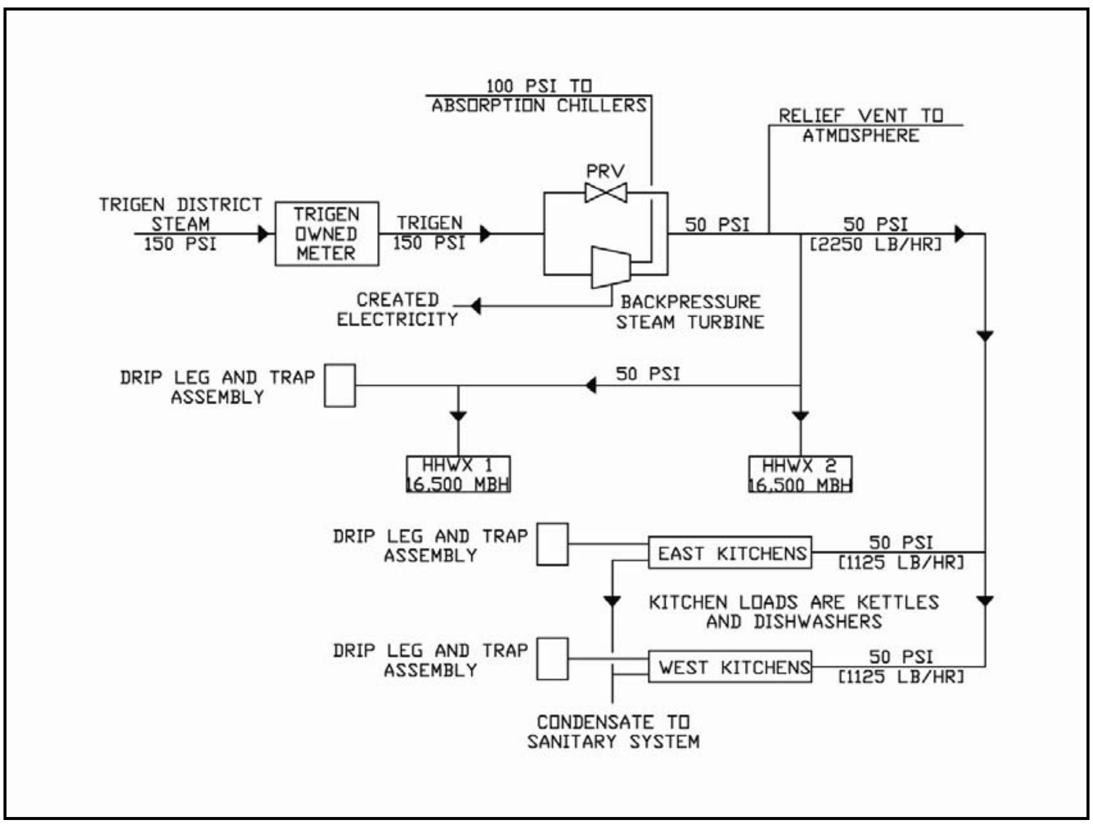


Figure-12: Absorption Chilling Steam Schematic with BST



Method of Analysis

In order to accurately compare all of the design alternatives described above, both first and operating costs for the systems need to be determined.

First Costs

First costs include any monetary expenses paid up front by the owner during the completion of a project. For the design alternatives considered in this report, first costs include equipment such as chillers, pumps, cooling towers, and a backpressure steam turbine. All first costs listed in Table-2 below were found using CostWorks 2005. The original base case scenario has zero first costs because the only on site equipment, two chilled water heat exchangers, is owned by the district chilled water supplier.

Table-2: Mechanical System First Cost

Mechanical System First Costs					
	District System, no CHP	District System w/ CHP	Centrifugal Chilling	Absorption Chilling, no CHP	Absorption Chilling w/ CHP
Chillers	$0	$0	$707,000	$879,000	$879,000
Cooling Towers	$0	$0	$174,000	$174,000	$174,000
Primary Pumps + Piping	$0	$0	$142,500	$249,375	$249,375
Condenser Water Pumps + Piping	$0	$0	$142,500	$249,375	$249,375
Backpressure Steam Turbine	$0	$21,000	$0	$0	$30,000
Total System First Cost	**$0**	**$21,000**	**$1,166,000**	**$1,551,750**	**$1,581,750**
Overall Rank	**1**	**2**	**3**	**4**	**5**

Operating Costs

Operating costs rely on two main factors: the amount of energy being used by the building and the rate being paid for that energy. In order for the design alternatives to be modeled accurately, actual utility rates for the HBCCH were required. Utility rates used in this report were obtained from ComfortLink, Trigen Baltimore, and Baltimore Gas & Electric.

Table-3: District Chilled Water Utility Rate

Charge	Monthly Rate
Capacity Charge	$210/ton of capacity
Usage Charge	$0.15/tonhr

Table-4: District Steam Utility Rate

Charge	Monthly Rate
Capacity Charge	$15,000
Usage Charge	$0.43/Therm

Table-5: Electrical Utility Cost

Charge	Rate	
	Summer	Non-Summer
Minimum Customer Charge	$110	$110
Delivery Service Charge (cents/kWh)	1.239	1.239
Demand Charges (per kW)		
Generation Charge	-	-
Transmission Charge	$1.05	$1.05
Delivery Service	$2.67	$2.67
Energy Charges (cents/kWh)		
Peak	9.319	5.534
Intermediate	8.802	5.406
Off-Peak	8.464	5.118
Hours		
Peak	10am-8pm	7am-11am 5pm-9pm
Intermediate	7am-10am 8pm-11pm	11am-5pm
Off-Peak	11pm-7am	9pm-7am

Now that the rates being paid for energy consumption are known, only the amount of energy being used is left to be determined. Since the HBCCH is not yet completed, no real data is available. This meant that a building model was required so that the necessary analysis could be carried out. In order to obtain hourly energy data, a detailed model of the HBCCH was created using eQuest 3-6.

Step One: Constructing the Virtual HBCCH

First, the HBCCH was "constructed" in the model. Each type of space in the building was inputted into the model along with its associated occupancy schedule, dimensions, location in the building, and lighting and equipment heat gain criteria. For schedules and criteria used please see Appendix A of this report. Utility rates for electricity and steam were also included. District chilled water rates could not be modeled in eQuest, so an extensive Excel spreadsheet was created to carry out that task. This spreadsheet will be discussed in greater detail later in this report. Once the building model was finished, nothing outside of the chiller plant was altered. This ensured that all of the design alternatives were considered on a level playing field.

Step Two: Generating Hourly Energy Usage Data

After finalizing the building model, the chilled water plant information was altered to reflect the differences in the alternative designs considered. First, information from the absorption chillers and all associated equipment was entered into eQuest, and a simulation was run. This simulation calculated the electrical and thermal energy uses for the HBCCH during each hour of the simulated year.

Once the absorption cooling simulation was completed, the chilled water plant information was changed to reflect the system characteristics of the centrifugal chillers and associated equipment. Again, a simulation was run which calculated the electrical and thermal energy uses for the HBCCH during each hour of the simulated year.

Both of the design alternatives simulated thus far, on site absorption cooling and on site centrifugal cooling, could be entirely simulated in eQuest since district chilled water utility rates were not required. As a result, yearly operating costs were calculated by eQuest directly. The results of these two simulations are shown in Table-6 below. In order to model the other two design alternatives and the base case scenario, the results from the original two simulations were exported into Microsoft Excel.

Step Three: Modeling the District System in Excel

The data obtained from the on site centrifugal chilling design alternative was used to model the base case district chilled water and steam scenario in Excel. Hourly eQuest output data for total electrical usage, cooling electrical usage, and total thermal usage was exported into an Excel spreadsheet. The cooling electrical usage was subtracted from the total electrical usage to determine how much of the electrical energy used by the HBCCH was for non-cooling purposes (lighting, plug loads, etc…). Using the spreadsheet, the standard Baltimore Gas & Electric rate was applied to this amount of energy usage.

The remainder of the electrical energy, the amount used to cool the HBCCH, was converted back into Btu/Hr and Tons using EER. The ComfortLink district chilled water rate was then applied to the tons of cooling required for the HBCCH. The district steam rate for this design alternative is equal to the rate calculated in the previous centrifugal cooling simulation. A portion of the Excel spreadsheet used to simulate the district system can be seen in Appendix C of this report. Due to its length (one line for every hour of the year), the entire spreadsheet is not included. The results of this simulation are shown in Table-6 below.

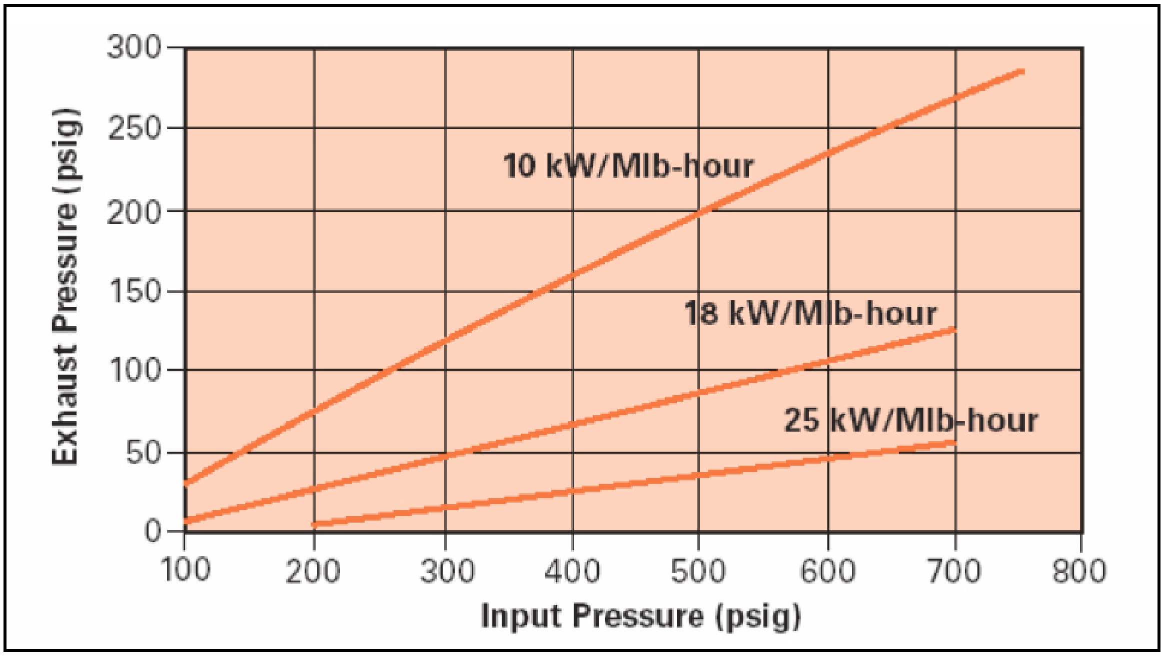
Step Four: Modeling the Backpressure Steam Turbine in Excel

In order to model the backpressure steam turbine in the two design alternatives which utilize it, Microsoft Excel was again employed. Hourly eQuest output data for total electrical usage, cooling electrical usage, and total thermal usage was exported into an Excel spreadsheet. First, the amount of thermal energy required was converted to lbs of steam used during each hour of the year using the following conversion:

$$(X\ \text{Btu})*(1\ \text{ft}^3 / 1{,}000\ \text{Btu})*(0.332\ \text{lb} / 1\ \text{ft}^3) = Y\ \text{lb of steam}$$

Once the amount of steam being used was determined, it was next necessary to find out how much electricity could be produced with that amount of steam passing through the backpressure steam turbine. Figure-13, listed below and found on both government and manufacturer handouts, was used to determine how much electricity would be produced under the given conditions. For the HBCCH, roughly 10 kW of electricity can be produced for every 1,000 pounds of steam-hour that passes through the backpressure steam turbine.

Figure 13: Electricity Produced by Backpressure Steam Turbine



This electricity, produced without the help of the Baltimore Gas & Electric grid, then had to be considered in the electrical utility costs for the HBCCH. Using the Excel spreadsheet, the produced electricity was subtracted from the required electricity value. This allowed both the demand and usage charges to change every month, saving the HBCCH money in the process. Again, a portion of the Excel spreadsheet used to simulate the backpressure steam turbine in both the district and absorption systems can be seen in Appendix C of this report. Due to their length (one line for every hour of the year), the entire spreadsheets are not included. The results of these simulations are shown in Table-6 below.

Step Five: Totaling the Mechanical System Operating Costs

Once all five simulations were completed, the resulting yearly operating costs were totaled and compared. The results of all five simulations can be seen in Table-6 below. Surprisingly, the centrifugal chilling design alternative has the lowest operating cost, with the absorption cooling with extraction backpressure steam turbine following as the next lowest. As expected, the district systems have the highest yearly operating costs.

Table-6: Mechanical System Operating Cost

Mechanical System Operating Costs					
	District System, no CHP	District System w/ CHP	Centrifugal Chilling	Absorption Chilling, no CHP	Absorption Chilling w/ CHP
Electrical Utility Cost	$519,061	$511,225	$628,147	$537,072	$520,438
Steam Utility Cost	$344,812	$344,812	$344,812	$477,028	$477,028
Chilled Water Utility Cost	$450,924	$450,924	$0	$0	$0
Yearly Operating Cost	**$1,314,797**	**$1,306,961**	**$972,959**	**$1,014,100**	**$997,466**
Overall Rank	**5**	**4**	**1**	**3**	**2**

Life-Cycle Cost Analysis

Now that both the first cost and yearly operating cost of each system is known, a life-cycle cost analysis can be carried out. In order to compare values of money spent at different times during the life-cycle of the system, all costs must be brought back to the present. The present worth of all costs was calculated using the following equation:

$$PV = A * [(1+i)^n - 1] / [i(1+i)^n]$$

Where:

PV = Present Value
A = Annual Payment
n = Life-Cycle Duration
i = Discount Rate

No equation for present worth of the first costs was required since first costs already occur during the assumed present. For this report, a life-cycle of twenty years with a discount rate of five percent is assumed. The results of the life-cycle cost analysis can be seen in Table-7 below.

Table-7: Life-Cycle Cost Analysis

Life-Cycle Cost Analysis					
	District System, no CHP	District System w/ CHP	Centrifugal Chilling	Absorption Chilling, no CHP	Absorption Chilling w/ CHP
Mechanical First Cost	$0	$21,000	$1,166,000	$1,551,750	$1,581,750
Electrical Utility Cost	$519,061	$511,225	$628,147	$537,072	$520,438
Steam Utility Cost	$344,812	$344,812	$344,812	$477,028	$477,028
Chilled Water Utility Cost	$450,924	$450,924	$0	$0	$0
Discount Rate	0.05	0.05	0.05	0.05	0.05
Life-Cycle Length	20	20	20	20	20
PV of Utility Costs	$16,385,277	$16,287,623	$12,125,220	$12,637,928	$12,430,631
Total Life-Cycle Cost	**$16,385,277**	**$16,308,623**	**$13,291,220**	**$14,189,678**	**$14,012,381**
Overall Rank	**5**	**4**	**1**	**3**	**2**

Conclusion

For the HBCCH, the design alternative using on site centrifugal cooling is the most cost-effective. Its life-cycle cost of $13,291,220 is over $700,000 less expensive than the next best option. This came as somewhat of a surprise. Throughout the completion of the chiller plant optimization study this semester, it was always assumed that the on site absorption cooling with backpressure steam turbine design alternative would prove to be the most cost-effective. A more detailed conclusion/analysis as to why the results turned out the way they did can be found in Section 8.0 (Conclusions and Final Recommendations) of this Report. It’s also interesting to note that the base case scenario (the design actually being employed for the project), using district steam and district chilled water without any form of combined heat and power, is the most expensive of all the design alternatives considered.

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6.0 Electrical Breadth

Purpose

The purpose of the Electrical Breadth is to provide electrical service to the equipment selected in the most cost-effective design alternative discovered in the Mechanical Depth. Since the on site centrifugal cooling design alternative was the best, equipment includes two chillers, the cooling tower cells, two primary water pumps, and two condenser water pumps. Providing electrical service includes sizing wire, conduit, and breakers, laying out a new panelboard, and resizing the existing Switchgear F so that it may handle the newly added loads. Since no mechanical equipment is being removed from the base case scenario in the on site centrifugal cooling design alternative, no electrical equipment needs to be taken out either.

Justification

Justification of the work to be carried out in the electrical breadth is fairly straightforward. Without providing electrical service to the equipment selected in the most cost-effective design alternative found in the Mechanical Depth, the equipment can not run. Failing to resize Switchgear F would also put other systems throughout the HBCCH at risk, too.

Method of Analysis

The first required task was to determine which pieces of equipment would be placed onto new electrical panelboards and which equipment would be directly tied into Switchgear F. Due to their extremely large start up load requirements, it was decided that both of the chillers would be directly tied into Switchgear F, while the remaining equipment would be placed on a panelboard.

Creating a Panelboard

First, the full load current for each piece of equipment was determined using Table 430.250 of the 2005 National Electric Code. Once the full load current was known, Table 310.16 and Table C.1 of the National Electric Code were used in order to size the wire and associated conduit. Breakers were sized based on 250% of the full load current in order to allow for higher start up load requirements. The resulting sizes can be seen in Table-8 below.

Table-8: Sizing of Wires, Conduit, and Breakers for Panelboard

Wire, Conduit, and Breaker Sizes for Panelboard Equipment				
Equipment	Full Load Current (A)	Wire Size	Conduit Size (Inches)	Breaker Size (A)
Cooling Tower Cell A	77	#4 AWG	1	200
Cooling Tower Cell B	77	#4 AWG	1	200
Primary Pump A	27	#8 AWG	3/4	80
Primary Pump B	27	#8 AWG	3/4	80
Condenser Pump A	77	#4 AWG	1	200
Condenser Pump B	77	#4 AWG	1	200

Note: All wires sized as Copper THW at 75 degrees centigrade

Next the panelboard was laid out. Effort was taken to ensure that the loads on all three phases were similar. In this case, the loads on each phases are identical since all equipment was three phase and there was an even number of each piece of equipment. Once the panelboard was designed, the main circuit breaker could be sized. This was achieved using the following equation:

$$\text{Breaker Requirement} = (1.25)(\text{Highest Load}) + (1.0)(\text{Remaining Loads})$$

The resulting breaker size is 400A. Table 310.16 of the National Electric Code was then employed yet again to determine the feeder size. For the new panelboard, 500 kcmil wire in 2 ½” conduit is required. The new panelboard for the HBCCH can be seen in Figure-14 below.

Figure-14: New Electrical Panelboard

Voltage: 480 V 3 Φ **Main Breaker:** 400 A **Feeder:** 500 kcmil (2 1/2" C)
(#, size wire & conduit)

Description	LOAD (kVA) A	LOAD (kVA) B	LOAD (kVA) C	Brk. Trip (A)	New Panelboard Cond. Size	Ckt. #		Cond. Size	LOAD (kVA) A	LOAD (kVA) B	LOAD (kVA) C	Brk. Trip (A)	Description
Cooling Tower Cell A	21.33			200/3	1"	1	2	1"	21.33			200/3	Cooling Tower Cell B
		21.33				3	4			21.33			
			21.33			5	6				21.33		
Primary Pump A	7.48			80/3	3/4"	7	8	3/4"	7.48			80/3	Primary Pump B
		7.48				9	10			7.48			
			7.48			11	12				7.48		
Condenser Pump A	21.33			200/3	1"	13	14	1"	21.33			200/3	Condenser Pump B
		21.33				15	16			21.33			
			21.33			17	18				21.33		
						19	20						
						21	22						
						23	24						
						25	26						
						27	28						
						29	30						
						31	32						
						33	34						
						35	36						
						37	38						
						39	40						
						41	42						

Total Load on Phase A: 100.28 kVA
Total Load on Phase B: 100.28 kVA
Total Load on Phase C: 100.28 kVA

Total Load on Panel: 300.84 kVA Demand
361.85 A

Providing Service for Chillers

Both of the new 950 ton centrifugal chillers will be wired directly to Switchgear F. Cutsheets for the chillers indicate that a 1600 A breaker is required in order for the chiller to operate as designed. Using the National Electric Code, it was determined that each chiller requires two sets of 800 kcmil wiring in 3 inch conduit.

Another option for wiring up the chillers and other equipment would have been the installation of a motor control center. Motor control centers help reduce cost and save space by only needing one main feeder to run from the distribution panel to the loads. The motor control center then has a motor starter inside for each individual load. For the HBCCH, a motor control center was not selected for two main reasons. First, Switchgear F, the main distribution panel being utilized, is in the room next to the mechanical room. Feeders will not have to travel large distances to get to the loads. Also, there just wasn't enough equipment to justify buying an entire motor control center.

Resizing Switchgear F

Since numerous pieces of equipment were added to the HBCCH and none were removed, it was a concern that the current electrical service would not be sufficient. The current distribution panel for the loads, Switchgear F, is only sized at 2000A. A one line diagram of the original Switchgear F can be seen in Figure-15 below. Fortunately, there were three spare spaces available. These three spaces were used for the new panelboard, Chiller 1, and Chiller 2. In order to resize the switchgear, the following equation was used:

$$\text{Switchgear Size} = (0.8)(\text{Original Breaker Sizes}) + (1.0)(\text{FLC of New Equipment})$$

This equation was used because panelboard schedules for the panels connected to Switchgear F could not be obtained. The National Electric Code assumes that all panels under 600 A (which all of the original loads are) can be considered lighting and appliance panels. These are fairly consistent loads. The 0.8 multiplier was recommended by industry professionals. The newly resized Switchgear F can be seen in Figure-16 below.

Figure-15: Original Switchgear F Layout

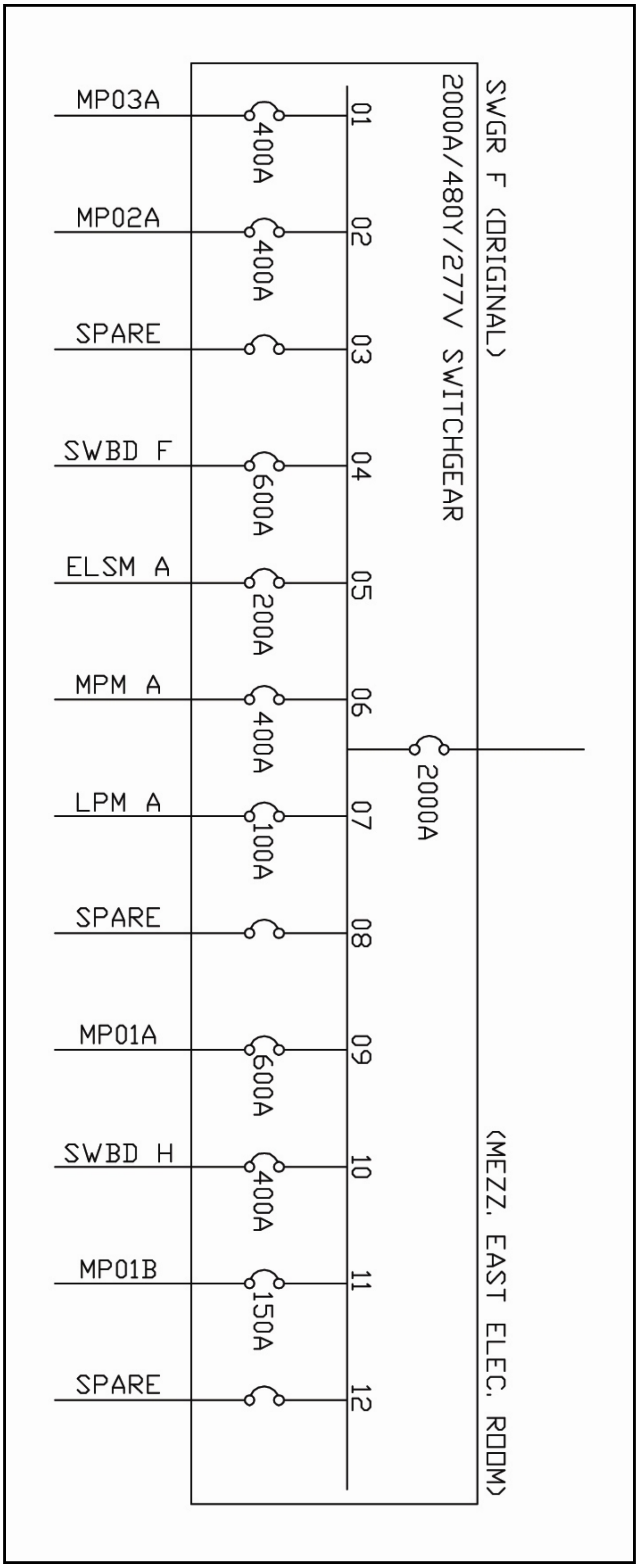
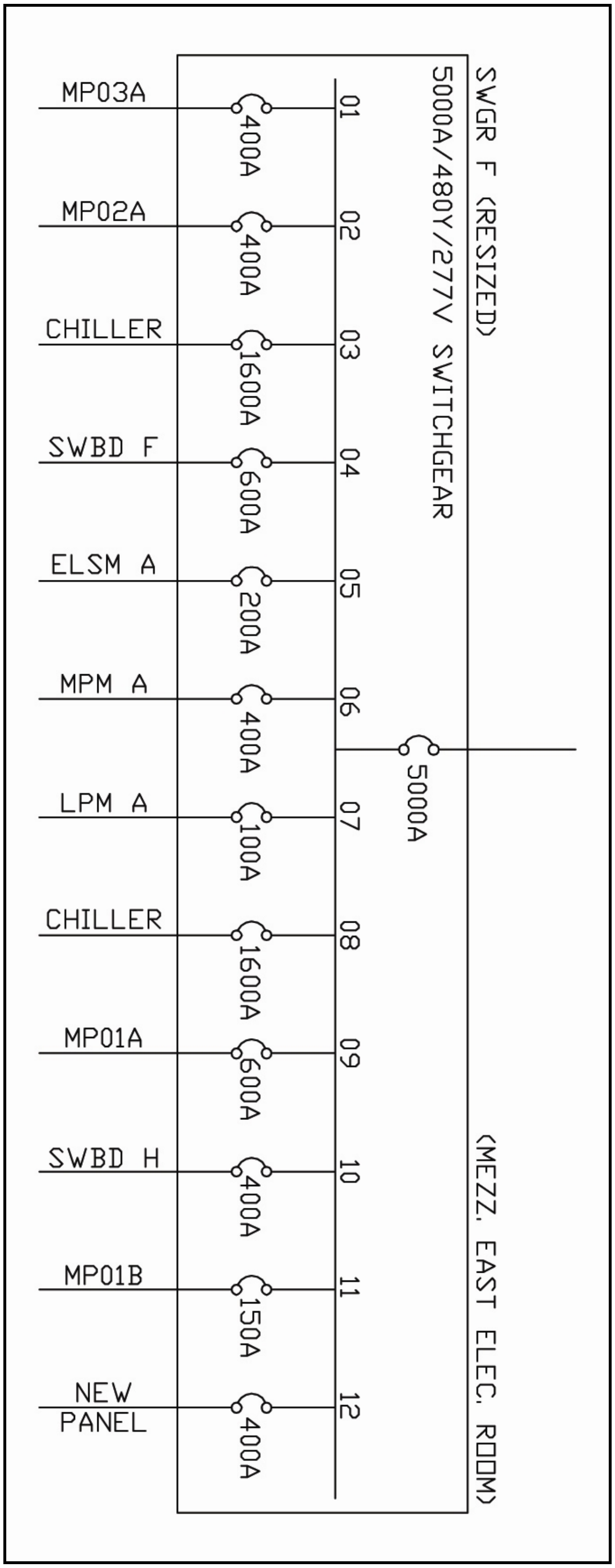


Figure-16: Resized Switchgear F Layout



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7.0 Construction Management Breadth

Purpose

The purpose of the Construction Management Breadth is to shorten the construction time of the guest room towers of the HBCCH. Currently, the guest room towers are scheduled to take 51 weeks for completion once all structural elements are completed. The construction time will be completed through the use of a Short Interval Production Schedule (SIPS).

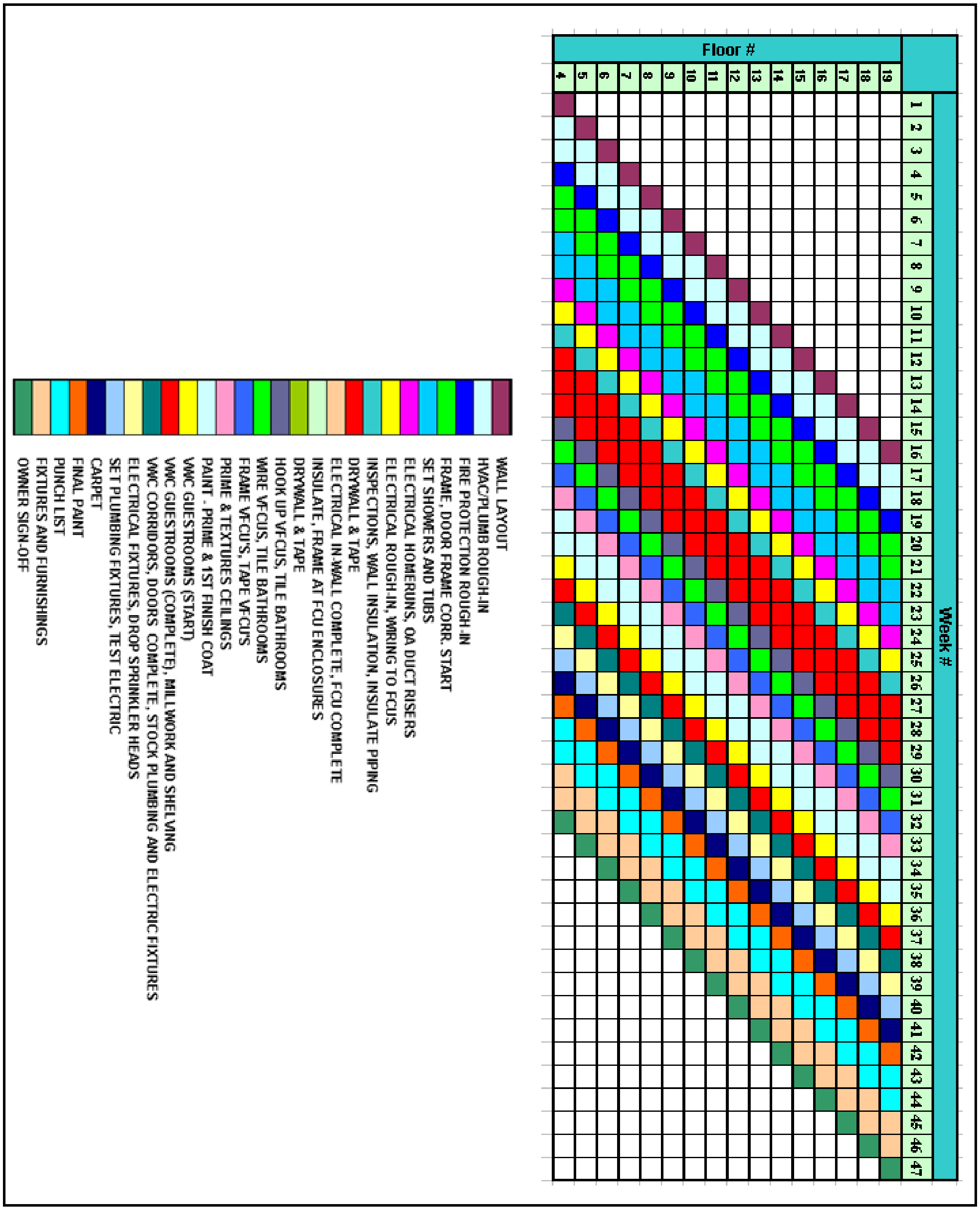
Justification

Short Interval Production Schedules thrive on efficiency and organization of work rather than speed. As a result, they are perfectly suited for construction jobs with repetitive work. Repetition reduces the learning curve of construction work, so workers become more efficient and skilled as they repeat tasks over and over during the completion of a project. Floors 4-19 of the HBCCH, the guest room towers, are essentially the same floor plan stacked on top of each other, making them a perfect candidate for a SIPS. SIPS also eliminate trade stacking, improve predictability and job-tracking, and help to better job site communication.

Method of Analysis

In order to complete the SIPS, the construction activities carried out on each floor of the guest room towers had to be determined. Once the activities were determined, each one had to be assigned a production rate. Production rates were assigned with the help of industry professionals. Next, related trades that logically work together were combined and overlapped, breaking the construction of each floor of the guest room tower into a list of finalized tasks. These tasks were then arranged into a resource-loaded, time-scaled bar graph, the SIPS. The finalized SIPS can be seen in Figure-17 below. Overall, the SIPS created for this report decreases the construction time of the guest room towers to 47 weeks. This means that four full weeks of construction time are saved.

Figure-17: Completed SIPS



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8.0 Conclusions and Final Recommendation

Conclusions

In the conclusion portion of Section 5.0 of this report, it was mentioned that the results of the chiller plant optimization study did not turn out as expected. Originally, absorption cooling with a backpressure steam turbine was assumed to be the best design alternative. Since it did not turn out as the best, time was taken to analyze why this was the case. The required Trigen district steam price that would make this design alternative optimal was calculated, and this rate was then compared to current 2007 fuel prices.

First, the cost of Trigen district steam per therm used was calculated. This value was found using the following equation:

Trigen Price = Usage Rate + (Set Rate / # Therms)

Where…
Usage Rate = $0.43
Set Rate = $180,000
Therms = 688,200

Figure-18 below shows how this calculation was carried out in an Excel spreadsheet, and it shows that a district steam cost of $0.69 per therm is currently being paid. In order to calculate the required price of steam that would make combined heat and power worthwhile, a difference in yearly steam utility costs was found which made the overall life-cycle cost equal to the on site centrifugal cooling design alternative. This difference was $55,926 per year. This value was subtracted from the current steam cost and then divided by the total number of therms used. The resulting steam cost, seen in Figure-18, is $0.61 per them, or $0.08 per therm less than the current rate.

Figure-18: Making CHP Worthwhile

What Steam Rate Would Be Needed to Make CHP Worthwhile?						
Usage Rate ($/Therm)	# Therms	Set Rate ($)	**Current Price ($/Therm)**	Current Steam Cost	Reduction in Steam Cost to make CHP Worthwhile	**Steam Price Required to make CHP Worthwhile**
$0.43	688,200	$180,000.00	**$0.69**	$475,926.00	$55,926.00	**$0.61**

Now that the actual and required steam costs are known, they will be compared to the cost of generating steam using various fuels. Data used in Figure-19 below was taken from www.eia.doe.gov. It is interesting that the rates for steam generation are higher than the rate being paid by the HBCCH for both natural gas and oil generation. Only producing steam using coal appears to be a viable option for Trigen.

Figure-19: Current Fuel Prices

Current Fuel Prices ($/Therm)			
Fuel	Unit Price ($/ft^3)	Heating Value (Btu/ft^3)	**Price ($/Therm)**
Natural Gas	$0.0121	0.001078749	**$1.31**
Fuel	Unit Price ($/lb)	Heating Value (Btu/lb)	**Price ($/Therm)**
Coal	$0.03	12500	**$0.22**
Fuel	Unit Price ($/gallon)	Heating Value (Btu/gallon)	**Price ($/Therm)**
Oil	$2.00	140000	**$1.43**

Once the values in Figure-19 were known, a phone call was made and numerous emails were sent to the manager of Trigen's Baltimore plant in order to find out how they generate their steam. The manager refused to give specific information as to how steam is produced, but he did definitively say that coal is not a means of generation. If coal isn't used, then how does Trigen make money? Obviously Trigen produces so much steam that they were able to strike a deal in order to create it at a cost that is lower than expected. This allows them to sell their steam to customers like the HBCCH at a perceived "low rate" while still making a profit. Unfortunately, this perceived low rate is not low enough to justify installing a backpressure steam turbine with absorption cooling at the HBCCH. The manager at Trigen also refused to disclose how long their contract with Hilton Hotels lasts, so it is impossible to know how soon steam rates could be changed, regardless of whether or not the change if for better or for worse.

Final Recommendation

Hilton Hotels chose the base case scenario, district chilled water and district steam, for two main reasons. First, they utilize district systems at other hotels and are happy with their performance. Little maintenance is needed, and system operation is guaranteed. Second, original conceptual designs for the HBCCH placed cooling towers on the roof of the west podium. With baseball fans at Oriole Park at Camden Yards having a clear view of the hotel, Hilton Hotels felt the on site equipment would detract from the aesthetic beauty of their building. The immediately looked for district systems to be used instead of on site cooling and heating.

Neither of these considerations is within the scope of this report. The main purpose of this report was to improve economics by lowering the life-cycle cost of the mechanical system of the HBCCH. This means that the system with the lowest life-cycle cost is considered the best. After completing the chiller plant optimization study, it is the final recommendation of this report that on site centrifugal cooling, along with associated cooling towers and pumps, be installed at the HBCCH. With an overall life-cycle cost of $13,291,220, this design alternative saves $3,094,057 compared to the base case scenario.

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Appendix A

Building Model Inputs

Schedules:
Hilton Hotels supplied the design engineering team with the following schedules

People – Hotel General

Start Time	End Time	%
Midnight	9 a.m.	70.0
9 a.m.	10 a.m.	50.0
10 a.m.	4 p.m.	30.0
4 p.m.	5 p.m.	50.0
5. p.m.	Midnight	70.0

Lights – Hotel General

Start Time	End Time	%
Midnight	6 a.m.	50.0
6 a.m.	7 a.m.	80.0
7 a.m.	5 p.m.	100.0
5 p.m.	10 p.m.	80.0
10 p.m.	Midnight	50.0

People – Hotel Lobby

Start Time	End Time	%
Midnight	7 a.m.	20.0
7 a.m.	8 a.m.	80.0
8 a.m.	9 a.m.	100.0
9 a.m.	9 p.m.	60.0
9 p.m.	Midnight	20.0

Lights – Hotel Lobby

Start Time	End Time	%
Midnight	6 a.m.	50.0
6 a.m.	7 a.m.	80.0
7 a.m.	5 p.m.	100.0
5 p.m.	10 p.m.	80.0
10 p.m.	Midnight	50.0

People – Hotel Dining Room

Start Time	End Time	%
Midnight	6 a.m.	0.0
6 a.m.	8 a.m.	50.0
8 a.m.	9 a.m.	100.0

9 a.m.	10 a.m.	80.0
10 a.m.	11 a.m.	20.0
11 a.m.	noon	80.0
noon	1 p.m.	100.0
1 p.m.	5 p.m.	20.0
5 p.m.	8 p.m.	100.0
8 p.m.	9 p.m.	10.0
9 p.m.	Midnight	0.0

Lights – Hotel Dining Room

Start Time	End Time	%
Midnight	5 a.m.	0.0
5 a.m.	6 a.m.	50.0
6 a.m.	9 p.m.	100.0
9 p.m.	10 p.m.	50.0
10 p.m.	Midnight	0.0

People – Hotel Ballroom

Start Time	End Time	%
Midnight	11 a.m.	0.0
11 a.m.	3 p.m.	100.0
3 p.m.	5 p.m.	20.0
5 p.m.	10 p.m.	100.0
10 p.m.	11 p.m.	20.0
11 p.m.	Midnight	0.0

Lights – Hotel Ballroom

Start Time	End Time	%
Midnight	11 a.m.	0.0
11 a.m.	3 p.m.	100.0
3 p.m.	5 p.m.	50.0
5 p.m.	10 p.m.	100.0
10 p.m.	11 p.m.	20.0
11 p.m.	Midnight	0.0

Hotel Prefunction

Start Time	End Time	%
Midnight	10 a.m.	0.0
10 a.m.	11 a.m.	100.0
11 a.m.	4 p.m.	20.0
4 p.m.	5 p.m.	100.0
5 p.m.	10 p.m.	20.0
10 p.m.	Midnight	30.0

People - Hotel Meeting Rooms

Start Time	End Time	%
Midnight	7 a.m.	0.0
7 a.m.	8 a.m.	20.0
8 a.m.	noon	100.0
noon	1 p.m.	20.0
1 p.m.	5 p.m.	100.0
5 p.m.	8 p.m.	30.0
8 p.m.	Midnight	10.0

Lights - Hotel Meeting Rooms

Start Time	End Time	%
Midnight	7 a.m.	0.0
7 a.m.	5 p.m.	100.0
5 p.m.	8 p.m.	50.0
8 p.m.	Midnight	20.0

People – Retail Store

Start Time	End Time	%
Midnight	8 a.m.	0.0
8 a.m.	9 a.m.	10.0
9 a.m.	10 a.m.	30.0
10 a.m.	11 a.m.	60.0
11 a.m.	4 p.m.	100.0
4 p.m.	5 p.m.	80.0
5 p.m.	9 p.m.	40.0
9 p.m.	10 p.m.	10.0
10 p.m.	Midnight	0.0

Lights – Retail Store

Cooling Design

Start Time	End Time	%

Midnight	8 a.m.	10.0
8 a.m.	9 a.m.	80.0
9 a.m.	9 p.m.	100.0
9 p.m.	10 p.m.	20.0
10 p.m.	Midnight	10.0

People – Low Rise Office

Start Time	End Time	%
Midnight	7 a.m.	0.0
7 a.m.	8 a.m.	30.0
8 a.m.	11 a.m.	100.0
11 a.m.	noon	80.0
noon	1 p.m.	40.0
1 p.m.	2 p.m.	80.0
2 p.m.	5 p.m.	100.0
5 p.m.	6 p.m.	30.0
6 p.m.	9 p.m.	10.0
9 p.m.	Midnight	5.0

Lights – Low Rise Office

Start Time	End Time	%
Midnight	7 a.m.	5.0
7 a.m.	8 a.m.	80.0
8 a.m.	10 a.m.	90.0
10 a.m.	noon	95.0
noon	2 p.m.	80.0
2 p.m.	4 p.m.	90.0
4 p.m.	5 p.m.	95.0
5 p.m.	6 p.m.	80.0
6 p.m.	7 p.m.	70.0
7 p.m.	8 p.m.	60.0
8 p.m.	9 p.m.	40.0
9 p.m.	10 p.m.	30.0
10 p.m.	Midnight	20.0

People – Hotel Rooms

Start Time	End Time	%
Midnight	9 a.m.	100.0
9 a.m.	11 a.m.	20.0
11 a.m.	5 p.m.	0.0
5 p.m.	Midnight	100.0

Lights – Hotel Rooms

Start Time	End Time	%
Midnight	6 a.m.	5.0
6 a.m.	9 a.m.	100.0
9 a.m.	11 a.m.	50.0
11 a.m.	5 p.m.	0.0
5 p.m.	9 p.m.	100.0
9 p.m.	Midnight	5.0

Heat Gain Criteria

The following heat gain criteria was supplied by Southland Industries.

OCCUPANCY HEAT GAIN CRITERIA				
ROOM NAME	OCCUPANCY DENSITY	ACTIVITY LEVEL	SPACE PEAK DIVERSITY	PLANT LOAD DVISERITY
Ballrooms	120 people per 1000 ft²	3	100%	Per Occupancy Schedules
Conference Rooms	50 people per 1000 ft²	2	100%	100%
Electrical Rooms	-	-	100%	100%
Elevator Machine Rooms	-	-	100%	100%
Elevator Lobbies	4 people per 1000 ft²	2	100%	100%
Exercise Room	30 people per 1000 ft²	5	100%	100%
Guest Rooms	2 people per room	1	100%	Per Occupancy Schedules
Kitchen / Pantry	20 people per 1000 ft²	4	100%	100%
Lobby	30 people per 1000 ft²	2	100%	100%
Mechanical Rooms	4 people per 1000 ft²	4	100%	100%
Meeting Rooms	50 people per 1000 ft²	2	100%	Per Occupancy Schedules
Offices and Open Office Area	7 people per 1000 ft²	2	100%	100%
Pre-function	50 people per 1000 ft²	2	100%	Per Occupancy Schedules
Pool (indoor)	8 people per 1000 ft²	4	100%	100%
Public Corridors	4 people per 1000 ft²	2	100%	100%
Restaurants & Cafeteria	70 people per 1000 ft²	3	100%	Per Occupancy Schedules
Restrooms	20 people per 1000 ft²	1	100%	100%
Retail (Street Level)	By others	By others	By others	By others

OCCUPANCY HEAT GAIN CRITERIA				
ROOM NAME	OCCUPANCY DENSITY	ACTIVITY LEVEL	SPACE PEAK DIVERSITY	PLANT LOAD DVISERITY
Service Corridors	4 people per 1000 ft²	3	100%	100%
Storage Rooms	4 people per 1000 ft²	4	100%	100%
Training Rooms	50 people per 1000 ft²	2	100%	100%
Telecom Rooms	-	-	100%	100%
Work Areas & Housekeeping	5 people per 1000 ft²	4	100%	100%

Notes:

1. Activity level heat gain (btuh) is defined as follows:

Level	Activity	Sensible	Latent
1	Seated, very light work	245	155
2	Office work	250	200
3	Sedentary work	275	275
4	Light work	275	475
5	Heavy Work	580	870

HEAT GAIN CRITERIA				
ROOM NAME	EQUIPMENT HEAT GAIN		LIGHTING HEAT GAIN	REMARKS
	PLUG LOAD	SPECIFIC EQUIPMENT		
Ballrooms (Assembly)	-	-	8.0 watts/ft²	Combo plug & lighting
Conference Rooms	1.0 watts/ft²	-	3.0 watts/ft²	-
Electrical Rooms	See Remarks	See Remarks	1.50 watts/ft²	3.00 watts/ft² nominal or per equipment list
Elevator Machine Rooms	See Remarks	See Remarks	1.50 watts/ft²	3.00 watts/ft² nominal or per equipment list
Elevator Lobbies	-	-	1.50 watts/ft²	-
Exercise Room	1.0 watts/ft²	-	2.0 watts/ft²	-
Guest Rooms	-	-	200 watts	-
Kitchen / Pantry	6.0 watts/ft²	-	1.5 watts/ft²	Adjusted per equipment list
Lobby	0.5 watts/ft²	-	3.0 watts/ft²	-
Mechanical Rooms	-	-	1.5 watts/ft²	-
Meeting Rooms	1.0 watts/ft²	-	3.0 watts/ft²	-
Offices and Open Office Area	1.50 watts/ft²	-	1.50 watts/ft²	-
Pre-function	-	-	2.50 watts/ft²	-

HEAT GAIN CRITERIA				
ROOM NAME	EQUIPMENT HEAT GAIN		LIGHTING HEAT GAIN	REMARKS
	PLUG LOAD	SPECIFIC EQUIPMENT		
Pool (indoor)	-	-	2.50 watts/ft²	-
Public Corridors	-	-	1.50 watts/ft²	-
Restaurants & Cafeteria	-	-	2.00 watts/ft²	-
Restrooms	-	-	1.50 watts/ft²	-
Retail (Street Level)	-	-	By others	-
Service Corridors	-	-	1.50 watts/ft²	-
Storage Rooms	-	-	1.50 watts/ft²	-
Training Rooms	1.0 watts/ft²	-	3.0 watts/ft²	-
Telecom Rooms	See Remarks	See Remarks	1.50 watts/ft²	6.00 watts/ft² nominal or per equipment
Work Areas & Housekeeping	0.50 watts/ft²	-	1.50 watts/ft²	-

Andrew Rhodes

The Pennsylvania State University
Architectural Engineering – Mechanical

The Hilton Baltimore Convention Center Hotel

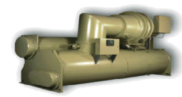
Appendix B

Equipment Selection Cutsheets

Centrifugal Chiller

Job Information

Hilton Baltimore Chillers
Washington DC
(D46)Joe Mulligan



Tag	**CTV-0023**	Model number	**CVHF0910**
Quantity	**1**		

Certified in accordance with the Water-Chilling Packages Using the Vapor Compression Cycle Certification Program, which is based on ARI Standard 550/590.

Sound pressure measured in accordance with ARI Standard 575-94.

ASHRAE 90.1 compliance	Yes	ASHRAE 90.1 Full Load Requirement: 0.639 kW/ton
		ASHRAE 90.1 Part Load Requirement: 0.609 kW/ton

Unit Information

Model	**CVHF**	Evap tube type	**IECU**
Compressor size	**910**	Evap tube thickness	**0.025"**
Motor size	**588**	Evap passes	**2**
Motor frequency	**60 Hz**	Cond shell size	**142L**
Motor voltage	**460**	Cond bundle size	**980**
Impeller size	**281**	Cond tube type	**TECU**
Orifice size	**1335**	Cond tube thickness	**0.028"**
Evap shell size	**142L**	Cond passes	**2**
Evap bundle size	**1420**		

Design Information

Cooling capacity	**950.0 tons**	HCFC 123 refrigerant charge	**1700 lb**
Primary power	**541.7 kW**	Shipping weight	**31974 lb**
Primary efficiency	**0.570 kW/ton**	Operating weight	**37870 lb**
NPLV	**0.459 kW/ton**	Sound level	**87 dBA**
Wye-delta starter type	**Unit Mounted WyeD**	Green Seal certification	**Yes**
Application type	**Standard cooling**	Free cooling option	**No**
		Heat rejected into equip room	**9.25 MBh**

Evaporator Information

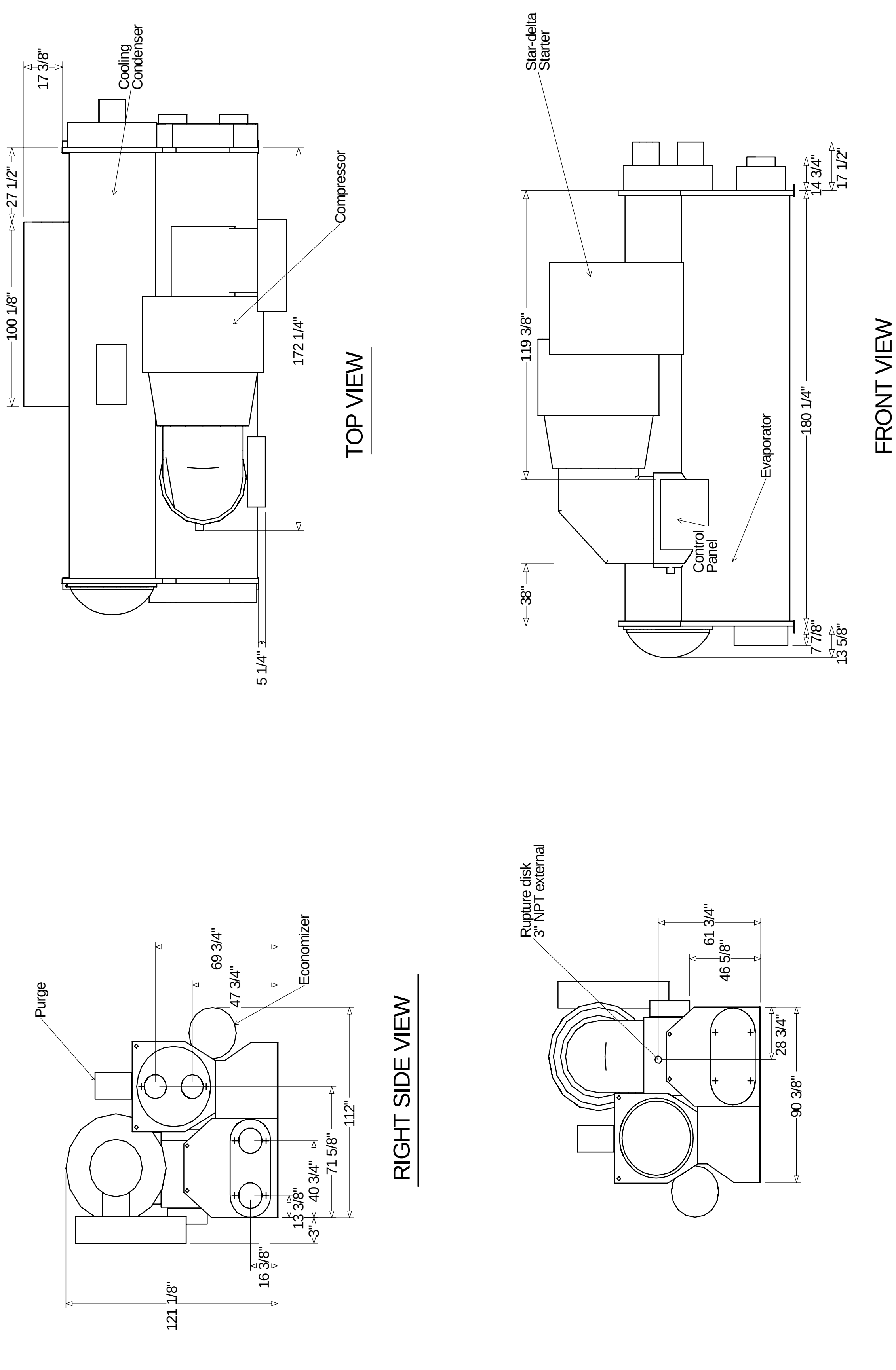
Evap leaving temp	**42.00 F**
Evap flow rate	**1620.6 gpm**
Evap entering temp	**56.00 F**
Evap flow/capacity	**1.71 gpm/ton**
Evap water box type	**non-marine**
Evap pressure drop	**6.82 ft H2O**
Evap fouling factor	**0.00010 hr-sq ft-deg F/Btu**
Evap fluid type	**water**
Evap fluid concentration	**N/A**
Evap water box pressure	**150 psig evap. water pressure**
Evap min flow rate	**558.30 gpm**

Condenser Information

Cond entering temp	**85.00 F**
Cond flow rate	**2280.0 gpm**
Cond leaving temp	**96.75 F**
Cond flow/capacity	**2.40 gpm/ton**
Cond water box type	**non-marine**
Cond pressure drop	**25.74 ft H2O**
Cond fouling factor	**0.00025 hr-sq ft-deg F/Btu**
Cond fluid type	**water**
Cond fluid concentration	**N/A**
Cond water box pressure	**150 psig cond. water pressure**

Electrical Information

Motor LRA	**4389 A**	Min circuit ampacity	**960 A**
Primary RLA	**760.3 A**	Max over current protection	**1600 A**



CONNECTION SIZE	in	CONNECTION TYPE
EVAPORATOR	12	VICTAULIC
COOLING COND	12	VICTAULIC

CUSTOMER NOTES:

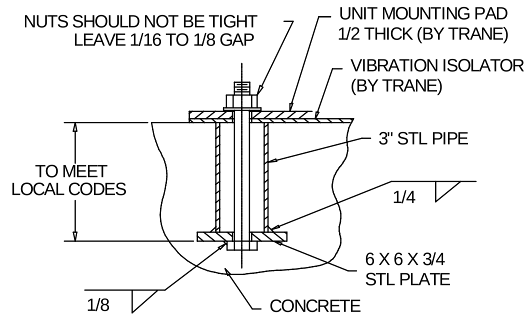
UNLESS OTHERWISE SPECIFIED DIMENSIONAL TOLERANCE +/-1/2" (13mm).
COOLING CONDENSER CONNECTIONS ARE STRAIGHT OUT THE END OF THE WATER BOX, WITH INLET ON THE BOTTOM AND OUTLET ON TOP.
WATER BOX DRAIN AND VENT LOCATIONS ARE INDICATED BY PLUS SYMBOLS ON THE WATER BOX END PLATES.
EVAPORATOR INLET / OUTLET CONNECTIONS ARE INTERCHANGEABLE.

⚠ WARNING

1. HEAVY OBJECTS!
   DO NOT USE CABLES (CHAINS OR SLINGS) EXCEPT AS SHOWN. EACH OF THE CABLES (CHAINS OR SLINGS) USED TO LIFT THE UNIT MUST BE CAPABLE OF SUPPORTING THE ENTIRE WEIGHT OF THE UNIT. LIFTING CABLES (CHAINS OR SLINGS) MAY NOT BE OF THE SAME LENGTH. ADJUST AS NECESSARY FOR EVEN UNIT LIFT. OTHER LIFTING ARRANGEMENTS MAY CAUSE EQUIPMENT OR PROPERTY-ONLY DAMAGE. FAILURE TO PROPERLY LIFT UNIT MAY RESULT IN DEATH OR SERIOUS INJURY. SEE DETAILS BELOW.
2. IMPROPER UNIT LIFT!
   TEST LIFT UNIT APPROXIMATELY 24 INCHES TO VERIFY PROPER CENTER OF GRAVITY LIFT POINT. TO AVOID DROPPING OF UNIT, REPOSITION LIFTING POINT IF UNIT IS NOT LEVEL. FAILURE TO PROPERLY LIFT UNIT COULD RESULT IN DEATH OR SERIOUS INJURY OR POSSIBLE EQUIPMENT OR PROPERTY-ONLY DAMAGE.
3. ATTACH SAFETY CHAIN OR CABLE AS SHOWN WITHOUT TENSION, NOT AS A LIFTING CHAIN OR CABLE, BUT TO PREVENT THE UNIT FROM ROLLING.
4. DO NOT FORKLIFT THE UNIT TO MOVE OR LIFT.
5. LIFTING HOLES PROVIDED ON CHILLER TO ATTACH CABLES (CHAINS OR SLINGS).
6. 36" (900 MM) RECOMMENDED CLEARANCE ABOVE HIGHEST POINT OF COMPRESSOR.
7. FOLLOW NEC SECTION 110 AND OTHER APPLICABLE LOCAL CODES FOR CLEARANCES IN FRONT OF ELECTRICAL ENCLOSURES.
8. THE "MAXIMUM SHIPPING AND OPERATING WEIGHTS" SHOWN BELOW ARE AN ESTIMATE OF THE "MAXIMUM" WEIGHT FOR THE CHILLER "FAMILY" OF THE PROPOSED TRANE CHILLER. THIS MAXIMUM WEIGHT INCLUDES THE LARGEST COMPRESSOR OF THE CHILLER FAMILY AND INCLUDES OPTIONS FOR 300 LB. MARINE STYLE WATER BOXES AND AN OPTIONAL UNIT MOUNTED STARTER. (SEE YOUR SPECIFIC SUBMITTAL DATA SHEET FOR SPECIFIC CHILLER COMPONENTS ORDERED.)

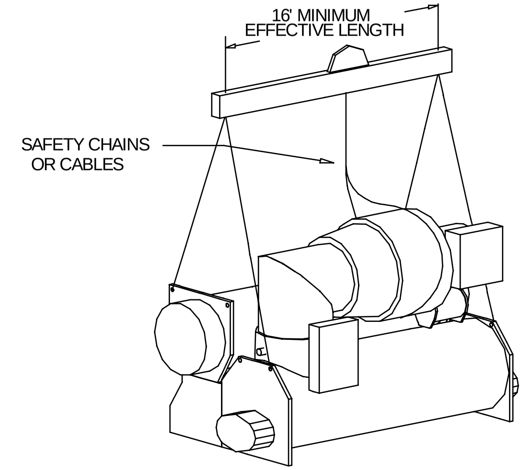
   SPECIFIC SHIPPING AND OPERATING WEIGHTS OF THE SUBMITTED CHILLER ARE PROVIDED ON THE CENTRIFUGAL CHILLER SELECTION OUTPUT INCLUDED IN THE TRANE SUBMITTAL PACKAGE. DETAILED LOAD POINT AND SPRING ISOLATOR APPLICATION WEIGHTS ARE AVAILABLE FROM "CENTRAVAC ISOLATOR SELECTION REPORT" AVAILABLE FROM THE REPORT GENERATOR OF THE TRANE TOPSS CHILLER SELECTION PROGRAM. CONTACT YOUR LOCAL TRANE SALES ENGINEER IF THIS DATA IS REQUIRED.

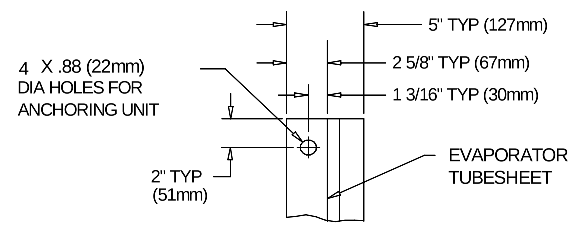
(SEE NOTE 8 ABOVE) WEIGHT IN	lb
MAXIMUM SHIPPING	52342
MAXIMUM OPERATING	59780



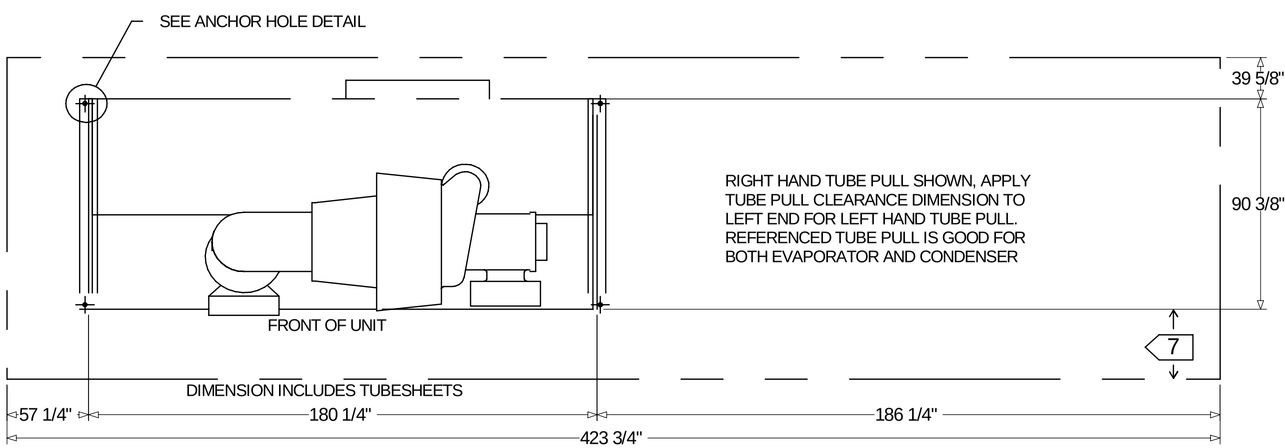
ANCHOR BOLT DETAIL

RECOMMENDED PROCEDURE TO ALLOW FOR THERMAL EXPANSION. (UNLESS OTHERWISE SPECIFIED, PARTS ARE FURNISHED BY CUSTOMER)





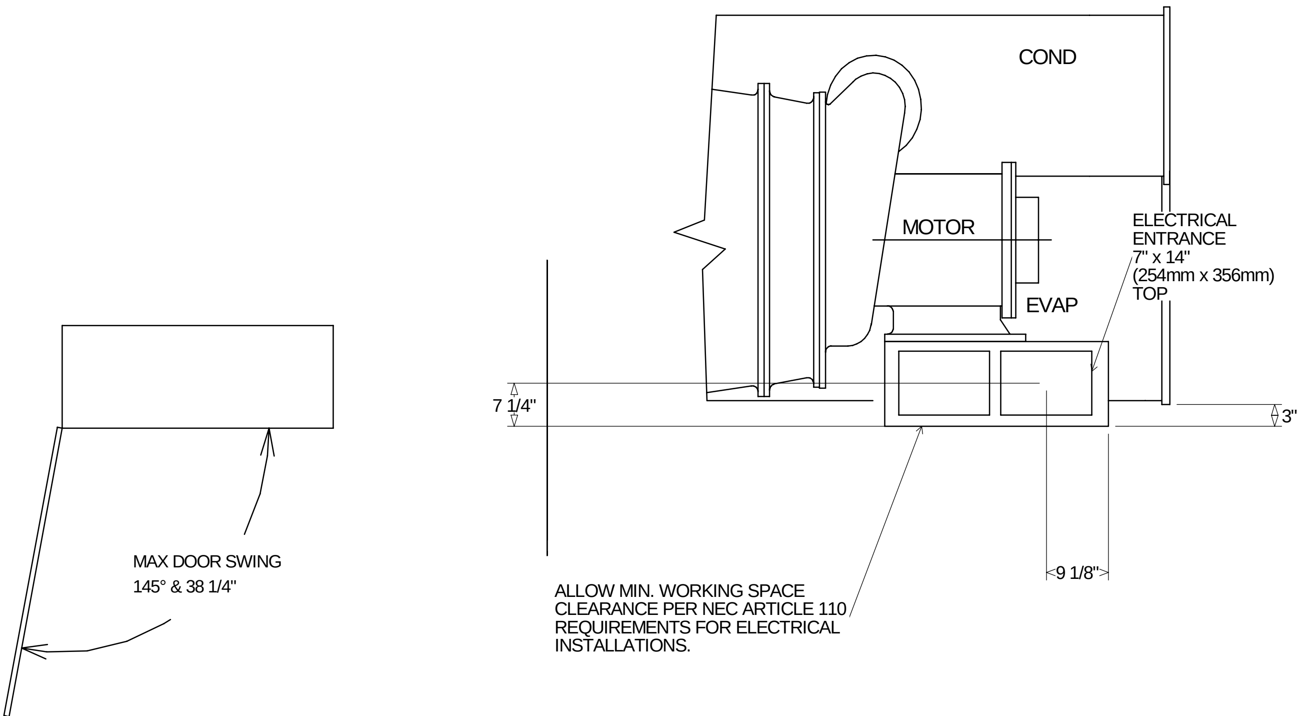
ANCHOR HOLE DETAIL
EACH CORNER



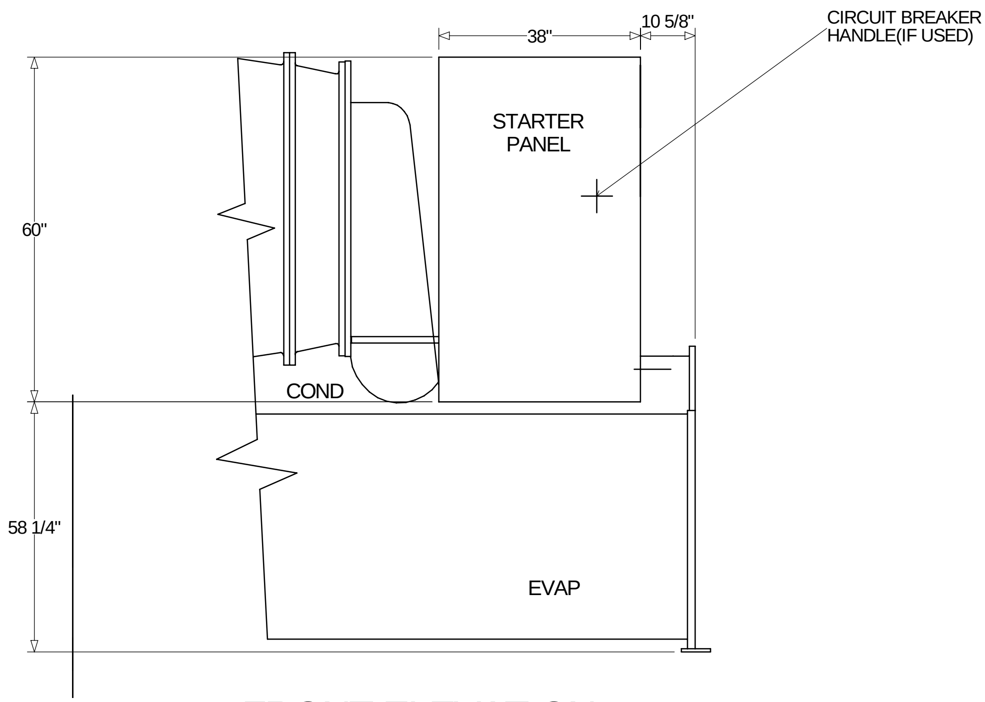
SIZE	MAX RLA	BREAKER AIC AMPS	SHORT CIRCUIT WITHSTAND RATINGS (RMS SYMETRICAL AMPS)	LINE CONNECTION LUGS WYE-DELTA STARTERS	PANEL CONNECTION	INTERNAL WIRE LENGTH
6	935	N/A	42,000	(4) 4/0-500	TERM	25

POWER FACTOR CORRECTION CAPACITORS, WHEN SELECTED, ARE NOT INCLUDED IN THE UL SHORT CIRCUIT RATING OF THE STARTER.

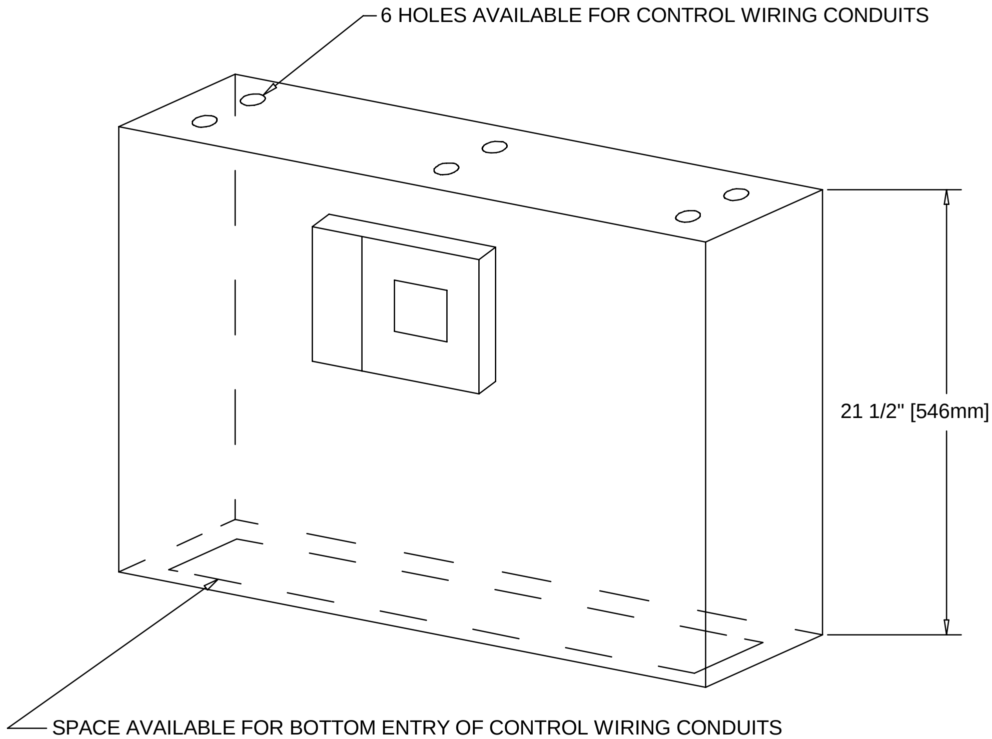
TERM = TERMINAL BLOCK

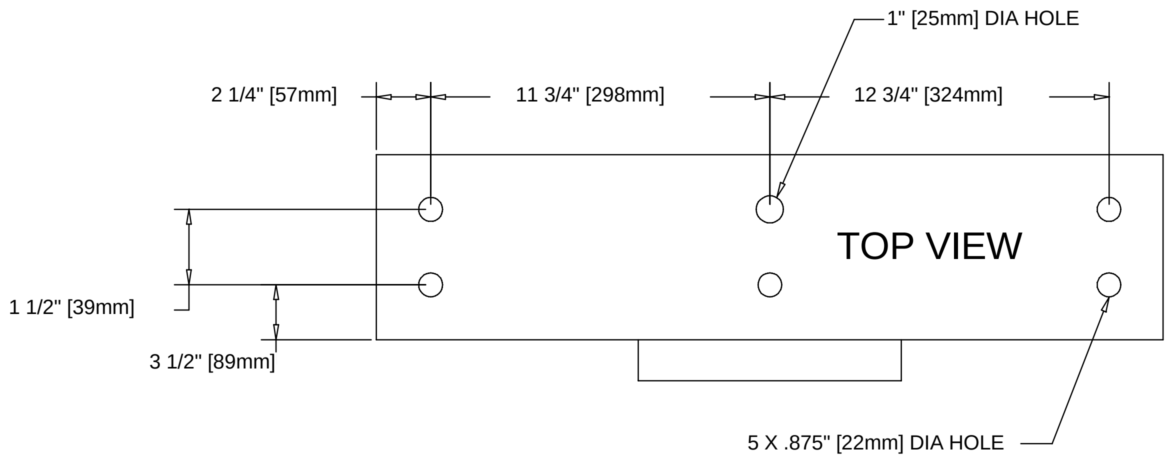


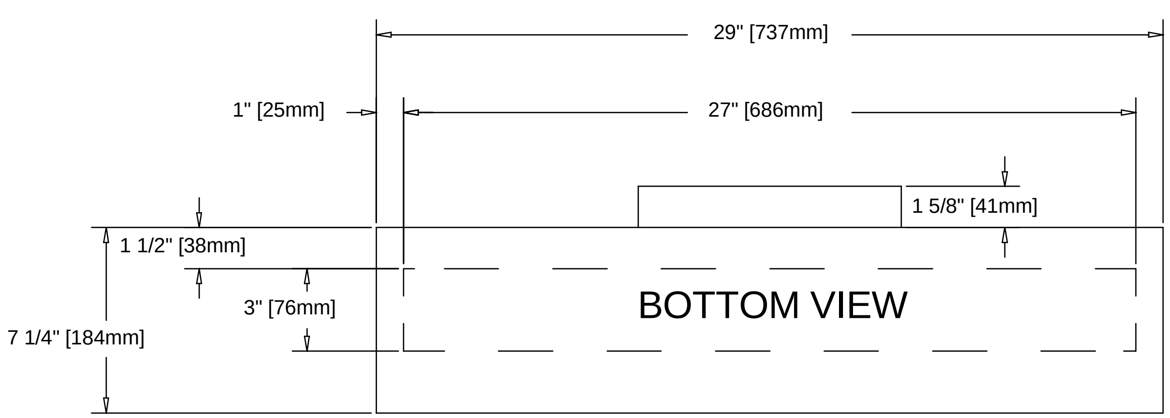
TOP VIEW



FRONT ELEVATION


6 HOLES AVAILABLE FOR CONTROL WIRING CONDUITS
21 1/2" [546mm]
SPACE AVAILABLE FOR BOTTOM ENTRY OF CONTROL WIRING CONDUITS


1" [25mm] DIA HOLE
2 1/4" [57mm]
11 3/4" [298mm]
12 3/4" [324mm]
TOP VIEW
1 1/2" [39mm]
3 1/2" [89mm]
5 X .875" [22mm] DIA HOLE


29" [737mm]
1" [25mm]
27" [686mm]
1 5/8" [41mm]
1 1/2" [38mm]
3" [76mm]
BOTTOM VIEW
7 1/4" [184mm]

WARNING	AVERTISSEMENT	ADVERTENCIA
HAZARDOUS VOLTAGE!	TENSION DANGEREUSE!	¡VOLTAJE PELIGROSO!
DISCONNECT ALL ELECTRIC POWER INCLUDING REMOTE DISCONNECTS AND FOLLOW LOCK OUT AND TAG PROCEDURES BEFORE SERVICING. INSURE THAT ALL MOTOR CAPACITORS HAVE DISCHARGED STORED VOLTAGE. UNITS WITH VARIABLE SPEED DRIVE, REFER TO DRIVE INSTRUCTIONS FOR CAPACITOR DISCHARGE.	COUPER TOUTES LES TENSIONS ET OUVRIR LES SECTIONNEURS À DISTANCE, PUIS SUIVRE LES PROCÉDURES DE VERROUILLAGE ET DES ÉTIQUETTES AVANT TOUTE INTERVENTION. VÉRIFIER QUE TOUS LES CONDENSATEURS DES MOTEURS SONT DÉCHARGÉS. DANS LE CAS D'UNITÉS COMPORTANT DES ENTRAÎNEMENTS À VITESSE VARIABLE, SE REPORTER AUX INSTRUCTIONS DE L'ENTRAÎNEMENT POUR DÉCHARGER LES CONDENSATEURS.	DESCONECTE TODA LA ENERGÍA ELÉCTRICA, INCLUSO LAS DESCONEXIONES REMOTAS Y SIGA LOS PROCEDIMIENTOS DE CIERRE Y ETIQUETADO ANTES DE PROCEDER AL SERVICIO. ASEGÚRESE DE QUE TODOS LOS CAPACITORES DEL MOTOR HAYAN DESCARGADO EL VOLTAJE ALMACENADO. PARA LAS UNIDADES CON EJE DE DIRECCIÓN DE VELOCIDAD VARIABLE, CONSULTE LAS INSTRUCCIONES PARA LA DESCARGA DEL CONDENSADOR.
FAILURE TO DO THE ABOVE BEFORE SERVICING COULD RESULT IN DEATH OR SERIOUS INJURY.	NE PAS RESPECTER CES MESURES DE PRÉCAUTION PEUT ENTRAÎNER DES BLESSURES GRAVES POUVANT ÊTRE MORTELLES.	EL NO REALIZAR LO ANTERIORMENTE INDICADO, PODRÍA OCASIONAR LA MUERTE O SERIAS LESIONES PERSONALES.

CAUTION	ATTENTION	PRECAUCIÓN
USE COPPER CONDUCTORS ONLY!	N'UTILISER QUE DES CONDUCTEURS EN CUIVRE!	¡UTILICE ÚNICAMENTE CONDUCTORES DE COBRE!
UNIT TERMINALS ARE NOT DESIGNED TO ACCEPT OTHER TYPES OF CONDUCTORS.	LES BORNES DE L'UNITÉ NE SONT PAS CONÇUES POUR RECEVOIR D'AUTRES TYPES DE CONDUCTEURS.	LAS TERMINALES DE LA UNIDAD NO ESTÁN DISEÑADAS PARA ACEPTAR OTROS TIPOS DE CONDUCTORES.
FAILURE TO DO SO MAY CAUSE DAMAGE TO THE EQUIPMENT.	L'UTILISATION DE TOUT AUTRE CONDUCTEUR PEUT ENDOMMAGER L'ÉQUIPEMENT.	SI NO LO HACE, PUEDE OCASIONAR DAÑO AL EQUIPO.

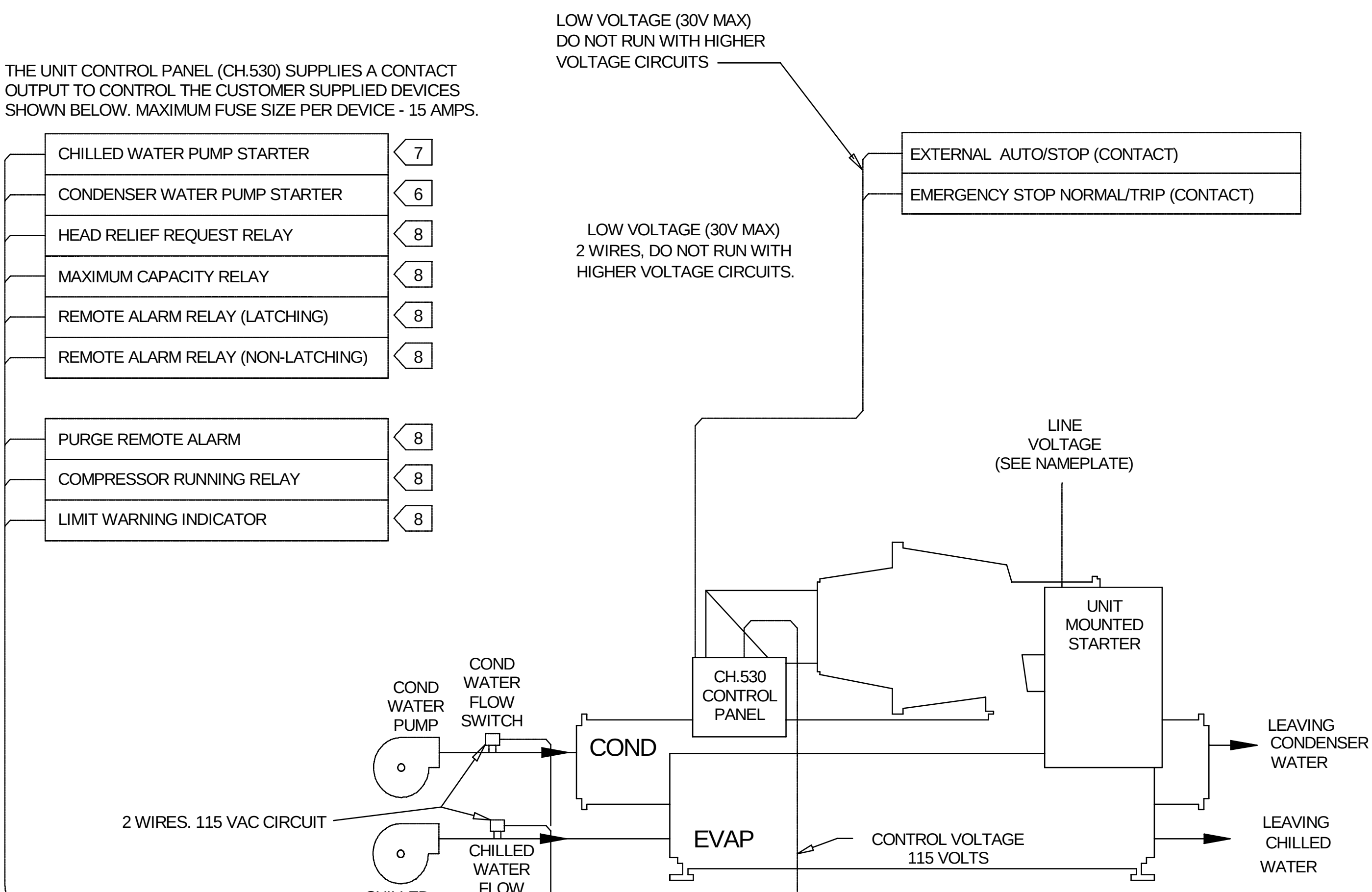
* CONNECTION DIAGRAMS ARE AVAILABLE AT THE WEBPAGE SHOWN IN THE MECHANICAL SPECIFICATIONS SECTION OF THIS SUBMITTAL.

NOTES:

1. DASHED LINES INDICATE RECOMMENDED FIELD WIRING BY OTHERS. CHECK SALES ORDER TO DETERMINE IF WIRING IS REQUIRED FOR SPECIFIC OPTIONS.
2. CAUTION - DO NOT ENERGIZE UNIT UNTIL CHECK-OUT AND START-UP PROCEDURES HAVE BEEN COMPLETED.

REQUIRED

3. ALL CUSTOMER CONTROL CIRCUIT WIRING MUST HAVE A MINIMUM RATING OF 150 VOLTS.
4. ALL FIELD WIRING MUST BE IN ACCORDANCE WITH THE NATIONAL ELECTRICAL CODE (NEC), STATE AND LOCAL REQUIREMENTS. OUTSIDE THE UNITED STATES, OTHER COUNTRIES APPLICABLE NATIONAL AND/OR LOCAL REQUIREMENTS SHALL APPLY.
5. EVAPORATOR AND CONDENSER FLOW SWITCHES ARE REQUIRED. THEY MUST BE INSTALLED AND WIRED TO THE TRANE PANEL BY THE INSTALLING CONTRACTOR. PURCHASE OF SWITCHES FROM TRANE IS OPTIONAL.
6. 2 WIRES, 115 VAC CIRCUIT, SEPARATE POWER SUPPLY IS REQUIRED. MINIMUM CONTACT RATING AT 115 VAC - 2.88 INDUCTIVE 1/3 H.P.(.25 kW) AT 115 VAC REQUIRED.
7. 2 WIRES, 115 VAC CIRCUIT, SEPARATE POWER SUPPLY IS REQUIRED. CONTACTS ARE N.O. CONTACT RATING - 2.88 INDUCTIVE 1/3 H.P.(.25 kW) AT 115 VAC OPTIONAL.
8. 2 OR 3 WIRES(N.O. &/OR N.C.), 115 VAC CIRCUIT, SEPARATE 115 VAC POWER SUPPLY IS REQUIRED. CONTACTS ARE NO/NC RATINGS - 2.88 INDUCTIVE 1/3 H.P.(.25 kW) AT 115 VAC.



FRONT ELEVATION

⚠WARNING

HAZARDOUS VOLTAGE!

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FAILURE TO DO THE ABOVE BEFORE SERVICING COULD RESULT IN DEATH OR SERIOUS INJURY.

⚠AVERTISSEMENT

TENSION DANGEREUSE!

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NE PAS RESPECTER CES MESURES DE PRÉCAUTION PEUT ENTRAÎNER DES BLESSURES GRAVES POUVANT ÊTRE MORTELLES.

⚠ADVERTENCIA

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EL NO REALIZAR LO ANTERIORMENTE INDICADO, PODRÍA OCASIONAR LA MUERTE O SERIAS LESIONES PERSONALES.

CAUTION

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FAILURE TO DO SO MAY CAUSE DAMAGE TO THE EQUIPMENT.

ATTENTION

N'UTILISER QUE DES CONDUCTEURS EN CUIVRE!

LES BORNES DE L'UNITÉ NE SONT PAS CONÇUES POUR RECEVOIR D'AUTRES TYPES DE CONDUCTEURS.

L'UTILISATION DE TOUT AUTRE CONDUCTEUR PEUT ENDOMMAGER L'ÉQUIPEMENT.

PRECAUCIÓN

¡UTILICE ÚNICAMENTE CONDUCTORES DE COBRE!

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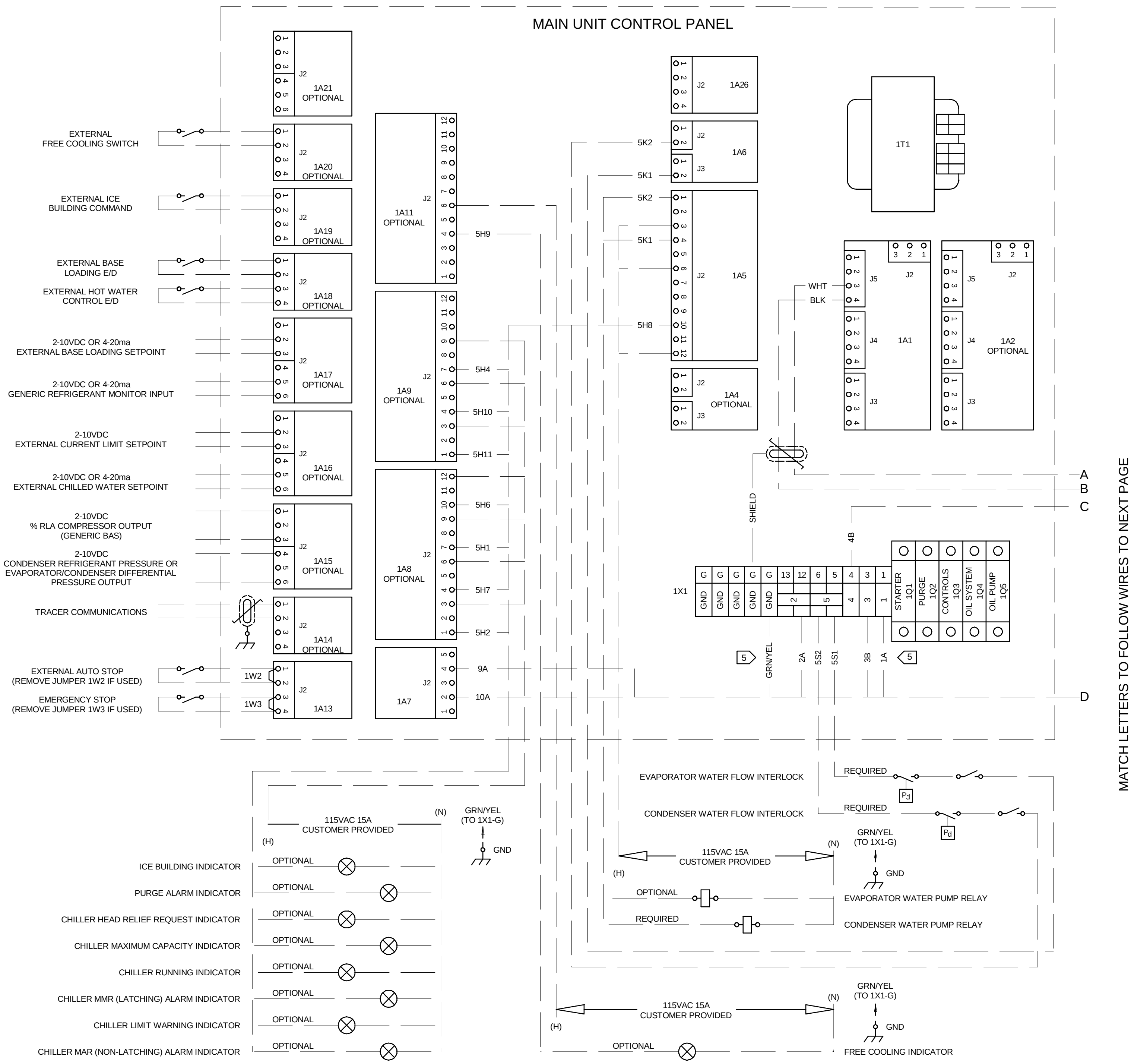

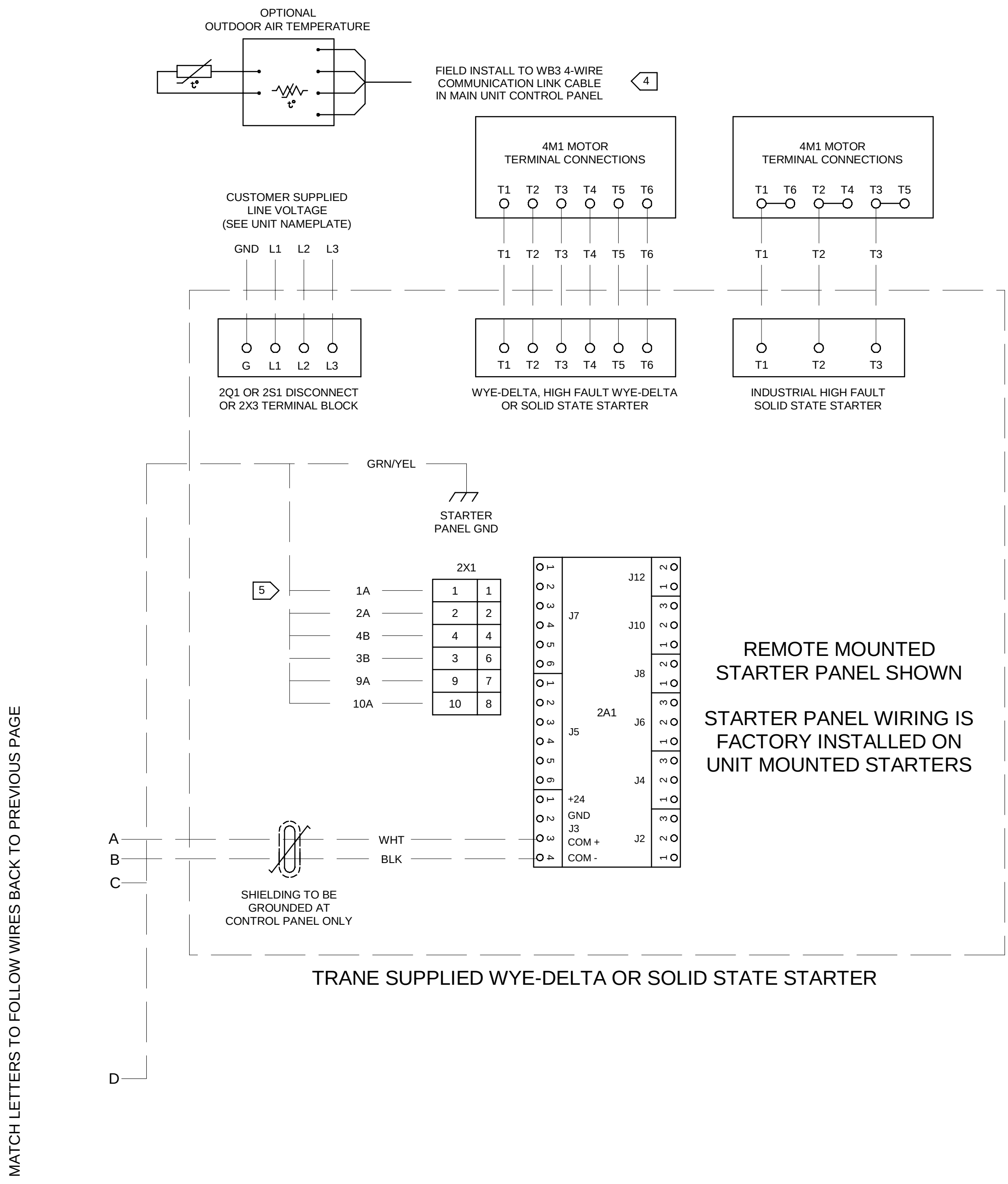

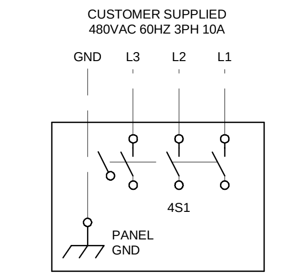

OPTIONAL TRANE SUPPLIED
CONTROL POWER TRANSFORMER

⚠ WARNING

HAZARDOUS VOLTAGE!

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⚠ AVERTISSEMENT

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NE PAS RESPECTER CES MESURES DE PRÉCAUTION PEUT ENTRAÎNER DES BLESSURES GRAVES POUVANT ÊTRE MORTELLES.

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L'UTILISATION DE TOUT AUTRE CONDUCTEUR PEUT ENDOMMAGER L'ÉQUIPEMENT.

PRECAUCIÓN

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SI NO LO HACE, PUEDE OCASIONAR DAÑO AL EQUIPO.

FIELD WIRING CIRCUIT SELECTION INFORMATION

WIRE NO OR DEVICE	CIRCUIT INFORMATION
SUPPLY AND MOTOR LEADS	SEE NAMEPLATE; MINIMUM CIRCUIT AMPACITY
1A*, 2A* AND GRN/YEL	4000VA AT 115 VAC, 8 AWG MAX WIRE SIZE
9A* AND 10A*	PUMP MOTOR; 1PH 3/4 HP, 11.7 FULL LOAD AMPS AT 115 VAC 14 AWG MAX WIRE SIZE
WB4	TWISTED, SHIELDED PAIR, 30 VDC, MAX LENGTH 1500 FT (BELDON TYPE 8760 RECOMMENDED)
5S1*, 5S2*, 3B* AND 4B*	CIRCUIT PROTECTED AT 20A, 115 VAC 1PH, 10 AWG MAX WIRE SIZE
5S3 THRU 5S8	24 VDC, 12mA RESISTIVE LOAD, 14 AWG MAX WIRE SIZE
ALL REMAINING CH530 LLID TERMINALS	CONTACT RATING; 2.88A INDUCTIVE, 1/3 HP, 0.25KW AT 115 VAC 14 AWG MAX WIRE SIZE

* TAPPED CONTROL CONDUCTORS

NOTES:

1. DASHED LINES INDICATE FIELD WIRING BY OTHERS. WIRE NUMBERS SHOWN ARE RECOMMENDED BY TRANE. CHECK SALES ORDER TO DETERMINE WHICH OPTIONS ARE PRESENT ON THE UNIT.
2. DO NOT ROUTE LOW VOLTAGE (30V) WITH CONTROL VOLTAGE (115V) AND DO NOT POWER UNIT UNTIL CHECK-OUT AND START-UP PROCEDURES HAVE BEEN COMPLETED.
3. EVAPORATOR AND CONDENSER WATER FLOW SWITCHES ARE REQUIRED AND MUST CONTAIN DPDT CONTACTS. THE SEPARATE FLOW SWITCHES ARE TO BE RUN IN SERIES WITH SEPARATE AUX CONTACTS FOR THE EVAPORATOR AND CONDENSER PUMPS. THEY MUST BE INSTALLED AND WIRED TO THE TRANE MAIN UNIT CONTROL PANEL BY THE INSTALLING CONTRACTOR. THE PURCHASE OF FLOW SWITCHES FROM TRANE IS OPTIONAL.

4 OPTIONAL 4R13 OUTDOOR AIR TEMPERATURE SENSOR IS SHIPPED WITH THE UNIT FOR FIELD INSTALLATION. REFER TO THE UNIT INSTALLATION LITERATURE FOR INSTALLATION OPTIONS AT THE JOB SITE.

5 WHEN CONTROL POWER TRANSFORMER (CPTR OPTION) IS PRESENT, WIRE 1A IS NOT REQUIRED, WIRE 2A CONNECTS TO 1X1-13 AND GRN/YEL STARTER PANEL GROUND WIRE IS CONNECTED ONE TERMINAL TO THE LEFT FROM WHERE IT IS CURRENTLY SHOWN ON 1X1.

Marley UPDATE™ Version 4.8.1
Product Data: 3/16/2007 (Current)

3/29/2007 4:14:44 PM

Job Information

Hilton Baltimore Convention Center Hotel
Centrifugal System
Baltimore Maryland

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	60.00 BHp
Model	NC8310H2	Fan Motor Output per cell	60.00 BHp
Cells	2	Fan Motor Output total	120.00 BHp
CTI Certified	Yes	Air Flow per cell	222000 cfm
Fan	10.00 ft, 6 Blades	Air Flow total	444100 cfm
Fan Speed	347 rpm, 10901 fpm	ASHRAE 90.1 Performance	49.7 gpm/Hp
Fans per cell	1		

Model Group: Standard
Sound Pressure Level: 81 dBA (Single Cell), 5.00 ft from Air Inlet Face. See sound report for details.

Conditions

Tower Water Flow	4560 gpm	Air Density In	0.07094 lb/ft³
Hot Water Temperature	96.75 °F	Air Density Out	0.07075 lb/ft³
Range	11.75 °F	Humidity Ratio In	0.01712
Cold Water Temperature	85.00 °F	Humidity Ratio Out	0.03184
Approach	7.00 °F	Wet-Bulb Temp. Out	90.64 °F
Wet-Bulb Temperature	78.00 °F	Estimated Evaporation	54 gpm
Relative Humidity	50 %	Total Heat Rejection	26692000 Btu/h

- This selection satisfies your design conditions.

Weights & Dimensions

	Per Cell	Total
Shipping Weight	14530 lb	29050 lb
Max Operating Weight	32200 lb	64400 lb
Width	22.42 ft	22.42 ft
Length	10.90 ft	22.08 ft
Height	19.81 ft	
Static Lift	19.07 ft	

Minimum Enclosure Clearance

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

Solid Wall	13.26 ft
50 % Open Wall	9.95 ft

Weights and dimensions do not include options; refer to sales drawings. For CAD layouts refer to file NC8310.dxf

Cold Weather Operation

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

Heater kW/Cell	24.0	18.0	15.0	12.0	9.0	7.5	6.0
Ambient Temperature °F	-21.02	-4.71	3.45	11.61	19.77	23.85	27.93

Marley UPDATE™ Version 4.8.1
Product Data: 3/16/2007 (Current)

3/29/2007 4:21:37 PM

Job Information

Hilton Baltimore Convention Center Hotel
Centrifugal System
Baltimore Maryland

Selected By

Penn State
104 Engineering Unit A
University Park, PA
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Tel 814-863-2076

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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	Design Range	11.75 °F
Product	NC Class	Fan Motor Output per cell	60.00 BHp	Design Wet-Bulb	78.00 °F
Model	NC8310H2	Fan Motor Efficiency	90.0 %	Cold Water Set Point	85.00 °F
Cells	2	Tower Water Flow	4560 gpm	Average Wet-Bulb	78.00 °F
Fan	10.00 ft, 6 Blades	Static Lift	19.07 ft	Range at Avg. Wet-Bulb	11.75 °F
Fans per cell	1	Pump Efficiency	70.0 %	Maximum Wet-Bulb	78.00 °F
Wet-Bulb Profile	Linear				

Interval Information					Single-Speed Fan			Two-Speed Fan				Variable-Speed Fan		Pump
Wet-Bulb Interval °F		Cold Water °F	Range °F	Hours	Hours Full	Hours Off	Energy kWh	Hours Full	Hours Half	Hours Off	Energy kWh	Total Fan Motor Output BHp	Energy kWh	Energy kWh
78.00	78.00	85.00	11.75	2000.0	1997.8	2.2	198635.9	1980.4	19.6	0.0	197187.9	116.83	193602.5	46831.2
Totals				2000.0	1997.8	2.2	198635.9	1980.4	19.6	0.0	197187.9		193602.5	46831.2

Horizon Absorption Units

Job Information

Hilton Baltimore Chillers
Washington DC
(D46)Joe Mulligan

Unit Information

Model number	**ABTF1050**
Tag	**ABH-2**
Quantity	**1**
Absorption unit model	**Two stage**
Unit nominal tonnage	**1050**
Unit energy source	**Steam**
Cooling capacity	**950.00 tons**
Unit coefficient of performance	**1.20 COP**
Elevation	**Sea Level**

Evaporator Information

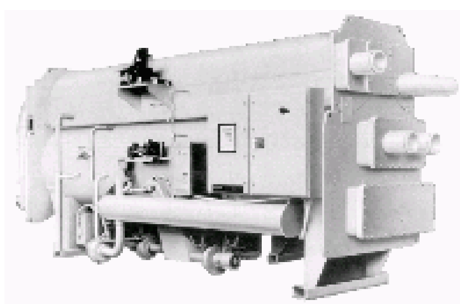
Evaporator LWT	**42.00 F**
Evaporator flow	**1621.13 gpm**
Evaporator EWT	**56.00 F**
Evaporator fouling factor	**0.00010 hr-sq ft-deg F/Btu**
Evaporator fluid type	**Water**
Evaporator fluid conc	**0.00 %**
Evaporator tube matl	**.025w Cu I/E**
Evaporator passes	**2P 150 psi non-marine victaulic**
Evaporator fluid velocity	**4.08 ft/s**
Evaporator pressure drop	**11.20 ft H2O**

Absorber / Condenser Information

Absorber EWT	**85.00 F**
Abs-Cond flow	**3440.32 gpm**
Condenser LWT	**97.00 F**
Abs-Cond fouling factor	**0.00025 hr-sq ft-deg F/Btu**
Abs-Cond fluid type	**Water**
Abs-Cond fluid conc	**0.00 %**
Absorber tube matl	**.022w 95-5 CuNi smooth surface**
Condenser tube matl	**.028 Cu smooth**
Absorber fluid velocity	**6.02 ft/s**
Condenser fluid velocity	**5.57 ft/s**
Abs-Cond pressure drop	**15.71 ft H2O**

Generator Information

Steam pressure to machine after valv	**102.18 psig**
Steam flow	**9344.49 lb/hr**
Steam rate	**9.84 lb/ton-hr**
High-temp generator tube matl	**.028 439 sstl smooth**
Low-temp generator tube matl	**.028 95-5 CuNi smooth**



ES:

NIT TO BE INSTALLED ON LEVEL SURFACE.

SE ANCHORING HOLES, AS REQUIRED, TO MEET LOCAL CODES.
NCHORING HARDWARE IS PROVIDED BY CUSTOMER.

OLATION PADS ARE SHIPPED IN LOOSE PARTS BOX FOR FIELD INSTALLATION.

ECOMMENDED SPACE ENVELOPE PROVIDES MINIMUM OF 36" (914mm)
LEARANCE AT RIGHT, LEFT, AND BACK ENDS OF UNIT WITH
" (1219 mm) AT FRONT. ALLOW MINIMUM OF
" (457mm) CLEARANCE ABOVE UNIT.

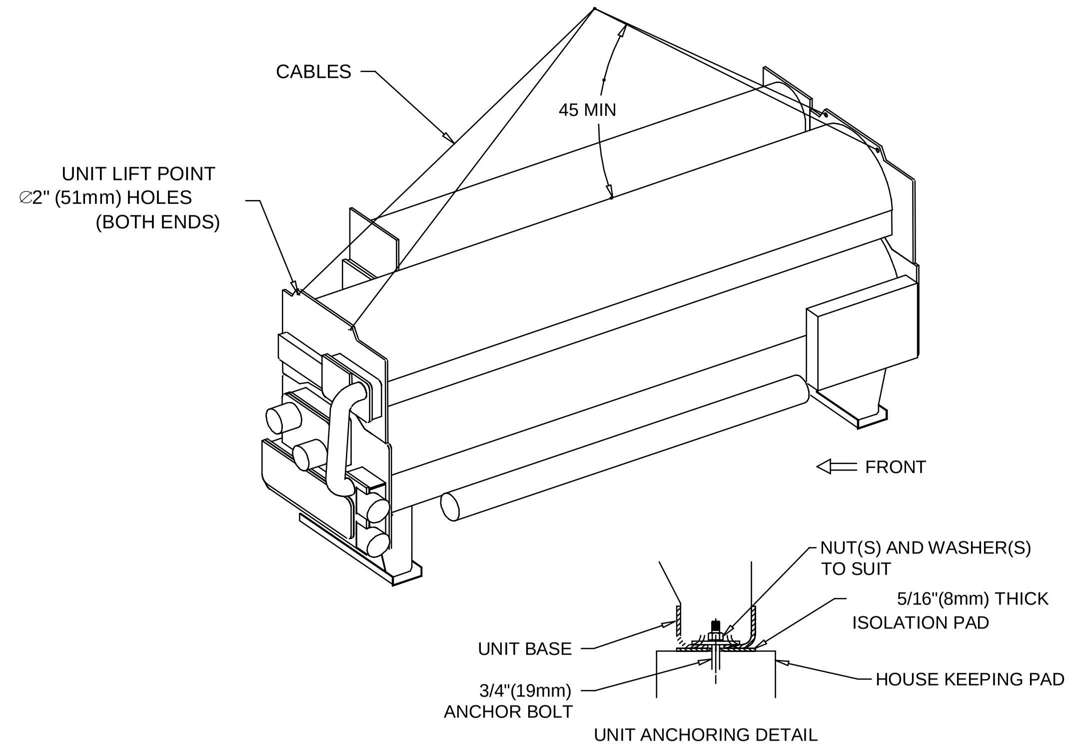
NINGS:

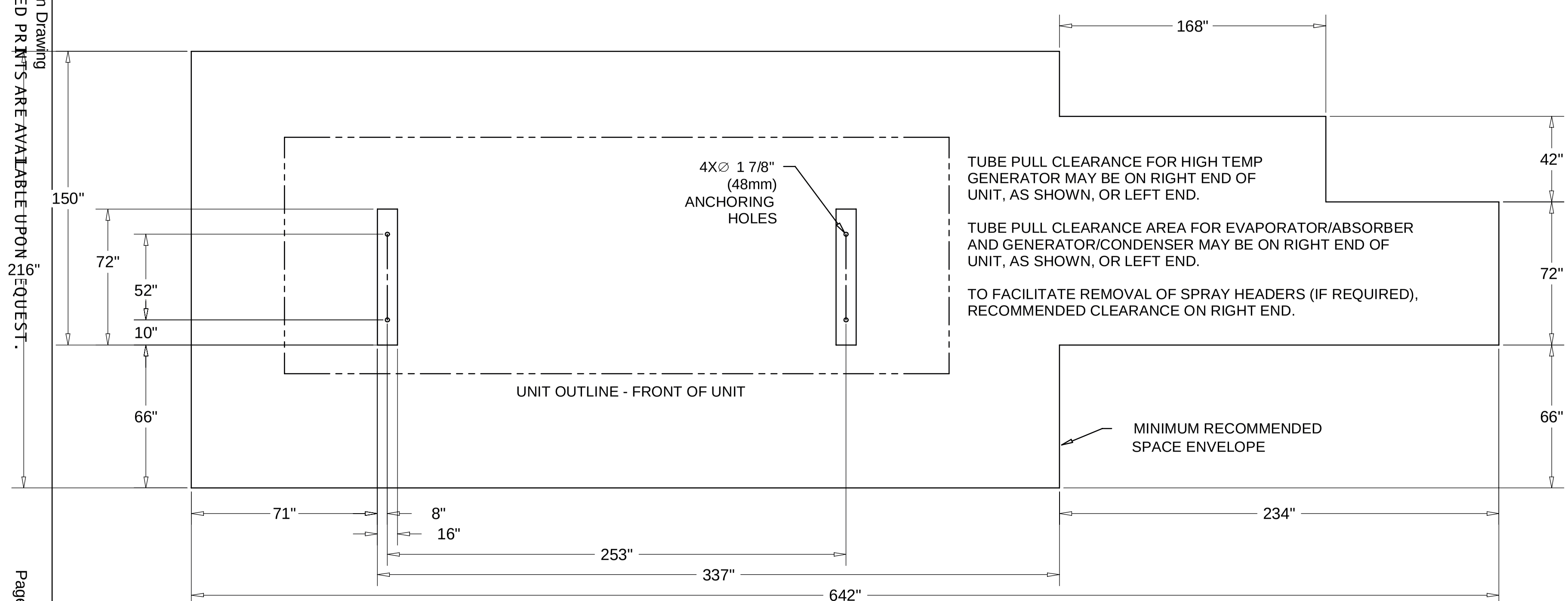
TACH CABLES ONLY AS SHOWN FOR 4 POINT LIFT
F UNIT. THE ANGLE FORMED BY THE CABLE RELATIVE TO THE
OP OF THE UNIT SHOULD NOT BE LESS THAN 45 °. OTHER
RRANGEMENTS MAY CAUSE EQUIPMENT DAMAGE
R SERIOUS PERSONAL INJURY.

ACH CABLE MUST BE CAPABLE OF SUPPORTING
HE ENTIRE WEIGHT OF THE UNIT.

TACH SAFETY CABLES AS RECOMMENDED IN INSTALLATION MANUAL.

PROXIMATE WEIGHT IN lb		MAXIMUM FLOOR LOAD IN psi
HIPPING/ GGING	OPERATING	
59900.0 lb	83100.0 lb	59.00 psi





Marley UPDATE™ Version 4.8.1
Product Data: 3/16/2007 (Current)

3/29/2007 4:26:52 PM

Job Information

Hilton Baltimore Convention Center Hotel
Absorption System
Baltimore Maryland

Selected By

Penn State
104 Engineering Unit A
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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	125.0 BHp
Model	NC8312R2	Fan Motor Output per cell	125.0 BHp
Cells	2	Fan Motor Output total	250.0 BHp
CTI Certified	Yes	Air Flow per cell	337300 cfm
Fan	12.00 ft, 7 Blades	Air Flow total	674600 cfm
Fan Speed	289 rpm, 10895 fpm	ASHRAE 90.1 Performance	36.7 gpm/Hp
Fans per cell	1		

Model Group: Standard
Sound Pressure Level: 85 dBA (Single Cell), 5.00 ft from Air Inlet Face. See sound report for details.

Conditions

Tower Water Flow	6880 gpm	Air Density In	0.07094 lb/ft³
Hot Water Temperature	97.00 °F	Air Density Out	0.07072 lb/ft³
Range	12.00 °F	Humidity Ratio In	0.01712
Cold Water Temperature	85.00 °F	Humidity Ratio Out	0.03201
Approach	7.00 °F	Wet-Bulb Temp. Out	90.80 °F
Wet-Bulb Temperature	78.00 °F	Estimated Evaporation	83 gpm
Relative Humidity	50 %	Total Heat Rejection	41128000 Btu/h

- This selection satisfies your design conditions.

Weights & Dimensions

	Per Cell	Total
Shipping Weight	22070 lb	44150 lb
Max Operating Weight	44710 lb	89430 lb
Width	22.42 ft	22.42 ft
Length	13.90 ft	28.08 ft
Height	23.33 ft	
Static Lift	19.21 ft	

Minimum Enclosure Clearance

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

Solid Wall	17.66 ft
50 % Open Wall	13.87 ft

Weights and dimensions do not include options; refer to sales drawings. For CAD layouts refer to file NC8312K.dxf

Cold Weather Operation

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

Heater kW/Cell	30.0	24.0	18.0	15.0	12.0	9.0	7.5
Ambient Temperature °F	-20.40	-7.45	5.50	11.98	18.45	24.93	28.17

Marley UPDATE™ Version 4.8.1
Product Data: 3/16/2007 (Current)

3/29/2007 4:29:04 PM

Job Information

Hilton Baltimore Convention Center Hotel
Absorption System
Baltimore Maryland

Selected By

Penn State
104 Engineering Unit A
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frank@hhassociates.com
Tel 717-796-2401
Fax 717-796-9717

Cooling Tower Definition

Manufacturer	Marley	Fan Motor Speed	1800 rpm	Design Range	12.00 °F
Product	NC Class	Fan Motor Output per cell	125.0 BHp	Design Wet-Bulb	78.00 °F
Model	NC8312R2	Fan Motor Efficiency	90.0 %	Cold Water Set Point	85.00 °F
Cells	2	Tower Water Flow	6880 gpm	Average Wet-Bulb	78.00 °F
Fan	12.00 ft, 7 Blades	Static Lift	19.21 ft	Range at Avg. Wet-Bulb	12.00 °F
Fans per cell	1	Pump Efficiency	70.0 %	Maximum Wet-Bulb	78.00 °F
Wet-Bulb Profile	Linear				

Interval Information					Single-Speed Fan			Two-Speed Fan				Variable-Speed Fan		Pump
Wet-Bulb Interval °F		Cold Water °F	Range °F	Hours	Hours Full	Hours Off	Energy kWh	Hours Full	Hours Half	Hours Off	Energy kWh	Total Fan Motor Output BHp	Energy kWh	Energy kWh
78.00	78.00	85.00	12.00	2000.0	1991.3	8.7	412484.8	1906.2	93.8	0.0	397621.4	221.1	366472.9	71198.0
Totals				2000.0	1991.3	8.7	412484.8	1906.2	93.8	0.0	397621.4		366472.9	71198.0

Bell & Gossett

SUBMITTAL

B-229.5B

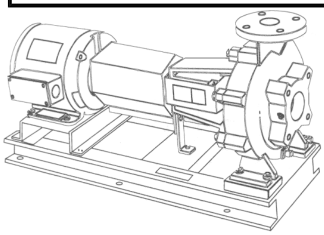
JOB:

REPRESENTATIVE:

UNIT TAG: | **SUBMITTED BY:** | **DATE:**

ENGINEER: | **APPROVED BY:** | **DATE:**

CONTRACTOR:



8G
Series 1510
Centrifugal Pumps - Base Mounted

SPECIFICATIONS

FLOW ______ HEAD ______

HP ______ RPM ______

VOLTS ______

CYCLE ______ PHASE ______

ENCLOSURE ______

APPROX. WEIGHT ______

SPECIALS ______

MATERIALS OF CONSTRUCTION

☐ BRONZE FITTED ☐ ALL IRON

FEATURES

☒ ANSI/OSHA Coupling Guard

☒ Fabricated Heavy Duty Baseplate

MAXIMUM WORKING PRESSURE

☐ 175 psi (12 bar) W.P.
w/ 125# ANSI flange drilling
(Max. Suction Pressure 75 psi [5.2 bar])

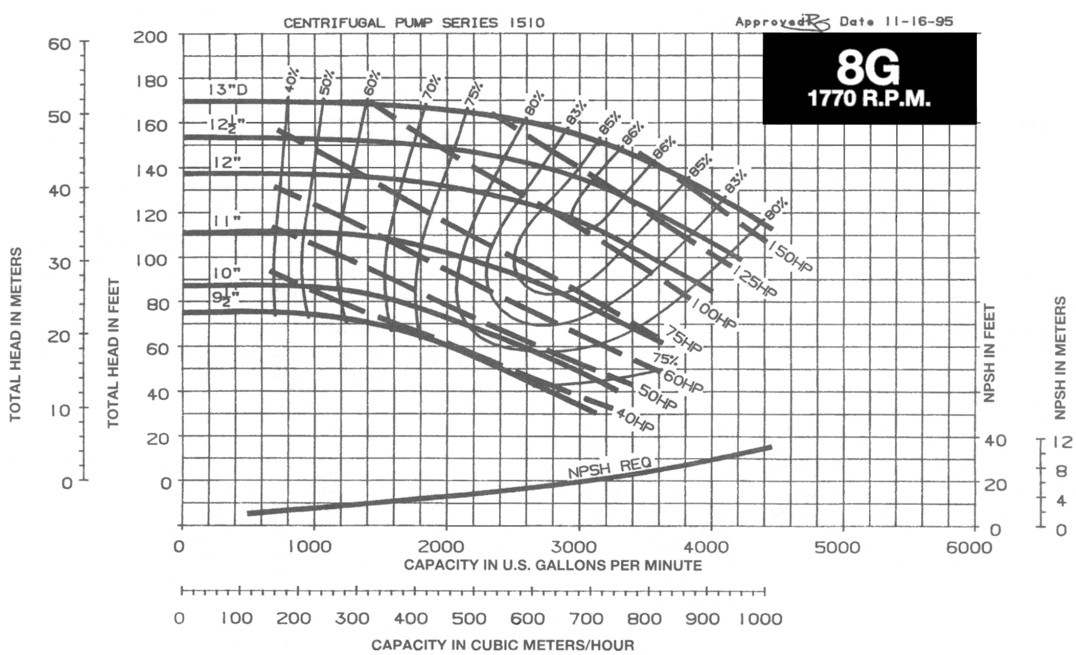
TYPE OF SEAL

☐ 1510 -S, Stuffing Box Construction
w/ Flushed Single Mechanical Seal
EPR-Carbon NiResist
Max 250°F[120°C]

☐ 1510 -S, Stuffing Box construction
w/ Flushed Mechanical Single Seal
EPR-Carbon/Tungsten Carbide
Max 250°F[120°C]

☐ 1510 -S, Stuffing Box construction
w/ Flushed Mechanical Seal
Buna-Carbon/Ceramic
Max 225°F[106°C]

Note: Equipped with EPDM coupling



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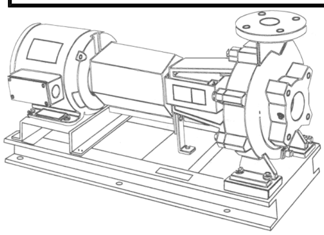
ITT Industries
Engineered for life

Bell & Gossett

SUBMITTAL

B-229.5B

JOB:	**REPRESENTATIVE:**	
UNIT TAG:	**SUBMITTED BY:**	**DATE:**
ENGINEER:	**APPROVED BY:**	**DATE:**
CONTRACTOR:		



8G
Series 1510
Centrifugal Pumps - Base Mounted

SPECIFICATIONS

FLOW ____________ HEAD ____________

HP ____________ RPM ____________

VOLTS ____________

CYCLE ____________ PHASE ____________

ENCLOSURE ____________

APPROX. WEIGHT ____________

SPECIALS ____________

MATERIALS OF CONSTRUCTION

☐ BRONZE FITTED ☐ ALL IRON

FEATURES

☒ ANSI/OSHA Coupling Guard

☒ Fabricated Heavy Duty Baseplate

MAXIMUM WORKING PRESSURE

☐ 175 psi (12 bar) W.P.
w/ 125# ANSI flange drilling
(Max. Suction Pressure 75 psi [5.2 bar])

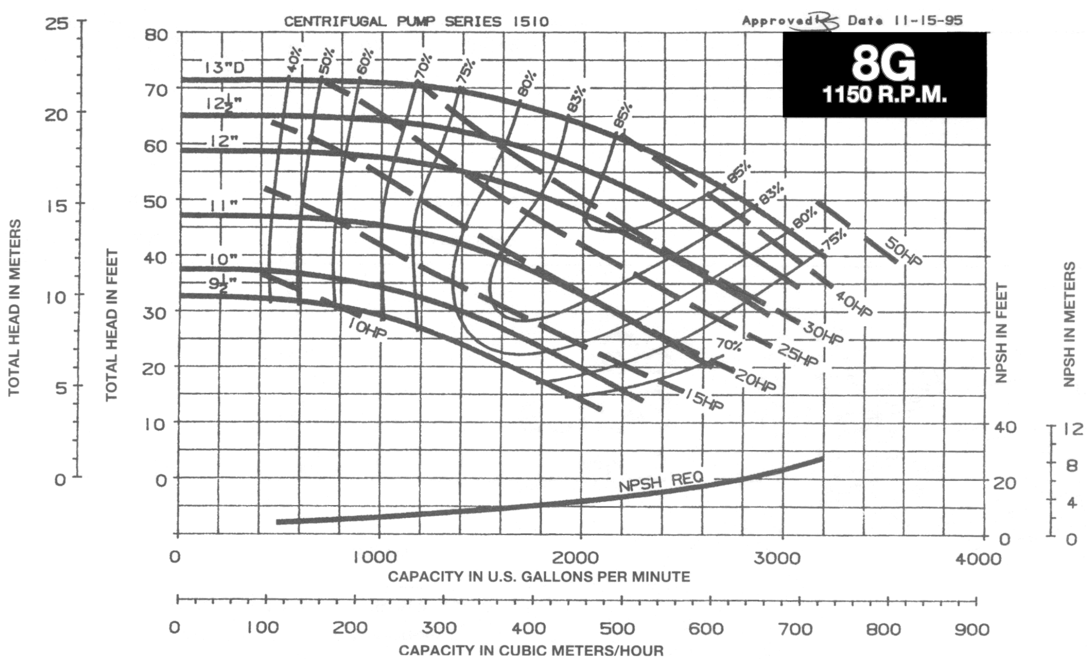
TYPE OF SEAL

☐ 1510 -S, Stuffing Box Construction
w/ Flushed Single Mechanical Seal
EPR-Carbon NiResist
Max 250°F[120°C]

☐ 1510 -S, Stuffing Box construction
w/ Flushed Mechanical Single Seal
EPR-Carbon/Tungsten Carbide
Max 250°F[120°C]

☐ 1510 -S, Stuffing Box construction
w/ Flushed Mechanical Seal
Buna-Carbon/Ceramic
Max 225°F[106°C]

Note: Equipped with EPDM coupling



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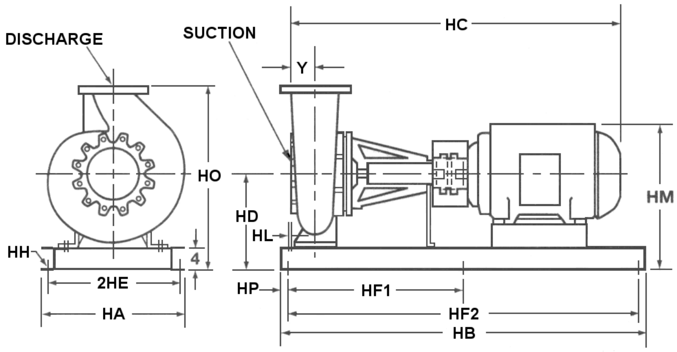
Series 1510 8G Centrifugal Pump Submittal　　B-229.5B



FLANGE DIMENSIONS IN INCHES (MM)	
	SIZE
Discharge	8" (127)
Suction	10" (152)

FLANGES ARE: 125# ANSI - STANDARD

DIMENSIONS - Inches (mm)　　**STUFFING BOX 1510-S**

MOTOR FRAME	HA	HB	HC MAX	HD	2HE	HF_1	HF_2	HH	HL	HM MAX	HO	HP	Y
284T	28 (711)	70 (1778)	57-3/8 (1457)	18-3/8 (467)	26 (660)	33-3/4 (857)	67-1/2 (1715)	1 (25)	7/16 (11)	26-1/8 (664)	35-11/16 (907)	1-1/4 (32)	4-5/64 (121)
286T	28 (711)	70 (1778)	58-7/8 (1495)	18-3/8 (467)	26 (660)	33-3/4 (857)	67-1/2 (1715)	1 (25)	7/16 (11)	26-1/8 (664)	35-11/16 (907)	1-1/4 (32)	4-5/64 (121)
324T	28 (711)	70 (1778)	60-1/2 (1537)	18-3/8 (467)	26 (660)	33-3/4 (857)	67-1/2 (1715)	1 (25)	7/16 (11)	27 (686)	35-11/16 (907)	1-1/4 (32)	4-5/64 (121)
326T	28 (711)	70 (1778)	62 (1575)	18-3/8 (467)	26 (660)	33-3/4 (857)	67-1/2 (1715)	1 (25)	7/16 (11)	27 (686)	35-11/16 (907)	1-1/4 (32)	4-5/64 (121)
364T	28 (711)	70 (1778)	65-1/8 (1654)	18-3/8 (467)	26 (660)	33-3/4 (857)	67-1/2 (1715)	1 (25)	7/16 (11)	27-1/2 (699)	35-11/16 (907)	1-1/4 (32)	4-5/64 (121)
364TS	28 (711)	70 (1778)	63-5/8 (1616)	18-3/8 (467)	26 (660)	33-3/4 (857)	67-1/2 (1715)	1 (25)	7/16 (11)	27-1/2 (699)	35-11/16 (907)	1-1/4 (32)	4-5/64 (121)
365T	28 (711)	70 (1778)	66-1/8 (1680)	18-3/8 (467)	26 (660)	33-3/4 (857)	67-1/2 (1715)	1 (25)	7/16 (11)	27-1/2 (699)	35-11/16 (907)	1-1/4 (32)	4-5/64 (121)
365TS	28 (711)	70 (1778)	64-11/16 (1643)	18-3/8 (467)	26 (660)	33-3/4 (857)	67-1/2 (1715)	1 (25)	7/16 (11)	27-1/2 (699)	35-11/16 (907)	1-1/4 (32)	4-5/64 (121)
404TS	28 (711)	70 (1778)	68-1/4 (1734)	18-3/8 (467)	26 (660)	33-3/4 (857)	67-1/2 (1715)	1 (25)	7/16 (11)	28-3/4 (730)	35-11/16 (907)	1-1/4 (32)	4-5/64 (121)
405TS	28 (711)	70 (1778)	69-3/4 (1772)	18-3/8 (467)	26 (660)	33-3/4 (857)	67-1/2 (1715)	1 (25)	7/16 (11)	28-3/4 (730)	35-11/16 (907)	1-1/4 (32)	4-5/64 (121)
444TS	28 (711)	70 (1778)	73-3/8 (1864)	18-3/8 (467)	26 (660)	33-3/4 (857)	67-1/2 (1715)	1 (25)	7/16 (11)	30-1/8 (765)	35-11/16 (907)	1-1/4 (32)	4-5/64 (121)
445TS	28 (711)	70 (1778)	75-3/8 (407)	18-3/8 (467)	26 (660)	33-3/4 (857)	67-1/2 (1715)	1 (25)	7/16 (11)	30-1/8 (765)	35-11/16 (907)	1-1/4 (32)	4-5/64 (121)

Dimensions are subject to change. Not to be used for construction purposes unless certified.

ITT Industries

Bell & Gossett

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Phone (847)966-3700
Facsimile (847)966-9052
www.bellgossett.com

TÜV CERT DIN ISO 9001
ISO 9001 Certified

Andrew Rhodes

The Pennsylvania State University
Architectural Engineering – Mechanical

The Hilton Baltimore Convention Center Hotel

Appendix C

Building Model Outputs

Hourly Analysis of Absorption with Backpressure Steam Turbine														
Day	Hour	Total Electrical Usage (kWh)	Total Thermal Usage (Btu)	Mlb of Steam Use	PRSG Power Output (kWh/Mlb)	Electricity Produced (kWh)	Electricity From Grid (kWh)	Energy Charge ($/kWh)	Energy Charge ($)	Running Tally of Highest Monthly kW	Highest Monthly kW	$ per kW Demand Charge	Demand Charge ($)	Minimum Monthly Charge ($)
1-Jan	1	659	12337150	4.096	10	41	618	0.05118	31.63	618	1617	3.72	6015.24	110
	2	659	9257494	3.073	10	31	628	0.05118	32.15	628			0	
	3	537	9447993	3.137	10	31	505	0.05118	25.85	628			0	
	4	537	9584991	3.182	10	32	505	0.05118	25.83	628			0	
	5	537	9986707	3.316	10	33	503	0.05118	25.76	628			0	
	6	537	11049524	3.668	10	37	500	0.05118	25.58	628			0	
	7	659	10823139	3.593	10	36	623	0.05118	31.89	628			0	
	8	850	11282881	3.746	10	37	813	0.05534	44.97	813			0	
	9	877	12043474	3.998	10	40	837	0.05534	46.29	837			0	
	10	754	10755498	3.571	10	36	718	0.05534	39.75	837			0	
	11	754	9401457	3.121	10	31	723	0.05534	39.99	837			0	
	12	723	8989510	2.985	10	30	693	0.05406	37.44	837			0	
	13	662	9168273	3.044	10	30	632	0.05406	34.14	837			0	
	14	457	9470908	3.144	10	31	425	0.05406	22.98	837			0	
	15	457	9083970	3.016	10	30	426	0.05406	23.05	837			0	
	16	457	9294736	3.086	10	31	426	0.05406	23.02	837			0	
	17	474	9653088	3.205	10	32	441	0.05406	23.86	837			0	
	18	488	9773721	3.245	10	32	456	0.05534	25.21	837			0	
	19	853	9362851	3.108	10	31	821	0.05534	45.46	837			0	
	20	1126	9299124	3.087	10	31	1095	0.05534	60.60	1095			0	
	21	1248	8749572	2.905	10	29	1219	0.05534	67.48	1219			0	
	22	1040	9201314	3.055	10	31	1010	0.05118	51.68	1219			0	
	23	915	9515624	3.159	10	32	884	0.05118	45.23	1219			0	
	24	676	9753140	3.238	10	32	643	0.05118	32.93	1219			0	

2-Jan	1	572	9094808	3.019	10	30	542	0.05118	27.73	1219			0	
	2	572	8721929	2.896	10	29	543	0.05118	27.79	1219			0	
	3	448	8807466	2.924	10	29	419	0.05118	21.45	1219			0	
	4	448	8892743	2.952	10	30	419	0.05118	21.43	1219			0	
	5	448	9423132	3.128	10	31	417	0.05118	21.34	1219			0	
	6	572	10332105	3.430	10	34	538	0.05118	27.52	1219			0	
	7	779	11191114	3.715	10	37	742	0.05118	37.98	1219			0	
	8	848	12452132	4.134	10	41	807	0.05534	44.66	1219			0	
	9	733	11639875	3.864	10	39	695	0.05534	38.44	1219			0	
	10	702	10591422	3.516	10	35	666	0.05534	36.88	1219			0	
	11	575	10626192	3.528	10	35	540	0.05534	29.87	1219			0	
	12	460	9806657	3.256	10	33	427	0.05406	23.10	1219			0	
	13	460	9774869	3.245	10	32	427	0.05406	23.10	1219			0	
	14	460	9321148	3.095	10	31	429	0.05406	23.18	1219			0	
	15	529	8515930	2.827	10	28	501	0.05406	27.06	1219			0	
	16	546	8410915	2.792	10	28	518	0.05406	28.01	1219			0	
	17	578	7882587	2.617	10	26	551	0.05406	29.81	1219			0	
	18	621	7709369	2.560	10	26	595	0.05534	32.94	1219			0	
	19	1119	7625540	2.532	10	25	1093	0.05534	60.50	1219			0	
	20	1392	7678044	2.549	10	25	1366	0.05534	75.62	1366			0	
	21	1647	10933968	3.630	10	36	1611	0.05534	89.15	1611			0	
	22	1501	8288322	2.752	10	28	1473	0.05118	75.39	1611			0	
	23	1182	7203914	2.392	10	24	1158	0.05118	59.26	1611			0	
	24	756	7320088	2.430	10	24	732	0.05118	37.45	1611			0	

	9	733	12039425	3.997	10	40	693	0.05534	38.37	1614			0	
	10	702	10799073	3.585	10	36	666	0.05534	36.85	1614			0	
	11	575	9931868	3.297	10	33	542	0.05534	29.99	1614			0	
	12	460	9857849	3.273	10	33	427	0.05406	23.09	1614			0	
	13	460	9921362	3.294	10	33	427	0.05406	23.08	1614			0	
	14	460	9584190	3.182	10	32	428	0.05406	23.14	1614			0	
	15	529	9060088	3.008	10	30	499	0.05406	26.97	1614			0	
	16	546	9115506	3.026	10	30	516	0.05406	27.89	1614			0	
	17	578	8933073	2.966	10	30	548	0.05406	29.63	1614			0	
	18	621	8563232	2.843	10	28	592	0.05534	32.79	1614			0	
	19	1119	8041130	2.670	10	27	1092	0.05534	60.42	1614			0	
	20	1392	8069778	2.679	10	27	1365	0.05534	75.55	1614			0	
	21	1516	7441225	2.470	10	25	1491	0.05534	82.51	1614			0	
	22	1406	7347218	2.439	10	24	1382	0.05118	70.73	1614			0	
	23	1182	7284885	2.419	10	24	1158	0.05118	59.25	1614			0	
	24	756	6871632	2.281	10	23	733	0.05118	37.52	1614			0	
Totals									**445692.33**				**73425.4**	**1320**

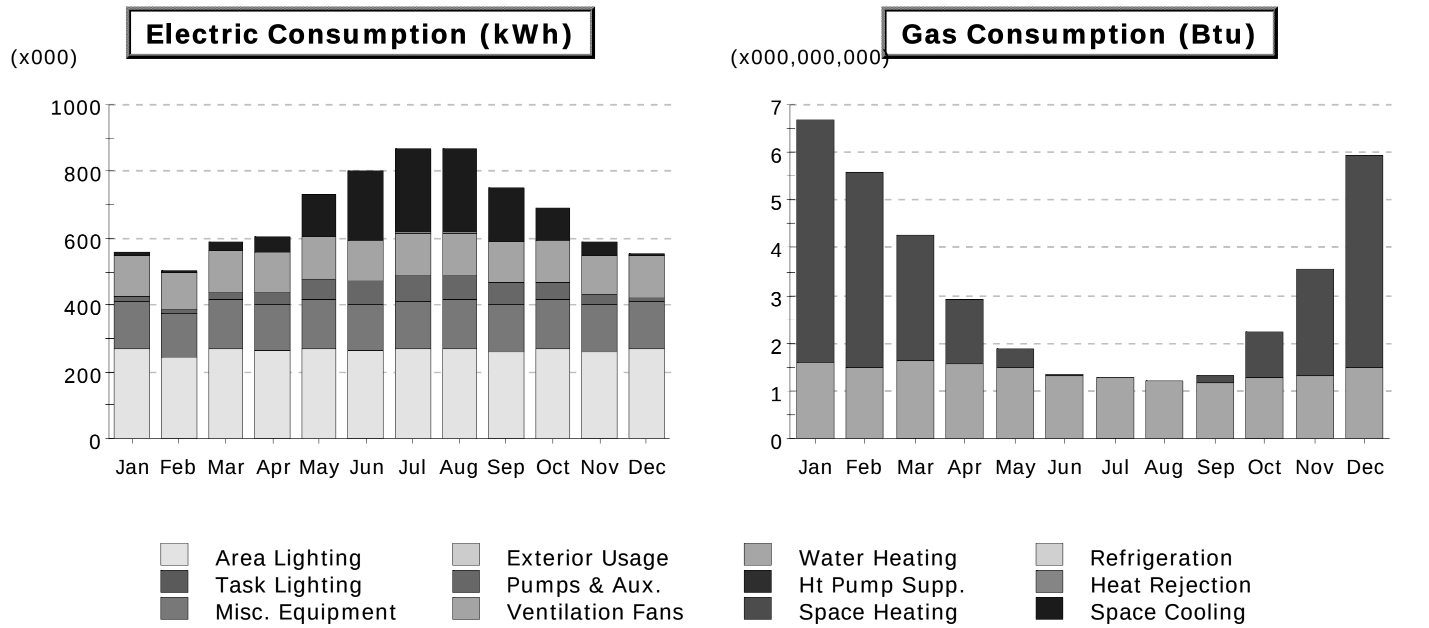
Total Electric Bill =	**$520,437.69**
Total Steam Bill =	**$477,028.00**
Yearly Utility Bill =	**$997,465.69**

Hourly Analysis of Pressure Reducing Steam Turbine in District System											
Day	**Hour**	**Cooling Electrical Usage (kWh)**	**Cooling (Ton-Hr)**	**Cooling Usage Charge ($/Ton-Hr)**	**Cooling Usage Charge ($)**	**Total Electrical Usage (kWh)**	**Total Non-Cooling Electrical Usage (kWh)**	**Total Thermal Usage (Btu)**	**Mlb of Steam Use**	**PRSG Power Output (kWh/Mlb)**	**Electricity Produced (kWh)**
1-Jan	1	0	0	0.15	0.00	659	659	10353612	3.437	10	34
	2	0	0	0.15	0.00	658.9	658.9	8223869	2.730	10	27
	3	0	0	0.15	0.00	536.5	536.5	8391002	2.786	10	28
	4	0	0	0.15	0.00	536.5	536.5	8521653	2.829	10	28
	5	0	0	0.15	0.00	536.5	536.5	8925100	2.963	10	30
	6	0	0	0.15	0.00	536.6	536.6	9982558	3.314	10	33
	7	0	0	0.15	0.00	659	659	9764760	3.242	10	32
	8	0	0	0.15	0.00	850	850	10241005	3.400	10	34
	9	0	0	0.15	0.00	876.6	876.6	11046474	3.667	10	37
	10	0	0	0.15	0.00	754	754	9816640	3.259	10	33
	11	0	0	0.15	0.00	754	754	8528824	2.832	10	28
	12	0	0	0.15	0.00	722.5	722.5	8174103	2.714	10	27
	13	0	0	0.15	0.00	662	662	8329801	2.765	10	28
	14	0	0	0.15	0.00	456.5	456.5	8526815	2.831	10	28
	15	0	0	0.15	0.00	456.5	456.5	8129063	2.699	10	27
	16	0	0	0.15	0.00	456.6	456.6	8308617	2.758	10	28
	17	0	0	0.15	0.00	473.6	473.6	8621093	2.862	10	29
	18	0	0	0.15	0.00	488.1	488.1	8737384	2.901	10	29
	19	0	0	0.15	0.00	852.5	852.5	8436732	2.801	10	28
	20	0	0	0.15	0.00	1125.9	1125.9	8508358	2.825	10	28
	21	0	0	0.15	0.00	1248.4	1248.4	7957464	2.642	10	26
	22	0	0	0.15	0.00	1040.3	1040.3	8496043	2.821	10	28
	23	0	0	0.15	0.00	915.3	915.3	8693500	2.886	10	29
	24	0	0	0.15	0.00	675.8	675.8	8831052	2.932	10	29

Electricity From Grid (kWh)	Energy Charge ($/kWh)	Energy Charge ($)	Running Tally of Highest Monthly kW	Highest Monthly kW	$ per kW Demand Charge	Demand Charge ($)	
625	0.05118	31.97	625	1593	3.72	5925.96	
632	0.05118	32.33	632			0	
509	0.05118	26.03	632			0	
508	0.05118	26.01	632			0	
507	0.05118	25.94	632			0	
503	0.05118	25.77	632			0	
627	0.05118	32.07	632			0	
816	0.05534	45.16	816			0	
840	0.05534	46.48	840			0	
721	0.05534	39.92	840			0	
726	0.05534	40.16	840			0	
695	0.05406	37.59	840			0	
634	0.05406	34.29	840			0	
428	0.05406	23.15	840			0	
430	0.05406	23.22	840			0	
429	0.05406	23.19	840			0	
445	0.05406	24.06	840			0	
459	0.05534	25.41	840			0	
824	0.05534	45.63	840			0	
1098	0.05534	60.74	1098			0	
1222	0.05534	67.62	1222			0	
1012	0.05118	51.80	1222			0	
886	0.05118	45.37	1222			0	
646	0.05118	33.09	1222			0	

Hourly Analysis of District System Without CHP														
Day	Hour	Cooling Electrical Usage (kWh)	Cooling (Ton-Hr)	Cooling Usage Charge ($/Ton-Hr)	Cooling Usage Charge ($)	Total Electrical Usage (kWh)	Total Non-Cooling Electrical Usage (kWh)	Energy Charge ($/kWh)	Energy Charge ($)	Running Tally of Highest Monthly kW	Highest Monthly kW	$ per kW Demand Charge	Demand Charge ($)	
1-Jan	1	0	0	0.15	0.00	659	659	0.05118	33.73	659	1614	3.72	6004.08	
	2	0	0	0.15	0.00	658.9	658.9	0.05118	33.72	659			0	
	3	0	0	0.15	0.00	536.5	536.5	0.05118	27.46	659			0	
	4	0	0	0.15	0.00	536.5	536.5	0.05118	27.46	659			0	
	5	0	0	0.15	0.00	536.5	536.5	0.05118	27.46	659			0	
	6	0	0	0.15	0.00	536.6	536.6	0.05118	27.46	659			0	
	7	0	0	0.15	0.00	659	659	0.05118	33.73	659			0	
	8	0	0	0.15	0.00	850	850	0.05534	47.04	850			0	
	9	0	0	0.15	0.00	876.6	876.6	0.05534	48.51	877			0	
	10	0	0	0.15	0.00	754	754	0.05534	41.73	877			0	
	11	0	0	0.15	0.00	754	754	0.05534	41.73	877			0	
	12	0	0	0.15	0.00	722.5	722.5	0.05406	39.06	877			0	
	13	0	0	0.15	0.00	662	662	0.05406	35.79	877			0	
	14	0	0	0.15	0.00	456.5	456.5	0.05406	24.68	877			0	
	15	0	0	0.15	0.00	456.5	456.5	0.05406	24.68	877			0	
	16	0	0	0.15	0.00	456.6	456.6	0.05406	24.68	877			0	
	17	0	0	0.15	0.00	473.6	473.6	0.05406	25.60	877			0	
	18	0	0	0.15	0.00	488.1	488.1	0.05534	27.01	877			0	
	19	0	0	0.15	0.00	852.5	852.5	0.05534	47.18	877			0	
	20	0	0	0.15	0.00	1125.9	1125.9	0.05534	62.31	1126			0	
	21	0	0	0.15	0.00	1248.4	1248.4	0.05534	69.09	1248			0	
	22	0	0	0.15	0.00	1040.3	1040.3	0.05118	53.24	1248			0	
	23	0	0	0.15	0.00	915.3	915.3	0.05118	46.85	1248			0	
	24	0	0	0.15	0.00	675.8	675.8	0.05118	34.59	1248			0	

2-Jan	1	0	0	0.15	0.00	572	572	0.05118	29.27	1248			0	
	2	0	0	0.15	0.00	572	572	0.05118	29.27	1248			0	
	3	0	0	0.15	0.00	448.3	448.3	0.05118	22.94	1248			0	
	4	0	0	0.15	0.00	448.3	448.3	0.05118	22.94	1248			0	
	5	0	0	0.15	0.00	448.4	448.4	0.05118	22.95	1248			0	
	6	0	0	0.15	0.00	572.1	572.1	0.05118	29.28	1248			0	
	7	0	0	0.15	0.00	779.3	779.3	0.05118	39.88	1248			0	
	8	0	0	0.15	0.00	848.4	848.4	0.05534	46.95	1248			0	
	9	0	0	0.15	0.00	733.3	733.3	0.05534	40.58	1248			0	
	10	0	0	0.15	0.00	701.6	701.6	0.05534	38.83	1248			0	
	11	0	0	0.15	0.00	575	575	0.05534	31.82	1248			0	
	12	0	0	0.15	0.00	459.9	459.9	0.05406	24.86	1248			0	
	13	0	0	0.15	0.00	459.8	459.8	0.05406	24.86	1248			0	
	14	0	0	0.15	0.00	459.8	459.8	0.05406	24.86	1248			0	
	15	0	0	0.15	0.00	528.8	528.8	0.05406	28.59	1248			0	
	16	0	0	0.15	0.00	546	546	0.05406	29.52	1248			0	
	17	0	0	0.15	0.00	577.6	577.6	0.05406	31.23	1248			0	
	18	0	0	0.15	0.00	620.8	620.8	0.05534	34.36	1248			0	
	19	0	0	0.15	0.00	1118.4	1118.4	0.05534	61.89	1248			0	
	20	0	0	0.15	0.00	1391.7	1391.7	0.05534	77.02	1392			0	
	21	228	65	0.15	9.72	1842.3	1614.3	0.05534	89.34	1614			0	
	22	46.6	13	0.15	1.99	1513.7	1467.1	0.05118	75.09	1614			0	
	23	0	0	0.15	0.00	1181.6	1181.6	0.05118	60.47	1614			0	
	24	0	0	0.15	0.00	755.9	755.9	0.05118	38.69	1614			0	

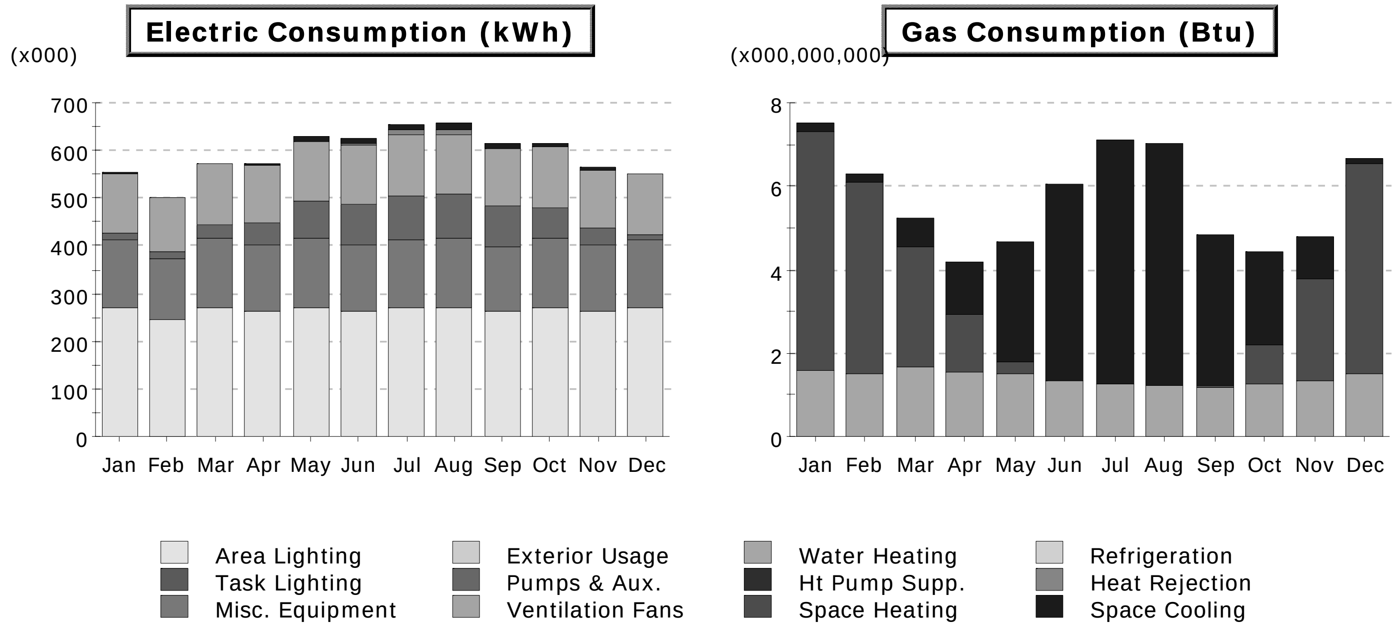


Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	6.8	6.4	25.6	47.6	128.5	205.6	247.9	246.4	161.4	97.5	39.2	4.6	1,217.5
Heat Reject.	-	-	-	-	0.3	3.1	6.0	6.6	0.5	0.1	0.0	-	16.7
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	125.6	113.5	125.6	121.6	125.6	121.6	125.6	125.6	121.6	125.6	121.6	125.6	1,479.3
Pumps & Aux.	10.6	10.2	23.3	35.8	62.8	70.7	74.7	74.4	67.5	52.1	29.3	8.6	520.1
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	143.1	129.3	143.3	138.6	143.3	138.6	143.1	143.5	138.2	143.3	138.4	142.9	1,685.7
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	270.2	244.2	271.2	261.8	270.8	262.4	270.1	271.3	261.2	270.9	261.3	270.0	3,185.5
Total	556.4	503.5	589.1	605.5	731.4	802.0	867.5	867.9	750.4	689.5	589.9	551.8	8,104.8

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	5.10	4.08	2.62	1.35	0.39	0.04	0.01	0.01	0.13	0.95	2.24	4.44	21.35
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	1.59	1.49	1.65	1.56	1.49	1.32	1.27	1.21	1.17	1.27	1.33	1.49	16.83
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	6.69	5.57	4.26	2.90	1.88	1.36	1.27	1.22	1.30	2.22	3.57	5.93	38.19



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.9	0.9	2.8	4.6	9.0	10.6	11.5	11.5	10.0	7.3	3.7	0.7	73.6
Heat Reject.	-	-	-	-	0.4	4.9	10.1	11.3	0.7	0.1	0.0	-	27.5
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	125.6	113.5	125.6	121.6	125.6	121.6	125.6	125.6	121.6	125.6	121.6	125.6	1,479.3
Pumps & Aux.	13.5	13.1	30.8	46.9	79.2	87.5	92.7	92.6	84.0	66.1	38.2	10.7	655.1
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	143.1	129.3	143.3	138.6	143.3	138.6	143.1	143.5	138.2	143.3	138.4	142.9	1,685.7
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	270.2	244.2	271.2	261.8	270.8	262.4	270.1	271.3	261.2	270.9	261.3	270.0	3,185.5
Total	553.4	500.9	573.6	573.6	628.4	625.7	653.2	655.9	615.7	613.3	563.3	549.9	7,106.8

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.20	0.19	0.71	1.25	2.91	4.73	5.83	5.81	3.61	2.22	1.00	0.14	28.59
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	5.73	4.60	2.90	1.39	0.28	0.01	0.00	0.00	0.06	0.94	2.45	5.03	23.39
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	1.59	1.49	1.65	1.56	1.49	1.32	1.27	1.21	1.17	1.27	1.33	1.49	16.83
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	7.52	6.28	5.25	4.19	4.68	6.06	7.10	7.02	4.84	4.43	4.78	6.66	68.82