Architectural Engineering Senior Thesis Report

Energy Efficient Central Chilled Water Plant Design

Hilton Hotel at BWI Airport
Linthicum Heights, MD

Nathan Patrick
Mechanical Option

Prepared For:
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Friday, April 7, 2006

Hilton Hotel at BWI Airport

Linthicum Heights, MD

Project Information

Estimated Project Cost: $27 million
Size: 277,000 sq ft (gross)
Project Delivery Method: Design-Build
Construction: June 2005–October 2006
Stories: 11 above grade and a penthouse, 1 below grade parking garage level
Function: Full-service hotel
Occupancy: Guest rooms, restaurant, bar, meeting rooms, offices, pool, exercise room

Project Team

Owner: Buccini/Pollin Group, Inc
GC: Hitt Contracting, Inc
Architect: Brennan Beer Gorman Monk PLLC
Interior Designer: PGAL
Civil Engineer: Century Engineering, Inc
Structural Engineer: Holbert Apple Assoc, Inc
MEP Engineer: RG Vanderweil Engineers

Architecture

- Modern exterior design w/ curtain walls, metal panels, and pre-cast concrete panels
- Modern interior feel w/ wood paneling walls and metal detailing throughout
- Ornamental sun shades above south-facing windows
- Covered porte cochere valet parking area and entrance

Structural System

- Cast-in-place concrete framed slabs 9 in thick on ground, second, and third floors
- Post-tensioned concrete beams, columns, and 7-1/2 in slabs on fourth through eleventh floors
- Various W-shaped structural steel members and open-web joists in porte cochere, lobby, meeting rooms, and pool areas

Lighting/Electrical System

- 480Y/277V, 3Φ, 4W service from (1) 1500kVA and (1) 2500kVA transformer, (14) 30–500kVA transformers to 208Y/120V, 3 Φ, 4W service
- (1) 600kW diesel standby generator
- 120V and 277V fixtures: wall washers, recessed fluorescent troffers, and various downlights

Mechanical System

- VAV system w/ hot water reheat coils in public spaces on ground and second floors
- Individual guest room 11 or 13.6 btuh water source heat pumps w/ master thermostats
- (3) 3350 MBH fossil-fuel boilers
- (1) 2-cell, 2540 gpm, 848 ton, 247,100 cfm cooling tower for condenser water system
- (4) 7500-25,000 cfm, 364-1754 MBH AHUs
- (6) 3400-11,100 cfm, 115-833 MBH RTUs

Nathan Patrick — **Mechanical Option**
http://www.arche.psu.edu/thesis/eportfolio/current/portfolios/ntp111/
The Pennsylvania State University — **Architectural Engineering**

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Acknowledgements

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Executive Summary

The Hilton Hotel at BWI Airport is a full-service hotel located less than two miles from the BWI Airport in Linthicum Heights, Maryland. The 277,000 sf building will cost about $27 million for design and construction. In the original mechanical systems design, all the equipment is served by a boiler and condenser water system. The ground and second floors of the building are served by four air handling units through a VAV system with hot water reheat coils at the boxes. The third through eleventh floors have 279 guest rooms with individual water source heat pumps. Five rooftop units provide 100% outdoor air to the guest room corridors, service areas, laundry rooms, and kitchen.

The goals and methods of research and design for this thesis project have changed significantly from the original thesis proposal. This is because many new ideas and methodologies have been developed since then.

The primary goal for this thesis project is to improve energy efficiency. Energy efficiency is beneficial because it saves energy, reduces the amount of resources used, decreases environmental impacts, and saves money. As a result of this, other objectives include reducing life cycle cots, promoting sustainability, design innovation, and indoor environmental quality improvement.

In order to achieve this goal of energy efficiency, the mechanical systems of the BWI Hilton need to be improved. This thesis report details the steps taken to improve the original design. The new mechanical systems for the BWI Hilton are based on a 700 ton central chilled water plant. The central plant is designed with two new centrifugal chillers operating in a variable primary flow system. The cooling towers for the building are also reduced from the original design. All the original systems in the building are replaced with equipment designed with chilled water coils, including the air handling units, rooftop units, dedicated outdoor air units, and fan coil units. Water-side free cooling is also studied and implemented to further increase the energy efficiency of the chilled water system.

This thesis report compares the energy consumption of the original design to the new design with the central chilled water plant. As is evident throughout the project, energy is saved in nearly every area, except for natural gas usage. However, the increase in natural gas consumption is offset by the much larger reduction in electric usage. Electric energy usage is reduced by 82%, but the natural gas consumption increases by 127%. However, the total energy costs for the BWI Hilton are reduced by 62%.

The new and more energy efficient design has a much lower operating cost than the original design and is more environmentally-friendly with reduced emissions by about 64%. Despite increasing the first costs by $685,000, the operating costs are decreased by $750,000, and a life cycle cost analysis yields a one year payback period and a net present worth savings of almost $8 million.

Project Background

Project Information

The Hilton Hotel at BWI Airport is a full-service hotel that is located less than two miles from the Baltimore-Washington International (BWI) Airport in Linthicum Heights, Maryland. The primary customers at the hotel will be both business and leisure travelers flying in and out of BWI Airport. There are two main floors and nine floors in the guest room tower above grade; below grade is a below-grade parking garage. The hotel is approximately 277,000 square feet, and has a variety of functions. Not only does it have 280 guest rooms, but it also includes several large and small meeting rooms, offices, restaurant, two bars, swimming pool, exercise room, and attached parking garage. The hotel will have the largest conference space in the area near the airport, and it will be a strong tool to attract business to the hotel and Anne Arundel County, Maryland.

Space Designations

The hotel is primarily comprised of three different sectors – the public spaces, the private spaces, and the service spaces. The public spaces include the lobby seating area, pre-function area, eating areas, egress/transportation areas, and the large and small meeting rooms. The eating areas include the restaurant, bar, coffee bar, and the bar lounge. The large meeting rooms are double-story height areas and have movable walls that can open up into one large ballroom. The means of egress in the building include the numerous corridors, two stairwells up through the guest room tower, and the four elevators.

The ground and second floors of the BWI Hilton are the primary public and service spaces in the hotel. The public spaces in the building have occupancies that are changing throughout the course of the day. This ever-changing fluctuation in these spaces lends itself well for use of a variable air volume (VAV) system in the public spaces.

The meeting rooms could be completely full with a convention or other gathering or completely empty when no one is using the spaces. The restaurant will be heavily used for limited around breakfast, lunch, and dinner. The bar and coffee bar will primarily be used in the evening hours. The offices will be used most when many employees are working. During the day hours, mostly the room cleaning personnel are in the hotel, while the caterers are there more during the evening and dinner times. The lobby areas will be used almost constantly during both the day night hours as customers and employees are continually coming or leaving, but the number of the occupants there at the same time will change throughout the day.

The other public spaces in the BWI Hilton include the swimming pool area and the exercise room. The swimming pool and exercise room will mostly be used in the morning and evening hours and possibly some during the day. However, the swimming pool has special temperature and humidity requirements that necessitate an air conditioning and dehumidification system separate from all the other public spaces.

The private spaces include the offices, employee rooms, kitchen, storage, laundry room, and the mechanical and electrical rooms. Some of the employee rooms are the offices, locker rooms, and cafeteria on the ground and second floors. There is also a concierge lounge on the eleventh floor. Other spaces in the building include the parking level below grade, exercise room, swimming pool, and the guest rooms. The guest rooms come in 15 different varieties, and there are a total of 280 guest rooms in the guest room tower of the hotel.

The guest rooms will primarily be occupied at night when customers will be sleeping, and some during the morning and evening hours. It is intended that each guest room has a separate air conditioning unit with individual control over the space temperature. Noise issues are also a concern, which affects the type of system chosen.

The service spaces in the BWI Hilton are made up of the spaces that only employees typically use. These include the offices, boardroom, kitchen, employee cafeteria, employee locker rooms/toilets, and banquet storage spaces. The service spaces, like the public spaces, have changing occupancy conditions all through the day. A VAV system could also work well for these types of spaces. The kitchen also requires make-up air to replace the exhausted air through exhaust fans and fume hoods.

Other service spaces include mechanical and electrical equipment rooms, communication rooms, vending areas, as well as the laundry facilities. All of these spaces contain certain types of equipment that require ventilation to provide conditioning for the equipment-generated heat.

All the previously discussed spaces in the BWI Hilton are listed with their corresponding areas and percentages of total building area in Figure 1 – Building Spaces Table. A visual representation of this information is also shown in Figure 2 – Building Spaces Chart.

Table 1 - Building Spaces Breakdown

Function / Use	Space Area (sf)	% of Total Area	No. of Spaces
Bedroom/Living Room	88,872	40.05%	280
Parking Garage	41,084	18.51%	1
Corridor	24,886	11.22%	26
Service Area	13,024	5.87%	48
Conference/Meeting	11,394	5.13%	9
Lobby/Pre-function	7984	3.60%	4
Storage Room	7369	3.32%	19
Office Space	6013	2.71%	31
Restaurant/Cafeteria	4872	2.20%	2
Swimming Pool	3477	1.57%	2
Kitchen	3363	1.52%	1
Bar	2795	1.26%	2
Laundry Area	2593	1.17%	3
Toilets	2507	1.13%	8
Health Club/Aerobics	1665	0.75%	1
Total Area	**221,898**		

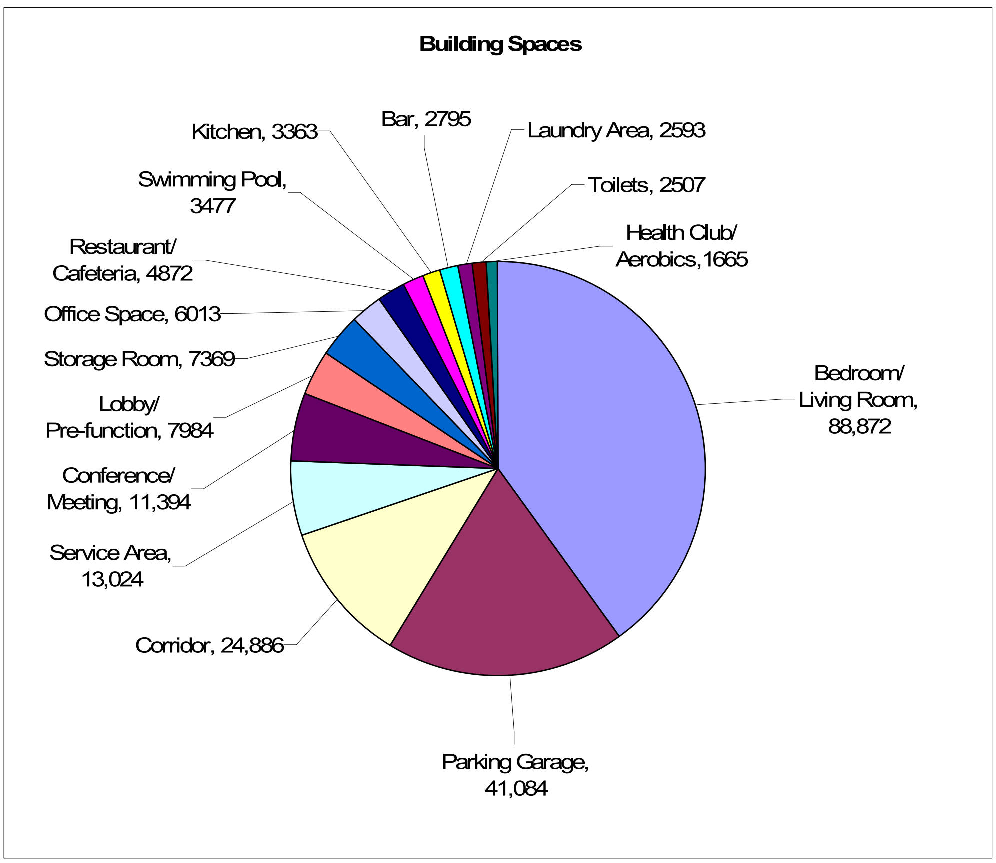

Figure 1 - Areas of Building Spaces

Building Systems Overview

Plumbing Systems

Natural Gas:

The natural gas service main has 22,905 MBH heating capacity and enters the building through 6 inch piping. The main pipe branches off and splits before entering the building in the parking level through water-tight sleeves with a 4 inch pipe at 12,105 MBH and an 8 in pipe at 10,800 MBH. The 4 inch pipe has a pressure of 2 psi, and it runs to the three fossil-fuel boilers in the parking level mechanical room. The 8 in pipe is at 10 in wc and runs through the hotel to all the RTUs and the laundry room equipment.

Domestic Hot Water:

The 4 in domestic water service main enters the building through the parking level. The piping then goes through a 250 gpm water softener system and a 270 gpm triplex domestic booster pump system. Also on the parking level are two hot water heat exchangers, two thermostatic mixing valves, and a 158 gal thermal expansion tank. A 4 inch cold water line runs up to the penthouse to two 900 gal duplex gas-fired domestic water heaters with a 77 gal thermal expansion tank and two thermostatic mixing valves.

There are three different temperature ratings for the hot water piping in the building. They include supply and return lines at 120^{o}F, 140 ^{o}F, and 160 ^{o}F running to various plumbing equipment throughout the hotel. The domestic hot water services all the plumbing fixtures, including the lavatories, sinks, showers, and bathtubs in all 280 bathrooms of the guest room tower.

Lighting Systems

The lighting system in the hotel consists of both 277V fixtures and 120V fixtures. The lighting fixtures in the parking areas are of the 277V type. Throughout the rest of the building, there is a mixture of lighting fixtures with the two different voltage levels.

Some of the most common types of lights are the incandescent downlights found above the large and small meeting rooms on the ground floor. Another common light is the 1 ft x 4 ft strip fixtures located in all the storage rooms, mechanical rooms, and electrical rooms, as well as in the penthouse.

Other types of lighting in the hotel include the following kinds of fixtures. The pre-function area has many compact fluorescent downlights. More compact fluorescent downlights and metal halide downlights are located in the lobby seating area. The kitchen and employee rooms use 2 ft x 4 ft recessed fluorescent troffers. The restaurant, bar, and coffee bar all have low-voltage incandescent downlights. Accent lighting in these areas is accomplished using compact fluorescent wall washers.

Many of the bathrooms have compact fluorescent downlights. Also, there is a series of compact fluorescent downlights found in the porte cochere area. The swimming pool area on the second floor is the only place to use compact fluorescent lensed downlights. Incandescent downlights and incandescent lensed wall washers are used in the small meeting rooms on second floor.

The hotel has several common types of lights found on all floors of the guest room tower. Compact fluorescent corridor ceiling lights are located in the elevator lobby areas and corridors on all floors. The corridors also have compact fluorescent wall sconces. The two stairwells in the guest room tower have 3 ft long wall mount fluorescent fixtures at all the landings.

There are six aircraft warning lights mounted on the roof of the guest room tower and the penthouse.

Electrical Systems

The main electrical service comes in to the building on the north side from BGE. The main connects into the utility-owned 2500 kVA transformer. The delta primary side is 13,800V, 3 phase, 3 wire and that steps down to the 480Y/277V, 3 phase, 4 wire secondary side of the transformer. This 4000A feeder runs to the main 4000A – 277/480V, 3 phase, 4 wire switchboard in the main electrical room on the parking level.

From the main 4000A switchboard, the 400A feeder runs to the electric panelboards in the building and the 800A – 277/480V, 3 phase, 4 wire distribution panel. There are numerous smaller transformers throughout the building that step down from 277/480V, 3 phase, 4 wire primary to 120/277V, 3 phase, 4 wire secondary.

A 1200A feeder runs from the main lugs only on the distribution panel to the 600 kW diesel standby generator on grade level just north of the building. Junction boxes for the battery charger, jacket water heater, controls, and lighting and receptacles are all mounted on the generator.

The penthouse contains the 2000A – 277/480V, 3 phase, 4 wire switchboard, transformer, and 4000A – 120/208V, 3 phase, 4 wire switchboard. The 2000A switchboard connects to a 2000A busduct that runs up from the main 2000A – 277/480V, 3 phase, 4 wire switchboard located in the main electrical room on the parking level. There are also four 4 inch conduits for stand-by power, two 3 in conduits for emergency power, and two 2 in conduits for controls that run between the penthouse and the ground floor electrical room.

The duplex receptacles in the building have 20A – 125V, 2 pole, 3 wire configurations.

Structural Systems

The ground and second floors are made of cast-in-place concrete with structural slabs. Post-tensioned concrete makes up the third through the eleventh floors, or the guest room floors. The exterior walls of the all the guest room floors are composed of pre-cast concrete panels. The below-grade parking level is comprised of concrete masonry unit (CMU) block walls.

The only structural steel in the building is located above the double-story height spaces on the ground and second floors. The use of steel allows for longer spans to provide more open space in these areas.

The parking level floor is made of 5 in thick slab-on-grade concrete, reinforced with 6x6 W2.0x2.0 welded wire fabric. The ground floor concrete framed slab is mostly 9 in thick and is reinforced with #5 rebar at 12 in on-center each way. The concrete columns for the parking level and ground floor vary in size and shape. Typical shapes are square and rectangular, and sizes range from 12 in x 12 in to 18 in x 18 in and 14 in x 26 in to 18 in x 26. These columns all have different amounts of rebar reinforcing depending on location and loading. There are a total of 93 different concrete beam sizes ranging in sizes from 14 in x 8 in all the way up to 14 in x 75 in and 42 in x 42 in. Other non-typical concrete floor slabs vary in size from 5 in to 12 in thick.

The second floor is primarily 9 in concrete framed slab, reinforced with #5 rebar at 12 in on-center each way. This is the flooring under the mechanical room, exercise room, laundry room, offices, and meeting rooms. The rest of the second floor is the double-story height area above the meeting rooms. Here the main structural steel supports are W8x31 beams, framed around the perimeter by W16x26 beams and several HSS 8x8x1/2 columns along the exterior wall. The adjacent pre-function area is framed by W16x45 beams and W16x40 girders along the perimeter and is spanned by 20LH4 open-web joists and diagonal bracing. The porte cochere also has a structural steel frame with varying sizes of W18 beams and 28LH11, 28LH09, and 28LH07 open-web joists.

The third floor is mostly 9 in concrete framed slab, reinforced with #5 rebar at 12 in on-center each way, under the guest room areas. The roof above the large meeting rooms is composed of 52DLH13 joists, framed by W12x26 and W16x50 beams and W10x33 and W10x39 columns along the exterior walls. The swimming pool roof has W27x94 and W14x30 beams, W24x55 girders, and W10x33 columns. The double-story height lobby area has 24LH11 joists, framed by W18x50 beams.

The fourth through eleventh floors and the penthouse are made of 7-1/2 in post-tensioned concrete slabs, reinforced with #4 rebar at 30 in on-center each way. The penthouse floor and eleventh floor roof is made of 9 in post-tensioned concrete slab, reinforced with #5 rebar at 24 in on-center each way.

The interior and exterior walls have different construction types. The interior partitions most typically use either 1-1/2 inch or 3-5/8 inch metal studs in the walls with fiberglass batt insulation and gypsum wall board. Most of the exterior walls are made primarily of concrete.

There are two main types of roofing structure on the hotel: 8 in cast-in-place concrete slab or 3 in 18 gauge type N galvanized metal roof deck. However, in both cases there is a minimum required layer of 3 in thick R30 rigid roof insulation and fully-adhered EPDM roofing membrane.

The shaft surrounding the bank of four elevators is comprised of concrete shear walls. These shear walls are used to resist the shear forces from the wind load transferred from the exterior walls through the floor slabs to the central core of the guest room tower.

Building Envelope

The exterior wall systems of the building consist entirely of different curtain wall systems, including metal panel systems and pre-cast concrete panels on the exterior. The majority of the walls consist of 5-1/2 in pre-cast concrete panels, 3-5/8 in metal studs with semi-rigid insulation, and 1/2 in gypsum wall board.

There is a significant amount of glass in the building envelope of the BWI Hilton. All along the pre-function area curved exterior wall is a large amount of store-front windows. Granite base panels on the first story and metal panels on the second story frame all this vision glass. The restaurant area is also primarily composed of store-front windows on the north side of the building.

In the nine floors of the tower part of the hotel, every guest room has both casement windows and sliding windows made of either spandrel glass or vision glass. However, all these window sizes differ due to the varying and numerous sizes of the guest rooms.

Most of the roofing system of the BWI Hilton consists of 3 in thick R30 rigid roof insulation and fully-adhered EPDM roofing membrane. Part of the roof is made of an 8 in thick concrete slab on the guest room tower and above the restaurant area. The sections of the roof above the lobby area and swimming pool area are built with 3 in metal roof decks spanning between the steel structure.

Acoustics

There is not much detail included in the plans of the Hilton Hotel at BWI Airport on the topic of acoustics. However, it is noted that several locations under the third floor slab require 2 in of rigid sound insulation to inhibit the transfer of sound from the mechanical rooms and laundry rooms on the second floor to the guest room areas above.

Also detailed in the BWI Hilton plans are several different wall construction required noise ratings. For the numerous types of walls used in the building, only several of the walls had a minimum STC (sound transmission class) value specified in the drawings. These STC values range between 35 and 55, depending on the wall construction materials and the location of the wall in the building. Also, it is important to point out that many of the walls have no minimum STC value assigned to them since noise considerations are not a major concern in those areas.

Existing Mechanical Systems

Air-Side Systems

The primary air-side components of the mechanical system on the ground and second floors use a VAV system with reheat hot water coils at the boxes in the public and service spaces.

One air handling unit and one rooftop unit on the north side roof of the ground floor provide conditioned air to many of the spaces on the ground level. Also located on the same roof is a make-up air unit to provide adequate ventilation to the kitchen. A long string of linear slot diffusers provide the required amounts of supply air to the spaces from above the large areas of windows in the pre-function area, meeting rooms, coffee bar, and restaurant. Since the sidewall supply registers in the lobby seating area dispense the necessary quantity of supply air for cooling and ventilation requirements, a parallel system of fin tube radiators help to balance the heat loss from the large sections of windows located along the exterior walls.

The second floor mechanical room houses several pieces of large mechanical equipment. One air handling unit (AHU) conditions air for the large double-story height meeting rooms, smaller meeting rooms, and the pre-function area on the ground floor. A second AHU services many of the employee services rooms and offices on the ground floor. Also in the same mechanical room is a pool dehumidifier unit that conditions for the swimming pool area. A rooftop unit on the ground level roof conditions air for several of the laundry and service spaces that are on the second floor. From the mechanical room on the northeast corner of the second floor, another AHU provides air to the offices, meeting rooms, and exercise room/health club.

The positive pressure in both stairwells is maintained by two stair pressurization fans that deliver 11,700 cfm to each stairway. The pressurization required in the corridors on the third through eleventh floors is maintained by three rooftop units located in the penthouse. These rooftop units also provide supply air to the housekeeping areas on all the guest room floors.

Exhaust registers in all of the guest room bathrooms are ducted to sub-ducts and then tapped into the exhaust stacks. There are a total of 17 main toilet exhaust riser stacks connected to toilet exhaust fans mounted on either the eleventh floor roof or the penthouse roof. This sub-duct method, which received a variance prior to design and construction, aims to prevent the spread of smoke to the other guest room floors without using smoke dampers in each of the ducts.

Water-Side Systems

The primary water-side components of the mechanical system include the condenser water system and the hot water system. Due to budget constraints, the originally designed chilled water system was eliminated along with two water cooled chillers and two chilled water pumps. Two induced-draft open-cell cooling towers are located on the north side of the building on grade with the ground floor level. These cooling towers provide condenser water to the air handling units, which operate similarly to heat pumps, and to all the guest room water source heat pumps. Each heat pump is tapped off 1-1/2 inch supply and return piping, and it also has 1 inch drain piping. The condenser water is then looped back to the cooling towers through a reverse return system. For a schematic representation of the condenser water system, please see Figure 2 – Condenser Water Flow Diagram. For a schematic representation of the hot water system, please see Figure 3 – Hot Water Flow Diagram.

Three fossil-fuel boilers in the parking level mechanical room provide hot water for all the reheat coils in the VAV boxes, the freeze protection pumps for the air handling units, and the pool dehumidifier unit. Other pieces of equipment served by the hot water are the unit heaters, finned tube radiators, and hot air curtains located in the vestibules.

The large mechanical room located on the north side of the parking level contains much of the water-side equipment used in the hotel. This includes three boilers and their corresponding pumps, two condenser water pumps, one sedimentation separator filter, two plate and frame heat exchangers, two hot water pumps with variable frequency drives, two diaphragm expansion tanks, and some other pieces of equipment.

Controls

All sequences of controls for the entire building are performed by direct digital controls (DDC). This DDC system monitors all the sensors, and it is able to adjust all the set points and time delays for the equipment. The DDC system also provides start/stop, speed control, monitoring, and alarms for the variable frequency drives (VFD).

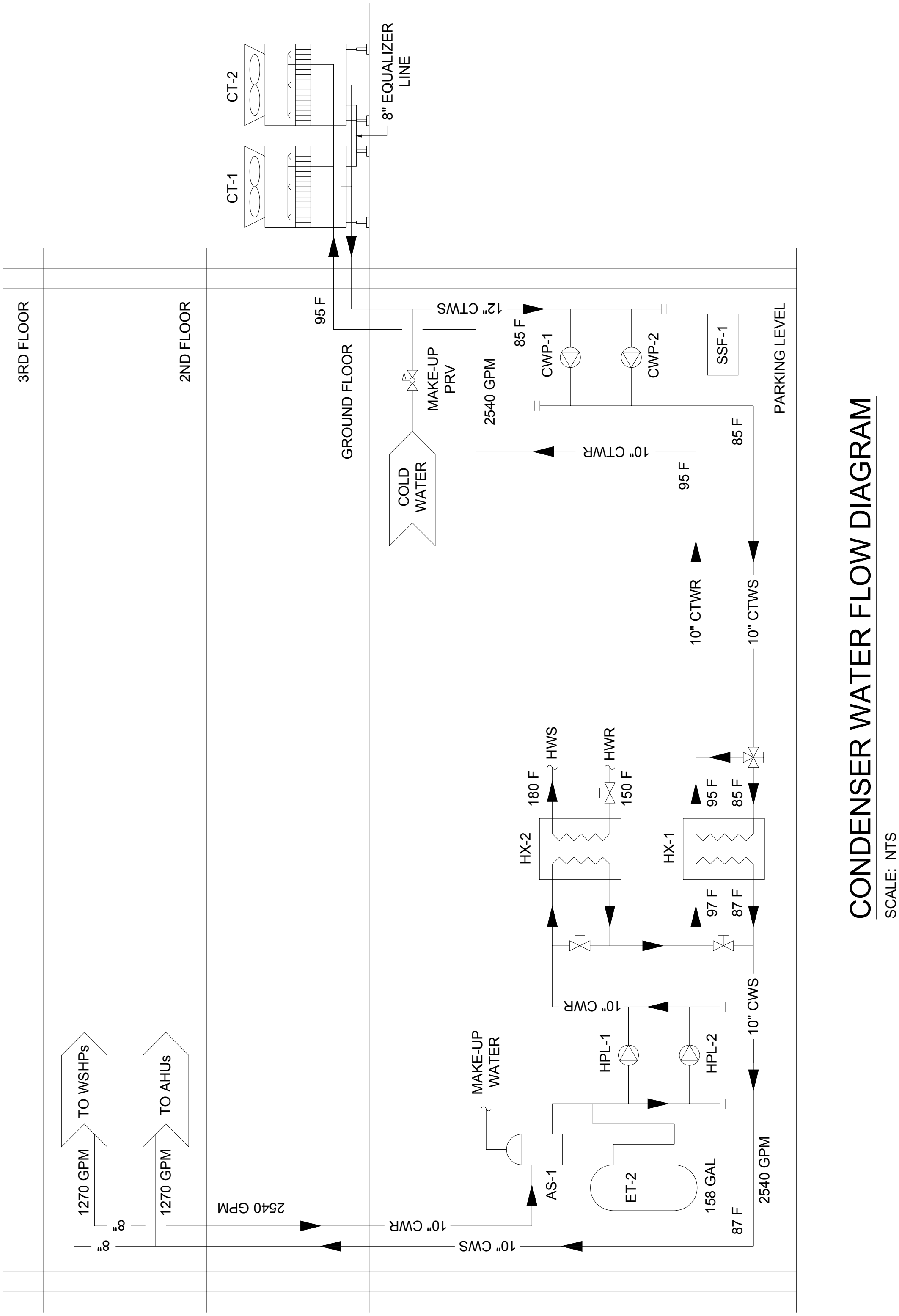

Figure 2 - Condenser Water Flow Diagram

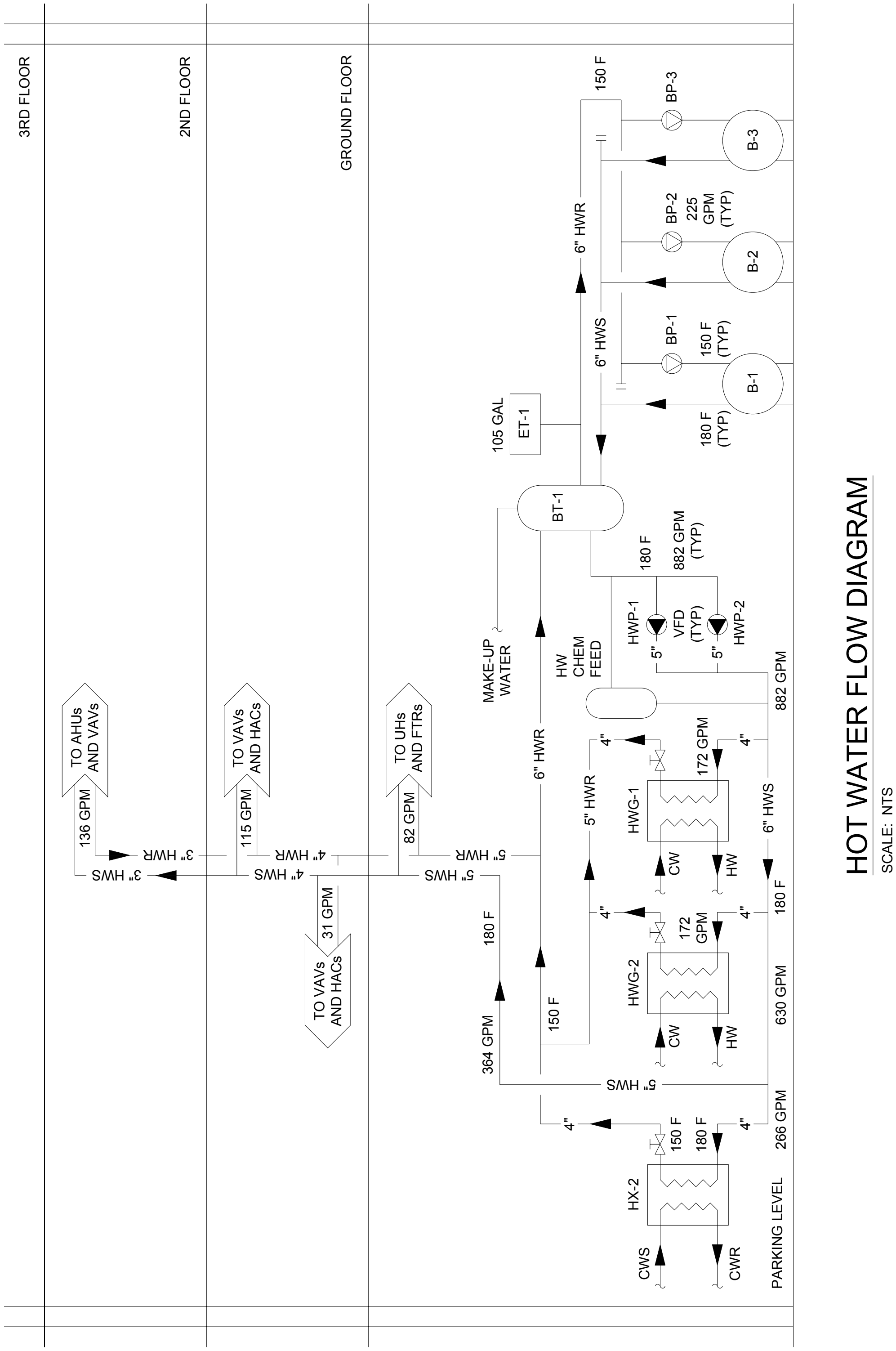

Figure 3 - Hot Water Flow Diagram

Guest Rooms

The “Hilton Design and Construction Standards” list several choices for the possible air conditioning unit types available for use in its guest rooms. For example, the lower-end Hilton hotels mainly use of packaged terminal air conditioning (PTAC) units for all the guest rooms; the higher-end Hilton hotels require the use of a four-pipe fan coil unit (FCU) system with both chilled and hot water for the guest rooms. In this case, the BWI Hilton is allowed to have one of three different guest room units: two-pipe FCUs with resistance heating, water source heat pumps (WSHPs), or four-pipe FCUs.

The four-pipe FCU system is the highest quality system that is currently being used in hotels. The other two options are either the two-pipe FCU system with resistance heating or the water source heat pumps. It was suggested by the mechanical contractor, Southland Industries, Inc., to use the two-pipe FCU system. However, Hilton Hotels preferred the use of the WSHP system for this project, so the original design was completed based on a condenser water and boiler loop.

On the third through eleventh floors, all the guest rooms are equipped with individual water source heat pumps, master thermostats, and control valves in each room. Through the process of value engineering, two air conditioning units located in the penthouse, which were originally scheduled to supply each guest room with 60 cfm of outside air, and all the related ductwork and fire dampers were eliminated.

Design Considerations

Energy Sources and Rates

The Hilton Hotel at BWI Airport is serviced by both electricity and natural gas energy sources. Since the hotel is still under construction, the energy rates were assumed based on information gathered from the websites of both energy providers.

The natural gas service is provided by Washington Gas, and the rates and tariffs were found on their website (http://www.washgas.com/). The natural gas rates were determined to be from rate schedule Number 2, which is for Firm Commercial and Industrial Sales service.

The natural gas rates are divided into the system charge and the distribution charge. The distribution charge is broken down based on the amount of gas (therms) used in one month. Please see Table 2 – Natural Gas Rates for the breakdown.

Table 2 - Natural Gas Rates

System Charge		
	$36.25	per customer
Distribution Charge		
First 300 therms:	$0.3158	per therm
Next 6700 therms:	$0.2152	per therm
Over 7000 therms:	$0.1573	per therm

The electric service in the Linthicum Heights area is provided by Baltimore Gas and Electric (BGE). The appropriate electric rates and tariffs were obtained from BGE's website (http://www.bge.com/) and with the assistance of a customer service representative. The rate schedule used for the BWI Hilton is the General Service Large (GL).

The electric service rates are separated out into delivery service customer charge, demand charges, energy charges, and delivery service charge. The energy charges are divided into peak, intermediate, and off-peak periods. The electric rates breakdown is shown below in Table 3 – Electric Rates.

Table 3 - Electric Rates

GENERAL SERVICE LARGE -- ELECTRIC SCHEDULE GL		
Delivery Service Customer Charge:	$110	per month
Demand Charges:	Summer	Non-Summer
Generation Market-Priced Service:	(per kW)	(per kW)
Type II	-	-
Transmission Charge for Market-Priced Service:		
Type II	$1.05	$1.05
Delivery Service	$2.67	$2.67
Energy Charges:		
Generation Market-Priced Service (¢/kWh): (Excludes Rider 8 – Energy Cost Adjustment)	Summer	Non-Summer
Type II		
Peak	9.319	5.534
Intermediate	8.802	5.406
Off-Peak	8.464	5.118
Delivery Service Charge:	1.239	¢/kWh
Hours:	Summer	Non-Summer
Peak	10 am - 8 pm	7 am - 11 am 5 pm - 9 pm
Off-Peak	11 pm - 7 am	9 pm - 7 am
Intermediate	7 am - 10 am 8 pm - 11 pm	11 am - 5 pm

Outdoor and Indoor Design Conditions

The outdoor design conditions for Maryland – Baltimore, BWI Airport were found in Chapter 27 of the 2001 ASHRAE Fundamentals Handbook. This information for the Hilton Hotel at BWI Airport was gathered from the values for the most extreme conditions listed (at either 0.4% or 99.6%). Carrier's Hourly Analysis Program (HAP), which was used to model the building's energy usage, also used these same values to simulate the weather. Please see Table 4 – Outdoor Design Conditions for the summer and winter design conditions.

Table 4 - Outdoor Design Conditions

Summer Cooling		Winter Heating	
Design DB	93.0 ^{o}F	Design DB	11.0 ^{o}F
Coincident WB	75.0 ^{o}F	Coincident WB	8.6 ^{o}F

The indoor design conditions for the BWI Hilton were originally defined in the Sequence of Operations. The dry bulb and relative humidity conditions are set at typical setpoints for buildings. The winter heating relative humidity is not explicitly defined, and it often drops to 30% or below during the winter heating season. These conditions are shown below in Table 5 – Indoor Design Conditions.

Table 5 - Indoor Design Conditions

Summer Cooling		Winter Heating	
DB	74.0 ^oF	DB	70.0 ^oF
RH	50%	RH	N/A

Design Ventilation Requirements

The minimum required ventilation rates for the Hilton Hotel at BWI Airport were found using ASHRAE Standard 62.1-2004. The existing air-side equipment serving the building includes the four air handling units (AHUs) and six rooftop units (RTUs). The ventilation rates used in the RTUs are shown in Table 6 – RTU Ventilation Summary. The ventilation rates used in the AHUs are shown in Table 7 – AHU Ventilation Summary.

Table 6 - RTU Ventilation Requirements

Space / Function	People Outdoor Air Rate R_p (cfm/person)	Area Outdoor Air Rate R_a (cfm/sf)	Default Occ. Density (#/1000 sf)
Corridor	0	0.06	0
Communications Room	0	0.5	0
Housekeeping Area	7.5	0.06	20
Vending Area	0	0.5	0
Elevator Lobby	0	0.5	0
Bedroom/Living Room	5	0.06	10
Kitchen	15	0.06	20
Storage Room	0	0.12	0
Office Space	5	0.06	5
Laundry Area	7.5	0.06	20
Service Elevator Lobby	0	0.5	0
Elevator Machine Room	0	0.5	0

Table 7 - AHU Ventilation Summary

Space / Function	People Outdoor Air Rate Rp (cfm/person)	Area Outdoor Air Rate Ra (cfm/sf)	Default Occ. Density (#/1000 sf)
Conference/Meeting Room	5	0.06	50
Lobby/Pre-function Area	7.5	0.06	120
Restaurant Dining Rooms	7.5	0.18	70
Toilet Room	0	0.2	0
Electrical Room	0	0.5	0
Bar	7.5	0.18	100
Telephone/Data Entry	5	0.06	60
Office Space	5	0.06	5
Corridor	0	0.06	0
Storage Room	0	0.12	0
Elevator Lobby	0	0.5	0
Mechanical Room	0	0.3	0
Health Club/Aerobics Room	20	0.06	40
Cafeteria	7.5	0.18	100

The new mechanical design incorporates the use of two new dedicated outdoor air (DOAS) units. The minimum ventilation rates for the new DOAS units are shown in Table 8 – DOAS Ventilation Requirements.

Table 8 - DOAS Ventilation Requirements

Space / Function	People Outdoor Air Rate R_p (cfm/person)	Area Outdoor Air Rate R_a (cfm/sf)	Occupancy (persons)
Guest Room	5	0.06	4

Building Energy Simulation Model

A means of predicting the annual energy usage of a building is a major component of the mechanical systems design procedure. For this system design, Carrier's Hourly Analysis Program (HAP) was used extensively to compare design options and energy consumption of all the mechanical equipment.

Much time and care was used in entering design conditions for all the spaces in the BWI Hilton. All the equipment used in the systems was intended to be modeled as an accurate representation of how it will actually operate. Despite this effort to model the spaces, systems, central plants, and building as accurately as possible, it was necessary to make assumptions throughout the process. Default values provided in HAP were used in situations when the actual values were unknown or could not be found. All these assumptions and default values are not listed anywhere in this report because they do not make a huge impact on the overall building energy usage.

In order to accurately simulate the energy usage of the building, it is also critical to accurately define the occupancy and other types of schedules. However, all these schedules were unknown for the whole building, including the guest rooms. Since they were unknown, they were assumed to be equivalent to those defined by ASHRAE/IES Standard 90.1-1989 in Table 13-3: Building Schedule Percentage Multipliers.

For the occupancy schedule used in HAP for all the public, private, and service spaces, please refer to Table 9 – Hotel Occupancy Schedule. For the lighting schedule used in HAP, please refer to Table 10 – Hotel Lighting Schedule. For the HVAC schedule used in HAP, please refer to Table 11 – Hotel HVAC Schedule.

Table 9 - Hotel Occupancy Schedule

		Hour																							
Schedule	**Day**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Hotel Occupancy	Weekday	90	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90
	Saturday	90	90	90	90	90	90	90	70	50	30	30	30	30	30	30	30	30	30	50	60	60	60	70	70
	Sunday	80	70	70	70	70	70	70	70	70	50	50	50	30	30	20	20	20	30	40	40	60	60	80	80

Table 10 - Hotel Lighting Schedule

		Hour																							
Schedule	**Day**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Hotel Lighting	Weekday	30	20	15	10	10	10	20	40	50	40	40	25	25	25	25	25	25	25	25	60	80	90	80	60
	Saturday	30	20	20	10	10	10	10	30	30	40	40	30	25	25	25	25	25	25	25	60	70	70	70	60
	Sunday	30	30	30	20	20	20	20	30	40	40	30	30	30	30	20	20	20	20	20	50	70	80	60	50

Table 11 - Hotel HVAC Schedule

		Hour																							
Schedule	**Day**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Hotel HVAC	Weekday	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
	Saturday	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
	Sunday	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on

Mechanical Systems Design

After much deliberation and a long process of brainstorming ideas for potential mechanical system designs for the Hilton Hotel at BWI Airport, it was finally decided to design a central chilled water plant for the building. This report clearly details the ideas for replacement and improvement of the hotel's mechanical systems. The goals for the project and the steps taken in this design process are described next.

Design Objectives

The original design of the mechanical systems for the Hilton Hotel at BWI Airport could be classified as a possible solution or workable design for the hotel. However, it is not by any means the best possible solution, and it is definitely possible to develop improved mechanical systems that will either replace or supplement the existing design.

In order to improve the mechanical systems design, a means of measuring the performance and relative costs must be established. The primary goals of this thesis design project for the BWI Hilton are to increase the energy efficiency of the building and decrease the life cycle costs of the systems and equipment. Other objectives sought for in this project include sustainability, design innovation, and improvement of the overall indoor environmental quality of the hotel.

As stated above, one of the major goals is to improve the energy efficiency of the BWI Hilton, and it is the primary objective of this thesis design project. All design ideas and decisions should be made based on this principle. To accomplish this goal of using energy more effectively, it is necessary to decrease the building's annual energy consumption of electricity and natural gas. In doing so, it will also be possible to make a more environmentally-friendly facility with reduced emissions.

Additionally, improvement to the mechanical systems could also result in a reduction of the life cycle costs of the BWI Hilton. Reduced life cycle costs will also cause the payback period on some of the equipment to become more reasonable. However, despite the lower life cycle costs, the first costs of the equipment could possibly increase. Unfortunately, too many times the primary objective of a building project is to decrease the first costs. The lower first costs look good for the owner, but this could be counter-productive in the long run. This is why the life cycle costs are more of a concern than the first costs for this design project.

Original Mechanical System Design

The original mechanical systems use a simple condenser water loop throughout the entire building. Water source heat pumps are used in all the guest rooms to exchange heat between the air and the water to cool the rooms. The four air handling units all have cooling coils served by the condenser water, which in turn operate similarly to heat pumps. The six rooftop units all use air-cooled DX coils for the cooling. Any heating in the system is provided by a boiler system that adds heat to the condenser water loop via a heat exchanger between the two systems.

The overall goal of energy efficiency for this thesis project could be realized in a variety of ways. The means chosen to accomplish this goal will be based on the existing design of the Hilton Hotel at BWI Airport and the potential to greatly improve the mechanical systems. A new central chilled water plant system to replace this condenser water loop system will be designed, developed, and to a certain degree, optimized. Many design alternatives and a variety of choices of equipment are available, but only a few could be properly researched and used for this thesis design project.

Chilled Water Plant Design

The design of a central chilled water plant system is a very long and complicated process. However, two books, many magazine articles, and the opinions of several manufacturers and mechanical designers served as guidance throughout the design of the chiller plant. According to the "CoolTools Chilled Water Plant Design Guide", there are seven main steps in the design of a chilled water plant. The steps taken in the process are described next.

Pre-requisite:

To be able to follow these seven steps, it was first assumed that the required building cooling load was previously determined.

In this case, the peak cooling load for the chiller plant was found to be 640 tons by using HAP to simulate the hourly loads on the BWI Hilton. But to slightly oversize the system and provide some cushion in case any of the load calculations are not exact, a 10% safety factor was used. This then caused the total cooling load to be 700 tons.

Step 1:

According to “CoolTools”, the first step is to choose the chilled water flow distribution arrangement. If multiple pumps are used, the possible arrangements either use series pumping or parallel pumping. Possible choices for distribution include constant primary flow, constant primary/constant secondary flow, constant primary/variable secondary flow, and variable primary flow.

The chilled water flow distribution flow arrangement was chosen to be a two-pump parallel configuration with variable primary flow (VPF). This was done for several reasons. First, after running a HAP analysis to model each of the possible pumping arrangements, it was determined that the VPF system was the most energy efficient. This is mostly due to the reductions in pump energy as compared to the other main possibility of a constant primary/variable secondary flow configuration.

Additional savings can be realized when a comparison is made with the number of required pumps. In a constant primary/variable secondary flow system, two constant speed primary pumps and two variable speed secondary pumps are needed, and both sets are piped in parallel. In a VPF system, only two primary pumps with variable speed drives are required. Even though the two pumps will be larger than the primary pumps of the primary/secondary arrangement, the first costs will still be less than having to purchase four smaller pumps.

Step 2:

The second step in the “CoolTools” design process is to determine the characteristics of the chilled water system. These characteristics include the chilled water supply (CHWS) temperature, maximum flow rate, and main pipe sizes. A variety of choices are available for all the CHWS temperature, flow rate and pipe sizes.

A range of CHWS temperature could be used in the chiller plant, as can be seen in Table 12 – Temperature Limits. After running some HAP simulations and discussing the options with several mechanical design engineers and manufacturer representatives, it was decided that the CHWS temperature would be best at 44 F.

Table 12 – Chiller Plant System Limits

	CHW		CW	
Limit	**LWT (F)**	**ΔT (F)**	**EWT (F)**	**ΔT (F)**
Low	40	10	85	10
High	48	20	85	20
Typical	45	10	85	10

A range of delta-Ts could be used for the design chilled water (CHW) temperature difference (delta-T). A similar method was used to choose this design condition as was described above. The most traditional CHW delta-T used is 10 F, but a higher delta-T of 12 F was chosen to be used for this chiller plant design. This was done because higher delta-Ts typically result in lower water flow rates and less pump energy consumption, as is described next.

Next, a maximum flow rate must be determined. A range of CHW and condenser water flow rates are listed in Table 13 – Relative Flow Rates. These flow rates are all directly related to the corresponding delta-Ts. At a typical delta-T of 10 F, the CHW flow rate would be 2.4 gpm/ton. But with the selected range of 12 F, a CHW flow rate of 2.0 gpm/ton will be used for this design. Therefore, with a peak cooling load of 700 tons, the CHW flow rate will be no more than 1400 gpm.

Table 13 - Flow Characteristics at Various Delta-Ts

ΔT (F)	CHW gpm/ton	CW gpm/ton	CHW Btuh/gpm	CW Btuh/gpm
10	2.4	3.0	5000	5000
12	2.0	2.5	6000	6000
14	1.71	2.14	7018	7009
15	1.6	2.0	7500	7500
16	1.5	1.88	8000	7979
18	1.33	1.67	9023	8982
20	1.2	1.5	10,000	10,000

The main pipe sizes right at the chiller(s) are selected next. In this case, with a maximum flow rate of 1400 gpm on the CHW side, and an assumed friction rate of 3 ft/100 ft, the required piping has an 8 in pipe size.

For a simple representation of the chilled water and condenser water systems, please see Figure 4 – Chilled Water Flow Diagram on the following page. Assumed temperatures and flow rates are shown for both the condenser water and the chilled water, as is discussed here in the design steps.

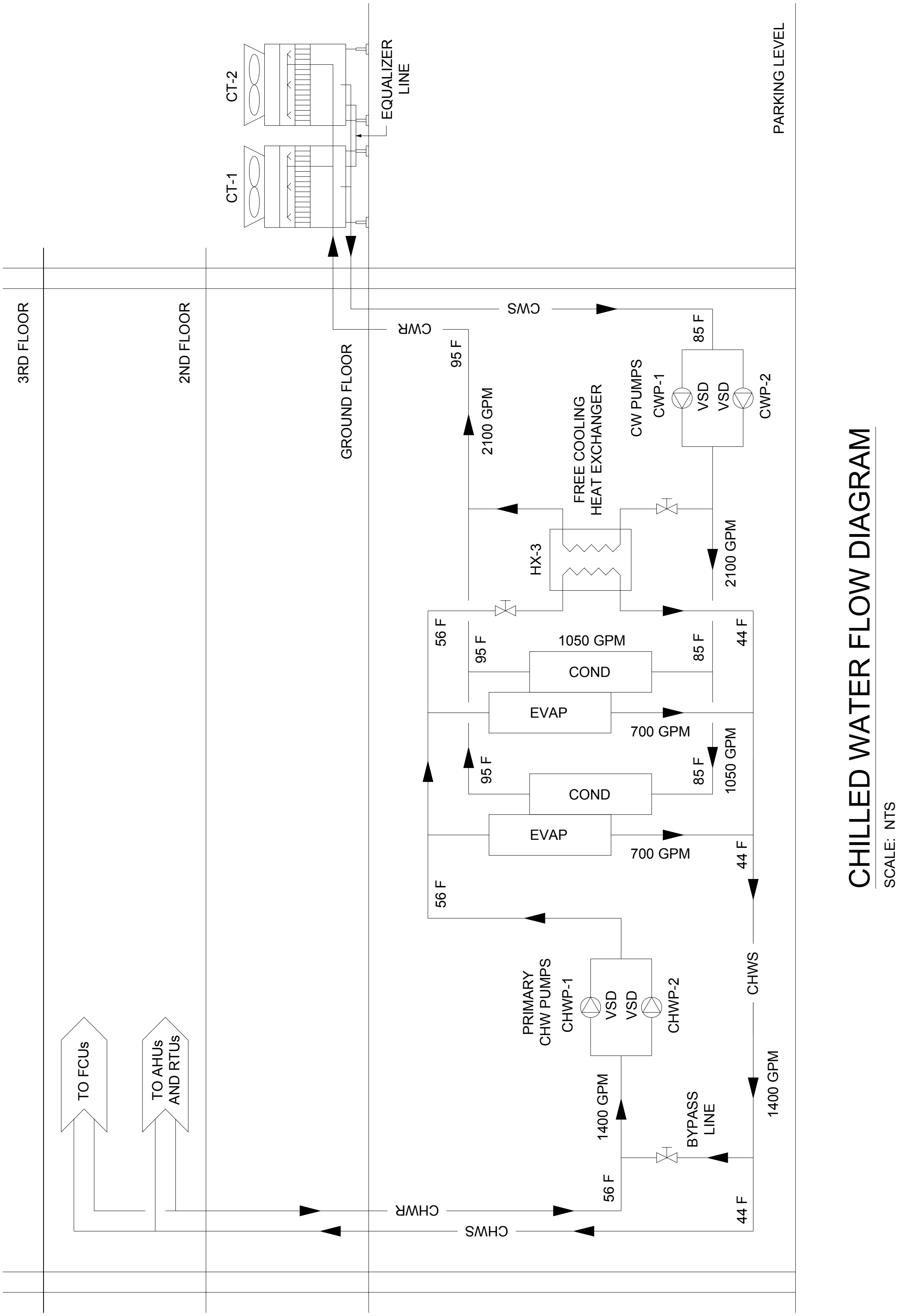

Figure 4 - Chilled Water Flow Diagram

Step 3:

> The third step is to choose the characteristics of the condenser water (CW) system. These include the CW temperature, delta-T, CW flow rate, cooling tower fan speed control, and cooling tower efficiency. After making all these decisions, a cooling tower size and selection should be made.

A range of acceptable CW delta-Ts was listed above in Table 12 – Temperature Limits. The most typical case uses a 10 F delta-T, and that is what will be used in this design. The condenser water supply (CWS) temperature (leaving the cooling tower) is the standard 85 F.

The cooling tower range (R) can be found using the following equation: R = CWR – CWS, where CWR is the condenser water return temperature (entering the cooling tower). Since the range is 10 F and the CWS is 85 F, the CWR was found to be 95 F.

With a summer design wet bulb temperature (WBT) of 79 F (not the coincident wet bulb temperature), the cooling tower approach (A) can be found next. Using the appropriate equation: A = CWS – WBT, the approach was calculated to be 6 F.

Next, the flow rate of the CW can be determined. Knowing the CW delta-T of 10F, the CW flow rate is 3.0 gpm/ton, as noted in Table 13 – Relative Flow Rates. This corresponds to a total CW flow rate of 2100 gpm with a 700 ton cooling load.

Several different choices are available for the cooling tower fan control. Possibilities include: one-speed motors, 100%/67% two-speed motor, 100%/50% two-speed motor, pony motors, or variable speed drives. The best option to use with the BWI Hilton is the one with variable speed drives (VSD) because it provides the greatest amount of control for the fan speeds related to the changing cooling tower loads.

The cooling tower efficiency is comprised of two different things – fan type and fill pressure drop. The efficiency is the ratio of CW flow rate to the motor horsepower (gpm/hp) at Cooling Tower Institute (CTI) standard conditions (CWR = 95 F, CWR = 85 F, and WBT = 78 F). For the cooling tower fan type, the choices are either centrifugal fans or propeller fans. The propeller fans use half the energy centrifugal fans, so propeller fans were chosen. For the BWI Hilton project, draw-through type propeller fans will be used. The pressure drop in the fill affects the size and efficiency of the cooling tower. The greater the fill area is, the less pressure drop, the larger the tower size, and the greater the efficiency. It was recommended by "CoolTools" that the tower efficiency be greater than 80 gpm/hp at CTI standard conditions.

Step 4:

The fourth step, as outlined by “CoolTools”, is to choose the characteristics of the chillers for the chilled water plant. These include the type of chillers, how many of them, and their sizes. Other chiller selection options are looked at, such as controllers, inlet guide vanes, motor drives, and refrigerant choices.

When selecting the type of chillers to use, choices include air-cooled chillers, water-cooled chillers, and absorption chillers. There are other varieties of each chiller type, as well, like single-effect or double-effect absorption chillers, or screw or reciprocating electric chillers, for example. Another possibility that has benefits in some applications is a hybrid plant. A hybrid plant incorporates different types of chillers in the same cooling plant, which is oftentimes used to offset peak electric loads in an electric chiller by using a natural gas chiller during those times. Based on the total cooling load of the building of 700 tons and comparing capacities of different types of chillers, it was decided that the best option for the BWI Hilton would be centrifugal water-cooled chillers.

When comparing the number and size for the centrifugal chillers, there were several possibilities to choose from. The first option is just using one chiller to meet the full peak load. The second option would be to have two chillers in parallel that each meets half the peak load. A third option would be to have two chillers sized at a 60/40 split of the peak load. However, this option was not as lucrative as the regular 50/50 load split when compared to the chiller load profiles developed in HAP. The 280 load of the 40% chiller (at 280 tons) would only meet the cooling demands of a few hours during the winter months. The 60% chiller (at 420 tons) would have to operate for almost the entire year. In comparison, one of the 50% chillers (at 350 tons) could meet the cooling loads of the building for about four months out of the year. Additional options for the chiller plant arrangement include using three chillers each at one-third of the peak load (at 233 tons each). This was not a feasible solution for the same reasons described for the 60/40 split.

After comparing all these possibilities, it was determined that two centrifugal chillers should operate in parallel and split the load in half at 350 tons each. This way, if one chiller would break down, the second chiller could meet up to half the load of the building. This is much better than if there was just one chiller to meet the entire cooling load: if the single chiller required servicing, there would not be any cooling capacity available for the hotel during those hours. A hotel is not a critical facility like a hospital or data center, but some redundancy is important and logical.

Another benefit to using the 50/50 load split with the two chillers is the typical operating efficiencies. The most efficient operating range for chillers is in the 40-80% capacity range. With a 350 ton chiller, this range is from 140-280 tons. And with both chillers operating together, even at low loads, the minimum cooling load can be met in 5 months out of the year. This provides some flexibility in the way the chillers are cycled on and off, since this method could be about as energy efficient, if not more, than that of just operating one chiller. Further analysis of the chiller loading profiles would be required to determine the optimum loading and unloading sequences for the two chillers. But as was stated previously, it is not imperative that the chillers respond immediately to decreased loads since the two chillers operating together at part load conditions is still very energy efficient.

Another design consideration deals with the speed control of the compressors on the chillers. It is recommended to use VSDs on the chillers to increase the overall energy efficiency. This slightly increases the energy usage at peak loading with the rated kW/ton of the chillers. But in perspective, the chiller plant will only be operating at peak load conditions for a very small percentage (5% or less) of the time during the year. About 95% of the time is spent at part load conditions which operate more efficiently with the use of VSD controllers on both chillers.

There are several other chiller selection options for electric-drive chillers that affect the maintenance costs. A good design choice is to vary the impeller speed by using inlet guide vanes. This is another means to improve the energy efficiency of the chillers. Other methods to reduce maintenance costs include using direct-drive motors in place of gear-drive motors and hermetic centrifugal compressors instead of open-drive centrifugal compressors.

Table 14 - Refrigerant Environmental Impacts

Refrigerant	Type	Global Warming Potential	Ozone Depletion Potential	Heat of Vaporization (Btu/lbm)	Safety Group
R-11	CFC	4000	1	81	A1
R-12	CFC	7100	1	65	A1
R-22	HCFC	1700	0.055	86	A1
R-123	HCFC	93	0.016	66	B1
R-134A	HFC	1300	0	83	A1
R-718	Water	0	0	1070	A1

The final major chiller selection issue deals with the refrigerant choice used in the machines. Chillers are designed to be used with one of several different refrigerants. However, certain refrigerants have more detrimental effects on the environment than others. For example, chlorofluorocarbons (CFCs) have the highest global warming potential and the highest ozone depletion potential. Hydrochlorofluorocarbons (HCFCs) have a lower global warming potential and lower ozone depletion potential than CFCs. Use of newer hydrofluorocarbons (HFCs) have lower global warming potential than CFCs and zero ozone depletion potential. Please see the data above in Table 14 –

Refrigerant Environmental Impacts for a full listing of all the refrigerant types being used recently. For definitions of the various safety groups, please refer to Table 15 – Refrigerant Safety Groups.

Table 15 - Refrigerant Safety Groups

Flammability	Lower Toxicity	Higher Toxicity	Comments
Higher Flammability	A3	B3	LFL </= 0.10 kg/m3 or heat of combustion >/= 19 kJ/kg
Lower Flammability	A2	B2	LFL > 0.10 kg/m3 and heat of combustion < 19 kJ/kg
No Flammability	A1	B1	No LFL in air at 21C and 101 kPa
	No toxicity </= 400 ppm	Evidence of toxicity < 400 ppm	

As is listed below in Table 16 – CFC and HCFC Refrigerant Phase-out, CFCs used as refrigerants have not been produced for ten years. Also, HCFCs like R-22 and R-123 are on their way out of production within the next 25 years. However, there are no restrictions on HFCs like R-134A. These restrictions could play a significant role in deciding on what type of chiller to use. R-134A is the most likely choice if phase-out and restrictions are a major concern. But, R-123 will still be available through the probable life-cycle of the chillers chosen.

Table 16 - CFC and HCFC Refrigerant Phase-out

Refrigerant	Type	Year	Restrictions
R-11	CFC	1996	End of production
R-12	CFC	1996	End of production
R-22	HCFC	2010	End of production and no use in new equipment
		2020	End of production
R-123	HCFC	2015	End of production
		2020	No use in new equipment
		2030	End of production
R-134A	HFC	-	None
R-718	Water	-	None

Step 5:

The fifth step in the chiller plant selection process is to adjust the cooling tower sizing and number of cells, if necessary. According to “CoolTools”, this ultimately depends on the chiller configuration and its effects on the condenser water system.

In the case of the BWI Hilton, the chiller selection was done prior to the actual selection of the cooling towers. Step 3 was done to outline the process of looking at the different aspects of cooling towers, but the actual selection of the cooling towers was done in Step 5. Please refer to Step 3 for a detailed description of this selection process

Step 6:

The sixth step in the "CoolTools" process is to optimize the piping design and pumps for the chilled water and condenser water systems.

In this case, the actual piping design and layout for both the CHW and CW systems was not done, as it was beyond the scope of this thesis report. However, the friction loss through the piping systems was estimated, and the calculations were used to estimate and select the size of the pumps used in both systems. End suction pumps were selected for both the CHW and CW pumps since they are typically good for this application, and since they were used in the original design. The pump head calculations are shown below in Table 17 – CHW Pump Head Calculation and Table 18 – CW Pump Head Calculation.

Table 17 - CHW Pump Head Calculation

Pipe Friction Loss		
Height to Penthouse	143	ft
Guestroom Riser Height	127	ft
Horizontal Distances	300	ft
System Length	1140	ft
Friction Rate	3	ft/100 ft
Multiplier	1.5	
Pipe friction loss	51.3	ft wg
Other Head Losses		
Coil Head Loss	15	ft wg
Control Valve Head Loss	10	ft wg
Evaporator Head	15	ft wg
Heat Exchanger	5	ft wg
Total Other Losses	45	ft wg
Total Pump Head		
Pipe Friction Loss	51.3	ft wg
Other Head Losses	45	ft wg
Subtotal	96.3	ft wg
Safety Factor	15	%
Total Pump Head	**110.7**	**ft wg**

Table 18 - CW Pump Head Calculation

Pipe Friction Loss		
Distance - CH to CT	150	ft
System Length	200	ft
Friction Rate	3	ft/100 ft
Multiplier	1.5	
Pipe friction loss	9.0	ft wg
Other Head Losses		
Cooling Tower Lift	15	ft wg
Heat Exchanger Head	5	ft wg
Control Valve Head Loss	10	ft wg
Condenser Head	20	ft wg
Total Other Losses	50	ft wg
Total Pump Head		
Pipe Friction Loss	9.0	ft wg
Other Head Losses	50	ft wg
Subtotal	59.0	ft wg
Safety Factor	20	%
Total Pump Head	**70.8**	**ft wg**

Other piping design issues deal with the pumping arrangement. This was discussed previously in Step 1 with the CHW distribution arrangement. It is recommended that a reverse return piping system be used instead of a direct return system. This is because the reverse return system will self-balance itself to a certain degree because the lengths of the supply piping to the loads and the return piping back from each load is nearly the same. This is not the case in a direct return system where some loads may have the shortest (or the longest) supply and return water piping.

Step 7:

The seventh step in the chiller plant selection process deals with optimizing the control sequences for the entire central chilled water plant.

For the BWI Hilton project, the controls were not studied in great detail since it is beyond the scope of this thesis. However, some recommendations can be made as to what should be done with the staging of the chillers, pump operations, CHW temperature reset, CW temperature reset, and thermal storage.

With the controls of staging chillers, issues of energy efficiency at part load conditions were discussed previously in Step 4. According to “CoolTools”, it is typically more efficient to run two chillers in parallel at part load than one chiller at full load. It is recommended to not run the VSDs on the chillers at less than 20-35% of the load conditions. Also, there are less complex staging issues with using VSDs because it is not crucial to stage the chillers on and off with precision. This was discussed previously in Step 4.

The pumps used for the CHW and CW systems were described previously in Step 6. It is recommended that these pumps all be equipped with VSDs. A minimum pump flow should also be determined. This is important because pumps do not respond to loads, but rather to flow and head requirements.

Another pumping control issue deals with the arrangement of the pumps in a variable primary flow, as there is in the BWI Hilton project. It is recommended that the two pumps in parallel should be headered together and then piped to each of the chillers. This is a better arrangement than having one pump directly serving each chiller for several reasons. First, a pump is not required to start immediately when a chiller starts. This is evident when only one chiller is in operation. If the second chiller starts, the one headered pump may be able to meet the flow and head demands of both chillers until the second pump can start up. The other benefit of the headered pumps is that they also provide some redundancy. In case one of the pumps goes down for repairs, the other pump can meet half the flow requirements and all the head for the CHW system. Both chillers could be in operation at part loads, as well. This would not be possible in a “one pump per chiller” arrangement.

The control strategies necessary to accomplish CHW temperature reset are not defined in this thesis report because they go beyond the scope of the research and study. In spite of this, the chilled water reset may not be that much of an advantage in the case of the BWI Hilton, anyway. This is because it is not as beneficial for the selected chilled water plant design as with other possible configurations. CHW reset is more beneficial in applications with screw chillers and constant speed pumping, and the BWI Hilton uses centrifugal chillers with variable primary flow pumping.

Similarly to the case above, the condenser water temperature reset is also not defined. However, CW reset is used with the application of water-side free cooling during the winter months. More explanation of this can be found later in the section on “Free Cooling”.

The last control strategy deals with thermal energy storage. It could have been possible to size and use a chilled water storage tank with the BWI Hilton. However, this was not considered during the research or design stages of this thesis project. Thermal energy storage could be its own topic of future study to see if it also contributes to the energy efficiency improvements of the building’s mechanical systems.

Step 8:

The final step in the "CoolTools" guide is to calculate the life cycle costs of the chiller plant with optimized design and selection of both the chillers and cooling towers.

The selection procedures to select the best possible chillers and cooling towers were previously described in Step 4 and Step 5, respectively, so please refer to those steps for more information.

The life cycle cost analysis was performed in depth in the section "Overall Cost Analysis". Please refer to that section for details on the comparisons of all the chiller plant equipment selection options with respect to first costs and operating costs.

<u>Chillers</u>

After examining all the chiller selection guidelines, as described in Table 16 – Chiller Selection Criteria, several manufacturer representatives were contacted to get actual chiller selections and pricing. All the necessary information for chiller selection was received from Carrier, McQuay, Trane, and York. All the chillers quoted used R-134A, except for Trane, which used R-123. The McQuay quote also included three different chillers to select from. All these options were examined and comparisons were made to determine which chiller best fits the application at the Hilton Hotel at BWI Airport. Both the first costs and energy costs were studied during this process.

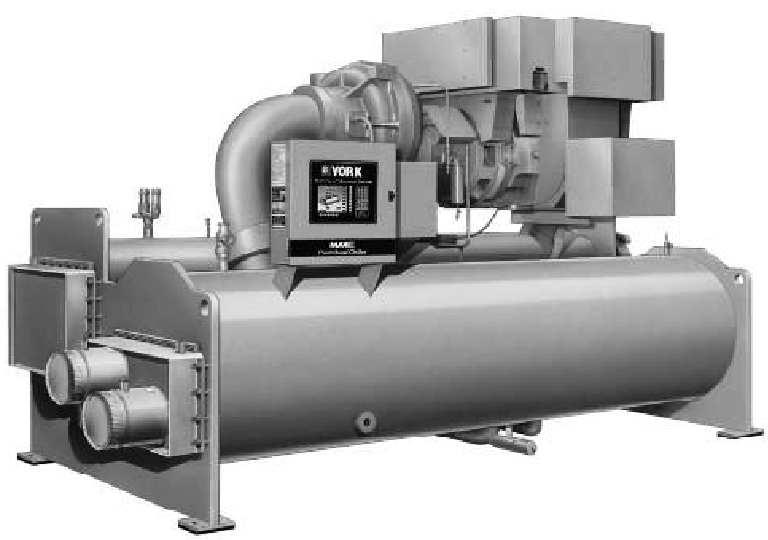

Figure 5 - York Chiller

As was described earlier in Step 2 of the design process, a 12 F delta-T was chosen for this project. However, when price quotes were gathered from manufacturers, one quote was given at a 10 F delta-T. The 10 F delta-T on Chiller Option No 1 used the traditional flow rates associated with the chilled water and condenser water. In the midst of the newer thinking with using lower flows (gpm/ton) with higher delta-Ts, there has been concern over the performance and maintenance issues on the evaporators of chillers. This question was asked to the manufacturer representatives, but they all said the lower flow rates and 12 F delta-Ts will not damage the equipment. A summary of all the chiller selection choices can be seen in Table 19 – Chiller Selection Comparison.

Table 19 - Chiller Selection Comparison

Option No	Manuf	Qty	Refrig	VSD	Capac (tons)	Input Power (kW)	Perf (kW/ton)	Comments
1	Carrier	2	R-134A	Yes	350	231.0	0.661	
2	York	2	R-134A	Yes	350	216.0	0.617	
3	McQuay	2	R-134A	Yes	350	207.6	0.593	
4	McQuay	1	R-134A	IGV	700	403.0	0.576	Inlet Guide Vanes
5	McQuay	1	R-134A	Yes	700	418.2	0.597	
6	Trane	1	R-123	No	350	178.8	0.511	
6	Trane	1	R-123	AFD	350	184.3	0.526	Adaptive Freq Drive
7	Trane	2	R-123	AFD	350	184.3	0.526	Adaptive Freq Drive

Option No	Manuf	CHWR	CHWS	Evap delta-T (F)	Evap Flow Rate (gpm)	CWR	CWS	Cond delta-T (F)	Cond Flow Rate (gpm)
		Evap EWT (F)	Evap LWT (F)			Cond LWT (F)	Cond EWT (F)		
1	Carrier	54.0	44.0	10.0	840	94.5	85.0	9.5	1050
2	York	56.0	54.0	12.0	700	94.3	85.0	9.3	1050
3	McQuay	56.0	44.0	12.0	700	95.0	85.0	10.0	1050
4	McQuay	56.0	44.0	12.0	1400	95.0	85.0	10.0	2100
5	McQuay	56.0	44.0	12.0	1400	95.0	85.0	10.0	2100
6	Trane	56.0	44.0	12.0	696.7	95.0	85.0	10.0	970.7
6	Trane	56.0	44.0	12.0	696.7	95.0	85.0	10.0	976.8
7	Trane	56.0	44.0	12.0	696.7	95.0	85.0	10.0	976.8

After comparing all the first costs and annual operating costs in the life cycle cost analysis, it was decided that Option No 7 with the two Trane Chillers with adaptive frequency drives (same thing as VSD or VFD controls) was the best choice chiller for the BWI Hilton. More information can be found in Appendix A – Chiller Selection with the selected chiller cut sheets from the manufacturers. For all the information regarding the life cycle costs, which incorporate the first costs, energy usage, and annual operating costs, please refer to the section "Overall Cost Analysis".

Cooling Towers

Figure 2 - Marley Cooling Tower

The selection of the cooling towers was based on Marley NC Class cooling towers. The type of unit used is a two-cell, induced-draft, cross-flow, galvanized steel cooling tower. Several choices of cooling towers were looked at for the BWI Hilton project. Two different towers at standard sound ratings (with 1800 rpm fan motors) were examined and compared to two comparable towers that have lower sound ratings (with 1200 rpm fan motors). The energy consumption and acoustics of all four cooling towers were examined prior to the final selection. A comparison of the four cooling towers is shown below in Table 20 – Cooling Tower Selection Comparison.

Table 20 - Cooling Tower Selection Comparison

Cooling Tower Model	No of Cells	Fan				Motor			gpm/hp
		Blades	Length (ft)	Speed (rpm)	Speed (fpm)	Speed (rpm)	Output (BHP)	Air Flow (cfm)	
NC8305FL2	2	8	8	313	7866.5	1200	40	228,800	72.6
NC8306EL2	2	8	10	191	6000.4	1200	30	244,000	99.4
NC8305F2	2	6	8	370	9299.1	1800	40	232100	73.8
NC8307E2	2	6	10	241	7571.2	1800	30	242300	103

Cooling Tower Model	Water Flow (gpm)	HWT (F)	Range (F)	CWT (F)	Approach (F)	WBT (F)	RH (%)	Total Heat Rejection (Btu/hr)	Price
NC8305FL2	2100	95	10	85	6	79	50	10,463,000	$80,600
NC8306EL2	2100	95	10	85	6	79	50	10,463,000	$92,300
NC8305F2	2100	95	10	85	6	79	50	10,463,000	$78,000
NC8307E2	2100	95	10	85	6	79	50	10,463,000	$94,900

After comparing all the first costs and annual operating costs in the life cycle cost analysis, it was decided that Option No 3 with the NC8305F2 was the best choice cooling tower for the BWI Hilton. More information can be found in Appendix B – Cooling Tower Selection with the selected chiller cut sheets from the manufacturer. Please also refer to the section “Overall Cost Analysis” for additional life cycle cost information.

On the BWI Hilton project, the two-cell cooling towers will be located at the same spot as the original cooling towers just north of the building outside of the kitchen. Please see the section “Cooling Tower Acoustical Analysis” for more information on the acoustics study done on the four cooling towers.

Pumps

The pump energy consumed in the Hilton Hotel at BWI Airport is a major contributing factor to the total building energy usage. Therefore, the pump sizing and selection is an important issue with the chilled water plant design. Pumps are needed on the project for both the chilled water and condenser water systems. However, since the exact piping layouts, sizing, lengths, and fittings were not known, an estimate of the total pump head required for each of the pumps was made. These estimates are shown previously in Step 6 of the “Chilled Water Plant Design” section.

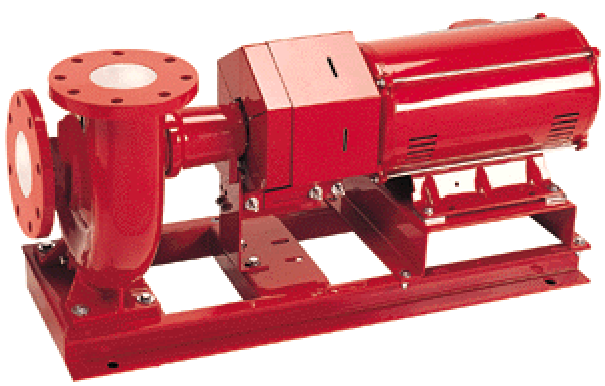

Figure 7 - Bell & Gossett Pump

For both systems, two Bell & Gossett Series 1510 end suction pumps piped in parallel will meet the calculated flow and head requirements. All four pumps were selected with variable frequency drives (VFDs) with manual bypasses for improved partial flow performance. A summary of the pumps selected for the condenser water and chilled water systems can be seen below in Table 21 – Pump Selections. More information on the pump curves and cut sheets can be found in Appendix C – Pump Selection.

Table 21 - Pump Selections

Chilled Water Pumps			Condenser Water Pumps		
No of Pumps	2	pumps	No of Pumps	2	pumps
Pump Flow	700	gpm ea	Pump Flow	1050	gpm ea
Pump Head	110.7	ft wg ea	Pump Head	70.8	ft wg ea
Pump Speed	1750	rpm	Pump Speed	1750	rpm
Manufacturer	Bell&Gossett		Manufacturer	Bell&Gossett	
Model	1510 Base mounted centrifugal		Model	1510 Base mounted centrifugal	
Size	5G		Size	5E	
Impeller Dia	10.875	in	Impeller Dia	9.875	in
Motor Size	40	HP	Motor Size	25	HP
BHP	24.91	BHP	BHP	23.16	BHP
Efficiency	79.19	%	Efficiency	82.14	%

Water-Side Free Cooling

One of the energy saving techniques used in the Hilton Hotel at BWI Airport project involved water-side free cooling. Free cooling can be used when the outdoor wet bulb temperature is below a certain temperature, and the cooling tower can produce lower temperature condenser water. The chilled water bypasses around the chillers and goes through a plate-and-frame heat exchanger that is piped in parallel to the chillers. Here the CHWR water is cooled down by giving up its heat to the CWS water instead of passing through the evaporator of the chiller. An example of a plate-and-frame heat exchanger is shown below in Figure 8 – Bell & Gossett Heat Exchanger.

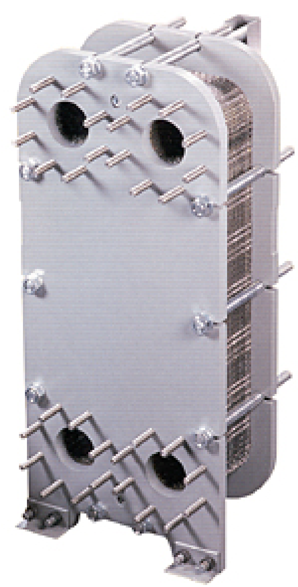

Figure 8 - Bell & Gossett Heat Exchanger

There can be significant energy savings realized by installing the heat exchanger and piping to utilize water-side free cooling. A simple comparison was done in HAP to determine how much energy was saved by using free cooling with (2) York MaxE Chillers (Option 2). The results are summarized below in Table 22 – Free Cooling Energy and Cost Savings.

Table 22 - Free Cooling Energy and Cost Savings

Component	With Free Cooling Site Energy (kBtu)	No Free Cooling Site Energy (kBtu)	Savings with Free Cooling (kBtu)	% Savings
Air System Fans	3,423,614	3,423,614	0	0.00%
Cooling	3,452,357	4,255,716	803,359	18.88%
Heating	17,442,574	17,442,574	0	0.00%
Pumps	1,605,084	1,604,931	-153	-0.01%
Cooling Towers	759,293	686,163	-73,130	-10.66%
HVAC Sub-Total	**26,682,921**	**27,412,998**	**730,077**	**2.66%**

Component	With Free Cooling Annual Cost	No Free Cooling Annual Cost	Savings with Free Cooling	% Savings
Air System Fans	$70,297	$70,209	-$88	-0.13%
Cooling	$79,914	$93,363	$13,449	14.41%
Heating	$36,124	$36,121	-$3	-0.01%
Pumps	$33,274	$33,232	-$42	-0.13%
Cooling Towers	$17,486	$16,247	-$1,239	-7.63%
HVAC Sub-Total	**$237,094**	**$249,172**	**$12,078**	**4.85%**

For the BWI Hilton project, it was determined that when the WBT is 30 F or lower, water-side free cooling can be used to cool the chilled water to its specified setpoint of 44 F. After talking with a Marley sales representative, it was determined that the minimum CW temperature can be 40 F. This is because air passing through the cooling tower fill will be stratified and it could potentially produce CW that is near freezing when the average CW temperature gets below 40 F. In order to get 42 F CWS entering the heat exchanger, a 6 F range (or delta-T) on the cold side of the heat exchanger is used to get a wet bulb temperature (WBT) of about 30 F. Please see the graph below in Figure 9 – CWS vs WBT (the lowest line was used since it represents the 6 F range).

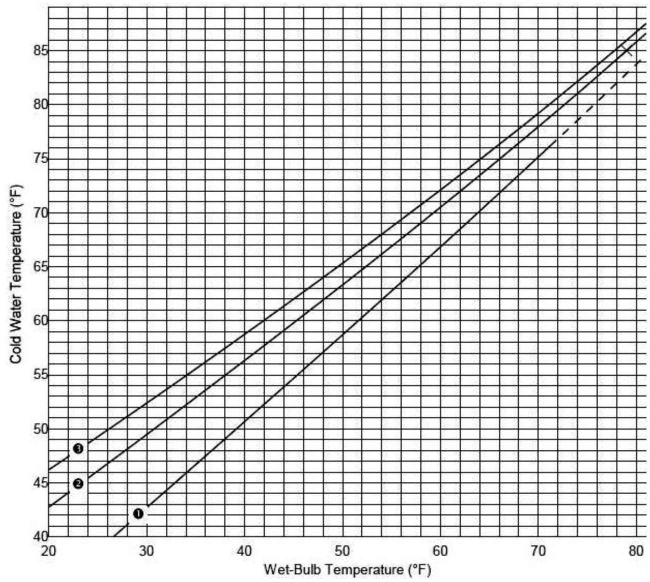

Figure 9 - CWS vs WBT

If a plate-and-frame heat exchanger with a 2 F approach is selected and the CWS temperature entering the cold side of the heat exchanger is 42 F, then the CHWS temperature leaving the heat exchanger on the hot side is 44 F. This works because 44 F is the desired CHWS temperature setpoint. The number of hours when the outdoor WBT is less than or equal to 30 F can be seen in Table 23 – Free Cooling at WBT < 30 F. This occurs for a total of 1357 hours each year, which is about 15.5% of the year.

Table 23 - Free Cooling at WBT < 30 F

No of hr WB </= 30F	
January	432
February	312
March	184
April	45
May	3
June	0
July	0
August	0
September	0
October	0
November	75
December	306
Total	**1357**
% of yr	15.49%

To size the plate-and-frame heat exchanger, the total load on it needs to be calculated. Using hourly simulation results of the chiller load profiles from HAP, the number of hours when free cooling occurs was determined. This can be seen above in Table 23 – Free Cooling at WBT < 30 F above. Also, the maximum free cooling load that occurs during those hours is shown below in Table 24 – Max Free Cooling Load. Using these values, the maximum load is 3523 MBH, which is about 294 tons. Using a safety factor of 10% and rounding to the next even size, the total load on the heat exchanger was found to be 325 tons.

Table 24 - Max Free Cooling Load

January	3406.1
February	3459.7
March	3523.0
April	3462.0
May	3476.2
June	0.0
July	0.0
August	0.0
September	0.0
October	3463.2
November	3449.8
December	3435.8
Max (MBH)	3523.0
Max (tons)	293.58
Safety Factor	10%
Total Load (tons)	322.94
HTX Size (tons)	**325**

Using this total cooling of 325 tons (Q=3,900,000 Btu/hr), the water temperature conditions and flow rates could be calculated. On the cold side of the heat exchanger, the CW delta-T is known to be 6 F, since that is the selected range for the cooling tower. Using the equation Q = 500 x gpm x delta-T, the CW flow rate was calculated. The maximum CW flow rate is 1300 gpm during free cooling operations. This should not be a problem for the cooling towers or the CW pumps since they all have VSDs to modulate their speeds.

The same calculation (with the same Q) can be used on the hot side of the heat exchanger. After talking with a sales representative from Bell & Gossett, it was determined the the CHW delta-T = 10 F during winter operation. With the CHWS = 44 F, the CHWR must be 56 F. Therefore, the maximum flow rate of the CHW is 780 gpm, when the same Q equation is used as above.

For a schematic of the heat exchanger with the free cooling design temperatures and flow rates, please see Figure 10 – Free Cooling Heat Exchanger below.

For more information on the heat exchanger used and the cut sheets, please see Appendix D – Heat Exchanger Selection.

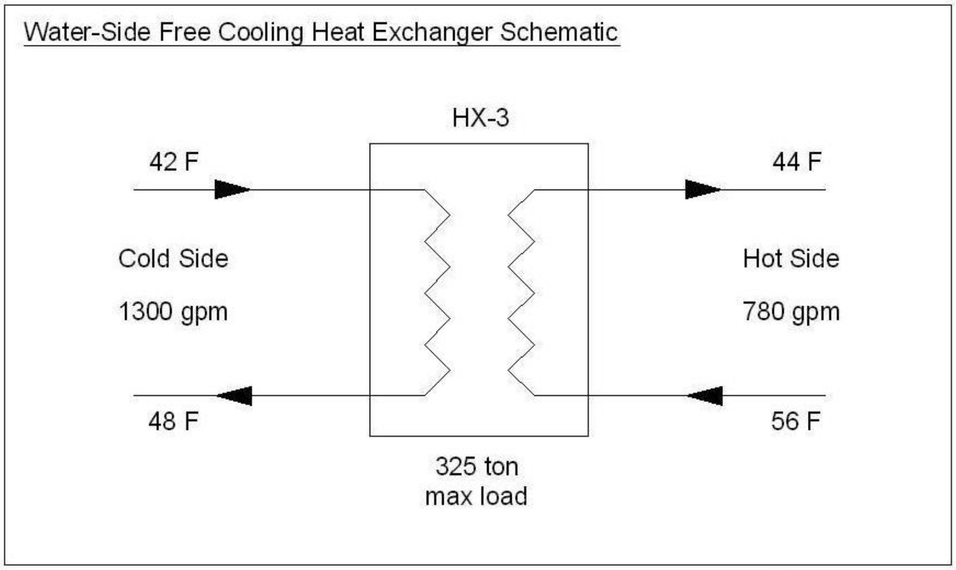

Figure 10 - Free Cooling Heat Exchanger

Please note that if CHWS temperature reset was used, which it was not for this project, then higher WBTs could be used to achieve higher CWS temperatures. However, additional calculations would be necessary to determine if all the chilled water coils in the building could handle a higher temperature CHWS. The total building cooling loads would also have to be compared to the maximum cooling capacity of the heat exchanger (325 tons) to see if this is feasible. Not enough time was allotted to all these supplementary equations, and the CHWS temperature reset option was not studiesd. Despite the more complicated controls, the main benefit to the CHWS temperature reset is that free cooling could be used for a greater percentage of hours during the year. This can be seen from the data shown in Table 25 – Free Cooling WBTs.

Table 25 - Free Cooling WBTs

No of hr WB </= 35F		No of hr WB </= 40F	
January	582	January	679
February	414	February	524
March	351	March	501
April	99	April	208
May	26	May	62
June	0	June	0
July	0	July	0
August	0	August	0
September	0	September	0
October	20	October	85
November	192	November	406
December	514	December	648
Total	**2198**	**Total**	**3113**
% of yr	25.09%	% of yr	35.54%

Impact on Air-Side Equipment

The addition of the chilled water central plant in the Hilton Hotel at BWI Airport did not have many major effects on the air-side equipment of the existing mechanical systems design for the building. The design conditions for all four air handling units (AHUs) and the six rooftop units (RTUs) remained the same as in the original design. The loads from all the spaces in the hotel also did not change. However, the new calculated HAP outputs were used to determine the size and capacities of all the AHUs and RTUs. The other significant impact on the equipment design and selection equipment was the changeover to operating with the new chilled water system instead of the original condenser water system, so the new AHUs and RTUs were selected to have chilled water coils.

Air Handling Units

All the data for the AHUs is based on selection of Carrier 39MN air handling units. All four units were selected to have a mixing box, hot water heating coil, chilled water cooling coil, and draw-through supply fan. A sample cross-section view of a Carrier AHU can be seen below in Figure 11 – Carrier AHU.

Figure 11 - Carrier AHU

The original unit price for each individual air handling unit was not known, so a cost analysis between the existing design and the new AHUs was not calculated. Please refer to the original equipment cost estimate in Table 53 – Original Mechanical Equipment Costs in the “Overall Cost Analysis” section. Please see Appendix E – Air Handling Unit and Rooftop Unit Selection for information and cut sheets for the new AHUs with chilled water cooling coils.

Rooftop Units

All the data for the RTUs is based on the selection of Carrier 39MW rooftop units. Five of the six units were selected to have a mixing box, hot water preheat coil, chilled water cooling coil, hot water reheat coil, and draw-through supply fan. The only unit that did not change is RTU-11, which serves the elevator machine room in the penthouse. This unit remained the same as in the original design since it had such a small load and a minimal impact on the operating costs of the rest of the building. Therefore, RTU-11 was not included in any of the cost calculations or energy usage comparisons between the original design and the new design.

The original unit price for each individual rooftop unit was not known, so a cost analysis between the existing design and the new RTUs was not calculated. Please refer to the original equipment cost estimate in Table 53 – Original Mechanical Equipment Costs in the "Overall Cost Analysis" section. Please see Appendix E – Air Handling Unit and Rooftop Unit Selection for more information and the cut sheets for the new RTUs with chilled water cooling coils and hot water preheat and reheat coils.

Guest Room Indoor Air Quality

In the original design of the Hilton Hotel at BWI Airport, two air conditioning units located in the penthouse provided 60 cfm of ventilation air to each of the guest rooms. However, during the value engineering process for the project, these two air conditioning units in the penthouse were eliminated. After eliminating the primary source of outdoor air, a variance was granted for the BWI Hilton project to use an alternative method of ventilation. This method takes the supply air that the RTUs provide for pressurization and ventilation to the guest room tower corridors and has it drawn into each of the guest rooms through the undercut in the doors. The corridor air is drawn into the guest rooms either by the continuously operating mechanical exhaust fans through all the bathrooms or by the use of operable windows in each guest room.

However, this method does not seem to be a very effective method to adequately ventilate the guest rooms. Unfortunately, there is no way to accurately measure, predict, or record the levels of carbon dioxide or other airborne contaminants in each guest room. But, the indoor air quality (IAQ) of the guest rooms is one of the biggest design issues of the building. There is major concern with the ventilation of the 279 guest rooms of the BWI Hilton. An improved system is needed to provide fresh air to the rooms, as well as reducing the concentration of odors and other contaminants that result from poor ventilation techniques.

Therefore, to increase the IAQ of the spaces, it was decided to install new outdoor air units to provide ventilation for all the guest rooms. Two new units will be located in the penthouse on top of the guest room tower, and the air will be ducted down through vertical risers, which was the same way it was done in the original design before it was valued engineered out of the project. This will be accomplished through the use of two Dedicated Outdoor Air System (DOAS) units with energy recovery wheels. In this case for the BWI Hilton, the term "DOAS" is used to simply refer to a unit that continuously provides conditioned 100% outside air.

The DOAS units will provide ventilation air into the guest rooms through the fan coil units. The DOAS units supply 60 cfm of pre-conditioned ventilation air at continuous operation. The fan coil units will be used to meet the space cooling and heating loads in all 279 guest rooms of the BWI Hilton. The FCU recirculates a certain amount of the room air and mixes the two air streams together. After the mixing, the air stream passes over the coil section where it is either cooled or heated, depending on what the room calls for. The draw-through fan then supplies the guest room with the conditioned air.

During times when no additional cooling loads are called for by the FCU, the 60 cfm of ventilation air will still be supplied to the space. This has several benefits which are described below.

Even though ASHRAE Standard 62.1-2004 only requires a minimum ventilation rate of 5 cfm/person and 0.06 cfm/sf in hotel guest rooms, the DOAS units were sized and selected to provide 60 cfm of conditioned outside air to each guest room. The 60 cfm of outdoor air was chosen for several reasons. First, 60 cfm was the quantity used in the original design prior to the value engineering, and this way a comparison can be made between the two scenarios. Next, it was known that all guest rooms have 50 cfm of continuous exhaust from the bathrooms. Pressurization of the guest rooms is important to prevent air flow in the wrong direction, so the guest room should always have positive pressure compared to the spaces around it.

There are also some benefits to having positive pressure in the guest rooms. This will prevent unwanted infiltration from the moist summer outside air, which has the potential to cause mold in the walls. Compared to the bathroom, the guest room will always be provided with 10 cfm more than is exhausted. This will help to prevent air flow and unwanted odors from quickly moving from the bathroom into the guest room. Also, the guest rooms will have slightly higher pressure as compared to the corridors to prevent any unwanted infiltration of odors from the more public areas.

Continuous supply of outdoor air to all the guest rooms and proper pressurization are the main reasons to use DOAS units to maintain improved indoor air quality of the guest rooms. In comparison, this method is a significant improvement over the original method of ventilation.

Dedicated Outdoor Air System

All the data for the DOAS units is based on selection of Semco Pinnacle units. Both units were selected to have a total energy enthalpy wheel, chilled water cooling coil, passive dehumidification wheel, supply fan, and exhaust fan. Please see Appendix F – Dedicated Outdoor Air System Unit Selection for cut sheets and more information on the selection of the two new DOAS units.

The two DOAS units both use two energy recovery wheels. The first wheel does total energy recovery with an exchange between the outside and exhaust air streams. This enthalpy wheel has a 3A (Angstrom) molecular sieve with a desiccant coating that prohibits the adsorption of any particles larger than a water molecule, which is 2.8A. The second wheel is a passive dehumidification energy recovery wheel that is used to dehumidify the outdoor air after it passes through the cooling coil. This wheel has adsorbent desiccant material that has optimum dehumidification performance. Also, both wheels operate with variable speed drives to modulate to the appropriate speed at part load based on the indoor and outdoor air conditions.

Figure 12 - Semco DOAS Unit

A schematic of one of the DOAS units is shown below in Figure 13 – DOAS Unit Schematic. The one shown actually shows the typical operation of the unit during peak sensible cooling load.

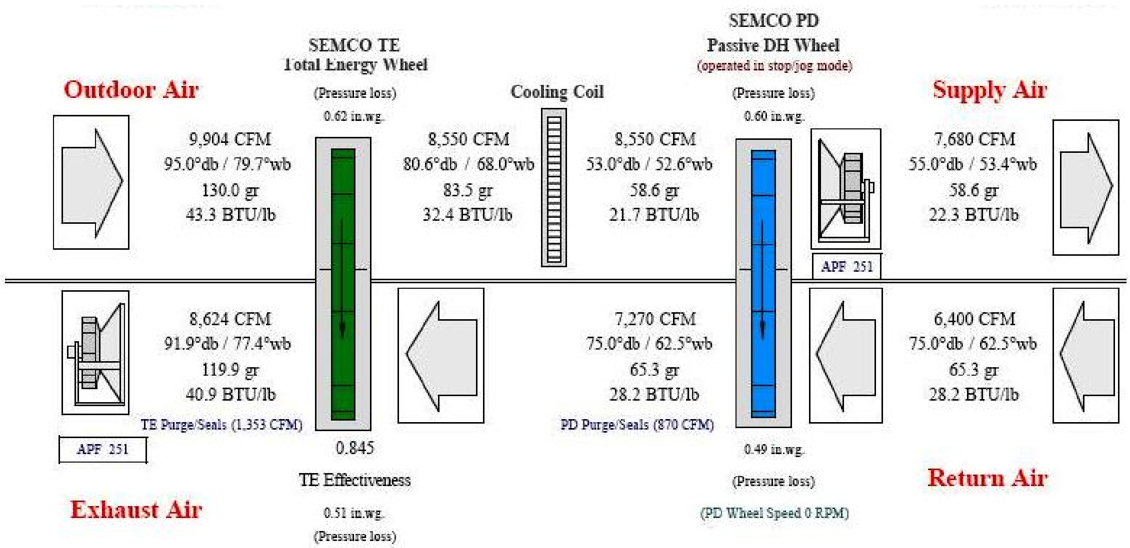

Figure 13 - DOAS Unit Schematic

The airflow sizing of both of the units was done with the following procedure for the calculation of the ventilation air and the exhaust air. The ventilation sizing is shown in Table 26 – DOAS Ventilation Air Quantity Sizing. The exhaust sizing is shown in Table 27 – DOAS Exhaust Air Quantity Sizing.

Table 26 - DOAS Ventilation Air Quantity Sizing

Unit	Floor(s)	No of Floors	No of Rooms	Units/Room	Airflow/Room (cfm)	Total Airflow (cfm)
DOAS-1	3	1	14	1	60	840
	4 - 10	7	14	1	60	5880
	11	1	10	1	60	600
	11	1	3	2	60	360
					Total	**7680**
DOAS-2	3	1	18	1	60	1080
	4 - 10	7	18	1	60	7560
	11	1	10	1	60	600
	11	1	2	3	60	360
					Total	**9600**

Table 27 - DOAS Exhaust Air Quantity Sizing

Unit	Floor(s)	No of Floors	No of Rooms	Units/Room	Airflow/Room (cfm)	Total Airflow (cfm)
DOAS-1	3	1	14	1	50	700
	4 - 10	7	14	1	50	4900
	11	1	10	1	50	500
	11	1	3	2	50	300
					Total	**6400**
DOAS-2	3	1	18	1	50	900
	4 - 10	7	18	1	50	6300
	11	1	10	1	50	500
	11	1	2	3	50	300
					Total	**8000**

Fan Coil Units

Four-pipe fan coil units (FCUs) were selected to be used in each guest room. These FCUs are vertical stack units that are made specifically for applications where multiple units will be lined up and stacked above each other, like in hotels. This way, minimal piping is required between units on adjacent floors. The connections for all four pipes are made at each unit the entire way up the riser.

A four-pipe FCU system was chosen to replace the existing water source heat pump (WSHP) system in the original design. This was done for two reasons. The primary reason was because the overall system could operate more efficiently using a central cooling plant as compared to individual units that require refrigerant loops and compressors to provide space cooling. Another benefit of using the FCU system was the ability to have units that do not contain a compressor. This reduces both the noise levels of the units as well as the maintenance needs.

The four-pipe was also chosen over a two-pipe FCU system because of the increased comfort levels and flexibility that it provides, especially in the mid-seasons. Some rooms call for heating while other rooms call for cooling oftentimes during the spring and fall. With a two-pipe system, there is limited flexibility and all the rooms must either use all heating or all cooling. With the four-pipe system, both the boiler and the chiller can be running at the same time during these swing periods to provide room-by-room options for either heating or cooling. The four-pipe FCU system has much simpler controls than a two-pipe FCU system because of the changeover between hot and chilled water.

A two-pipe system with electric reheat was also considered as an alternative. However, it was presumed that the four-pipe system could operate more efficiently than a half-electric system, provided the natural gas fuel rates do not escalate greatly in the future, it will continue to be more economical to use natural gas boilers for heating in place of electric reheat coils.

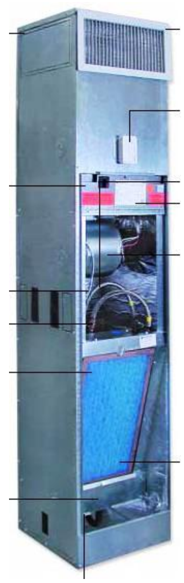

Figure 14 – Enviro-Tec Fan Coil Unit

Using HAP, the block loads for a typical guest room were calculated, and they are shown in Table 28 – Guest Room Block Loads. The main loads on the spaces were from the solar loads, lighting, electric equipment, and the people. These broken loads are shown for two sample rooms, one from each FCU. They are shown below in Table 29 – FCU-1 Sample Guest Room Loads and Table 30 – FCU-2 Sample Guest Room Loads. There were some slight variations between some of the rooms, but all the loads of the rooms will be met easily by either of the possible units shown above in Table 31 – FCU Comparison.

Table 28 - Guest Room Block Loads

No	Cooling			Heating	
	Sensible (Btu/hr)	Latent (Btu/hr)	Total (Btu/hr)	Sensible (Btu/hr)	Latent (Btu/hr)
FCU-1	7094	738	7832	938	0
FCU-2	7873	738	8611	938	0

Table 29 - FCU-1 Sample Guest Room Loads

Zone 3	DESIGN COOLING			DESIGN HEATING		
	OCCUPIED T-STAT 74.0 °F			OCCUPIED T-STAT 70.0 °F		
		Sensible	Latent		Sensible	Latent
ZONE LOADS	Details	(BTU/hr)	(BTU/hr)	Details	(BTU/hr)	(BTU/hr)
Window & Skylight Solar Loads	49 ft²	544	-	49 ft²	-	-
Wall Transmission	35 ft²	13	-	35 ft²	97	-
Window Transmission	49 ft²	-7	-	49 ft²	841	-
Overhead Lighting	314 W	1005	-	0	0	-
Electric Equipment	1476 W	4781	-	0	0	-
People	4	757	738	0	0	0
>> Total Zone Loads	-	7094	738	-	938	0

Table 30 - FCU-2 Sample Guest Room Loads

Zone 15	DESIGN COOLING			DESIGN HEATING		
	OCCUPIED T-STAT 74.0 °F			OCCUPIED T-STAT 70.0 °F		
		Sensible	Latent		Sensible	Latent
ZONE LOADS	Details	(BTU/hr)	(BTU/hr)	Details	(BTU/hr)	(BTU/hr)
Window & Skylight Solar Loads	49 ft²	1669	-	49 ft²	-	-
Wall Transmission	35 ft²	19	-	35 ft²	97	-
Window Transmission	49 ft²	-86	-	49 ft²	841	-
Overhead Lighting	314 W	964	-	0	0	-
Electric Equipment	1476 W	4626	-	0	0	-
People	4	681	738	0	0	0
>> Total Zone Loads	-	7873	738	-	938	0

As a point of reference, FCU-1 units are located in all the even-numbered guest rooms, which are the ones that face the north. The FCU-2 units are located in all the odd-numbered guest rooms, which are the ones that face the south.

Table 31 - FCU Comparison

Option No	Tag	Manuf	Model	Dimensions Length (in)	Width (in)	Height (in)	Airflow (cfm)
1	FCU-1	Carrier	42SGA03	17	17	88	330
1	FCU-2	Carrier	42SGA04	17	17	88	400
2	FCU-1	Enviro-Tec	VHC04	18	23.38	88	358
2	FCU-2	Enviro-Tec	VHC04	19	23.38	89	454

Option No	Tag	Total Clg Capac (Btu/hr)	Sens Clg Capac (Btu/hr)	Clg LAT (F)	CHW Flow (gpm)	Sens Htg Capac (Btu/hr)	Htg LAT (F)	HW Flow (gpm)
1	FCU-1	12,633	8825	55.5	2.1	19,597	114.3	2.0
1	FCU-2	13,877	9924	57.3	2.3	21,020	108.1	2.1
2	FCU-1	9,992	7688	55.2	1.66	20,630	123.2	2.12
2	FCU-2	11,854	9263	56.2	1.97	2,443	119.7	2.5

After the basic sizing of the fan coils was complete, a comparison between two manufacturers was done to determine which FCU to use in all the guest rooms, and this can be seen above in Table 31 – FCU Comparison.

After looking at the manufacturer's data for the two fan coil units, the necessary information was put into HAP. Comparing the results of simulations for both options showed very little difference in their operating costs. Option 2 had an annual operating cost that was only $5 more than Option 1. Therefore, the process used to select which units to use was simply done by only comparing their first costs, not their life cycle costs.

By simple observation, it can be seen that the Carrier FCUs cost about $500 less per unit than the Enviro-Tec FCUs. So the Carrier 42SGA units will be used in all the guest rooms in the BWI Hilton. Please see the detail drawings included in Appendix G – Fan Coil Unit Selection.

After the selection of the Carrier FCUs was made, a calculation was done to one of the guest rooms on the north-side of the hotel to ensure that the selected coil size was sufficient to meet the space ventilation and cooling loads. With the DOAS unit providing DBT = 68.1 F and WBT = 56.7 F, the cooling loads required by the fan coil units will be decreased. This is because they were selected based on entering air conditions of DBT = 80.0 F and WBT = 67.0 F. Since 330 cfm is the actual airflow provided by the fan, and there is 60 cfm of ventilation air supplied to the FCU, only 270 cfm of recirculation air is needed. After mixing, the air has a DBT = 75.5 F, and the unit leaving air temperature is DBT = 55.5 F, which gives a delta-T = 20 F. Using the equation Q = 1.08 x cfm x delta-T, the required load of the cooling coil can be calculated. With the above conditions, the required cooling load of the FCU is Q = 7128 Btu/hr. As was expected, this is less than the 12,633 Btu/hr capacity of the cooling coils in the fan coil unit. Therefore, the FCU meets the required load, and it is oversized enough to meet any atypical loads in all the other guest rooms.

Another step taken after the Carrier FCUs were selected was to verify that the units will fit into the area used previously for the water-source heat pumps in the original design. Several items were looked at, and they are described next.

The overall dimensions of each FCU were listed above in Table 28 – FCU Comparison. For the Carrier units, the length and width are both 17 inches. When the available area was measured on the guest room floor plans, it was found to be 23 in x 25 in. The selected units have enough space in that area and the shafts will not have to be resized. This can be seen below in Figure 15 – Typical Maximum Dimensions.

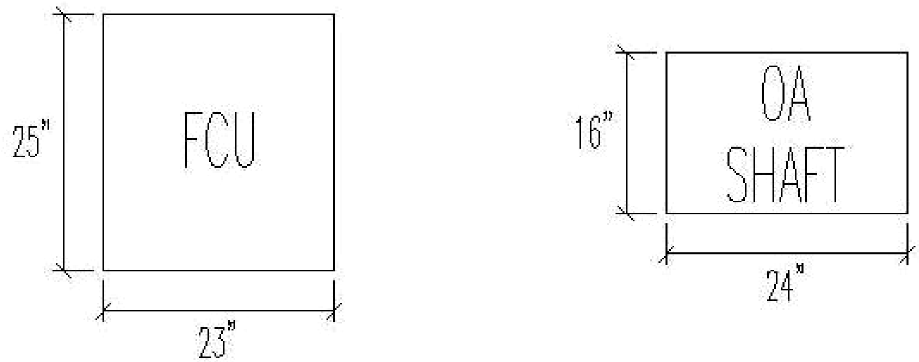

Figure 15 - Typical Maximum Dimensions

The guest rooms all have FCUs adjacent to the neighboring FCU, and they are also beside the outdoor air shaft coming from the DOAS units in the penthouse. This is important because the OA shaft must be tapped at each floor for the connections to the FCUs. The five pipes at each FCU are also shown in the detail. A typical detail of this arrangement is shown in Figure 16 – Typical FCU and OA Detail.

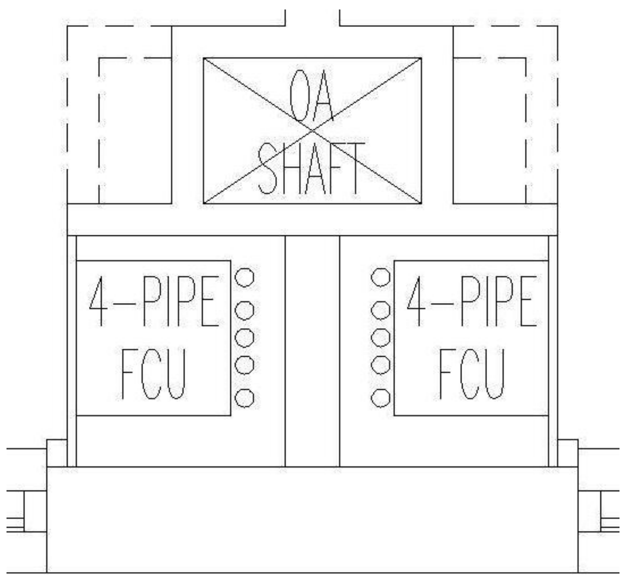

Figure 16 - Typical FCU and OA Detail

Energy and Emissions Analyses

This section simply compares the energy usage in the base case and the new design. The differences and percentages are listed in the following tables. A basic emissions analysis is also included.

Energy Usage

The amount of electric and natural gas both changed between the base case and the new design. While the electrical usage greatly decreased, the natural gas usage increased some. This is primarily due to the increased heating loads required by the guest rooms. The original design used water-source heat pumps run off the condenser water loop that was heated indirectly by boilers. The new design uses fan coil units in all the guest rooms that operate directly off the hot water generated by the boiler.

For a comparison of the electric and natural gas usage differences between the base case and the new design, please refer to Table A – Fuel Source Energy Comparisons and Table B – Component Energy Comparison. Positive numbers refer to a savings in energy for the new design over the base case. Negative numbers imply that the new design uses more energy than the base case.

Comparison of the electric and natural gas annual costs are shown after the energy comparisons in Table C – Fuel Source Annual Costs Comparisons and Table D – Component Annual Energy Comparisons. Positive numbers refer to a savings in annual costs for the new design over the base case. Negative numbers imply that the new design costs more than the base case.

Table A - Fuel Source Energy Comparisons

Component	Base Case	New Design	Difference	% Diff
HVAC Components				
Electric (kWh)	13,813,310	2,457,286	11,356,024	82.21%
Natural Gas (Therm)	76,290	173,622	-97,332	-127.58%
Non-HVAC Components				
Electric (kWh)	3,682,840	3,682,840	0	0.00%
Natural Gas (Therm)	0	0	0	0.00%
Totals				
Electric (kWh)	17,496,150	6,140,126	11,356,024	64.91%
Natural Gas (Therm)	76,290	173,622	-97,332	-127.58%

Table B - Component Energy Comparison

Component	Base Case (kBtu)	New Design (kBtu)	Difference (kBtu)	% Diff
Air System Fans	1,611,165	3,423,614	-1,812,449	-112.49%
Cooling	9,513,890	2,735,189	6,778,701	71.25%
Heating	8,101,048	17,442,574	-9,341,526	-115.31%
Pumps	33,564,252	1,527,502	32,036,750	95.45%
Cooling Towers	1,966,906	618,064	1,348,842	68.58%
HVAC Sub-Total	54,757,261	25,746,942	29,010,319	52.98%
Lights	3,954,558	3,954,558	0	0.00%
Electric Equipment	8,611,752	8,611,752	0	0.00%
Non-HVAC Sub-Total	12,566,310	12,566,310	0	0.00%
Grand Total	67,323,571	38,313,252	29,010,319	43.09%

Table C - Fuel Source Annual Costs Comparison

Component	Base Case (/yr)	New Design (/yr)	Difference (/yr)	% Diff
HVAC Components				
Electric	$959,905	$181,074	$778,831	81.14%
Natural Gas	$17,113	$34,616	($17,503)	-102.28%
HVAC Sub-Total	$977,018	$215,690	$761,328	77.92%
Non-HVAC Components				
Electric	$255,027	$256,782	($1,755)	-0.69%
Non-HVAC Sub-Total	$255,027	$256,782	($1,755)	-0.69%
Grand Total	$1,232,045	$472,472	$759,573	61.65%

Table D - Component Annual Costs Comparison

Component	Base Case	New Design	Difference	% Diff
Air System Fans	$32,896	$70,277	($37,381)	-113.63%
Cooling	$196,738	$63,402	$133,336	67.77%
Heating	$26,381	$36,124	($9,743)	-36.93%
Pumps	$681,147	$31,683	$649,464	95.35%
Cooling Tower Fans	$39,921	$14,213	$25,708	64.40%
HVAC Sub-Total	$977,082	$215,698	$761,384	77.92%
Lights	$80,260	$80,812	($552)	-0.69%
Electric Equipment	$174,777	$175,979	($1,202)	-0.69%
Non-HVAC Sub-Total	$255,037	$256,791	($1,754)	-0.69%
Grand Total	$1,232,119	$472,490	$759,629	61.65%

Emissions Analysis

A simple emissions analysis was done for the BWI Hilton to compare the carbon dioxide (CO_2), sulfuric acid (SO_2), and nitrous oxides (NO_x) generated by the building's use of electricity and natural gas. The values used for the emissions quantities were calculated by HAP.

For a comparison of the emissions between the base case and the new design, please refer to Table E – Emissions Comparison. Positive numbers refer to a savings in energy for the new design over the base case. Negative numbers imply that the new design uses more energy than the base case.

Table E - Emissions Comparison

Component	Base Case	New Design	Difference	% Diff
CO2 (lb)	24,243,440	8,706,425	15,537,015	64.09%
SO2 (kg)	59,829	21,002	38,827	64.90%
NOx (kg)	35,250	12,542	22,708	64.42%

As can be seen in the table above, there is about a 64% reduction in all emissions from the base case to the new design. This can be directly associated to the reduction in the total energy use for the BWI Hilton.

Lighting Analysis

The current lighting system in the Hilton Hotel at BWI Airport encompasses a variety of spaces and uses many different types of light fixtures and lamps. The main reason for studying the lighting systems of the guest rooms was to decrease the amount of electrical energy used. Economics were also an issue with choosing between various lighting design options. An analysis was done comparing several different lighting schemes to find the one that used the least amount of energy. An economic analysis was done on the same schemes to determine the most cost effective means of properly lighting the guest rooms.

Original Guest Room Lighting Design

Each guest room consists of the living space, entry, and bathroom. The lighting design in the entry and bathroom was not studied or altered, so the costs of the fixtures, lamps, and energy usage did not change from the original design. Therefore any of the energy and economical analyses done for the guest rooms did not include these two spaces. The analyses were done first for just the living space of one typical guest room, and then those results were multiplied by 279 to examine the results for all the guest rooms in the guest room tower of the BWI Hilton. Information on a typical size guest room used for all the analyses is shown in Table 32 – Guest Room Info.

The original lighting design of the living space in each guest room consisted of two table lamps, one floor lamp, and one desk lamp. The "Hilton Design and Construction Standards" specified that each lighting fixture was to be lamped with a 100 W incandescent bulb. A typical A19 100 W incandescent lamp was found on the Philips website to be used as the base case of the original design. The "Hilton Design and Construction Standards" also specified that 30 footcandles (fc) be provided at the work plane (2.5 ft above floor) for reading tasks.

Table 32 - Typical Guest Room

Length	18 ft
Width	13 ft
Area	234 sq ft
Total No of Guest Rooms	279 rooms

Lighting Design Alternatives

In almost all applications, incandescent lamps use more energy, give off more heat to their surroundings, and need replaced more often than compact fluorescent lamps. For these reasons, a replacement of all the incandescent lamps in the guest rooms was studied. The other problem with the incandescent fixtures was that the lighting power density was greater than that allowed by ASHRAE Standard 90.1-2004. The calculated value for the original design was 1.73 W/sf, and the maximum allowable for hotel guest rooms was listed as 1.1 W/sf in Table 9.6.1.

Several options were available to be used as alternative designs to the original incandescent lamps. The effects of the lamp color rendering index, color temperature, and lumen output were all studied to ensure that the new lighting schemes were just as good, if not better, than the original designs. Philips lamps were used for all the options. Prices for all the Philips lamps were found online at bulbs.com. To see renderings for some of the lighting design options, please see Appendix H – Typical Guest Room Lighting Renderings.

The first design option was to simply replace all the incandescent lamps with compact fluorescent lamps with screw-in bases. This method would simply use the four existing fixtures and just change the lamp type. Philips 27 W Mini-Deco Twister lamps were found to be suitable replacements for the A19 incandescent bulbs. The lumen output of these lamps was more than the original incandescent ones, and they also had the same color temperature of 2700 K. The color rendering index (CRI) of the compact fluorescents was 82, and they had a warm white finish. This was all done to ensure that the light would look the same as if there were traditional incandescent lamps being used.

The other alternatives all incorporate the use of other lighting design schemes. One possibility involved compact fluorescent recessed downlights. However, this was found to be unfeasible because of the guest room tower structure. The floor-to-floor height of each floor was 9 ft, and there was a 7-1/2 in post-tensioned concrete slab between floors, as was described in the Structural Systems section of the Building Systems Overview. With this type of structure, it was determined that using recessed fixtures would be a poor decision. Therefore, other means of using ceiling lighting was studied, namely using surface mounted fixtures.

The second and third design options involved using small surface mounted downlights with two compact fluorescent lamps in each fixture. The second option used a layout of four fixtures, and the third option used a layout of six fixtures. However, in both cases, the lighting levels were much below the required 30 fc minimum. Since these two options still did not provide adequate amounts of light, additional lighting options were studied.

The fourth and fifth design options used ceiling surface mounted fluted disk fixtures. One of these Lightolier fixtures could be used in each guestroom because of their high light output. This option replaced all the table lamps and floor lamp fixtures with a single ceiling fixture. Two options existed for the spectral fluted disk fixtures. The first option used two T5 circular fluorescent lamps (option 4), and the second option used four 18 W compact fluorescent lamps for in the fixtures (option 5). These two options were compared to see which had the better light output, lamp replacement costs, and energy costs. However, with both of these options, the light levels were still too low.

One final design option was considered after all the other options failed to meet the minimum of 30 fc at the working plane. This sixth design option involved using one Lightolier ceiling fluted disk fixture along with the four compact fluorescent fixtures for task lighting. This method increased the amount of light in the room, as well as the energy usage, energy costs, and lamp costs.

Cut sheets for some of the lamps and fixtures used can be found in Appendix J – Lighting Selection. More information on energy and cost comparisons made between all six lighting design options can be found in the following sections. For a summary of all six lighting design options with the lamp and fixture information, please see the table shown below, Table 34 – Lamp and Fixture Info. All the abbreviations used for each lighting option are listed in Table 33 – Option Abbreviations.

A few assumptions were made consistently for all the different options. An estimated light loss factor (LLF) of 0.65 was used. Also, average reflectances were assumed for the guest room surfaces: walls = 0.50, ceiling = 0.86, and floor = 0.20.

Table 33 - Option Abbreviations

Inc	Incandescent
CFL	Compact Fluorescent
SM	Surface Mounted
Combo	Both Compact Fluorescent and Surface Mounted

Table 34 - Lamp and Fixture Info

Option No	Option	Fixture Qty	Lamp Qty	Watts Ea	Total Watts	Watts per sf	Lumens ****	Total Lumens	Lumens per sf	Avg fc	Avg Life (hr)	Avg Life (yr)	Lamp Cost Ea
Base	Inc	4	1	100	400	1.71	1550	6200	26.50	2.37	1500	1.0	$0.59
1	CFL	4	1	27	108	0.46	1750	7000	29.91	2.61	10,000	6.8	$4.59
2	SM 1	4	2	13	104	0.44	825	3300	14.10	9.02	10,000	6.8	$1.99
3	SM 2	6	2	13	156	0.67	825	4950	21.15	13.63	10,000	6.8	$1.99
4	SM Disk 1	1	1	-	62	0.26	4830	4830	20.64	17.95	16,000	11.0	$31.98
5	SM Disk 2	1	4	18	72	0.31	4300	4300	18.38	15.99	16,000	11.0	$7.69
6	Combo	5	6	-	170	0.73	-	11830	50.56	20.56	-	-	-

****Based on initial lumens

Typical Guest Room Lighting Rendering

In order to have an idea of what each lighting design option actually looked like, Lighting Analysts AGI v1.8 was used to calculate the average illuminance levels at the work plane. A plan view of a typical guest room was drawn and the footcandles at various points were shown on each plan. Isometric views of a typical guest room were also developed, and a rendering of the space, illuminance levels, and luminance levels were all created for some of the design options. These renderings can be found in Appendix H - Typical Guest Room Lighting Renderings.

For the typical guest room layout, a single king bed guest room was used as the basis since it is the most common room type in the hotel. Other guest rooms are very similar, except for the exact placement of the beds and nightstand tables on the floor plan. All furniture was taken directly from the original plans for the BWI Hilton. For simplicity, each piece of furniture was simply assumed to have a geometric cubic shape. The only problem with this was with the two chairs in the room. It shows that the illuminance levels are very low, but in actuality, they would be much closer to those on the ottoman at the foot of the chair or the desk.

It was very difficult to find any .ies files on the internet for any kind of desk lamp or floor lamp. Ones were finally found and used for the AGI renderings of the typical guest room. But-the way the fixtures were shaped automatically by the program was not the shape in the original design. This was just a minor detail, and the main concern was with the actual light output of the light fixtures. However, illuminance levels may not be exactly the same as was intended by the architect. This most likely was because of the .ies file used. A more accurate representation of the actual light fixtures selected for the guest rooms would give better results than the approximations made in this case.

Despite these approximations, significant differences can be seen the light levels between many of the options. It can also be seen that the original design with only incandescent fixtures does not adequately meet the 30 fc minimum requirement. However, many of the proposed lighting design options also do not fully meet the illuminance level of 30 fc, as for reasons given above.

Energy Savings

The primary reason for altering the design of the guest room lighting was to decrease the amount of electrical energy used in the Hilton Hotel at BWI Airport. The original design with the incandescent lamps used the most electrical energy out of all the options studied. Calculations were done to compare each of the six design options with the base case. It was assumed that each fixture was only used for four hours each day. As can be seen in the table below, Option 4 with the surface mounted fluted disk with two circular fluorescent lamps had the greatest amount of energy savings as compared to the incandescent base case. For a comparison of the energy usage of all six options, please see below in Table 35 – Energy Use Comparison.

Table 35 - Energy Use Comparison

Option No	Option	Watts per Room	Total Elec Use (kW)	Avg hr per day	Avg hr per yr	Total Elec Use (kWh per yr)	Energy Savings (kWh)**
Base	Inc	400	111.60	4	1460	162,936	-
1	CFL	108	30.13	4	1460	43,993	118,943
2	SM 1	104	29.02	4	1460	42,363	120,573
3	SM 2	156	43.52	4	1460	63,545	99,391
4	SM Disk 1	62	17.30	4	1460	25,255	137,681
5	SM Disk 2	72	20.09	4	1460	29,328	133,608
6	Combo	170	47.43	4	1460	69,248	93,688

**vs Base

Cost Comparisons

Several cost comparisons were also done between the six different lighting design options. They are all described next. Based on the energy usage savings above, energy cost savings were calculated next. An energy cost analysis was done using an average calculated cost of electricity at $0.071/kWh. Consistent with the previous table, Option 4 again had the greatest amount of savings compared to the base case. Please see the table below, Table 36 – Energy Cost Comparison.

Table 36 - Energy Cost Comparison

Option No	Option	Avg Elec Cost (per kWh)***	Elec Cost (per yr)	Elec Cost Savings**
Base	Inc	$0.071	$11,568.46	-
1	CFL	$0.071	$3,123.48	$8,444.97
2	SM 1	$0.071	$3,007.80	$8,560.66
3	SM 2	$0.071	$4,511.70	$7,056.76
4	SM Disk 1	$0.071	$1,793.11	$9,775.35
5	SM Disk 2	$0.071	$2,082.32	$9,486.13
6	Combo	$0.071	$4,916.59	$6,651.86

***Calc avg from rates **vs Base

A comparison of the costs of the lamps was also done. The costs only included the cost of the bulb itself; it did not account for the cost of the fixture, labor rates for relamping all the fixtures, and labor rates for installation and wiring of the fixtures. The information required for those things was not done because only a basic comparison of lamp prices was desired. As can be seen below, each of the six options resulted in no lamp cost savings. Instead, each option cost more money per year since the compact fluorescent lamps were still much more expensive than the incandescent lamps. However, the average life of each of the compact fluorescent lamps was much longer. An average relamp cost per year was calculated based on the four hours per day operation and the specified lamp life by Philips. Please refer to Table 37 – Lamp Cost Comparison below.

Table 37 - Lamp Cost Comparison

Option No	Option	Total Lamp Cost	Avg Relamp Cost (per yr)*	Total Cost (per yr)	Lamp Cost Savings**
Base	Inc	$2.36	$2.30	$640.88	-
1	CFL	$18.36	$2.68	$747.88	-$106.99
2	SM 1	$15.92	$2.32	$648.49	-$7.60
3	SM 2	$23.88	$3.49	$972.73	-$331.85
4	SM Disk 1	$31.98	$2.92	$814.17	-$173.29
5	SM Disk 2	$30.76	$2.81	$783.11	-$142.23
6	Combo	$50.34	$5.60	$1,562.05	-$921.17

*(Total lamp cost)/(avg life) **vs Base

After calculating both the energy cost savings and the lamp costs, a total cost comparison was made. After comparing all the numbers, the greatest cost savings per year was with Option 4. This option used two circular fluorescent lamps in each fixture. Please see Table 38 – Total Cost Comparison below for the details of this comparison.

Table 38 - Total Cost Comparison

Option No	Option	Yearly Total Cost Savings**
Base	Inc	-
1	CFL	$8,337.98
2	SM 1	$8,553.05
3	SM 2	$6,724.91
4	SM Disk 1	$9,602.06
5	SM Disk 2	$9,343.90
6	Combo	$5,730.70

**vs Base

Lighting Conclusions

To make a proper recommendation on the guest room lighting design, it is necessary to analyze all the information and data from all six design options. This includes looking at the electrical energy usage, energy costs, lamp costs, and light levels.

The effects of these different lighting schemes can be realized in both the amount of energy consumed by the hotel and with the heat generated by the lighting fixtures. The lower amount of heat generated by the lamps could potentially reduce the block loads of the guest rooms on the fan coil units that condition those spaces. However, since this amount of generated heat is such a small fraction of the total room block load, the differences between the base case and new design will be negligible. This is especially true when re-sizing a new fan coil unit is considered.

However, the amount of energy consumed is a much bigger deciding factor. Significant amounts of energy can be reduced by using different lamps and light fixtures. Simply interchanging compact fluorescent lamps for the incandescent lamps has a significant reduction in energy consumption, but additional savings can be found using ceiling light fixtures.

The other major factor deals with the light output of the selected fixtures. To properly analyze the light output of the originally selected fixtures, a more exact photometric (.ies) file should be used. Also, using the exact shapes of the chairs and other furniture may have some benefits.

If the illuminance levels in the guest rooms were not set in stone, the surface mounted fluted disk option with two circular fluorescent lamps would be the best option to use. This is because it has the greatest amount of energy savings. However, if the 30 fc is more rigid, then additional fixtures should be added to the space that can be used as task lights for reading. This way, the energy consumption would be decreased and the proper light levels would also be met.

Acoustical Analysis

There are many different acoustical issues that could be studied and dealt with in a hotel similar to the BWI Hilton. But the new mechanical design work previously described in the "Mechanical Systems Design" section provided several specific areas to be studied. These include the acoustics related to the new chillers, cooling towers, and fan coil units. Each topic is described next, and the corresponding calculations are also included. Please refer to Appendix K – Acoustical Analysis for additional information.

Chiller Acoustical Analysis

The most significant difference between the original mechanical system and the new design involves the new chiller units placed in the main mechanical equipment room. The location of the chillers is not a problem since they are on the parking level. However, the restaurant of the BWI Hilton is located directly above the mechanical room. So the acoustics of the chiller and how it affects the restaurant are described next.

The mechanical equipment room surface areas are shown below in Table 39 – Mechanical Room Surfaces. Sound absorption coefficients were assumed for the given surface materials from provided data given by M. David Egan. Typical values for pump sound pressure levels were assumed from data given by Egan. The values used for the chillers in the room were provided for the York MaxE centrifugal chillers operating at full load (part loads typically have different sound pressure levels).

For these calculations, it was assumed that the size of the mechanical room did not get any larger. The surface areas are given next in Table 39 – Mechanical Room Surfaces.

Table 39 - Mechanical Room Surfaces

Surface	Area (sf)
Floor	1206.0
Ceiling	1206.0
Exterior Walls	1483.6
Interior Walls	1350.3
Total	**5245.9**

Typical Room Criteria (RC) levels are defined below in Table 40 – Restaurant RC Levels.

Table 40 – Restaurant RC Levels

Space	RC Level Range	RC Level Used
Restaurant	35-40	35

All the calculations were modeled after those provided by Egan for transmission loss (TL) design. The following equations were used for these calculations.

Sound absorption:

$a_2=\Sigma(S*\alpha)$

Total sound pressure level (dB):

$L_{p,tot}=10*\log(10\text{^}(L_1/10)+10\text{^}(L_2/10))$

Transmission Loss (dB):

$TL=NR-10*\log(a_2/S)$

Noise Reduction (dB):

NR=L1-L2 *(source minus receiver)*

Mass Law:

$TL=10*\log(1/\tau)=20*\log(\omega*m/(2*\rho_0*c))$

The sound absorption coefficients and the absorption values (sabins) were calculated first for the surface materials in the mechanical room (source room). Only the exposed insulation material was used for the ceiling, and the 12 in concrete slab was not used for the absorption calculations. These calculations are shown below in Table 41 – Mechanical Room Absorption.

Table 41 - Mechanical Room Absorption

Surface Material	Surface Area (sf)	Sound Absorption Coefficient					
		125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
12 in Concrete Walls	1483.6	0.01	0.02	0.04	0.06	0.08	0.10
8 in CMU Block Walls	1350.3	0.10	0.05	0.06	0.07	0.09	0.08
Concrete Floor	1206.0	0.01	0.02	0.04	0.06	0.08	0.10
2 in Rigid Insulation Ceiling	1206.0	0.38	0.60	0.78	0.80	0.78	0.70

Surface Material	Surface Area (sf)	Sound Absorption Coefficient					
		125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
12 in Concrete Walls	1483.6	14.84	29.67	59.35	89.02	118.69	148.36
8 in CMU Block Walls	1350.3	135.03	67.51	81.02	94.52	121.52	108.02
Concrete Floor	1206.0	12.06	24.12	48.24	72.36	96.48	120.60
2 in Rigid Insulation Ceiling	1206.0	458.28	723.60	940.68	964.80	940.68	844.20
a_2 = ΣSα (sabins)	-	620.20	844.91	1129.28	1220.70	1277.37	1221.18

The second step was to determine the sound pressure levels in the mechanical room that were emitted by the mechanical equipment. Table 42 –

Sound Pressure Levels defines all the values used for the equipment. The sound data listed for the chillers is actual sound levels provided for the York MaxE centrifugal chillers. Since the actual sound levels of the pumps and boilers were not know, the sound levels used were assumed based on typical values given by Egan.

Table 42 - Sound Pressure Levels

(2) York MaxE Chillers	Sound Pressure Level (dB)					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
(1) Centrifugal Chiller	70	72	74	74	78	79
(2) Centrifugal Chillers	73	75	77	77	81	82
Original Mech Room	**Sound Pressure Level (dB)**					
	125 Hz	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
(1) Pump	80	82	87	86	80	77
(6) Pumps	88	90	95	94	88	85
(1) Boiler	92	89	86	83	80	77
(3) Boilers	95	92	89	86	83	80
Total	**96**	**94**	**96**	**94**	**89**	**86**
New Mech Room	**Sound Pressure Level (dB)**					
	125 Hz	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
(1) Centrifugal Chiller	70	72	74	74	78	79
(2) Centrifugal Chillers	73	75	77	77	81	82
(1) Pump	80	82	87	86	80	77
(6) Pumps	88	90	95	94	88	85
(1) Boiler	92	89	86	83	80	77
(3) Boilers	95	92	89	86	83	80
Total	**96**	**94**	**96**	**95**	**90**	**87**

The third step is to calculate the transmission loss required by the ceiling that separates the mechanical room from the restaurant. Egan only provides values for a 6 in concrete slab ceiling, but the BWI Hilton has a 12 in concrete slab. Therefore, the mass law was used to determine approximate values for the thicker slab. The mass law for transmission loss is simply a 6 dB increase in TL with the doubling of mass of the material. The 12 in slab would have twice as much mass as the 6 in slab, so 6 dB are added at each octave band to the given 6 in concrete slab values. The mass law affects on the sound pressure levels are shown below in Table 43 – Mass Law.

Table 9 - Mass Law

Material	Sound Pressure Level (dB)					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
6 in concrete slab ceiling	38	43	52	59	67	72
Mass Law: +6 dB	6	6	6	6	6	6
12 in concrete slab ceiling	44	49	58	65	73	78

The required transmission loss values for the ceiling construction are shown below in Table 44 – Transmission Loss Calculations.

Table 44 - Transmission Loss Calculations

Chiller Noise Only	**Sound Pressure Level (dB)**					
	125 Hz	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
Chiller Noise	73	75	77	77	81	82
RC-30 Background Noise	45	40	35	30	25	20
Required NR (dB)	28	35	42	47	56	62
10*log(a_2/S)	-3	-2	0	0	0	0
Required TL (dB)	25	33	42	47	56	62
12 in Concrete Slab Ceiling	44	49	58	65	73	78
Original Mech System Design	**Sound Pressure Level (dB)**					
	125 Hz	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
Mech Room Noise	96	94	96	94	89	86
RC-30 Background Noise	45	40	35	30	25	20
Required NR (dB)	51	54	61	64	64	66
10*log(a_2/S)	-3	-2	0	0	0	0
Required TL (dB)	48	53	61	65	64	66
12 in Concrete Slab Ceiling	44	49	58	65	73	78
New Mech System Design	**Sound Pressure Level (dB)**					
	125 Hz	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
Mech Room Noise	96	94	96	95	90	87
RC-30 Background Noise	45	40	35	30	25	20
Required NR (dB)	51	54	61	65	65	67
10*log(a_2/S)	-3	-2	0	0	0	0
Required TL (dB)	48	53	61	65	65	68
12 in Concrete Slab Ceiling	44	49	58	65	73	78

To determine if the given ceiling construction is sufficient to meet the RC-30 criteria, the TL values given for the 12 in concrete slab ceiling should be higher than the required TL values listed for each design case. The 12 in slab easily exceeds the requirements for the chillers only. The TL values for the 12 in slab in the original and new mechanical systems designs are not sufficient to meet the required TL values. However, this TL of the 12 in slab only takes into account the transmission loss through the slab itself. It does not consider the 2 in of rigid insulation under the slab or the flooring materials used for the restaurant floor. Therefore, it can be assumed that the 12 in slab with the 2 in rigid insulation and restaurant floor materials will be sufficient to reduce the mechanical equipment sound levels into the restaurant.

Fan Coil Unit Acoustical Analysis

It is known that the fan coil units in all the guest rooms will emit certain sound power levels. It is important to know if these sound levels are at appropriate levels for typical guest rooms. To analyze the acoustics of the fan coil units in the guest rooms, the maximum sound power levels will be computed for the desired guest room RC level.

For these calculations, a typical guest room size was assumed to be nearly consistent for all 279 guest rooms in the BWI Hilton. Any minor changes to the size and shape of the guest rooms was assumed to be negligible. The surface areas are given next in Table 45 – Guest Room Surfaces.

Table 45 – Guest Room Surfaces

Surface	Area (sf)
Floor	282.0
Ceiling	282.0
Exterior Walls	108.3
Interior Walls	541.5
Total	**1213.7**

Typical Room Criteria (RC) levels are defined below in Table 46 – Guest Room RC Levels.

Table 46 – Guest Room RC Levels

Space	RC Level Range	RC Level Used
Guest Room	25-35	30

The following equations, as outlined by Professor Courtney Burroughs, were used for these calculations.

Sound power level (dB):

$L_w=L_p+10*\log(R_T)-6$

Room constant:

$R_T=a_2/(1-\alpha_{SAB})$

Sound absorption:

$a_2=\Sigma(S*\alpha)$

Sabine absorption:

$\alpha_{SAB}=\Sigma(S*\alpha)/\Sigma S$

The maximum sound power levels will be compared to the given sound power levels of the two selected fan coil units to be used in the guest rooms of the BWI Hilton project. The sound data provided from Carrier is shown below in Table 47 – FCU Sound Power Levels.

Table 47 - FCU Sound Power Levels

Carrier 42S Fan Coil Unit	Sound Power Level (dB)					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
FCU-1: 42SGA03	65	57	53	49	41	39
FCU-2: 42SGA04	69	60	56	51	42	40

The sound absorption coefficients and the absorption values (sabins) were calculated first for the surface materials in a typical guest room. These calculations are shown below in Table 48 – Guest Room Absorption.

Table 48 - Guest Room Absorption

Surface Material	Surface Area (sf)	Sound Absorption Coefficient					
		125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
12 in Precast Concrete Wall	108.3	0.10	0.05	0.06	0.07	0.09	0.08
5/8 in GWB w/ Insulation	541.5	0.55	0.14	0.08	0.04	0.12	0.11
Carpet on Concrete Floor	282.0	0.02	0.06	0.14	0.37	0.60	0.65
Painted 1/2 in GWB Ceiling	282.0	0.29	0.10	0.05	0.04	0.07	0.09

Surface Material	Surface Area (sf)	Sound Absorption Coefficient					
		125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
12 in Precast Concrete Wall	108.3	10.83	5.41	6.50	7.58	9.75	8.66
5/8 in GWB w/ Insulation	541.5	297.80	75.80	43.32	21.66	64.97	59.56
Carpet on Concrete Floor	282.0	5.64	16.92	39.48	104.34	169.20	183.30
Concrete Ceiling	282.0	81.78	28.20	14.10	11.28	19.74	25.38
$a_2 = \Sigma S\alpha$ (sabins)	-	396.05	126.34	103.39	144.86	263.66	276.90

The next step is to calculate the maximum sound power levels in a typical guest room based on an assumed level of RC-30. The values used in the equations listed from above are given below in Table 49 – Sound Power Level Calculation.

Table 49 - Sound Power Level Calculation

Typical Guest Room	Octave Band Center Frequency					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
RC-30 Sound Pressure Level (dB)	45	40	35	30	25	20
Sabine Absorption (α_{SAB})	0.33	0.10	0.09	0.12	0.22	0.23
Room Constant (R_T)	587.87	141.02	113.02	164.49	336.83	358.75
Max Sound Power Level (dB)	67	55	50	46	44	40

The final step is to compare the maximum sound power levels with the actual fan coil unit sound power levels. Please see Table 50 – FCU Compliance at RC-30 for the comparison between the FCUs and the maximum values.

Table 50 - FCU Compliance at RC-30

Typical Guest Room	Sound Power Level (dB)					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Max Sound Power Level	67	55	50	46	44	40
FCU-1: 42SGA03	65	57	53	49	41	39
FCU-1 Compliance?	Yes	No	No	No	Yes	Yes
FCU-2: 42SGA04	69	60	56	51	42	40
FCU-2 Compliance?	No	No	No	No	Yes	Yes

It can be seen from the data below that both FCU-1 and FCU-2 only comply with the RC-30 levels at 125 Hz, 2000 Hz, and 4000 Hz. Therefore, something must be changed. Either the sound power levels of the fan coil units, the materials and absorption in the guest room, or the maximum allowable sound pressure levels must change.

Table 51 - Adjusted Sound Power Level Calculation

Typical Guest Room	Octave Band Center Frequency					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
RC-35 Sound Pressure Level (dB)	50	45	40	35	30	25
Sabine Absorption (αSAB)	0.33	0.10	0.09	0.12	0.22	0.23
Room Constant (RT)	587.87	141.02	113.02	164.49	336.83	358.75
Max Sound Power Level (dB)	72	60	55	51	49	45

If the RC-30 level is strictly set, then either the fan coil units will need to be changed or adjusted or the guest room surface materials will have to change. If not, the easiest way to get compliance is to adjust the RC level rating that is acceptable for the guest rooms. The adjusted sound power levels and adjusted compliance of the FCUs can be seen above in Table 51 and below in Table 52, respectively.

Table 52 - Adjusted FCU Compliance at RC-35

Typical Guest Room	Sound Power Level (dB)					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Max Sound Power Level	72	60	55	51	49	45
FCU-1: 42SGA03	65	57	53	49	41	39
FCU-1 Compliance?	Yes	Yes	Yes	Yes	Yes	Yes
FCU-2: 42SGA04	69	60	56	51	42	40
FCU-2 Compliance?	Yes	Yes	No	Yes	Yes	Yes

As can be seen above in Table 52 – Adjusted FCU Compliance at RC-35, the fan coil units comply at all the center octave band frequencies for both FCU-1 and FCU-2. The RC-35 is the upper limit of the acceptable range of RC levels for hotel guest rooms, as listed in Table 34 of Chapter 47 – Sound and Vibration Control in the 2003 ASHRAE Applications Handbook.

Cooling Tower Acoustical Analysis

The original mechanical system design required the use of a two-cell induced draft cooling tower that was located on the ground outside of the BWI Hilton. The new mechanical system design also uses a very similar model cooling tower, and the location remained the same, as well. However, the noise levels of the cooling tower are compared to determine if there will be any community objection to their location.

A big benefit to the new cooling towers used on the Hilton Hotel at BWI Airport project is that the new cooling towers have a smaller capacity than the original cooling towers. This reduced load may have some affect on fan size and fan speed, which could affect the overall sound levels emitted by the cooling towers.

When researching the cooling tower acoustical analysis procedure, the method of calculating the outdoor noise levels is typically done with Composite Noise Rating (CNR) curves. These curves are then “corrected” and the corresponding predicted community reaction levels are determined. A comparison could be done between one of the standard cooling towers (with 1800 rpm fan motor speeds) and one at lower noise levels (with 1200 rpm fan motor speeds).

However, a Marley cooling tower sales representative said that the 1200 rpm cooling towers are only quieter than the 1800 rpm cooling towers by about 4 dBA total. Since this difference is not that significant and the community reaction levels can only be predicted, the entire CNR procedure was not done for this thesis project.

It can be expected that the community reactions to the lower dBA levels of the 1200 rpm cooling towers will be more favorable (or at least less negative) than that of the 1800 rpm cooling towers. Even though community reaction of the cooling towers affects the image of the BWI Hilton, it is only a small portion of the design decisions used in selecting the equipment to be used on the project. Since the BWI Hilton is located in a commercial area with many other hotels and away from any individual residences, it is not expected that there will be much of a reaction from the community.

Acoustics Conclusions

Of the many important issues dealing with the acoustics related to the mechanical systems, the chillers, fan coil units, and cooling towers were all analyzed. Separate conclusions for each type of equipment and application are described previously within each of the analyses.

Overall Cost Analysis

A project is often defined by how much it costs or how much money it saves. There are many ways to determine these costs or savings, and the ones used on this project include the first costs, operating costs, and life cycle costs. Unfortunately, all too often project design decisions are driven solely by the first costs, and not their operating costs or life cycle costs. It will be shown here that the life cycle cost analysis is a much more important and valuable tool to define the bottom line of a project.

This section is broken down into smaller sub-sections. They include: first costs of the original mechanical system, new equipment first costs, operating costs for the new equipment, and the life cycle costs. For additional information and full life cycle cost analysis reports, please refer to Appendix L – Overall Cost Analysis.

First Costs of Original Mechanical Systems

In order to properly evaluate the effects of changing the mechanical systems and equipment in the Hilton Hotel at BWI Airport, the original equipment costs must be known. If cost estimates must be made, the calculations and data will not be nearly as accurate. Please see Table 53 – Original Mechanical Equipment Costs below.

Table 53 - Original Mechanical Equipment Costs

(288) Water-Source Heat Pumps	$430,000
(4) AHUs, (6) RTUs,(43) VAVs, (70') FTRs, and other equipment	$507,100
(2) Cooling Towers	$61,315
(2) Heat Exchangers	$31,810
(4) HW Boilers	$61,000
(23) Pumps	$33,686
(2) HW Generators	$46,430
(2) Water Heaters	$38,548
(43) Fans	$65,200
(5) Sump Pumps	$29,800
(1131) Diffusers	$26,971
(3) Valves and (3) Traps	$30,873
Plumbing Fixtures	$192,896
Sheetmetal Specialties	$25,785
Pipe Fitting Specialties	$17,418
Plumbing Specialties	$61,556
Misc. Equipment	$40,949
Grand Total	**$1,701,337**
Total Used	**$491,315**

The data and information required for the existing mechanical system first cost was provided by Southland Industries, Inc., who is the mechanical contractor for the Hilton Hotel at BWI Airport project.

The first costs can be broken down into several pieces. The sheet metal, pipe fitting, and plumbing all depend on their related costs for labor, materials, and fabrication. The mechanical equipment, which totals about $1.7 million, can be looked at in smaller categories indicating both quantity and prices of certain pieces of equipment. Other costs include the work being sub-contracted out, the start/test labor, and the general conditions fees. After totaling all of these costs together, the total mechanical system first cost was almost $6.5 million. The cost per square foot was found to be about $23.68/sf.

However, in order to compare the first costs of the existing mechanical systems and the new mechanical systems design, only the equipment costs are taken into consideration. This is because exact quantities of piping and ductwork with their corresponding costs for labor, materials, and fabrication were not determined for the new mechanical systems. The amount of sub-contracted work, the start/test labor, and the general conditions fees are also unknown. Many assumptions could be made about these things, but it is more accurate to only compare those items which have known values.

In addition to this, some of the equipment listed in Table 53 – Original Mechanical Equipment Costs is lumped together with other components. For example, the actual costs for the four AHUs and the six RTUs would be helpful in comparing the new selections to the original equipment. However, the AHUs and RTUs were lumped together with numerous VAV boxes, fin tube radiators, and other equipment.

Even though there are many difficulties with the provided equipment costs for the original system, only those costs that are know for sure will be used in the cost analysis. Those costs are for the 288 water-source heat pumps (WSHPs) and the two cooling towers. The equipment costs used from the original design are listed below in Table 54 – Original Equipment Costs Used for Analysis.

Table 54 - Original Equipment Costs Used for Analysis

Original Equipment Costs	
(288) Water-Source Heat Pumps	$430,000
(2) Cooling Towers	$61,315
Total	**$491,315**

New Equipment First Costs

Although they are not the most important factor in determining the life cycle costs, the first costs are still a major contributor. The following tables all show the first costs of the new mechanical equipment selected and used for study in this thesis project. Please note that none of the first costs for the necessary piping or ductwork was included in this analysis. These items would require proper sizing and measurement of lengths to determine their first costs. Only the equipment first costs were determined for this project.

Table 55 - Chiller First Costs

Option No	Manuf	Qty	Model	Misc	Price Ea	Total Price
1	Carrier	2	19XRV	10 F delta-T	$84,600	$169,200
2	York	2	MaxE	12 F delta-T	$112,500	$225,000
3	McQuay	2	WSC	12 F delta-T	$125,000	$250,000
4	McQuay	1	WDC-IGV	12 F delta-T	$196,500	$196,500
5	McQuay	1	WDC-VFD	12 F delta-T	$227,000	$227,000
6	Trane	1	CTV	12 F delta-T	$114,518	$251,704
6	Trane	1	CTV-AFD	12 F delta-T	$137,186	
7	Trane	2	CTV-AFD	12 F delta-T	$137,186	$274,372

Table 56 - Cooling Tower First Costs

Option No	Manuf	Model	Misc	Qty	Price Ea	Total Price
1	Marley	NC8305FL2	1200 rpm	2	$40,300	$80,600
2	Marley	NC8306EL2	1200 rpm	2	$46,150	$92,300
3	Marley	NC8305F2	1800 rpm	2	$39,000	$78,000
4	Marley	NC8307E2	1800 rpm	2	$47,450	$94,900

Table 57 - FCU First Costs

Option No	Manuf	Model	Qty	Price Ea	Total Price
1	Carrier	42S-300	128	$1,335	$170,880
1	Carrier	42S-400	160	$1,350	$216,000
2	Enviro-Tec	VHC-04	128	$1,850	$236,800
2	Enviro-Tec	VHC-04	160	$1,850	$296,000

Table 58 - Air Handling Unit First Costs

Option No	Manuf	Model	Qty	Price Ea	Total Price
1	Carrier	39MN-50	1	$30,100	$30,100
1	Carrier	39MN-40	1	$29,500	$29,500
1	Carrier	39MN-21	1	$17,600	$17,600
1	Carrier	39MN-12	1	$13,700	$13,700

Table 59 - Rooftop Unit First Costs

Option No	Manuf	Model	Qty	Price Ea	Total Price
1	Carrier	39MW-06	1	$17,600	$17,600
1	Carrier	39MW-30	1	$30,400	$30,400
1	Carrier	39MW-12	1	$20,400	$20,400
1	Carrier	39MW-06	1	$17,400	$17,400
1	Carrier	39MW-03	1	$16,000	$16,000

Table 60 - Dedicated Outdoor Air System Unit First Costs

Option No	Manuf	Model	Qty	Price Ea	Total Price
1	Semco	PVS-13	1	$90,193	$90,193
1	Semco	PVS-18	1	$102,993	$102,993

Table 61 - Pump First Costs

Option No	Manuf	Model	Qty	Price Ea	Total Price
1	Bell&Gossett	1510-5G	2	$8,389	$16,778
1	Bell&Gossett	1510-5BC	2	$6,986	$13,972

Table 62 - Heat Exchanger First Costs

Option No	Manuf	Model	Qty	Price Ea	Total Price
1	Bell&Gossett	P41	1	$28,150	$28,150

New Equipment Annual Operating Costs

One of the most important parts of the project costs are the annual costs. These are often related to the energy consumption and operating costs of the mechanical equipment, as well as the relative maintenance. Since this thesis design project is entirely theoretical, actual data for maintenance and replacement of equipment is unknown. Guesses could be made values could be estimated. However, this would not yield very useful results. Therefore, only the operating costs of the equipment related to the electrical and natural gas energy usage and costs are considered for the annual costs.

The following tables all show the energy usage and operating costs of some of the new mechanical equipment selected and used for study in this thesis project. Since only the chillers and cooling towers were studied to find the best option to be used in the new design with specific life cycle cost analyses, only the operating cost information for that equipment is shown in the tables below.

Table 63 - Chiller Energy Usage and Operating Costs

Option No	Manuf	Model	Qty	HAP Cooling Energy (kBtu)	HAP HVAC Energy (kBtu)	HAP Cooling Cost	HAP HVAC Cost
1	Carrier	19XRV	2	3,181,062	26,486,885	$73,875	$232,709
2	York	MaxE	2	3,452,357	26,682,921	$79,914	$237,094
3	McQuay	WSC	2	3,096,184	26,339,122	$71,685	$228,972
4	McQuay	WDC-IGV	1	3,500,117	26,730,690	$80,947	$238,114
5	McQuay	WDC-VFD	1	3,027,870	26,270,535	$70,774	$228,069
6	Trane	CTV	1	3,276,105	26,520,763	$75,078	$232,361
	Trane	CTV-AFD	1				
7	Trane	CTV-AFD	2	2,696,646	25,937,498	$62,655	$219,876

Table 64 - Cooling Tower Energy Usage and Operating Costs

Cooling Tower	No of Cells	HAP Cooling Tower Energy (kBtu)	HAP HVAC Energy (kBtu)	HAP Cooling Tower Annual Costs	HAP HVAC Annual Costs
NC8305FL2	2	525,710	27,243,670	$11,946	$248,391
NC8306EL2	2	395,166	27,113,125	$8,979	$245,422
NC8305F2	2	525,710	27,243,670	$11,946	$248,391
NC8307E2	2	395,166	27,113,125	$8,979	$245,422

The energy usage and operating costs could not be directly found using HAP. However, the annual component costs were compared for Option 1 (Carrier 42S FCUs) and Option 2 (Enviro-Tec VHC04 FCUs), and the total HVAC costs for Option 1 was $5 less than Option 2.

New Equipment Life Cycle Costs

The combination of the first costs and annual operating costs are used to evaluate the mechanical equipment for the Hilton Hotel at BWI Airport in the life cycle cost analyses. These analyses were done on several different items, including the chillers, cooling towers, and all the entire mechanical system. Carrier’s Engineering Economic Analysis (EEA) program was used to do all the life cycle cost analyses since the inputs were straightforward and useful graphs and information was gathered easily from the results. A 20 year analysis period was used, and a minimum attractive rate of return (MARR) was assumed to be 8%. The escalation rate was used at 2%. This was assumed, but when compared to all other options at the same analysis period, it did not matter what MARR or escalation rate was used.

Chiller Life Cycle Costs

The life cycle cost analysis done on the chillers involved comparing the first costs and operating costs for seven different scenarios (Option 1 through 7). Option 1 had the lowest first cost, but Option 7 had the lowest operating costs. After the comparison was made, the life cycle costs were found to be the lowest for Option 7. A graphical representation of this can be seen below in Figure 17 – Chiller Life Cycle Cost Graphs.

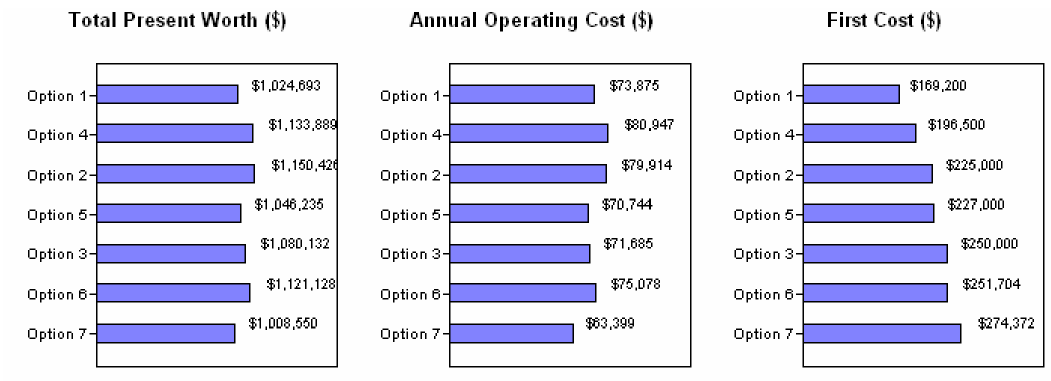

Figure 17 - Chiller Life Cycle Cost Graphs

Since Option 7 had the lowest life cycle costs, noted as the lowest total present worth, that chiller arrangement was chosen to be used in the BWI Hilton new mechanical system design. Please refer to the "Chillers" section previously described for more information about this design and selection process. The breakdown of all the chiller costs are listed below in Table 65 – Chiller Life Cycle Cost Breakdown.

Table 65 - Chiller Life Cycle Cost Breakdown

Design Case Name	Design Case Short Name	Total Present Worth ($)	Annual Operating Cost ($/yr)	First Cost ($)
Option 1 - (2) Carrier 19XRVs	Option 1	$1,024,693	$73,875	$169,200
Option 4 - (1) McQuay WDC w/ IGV	Option 4	$1,133,889	$80,947	$196,500
Option 2 - (2) York MaxEs	Option 2	$1,150,426	$79,914	$225,000
Option 5 - (1) McQuay WDC w/ VFD	Option 5	$1,046,235	$70,744	$227,000
Option 3 - (2) McQuay WSCs	Option 3	$1,080,132	$71,685	$250,000
Option 6 - (1) Trane CTV, (1) CTV-AFD (12F)	Option 6	$1,121,128	$75,078	$251,704
Option 7 - (2) Trane CTV-AFD (12F)	Option 7	$1,008,550	$63,399	$274,372

Cooling Tower Life Cycle Costs

The next life cycle cost analysis was done for the cooling towers. There were four possible options of cooling towers to be used on the BWI Hilton project. Two of the cooling towers had lower first costs and lower efficiencies (Options 3 and 4), and the other two cooling towers had higher first costs and higher efficiencies (Options 1 and 2). These four new options were also compared to the original cooling towers used, which was referred to as the Base Case.

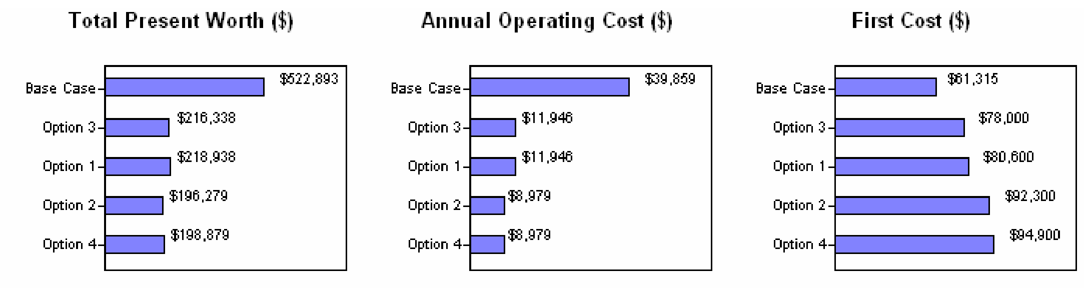

Figure 18 - Cooling Tower Life Cycle Cost Graphs

The graphical representation of the life cycle costs are shown above in Figure 18 – Cooling Tower Life Cycle Cost Graphs. All four of the new cooling towers being studied had significantly lower operating costs than the base case cooling tower, even though the base case had the lowest first cost. Option 2 had the lowest total present worth, so it was chosen to be used in the new mechanical system design. The breakdown of all the cooling tower costs is listed below in Table 66 – Cooling Tower Life Cycle Cost Breakdown.

Table 66 - Cooling Tower Life Cycle Cost Breakdown

Design Case Name	Design Case Short Name	Total Present Worth ($)	Annual Operating Cost ($/yr)	First Cost ($)
Base Case - Original Design	Base Case	$522,893	$39,859	$61,315
Option 3 - Marley NC8305F2	Option 3	$216,338	$11,946	$78,000
Option 1 - Marley NC8305FL2	Option 1	$218,938	$11,946	$80,600
Option 2 - Marley NC8306EL2	Option 2	$196,279	$8,979	$92,300
Option 4 - Marley NC8307E2	Option 4	$198,879	$8,979	$94,900

Mechanical System Life Cycle Costs

The final life cycle cost analysis was done on the entire mechanical system. The new mechanical systems design was compared to the original mechanical system base case for the Hilton Hotel at BWI Airport. A graphical representation of the two cases is shown below in Figure 19 - Mechanical Systems Life Cycle Cost Graphs.

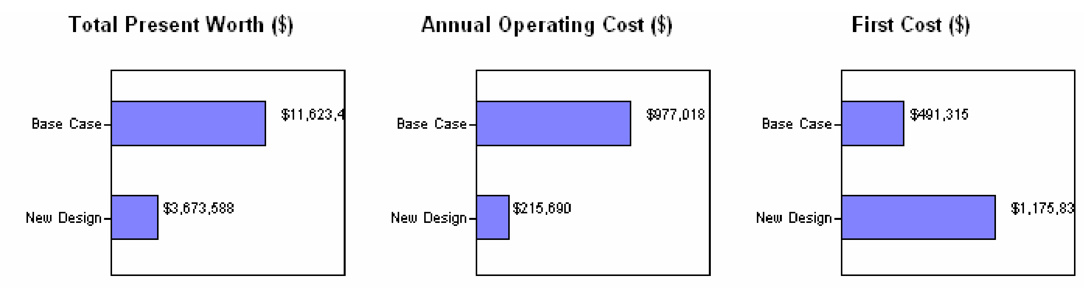

Figure 19 - Mechanical Systems Life Cycle Cost Graphs

It can clearly be seen that the base case had a much lower first cost than did the new design ($684,523). However, the annual operating costs of the new design were much lower than those for the base case ($761,328). This translated into a significant difference in the overall life cycle costs between the base case and the new design. The breakdown of all the mechanical system costs is listed below in Table 67 – Mechanical Systems Life Cycle Cost Breakdown.

Table 67 - Mechanical Systems Life Cycle Cost Breakdown

Design Case Name	Design Case Short Name	Total Present Worth ($)	Annual Operating Cost ($/yr)	First Cost ($)
Base Case - Original Design	Base Case	$11,623,441	$977,018	$491,315
Chilled Water Plant Design	New Design	$3,673,588	$215,690	$1,175,838
Difference	-	$7,949,853	$761,328	($684,523)
% Diff	-	68.40%	77.92%	-139.32%

A summary of all the life cycle cost results for the new design over the base case is shown below in Table 68 – New Design Life Cycle Cost Summary. The payback period was calculated to be 1.0 years, which is an extremely short period of time. Also, an internal rate of return over 100% is exceptionally high. A graph of the payback period can be seen in Figure 20 - Payback Period Graph.

Table 68 - New Design Life Cycle Cost Summary

Challenger	Base Case	Additional First Cost ($)	NPW Savings ($)	IRR (%)	Payback Period (yrs)
New Design [Winner]	Base Case	$684,523	$7,949,854	114.23	1.0

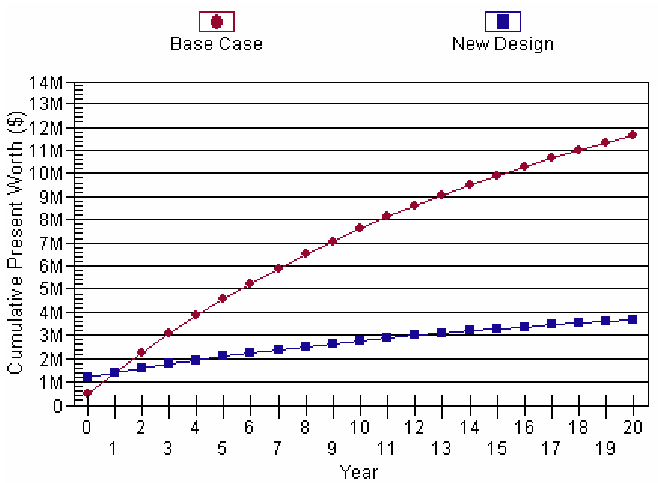

Figure 20 - Payback Period Graph

Overall Cost Analysis Conclusions

Several conclusions can be made about the life cycle cost analyses performed for the Hilton Hotel at BWI Airport. First, only life cost analyses were done for equipment that more than one possible choice during the design. For example, there were price quotes given for seven different chillers and four different cooling towers. The fan coil units had two quotes given, but direct annual operating costs could not be taken straight from HAP. Therefore, the overall system operating costs were used to compare these two items (but they only differed by $5). Since the operating costs were nearly identical, the first costs were used to determine which option to choose. All the other equipment selected to be used in the new mechanical systems design only had one price quote provided by the manufacturers. For this reason, no other equipment life cycle costs were calculated. Only the overall system life cycle costs were compared.

The overall system life cycle costs were drastically different. The first cost of the new design was about 2.4 times that of the base case. But the annual operating costs of the base case were 4.5 times that of the new design. This resulted in a very high internal rate of return and an extremely fast payback period of only one year. Please note that the results would change if the new piping and ductwork first costs and all the appropriate original equipment first costs were included in the analysis. However, this method was a good estimate.

Conclusions and Recommendations

The Hilton Hotel at BWI Airport is a project that has many areas where the possibility exists for mechanical systems design. The main area chosen for this thesis design project is related to the design of a central chilled water plant for the building. The original design involved a boiler and condenser water system serving various air handling units, rooftop units, and water-source heat pumps. The original design first had chillers in the design, but after value engineering, the chillers were eliminated, and the air handling units were designed to operate like air-to-water heat pumps. All the ventilation air provided directly to the guest rooms was also eliminated during value engineering stage.

In order to achieve this goal of energy efficiency, the mechanical systems of the BWI Hilton needed to be improved. All the main mechanical equipment served by the condenser water was replaced with ones using chilled water, including the air handling units, rooftop units, dedicated outdoor air units, and fan coil units. The guest rooms were also provided with a continuous 60 cfm of ventilation air from the dedicated outdoor air units. Water-side free cooling was also studied and implemented to further increase the energy efficiency of the chilled water system.

This thesis report compared the energy consumption of the original design to the new design with the central chilled water plant. As was evident throughout the project, energy was saved in nearly every area, except for natural gas. However, the increase in natural gas consumption was offset by the larger reduction in electric usage. Electric energy usage was reduced by 82%, but the natural gas consumption increased by 127%. However, the total energy costs for the BWI Hilton were reduced by 62%. The overall emissions from the natural gas used on site were also reduced by about 64%.

Other goals of this thesis include decreasing life cycle costs, promoting sustainability, design innovation, and indoor environmental quality improvement. Many of these goals were also accomplished by means of improving the overall energy efficiency of the building. The more energy efficient mechanical systems designed had a much lower operating cost than the original design, were more environmentally-friendly with reduced emissions, and involved more creativity in the design process. Despite increasing the first costs by about $685,000, the operating costs were decreased by over $750,000, and a life cycle cost analysis for the BWI Hilton resulted in a one year payback period and a net present worth savings of almost $8 million.

Overall, the new mechanical systems design involving the new central chilled water plant was an improvement in every area studied. Therefore, it is recommended to use a chilled water system in place of a boiler and condenser water system. The benefits can be tremendous.

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Appendices

The Appendix for this thesis report contains all the information that was too extensive to include in the actual body of the report.

The Appendix contains the following sections:

Appendix A – Chiller Selection

Appendix B – Cooling Tower Selection

Appendix C – Pump Selection

Appendix D – Heat Exchanger Selection

Appendix E – Air Handling Unit and Rooftop Unit Selection

Appendix F – Dedicated Outdoor Air System Unit Selection

Appendix G – Fan Coil Unit Selection

Appendix H – Typical Guest Room Lighting Renderings

Appendix J – Lighting Selection

Appendix K – Acoustical Analysis

Appendix L – Overall Cost Analysis

Appendix M – HAP Report Files

Please Note: Not all the pages of the Appendix are numbered. Manufacturer's equipment cut sheets, HAP and EEA outputs, and other external sources are just included in their appropriate sections.

Appendix A – Chiller Selection

This appendix contains the cut sheets and other data for the manufacturer information provided for the chillers used as a part of the design process. There is data from Trane, Carrier, York, and McQuay included.

Please see the all the chiller information on the following pages.

Centrifugal Chiller

Job Information

Name	**Nathan**	Tag	**CH-1B**
Address		Quantity	**1**
Sales Team	**Washington DC**	Model Number	**CVHE0450**
Comments			

Base unit module

Hot gas by pass	**Without hot gas bypass**	Accessory line item 1	**Accessory line item 1**
Accessory line item 2	**Accessory line item 2**		

General

Manufacturing Facility	**La Crosse**	Agency Listing	**No agency listing (Export use only)**
Motor frequency	**60 Hz**	Motor voltage	**460**
Model	**CVHE**	Compressor size	**450**
Motor size	**231**	Impeller size	**213**
Orifice size	**400**	Distribution	**North America region**
Primary power	**184.30 kW**	Primary efficiency	**0.526 kW/ton**
NPLV	**0.343 kW/ton**	Primary RLA	**257.10 A**
Motor LRA	**2234.00 A**	Min circuit ampacity	**331.00 A**
Max over current protection	**500.00 A**	ARI std 550/590-98 classification	**Certified**
Selection code revision level	**55077.00 Each**	HCFC 123 refrigerant charge	**950.0 lb**
Shipping weight	**19687.0 lb**	Operating weight	**22274.0 lb**
Full load sound pressure	**0 dBA**	IGV position	**90.00 deg**
Compressor speed	**3555 rpm**	ASHRAE 90.1 compliance	**Yes**
Max 90.1 IPLV/NPLV	**0.558 kW/ton**	Max 90.1 efficiency	**0.585 kW/ton**
Green Seal certification	**Yes**	Heat rejected into equip room	**3.15 MBh**
Selection ID	**1111111100.00 Each**		

Evaporator

Cooling capacity	**350.00 tons**	Evap leaving temp	**44.00 F**
Evap flow rate	**696.70 gpm**	Evap flow/capacity	**1.99 gpm/ton**
Evap entering temp	**56.00 F**	Evap fouling factor	**0.00010 hr-sq ft-deg F/Btu**
Evap water box type	**non-marine**	Evap fluid type	**water**
Evap fluid concentration	**0.00 %**	Evap passes	**2**
Evap tube thickness	**0.025"**	Evap tube type	**TECU**
Evap shell size	**050L**	Evap bundle size	**500**
Evap pressure drop	**13.18 ft H2O**	Evap refrig saturation temp	**42.28 F**
Evap fluid velocity	**4.67 ft/s**	Evap min flow rate	**298.40 gpm**

Condenser

Cond entering temp	**85.00 F**	Cond flow rate	**976.80 gpm**
Cond flow/capacity	**2.79 gpm/ton**	Cond leaving temp	**95.00 F**
Cond fouling factor	**0.00025 hr-sq ft-deg F/Btu**	Cond water box type	**non-marine**
Cond fluid type	**water**	Cond fluid concentration	**0.00 %**
Cond tube thickness	**0.028"**	Cond tube type	**TECU**
Cond shell size	**050L**	Cond bundle size	**500**
Cond pressure drop	**19.95 ft H2O**	Cond refrig saturation temp	**96.08 F**
Cond fluid velocity	**6.34 ft/s**	Cond shell construction	**Standard condenser construction**

Starter

AFD model	**AFDE**	AFD frame size	**405 max RLA**
Nameplate power	**184.30 kW**	Nameplate RLA	**257.10 A**
Nameplate MCA	**331.00 A**	Nameplate MOP	**500.00 A**
Adaptive frequency drive	**AFD**		

Submittal Only

Search level	**Comprehensive**	Evap water box pressure	**150 psig evap. water pressure**
Cond water box pressure	**150 psig cond. water pressure**	Evap water box connection	**Victaulic connection evap.**
Cond water box connection	**Victaulic connection cond.**	Evap water box arrgmt	**In RH end - out RH end**
Cond water box arrgmt	**In RH end - out RH end**	Evap water box weld type	**Standard waterbox construction**
Cond water box weld type	**Standard waterbox construction**	Free cooling option	**Without free cooling**
Gas powered chiller	**No gas powered chiller**	Industrial chiller package	**Without industrial chiller package**
Enhanced protection	**Without enhanced protection**		

Settings

Search level	**Comprehensive**	Optimization mode	**kW/TON**
Impeller optimization	**Yes**	Additional condenser	**Without additional condenser**
Application type	**Standard cooling**	Minimum unload point	**25.00 %**
Operating status	**Operating Status**	Trane supplied refrigerant	**Trane Supplied Refrig.**

Test Targets

Factory performance test	**Standard air run and vibration.**

Test Tolerances

Factory tolerance test (SEE NOTES)	**Standard air run and vibration**	Apply special kW/ton tolerance	**No**
Apply special ton tolerance	**No**		

Warranty

Labor 1st year	**1st year labor warranty whole unit**

Evergreen Chiller Performance Outputs

Tag Name: Selection1

Chiller
- Chiller Model **19XRV2022206BHS64**
- Starter / VFD .... **VFD - Unit Mounted**
- Refrigerant Type **R-134a**

Cooler
- Size **20**
- Waterbox Type .... **Nozzle-in-Head, 150 psi**
- Passes **2**
- Tubing .... **Super E2 (SUPE2), .025 in, Copper**
- Fluid Type .... **Fresh Water**
- Fouling Factor (hr-sqft-F)/BTU **0.00010**

Compressor
- Size **206**

Flow Controls
- Float Valve Size **3**
- Flasc Orifice **21**

Weights
- Total Rigging Weight .... **11331** lb
- Total Operating Weight .... **12829** lb
- Refrigerant Weight .... **570** lb

Condenser
- Size **22**
- Waterbox Type .... **Nozzle-in-Head, 150 psi**
- Passes **2**
- Tubing .... **Spike Fin III (SPK3), .025 in, Copper**
- Fluid Type .... **Fresh Water**
- Fouling Factor (hr-sqft-F)/BTU **0.00025**

Motor
- Size .... **BHS**
- Line Voltage/Hertz **460-3-60**

Output Type	Full Load
Percent Load	100.00
Chiller Capacity	350 Tons
Chiller Input kW	231 kW
Chiller Input Power	0.661 kW/Ton
Cooler	
Entering Temp.	54.0 F
Leaving Temp.	44.0 F
Flow Rate	840.0 gpm
Pressure Drop	26.8 ft wg
Condenser	
Leaving Temp.	94.5 F
Entering Temp.	85.0 F
Flow Rate	1050.0 gpm
Pressure Drop	17.4 ft wg
Motor	
Motor Rated Load Amps	341
Motor OLTA	368
Motor LRDA	1732
Chiller Rated Line Amps	319
Chiller Inrush Amps	319
Max Fuse/CB Amps	600
Min Circuit Ampacity	399

Messages:

(1) Certified in accordance with the ARI Water-Chilling Packages using the Vapor Compression Cycle Certification Program, which is based on ARI Standard 550/590-2003.

YORK
A JOHNSON CONTROLS COMPANY

YK MAXE CHILLER PERFORMANCE SPECIFICATION

Unit Tag	Qty	Model No.	Capacity (tons)	Power	Refrigerant
CH-1,2	2	YKACADQ3-CKF	350	460/3/60	R-134A

Unit Data	Evaporator	Condenser
EWT (°F):	56.00	85.00
LWT (°F):	44.00	94.31
Flow Rate (gpm):	700	1050
Pressure Drop (ft):	11.5	10.9
Fluid Type (%):	WATER	WATER
Circuit No. of Passes:	2	2
Fouling Factor (ft^2 °F hr / Btu):	0.00010	0.00025
Tube No. / Description:	271 - 0.025" Enhanced Copper	260 - 0.025" CSL Enhanced Copper
Design Working Pressure (psig):	150	150
Entering Water Nozzle @ Location:	C	R
Leaving Water Nozzle @ Location:	B	S
Water Box Weight, ea (lbs) :	209	170
Cover Plate Weight , ea (lbs):	N/A	N/A
Return Head Weight (lbs):	165	132
Water Weight (lbs):	716	848

Performance Data		Electrical Data		Other	
Job KW:	216	Job FLA:	311	Operating Wt. (lbs):	17876
Motor KW:	212	Motor FLA:	301	Per Isolator (lbs):	4469
KW/Ton:	0.617	LRA:	1950	Refrigerant Wt. (lbs):	1250
NPLV (1):	0.381	Inrush Amps:	311	Oil Charge (gal):	10
Shaft HP:	266	Min Circuit Ampacity (Amps):	388	Motor Wt. (lbs):	1460
		Max Fuse/Breaker:	600	Compressor Wt. (lbs):	1807
				Starter Wt. (lbs):	1150
				Shipping Wt. (lbs):	16312
		Type Starter: Variable Speed Drive			

Notes:

(1) Chiller NPLV value calculated to ARI Standard 550/590 equation.

JOB NAME	BJ0652	**REP. OFFICE**	TriState HVAC-York
JOB DESCRIPTION	PSU Project	**SALESMAN**	SW
		CUSTOMER	
MODEL NUMBER	WSC087LBD35R/E2612-BE-2*A/C2612-DLYY-2*AYYY/R134-BAABM		
UNIT TAGGING	CH-1 (350 Ton w/ VFD)	**VERSION**	4.61

GENERAL DATA	
Approval	ETL Listed / ETL Listed to Canadian Safety Standards (ETL Label / ETLc Label)

COMPRESSOR DATA			
Type / quantity-size	Centrifugal / 1 - 087		
Capacity control	VFD	Refrigerant charge (lbs)	891
Refrigerant	R134-a	Oil cooler type	Water cooled

EVAPORATOR DATA		**CONDENSER DATA**	
Flow (US gpm)	700.00	Flow (US gpm)	1050.00
LWT (ºF)	44.00	EWT (ºF)	85.00
Number of passes	2	Number of passes	2
Fouling factor	0.00010	Fouling factor	0.00025
Tube material	Cu	Tube material	Cu
Tube wall thickness (in)	0.025	Tube wall thickness (in)	0.025
Fluid type	Water	Fluid type	Water
Percentage of fluid	100	Percentage of fluid	100

MOTOR / STARTER DATA			
Unit voltage (V/Hz/P)	460 / 60 / 3	MCA (A)	370.9
RLA (amps) per compressor	292	MOCP (A)	516.8
Starter type	VFD	LRA (A) per compressor	2273
Enclosure type	NEMA 1	Model number	VFD047YMW
Location	Terminal mounted	Approval listing	ETL/ETLc Label
Disconnect type	Circuit breaker high interrupt	Motor protection	Standard
Control circuit transformer	Without taps	Surge capacitor	None
Ammeter with selector switch	Yes	Ground fault	No
Voltmeter with selector switch	Yes	Auxiliary control relay	None
Phase / voltage protection	Yes	Indicator lights	None
Lightening arrestors	No	P.F. correction (Kvar)	Inherent
Power factor	0.858	Corrected power factor	0.96
Shipped loose with bracket and cable kit	No	Inrush value	350.26

DESIGN PERFORMANCE

Capacity (Tons)	Power (kW)	Performance (kW/Ton)	RLA (A)	IPLV\ NPLV (kW/Ton)	75% load (kW/Ton)	50% load (kW/Ton)	25% load (kW/Ton)	Evaporator PD (ft)	Evaporator T in (ºF)	Condenser PD (ft)	Condenser T out (ºF)
350.0	207.6	0.593	292	0.394	0.444	0.345	0.439	16.0	56.0	16.9	94.2

PART LOAD PERFORMANCE

P#	%load	Capacity	Input	Perf	RLA	Evaporator	Condenser

	request	(Tons)	power (kW)	(kW/Ton)	(A)	Flow (US gpm)	T in (ºF)	T out (ºF)	PD (ft)	Flow (US gpm)	T in (ºF)	T out (ºF)	PD (ft)
1	100.0	350.0	207.6	0.593	292	700.0	56.0	44.0	16.0	1050.0	85.0	94.2	16.9
2	75.0	262.5	116.6	0.444	187	700.0	53.0	44.0	16.1	1050.0	75.0	81.6	17.6
3	50.0	175.0	60.4	0.345	131	700.0	50.0	44.0	16.1	1050.0	65.0	69.2	18.3
4	25.0	87.5	38.4	0.438	112	700.0	47.0	44.0	16.2	1050.0	65.0	67.1	18.4

SOUND DATA

Sound data (in dB RE 10^{-12} Pa) measured in accordance with ARI 575 (without sound insulation)

63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	Overall
69.0	67.0	69.0	71.0	76.0	78.0	78.0	74.0	83.5
							75% load	81.5
							50% load	81.5
							25% load	82.5

SERVICE PERFORMANCE

P#	Refrig Charge (lb)	LRAD (A)	PD capacity	SH	SC	Evaporator			Condenser		
						Temp (ºF)	Pressure (psi)	Velocity (fps)	Temp (ºF)	Pressure (psi)	Velocity (fps)
1	891	2273	1869	1.0	8.5	43.0	38.6	6.3	95.5	115.6	6.8
2	891	2273	1869	1.0	6.5	43.2	38.9	6.3	82.6	91.7	6.8
3	891	2273	1869	1.0	4.4	43.5	39.1	6.3	70.0	71.7	6.8
4	891	2273	1869	1.0	2.3	43.7	39.4	6.3	67.5	68.1	6.8

NOTES:

The ARI 60 hertz Certification Program covers models that:
- are rated up to 2000 tons (7032 kW cooling) at ARI Standard Rating Conditions
- have voltages less than or equal to 5000 volts
- are within the scope of the Application Rating Conditions of ARI Standard 550/590-2003
- have a leaving chilled water temperature of 40 to 48 ºF (4.4 to 8.9 ºC)
- have an entering condenser water temperature of 65 to 105 ºF (18.3 to 40.6 ºC)

The ARI Certification Program specifically excludes:
- chillers above 2000 tons (7032 kW cooling)
- chillers with voltages above 5000 volts
- secondary coolant ratings other than water (e.g. glycol ratings)

Chiller performance is certified in accordance with the latest edition of ARI Standard 550/590-2003.
Above RLA values are per compressor. kW values are total unit kW.

- WSC/WDC063, 079, 087, 100, 113, 126 models utilize water-cooled oil cooler as standard equipment
- WSC/WDC050's utilize a refrigerant-cooled oil cooler as standard equipment.

JOB NAME	BJ0652	**REP. OFFICE**	TriState HVAC-York
JOB DESCRIPTION	PSU Project	**SALESMAN**	SW
		CUSTOMER	
MODEL NUMBER	WDC087LBD35R/E3016-SE-2*A/C3016-SLYY-2*AYYY/R134-BCCCM		
UNIT TAGGING	CH-2 (700 Ton Dual)	**VERSION**	4.61

GENERAL DATA	
Approval	ETL Listed / ETL Listed to Canadian Safety Standards (ETL Label / ETLc Label)

COMPRESSOR DATA			
Type / quantity-size	Centrifugal / 2 - 087		
Capacity control	Inlet guide vanes	Refrigerant charge (lbs)	1936
Refrigerant	R134-a	Oil cooler type	Water cooled

EVAPORATOR DATA		**CONDENSER DATA**	
Flow (US gpm)	1400.00	Flow (US gpm)	2100.00
LWT (ºF)	44.00	EWT (ºF)	85.00
Number of passes	2	Number of passes	2
Fouling factor	0.00010	Fouling factor	0.00025
Tube material	Cu	Tube material	Cu
Tube wall thickness (in)	0.025	Tube wall thickness (in)	0.025
Fluid type	Water	Fluid type	Water
Percentage of fluid	100	Percentage of fluid	100

MOTOR / STARTER DATA			
Unit voltage (V/Hz/P)	460 / 60 / 3	MCA (A)	359.8
RLA (amps) per compressor	283	MOCP (A)	501.3
Starter type	Wye-Delta	LRA (A) per compressor	2273
Enclosure type	NEMA 1 gasketed	Model number	BSRD3WT31
Location	Terminal mounted	Approval listing	CSA ETL
Disconnect type	Circuit breaker	Motor protection	Standard
Control circuit transformer	Without taps	Surge capacitor	Standard
Ammeter with selector switch	None	Ground fault	No
Voltmeter with selector switch	None	Auxiliary control relay	None
Phase / voltage protection	Yes	Indicator lights	None
Lightening arrestors	No	P.F. correction (Kvar)	None
Power factor	0.894	Corrected power factor	None
Shipped loose with bracket and cable kit	No		

DESIGN PERFORMANCE

Capacity (Tons)	Power (kW)	Performance (kW/Ton)	RLA (A)	IPLV\ NPLV (kW/Ton)	75% load (kW/Ton)	50% load (kW/Ton)	25% load (kW/Ton)	Evaporator PD (ft)	Evaporator T in (ºF)	Condenser PD (ft)	Condenser T out (ºF)
700.0	403.0	0.576	283	0.443	0.515	0.375	0.537	21.3	56.0	23.8	94.2

PART LOAD PERFORMANCE

P#	%load request	Capacity (Tons)	Input power (kW)	Perf (kW/Ton)	RLA (A)	Evaporator Flow (US gpm)	Evaporator T in (ºF)	Evaporator T out (ºF)	Evaporator PD (ft)	Condenser Flow (US gpm)	Condenser T in (ºF)	Condenser T out (ºF)	Condenser PD (ft)

(CH-1A)

1	100.0	700.0	403.0	0.576	283	1400.0	56.0	44.0	21.3	2100.0	85.0	94.2	23.8
2	75.0	525.0	270.2	0.515	204	1400.0	53.0	44.0	21.4	2100.0	75.0	81.8	24.7
3	50.0	350.0	131.4	0.375	201	1400.0	50.0	44.0	21.5	2100.0	65.0	69.4	25.8
4	25.0	175.0	94.0	0.537	161	1400.0	47.0	44.0	21.6	2100.0	65.0	67.2	25.9

SOUND DATA

Sound data (in dB RE 10^{-12} Pa) measured in accordance with ARI 575 (without sound insulation)

63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	Overall
69.0	68.0	70.0	74.0	78.0	81.0	81.0	77.0	86.5
							75% load	84.5
							50% load	80.5
							25% load	79.5

SERVICE PERFORMANCE

P#	Refrig Charge (lb)	LRAD (A)	PD capacity	SH	SC	Evaporator			Condenser		
						Temp (ºF)	Pressure (psi)	Velocity (fps)	Temp (ºF)	Pressure (psi)	Velocity (fps)
1	1936	2273	2751	1.0	8.3	42.5	38.1	6.3	95.1	114.8	7.0
2	1936	2273	2751	1.0	6.5	42.5	38.1	6.3	82.5	91.5	7.0
3	1936	2273	2751	1.0	3.9	43.8	39.4	6.3	69.7	71.4	7.0
4	1936	2273	2751	1.0	2.2	43.9	39.5	6.3	67.4	68.0	7.0

NOTES:

The ARI 60 hertz Certification Program covers models that:

- are rated up to 2000 tons (7032 kW cooling) at ARI Standard Rating Conditions
- have voltages less than or equal to 5000 volts
- are within the scope of the Application Rating Conditions of ARI Standard 550/590-2003
- have a leaving chilled water temperature of 40 to 48 ºF (4.4 to 8.9 ºC)
- have an entering condenser water temperature of 65 to 105 ºF (18.3 to 40.6 ºC)

The ARI Certification Program specifically excludes:

- chillers above 2000 tons (7032 kW cooling)
- chillers with voltages above 5000 volts
- secondary coolant ratings other than water (e.g. glycol ratings)

Chiller performance is certified in accordance with the latest edition of ARI Standard 550/590-2003.
Above RLA values are per compressor. kW values are total unit kW.

- WSC/WDC063, 079, 087, 100, 113, 126 models utilize water-cooled oil cooler as standard equipment
- WSC/WDC050's utilize a refrigerant-cooled oil cooler as standard equipment.

JOB NAME	BJ0652	**REP. OFFICE**	TriState HVAC-York
JOB DESCRIPTION	PSU Project	**SALESMAN**	SW
		CUSTOMER	
MODEL NUMBER	WDC087LBD35R/E3016-SE-2*A/C3016-SLYY-2*AYYY/R134-BCCCM		
UNIT TAGGING	CH-3 (700 Ton Dual VFD)	**VERSION**	4.61

GENERAL DATA	
Approval	ETL Listed / ETL Listed to Canadian Safety Standards (ETL Label / ETLc Label)

COMPRESSOR DATA			
Type / quantity-size	Centrifugal / 2 - 087		
Capacity control	VFD	Refrigerant charge (lbs)	1936
Refrigerant	R134-a	Oil cooler type	Water cooled

EVAPORATOR DATA		**CONDENSER DATA**	
Flow (US gpm)	1400.00	Flow (US gpm)	2100.00
LWT (ºF)	44.00	EWT (ºF)	85.00
Number of passes	2	Number of passes	2
Fouling factor	0.00010	Fouling factor	0.00025
Tube material	Cu	Tube material	Cu
Tube wall thickness (in)	0.025	Tube wall thickness (in)	0.025
Fluid type	Water	Fluid type	Water
Percentage of fluid	100	Percentage of fluid	100

MOTOR / STARTER DATA			
Unit voltage (V/Hz/P)	460 / 60 / 3	MCA (A)	373.2
RLA (amps) per compressor	294	MOCP (A)	520.1
Starter type	VFD	LRA (A) per compressor	2273
Enclosure type	NEMA 1	Model number	VFD047YMW
Location	Terminal mounted	Approval listing	ETL/ETLc Label
Disconnect type	Circuit breaker high interrupt	Motor protection	Standard
Control circuit transformer	Without taps	Surge capacitor	None
Ammeter with selector switch	Yes	Ground fault	No
Voltmeter with selector switch	Yes	Auxiliary control relay	None
Phase / voltage protection	Yes	Indicator lights	None
Lightening arrestors	No	P.F. correction (Kvar)	Inherent
Power factor	0.859	Corrected power factor	0.96
Shipped loose with bracket and cable kit	No	Inrush value	352.55

DESIGN PERFORMANCE											
Capacity (Tons)	Power (kW)	Performance (kW/Ton)	RLA (A)	IPLV\ NPLV (kW/Ton)	75% load (kW/Ton)	50% load (kW/Ton)	25% load (kW/Ton)	Evaporator		Condenser	
								PD (ft)	T in (ºF)	PD (ft)	T out (ºF)
700.0	418.2	0.597	294	0.386	0.451	0.355	0.318	21.3	56.0	23.8	94.2

PART LOAD PERFORMANCE							
P#	%load	Capacity	Input	Perf	RLA	Evaporator	Condenser

	request	(Tons)	power (kW)	(kW/Ton)	(A)	Flow (US gpm)	T in (ºF)	T out (ºF)	PD (ft)	Flow (US gpm)	T in (ºF)	T out (ºF)	PD (ft)
1	100.0	700.0	418.2	0.597	294	1400.0	56.0	44.0	21.3	2100.0	85.0	94.2	23.8
2	75.0	525.0	236.7	0.451	189	1400.0	53.0	44.0	21.4	2100.0	75.0	81.6	24.7
3	50.0	350.0	124.2	0.355	133	1400.0	50.0	44.0	21.5	2100.0	65.0	69.3	25.8
4	25.0	175.0	55.7	0.318	127	1400.0	47.0	44.0	21.6	2100.0	65.0	67.1	25.9

SOUND DATA

Sound data (in dB RE 10^{-12} Pa) measured in accordance with ARI 575 (without sound insulation)

63Hz	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	Overall
69.0	68.0	70.0	74.0	78.0	81.0	81.0	77.0	86.5
							75% load	84.5
							50% load	80.5
							25% load	79.5

SERVICE PERFORMANCE

P#	Refrig Charge (lb)	LRAD (A)	PD capacity	SH	SC	Evaporator			Condenser		
						Temp (ºF)	Pressure (psi)	Velocity (fps)	Temp (ºF)	Pressure (psi)	Velocity (fps)
1	1936	2273	2751	1.0	8.2	42.5	38.1	6.3	95.1	114.8	7.0
2	1936	2273	2751	1.0	6.4	42.5	38.1	6.3	82.3	91.2	7.0
3	1936	2273	2751	1.0	4.3	42.4	38.0	6.3	69.8	71.4	7.0
4	1936	2273	2751	1.0	2.1	43.9	39.5	6.3	67.3	67.8	7.0

NOTES:

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- have voltages less than or equal to 5000 volts
- are within the scope of the Application Rating Conditions of ARI Standard 550/590-2003
- have a leaving chilled water temperature of 40 to 48 ºF (4.4 to 8.9 ºC)
- have an entering condenser water temperature of 65 to 105 ºF (18.3 to 40.6 ºC)

The ARI Certification Program specifically excludes:

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Above RLA values are per compressor. kW values are total unit kW.

- WSC/WDC063, 079, 087, 100, 113, 126 models utilize water-cooled oil cooler as standard equipment
- WSC/WDC050's utilize a refrigerant-cooled oil cooler as standard equipment.

Proposal

TRANE

Trane
A Division of American Standard Inc.

Prepared For:
M.Contractor: Southland Industries

Date: March 31, 2006

Proposal Number: E2-68290-1

Job Name:
Nathan

Engineer:
Southland Industries
22960 Shaw Road
Suite 800
Sterling, VA 20166

Delivery Terms:
Freight Allowed and Prepaid - F.O.B. Factory

Payment Terms:
Net 30 Days

Trane is pleased to provide the enclosed proposal for your review and approval.

Tag Data - Centrifugal Water Chillers (Qty: 4)

Item	Tag(s)	Qty	Description	Model Number
A1	CH-1A	1	Centrifugal Chiller (CTV)	CVHE0450
A2	CH-1B	1	Centrifugal Chiller (CTV)	CVHE0450
A3	CH-2A	1	Centrifugal Chiller (CTV)	CVHE0450
A4	CH-2B	1	Centrifugal Chiller (CTV)	CVHE0450

Product Data - Centrifugal Water Chillers
All Units

North America region
Centrifugal liquid chiller with 3 stage compressor R-123 refrigerant
Compressor size: 450 nominal tons
Without industrial chiller package
Compressor hertz: 60
Compressor voltage: 460 volt 3 phase
Compressor impeller cutback: 213
Standard cooling
Evaporator shell size: 050 long
Evaporator bundle size: 500 nominal tons
Evaporator tubes: 0.75 inch (19.1 mm) dia. internally enhanced copper
Evaporator tube wall: .025 inch (0.6 mm) thick
Evaporator fluid type: Water
Evaporator waterbox type: Non-marine
Evaporator waterbox construction: Standard
Evaporator waterbox passes: Two pass
Evaporator waterbox pressure: 150 psig (1034 kPa)
Evaporator waterbox connection: Victaulic
Evaporator waterbox arrangement: in RH end - out RH end
Condenser shell size: 050 long
Condenser bundle size: 500 nominal tons
Condenser tube: 0.75 inch (19.1 mm) internally enhanced copper
Condenser tube wall: .028 inch (0.7 mm) thick
Condenser shell construction: Standard

Condenser fluid type: Water
Condenser waterbox type: 2 pass non-marine
Condenser waterbox construction: Standard
Condenser waterbox pressure: 150 psig (1034 kPa)
Condenser waterbox connection: Victaulic
Condenser waterbox arrangement: in RH end - out RH end
Orifice size: 400 nominal tons
Factory performance test: Standard air run and vibration test
Factory tolerance test: Standard air run and vibration test
Don't apply special ton tolerance
Don't apply special kW/ton tolerance
Complies with all versions of ASHRAE/IESNA 90.1
Operating Status
Without enhanced protection
Accessory line item 1
Accessory line item 2
Trane Supplied Refrigerant
1st Year Labor Warranty Whole Unit with Trane Supplied Starter

Item: A1, A3 Qty: 2 Tag(s): CH-1A, CH-2A

60 hz Compressor motor power: 204 kW
Green Seal not qualified
Low Voltage Wye-Delta Starters
Starter type: Unit Mounted Wye-Delta
Starter maximum RLA: 346 Amps
Starter power connection: Non-fused Disconnect Switch
Starter power connection maximum RLA: 296 Amps

Item: A2, A4 Qty: 2 Tag(s): CH-1B, CH-2B

60 hz Compressor motor power: 231 kW
Green Seal certified
Refrigerant Cooled AFD CH530 Development
Unit mounted adaptive frequency drive
Adaptive frequency drive maximum RLA: 405 amps

Total Net Price CH-1A *(Excluding Sales Tax)* ....$ 114,518.00
Total Net Price CH-1B *(Excluding Sales Tax)* ....$ 137,186.00
Total Net Price CH-2A *(Excluding Sales Tax)* ....$ 114,518.00
Total Net Price CH-2B *(Excluding Sales Tax)* ....$ 137,186.00

Trane is pleased to offer you an opportunity to maximize the value of your purchase by offering you *savings* with the Anticipation Discount Program (ADP). Contact your Trane representative for more details or an ADP discount calculation.

Sincerely,

Jim Fusco - Trane
12320 Parklawn Drive
Rockville, MD 20852-1726
Phone: (301)984-2400
Fax: (301)881-4787

Appendix B – Cooling Tower Selection

This appendix contains the cut sheets and other data for the Marley cooling towers studied and compared as a part of the design process.

Please see the all the cooling towers information on the following pages.

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

3/28/2006 11:59:13 PM

Job Information

Hilton Hotel at BWI Airport
Nathan Patrick
Linthicum Heights, MD

Selected By

SPX Cooling Technologies Contact

Marley Cooling Technologies, Inc.
7401 W. 129 Street
Overland Park, KS 66213
info@marleyct.spx.com
Tel 1-800-462-7539

Cooling Tower Definition

Manufacturer	Marley	Fan Motor Speed	1200 rpm
Product	NC Class	Fan Motor Capacity per cell	15.00 BHp
Model	NC8306EL2	Fan Motor Output per cell	15.00 BHp
Cells	2	Fan Motor Output total	30.00 BHp
CTI Certified	Yes	Air Flow per cell	122000 cfm
Fan	10.00 ft, 8 Blades	Air Flow total	244000 cfm
Fan Speed	191 rpm, 6000.4 fpm	ASHRAE 90.1 Performance	99.4 gpm/Hp
Fans per cell	1		

Conditions

Tower Water Flow	2100 gpm	Air Density In	0.07076 lb/ft³
Hot Water Temperature	95.00 °F	Air Density Out	0.07117 lb/ft³
Range	10.00 °F	Humidity Ratio In	0.01779
Cold Water Temperature	85.00 °F	Humidity Ratio Out	0.02931
Approach	6.00 °F	Wet-Bulb Temp. Out	88.12 °F
Wet-Bulb Temperature	79.00 °F	Estimated Evaporation	23 gpm
Relative Humidity	50 %	Total Heat Rejection	10463000 Btu/h

- This selection meets your design conditions.

Weights & Dimensions

	Per Cell	Total
Shipping Weight	10170 lb	20340 lb
Max Operating Weight	21980 lb	43960 lb
Width	19.83 ft	19.83 ft
Length	11.90 ft	24.08 ft
Height	12.98 ft	
Static Lift	12.23 ft	

Minimum Enclosure Clearance

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

Solid Wall	8.70 ft
50 % Open Wall	6.00 ft

Weights and dimensions do not include options; refer to sales drawings. For CAD layouts refer to file NC8306.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	-25.81	-8.25	0.53	9.31	18.09	22.48	26.87

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

3/31/2006 2:13:09 AM

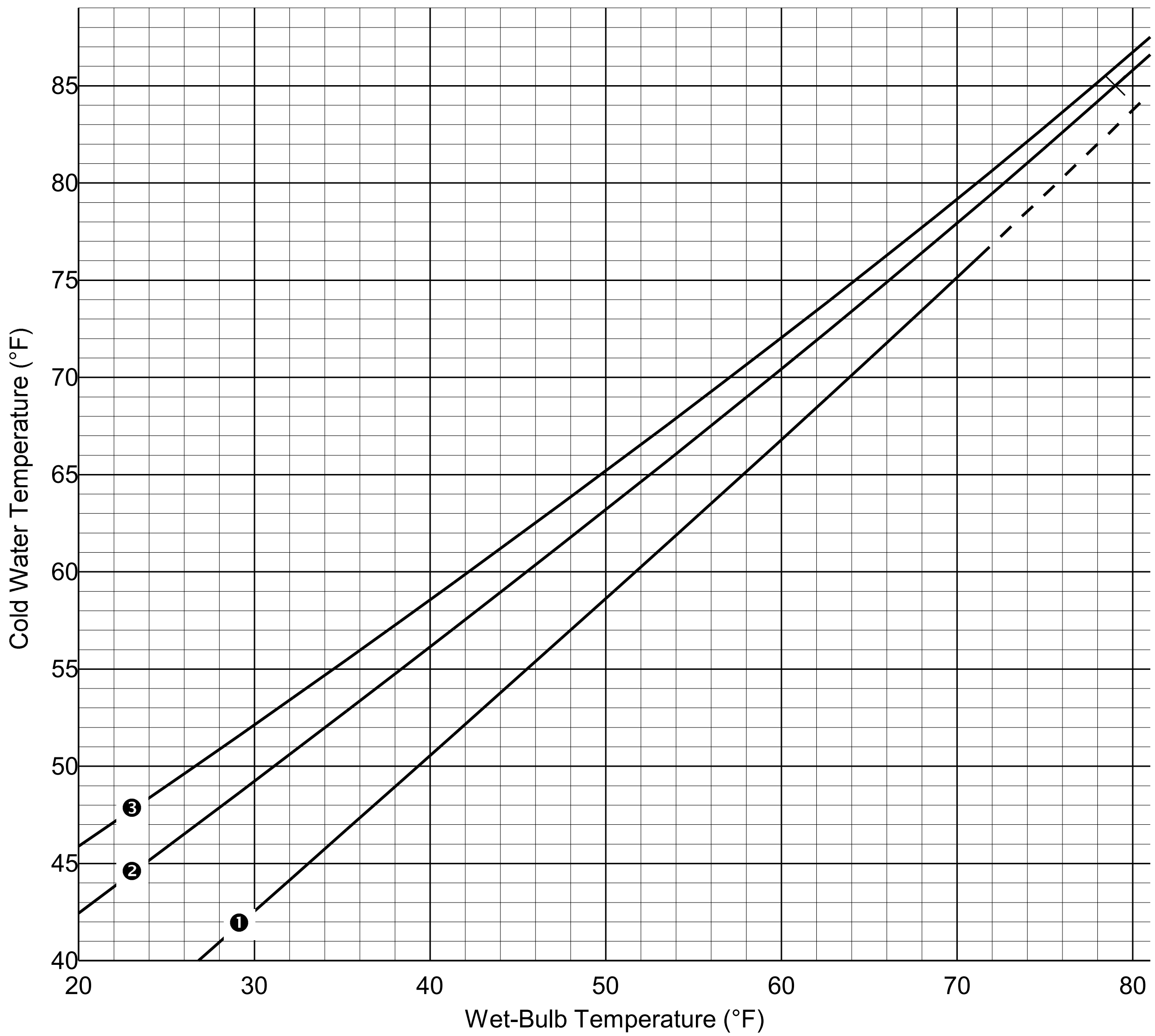
Job Information
Hilton Hotel at BWI Airport
Nathan Patrick
Linthicum Heights, MD

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

PSUAE
Tel 814-863-2076
Fax

Cooling Tower Definition

Manufacturer	Marley
Product	NC Class
Model	NC8306EL2
Cells	2
Fan	10.00 ft, 8 Blades
Fans per cell	1
Fan Motor Capacity per cell	15.00 BHp



Design Conditions

Tower Water Flow	2100 gpm
Hot Water Temperature	95.00 °F
Cold Water Temperature	85.00 °F
Wet-Bulb Temperature	79.00 °F

Curve Conditions

Tower Water Flow (100.0 %)	2100 gpm
Fan Speed (100.0 %)	191 rpm
Fan Motor Speed (100.0 %)	1200 rpm
Fan Motor Output per cell	15.00 BHp
Fan Motor Output total	30.00 BHp

Legend
❶ 6 °F Range
❷ 10 °F Range
❸ 12 °F Range
╳ Design Point

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

3/28/2006 11:58:01 PM

Job Information

Hilton Hotel at BWI Airport
Nathan Patrick
Linthicum Heights, MD

Selected By

SPX Cooling Technologies Contact

Marley Cooling Technologies, Inc.
7401 W. 129 Street
Overland Park, KS 66213
info@marleyct.spx.com
Tel 1-800-462-7539

Cooling Tower Definition

Manufacturer	Marley	Fan Motor Speed	1200 rpm
Product	NC Class	Fan Motor Capacity per cell	20.00 BHp
Model	NC8305FL2	Fan Motor Output per cell	20.00 BHp
Cells	2	Fan Motor Output total	40.00 BHp
CTI Certified	Yes	Air Flow per cell	114400 cfm
Fan	8.000 ft, 8 Blades	Air Flow total	228800 cfm
Fan Speed	313 rpm, 7866.5 fpm	ASHRAE 90.1 Performance	72.6 gpm/Hp
Fans per cell	1		

Conditions

Tower Water Flow	2100 gpm	Air Density In	0.07076 lb/ft³
Hot Water Temperature	95.00 °F	Air Density Out	0.07108 lb/ft³
Range	10.00 °F	Humidity Ratio In	0.01779
Cold Water Temperature	85.00 °F	Humidity Ratio Out	0.02985
Approach	6.00 °F	Wet-Bulb Temp. Out	88.68 °F
Wet-Bulb Temperature	79.00 °F	Estimated Evaporation	23 gpm
Relative Humidity	50 %	Total Heat Rejection	10463000 Btu/h

- This selection meets your design conditions.

Weights & Dimensions

	Per Cell	Total
Shipping Weight	8870 lb	17740 lb
Max Operating Weight	19170 lb	38330 lb
Width	18.750 ft	18.750 ft
Length	10.896 ft	22.083 ft
Height	12.979 ft	
Static Lift	12.234 ft	

Minimum Enclosure Clearance

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

Solid Wall	8.829 ft
50 % Open Wall	6.234 ft

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

Cold Weather Operation

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

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

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

3/29/2006 7:16:12 PM

Job Information

Hilton Hotel at BWI Airport
Nathan Patrick
Linthicum Heights, MD

Selected By

SPX Cooling Technologies Contact

Marley Cooling Technologies, Inc.
7401 W. 129 Street
Overland Park, KS 66213
info@marleyct.spx.com
Tel 1-800-462-7539

Cooling Tower Definition

Manufacturer	Marley	Fan Motor Speed	1800 rpm
Product	NC Class	Fan Motor Capacity per cell	20.00 BHp
Model	NC8305F2	Fan Motor Output per cell	20.00 BHp
Cells	2	Fan Motor Output total	40.00 BHp
CTI Certified	Yes	Air Flow per cell	116100 cfm
Fan	8.000 ft, 6 Blades	Air Flow total	232100 cfm
Fan Speed	370 rpm, 9299.1 fpm	ASHRAE 90.1 Performance	73.8 gpm/Hp
Fans per cell	1		

Conditions

Tower Water Flow	2100 gpm	Air Density In	0.07076 lb/ft³
Hot Water Temperature	95.00 °F	Air Density Out	0.07110 lb/ft³
Range	10.00 °F	Humidity Ratio In	0.01779
Cold Water Temperature	85.00 °F	Humidity Ratio Out	0.02973
Approach	6.00 °F	Wet-Bulb Temp. Out	88.55 °F
Wet-Bulb Temperature	79.00 °F	Estimated Evaporation	23 gpm
Relative Humidity	50 %	Total Heat Rejection	10463000 Btu/h

- This selection meets your design conditions.

Weights & Dimensions

	Per Cell	Total
Shipping Weight	8730 lb	17460 lb
Max Operating Weight	19030 lb	38050 lb
Width	18.750 ft	18.750 ft
Length	10.896 ft	22.083 ft
Height	12.979 ft	
Static Lift	12.234 ft	

Minimum Enclosure Clearance

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

Solid Wall	8.795 ft
50 % Open Wall	6.201 ft

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

Cold Weather Operation

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

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

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

3/29/2006 7:16:55 PM

Job Information

Hilton Hotel at BWI Airport
Nathan Patrick
Linthicum Heights, MD

Selected By

SPX Cooling Technologies Contact

Marley Cooling Technologies, Inc.
7401 W. 129 Street
Overland Park, KS 66213
info@marleyct.spx.com
Tel 1-800-462-7539

Cooling Tower Definition

Manufacturer	Marley	Fan Motor Speed	1800 rpm
Product	NC Class	Fan Motor Capacity per cell	15.00 BHp
Model	NC8307E2	Fan Motor Output per cell	15.00 BHp
Cells	2	Fan Motor Output total	30.00 BHp
CTI Certified	Yes	Air Flow per cell	121100 cfm
Fan	10.00 ft, 6 Blades	Air Flow total	242300 cfm
Fan Speed	241 rpm, 7571.2 fpm	ASHRAE 90.1 Performance	103 gpm/Hp
Fans per cell	1		

Conditions

Tower Water Flow	2100 gpm	Air Density In	0.07076 lb/ft³
Hot Water Temperature	95.00 °F	Air Density Out	0.07116 lb/ft³
Range	10.00 °F	Humidity Ratio In	0.01779
Cold Water Temperature	85.00 °F	Humidity Ratio Out	0.02937
Approach	6.00 °F	Wet-Bulb Temp. Out	88.18 °F
Wet-Bulb Temperature	79.00 °F	Estimated Evaporation	23 gpm
Relative Humidity	50 %	Total Heat Rejection	10463000 Btu/h

- This selection meets your design conditions.

Weights & Dimensions

	Per Cell	Total
Shipping Weight	11040 lb	22070 lb
Max Operating Weight	26090 lb	52190 lb
Width	22.42 ft	22.42 ft
Length	11.90 ft	24.08 ft
Height	13.31 ft	
Static Lift	12.57 ft	

Minimum Enclosure Clearance

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

Solid Wall	8.19 ft
50 % Open Wall	5.44 ft

Weights and dimensions do not include options; refer to sales drawings. For CAD layouts refer to file NC8307.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	-17.30	-1.86	5.85	13.57	21.28	25.14	29.00

Appendix C – Pump Selection

This appendix contains the cut sheets and other data for the Bell & Gossett pumps used as a part of the design process.

Please see the all the pump information on the following pages.

<u>Pump Selection Charts</u>

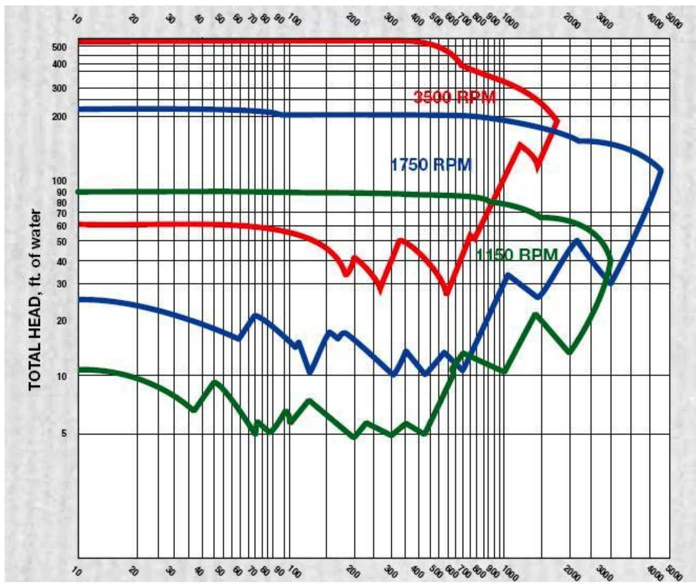


Figure C1 - Pump Selection Curves

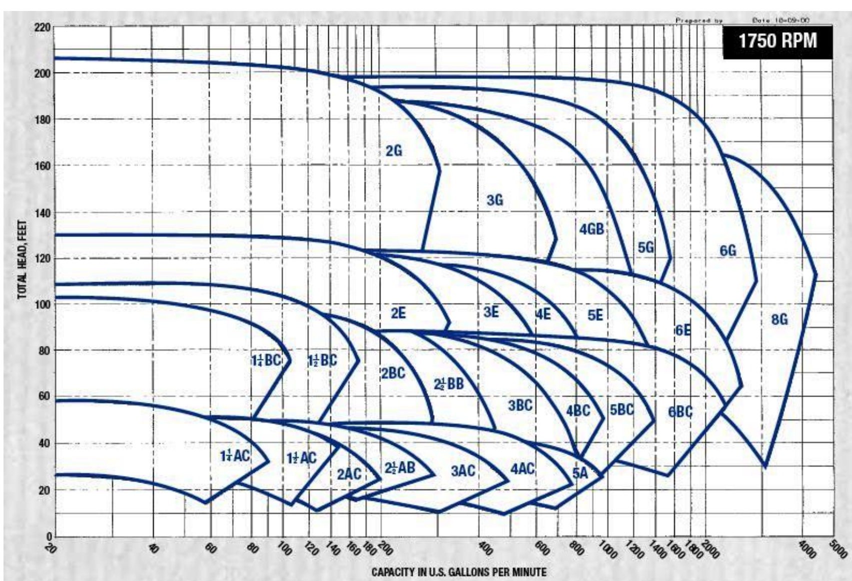


Figure C2 - 1750 rpm Performance Curves

"UMMINS·WAGNER
10901 Pump House Road Annapolis Junction, Md 20701
Washington: 301-953-9370 Baltimore: 410-792-4230 Fax: 301-490-7156

Го: Nathan — Job Name: Thesis
Engineer:
3/31/06 — Quote Number:

************ Quotation **************** Quotation ***************

Item	Quantity	Description	Unit Price	Extended Price
1)	1	**Chilled Water Pumps P-1** Bell & Gossett End Suction Pump Series: 1510 Model: 5 G 700 GPM @ 110.7 'TDH 40 HP 1800 RPM 460/3/60 Inverter Duty Frame: 324T ODP High Efficiency Motor Dodge Para-Flex Coupling Shipping Weight: 1055 lbs.	$5,164.00	$5,164.00
2)	1	**Condenser Water Pumps P-2** Bell & Gossett End Suction Pump Series: 1510 Model: 5 E 1050 GPM @ 70.8 'TDH 25 HP 1800 RPM 460/3/60 Inverter Duty Frame: 284T ODP High Efficiency Motor Dodge Para-Flex Coupling Shipping Weight: 710 lbs.	$4,337.00	$4,337.00
3)	1	**Geothermal Pumps P-3** Bell & Gossett End Suction Pump Series: 1510 Model: 4 BC 570 GPM @ 54 'TDH 15 HP 1800 RPM 460/3/60 Inverter Duty Frame: 254T ODP High Efficiency Motor Dodge Para-Flex Coupling Shipping Weight: 475 lbs.	$3,050.00	$3,050.00

CUMMINS·WAGNER
10901 Pump House Road Annapolis Junction, Md 20701
Washington: 301-953-9370 Baltimore: 410-792-4230 Fax: 301-490-7156

To: Nathan — Job Name: Thesis
Engineer:
3/31/06 — Quote Number:

************** Quotation **************** Quotation ***************

Item	Quantity	Description	Unit Price	Extended Price
4)	1	**Geothermal Pumps P-5** Bell & Gossett End Suction Pump Series: 1510 Model: 5 A 570 GPM @ 27 'TDH 7.5 HP 1800 RPM 460/3/60 Inverter Duty Frame: 213T ODP High Efficiency Motor Dodge Para-Flex Coupling Shipping Weight: 455 lbs.	$2,812.00	$2,812.00
5)	1	**Variable Speed Drive P-1** AC Tech Model: MCH4400BG 40 HP 480/400/3/60 52/60 amps Basic Drive With Manual By Pass, NEMA 1 Enclosure Standard Features : Bypass AC Line Terminals 3 Contactor Manual Transfer Bypass Class 10 Thermal Overload VFD Input Fuses Hand - Off - Automatic Switch Drive Mode - Off - Bypass Mode Switch Drive Normal - Off - Drive Test Switch Lights: Power On, Drive Mode, Bypass Mode, Safety Fail Circuit 120 VAC Transformer (2) Form C Relays For Logic Output Communication Protocol : Modbus RTU 2 Year Warranty Parts And Labor Motor Fuses 2 Year Warranty Parts And Labor	$3,225.00	$3,225.00

CUMMINS-WAGNER
10901 Pump House Road Annapolis Junction, Md 20701
Washington: 301-953-9370 Baltimore: 410-792-4230 Fax: 301-490-7156

To: Nathan
Job Name: Thesis
Engineer:
3/31/06
Quote Number:

*************** Quotation ***************** Quotation ****************

Item	Quantity	Description	Unit Price	Extended Price
		Variable Speed Drive P-2 AC Tech		
6)	1	Model: MCH4250BG15 25 HP 480/400/3/60 34/39 amps Basic Drive With Manual By Pass, NEMA 1 Enclosure Standard Features : Bypass AC Line Terminals 3 Contactor Manual Transfer Bypass Class 10 Thermal Overload VFD Input Fuses Hand - Off - Automatic Switch Drive Mode - Off - Bypass Mode Switch Drive Normal - Off - Drive Test Switch Lights: Power On, Drive Mode, Bypass Mode, Safety Fail Circuit 120 VAC Transformer (2) Form C Relays For Logic Output Communication Protocol : Modbus RTU Disconnect Motor Fuses 2 Year Warranty Parts And Labor	$2,649.00	$2,649.00
		Variable Speed Drive P-3 AC Tech		
7)	1	Model: MCH4150BG 15 HP 480/400/3/60 21/24 amps Basic Drive With Manual By Pass, NEMA 1 Enclosure Standard Features : Bypass AC Line Terminals 3 Contactor Manual Transfer Bypass Class 10 Thermal Overload VFD Input Fuses Hand - Off - Automatic Switch Drive Mode - Off - Bypass Mode Switch Drive Normal - Off - Drive Test Switch Lights: Power On, Drive Mode, Bypass Mode, Safety Fail Circuit	$1,886.00	$1,886.00

Bell & Gossett

SUBMITTAL

B-229.3E

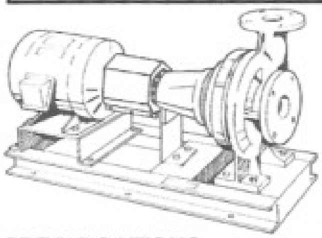
JOB: Thesis Report

REPRESENTATIVE: Cummins-Wagner Co., Inc.

UNIT TAG: P-1
ENGINEER:
CONTRACTOR:

ORDER NO.
SUBMITTED BY:
APPROVED BY:

DATE: 3/31/2006
DATE:
DATE:



5G
Series 1510
Centrifugal Pumps - Base Mounted

SPECIFICATIONS

FLOW 700 (GPM) HEAD 110.7 (FT)
HP 40 RPM 1800
VOLTS 230/460
CYCLE 60 PHASE 3
Lincoln ODP Inverter Duty
APPROX. WEIGHT 1019
SPECIALS Special Coupling(Dodge Paraflex)

Note: Equipped with EPDM coupling

MATERIALS OF CONSTRUCTION

☒ BRONZE FITTED ☐ ALL IRON

FEATURES

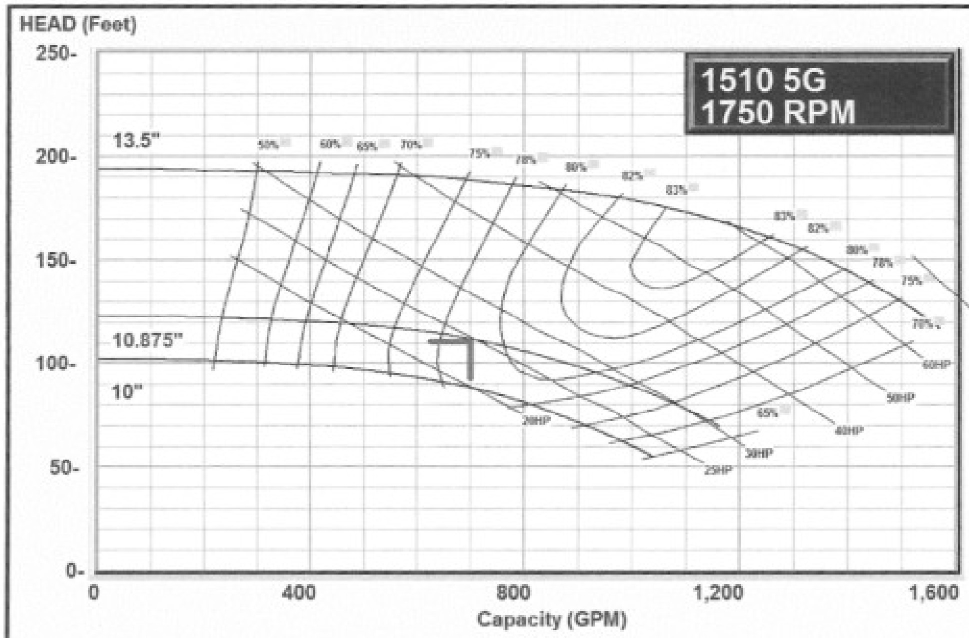
☒ ANSI/OSHA Coupling Guard
☒ Center Drop Out Spacer Coupling
☒ Fabricated Heavy Duty Baseplate

MAXIMUM WORKING PRESSURE

☒ 175 psi (12 bar) W.P. w/ 125# ANSI flange drilling
☐ 250 psi (17 bar) W.P. w/ 250# ANSI flange drilling (requires 1510-S)

TYPE OF SEAL

☒ 1510 Standard Seal (Buna-Carbon/Ceramic)
☐ 1510 -F Standard Seal w/ Flush Line (Buna-Carbon/Ceramic)
☐ 1510 -S Stuffing Box construction w/ Flushe Mechanical Single Seal (EPR-Tungsten Carbide/Carbon)
☐ 1510 -D Stuffing Box construction w/ Flushed Double Mechanical Seal (EPR-Carbon/Ceramic) Requires external water source
☐ 1510 -PF Stuffing Box Construction w/ Packing (Graphite Impregnated Teflon)



Design Capacity =700.0 GPM
Design Head =110.7 Feet

Suction Size = 6 "
Suct. Velocity = 7.8 fps
Discharge Size = 5 "
Disc. Velocity = 11.2 fps

Min. Imp. Dia. = 10 "
Max. Imp. Dia. = 13.5 "
Cut Dia. = 10.875 "

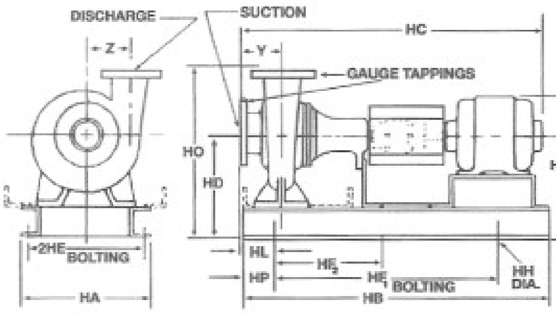
Max. Flow = 1194 GPM
B.E.P. Flow = 840 GPM

Eff. @ Duty-Point = 79.19 %
Motor Size =40 HP

B.H.P. @ Duty-Point = 24.91 BHP
Max. B.H.P. for Imp. Cut = 30.32 BHP

Series 1510 5G Centrifugal Pump Submittal

B-229.3E



FLANGE DIMENSIONS IN INCHES (MM)			
	SIZE	THICKNESS	O.D.
Discharge	5" (127)	1-3/8 (35)	10-3/4 (273)
Suction	6" (152)	1-7/16 (37)	12-1/8 (308)

FLANGES ARE: **125# ANSI - STANDARD**
250# ANSI - AVAILABLE

DIMENSIONS - Inches (mm)

STANDARD SEAL 1510, 1510-F

MOTOR FRAME	HA	HB	HC MAX	HD	2HE	HF_1	HF_2	HH	HL	HM MAX	HO	HP	Y	Z
	"L" FRAME													
254T	24 (610)	56 (1422)	47-1/8 (1197)	16-1/2 (419)	21-1/2 (546)	44 (1118)	22 (559)	1 (25)	5-7/16 (138)	23-3/8 (594)	29-1/2 (749)	6 (152)	6 (152)	9 (229)
256T	24 (610)	56 (1422)	48-7/8 (1241)	16-1/2 (419)	21-1/2 (546)	44 (1118)	22 (559)	1 (25)	5-7/16 (138)	23-3/8 (594)	29-1/2 (749)	6 (152)	6 (152)	9 (229)
284T	24 (610)	56 (1422)	49-7/8 (1267)	16-1/2 (419)	21-1/2 (546)	44 (1118)	22 (559)	1 (25)	5-7/16 (138)	24-1/2 (622)	29-1/2 (749)	6 (152)	6 (152)	9 (229)
286T	24 (610)	56 (1422)	51-3/8 (1305)	16-1/2 (419)	21-1/2 (546)	44 (1118)	22 (559)	1 (25)	5-7/16 (138)	24-1/2 (622)	29-1/2 (749)	6 (152)	6 (152)	9 (229)
➡ 324T	24 (610)	56 (1422)	53-3/8 (1356)	16-1/2 (419)	21-1/2 (546)	44 (1118)	22 (559)	1 (25)	5-7/16 (138)	25-5/8 (651)	29-1/2 (749)	6 (152)	6 (152)	9 (229)
326T	24 (610)	56 (1422)	54-7/8 (1394)	16-1/2 (419)	21-1/2 (546)	44 (1118)	22 (559)	1 (25)	5-7/16 (138)	25-5/8 (651)	29-1/2 (749)	6 (152)	6 (152)	9 (229)
364T	24 (610)	56 (1422)	57-1/8 (1451)	16-1/2 (419)	21-1/2 (546)	44 (1118)	22 (559)	1 (25)	5-7/16 (138)	26-3/4 (679)	29-1/2 (749)	6 (152)	6 (152)	9 (229)
365T	24 (610)	56 (1422)	58-1/8 (1476)	16-1/2 (419)	21-1/2 (546)	44 (1118)	22 (559)	1 (25)	5-7/16 (138)	26-3/4 (679)	29-1/2 (749)	6 (152)	6 (152)	9 (229)

STUFFING BOX 1510-PF, 1510-S, 1510-D

MOTOR FRAME	HA	HB	HC MAX	HD	2HE	HF_1	HF_2	HH	HL	HM MAX	HO	HP	Y	Z
	"L" FRAME													
254T	24 (610)	56 (1422)	49-1/2 (1257)	16-1/2 (419)	21-1/2 (546)	44 (1118)	22 (559)	1 (25)	5-7/16 (138)	23-3/8 (594)	29-1/2 (749)	6 (152)	6 (152)	9 (229)
256T	24 (610)	56 (1422)	51-1/4 (1302)	16-1/2 (419)	21-1/2 (546)	44 (1118)	22 (559)	1 (25)	5-7/16 (138)	23-3/8 (594)	29-1/2 (749)	6 (152)	6 (152)	9 (229)
284T	24 (610)	56 (1422)	52-1/4 (1327)	16-1/2 (419)	21-1/2 (546)	44 (1118)	22 (559)	1 (25)	5-7/16 (138)	24-1/2 (622)	29-1/2 (749)	6 (152)	6 (152)	9 (229)
286T	24 (610)	56 (1422)	53-3/4 (1365)	16-1/2 (419)	21-1/2 (546)	44 (1118)	22 (559)	1 (25)	5-7/16 (138)	24-1/2 (622)	29-1/2 (749)	6 (152)	6 (152)	9 (229)
324T	24 (610)	56 (1422)	55-3/4 (1416)	16-1/2 (419)	21-1/2 (546)	44 (1118)	22 (559)	1 (25)	5-7/16 (138)	25-5/8 (651)	29-1/2 (749)	6 (152)	6 (152)	9 (229)
326T	24 (610)	56 (1422)	57-1/4 (1454)	16-1/2 (419)	21-1/2 (546)	44 (1118)	22 (559)	1 (25)	5-7/16 (138)	25-5/8 (651)	29-1/2 (749)	6 (152)	6 (152)	9 (229)
364T	24 (610)	56 (1422)	59-1/2 (1511)	16-1/2 (419)	21-1/2 (546)	44 (1118)	22 (559)	1 (25)	5-7/16 (138)	26-3/4 (679)	29-1/2 (749)	6 (152)	6 (152)	9 (229)
365T	24 (610)	56 (1422)	60-1/2 (1537)	16-1/2 (419)	21-1/2 (546)	44 (1118)	22 (559)	1 (25)	5-7/16 (138)	26-3/4 (679)	29-1/2 (749)	6 (152)	6 (152)	9 (229)

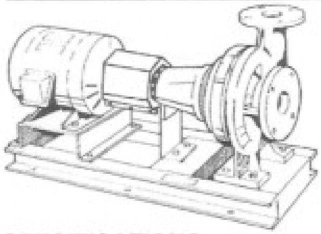
Dimensions are subject to change. Not to be used for construction purposes unless certified.

ITT Industries

Bell & Gossett

SUBMITTAL
B-226C

JOB: Thesis Report	**REPRESENTATIVE:** Cummins-Wagner Co., Inc.	
UNIT TAG: P-2	**ORDER NO.**	**DATE:** 3/31/2006
ENGINEER:	**SUBMITTED BY:**	**DATE:**
CONTRACTOR:	**APPROVED BY:**	**DATE:**



5E
Series 1510
Centrifugal Pumps - Base Mounted

SPECIFICATIONS

FLOW 1050 (GPM) HEAD 70.8 (FT)
HP 25 RPM 1800
VOLTS 230/460
CYCLE 60 PHASE 3
Lincoln ODP Inverter Duty
APPROX. WEIGHT 632
SPECIALS Special Coupling(Dodge Paraflex)

Note: Equipped with EPDM coupling

MATERIALS OF CONSTRUCTION

☒ BRONZE FITTED ☐ ALL IRON

FEATURES

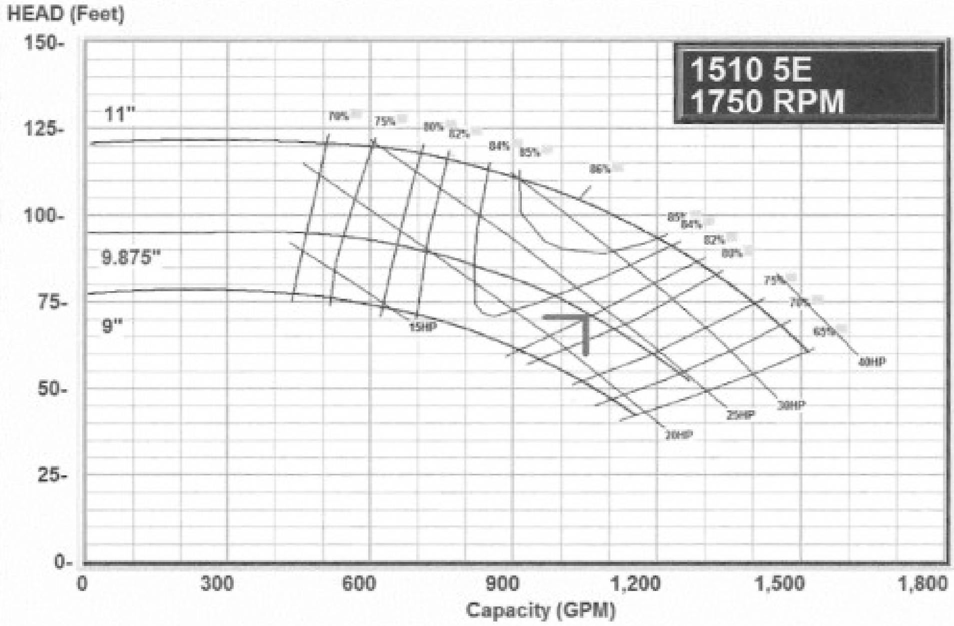
☒ ANSI/OSHA Coupling Guard
☒ Center Drop Out Spacer Coupling
☒ Fabricated Heavy Duty Baseplate

MAXIMUM WORKING PRESSURE

☒ 175 psi (12 bar) W.P.
w/ 125# ANSI flange drilling
☐ 250 psi (17 bar) W.P.
w/ 250# ANSI flange drilling (requires 1510-S)

TYPE OF SEAL

☒ 1510 Standard Seal
(Buna-Carbon/Ceramic)
☐ 1510 -F Standard Seal w/ Flush Line
(Buna-Carbon/Ceramic)
☐ 1510 -S Stuffing Box construction w/ Flushe
Mechanical Single Seal
(EPR-Tungsten Carbide/Carbon)
☐ 1510 -D Stuffing Box construction w/
Flushed Double Mechanical Seal
(EPR-Carbon/Ceramic)
Requires external water source
☐ 1510 -PF Stuffing Box Construction w/
Packing
(Graphite Impregnated Teflon)



Design Capacity =1050.0 GPM
Design Head =70.8 Feet

Suction Size = 6 "
Suct. Velocity = 11.7 fps
Discharge Size = 5 "
Disc. Velocity = 16.8 fps

Min. Imp. Dia. = 9 "
Max. Imp. Dia. = 11 "
Cut Dia. = 9.875 "

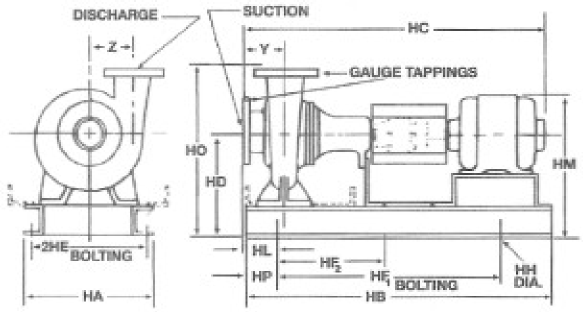
Max. Flow = 1303 GPM
B.E.P. Flow = 898 GPM

Eff. @ Duty-Point = 82.14 %
Motor Size =25 HP

B.H.P. @
Duty-Point = 23.16 BHP
Max. B.H.P. for
Imp. Cut = 24.8 BHP

Series 1510 5E Centrifugal Pump Submittal

B-226C



FLANGE DIMENSIONS IN INCHES (MM)	SIZE	THICKNESS	O.D.
Discharge	5" (127)	1-3/8" (35)	10-3/4" (273)
Suction	6" (152)	1-7/16" (37)	12-1/8" (308)

MAXIMUM WORKING PRESSURE 250 PSI

FLANGES ARE 125# ANSI - STANDARD
250# ANSI - AVAILABLE

DIMENSIONS - Inches (mm)

STANDARD SEAL 1510, 1510-F

MOTOR FRAME	HA	HB	HC MAX	HD	2HE	HF_1	HF_2	HH	HL	HM MAX	HO	HP	Y	Z
	"L" FRAME													
254T	16 (406)	46-1/2 (1181)	46-3/4 (1187)	15 (381)	14 (356)	36-1/2 (927)	18-1/4 (464)	7/8 (22)	4-7/16 (113)	21-7/8 (556)	25-1/2 (648)	5 (127)	5-7/16 (138)	7-15/16 (202)
256T	16 (406)	46-1/2 (1181)	48-1/2 (1232)	15 (381)	14 (356)	36-1/2 (927)	18-1/4 (464)	7/8 (22)	4-7/16 (113)	21-7/8 (556)	25-1/2 (648)	5 (127)	5-7/16 (138)	7-15/16 (202)
→ 284T	16 (406)	51-3/4 (1314)	49-1/4 (1251)	15 (381)	14 (356)	41-3/4 (1060)	20-7/8 (530)	7/8 (22)	4-7/16 (113)	23 (584)	25-1/2 (648)	5 (127)	5-7/16 (138)	7-15/16 (202)
286T	16 (406)	51-3/4 (1314)	50-3/4 (1289)	15 (381)	14 (356)	41-3/4 (1060)	20-7/8 (530)	7/8 (22)	4-7/16 (113)	23 (584)	25-1/2 (648)	5 (127)	5-7/16 (138)	7-15/16 (202)
324T	16 (406)	51-3/4 (1314)	53 (1346)	15 (381)	14 (356)	41-3/4 (1060)	20-7/8 (530)	7/8 (22)	4-7/16 (113)	24-1/8 (613)	25-1/2 (648)	5 (127)	5-7/16 (138)	7-15/16 (202)

STUFFING BOX 1510-PF, 1510-S, 1510-D

MOTOR FRAME	HA	HB	HC MAX	HD	2HE	HF_1	HF_2	HH	HL	HM MAX	HO	HP	Y	Z
	"L" FRAME													
254T	16 (406)	51-3/4 (1314)	49-1/8 (1248)	15 (381)	14 (356)	41-3/4 (1060)	20-7/8 (530)	7/8 (22)	4-7/16 (113)	21-7/8 (555)	25-1/2 (648)	5 (127)	5-7/16 (138)	7-15/16 (202)
256T	16 (406)	51-3/4 (1314)	50-7/8 (1292)	15 (381)	14 (356)	41-3/4 (1060)	20-7/8 (530)	7/8 (22)	4-7/16 (113)	21-7/8 (555)	25-1/2 (648)	5 (127)	5-7/16 (138)	7-15/16 (202)
284T	16 (406)	51-3/4 (1314)	51-5/8 (1311)	15 (381)	14 (356)	41-3/4 (1060)	20-7/8 (530)	7/8 (22)	4-7/16 (113)	23 (584)	25-1/2 (648)	5 (127)	5-7/16 (138)	7-15/16 (202)
286T	16 (406)	51-3/4 (1314)	53-1/8 (1349)	15 (381)	14 (356)	41-3/4 (1060)	20-7/8 (530)	7/8 (22)	4-7/16 (113)	23 (584)	25-1/2 (648)	5 (127)	5-7/16 (138)	7-15/16 (202)
324T	16 (406)	51-3/4 (1314)	55-3/8 (1407)	15 (381)	14 (356)	41-3/4 (1060)	20-7/8 (530)	7/8 (22)	4-7/16 (113)	24-1/8 (613)	25-1/2 (648)	5 (127)	5-7/16 (138)	7-15/16 (202)

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

ITT Industries

Appendix D – Heat Exchanger Selection

This appendix contains the cut sheets and other data for the Bell & Gossett heat exchanger used as a part of the design process.

Please see the all the heat exchanger information on the following pages.

CUMMINS·WAGNER

10901 Pump House Road Annapolis Junction, Md 20701
Washington: 301-953-9370 Baltimore: 410-792-4230 Fax: 301-490-7156

To: Nathan

Job Name: Thesis
Engineer:

4/1/06

Quote Number:

*************** Quotation ***************** Quotation ****************

Item	Quantity	Description	Unit Price	Extended Price
1)	1	**Heat Exchanger** Bell & Gossett Plate And Frame Heat Exchanger Model: P41 Side # 1: 777 GPM @ 54 F. EWT to 44 F. LWT Side # 2: 1300 GPM @ 42 F. EWT to 48 F. LWT Shipping Weight: 3352 lbs.		

Total Price Items .... $ 28,150.00
Full Freight Allowed

Cummins - Wagner Is Only Responsible For The Quantities And Materials Of Construction Listed.
The Material Listed Is Our Interpretation Of The Requirements.

Quotation Is Valid For Thirty (30) Days

Subject To Owner's Approval.

Internal Design & Datalist Today: 01-04-2006

Quotation.: 001

Att. Item 3 Ref.

Save to RTF PRINT RETURN

PHE-Type	P41-260-TMTL-70	Hot side		Cold side
Flowrate	(g.p.m.)	777.18		1300.00
Inlet temperature	(°F)	54.00		42.00
Outlet Temp. Cond./Fluid	(°F)	44.00		47.97
Pressure drop	(PSI)	3.77		10.08
Heat exchanged	(Btu/h)		3900000	
Thermodynamic proporties:		Water		Water
Density	(Lb/Ft³)	62.37		62.39
Specific heat	(Btu/Lb*F)	1.00		1.00
Thermal conductivity	(Btu/h*Ft*F)	0.34		0.33
Mean viscosity	(cP)	1.34		1.44
Wall viscosity	(cP)	1.44		1.34
LMTD	(°F)		3.7	
Excess Surface	(%)		0.0	
Inlet branch		F1		F3
Outlet branch		F4		F2
Design of Frame / Plates:				
Plate arrangement (passes*channe		1 × 129 + 0 × 0		1 × 130 + 0 × 0
Number of plates		260		
Effective heat surface	(Ft²)	1,194.15		
Overall K-value Duty/Clean	(Btu/Ft²*h*F)	892 / 892		
Plate material		0.0157 inch AISI 304		
Gasket material		NITRIL LOCK		
Max. working temperature	(°F)	257		
Working/test pressure	(PSI)	150.0 / 195.0		
Frame type		IS		
Connections HOT side		6.00 "	Unlined studded port, 150 # ANSI	
Connections COLD side		6.00 "	Unlined studded port, 150 # ANSI	
Liquid volume	(Ft³)	11.43		
Carry Bar Length	(Ft)	6.56	Max. No. of Plates	300
Net weight	(Lb)			
		Approval		ASME code

PRINT RETURN

Appendix E – Air Handling Unit and Rooftop Unit Selection

This appendix contains the cut sheets and other data for the Carrier air handling units and rooftop units used as a part of the design process.

Please see the all the air handling unit and rooftop unit information on the following pages.

Project Name: Nathan- Thesis Project

Mark For: AHU-1

Unit Parameters

Unit Size: Size 50 39MN

Insulation: R-13 Double Wall Sealed Panel

Exterior Finish: Galvanized Exterior Panels

Interior Finish: Galvanized Interior Panels

Level I Thermal Break

Filter Mixing Box

Damper: Top Standard Parallel

Damper: Rear Standard Opposed

2In. Angle Filter

Field Supplied 2in. Throwaway Filter

Qty (18) 16in. x 20in.

Qty (12) 16in. x 25in.

Hot Water Coil

Hot Water 50.6 sq.ft 1 Row 11 FPI Half Circuit

Coil Connection Right Side

1/2 in. Tube Diameter

AL fins Galv. Casing

Steel Header

No Coating

Heating Performance Ratings

Altitude, ft	0
Face Vel., fpm	408.4
Site Airflow, CFM	20650
Std. Airflow, CFM	20650
Heating Cap., MBH	1283.67
Flow Rate, gpm	92.7
Fluid PD, ft wg	7.7
Fluid Vel., ft/s	5.6
EWT, °F	180.00
LWT, °F	152.3
Drop, °F	27.7
Cv Rating	41.5
EAT, °F	22.50
LAT, °F	79.35
Air Friction, in wg	0.17

Chilled Water Coil

Shipping Split - Aero Latches

Standard Drain Pan Right Side Drain

Chilled Water 50.6 sq.ft 8 Row 14 FPI Double Circuit

Coil Connection Right Side
1/2 in. Tube Diameter
AL fins Galv. Casing
Steel Header
No Coating

Cooling Performance Ratings

Altitude, ft	0
Face Vel., fpm	408.4
Site Airflow, CFM	20650
Std. Airflow, CFM	20650
Total Clg. Cap, MBH	1386.45
Sen. Clg. Cap, MBH	824.29
Flow Rate, gpm	226.8
Fluid PD, ft wg	10.6
Fluid Vel., ft/s	3.4
EWT, °F	44.00
LWT, °F	56.22
Rise, °F	12.2
Cv Rating	101.4
EADB, °F	87.00
EAWB, °F	71.80
LADB, °F	50.50
LAWB, °F	50.44
Air Friction, in wg	0.97

Note: .

Draw-Thru Supply Fan

Horizontal
Rear Inlet

Performance Ratings

Site Airflow, CFM	20650
Altitude, ft	0
Std. Airflow, CFM	20650
Upstream Ext. Static, in wg	0.00
DownStream Ext. Static, in wg	2.00
Clg. Coil Static, in wg	0.97
Htg. Coil Static, in wg	0.17
Other Losses, in wg	0.00
Accessories Static, in wg	0.41
Total Static, in wg	3.55
Calculated Fan Speed, rpm	1348
Calculated Motor BHP	20.0

Acoustic Data:

Freq.	Disch.	Inlet	Casing
63 hz	106	103	99
125 hz	98	95	90
250 hz	106	100	94
500 hz	97	91	87
1000 hz	92	86	80
2000 hz	86	81	75
4000 hz	84	79	73
8000 hz	79	74	69

Fan Sled

1348 FanRPM Class II

AirFoil Standard Wheel AFMV01301

Top Horiz. Front Discharge

Right Side Fan Motor Location

Spring Fan Isolation

25 HP High Efficiency ODP 200/230/460 3Ph 60Hz 1800 RPM

Variable Frequency Drive 208/230 Volts 3 Phase 60Hz

5Factory Mounted No Bypass

1.5 Service Factor

Fixed Pitch Drive

Project Name: Nathan- Thesis Project
Mark For: AHU-2

Unit Parameters

Unit Size: Size 40 39MN
Insulation: R-13 Double Wall Sealed Panel
Exterior Finish: Galvanized Exterior Panels
Interior Finish: Galvanized Interior Panels
Level I Thermal Break

Filter Mixing Box

Damper: Top Standard Parallel
Damper: Rear Standard Opposed
2In. Angle Filter
Field Supplied 2in. Throwaway Filter
Qty (24) 16in. x 25in.

Hot Water Coil

Hot Water 40.0 sq.ft 1 Row 8 FPI Half Circuit
Coil Connection Right Side
1/2 in. Tube Diameter
AL fins Galv. Casing
Steel Header
No Coating

Heating Performance Ratings

Altitude, ft	0
Face Vel., fpm	469.4
Site Airflow, CFM	18777
Std. Airflow, CFM	18777
Heating Cap., MBH	917.70
Flow Rate, gpm	76.8
Fluid PD, ft wg	6.6
Fluid Vel., ft/s	5.4
EWT, °F	180.00
LWT, °F	156.1
Drop, °F	23.9
Cv Rating	34.3
EAT, °F	15.20
LAT, °F	59.89
Air Friction, in wg	0.17

Chilled Water Coil

Shipping Split - Aero Latches

Standard Drain Pan Right Side Drain
Chilled Water   40.0 sq.ft   8 Row   12 FPI   Double Circuit

Coil Connection Right Side
5/8 in. Tube Diameter
AL fins Galv. Casing
Steel Header
No Coating

Cooling Performance Ratings

Altitude, ft	0
Face Vel., fpm	469.4
Site Airflow, CFM	18777
Std. Airflow, CFM	18777
Total Clg. Cap, MBH	1407.94
Sen. Clg. Cap, MBH	834.53
Flow Rate, gpm	247.2
Fluid PD, ft wg	11.3
Fluid Vel., ft/s	3.4
EWT, °F	44.00
LWT, °F	55.39
Rise, °F	11.4
Cv Rating	110.6
EADB, °F	91.40
EAWB, °F	73.90
LADB, °F	50.76
LAWB, °F	50.68
Air Friction, in wg	1.30

Draw-Thru Supply Fan

Horizontal
Rear Inlet

Performance Ratings

Site Airflow, CFM	18777
Altitude, ft	0
Std. Airflow, CFM	18777
Upstream Ext. Static, in wg	0.00
DownStream Ext. Static, in wg	2.00
Clg. Coil Static, in wg	1.30
Htg. Coil Static, in wg	0.17
Other Losses, in wg	0.00
Accessories Static, in wg	0.43
Total Static, in wg	3.90
Calculated Fan Speed, rpm	1629
Calculated Motor BHP	21.8

Acoustic Data:

Freq.	Disch.	Inlet	Casing
63 hz	110	107	103
125 hz	99	96	91
250 hz	108	102	96
500 hz	100	94	90
1000 hz	95	89	83
2000 hz	90	85	79
4000 hz	87	82	76
8000 hz	83	78	73

Fan Sled

1629 FanRPM Class II

AirFoil Standard Wheel AFMV01271

Top Horiz. Front Discharge

Right Side Fan Motor Location

Spring Fan Isolation

25 HP High Efficiency ODP 200/230/460 3Ph 60Hz 1800 RPM

Variable Frequency Drive 208/230 Volts 3 Phase 60Hz

5Factory Mounted No Bypass

1.5 Service Factor

Fixed Pitch Drive

Project Name: **Nathan- Thesis Project**
Mark For: **AHU-3**

Unit Parameters

Unit Size: Size 21 39MN
Insulation: R-13 Double Wall Sealed Panel
Exterior Finish: Galvanized Exterior Panels
Interior Finish: Galvanized Interior Panels
Level I Thermal Break

Filter Mixing Box

Damper: Top Standard Parallel
Damper: Rear Standard Opposed
2In. Angle Filter
Field Supplied 2in. Throwaway Filter
Qty (12) 16in. x 25in.
Skid (factory)

Hot Water Coil

Hot Water 21.44 sq.ft 2 Row 8 FPI Full Circuit
Coil Connection Right Side
1/2 in. Tube Diameter
AL fins Galv. Casing
Steel Header
No Coating

Heating Performance Ratings

Altitude, ft	0
Face Vel., fpm	393.8
Site Airflow, CFM	8444
Std. Airflow, CFM	8444
Heating Cap., MBH	645.08
Flow Rate, gpm	59.8
Fluid PD, ft wg	3.1
Fluid Vel., ft/s	2.7
EWT, °F	180.00
LWT, °F	158.4
Drop, °F	21.6
Cv Rating	26.7
EAT, °F	11.00
LAT, °F	80.86
Air Friction, in wg	0.13

Chilled Water Coil

Shipping Split - Aero Latches

Standard Drain Pan Right Side Drain

Chilled Water   21.44 sq.ft   10 Row   14 FPI   Double Circuit

Coil Connection Right Side

1/2 in. Tube Diameter

AL fins Galv. Casing

Steel Header

No Coating

Cooling Performance Ratings

Altitude, ft	0
Face Vel., fpm	393.8
Site Airflow, CFM	8444
Std. Airflow, CFM	8444
Total Clg. Cap, MBH	715.21
Sen. Clg. Cap, MBH	409.71
Flow Rate, gpm	121.7
Fluid PD, ft wg	8.5
Fluid Vel., ft/s	3.3
EWT, °F	44.00
LWT, °F	55.75
Rise, °F	11.7
Cv Rating	54.4
EADB, °F	93.00
EAWB, °F	75.00
LADB, °F	48.63
LAWB, °F	48.62
Air Friction, in wg	1.15

Draw-Thru Supply Fan

Horizontal

Rear Inlet

Performance Ratings

Site Airflow, CFM	8444
Altitude, ft	0
Std. Airflow, CFM	8444
Upstream Ext. Static, in wg	0.00
DownStream Ext. Static, in wg	2.00
Clg. Coil Static, in wg	1.15
Htg. Coil Static, in wg	0.13
Other Losses, in wg	0.00
Accessories Static, in wg	0.43
Total Static, in wg	3.71
Calculated Fan Speed, rpm	1889

Calculated Motor BHP 8.0

Acoustic Data:

Freq.	Disch.	Inlet	Casing
63 hz	100	92	91
125 hz	95	88	86
250 hz	97	82	81
500 hz	92	76	76
1000 hz	89	75	73
2000 hz	86	72	70
4000 hz	81	68	56
8000 hz	76	60	51

Fan Sled

1889 FanRPM Class I

AirFoil Standard Wheel AFMV01201

Top Horiz. Front Discharge

Right Side Fan Motor Location

Spring Fan Isolation

10 HP High Efficiency ODP 200/230/460 3Ph 60Hz 1800 RPM

Variable Frequency Drive 208/230 Volts 3 Phase 60Hz

5Factory Mounted No Bypass

1.5 Service Factor

Variable Pitch Drive

Skid (factory)

Project Name: Nathan- Thesis Project
Mark For: AHU-4

Unit Parameters
Unit Size: Size 12 39MN
Insulation: R-13 Double Wall Sealed Panel
Exterior Finish: Galvanized Exterior Panels
Interior Finish: Galvanized Interior Panels
Level I Thermal Break

Filter Mixing Box
Damper: Top Standard Parallel
Damper: Rear Standard Opposed
2In. Angle Filter
Field Supplied 2in. Throwaway Filter
Qty (6) 20in. x 20in.
Skid (factory)

Hot Water Coil
Hot Water 12.64 sq.ft 1 Row 11 FPI Half Circuit
Coil Connection Right Side
1/2 in. Tube Diameter
AL fins Galv. Casing
Steel Header
No Coating

Heating Performance Ratings

Altitude, ft	0
Face Vel., fpm	385.0
Site Airflow, CFM	4867
Std. Airflow, CFM	4867
Heating Cap., MBH	331.12
Flow Rate, gpm	31.2
Fluid PD, ft wg	6.0
Fluid Vel., ft/s	3.8
EWT, °F	180.00
LWT, °F	158.8
Drop, °F	21.2
Cv Rating	14.0
EAT, °F	12.90
LAT, °F	75.12
Air Friction, in wg	0.15

Chilled Water Coil

Shipping Split - Aero Latches
Standard Drain Pan Right Side Drain
Chilled Water   12.64 sq.ft   10 Row   14 FPI   Full Circuit
Coil Connection Right Side
1/2 in. Tube Diameter
AL fins Galv. Casing
Steel Header
No Coating

Cooling Performance Ratings

Altitude, ft	0
Face Vel., fpm	385.0
Site Airflow, CFM	4867
Std. Airflow, CFM	4867
Total Clg. Cap, MBH	409.46
Sen. Clg. Cap, MBH	236.24
Flow Rate, gpm	71.1
Fluid PD, ft wg	15.5
Fluid Vel., ft/s	4.3
EWT, °F	44.00
LWT, °F	55.51
Rise, °F	11.5
Cv Rating	27.4
EADB, °F	92.20
EAWB, °F	74.40
LADB, °F	47.81
LAWB, °F	47.81
Air Friction, in wg	1.12

Draw-Thru Supply Fan
Horizontal
Rear Inlet

Performance Ratings

Site Airflow, CFM	4867
Altitude, ft	0
Std. Airflow, CFM	4867
Upstream Ext. Static, in wg	0.00
DownStream Ext. Static, in wg	2.00
Clg. Coil Static, in wg	1.12
Htg. Coil Static, in wg	0.15
Other Losses, in wg	0.00
Accessories Static, in wg	0.43
Total Static, in wg	3.70
Calculated Fan Speed, rpm	2301

Calculated Motor BHP 5.0

Acoustic Data:

Freq.	Disch.	Inlet	Casing
63 hz	105	97	96
125 hz	95	88	86
250 hz	96	81	80
500 hz	92	76	76
1000 hz	88	74	72
2000 hz	85	71	69
4000 hz	80	67	55
8000 hz	74	58	49

Fan Sled

2301 FanRPM Class II

AirFoil Standard Wheel AFMV01161

Top Horiz. Front Discharge

Right Side Fan Motor Location

Spring Fan Isolation

7.5 HP High Efficiency ODP 200/230/460 3Ph 60Hz 1800 RPM

Variable Frequency Drive 208/230 Volts 3 Phase 60Hz

5Factory Mounted No Bypass

1.5 Service Factor

Variable Pitch Drive

Skid (factory)

Project Name: **Nathan- Thesis Project**
Mark For: **RTU-1**

Unit Parameters

Unit Size: Size 06 39MW
Insulation: R-13 Double Wall Sealed Panel
Exterior Finish: Galvanized Exterior Panels
Interior Finish: Galvanized Interior Panels
Level II Thermal Break
Ahu Curb Factory Supplied 14in. Curb
Coil Connection House Curb
24in. Deep Coil Connection Housing Single Wall

Filter Mixing Box

Damper: Rear Standard Opposed
Hood Rear
Damper: Bottom Standard Parallel
2In. Angle Filter
Construction Filter (disposable panel filter)
Field Supplied 2in. Throwaway Filter
Qty (4) 16in. x 20in.

Hot Water Coil

Hot Water 5.9 sq.ft 1 Row 8 FPI Half Circuit
Coil Connection Right Side
1/2 in. Tube Diameter
AL fins Galv. Casing
Steel Header
No Coating

Heating Performance Ratings

Altitude, ft	0
Face Vel., fpm	484.9
Site Airflow, CFM	2861
Std. Airflow, CFM	2861
Heating Cap., MBH	73.52
Flow Rate, gpm	3.0
Fluid PD, ft wg	0.1
Fluid Vel., ft/s	0.5
EWT, °F	180.00
LWT, °F	131.0
Drop, °F	49.0
Cv Rating	1.3

EAT, °F	41.50
LAT, °F	65.00
Air Friction, in wg	0.18

Skid

Chilled Water Coil

Standard Drain Pan Right Side Drain

Chilled Water   5.9 sq.ft   8 Row   11 FPI   Double Circuit

Coil Connection Right Side

1/2 in. Tube Diameter

AL fins Galv. Casing

Steel Header

No Coating

Cooling Performance Ratings

Altitude, ft	0
Face Vel., fpm	484.9
Site Airflow, CFM	2861
Std. Airflow, CFM	2861
Total Clg. Cap, MBH	110.14
Sen. Clg. Cap, MBH	85.03
Flow Rate, gpm	18.4
Fluid PD, ft wg	1.2
Fluid Vel., ft/s	0.9
EWT, °F	44.00
LWT, °F	55.97
Rise, °F	12.0
Cv Rating	8.2
EADB, °F	84.00
EAWB, °F	68.60
LADB, °F	56.82
LAWB, °F	56.58
Air Friction, in wg	1.06

Note: Fluid velocity for this application is outside the scope of ARI Std. 410.

Hot Water Coil

Hot Water   5.9 sq.ft   2 Row   8 FPI   Half Circuit

Coil Connection Right Side

1/2 in. Tube Diameter

AL fins Galv. Casing

Steel Header

No Coating

Heating Performance Ratings

Altitude, ft	0
Face Vel., fpm	484.9

Site Airflow, CFM	2861
Std. Airflow, CFM	2861
Heating Cap., MBH	160.18
Flow Rate, gpm	16.0
Fluid PD, ft wg	3.0
Fluid Vel., ft/s	2.7
EWT, °F	180.00
LWT, °F	160.0
Drop, °F	20.0
Cv Rating	7.2
EAT, °F	45.00
LAT, °F	96.20
Air Friction, in wg	0.20

Draw-Thru Supply Fan

Horizontal

Rear Inlet

Performance Ratings

Site Airflow, CFM	2861
Altitude, ft	0
Std. Airflow, CFM	2861
Upstream Ext. Static, in wg	0.00
DownStream Ext. Static, in wg	2.00
Clg. Coil Static, in wg	1.06
Htg. Coil Static, in wg	0.37
Other Losses, in wg	0.00
Accessories Static, in wg	0.75
Total Static, in wg	4.18
Calculated Fan Speed, rpm	3434
Calculated Motor BHP	4.0

Acoustic Data:

Freq.	Disch.	Inlet	Casing
63 hz	101	93	92
125 hz	95	88	86
250 hz	93	78	77
500 hz	95	79	79
1000 hz	89	75	73
2000 hz	87	73	71
4000 hz	82	69	57
8000 hz	77	61	52

Fan Sled

3434 FanRPM Class II

Project Name: Nathan- Thesis Project
Mark For: RTU-2

Unit Parameters

Unit Size: Size 30 39MW
Insulation: R-13 Double Wall Sealed Panel
Exterior Finish: Galvanized Exterior Panels
Interior Finish: Galvanized Interior Panels
Level II Thermal Break
Ahu Curb Factory Supplied 14in. Curb
Coil Connection House Curb
24in. Deep Coil Connection Housing Single Wall

Filter Mixing Box

Damper: Rear Standard Opposed
Hood Rear
Damper: Bottom Standard Parallel
2In. Angle Filter
Construction Filter (disposable panel filter)
Field Supplied 2in. Throwaway Filter
Qty (16) 16in. x 25in.

Hot Water Coil

Hot Water 30.35 sq.ft 1 Row 8 FPI Half Circuit
Coil Connection Right Side
1/2 in. Tube Diameter
AL fins Galv. Casing
Steel Header
No Coating

Heating Performance Ratings

Altitude, ft	0
Face Vel., fpm	502.1
Site Airflow, CFM	15238
Std. Airflow, CFM	15238
Heating Cap., MBH	657.11
Flow Rate, gpm	30.4
Fluid PD, ft wg	3.0
Fluid Vel., ft/s	2.7
EWT, °F	180.00
LWT, °F	136.8
Drop, °F	43.2
Cv Rating	13.6

EAT, °F	11.00
LAT, °F	50.44
Air Friction, in wg	0.18

Skid

Chilled Water Coil

Standard Drain Pan Right Side Drain

Chilled Water   30.35 sq.ft   4 Row   8 FPI   Double Circuit

Coil Connection Right Side

1/2 in. Tube Diameter

AL fins Galv. Casing

Steel Header

No Coating

Cooling Performance Ratings

Altitude, ft	0
Face Vel., fpm	502.1
Site Airflow, CFM	15238
Std. Airflow, CFM	15238
Total Clg. Cap, MBH	469.41
Sen. Clg. Cap, MBH	364.90
Flow Rate, gpm	60.9
Fluid PD, ft wg	1.2
Fluid Vel., ft/s	1.4
EWT, °F	44.00
LWT, °F	59.41
Rise, °F	15.4
Cv Rating	27.2
EADB, °F	92.40
EAWB, °F	74.80
LADB, °F	70.50
LAWB, °F	66.72
Air Friction, in wg	0.49

Hot Water Coil

Hot Water   30.35 sq.ft   1 Row   8 FPI   Half Circuit

Coil Connection Right Side

1/2 in. Tube Diameter

AL fins Galv. Casing

Steel Header

No Coating

Heating Performance Ratings

Altitude, ft	0
Face Vel., fpm	502.1
Site Airflow, CFM	15238

Std. Airflow, CFM	15238
Heating Cap., MBH	586.35
Flow Rate, gpm	58.7
Fluid PD, ft wg	10.5
Fluid Vel., ft/s	5.3
EWT, °F	180.00
LWT, °F	160.0
Drop, °F	20.0
Cv Rating	26.3
EAT, °F	45.00
LAT, °F	80.19
Air Friction, in wg	0.20

Draw-Thru Supply Fan

Horizontal

Rear Inlet

Performance Ratings

Site Airflow, CFM	15238
Altitude, ft	0
Std. Airflow, CFM	15238
Upstream Ext. Static, in wg	0.00
DownStream Ext. Static, in wg	2.00
Clg. Coil Static, in wg	0.49
Htg. Coil Static, in wg	0.38
Other Losses, in wg	0.00
Accessories Static, in wg	1.08
Total Static, in wg	3.95
Calculated Fan Speed, rpm	2226
Calculated Motor BHP	19.2

Acoustic Data:

Freq.	Disch.	Inlet	Casing
63 hz	102	94	93
125 hz	98	91	89
250 hz	102	87	86
500 hz	100	84	84
1000 hz	98	84	82
2000 hz	94	80	78
4000 hz	90	77	65
8000 hz	87	71	62

Fan Sled

2226 FanRPM Class II

AirFoil Standard Wheel AFMV01221

Project Name: Nathan- Thesis Project
Mark For: RTU-3

Unit Parameters

Unit Size: Size 12 39MW
Insulation: R-13 Double Wall Sealed Panel
Exterior Finish: Galvanized Exterior Panels
Interior Finish: Galvanized Interior Panels
Level II Thermal Break
Ahu Curb Factory Supplied 14in. Curb
Coil Connection House Curb
24in. Deep Coil Connection Housing Single Wall

Filter Mixing Box

Damper: Rear Standard Opposed
Hood Rear
Damper: Bottom Standard Parallel
2In. Angle Filter
Construction Filter (disposable panel filter)
Field Supplied 2in. Throwaway Filter
Qty (6) 20in. x 20in.

Hot Water Coil

Hot Water 12.64 sq.ft 1 Row 8 FPI Half Circuit
Coil Connection Right Side
1/2 in. Tube Diameter
AL fins Galv. Casing
Steel Header
No Coating

Heating Performance Ratings

Altitude, ft	0
Face Vel., fpm	481.6
Site Airflow, CFM	6088
Std. Airflow, CFM	6088
Heating Cap., MBH	152.79
Flow Rate, gpm	5.0
Fluid PD, ft wg	0.2
Fluid Vel., ft/s	0.6
EWT, °F	180.00
LWT, °F	118.9
Drop, °F	61.1
Cv Rating	2.2

EAT, °F	41.50
LAT, °F	64.45
Air Friction, in wg	0.18

Skid

Chilled Water Coil

Standard Drain Pan Right Side Drain

Chilled Water   12.64 sq.ft   4 Row   11 FPI   Full Circuit

Coil Connection Right Side

1/2 in. Tube Diameter

AL fins Galv. Casing

Steel Header

No Coating

Cooling Performance Ratings

Altitude, ft	0
Face Vel., fpm	481.6
Site Airflow, CFM	6088
Std. Airflow, CFM	6088
Total Clg. Cap, MBH	111.20
Sen. Clg. Cap, MBH	106.95
Flow Rate, gpm	13.0
Fluid PD, ft wg	0.8
Fluid Vel., ft/s	0.9
EWT, °F	44.00
LWT, °F	61.10
Rise, °F	17.1
Cv Rating	5.8
EADB, °F	78.40
EAWB, °F	66.40
LADB, °F	62.34
LAWB, °F	60.77
Air Friction, in wg	0.42

Note: Fluid velocity for this application is outside the scope of ARI Std. 410.

Hot Water Coil

Hot Water   12.64 sq.ft   1 Row   8 FPI   Half Circuit

Coil Connection Right Side

1/2 in. Tube Diameter

AL fins Galv. Casing

Steel Header

No Coating

Heating Performance Ratings

Altitude, ft	0
Face Vel., fpm	481.6

Site Airflow, CFM	6088
Std. Airflow, CFM	6088
Heating Cap., MBH	216.48
Flow Rate, gpm	21.6
Fluid PD, ft wg	2.9
Fluid Vel., ft/s	2.6
EWT, °F	180.00
LWT, °F	160.0
Drop, °F	20.0
Cv Rating	9.7
EAT, °F	51.60
LAT, °F	84.12
Air Friction, in wg	0.18

Draw-Thru Supply Fan

Horizontal

Rear Inlet

Performance Ratings

Site Airflow, CFM	6088
Altitude, ft	0
Std. Airflow, CFM	6088
Upstream Ext. Static, in wg	0.00
DownStream Ext. Static, in wg	2.00
Clg. Coil Static, in wg	0.42
Htg. Coil Static, in wg	0.36
Other Losses, in wg	0.00
Accessories Static, in wg	0.81
Total Static, in wg	3.59
Calculated Fan Speed, rpm	2553
Calculated Motor BHP	6.8

Acoustic Data:

Freq.	Disch.	Inlet	Casing
63 hz	107	99	98
125 hz	97	90	88
250 hz	97	82	81
500 hz	96	80	80
1000 hz	92	78	76
2000 hz	88	74	72
4000 hz	84	71	59
8000 hz	78	62	53

Fan Sled

2553 FanRPM Class II

Project Name: **Nathan- Thesis Project**
Mark For: **RTU-7**

Unit Parameters

Unit Size: Size 06 39MW
Insulation: R-13 Double Wall Sealed Panel
Exterior Finish: Galvanized Exterior Panels
Interior Finish: Galvanized Interior Panels
Level II Thermal Break
Ahu Curb Factory Supplied 14in. Curb
Coil Connection House Curb
24in. Deep Coil Connection Housing Single Wall

Filter Mixing Box

Damper: Rear Standard Opposed
Hood Rear
Damper: Bottom Standard Parallel
2In. Angle Filter
Construction Filter (disposable panel filter)
Field Supplied 2in. Throwaway Filter
Qty (4) 16in. x 20in.

Hot Water Coil

Hot Water 5.9 sq.ft 1 Row 8 FPI Half Circuit
Coil Connection Right Side
1/2 in. Tube Diameter
AL fins Galv. Casing
Steel Header
No Coating

Heating Performance Ratings

Altitude, ft	0
Face Vel., fpm	422.4
Site Airflow, CFM	2492
Std. Airflow, CFM	2492
Heating Cap., MBH	72.53
Flow Rate, gpm	3.0
Fluid PD, ft wg	0.1
Fluid Vel., ft/s	0.5
EWT, °F	180.00
LWT, °F	131.7
Drop, °F	48.3
Cv Rating	1.3

EAT, °F	38.40
LAT, °F	65.02
Air Friction, in wg	0.14

Skid

Chilled Water Coil

Standard Drain Pan Right Side Drain

Chilled Water   5.9 sq.ft   6 Row   11 FPI   Double Circuit

Coil Connection Right Side

1/2 in. Tube Diameter

AL fins Galv. Casing

Steel Header

No Coating

Cooling Performance Ratings

Altitude, ft	0
Face Vel., fpm	422.4
Site Airflow, CFM	2492
Std. Airflow, CFM	2492
Total Clg. Cap, MBH	82.35
Sen. Clg. Cap, MBH	56.34
Flow Rate, gpm	11.8
Fluid PD, ft wg	0.8
Fluid Vel., ft/s	0.9
EWT, °F	44.00
LWT, °F	57.95
Rise, °F	14.0
Cv Rating	5.3
EADB, °F	81.60
EAWB, °F	70.20
LADB, °F	60.93
LAWB, °F	60.49
Air Friction, in wg	0.66

Note: Fluid velocity for this application is outside the scope of ARI Std. 410.

Hot Water Coil

Hot Water   5.9 sq.ft   1 Row   8 FPI   Half Circuit

Coil Connection Right Side

1/2 in. Tube Diameter

AL fins Galv. Casing

Steel Header

No Coating

Heating Performance Ratings

Altitude, ft	0
Face Vel., fpm	422.4

Site Airflow, CFM	2492
Std. Airflow, CFM	2492
Heating Cap., MBH	96.36
Flow Rate, gpm	9.7
Fluid PD, ft wg	0.9
Fluid Vel., ft/s	1.6
EWT, °F	180.00
LWT, °F	160.0
Drop, °F	20.0
Cv Rating	4.3
EAT, °F	45.00
LAT, °F	80.36
Air Friction, in wg	0.14

Draw-Thru Supply Fan

Horizontal

Rear Inlet

Performance Ratings

Site Airflow, CFM	2492
Altitude, ft	0
Std. Airflow, CFM	2492
Upstream Ext. Static, in wg	0.00
DownStream Ext. Static, in wg	2.00
Clg. Coil Static, in wg	0.66
Htg. Coil Static, in wg	0.28
Other Losses, in wg	0.00
Accessories Static, in wg	0.64
Total Static, in wg	3.58
Calculated Fan Speed, rpm	3121
Calculated Motor BHP	2.9

Acoustic Data:

Freq.	Disch.	Inlet	Casing
63 hz	99	91	90
125 hz	94	87	85
250 hz	92	77	76
500 hz	92	76	76
1000 hz	87	73	71
2000 hz	84	70	68
4000 hz	79	66	54
8000 hz	74	58	49

Fan Sled

3121 FanRPM Class II

Project Name: Nathan- Thesis Project
Mark For: RTU-8

Unit Parameters

Unit Size: Size 03 39MW
Insulation: R-13 Double Wall Sealed Panel
Exterior Finish: Galvanized Exterior Panels
Interior Finish: Galvanized Interior Panels
Level II Thermal Break
Ahu Curb Factory Supplied 14in. Curb
Coil Connection House Curb
24in. Deep Coil Connection Housing Single Wall

Filter Mixing Box

Damper: Rear Standard Parallel
Hood Rear
Damper: Bottom Standard Parallel
2In. Angle Filter
Construction Filter (disposable panel filter)
Field Supplied 2in. Throwaway Filter
Qty (2) 16in. x 25in.

Hot Water Coil

Hot Water 3.47 sq.ft 1 Row 8 FPI Half Circuit
Coil Connection Right Side
1/2 in. Tube Diameter
AL fins Galv. Casing
Steel Header
No Coating

Heating Performance Ratings

Altitude, ft	0
Face Vel., fpm	427.4
Site Airflow, CFM	1483
Std. Airflow, CFM	1483
Heating Cap., MBH	60.81
Flow Rate, gpm	4.0
Fluid PD, ft wg	0.2
Fluid Vel., ft/s	0.7
EWT, °F	180.00
LWT, °F	149.6
Drop, °F	30.4
Cv Rating	1.8

EAT, °F	11.00
LAT, °F	48.50
Air Friction, in wg	0.14

Skid

Chilled Water Coil

Standard Drain Pan Right Side Drain

Chilled Water   3.47 sq.ft   8 Row   11 FPI   Full Circuit

Coil Connection Right Side

1/2 in. Tube Diameter

AL fins Galv. Casing

Steel Header

No Coating

Cooling Performance Ratings

Altitude, ft	0
Face Vel., fpm	427.4
Site Airflow, CFM	1483
Std. Airflow, CFM	1483
Total Clg. Cap, MBH	70.58
Sen. Clg. Cap, MBH	43.32
Flow Rate, gpm	8.9
Fluid PD, ft wg	0.6
Fluid Vel., ft/s	0.9
EWT, °F	44.00
LWT, °F	59.85
Rise, °F	15.9
Cv Rating	4.0
EADB, °F	86.60
EAWB, °F	73.30
LADB, °F	59.89
LAWB, °F	59.73
Air Friction, in wg	0.92

Note: Fluid velocity for this application is outside the scope of ARI Std. 410.

Hot Water Coil

Hot Water   3.47 sq.ft   1 Row   8 FPI   Half Circuit

Coil Connection Right Side

1/2 in. Tube Diameter

AL fins Galv. Casing

Steel Header

No Coating

Heating Performance Ratings

Altitude, ft	0
Face Vel., fpm	427.4

Site Airflow, CFM	1483
Std. Airflow, CFM	1483
Heating Cap., MBH	52.15
Flow Rate, gpm	5.2
Fluid PD, ft wg	0.3
Fluid Vel., ft/s	0.9
EWT, °F	180.00
LWT, °F	160.0
Drop, °F	20.0
Cv Rating	2.3
EAT, °F	45.00
LAT, °F	77.16
Air Friction, in wg	0.15

Draw-Thru Supply Fan

Horizontal

Rear Inlet

Performance Ratings

Site Airflow, CFM	1483
Altitude, ft	0
Std. Airflow, CFM	1483
Upstream Ext. Static, in wg	0.00
DownStream Ext. Static, in wg	2.00
Clg. Coil Static, in wg	0.92
Htg. Coil Static, in wg	0.28
Other Losses, in wg	0.00
Accessories Static, in wg	0.79
Total Static, in wg	3.99
Calculated Fan Speed, rpm	4000
Calculated Motor BHP	2.8

Acoustic Data:

Freq.	Disch.	Inlet	Casing
63 hz	105	97	96
125 hz	92	85	83
250 hz	89	74	73
500 hz	93	77	77
1000 hz	87	73	71
2000 hz	85	71	69
4000 hz	81	68	56
8000 hz	77	61	52

Fan Sled

4000 FanRPM Class II

Appendix F – Dedicated Outdoor Air System Unit Selection

This appendix contains the cut sheets and other data for the Semco dedicated outdoor air system units used as a part of the design process.

Please see the all the dedicated outdoor air system unit information on the following pages.

AIR TECTONICS inc.
The Offices At Oxford Crossing • Suite 401
333 North Oxford Valley Rd. • Fairless Hills, PA 19030
Phone 215/945-2600 • Fax 215/945-2602

LANCASTER OFFICE – 717-665-3971 FAX – 717-665-3976

MARCH 29, 2006

TO: Nathan Patrick

FROM: RITCHIE HALL

RE: Hilton Hotel - BWI location

Budget Quotation

PVS-13 (Unit Tag - ERU-1)

Unit Width - 98"
Unit Height - 86"_____
Unit Length - 295"_____
Max Module Weight - 13,700_____
Number Of Modules - 1_____

- SEMCO standard panels consisting of 2" thick dual wall 18 ga. Galvanized solid exterior skins and 22 ga. Galvanized steel solid interior skins enclosing 2" thick 3 pcf mineral wool insulation with a u-factor of 0.10 BTU/(hr-sq.ft.-deg). An all-welded painted structural base will support the housing. The base includes a welded floor with 3 pcf mineral wool insulation. The base is self-flashing when set on a properly sized curb. Floor openings have perimeter lip and are covered by protective grate. Lifting lugs will be welded to the base.
- Outdoor construction including 22 gauge galvanized steel standing seam sheet metal roof, door gutters and hoods on intake and exhaust openings.
- Self-flashing base is designed for curb mounting. Curb must provide support at all field joints. Contact SEMCO for more detail.
- Automated Logic Corporation DDC control package.
- Variable speed enthalpy recovery wheel with 3A molecular sieve desiccant and acid-resistant coating, variable speed drive motor , 480/3 inverter and 24 volt temperature controller.
- Variable speed aluminum dehumidification energy recovery wheel which is coated to prohibit corrosion, media surfaces coated with a non-migrating solid adsorbent layer, variable speed drive motor , 460/3/60 inverter and 24 volt temperature controller.
- 20 hp, EPACT compliant, ODP supply fan motor in centrifugal plenum type fan.
- 20 hp, EPACT compliant, ODP exhaust fan motor in centrifugal plenum type fan.
- Chilled water cooling coil consisting of round seamless 5/8 inch O.D. by .020 inch thick copper tube on 1.5 inch centers, secondary surface of .006 inch rippled aluminum plate fins, casings of galvanized steel, headers of seamless copper, and galvanized steel holding racks mounted in an insulated pitched 304 stainless steel condensate pan.
- Hot water coil consisting of primary surface of round seamless 5/8 inch O.D. by .020 inch thick copper tube on 1.5 inch centers, secondary surface of .0075 inch rippled aluminum plate fins, casings of galvanized steel, headers of seamless copper, and galvanized steel holding racks.

- Single point control panel, 480/3/60, including motor starters, motor short circuit and overload protection, low voltage transformer, damper interlocks and local HOA switch.
- Vapor tight lights wired to a single switch on the unit exterior and GFI receptacle mounted next to the light switch with separate 120 volt power connection at the GFI receptacle to provide power for the lights and receptacle.
- 30%, Class 2, 4-inch pleated filters in outdoor airstream.
- 65%, Class 2, 12-inch high efficiency pleated filters.
- 30%, Class 2, 2-inch pleated filters in return airstream.
- Outside air damper, galvanized steel frames and blades and two position electric actuators.
- Exhaust air damper, gravity back draft, aluminum frames and blades.

Price (Freight Allowed).. $90,193.00 (2nd Half-06)

PVS-18 (Unit Tag - ERU-2)

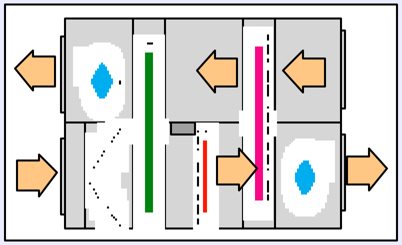
Unit Width - 122"
Unit Height - 98"_____
Unit Length - 308"_____
Max Module Weight - 10,000_____
Number Of Modules - 2____

- SEMCO standard panels consisting of 2” thick dual wall 18 ga. Galvanized solid exterior skins and 22 ga. Galvanized steel solid interior skins enclosing 2” thick 3 pcf mineral wool insulation with a u-factor of 0.10 BTU/(hr-sq.ft.-deg). An all-welded painted structural base will support the housing. The base includes a welded floor with 3 pcf mineral wool insulation. The base is self-flashing when set on a properly sized curb. Floor openings have perimeter lip and are covered by protective grate. Lifting lugs will be welded to the base.
- Outdoor construction including 22 gauge galvanized steel standing seam sheet metal roof, door gutters and hoods on intake and exhaust openings.
- Self-flashing base is designed for curb mounting. Curb must provide support at all field joints. Contact SEMCO for more detail.
- Automated Logic Corporation DDC control package.
- Variable speed enthalpy recovery wheel with 3A molecular sieve desiccant and acid-resistant coating, variable speed drive motor , 480/3 inverter and 24 volt temperature controller.
- Variable speed aluminum dehumidification energy recovery wheel which is coated to prohibit corrosion, media surfaces coated with a non-migrating solid adsorbent layer, variable speed drive motor , 460/3/60 inverter and 24 volt temperature controller.
- 25 hp, EPACT compliant, ODP supply fan motor in centrifugal plenum type fan.
- 20 hp, EPACT compliant, ODP exhaust fan motor in centrifugal plenum type fan.
- Chilled water cooling coil consisting of round seamless 5/8 inch O.D. by .020 inch thick copper tube on 1.5 inch centers, secondary surface of .006 inch rippled aluminum plate fins, casings of galvanized steel, headers of seamless copper, and galvanized steel holding racks mounted in an insulated pitched 304 stainless steel condensate pan.
- Hot water coil consisting of primary surface of round seamless 5/8 inch O.D. by .020 inch thick copper tube on 1.5 inch centers, secondary surface of .0075 inch rippled aluminum plate fins, casings of galvanized steel, headers of seamless copper, and galvanized steel holding racks.
- Single point control panel, 480/3/60, including motor starters, motor short circuit and overload protection, low voltage transformer, damper interlocks and local HOA switch.
- Vapor tight lights wired to a single switch on the unit exterior and GFI receptacle mounted next to the light switch with separate 120 volt power connection at the GFI receptacle to provide power for the lights and receptacle.
- 30%, Class 2, 4-inch pleated filters in outdoor airstream.
- 65%, Class 2, 12-inch high efficiency pleated filters.
- 30%, Class 2, 2-inch pleated filters in return airstream.
- Outside air damper, galvanized steel frames and blades and two position electric actuators.
- Exhaust air damper, gravity back draft, aluminum frames and blades.

Price (Freight Allowed).. $102,993.00 (2nd Half-06)

Version 2002.1

SEMCO PVS System Modeling Program



Input Parameters:

Unit #: ERU-1

Project Name:	Hilton Hotel	
Location:	Baltimore, Md	Choose System from below:
PVS Model Selected:	PVS-13	PVS-13

Airflow Conditions

Supply Air (SCFM):	7,680
Return Air (SCFM):	6,400

External Static Pressures:

Supply Air (inwg):	5
Return Air (inwg):	5

ESA Weather Data:

Austin, TX
Baltimore, MD
Billings, MT
Birmingham, AL
Bismarck, ND

Supply Air Conditions:

	Cooling Season	Heating Season	Suggestions
Dry Bulb Temp (DegF):	51.5	75.0	Input minimum grain level required for peak indoor latent load when sizing cooling capacity
Humidity (Grains):	46.0	20.0	

Outdoor Air Design Conditions:

	Cooling Season	Heating Season	Suggestions
Dry Bulb Temp (DegF):	95.0	10.0	For Accurate Design Data for City Selected:
Humidity (Grains):	130.0	0.5	

Space Design Conditions:

	Cooling Season	Heating Season	Suggestions
Dry Bulb Temp (DegF):	75.0	72.0	Input space temperature and relative humidity desired. (50% RH maximum recommended for cooling season design)
Humidity Level (%RH):	50%	30%	
Humidity (Grains):	65.3	35.2	

(calculated Value)

SEMCO INCORPORATED

Project: Hilton Hotel

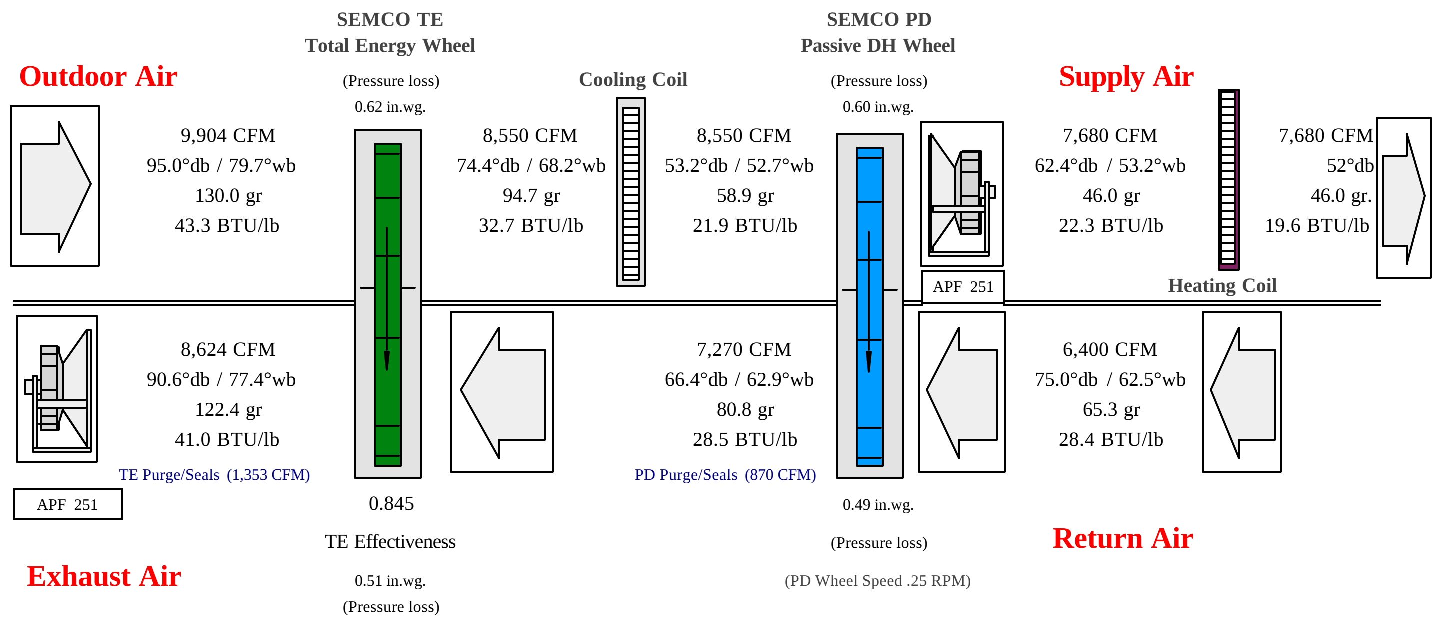
Location: Baltimore, Md

Model: PVS-13

Operating Mode:

Peak Space Latent Load

Unit #: ERU-1

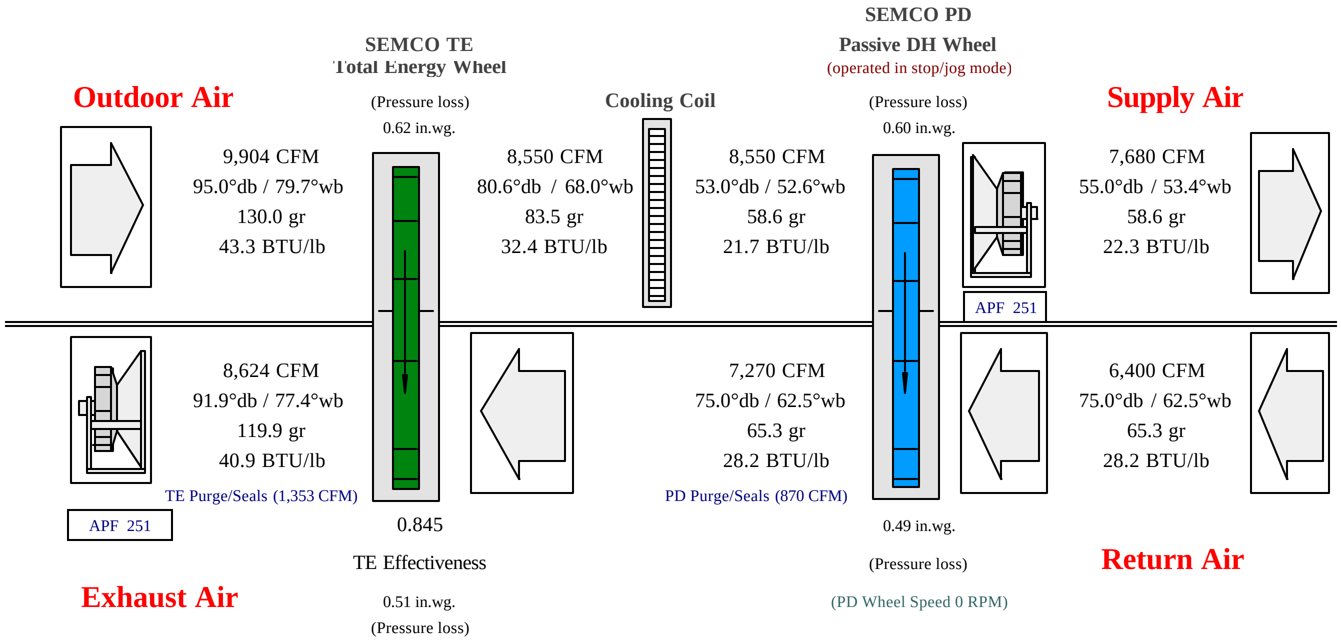


Operating Season: **Cooling**	Operating Mode: **Peak Latent Load**
SEMCO PVS Performance Analysis:	
Total Cooling Load Delivered:	**60.60** Tons of Total cooling provided
Latent Cooling Load Delivered:	**36.56** Tons of Latent cooling provided
Cooling Capacity Input Required:	**34.54** Tons of cooling Input required
Dewpoint Delivered to Space:	**45.9** Degree F dewpoint
Dewpoint Leaving Coil:	**52.2** Degree F dewpoint
Comparison with Conventional Approach:	
Cooling Capacity Required:	**69.47** Tons of cooling Input required
Reheat Energy Required:	**24,551** BTU/Hr. Reheat required
Dewpoint Delivered to Space:	**Not Met** Degree F dewpoint
Dewpoint Leaving Coil:	**48.0** Degree F dewpoint

SEMCO INCORPORATED

Project: Hilton Hotel
Location: Baltimore, Md
Model: PVS-13

Operating Mode:
Peak Space Sensible Load
Unit #: ERU-1



Operating Season: **Cooling**	Operating Mode: **Peak Sensible Load**
SEMCO PVS Performance Analysis:	
Total Cooling Load Delivered:	**60.49** Tons of Total cooling provided
Latent Cooling Load Delivered:	**31.08** Tons of Latent cooling provided
Cooling Capacity Input Required:	**34.54** Tons of cooling Input required
Dewpoint Delivered to Space:	**52.1** Degree F dewpoint
Dewpoint Leaving Coil:	**52.1** Degree F dewpoint
Comparison with Conventional Approach:	
Cooling Capacity Required:	**60.49** Tons of cooling Input required
Reheat Energy Required:	**N/A** BTU/Hr. Reheat required
Dewpoint Delivered to Space:	**52.1** Degree F dewpoint
Dewpoint Leaving Coil:	**52.1** Degree F dewpoint

SEMCO INCORPORATED

1800 East Pointe Drive, Columbia, Missouri 65201-3508

Project: Hilton Hotel

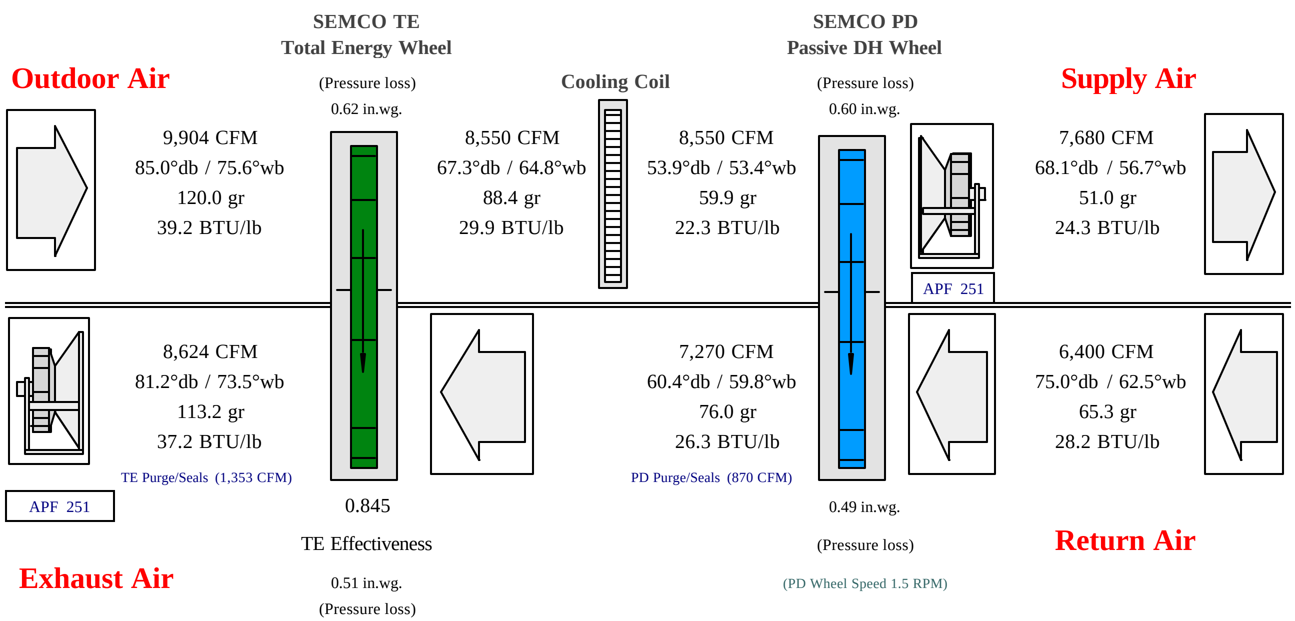
Location: Baltimore, Md

Model: PVS-13

Operating Mode:

Typical Part Load Condition *

Unit #: ERU-1



Operating Season: **Cooling**	Operating Mode: **Part Load Condition**
SEMCO PVS Performance Analysis:	
Total Cooling Load Delivered: Latent Cooling Load Delivered: Cooling Capacity Input Required: Dewpoint Delivered to Space: Dewpoint Leaving Coil:	**43.08** Tons of Total cooling provided **30.03** Tons of Latent cooling provided **24.51** Tons of cooling Input required **48.6** Degree F dewpoint **52.9** Degree F dewpoint
Comparison with Conventional Approach:	
Cooling Capacity Required: Reheat Energy Required: Dewpoint Delivered to Space: Dewpoint Leaving Coil:	**56.86** Tons of cooling Input required **161,389** BTU/Hr. Reheat required **48.6** Degree F dewpoint **48.6** Degree F dewpoint

Part Load Conditions:	Temperature	Humidity Content
Outdoor Air	**85°db**	**120.0 Grains**

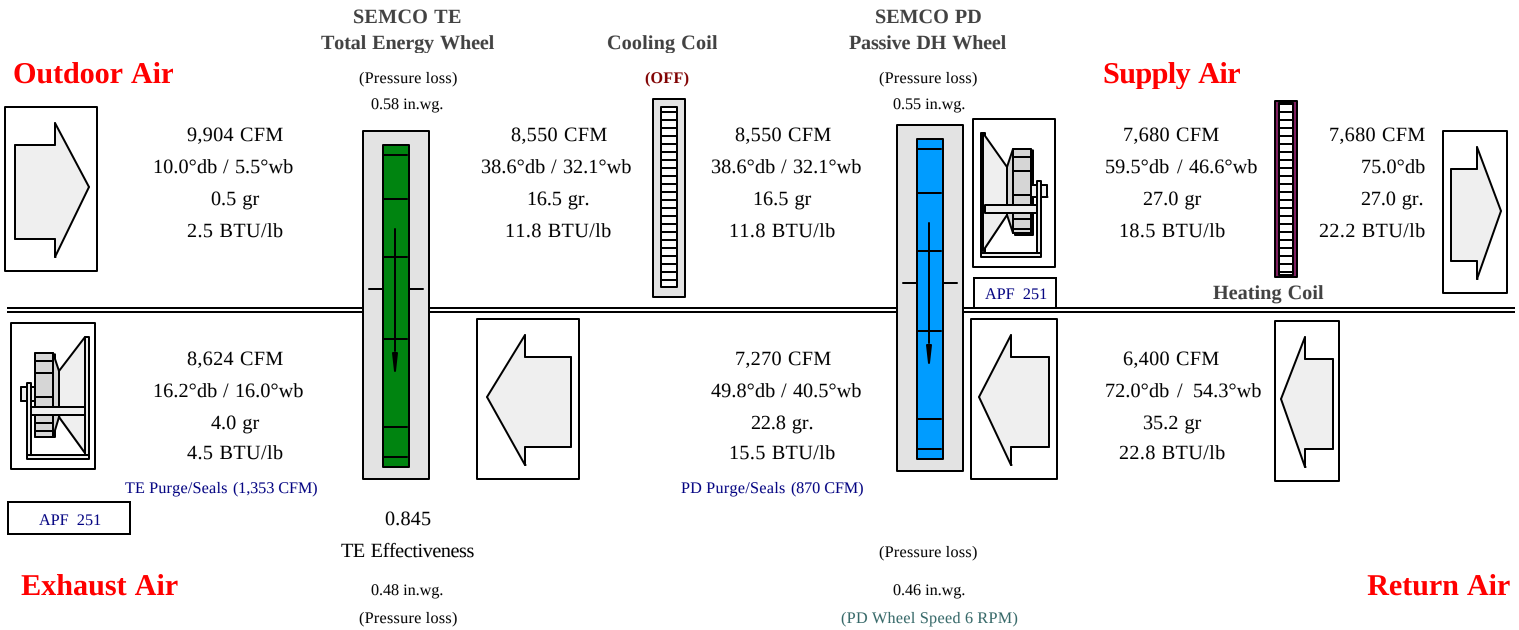
(Manual Input!)

SEMCO INCORPORATED

1800 East Pointe Drive, Columbia, Missouri 65201-3508

Project: Hilton Hotel
Location: Baltimore, Md
Model: PVS-13

Operating Mode:
Peak Heating Load
Unit #: ERU-1



Operating Season: **Heating**	Operating Mode: **Peak Heating Load**
SEMCO PVS Performance Analysis:	
Total Heating/Humid. Delivered: Humidification Load Delivered: Heating and/or Humid. Capacity Rqd:	**682,492** BTU/Hr provided **131** Pounds of Humidification/Hr. **128,920** BTU/Hr required
Comparison with Conventional Approach:	
Heating/Humid. Capacity Required:	**644,624** BTU/Hr required

PD Wheel Analyzer

PD Wheel **Reheat Effectiveness** (automatic=1, manual=0)	**0** Mode	Manual Input Value **55** % Max PD Wheel Eff. 36%

Note: Keep in mode 1 for automatic modulation of PD wheel
Use mode 0 for manual override to reheat beyond setpoint

SEMCO INCORPORATED

1800 East Pointe Drive, Columbia, Missouri 65201-3508

Performance Schedule: PVS System

Project:	Hilton Hotel		**SEMCO Model:**	PVS-13
Location:	Baltimore, Md		**Supply Fan:**	APF 251
Unit #:	ERU-1		**Exhaust Fan:**	APF 251

Fan Data

Airstream	Airflow Quantity (SCFM)	Airflow+Purge/Seal (SCFM)	External Static Pressure (inwg)	Fan Horsepower (Installed)
Supply	7680	7680	5	
Return	6400	8624	5	

Design Data

	Outdoor Air Design (Cooling)	Return Air Design (Cooling)	Outdoor Air Design (Heating)	Return Air Design (Heating)
Temperature (DB)	95.0	75.0	10.0	72.0
Temperature (WB)	79.7	62.5	5.5	54.3
Humidity (Gr.)	130.0	65.3	0.5	35.2
Enthalpy (btu/lb)	43.3	28.4	2.5	22.8

Delivered Conditions

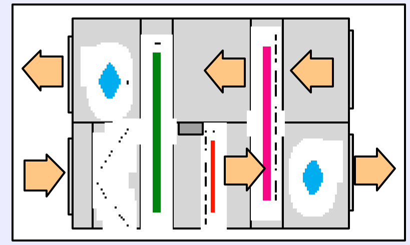
	TE Energy Wheel (Cooling)	PD DH Wheel (Cooling)	TE Energy Wheel (Heating)	PD DH Wheel (Heating)
Temperature (DB)	74.4	62.4	25.6	61.9
Humidity (Gr.)	94.7	46.0	9.2	28.3
Enthalpy (btu/lb)	32.7	22.3	7.6	19.3
Pressure Loss				
Supply Side	0.62	0.60	0.58	0.55
Return Side	0.51	0.49	0.48	0.46
TE Effectiveness	0.84		0.84	

Coil Data

	Cooling Coil (Entering)	Cooling Coil (Leaving)	Heating Coil (Entering)	Heating Coil (Leaving)
Temperature (DB)	74.4	53.2	61.9	75.0
Humidity (Gr.)	94.7	58.9	28.3	20.0
Enthalpy (btu/lb)	32.7	21.9	19.3	21.1
Air Pressure Loss				
Capacity MBH	414,435		109,053	
Fluid Temperature				
GPM Fluid Flow				
Fluid Pressure Loss				

Version 2002.1

SEMCO PVS System Modeling Program



Input Parameters:

Unit #: ERU-2

Project Name:	Hilton Hotel	
Location:	Baltimore, Md	Choose System from below:
PVS Model Selected:	PVS-18	PVS-18

Airflow Conditions

Supply Air (SCFM):	9,600
Return Air (SCFM):	8,000

External Static Pressures:

Supply Air (inwg):	5
Return Air (inwg):	5

ESA Weather Data:

- Austin, TX
- Baltimore, MD
- Billings, MT
- Birmingham, AL
- Bismarck, ND

Supply Air Conditions:

	Cooling Season	Heating Season	Suggestions
Dry Bulb Temp (DegF):	51.5	75.0	Input minimum grain level required for peak
Humidity (Grains):	46.0	20.0	indoor latent load when sizing cooling capacity

Outdoor Air Design Conditions:

	Cooling Season	Heating Season	Suggestions
Dry Bulb Temp (DegF):	95.0	10.0	For Accurate Design Data for City Selected:
Humidity (Grains):	130.0	0.5	

Space Design Conditions:

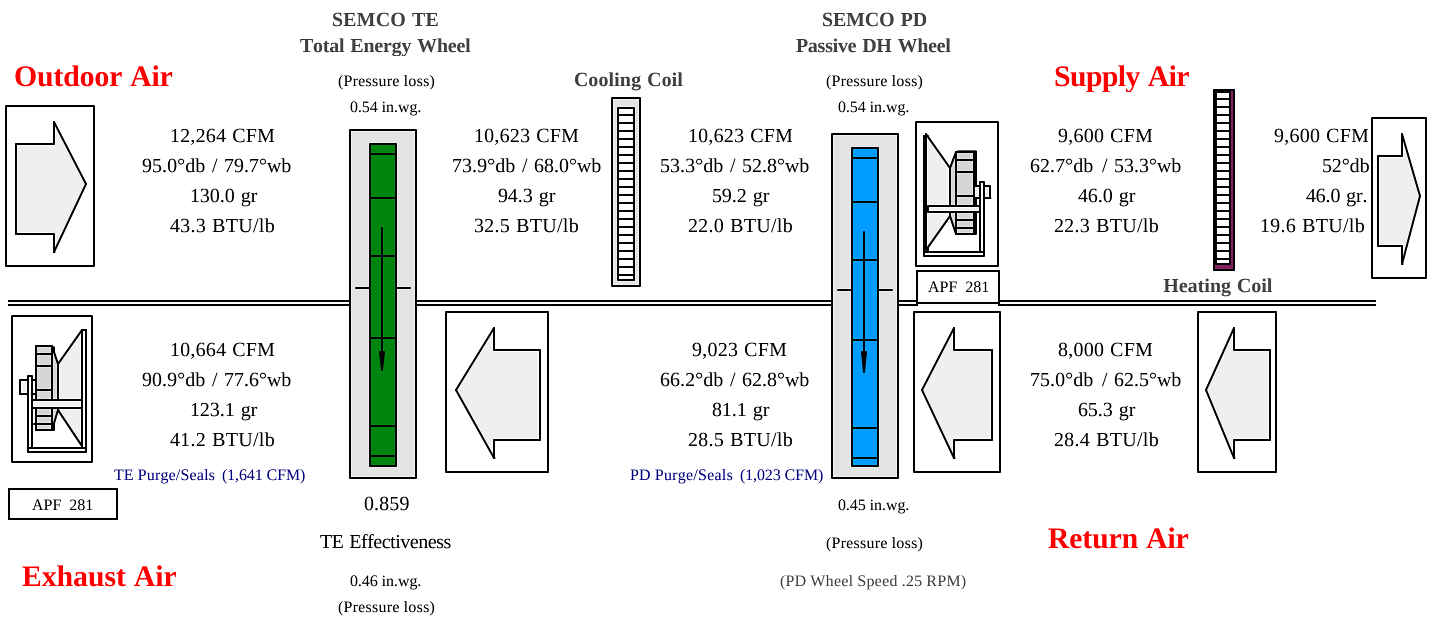
	Cooling Season	Heating Season	Suggestions
Dry Bulb Temp (DegF):	75.0	72.0	Input space temperature and relative humidity
Humidity Level (%RH):	50%	30%	desired. (50% RH maximum recommended for
Humidity (Grains):	65.3	35.2	cooling season design)

(calculated Value)

SEMCO INCORPORATED

Project: Hilton Hotel
Location: Baltimore, Md
Model: PVS-18

Operating Mode:
Peak Space Latent Load
Unit #: ERU-2



Operating Season: **Cooling**	Operating Mode: **Peak Latent Load**
SEMCO PVS Performance Analysis:	
Total Cooling Load Delivered: Latent Cooling Load Delivered: Cooling Capacity Input Required: Dewpoint Delivered to Space: Dewpoint Leaving Coil:	**75.48** Tons of Total cooling provided **45.70** Tons of Latent cooling provided **41.93** Tons of cooling Input required **45.9** Degree F dewpoint **52.3** Degree F dewpoint
Comparison with Conventional Approach:	
Cooling Capacity Required: Reheat Energy Required: Dewpoint Delivered to Space: Dewpoint Leaving Coil:	**86.84** Tons of cooling Input required **30,689** BTU/Hr. Reheat required **Not Met** Degree F dewpoint **48.0** Degree F dewpoint

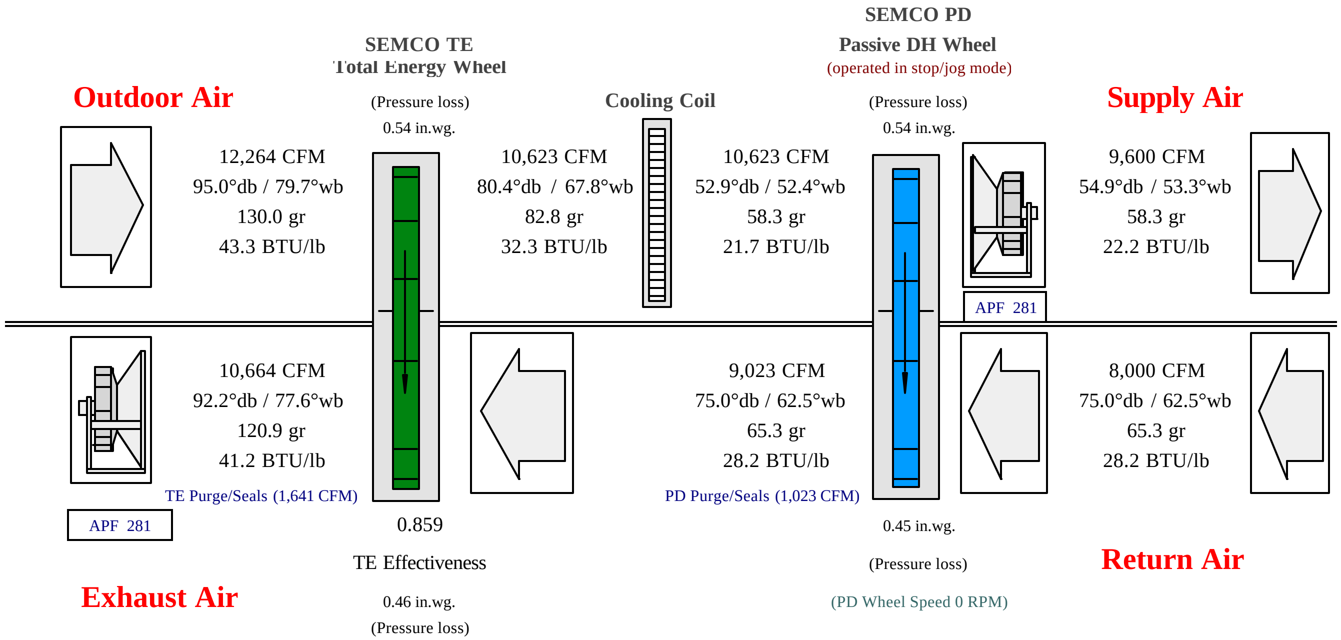
SEMCO INCORPORATED

Project: Hilton Hotel

Location: Baltimore, Md

Model: PVS-18

Operating Mode:
Peak Space Sensible Load
Unit #: ERU-2



Operating Season: **Cooling**	Operating Mode: **Peak Sensible Load**
SEMCO PVS Performance Analysis:	
Total Cooling Load Delivered:	**75.86** Tons of Total cooling provided
Latent Cooling Load Delivered:	**38.99** Tons of Latent cooling provided
Cooling Capacity Input Required:	**41.93** Tons of cooling Input required
Dewpoint Delivered to Space:	**51.9** Degree F dewpoint
Dewpoint Leaving Coil:	**51.9** Degree F dewpoint
Comparison with Conventional Approach:	
Cooling Capacity Required:	**75.86** Tons of cooling Input required
Reheat Energy Required:	**N/A** BTU/Hr. Reheat required
Dewpoint Delivered to Space:	**51.9** Degree F dewpoint
Dewpoint Leaving Coil:	**51.9** Degree F dewpoint

SEMCO INCORPORATED

1800 East Pointe Drive, Columbia, Missouri 65201-3508

Project: Hilton Hotel

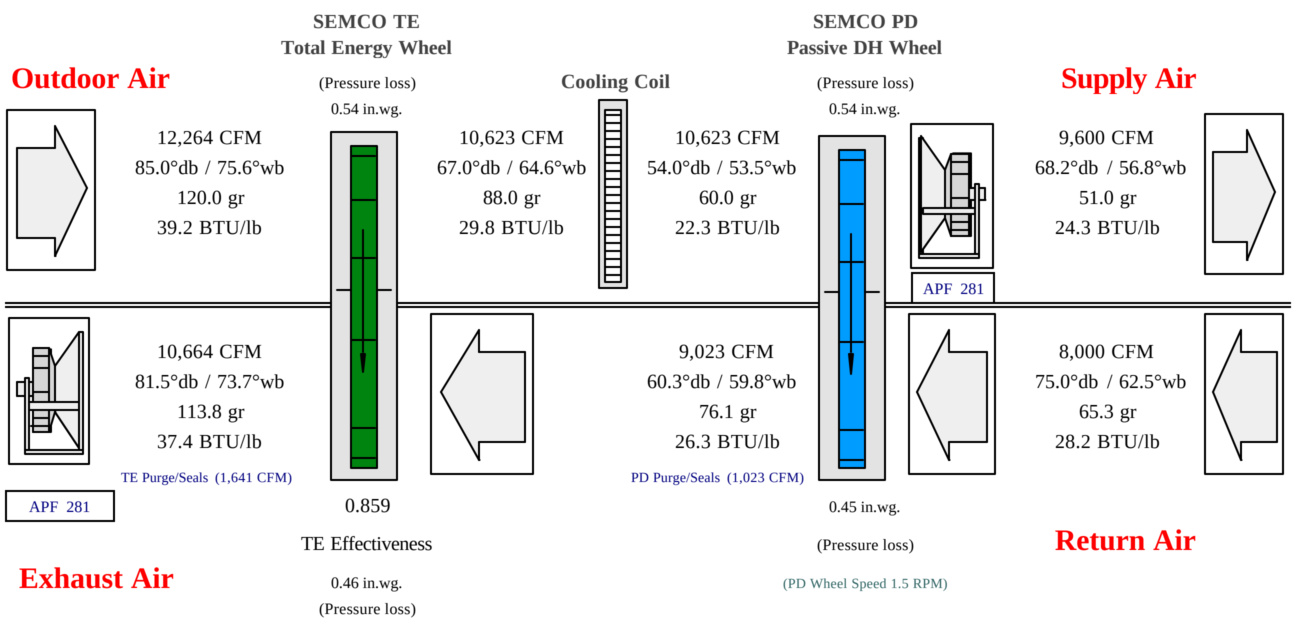
Location: Baltimore, Md

Model: PVS-18

Operating Mode:

Typical Part Load Condition *

Unit #: ERU-2



Operating Season: **Cooling**	Operating Mode: **Part Load Condition**
SEMCO PVS Performance Analysis:	
Total Cooling Load Delivered:	**53.70** Tons of Total cooling provided
Latent Cooling Load Delivered:	**37.54** Tons of Latent cooling provided
Cooling Capacity Input Required:	**29.68** Tons of cooling Input required
Dewpoint Delivered to Space:	**48.6** Degree F dewpoint
Dewpoint Leaving Coil:	**53.0** Degree F dewpoint
Comparison with Conventional Approach:	
Cooling Capacity Required:	**71.07** Tons of cooling Input required
Reheat Energy Required:	**203,458** BTU/Hr. Reheat required
Dewpoint Delivered to Space:	**48.6** Degree F dewpoint
Dewpoint Leaving Coil:	**48.6** Degree F dewpoint

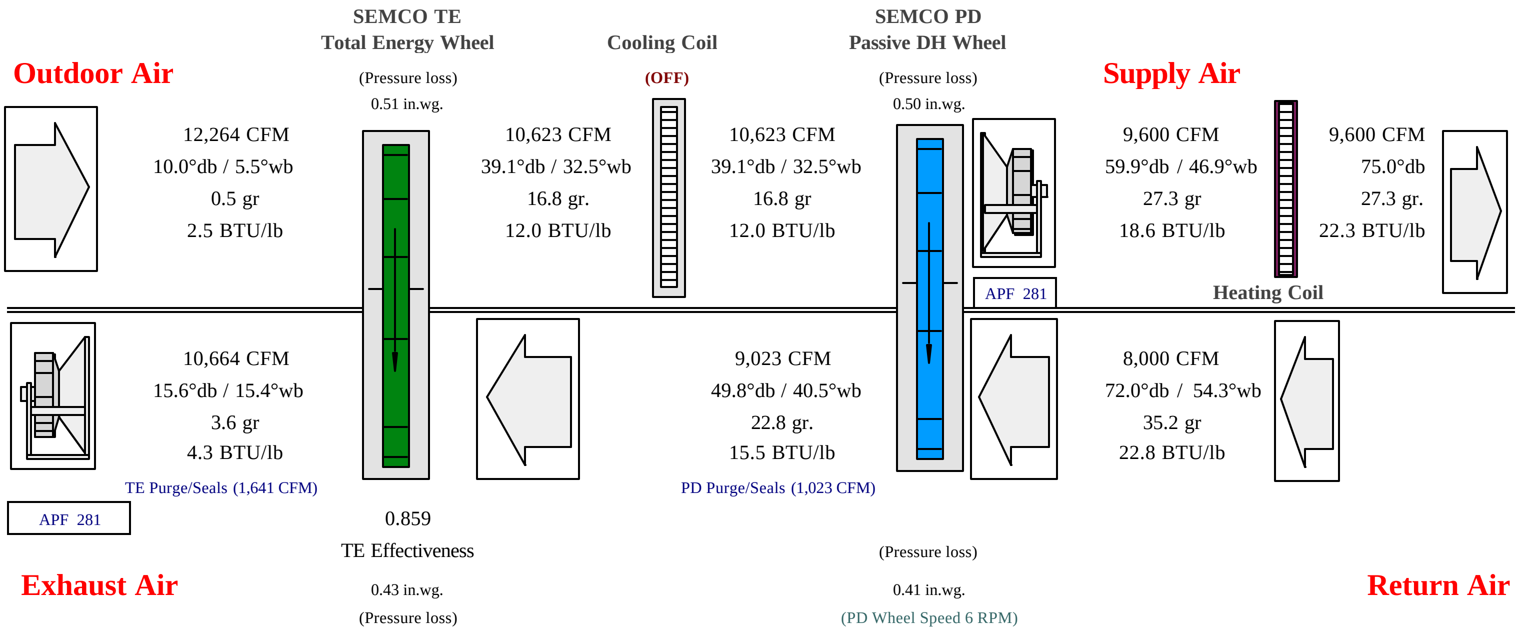
Part Load Conditions:	Temperature	Humidity Content
Outdoor Air	**85°db**	**120.0 Grains**

(Manual Input!)

1800 East Pointe Drive, Columbia, Missouri 65201-3508

Project: Hilton Hotel
Location: Baltimore, Md
Model: PVS-18

Operating Mode:
Peak Heating Load
Unit #: ERU-2



Operating Season: **Heating**	Operating Mode: **Peak Heating Load**
SEMCO PVS Performance Analysis:	
Total Heating/Humid. Delivered: Humidification Load Delivered: Heating and/or Humid. Capacity Rqd:	**854,848** BTU/Hr provided **165** Pounds of Humidification/Hr. **156,481** BTU/Hr required
Comparison with Conventional Approach:	
Heating/Humid. Capacity Required:	**805,780** BTU/Hr required

PD Wheel Analyzer

PD Wheel **Reheat Effectiveness** (automatic=1, manual=0)	**0** Mode	Manual Input Value **55** % Max PD Wheel Eff. 36%

Note: Keep in mode 1 for automatic modulation of PD wheel
Use mode 0 for manual override to reheat beyond setpoint

SEMCO INCORPORATED

1800 East Pointe Drive, Columbia, Missouri 65201-3508

Performance Schedule: PVS System

Project:	Hilton Hotel		**SEMCO Model:**	PVS-18
Location:	Baltimore, Md		**Supply Fan:**	APF 281
Unit #:	ERU-2		**Exhaust Fan:**	APF 281

Fan Data

Airstream	Airflow Quantity (SCFM)	Airflow+Purge/Seal (SCFM)	External Static Pressure (inwg)	Fan Horsepower (Installed)
Supply	9600	9600	5	
Return	8000	10664	5	

Design Data

	Outdoor Air Design (Cooling)	Return Air Design (Cooling)	Outdoor Air Design (Heating)	Return Air Design (Heating)
Temperature (DB)	95.0	75.0	10.0	72.0
Temperature (WB)	79.7	62.5	5.5	54.3
Humidity (Gr.)	130.0	65.3	0.5	35.2
Enthalpy (btu/lb)	43.3	28.4	2.5	22.8

Delivered Conditions

	TE Energy Wheel (Cooling)	PD DH Wheel (Cooling)	TE Energy Wheel (Heating)	PD DH Wheel (Heating)
Temperature (DB)	73.9	62.7	39.1	59.9
Humidity (Gr.)	94.3	46.0	16.8	27.3
Enthalpy (btu/lb)	32.5	22.3	12.0	18.6
Pressure Loss				
Supply Side	0.54	0.54	0.51	0.50
Return Side	0.46	0.45	0.43	0.41
TE Effectiveness	0.86		0.86	

Coil Data

	Cooling Coil (Entering)	Cooling Coil (Leaving)	Heating Coil (Entering)	Heating Coil (Leaving)
Temperature (DB)	73.9	53.3	59.9	75.0
Humidity (Gr.)	94.3	59.2	27.3	20.0
Enthalpy (btu/lb)	32.5	22.0	18.6	21.1
Air Pressure Loss				
Capacity MBH	503,182		156,481	
Fluid Temperature				
GPM Fluid Flow				
Fluid Pressure Loss				

Appendix G – Fan Coil Unit Selection

This appendix contains the cut sheets and other data for the manufacturer information provided for the fan coil units used as a part of the design process. There is data from Carrier and Enviro-Tec included.

Please see the all the dedicated outdoor air system unit information on the following pages.

Fan Coil Unit Zones

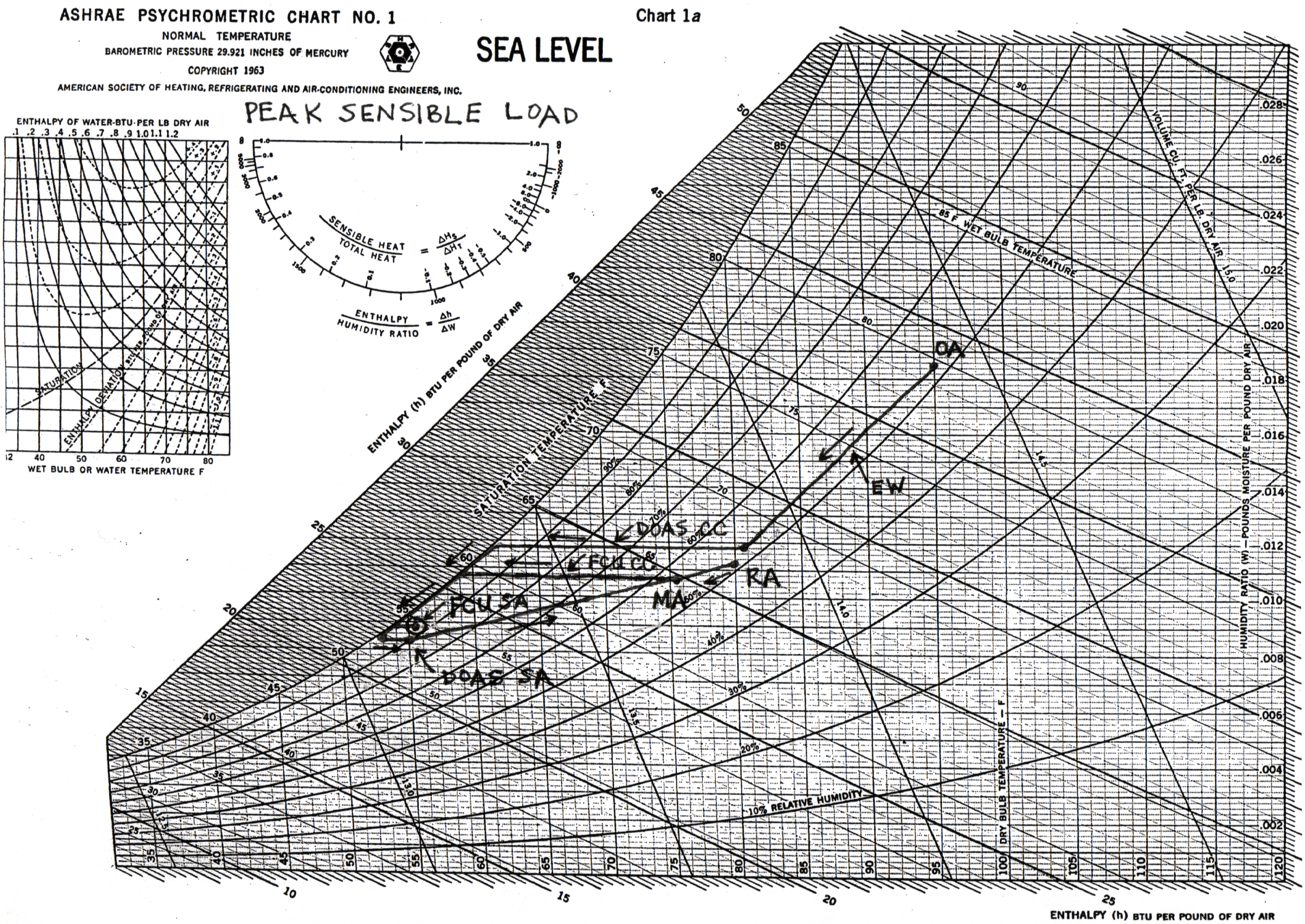
Table G1 - Fan Coil Unit Zones

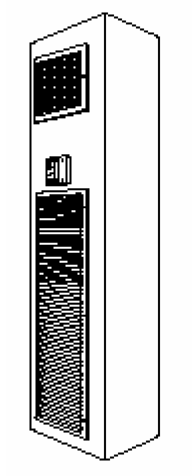
FCU-1			FCU-2		
Floors	4-10	11	Floors	4-10	11
Zone No	Space		Zone No	Space	
1	02	04	1	01	01
2	04	04	2	03	03
3	06	06	3	05	05
4	08	08	4	07	07
5	10	10	5	09	09
6	12	12	6	11	11
7	14	14	7	13	13
8	20	20	8	15	15
9	22	22	9	17	15
10	24	24	10	19	15
11	26	26	11	21	21
12	28	28	12	23	21
13	30	30	13	25	21
14	32	30	14	27	27
15	-	32	15	29	29
16	-	32	16	31	31
17	-	-	-	33	-
18	-	-	-	35	-

Table G2 - Hotel Guest Rooms

Floor	Room Types	No of Guestrooms													Total	
3	K/S	1	3	5	7	9	11	12	14	20	22	28	30	35	13	
3	QQ/S	4	6	17	19	25	27	29	31	33					9	
3	QQ/T	2	8	10	13	15	21	23	24	26					9	
3	QQ/AT	32													1	
4-10	K/S	1	3	5	7	9	11	12	14	19	20	28	30	35	13	x7
4-10	K/AT	17	22												2	x7
4-10	QQ/S	4	6	25	27	29	31	33							7	x7
4-10	QQ/T	2	8	10	13	15	21	23	24	26	32				10	x7
11	K/S	1	3	5	6	7	9	11	12	14	20	22	28	31	13	
11	K/T	13													1	
11	QQ/S	27	29												2	
11	QQ/T	8	10	24	26										4	
11	SK/AT	4													1	
11	SK/ST	30	32												2	
	Total														**279**	**rooms**

SAMPLE GUEST ROOM - NORTH SIDE DOAS + FCU





Unit Parameters

- Tag Name: **FCU-1**
- Quantity: **1**
- Unit Model: **42SGA03**
- Unit Type: **42SGA Concealed Modular Unit**
- Unit Size: **300**
- System Type: **4-Pipe Heating and Cooling**
- Cooling Coil: **Cold Fluid Cooling**
- Cooling Coil Rows: **3 Rows**
- Heating Coil: **Hot Fluid Heating**
- Heating Coil Rows: **1 Row**
- Shipping Options: **Standard**
- Fan Speed: **High**
- Motor/Drive: **Standard**

Electrical

- Motor Voltage: **208-1-60** V-Ph-Hz

Dimensions

- Unit Length: **17.00** in
- Unit Width: **17.00** in
- Unit Height: **88.00** in
- Shipping Weight: **225** lb

Warranty Information

First Year - Parts Only (Standard)

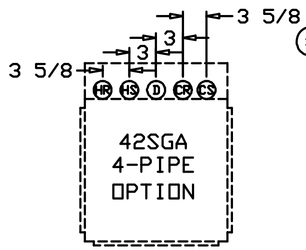
Ordering Information

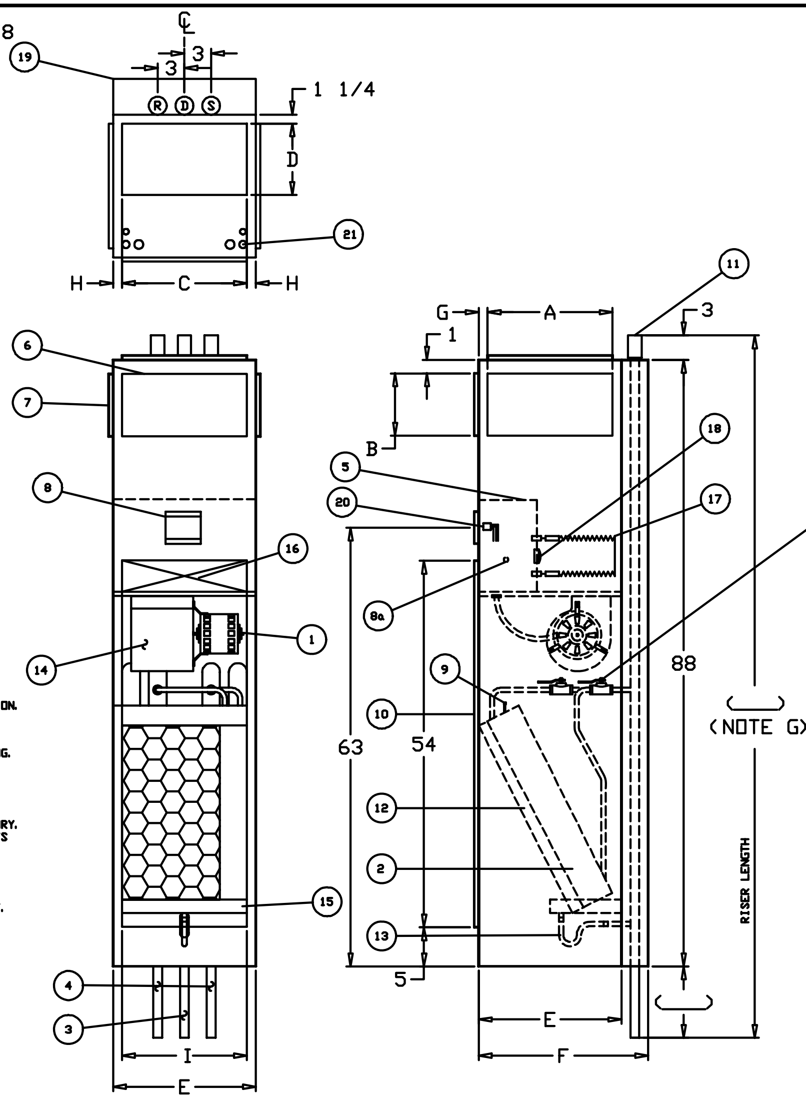
Part Number	Description	Quantity
Base Unit		
	42SGA03	1
	4-Pipe Heating and Cooling	
	208-1-60 Motor Voltage	
	1 in. Throwaway Glass-Fiber	
	Bar Type Alum Finish Return Air Grille (Mod Panel 3)	
	Field Supplied/Inst Remote-Mtd Therm	
	Full Riser Chase	
	Std. Tufskin II Insulation	
	3 Rows Cooling, 1 Row Heating, Same end	
	Front Return / Front Supply	
	Std. Cabinet Size, Std. 88 in. Cabinet Height, Std. Riser Piping Order	
	Riser, Cooling Coil, Return, 3/4 in., Type L Copper, 1/2 in. Insulation	
	Riser, Cooling Coil, Supply, 1 in., Type L Copper, 1/2 in. Insulation	
	Riser, Drain, 1 in., Type L Copper, 1/2 in. Insulation	
	Riser, Heating Coil, Return, 3/4 in., Type L Copper, 1/2 in. Insulation	
	Riser, Heating Coil, Supply, 3/4 in., Type L Copper, 1/2 in. Insulation	

	(1) Ball Valve, Return Line, Cooling Coil	
	(1) Ball Valve, Supply Line, Cooling Coil	
	(1) Ball Valve, Return Line, Heating Coil	
	(1) Ball Valve, Supply Line, Heating Coil	
	110 in. Floor to Floor Height	
	112 in. Risers	

42SGA UNIT (W/ CHASE) | **42SGA-1**

—	PCN 00-0210 08/10/00	TNW
A	PCN 05-0962 08/08/05	KDW





NOTES:

A. UNITS ARE FABRICATED OF GALVANIZED STEEL WITH A 16 GA GALVANIZED FAN DECK.
B. ALL RISERS ARE INSULATED WITH 1/2" CLOSED CELL INSULATION.
C. THERMOSTATS SHIPPED LOOSE FOR FIELD CONNECTION.
D. RISERS ARE PIPED TO COIL WITH VALVES AS SPECIFIED.
E. BLOWER, MOTOR, VALVES, COIL, AND FILTER ARE ACCESSIBLE THROUGH THE RETURN AIR OPENING.
F. UNIT AND CONTROL BOX ARE INSULATED WITH 1/2" COATED GLASS FIBER INSULATION.
G. RISER LENGTH=[(FLOOR TO FLOOR)+2"], MAXIMUM RISER LENGTH=115".
H. MAXIMUM RISER SIZE IS 2 1/2" DIA. IF LARGER SIZES ARE REQUIRED, PLEASE CONSULT THE FACTORY.
I. EXPANSION LOOPS IN HOT WATER HEATING CIRCUITS AS REQUIRED.
J. A 9"X2 1/4" SLOT IS PROVIDED IN THE INSIDE BACK PANEL FOR COIL CONNECTION PENETRATION TO PERMIT EXPANSION & CONTRACTION OF RISERS. CARE MUST BE TAKEN TO POSITION THE RISERS SO THAT COIL CONNECTION IS AT CENTER OF SLOT.
K. DWG IS PICTORIAL (SEE UNIT ARRANGEMENTS FOR ACTUAL SUPPLY AND RETURN AIR ORIENTATION).
L. FAN DECK AND CONTROL BOX ASSEMBLY RAISED 3" ON SIZES 08, 10, 12 ONLY. HIGH STATIC MOTOR/BLOWER ASSEMBLIES UTILIZED.
M. ** CABINET SIZE ON 08 HIGH STATIC MODELS IS 24" X 24".

ITEM	DESCRIPTION	QTY
1	MOTOR, 3 SPEED, PSC, SERIES 'L'	1
2	COIL 1/2" O.D. COPPER TUBE	1
3	RISER, DRAIN, (COPPER)	1
4	RISER, SUPPLY & RETURN (COPPER)	2/4
5	CONTROL BOX	1
6	SUPPLY AIR OPENING(S)	
7	DUCT COLLAR, 1/2' EXTENSION (TYPCIAL)	
8	CONTROL OPENING (SURFACE MOUNT STAT)	1
8a	KNOCKOUT (FOR OPTIONAL REMOTE MOUNTING)	2
9	AIR VENT, MANUAL	1
10	RETURN AIR OPENING	1
11	3" EXPANDED SECTION	3/5
12	FILTER, THROWAWAY, 1', (F&I)	1
13	FLEXIBLE DRAIN TUBE/P-TRAP	1
14	BLOWER	1
15	DRAIN PAN	1
16	ACCESS PANEL (CONTROL BOX)	1
17	STRIP HEATER (OPTIONAL)	1
18	LIMIT SWITCH, (F&I) (OPTIONAL)	1
19	RISER CHASE (OPTIONAL)	1
20	MOLEX CONNECTOR FOR FIELD INSTALLED STAT	1
21	ELECTRICAL KNOCKOUTS	1
22	1/2" ISOLATION BALL VALVES (F&I)	2/4

☐ *2 – PIPE* ☐ *4 – PIPE*

☐ *2 – PIPE W/ELECTRIC HEAT*

☐ *TOTAL* ☐ *AUXILIARY*

	MODEL	SGLE. SUPPLY			DBLE. SUPPLY			TOP SUPPLY			DIMENSIONS					FILTER SIZE
		A	B	SIZE	A	B	SIZE	C	D	SIZE	E	F	G	H	I	
	42SGA 03	14	8	14X8	14	6	14X6	14	10	14X10	17	22 3/8	1 1/2	1 1/2	14	12 1/2 X 24 3/4 X 1
	42SGA 04	14	12	14X12	14	6	14X6	14	10	14X10	17	22 3/8	1 1/2	1 1/2	14	12 1/2 X 24 3/4 X 1
	42SGA 06	18	10	18X10	18	6	18X6	16	12	16X12	20	25 3/8	1	2	18	16 1/2 X 27 1/4 X 1
**	42SGA 08	18	12	18X12	18	6	18X6	16	12	16X12	20	25 3/8	1	2	18	16 1/2 X 27 1/4 X 1
	42SGA 10				22	8	22X8	18	16	18X16	24	29 3/8	1	3	22	20 1/2 X 29 1/2 X 1
	42SGA 12				22	8	22X8	18	16	18X16	24	29 3/8	1	3	22	20 1/2 X 29 1/2 X 1

JOB NUMBER

FILE NAME

DRAWN BY
TNW

DRAWING NUMBER | REVISION | SHEET

Carrier

Unit Parameters

Tag Name:	FCU-1	
Quantity:	1	
Unit Model:	42SGA03	
Unit Type:	42SGA Concealed Modular Unit	
Unit Size:	300	
System Type:	4-Pipe Heating and Cooling	
Cooling Coil:	Cold Fluid Cooling	
Cooling Coil Rows:	3 Rows	
Heating Coil:	Hot Fluid Heating	
Heating Coil Rows:	1 Row	
Shipping Options:	Standard	
Fan Speed:	High	
Motor/Drive:	Standard	

Unit Performance

Actual Airflow:	330.0	CFM
Altitude:	0	ft
External Static Pressure:	.10	in wg
Voltage:	208-1-60	V-Ph-Hz

Cooling Data

Coil Type:	Cold Fluid Cooling	
Coil Rows:	3 Rows	
Fluid Type:	Fresh Water	
Total Capacity:	12633	BTU/hr
Sensible Capacity:	8825	BTU/hr
Entering Air Dry Bulb Temperature:	80.0	F
Entering Air Wet Bulb Temperature:	67.0	F
Leaving Air Dry Bulb Temperature:	55.5	F
Leaving Air Wet Bulb Temperature:	54.6	F
Fluid Flow Rate:	2.1	gpm
Fluid Pressure Drop:	21.86	ft wg
Fluid Entering Temperature:	44.0	F
Fluid Leaving Temperature:	56.0	F

Heating Data

Coil Type:	Hot Fluid Heating	
Coil Rows:	1 Row	
Fluid Type:	Fresh Water	
Sensible Capacity:	19597	BTU/hr
Entering Air Temperature:	60.0	F
Leaving Air Temperature:	114.3	F
Fluid Flow Rate:	2.0	gpm
Fluid Pressure Drop:	4.75	ft wg
Fluid Entering Temperature:	180.0	F
Fluid Leaving Temperature:	160.0	F

Electrical Data

Motor Voltage:	208-1-60	V-Ph-Hz
Motor Nominal HP:	1/30	hp
Total Motor Watts:	122	
Total Motor Amps:	0.31	

Acoustical Data

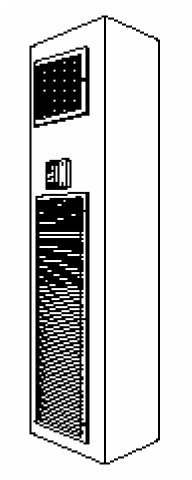
N/A

Sound Power 125 dB:	64.5
Sound Power 250 dB:	57
Sound Power 500 dB:	52.5
Sound Power 1000 dB:	49
Sound Power 2000 dB:	41

Sound Power 4000 dB:.................................... **39**
Sound Power 8000 dB:................................. **35.5**
Sound A Weight in dB: **55**

Factory-Installed Options

Coil Connections: .... **Same end**
Return:.. **Front Return**
Supply: .... **Front Supply**
Filters:.. **1 in. Throwaway Glass-Fiber**
Drain Pans:.. **Standard Main Drain Pan**
Return Air Options: .... **Bar Type Alum Finish (#3)**
Cabinet Size: .... **Standard Cabinet Size (17 in.)**
Cabinet Height:.. **Std.**
AAV / Drains:.. **Manual Air Vents only**
Control Packages: .... **Field Supplied/Inst Remote-Mtd Therm**
Single Power Source:.. **No**
Riser Chase:.. **Full Riser Chase**
Riser Piping Order:.. **Std.**



Unit Parameters
Tag Name: **FCU-2**
Quantity: **1**
Unit Model: **42SGA04**
Unit Type: **42SGA Concealed Modular Unit**
Unit Size: **400**
System Type: **4-Pipe Heating and Cooling**
Cooling Coil: **Cold Fluid Cooling**
Cooling Coil Rows: **3 Rows**
Heating Coil: **Hot Fluid Heating**
Heating Coil Rows: **1 Row**
Shipping Options: **Standard**
Fan Speed: **High**
Motor/Drive: **Standard**

Electrical
Motor Voltage: **208-1-60** V-Ph-Hz

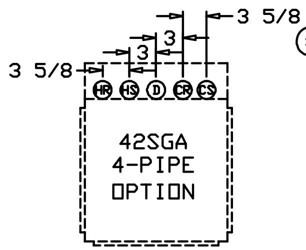
Dimensions
Unit Length: **17.00** in
Unit Width: **17.00** in
Unit Height: **88.00** in
Shipping Weight: **225** lb

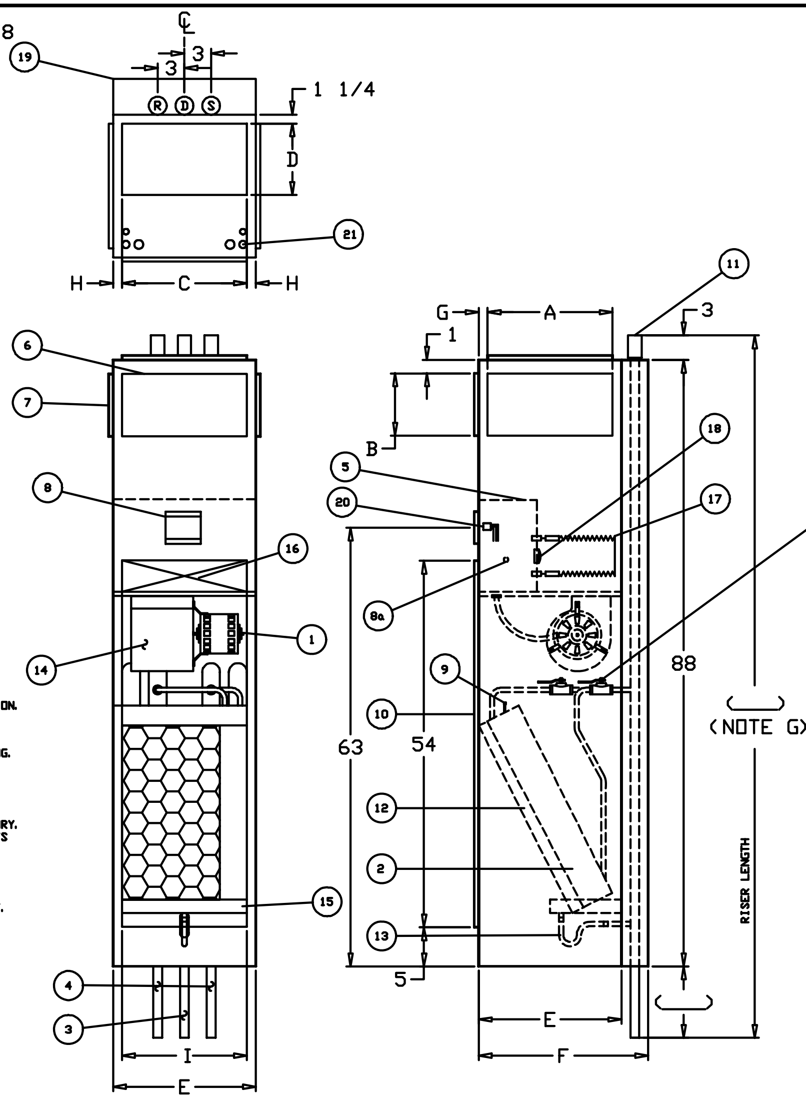
Warranty Information
First Year - Parts Only (Standard)

Ordering Information

Part Number	Description	Quantity
Base Unit		
	42SGA04	1
	4-Pipe Heating and Cooling	
	208-1-60 Motor Voltage	
	1 in. Throwaway Glass-Fiber	
	Bar Type Alum Finish Return Air Grille (Mod Panel 3)	
	Field Supplied/Inst Remote-Mtd Therm	
	Full Riser Chase	
	Std. Tufskin II Insulation	
	3 Rows Cooling, 1 Row Heating, Same end	
	Front Return / Front Supply	
	Std. Cabinet Size, Std. 88 in. Cabinet Height, Std. Riser Piping Order	
	Riser, Cooling Coil, Return, 3/4 in., Type L Copper, 1/2 in. Insulation	
	Riser, Cooling Coil, Supply, 1 in., Type L Copper, 1/2 in. Insulation	
	Riser, Drain, 1 in., Type L Copper, 1/2 in. Insulation	
	Riser, Heating Coil, Return, 3/4 in., Type L Copper, 1/2 in. Insulation	
	Riser, Heating Coil, Supply, 3/4 in., Type L Copper, 1/2 in. Insulation	

	(1) Ball Valve, Return Line, Cooling Coil	
	(1) Ball Valve, Supply Line, Cooling Coil	
	(1) Ball Valve, Return Line, Heating Coil	
	(1) Ball Valve, Supply Line, Heating Coil	
	110 in. Floor to Floor Height	
	112 in. Risers	





42SGA UNIT (W/ CHASE) | 42SGA-1

—	PCN 00-0210 08/10/00	TNW
A	PCN 05-0962 08/08/05	KDW

NOTES:

A. UNITS ARE FABRICATED OF GALVANIZED STEEL WITH A 16 GA GALVANIZED FAN DECK.
B. ALL RISERS ARE INSULATED WITH 1/2" CLOSED CELL INSULATION.
C. THERMOSTATS SHIPPED LOOSE FOR FIELD CONNECTION.
D. RISERS ARE PIPED TO COIL WITH VALVES AS SPECIFIED.
E. BLOWER, MOTOR, VALVES, COIL, AND FILTER ARE ACCESSIBLE THROUGH THE RETURN AIR OPENING.
F. UNIT AND CONTROL BOX ARE INSULATED WITH 1/2" COATED GLASS FIBER INSULATION.
G. RISER LENGTH=[(FLOOR TO FLOOR)+2"], MAXIMUM RISER LENGTH=115".
H. MAXIMUM RISER SIZE IS 2 1/2" DIA. IF LARGER SIZES ARE REQUIRED, PLEASE CONSULT THE FACTORY.
I. EXPANSION LOOPS IN HOT WATER HEATING CIRCUITS AS REQUIRED.
J. A 9"X2 1/4" SLOT IS PROVIDED IN THE INSIDE BACK PANEL FOR COIL CONNECTION PENETRATION TO PERMIT EXPANSION & CONTRACTION OF RISERS. CARE MUST BE TAKEN TO POSITION THE RISERS SO THAT COIL CONNECTION IS AT CENTER OF SLOT.
K. DWG IS PICTORIAL (SEE UNIT ARRANGEMENTS FOR ACTUAL SUPPLY AND RETURN AIR ORIENTATION).
L. FAN DECK AND CONTROL BOX ASSEMBLY RAISED 3" ON SIZES 08, 10, 12 ONLY. HIGH STATIC MOTOR/BLOWER ASSEMBLIES UTILIZED.
M. ** CABINET SIZE ON 08 HIGH STATIC MODELS IS 24" X 24".

ITEM	DESCRIPTION	QTY
1	MOTOR, 3 SPEED, PSC, SERIES 'L'	1
2	COIL 1/2" O.D. COPPER TUBE	1
3	RISER, DRAIN, (COPPER)	1
4	RISER, SUPPLY & RETURN (COPPER)	2/4
5	CONTROL BOX	1
6	SUPPLY AIR OPENING(S)	
7	DUCT COLLAR, 1/2' EXTENSION (TYPCIAL)	
8	CONTROL OPENING (SURFACE MOUNT STAT)	1
8a	KNOCKOUT (FOR OPTIONAL REMOTE MOUNTING)	2
9	AIR VENT, MANUAL	1
10	RETURN AIR OPENING	1
11	3" EXPANDED SECTION	3/5
12	FILTER, THROWAWAY, 1', (F&I)	1
13	FLEXIBLE DRAIN TUBE/P-TRAP	1
14	BLOWER	1
15	DRAIN PAN	1
16	ACCESS PANEL (CONTROL BOX)	1
17	STRIP HEATER (OPTIONAL)	1
18	LIMIT SWITCH, (F&I) (OPTIONAL)	1
19	RISER CHASE (OPTIONAL)	1
20	MOLEX CONNECTOR FOR FIELD INSTALLED STAT	1
21	ELECTRICAL KNOCKOUTS	1
22	1/2" ISOLATION BALL VALVES (F&I)	2/4

☐ *2 - PIPE* ☐ *4 - PIPE*

☐ *2 - PIPE W/ELECTRIC HEAT*

☐ *TOTAL* ☐ *AUXILIARY*

MODEL	SGLE. SUPPLY			DBLE. SUPPLY			TOP SUPPLY			DIMENSIONS					FILTER SIZE
	A	B	SIZE	A	B	SIZE	C	D	SIZE	E	F	G	H	I	
42SGA 03	14	8	14X8	14	6	14X6	14	10	14X10	17	22 3/8	1 1/2	1 1/2	14	12 1/2 X 24 3/4 X 1
42SGA 04	14	12	14X12	14	6	14X6	14	10	14X10	17	22 3/8	1 1/2	1 1/2	14	12 1/2 X 24 3/4 X 1
42SGA 06	18	10	18X10	18	6	18X6	16	12	16X12	20	25 3/8	1	2	18	16 1/2 X 27 1/4 X 1
** 42SGA 08	18	12	18X12	18	6	18X6	16	12	16X12	20	25 3/8	1	2	18	16 1/2 X 27 1/4 X 1
42SGA 10				22	8	22X8	18	16	18X16	24	29 3/8	1	3	22	20 1/2 X 29 1/2 X 1
42SGA 12				22	8	22X8	18	16	18X16	24	29 3/8	1	3	22	20 1/2 X 29 1/2 X 1

JOB NUMBER

FILE NAME

DRAWN BY TNW

DRAWING NUMBER | REVISION | SHEET

Carrier

Unit Parameters

Tag Name:	**FCU-2**	
Quantity:	**1**	
Unit Model:	**42SGA04**	
Unit Type:	**42SGA Concealed Modular Unit**	
Unit Size:	**400**	
System Type:	**4-Pipe Heating and Cooling**	
Cooling Coil:	**Cold Fluid Cooling**	
Cooling Coil Rows:	**3 Rows**	
Heating Coil:	**Hot Fluid Heating**	
Heating Coil Rows:	**1 Row**	
Shipping Options:	**Standard**	
Fan Speed:	**High**	
Motor/Drive:	**Standard**	

Unit Performance

Actual Airflow:	**400.0**	CFM
Altitude:	**0**	ft
External Static Pressure:	**.15**	in wg
Voltage:	**208-1-60**	V-Ph-Hz

Cooling Data

Coil Type:	**Cold Fluid Cooling**	
Coil Rows:	**3 Rows**	
Fluid Type:	**Fresh Water**	
Total Capacity:	**13877**	BTU/hr
Sensible Capacity:	**9924**	BTU/hr
Entering Air Dry Bulb Temperature:	**80.0**	F
Entering Air Wet Bulb Temperature:	**67.0**	F
Leaving Air Dry Bulb Temperature:	**57.3**	F
Leaving Air Wet Bulb Temperature:	**55.9**	F
Fluid Flow Rate:	**2.3**	gpm
Fluid Pressure Drop:	**26.37**	ft wg
Fluid Entering Temperature:	**44.0**	F
Fluid Leaving Temperature:	**56.0**	F

Heating Data

Coil Type:	**Hot Fluid Heating**	
Coil Rows:	**1 Row**	
Fluid Type:	**Fresh Water**	
Sensible Capacity:	**21020**	BTU/hr
Entering Air Temperature:	**60.0**	F
Leaving Air Temperature:	**108.1**	F
Fluid Flow Rate:	**2.1**	gpm
Fluid Pressure Drop:	**5.46**	ft wg
Fluid Entering Temperature:	**180.0**	F
Fluid Leaving Temperature:	**160.0**	F

Electrical Data

Motor Voltage:	**208-1-60**	V-Ph-Hz
Motor Nominal HP:	**1/20**	hp
Total Motor Watts:	**114**	
Total Motor Amps:	**0.6**	

Acoustical Data

N/A

Sound Power 125 dB:	**69**
Sound Power 250 dB:	**59.5**
Sound Power 500 dB:	**55.5**
Sound Power 1000 dB:	**50.5**
Sound Power 2000 dB:	**41.5**

Sound Power 4000 dB:................................ **39.5**
Sound Power 8000 dB:................................ **36.5**
Sound A Weight in dB: **58**

Factory-Installed Options

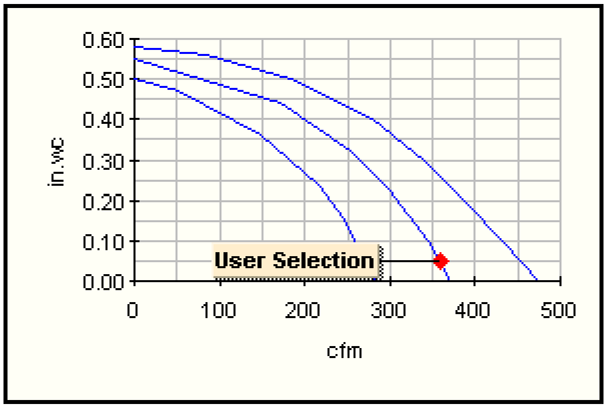
Coil Connections: .... **Same end**
Return:.. **Front Return**
Supply: .... **Front Supply**
Filters:.. **1 in. Throwaway Glass-Fiber**
Drain Pans:.. **Standard Main Drain Pan**
Return Air Options: .... **Bar Type Alum Finish (#3)**
Cabinet Size: .... **Standard Cabinet Size (17 in.)**
Cabinet Height:.. **Std.**
AAV / Drains:.. **Manual Air Vents only**
Control Packages: .... **Field Supplied/Inst Remote-Mtd Therm**
Single Power Source:.. **No**
Riser Chase:.. **Full Riser Chase**
Riser Piping Order:.. **Std.**

ENVIRO-TEC
ENGINEERING FOR EXCELLENCE

Project Name: PSU Arch Project
Line #: 1 Tag:
Date: 3/30/2006 8:45:34 AM ET Selection Version: 1.0.7
Selection Method: Fixed ESP/Nominal Airflow Elevation: 0 ft.
Notes:

General												
Mfg	Model	Unit Size	Airflow (cfm)	ESP (in.wc)	Motor (Hp)	Motor RPM	Fan Amps	Fan Watts	Fan Qty	V/P/Hz	Motor Speed	Weight* (lb)
Enviro-Tec	VHC	04	358	0.05	(1) 1/25	800	1	118	1	115/1/60	Medium	254

* Weight does not include accessories.



Fan selection and performance is shown at elevation of 0 ft.

Chilled Water Coil												
EAT DB/WB (deg.F)	LAT DB/WB (deg.F)	Total Capacity (Btuh)	Sensible Capacity (Btuh)	EWT/LWT (deg.F)	Fluid Flow (gpm)	Fluid PD (ft.)	Air PD (in.wc)	Coil Rows	Coil FPI	No. Circuits	Fin Material	Tube Wall
75 / 63	55.2 / 53.4	9992	7688	44 / 56	1.66	4.38	0.08	3	14	2	0.0055 in. Al	0.016 in.

Hot Water Coil											
EAT DB (deg.F)	LAT DB (deg.F)	Sensible Capacity (Btuh)	EWT/LWT (deg.F)	Fluid Flow (gpm)	Fluid PD (ft.)	Air PD (in.wc)	Coil Rows	Coil FPI	No. Circuits	Fin Material	Tube Wall
70	123.2	20630	180 / 160	2.12	11.07	0.02	1	14	1	0.0055 in. Al	0.016 in.

Sound Power By Octave Band (dB Re 10^{-12} Watts)							
Band	2	3	4	5	6	7	8
Frequency	125	250	500	1000	2000	4000	8000
Total	52	45	42	36	35	27	27

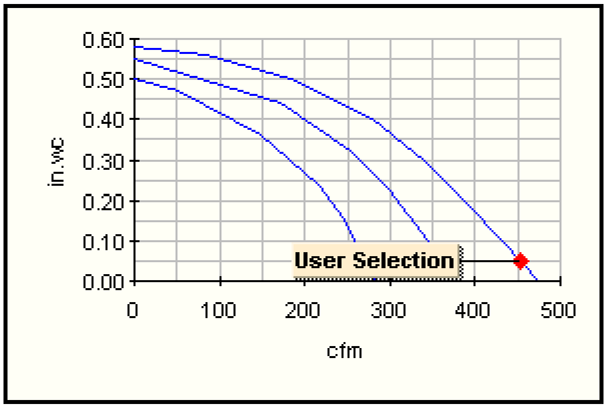
- Unit data is certified in accordance with ARI 440.
- Coils are manufactured in accordance with ARI 410.
- Sound data tested in accordance with ARI 350-2000.
  - Total sound power level data based on Model VHC with fan CFM at corresponding motor tap with 115/1/60 volt motor, 4 row coil, 1" throwaway filter, 0.05" external static pressure and standard rated internal pressure losses.
- Unit pressure drop and CFM based upon dry coil as required by ARI 440.
- Scheduled motor information is for Hi Speed.
- The coil selection has been made at Standard conditions.
- Outside Airflow is a user input value for scheduling purposes.

ENVIRO-TEC
ENGINEERING FOR EXCELLENCE

Project Name: PSU Arch Project
Line #: 2 Tag: FCU-2
Date: 3/30/2006 8:46:32 AM ET Selection Version: 1.0.7
Selection Method: Fixed ESP/Nominal Airflow Elevation: 0 ft.
Notes:

General													
Mfg	Model	Unit Size	Airflow (cfm)	ESP (in.wc)	Motor (Hp)	Motor RPM	Fan Amps	Fan Watts	Fan Qty	V/P/Hz	Motor Speed	Weight* (lb)
Enviro-Tec	VHC	04	454	0.05	(1) 1/25	800	1	118	1	115/1/60	High	254

* Weight does not include accessories.



Fan selection and performance is shown at elevation of 0 ft.

Chilled Water Coil												
EAT DB/WB (deg.F)	LAT DB/WB (deg.F)	Total Capacity (Btuh)	Sensible Capacity (Btuh)	EWT/LWT (deg.F)	Fluid Flow (gpm)	Fluid PD (ft.)	Air PD (in.wc)	Coil Rows	Coil FPI	No. Circuits	Fin Material	Tube Wall
75 / 63	56.2 / 54.1	11854	9263	44 / 56	1.97	5.43	0.12	3	14	2	0.0055 in. Al	0.016 in.

Hot Water Coil											
EAT DB (deg.F)	LAT DB (deg.F)	Sensible Capacity (Btuh)	EWT/LWT (deg.F)	Fluid Flow (gpm)	Fluid PD (ft.)	Air PD (in.wc)	Coil Rows	Coil FPI	No. Circuits	Fin Material	Tube Wall
70	119.7	24423	180 / 160	2.5	15.31	0.02	1	14	1	0.0055 in. Al	0.016 in.

Sound Power By Octave Band (dB Re 10^{-12} Watts)							
Band	2	3	4	5	6	7	8
Frequency	125	250	500	1000	2000	4000	8000
Total	57	49	47	40	36	30	27

- Unit data is certified in accordance with ARI 440.
- Coils are manufactured in accordance with ARI 410.
- Sound data tested in accordance with ARI 350-2000.
  - Total sound power level data based on Model VHC with fan CFM at corresponding motor tap with 115/1/60 volt motor, 4 row coil, 1" throwaway filter, 0.05" external static pressure and standard rated internal pressure losses.
- Unit pressure drop and CFM based upon dry coil as required by ARI 440.
- Scheduled motor information is for Hi Speed.
- The coil selection has been made at Standard conditions.
- Outside Airflow is a user input value for scheduling purposes.

Appendix H – Typical Guest Room Lighting Renderings

Base Case – Incandescent Lamps

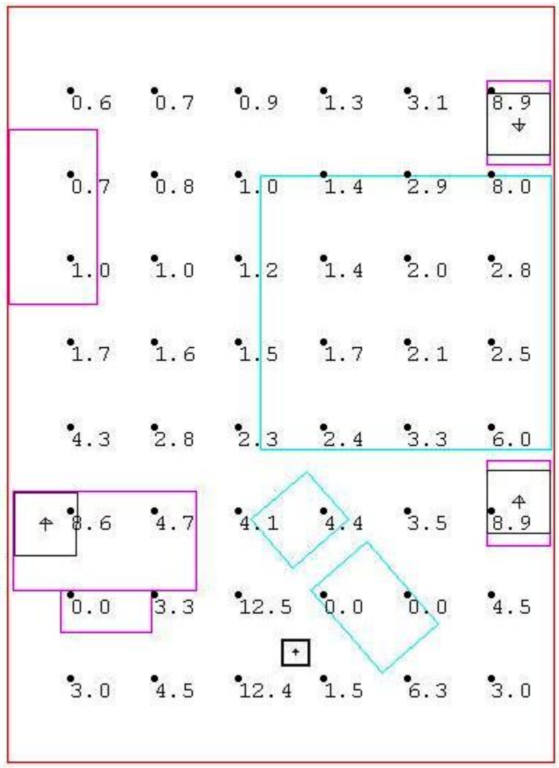


Figure H1 - Base Case Plan (footcandles)

Figure H2 - Base Case Rendering

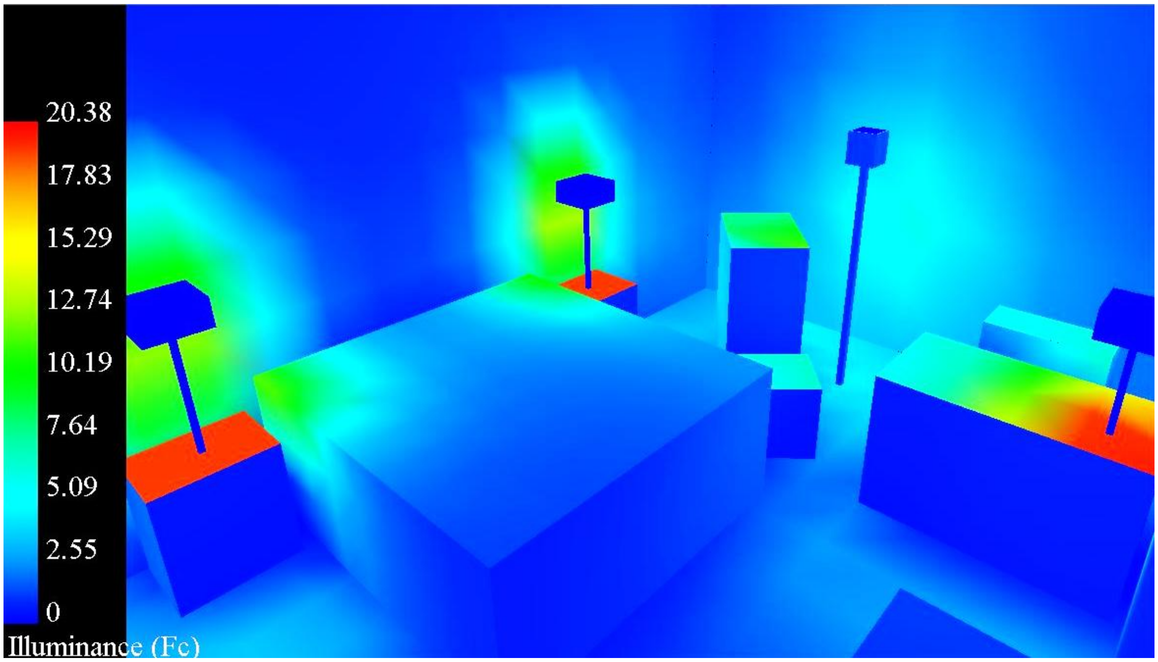


Figure H3 - Base Case Illuminance

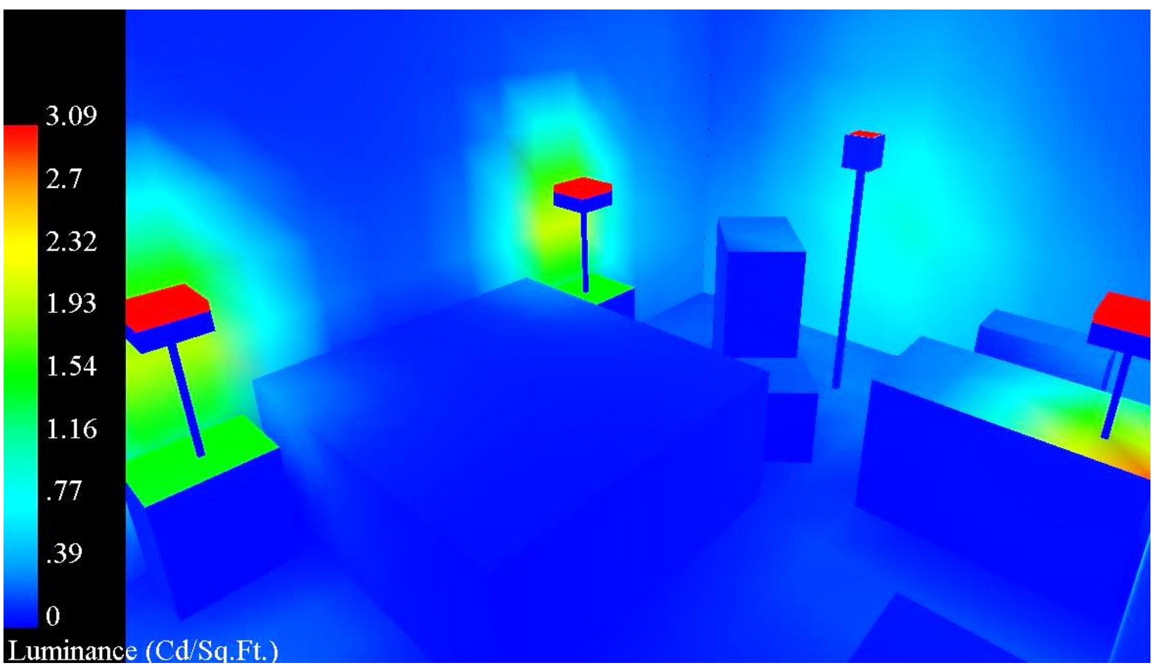


Figure H4 - Base Case Luminance

Option 1 – Compact Fluorescent Lamps

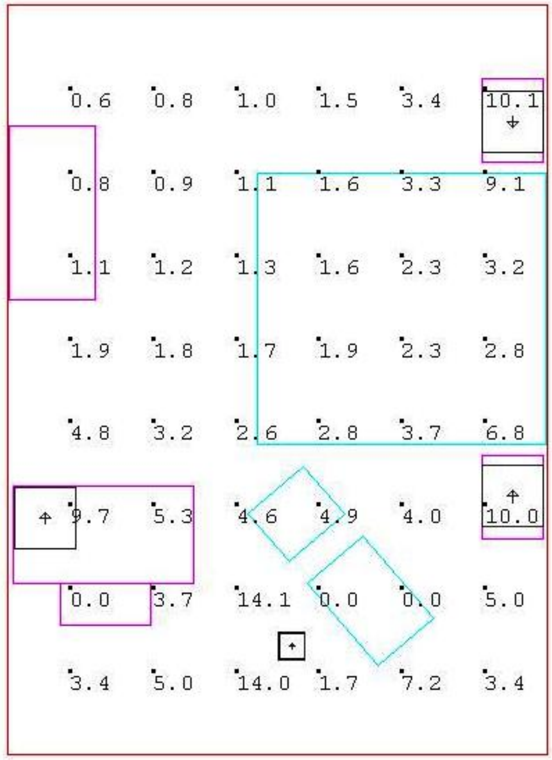


Figure H5 - Option 1 Plan (footcandles)

Figure H6 - Option 1 Rendering

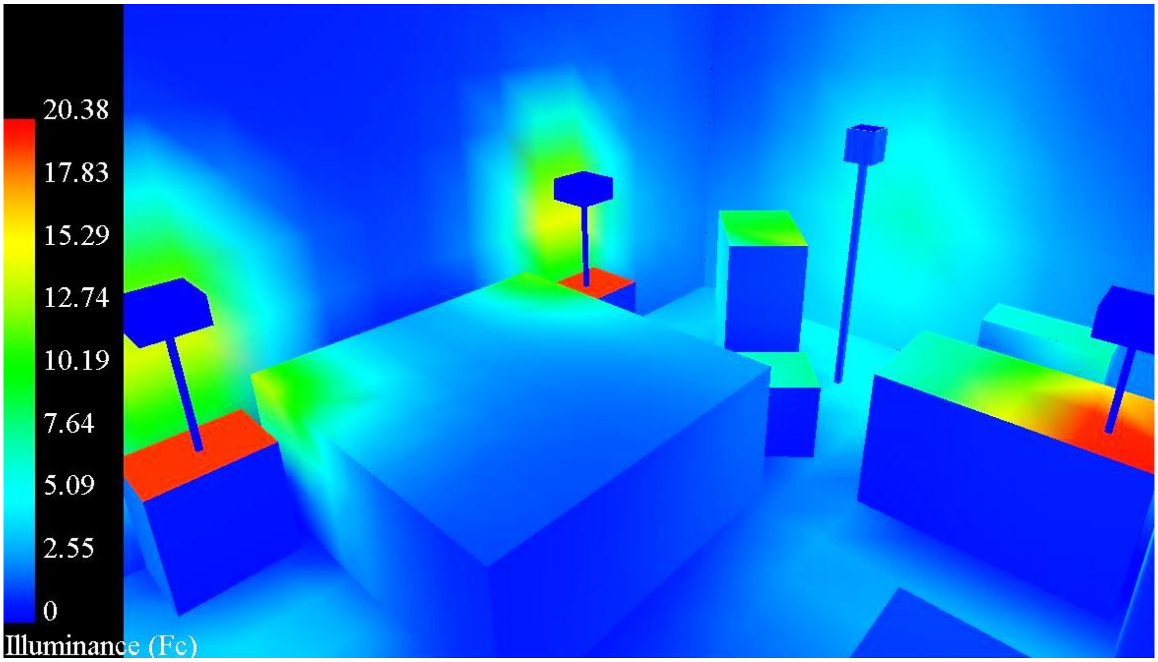


Figure H7 - Option 1 Illuminance

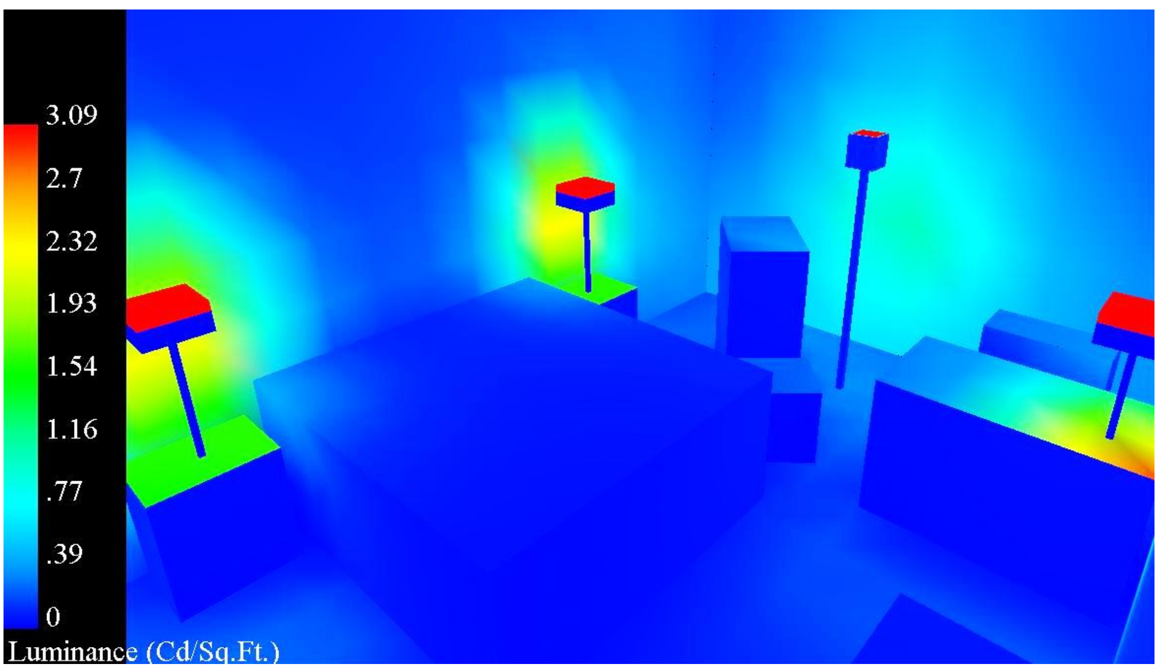


Figure H8 - Option 1 Luminance

Option 4 – Surface Mounted Spectral Fluted Disk

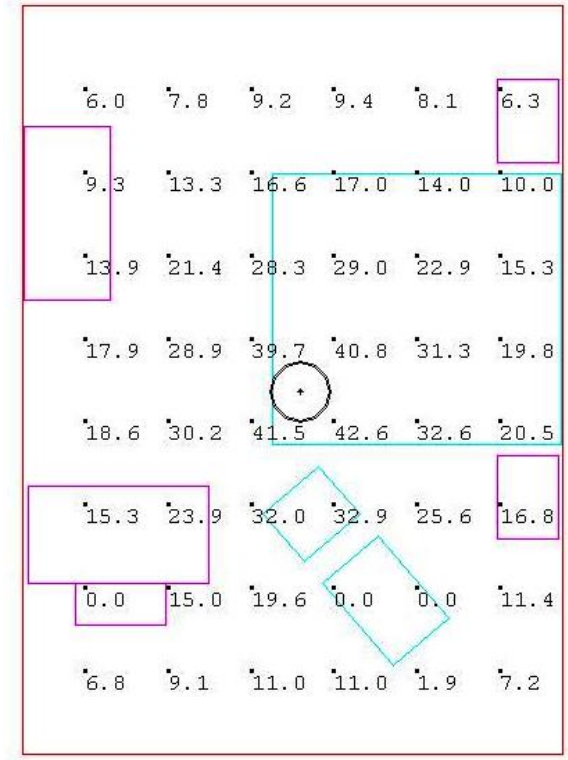


Figure H9 - Option 4 Plan (footcandles)

Figure H10 - Option 4 Rendering

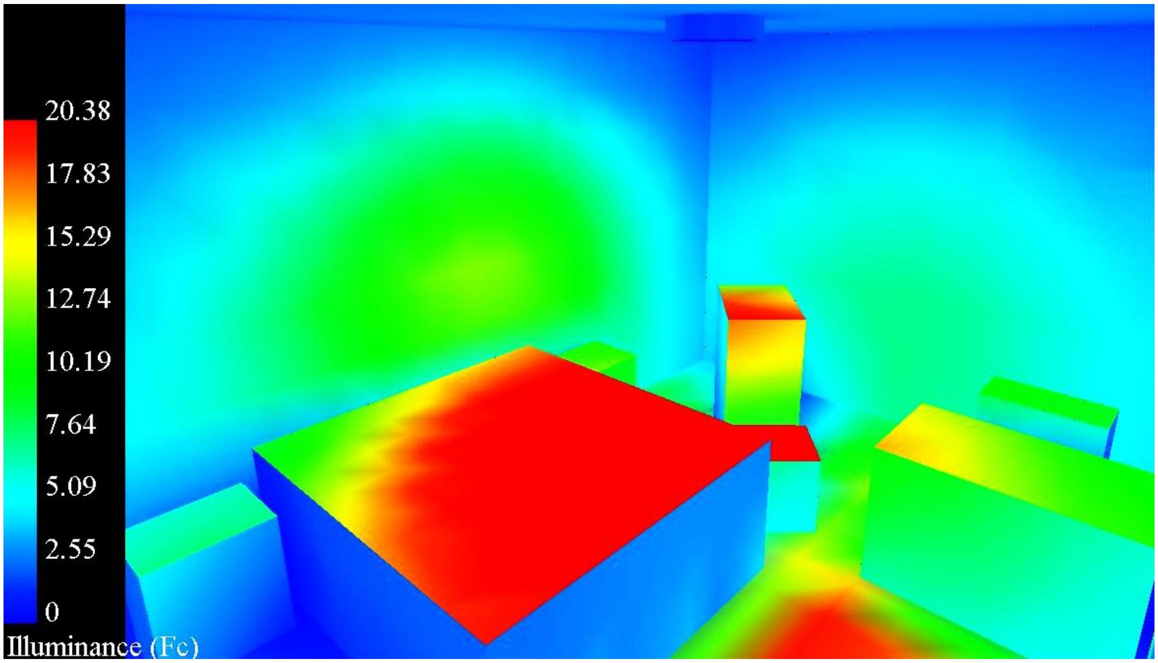


Figure H11 - Option 4 Illuminance

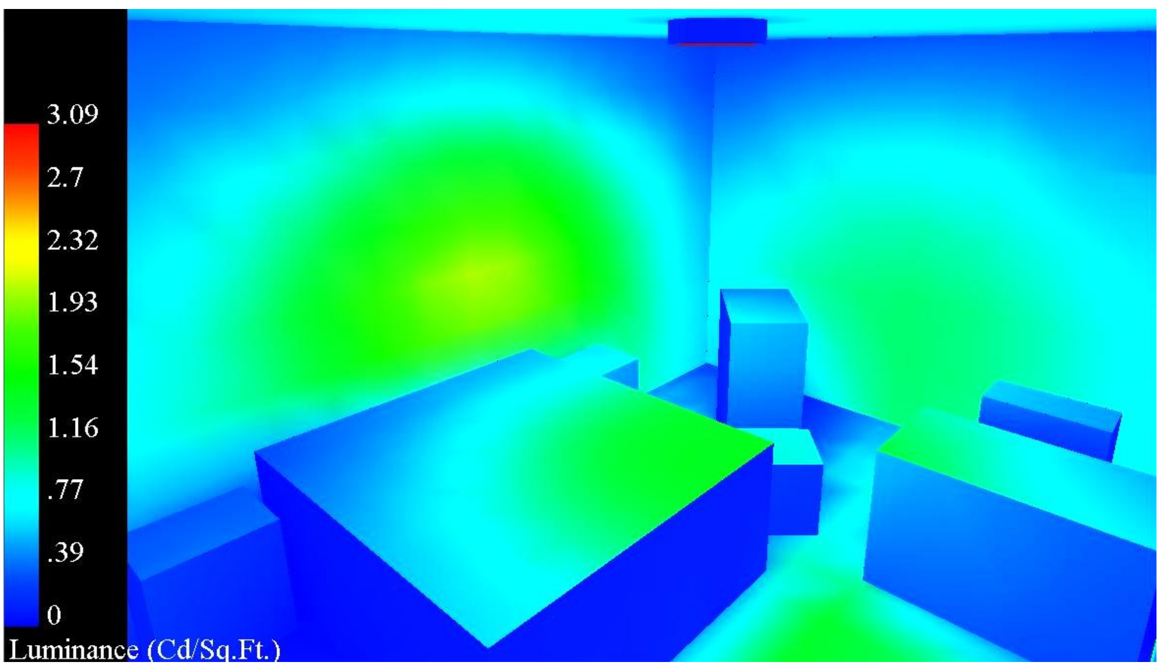


Figure H12 - Option 4 Luminance

Option 6 – Ceiling Fixture with Task Lighting

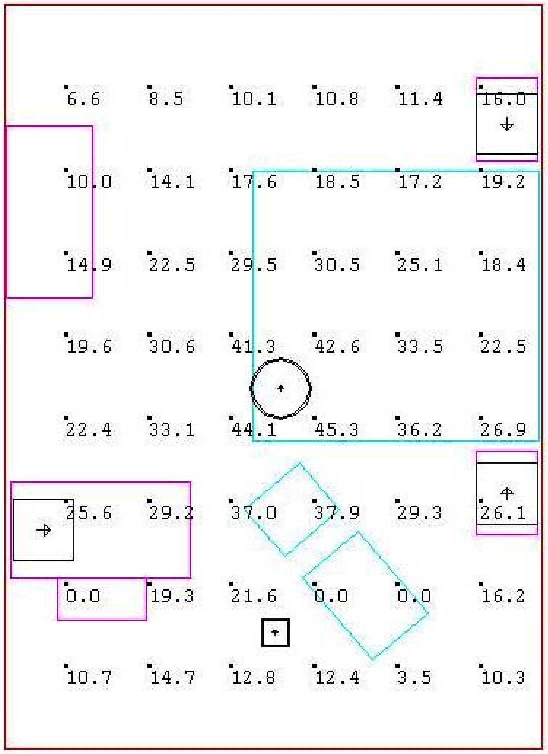


Figure H13 - Option 6 Plan (footcandles)

Figure H14 - Option 6 Rendering

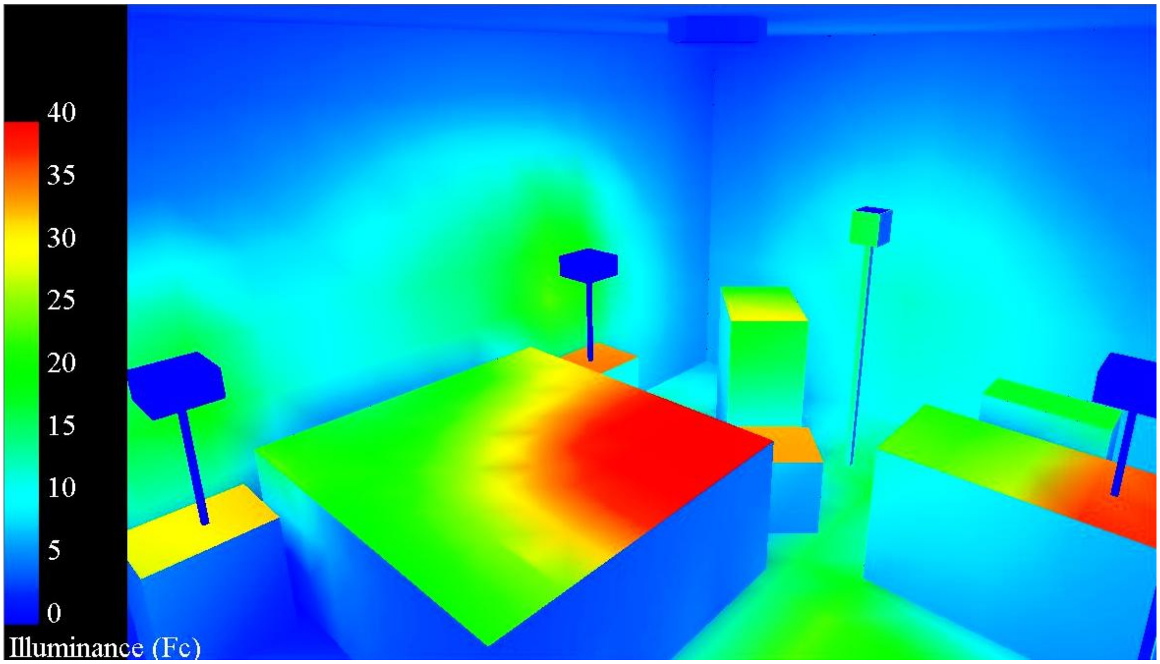


Figure H15 - Option 6 Illuminance

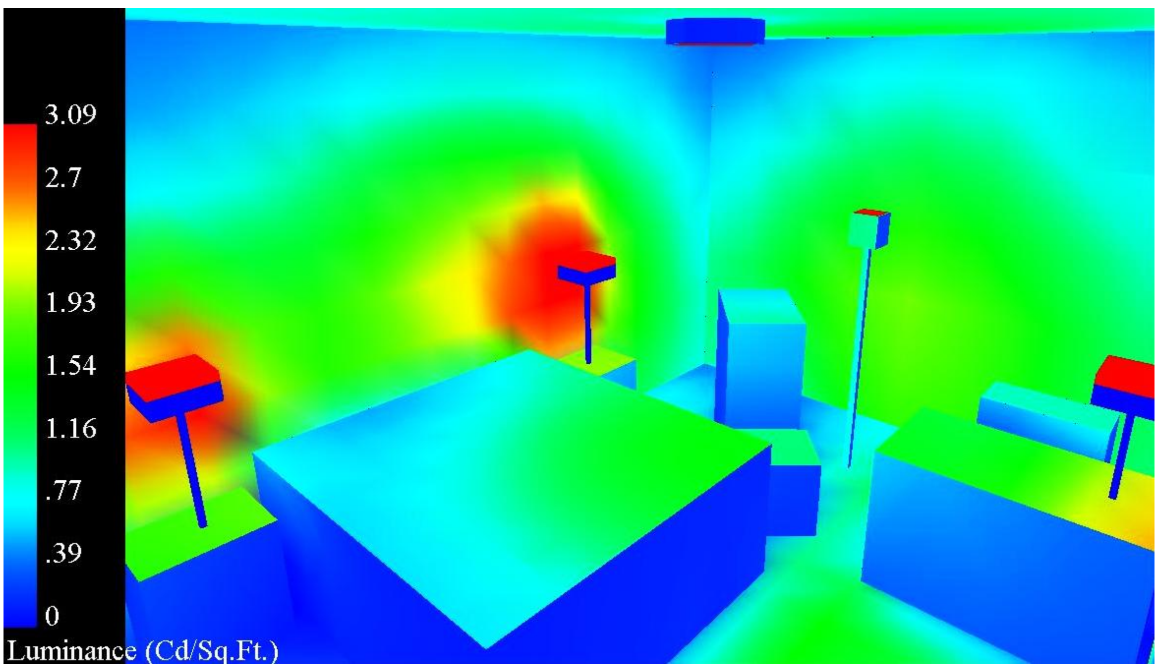


Figure H16 - Option 6 Luminance

Appendix J – Lighting Selection

This appendix contains the cut sheets and other data for the manufacturer information provided for the lighting fixtures and lamps used as a part of the lighting breadth work. There is data from Philips and Lightolier included.

Please see the all the lighting information on the following pages.

DuraMax™ LONG LIFE SOFT WHITE

Ideal for table and floor lamps

Lasts At Least One Year!*

Tired of changing light bulbs that burn out too frequently? DuraMax™ Soft White light bulbs now last at least one year!

Provides Soft White Light

Ideal for use in table and floor lamps.

Consumer Friendly Packaging

Fresh, new packaging graphics make life, lumen and wattage information easy to find and read.

Full Family of Products

Available in a variety of wattages, as well as popular 3-Way versions.

** See back page for details.*

PHILIPS

Philips Lighting Company
200 Franklin Square Drive
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Somerset, NJ 08875-6800
1-800-555-0050
A Division of Philips Electronics North America Corporation

www.philips.com

Philips Lighting
281 Hillmount Road
Markham, Ontario
Canada L6C 2S3
1-800-555-0050
A Division of Philips Electronics Ltd.

Updated 7/04 P-8493

DuraMax™ Long Life Soft White

Electrical, Technical and Ordering Data (Subject to change without notice)

DuraMax Product Number	Previous Product Number	Product Description	Bulb Finish	Nominal Watts	Bulb Type	Base Type	Volts	Published Lumens	Rated Avg Life (Hrs.)	Life, In Years*	M.O.L (In.)	Operating Position
A-Line Single Wattages												
168609	302562	15A/WL 120V 12/2	Soft White	15	A-15	MED.	120	115	3000	2	3 1/2	ANY
168682	204339	25A/WL 120V 12/2	Soft White	25	A-19	MED.	120	235	3000	2	4 7/16	ANY
168690	263723	40A/WL 120V 12/4	Soft White	40	A-19	MED.	120	475	1500	1	4 7/16	ANY
167379	297754	40A/WL 120V 24/4	Soft White	40	A-19	MED.	120	475	1500	1	4 7/16	ANY
168740	263764	60A/WL 120V 12/4	Soft White	60	A-19	MED.	120	830	1500	1	4 7/16	ANY
167387	266023	60A/WL 120V 24/4	Soft White	60	A-19	MED.	120	830	1500	1	4 7/16	ANY
168765	312140	60A/WL/TP SR2 120V 12/8	Soft White	60	A-19	MED.	120	830	1500	1	4 7/16	ANY
168799	263814	75A/WL 120V 12/4	Soft White	75	A-19	MED.	120	1040	1500	1	4 7/16	ANY
167395	266031	75A/WL 120V 24/4	Soft White	75	A-19	MED.	120	1040	1500	1	4 7/16	ANY
168815	312157	75A/WL/TP SR2 120V 12/8	Soft White	75	A-19	MED.	120	1040	1500	1	4 7/16	ANY
168625	263822	100A/WL 120V 12/4	Soft White	100	A-19	MED.	120	1550	1500	1	4 7/16	ANY
167403	266064	100A/WL 120V 24/4	Soft White	100	A-19	MED.	120	1550	1500	1	4 7/16	ANY
168633	312173	100A/WL/TP SR2 120V 12/8	Soft White	100	A-19	MED.	120	1550	1500	1	4 7/16	ANY
168666	204438	150A/WL 120V 12/1	Soft White	150	A-21	MED.	120	2310	2000	1	5 5/16	ANY
168674	389395	200A/WL 120V 6/1	Soft White	200	A-21	MED.	120	3300	1500	1	5 5/16	ANY
168674	204479	200A/WL 120V 6/1	Soft White	200	A-21	MED.	120	3300	1500	1	5 5/16	ANY
Case Pk—Single Wattage												
168773	391540	60A/WL 120V 120/4	Soft White	60	A-19	MED.	120	830	1500	1	4 7/16	ANY
168823	389403	75A/WL 120V 120/4	Soft White	75	A-19	MED.	120	1040	1500	1	4 7/16	ANY
168641	389387	100A/WL 120V 120/4	Soft White	100	A-19	MED.	120	1550	1500	1	4 7/16	ANY
Display—Single Wattage												
167189	291716	PAM60AWL 60/75/100 120V 1/240	Soft White	60, 75, 100	A-19	MED.	120	830, 1040, 1550	1500	1	4 7/16	ANY
A-Line—3-Way Wattages												
169474	204511	30/100A/WL 120V 12/1	Soft White	30/70/100	A-21	3CT. MED.	120	285/920/1205	1750	1	5 5/16	BASE DOWN
169482	204537	50/150A/WL 120V 12/1	Soft White	50/100/150	A-21	3CT. MED.	120	575/1440/2015	1750	1	5 5/16	BASE DOWN
169565	293597	50/150A/WL 120V 12/2	Soft White	50/100/150	A-21	3CT. MED.	120	575/1440/2015	1750	1	5 5/16	BASE DOWN
169532	267963	50/150A/WL 120V 4/3	Soft White	50/100/150	A-21	3CT. MED.	120	575/1440/2015	1750	1	5 5/16	BASE DOWN
169490	204545	50/250A/WL 120V 12/1	Soft White	50/200/250	A-21	3CT. MED.	120	575/3120/3695	1750	1	5 5/16	BASE DOWN
Display—3 Way Wattage												
167171	277533	50/150A/WL 120V 48/1	Soft White	50/100/150	A-21	3CT. MED.	120	575/1440/2015	1750	1	5 5/16	BASE DOWN

Shipping Data (Subject to change without notice)

DuraMax Product Number	Product Description	UPC Code 0 46677	Outer Bar Code 5 00 46677	Lamps Per SKU	Case Qty. Per SKU	Case Wt. (lbs.)	Case Cube (cu. ft.)	Pallet Qty. Per SKU	Pallet Qty. Per Case	Pallet Wt. (lbs.)	Pallet Cube (cu. ft.)	SKUs Per Layer	Layers High	SKU Dimension (in.) W x D x H	Case Dimension (in.) W x D x H	Pallet Dimension (in.) W x D x H
A-Line Single Wattages																
168609	15A/WL 120V 12/2	16860 5	16860 0	2	12/2	2	0.22	2520	210	420.0	46.20	252	10	3.4 x 2.1x x3.6	13.1 x 7.1 x 4.2	49.4 x 39.2 x 41.9
168682	25A/WL 120V 12/2	16868 1	16868 6	2	12/2	2	0.39	1800	150	300.0	58.50	180	10	3.9 x 2.6 x 4.6	16.1 x 8.1 x 5.2	48.4 x 40.7 x 51.9
168690	40A/WL 120V 12/4	16869 8	16869 3	4	12/4	4	0.65	1008	84	336.0	54.60	144	7	4.9 x 2.5 x 6.5	15.4 x 10.4 x 7.0	46.1 x 41.5 x 49.0
167379	40A/WL 120V 24/4	16869 8	16737 5	4	24/4	9	1.25	864	36	324.0	45.00	288	3	4.9 x 2.5 x 6.5	15.4 x 10.4 x 13.5	46.1 x 41.5 x 40.5
168740	60A/WL 120V 12/4	16874 2	16874 7	4	12/4	4	0.65	1008	84	336.0	54.60	144	7	4.9 x 2.5 x 6.5	15.4 x 10.4 x 7.0	46.1 x 41.5 x 49.0
167387	60A/WL 120V 24/4	16874 2	16738 2	4	24/4	9	1.25	864	36	324.0	45.00	288	3	4.9 x 2.5 x 6.5	15.4 x 10.4 x 13.5	46.1 x 41.5 x 40.5
168765	60A/WL/TP SR2 120V 12/8	16876 6	16876 1	8	12/8	9	1.25	432	36	324.0	45.00	144	3	9.8 x 2.5 x 6.5	15.4 x 10.4 x 13.5	46.1 x 41.5 x 40.5
168799	75A/WL 120V 12/4	16879 7	16879 2	4	12/4	4	0.65	1008	84	336.0	54.60	144	7	4.9 x 2.5 x 6.5	15.4 x 10.4 x 7.0	46.1 x 41.5 x 49.0
167395	75A/WL 120V 24/4	16879 7	16739 9	4	24/4	9	1.25	864	36	324.0	45.00	288	3	4.9 x 2.5 x 6.5	15.4 x 10.4 x 13.5	46.1 x 41.5 x 40.5
168815	75A/WL/TP SR2 120V 12/8	16881 0	16881 5	8	12/8	9	1.25	432	36	324.0	45.00	144	3	9.8 x 2.5 x 6.5	15.4 x 10.4 x 13.5	46.1 x 41.5 x 40.5
168625	100A/WL 120V 12/4	16862 9	16862 4	4	12/4	4	0.65	1008	84	336.0	54.60	144	7	4.9 x 2.5 x 6.5	15.4 x 10.4 x 7.0	46.1 x 41.5 x 49.0
167403	100A/WL 120V 24/4	16862 9	16740 5	4	24/4	9	1.25	864	36	324.0	45.00	288	3	4.9 x 2.5 x 6.5	15.4 x 10.4 x 13.5	46.1 x 41.5 x 40.5
168633	100A/WL/TP SR2 120V 12/8	16863 6	16863 1	8	12/8	9	1.25	432	36	324.0	45.00	144		9.8 x 2.5 x 6.5	15.4 x 10.4 x 13.5	46.1 x 41.5 x 40.5
168666	150A/WL 120V 12/1LP	16866 7	16866 2	1	12/1	1.9	0.38	1536	128	243.2	48.64	192	8	2.8 x 2.8 x 5.4	11.9 x 9.1 x 6.1	47.5 x 36.2 x 49.0
168674	200A/WL 120V 6/1	16867 4	16867 9	1	6/1	1.4	0.20	1536	256	358.4	51.20	192	8	2.8 x 2.8 x 5.4	9.2 x 6.1 x 6.1	49.0 x 36.8 x 49.0
Case Pk—Single Wattage																
168773	60A/WL 120V 120/4	16874 2	16877 8	4	120/4	43	6.87	720	6	258.0	41.22	720	1	4.9 x 2.5 x 6.5	21.0 x 16.8 x 33.8	50.3 x 42.0 x 33.8
168823	75A/WL 120V 120/4	16879 7	16882 2	4	120/4	43	6.87	720	6	258.0	41.22	720	1	4.9 x 2.5 x 6.5	21.0 x 16.8 x 33.8	50.3 x 42.0 x 33.8
168641	100A/WL 120V 120/4	16862 9	16864 8	4	120/4	43	6.87	720	6	258.0	41.22	720	1	4.9 x 2.5 x 6.5	21.0 x 16.8 x 33.8	50.3 x 42.0 x 33.8
Display—Single Wattage																
167189	PAM60AWL 60/75/100 120V 1/240	**	16718 4	4	60/4	22.6	3.22	720	12	271.2	38.64	180	4	4.9 x 2.5 x 6.5	32.9 x 15.4 x 11.0	46.1 x 32.9 x 44.0
A-Line—3 Way Wattages																
169474	30/100A/WL 120V 12/1	16947 3	16947 8	1	12/1	1.9	0.38	1536	128	243.2	48.64	192	8	2.8 x 2.8 x 5.4	11.9 x 9.1 x 6.1	47.5 x 36.2 x 49.0
169482	50/150A/WL 120V 12/1	16948 0	16948 5	1	12/1	1.9	0.38	1536	128	243.2	48.64	192	8	2.8 x 2.8 x 5.4	11.9 x 9.1 x 6.1	47.5 x 36.2 x 49.0
169565	50/150A/WL 120V 12/2	16956 5	16956 0	2	12/2	3	0.56	1152	96	288.0	53.76	144	8	4.3 x 2.8 x 5.6	13.1 x 12.1 x 6.1	48.2 x 39.2 x 49.0
169532	50/150A/WL 120V 4/3	16953 4	16953 5	3	4/3	1.9	0.38	1536	128	243.2	48.64	64	8	2.8 x 2.8 x 5.4	11.9 x 9.1 x 6.1	47.5 x 36.2 x 49.0
169490	50/250A/WL 120V 12/1	16949 7	16949 2	1	12/1	1.9	0.38	1536	128	243.2	48.64	192	8	2.8 x 2.8 x 5.4	11.9 x 9.1 x 6.1	47.5 x 36.2 x 49.0
Display—3 Way Wattage																
167171	50/150A/WL 120V 48/1	16948 0	16717 7	1	48/1	10.6	2.59	720	15	159.0	38.85	144	5	2.8 x 2.8 x 5.4	14.8 x 11.9 x 17.3	47.8 x 41.6 x 51.9

* Based on 4 hours usage per day/7 days per week

** See "Case Pk— Single Wattage" for UPC code of each product.

PHILIPS

Marathon™
ENERGY SAVER TABLE LAMP

Ideal for table and standing floor lamps

- **Provides Soft, White Light**
- **Fits into Standard Incandescent Sockets**
- **Super Long Life**
  Lasts 5 years, based on 3–4 hours average daily usage, 7 days per week (up to 7 times longer than standard incandescent lamps)
- **Energy Savings**
  Saves up to 70% in electricity costs compared to standard incandescent lamps
- **ENERGY STAR® Qualified**
  For more information on ENERGY STAR, visit www.energystar.gov

ENERGY STAR

PHILIPS

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Updated 7/04 P-5171-E

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A Division of Philips Electronics Ltd.

Marathon™ Table Lamp

Electrical, Technical and Ordering Data (Subject to change without notice)

Product Number	Description	Volts	Nom. Watts	Approx. Incand. Equiv./Lumens	Base	Color Temp. (Kelvin)	CRI	Approx. Initial Lumens	MOL (In.)	Rated Avg. Life (Hrs.)[1]	Min. Starting Temp. (°F)[2]	Max. Ambient Temp. (°F)	Lumen Maint.[3]
37082-5	Marathon Table Lamp EL/T 34	120	34	120W/1848	Med. (E26)	2700K	82	2100	6.2	7000	-10°F/-20°C	120°F/48°C	85%
37084-1	Marathon Table Lamp BC-EL/T 34	120	34	120W/1848	Med. (E26)	2700K	82	2100	6.2	7000	-10°F/-20°C	120°F/48°C	85%
37086-6	Marathon Table Lamp BC-EL/T 34 Canada	120	34	120W/1848	Med. (E26)	2700K	82	2100	6.2	7000	-10°F/-20°C	120°F/48°C	85%

Shipping Data

Product Number	SKU UPC (0-46677)	Outer Bar Code (5-00-46677)	Case Qty.	Case Weight (lbs.)	Case Cube (cu. ft.)	Pallet Qty.	SKUs Per Layer	Layers High	SKU Dimensions (W x D x H) (In.)	Case Dimensions (W x D x H) (In.)	Pallet Dimensions (W x D x H) (In.)
37082-5	37082-4	37082-9	6	2.0	0.20	1440	240	6	2.6 x 2.6 x 6.3	5.8 x 8.3 x 7.3	45.5 x 41.5 x 43.9
37084-1	37084-8	37084-3	6	3.0	0.67	384	96	4	5.36 x 2.69 x 9.91	6.1 x 18.1 x 10.6	36.3 x 48.5 x 42.3
37086-6	37084-8	37086-7	6	3.0	0.67	384	96	4	5.36 x 2.69 x 9.91	6.1 x 18.1 x 10.6	36.3 x 48.5 x 42.3

1) Do not use in recessed cans or totally enclosed indoor fixtures. Use base down only.
2) Suitable for indoor or outdoor use down to -10°F. UL listed for damp locations. Outdoor use requires an enclosed or weather-protected fixture.
3) Percentage of initial lumens at 40% of rated average life (2800 hours).

Marathon™

Bulb Type	Bulb Shape	Wattage Comparison*	Table/Floor Lamps	Outdoor Post Lights	Wall Sconce	Surface Mount	Enclosed Indoor Fixture	Reading Lamp	Border Lights	Recessed Lighting	Open Hanging	Bare Bulb	Vanity Strip
UNIVERSAL		15/20/25 = 60/75/100	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
DECO. TWISTER		15/20/23 = 60/75/90	✓		✓			✓			✓	✓	
MINI-DECO. TWISTER		15 = 60	✓		✓			✓			✓	✓	
HOUSEHOLD		20 = 75	✓	✓	✓			✓			✓	✓	
MINI-HOUSEHOLD		16 = 60	✓	✓	✓			✓	✓		✓	✓	
3-WAY		18/26/34 = 60/90/150	✓										
DIMMABLE		15/20/23 = 60/75/90	✓		✓					✓		✓	
TABLE		34 = 120	✓		✓			✓					
OUTDOOR		15 = 60 18 = 75		✓							✓	✓	
BUG-A-WAY		15 = 60		✓							✓	✓	
FLOOD		15 = 65 20 = 85								✓	✓	✓	
REFLECTOR FLOOD		16 = 65								✓	✓	✓	
DIMMABLE FLOOD		20 = 85								✓	✓	✓	
DÉCOR GLOBE		16 = 75 20 = 100									✓	✓	✓
VANITY GLOBE		12 = 40									✓	✓	✓

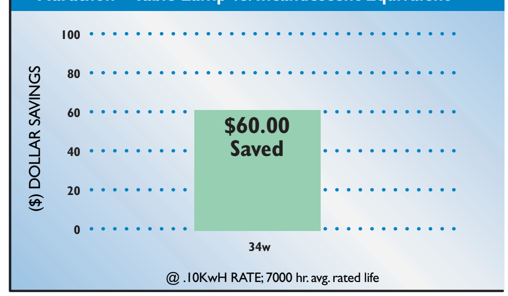
*Comparison shows Marathon wattage(s) and their equivalent to standard incandescent bulb wattages(s).

CAUTION: Risk of electric shock—do not use where directly exposed to water, rain or snow. Do not use with dimmers.

Before using this product with electronic timing or photocell devices, check to determine whether device is compatible with electronic compact fluorescent lamps. Use with incompatible devices will cause premature lamp failure. Do not use in recessed cans or totally enclosed indoor fixtures. Use base down only.

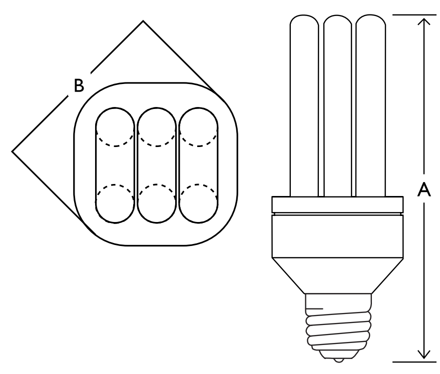
This product complies with Part 18 of the FCC rules. These products may cause interference with radios, cordless telephones, and remote control devices. Interference may cease after a brief 90 second lamp warm-up period. If interference continues, relocate the lamp away from the device or plug into a different outlet.

Energy Cost Savings Over Life, Marathon™ Table Lamp vs. Incandescent Equivalent



Lamp Dimensions

	EL/T 34
MOL **A**	6.2"/157mm
Max. Diameter **B**	2.6"/66mm
Weight (oz./g)	4.8 oz./135g
Lamp Harp Fit	9"



PHILIPS

Philips Marathon® Energy Saver Decorative Twister

Ideal for light fixtures where a smaller bulb size is desired, including table lamps, wall sconces and open ceiling fixtures

Similar Light Output as Standard Incandescent Light Bulbs

Compact Size
Reduced size fits many smaller fixtures

Instant On
Excellent starting performance and fast light run-up time

Super Long Life
Lasts 6 years, based on 3–4 hours average daily usage, 7 days per week (up to 13 times longer than standard incandescent lamps)

Terrific Energy Savings
Saves up to $86 over the life of the lamp compared to standard incandescent lamps[1]—a real impact to your bottom line!

ENERGY STAR® Qualified[2]

1) Energy savings based on 8,000 hours per year at $0.10 kW/hr.
2) As an ENERGY STAR® Partner, Philips has determined that these products meet the ENERGY STAR guidelines for energy efficiency.

PHILIPS

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A Division of Philips Electronics North America Corporation

Printed in USA 09/05 P-8514-B

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A Division of Philips Electronics Ltd.

Philips Marathon™ Energy Saver Decorative Twister

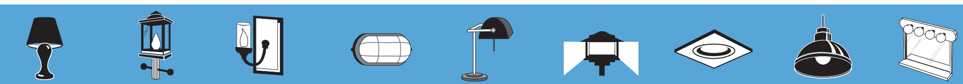
Electrical, Technical and Ordering Data (Subject to change without notice)

Product Number	Description	Volts	Nom. Watts	Approx. Incand. Equiv.	Base	Color Temp. (Kelvin)	CRI	Approx. Initial Lumens[1]	MOL (In.)	Diam. (In.)	Rated Avg. Life (Hrs.)[2]	Power Factor	Lamp Current (mAmps)	Min. Starting Temp.	Max. Ambient Temp.
■ 13804-0	Mini Dec Twister EL/mdT 11W	120	11	40A19	Med.	2700K	82	675	4 9/16	2.65	8000	.50–.60	150	-10°F/-20°C	120°F/48°C
■ 13581-4	Mini Dec Twister EL/mdT 15W	120	15	60A19	Med.	2700K	82	900	4 29/32	2.65	10,000	.50–.60	220	-10°F/-20°C	120°F/48°C
■ 13805-7	Mini Dec Twister EL/mdT 20W	120	20	75A19	Med.	2700K	82	1250	5 5/16	2.65	10,000	.50–.60	290	-10°F/-20°C	120°F/48°C
■ 13715-8	Mini Dec Twister EL/mdT 27W	120	27	100A19	Med.	2700K	82	1750	5 5/16	3.00	10,000	.50–.60	390	-10°F/-20°C	120°F/48°C
13948-5	Decorative Twister EL/dT 42W	120	42	150A19	Med.	2700K	82	2600	7 1/16	3.20	8000	.50–.60	390	-10°F/-20°C	120°F/48°C

Shipping Data (Subject to change without notice)

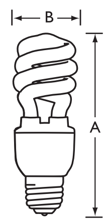
Product Number	SKU UPC (0-46677)	Outer Bar Code (5-00-46677)	Case Qty.	Case Weight (lbs.)	Case Cube (cu. ft.)	Pallet Qty.	SKUs Per Layer	Layers High	SKU Dimensions (W x D x H) (In.)	Case Dimensions (W x D x H) (In.)	Pallet Dimensions (W x D x H) (In.)
■ 13804-0	138042	138047	6	1.2	.55	540	108	5	5.0 x 2.7 x 8.1	5.75 x 18.6 x 8.9	48.8 x 40 x 44.7
■ 13581-4	135812	135817	6	1.2	.55	540	108	5	5.0 x 2.7 x 8.1	5.75 x 18.6 x 8.9	48.8 x 40 x 44.7
■ 13805-7	138059	138054	6	1.2	.55	540	108	5	5.0 x 2.7 x 8.1	5.75 x 18.6 x 8.9	48.8 x 40 x 44.7
■ 13715-8	137151	137156	6	1.2	.55	540	108	5	5.0 x 2.7 x 8.1	5.75 x 18.6 x 8.9	48.8 x 40 x 44.7
13948-5	139483	139488	6	2.7	.93	240	60	4	6.9 x 3.2 x 9.6	10.3 x 21 x 7.3	43.1 x 36.3 x 41

1) Approximate initial lumens. The lamp lumen output is based upon lamp performance after 100 hours of operating life under standard laboratory conditions.
2) Average life under specified test conditions with lamps turned off and restarted no more frequently than once every 3 operating hours. Use in recessed cans or enclosed indoor fixtures could result in reduced lamp life.
■ ENERGY STAR®



Marathon® Bulb Type	Table/Floor Lamp	Outdoor Postlight	Wall Sconce	Surface Mount	Reading Lamp	Border Lights	Recessed Fixture	Open Hanging	Vanity Strip
Decorative Twister	●		●		●			●	
Universal	●	●	●	●	●	●	●	●	
Table Lamps	●		●	●	●			●	
Dimmable	●		●	●	●			●	
3-Way	●								
Reflector Flood							●	●	
Dimmable Reflector Flood							●	●	
Candle		●	●		●				
Vanity & Décor Globe								●	●
Soft White Plus	●	●	●		●	●		●	
Outdoor		●				●		●	
Bug-A-Way		●						●	
Circline Adapter System	●							●	

ENERGY STAR



Lamp Dimensions

	11W	15W	20W	27W	42W
MOL **A**	4.49"	4.49"	5.24"	5.43"	7.08"
Max. Diameter **B**	2.65"	2.65"	2.65"	3.00"	3.20"

CAUTION: Risk of electric shock—do not use where directly exposed to water, rain or snow. Do not use with dimmers.

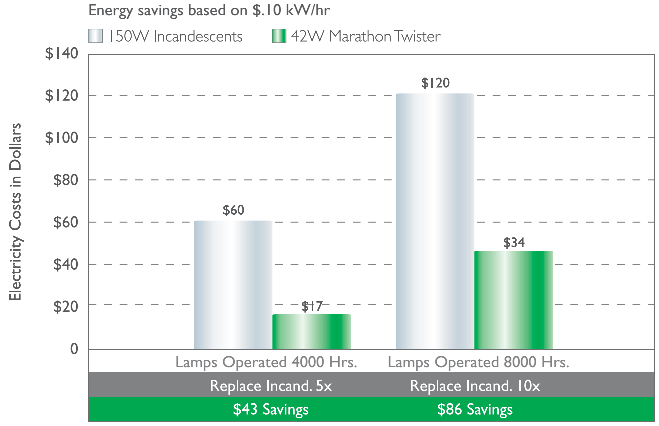
Before using this product with electronic timing or photocell devices, check to determine whether device is compatible with electronic compact fluorescent lamps. Use with incompatible devices will cause premature lamp failure. Do not use in totally enclosed indoor fixtures.

This product complies with Part 18 of the FCC rules. These products may cause interference with radios, cordless telephones, and remote control devices. Interference may cease after a brief 90 second lamp warm-up period. If interference continues, relocate the lamp away from the device or plug into a different outlet.

Energy Cost Savings Over Life

42W Marathon® Twister vs.
150W Standard Incandescent Lamps Operated for an Equivalent Number of Hours

Energy savings based on $.10 kW/hr



SILHOUETTE™ Series
T5 Circular Fluorescent Lamps

Ultra-slim lamps with improved color rendering, higher efficacy and longer life

Ideal for decorative and architectural lighting

Slim Profile Lamp and Ballast
– T5 diameter tube, available in 9" and 12" sizes
– Fixtures can be 45% smaller than T9 Circline systems

Trichromatic Phosphors
– 85 CRI
– 85% lumen maintenance
– Available in 3000, 3500 and 4100K

High Lamp Efficacy
– Up to 83 lumens per watt

33% Longer Life than T9 Circline Lamps
– 16,000 hours rated average life

Operates on Programmed Start Electronic Ballasts
– High system efficacy
– Quiet, flicker-free operation
– Dimmable

PHILIPS

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Updated 7/04 P-5386-A

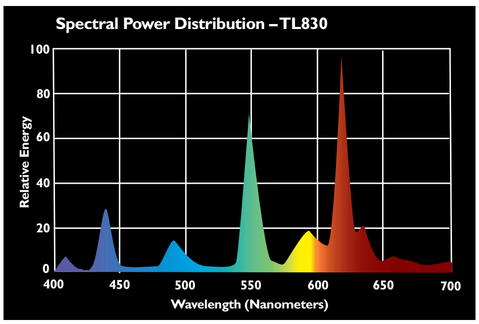
SILHOUETTE™ Series Circular Fluorescent Lamps

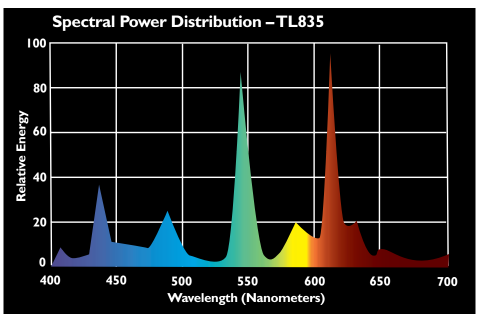
Electrical, Technical and Ordering Data (Subject to change without notice)

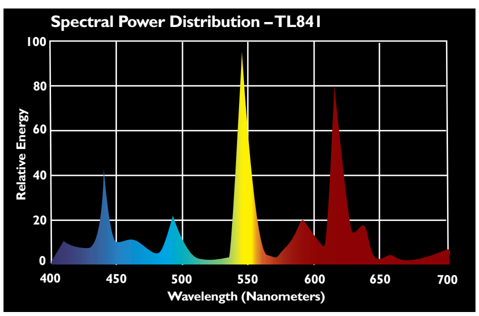
Product Number	Description	Nominal Watts	Bulb	Base	Std. Pkg. Qty.	Color Temp. (K)	Color Rendering (CRI)	Max. Outer Diameter (Inches)	Rated Life (Hours)(1)	Initial Lumens	Design Lumens(2)
29010-6	FC9T5/830	22	T5	2GX13	10	3000	85	9	16,000	1800	1530
29011-4	FC9T5/835	22	T5	2GX13	10	3500	85	9	16,000	1800	1530
29012-2	FC9T5/841	22	T5	2GX13	10	4100	85	9	16,000	1800	1530
29014-8	FC12T5/830	40	T5	2GX13	10	3000	85	12	16,000	3300	2805
29016-3	FC12T5/835	40	T5	2GX13	10	3500	85	12	16,000	3300	2805
29017-1	FC12T5/841	40	T5	2GX13	10	4100	85	12	16,000	3300	2805

(1) Average rated life under specified test conditions with lamps turned off and restarted once every 3 operating hours.
(2) Approximate lumens at 40% of rated average life (6400 Hours).

Spectral Power Distribution

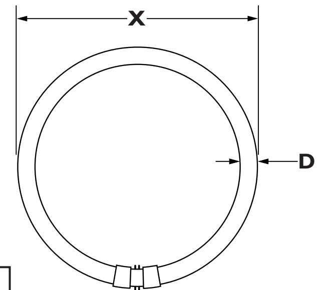






Lamp Dimensions

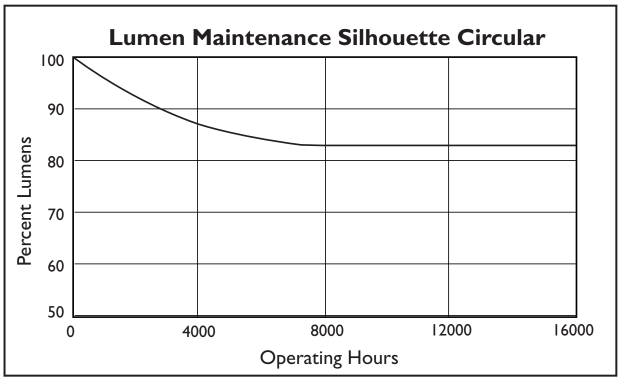
Lamp Type	X inches	X mm	D inches	D mm
FC9T5	8.8	225.0	0.63	16.0
FC12T5	11.79	300.0	0.63	16.0

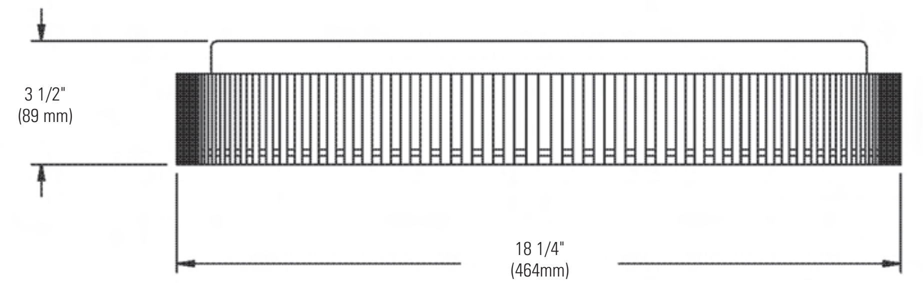


SILHOUETTE Lamp Specification

Lamps shall be Philips Silhouette Circular T5 lamps having:

- Color rendering index of 85
- T5 diameter bulb
- 2GX13 bases
- Color temperature of ___________K (3000 , 3500 or 4100)
- Initial lumens of ___________ (1800 or 3300)
- Design lumens of ___________(1530 or 2805)
- Nominal wattage of ___________ (22 or 40)
- Powered by electronic ballasts





Ordering Guide (complete unit only)

Cat. No.	Lamp (circular)	Volt	Finish
SL203APZU	1-22W / 1-40W CT5	120/277V	Anodized Aluminum & Sand Blasted Glass

Features

1. **Form:** Round form fabricated from slitted corrugated anodized aluminum. Slits hold the sand blasted glass and reflector element. The illuminated edge of the glass is visible through the corrugations.
2. **Glass:** Center sand blasted glass with clear outer ring. Image of lamps seen through the glass to create a geometric pattern on the wall or ceiling.
3. **Housing:** Spun painted steel construction. Mounting plate houses the ballast and lamp sockets.

Mounting

Mounting: Surface mounting to wall or ceiling surfaces.

Lamp Change: Fluted housing simply twists-off. Held in place by 3 locking pins.

Luminaire Weight: 10.5 lbs.

Electrical

Ballast: Electronic Program Rapid Start T5 circular lamps ballast. Universal voltage “U” ballast automatically detect 120 volts or 277 volts operation. Ballast use cathode heater shut-off to increase T5 round lamp life.

Lampholder: 2GX13 base, 4 Pin.

Options and Accessories

Double Switching: Consult your Lightolier representative for more information.

Perforated Form: Consult your Lightolier representative for more information.

Dimming Ballast: Consult your Lightolier representative for more information.

Finish

Anodized corrugated aluminum sheet with precise flutes.
All painted parts are with powder coat paint process.

Labels

UL “c/us” Listed. Suitable for damp locations.

Job Information	**Type:**
Job Name:	
Cat. No.:	
Lamp(s):	
Notes:	

Lightolier a Genlyte company www.lightolier.com
631 Airport Road, Fall River, MA 02720 • (508) 679-8131 • Fax (508) 674-4710

LIGHTOLIER®

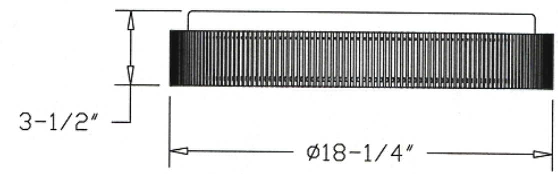
LIGHTOLIER
A Genlyte Thomas Compagny

FLUTED DISK IS:SL202

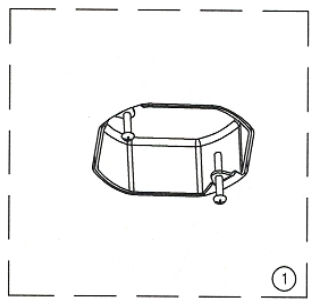
INSTALLATION INSTRUCTIONS

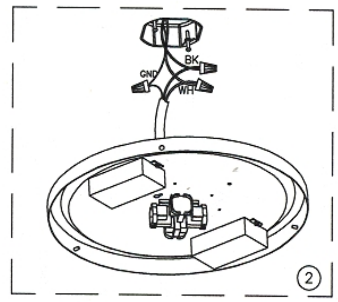
08-08/REV-01

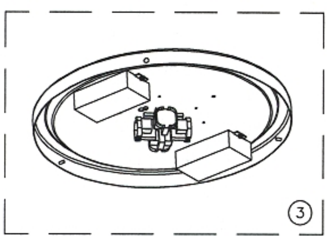
READ AND UNDERSTAND THESE INSTRUCTIONS BEFORE INSTALLING
Turn off electricity at fuse box before proceeding. Consult a qualified electrician to ensure that this luminaire is installed with the local application code.
RETAIN THESE INSTRUCTIONS FOR MAINTENANCE REFERENCE.

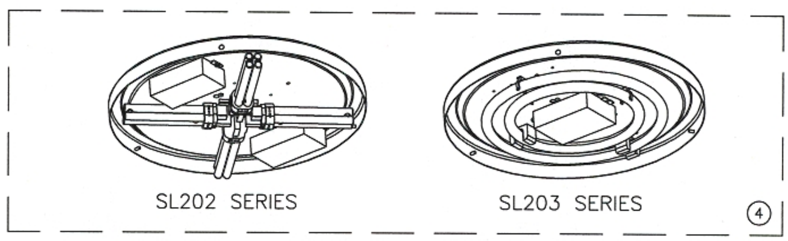


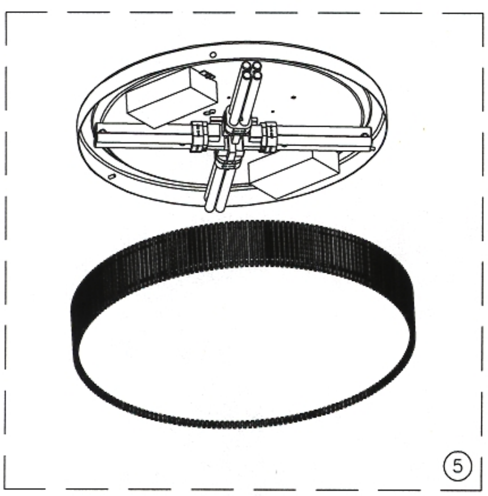
1. POSITION THE SCREWS ON THE OCTAGONAL BOX.
2. GROUND THE LUMINAIRE WITH THE GREEN WIRES. CONNECT THE WHITE (NEUTRAL) WIRES TOGETHER AND THE BLACK (120V OR 277V) OR RED (347V) TOGETHER.
3. INSTALL THE LUMINAIRES OVER THE OCTOGONAL BOX.
4. INSTALL THE LAMPS IN THE LUMINAIRE.
5. ALIGN THE PIN IN THE CANOPY WITH THE SLOT ON THE GLASS HOUSING PUSH UP AND TURN TO LOCK.

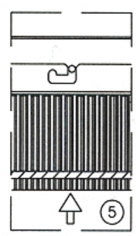


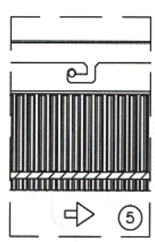


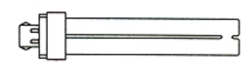




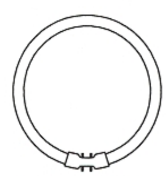








SL202 SERIES
4 x 26W QT 4 PIN



SL203 SERIES
1 x 22W CT5 &
1 x 40W CT5

Appendix K – Acoustical Analysis

This appendix contains the cut sheets and other data for the manufacturer information provided for chillers, fan coil units, and cooling towers used as a part of the acoustical breadth work. There is data from York, Carrier, and Marley included.

Please see the all the acoustical information on the following pages.

YORK®
A JOHNSON CONTROLS COMPANY

Issue Date: 03/06
Project: Project
Engineer: Sales Eng
Customer: customer

Program: LTC
Rev: v1_57.idd
Date: 03/29/06
Page: 2 of 2

MODEL	YKACADQ3-CKF		(MOTOR SELECTED BY USER)	
REFRIGERANT	134A		**GEAR CODE**	XC(SPEC)
RATED CAPACITY (TR)	350		**SPECIFIED CAPACITY (TR)**	350
INPUT POWER (KW)	216		**MAX MOTOR LOAD (KW)**	213
VOLTAGE / HZ	460 / 60			
ORIFICE (VARY)	VALVE:2		**DIFFUSER**	FIXED
FLA	311		**LRA**	1950
MIN CIR. AMPS.	388		**MAX C.B.**	600
FULL LOAD (kW/TR)	0.617		**NPLV**	0.381

STARTER TYPE (10) VARIABLE SPEED DRIVE

	Evaporator	**Condenser**
FLUID	WATER*	WATER*
% BY WEIGHT	0.0*	0.0*
TUBE MTI NO.	271*	260*
PASSES	2*	2*
FOUL FACTOR	0.00010*	0.00025*
FLUID ENT TEMP (°F)	56.00	85.00*
FLUID LEV TEMP (°F)	44.00*	94.31
FLUID FLOW (gpm)	700.0*	1050.0*
FLUID PRDROP (ft)	11.5	10.9

(*) Designates Specified Input

YORK CENTRIFUGAL LIQUID CHILLER SOUND PRESSURE LEVELS- Cooling (ARI 550)

SOUND PRESSURE LEVELS IN DB RE 20 MICROPASCALS (STANDARD)									
PCT LOAD	**OCTAVE BAND CENTER FREQUENCY, HZ**								**A-WEIGHTED DBA**
	63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	
100.0	75.0	75.0	75.0	74.0	74.0	75.0	71.0	67.0	79.5
75.0	75.0	74.0	72.0	70.5	71.0	72.0	70.0	65.0	77.0
50.0	75.0	73.5	70.5	68.0	68.0	69.0	68.0	62.0	74.5
25.0	75.0	80.0	78.0	76.0	75.0	78.0	76.0	69.0	82.5

The octave and A-Weighted sound pressure levels are the levels expected to be obtained if measurements are performed in accordance with ARI Standard 575-94, Method of measuring machinery sound within equipment rooms.

TOLERANCES: The sound level of identical unit selections can vary due to manufacturing tolerance and test repeatability. Variations of +-3 DBA on the A-Weighted levels and +-5 DB on the octave band levels are possible.

Rating certified in accordance with ARI STD. 550/590.
Water-chilling packages using the vapor compression cycle certification program.

Materials and construction per mechanical specifications - Form 160.73-EG1.

Unit Parameters

Tag Name:...**FCU-1**
Quantity:.. **1**
Unit Model: **42SGA03**
Unit Type:.......**42SGA Concealed Modular Unit**
Unit Size:... **300**
System Type: ....**4-Pipe Heating and Cooling**
Cooling Coil: .... **Cold Fluid Cooling**
Cooling Coil Rows: ....**3 Rows**
Heating Coil:...........................**Hot Fluid Heating**
Heating Coil Rows:...................................**1 Row**
Shipping Options: ....**Standard**
Fan Speed:... **High**
Motor/Drive:...**Standard**

Standard Fan Coil:

Octave Band Center Frequency, Hz	125	250	500	1k	2k	4k	8k	dBA
Sound Power, dB	64.5	57	52.5	49	41	39	35.5	
A-Weighted Sound Power, dBA								55

Notes

Estimated Sound Power levels – dB re: 1 picowatt

Estimated Sound Power levels given above are assumed to originate at the acoustic center of the fan coil.

Calculation methods used in this program are patterned after the ASHRAE Guide; other ASHRAE Publications and the ARI Acoustical Standards. While a very significant effort has been made to insure the technical accuracy of this program, it is assumed that the user is knowledgeable in the art of system sound estimation and is aware of the tolerances involved in real world acoustical estimation. This program makes certain assumptions as to the dominant sound sources and sound paths which may not always be appropriate to the real system being estimated. Because of this, no assurances can be offered that this software will always generate an accurate sound prediction from user supplied input data. If in doubt about the estimation of expected sound levels in a space, an Acoustical Engineer or a person with sound prediction expertise should be consulted.

Unit Parameters

Tag Name:...**FCU-2**
Quantity:.. **1**
Unit Model: **42SGA04**
Unit Type:.......**42SGA Concealed Modular Unit**
Unit Size:... **400**
System Type: ....**4-Pipe Heating and Cooling**
Cooling Coil:........................ **Cold Fluid Cooling**
Cooling Coil Rows: ....**3 Rows**
Heating Coil:...........................**Hot Fluid Heating**
Heating Coil Rows:....................................**1 Row**
Shipping Options: ....**Standard**
Fan Speed:.. **High**
Motor/Drive:...**Standard**

Standard Fan Coil:

Octave Band Center Frequency, Hz	125	250	500	1k	2k	4k	8k	dBA
Sound Power, dB	69	59.5	55.5	50.5	41.5	39.5	36.5	
A-Weighted Sound Power, dBA								58

Notes

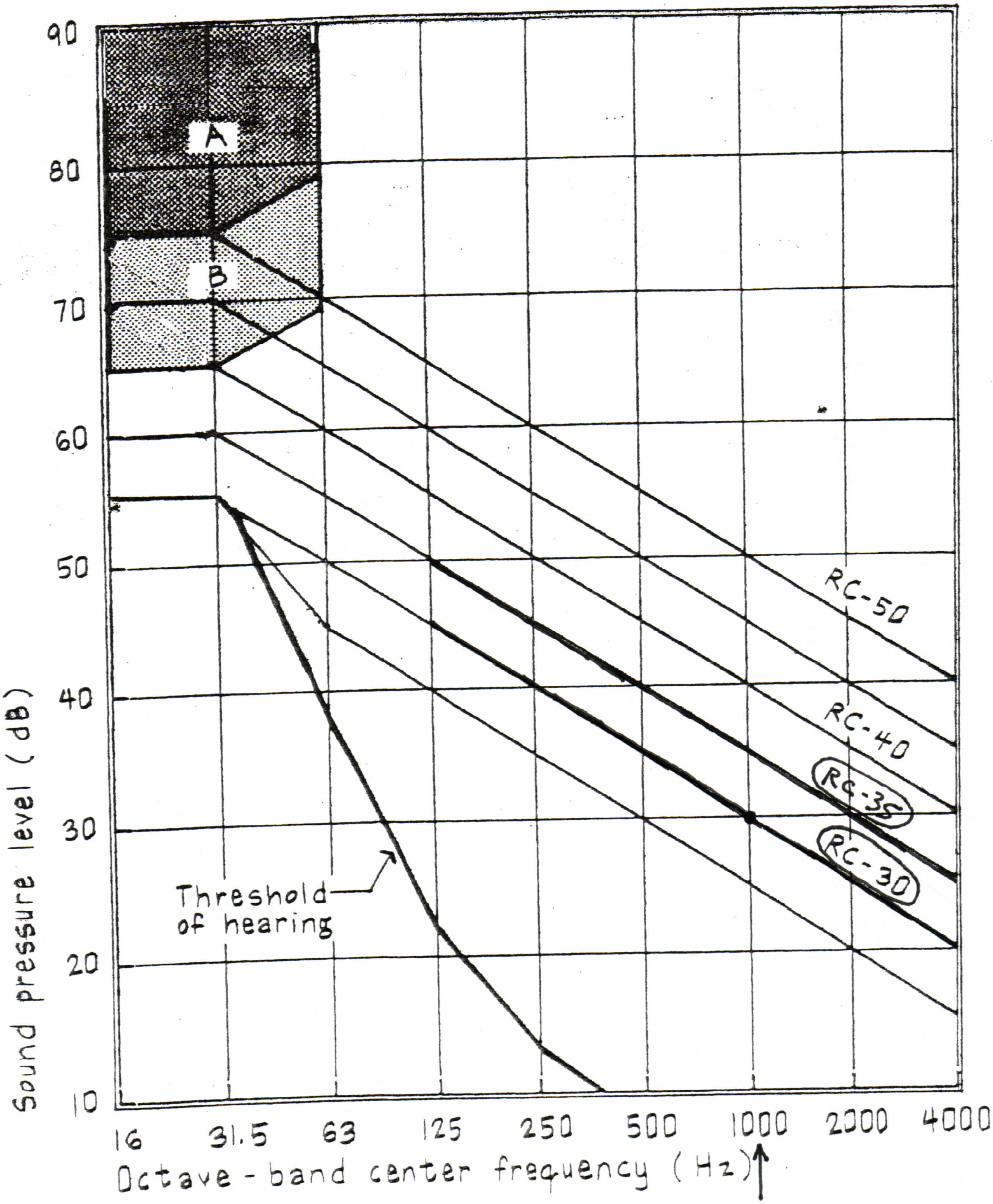
Estimated Sound Power levels – dB re: 1 picowatt

Estimated Sound Power levels given above are assumed to originate at the acoustic center of the fan coil.

Calculation methods used in this program are patterned after the ASHRAE Guide; other ASHRAE Publications and the ARI Acoustical Standards. While a very significant effort has been made to insure the technical accuracy of this program, it is assumed that the user is knowledgeable in the art of system sound estimation and is aware of the tolerances involved in real world acoustical estimation. This program makes certain assumptions as to the dominant sound sources and sound paths which may not always be appropriate to the real system being estimated. Because of this, no assurances can be offered that this software will always generate an accurate sound prediction from user supplied input data. If in doubt about the estimation of expected sound levels in a space, an Acoustical Engineer or a person with sound prediction expertise should be consulted.

CHILLER AND FAN COIL UNIT ACOUSTICS

Room Criteria (RC) Curves



CHILLER:

MECHANICAL ROOM TO RESTAURANT USE RC-35

FAN COIL UNIT:

GUEST ROOM RC-30

Appendix L – Overall Cost Analysis

This appendix contains the information used for the life cycle cost analyses for the chillers, cooling towers, and mechanical systems used as a part of the design process.

Please see the all the life cycle cost information on the following pages.

Lifecycle Summary

Project: Hilton Hotel at BWI Airport — 4/5/2006
Prepared By: The Pennsylvania State University — 5:48:06 PM

Chiller Selection

Life Cycle Cost Analysis

Type of Analysis .... Private Sector Lifecycle Analysis
Type of Design Alternatives .... Mutually Exclusive
Length of Analysis .... 20 yrs
Minimum Attractive Rate of Return .... 8.00 %
Income Taxes .... Not Considered

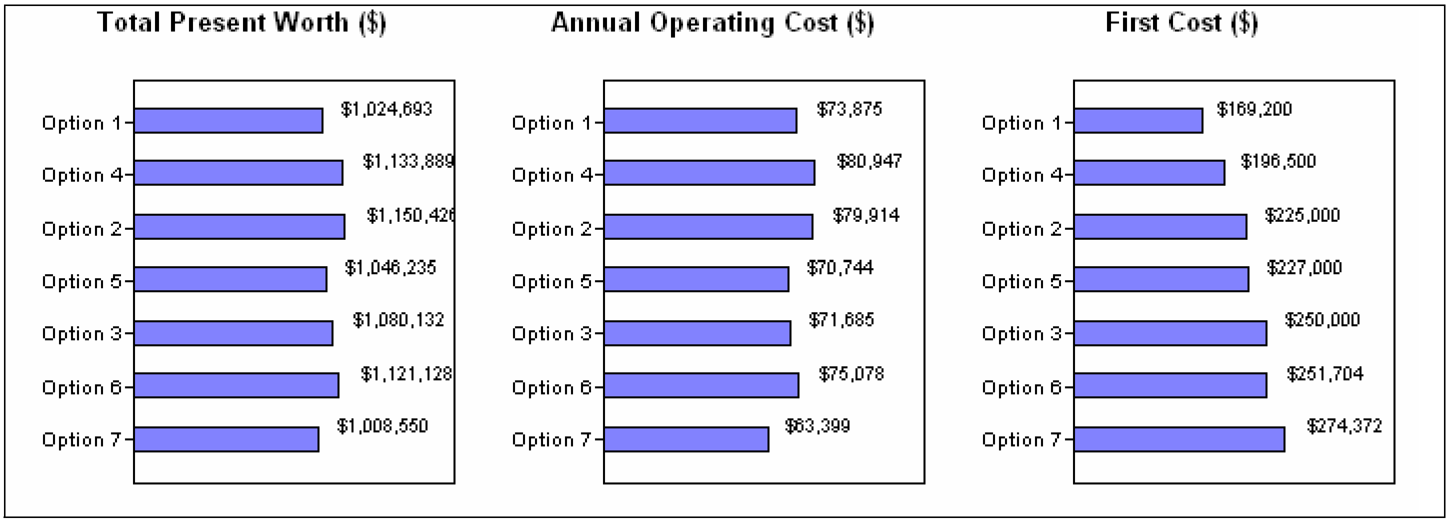


Table 1. Executive Summary

Economic Criteria	Best Design Case for Each Criteria	Value ($)
Incremental NPW Savings Analysis	Option 7 - (2) Trane CTV-AFD (12F)	-
Lowest Total Present Worth	Option 7 - (2) Trane CTV-AFD (12F)	$1,008,550
Lowest Annual Operating Cost	Option 7 - (2) Trane CTV-AFD (12F)	$63,399
Lowest First Cost	Option 1 - (2) Carrier 19XRVs	$169,200

Lifecycle Summary

Project: Hilton Hotel at BWI Airport — 4/5/2006
Prepared By: The Pennsylvania State University — 5:48:06 PM

Table 2. Design Cases Ranked by First Cost

Design Case Name	Design Case Short Name	Total Present Worth ($)	Annual Operating Cost ($/yr)	First Cost ($)
Option 1 - (2) Carrier 19XRVs	Option 1	$1,024,693	$73,875	$169,200
Option 4 - (1) McQuay WDC w/ IGV	Option 4	$1,133,889	$80,947	$196,500
Option 2 - (2) York MaxEs	Option 2	$1,150,426	$79,914	$225,000
Option 5 - (1) McQuay WDC w/ VFD	Option 5	$1,046,235	$70,744	$227,000
Option 3 - (2) McQuay WSCs	Option 3	$1,080,132	$71,685	$250,000
Option 6 - (1) Trane CTV, (1) CTV-AFD (12F)	Option 6	$1,121,128	$75,078	$251,704
Option 7 - (2) Trane CTV-AFD (12F)	Option 7	$1,008,550	$63,399	$274,372

Table 3. Incremental Analysis Data

Challenger	Base Case	Additional First Cost ($)	NPW Savings ($)	IRR (%)	Payback Period (yrs)
Option 4	Option 1 [Winner]	$27,300	$-109,196	n/a	n/a
Option 2	Option 1 [Winner]	$55,800	$-125,733	n/a	n/a
Option 5	Option 1 [Winner]	$57,800	$-21,542	2.79	n/a
Option 3	Option 1 [Winner]	$80,800	$-55,439	n/a	n/a
Option 6	Option 1 [Winner]	$82,504	$-96,435	n/a	n/a
Option 7 [Winner]	Option 1	$105,172	$16,143	9.86	15.6

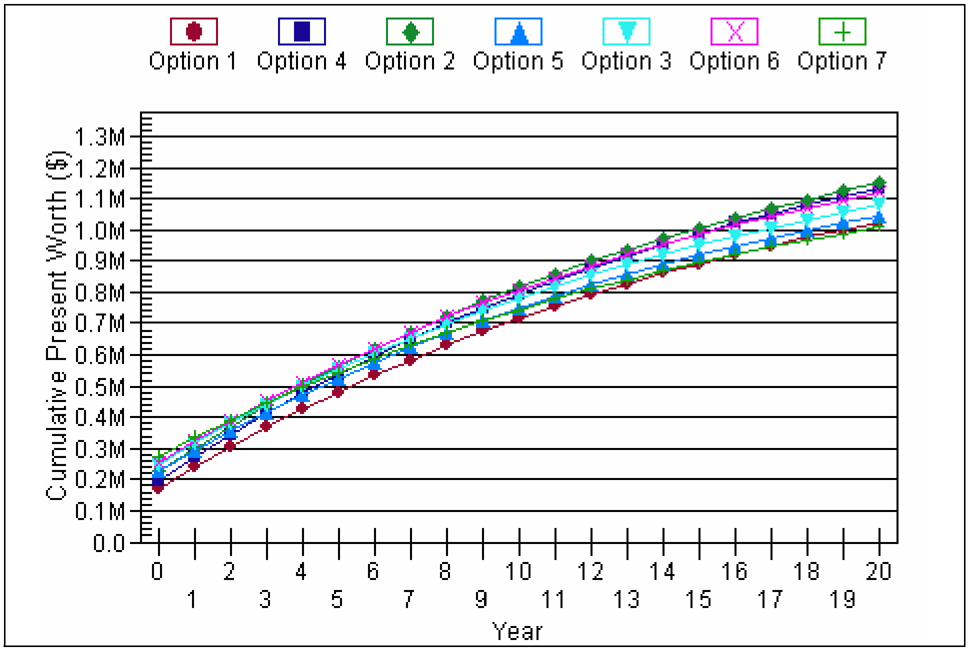
Total Present Worth Profiles

Project: Hilton Hotel at BWI Airport — 4/5/2006
Prepared By: The Pennsylvania State University — 5:48:08 PM

Chiller Selection

Life Cycle Cost Analysis

Type of Analysis .... Private Sector Lifecycle Analysis
Type of Design Alternatives .... Mutually Exclusive
Length of Analysis .... 20 yrs
Minimum Attractive Rate of Return .... 8.00 %
Income Taxes .... Not Considered



Design Cases Ranked by First Cost

Design Case Name	Design Case Short Name	Total Present Worth ($)	Annual Operating Cost ($/yr)	First Cost ($)
Option 1 - (2) Carrier 19XRVs	Option 1	$1,024,693	$73,875	$169,200
Option 4 - (1) McQuay WDC w/ IGV	Option 4	$1,133,889	$80,947	$196,500
Option 2 - (2) York MaxEs	Option 2	$1,150,426	$79,914	$225,000
Option 5 - (1) McQuay WDC w/ VFD	Option 5	$1,046,235	$70,744	$227,000
Option 3 - (2) McQuay WSCs	Option 3	$1,080,132	$71,685	$250,000
Option 6 - (1) Trane CTV, (1) CTV-AFD (12F)	Option 6	$1,121,128	$75,078	$251,704
Option 7 - (2) Trane CTV-AFD (12F)	Option 7	$1,008,550	$63,399	$274,372

Lifecycle Summary

Project: Hilton Hotel at BWI Airport — 4/4/2006
Prepared By: The Pennsylvania State University — 6:02:52 PM

Cooling Tower Selection

Life Cycle Cost Analysis

Type of Analysis .... Private Sector Lifecycle Analysis
Type of Design Alternatives .... Mutually Exclusive
Length of Analysis .... 20 yrs
Minimum Attractive Rate of Return .... 8.00 %
Income Taxes .... Not Considered

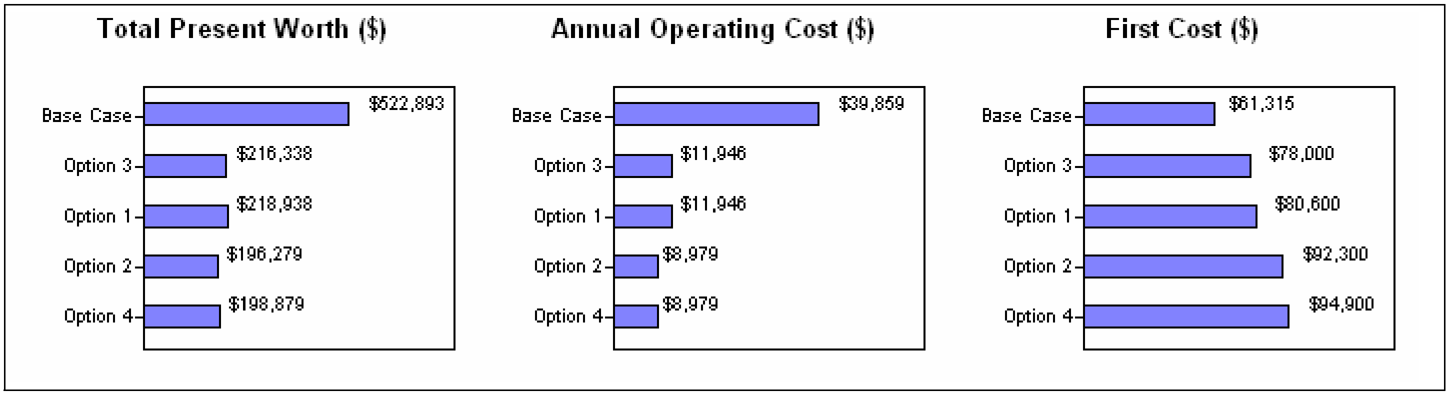


Table 1. Executive Summary

Economic Criteria	Best Design Case for Each Criteria	Value ($)
Incremental NPW Savings Analysis	Option 2 - Marley NC8306EL2	-
Lowest Total Present Worth	Option 2 - Marley NC8306EL2	$196,279
Lowest Annual Operating Cost	Option 2 - Marley NC8306EL2	$8,979
Lowest First Cost	Base Case - Original Design	$61,315

Table 2. Design Cases Ranked by First Cost

Design Case Name	Design Case Short Name	Total Present Worth ($)	Annual Operating Cost ($/yr)	First Cost ($)
Base Case - Original Design	Base Case	$522,893	$39,859	$61,315
Option 3 - Marley NC8305F2	Option 3	$216,338	$11,946	$78,000
Option 1 - Marley NC8305FL2	Option 1	$218,938	$11,946	$80,600
Option 2 - Marley NC8306EL2	Option 2	$196,279	$8,979	$92,300
Option 4 - Marley NC8307E2	Option 4	$198,879	$8,979	$94,900

Table 3. Incremental Analysis Data

Challenger	Base Case	Additional First Cost ($)	NPW Savings ($)	IRR (%)	Payback Period (yrs)
Option 3 [Winner]	Base Case	$16,685	$306,555	172.63	0.6
Option 1	Option 3 [Winner]	$2,600	$-2,600	n/a	n/a
Option 2 [Winner]	Option 3	$14,300	$20,059	22.63	5.8
Option 4	Option 2 [Winner]	$2,600	$-2,600	n/a	n/a

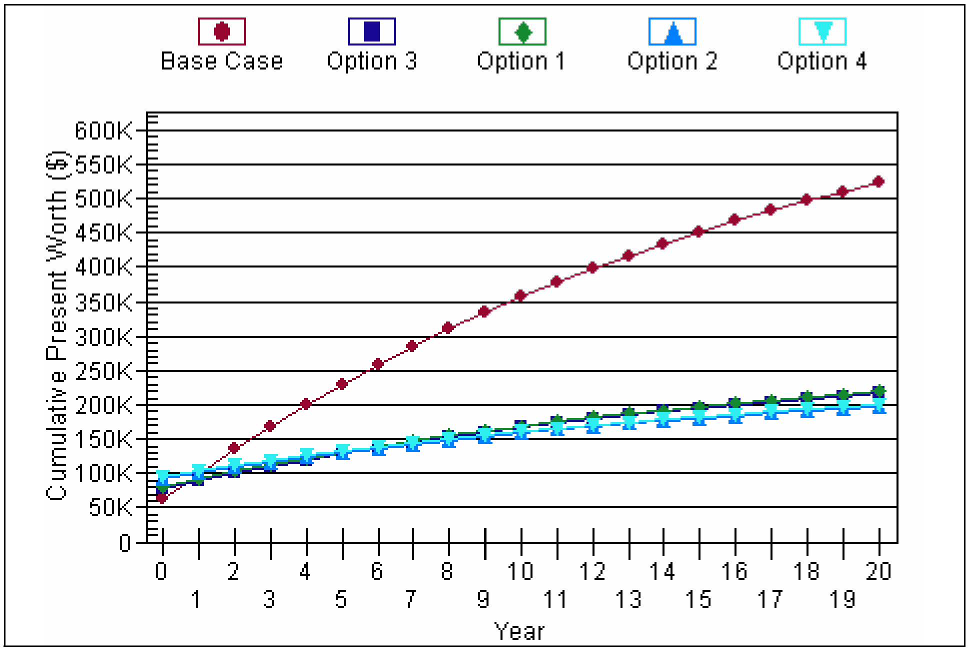
Total Present Worth Profiles

Project: Hilton Hotel at BWI Airport — 4/4/2006
Prepared By: The Pennsylvania State University — 6:02:53 PM

Cooling Tower Selection

Life Cycle Cost Analysis

Type of Analysis .... Private Sector Lifecycle Analysis
Type of Design Alternatives .... Mutually Exclusive
Length of Analysis .... 20 yrs
Minimum Attractive Rate of Return .... 8.00 %
Income Taxes .... Not Considered



Design Cases Ranked by First Cost

Design Case Name	Design Case Short Name	Total Present Worth ($)	Annual Operating Cost ($/yr)	First Cost ($)
Base Case - Original Design	Base Case	$522,893	$39,859	$61,315
Option 3 - Marley NC8305F2	Option 3	$216,338	$11,946	$78,000
Option 1 - Marley NC8305FL2	Option 1	$218,938	$11,946	$80,600
Option 2 - Marley NC8306EL2	Option 2	$196,279	$8,979	$92,300
Option 4 - Marley NC8307E2	Option 4	$198,879	$8,979	$94,900

Lifecycle Summary

Project: Hilton Hotel at BWI Airport | 4/5/2006
Prepared By: The Pennsylvania State University | 8:30:27 PM

Mechanical Systems

Life Cycle Cost Analysis

Type of Analysis .... Private Sector Lifecycle Analysis
Type of Design Alternatives .... Mutually Exclusive
Length of Analysis .... 20 yrs
Minimum Attractive Rate of Return .... 8.00 %
Income Taxes .... Not Considered

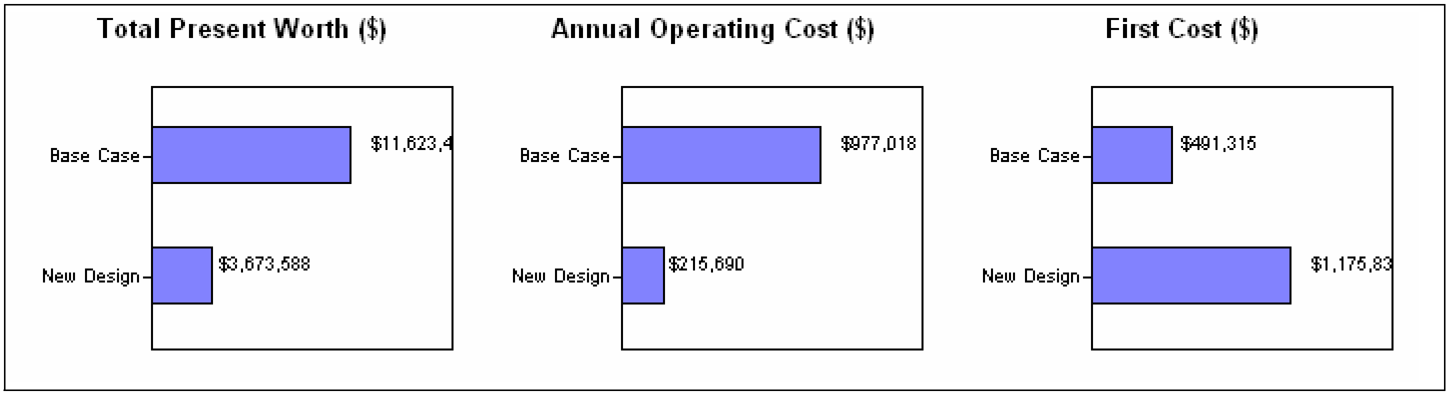


Table 1. Executive Summary

Economic Criteria	Best Design Case for Each Criteria	Value ($)
Incremental NPW Savings Analysis	Chilled Water Plant Design	-
Lowest Total Present Worth	Chilled Water Plant Design	$3,673,588
Lowest Annual Operating Cost	Chilled Water Plant Design	$215,690
Lowest First Cost	Base Case - Original Design	$491,315

Table 2. Design Cases Ranked by First Cost

Design Case Name	Design Case Short Name	Total Present Worth ($)	Annual Operating Cost ($/yr)	First Cost ($)
Base Case - Original Design	Base Case	$11,623,441	$977,018	$491,315
Chilled Water Plant Design	New Design	$3,673,588	$215,690	$1,175,838

Table 3. Incremental Analysis Data

Challenger	Base Case	Additional First Cost ($)	NPW Savings ($)	IRR (%)	Payback Period (yrs)
New Design [Winner]	Base Case	$684,523	$7,949,854	114.23	1.0

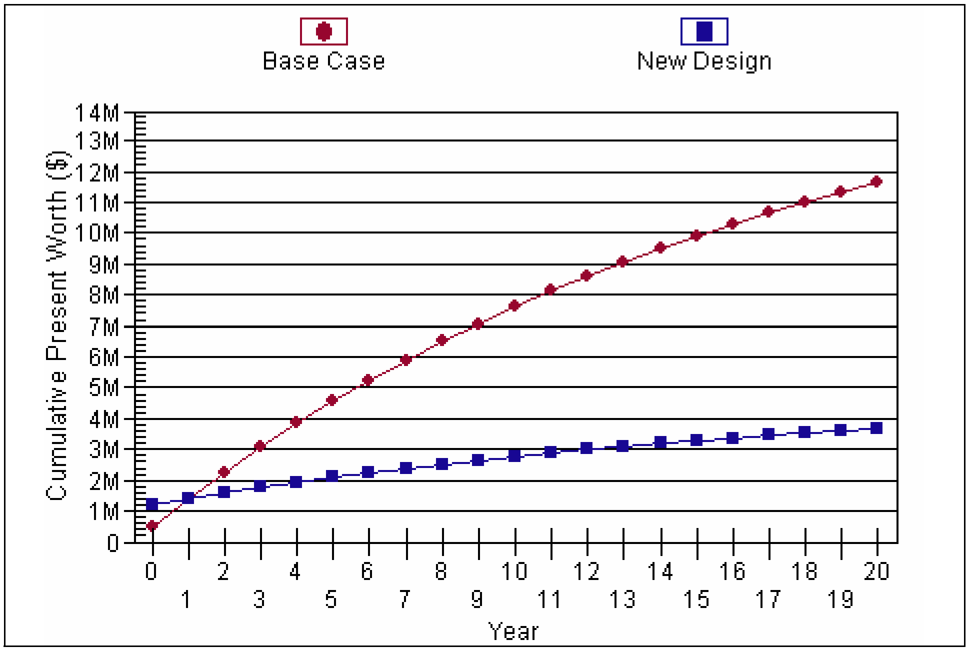
Total Present Worth Profiles

Project: Hilton Hotel at BWI Airport — 4/5/2006
Prepared By: The Pennsylvania State University — 8:30:28 PM

Mechanical Systems

Life Cycle Cost Analysis

Type of Analysis .... Private Sector Lifecycle Analysis
Type of Design Alternatives .... Mutually Exclusive
Length of Analysis .... 20 yrs
Minimum Attractive Rate of Return .... 8.00 %
Income Taxes .... Not Considered



Design Cases Ranked by First Cost

Design Case Name	Design Case Short Name	Total Present Worth ($)	Annual Operating Cost ($/yr)	First Cost ($)
Base Case - Original Design	Base Case	$11,623,441	$977,018	$491,315
Chilled Water Plant Design	New Design	$3,673,588	$215,690	$1,175,838

Analysis Details

Mechanical Systems

Life Cycle Cost Analysis

Type of Analysis .... Private Sector Lifecycle Analysis
Type of Design Alternatives .... Mutually Exclusive
Length of Analysis .... 20 yrs
Minimum Attractive Rate of Return .... 8.00 %
Income Taxes .... Not Considered

1A. Summary of Results

Base Case	Base Case - Original Design [Base Case]
Challenger **[Winner]**	Chilled Water Plant Design [New Design]
[Base Case] Total Present Worth ($)	$11,623,441
[New Design] Total Present Worth ($)	$3,673,588
Net Present Worth Savings ($)	$7,949,854
Internal Rate of Return	114.2 %
Payback Period (yrs)	1.0 years

1B. Comparative Analysis Details

		Cash Flow (Present Worth $)			SIR and Payback Calculation (Present Worth $)				
Year	**Date**	**[Base Case] Cash Flow ($)**	**[New Design] Cash Flow ($)**	**Net Present Worth Savings ($)**	**Operating Cost Savings ($)**	**Cumulative Operating Cost Savings ($)**	**Additional Investment Cost ($)**	**Cumulative Additional Investment Cost ($)**	**Year-End SIR**
0	Initial	491,315	1,175,838	-684,523	0	0	684,523	684,523	0.000
1	1	922,739	203,707	719,032	719,032	719,032	0	684,523	1.050
2	2	856,212	192,390	663,821	663,821	1,382,853	0	684,523	2.020
3	3	808,644	181,702	626,942	626,942	2,009,796	0	684,523	2.936
4	4	763,720	171,607	592,112	592,112	2,601,908	0	684,523	3.801
5	5	721,291	162,074	559,217	559,217	3,161,125	0	684,523	4.618
6	6	681,219	153,069	528,150	528,150	3,689,275	0	684,523	5.390
7	7	643,373	144,566	498,808	498,808	4,188,083	0	684,523	6.118
8	8	607,631	136,534	471,096	471,096	4,659,179	0	684,523	6.806
9	9	573,873	128,949	444,924	444,924	5,104,103	0	684,523	7.456
10	10	541,991	121,785	420,206	420,206	5,524,310	0	684,523	8.070
11	11	511,881	115,019	396,862	396,862	5,921,171	0	684,523	8.650
12	12	483,443	108,629	374,814	374,814	6,295,985	0	684,523	9.198
13	13	456,585	102,594	353,991	353,991	6,649,976	0	684,523	9.715
14	14	431,219	96,895	334,325	334,325	6,984,300	0	684,523	10.203
15	15	407,263	91,512	315,751	315,751	7,300,051	0	684,523	10.664
16	16	384,637	86,428	298,209	298,209	7,598,260	0	684,523	11.100
17	17	363,268	81,626	281,642	281,642	7,879,902	0	684,523	11.512
18	18	343,087	77,091	265,995	265,995	8,145,898	0	684,523	11.900
19	19	324,026	72,808	251,218	251,218	8,397,115	0	684,523	12.267
20	20	306,025	68,764	237,261	237,261	8,634,377	0	684,523	12.614
Totals		11,623,441	3,673,588	7,949,854	8,634,377		684,523		

Mechanical Equipment First Costs

Table L1 - Mechanical Equipment Options First Costs

Equipment	Option	Manufacturer	Model	Quantity	Price Each	Total Price	Option Total
Chillers							
	1	Carrier	19XRV	2	$84,600	$169,200	$169,200
	2	York	MaxE	2	$112,500	$225,000	$225,000
	3	McQuay	WSC	2	$125,000	$250,000	$250,000
	4	McQuay	WDC-IGV	1	$196,500	$196,500	$196,500
	5	McQuay	WDC-VFD	1	$227,000	$227,000	$227,000
	6	Trane	CTV	1	$114,518	$251,704	$251,704
	6	Trane	CTV-AFD	1	$137,186	-	-
	7	Trane	CTV-AFD	2	$137,186	$274,372	$274,372
Cooling Towers							
	1	Marley	NC8305FL2	2	$40,300	$80,600	$80,600
	2	Marley	NC8306EL2	2	$46,150	$92,300	$92,300
	3	Marley	NC8305F2	2	$39,000	$78,000	$78,000
	4	Marley	NC8307E2	2	$47,450	$94,900	$94,900
Air Handling Units							
	1	Carrier	39MN-50	1	$30,100	$30,100	$90,900
	1	Carrier	39MN-40	1	$29,500	$29,500	-
	1	Carrier	39MN-21	1	$17,600	$17,600	-
	1	Carrier	39MN-12	1	$13,700	$13,700	-
Rooftop Units							
	1	Carrier	39MW-06	1	$17,600	$17,600	$101,800
	1	Carrier	39MW-30	1	$30,400	$30,400	-
	1	Carrier	39MW-12	1	$20,400	$20,400	-
	1	Carrier	39MW-06	1	$17,400	$17,400	-
	1	Carrier	39MW-03	1	$16,000	$16,000	-
Dedicated Outside Air Units							
	1	Semco	PVS-13	1	$90,193	$90,193	$193,186
	1	Semco	PVS-18	1	$102,993	$102,993	-
Fan Coil Units							
	1	Carrier	42S-300	128	$1,335	$170,880	$386,880
	1	Carrier	42S-400	160	$1,350	$216,000	-
	2	Enviro-Tec	VHC-04	128	$1,850	$236,800	$532,800
	2	Enviro-Tec	VHC-04	160	$1,850	$296,000	-
Pumps							
	1	Bell&Gossett	1510-5G	2	$8,389	$16,778	$30,750
	1	Bell&Gossett	1510-5BC	2	$6,986	$13,972	-
Heat Exchanger							
	1	Bell&Gossett	P41	1	28150	$28,150	$28,150

Table L2 - Mechanical Equipment Selected First Costs

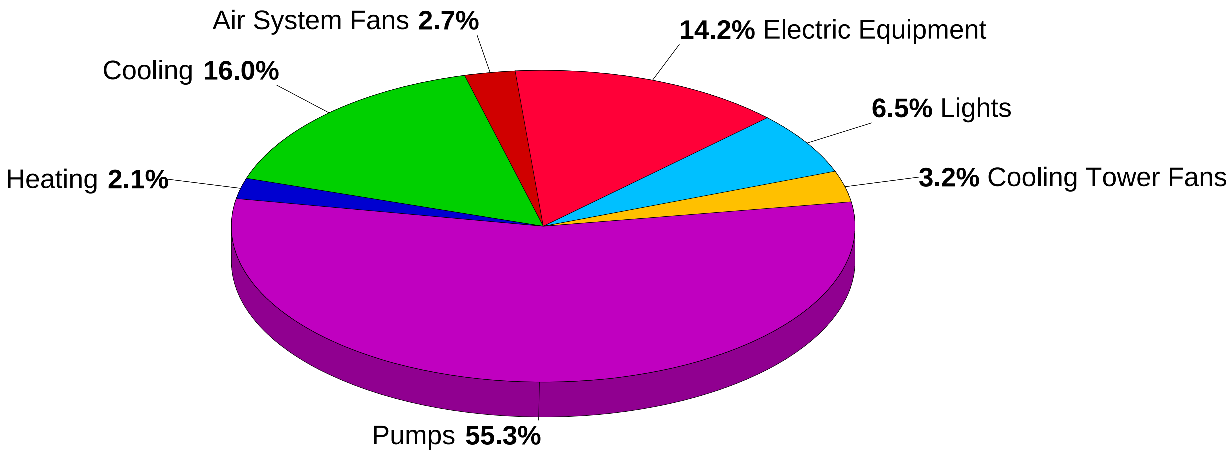
Equipment Costs	Option No	Manufacturer	Model No	Qty	Price Each	Total Price	Option Total	Annual Energy Costs
Chillers								
First Cost	1	Carrier	19XRV	2	$84,600	$169,200	$169,200	$73,875
Operating Cost	7	Trane	CTV-AFD	2	$137,186	$274,372	$274,372	$63,399
Selected	7	Trane	CTV-AFD	2	$137,186	$274,372	$274,372	$63,399
Cooling Towers								
First Cost	3	Marley	NC8305F2	2	$39,000	$78,000	$78,000	$11,946
Operating Cost	2	Marley	NC8306EL2	2	$46,150	$92,300	$92,300	$8,979
Selected	2	Marley	NC8306EL2	2	$46,150	$92,300	$92,300	$8,979
Fan Coil Units								
First Cost	1	Carrier	42S	288	$2,685	$386,880	$386,880	$5 < Option 2
Operating Cost	1	Carrier	42S	288	$2,685	$386,880	$386,880	$5 < Option 2
Selected	1	Carrier	42S	288	$2,685	$386,880	$386,880	$5 < Option 2
Air Handling Units								
Selected (incl all)	1	Carrier	39MN	1	$90,900	$90,900	$90,900	N/A
Rooftop Units								
Selected (incl all)	1	Carrier	39MW	1	$79,300	$79,300	$79,300	N/A
Dedicated Outdoor Air Units								
Selected (incl all)	1	Semco	PVS	1	$193,186	$193,186	$193,186	N/A
Pumps								
Selected (incl all)	1	Bell & Gossett	1510	2	$15,375	$30,750	$30,750	N/A
Heat Exchanger								
Selected	1	Bell & Gossett	P41	1	$28,150	$28,150	$28,150	N/A

Mechanical System Total Equipment First Cost: **$1,175,838**

Appendix M - HAP Report Files

This appendix contains selected HAP report files design process. The files for the base case are listed first. The files for the new mechanical systems design are listed last.

Please see the all the HAP report files on the following pages.



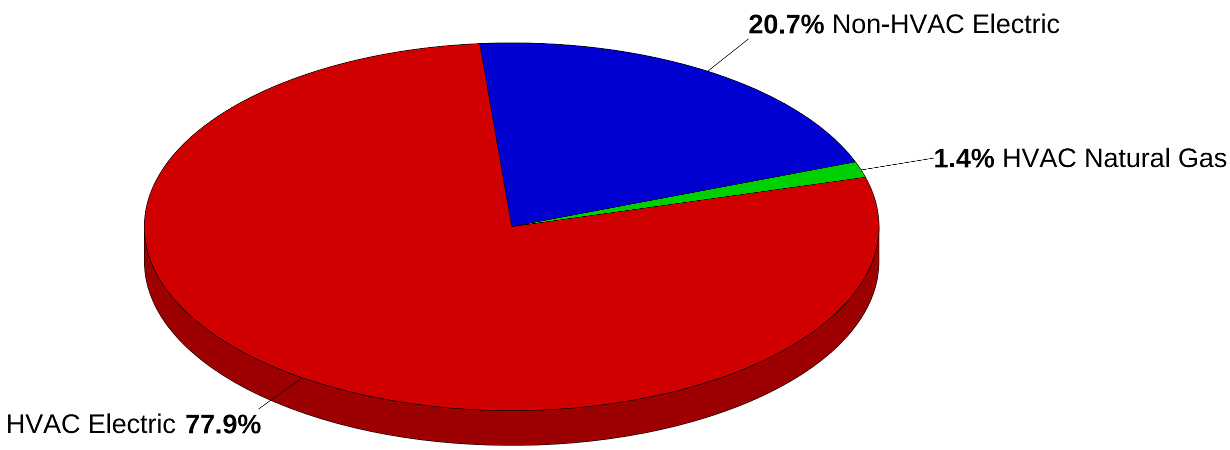
1. Annual Costs

Component	Annual Cost ($)	($/ft²)	Percent of Total (%)
Air System Fans	32,896	0.167	2.7
Cooling	196,737	1.001	16.0
Heating	26,399	0.134	2.1
Pumps	681,072	3.467	55.3
Cooling Tower Fans	39,859	0.203	3.2
HVAC Sub-Total	**976,962**	**4.973**	**79.3**
Lights	80,260	0.409	6.5
Electric Equipment	174,776	0.890	14.2
Misc. Electric	0	0.000	0.0
Misc. Fuel Use	0	0.000	0.0
Non-HVAC Sub-Total	**255,036**	**1.298**	**20.7**
Grand Total	**1,231,999**	**6.271**	**100.0**

Note: Cost per unit floor area is based on the gross building floor area.

Gross Floor Area .... **196455.0** ft²
Conditioned Floor Area .... **196455.0** ft²

Annual Energy Costs - Hilton Hotel at BWI Airport



1. Annual Costs

Component	Annual Cost ($/yr)	($/ft²)	Percent of Total (%)
HVAC Components			
Electric	959,905	4.886	77.9
Natural Gas	17,113	0.087	1.4
Fuel Oil	0	0.000	0.0
Propane	0	0.000	0.0
Remote Hot Water	0	0.000	0.0
Remote Steam	0	0.000	0.0
Remote Chilled Water	0	0.000	0.0
HVAC Sub-Total	**977,018**	**4.973**	**79.3**
Non-HVAC Components			
Electric	255,027	1.298	20.7
Natural Gas	0	0.000	0.0
Fuel Oil	0	0.000	0.0
Propane	0	0.000	0.0
Remote Hot Water	0	0.000	0.0
Remote Steam	0	0.000	0.0
Non-HVAC Sub-Total	**255,027**	**1.298**	**20.7**
Grand Total	**1,232,045**	**6.271**	**100.0**

Note: Cost per unit floor area is based on the gross building floor area.

Gross Floor Area .... **196455.0** ft²
Conditioned Floor Area .... **196455.0** ft²

Energy Budget by System Component - Hilton Hotel at BWI Airport

BWI Hilton Base Case — 03/24/2006
The Pennsylvania State University — 09:51PM

1. Annual Coil Loads

Component	Load (kBTU)	(kBTU/ft²)
Cooling Coil Loads	24,961,130	127.058
Heating Coil Loads	6,538,300	33.281
Grand Total	**31,499,434**	**160.339**

2. Energy Consumption by System Component

Component	Site Energy (kBTU)	Site Energy (kBTU/ft²)	Source Energy (kBTU)	Source Energy (kBTU/ft²)
Air System Fans	1,611,165	8.201	5,754,161	29.290
Cooling	9,513,890	48.428	33,978,184	172.957
Heating	8,109,678	41.280	9,323,703	47.460
Pumps	33,560,676	170.831	119,859,576	610.112
Cooling Towers	1,964,605	10.000	7,016,446	35.715
HVAC Sub-Total	**54,760,014**	**278.741**	**175,932,070**	**895.534**
Lights	3,954,558	20.130	14,123,420	71.891
Electric Equipment	8,611,752	43.836	30,756,254	156.556
Misc. Electric	0	0.000	0	0.000
Misc. Fuel Use	0	0.000	0	0.000
Non-HVAC Sub-Total	**12,566,310**	**63.965**	**44,879,674**	**228.448**
Grand Total	**67,326,323**	**342.706**	**220,811,744**	**1123.981**

Notes:
1. 'Cooling Coil Loads' is the sum of all air system cooling coil loads.
2. 'Heating Coil Loads' is the sum of all air system heating coil loads.
3. Site Energy is the actual energy consumed.
4. Source Energy is the site energy divided by the electric generating efficiency (28.0%).
5. Source Energy for fuels equals the site energy value.
6. Energy per unit floor area is based on the gross building floor area.
   Gross Floor Area .... **196455.0** ft²
   Conditioned Floor Area .... **196455.0** ft²

Energy Budget by Energy Source - Hilton Hotel at BWI Airport

1. Annual Coil Loads

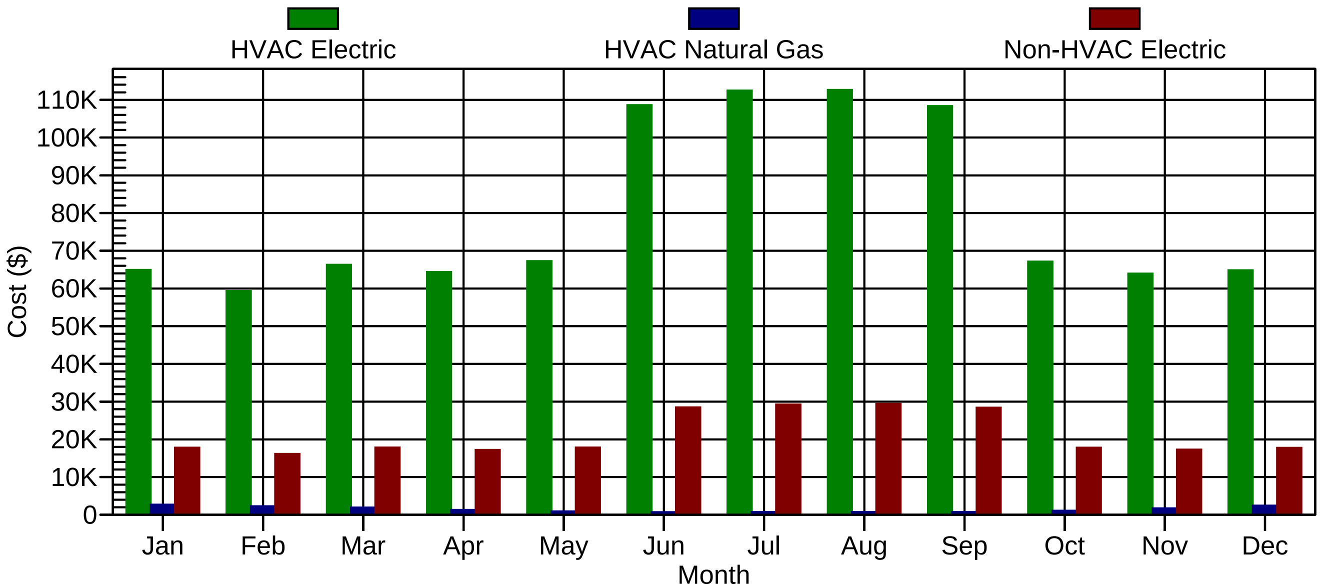
Component	Load (kBTU)	(kBTU/ft²)
Cooling Coil Loads	24,961,130	127.058
Heating Coil Loads	6,538,300	33.281
Grand Total	**31,499,434**	**160.339**

2. Energy Consumption by Energy Source

Component	Site Energy (kBTU)	Site Energy (kBTU/ft²)	Source Energy (kBTU)	Source Energy (kBTU/ft²)
HVAC Components				
Electric	47,125,188	239.878	168,304,240	856.706
Natural Gas	7,637,556	38.877	7,637,556	38.877
Fuel Oil	0	0.000	0	0.000
Propane	0	0.000	0	0.000
Remote Hot Water	0	0.000	0	0.000
Remote Steam	0	0.000	0	0.000
Remote Chilled Water	0	0.000	0	0.000
HVAC Sub-Total	**54,762,744**	**278.755**	**175,941,796**	**895.583**
Non-HVAC Components				
Electric	12,565,848	63.963	44,878,028	228.439
Natural Gas	0	0.000	0	0.000
Fuel Oil	0	0.000	0	0.000
Propane	0	0.000	0	0.000
Remote Hot Water	0	0.000	0	0.000
Remote Steam	0	0.000	0	0.000
Non-HVAC Sub-Total	**12,565,848**	**63.963**	**44,878,028**	**228.439**
Grand Total	**67,328,592**	**342.718**	**220,819,824**	**1124.022**

Notes:

1. 'Cooling Coil Loads' is the sum of all air system cooling coil loads.
2. 'Heating Coil Loads' is the sum of all air system heating coil loads.
3. Site Energy is the actual energy consumed.
4. Source Energy is the site energy divided by the electric generating efficiency (28.0%).
5. Source Energy for fuels equals the site energy value.
6. Energy per unit floor area is based on the gross building floor area.
   Gross Floor Area .... **196455.0** ft²
   Conditioned Floor Area .... **196455.0** ft²



1. HVAC Costs

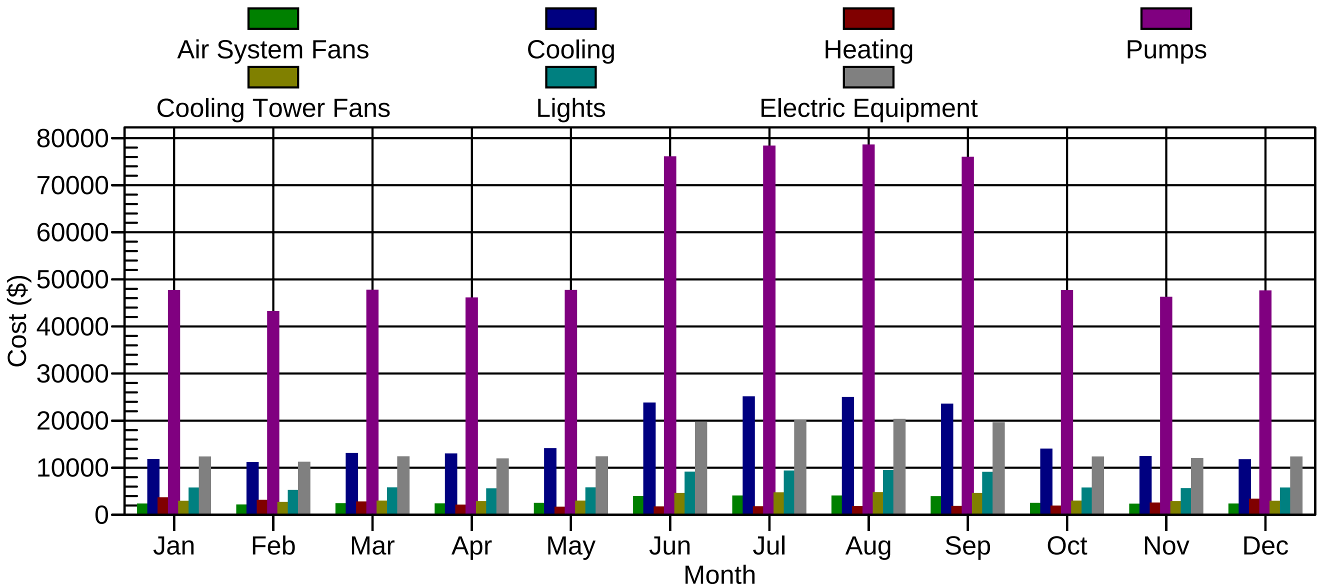
Month	Electric ($)	Natural Gas ($)	Fuel Oil ($)	Propane ($)	Remote Hot Water ($)	Remote Steam ($)	Remote Chilled Water ($)
January	64,899	2,697	0	0	0	0	0
February	59,320	2,236	0	0	0	0	0
March	66,263	1,893	0	0	0	0	0
April	64,337	1,295	0	0	0	0	0
May	67,209	911	0	0	0	0	0
June	108,612	706	0	0	0	0	0
July	112,470	719	0	0	0	0	0
August	112,627	731	0	0	0	0	0
September	108,324	750	0	0	0	0	0
October	67,112	1,076	0	0	0	0	0
November	63,926	1,692	0	0	0	0	0
December	64,806	2,407	0	0	0	0	0
Total	**959,905**	**17,113**	**0**	**0**	**0**	**0**	**0**

2. Non-HVAC Costs

Month	Electric ($)	Natural Gas ($)	Fuel Oil ($)	Propane ($)	Remote Hot Water ($)	Remote Steam ($)
January	17,771	0	0	0	0	0
February	16,131	0	0	0	0	0
March	17,838	0	0	0	0	0
April	17,173	0	0	0	0	0
May	17,832	0	0	0	0	0
June	28,458	0	0	0	0	0
July	29,230	0	0	0	0	0
August	29,413	0	0	0	0	0
September	28,400	0	0	0	0	0
October	17,770	0	0	0	0	0
November	17,269	0	0	0	0	0
December	17,741	0	0	0	0	0
Total	**255,027**	**0**	**0**	**0**	**0**	**0**

Monthly Component Costs - Hilton Hotel at BWI Airport

BWI Hilton Base Case — 03/24/2006
The Pennsylvania State University — 09:51PM



1. HVAC Component Costs

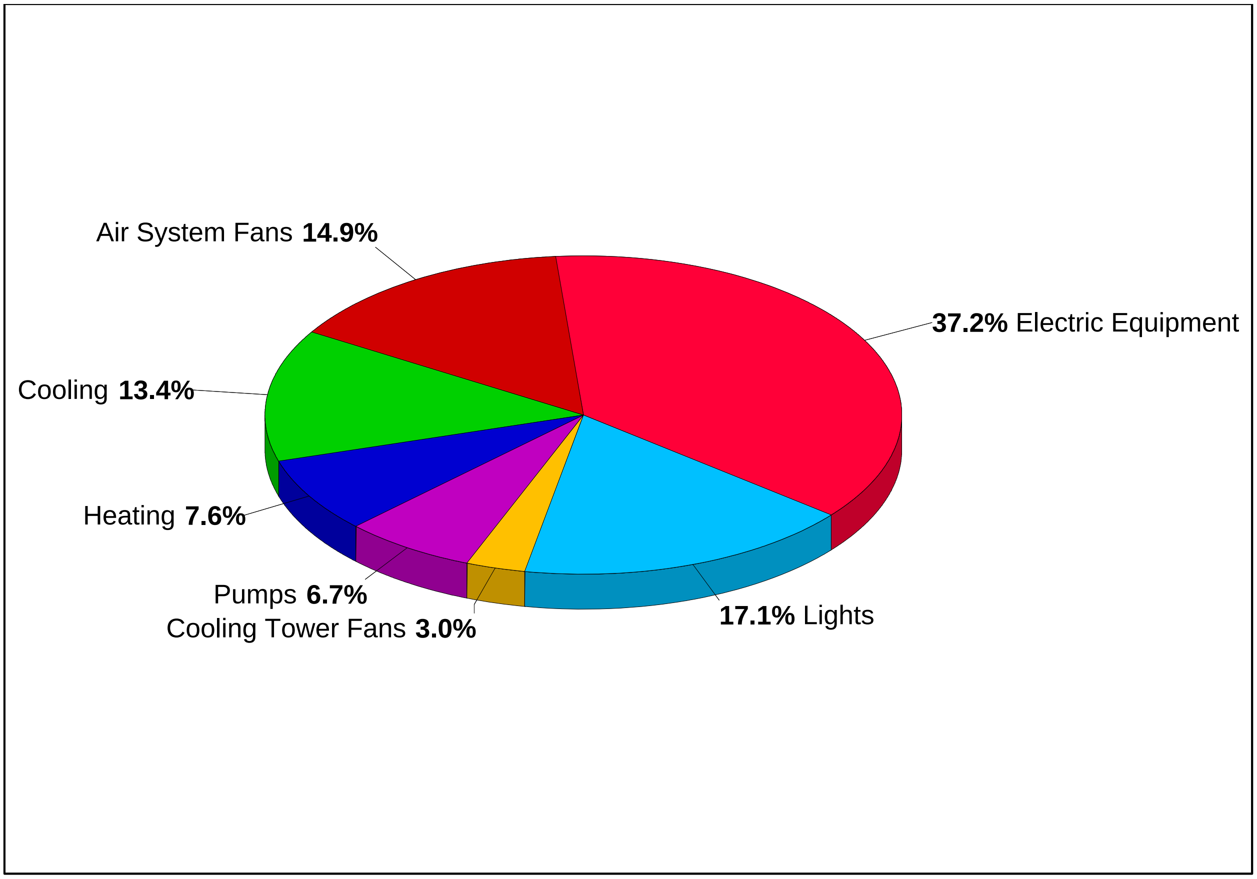
Month	Air System Fans ($)	Cooling ($)	Heating ($)	Pumps ($)	Cooling Towers ($)	HVAC Total ($)
January	2,171	11,608	3,526	47,517	2,770	67,592
February	1,990	10,996	2,969	43,074	2,523	61,552
March	2,252	12,920	2,621	47,568	2,790	68,151
April	2,205	12,826	1,938	45,964	2,696	65,629
May	2,317	13,946	1,512	47,553	2,789	68,117
June	3,761	23,606	1,583	75,919	4,442	109,311
July	3,888	24,941	1,598	78,194	4,562	113,183
August	3,904	24,790	1,640	78,434	4,582	113,350
September	3,757	23,397	1,671	75,806	4,438	109,069
October	2,317	13,844	1,725	47,511	2,787	68,184
November	2,163	12,283	2,395	46,071	2,702	65,614
December	2,171	11,579	3,220	47,461	2,778	67,209
Total	**32,896**	**196,737**	**26,399**	**681,072**	**39,859**	**976,962**

2. Non-HVAC Component Costs

Month	Lights ($)	Electric Equipment ($)	Misc. Electric ($)	Misc. Fuel Use ($)	Non-HVAC Total ($)	Grand Total ($)
January	5,592	12,181	0	0	17,772	85,364
February	5,077	11,055	0	0	16,132	77,684
March	5,619	12,220	0	0	17,839	85,990
April	5,397	11,777	0	0	17,174	82,803
May	5,617	12,216	0	0	17,833	85,950
June	8,962	19,497	0	0	28,459	137,770
July	9,189	20,042	0	0	29,231	142,414
August	9,265	20,149	0	0	29,414	142,764
September	8,936	19,465	0	0	28,401	137,470
October	5,591	12,179	0	0	17,770	85,954
November	5,438	11,832	0	0	17,270	82,884
December	5,577	12,165	0	0	17,742	84,951
Total	**80,260**	**174,776**	**0**	**0**	**255,036**	**1,231,998**

Annual Component Costs - Hilton Hotel at BWI Airport

BWI Hilton - New Mechanical System Design 04/05/2006
The Pennsylvania State University 08:00PM

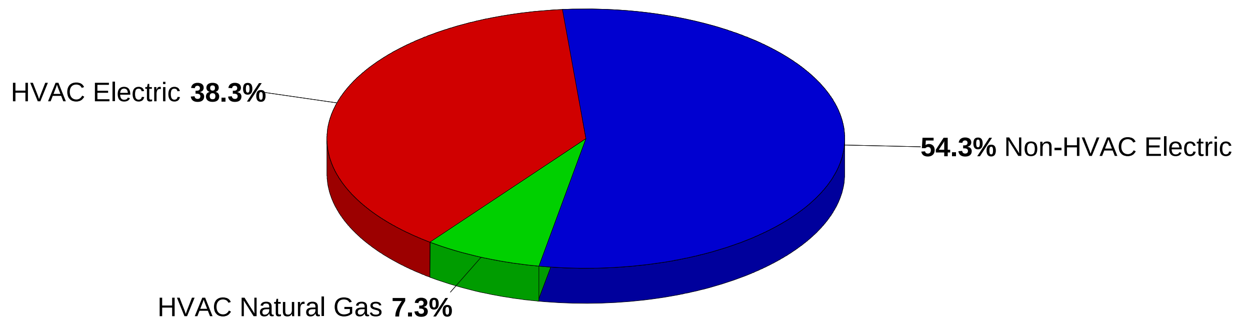


1. Annual Costs

Component	Annual Cost ($)	($/ft²)	Percent of Total (%)
Air System Fans	70,277	0.245	14.9
Cooling	63,402	0.221	13.4
Heating	36,124	0.126	7.6
Pumps	31,683	0.110	6.7
Cooling Tower Fans	14,213	0.050	3.0
HVAC Sub-Total	**215,698**	**0.751**	**45.7**
Lights	80,812	0.282	17.1
Electric Equipment	175,979	0.613	37.2
Misc. Electric	0	0.000	0.0
Misc. Fuel Use	0	0.000	0.0
Non-HVAC Sub-Total	**256,791**	**0.895**	**54.3**
Grand Total	**472,490**	**1.646**	**100.0**

Note: Cost per unit floor area is based on the gross building floor area.

Gross Floor Area .... **287071.0** ft²
Conditioned Floor Area .... **287071.0** ft²



1. Annual Costs

Component	Annual Cost ($/yr)	($/ft²)	Percent of Total (%)
HVAC Components			
Electric	181,074	0.631	38.3
Natural Gas	34,616	0.121	7.3
Fuel Oil	0	0.000	0.0
Propane	0	0.000	0.0
Remote Hot Water	0	0.000	0.0
Remote Steam	0	0.000	0.0
Remote Chilled Water	0	0.000	0.0
HVAC Sub-Total	**215,690**	**0.751**	**45.7**
Non-HVAC Components			
Electric	256,782	0.895	54.3
Natural Gas	0	0.000	0.0
Fuel Oil	0	0.000	0.0
Propane	0	0.000	0.0
Remote Hot Water	0	0.000	0.0
Remote Steam	0	0.000	0.0
Non-HVAC Sub-Total	**256,782**	**0.895**	**54.3**
Grand Total	**472,472**	**1.646**	**100.0**

Note: Cost per unit floor area is based on the gross building floor area.

Gross Floor Area .... **287071.0** ft²
Conditioned Floor Area .... **287071.0** ft²

Energy Budget by System Component - Hilton Hotel at BWI Airport

BWI Hilton - New Mechanical System Design 04/05/2006
The Pennsylvania State University 08:00PM

1. Annual Coil Loads

Component	Load (kBTU)	(kBTU/ft²)
Cooling Coil Loads	33,247,980	115.818
Heating Coil Loads	13,632,590	47.489
Grand Total	**46,880,564**	**163.307**

2. Energy Consumption by System Component

Component	Site Energy (kBTU)	Site Energy (kBTU/ft²)	Source Energy (kBTU)	Source Energy (kBTU/ft²)
Air System Fans	3,423,614	11.926	12,227,194	42.593
Cooling	2,735,189	9.528	9,768,529	34.028
Heating	17,442,574	60.761	17,649,220	61.480
Pumps	1,527,502	5.321	5,455,364	19.004
Cooling Towers	618,064	2.153	2,207,370	7.689
HVAC Sub-Total	**25,746,942**	**89.688**	**47,307,677**	**164.794**
Lights	3,954,558	13.776	14,123,420	49.198
Electric Equipment	8,611,752	29.999	30,756,254	107.138
Misc. Electric	0	0.000	0	0.000
Misc. Fuel Use	0	0.000	0	0.000
Non-HVAC Sub-Total	**12,566,310**	**43.774**	**44,879,674**	**156.337**
Grand Total	**38,313,252**	**133.463**	**92,187,351**	**321.131**

Notes:

1. 'Cooling Coil Loads' is the sum of all air system cooling coil loads.
2. 'Heating Coil Loads' is the sum of all air system heating coil loads.
3. Site Energy is the actual energy consumed.
4. Source Energy is the site energy divided by the electric generating efficiency (28.0%).
5. Source Energy for fuels equals the site energy value.
6. Energy per unit floor area is based on the gross building floor area.
   Gross Floor Area .... **287071.0** ft²
   Conditioned Floor Area .... **287071.0** ft²

Energy Budget by Energy Source - Hilton Hotel at BWI Airport

BWI Hilton - New Mechanical System Design
The Pennsylvania State University

04/05/2006
08:00PM

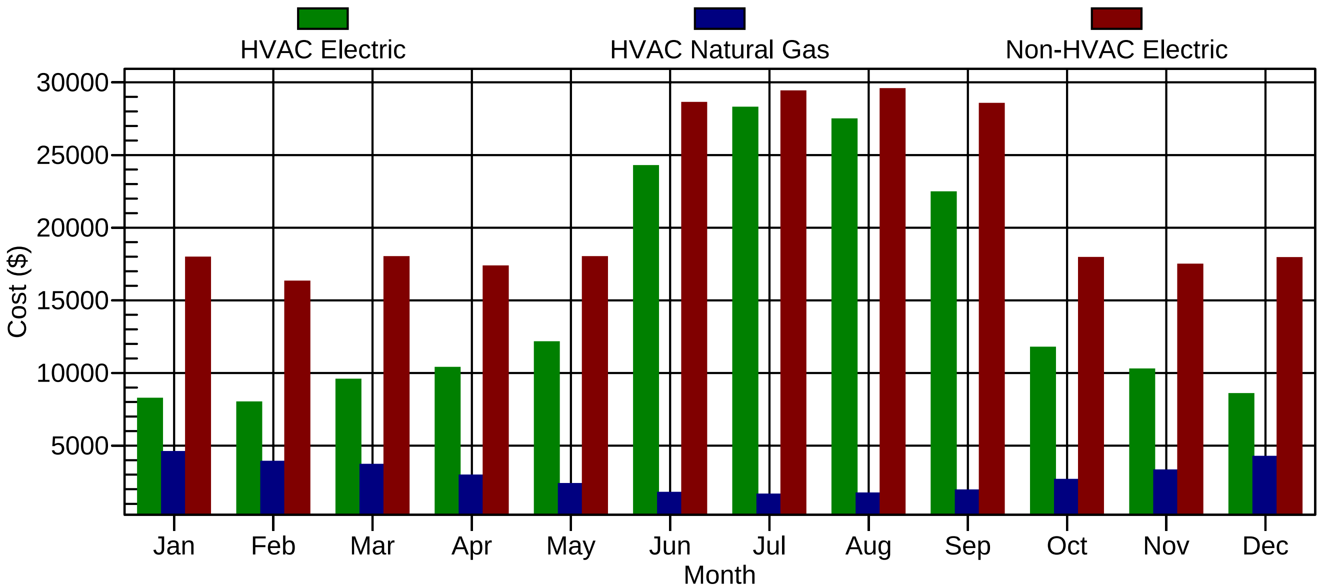
1. Annual Coil Loads

Component	Load (kBTU)	(kBTU/ft²)
Cooling Coil Loads	33,247,980	115.818
Heating Coil Loads	13,632,590	47.489
Grand Total	**46,880,564**	**163.307**

2. Energy Consumption by Energy Source

Component	Site Energy (kBTU)	Site Energy (kBTU/ft²)	Source Energy (kBTU)	Source Energy (kBTU/ft²)
HVAC Components				
Electric	8,384,262	29.206	29,943,796	104.308
Natural Gas	17,362,210	60.481	17,362,210	60.481
Fuel Oil	0	0.000	0	0.000
Propane	0	0.000	0	0.000
Remote Hot Water	0	0.000	0	0.000
Remote Steam	0	0.000	0	0.000
Remote Chilled Water	0	0.000	0	0.000
HVAC Sub-Total	**25,746,472**	**89.687**	**47,306,006**	**164.789**
Non-HVAC Components				
Electric	12,565,848	43.773	44,878,028	156.331
Natural Gas	0	0.000	0	0.000
Fuel Oil	0	0.000	0	0.000
Propane	0	0.000	0	0.000
Remote Hot Water	0	0.000	0	0.000
Remote Steam	0	0.000	0	0.000
Non-HVAC Sub-Total	**12,565,848**	**43.773**	**44,878,028**	**156.331**
Grand Total	**38,312,320**	**133.459**	**92,184,034**	**321.119**

Notes:
1. 'Cooling Coil Loads' is the sum of all air system cooling coil loads.
2. 'Heating Coil Loads' is the sum of all air system heating coil loads.
3. Site Energy is the actual energy consumed.
4. Source Energy is the site energy divided by the electric generating efficiency (28.0%).
5. Source Energy for fuels equals the site energy value.
6. Energy per unit floor area is based on the gross building floor area.
   Gross Floor Area .... **287071.0** ft²
   Conditioned Floor Area .... **287071.0** ft²



1. HVAC Costs

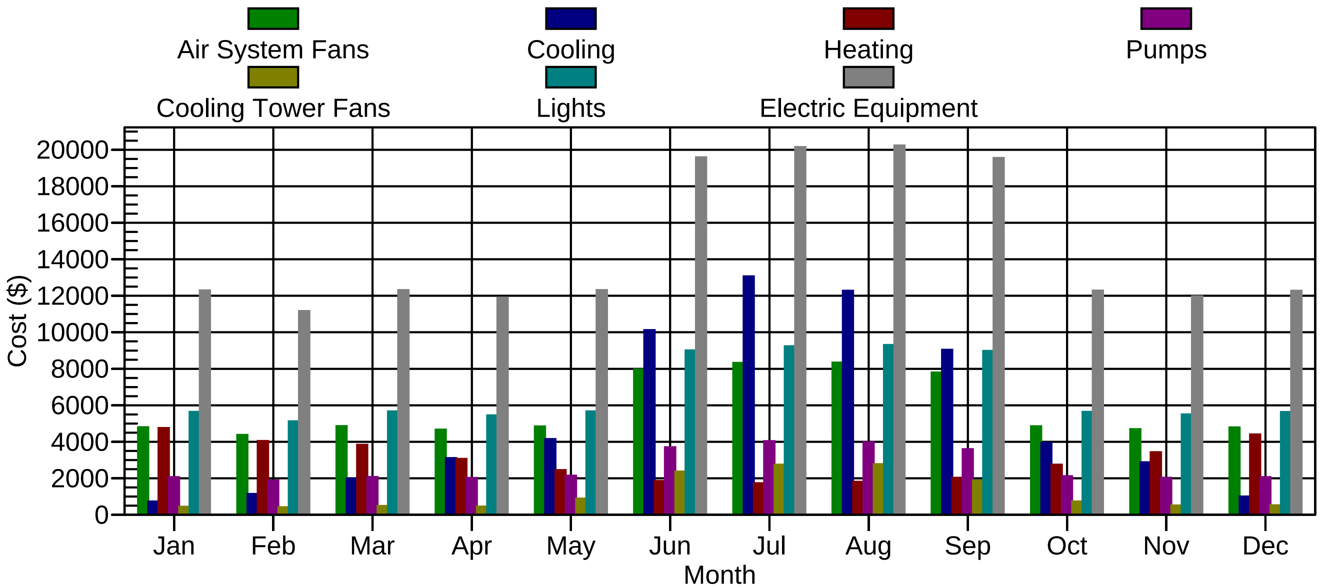
Month	Electric ($)	Natural Gas ($)	Fuel Oil ($)	Propane ($)	Remote Hot Water ($)	Remote Steam ($)	Remote Chilled Water ($)
January	8,226	4,561	0	0	0	0	0
February	7,972	3,886	0	0	0	0	0
March	9,533	3,684	0	0	0	0	0
April	10,354	2,946	0	0	0	0	0
May	12,107	2,359	0	0	0	0	0
June	24,236	1,749	0	0	0	0	0
July	28,258	1,636	0	0	0	0	0
August	27,452	1,709	0	0	0	0	0
September	22,425	1,917	0	0	0	0	0
October	11,734	2,643	0	0	0	0	0
November	10,235	3,296	0	0	0	0	0
December	8,543	4,231	0	0	0	0	0
Total	**181,074**	**34,616**	**0**	**0**	**0**	**0**	**0**

2. Non-HVAC Costs

Month	Electric ($)	Natural Gas ($)	Fuel Oil ($)	Propane ($)	Remote Hot Water ($)	Remote Steam ($)
January	17,929	0	0	0	0	0
February	16,285	0	0	0	0	0
March	17,971	0	0	0	0	0
April	17,336	0	0	0	0	0
May	17,972	0	0	0	0	0
June	28,585	0	0	0	0	0
July	29,379	0	0	0	0	0
August	29,534	0	0	0	0	0
September	28,518	0	0	0	0	0
October	17,914	0	0	0	0	0
November	17,459	0	0	0	0	0
December	17,900	0	0	0	0	0
Total	**256,782**	**0**	**0**	**0**	**0**	**0**

Monthly Component Costs - Hilton Hotel at BWI Airport

BWI Hilton - New Mechanical System Design 04/05/2006
The Pennsylvania State University 08:00PM



1. HVAC Component Costs

Month	Air System Fans ($)	Cooling ($)	Heating ($)	Pumps ($)	Cooling Towers ($)	HVAC Total ($)
January	4,794	734	4,751	2,065	445	12,789
February	4,377	1,143	4,045	1,876	417	11,858
March	4,856	1,979	3,832	2,071	480	13,218
April	4,668	3,102	3,060	2,017	453	13,300
May	4,841	4,150	2,447	2,140	889	14,467
June	7,960	10,114	1,849	3,698	2,365	25,986
July	8,323	13,059	1,726	4,035	2,750	29,893
August	8,339	12,275	1,805	3,974	2,767	29,160
September	7,795	9,043	2,029	3,596	1,880	24,343
October	4,846	3,935	2,745	2,118	733	14,377
November	4,690	2,872	3,429	2,031	511	13,533
December	4,789	996	4,406	2,060	524	12,775
Total	**70,277**	**63,402**	**36,124**	**31,683**	**14,213**	**215,698**

2. Non-HVAC Component Costs

Month	Lights ($)	Electric Equipment ($)	Misc. Electric ($)	Misc. Fuel Use ($)	Non-HVAC Total ($)	Grand Total ($)
January	5,641	12,289	0	0	17,930	30,719
February	5,126	11,160	0	0	16,286	28,144
March	5,661	12,311	0	0	17,972	31,190
April	5,448	11,889	0	0	17,337	30,637
May	5,661	12,311	0	0	17,972	32,439
June	9,002	19,584	0	0	28,586	54,572
July	9,236	20,144	0	0	29,380	59,273
August	9,303	20,232	0	0	29,535	58,695
September	8,973	19,546	0	0	28,519	52,862
October	5,636	12,278	0	0	17,914	32,291
November	5,498	11,962	0	0	17,460	30,993
December	5,627	12,274	0	0	17,901	30,676
Total	**80,812**	**175,979**	**0**	**0**	**256,791**	**472,490**