Final Report

Butler Memorial Hospital | New Inpatient Tower

Butler Healthcare Providers

Butler, PA

Advisor: Dr. William Bahnfleth

Butler Memorial Hospital | New Inpatient Tower

Butler, PA

Statistics

Occupancy: Hospital: Surgery, Recovery, CCU
Cost: 93 Million (Guaranteed Maximum Price)
Size: 209,678 Square Feet
Levels: 6 Above Grade - 2 Below Grade
Construction: September 2008 – July 2010
Delivery: Design – Bid – Build

Architecture

The state of the art hospital welcomes patients and visitors with a grand atrium invigorating guests with hope and light. An abundance of natural daylight and cheerful colors splash off the interior of the hospital creating a youthful vibe within the confines. Cutting edge operating and recovery rooms allow patients to experience the finest in healthcare quality.

The exterior of the hospital bridges the contemporary hospital interior with the historic reverence of a town like Butler, Pennsylvania. Red brick veneer and a series of aluminum curtain wall systems are the main highlight as the north façade gently curves around to the west taking into account the natural lay of the land.

Project Team

Owner: Butler Healthcare Providers
General Contractor: Turner Construction
Owners Rep: Ritter Construction
Architect: Design Group
Engineers: Hammel, Green, & Abrahamson

Mechanical

Comprised mainly of (3) large rooftop air handlers supplying 62,000 CFM each with (5)smaller air handling units supplying the balance. In the mechanical room at ground level, (2) 400 ton chillers and (1) 119 ton chiller supply the air handlers with cool water., while (2) 7200 MBH boilers supply hot water used for heating. The system also takes advantage of variable air volume boxes and finned radiant heat along the perimeter of the building in patient rooms.

Electrical

The hospital is serviced with 3 phase, 4 wire incoming service at 480/277V. The high voltage is used primarily for running heavy equipment, motors, and fans as well as fluorescent lights before being stepped down to 208/120V. The lower voltage is for general use throughout the hospital.

Structural

The hospital is supported by steel wide flange beams and columns which are carried by poured concrete caissons and grade beams. Resting on top of the wide flange beams is a composite metal deck system with shear studs and 3-1/2" of concrete topping. Columns are laterally braced using K frame braces. Typical exterior wall construction is face brick with 2" rigid insulation mounted on 6" steel studs with gypsum wall board on both sides.

Matthew S. Geary | Mechanical Option

www.engr.psu.edu/ae/thesis/portfolios/2011/msg5039

Table of Contents

1.0 Introduction

1.1 Acknowledgments

I would like to thank Butler Healthcare Providers for allowing me to utilize their New Inpatient Tower at the Butler Memorial Hospital as the focus for my senior thesis. I would also like to thank Turner Construction for their continued participation in actively sponsoring Architectural Engineering students and the thesis program. Within Turner, I would especially like to extend my deepest gratitude towards Megan Corrie, who aided and helped drastically during the information gathering phase.

Next, I would like to thank the engineers at Hammel, Green, & Abrahamson for providing me with professional advice and design history of the New Inpatient Tower. Mr. Tim Anderson and Mr. Michael Woodson who served as the lead mechanical and electrical project engineers, respectively, deserve much credit for providing me with necessary information and feedback when performing my research. I would also like to extend my thanks to David Miller of H.F. Lenz Company for assisting with the development of the Trane Trace energy model.

The design and selection of the chilled beam system and pinnacle unit could not have been done without the guidance and expertise of Semco Incorporated, including Matt Pemberton, Randy Phillips, and especially Thomas Kitchen. Limbach Facility Services deserves much recognition as well. They helped to clarify any issue that arose regarding the installation and pricing of mechanical equipment as well as providing a significant amount of information regarding the original design. Without their help, especially that of Mr. John Hilf, a large portion of this report would not have been possible.

Finally, I would like to thank the faculty and my fellow students at Penn State. The assistance and vast knowledge of my senior thesis advisor, Dr. William Bahnfleth, must be recognized for providing me with guidance and professional expertise both in and out of class. Other faculty members who should be commended are Professor Kevin Parfitt and Professor Bob Holland. These two individuals worked diligently all year to ensure that the senior thesis project progressed smoothly and in a timely manner. Thanks to all of the people and companies mentioned above, this senior thesis project was completed as comprehensive and accurate as possible, which truly made it an enjoyable learning experience.

1.2 Executive Summary

The New Inpatient Tower at the Butler Memorial Hospital is a 209,000 square foot addition seated in Butler, Pennsylvania that was recently completed in July 2010. The eight story tower was built to house state of the art operating and recovery rooms as well as intensive care units.

This document is an assemblage of research, documentation, and data collected from the New Inpatient Tower specifically targeted to analyze the implementation of a redesigned mechanical system. The goal of this thesis project was to design the HVAC system to make it more energy efficient thereby decreasing utility costs and lowering the carbon footprint as well as providing a comfortable environment for patients and staff. It was also a primary goal to analyze the effects of the HVAC redesign on the life cycle cost and on other building components to evaluate the feasibility and the economic impact that the redesign would have on the building as a whole.

The original mechanical design was on a strict budget and performed well meeting the design criteria at minimal cost. Originally the hospital was designed to operate as a variable air volume system with reheat. The system was comprised of (2) 400 ton chillers and (2) 7,200 MBH boilers supplying chilled and heating water to (3) 62,000 CFM rooftop air handlers which make up a loop system delivering air to the entire hospital. The operating rooms and their support space were served by an independent VAV system consisting of (1) 120 ton chiller feeding (2) 18,500 CFM air handlers.

The redesigned system was designed to be a dedicated outside air system with supplemental active chilled beams. Due to a decreased amount of ventilation air, heat recovery via enthalpy wheels, and reduced heat from supply fans, the cooling and heating loads were reduced which allowed for the redesign of the central plant. The redesigned system will not affect the mechanical design of the operating rooms and their support spaces; however, the remainder of the inpatient tower will be served by (1) 40,000 CFM DOAS Pinnacle air handler and 476 chilled beams of assorted sizes. (3) 180 ton screw chillers will replace the original chillers: one supplying the rooftop air handler, one supplying the chilled beams, and the third acting as a redundant back-up capable of meeting either load.

A first cost comparison was done between the two systems and it was found that the redesigned system will save **$277,000** in construction and equipment costs. The redesigned system will also reduce annual operational costs by **$33,800/year** and energy consumption by **2,700 MMBtu/year.**

In order to analyze the effects of the redesigned mechanical system on other building components, a structural and electrical breadth was instituted. Due to the elimination of (2) 62,000 CFM rooftop air handlers and a reduction to the third, the overall amount of structural steel in the roof decreased by **6.4 tons** and **$18,000** in construction costs. Because the redesigned system decreases the size and quantity of the mechanical equipment requiring electricity, the overall power demand of the HVAC equipment was reduced by **426 KVA.**

It was found that the redesigned system will save money both in first costs and operational costs, lower annual energy consumption, decrease the carbon footprint, and provide patients and medical staff with a comfortable environment.

2.0 Project Information

2.1 Design Goals

The Butler Healthcare Providers developed the idea for a New Inpatient Tower to address an increased need for a state of the art operating facility and recovery area. The 193,000 square foot addition was designed to be attached to the Northern end of the existing hospital and integrate nicely with the existing structure. Medical procedures and operation within the space require very sophisticated equipment and strictly controlled environment to provide the maximum amount of comfort and cleanliness to patients and staff. To meet these challenges, engineers implemented a strategy that put patient comfort and functionality first.

2.2 Location

The New Inpatient Tower at the Butler Memorial Hospital is located in Butler, Pennsylvania, which is roughly 30 miles north of Pittsburgh, PA. One of the challenges designers faced was incorporating a contemporary building into a historic setting, as is the case in Butler. The Butler Memorial Hospital site can be seen in the aerial view in ***Figure 1.*** The white rooftop in the Northeast corner is the New Inpatient Tower which will be analyzed throughout this report.

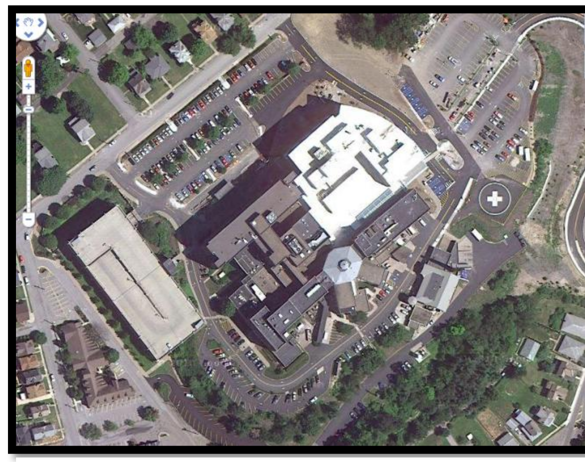

Figure 1: Project Site

2.3 Project Team

- **Owner** *Butler Healthcare Providers*
- **Owner's Representative** *Ritter Construction Management*
- **Construction Manager** *Turner Construction Company*
- **Mechanical Contractor** *Limbach Facility Services*
- **Architect** *Design Group*
- **MEP/Structural Engineers** *Hammel, Green and Abrahamson*
- **Civil Engineer** *Pedersen & Pedersen*
- **Technology Engineer** *KJWW Engineering Consultants*
- **Equipment Planner** *Korbel Associates*
- **Elevator Consultant** VDA

3.0 Building Overview & Existing Conditions

3.1 Architecture

The overall architecture of the New Inpatient Tower of the Butler Memorial Hospital is integrated very nicely into the existing portions of the hospital as well as surrounding buildings scattered about downtown Butler. Red brick veneer and tinted curtainwalls with aluminum trim comprise the majority of the exterior, which also happens to blend nicely with the existing red brick of the original hospital. As seen in ***Figure 2*** the North elevation is curved and also steps down with the contour of the existing hillside as it wraps around towards the west side of the building. After making the turn west, the ground continues to slope which is highlighted by aluminum cladded columns which dot the North and West perimeter of the building.

Figure 2: North Facade and Main Entrance

Figure 3: Atrium

Upon entering the inpatient tower through the main entry of the north façade on the second floor, a grand atrium, ***Figure 3,*** two stories high is capped off by a full length triangular skylight in order to greet visitors with open arms. The remainder of the second floor is filled with public retail, convenience, and waiting areas, an auditorium, a chapel, several offices and conference rooms, as well as employee locker rooms. The third floor is mainly dedicated to surgery, equipped with operating rooms, an anesthesia administration area, and immediate recovery rooms. In order to match the existing hospital, the floor above the third floor is not the fourth, but instead the fifth floor which is primarily composed of critical care units.

The upper floors, six and seven, are identical and devoted to long term surgery recovery rooms as shown in ***Figure 4***. Above the seventh floor is the penthouse, which houses the elevator machine room and is adjacent to the rooftop air handlers. A second entrance at a lower elevation on the west façade allows maintenance personnel to enter directly on the ground floor with

Figure 4: Typical Patient Room

immediate access to the emergency generators and storage areas. Between the ground floor and second floor, the first floor is home to the mechanical and electrical rooms. The overall architecture of the hospital has a contemporary vibe equipped with flat screen televisions in every patient's room, vibrant and lively color schemes, and architectural sculptures which help to create a positive feeling within the tower.

3.2 Building Enclosure

Figure 5: North/West Facade

The majority of the exterior façade is deep red face brick veneer shown in ***Figure 5.*** Behind the brick is a 1" air cavity, followed by 2" rigid insulation, and 5/8" gypsum wall board attached to 6" steel studs which are filled with batt insulation between studs. The exterior glazing is primarily 1" tinted insulating glass comprised of ¼" tinted exterior lite equal to PPG Gray with low "E" coating matching Viracon VE3-2M with a ½" air space and then ¼" clear interior lite; and 1" insulating spandrel glass comprised of ¼" clear exterior light, ½" air space, and ¼" spandrel interior light with ceramic frit equal to Viracon Subdued Gray. These two window types are used exclusively with 1/8" Aluminum panels to create a glazed aluminum curtainwall system. Wire cloth screening, clear glass, laminate glass, and fretted glass are also used sparingly in order to make the façade more interesting.

The roof of the new tower is comprised mainly of a mechanically fastened membrane system. The system uses a white 60 mil thermoplastic polyolefin (TPO) membrane formed into flexible, uniform sheets and then mechanically fastened together. Fully adhered EPDM single ply membrane is to be used to top of canopy roofs.

3.3 Structural System

The hospital is supported by steel wide flange beams and columns which are carried by poured concrete caissons, ranging in diameter from 30" – 80", and grade beams. The majority of the columns are W 14 with weights ranging from 43 – 176 lbs/ft. Although various wide flange beam sizes are used, the majority of the hospital is supported by either W16x26 or W18x40. Resting on top of the wide flange beams is a composite metal deck system with 5" shear studs and 3-1/2" of concrete topping for a total floor height of 6-1/2". Columns are laterally braced using K frame braces in both directions. 10" K frames are used on levels 1 – 3, and 8" K frames are used on the upper levels. Typical exterior wall construction is face brick with 2" rigid insulation mounted on 6" steel studs with gypsum wall board on both sides.

3.4 Electrical System

The hospital is serviced with 3 phase, 4 wire incoming service at 480/277V. The main feed is from the existing hospital and enters the addition vie the first floor mechanical room. Within the mechanical room a 2,500 kVA transformer reduces the voltage to that which is suitable for building distribution. There are electrical rooms on every level capable of supplying 480/277V and

208/120V. The high voltage is used primarily for running heavy equipment, motors, and fans as well as fluorescent lights. The lower voltage is for general use throughout the hospital including incandescent lights, receptacles, and office equipment. There are also (2) emergency generators located on the ground floor directly under the main electrical room. These will provide back-up power in the case of a power outage.

3.5 Lighting System

Within a hospital, there is obviously a need for various kinds of light fixtures. The Butler Memorial Hospital New Inpatient Tower is no exception. There are over 85 different types of light bulbs which are all serving a specific function. The lighting is all served by either 277V, which is used for all fluorescents, or 120V which is used for incandescent, and halogen luminaires. These lights serve various functions from wall washing, to accent lighting in the chapel, to providing the highest quality of light for the operating rooms.

3.6 Fire Protection

The hospital is equipped with state of the art fire protection. When designing the building, engineers took special care to install smoke partitions and dividers so that smoke cannot travel freely throughout the building. A spray on fire-proofing has been applied to all steel structural members to ensure the integrity of the steel under fire conditions. Lastly, there is an integrated sprinkler system which supplies every room within the hospital served by a Siamese connection at ground level for fire department hook-up.

3.7 Pneumatic Tube Delivery

The hospital is equipped with a compressed air driven tube delivery system which allows nurses to transport tangible objects in a more expedient manner. Hospital personnel are able to send documents, files, and even medications through the system. The system was designed and developed by Swisslog, which uses a compressor manufactured by Amico. By using the pneumatic system, it allows for less corridor traffic and busy work for staff, thereby increasing efficiency and the standard of care for patients.

3.8 Construction Statistics

- **Dates of Construction:** September 2008 – July 2010
- **Costs:** 93 Million (GMP)
- **Project Delivery Method:** Design Bid Build

4.0 Existing Mechanical System

4.1 Introduction

The New Inpatient Tower at the Butler Memorial Hospital serves as the newest attraction to the hospital, and at 209,000 square feet of space it houses much of the hospital's activity. The new tower includes many public spaces including a chapel, retail space, a café, waiting areas, and conference rooms on the main level. Below the main level is mostly mechanical space and storage; however, the focal point of the tower lies on the floor above. Eight state-of-the-art operating rooms are the main attraction of the entire addition. The remainder of the tower is comprised of recovery rooms, critical care units, and patient rooms for those recovering from surgery.

4.2 Design Criteria

When designing the New Inpatient Tower, engineers and architects took a very direct approach: build a patient tower that will be energy efficient, reliable, and comfortable for patients and families. When designing the HVAC systems, reliability and comfort were the two most important factors. Any HVAC system looks to provide comfortable temperature and humidity levels, which this system easily accomplishes. Every main piece of equipment within the mechanical system has inherent redundancy. Due to the loop system and other design specifications, the hospital can lose an air handler, cooling tower, primary pump, secondary pump, chiller, or boiler and is still able to meet the majority of loads under normal operating conditions. It should be noted that there were no design influences based upon the site, rebates, or tax relief.

Due to the nature of the hospital, a great deal of the thermal and energy loads are a direct effect of lighting and hospital equipment operation. Both of these areas are essential for the tower to function and are fairly constant loads. Variable loads which occur are due to infiltration, conditioning of ventilation air, solar gain, and mechanical equipment loads.

Designers oversized the outside air fraction to ensure proper indoor air quality providing patients and staff with high quality supply air. The building is designed for every space to receive 33% outside air at design loads. The minimum ventilation rates used by engineers also significantly exceeds ASHRAE Standard 62.1, reinforcing the fact that air quality within the tower is a large concern.

Solar gain during the cooling season is not a large problem for the inpatient tower. The hospital design is fairly conservative when it comes to fenestration, which will lower the effects of solar gain. Also, the majority of fenestration is located on the North and Northwest facades of the building with only a small portion of exterior glass occurring along the southern face.

Mechanical equipment operation accounts for a large portion of the overall energy consumption. The system could very well be sized down to become more efficient; however, design engineers were more focused on reliability and redundancy than efficiency. This approach is understandable since there will be human lives in jeopardy every day, demanding certain environmental conditions for the best chance of survival.

An extremely important facet of the hospital design is linked to the (8) operating rooms on the third floor. These operating rooms are served by two identical air handlers and are 100% redundant in the case that one air handler malfunctions. The two air handlers are fed by a 120 ton scroll chiller supplying 34°F chilled water in order to keep the operating rooms at exactly 60°F year round. The system is backed up by the (2) main chillers in an emergency case. Hepa filters at the terminal boxes also ensure the highest quality air within the operating rooms.

The mechanical system also had to be designed for the overhanging floor on the third level. As a result of the third floor overhanging the second, extra thermal loads coming through the floor had to be accounted for. The perimeter of the tower is also home to the majority of patient rooms and subject to extra heating loads at the perimeter and windows. In order to give patients thermal control and to account for the additional envelope loads, designers implemented finned tube radiant coils along the perimeter of patient rooms and in the floor of the overhanging third level.

4.3 Design Conditions

The weather data and outdoor conditions were taken from the design data within ASHRAE Fundamentals 2009 and are shown below in ***Table 1***. Indoor design conditions were taken from the design documents basis of design. The driftpoint was also specified.

Outdoor Design Conditions	
Location	Butler, PA
Summer Dry Bulb (°F)	89
Summer Wet Bulb (°F)	73
Winter Dry Bulb (°F)	2
Carbon Dioxide Level	400

Table 1: Outdoor Design Conditions

As depicted in ***Tables 2 &3*** below, the thermostat setpoints for the hospital vary depending upon which space we are examining. The bulk of the hospital attempts to keep the inside environment within the thermal comfort region specifying a set point 75°F in the summer and 72°F in the winter and 50% relative humidity. However, the operating rooms are under more stringent requirements and require that the environment is maintained year round at 60°F and 50% relative humidity to reduce the chance of infection and bacteria growth within the operating rooms.

Operating Room Thermostat Parameter	
Cooling Dry Bulb (°F)	60
Heating Dry Bulb (°F)	60
Relative Humidity (%)	50
Cooling Driftpoint (°F)	62
Heating Driftpoint (°F)	58

Table 2: Operating Room Parameters

Typical Thermostat Parameter	
Cooling Dry Bulb (°F)	75
Heating Dry Bulb (°F)	72
Relative Humidity (%)	50
Cooling Driftpoint (°F)	77
Heating Driftpoint (°F)	70

Table 3: Typical Thermostat Parameters

4.4 Ventilation Requirements

After analyzing the entire ventilation system of the Butler Memorial Hospital, it has been determined that every space exceeds the required amount of ventilation air according to ASHRAE Std 62.1. As noted earlier, the bulk of the ventilation is done by AHU-1, 2, & 3 which comprise a loop sytem serving every area except for the operating rooms.

The total outside air intake V_{ot} = (14,366)/0.9 = 15,962 CFM according to standard 62.1. The design calls for 53,812 CFM of outside air, and 153,848 CFM of total supply air. The "as designed" outdoor airflow rate is considerably higher, likely due to engineers using an outside airflow rate of 20 CFM/person which is well above ASHRAE standards and designing the facility to meet AIA minimum air change rates. Due to the fact that AHU-1, 2, & 3 are each 62,000 CFM resulting in a total of 186,000 CFM, the air handlers are more than capable of meeting the load. The operating rooms require a minimum of 2,307 CFM of outside air according to Standard 62.1, but are designed for 9,682 CFM of outside air and 29,340 CFM of total supply air. AHU-4 & 5 are both 18,500 CFM, resulting in a combined 37,000 CFM which can easily meet the required load.

It is apparent that the designers oversized all the air handlers to ensure the best indoor air quality and to improve reliability. They coupled AHU-1, 2, and 3 to improve redundancy in case one air handler fails. They also designed the building to supply a great deal more outside air than required by ASHRAE to ensure patients receive the finest air quality. All spaces have an outside air fraction of 0.33.

4.5 Mechanical Equipment Summary

The primary heating, air conditioning, and ventilation is performed by a variable air volume system equipped with (3) 62,000 CFM rooftop air handlers. These three air handlers comprise a loop system which serves every area of the hospital except for operating rooms and a few mechanical rooms. Due to the nature of the loop system, all 3 air handlers are coupled feeding every diffuser. There is natural redundancy built into the mechanical system. (2) 400 ton centrifugal chillers with variable speed drives provide AHU-1, 2, & 3 with cold water used for dehumidification and cooling via (2) constant volume primary chilled water pumps and (2) VSD secondary pumps. A central rooftop cooling tower serves as the primary means of cooling the condenser water which exits the two centrifugal chillers.

Rooftop air handling units 4 and 5 are located on a lower level roof (Floor 5) and provide the necessary heating, ventilating, and air-conditioning to the (8) operating rooms which are located on the 3rd floor. The operating room air handlers are serviced by an adjacent 119 ton air-cooled scroll chiller supplying 34°F water. The lower temperature system is backed up by the primary chillers in case of emergency; 45°F primary water can still be supplied. Air Handling Units 6, 7, & 8 are all smaller units which serve specific mechanical rooms with an extra need for cooling. ***Figure 6*** below shows the location of the air handlers. It should be noted AHU-8 is not shown.

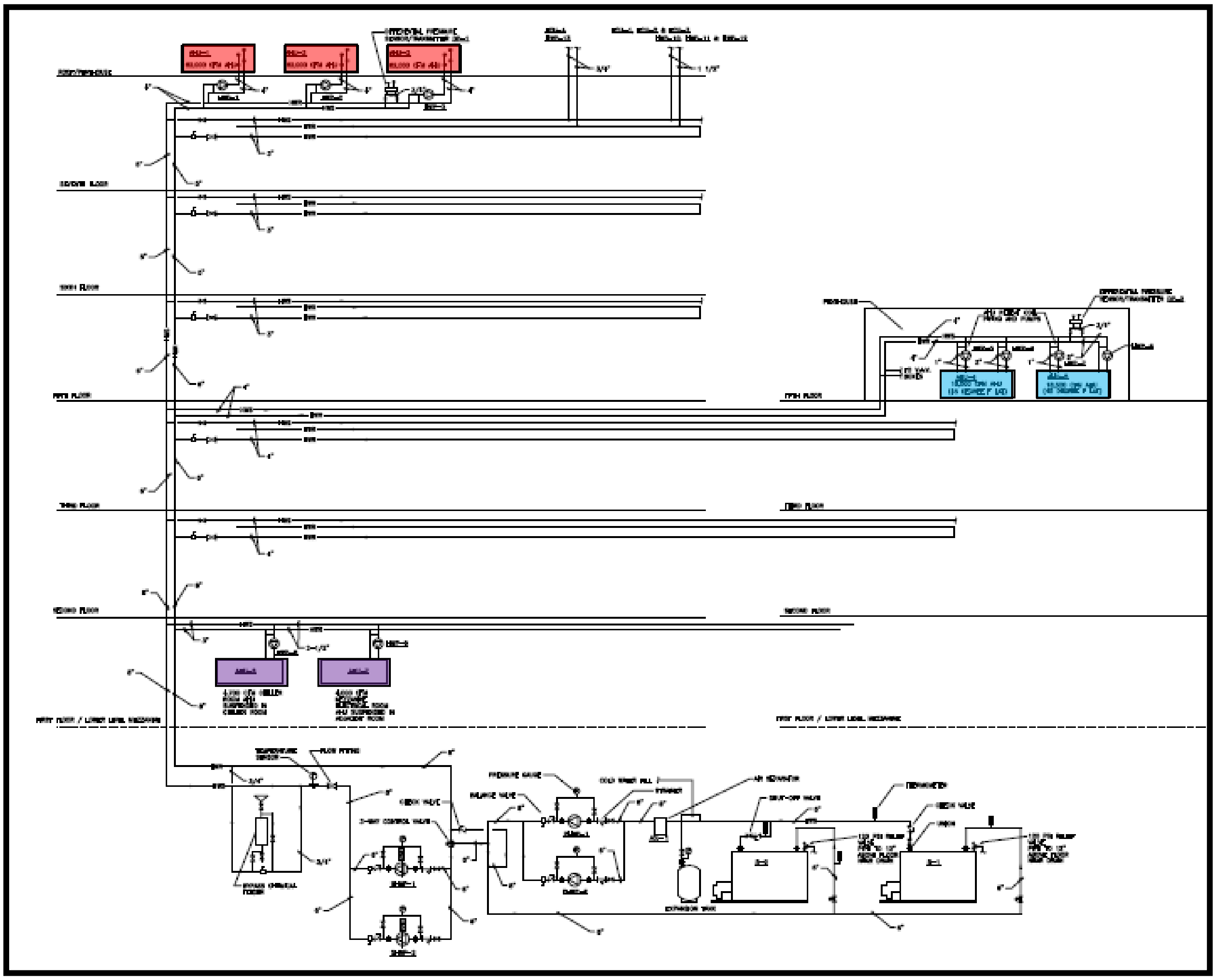

Figure 6: Original Air Handler Location

AHU-1, 2, 3 Serving Ground – 7th Floor

AHU- 4 & 5 Serving Operating Rooms

AHU- 6 & 7 Serving Chiller & Electrical Rooms

On the heating side, (2) 215 BHP combustion gas/oil-fired hot water boilers supply all of the heating water for the entire building: this includes heating water to the air handling unit heating coils, unit heaters used for reheat within terminal boxes, duct heating coils, radiant ceiling panels around the perimeter of patient rooms, and finned tube radiation in the soffit/plenum area above the second floor to keep the cantilevered floor warm. Two constant volume primary pumps and (2) VSD secondary pumps circulate the heating water. ***Tables 4 – 10*** break down the mechanical equipment used.

Air Handler Schedule					
System #	Area Served	Type	Supply CFM	Cooling Coil (EWT)	Heating Coil (EWT)
AHU-1	7th through lower level	VAV	62,000	44°F	180°F
AHU-2	7th through lower level	VAV	62,000	44°F	180°F
AHU-3	7th through lower level	VAV	62,000	44°F	180°F
AHU-4	Operating Rooms	VAV	18,500	34°F	180°F
AHU-5	Operating Rooms	VAV	18,500	34°F	180°F
AHU-6	1st Floor Chiller Room	CV	4,700	44°F	180°F
AHU-7	1st Floor Electrical Room	CV	4,000	44°F	180°F
AHU-8	Elevator Penthouse	CV	4,700	44°F	180°F

Table 4: Original Air Handler Schedule

Air Handler Fan Schedule						
System	Area Served	Supply Fans			Return Fans	
		Type	CFM	HP	CFM	HP
AHU-1	7th through lower level	VAV	62,000	125	52,000	50
AHU-2	7th through lower level	VAV	62,000	125	52,000	50
AHU-3	7th through lower level	VAV	62,000	125	52,000	50
AHU-4	Operating Rooms	VAV	18,500	30	16,500	15
AHU-5	Operating Rooms	VAV	18,500	30	16,500	15
AHU-6	1st Floor Chiller Room	CV	4,700	5	-	-
AHU-7	1st Floor Electrical Room	CV	4,000	5	4,000	1
AHU-8	Elevator Penthouse	CV	4,700	5	-	-

Table 5: Original AHU Fan Schedule

Exhaust Fan Schedule				
System #	Area Served	Type	hp	CFM
E-1	7th Floor Roof	CV	7.5	13,000
E-2	7th Floor Roof	CV	7.5	12,200
E-3	7th Floor Roof (Iso Rooms)	CV	10	7,000
E-4	Chiller Room	CV	1	4,700
PV-1	Ground and 1st General	CV	5	6,500
PV-2	Ground Med Gas Storage	CV	.25	450
PV-3	OR Suite Substerile	CV	.75	3,000
PV-4	1st Central Sterile	CV	.25	250

Table 6: Original Exhaust Fan Schedule

Chiller Schedule						
System #	Type	Tons	COP	EWT	LWT	GPM
CH-1	Centrifugal Chiller (AHU-1, 2, & 3)	400	5.93	54°F	42°F	800
CH-2	Centrifugal Chiller (AHU-1, 2, & 3)	400	5.93	54°F	42°F	800
CH-3	Air Cooled Scroll Chiller (AHU-4 & 5)	119	2.6	46.6°F	34°F	253

Table 7: Original Chiller Schedule

Boiler Schedule						
System #	Type	Capacity (MBH)	Eff.	EWT	LWT	GPM
B-1	Gas/Oil Fired Hot Water Boiler	7200	81%	160°F	180°F	720
B-2	Gas/Oil Fired Hot Water Boiler	7200	81%	160°F	180°F	720

Table 8: Original Boiler Schedule

Cooling Tower Schedule					
System #	Type	hp	EWT	LWT	GPM
CT-1	VSD Axial Fan Cooling Tower	20	95°F	85°F	1200
CT-2	VSD Axial Fan Cooling Tower	20	95°F	85°F	1200

Table 9: Original Cooling Tower Schedule

Pump Schedule						
System #	Location	System	Type	GPM	Head	VSD
PCHWP-1	Mech. Room	Chilled Water	End-Suct.	800	30	N
PCHWP-2	Mech. Room	Chilled Water	End-Suct.	800	30	N
PCHWP-3	5th Flr Pent.	Chilled Water	End-Suct.	260	70	N
SCHWP-1	Mech. Room	Chilled Water	End-Suct.	600	100	Y
SCHWP-2	Mech. Room	Chilled Water	End-Suct.	600	100	Y
CWP-1	Mech. Room	Cond. Water	End-Suct.	1200	65	N
CWP-2	Mech. Room	Cond. Water	End-Suct.	1200	65	N
PHWP-1	Mech. Room	Hot Water	End-Suct.	720	25	N
PHWP-2	Mech. Room	Hot Water	End-Suct.	720	25	N
SHWP-1	Mech. Room	Hot Water	End-Suct.	550	90	Y
SHWP-2	Mech. Room	Hot Water	End-Suct.	550	90	Y
HWP-1	AHU-1	Hot Water	Inline	174	15	N
HWP-2	AHU-2	Hot Water	Inline	174	15	N
HWP-3	AHU-3	Hot Water	Inline	174	15	N
HWP-4	AHU-4	Hot Water	Inline	44	10	N
HWP-5	AHU-4	Hot Water	Inline	10	5	N
HWP-6	AHU-5	Hot Water	Inline	44	10	N
HWP-7	AHU-5	Hot Water	Inline	10	5	N
HWP-8	AHU-6	Hot Water	Inline	25	10	N
HWP-9	AHU-7	Hot Water	Inline	17	10	N
HWP-10	AHU-8	Hot Water	Inline	20	10	N

Table 10: Original Pump Schedule

4.6 Mechanical System 1st Costs

The following is a breakdown of first costs associated with the mechanical system equipment and installation costs. The HVAC installation estimate includes all VFD's, ductwork, piping, miscellaneous pumps, valves, fuel oil system, and installation of equipment listed below. From ***Table 11*** it can be determined that the overall cost for the HVAC system is **$12,223,053.00** or **$62.10/sqft**.

Mechanical Costs			
HVAC Equipment	**Description**	**Total Cost**	**Cost/sqft**
AHU 1-3	Primary air handlers serving floors 1-7	$900,000	$4.57
AHU 4-5	Air handlers serving operating rooms	$308,000	$1.56
AHU 6-8	Air handlers serving mechanical rooms	$35,000	$0.18
Boiler 1-2	Gas/oil fired boiler	$127,000	$0.64
Chiller 1-2	Centrifugal water-cooled chiller	$305,000	$1.55
Chiller 3	Air-cooled scroll chiller	$48,000	$0.24
Makeup AHU 1-3	Makeup Units for AHU-1, 2, & 3	$62,000	$0.31
CT - 1 & 2	Cooling towers	$130,000	$0.66
Pumps (21)	PCHWP, SCHWP, CWP, PHWP, SHWP, HWP	$70,000	$0.36
Humidifiers (5)	Humidifiers used in AHU 1-5	$30,000	$0.15
HVAC Controls	Cost of control system	$1,062,592	$5.39
HVAC Installation	Mechanical contractor estimate	$9,155,461	$46.47
Total HVAC Cost		**$12,233,053**	**$62.10**
Plumbing	Fixtures, Equipment, & Installation	$5,313,603	$26.97
Total Mechanical Cost	(Includes HVAC and plumbing)	**$17,546,656**	**$89.07**

Table 11: Mechanical Costs

4.7 Lost Usable Space

Usable Space Occupied	
Floor	Sqft
First Floor	4,520
Second Floor	249
Third Floor	694
Fifth Floor	1094
Sixth Floor	534
Seventh Floor	534
Total	**7,625**

Table 12: Lost Usable Space

The total usable building space lost due to the mechanical system is shown in ***Table 12***. The usable space occupied on the first floor is extremely high because the mechanical room, chiller room, and boiler room are all housed on this floor. The 3rd – 7th floors are identical except for a few items. The 3rd floor loses more usable space than the 6th and 7th floor due to supply and return ducts entering the operating rooms. The 5th floor also loses more usable space due to the large penthouse which sits outside, on the roof of the third level, and houses the air handlers for the operating rooms.

4.8 Air Side Control

AHU-1, 2, and 3 are separate and independent air handling units which, when operated in parallel, provide building heating, ventilating, and air conditioning through a common duct system to all floors of the new addition. Each air handling unit includes a supply fan, inlet and outlet dampers, outside air / return air / relief air dampers, hot water heating coil, chilled water cooling coil, steam humidifiers, air filters, return /relief fan, and separate and independent controls. With the VAV system, the supply fans are enabled anytime that the air handler is in use and must always be able to supply the minimum amount of outdoor air required. The variable frequency drive in the supply fans modulate the amount of supply air to the zones according to duct static pressure set points read by sensors within the ductwork which is common to all AHUs. In most cases the return fan is operating in unison with the supply fan always attempting to maintain a positive pressure within the building.

Typically supply fans 1, 2 and 3 will be operated continuously with the lower limit at 31,000 CFM and upper limit set at 62,000 CFM for each. A high limit pressure control shall stop the supply fan if the static pressure at the discharge, between the fan outlet and outlet damper, reaches 4.0 inches of wg positive or if the mixed air plenum exceeds 2.0 inches of wg negative. All three main supply fans shall also operate at the same speed and airflow to provide quality and efficient usage of the mechanical equipment.

Supply air temperature control is done with a temperature sensor located in the supply air plenum of each unit which shall modulate the outside air/ return air/ relief air dampers, the hot water heating coil, and the chilled water coil all in sequence. Initial cooling setpoint will be at 53°F with the ability to drop as low as 45°F to provide dehumidification in response to return air humidity controls. When ambient temperature drops below 60°F the economizer mode begins to function; however, only after the outside temperature has reached 45°F does the economizer operate at 100%. The heating coil control valve shall be proportionally controlled to maintain a leaving air temperature setpoint 2°F lower than the supply air setpoint. The cooling coil control valve shall maintain the supply air at the setpoint specified. In the case of winter heating, a steam humidifier in the supply air will be controlled by a relative humidity sensor in the return air in an effort to keep the relative humidity in the space at a minimum of 30%. Reheat coils at the zone have the ability to alter the temperature of the air, prior to the supply air entering the zone.

Air handler units 4 and 5, which supply the operating rooms, function under almost identical conditions as AHU-1, 2, and 3 with the following exceptions: Each supply fan can only supply a maximum of 18,500 CFM and minimum of 14,610 CFM with a minimum outside air setpoint of 2,925 CFM if both fans are on or 3,700 CFM if only one fan is operating. The supply air temperature setpoint will be modulated between 40°F and 60°F in an effort to keep the zone temperature at exactly 60°F. It should be noted that the supply air temperature control can be overridden by dehumidification controls if necessary.

4.9 Water Side Control

4.9.1 Chilled Water System

The primary chilled water system includes (2) centrifugal water chillers, (2) primary chiller circulating pumps, (2) distribution chilled water system pumps, and controls. The chilled water system shall be controlled automatically through a local direct digital control panel, packaged chiller controls, and pump variable speed drives using PI and PID control methods.

The packaged chiller controls shall cycle and modulate the chiller compressor to maintain the chilled water supply temperature at 42°F. It should be noted that if the supply fan is stopped, flow through that cooling coil will also be eliminated. After the chiller is enabled, the control panel will send a signal to start the condenser water and chilled water pumps. Once there is proof of flow in the condenser and chilled water piping, the chillers will operate under their own control system.

Referencing ***Figure 7*** below, the primary chilled water pumps are in parallel and pump a constant volume of water through the chillers. Because the pumps are in parallel, they provide inherent redundancy. Once the primary flow enters the chiller, secondary variable speed drive chilled water pumps, also in parallel, distribute the necessary quantity of chilled water to the loads. The secondary pumps are VSD so that they can match the load required at the zone. A differential pressure sensor in the chilled water supply and return will control the speed on the secondary pumps to maintain the appropriate setpoint. If the load does not call for 100% of the primary flow, a fraction of the primary flow gets returned to the chiller via the bypass. The first chiller is enabled when outside air temperature is 44°F or higher. If only one chiller is being used, the second chiller will come on-line if flow through the bypass is reversed for longer than 15 minutes, indicating a shortage of capacity. This is done using a flow sensor. If both chillers are running, the second chiller will come off line when the excess primary flow is equal to the flow through the second chiller for longer than 15 minutes, indicating a surplus of capacity. The first chiller is disabled when outside air temperature is below 43°F. After the chilled water is pumped through the secondary pumps and the load, it is circulated back to the return where the primary pumps begin the cycle again.

The operating room chilled water system is independent of the primary chilled water system and consist of (1) 119 ton air-cooled scroll chiller, (1) circulating pump, and controls. The chiller controls will modulate chiller operation in order to maintain the desired chilled water leaving temperature setpoint of 34°F. A proof of flow sensor in the primary loop will prevent the chiller from operating if there is a lack of chilled water flow. The primary pump will operate continuously whenever the outside air temperature is above 40°F and shall be off when the outside air temperature is below 40°F, in which case the economizer will be utilized. Once again referencing ***Figure 7,*** it can be shown that the operating room cooling coils (AHU-4 and 5) are backed up by the primary chilled water flow in the case that chilled water supply from the scroll chiller (CH-3) is interrupted. It should be noted that although the primary chilled water system doesn't supply 34°F water, it will still be able to meet the majority of the load.

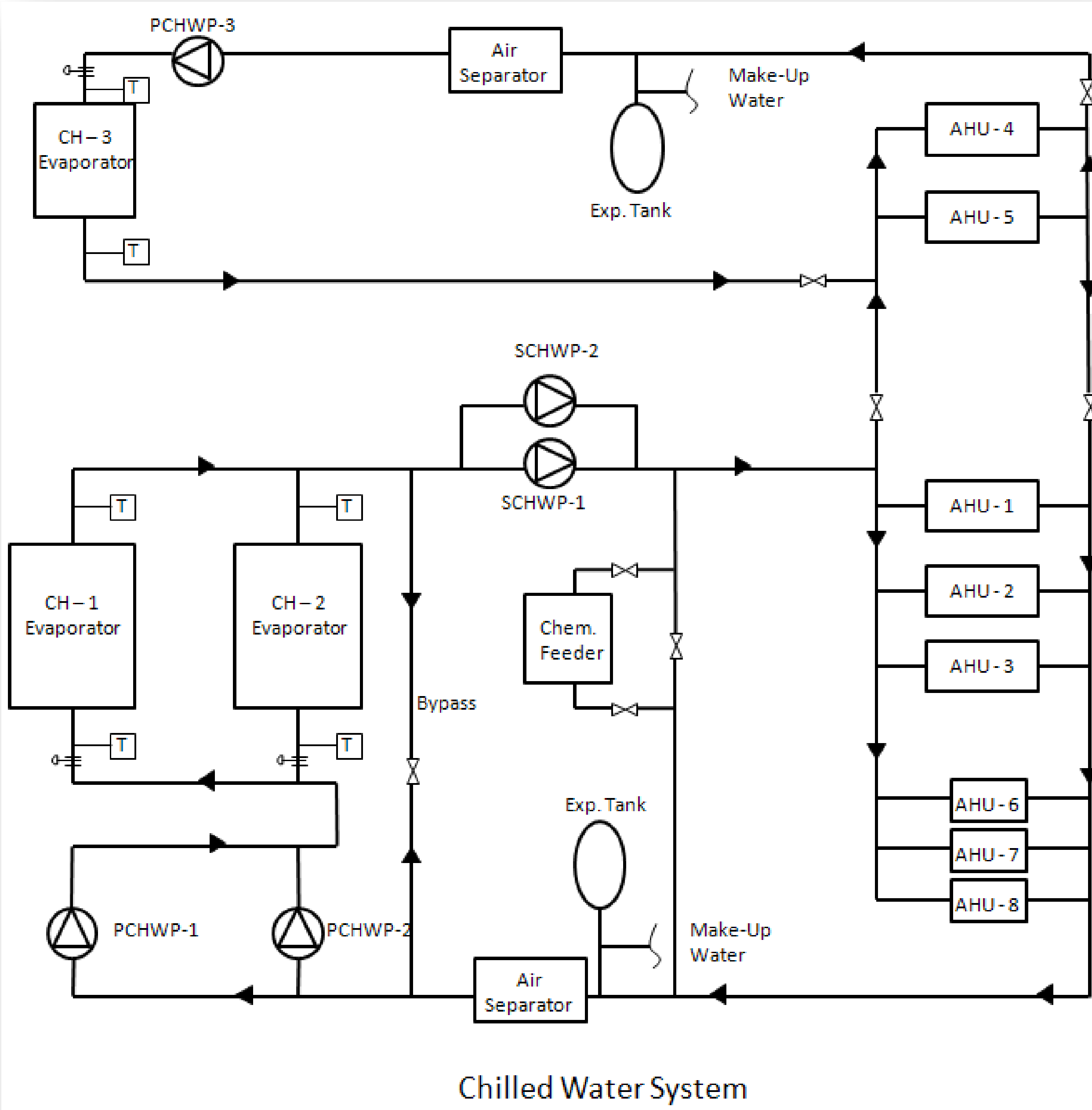

Figure 7: Original Chilled Water System

4.9.2 Condenser Water System

The condenser water system control includes the cooling towers, manual control valves at the cooling tower sump, the condenser water pumps, the cooling tower water treatment system and controls. The cooling tower water system shall be controlled automatically through the BAS from local direct digital control panels, cooling tower fan variable speed drives, and cooling tower circulating pumps using PID control methods.

The cooling towers are one packaged double cell cooling tower that provides condenser water for CH-1 and CH-2, which can be seen in ***Figure 8.*** The tower controls monitor the condenser water temperature entering the chiller and send a signal to the variable frequency drive radial fans to vary the speed or cycle the fans in order to maintain the setpoint. Each tower has manual control valves on the condenser water inlet side and on the tower discharge, which are always open when the respective pump is in operation. The cooling tower fan shall be operational whenever there is water flow through the chiller and not operational when there is no condenser water flow. An equalizing line connects the basins of the two cells to ensure equal water levels within the basins.

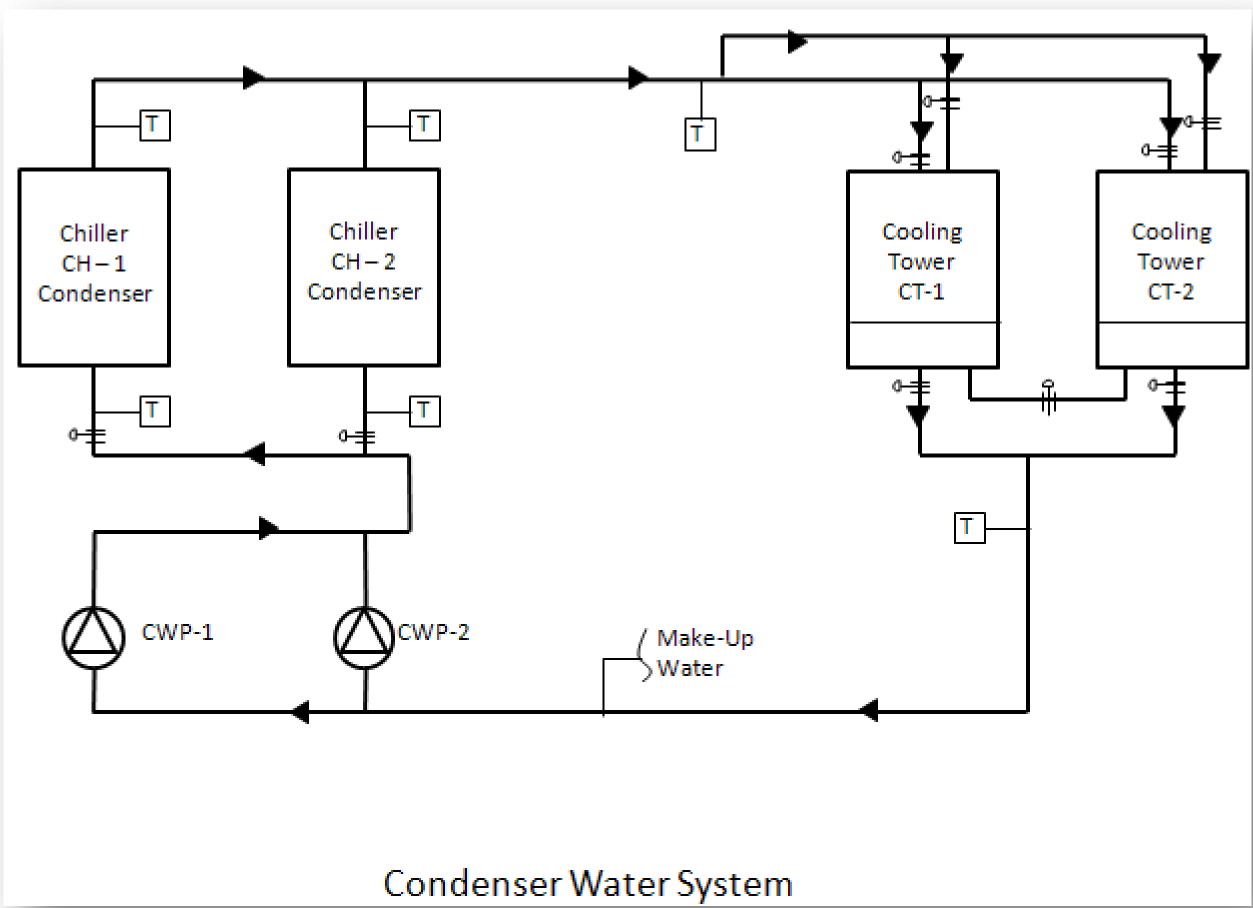

Figure 8: Original Condenser Water System

4.9.3 Heating Water System

The integral boiler controls modulate burners, stage lead-lag boilers, or stage burner level to maintain primary heating water loop temperature set point of 195 degrees F. Primary heating water pumps circulate hot water around the primary loop, as referenced in ***Figure 9***. Primary heating water pump PHWP-1 runs whenever Boiler B-1 runs and will be off when B-1 is off. Pump PHWP-2 will run whenever Boiler B-2 runs and will be off when B-2 is off. The boiler isolation valve shall open whenever the related boiler runs, and shall close whenever the related boiler is off.

The secondary heating water pumps provide heating water distribution from the Boiler Room to the building heating systems. The pumps have variable speed motor drives to provide variable heating water flow based on system heating load. A selected differential pressure sensor with its sensing elements in the heating water supply and return piping shall provide a signal to maintain the differential pressure at the setpoint by varying the pump(s) rotational speed, and by cycling the pump(s) on and off. The control setpoint at the sensor shall be the minimum differential pressure necessary to operate the most remote heating water coil or terminal unit. Actual setpoint shall be field determined, but the initial setpoint shall be 5 psig (between heating water supply and return piping).

When one operating pump is at 100% speed and the differential pressure setpoint cannot be satisfied, start the next pump. Ramp up the additional pump until the two pumps operate at equal speeds. When two pumps are operating at 30% speed, one pump shall be shut down. On every start the heating pumps will be alternated so that the pump with the least run time becomes the lead.

The secondary heating water system modulates a three-way control valve to maintain secondary loop heating-water supply temperature. The heating-water supply temperature should be reset according to outside temperature with a straight line relationship for the following conditions: 180°F heating water when outside temperature is minus 10°F or lower and 140°F heating water when outside temperature is 75 degrees F or warmer. After the water enters the secondary loop, it is distributed to the loads via the secondary hot water pumps, which operate in parallel. Inline hot water pumps are also integrated into the system and can be found at each heating coil. Other than heating coils, the secondary hot water loop also provides terminal boxes, duct heaters, radiant ceiling panels, and finned tube coils with hot water. Please refer to ***Figure 9*** on the following page for a schematic diagram of the heating water system.

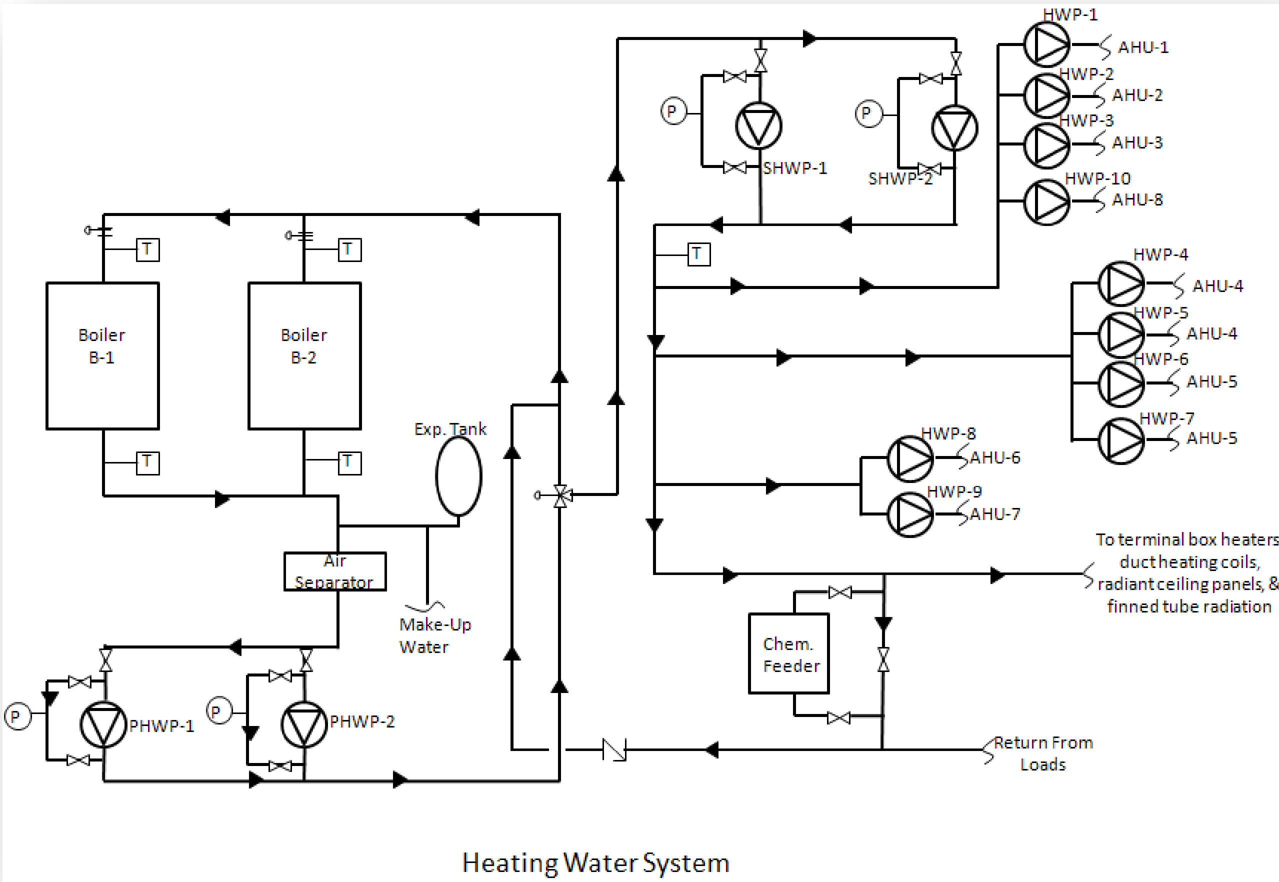

Figure 9: Original Heating Water System

5.0 Existing Building Performance

5.1 Thermal Loads

The energy analysis which follows in this report is a direct result of a simulated model performed using Trane Trace 700H. In order to model the simulation, a number of assumptions were made using available data within schedules, historic weather information, and best judgment. A number of design variables were given in the basis of design provided by HGA Engineers and certain values were used.

The Trace model used for this report is a block model which will attempt to accurately depict all of the zones without doing a room by room comparison. When analyzing a block zone, all the interior zones were considered and then the weighted averages were calculated when entering the "block" data. Building U-values shown in ***Figure 10*** were taken directly from the basis of design performed by HGA Engineering and utilized for the purpose of the energy simulation. Wall parameters entered in the Trane Trace program are shown in ***Figure 11.***

Construction Type		
Type	**Construction**	**U-Value**
Slab	4" LW Concrete	0.2
Roof	Thermoplastic Membrane W/ Insulation	0.06
Walls	6" Steel Stud W/ Insulation and Brick	0.1
Glass	Low e Tinted Glass (Shading Co = 0.28)	0.26

Figure 10: Construction Materials

Wall Heights	
Walls	9'
Floor to Floor	14.75'
Plenum	5.75'

Figure 11: Wall Heights

5.1.1 Energy Simulation Block Zones

The block load model used to project the energy consumption of the New Inpatient Tower was set to alleviate tedious configuration which is necessary if the analysis is performed on a room by room basis. The block load approach has broken up the building into the seven different floors. Within each floor there are core and perimeter zones. The perimeter zones are further broken down into North, South, East, and West zones. This is to account for solar gain due to windows facing in different directions. It should be noted that AHU-6, 7, & 8 which all serve single rooms were excluded from the analysis due to their negligible impact.

The following figures identify each zone within the building:

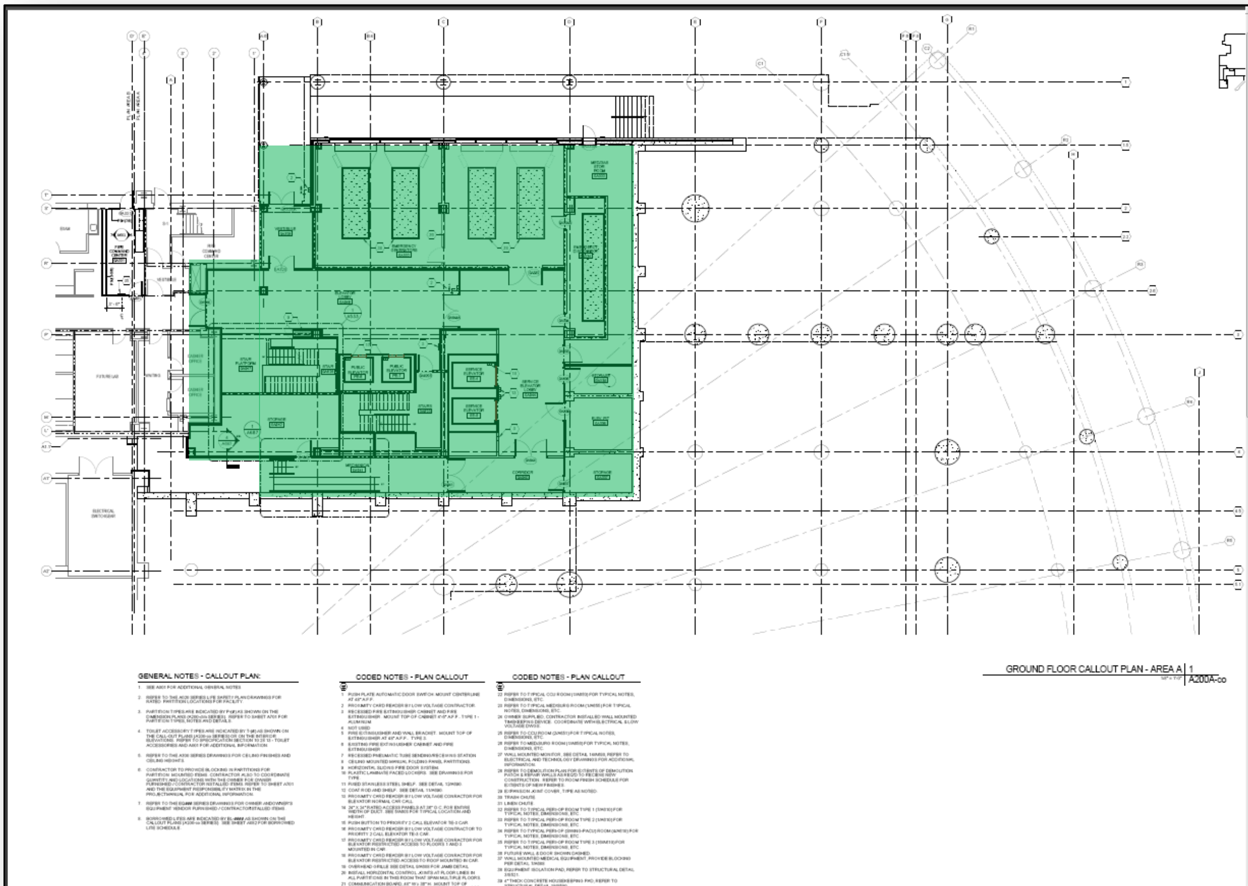

Figure 12: Ground Floor Block Zones

= Core Zone

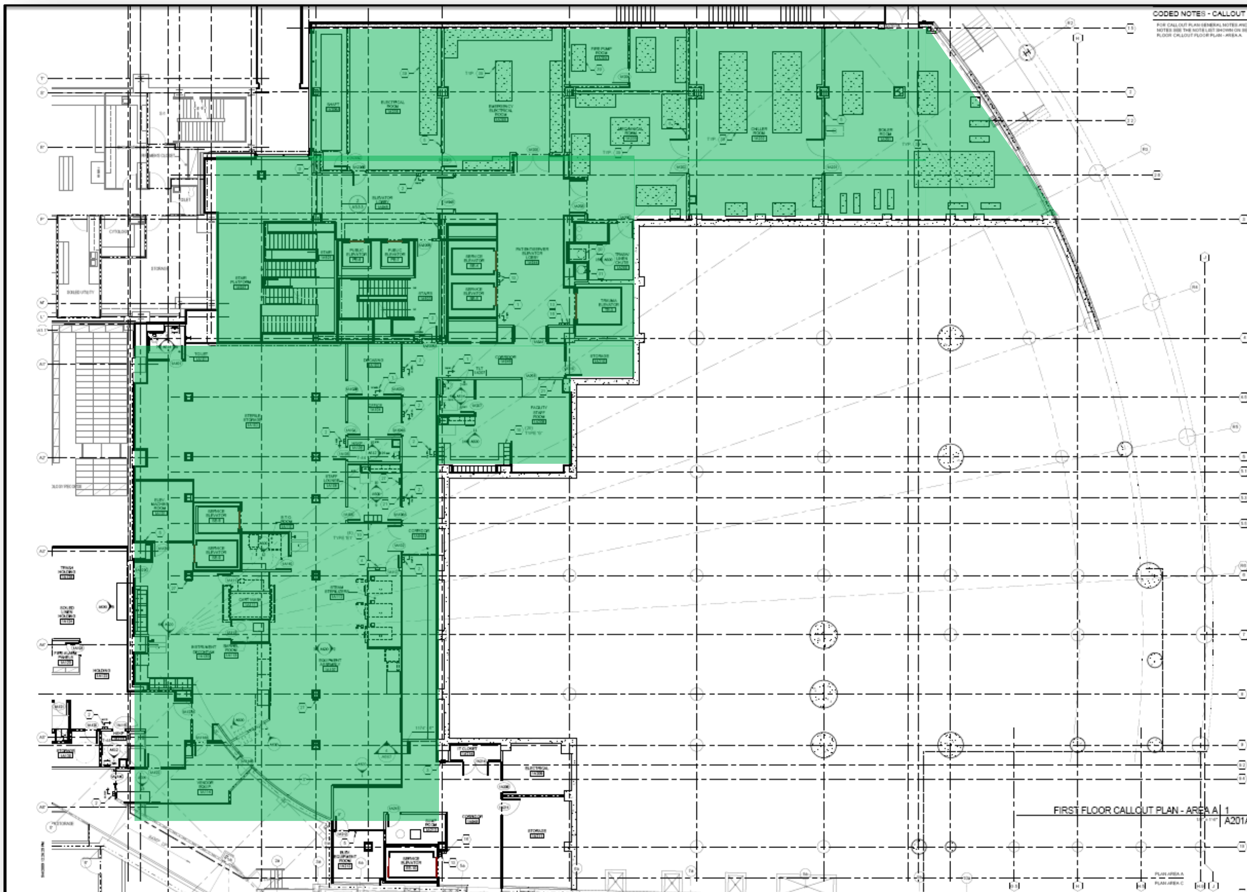

Figure 13: First Floor Block Zones

= Core Zone

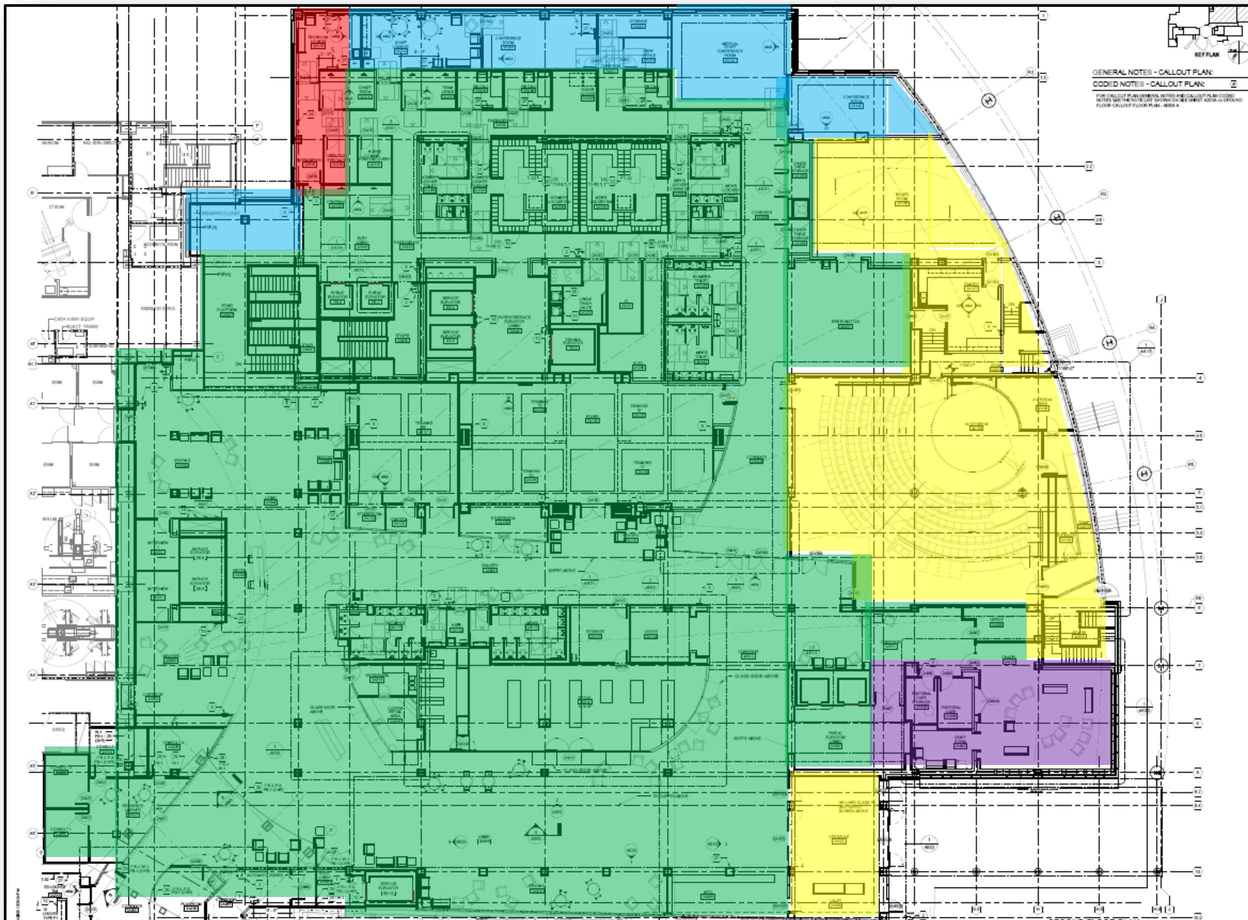

Figure 14: Second Floor Block Zones

= Core Zone

= Perimeter North

= Perimeter South

= Perimeter East

= Perimeter West

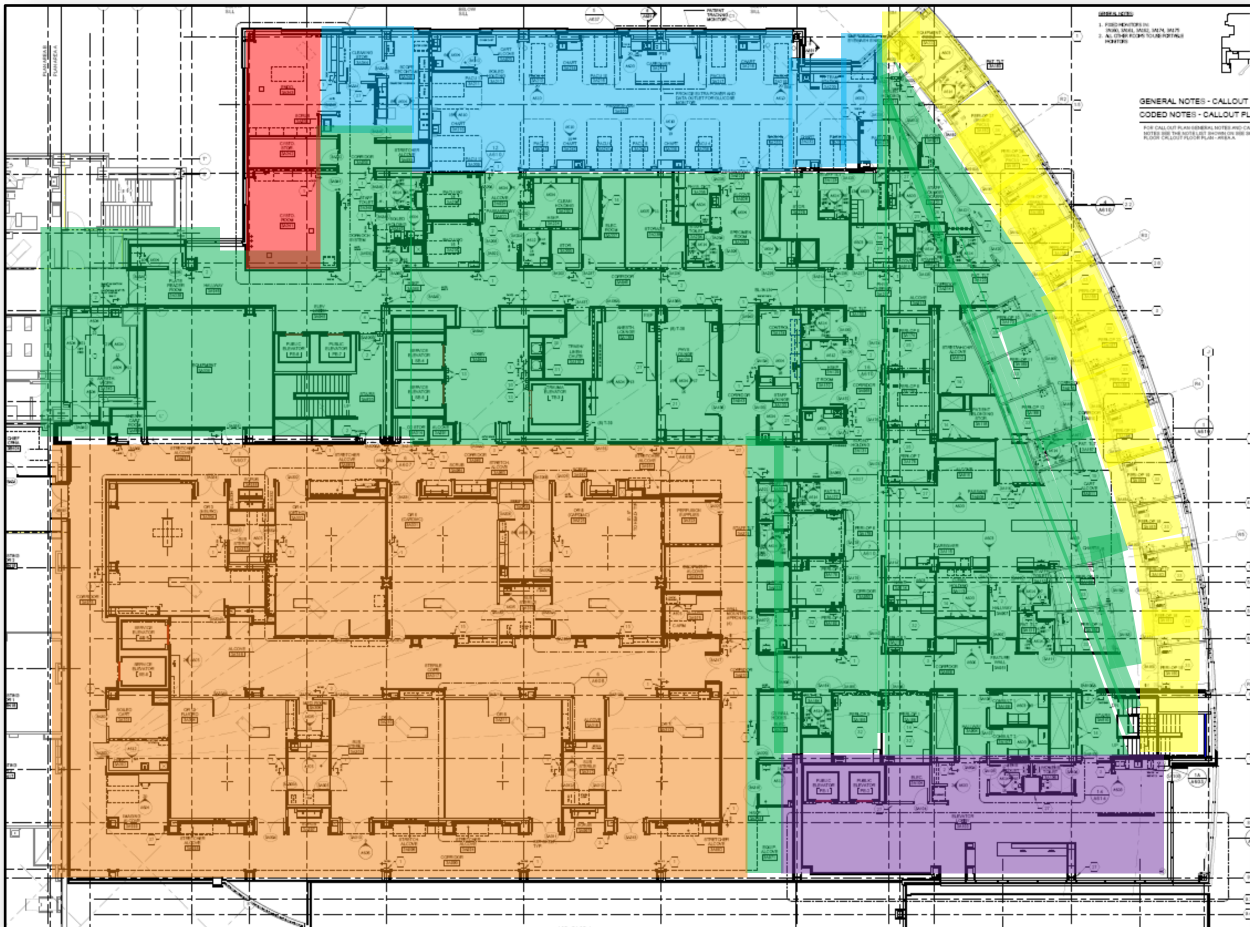

Figure 15: Third Floor Block Zones

= Core Zone

= Perimeter North

= Perimeter South

= Perimeter East

= Perimeter West

= Core Operating Rooms

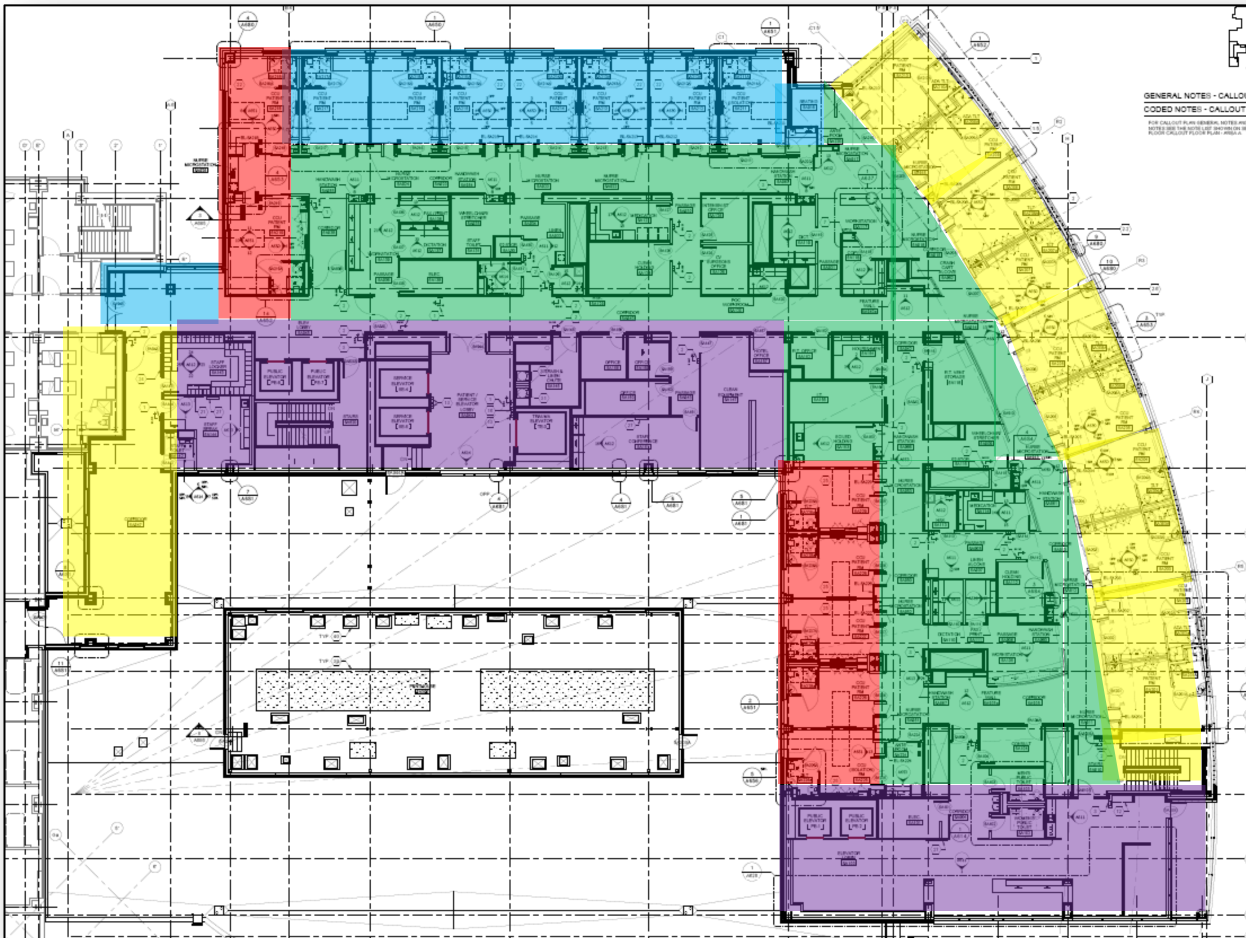

Figure 16: Typical Fifth, Sixth, & Seventh Floor Block Zones

= Core Zone

= Perimeter North

= Perimeter South

= Perimeter East

= Perimeter West

The individual rooms were broken down into block loads by using the room schedule. Below is a sample schedule depicting how the second floor rooms were broken up into blocks. Please note that all rooms and corresponding blocks were properly correlated and the results are displayed in ***Appendix B.***

BUTLER MEMORIAL HOSPITAL
INPATIENT TOWER ADDITION & RENOVATION - SECOND FLOOR
Thermal Load Zones

ROOM NO.	ROOM NAME	ZONE	FACE	TYPE	ROOM DATA AREA	ROOM DATA PEOPLE	OA CFM MIN	OA CFM ACTUAL	OA ACH ACTUAL	ACH ACTUAL	SUPPLY CFM TOTAL	RETURN CFM TOTAL	EXHAUST CFM TOTAL
2A112	STORAGE	Core		Corridor	198	0	---	59	2	7	180	180	
2A113	WOMEN'S	Core		Restroom	280	0	375	500	4	13	500		500
2A124	TRAINGING 'D'	Core		Office	388	19	285	297	4	13	900	900	
2A126	FOYER	Core		Corridor	320	0	16	231	4	13	700	700	
2A127	TRAINING 'B'	Core		Office	379	19	285	297	4	14	900	900	
2A128	TRAINING 'C'	Core		Office	351	18	270	297	5	15	900	900	
2A135	AUDITORIUM	Ext	North	Conference	3077	159	795	1434	3	8	4345	4345	
2A136	A/V ROOM/PREP	Ext	North	Mechanical	178	1	20	56	2	7	170	170	
2A137	PANTRY	Ext	North	Corridor	304	1	20	165	4	12	500	500	
2A138	BOARD ROOM	Ext	North	Conference	1186	32	480	535	3	9	1620	1620	
2A140	CONFERENCE ROOM	Ext	West	Conference	463	16	320	353	5	14	1070	1070	
2A141	MEDICAL STAFF CONFERENCE ROOM	Ext	West	Conference	661	16	320	353	3	10	1070	1070	
2A142	MEN'S	Core		Restroom	214		225	430	5	14	430		430
2A143	WOMEN'S	Core		Restroom	212		225	430	5	14	430		430
2A201	ON CALL	Core		Office	98	1	20	33	3	8	100	100	
2A202	PERF. OFFICE	Core		Office	86	1	20	33	3	9	100	100	
2A203	STORAGE	Ext	West	Corridor	95	0	---	33	3	8	100	100	
2A204	CONFERENCE ROOM	Ext	West	Conference	372	16	240	248	4	13	750	750	
2A205	SCRUB ALCOVE	Core		Corridor	102	1	20	33	2	7	100	100	

Table 13: Example Zone Breakout from Room Schedule

Referencing ***Table 13*** above, green highlighted cells correspond to core zones, yellow to north perimeter zones, and blue corresponds to west perimeter zones. It should be noted that the colors are coordinated between the plan view of the room layouts (***Figures 12 – 16***) and the room schedule zone breakout shown in ***Table 13*** and ***Appendix B***.

Block Load Zones	
Ground Floor - Core	Fifth Floor - North
First Floor - Core	Fifth Floor - South
Second Floor - Core	Fifth Floor - East
Second Floor - North	Fifth Floor - West
Second Floor - South	Sixth Floor - Core
Second Floor - East	Sixth Floor - North
Second Floor - West	Sixth Floor - South
Third Floor - Core	Sixth Floor - East
Third Floor - North	Sixth Floor - West
Third Floor - South	Seventh Floor - Core
Third Floor - East	Seventh Floor - North
Third Floor - West	Seventh Floor - South
Third Floor - Operating Rooms	Seventh Floor - East
Fifth Floor - Core	Seventh Floor - West

Table 14: Summary of Block Zones

Table 14 to the right is a list of all the different zones that were used within the Trane Trace model. A list of rooms within each zone can be found in ***Appendix B***, as previously mentioned.

When performing block load calculations, it is imperative that each room within the block is accounted for to ensure that any critical loads are not overlooked. To ensure that each zone is well representative of their rooms within, a weighted average of every room and their respective loads has been calculated. The weighted average of all the rooms within the zone was used in the final zone calculation. An example of how this procedure was performed is shown below:

Second Floor - Core							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Corridor	6502	0.24	3	1.20	0.28	1.00	0.24
Lobby	13336	0.49	70	1.80	0.88	1.00	0.49
Mechanical	262	0.01	0	1.40	0.01	25.00	0.24
Office	4713	0.17	101	1.70	0.29	2.00	0.34
Restroom	2620	0.10	0	1.10	0.11	0.00	0.00
	27433		174		1.57		1.31

Table 15: Example Calculation of Weighted Zone Calculation Method

In the above example, the following values were placed into the model for the Second Floor-Core. Referencing ***Table 15*** above, the number of people in the zone was entered as 174, lighting load entered as 1.57 W/sqft, and equipment load entered as 1.31 W/sqft. The overall size of the zone is also shown and was entered as 27,433 sqft. All values were calculated for each zone and are shown in ***Appendix M***.

Similarly, each perimeter zone within the building has an exterior wall and glazing, which needs to be taken into account for the envelope loads when doing the thermal load model. In order to determine the exterior wall and glazing area of each perimeter zone, a calculation was performed combining all the rooms within each zone. A sample calculation for the Second Floor - Perimeter zones are shown in ***Table 16.*** A compilation of all exterior walls for various zones can be found in ***Appendix M.***

Second Floor						
Ext. Face	(ft) Wall Length	(ft) Wall Height	(sqft) Wall Area	(ft) Window Length	(ft) Window Height	(sqft) Window Area
North	238	14.75	3510.5	59	8	472
South	44	14.75	649	12	6	72
East	55	14.75	811.25	53	2	106
West	154	14.75	2271.5	72	6	432
			7242.25			1082

Table 16: Example Calculation of Window and Wall Areas

5.1.2 Energy Simulation Results

After analyzing the Trace model, it was found that the thermal loads predicted by Trace are much lower than the thermal loads that design engineers predicted. The reason for such discrepancy is due to the fact that engineers designed the thermal loads for 100% outside air. Why this was done is not clear since the design calls for supply air consisting of 33% outside air and 67% return air. ***Table 17*** clearly shows the original thermal load calculations from the Trane Trace model. The results of the energy model peak loads can be seen in ***Table 18*** below.

Air Handler Loads					
Air Handler	Zones Served	(cfm) Ventilation	(cfm) Supply	(ton) Cooling	(Mbh) Heating
AHU-1	Ground - 2nd Floor	12,604	38,193	143	2,464
AHU-2	3rd & 5th Floor	12,534	37,982	142	2,160
AHU-3	6th & 7th Floor	10,321	31,277	122	1,864
AHU-4	Operating # 1	4,621	14,002	42	317
AHU-5	Operating # 2	4,621	14,002	42	317
		44,700	**135,456**	**491**	**7,122**

Table 17: Original Thermal Loads

Energy Model Loads	
Parameters	Loads
Building Area (sqft)	146,095
Ventilation Air (cfm)	44,700
Ventilation Air (cfm/sqft)	0.31
Supply Air (cfm)	135,456
Supply Air (cfm/sqft)	0.93
Cooling Capacity (tons)	491
Cooling Capacity (sqft/ton)	297.55
Heating Capacity (Mbh)	7,122
Heating Capacity (Btu/sqft)	48.75

Table 18: Original Design Loads

5.2 Energy Consumption

After developing and fine tuning a Trane Trace model to develop heating and cooling loads within the New Inpatient Tower, Trace was then utilized to account for total building energy consumption and operating costs. The bulk of the energy consumption is due to lighting and receptacle loads. Since this is a hospital which requires extensive amounts of medical equipment and proper lighting twenty four hours a day seven days a week, it is appropriate to assume these values are fairly accurate.

The utility company rates used in ***Table 19*** reflects those of Allegheny Power and Columbia Gas, both of which are large utility providers in the Butler, PA area.

Utility Rates			
Electricity			Gas
Consumption (cents/KWH)		Demand (cents/KW)	Consumption ($/1000 ft^3)
On- Peak	Off- Peak	Avg	Avg
7.54	5.13	0.22	5.501

Table 19: Utility Rates

A further breakdown of the actual amount of energy used for each process on a yearly square foot basis is depicted in ***Table 20*** below. Besides the lighting and receptacle loads, the largest contributors to energy use are the supply fans and cooling processes. Both of these issues will be addressed later on in the report. ***Table 21*** on the following page breaks down the energy costs by utility and shows that the overall energy cost of for the New Inpatient Tower is approximately $305,000 per year.

Equipment Energy Consumption			
Type	Energy (10^6 Btu/yr)	Cost	Cost/sqft
Lights	6751.4	$79,957	$0.55
Heating	1465.7	$8,756	$0.06
Cooling	2161.0	$25,592	$0.18
Pumps	703.7	$8,334	$0.06
Heat Rejection	211.0	$2,499	$0.02
Fans	5813.0	$68,844	$0.47
Receptacles	9305.7	$110,207	$0.75

Table 20: Breakdown of Energy Consumption

Energy Cost			
Type	Energy (10^6 Btu/yr)	Cost ($/yr)	Cost ($/sqft)
On Peak Elec.	11,618	$170,480	
Off Peak Elec.	14,219	$125,197	
Total Electricity	25,837	$295,677	$2.03
Gas	1,257	$7,509	$0.05
	27,094	$303,186	$2.08
Type	**Energy (1000gal/yr)**	**Cost ($/yr)**	**Cost ($/sqft)**
Water	2,072	$2,072.00	$0.01
		$305,258.42	**$2.09**

Table 21: Breakdown of Energy Costs by Utility

An energy analysis was not done on the New Inpatient Tower when the building was designed. The reason that an energy analysis was not done is due to the fact that the addition is not a LEED certified building, and to perform an energy analysis adds extra costs which the owners and engineers did not desire to support. Actual utility bills could not be compared to the model accurately due to the fact that the actual bills included the entire hospital, not just the new inpatient tower. However, when compared on a square foot basis the actual costs and modeled costs were within 8% of one another.

6.0 Proposed Redesign Overview

6.1 Introduction

The hospital has overdesigned the entire mechanical system and presents multiple avenues to explore when re-designing the mechanical system. Due to the fact that the current system is variable air volume with many of the components and designed airflows well above baseline requirements, a number of ideas have been researched and scrutinized to make the hospital more energy efficient, reliable, and easier to maintain. It should be noted that due to the critical nature of the mechanical system supplying the operating rooms, only the (3) primary air handlers will be altered. Air handlers 4 and 5, which independently serve the operating rooms, will not be altered.

The first implementation will be to eliminate the variable air volume system including the (3) main air handlers and all of the associated terminal boxes. In lieu of using a VAV system with 33% outside air, a dedicated outdoor air system will be instituted providing the hospital with 100% fresh, clean outdoor air to all spaces within the hospital.

Dedicated outdoor air systems work under the principle of conditioning the minimum requirement of ventilation air and supplying it directly to the space. Because the DOAS air handler can only remove the latent and some sensible heat from the entering outside air, a parallel system will need to be implemented to account for sensible loads within the space. The use of chilled beams will be researched and discussed to account for the extra sensible load created within the space.

Inherently, a hospital exhausts a great deal of the air due to restrooms, both public and in patient rooms, as well as janitor closets, and specialty medical equipment rooms. The current design simply discharges this air into the environment. The redesign will attempt to transfer the enthalpy from the conditioned exhaust air to that of the incoming outdoor air.

Another potential savings of a dedicated outside air system with chilled beams can be achieved by the use of water-side free cooling. Water-side free cooling works extremely well with chilled beams. Water-side free cooling works as an economizer during mild or cold temperatures allowing the chiller to turn off thereby saving mechanical energy.

6.2 Dedicated Outdoor Air System

After analyzing the Trane Trace energy model, it is clear that a great majority of the heating and cooling load within the hospital is a result of conditioning the ventilation air. The amount of ventilation air being introduced into the hospital is well above the minimum requirements set forth by AIA guidelines. As designed, the hospital supplies 53,812 CFM of outside air; however, the minimum requirements set forth by AIA, & IMC requires only 38,500 CFM of outside air be supplied for ventilation. Therefore, the overall amount of ventilation air can be reduced by almost one third, which will also greatly reduce the load imposed on the cooling and heating systems.

The hospital is currently transporting roughly 154,000 CFM of supply air through the duct work. By switching to a dedicated outdoor air system, only 38,500 CFM of outdoor air will need to be supplied therefore reducing the amount of fan energy required and duct sizes within the hospital. As depicted in ***Figure 17*** below, almost 20% of the overall energy usage within the hospital is due to the supply fans. By decreasing the airflow, the size of the air handlers and supply fans will also be reduced which will save energy and money during operation and first cost.

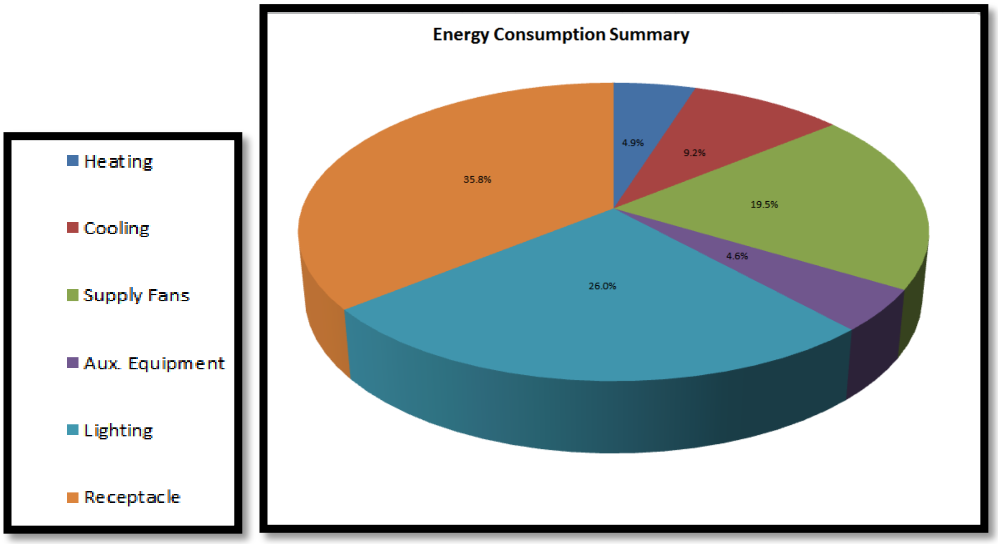

Figure 17: Energy Consumption Summary

A common problem among variable air volume systems is the failure to deliver adequate amounts of ventilation air at part loads. Because the dedicated outdoor air system is a constant volume system and always supplies the same amount of ventilation air, this problem is avoided and indoor air quality remains high.

6.3 Chilled Beams

A DOAS air handler will condition the ventilation air by removing sensible and latent heat from incoming outdoor air during the summer and adding sensible and latent heat to the outdoor air during the winter. With this being said, although the DOAS air handler can meet the entire latent and sensible load from the outside air, a parallel system must also be installed to meet the demand of sensible loads created within the space.

In order to meet the added demand for sensible heat transfer, the implementation of chilled beams has been studied. There are two types of chilled beams, active and passive. As depicted in ***Figure 18*** an active chilled beam is much like a cooling coil which induces high velocity supply air through it and then delivers the air to the room. Referencing ***Figure*** **19**, a passive chilled beam is simply a radiant panel located in the ceiling, decoupled from the ventilation system operating solely on radiation principles.

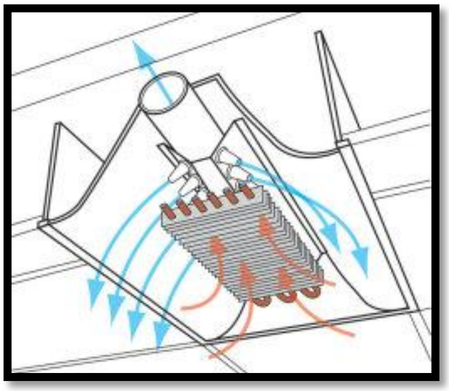

Figure 18: Active Chilled Beam

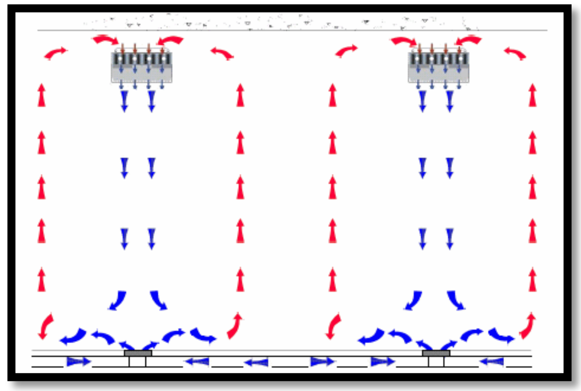

Figure 19: Passive Chilled Beam

Chilled beams can be used for both supplemental heating and cooling purposes. This can be done with a variety of piping arrangements. The two arrangements that will be studied include a 4 pipe system which contains a supply and return line for both heating and cooling, and a 2 pipe changeover which will allow the same piping to carry either heating water or chilled water depending on the season.

Potential advantages of chilled beams is the elimination of wasteful terminal reheat boxes, better air mixing within the space, and better utilization of heat transfer. As a comparison 1 cubic foot of water has a heat capacity of 20,050 J. One cubic foot of air at STP has a heat capacity of 37 J K. After accounting for differences in density it is apparent that a 1" diameter pipe can carry the same amount of energy as an 18" x 18" duct. Using water instead of air to heat or cool a space is much more efficient, not to mention space savings due to reduced duct sizes and hydronic piping.

6.4 Exhaust Energy Recovery

As specified in ASHRAE Standard 90.1, any mechanical system using 100% outside air must have some means of energy recovery. In order to account for this and to save energy, a few different options will be analyzed when looking at energy recovery. The hospital currently exhausts a great deal of air due to the abundance of restrooms, janitor closets, and medical laboratory spaces. The current design simply discharges all exhaust air to the atmosphere.

One of the options analyzed for heat recovery will be a glycol filled run-around loop. This system works well for exhaust ducts which are not in close proximity to supply ductwork, which is the case in the New Inpatient Tower. However, because the loop is distributed throughout the building and relies on heat exchangers in both airways, it lacks in efficiency and performance. Another method of heat recovery is via a total heat recovery wheel. A heat recovery wheel can transfer latent and sensible heat from one airway to the other with much higher efficiency. The only downfalls of the heat recovery wheel are proximity restrictions between the two airways and possible contamination of supply air from the exhaust air. An example of an energy recovery wheel operating in the summer is shown below in ***Figure 20.***

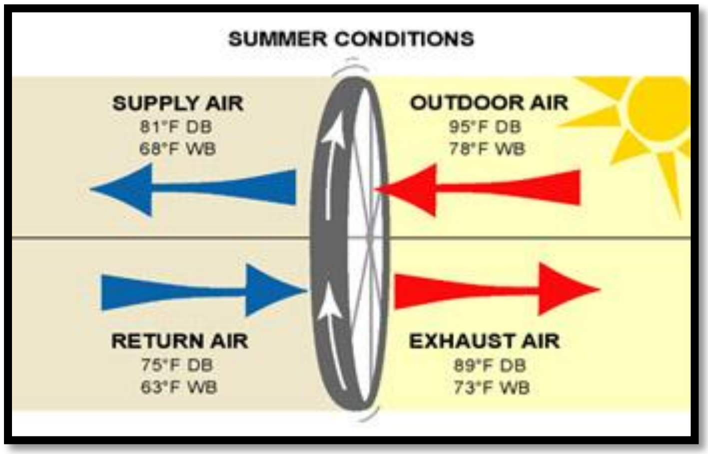

Figure 20: Enthalpy Wheel

6.5 Water-Side Free Cooling

Water-side free cooling is an economizer method which should work very well with the DOAS chilled beam system. Water-side free cooling refers to using the cooled condenser water from the cooling tower as a chilled water source to cool a load, therefore eliminating the need for a chiller. Water-side free cooling works best when the outdoor wet bulb temperature is around 40°F for typical applications that desire to produce average chilled water temperatures. However, a chilled beam uses water temperatures between 55°F and 60°F which is much higher than typical applications. Because the chilled beam uses higher temperature water, water-side free cooling will be available for a greater portion of the year which should reduce the amount of chiller hours and save energy.

7.0 Mechanical -DOAS with Active Chilled Beams

7.1 Redesign Objectives

The objective of the redesign is to enhance the hospital's energy performance and sustainability, as well as decrease the life cycle costs and maintenance. As stated earlier, the proposed route for this will be to implement a dedicated outside air system with supplemental chilled beams. The chilled beams will be used for both sensible cooling and heating.

Due to the required air change rates, ventilation requirements, and strict psychometric criteria of the operating rooms and their support spaces, these vital areas will remain on the original independent VAV system in lieu of the DOAS chilled beam system. However, the primary chillers serving the dedicated outdoor air system will provide redundancy, in the case that the VAV system serving the operating rooms malfunctions.

The redesign of the mechanical systems within the New Inpatient Hospital will be a completely new concept, and because of this, many new pieces of equipment will replace items from the original design. The following summary will depict the components that make up the dedicated outside air system and the conditions under which they operate.

7.2 Design Considerations

7.2.1 Active vs. Passive Chilled Beams

When considering which type of chilled beam to use, there are two types to consider. An active chilled beam is fed by the supply ductwork, chilled water piping, and heating water piping. The active chilled beam ejects the supply air through an induction nozzle which induces room air into the supply air and then distributes both airstreams across the coil. The coil can be used for heating or cooling. A passive chilled beam is not fed by the supply ductwork. Passive chilled beams act like a radiant panel in the ceiling and have the capacity to both heat and cool.

Of the two, it was found that although active chilled beams have a higher first cost, their increased efficiency makes them a better choice than the passive chilled beam. Active beams are more efficient because they rely on the principles of convection and radiation. As the induced air moves across the coil, there is much more heat transfer than a passive chilled beam which only transfers heat via radiation.

7.2.2 Two Pipe Configuration vs. Four Pipe Configuration

There are obviously different types of chilled beams to choose from. Two pipe systems can either be used for cooling only or they may have a two pipe changeover which allows the same distribution piping to carry both chilled water and heating water. The other configuration is a four pipe system. A four pipe system has a supply and return for both the heating water and chilled water.

Because the chilled beams will have to meet the extra sensible load in the cooling and heating season, the chilled beams will be designed to have both heating water and chilled water capability. The four pipe configuration was chosen over the two pipe changeover for a number of reasons. First, the four pipe arrangement will allow for heating and cooling at the same time in different spaces. This is essential in a hospital environment since core areas will often need cooling year round, but perimeter spaces may call for heating in the winter. In a two pipe system, the changeover from heating to cooling or vice versa is made manually, and there is always the possibility that unpredicted weather patterns might cause occupant discomfort. The four pipe system offers more design flexibility and reliability. The only downfall of the four pipe system over a two pipe changeover is that the contractor will have to install both chilled water and heating water distribution piping, therefore increasing the first cost of the system.

7.2.3 Run-Around Coil vs. Heat Recovery Wheel

The new design of the inpatient tower will be a dedicated outdoor air system. Such systems are required by ASHRAE 90.1 to be equipped with some means of energy recovery. Two systems will be analyzed for energy recovery: run-around coils and heat recovery wheels. Both systems have advantages and disadvantages which are depicted below:

Run-Around Coils

Pros:

- Supply and exhaust airstreams do not need to be in close proximity
- No chance for cross contamination

Cons:

- Only transfers sensible heat
- Maximum sensible effectiveness is only 65%
- Increased pumping costs to transport refrigerant
- Requires additional pumps, piping, and coils

Heat Recovery Wheel

Pros:

- Transfers both sensible and latent energy
- Total effectiveness for sensible and latent heat transfer can reach 75%
- Integrated design within air handler

Cons:

- Need ductwork to link supply and exhaust
- Wheel requires maintenance
- Significant pressure drop across the wheel

After analyzing both systems, it has been determined that the New Inpatient Tower will use two heat recovery wheels in lieu of the run around loops. The supply air will enter a total enthalpy wheel first which will transfer both latent and sensible heat from the exhaust stream to the supply stream. The air will then pass over the heating or cooling coil and then enter the second sensible wheel next. Although ductwork will need to be altered slightly to accommodate for the exhaust airstream, the increased effectiveness was the main driver behind the use of the heat recovery wheel.

7.2.4 Distributed vs. Centralized Secondary Pumping

When designing the distribution piping and pumping, two alternatives were considered. The first option was to use distributed pumping. This entails that the primary pump will push the water through either the chiller or boiler and then secondary pumps will distribute the water to the loads. With this arrangement the secondary pumps are distributed throughout the building and in this case on each floor level. Centralized pumping refers to the idea of a having a primary pump pushing water through the chiller or boiler but then using secondary pumps which are adjacent to the primary pumps to distribute the water. Advantages and disadvantages of the two systems are listed below.

Centralized Secondary Pumps

Pros:

- Easy maintenance, all pumps central
- Feeder wires don't need to be run
- Decrease first cost
- Can implement redundancy easier
- More flexibility for system growth

Cons:

- Must size pumps for max gpm and head for the entire system
- Increased pumping energy cost and hp

Distributed Secondary Pumps

Pros:

- More pumps, but less horsepower results in energy savings
- Gives individual speed control to groups of loads

Cons:

- Lacks inherent redundancy
- Increased first cost due to more pumps
- Many pumps to maintain
- May result in dueling pumps
- Less flexibility for growth
- Must run feeder wires to all pumps

The two systems were compared further to analyze the life cycle cost of each. A pump schedule breakdown is shown below in ***Table 22***.

Table 22: Centralized vs. Distributed Pumps

HVAC PUMP SCHEDULE CENTRALIZED					
			DESIGN PUMP DATA		MOTOR
PUMP NO.	LOCATION	SYSTEM	CAPACITY (GPM)	HEAD (FT)	HP
PCHWP-1	MECH RM	CHILLED WATER	360	30	5
PCHWP-2	MECH RM	CHILLED WATER	540	30	7.5
PCHWP-3	MECH RM	CHILLED WATER	540	30	7.5
SCHWP-1	MECH RM	CHILLED WATER	360	100	15
SCHWP-2	MECH RM	CHILLED WATER	540	100	25
SCHWP-3	MECH RM	CHILLED WATER	540	100	25
PHWP-1	MECH RM	HOT WATER	720	25	7.5
PHWP-2	MECH RM	HOT WATER	720	25	7.5
SHWP-1	MECH RM	HOT WATER	550	90	20
SHWP-2	MECH RM	HOT WATER	550	90	20

HVAC PUMP SCHEDULE DISTRIBUTED					
			DESIGN PUMP DATA		MOTOR
PUMP NO.	LOCATION	SYSTEM	CAPACITY (GPM)	HEAD (FT)	HP
PCHWP-1	MECH RM	CHILLED WATER	360	30	5
PCHWP-2	MECH RM	CHILLED WATER	540	30	7.5
PCHWP-3	MECH RM	CHILLED WATER	540	30	7.5
CHWP-1	GRD FLOOR	CHILLED WATER	30	10	1/2
CHWP-2	1ST FLOOR	CHILLED WATER	50	10	1/2
CHWP-3	2ND FLOOR	CHILLED WATER	110	30	2
CHWP-4	3RD FLOOR	CHILLED WATER	110	25	1 1/2
CHWP-5	5TH FLOOR	CHILLED WATER	80	25	1
CHWP-6	6TH FLOOR	CHILLED WATER	80	25	1
CHWP-7	7TH FLOOR	CHILLED WATER	80	25	1
PHWP-1	MECH RM	HOT WATER	720	25	7.5
PHWP-2	MECH RM	HOT WATER	720	25	7.5
HWP-1	GRD FLOOR	HOT WATER	50	10	1/2
HWP-2	1ST FLOOR	HOT WATER	50	10	1/2
HWP-3	2ND FLOOR	HOT WATER	160	30	2
HWP-4	3RD FLOOR	HOT WATER	140	25	1 1/2
HWP-5	5TH FLOOR	HOT WATER	100	25	1
HWP-6	6TH FLOOR	HOT WATER	100	25	1
HWP-7	7TH FLOOR	HOT WATER	100	25	1

The schedule shown in ***Table 22 (Distributed)*** does not allow for redundancy in the distributed system. If redundancy is required, there will need to be two additional distributed pumps on each floor, one for chilled water and one for heating water, therefore adding 14 additional pumps. A breakdown of the life cycle cost is shown below assuming redundancy in the distributed piping system. Installation and pump costs were interpolated using existing data from the mechanical contractor's estimate. ***Table 23*** shows the first cost implication of installing a distributed pumping system compared to a centralized system. Unit cost includes equipment and installation.

Centralized vs. Distributed Pumping First Cost							
Centralized				Distributed			
Item	Units	Unit Cost	Total Cost	Item	Units	Unit Cost	Total Cost
PCHW Pumps	3	$13,600.00	$40,800.00	PCHW Pumps	3	$13,600.00	$40,800.00
SCHW Pumps	3	$13,600.00	$40,800.00	Dist. CHW Pumps	14	$6,750.00	$94,500.00
PHW Pumps	2	$18,350.00	$36,700.00	PHW Pumps	2	$18,350.00	$36,700.00
SHW Pumps	2	$13,600.00	$27,200.00	Dist. HW Pumps	14	$6,750.00	$94,500.00
Total			$145,500.00				$266,500.00

Table 23: Centralized vs. Distributed First Cost

The difference in first cost between the two systems is roughly $121,000. Annual energy consumption and electrical cost were taken from a Trane Trace 700 simulation. The results of the simulation showed that the centralized system would utilize 511.5 MBtu/yr costing the hospital $6,057.00/year. The distributed system would only consume 383.8 MBtu/yr which would only cost the hospital $4,664.00/year. This is an annual difference of $1,393.00. Applying a simple payback calculation and assuming that electric rates remain constant, it will take 86.8 years to recovery the cost of installing a distributed system with redundancy.

Because of this large difference in life cycle costs, the centralized pumping arrangement has been chosen. Not only will the life cycle cost be reduced, but maintenance will be easier and more affordable. Contractors will only have to run feed wiring to 10 pumps instead of 33. All of the above reasons make choosing a centralized pumping system a clear choice.

7.2.5 Piping Layout

When designing the piping layout and distribution, careful attention was made to ensure that all components within the HVAC system are redundant. During the design concept stage there were two possibilities for supplying chilled water to the chilled beams. The first was to have 2 separate chillers, one serving the main DOAS air handler and one dedicated to the chilled beams. The other layout explored was to use return water from the air handler as the supply water for the chilled beams. Since chilled beams utilize 55°F - 60°F supply water, it makes this application possible.

By using the return water from the air handler, only one chiller would be needed and the same water that passes through the air handler will be used for the chilled beams, essentially getting twice the cooling power out of the same quantity of water. However, controlling this system can be very difficult. If there is low delta T across the air handler coil then the water being supplied to the chilled beams will be too cold and may cause condensation. Condensation is one of the biggest drawbacks of a chilled beam system and should be avoided at all costs. Instead of trying to balance the water temperatures and flow rates between the air handler and chilled beams, the two chiller approach will be used with regards to this process.

The two chiller approach will allow the air handler and chilled beam systems to act independently and gives greater flexibility to the system. The dual chiller approach also ensures that chilled beam supply water temperature can be closely monitored so that condensation on the beam never occurs. When designing the piping layout and distribution, careful attention was made to ensure that all components within the HVAC system are redundant. A third chiller will be added to the system to ensure that if one malfunctions there will be a back-up.

Water side free cooling will also be implemented within the redesign with the sole purpose of supplying chilled water to the chilled beams under moderate outside air conditions. The chillers will share common condenser water piping; however, only the chilled beam system will be able to draw water through the plate and frame heat exchanger to deliver capacity to the loads.

7.3 Air Side Summary

The biggest difference between the original system and the new system will be the air side control. In the original system (3) rooftop air handlers supplied 154,000 CFM of supply air to the entire building. The original system also called for 53,000 CFM of ventilation air, which is well above the baseline set forth by ASHRAE 62.1, the IMC, and the AIA air change guidelines.

The new system will only need to supply roughly 38,500 CFM of ventilation air to meet the minimum ventilation and air change requirements. Due to the drastic decrease in supply air, only one air handler will be needed. The air handler selected is a 40,000 CFM "Pinnacle" unit manufactured by Semco which can be seen in ***Figure 21*** and ***Appendix H***. The Pinnacle unit is unlike most other DOAS air handlers because it implements dual wheel technology capable of drastically lowering the dew point allowing for the minimum amount of air necessary to meet the latent loads. When the outdoor air enters the air handler it first passes through a total enthalpy recovery wheel which will cool and dehumidify the air by passing it through a dry and cool zone of the wheel which has been rotated through and reached near equilibrium with the relatively cool, dry exhaust air. The outdoor air then passes through the cooling coil which further cools and dehumidifies the air. Before being supplied to the space, the air is further dehumidified and moderately reheated by passing it through the warm and dry zone of the second passive dehumidification wheel.

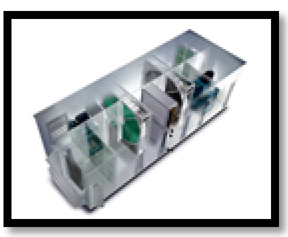

Figure 21: Pinnacle unit

By using this dual wheel technology, it enables designers to supply the space with roughly 62°F supply air with only 48 gr/lb of relative humidity. By lowering the dew point of the supply air in this way, we are able to decrease the chiller capacity and reduce the risk of condensation on the chilled beams within the space. ***Figure 22*** below is provided by Semco "Chilled Beams & Pinnacle Application Guide" and shows the arrangment of the Pinnacle system as well as the corresponding air temperature and humidity at each point during a typical cooling scenario.

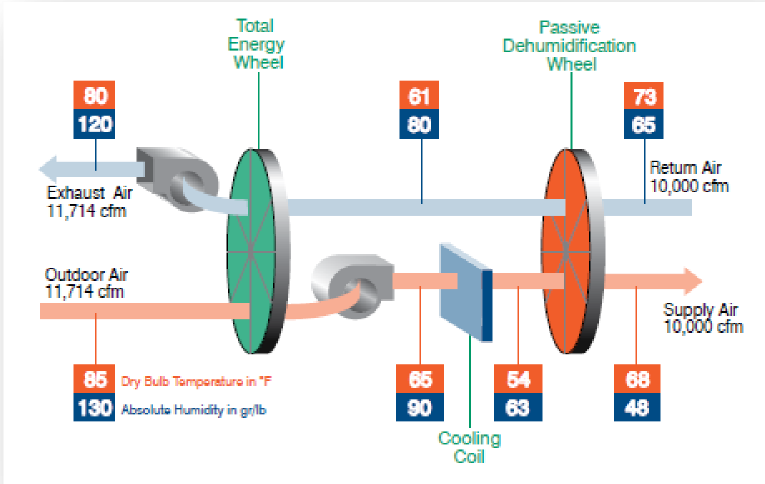

Figure 22: Pinnacle System Cooling Mode

The Pinnacle system is also extremely effective during the heating season. It is controlled to optimize the performance of both temperature and humidity recovery to the desired extent by increasing the speed of the passive dehumidification wheel from .25 RPM to roughly 5 RPM. A schematic of the system in a heating mode is shown in ***Figure 23.***

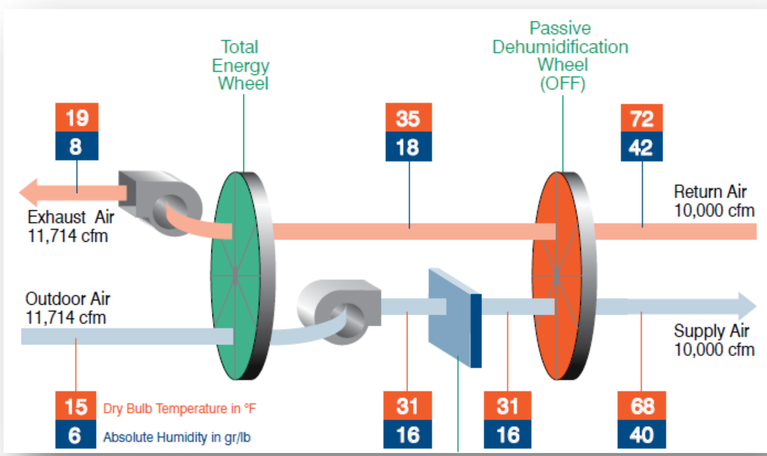

Figure 23: Pinnacle System Heating Mode

Once the supply air reaches the zone, it will be forced through an induction nozzle within the chilled beam assembly. For every 1 CFM of supply air exiting the duct, roughly 3 CFM of room condition air will be induced across the chilled beam coil, and the total amount of convective airflow that transfers heat will be roughly 4 CFM for every 1 CFM of fresh supply air. In essence, the chilled beam will operate similar to a fan coil unit except there won't need to be a power supply or fan. The chilled beam will function solely by the principle of induction and convection.

Due to the fact that we are only conditioning the minimum amount of outside air, the quantity of airflow being forced through the duct work will decrease from the original design of 154,000 CFM to only 38,500 CFM. Because of the drastic reduction in airflow, the size of the ductwork will also be decreased, which will decrease the material and installation cost. In some situations decreasing the duct size will allow designers to decrease the floor to floor height, thereby saving money on building enclosure costs. However, because the new inpatient tower is an addition and needs to match the existing structure, decreasing the floor to floor height is not possible. However, with a reduction in ductwork, the plenum space will be less congested allowing for easier installation and maintenance of mechanical and electrical components.

In order to maintain redundancy with a one air handler system, a fan array will be used in lieu of a single supply fan. The fan array will consist of (2) supply fans in a 2x1 array. Each fan will be sized for 40,000 CFM, or 100% of the overall CFM required. At any time, the air handler will only need 1 out of the 2 fans to operate. By arranging the air handler in a (2) fan array, if one of the fans malfunctions, the idle fan will turn on and replace it. The fans will be staged to alternate starts so that there is an even age and wear distribution among the two supply fans.

Not all rooms in the New Inpatient Hospital will be served by chilled beams. In small areas that require less than 30 CFM of airflow and do not have a large sensible load, ventilation air will be supplied to the room via a diffuser, not a chilled beam. This application is intended for areas such as storage spaces, housekeeping rooms, small alcoves, and short passage ways. Since the ventilation air will leave the air handler at roughly 62°F it will still be able to meet small sensible loads. This idea was implemented to save money on first costs due to chilled beam installation as well as water distribution piping.

7.4 Water Side Summary

7.4.1 Chilled Water System

Due to the decrease in ventilation air from the original design, the use of the Pinnacle Unit, and the use of the energy recovery wheels, the overall cooling load of the redesign has dropped from 491 tons down to 400 tons. The DOAS air handler will need 177 tons of cooling and the chilled beams will require 138 tons of cooling. The remaining cooling load will be in the operating rooms and support areas which are not served by the new DOAS system. In order to provide redundancy and ensure reliability, both chillers have been sized for 180 tons, with a third chiller, also rated for 180 tons providing additional redundancy. Chilled water distribution piping will need to be routed throughout the hospital to connect the chilled beams to the chiller. Schematics of this will be shown later in the report.

The primary chilled water system includes (3) 180 ton scroll water chillers, (3) primary chiller circulating pumps, (3) secondary chilled water distribution pumps, (1) plate and frame heat exchanger used for free cooling with the chilled beams, and controls. The Carrier 30HXC186 180 ton screw chiller was chosen for the redesign. Chiller 1 provides chilled water for the dedicated outside air handler while

Chiller 2 provides the chilled beams with chilled water. The third chiller (Ch-4) will be for redundancy issues only and will have the capability to serve either the chilled beams or the air handler. The chilled water system shall be controlled automatically through a local direct digital control panel, packaged chiller controls, and pump variable speed drives using PI and PID control methods.

The packaged chiller controls shall cycle and modulate the chiller compressor to maintain the chilled water supply temperature at 42°F for Chiller 1 serving the DOAS air handler and at 57°F for Chiller 2 which serves the chilled beams. If the supply fan in the air handler is stopped, flow through that cooling coil will be eliminated. After a chiller is enabled, the control panel will send a signal to start the condenser water and chilled water pumps. Once there is proof of flow, the chillers will operate normally.

Referencing ***Figure 24,*** the primary chilled water pumps are in parallel and pump a constant volume of water through the chillers. Because the pumps are in parallel, they provide inherent redundancy. In normal operation PCHWP-1 will supply CH-1 and PCHWP-2 will supply CH-2. PCHWP-4 is a backup and can supply any one of the chillers. PCHWP-1 and PCHWP-2 can also supply CH-4 if need be. Once the primary flow enters the chiller, it is distributed to the VSD secondary pumps. SCHWP -1 is linked with Chiller-1 and feeds the DOAS air handler. SCHWP-2 is associated with Chiller-2 and will supply the chilled beams. SCHWP-3 is a redundant pump that can supply either the chilled beams or the air handler in the case that SCHWP-1 or SCHWP-2 malfunctions.

Free cooling will be enabled via a plate and frame heat exchanger for the chilled water system supplying the chilled beams. For this reason the plate and frame heat exchanger will be supplied by PCHWP-2 in most cases. If for some reason PCHWP-2 malfunctions, PCHWP-4 will be activated and can meet the loads. When the outside air wet bulb temperature reaches 53°F, CH-2, serving the chilled beams, will be deactivated and the control valve to CH-2 will close. The control valve ahead of the plate and frame heat exchanger will open allowing PCHWP-2 to pump chilled water through the plate and frame heat exchanger which is acting as a chiller.

The operating room chilled water system is independent of the primary chilled water system and consists of (1) 119 ton air cooled scroll chiller, (1) circulating pump, and controls. The chiller controls will modulate CH-3 in order to maintain the desired chilled water leaving temperature setpoint of 34°F. Referencing ***Figure 24*** it can be shown that the operating room cooling coils (AHU-4 and AHU-5) are backed up by the primary chilled water flow in the case that the chilled water supply from CH-3 is interrupted. Although the primary water doesn't supply 34°F chilled water, it will still meet the majority of the load.

Individual control of space temperature is fairly simple. A wall thermostat will influence the control valve of the entering chilled water, thereby modulating the flow rate and cooling output of the chilled beam. The controls are extremely simple, reliable, and easy to maintain.

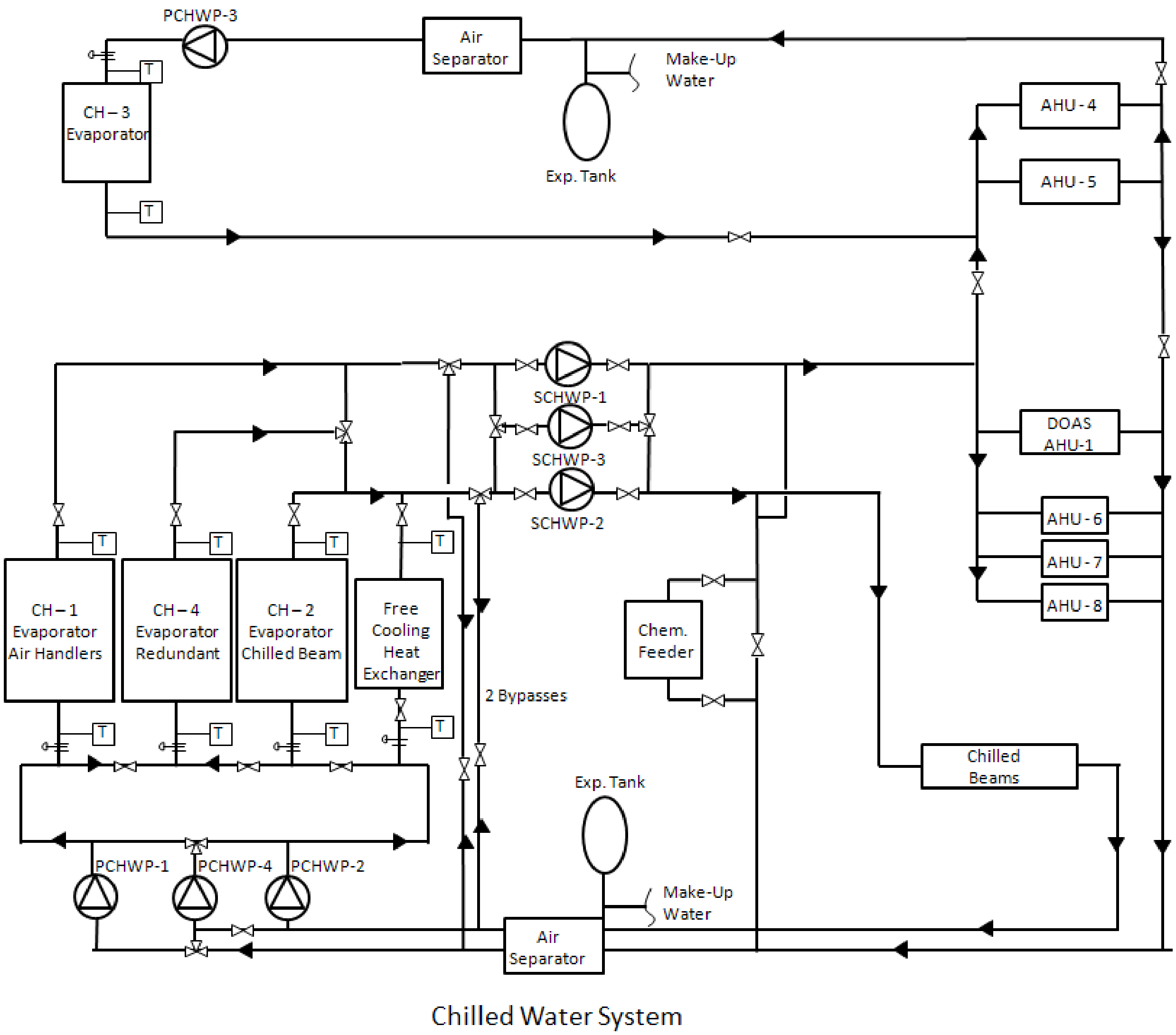

Figure 24: Redesigned Chilled Water Diagram

7.4.2 Condenser Water System

The condenser water system includes the cooling tower, manual control valves at the cooling tower sump, the condenser water pumps, the cooling tower water treatment system, a plate a frame heat exchanger for free cooling of the chilled beams and controls. The cooling tower shall be controlled automatically through the BAS from the local direct digital control panels, cooling tower fan variable speed drives, and circulating pumps using PID control methods.

The cooling tower is one packaged double cell tower that provides condenser water for CH-1, CH-2, and CH-4 which can be seen in ***Figure 25.*** The cooling towers will also supply the plate and frame heat exchanger with chilled water used for free cooling under cool outdoor temperatures. When the wet bulb temperature drops below 54°F, the control valve for CH-2 will be closed and the control valve for the plate frame and heat exchanger will be opened to allow for free cooling.

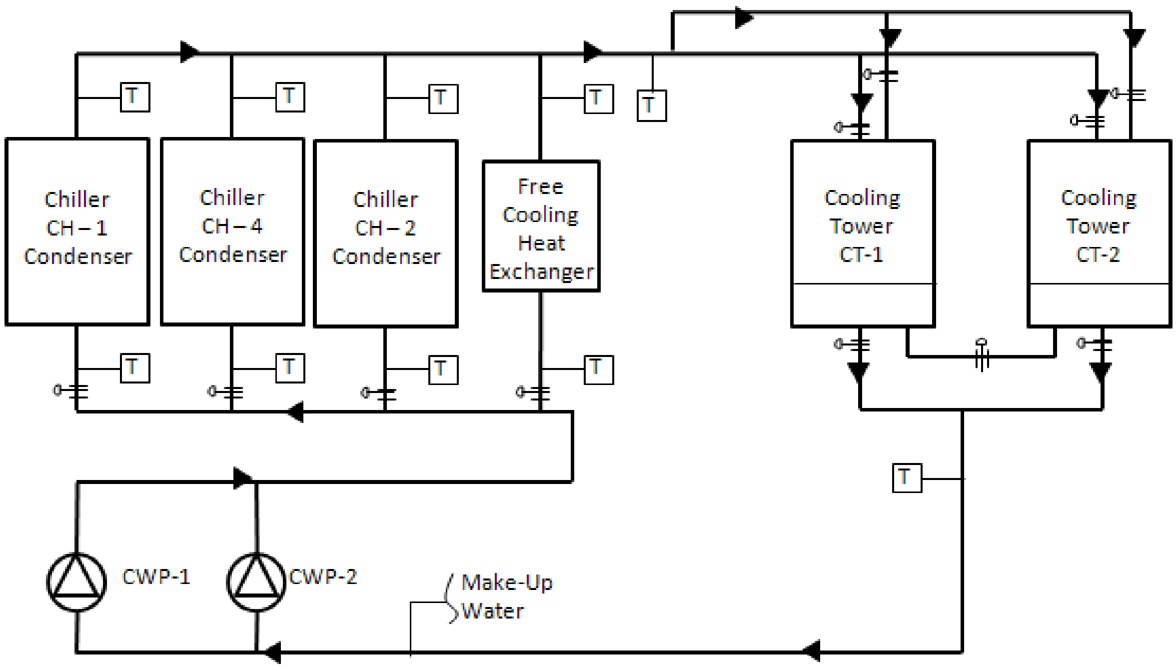

Figure 25: Redesigned Condenser Water Diagram

7.4.3 Heating Water System

The heating load under the redesign was not significantly affected and therefore many of the same components in the original design will remain in the redesign. The only significant changes are the removal of inline hot water pumps and distribution piping serving AHU-2 and AHU-3, along with the fin tube radiant panels along the perimeter of the patient rooms. AHU-2 and 3 have been eliminated. Although distribution piping to the reheat coils in terminal boxes will be eliminated, the chilled beams will need to be supplied with heating water; therefore, that system will remain relatively constant.

The integral boiler controls modulate burners, stage lead-lag boilers, or stage burner level to maintain primary heating water loop temperature set point of 195 degrees F. Primary heating water pumps circulate hot water around the primary loop, as referenced in ***Figure 26***. Primary heating water pump PHWP-1 runs whenever Boiler B-1 runs and will be off when B-1 is off. Pump PHWP-2 will run whenever Boiler B-2 runs and will be off when B-2 is off. The boiler isolation valve shall open whenever the related boiler runs, and shall close whenever the related boiler is off.

The secondary heating water pumps provide heating water distribution from the Boiler Room to the building heating systems. The pumps have variable speed motor drives to provide variable heating water flow based on system heating load. A selected differential pressure sensor with its sensing elements in the heating water supply and return piping shall provide a signal to maintain the differential pressure at the setpoint by varying the pump(s) rotational speed, and by cycling the pump(s) on and off. The control setpoint at the sensor shall be the minimum differential pressure necessary to operate the most remote heating water coil or terminal unit. Actual setpoint shall be field determined, but the initial setpoint shall be 5 psig (between heating water supply and return piping).

When one operating pump is at 100% speed and the differential pressure setpoint cannot be satisfied, start the next pump. Ramp up the additional pump until the two pumps operate at equal speeds. When two pumps are operating at 30% speed, one pump shall be shut down. On every start the heating pumps will be alternated so that the pump with the least run time becomes the lead.

The secondary heating water system modulates a three-way control valve to maintain secondary loop heating-water supply temperature. The heating-water supply temperature should be reset according to outside temperature with a straight line relationship for the following conditions: 180°F heating water when outside temperature is minus 10°F or lower and 140°F heating water when outside temperature is 75 °F or warmer. After the water enters the secondary loop, it is distributed to the loads via the secondary hot water pumps, which operate in parallel. Inline hot water pumps are also integrated into the system and can be found at each heating coil. Other than heating coils, the secondary hot water loop also provides chilled beams with hot water. Please refer to ***Figure 26*** for a schematic diagram of the heating water system.

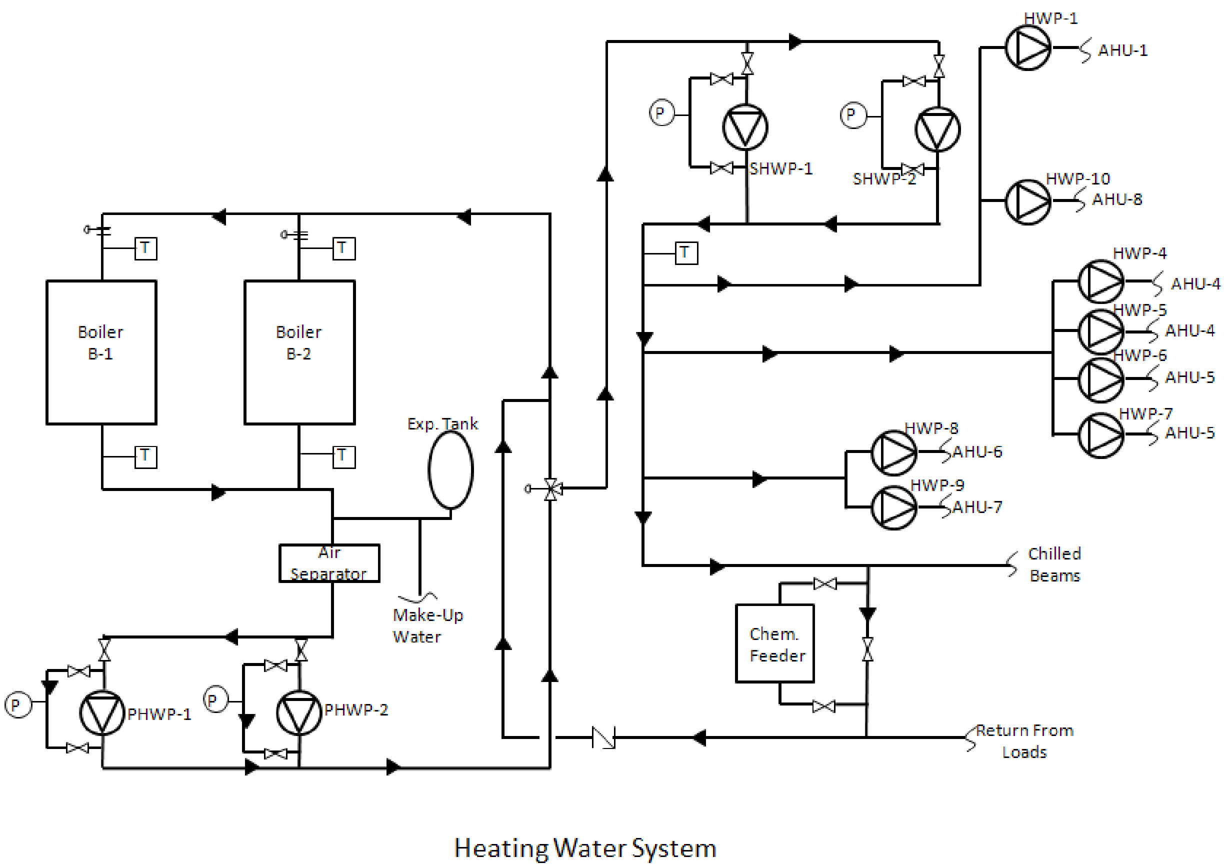

Figure 26: Redesigned Heating Water Diagram

7.5 Advantages of DOAS Chilled Beam System

Implementing a dedicated outdoor air system with chilled beams has many positive impacts on the life cycle costs, maintainability, thermal comfort, and quality of the air. Highlighted below are some of the advantages of a dedicated outdoor air system with chilled beam system.

A. Less supply air flow means less fan energy, smaller duct sizes, and smaller air handlers.
B. Smaller ductwork creates more space in the plenum and takes up less usable space.
C. Providing a constant ventilation airflow rate ensures that every room is properly ventilated without relying on a VAV box.
D. Water is much more efficient at transferring heat than air: 1" diameter pipe carrying water can carry the same amount of energy as an 18" x 18" duct.
E. Hours of operation of the chillers can be reduced by the use of a water side economizer. Since the chilled beams utilize higher temperature supply water, the water side economizer will be available for a larger portion of the year.
F. Decouple ventilation from heating and cooling air which makes systems more flexible.
G. COP of chiller serving the chilled beams is much higher due to warmer water temperatures.
H. Excellent air movement and uniform air temperature within the space.
I. No power connection to dampers reduces wiring costs.
J. No moving parts within the chilled beam, therefore low or no maintenance (may require infrequent vacuuming of coils).
K. No wasted energy due to reheat coils within terminal boxes.
L. Low cost zone valves used for temperature control opposed to complicated expensive controls used in terminal boxes; therefore, commissioning only involves adjustment to water balancing valves and primary air balancing dampers.
M. Low noise because there is not a terminal unit fan or motor.
N. Reduce costs for the following components:
    a. Chillers
    b. Condenser water pumps
    c. Ductwork
    d. Air distribution plenums and terminal boxes
    e. Air handlers
    f. Electrical service
    g. Wasted space due to mechanical equipment
O. With regards to a hospital application, the proposed system also has many advantages over a traditional VAV system. Such advantages include:
    a. In a hospital application which is governed by AIA air change guidelines, by using a chilled beam the total air changes per hour can be reduced by 4 because of the forced airflow principle. This is because for every 1 cfm of supply air entering a chilled beam there is a total of 4 cfm of total air that is induced across the coil and mixed.
    b. Indoor air quality will be drastically improved by not inducing any return air into the supply air. The rooms will be supplied with clean, fresh outside air at all times. This will increase employee and patient satisfaction as well as recovery rates.

c. Hospitals by nature exhaust a great deal of air due to medical equipment rooms, procedure, rooms, toilets, and janitor's closets just to name a few. In a VAV system, this energy is simply exhausted to the outdoors with no means of energy recovery. With the DOAS, much of the exhaust energy will be captured and returned to the space.
d. Hygiene chilled beams are equipped with an inbuilt filter which will capture the airborne bacteria entrained in air as the air is re-circulated across the chilled beam.

7.6 Design Calculations

7.6.1 Design Overview

When designing a DOAS with chilled beams, a few basic concepts must be understood. The following list of items is crucial to understanding how to design this type of system in a hospital.

A. The ventilation air has to meet minimum standards set forth by ASHRAE 62.1, the International Mechanical Code, and the American Institute of Architects for air changes per hour.
B. The cooling coil in the air handler must be able to meet the entire latent heat load within the space. If the cooling coil cannot meet the entire latent load it is possible for the room dew point to increase which can lead to condensation on chilled beams and mold problems.
C. The chilled beam within the space must be able to meet the remaining sensible load of the space. The sensible capacity of a chilled beam is dependent on the water flow rate, the volumetric flow rate of induced air, and the difference in temperature of the water temperature compared to the room temperature.
D. Every chilled beam will have to be sized individually to ensure that each zone is supplied with the minimum amount of ventilation air and enough sensible cooling capacity to cool the space.

7.6.2 Design Assumptions

A. General Hospital Space Design Conditions
    a. Summer : 75 degrees F and 50% RH
    b. Winter: 72 degrees F and 30% RH
B. Outside Design Conditions
    a. Summer: 89 degrees F dry bulb and 73 degrees F wet bulb
    b. Winter: 2 degrees F dry bulb
C. Outside Air Ventilation: 20 CFM/person and /or ASHRAE 62.1 and/or IMC and AIA hospital guidelines.
D. Toilet Room Exhaust Ventilation: 75 CFM/water closet, 50 CFM/urinal, or 2 CFM/SF, whichever is greater.
E. The anticipated maximum number of people per space is listed in ***Appendix B.***
F. The anticipated occupancy schedule is 24/7 for all patient areas and 7am to 7pm for all others.
G. Building "U" values used in heating and cooling calculations, Glass .26 with a .28 shading coefficient, Walls .10, and Roof .06.
H. Supply air ductwork was sized based on .08" per 100'.
I. The chilled water system is a direct return and heating water system is reverse return.

J. Nominal water flow rate to chilled beam is 1 gpm .
K. Supply temperature of chilled water to beam is 57 degrees F.
L. Supply temperature of air leaving DOAS air handler is 62 degrees F.
M. Any room requiring less than 30 cfm of ventilation air was not equipped with a chilled beam. Instead a ducted diffuser will supply 62 degree F air to the room. (Increase first cost savings)
N. All other building data entered into the Trane Trace model will be equal to that entered into the original energy model found in chapter ***5.0 Existing Building Performance.***

7.6.3 Energy Model Results

After conducting a revised Trane Trace energy simulation it was found that overall energy consumption of the redesigned system was lower than that of the VAV system. Two different redesign systems were analyzed. The first system analyzed was a DOAS with chilled beams without water side free cooling. The second simulation included the results of the water side free cooling. ***Table 24*** highlights the system loads of the original VAV design against the redesigned DOAS.

Original vs. Redesign Comparison		
Data Compared	Original Design	DOAS w/ Chilled Beam
Building Area (sqft)	146,095	146,095
Ventilation Air (cfm)	53,000	38,500
Ventilation Air (cfm/sqft)	0.36	0.26
Supply Air (cfm)	135,456	38,500
Supply Air (cfm/sqft)	0.93	0.26
Cooling Capacity (tons)	491	401
Cooling Capacity (sqft/ton)	297.55	364.33
Heating Capacity (Mbh)	7,122	6,856
Heating Capacity (Btu/sqft)	48.75	46.93

Table 24: Original vs. Redesign Load Comparison

Table 25 shows the energy consumption distribution between the original VAV design, the DOAS without free cooling, and the DOAS with free cooling being supplied to the chilled beams. The redesign was evaluated with and without a free cooling application in order to do a feasibility study to determine if the free cooling system is an economically smart decision.

Energy Consumption									
	Original VAV System			DOAS without Free Cooling			DOAS with Free Cooling		
Type	Energy (10^6 Btu/yr)	Cost	Cost/sqft	Energy (10^6 Btu/yr)	Cost	Cost/sqft	Energy (10^6 Btu/yr)	Cost	Cost/sqft
Lights	6751.4	$79,957	$0.55	6751.4	$79,957	$0.55	6751.4	$79,957	$0.55
Heating	1465.7	$8,756	$0.06	1092.3	$6,525	$0.04	1092.3	$6,525	$0.04
Cooling	2161.0	$25,592	$0.18	1800.8	$21,327	$0.15	1330.8	$15,761	$0.11
Pumps	703.7	$8,334	$0.06	1441.1	$17,067	$0.12	1591.1	$18,843	$0.13
Heat Rejection	211.0	$2,499	$0.02	203.9	$2,499	$0.02	203.9	$2,499	$0.02
Fans	5813.0	$68,844	$0.47	2892.6	$34,257	$0.23	2892.6	$34,257	$0.23
Receptacles	9305.7	$110,207	$0.75	9305.7	$110,207	$0.75	9305.7	$110,207	$0.75
Total		$304,189	$2.08		$271,840	$1.86		$268,049.76	$1.84

* Does not include energy consumption due to domestic water heating or water usage

Table 25: Energy Consumption Summary

The biggest energy savings when comparing the original VAV system to the DOAS system is due to the decrease in fan power. $34,587.00 were saved due to decreased fan power input. The fan savings are offset slightly, however, by the increase in pumping costs for the DOAS system. Pumping energy and cost increased by $8,733.00 due to additional chilled water pumping for the chilled beams. Cooling energy was decreased using the DOAS due to increased COP, heat recovery in the Pinnacle unit air handler, and lower ventilation rates. When implementing the free cooling application an additional $3,791.00 were saved due to a decrease in chiller hours. With the current redesign configuration and implementation of water-side free cooling, the annual energy bill was decreased by **$36,140.00** per year compared to the original VAV system.

7.6.4 Chilled Beam Sizing and Selection

When sizing chilled beams three factors have to be taken into consideration. The design must be able to meet the sensible heating and cooling load within the space, they must provide the space with the minimum ventilation requirements, and maintain pressure relationships within the zones. After performing an energy analysis using Trane Trace 700, sizing the chilled beams becomes possible. The energy model provides a detailed breakdown of the peak sensible heating and cooling load of each room. A detailed breakdown of each room, and the corresponding sensible load and airflow can be found in ***Appendix B.***

It should be noted that due to the nature of the hospital, the outside air required to each zone has to meet multiple criteria. The ventilation air has to meet minimum standards set forth by both ASHRAE 62.1 and the International Mechanical Code for hospital spaces. Because the redesign is a dedicated outdoor air system and 100% of the supply air is outside air, the outside air requirement also has to meet guidelines set forth by the American Institute of Architects for outside ACH and total ACH. Ventilation air must also be calculated to meet the latent load. The criteria with the largest requirement for ventilation air was used in the final calculations. ***Table 26*** depicts the minimum number of outside air changes and total air changes required in various hospital areas based upon AIA guidelines.

AIA Air Change Guidelines				
	PRESSURE RELATION	MIN OA ACH	TOTAL ACH	TOTAL ACH W/ BEAM
INPATIENT NURSING				
Patient rooms	N/R	2	6	1.5
Toilet room	Negative	N/R	10	2.5
Corridor	N/R	N/R	2	0.5
DIAGNOSTIC AND TREATMENT				
Laboratory, general	Negative	2	6	1.5
Examination Room	N/R	2	6	1.5
Medication Room	Positive	2	4	1
Endoscopic cleaning	Negative	2	6	1.5
STERILIZING				
Sterilizer equipment room	N/R	N/R	10	2.5
CENTRAL MEDICAL AND SURGICAL SUPPLY				
Soiled or decontamination room	Negative	2	6	1.5
Clean workroom	Positive	2	4	1
Sterile storage	Positive	2	4	1
SERVICE				
Soiled linen sorting and storage	Negative	N/R	10	2.5
Clean linen storage	Positive	N/R	2	0.5
Linen and trash chute room	Negative	N/R	10	2.5
Bathroom	Negative	N/R	10	2.5
Janitor's closet	Negative	N/R	10	2.5
SUPPORT SPACE				
Soiled workroom or soiled holding	Negative	2	10	2.5
Clean workroom or clean holding	Positive	2	4	1

Table 26: AIA Air Change Guidelines

Note: *Because the chilled beam is a forced air discharge system and induces four cfm of air for every one cfm of supply air, the total amount of room air changes may be reduced by 1/4. For non chilled beam zones the total air change rate must follow traditional AIA guidelines.*

Each room was analyzed independently to determine the sensible load and ventilation rate required within that specific room. In most cases, the ventilation rate governed the size of the chilled beam installation. As previously noted, supply water enters the chilled beam at 1 gpm and 57°F. The following quick selection chart, ***Figure 27*** was utilized for preliminary chilled beam sizing. ***Figure 27*** is courtesy of Semco ExSel Air Software.

In order to size the chilled beams more precisely, further calculations were performed using the ExSel Air software. In-house Semco engineers were consulted for chilled beam selection guidance and played a vital role in determining which chilled beams should be used for each application. An example of the ExSel Air chilled beam calculator is shown in ***Figure 28.*** Semco is a Flaktwoods company, which is the reason behind the Flaktwoods chilled beams being chosen.

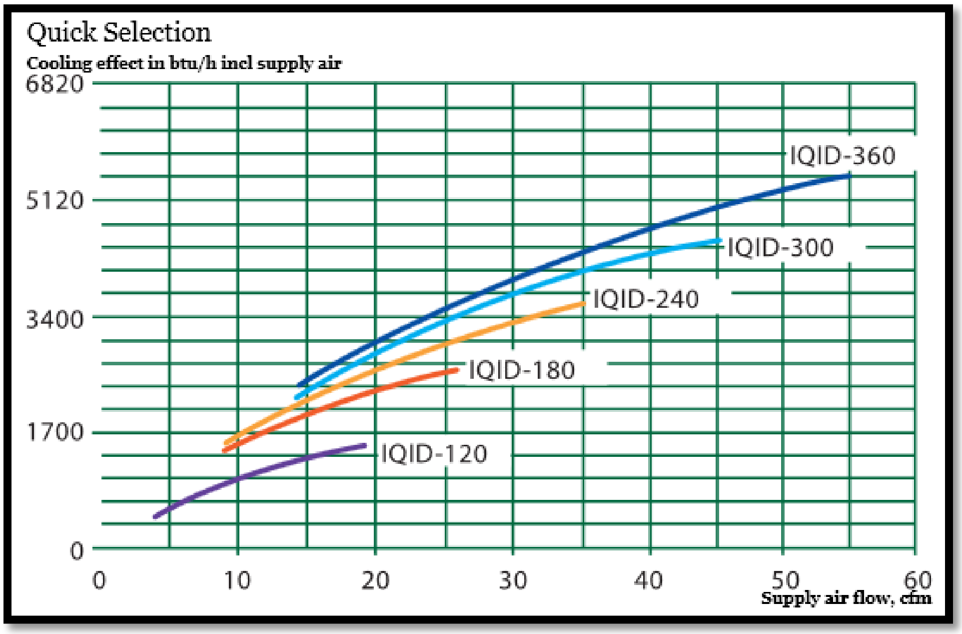

Figure 27: Semco Chilled Beam Quick Selection Chart

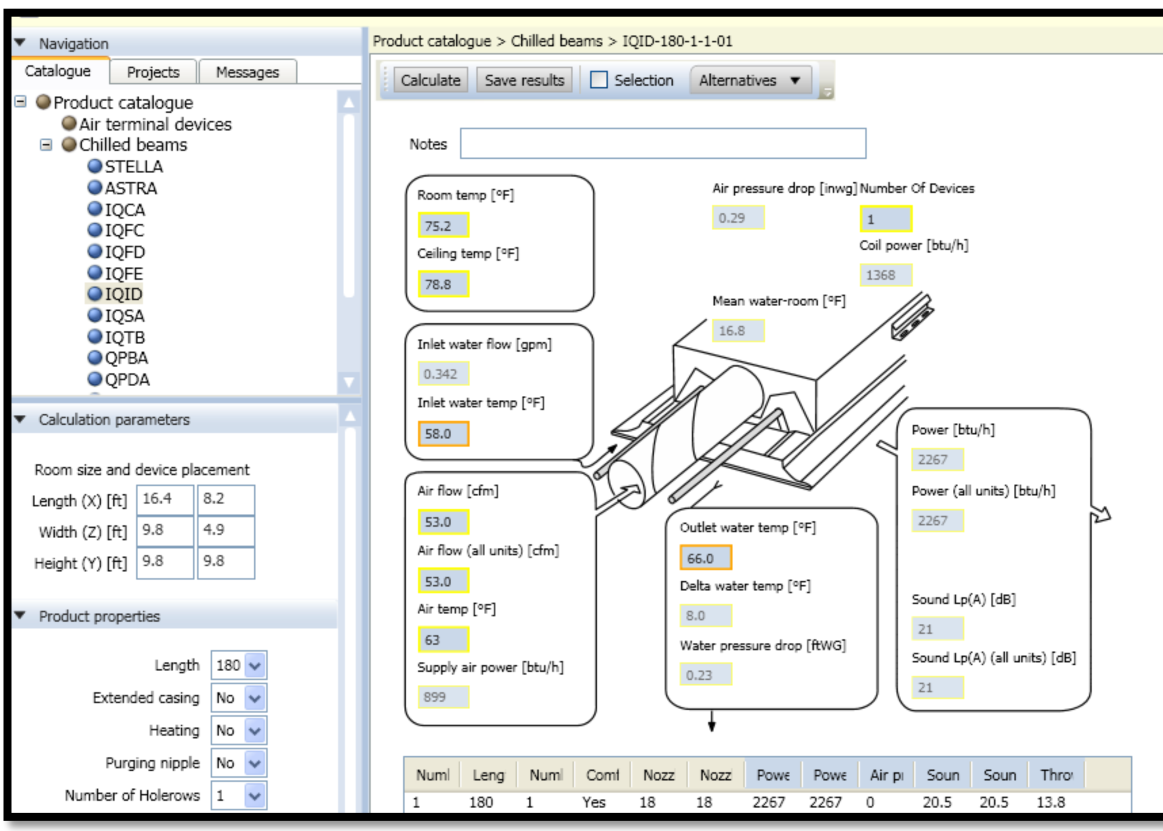

Figure 28: ExSel Air Chilled Beam Calculator

Smaller rooms that required less than 30 cfm and have a low sensible load were exempt from the chilled beam application. Such areas received direct air from the air handler via a supply air diffuser. ***Table 27*** below shows an example from the 5th floor depicting how the beams were sized. It should be noted that any cell reading "included" means that the ventilation requirement or sensible load for that space has been included in an adjacent space. Any cells that appear bright red represent a space that receives direct air from a diffuser and is not equipped with a chilled beam. The highest ventilation of the three codes was chosen and entered into the column "Selected CFM". Sensible loads for each space were also depicted. After both sensible load and airflow quantities were known, selecting a chilled beam was done. A complete breakdown of every room and the corresponding design criteria can be found in ***Appendix B.***

BUTLER MEMORIAL HOSPITAL

INPATIENT TOWER ADDITION & RENOVATION - FIFTH FLOOR

Thermal Load Zones

ROOM NO.	ROOM NAME	ROOM DATA AREA	ROOM DATA PEOPLE	SENSIBLE LOAD BTUH	SELECTED LOAD BTUH	SELECTED CFM	BEAMS SELECTED	SELECTED CFM w/o beams	IMC OA CFM MIN	AIA OA ACH MIN	AIA OA CFM MIN	AIA TOT ACH MIN	AIA TOT CFM MIN	AIA TOT ACH W/BEAM	AIA TOT CFM W/BEAM
									1		2		3		4
5A129	HSK	45	0	425	899			64	---			10	64	2.5	16
5A120	POC WORKROOM	48	1	453	453			32	20						
5A905	CORRIDOR	285		2691	2699	35	1-6'		30			2	81	1	20
5A226	CCU PATIENT ROOM	210	2	2717	2903	60	1-4'ds		40	2	60	4	119	1	30
5A227	CCU PATIENT ROOM	210	2	2717	2903	60	1-4'ds		40	2	60	4	119	1	30
5A228	CCU PATIENT ROOM	210	2	2717	2903	60	1-4'ds		40	2	60	4	119	1	30
5A229	CCU PATIENT ROOM	210	2	2717	2903	60	1-4'ds		40	2	60	4	119	1	30
5A103	MEN'S PUBLIC TOILET	68	0	Included					—			10	Included	2.5	Included
5A131	STAFF TOILET	60		Included					---			10	Included	2.5	Included

Table 27: Example of Room/Chilled Beam Schedule from Appendix B

**It should be noted that if the room was equipped with a chilled beam the AIA Total ACH cfm must be read from the far right column. If the room simply has a diffuser AIA Total ACH cfm must be read from the 3rd column from the right.*

After all rooms deserving a chilled beam were accounted for, the total number of chilled beams was determined, as well as the overall flow rate through CH-2. The results are shown below in ***Table 28.*** A chilled beam summary schedule courtesy of Semco can be found in ***Appendix C.*** The chilled beam quote from Semco can be found in ***Appendix F.***

Chilled Beam Summary

Model	Qty	Length	GPM/Beam	Total GPM	Price
IQIC-4	33	4'	1.0	33.0	$28,124.00
IQIC-6	48	6'	1.0	48.0	$45,772.00
IQIC-8	244	8'	1.0	244.0	$258,594.00
IQIC-10	59	10'	1.0	59.0	$69,662.00
IQCA-060	92	2'	1.0	92.0	$71,313.00
TOTAL	**476**			**476.0**	**$473,465.00**

Table 28: Chilled Beam Selection Summary

When selecting chilled beams, two different models were chosen. The two models chosen were the Flaktwoods IQCA Series depicted in ***Figure 29*** and the Flaktwoods IQIC Series shown in ***Figure 30.*** Both models are active chilled beam systems equipped for 2'x2' ceiling grid and a 4 pipe design.

Figure 29: IQCA Series

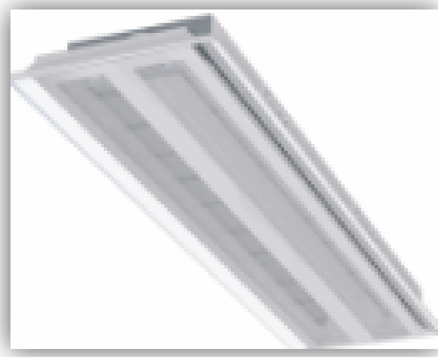

Figure 30: IQIC Series

7.6.5 Ductwork Calculations

One of the main features of the dedicated outdoor air system is the reduction of supply air flow. In the case of the New Inpatient Tower, the supply air was reduced from 154,000 cfm in the original VAV system down to 38,500 cfm with the redesigned system. Due to the drastic decrease in volumetric flow rate, the ducts were able to be downsized. The 5^{th} floor was chosen to be a representative floor and will be used to demonstrate how the ductwork was resized for the entire building. After ventilation rates for each room were determined, new duct sizes were calculated.

Figure 31 shows a representative sample of supply ductwork on the 5^{th} floor which will be used to do a takeoff comparison. A takeoff was done on the original 5^{th} floor supply ductwork. The results of this takeoff can be seen in ***Appendix D***. Next, the redesigned ductwork was sized based on volumetric flow rate and assumed friction loss of 0.08" wg per 100' of duct using a duct calculator. An example of how this process was done is shown in ***Figure 32.*** After all of the ductwork on the 5^{th} floor was resized for the lower volumetric flow rate, a second takeoff was calculated and the results are also shown in ***Appendix D.***

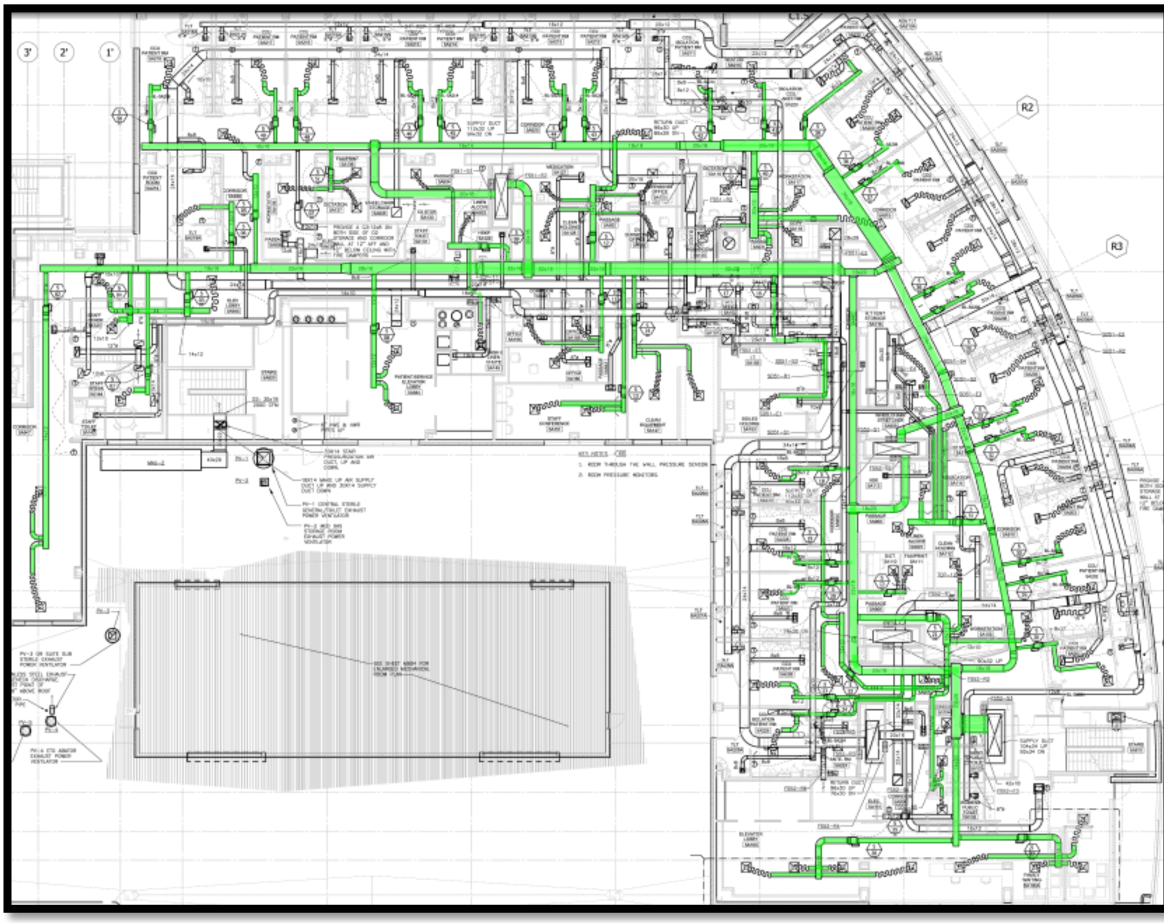

Figure 31: 5th Floor Supply Ductwork

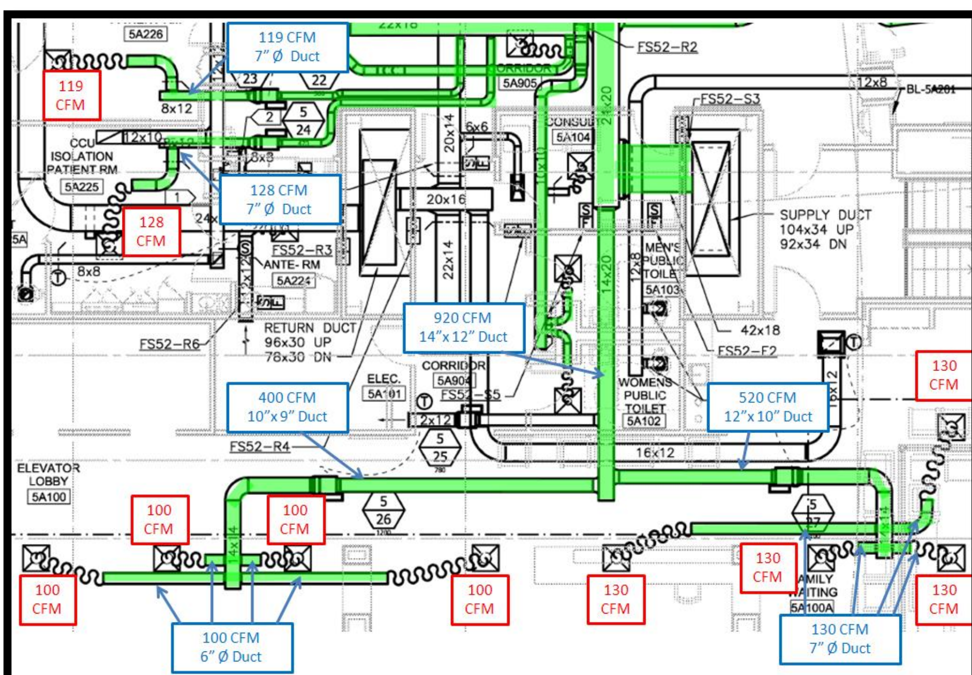

Figure 32: Ductwork Sizing Example

The results of the ductwork takeoff for the 5th floor supply ductwork can be seen in ***Table 29***. The table compares the original design to the redesign. As shown, the weight ratio of the redesign/original is .562.

Ductwork Comparison		
	Original	Re-Design
5th Floor Supply	11603 lbs	6521 lbs
Total Building	$832,000.00	$467,584.00
Ratio = 6521/11603 = .562 (56.2%)		

Table 29: 5th Floor Supply Ductwork

In order to calculate the cost difference between the original design and the redesign this ratio was used. The original cost for supply ductwork and installation for AHU-1,2, and 3 was $832,000.00. Applying the .562 ratio it was determined that the overall first cost for the DOAS ductwork will only be $467,584.00. This is a substantial savings when evaluating life cycle costs.

All supply ductwork in the hospital will be insulated with 1" foil faced fiberglass insulation. It was assumed that 1 sqft of insulation will cost $1.00. A separate takeoff and calculation was done for ductwork insulation which can also be found in ***Appendix D.*** The results of the insulation takeoff and cost comparison is illustrated in ***Table 30. Table 31*** compares the overall cost of the VAV system ductwork against the overall cost of the DOAS ductwork.

Supply Duct Insulation		
	Original	Re-Design
5th Floor	$10,094	$6,403
Building	$69,144	$43,861
Area Ratio = (Building-OR)/5th Floor 138,083/20,156 = 6.85		

Table 30: Duct Insulation Summary

Ductwork Cost		
	Original	Re-Design
Duct	$832,000	$467,584
Insulation	$69,144	$43,861
Total	**$901,144**	**$511,445**

Table 31: Ductwork Cost Comparison

7.6.6 Chilled Water Distribution

Chilled water distribution piping will have to be designed in order to supply the chilled beams with cooling energy. Distribution piping was designed for the 5th floor only. After the piping was designed, a takeoff was done and economic costs were calculated for the whole building using a weighted average approach. ***Figure 33*** illustrates the chilled water design layout for the 5th floor.

Also shown in ***Figure 33*** is the location and quantity of chilled beams within the rooms on the 5th floor. When performing the chilled water piping design it was assumed that all piping 1" and greater was made of Schedule 40 steel pipe with Class 150 malleable-iron fittings and threaded joints. Branch piping under 1" was assumed to be Type L drawn-temper copper tubing with wrought copper fittings and soldered joints. This will allow for easier connection to the ½" copper tubing which is used in the coils of chilled beams. The chilled water piping was designed under the following specifications:

- Piping ≤2" was designed for a maximum velocity of 4 ft/s
- Piping >2" was designed for maximum head loss of 4'/100' of piping

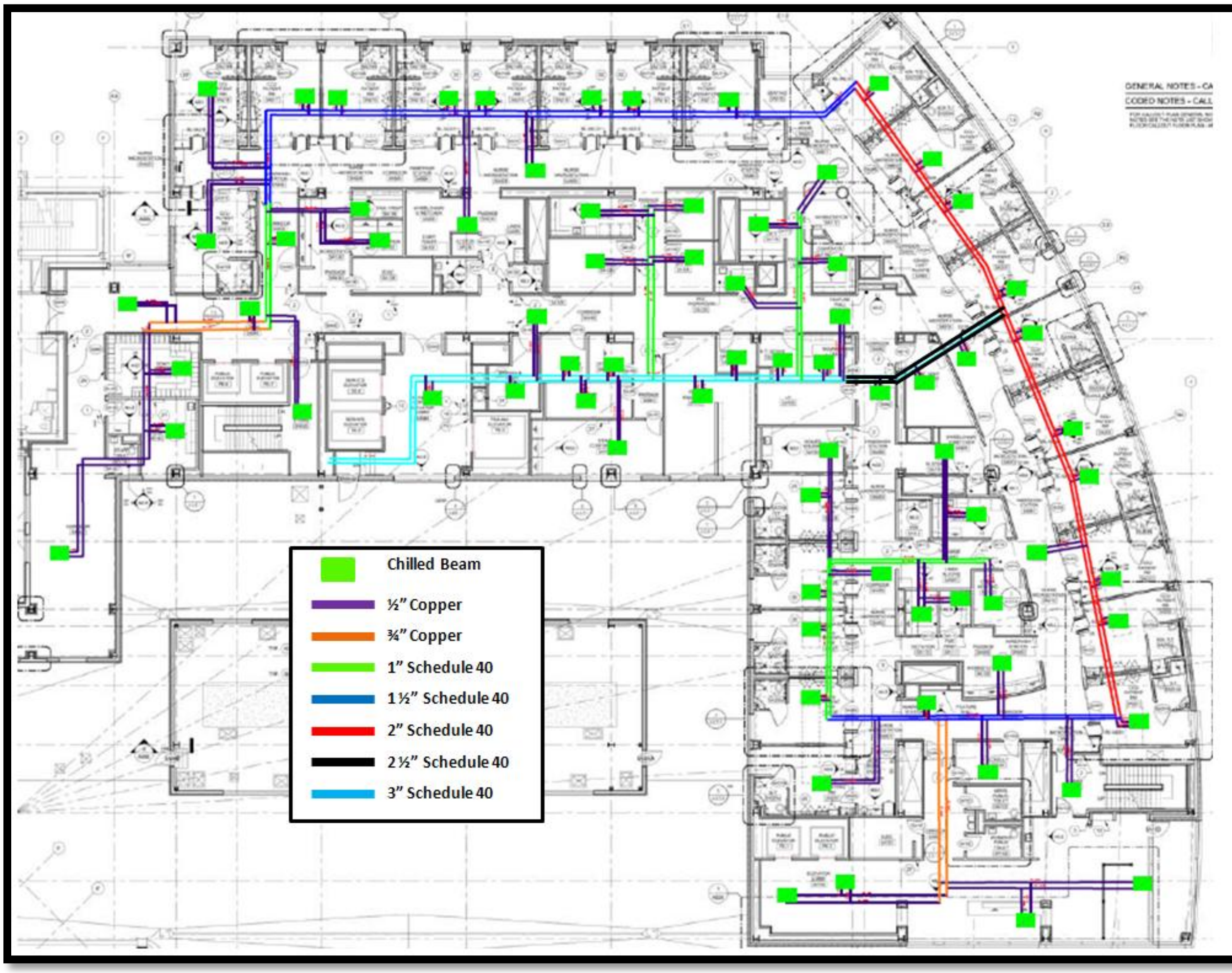

Figure 33: 5th Floor Chilled Water Distribution Piping

After designing the chilled water piping for the 5th floor, a takeoff was performed and data was recorded. The results of the chilled water distribution piping takeoff can be found in ***Appendix E.*** All chilled water piping was assumed to be insulated with 2" snap-on fiberglass with a standard service jacket. The results of the takeoff and cost of the chilled water distribution is shown below in ***Table 32.***

Chilled Water Piping	
Area Served	**Total Cost**
5th Floor	$51,194
Building	**$350,679**
Area Ratio = Building/5th Floor 138,083/20,156 = 6.85	

Table 32: Chilled Water Piping Cost

7.7 Water-Side Free Cooling

Water-side free cooling appeared to be an advantageous idea early on in the conceptual design. In most cases, water side free cooling is used to supply chilled water to an air handler which requires supply water around 42°F. In this application water side free cooling cannot be utilized until the outside wet bulb temperature is around 40°F. Since the chilled beams call for a higher temperature supply water, 57°F, water side free cooling can be implemented as soon as the wet bulb temperature drops below 54°F. With this application, free cooling will be available for a larger portion of the year, thereby reducing chiller hours and saving energy.

A feasibility study was done to compare the first cost and operation costs savings that are associated with the free cooling system. The primary chilled water pumps and condenser water pumps will be used to manage the flow in the two water streams within the plate and frame heat exchanger. The heat exchanger will obviously require installation, additional controls, and miscellaneous fixtures such as a basket strainer to prevent particulate accumulation within the strainer. Installation cost and configuration were devised with the help of Limbach Facility Services based on similar projects designed in the past. After specifications were given, the heat exchanger was quoted by Alfa Laval Inc. as a M15B-FG costing **$14,600**. The plate and frame specifications and quote can be found in ***Appendix G***. ***Table 33*** below shows the breakdown of additional equipment needed and the associated cost.

Free Cooling Application			
Added Equipment			
Item Description	Equipment	Installation	Total
Cooling Tower Piping Bypass			$8,600.00
Free Cooling Controls			$4,000.00
Plate & Frame Heat Exchanger	$14,600.00	$4,000.00	$18,600.00
Heat Exchanger Final Connections			$10,000.00
Total			**$41,200.00**

Table 33: Free Cooling Equipment

In order to do a life cycle cost, two Trane Trace simulations were performed. The first simulation was without free cooling and the second simulation included free cooling. The results are illustrated in ***Table 34***.

Water side free cooling will reduce the annual energy costs by **$3,790.** It was determined the payback period for water side free cooling is **10.8 years**, therefore this application will be utilized in the design.

	Energy Consumption					
	DOAS without Free Cooling			DOAS with Free Cooling		
Type	Energy (10^6 Btu/yr)	Cost	Cost/sqft	Energy (10^6 Btu/yr)	Cost	Cost/sqft
Lights	6751.4	$79,957	$0.55	6751.4	$79,957	$0.55
Heating	1092.3	$6,525	$0.04	1092.3	$6,525	$0.04
Cooling	1800.8	$21,327	$0.15	1330.8	$15,761	$0.11
Pumps	1441.1	$17,067	$0.12	1591.1	$18,843	$0.13
Heat Rejection	203.9	$2,499	$0.02	203.9	$2,499	$0.02
Fans	2892.6	$34,257	$0.23	2892.6	$34,257	$0.23
Receptacles	9305.7	$110,207	$0.75	9305.7	$110,207	$0.75
Total		**$271,840**	$1.86		**$268,050**	$1.84

Table 34: Free Cooling Cost Comparison

7.8 Summary

7.8.1 Redesigned Equipment Summary

After all design changes were calculated and implemented, a life cycle cost analysis was performed to verify the economic feasibility of the new redesigned system. Many pieces of equipment were either added, subtracted, or reduced in size. Summary schedules of the mechanical equipment for the redesign are shown in ***Tables 35-40*** below.

Air Handler Schedule					
System #	Area Served	Type	Supply CFM	Cooling Coil (EWT)	Heating Coil (EWT)
AHU-1	7th through lower level	DOAS	40,000	44°F	180°F
AHU-4	Operating Rooms	VAV	18,500	34°F	180°F
AHU-5	Operating Rooms	VAV	18,500	34°F	180°F
AHU-6	1st Floor Chiller Room	CV	4,700	44°F	180°F
AHU-7	1st Floor Electrical Room	CV	4,000	44°F	180°F
AHU-8	Elevator Penthouse	CV	4,700	44°F	180°F

Table 35: Redesigned Air Handler Schedule

Air Handler Fan Schedule						
System	Area Served	Supply Fans			Exhaust Fans	
		Type	CFM	HP	CFM	HP
AHU-1	7th through lower level	DOAS	(2) 40,000	(2) 75	(2) 40,000	(2) 40
AHU-4	Operating Rooms	VAV	18,500	30	16,500	15
AHU-5	Operating Rooms	VAV	18,500	30	16,500	15
AHU-6	1st Floor Chiller Room	CV	4,700	5	-	-
AHU-7	1st Floor Electrical Room	CV	4,000	5	4,000	1
AHU-8	Elevator Penthouse	CV	4,700	5	-	-

Table 36: Redesigned AHU Fan Schedule

Chiller Schedule						
System #	Type	Tons	COP	EWT	LWT	GPM
CH-1	Screw Chiller (DOAS AHU)	180	5.96	54°F	42°F	360
CH-2	Screw Chiller (Chilled Beams)	180	5.96	65°F	57°F	540
CH-3	Air Cooled Scroll Chiller (AHU-4 & 5)	119	2.6	46.6°F	34°F	253
CH-4	Screw Chiller (Redundant)	180	5.96	N/A	N/A	N/A

Table 37: Redesigned Chiller Schedule

Boiler Schedule						
System #	Type	Capacity (MBH)	Eff.	EWT	LWT	GPM
B-1	Gas/Oil Fired Hot Water Boiler	7200	81%	160°F	180°F	720
B-2	Gas/Oil Fired Hot Water Boiler	7200	81%	160°F	180°F	720

Table 38: Redesigned Boiler Schedule

Cooling Tower Schedule					
System #	Type	hp	EWT	LWT	GPM
CT-1	VSD Axial Fan Cooling Tower	15	95°F	85°F	600
CT-2	VSD Axial Fan Cooling Tower	15	95°F	85°F	600

Table 39: Redesigned Cooling Tower Schedule

Pump Schedule						
System #	Location	System	Type	GPM	Head	VSD
PCHWP-1	Mech. Room	Chilled Water	End-Suct.	360	30	N
PCHWP-2	Mech. Room	Chilled Water	End-Suct.	540	30	Y
PCHWP-3	Mech. Room	Chilled Water	End-Suct.	540	30	N
SCHWP-1	Mech. Room	Chilled Water	End-Suct.	360	100	Y
SCHWP-2	Mech. Room	Chilled Water	End-Suct.	540	100	Y
SCHWP-3	Mech. Room	Chilled Water	End-Suct.	540	100	Y
CWP-1	Mech. Room	Cond. Water	End-Suct.	600	65	N
CWP-2	Mech. Room	Cond. Water	End-Suct.	600	65	N
PHWP-1	Mech. Room	Hot Water	End-Suct.	720	25	N
PHWP-2	Mech. Room	Hot Water	End-Suct.	720	25	N
SHWP-1	Mech. Room	Hot Water	End-Suct.	550	90	Y
SHWP-2	Mech. Room	Hot Water	End-Suct.	550	90	Y
HWP-1	AHU-1	Hot Water	Inline	174	15	N
HWP-4	AHU-4	Hot Water	Inline	44	10	N
HWP-5	AHU-4	Hot Water	Inline	10	5	N
HWP-6	AHU-5	Hot Water	Inline	44	10	N
HWP-7	AHU-5	Hot Water	Inline	10	5	N
HWP-8	AHU-6	Hot Water	Inline	25	10	N
HWP-9	AHU-7	Hot Water	Inline	17	10	N
HWP-10	AHU-8	Hot Water	Inline	20	10	N

Table 40: Redesigned Pump Schedule

7.8.2 First Cost Summary

After all new equipment was designed and sized a first cost comparison was done to evaluate the redesigned system against the original system. ***Table 41*** illustrates which pieces of equipment were subtracted, added, or reduced and the associated cost. It should be noted, all original design deducts are actual costs provided by the general contractor or mechanical contractor. Equipment and associated installation costs of the added equipment were computed by using a combination of RS Means 2007, actual equipment quotes, and the mechanical contractor's cost data from this project and similar previous projects.

After completing the first cost comparison it becomes evident that the redesigned system will cost less money upfront than the original VAV system. The bulk of the savings in first cost are a direct result of the reduced airflow. The air handlers and ductwork are both downsized drastically. The biggest first cost expenditure of the redesigned system is the chilled water distribution piping and the equipment and installation cost of the chilled beams. The complete breakdown is in ***Table 41*** below.

First Cost Comparison				
Subtracted Items				
Qty	**Item Description**	**Equipment**	**Installation**	**Total**
3	62,000 CFM Rooftop AHU	$900,000.00	$51,000.00	-$951,000.00
272	VAV Boxes/Reheat Coils	$116,800.00	$50,500.00	-$167,300.00
2	400 Ton Centrifugal Chillers	$305,000.00	$39,500.00	-$344,500.00
	Original Ductwork (AHU-1,2 &3)			-$901,144.00
	Supply Duct Diffusers			-$63,000.00
2100	Finned Tube Radient Panels	$75,000.00	$41,716.00	-$116,716.00
3	Humidifiers in AHU 1-3	$22,000.00	$20,283.00	-$42,283.00
2	Inline Hot Water Pumps	$3,450.00	$2,250.00	-$5,700.00
	TOTAL			**-$2,591,643.00**
Added Items				
Qty	**Item Description**	**Equipment**	**Installation**	**Total**
1	40,000 CFM DOAS AHU (Pinnacle)	(1) $277,904.00	(2) $17,000.00	$294,904.00
476	Active Chilled Beams	(1) $473,415.00	(2) $62,494.00	$535,909.00
476	Connection to Active Chilled Beam		(2) $309,400.00	$309,400.00
	Chilled Water Distribution Piping			(3) $350,679.00
3	180 Ton Screw Chillers (Trane RTWD)	(1) $189,000.00	(2) $39,000.00	$228,000.00
	Cooling Tower Piping Bypass			(2) $8,600.00
	Free Cooling Controls			(2) $4,000.00
1	Plate & Frame Heat Exchanger	(1) $14,600.00	(2) $4,000.00	$18,600.00
	Heat Exchanger Final Connections			(2) $10,000.00
2	Add. Primary/Secondary CHW Pumps	(2) $12,700.00	(2) $16,500.00	$29,200.00
1	Humidifier in DOAS AHU	(2) $7,200.00	(2) $6,800.00	$14,000.00
	New Ductwork			(3) $511,445.00
	TOTAL			**$2,314,737.00**
Net Savings = $276,906.00				

Note

(1) Actual Quote from Vendor

(2) Mechanical Contractor (Limbach Facility Services)

(3) RS Means 2007

Table 41: First Cost Comparison

7.8.3 Life Cycle Cost Analysis

In order to perform a life-cycle cost analysis, the first cost will be compared to operational costs to determine the feasibility of the chilled beam system. As shown above, the chilled beam system will save almost **$277,000** in first costs compared to the original VAV design. The annual energy consumption and operational cost data was taken from the Trane Trace 700 energy model and is shown below in ***Tables 42 & 43. Table 42*** depicts the energy costs associated with the original VAV system while ***Table 43*** breaks down the energy costs associated with redesigned DOAS system.

Original VAV System							
Equipment Energy Consumption				Total Energy Cost			
Type	Energy (10^6 Btu/yr)	Cost	Cost/sqft	Type	Energy (10^6 Btu/yr)	Cost ($/yr)	Cost ($/sqft)
Lights	6751.4	$79,957	$0.55	On Peak Elec.	11,618	$170,480	
Heating	1465.7	$8,756	$0.06	Off Peak Elec.	14,219	$125,197	
Cooling	2161.0	$25,592	$0.18	Total Electricity	25,837	$295,677	$2.03
Pumps	703.7	$8,334	$0.06	Gas	1,257	$7,509	$0.05
Heat Rejection	211.0	$2,499	$0.02		27,094	$303,186	$2.08
Fans	5813.0	$68,844	$0.47	Type	Energy (1000gal/yr)	Cost ($/yr)	Cost ($/sqft)
Receptacles	9305.7	$110,207	$0.75	Water	2,072	$2,072.00	$0.01
				Total		**$305,258.42**	**$2.09**

Table 42: Original VAV System Energy Costs

Redesigned DOAS System							
Equipment Energy Consumption				Energy Cost			
Type	Energy (10^6 Btu/yr)	Cost	Cost/sqft	Type	Energy (10^6 Btu/yr)	Cost ($/yr)	Cost ($/sqft)
Lights	6751.4	$79,957	$0.55	On Peak Elec.	10,734	$157,468	
Heating	1092.3	$6,525	$0.04	Off Peak Elec.	11,977	$105,457	
Cooling	1330.8	$15,761	$0.11	Total Electricity	22,711	$262,925	$1.80
Pumps	1591.1	$18,843	$0.13	Gas	956	$5,711	$0.04
Heat Rejection	203.9	$2,499	$0.02		23,667	$268,636	$1.84
Fans	2892.6	$34,257	$0.23	Type	Energy (1000gal/yr)	Cost ($/yr)	Cost ($/sqft)
Receptacles	9305.7	$110,207	$0.75	Water	2,806	$2,806.00	$0.02
				Total		**$271,442.41**	**$1.86**

Table 43: Redesigned DOAS System Energy Costs

Cost Savings	
First Cost	$276,906.00
Operational Cost/Year	$33,800.00

Table 44: Cost Summary

From this comparison it is determined that the DOAS system will also save roughly **$33,800** in annual energy costs. The redesigned system will have an annual energy savings of nearly **2,700 MMBtu/year.** Overall cost savings are shown in ***Table 44*** above. Although maintenance costs cannot be estimated exactly, it is an accepted assumption that since there are no moving parts in a chilled beam system, chilled beams with a DOAS system require much less maintenance than terminal boxes and a VAV system.

7.8.4 Emissions Summary

After completing the energy model, Trane Trace 700 was utilized to determine the environmental impact of the original VAV design compared to the redesigned DOAS system. The analysis was performed on carbon dioxide, sulfur dioxide, and nitrogen oxide emissions. The results are shown below in ***Figures 34 & 35.***

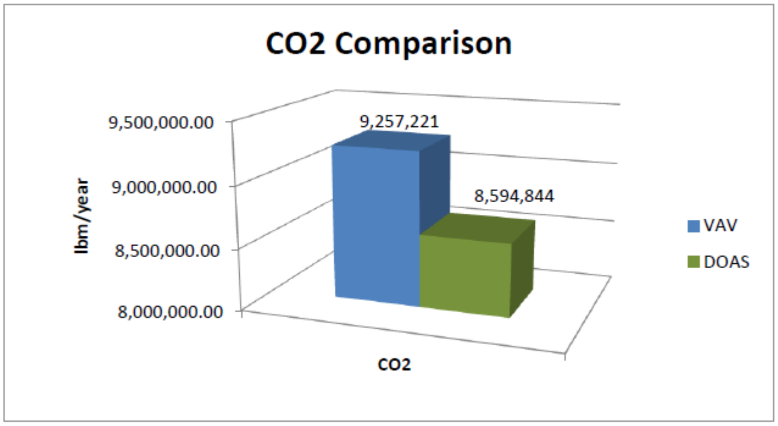

Figure 34: CO2 Comparison

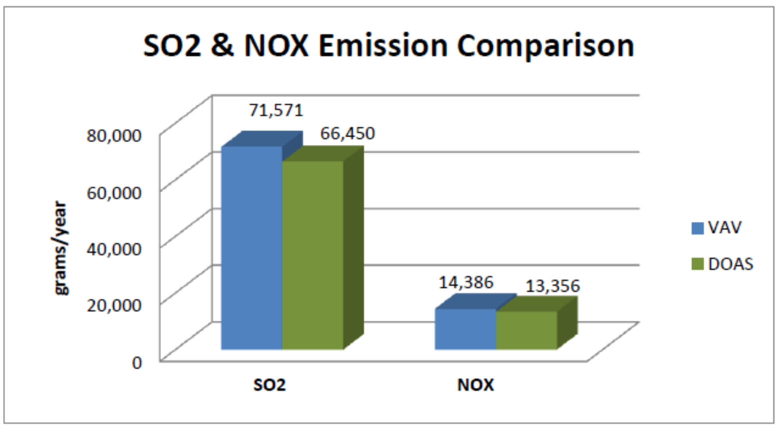

Figure 35: SO2 & NOX Comparison

In conclusion, it was determined that the redesigned system will have a lower construction costs, lower operating costs, less maintenance, and a smaller carbon footprint. It is under these premises that the use of a DOAS system with supplemental chilled beams is recommended in lieu of the VAV system currently installed in the New Inpatient Tower at the Butler Memorial Hospital.

8.0 Structural Breadth

8.1 Introduction

A structural breadth was scrutinized to determine the effects of the mechanical redesign on the structural support system. Of the (3) main original rooftop air handlers, two were eliminated and the third was downsized from 62,000 CFM to 40,000 CFM. Due to the reduction in air handlers contributing to a reduced load on the roof, an analysis of the structural system was performed to resize roofing members and distinguish any cost savings that may be a result of the redesign.

The structural steel members will be resized in the AHU-1 and AHU-3 areas shown below in ***Figure 36.*** The new DOAS air handler is approximately the same size and weight as AHU-2 and will be placed in the same location to avoid ductwork penetration issues.

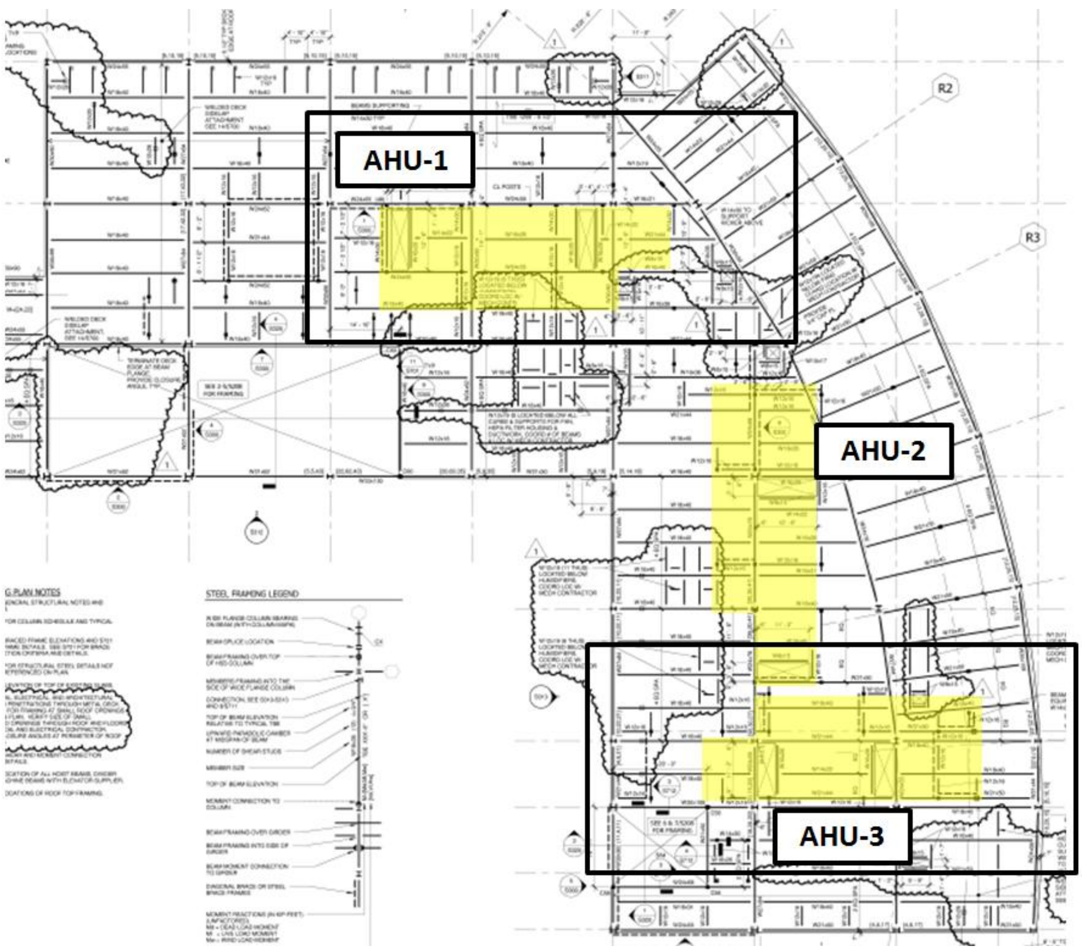

Figure 36: Rooftop Plan View Showing AHU Locations

8.2 Assumptions

When calculating the redesigned roof loads and beam member sizes, a number of assumptions were made and are listed below:

A. AHU- 1 and 3 were eliminated; therefore, the additional roof load due to these two units will be eliminated.
B. The metal decking supporting the roof will remain the same as the original design (3" 20 gauge galvanized decking).
C. The remaining roof components consist of the following materials.
   a. 4" Rigid Insulation (tapered for drainage therefore thickness ranges)
   b. ½" Cover Board (Georgia Pacific "Dens Deck" Gypsum)
   c. 60 mil Thermoplastic Polyolefin Membrane
D. Miscellaneous dead load of 10 psf.
E. Snow load for the Butler, PA region is 30 psf.
F. Roof live load is 115 psf.
G. Live load cannot be reduced because it is a roof application.
H. Load will be uniformly distributed.
I. Since the size, shape, and weight of the new DOAS air handler is slightly less, but comparable to the existing rooftop AHU-2, the structural members in that area were assumed to be sufficient to carry the load and therefore will remain as originally designed.

8.3 Design Calculations for AHU-1 Area

8.3.1 Typical Layout (AHU-1)

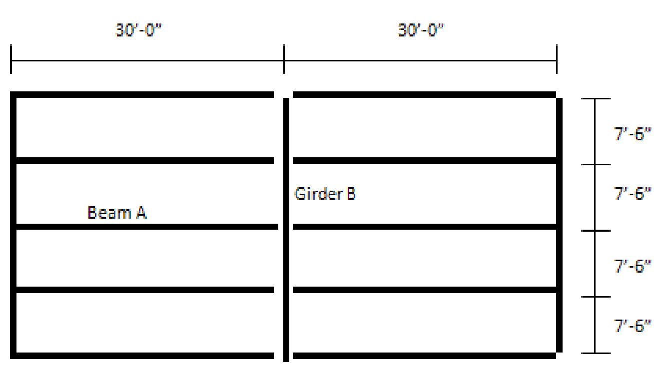

Figure 37: Typical Steel Layout at AHU-1

8.3.2 Design Loads

Live Loads

1. Roof Live Load = 115 psf
2. Snow Load = 30 psf

Total = 145 psf

Dead Loads

1. Beam Self Weight = 5 psf
2. 3’” Roof Deck = 3 psf
3. 4” Rigid Insulation = 4 psf
4. ½” Cover Board = 1 psf
5. 60 mil Roof Membrane = 2 psf
6. Miscellaneous Dead Load = 10 psf

Total = 25 psf

8.3.3 Beam “A” Design

Factored Distributed Load

W_u = 1.2D + 1.6L

W_u = 1.2(25) + 1.6(145)

W_u = 262 psf

w_u = 7.5’ x 262 psf = 1.97 klf

Shear and Moment Diagrams

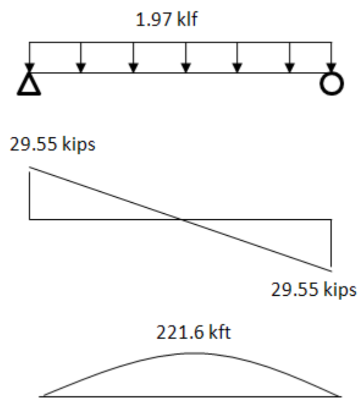

Figure 38: Shear & Moment Diagrams for Beam A

From the Steel Manual in ***Appendix I*** p. 3-18 W18x35 ϕM_{px} = 249 kft > 222 kft therefore it would be the most economical beam choice. However, since the standard size beam on the existing roof is a W18x40 which has a ϕM_{px} = 294 kft which will also carry the 222 kft load, the W18x40 was chosen.

8.3.4 Girder “B” Design

Factored Distributed Load

W_u = 1.2D + 1.6L

W_u = 1.2(25) + 1.6(145)

W_u = 262 psf

P_u = 262 psf x 7.5ft (30 ft + 30 ft)/2

P_u = 58.9 kips

Shear and Moment Diagrams

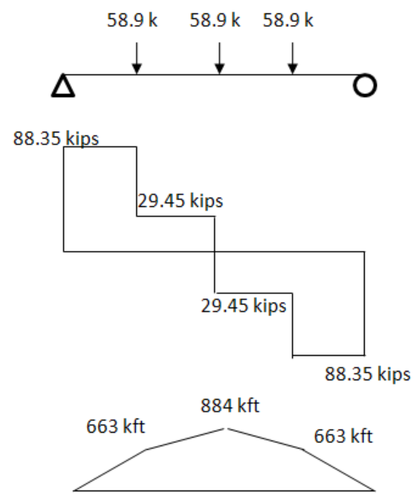

Figure 39: Shear & Moment Diagram for Girder B

From the Steel Manual in ***Appendix I*** p. 3-15 W27x84 ϕM_{px} = 915 kft > 884 kft therefore it would be the most economical girder choice. This was also the girder size used throughout the remainder of the roof. The moment load governs the girder size; therefore, max shear stress was not a factor.

Figure 40 illustrates the original design depicting which beams were eliminated or reduced. ***Figure 41*** shows the location and size of the redesigned steel at AHU-1 area.

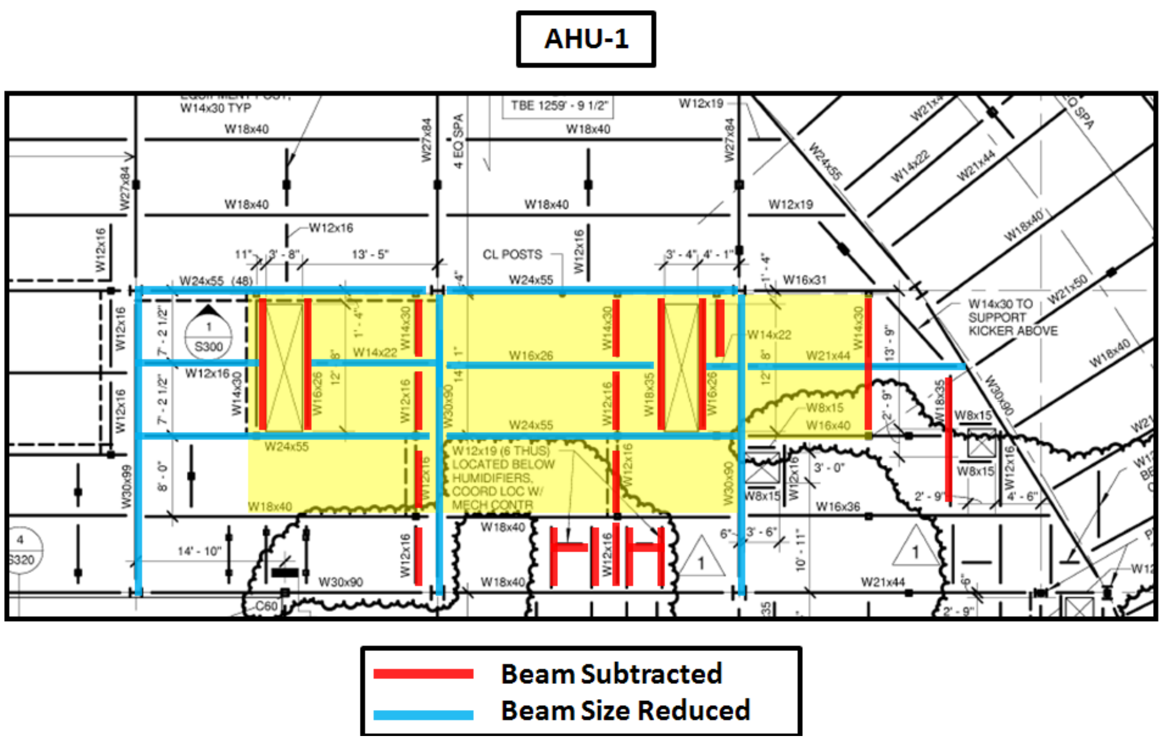

Figure 40: Original Steel Layout at AHU-1

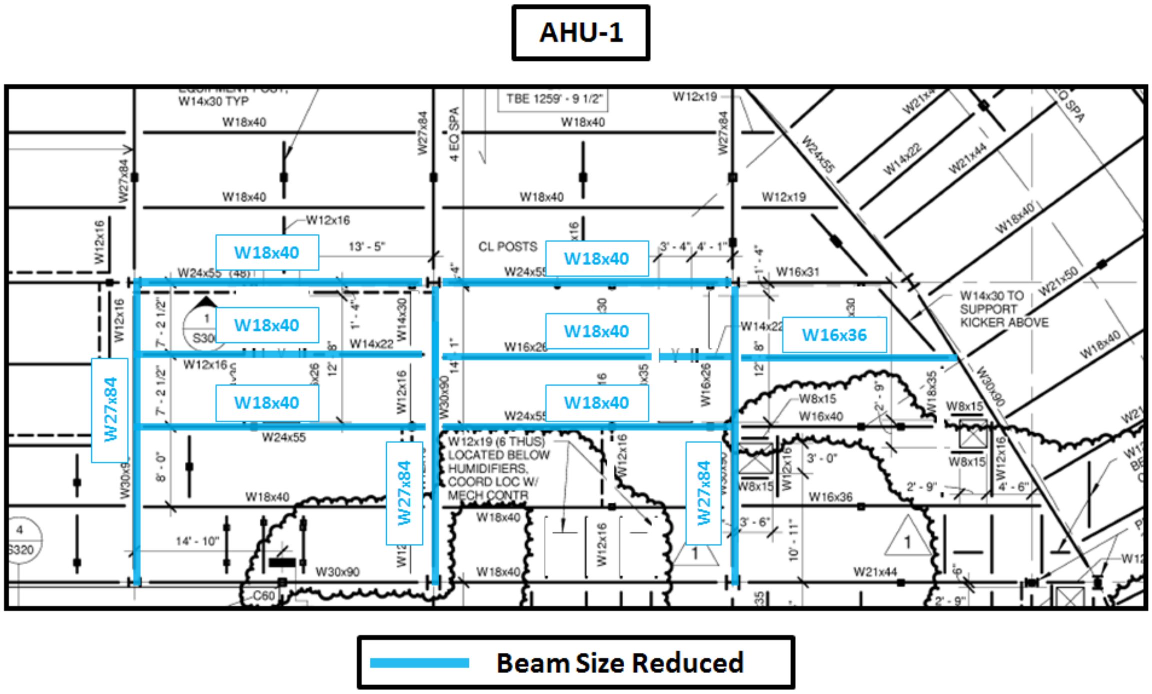

Figure 41: Redesigned Steel Size and Location at AHU-1

8.4 Design Calculations for AHU-3 Area

8.4.1 Typical Layout (AHU-3)

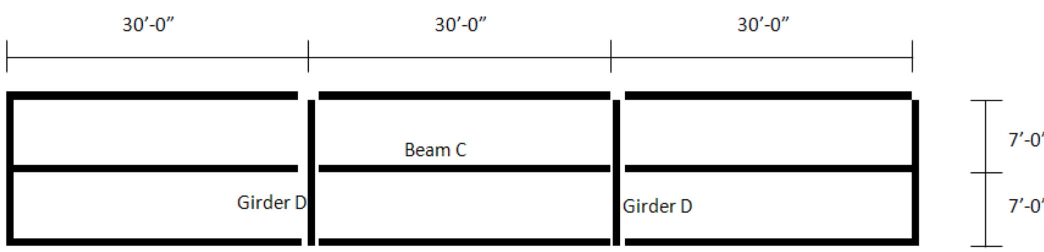

Figure 42: Typical Steel Layout at AHU-3

8.4.2 Design Loads

(Same as Above)

Live Load = 145

Dead Load = 25

8.4.3 Beam "C" Design

Factored Distributed Load

$W_u = 1.2D + 1.6L$

$W_u = 1.2(25) + 1.6(145)$

$W_u = 262$ psf

$w_u = 7' \times 262$ psf $= 1.83$ klf

Shear and Moment Diagrams

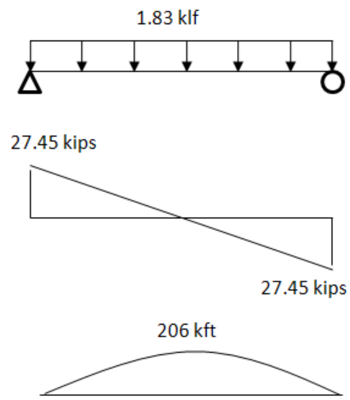

Figure 43: Shear & Moment Diagram for Beam C

From the Steel Manual in ***Appendix I*** W18x35 $\phi M_{px} = 249$ kft > 206 kft therefore it would be the most economical beam choice. However, since the standard size beam on the existing roof is a W18x40 which has a $\phi M_{px} = 294$ kft which will also carry the 206 kft load, the W18x40 was chosen instead. The moment load governs the beam size in both cases; therefore, max shear stress was not a factor.

8.4.4 Girder "D" Design

Factored Distributed Load

$W_u = 1.2D + 1.6L$

$W_u = 1.2(25) + 1.6(145)$

$W_u = 262$ psf

$P_u = 262$ psf x 7ft (30 ft + 30 ft)/2

$P_u = 55$ kips

Shear and Moment Diagrams

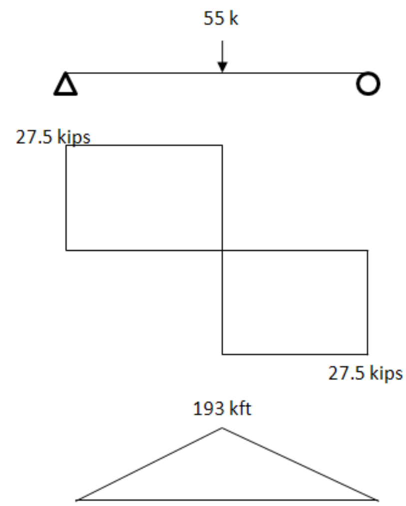

Figure 44: Steel and Moment Diagram for Girder D

From the Steel Manual in ***Appendix I*** p. 3-18 W16x31 ϕM_{px} = 203 kft > 193 kft therefore it would be the most economical girder choice. However, since the standard size beam on the existing roof is a W18x40 which is 18" deep, the girder chosen must have more depth for installation and attachment purposes. The next smallest beam size above a W18x40 is a W21x44 which has ϕM_{px} = 358 kft. 358 kft >> 193 kft therefore this girder size was chosen. ***Figure 45*** below illustrates the original design depicting which beams were eliminated or reduced. ***Figure 46*** shows the location and size of the redesigned steel at AHU-3 area.

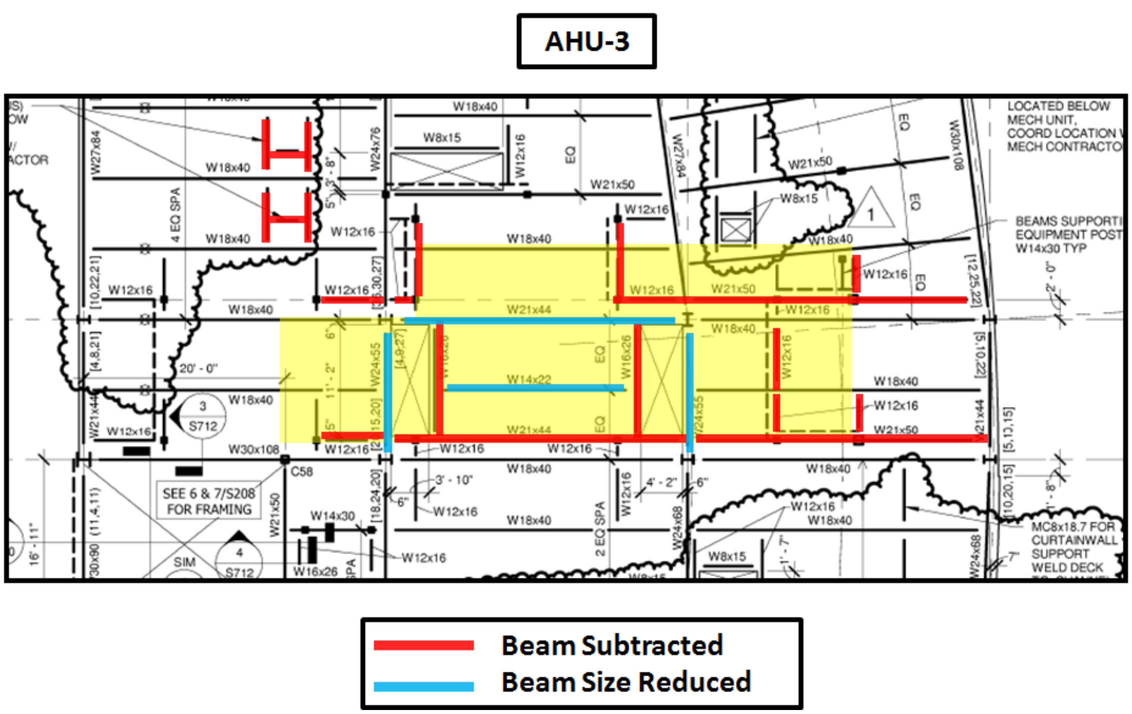

Figure 45: Original Steel Size & Location at AHU-3

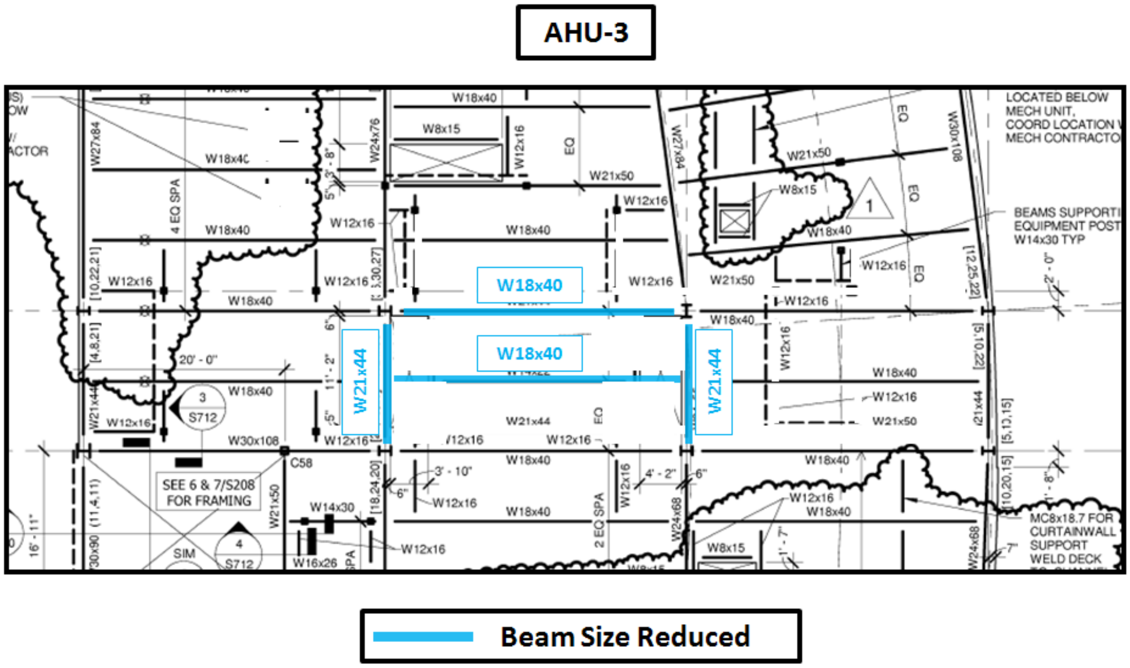

Figure 46: Redesign Steel Size & Location at AHU-3

8.5 Summary

By eliminating (2) of the rooftop air handling units, the size of the structural steel members in those areas was drastically reduced. In order to an economic comparison of the original and redesigned steel layouts a detailed takeoff was performed. The detailed breakdown of this takeoff can be found in ***Appendix J.***

Table 45 below shows a summary of the results of the takeoff and first cost price comparison between the two designs. The redesigned steel layout will save over **$18,000.00** in construction costs.

Subtracted Steel					
Size	Length (ft)	Wt./foot (lb/ft)	Weight (lb)	Unit Cost ($/ft)	Total Cost
W12x16	130.75	16	2,092.0	$26.50	$3,464.88
W12x19	64.6	19	1,227.4	$31.00	$2,002.60
W14x22	37.4	22	822.8	$38.00	$1,421.20
W14x30	43.75	30	1,312.5	$43.00	$1,881.25
W16x26	79.8	26	2,074.8	$38.00	$3,032.40
W18x35	29.5	35	1,032.5	$51.50	$1,519.25
W21x44	113.4	44	4,989.6	$61.50	$6,974.10
W21x50	30	50	1,500.0	$69.00	$2,070.00
W24x55	148	55	8,140.0	$75.00	$11,100.00
W30x99	90	99	8,910.0	$129.00	$11,610.00
Total			32,101.6		$45,075.68

Added Steel					
Size	Length (ft)	Wt./foot (lb/ft)	Weight (lb)	Unit Cost ($/ft)	Total Cost
W16x36	23.2	36	835.2	$56.50	$1,310.80
W18x40	240	40	9,600.0	$57.50	$13,800.00
W21x44	28	44	1,232.0	$61.50	$1,722.00
W27x84	90	84	7,560.0	$110.00	$9,900.00
Total			19,227.2		$26,732.80

Net Savings = $18,343.00

Table 45: Steel Comparison

9.0 Electrical Breadth

9.1 Introduction

An electrical breadth topic was investigated to determine the impact of the new mechanical system on the electrical distribution. Because some of the equipment will be downsized or eliminated and other equipment added, a new inspection of the power distribution will need to be analyzed. Over current protection, feeder sizes, and feasibility issues will need to be examined and resolved.

9.2 Electrical Load Calculations

9.2.1 Equipment Electrical Loads

Since some of the equipment from the original design will be downsized or eliminated and other pieces of equipment added an electrical load comparison was calculated. First, the horsepower of the equipment added and removed from the system was determined. ***Tables 46 & 47*** below show the equipment that was subtracted and added, respectively.

9.2.2 Full Load Current

Utilizing ***NEC 2008 Table 430.250*** *Full Load Amperes Three Phase Alternating Current Motors* found in ***Appendix K,*** each of the motors' full load amps was determined. The results of this can be seen in ***Table 47.***

9.2.3 Connected Load

After determining the FLA at each motor, the overall connected load was calculated. The following two equations were used to find total KW and KVA which are found in ***Table 47***.

KVA = Volts x FLA x 1.73 / 1000

KW = KVA x PF

The following power factors were assumed:

Motors < 5 HP – **PF= 0.85**
Motors > 5 HP – **PF = 0.90**
Chillers **PF = 0.85**

9.2.4 Over Current Protection Device

After calculating the full load amperage on each motor sizing the circuit breakers becomes possible. Common circuit breaker sizes were taken from **NEC 2008 240.6 Standard Ampere Ratings** which can be found in **Appendix K.** The circuit breaker sizes can are shown in ***Table 47*** as well as ***Appendix L.*** When sizing circuit breakers the following equation was used:

Circuit Breaker Size < 2.5 x FLA

9.2.5 Branch Circuit Feeder Sizing

In order to size the feeder wires going to each motor ***NEC 2008 Table 310.16*** was utilized. This table can be found in ***Appendix K.*** It was assumed that the feeder wires would be Copper, Type THW at 75 °C. The feeder sizes are shown in ***Table 47*** below. The following equation was used to size the feeder wires:

Wire Size > 1.25 x FLA

9.2.6 Conduit Sizing

After the feeder wires were sized, sizing the conduit was performed by referencing ***NEC 2008 Table C.1*** *Maximum Number of Conductors in Electric Metallic Tubing.* This table can also be found in ***Appendix K.*** The resulting conduit sizes for the redesigned feeder wires are shown in ***Table 47*** below.

9.2.7 Motor Starter Sizing

After determining the FLA from each motor, the motor started sizes were also chosen using the ***NEMA Motor Started Sizes*** found in ***Appendix K.*** The motor starters chosen for the redesign are shown in ***Table 47.***

Electrical Equipment Subtracted From Original									
Equip. Tag	HP	FLA	Voltage	KVA	PF	KW	OCP	Conduit & Wires	Starter Size
AHU-1 S-1	125	156	480	129.5	0.9	116.6	225	2" C, 3#4/0, 1#4	N/A
AHU-1 R-1	50	65	480	54.0	0.9	48.6	100	1-1/2"C, 3#1, 1#6	N/A
AHU-2 S-2	125	156	480	129.5	0.9	116.6	225	2" C, 3#4/0, 1#4	N/A
AHU-2 R-2	50	65	480	54.0	0.9	48.6	100	1-1/2"C, 3#1, 1#6	N/A
AHU-3 S-3	125	156	480	129.5	0.9	116.6	225	2" C, 3#4/0, 1#4	N/A
AHU-3 R-3	50	65	480	54.0	0.9	48.6	100	1-1/2"C, 3#1, 1#6	N/A
PCHWP-1	10	14	480	11.6	0.9	10.5	25	3/4" C, 3#10, 1#10	1
PCHWP-2	10	14	480	11.6	0.9	10.5	25	3/4" C, 3#10, 1#10	1
SCHWP-1	25	34	480	28.2	0.9	25.4	70	1"C, 3#6, 1#8	2
SCHWP-2	25	34	480	28.2	0.9	25.4	70	1"C, 3#6, 1#8	2
CWP-1	30	40	480	33.2	0.9	29.9	80	1"C, 3#6, 1#8	3
CWP-2	30	40	480	33.2	0.9	29.9	80	1"C, 3#6, 1#8	3
CH-1		335	480	278.2	0.85	237.0	450	(2) 2" C, 3#4/0, 1#2	N/A
CH-2		335	480	278.2	0.85	237.0	450	(2) 2" C, 3#4/0, 1#2	N/A
Total		**1,509**		**1,253.1**					

Table 46: Power Distribution to Equipment Subtracted from Design

Electrical Equipment Added in Redesign									
Equip. Tag	HP	FLA	Voltage	KVA	PF	KW	OCP	Conduit & Wires	Starter Size
DOAS-1 S-1	75	96	480	79.7	0.9	71.7	225	1-1/2" C, 3#1, 1#6	N/A
DOAS-1 S-2	75	96	480	79.7	0.9	71.7	225	1-1/2" C, 3#1, 1#6	N/A
DOAS-1 R-1	40	52	480	43.2	0.9	38.9	110	1" C, 3#6, 1#8	N/A
DOAS-1 R-2	40	52	480	43.2	0.9	38.9	110	1" C, 3#6, 1#8	N/A
PCHWP-1	5	7.6	480	6.3	0.85	5.4	15	1/2" C, 3#14, 1#14	00
PCHWP-2	7.5	10.8	480	9.0	0.9	8.1	25	3/4" C, 3#12, 1#12	0
PCHWP-3	7.5	10.8	480	9.0	0.9	8.1	25	3/4" C, 3#12, 1#12	0
SCHWP-1	15	21	480	17.4	0.9	15.7	40	3/4" C, 3#10, 1#10	0
SCHWP-2	25	34	480	28.2	0.9	25.4	80	3/4" C, 3#8, 1#10	2
SCHWP-3	25	34	480	28.2	0.9	25.4	80	3/4" C, 3#8, 1#10	2
CWP-1	15	21	480	17.4	0.9	15.7	40	3/4" C, 3#10, 1#10	0
CWP-2	15	21	480	17.4	0.9	15.7	40	3/4" C, 3#10, 1#10	0
CH-1		180	480	149.4	0.85	127.0	350	2" C, 3#4/0, 1#2	N/A
CH-2		180	480	149.4	0.85	127.0	350	2" C, 3#4/0, 1#2	N/A
CH-4		180	480	149.4	0.85	127.0	350	2" C, 3#4/0, 1#2	N/A
Total		**966**		**827.0**					

Table 47: Power Distribution to Equipment Added to Redesign

9.3 Panelboard Schedules

The panelboards will also need to be resized and laid out due to the change in electrical load and equipment. A complete breakdown of the panelboards affected, as well as the original panelboard layout and redesigned panelboard layout, can be found in ***Appendix L.***

9.4 Electrical System Comparison Summary

After all design calculations were performed and the panel boards, feeder wires, circuit breakers, and conduit were sized, an overall comparison was done between the original design and the redesign. The results of this comparison are shown in ***Tables 46 & 47***.

It was found that the equipment subtracted from the original design accounted for **1,253 KVA** of power. The redesigned system will only need **827 KVA** for a net savings of **426 KVA.** The reduced KVA load will reduce feeder sizes, panel boards, and the overall electrical demand from the HVAC equipment. Because of this, both electrical contractor construction costs and electrical costs will decrease.

10.0 Summary

10.1 MAE Requirements

Throughout this report, a number of references were made to items pertaining to the MAE curriculum. Calculating lifecycle costs and payback periods was performed, which is a direct correlation to the material learned in AE 558 Central Heating. Water-side free cooling is a topic discussed in AE 557 Central Cooling and was an integral part of the mechanical depth analysis. Comparing centralized vs. distributed pumps was also analyzed with the mechanical depth portion of the report. This topic was discussed heavily in AE 557, Central Cooling. Lastly, the improvements in indoor air quality as a result of the DOAS system ties in nicely with AE 552 Indoor Air Quality.

10.2 Conclusion

In conclusion, an overall mechanical system re-design was implemented by removing the current variable air volume system and designing a new dedicated outdoor air system with a parallel chilled beam secondary system to account for sensible loads within the space. A heat recovery wheel was utilized to recover energy from the exhaust air. The new system met the original goals resulting in less equipment, more plenum space, smaller duct work and air handlers, and ultimately a reduction in construction costs, operational costs, and energy usage. The redesigned system saved **$276,900** in first costs as well as **$33,800/year** in operational costs and **2,700 MMBTU/year** in energy savings.

The examination of the mechanical system allowed further analysis into the impact that the mechanical redesign had on the electrical and structural components of the building. New designs for both were implemented to account for the change in the mechanical design. The redesigned structural system saved over **$18,000** in first costs. The electrical redesign reduced the overall power demand of mechanical equipment by **426 KVA**.

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Appendix A: Tables and Figures

List of Tables

List of Figures

Appendix B: Room Schedules

BUTLER MEMORIAL HOSPITAL

INPATIENT TOWER ADDITION & RENOVATION - GROUND FLOOR

Thermal Load Zones

ROOM NO.	ROOM NAME	ROOM DATA AREA	ROOM DATA PEOPLE	SENSIBLE LOAD BTUH	Selected Load	Selected CFM	Beams Select.	Selected CFM w/o beam	IMC OA CFM MIN	AIA OA ACH MIN	AIA OA CFM MIN	AIA Tot ACH MIN	AIA Tot Ach Min	AIA Tot ACH W/ Beam	AIA Tot CFM W/ Beam
									1		2		3		4
0A940	CORRIDOR	227	N/A	912					11.35						0
0A337	STORAGE	146	N/A	1002	1944	26	1-4'		7.3						0
0A335	STORAGE	104	N/A	956					5.2						0
0A944	ELEVATOR LOBBY	807	N/A	5683	6662	84	2-8'		40.35						0
0A333	MED/GAS STORAGE ROOM	186	N/A	1770	2976			211	9.3			8	211	2	53
0A942	STORAGE	446	N/A	2956	2971	40	1-6'		22.3						0
0A334	EMERGENCY DISCONNECT	285	N/A	3100	3126	40	1-8'		14.25						0
0A941	MECHANICAL CORRIDOR	657	N/A	4263	4294	62	2-6'		33						0
0A946	ELEVATOR LOBBY	993	N/A	5821	5918	60	2-10'		49.65						0

BUTLER MEMORIAL HOSPITAL

INPATIENT TOWER ADDITION & RENOVATION - FIRST FLOOR

Thermal Load Zones

ROOM NO.	ROOM NAME	ROOM DATA AREA	ROOM DATA PEOPLE	SENSIBLE LOAD BTUH	Selected Load	Selected CFM	Beams Selected	Selected CFM W/O Beam	IMC OA CFM MIN	AIA OA ACH MIN	AIA OA CFM MIN	AIA Tot ACH MIN	AIA Tot CFM MIN	AIA Tot ACH W/ Beam	AIA Tot CFM W/ Beam
									1		2		3		4
1A113	BARREL ROOM	43	0	365	365			26	---			4	24	1	6
1A123	FIRE ALARM PANELS	66	1	561	561			40	20						
1A110	E.T.O. ROOM	95	0	807	1143			81	---			6	81	1.5	20
1A111	CART WASH	95	0	807	1143			81	---			6	81	1.5	20
1A213	SUMP ROOM	99	0	841	1049	10	1-4'		6			2	28	0.5	7
1A950	STORAGE	101	0	858					6						
1A200	TRASH/LINEN CHUTE	114	0	968	1367			97	---			6	97	1.5	24
1A104	OFFICE	115	1	977	1319	20	1-2'		20						
1A112	STEAM STERILIZERS	137	0	1164	1636			116	---			6	116	1.5	29
1A210	STORAGE	143	0	1215	1299	14	1-4'		9						
1A212	ELEV. EQUIPMENT ROOM	143	0	1215	1299	14	1-4'		9						
1A103	DECASING	159	2	1351	2122	40	1-2'		40						
1A106	STAFF LOUNGE	171	2	1453	2122	40	1-2'		40						
1A951	STORAGE	246	0	2090					15						
1A114	VENDOR EQUIPMENT	291	0	2472	8195	165	2-6'		15			4	165	1	41
1A211	STORAGE	338	0	2871	2906	32	1-8'		20						
1A120	STORAGE	108	0	917	14932	318			5			2	31	0.5	8
1A122	HOLDING	506	0	4298			2-10'ds		---			4	287	1	72
1A208	FACILITY STAFF ROOM	580	4	4927	5078	80	1-8'		5			2	164	0.5	41
1A944	ELEVATOR LOBBY	785	0	6668	6710	76	2-8'		47			2	222	0.5	56
1A945	PATIENT/SERVER ELEVATOR LOBBY	815	0	6923	6965	80	2-8'		5			2	231	0.5	58
1A130	INSTRUMENT DECONTAM	955	0	8112	8376	135	3-6'		---			4	541	1	135
1A948	CORRIDOR	1719	0	14602	14749	162	6-6'		12			2	487	0.5	122
1A107	ASSEMBLY	1799	0	15281	27038	510	4-10'		108			2	510	0.5	127
1A102	STERILE STORAGE	1869	0	15876	27862	530	4-10'		94			2	530	0.5	132
1A101	TOILET	60	1	Included					---			10		2.5	Included
1A105	HSKP	67	0	Included					---			6		1.5	Included
1A115	HSKP	71	0	Included					---			6		1.5	Included
1A121	TOILET/SHOWER	72	0	Included					75			10		2.5	Included
1A131	ELEV. MACHINE ROOM	188	0	Included					---						
1A203	MECH. ROOM	1023	0	Included					---						
1A204	FIRE PUMP ROOM	197	0	Included					---						
1A207	TOILET	65	0	Included					---			10	92	2.5	23
1A209	ELECTRICAL	184	0	Included					---			2	Included	0.5	Included
1A214	IT CLOSET	43	0	Included					Included			2	Included	0.5	Included

BUTLER MEMORIAL HOSPITAL

INPATIENT TOWER ADDITION & RENOVATION - SECOND FLOOR

Thermal Load Zones

ROOM NO.	ROOM NAME	ROOM DATA AREA	ROOM DATA PEOPLE	SENSIBLE LOAD BTUH	Selected Load	Selected CFM	Beams selected	Selected CFM W/O Beam	IMC OA CFM MIN	AIA OA ACH MIN	AIA OA CFM MIN	AIA TOT ACH MIN	AIA TOT CFM MIN	AIA TOT ACH W/ BEAM	AIA TOT CFM W/ BEAM
2A114	HWKP	50	0	370	1001			71	3			10	71	2.5	18
2A120	CONTROL	53	1	392	392			28	20						
2A322	CONSULT 1	66	1	489	489			35	20						
2A203	STORAGE	95	0	530	530			38	6			2	27	0.5	7
2A306	PASTORAL CARE	80	1	592	592			42	20						
2A202	PERF. OFFICE	86	1	637	637			45	20						
2A918	PASSAGEWAY	73		657	657			47	4						
2A218	PRACTICE SPECIALIST	90	1	666	666			47	20						
2A219	NURSE MGR PREP/RECOVERY	90	1	666	666			47	20						
2A201	ON CALL	98	1	726	1319	20	1-2'		20						
2A208	ON CALL	98	1	726	1319	20	1-2'		20						
2A209	ON CALL	98	1	726	1319	20	1-2'		20						
2A205	SCRUB ALCOVE	102	1	755	1319	20	1-2'		20						
2A215	CHART ROOM	120	1	889	1319	20	1-2'		20						
2A331	INTERVIEW 2	114	2	844	844			60	40						
2A210	TEAM LEADS	117	2	866	866			61	40						
2A332	INTERVIEW 1	117	2	866	866			61	40						
2A316	WORKROOM	118	2	874	874			62	40						
2A324	CONSULT 3	125	1	926	1143			81	81						
2A232	LINEN/TRASH CHUTE	128		948	1030	15	1-2'		8			2	36	0.5	9
2A220	CRN/PAC	130	1	963	1319	20	1-2'		20						
2A323	CONSULT 2	132	1	978	1319	20	1-2'		20						
2A315	COFFEE RETAIL AREA	142		1052	1103	16	1-2'		7						
2A305	QUIET ROOM	150	3	1111	1111			79	60						
2A950	ELEVATOR LOBBY	150		1111	1217	18	1-2'		8						
2A319	ED LOCKER ROOM	162		1200	1298			92	81			4	92	1	23
2A325	CONSULT 4	165	1	1222	1319	20	1-2'		20						
2A112	STORAGE	198	0	1466	1482	21	1-2'		12			2	56	0.5	14
2A143	WOMEN'S	212		1570				-	225			10	300	2.5	75
2A142	MEN'S	214		1585				-	225			10	303	2.5	76
2A308	VELET	228	1	1688	1733	21	1-4'		20						
2A116	COATS	238	0	1762	1791	22	1-4'		12						
2A119	SEATING	250	9	1851	7395	180	1-8'ds		180						
2A115	MEN'S	270	0	1999				-	525			10	383	2.5	96
2A320	AUSTIN'S PLAYROOM	270	4	1999	4003	80	1-6'		80						
2A309	INFO	274	2	2029	2176	40	1-4'		40						
2A113	WOMEN'S	280	0	2074				-	375			10	531	2.5	99
2A303	OFFICE	126	1	2088	2120	31	1-4'		20						
2A333	RECEP.	300	2	2222	2381	40	1-6'		40						
2A330	SEATING	323	12	2392	9370	240	1-10'ds		240						
2A321	RESOURCE LIBRARY	327	4	2422	4003	80	1-6'		80						
2A126	FOYER	320	0	2370					16						
2A128	TRAINING 'C'	351	18	2599					270						
2A123	TRAINING 'A'	362	18	2681					270						
2A127	TRAINING 'B'	379	19	2807					285						
2A124	TRAINGING 'D'	388	19	2873	53587	1126	8-10"		285						
2A136	A/V ROOM/PREP	178	1	2950	2972	40	1-8'		20						
2A216	PHYSICIAN LOUNGE	227	2	3082	3126	40	1-8'		40						
2A334	SEATING	1440	14	10664					280						
2A335	SEATING	480	14	3555	29419	560	6-10"		280						
2A310	SEATING	638	12	4725	10471	240	2-6'ds		240						
2A901	CORRIDOR	639		4732	4812	64	2-6'		32						
2A920	PASSAGEWAY	654		4843	4912	64	2-6'		33						
2A919	PASSAGEWAY	655		4851	4912	64	2-6'		33						
2A137	PANTRY	304	1	5039	5085	75	1-10"		20						
2A911	CORRIDOR	690		5110	5134	76	1-10"		35						
2A945	ELEVATOR LOBBY	737		5458	5470	60	2-8'		37						
2A930	CORRIDOR	739		5473	5553	60	2-8'		37						
2A121	TRAINING 'E'	753	38	5576	23147	570	3-8'ds		570						
2A932	PRE-FUNCTION	798		5909	6021	70	2-8'		40						
2A225	WOMEN'S LOCKER ROOM	822	0	6087	16382	410	2-8'ds		410			10		2.5	291
2A228	MEN'S LOCKER ROOM	822	0	6087	16382	410	2-8'ds		410			10		2.5	291
2A910	CORRIDOR	860		6369	6384	76	2-8'		43						
2A912	CORRIDOR	960		7109	7111	92	2-8'		48						
2A307	PUBLIC ELEVATOR LOBBY	413		7117	7111	92	2-8'		21						
2A214	STAFF LOUNGE	405	4	7193	7221	94	2-8'		80						
2A204	CONFERENCE ROOM	372	16	7985	10792	240	2-8'ds		240			4	211	1	53
2A905	GALLERY	1370		10145	10204	182	2-8'ds		69						
2A314	RETAIL	1421		10523	10600	182	2-10"		71						
2A948	LOBBY	1800		13330	13657	200	3-10"		90						
2A140	CONFERENCE ROOM	463	16	13738	13866	320	2-8'ds		320						
2A304	CHAPEL	870	16	14420	15699	320	3-8'		320						
2A141	MEDICAL STAFF CONFERENCE ROOM	661	16	15188	15699	320	3-8'		320						

2A138	BOARD ROOM	1186	32	19657	21583	480	4-8'ds		480						
2A949	LOBBY	2715		20106	20325	258	6-8'		135						
2A135	AUDITORIUM	3077	159	50999	51296	960	8-10'ds		795						
2A230	ELEC.	262		Included					--						
2A231	IT	141		Included					--						

BUTLER MEMORIAL HOSPITAL

INPATIENT TOWER ADDITION & RENOVATION - THIRD FLOOR

Thermal Load Zones

ROOM NO.	ROOM NAME	ROOM DATA AREA	ROOM DATA PEOPLE	SENSIBLE LOAD BTUH	Selected Load	Selected CFM	Beams Selected	Selected CFM W/O Beam	IMC OA CFM MIN	AIA OA ACH MIN	AIA OA CFM MIN	AIA TOT ACH MIN	AIA TOT CFM Min	AIA TOT ACH w/ Beam	AIA TOT CFM w/ Beam
3A129	HSKP	42	0	544	839			60	21			10	60	2.5	15
3A229	SPECIMEN ROOM	47	1	609	609			43	20			4	27	1	7
3A336	PLATE READER ROOM	52	1	684	684			49	20			4	29	1	7
3A112	STAFF TOILET	55	0	713	713			51	75						
3A131	SOILED HOLDING	64	0	830	830			59	--			4	36	1	9
3A349	SOILED HOLDING	74		959	959			68	--			4	42	1	10
3A209	PACU 13	80	1	1053	17605	272	6-8'		20	2	23	4	45	1	11
3A211	PACU 12	80	1	1053					20	2	23	4	45	1	11
3A213	PACU 11	80	1	1053					20	2	23	4	45	1	11
3A215	PACU 10	80	1	1053					20	2	23	4	45	1	11
3A217	PACU 9	80	1	1053					20	2	23	4	45	1	11
3A219	PACU 8	80	1	1053					20	2	23	4	45	1	11
3A231	PACU 2	80	1	1053					20	2	23	4	45	1	11
3A233	PACU 3	80	1	1053					20	2	23	4	45	1	11
3A238	PACU 4	80	1	1053					20	2	23	4	45	1	11
3A240	PACU 5	80	1	1053					20	2	23	4	45	1	11
3A241	PACU 6	80	1	1053					20	2	23	4	45	1	11
3A243	PACU 7	80	1	1053					20	2	23	4	45	1	11
3A227	PHYS. THERAPY	88	2	1141	1141			81	40	2	25	4	50	1	12
3A114	NOURISHMENT	90	1	1167	1319	20	1-2'		20			2		0.5	6
3A107	CONSULT 2	95	2	1231	2123	40	1-2'		40						
3A108	CONSULT 1	95	2	1231	2123	40	1-2'		40						
3A235	PHYS. DICT.	99	2	1283	2123	40	1-2'		40						
3A344	CLEANING STOR.	99		1303	1319	20	1-2'		5						
3A133	STAFF LOUNGE	101	2	1309	2123	40	1-2'		40						
3B408	NURSE STATION	104	2	1348	1394	20	1-2'		6			2	29	0.5	7
3B401	ANESTH. CHAIR	105	1	1361	1394	20	1-2'		20						
3B403	CLINICAL SUPERVISOR	105	1	1361	1394	20	1-2'		20						
3B409	OR DIRECTOR	105	1	1361	2123	40	1-2'		40						
3A110	PERI-OP3	107	1	1387	1387			98	20	2	30	4	62	1	15
3A166	PERI-OP 13	109	1	1413	1413			100	20	2	31	4	62	1	15
3A168	PERI-OP 12	110	1	1426	1426			101	20	2	31	4	62	1	16
3A179	PERI-OP 5	110	1	1426	1426			101	20	2	31	4	62	1	16
3A180	PERI-OP 4	110	1	1426	1426			101	20	2	31	4	62	1	16
3B404	CHIF CRNA	110	1	1426	1482	21	1-2'		20						
3A165	PERI-OP 14	111	1	1439	1439			102	20	2	31	4	63	1	16
3A178	PERI-OP 6	111	1	1439	1439			102	20	2	31	4	63	1	16
3B410	SCHEDULING OFFICE	111	1	1439	1482	21	1-2'		20						
3A220	IV TEAM STATION	110	1	1447	1482	21	1-2'		20				0		
3A169	PERI-OP 11	114	1	1478	1478			105	20	2	32	4	65	1	16
3A176	PERI-OP 7	115	1	1491	1491			106	20	2	33	4	65	1	16
3A170	PERI-OP 10	116	1	1504	1504			107	20	2	33	4	66	1	16
3A113	CLEAN HOLDING	118	0	1530	1562	22	1-2'		--			4		1	17
3A225	PACU ISO 1	118	1	1530	1562	22	1-2'		20			4	67	1	17
3A205	PACU ISO 15	120	1	1555	1562	22	1-2'		20			4	68	1	17
3A206	PACU ISO 14	120	1	1555	1562	22	1-2'		20			4	68	1	17
3A342	CYSTO. STORAGE	136		1557	1557			110	7	2	39	2	39	0.5	10
3A202	CLEAN HOLDING	122		1581	1628	23	1-2'		6			4	69	1	17
3A301	SOILED CART	123	0	1594	1628	23	1-2'		--			2	44	0.5	11
3A323	PERFUSION SUPPLIES	123	1	1594	1628	23	1-2'		20			4	70	1	17
3A174	PERI-OP 9	126	1	1633	1633			116	20	2	36	4	71	1	18
3A175	PERI-OP 8	126	1	1633	1633			116	20	2	36	4	71	1	18
3A137	TRASH/LINEN CHUTE	129	0	1672	3065	65	1-2'		65			10	183	2.5	46
3A922	PASSAGEWAY	140		1815	1870	24	1-4'		8			2	40	0.5	10
3A925	PASSAGEWAY	140		1815	1870	24	1-4'		8			2	40	0.5	10
3A134	CONTROL	150	2	1944	2176	40	1-4'		40						
3A150	PERI-OP 15	101	1	1970	1970			140	20	2	29	4	57	1	14
3A185	PERI-OP 2	158	1	2048	2048			145	20	2	45	4	90	1	22
3A186	PERI-OP 1	158	1	2048	2048			145	20	2	45	4	90	1	22
3A152	PERI-OP 17	112	1	2184	2184			155	20	2	32	4	63	1	16
3A153	PERI-OP 18	112	1	2184	2184			155	20	2	32	4	63	1	16

3A155	PERI-OP 20	112	1	2184	2184			155	20	2	32	4	63	1	16
3A156	PERI-OP 21	112	1	2184	2184			155	20	2	32	4	63	1	16
3A157	PERI-OP 22	112	1	2184	2184			155	20	2	32	4	63	1	16
3A158	PERI-OP 23	112	1	2184	2184			155	20	2	32	4	63	1	16
3A159	PERI-OP 24	112	1	2184	2184			155	20	2	32	4	63	1	16
3A160	PERI-OP 25	112	1	2184	2184			155	20	2	32	4	63	1	16
3A161	PERI-OP 26	112	1	2184	2184			155	20	2	32	4	63	1	16
3A151	PERI-OP 16	113	1	2204	2204			156	20	2	32	4	64	1	16
3A154	PERI-OP 19	113	1	2204	2204			156	20	2	32	4	64	1	16
3A222	EQUIPMENT ROOM	115		2243	2243	40	1-4"		6						
3A116	PATIENT BELONGING STOR.	180	0	2333	2330	42	1-4"		--			2	51	0.5	13
3A228	STORAGE	182		2359	2371	43	1-4"		9						
3A216	CAREGIVER	190	2	2500	2354	47	1-4"		40						
3A345	SCOPE DECONTAM.	198		2605	2640	33	1-6"		---			1	112	0.25	28
3A943	CORRIDOR	207		2683	2697	34	1-6"		12			2	59	0.5	15
3A236	STORAGE	225		2916	2949	34	1-8"		11						
3A162	PERI-OP 27 (SWING-PACU)	112	1	3315	3315			235	20	2	32	4	63	1	16
3A121	STAFF LOUNGE/LOCKERS	271	0	3513	5416			384	136			10	384	2.5	96
3B402	ANESTH. OFFICE	275	4	3565	4003	80	1-6"		80						
3A930	CORRIDOR	287		3720	3740	48	2-4"		17			2	81	0.5	20
3B414	STORAGE	289		3746	3740	48	2-4"		20						
3A946	HALLWAY	286		3763	3780	50	2-4"		17			2	81	0.5	20
3A914	CORRIDOR	319		4135	4140	60	2-4"		19			2	90	0.5	23
3A340	ANESTH. WORK	320	2	4148	4157	61	1-8"		40						
3B981	CORRIDOR	340		4407	4501	50	2-6"		14			2	96	0.5	24
3A341	CYSTO. ROOM	410	4	4694	4734	80	1-8"		80	3	174	4	232	1	58
3A343	ENDO.	410	3	4694	4734	80	1-8"		39			4	232	1	58
3A135	PHYS. LOUNGE	382	4	4952	4958	92	1-8"		40						
3A950	CORRIDOR	399		5172	5357	54	3-6"		40			2	113	0.5	28
3A136	ANESTH. LOUNGE	415	4	5379	5407	80	2-6"		37						
3A945	ELEVATOR LOBBY	419		5431	5599	62	2-8"		64			2	119	0.5	30
3A908	PASSAGEWAY	431		5587	5599	62	2-8"		--			2	122	0.5	31
3A115	CAREGIVER	490	1	6351	6384	76	2-8"		--						
3A970	CORRIDOR	652		8451	8524	93	3-8"		--			2	185	0.5	46
3A985	CORRIDOR	664		8607	8653	95	3-8"		--			2	188	0.5	47
3A906	CORRIDOR	665		8620	8653	95	3-8"		--			2	188	0.5	47
3A940	CORRIDOR	672		8711	8717	96	3-8"		--			2	190	0.5	48
3A335	EQUIPMENT	744		9644	9672	140	2-10"		--						
3A920	CORRIDOR	1073		14118					0			2	304	0.5	76
3A910	CORRIDOR	1023		15191	15230	156	6-8"		--			2	290	0.5	72
3A990	CORRIDOR	1312		17006	17048	186	6-8"		--			2	372	0.5	93
3A100	ELEVATOR LOBBY	1316	0	17941	18135	248	4-10"		--						
3A960	CORRIDOR	1748		22658	22761	273	7-8"		--			2	495	0.5	124
3A104	ELEC.	78	0	Included					--						
3A105	MENS TOILET	51	0	Included					--			10		2.5	Included
3A106	WOMENS TOILET	51	0	Included					--			10		2.5	Included
3A111	PAT. TLT	58	0	Included					--			10		2.5	Included
3A120	PAT. TLT	54	0	Included					--			10	Included	2.5	Included
3A123	STAFF TOILET	60	0	Included					--			10	Included	2.5	Included
3A125	STAFF TOILET	53	0	Included					--			10	Included	2.5	Included
3A130	PAT. TLT	53	0	Included					--			10	Included	2.5	Included
3A132	IT ROOM	88	0	Included					--						
3A163	PAT. TLT	58	0	Included					--			10	Included	2.5	Included
3A167	PAT. TLT	51	0	Included					Included			10	Included	2.5	Included
3A177	PAT. TLT	66		Included								10	Included	2.5	Included
3A184	PAT. TLT	55		Included								10	Included	2.5	Included
3A204	HSKP	50		Included								2	Included	0.5	Included
3A212	SOILED HOLDING	72		Included								10	Included	2.5	Included
3A221	SOILED HOLDING	58		Included								4	Included	1	Included
3A234	STAFF TOILET	56		Included								10	Included	2.5	Included
3A237	ELEC. ROOM	126		Included											
3A302	HSKP	88	0	Included								2	Included	0.5	Included
3A315	HSKP	68		Included								4	Included	1	Included
3A320	ELEC.	129		Included									Included		Included
3A321	STAFF TLT	51		Included								10	Included	2.5	Included
3A322	STAFF TLT	51		Included								10	Included	2.5	Included
3A348	STAFF TOILET	59		Included								10	Included	2.5	Included
3A350	HSKP	53		Included								2	Included	0.5	Included
3A912	STRET/WHCHR. ALCOVE	149		Included								2	Included	0.5	Included

BUTLER MEMORIAL HOSPITAL

INPATIENT TOWER ADDITION & RENOVATION - FIFTH FLOOR

Thermal Load Zones

ROOM NO.	ROOM NAME	ROOM DATA AREA	PEOPLE	SENSIBLE LOAD BTUH	SELECTED LOAD BTUH	SELECTED CFM	BEAMS SELECTED	SELECTED CFM w/o beams	IMC OA CFM MIN	AIA OA ACH MIN	AIA OA CFM MIN	AIA TOT ACH MIN	AIA TOT CFM MIN	AIA TOT ACH W/ BEAM	AIA TOT CFM W/ BEAM
									1		2		3		4
5A129	HSK	45	0	425	899			64	---			10	64	2.5	16
5A120	POC WORKROOM	48	1	453	453			32	20						
5A113	HSK	52	0	491	1039			74	---			10	74	2.5	18
5A111	FAX/PRINT	60	1	567	567			40	20						
5A142	STAFF TOILET	48	0	576	959			68	75			10	68	2.5	17
5A136	FAX/PRINT	61	1	576	576			41	20						
5A157	HOTEL OFFICE	61	1	576	576			41	20						
5A152	R.T. OFFICE	67	1	633	633			45	20						
5A110	DICTATION	70	1	661	661			47	20						
5A159	OFFICE	76	1	718	1319	20	1-2'		20						
5A139	WORKSTATION	78	3	736	736			52	60						
5A137	DICTATION	79	1	746	1319	20	1-2'		20						
5A118	COPY	83	1	784	1319	20	1-2'		20						
5A158	OFFICE	90	1	850	1319	20	1-2'		20						
5A220	ANTE-ROOM	37		856	1319	20	1-2'		---			4	21	1	5
5A125	INTENSIVIST OFFICE	99	1	935	1319	20	1-2'		20						
5A126	CV SURGEONS OFFICE	103	1	973	1319	20	1-2'		20						
5A154	NOURISHMENT	104	1	982	1319	20	1-2'		20						
5A104	CONSULT	115	1	1086	1319	20	1-2'		20						
5A119	DICTATION	116	1	1095	1319	20	1-2'		20						
5A224	ANTE-ROOM	90		1153	2435	51	1-2'		---			4	204	1	51
5A145	TRASH & LINEN CHUTE	124	0	1171	2225	44	1-2'		---			10	176	2.5	44
5A904	RESTROOM	124		1171	1171			83	7			2	14	0	3
5A114	MEDICATION	131	1	1237	1319	20	1-2'		20						
5A112	CLEAN HOLDING	138	0	1303	1319	20	1-2'		---			4	78	1	20
5A127	MEDICATION	138	1	1303	1319	20	1-2'		20						
5A160	OFFICE	138	1	1303	1319	20	1-2'		20						
5A117	RESTROOM	142	3	1341	1341			95	60						
5A937	WORKSTATION	145	3	1369	2903	60	1-4'ds		60						
5A909	WHEELCHAIR/STRETCHER	148		1397	1402	21	1-2'		9			2	42	0	10
5A153	SOILED HOLDING	158	0	1492	1562	22	1-2'		---						
5A105	WORKSTATION	179	2	1690	2176	40	1-4'		40						
5A128	CLEAN HOLDING	193	0	1822	1890	25	1-4'		---						
5A116	R.T. VENT STORAGE	199	0	1879	1890	25	1-4'		10						
5A143	STAFF LOCKER	233	0	2200	4656			--	---			10	330	2.5	83
5A218	CCU PATIENT ROOM	232	2	2387	3330	66	1-6'ds		40	2	66	4	131	1	33
5A905	CORRIDOR	285		2691	2699	35	1-6'		30			2	81	1	20
5A226	CCU PATIENT ROOM	210	2	2717	2903	60	1-4'ds		40	2	60	4	119	1	30
5A227	CCU PATIENT ROOM	210	2	2717	2903	60	1-4'ds		40	2	60	4	119	1	30
5A228	CCU PATIENT ROOM	210	2	2717	2903	60	1-4'ds		40	2	60	4	119	1	30
5A229	CCU PATIENT ROOM	210	2	2717	2903	60	1-4'ds		40	2	60	4	119	1	30
5A219	CCU PATIENT ROOM	273	2	2809	3719	77	1-8'ds		40	2	77	4	155	1	39
5A225	CCU (ISOLATION) ROOM	226	2	2881	3050	64	1-4'ds		40	2	64	4	128	1	32
5A945	ELEVATOR LOBBY	330		3116	3174	37	1-8'		20			2	94	0.5	23
5A934	PASSAGE	177		3163	3174	37	1-8'		20			2	50	1	13
5A201	CCU PATIENT ROOM	225	2	3347	3356	41	1-6'ds		40	2	64	4	148	1	37
5A202	CCU PATIENT ROOM	235	2	3467	3474	67	1-6'ds		40	2	67	4	148	1	37
5A204	CCU PATIENT ROOM	248	2	3623	3641	70	1-6'ds		40	2	70	4	148	1	37
5A205	CCU PATIENT ROOM	248	2	3623	3641	70	1-6'ds		40	2	70	4	148	1	37
5A206	CCU PATIENT ROOM	248	2	3623	3641	70	1-6'ds		40	2	70	4	148	1	37
5A208	CCU PATIENT ROOM	248	2	3623	3641	70	1-6'ds		40	2	70	4	148	1	37
5A203	CCU PATIENT ROOM	249	2	3635	3681	71	1-6'ds		40	2	71	4	148	1	37
5A209	CCU PATIENT ROOM	250	2	3647	3681	71	1-6'ds		40	2	71	4	148	1	37
5A207	CCU PATIENT ROOM	259	2	3755	3759	73	1-6'ds		40	2	73	4	148	1	37
5A210	CCU PATIENT ROOM	262	2	3791	3797	74	1-6'ds		40	2	74	4	148	1	37
5A144	STAFF BREAK	224	6	4166	5396	120	1-8'ds		120						
5A212	CCU PATIENT ROOM	232	2	4917	4958	92	1-8'		40	2	66	4	131	1	33
5A213	CCU PATIENT ROOM	232	2	4917	4958	92	1-8'		40	2	66	4	131	1	33
5A214	CCU PATIENT ROOM	232	2	4917	4958	92	1-8'		40	2	66	4	131	1	33
5A215	CCU PATIENT ROOM	232	2	4917	4958	92	1-8'		40	2	66	4	131	1	33
5A216	CCU PATIENT ROOM	232	2	4917	4958	92	1-8'		40	2	66	4	131	1	33
5A217	CCU PATIENT ROOM	232	2	4917	4958	92	1-8'		40	2	66	4	131	1	33
5A211	CCU PATIENT ROOM (ISOLATION)	248	2	5192	5193	103	1-8'		40	2	70	4	141	1	35
5A151	STAFF CONFERENCE	313	3	5821	5852	66	2-8'		60						
5A944	PATIENT/SERVICE ELEVATOR LOBBY	325		6045	6101	70	2-8'		20			2	92	0.5	23
5A910	CORRIDOR	669		6317	6336	60	3-8'		40			2	190	0.5	47
5A147	CLEAN EQUIPMENT	466	0	8667	8687	125	2-10'		--			2	132	0.5	33
5A920	CORRIDOR	977		10471	10561	100	5-8'		67			2	277	0	69
5A100	ELEVATOR LOBBY	640	20	11903	17561	400	3-8'ds		400						
5A947	CORRIDOR	1021		12248	12476	165	3-10'		61			2	289	0.5	72
5A100A	FAMILY WAITING	733	26	13633	21540	520	3-8'ds		520			2	208	0.5	52
5A940	CORRIDOR	1042		16449	16554	200	5-8'		105			2	295	0	74

5A101	ELEC.	126	0	Included					--						
5A102	WOMEN'S PUBLIC TOILET	68	0	Included					--			10	Included	2.5	Included
5A103	MEN'S PUBLIC TOILET	68	0	Included					--			10	Included	2.5	Included
5A131	STAFF TOILET	60		Included					---			10	Included	2.5	Included
5A138	ELEC.	120	0	Included					---						
5A155	I.T.	178	0	Included					---						
5A201a	TLT	54		Included					---			10	Included	2.5	Included
5A202a	TLT	54		Included					---			10	Included	2.5	Included
5A203a	TLT	54	0	Included					---			10	Included	2.5	Included
5A204a	TLT	54		Included					---			10	Included	2.5	Included
5A205a	TLT	54		Included					---			10	Included	2.5	Included
5A206a	TLT	54		Included					---			10	Included	2.5	Included
5A207a	TLT	54		Included					---			10	Included	2.5	Included
5A208a	TLT	54		Included					---			10	Included	2.5	Included
5A209a	TLT	54		Included					---			10	Included	2.5	Included
5A210a	TLT	54		Included					---			10	Included	2.5	Included
5A211a	TLT	54		Included					---			10	Included	2.5	Included
5A212a	TLT	54		Included					---			10	Included	2.5	Included
5A213a	TLT	54		Included					---			10	Included	2.5	Included
5A214a	TLT	54		Included					---			10	Included	2.5	Included
5A215a	TLT	54		Included					---			10	Included	2.5	Included
5A216a	TLT	54		Included					---			10	Included	2.5	Included
5A217a	TLT	54		Included					---			10	Included	2.5	Included
5A218a	TLT	54		Included					---			10	Included	2.5	Included
5A219a	TLT	54		Included					---			10	Included	2.5	Included
5A225a	TLT	54		Included					---			10	Included	2.5	Included
5A226a	TLT	54		Included					---			10	Included	2.5	Included
5A227a	TLT	54		Included					---			10	Included	2.5	Included
5A228a	TLT	54		Included					---			10	Included	2.5	Included
5A229a	TLT	54		Included					---			10	Included	2.5	Included
5A908	PASSAGE	215		Included					Included			2	Included	0.5	Included
5A932	PASSAGE	132		Included					Included			2	Included	0.5	Included
5A935	WHEELCHAIR/STRETCHER	158		Included					Included			2	Included	0.5	Included
5A950	CORRIDOR	700		Included					Included			2	Included	0.5	Included

BUTLER MEMORIAL HOSPITAL

INPATIENT TOWER ADDITION & RENOVATION - SIXTH FLOOR

Thermal Load Zones

ROOM NO.	ROOM NAME	ROOM DATA AREA	PEOPLE	Sensible Load BTUH	Selected Load BTUH	Selected CFM	Beams Selected	Selected CFM W/O Beams	IMC OA CFM MIN	AIA OA ACH MIN	AIA OA CFM MIN	AIA Tot ACH MIN	AIA Tot CFM MIN	AIA Tot ACH W/ BEAM	AIA Tot CFM W/ BEAM
									1		2		3		4
6A113	STAFF TOILET	52	0	538	1044			74	75			10	74	2.5	18
6A111	FAX/PRINT	60	1	621	621			44	20						
6A136	FAX/PRINT	61	1	631	631			45	20						
6A118	MONITOR WORKROOM	65	2	673	673			48	40						
6A149	POC WORKROOM	69	1	714	714			51	20						
6A110	DICTATION	70	1	725	1319	20	1-2'		20						
6A119	DICTATION	72	1	745	1319	20	1-2'		20						
6A137	DICTATION	79	1	818	1319	20	1-2'		20						
6A135	STAFF TOILET	80		828	1599			113	75			10	113	2.5	28
6A141	OFFICE	88	1	911	1319	20	1-2'		20						
6A140	OFFICE	91	1	942	1319	20	1-2'		20						
6A120	COPY	101	1	1046					20						
6A151	NOURISHMENT	104	1	1077	1319	20	1-2'		20						
6A231	ANTE-ROOM	105		1087	1319	20	1-2'		7						
6A233	ANTE-ROOM	105		1087	1319	20	1-2'		7						
6A235	ANTE-ROOM	105		1087	1319	20	1-2'		7						
6A104	CONSULT	115	1	1190	1319	20	1-2'		20						
6A127	MEDICATION	122	1	1263	1319	20	1-2'		20						
6A937	WORKSTATION	128	2	1325					40			2	36	0.5	9
6A114	MEDICATION ROOM	131	1	1356	1319	20	1-2'		20						
6A112	CLEAN HOLDING	138	0	1429	1489	22	1-2'		---			2	39	0.5	10
6A125	HOTELING OFFICE	138	1	1429	1489	22	1-2'		20						
6A117	WORKSTATION	142	2	1470	2123	40	1-2'		40						
6A128	CLEAN HOLDING	174	0	1801	1832	32	1-2'		---			2	49	0.5	12
6A105	WORKSTATION	179	2	1853	2123	40	1-2'		40						
6A152	I.T.	179	0	1853	1893	34	1-2'		9						
6A116	EQUIPMENT	199	1	2060	2097	32	1-2'		10						
6A143	STAFF LOCKER	233	2	2412	4656	---	---		40			10	330	2.5	83
6A905	CORRIDOR	285		2950	2969	41	1-6'		17			2	81	0.5	20
6A932	PASSAGE	132		3002	3011	35	1-8'		17			2	37	0.5	9
6A945	ELEVATOR LOBBY	330		3416	3444	44	1-8'		20			2	94	0.5	23
6A201	MED/SURG	225	2	3455	3560	64	1-8'		40	2	64	4	128	1	32
5A202	MED/SURG	235	2	3579	3684	67	1-8'		40	2	67	4	133	1	33
6A204	MED/SURG	248	2	3740	3807	70	1-8'		40	2	70	4	141	1	35
6A205	MED/SURG	248	2	3740	3807	70	1-8'		40	2	70	4	141	1	35
6A206	MED/SURG	248	2	3740	3807	70	1-8'		40	2	70	4	141	1	35
6A208	MED/SURG	248	2	3740	3807	70	1-8'		40	2	70	4	141	1	35
6A203	MED/SURG	249	2	3752	3848	71	1-8'		40	2	71	4	141	1	35
6A908	PASSAGE	215		3758	3776	52	1-8'		21			2	61	0.5	15

6A209	MED/SURG	250	2	3765	3848	71	1-8'		40	2	71	4	142	1	35
6A142	STAFF CONFERENCE	247	6	3824	5396	120	1-8'ds		120						
6A207	MED/SURG	259	2	3876	3929	73	1-8'		40	2	73	4	147	1	37
6A210	MED/SURG	262	2	3913	3969	74	1-8'		40	2	74	4	148	1	37
6A144	STAFF BREAK	224	4	4081	4209	80	1-8'		80						
6A226	MED/SURG	210	2	4087	4108	60	1-8'		40	2	60	4	119	1	30
6A227	MED/SURG	210	2	4087	4108	60	1-8'		40	2	60	4	120	1	30
6A228	MED/SURG	210	2	4087	4108	60	1-8'		40	2	60	4	120	1	30
6A229	MED/SURG	210	2	4087	4108	60	1-8'		40	2	60	4	120	1	30
6A225	MED/SURG	226	2	4335	4372	68	1-8'		40	2	64	4	128	1	32
6A218	MED/SURG	232	2	4428	4466	70	1-8'		40	2	66	4	131	1	33
6A232	MED/SURG (ISOLATION)	248	2	5175	5182	95	1-8'ds		40			4	141	1	35
6A234	MED/SURG (ISOLATION)	248	2	5175	5182	95	1-8'ds		40			4	140	1	35
6A236	MED/SURG (ISOLATION)	248	2	5175	5182	95	1-8'ds		40			4	140	1	35
6A212	MED/SURG	232	2	5470	5483	106	1-8'ds		40	2	66	4	131	1	33
6A213	MED/SURG	232	2	5470	5483	106	1-8'ds		40	2	66	4	131	1	33
6A214	MED/SURG	232	2	5470	5483	106	1-8'ds		40	2	66	4	132	1	33
6A215	MED/SURG	232	2	5470	5483	106	1-8'ds		40	2	66	4	132	1	33
6A216	MED/SURG	232	2	5470	5483	106	1-8'ds		40	2	66	4	132	1	33
6A217	MED/SURG	232	2	5470	5483	106	1-8'ds		40	2	66	4	132	1	33
6A211	MED/SURG	248	2	5775	5786	117	1-8'ds		40	2	70	4	141	1	35
6A944	PATIENT/SERVICE ELEVATOR LOBBY	325		5922	6101	70	2-8'		20			2	92	0.5	23
6A910	CORRIDOR	669		6925	7118	75	3-8'		40			2	190	0.5	47
6A950	CORRIDOR	700		7246	7325	75	3-8'		42			2	198	0.5	50
6A920	CORRIDOR	977		10114	10143	100	5-8'		59			2	277	0.5	69
6A940	CORRIDOR	1042		10786	10804	105	5-8'		63			2	295	0.5	74
6A100	ELEVATOR LOBBY	640	10	11661	17561	400	3-8'ds		400						
6A947	CORRIDOR	1021		12643	12927	165	3-10'		61			2	289	0.5	72
6A100A	FAMILY WAITING	733	26	13355	21540	520	3-8'ds		520			2	208	0.5	52
6A101	ELEC.	126	0	Included					--						
6A102	WOMEN'S PUBLIC TOILET	68	0	Included					--			10	Included	2.5	Included
6A103	MEN'S PUBLIC TOILET	68	0	Included					--			10	Included	2.5	Included
6A126	HSK	111	0	Included					---						
6A138	ELEC.	120	0	Included					--						
6A146	TRASH & LINEN CHUTE	124	0	Included					---			6	Included	1.5	Included
6A150	SOILED HOLDING	148	0	Included					---			6	Included	1.5	Included
6A201a	TLT	54		Included					--			10	Included	2.5	Included
6A202a	TLT	54		Included					--			10	Included	2.5	Included
6A203a	TLT	54	0	Included					--			10	Included	2.5	Included
6A204a	TLT	54	0	Included					--			10	Included	2.5	Included
6A205a	TLT	54	0	Included					--			10	Included	2.5	Included
6A206a	TLT	54	0	Included					--			10	Included	2.5	Included
6A207a	TLT	54	0	Included					--			10	Included	2.5	Included
6A208a	TLT	54	0	Included					--			10	Included	2.5	Included
6A209a	TLT	54	0	Included					--			10	Included	2.5	Included
6A210a	TLT	54	0	Included					--			10	Included	2.5	Included
6A211a	TLT	54	0	Included					--			10	Included	2.5	Included
6A212a	TLT	54	0	Included					--			10	Included	2.5	Included
6A213a	TLT	54	0	Included					--			10	Included	2.5	Included
6A214a	TLT	54	0	Included					--			10	Included	2.5	Included
6A215a	TLT	54	0	Included					--			10	Included	2.5	Included
6A216a	TLT	54	0	Included					--			10	Included	2.5	Included
6A217a	TLT	54	0	Included					--			10	Included	2.5	Included
6A218a	TLT	54	0	Included					--			10	Included	2.5	Included
6A225a	TLT	54		Included					--			10	Included	2.5	Included
6A226a	TLT	54		Included					--			10	Included	2.5	Included
6A227a	TLT	54		Included					--			10	Included	2.5	Included
6A228a	TLT	54		Included					--			10	Included	2.5	Included
6A229a	TLT	54		Included					--			10	Included	2.5	Included
6A232a	TLT	36		Included					--			10	Included	2.5	Included
6A234a	TLT	36		Included					--			10	Included	2.5	Included
6A236a	TLT	36		Included					--			10	Included	2.5	Included
6A909	WHEELCHAIR/STRETCHER	148		Included					Included			2	Included	0.5	Included
6A935	WHEELCHAIR/STRETCHER	158		Included					Included			2	Included	0.5	Included

BUTLER MEMORIAL HOSPITAL

INPATIENT TOWER ADDITION & RENOVATION - SEVENTH FLOOR

Thermal Load Zones

ROOM NO.	ROOM NAME	ROOM DATA AREA	PEOPLE	Sensible Load BTUH	Selected Load BTUH	Selected CFM	Beams Selected	Selected CFM W/O Beams	IMC OA CFM MIN	AIA OA ACH MIN	AIA OA CFM MIN	AIA Tot ACH MIN	AIA Tot CFM MIN	AIA Tot ACH W/ BEAM	AIA Tot CFM W/ BEAM
									1		2		3		4
7A113	STAFF TOILET	52	0	538	1044			74	75			10	74	2.5	18
7A111	FAX/PRINT	60	1	621	621			44	20						
7136	FAX/PRINT	61	1	631	631			45	20						
7A118	MONITOR WORKROOM	65	2	673	673			48	40						
7A149	POC WORKROOM	69	1	714	714			51	20						
7A110	DICTATION	70	1	725	1319	20	1-2'		20						
7A119	DICTATION	72	1	745	1319	20	1-2'		20						
7A137	DICTATION	79	1	818	1319	20	1-2'		20						
7A135	STAFF TOILET	80		828	1599			113	75			10	113	2.5	28
7A141	OFFICE	88	1	911	1319	20	1-2'		20						
7A140	OFFICE	91	1	942	1319	20	1-2'		20						

7A120	COPY	101	1	1046					20						
7A151	NOURISHMENT	104	1	1077	1319	20	1-2'		20						
7A231	ANTE-ROOM	105		1087	1319	20	1-2'		7						
7A233	ANTE-ROOM	105		1087	1319	20	1-2'		7						
7A235	ANTE-ROOM	105		1087	1319	20	1-2'		7						
7104	CONSULT	115	1	1190	1319	20	1-2'		20						
7A127	MEDICATION	122	1	1263	1319	20	1-2'		20						
7A937	WORKSTATION	128	2	1325					40			2	36	0.5	9
7A114	MEDICATION ROOM	131	1	1356	1319	20	1-2'		20						
7A112	CLEAN HOLDING	136	0	1429	1489	22	1-2'		---			2	39	0.5	10
7A125	HOTELING OFFICE	138	1	1429	1489	22	1-2'		20						
7A117	WORKSTATION	142	2	1470	2123	40	1-2'		40						
7A128	CLEAN HOLDING	174	0	1801	1832	32	1-2'		---			2	49	0.5	12
7A105	WORKSTATION	179	2	1853	2123	40	1-2'		40						
7A152	I.T.	179	0	1853	1893	34	1-2'		9						
7A116	EQUIPMENT	199	1	2060	2097	32	1-2'		10						
7A143	STAFF LOCKER	233	2	2412	4656	---	---		40			10	330	2.5	83
7A905	CORRIDOR	285		2950	2969	41	1-6'		17			2	81	0.5	20
7A932	PASSAGE	132		3002	3011	35	1-8'		17			2	37	0.5	9
7A945	ELEVATOR LOBBY	330		3416	3444	44	1-8'		20			2	94	0.5	23
7A201	MED/SURG	225	2	3455	3560	64	1-8'		40	2	64	4	128	1	32
7A202	MED/SURG	235	2	3579	3684	67	1-8'		40	2	67	4	133	1	33
7A204	MED/SURG	246	2	3740	3807	70	1-8'		40	2	70	4	141	1	35
7A205	MED/SURG	246	2	3740	3807	70	1-8'		40	2	70	4	141	1	35
7A206	MED/SURG	246	2	3740	3807	70	1-8'		40	2	70	4	141	1	35
7A208	MED/SURG	246	2	3740	3807	70	1-8'		40	2	70	4	141	1	35
7A203	MED/SURG	249	2	3752	3848	71	1-8'		40	2	71	4	141	1	35
7A908	PASSAGE	215		3758	3776	52	1-8'		21			2	61	0.5	15
7A209	MED/SURG	250	2	3765	3848	71	1-8'		40	2	71	4	142	1	35
7A142	STAFF CONFERENCE	247	6	3824	5396	120	1-8'ds		120						
7A207	MED/SURG	259	2	3876	3929	73	1-8'		40	2	73	4	147	1	37
7A210	MED/SURG	262	2	3913	3969	74	1-8'		40	2	74	4	148	1	37
7A144	STAFF BREAK	224	4	4081	4209	80	1-8'		80						
7A226	MED/SURG	210	2	4087	4108	60	1-8'		40	2	60	4	119	1	30
7A227	MED/SURG	210	2	4087	4108	60	1-8'		40	2	60	4	120	1	30
7A228	MED/SURG	210	2	4087	4108	60	1-8'		40	2	60	4	120	1	30
7A229	MED/SURG	210	2	4087	4108	60	1-8'		40	2	60	4	120	1	30
7A225	MED/SURG	226	2	4335	4372	68	1-8'		40	2	64	4	128	1	32
7A218	MED/SURG	232	2	4428	4466	70	1-8'		40	2	66	4	131	1	33
7A232	MED/SURG (ISOLATION)	248	2	5175	5182	95	1-8'ds		40			4	141	1	35
7A234	MED/SURG (ISOLATION)	248	2	5175	5182	95	1-8'ds		40			4	140	1	35
7A236	MED/SURG (ISOLATION)	248	2	5175	5182	95	1-8'ds		40			4	140	1	35
7A212	MED/SURG	232	2	5470	5483	106	1-8'ds		40	2	66	4	131	1	33
7A213	MED/SURG	232	2	5470	5483	106	1-8'ds		40	2	66	4	131	1	33
7A214	MED/SURG	232	2	5470	5483	106	1-8'ds		40	2	66	4	132	1	33
7A215	MED/SURG	232	2	5470	5483	106	1-8'ds		40	2	66	4	132	1	33
7A216	MED/SURG	232	2	5470	5483	106	1-8'ds		40	2	66	4	132	1	33
7A217	MED/SURG	232	2	5470	5483	106	1-8'ds		40	2	66	4	132	1	33
7A211	MED/SURG	246	2	5775	5786	117	1-8'ds		40	2	70	4	141	1	35
7A944	PATIENT/SERVICE ELEVATOR LOBBY	325		5922	6101	70	2-8'		20			2	92	0.5	23
7A910	CORRIDOR	669		6925	7118	75	3-8'		40			2	190	0.5	47
7A950	CORRIDOR	700		7246	7325	75	3-8'		42			2	198	0.5	50
7A920	CORRIDOR	977		10114	10143	100	5-8'		59			2	277	0.5	69
7A940	CORRIDOR	1042		10786	10804	105	5-8'		63			2	295	0.5	74
7A100	ELEVATOR LOBBY	640	10	11661	17561	400	3-8'ds		400						
7A947	CORRIDOR	1021		12643	12927	165	3-10'		61			2	289	0.5	72
7A100A	FAMILY WAITING	733	26	13355	21540	520	3-8'ds		520			2	208	0.5	52
7A101	ELEC.	126	0	Included					--						
7102	WOMEN'S PUBLIC TOILET	68	0	Included					--			10	Included	2.5	Included
7A103	MEN'S PUBLIC TOILET	68	0	Included					--			10	Included	2.5	Included
7A126	HSK	111	0	Included					---						
7A138	ELEC.	120	0	Included					--						
7A146	TRASH & LINEN CHUTE	124	0	Included					---			6	Included	1.5	Included
7A150	SOILED HOLDING	146	0	Included					---			6	Included	1.5	Included
7A201a	TLT	54		Included					--			10	Included	2.5	Included
7A202a	TLT	54		Included					--			10	Included	2.5	Included
7A203a	TLT	54	0	Included					--			10	Included	2.5	Included
7A204a	TLT	54	0	Included					--			10	Included	2.5	Included
7A205a	TLT	54	0	Included					--			10	Included	2.5	Included
7A206a	TLT	54	0	Included					--			10	Included	2.5	Included
7A207a	TLT	54	0	Included					--			10	Included	2.5	Included
7A208a	TLT	54	0	Included					--			10	Included	2.5	Included
7A209a	TLT	54	0	Included					--			10	Included	2.5	Included
7A210a	TLT	54	0	Included					--			10	Included	2.5	Included
7A211a	TLT	54	0	Included					--			10	Included	2.5	Included
7A212a	TLT	54	0	Included					--			10	Included	2.5	Included
7A213a	TLT	54	0	Included					--			10	Included	2.5	Included
7A214a	TLT	54	0	Included					--			10	Included	2.5	Included
7A215a	TLT	54	0	Included					--			10	Included	2.5	Included
7A216a	TLT	54	0	Included					--			10	Included	2.5	Included
7A217a	TLT	54	0	Included					--			10	Included	2.5	Included
7A218a	TLT	54	0	Included					--			10	Included	2.5	Included
7A225a	TLT	54		Included					--			10	Included	2.5	Included
7A226a	TLT	54		Included					--			10	Included	2.5	Included
7A227a	TLT	54		Included					--			10	Included	2.5	Included
7A228a	TLT	54		Included					--			10	Included	2.5	Included
7A229a	TLT	54		Included					--			10	Included	2.5	Included
7A232a	TLT	36		Included					--			10	Included	2.5	Included
7A234a	TLT	36		Included					--			10	Included	2.5	Included
7A236a	TLT	36		Included					--			10	Included	2.5	Included
7A909	WHEELCHAIR/STRETCHER	148		Included					Included			2	Included	0.5	Included
7A935	WHEELCHAIR/STRETCHER	158		Included					Included			2	Included	0.5	Included

Appendix C: Chilled Beam Summary

Room	Style-Length	Number of units	Nozzle Size	Number of Holerows	Outlet water temp	Total CFM Per Room	Water pressure drop	Air pressure drop	Sound (db(A))	Total Cooling Sensible
0A334	IQIC-8	1	9	1	63.45	40	2.85	0.27	20	3126
0A335 & 0A944	IQIC-8	2	8	1	63.75	84	2.85	0.39	23.3	6660
0A940 & 0A337	IQIC-4	1	9	1	61.5	26	1.4	0.5	21.5	1945
0A941	IQIC-6	2	5	1	62.1	46	2.11	0.51	24.6	4292
0A942	IQIC-6	1	9	1	63.15	40	2.11	0.54	26.7	2972
0A946	IQIC-10	2	3	1	63.45	60	3.58	0.48	23.3	5916
1A102	IQIC-10	4	18	1	67.05	530	3.58	0.5	37.7	27856
1A103	IQCA-060	1	14	1	61.5	40	6.95	0.23	20.4	2122
1A104	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
1A106	IQCA-060	1	14	1	61.5	40	6.95	0.23	20.4	2122
1A107	IQIC-10	4	18	1	66.75	510	3.58	0.47	36.4	27036
1A114	IQIC-6	2	18	1	64.05	165	2.11	0.55	35.4	8196
1A120 & 1A122	IQIC-10	2	18	2	66.9	318	3.58	0.18	32.3	14932
1A130	IQIC-6	3	18	1	62.25	135	2.11	0.16	20	8373
1A208	IQIC-8	1	13	1	65.4	80	2.85	0.56	31.2	5077
1A210	IQIC-4	1	7	1	60.6	14	1.4	0.22	20	1300
1A211	IQIC-8	1	5	1	63.3	32	2.85	0.55	29.5	2907
1A212	IQIC-4	1	7	1	60.6	14	1.4	0.22	20	1300
1A213	IQIC-4	1	6	1	60.3	10	1.4	0.15	20	1048
1A944	IQIC-8	2	7	1	63.6	76	2.85	0.46	26	6708
1A945	IQIC-8	2	7	1	63.9	80	2.85	0.51	27.9	6968
1A948	IQIC-6	6	7	1	62.25	162	2.11	0.42	22	14742
2A112	IQCA-060	1	5	1	60.75	21	6.95	0.34	22.4	1481
2A116	IQIC-4	1	7	1	61.35	22	1.4	0.54	22.6	1791
2A119	IQIC-8	1	18	2	67.5	180	2.85	0.42	38	7394
2A121	IQIC-8	3	18	2	67.8	570	2.85	0.47	39.2	23145
2A123,2A124,2A126,2A127,2A128	IQIC-10	8	18	1	67.35	1126	3.58	0.57	39.6	53584
2A135	IQIC-10	8	7	2	67.5	960	3.58	0.53	39.6	51288
2A136	IQIC-8	1	11	1	63.15	40	2.85	0.18	20	2972
2A137	IQIC-10	1	9	1	66.3	75	3.58	0.57	33.1	5084
2A138	IQIC-8	4	18	2	65.4	480	2.85	0.19	29.5	21580
2A140	IQIC-8	2	14	2	67.2	320	2.85	0.51	39.3	13866
2A141	IQIC-8	3	18	1	65.55	320	2.85	0.5	34	15702
2A201	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
2A204	IQIC-8	2	18	2	65.4	240	2.85	0.19	29.5	10790
2A205	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
2A208	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
2A209	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
2A214	IQIC-8	2	8	1	64.05	92	2.85	0.47	26.9	7110
2A215	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
2A216	IQIC-8	1	9	1	63.45	40	2.85	0.27	20	3126
2A220	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
2A225	IQIC-8	2	18	2	68.25	410	2.85	0.55	40.7	16378
2A228	IQIC-8	2	18	2	68.25	410	2.85	0.55	40.7	16378
2A232	IQCA-060	1	3	1	60.15	15	6.95	0.35	20	1030
2A303	IQIC-4	1	18	1	61.5	40	1.4	0.32	21.6	2177
2A303	IQIC-4	1	11	1	61.8	31	1.4	0.51	22.2	2119
2A304	IQIC-8	3	18	1	65.55	320	2.85	0.5	34	15702
2A307	IQIC-8	2	8	1	64.05	92	2.85	0.47	26.9	7110
2A308	IQIC-4	1	7	1	61.35	21	1.4	0.49	20.8	1733
2A309	IQIC-4	1	18	1	61.5	40	1.4	0.32	21.6	2177
2A310	IQIC-6	2	17	2	65.1	240	2.11	0.36	36.9	10468
2A314	IQIC-10	2	11	1	66.3	170	3.58	0.5	31.6	10598
2A315	IQCA-060	1	3	1	60.15	16	6.95	0.39	21.3	1102
2A320	IQIC-6	1	18	1	63.9	80	2.11	0.52	34.5	4002
2A321	IQIC-6	1	18	1	63.9	80	2.11	0.52	34.5	4002
2A323	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
2A325	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320

Room	Style-Length	Number of units	Nozzle Size	Number of Holerows	Outlet water temp	Total CFM Per Room	Water pressure drop	Air pressure drop	Sound (db(A))	Total Cooling Sensible
2A330	IQIC-10	1	18	2	69.45	240	3.58	0.4	43.7	9370
2A333	IQIC-6	1	18	1	61.95	40	2.11	0.13	20	2382
2A334 & 2A335	IQIC-10	6	18	1	65.25	560	3.58	0.25	26.5	29418
2A901	IQIC-6	2	11	1	62.25	64	2.11	0.23	20	4812
2A905	IQIC-8	2	7	2	65.7	182	2.85	0.52	35.2	10202
2A910	IQIC-8	2	7	1	63.6	76	2.85	0.46	26	6380
2A911	IQIC-10	1	9	1	66.3	76	3.58	0.59	33.6	5135
2A912	IQIC-8	2	8	1	64.05	92	2.85	0.47	26.9	7110
2A919	IQIC-6	2	10	1	62.4	64	2.11	0.29	20	4968
2A920	IQIC-6	2	10	1	62.4	64	2.11	0.29	20	4968
2A930	IQIC-8	2	5	1	63.15	60	2.85	0.49	26.9	5554
2A932	IQIC-8	2	7	1	63.45	70	2.85	0.39	22.8	6020
2A945	IQIC-8	2	6	1	63	60	2.85	0.36	21.1	5474
2A948	IQIC-10	3	10	1	65.4	200	3.58	0.37	24.3	13656
2A949	IQIC-8	6	8	1	63.9	258	2.85	0.41	24.3	20328
2A950	IQCA-060	1	5	1	60.3	18	6.95	0.26	20	1218
3A100	IQIC-10	4	8	1	65.55	248	3.58	0.48	27.5	18140
3A107	IQCA-060	1	14	1	61.5	40	6.95	0.23	20.4	2122
3A108	IQCA-060	1	14	1	61.5	40	6.95	0.23	20.4	2122
3A113	IQCA-060	1	5	1	60.9	22	6.95	0.37	23.8	1563
3A114	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
3A115	IQIC-8	2	7	1	63.6	76	2.85	0.46	26	6380
3A116	IQIC-4	1	17	1	61.8	42	1.4	0.42	24	2330
3A133	IQCA-060	1	14	1	61.5	40	6.95	0.23	20.4	2122
3A134	IQIC-4	1	18	1	61.5	40	1.4	0.32	21.6	2177
3A135	IQIC-8	1	15	1	65.4	92	2.85	0.52	32	4958
3A136	IQIC-6	2	13	1	62.55	80	2.11	0.26	20	5404
3A137	IQCA-060	1	18	1	62.55	65	6.95	0.38	31.7	3064
3A202	IQCA-060	1	5	1	61.05	23	6.95	0.41	25.3	1628
3A205	IQCA-060	1	5	1	60.9	22	6.95	0.37	23.8	1563
3A206	IQCA-060	1	5	1	60.9	22	6.95	0.37	23.8	1563
3A209,211,213,215,217,219,231,233	IQIC-8	6	15	1	62.85 -28.5	272	2.85	0.13	20	17604
3A216	IQIC-4	1	17	1	62.1	47	1.4	0.53	27.7	2535
3A220	IQCA-060	1	5	1	60.75	21	6.95	0.34	22.4	1481
3A222	IQIC-4	1	17	1	61.65	40	1.4	0.38	22.5	2245
3A225	IQCA-060	1	5	1	60.9	22	6.95	0.37	23.8	1563
3A228	IQIC-4	1	17	1	61.8	43	1.4	0.44	24.8	2371
3A235	IQCA-060	1	14	1	61.5	40	6.95	0.23	20.4	2122
3A236	IQIC-8	1	7	1	63.3	34	2.85	0.37	21.7	2948
3A301	IQCA-060	1	5	1	61.05	23	6.95	0.41	25.3	1628
3A323	IQCA-060	1	5	1	61.05	23	6.95	0.41	25.3	1628
3A335	IQIC-10	2	9	1	65.85	140	3.58	0.5	30.2	9670
3A340	IQIC-8	1	10	1	64.8	61	2.85	0.53	29.5	4156
3A341	IQIC-8	1	13	1	65.4	80	2.85	0.56	31.2	4736
3A343	IQIC-8	1	13	1	65.4	80	2.85	0.56	31.2	4736
3A344	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
3A345	IQIC-6	1	8	1	62.7	33	2.11	0.46	24.2	2641
3A906	IQIC-8	3	5	1	63.3	95	2.85	0.54	29.1	8649
3A910	IQIC-8	6	4	1	62.7	156	2.85	0.5	27.4	15234
3A914	IQIC-4	2	11	1	61.65	60	1.4	0.48	21.2	4142
3A922	IQIC-4	1	8	1	61.5	24	1.4	0.51	22.5	1870
3A925	IQIC-4	1	8	1	61.5	24	1.4	0.51	22.5	1870
3A930	IQIC-4	2	8	1	61.5	48	1.4	0.51	22.5	3740
3A940	IQIC-8	3	5	1	63.3	96	2.85	0.55	29.5	8721
3A943	IQIC-6	1	8	1	62.85	34	2.11	0.48	25.1	2696
3A945	IQIC-8	2	6	1	63.15	62	2.85	0.38	22.3	5596
3A946	IQIC-4	2	9	1	61.5	50	1.4	0.46	20	3780
3A950	IQIC-6	3	6	1	61.5	54	2.11	0.24	20	5355

Room	Style-Length	Number of units	Nozzle Size	Number of Holerows	Outlet water temp	Total CFM Per Room	Water pressure drop	Air pressure drop	Sound (db(A))	Total Cooling Sensible
3A960	IQIC-8	7	7	1	63.75	273	2.85	0.49	27	22764
3A970	IQIC-8	3	5	1	63.15	93	2.85	0.52	28.2	8526
3A985	IQIC-8	3	5	1	63.3	95	2.85	0.54	29.1	8649
3A990	IQIC-8	6	5	1	63.15	186	2.85	0.52	28.2	17052
3B401	IQCA-060	1	5	1	60.6	20	6.95	0.31	20.8	1396
3B402	IQIC-6	1	18	1	63.9	80	2.11	0.52	34.5	4002
3B403	IQCA-060	1	5	1	60.6	20	6.95	0.31	20.8	1396
3B404	IQCA-060	1	5	1	60.75	21	6.95	0.34	22.4	1481
3B408	IQCA-060	1	5	1	60.6	20	6.95	0.31	20.8	1396
3B409	IQCA-060	1	14	1	61.5	40	6.95	0.23	20.4	2122
3B410	IQCA-060	1	5	1	60.75	21	6.95	0.34	22.4	1481
3B414	IQIC-4	2	8	1	61.5	48	1.4	0.51	22.5	3740
3B981	IQIC-6	2	6	1	62.25	50	2.11	0.46	23.6	4504
5A100	IQIC-8	3	18	2	65.85	400	2.85	0.23	31.7	17565
5A100A	IQIC-8	3	18	2	67.2	520	2.85	0.39	37.2	21537
5A104	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
5A105	IQIC-4	1	18	1	61.5	40	1.4	0.32	21.6	2177
5A112	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
5A114	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
5A116	IQIC-4	1	9	1	61.5	25	1.4	0.46	20	1890
5A118	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
5A119	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
5A125	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
5A126	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
5A127	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
5A128	IQIC-4	1	9	1	61.5	25	1.4	0.46	20	1890
5A137	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
5A144	IQIC-8	1	18	2	65.4	120	2.85	0.19	29.5	5395
5A145	IQCA-060	1	16	1	61.5	44	6.95	0.22	22.4	2225
5A147	IQIC-10	2	10	1	65.1	125	3.58	0.32	21.7	8688
5A151	IQIC-8	2	6	1	63.3	66	2.85	0.43	24.7	5856
5A153	IQCA-060	1	5	1	60.9	22	6.95	0.37	23.8	1563
5A154	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
5A158	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
5A159	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
5A160	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
5A202	IQIC-6	1	12	2	63.3	67	2.11	0.19	24.3	3474
5A203	IQIC-6	1	11	2	63.6	71	2.11	0.25	28.6	3682
5A204	IQIC-6	1	11	2	63.45	70	2.11	0.24	28.1	3641
5A206	IQIC-6	1	11	2	63.45	70	2.11	0.24	28.1	3641
5A207	IQIC-6	1	11	2	63.6	73	2.11	0.26	29.5	3760
5A208	IQIC-6	1	11	2	63.45	70	2.11	0.24	28.1	3641
5A209	IQIC-6	1	11	2	63.6	71	2.11	0.25	28.6	3682
5A210	IQIC-6	1	11	2	63.75	74	2.11	0.27	29.9	3798
5A211	IQIC-8	1	17	1	65.55	103	2.85	0.52	32.9	5193
5A212	IQIC-8	1	15	1	65.4	92	2.85	0.52	32	4958
5A213	IQIC-8	1	15	1	65.4	92	2.85	0.52	32	4958
5A214	IQIC-8	1	15	1	65.4	92	2.85	0.52	32	4958
5A215	IQIC-8	1	15	1	65.4	92	2.85	0.52	32	4958
5A216	IQIC-8	1	15	1	65.4	92	2.85	0.52	32	4958
5A217	IQIC-8	1	15	1	65.4	92	2.85	0.52	32	4958
5A218	IQIC-6	1	15	2	63	66	2.11	0.13	20	3330
5A219	IQIC-6	1	18	2	63.45	77	2.11	0.13	20.3	3719
5A220	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
5A224	IQCA-060	1	18	1	61.8	50	6.95	0.22	23.2	2436
5A225	IQIC-4	1	18	2	62.55	64	1.4	0.2	37.3	3050
5A226	IQIC-4	1	18	2	62.4	60	1.4	0.18	35.1	2904
5A227	IQIC-4	1	18	2	62.4	60	1.4	0.18	35.1	2904
5A228	IQIC-4	1	18	2	62.4	60	1.4	0.18	35.1	2904

Room	Style-Length	Number of units	Nozzle Size	Number of Holerows	Outlet water temp	Total CFM Per Room	Water pressure drop	Air pressure drop	Sound (db(A))	Total Cooling Sensible
5A229	IQIC-4	1	18	2	62.4	60	1.4	0.18	35.1	2904
5A905	IQIC-6	1	9	1	62.7	35	2.11	0.41	22.9	2699
5A909	IQCA-060	1	6	1	60.6	21	6.95	0.27	20	1402
5A910	IQIC-8	3	4	1	62.1	60	2.85	0.3	20	6336
5A920	IQIC-8	5	4	1	62.1	100	2.85	0.3	20	10560
5A934	IQIC-8	1	6	1	63.6	37	2.85	0.54	29.1	3173
5A937	IQIC-4	1	18	2	62.4	60	1.4	0.18	35.1	2904
5A940	IQIC-8	5	7	1	63.9	200	2.85	0.51	27.9	16550
5A944	IQIC-8	2	6	1	63.45	70	2.85	0.49	27	6100
5A945	IQIC-8	1	6	1	63.6	37	2.85	0.54	29.1	3173
5A947	IQIC-10	3	8	1	65.1	165	3.58	0.38	22.7	12477
6A100	IQIC-8	3	18	2	65.85	400	2.85	0.23	31.7	17565
6A100A	IQIC-8	3	18	2	67.2	520	2.85	0.39	37.2	21537
6A104	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
6A105	IQCA-060	1	14	1	61.5	40	6.95	0.23	20.4	2122
6A110	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
6A112	IQCA-060	1	6	1	60.75	22	6.95	0.29	20.6	1488
6A114	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
6A116	IQCA-060	1	8	1	61.65	32	6.95	0.38	26.8	2098
6A117	IQCA-060	1	14	1	61.5	40	6.95	0.23	20.4	2122
6A119	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
6A125	IQCA-060	1	6	1	60.75	22	6.95	0.29	20.6	1488
6A127	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
6A128	IQCA-060	1	11	1	61.2	32	6.95	0.22	20	1832
6A137	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
6A140	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
6A141	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
6A142	IQIC-8	1	18	2	65.4	120	2.85	0.19	29.5	5395
6A144	IQIC-8	1	18	1	64.35	80	2.85	0.28	22.8	4211
6A151	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
6A152	IQCA-060	1	12	1	61.2	34	6.95	0.22	20	1894
6A201	IQIC-8	1	18	1	63.6	64	2.85	0.18	20	3559
6A202	IQIC-8	1	18	1	63.75	67	2.85	0.2	20	3685
6A203	IQIC-8	1	18	1	63.9	71	2.85	0.22	20	3849
6A204	IQIC-8	1	18	1	63.9	70	2.85	0.22	20	3808
6A205	IQIC-8	1	18	1	63.9	70	2.85	0.22	20	3808
6A206	IQIC-8	1	18	1	63.9	70	2.85	0.22	20	3808
6A207	IQIC-8	1	18	1	64.05	73	2.85	0.24	20	3927
6A208	IQIC-8	1	18	1	63.9	70	2.85	0.22	20	3808
6A209	IQIC-8	1	18	1	63.9	71	2.85	0.22	20	3849
6A210	IQIC-8	1	18	1	64.05	74	2.85	0.24	20	3968
6A211	IQIC-8	1	10	2	66.3	117	2.85	0.49	36.1	5787
6A212	IQIC-8	1	9	2	66	106	2.85	0.48	35.6	5483
6A213	IQIC-8	1	9	2	66	106	2.85	0.48	35.6	5483
6A214	IQIC-8	1	9	2	66	106	2.85	0.48	35.6	5483
6A215	IQIC-8	1	9	2	66	106	2.85	0.48	35.6	5483
6A216	IQIC-8	1	9	2	66	106	2.85	0.48	35.6	5483
6A217	IQIC-8	1	9	2	66	106	2.85	0.48	35.6	5483
6A218	IQIC-8	1	11	1	65.1	70	2.85	0.56	30.1	4466
6A225	IQIC-8	1	11	1	65.1	68	2.85	0.53	29	4371
6A226	IQIC-8	1	10	1	64.8	60	2.85	0.52	28.9	4108
6A227	IQIC-8	1	10	1	64.8	60	2.85	0.52	28.9	4108
6A228	IQIC-8	1	10	1	64.8	60	2.85	0.52	28.9	4108
6A229	IQIC-8	1	10	1	64.8	60	2.85	0.52	28.9	4108
6A231	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
6A232	IQIC-8	1	8	2	65.85	95	2.85	0.49	34.5	5183
6A233	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
6A234	IQIC-8	1	8	2	65.85	95	2.85	0.49	34.5	5183
6A235	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320

Room	Style-Length	Number of units	Nozzle Size	Number of Holerows	Outlet water temp	Total CFM Per Room	Water pressure drop	Air pressure drop	Sound (db(A))	Total Cooling Sensible
6A236	IQIC-8	1	8	2	65.85	95	2.85	0.49	34.5	5183
6A905	IQIC-6	1	10	1	63.15	41	2.11	0.48	25.6	2969
6A908	IQIC-8	1	9	1	64.35	52	2.85	0.46	25.8	3777
6A910	IQIC-8	3	7	1	62.4	75	2.85	0.2	20	7113
6A920	IQIC-8	5	7	1	61.95	100	2.85	0.13	20	10150
6A932	IQIC-8	1	7	1	63.45	35	2.85	0.39	22.8	3010
6A940	IQIC-8	5	5	1	62.1	105	2.85	0.24	20	10800
6A944	IQIC-8	2	6	1	63.45	70	2.85	0.49	27	6100
6A945	IQIC-8	1	8	1	63.9	44	2.85	0.43	25.1	3443
6A947	IQIC-10	3	7	1	65.4	165	3.58	0.56	30.2	12930
6A950	IQIC-8	3	5	1	62.55	75	2.85	0.34	20	7329
7A100	IQIC-8	3	18	2	65.85	400	2.85	0.23	31.7	17565
7A100A	IQIC-8	3	18	2	67.2	520	2.85	0.39	37.2	21537
7A104	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
7A105	IQCA-060	1	14	1	61.5	40	6.95	0.23	20.4	2122
7A110	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
7A112	IQCA-060	1	6	1	60.75	22	6.95	0.29	20.6	1488
7A114	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
7A116	IQCA-060	1	8	1	61.65	32	6.95	0.38	26.8	2098
7A117	IQCA-060	1	14	1	61.5	40	6.95	0.23	20.4	2122
7A119	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
7A125	IQCA-060	1	6	1	60.75	22	6.95	0.29	20.6	1488
7A127	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
7A128	IQCA-060	1	11	1	61.2	32	6.95	0.22	20	1832
7A137	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
7A140	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
7A141	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
7A142	IQIC-8	1	18	2	65.4	120	2.85	0.19	29.5	5395
7A144	IQIC-8	1	18	1	64.35	80	2.85	0.28	22.8	4211
7A151	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
7A152	IQCA-060	1	12	1	61.2	34	6.95	0.22	20	1894
7A201	IQIC-8	1	18	1	63.6	64	2.85	0.18	20	3559
7A202	IQIC-8	1	18	1	63.75	67	2.85	0.2	20	3685
7A203	IQIC-8	1	18	1	63.9	71	2.85	0.22	20	3849
7A204	IQIC-8	1	18	1	63.9	70	2.85	0.22	20	3808
7A205	IQIC-8	1	18	1	63.9	70	2.85	0.22	20	3808
7A206	IQIC-8	1	18	1	63.9	70	2.85	0.22	20	3808
7A207	IQIC-8	1	18	1	64.05	73	2.85	0.24	20	3927
7A208	IQIC-8	1	18	1	63.9	70	2.85	0.22	20	3808
7A209	IQIC-8	1	18	1	63.9	71	2.85	0.22	20	3849
7A210	IQIC-8	1	18	1	64.05	74	2.85	0.24	20	3968
7A211	IQIC-8	1	10	2	66.3	117	2.85	0.49	36.1	5787
7A212	IQIC-8	1	9	2	66	106	2.85	0.48	35.6	5483
7A213	IQIC-8	1	9	2	66	106	2.85	0.48	35.6	5483
7A214	IQIC-8	1	9	2	66	106	2.85	0.48	35.6	5483
7A215	IQIC-8	1	9	2	66	106	2.85	0.48	35.6	5483
7A216	IQIC-8	1	9	2	66	106	2.85	0.48	35.6	5483
7A217	IQIC-8	1	9	2	66	106	2.85	0.48	35.6	5483
7A218	IQIC-8	1	11	1	65.1	70	2.85	0.56	30.1	4466
7A225	IQIC-8	1	11	1	65.1	68	2.85	0.53	29	4371
7A226	IQIC-8	1	10	1	64.8	60	2.85	0.52	28.9	4108
7A227	IQIC-8	1	10	1	64.8	60	2.85	0.52	28.9	4108
7A228	IQIC-8	1	10	1	64.8	60	2.85	0.52	28.9	4108
7A229	IQIC-8	1	10	1	64.8	60	2.85	0.52	28.9	4108
7A231	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
7A232	IQIC-8	1	8	2	65.85	95	2.85	0.49	34.5	5183
7A233	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320
7A234	IQIC-8	1	8	2	65.85	95	2.85	0.49	34.5	5183
7A235	IQCA-060	1	6	1	60.45	20	6.95	0.24	20	1320

Room	Style-Length	Number of units	Nozzle Size	Number of Holerows	Outlet water temp	Total CFM Per Room	Water pressure drop	Air pressure drop	Sound (db(A))	Total Cooling Sensible
7A236	IQIC-8	1	8	2	65.85	95	2.85	0.49	34.5	5183
7A905	IQIC-6	1	10	1	63.15	41	2.11	0.48	25.6	2969
7A908	IQIC-8	1	9	1	64.35	52	2.85	0.46	25.8	3777
7A910	IQIC-8	3	7	1	62.4	75	2.85	0.2	20	7113
7A920	IQIC-8	5	7	1	61.95	100	2.85	0.13	20	10150
7A932	IQIC-8	1	7	1	63.45	35	2.85	0.39	22.8	3010
7A940	IQIC-8	5	5	1	62.1	105	2.85	0.24	20	10800
7A944	IQIC-8	2	6	1	63.45	70	2.85	0.49	27	6100
7A945	IQIC-8	1	8	1	63.9	44	2.85	0.43	25.1	3443
7A947	IQIC-10	3	7	1	65.4	165	3.58	0.56	30.2	12930
7A950	IQIC-8	3	5	1	62.55	75	2.85	0.34	20	7329

Noise Power (db(A)) shown are taken in a hard room and assume no space absorbtion/attenuation.
Cooling selections based on 75 degree setpoint room temperature and 77 degree setpoint ceiling temperature using 62 deree supply air temperature
Inlet water flow is based on 1.0 gpm and Inlet water temperature is based on 57 degrees.

Appendix D: Ductwork Takeoff

5th Floor Ductwork Takeoff

Original Duct Size (in)	8 Ø	8x8	10 Ø	10x10	12x8	12x10	12x12	14x10	14x12	14x14	16x12	16x14	16x16
Max Airflow (CFM)	220	270	345	480	450	600	775	730	950	1180	1100	1400	1700
Total (lf)	153	8	118	41	635	62	29	90	92	62	26	4	170
Weight (lb/lf)	2.2	2.7	2.7	3.3	3.3	3.7	4	4	4.3	4.7	4.7	5	5.3
Total Weight (lb)	337	22	319	135	2096	229	116	360	396	291	122	20	901

Original Duct Size (in)	18x16	18x18	20x14	20x18	21x20	22x16	22x18	24x16	28x18	32x16	32x20	34x18	104x34
Max Airflow (CFM)	1950	2200	1800	2600	3200	2700	2900	2700	3800	3800	5250	4900	45000
Total (lf)	18	74	40	124	16	30	56	33	54	28	50	22	45
Weight (lb/lf)	5.7	6	5.7	6.3	6.8	6.3	6.7	6.7	7.7	10.3	11.2	11.2	51.1
Total Weight (lb)	103	444	228	781	109	189	375	221	416	288	560	246	2300

Redesign Duct Size (in)	4 Ø	5 Ø	6 Ø	7Ø	8 Ø	6x5	7x6	8x6	9x9	10x6	10x9	12x10	12x12
Max Airflow (CFM)	40	65	100	150	220	100	155	180	385	240	425	600	800
Total (lf)	130	21	10	82	25	8	41	697	181	119	45	181	122
Weight (lb/lf)	1	1.3	1.5	1.8	2.2	1.8	2.2	2.3	3	2.7	3.2	3.7	4
Total Weight (lb)	130	27	15	148	55	14	90	1603	543	321	144	670	488

Redesign Duct Size (in)	14x10	14x12	14x14	16x12	18x16	32x30
Max Airflow (CFM)	750	950	1200	1100	1900	9250
Total (lf)	74	119	82	16	71	45
Weight (lb/lf)	4	4.3	4.7	4.7	5.7	13.3
Total Weight (lb)	296	512	385	75	405	599

5th Floor Supply Duct Insulation Takeoff
($1.00/Sqft Duct Surface Area)

Original Duct Size (in)	8 Ø	8x8	10 Ø	10x10	12x8	12x10	12x12	14x10	14x12	14x14	16x12	16x14	16x16
Total (lf)	153	8	118	41	635	62	29	90	92	62	26	4	170
Surface Area (sqft/lf)	2.1	2.7	2.6	3.3	3.3	3.7	4.0	4.0	4.3	4.7	4.7	5.0	5.3
Total Area (sqft)	320	21	309	137	2117	227	116	360	399	289	122	20	907

Original Duct Size (in)	18x16	18x18	20x14	20x18	21x20	22x16	22x18	24x16	28x18	32x16	32x20	34x18	104x34
Total (lf)	18	74	40	124	16	30	56	33	54	28	50	22	45
Surface Area (sqft/lf)	5.7	6.0	5.7	6.3	6.8	6.3	6.7	6.7	7.7	8.0	8.7	8.7	23.0
Total Area (sqft)	102	444	227	785	109	190	373	221	414	224	433	191	1035

Redesign Duct Size (in)	4 Ø	5 Ø	6 Ø	7Ø	8 Ø	6x5	7x6	8x6	9x9	10x6	10x9	12x10	12x12
Total (lf)	130	21	10	82	25	8	41	697	181	119	45	181	122
Surface Area (sqft/lf)	1.0	1.3	1.6	1.8	2.1	1.8	2.2	2.3	3.0	2.7	3.2	3.7	4.0
Total Area (sqft)	136	27	16	150	52	15	89	1626	543	317	143	664	488

Redesign Duct Size (in)	14x10	14x12	14x14	16x12	18x16	32x30
Total (lf)	74	119	82	16	71	45
Surface Area (sqft/lf)	4.0	4.3	4.7	4.7	5.7	10.3
Total Area (sqft)	296	516	383	75	402	465

Appendix E: Chilled Water Piping Takeoff

5th Floor CHW Distribution Piping						
Pipe Size/Type	Max Flow GPM	Quantity	Schedule 40 Steel		Type L Copper	
			Unit Price	Total Price	Unit Price	Total Price
1/2" Piping	**3.5**					
Piping (ft)		1317.2			$7.83	$10,313.68
Tee Fitting (ea)		58.0			$28.66	$1,662.28
45 Fitting (ea)		2.0			$19.14	$38.28
90 Fitting (ea)		26.0			$18.58	$483.08
2" Insulation (lf)		1317.2			$3.18	$4,188.70
3/4" Piping	**6.5**					
Piping (ft)		125.4			$9.92	$1,243.97
Tee Fitting (ea)		2.0			$32.79	$65.58
2" Insulation (lf)		125.4			$3.27	$410.06
1" Piping	**11**					
Piping (ft)		320.7	$9.83	$3,152.48		
Tee Fitting (ea)		61.0	$49.79	$3,037.19		
90 Fitting (ea)		2.0	$31.83	$63.66		
2" Insulation (lf)		320.7	$3.55	$1,138.49		
1 1/2" Piping	**25**					
Piping (ft)		405.4	$12.83	$5,201.28		
Tee Fitting (ea)		22.0	$60.85	$1,338.70		
45 Fitting (ea)		2.0	$44.40	$88.80		
90 Fitting (ea)		4.0	$39.65	$158.60		
2" Insulation (lf)		405.4	$3.72	$1,508.09		
2" Piping	**40**					
Piping (ft)		288.7	$16.50	$4,763.55		
45 Fitting (ea)		4.0	$49.75	$199.00		
2" Insulation (lf)		288.7	$4.22	$1,218.31		
2 1/2" Piping	**70**					
Piping (ft)		119.0	$22.90	$2,725.10		
Tee Fitting (ea)		2.0	$112.50	$225.00		
45 Fitting (ea)		2.0	$81.50	$163.00		
2" Insulation (lf)		119.0	$4.41	$524.79		
3" Piping	**130**					
Piping (ft)		202.1	$29.21	$5,903.34		
90 Fitting (ea)		4.0	$91.24	$364.96		
2" Insulation (lf)		202.1	$5.02	$1,014.54		
SUB TOTAL				$32,788.88		$18,405.62
TOTAL						$51,194.50

Appendix F: Chilled Beam Quote

SEMCO
A FLAKT WOODS COMPANY

QUOTATION

Page 1 of 3

To:		Job Name:	Butler Memorial Hospital
Company:		Location:	PA
Fax:		From:	Thomas Kitchen
		Date:	Thursday, 10 March, 2011

Based on specification # : Budget quote is not based on any schedule or specificaions and only offers the items listed below.

SEMCO proposes to furnish the materials described below for the above project in accordance with SEMCO's Standard Terms and Conditions of Sale (Form G SP 008 2M 023 S). SEMCO sales representative assumes responsibility for ensuring proper equipment is quoted to customer.

IQIC-4' (Qty - 33)
- Standard (start gable) 6"air duct connection
- Horizontal through start gable water connection
- Four pipe with standard capacity water coils
- Flow pattern diffuser with 15 degree increment adjustment
- Two mounting brackets per chilled beam for installation purposes
- Four braided flex hoses for water coil connections

Price (Freight Allowed to First US Destination)........... $28,124.00 (1st Half-12)

IQIC-6' (Qty - 48)
- Standard (start gable) 6"air duct connection
- Horizontal through start gable water connection
- Four pipe with standard capacity water coils
- Flow pattern diffuser with 15 degree increment adjustment
- Two mounting brackets per chilled beam for installation purposes
- Four braided flex hoses for water coil connections

Price (Freight Allowed to First US Destination)........... $45,722.00 (1st Half-12)

IQIC-8' (Qty - 244)
- Standard (start gable) 6"air duct connection
- Horizontal through start gable water connection
- Four pipe with standard capacity water coils
- Flow pattern diffuser with 15 degree increment adjustment
- Two mounting brackets per chilled beam for installation purposes
- Four braided flex hoses for water coil connections

Price (Freight Allowed to First US Destination)........... $258,594.00 (1st Half-12)

IQIC-10' (Qty - 59)

- Standard (start gable) 6"air duct connection
- Horizontal through start gable water connection
- Four pipe with standard capacity water coils
- Flow pattern diffuser with 15 degree increment adjustment
- Two mounting brackets per chilled beam for installation purposes
- Four braided flex hoses for water coil connections

Price (Freight Allowed to First US Destination).......... $69,662.00 (1st Half-12)

IQCA-060 (Qty - 92)

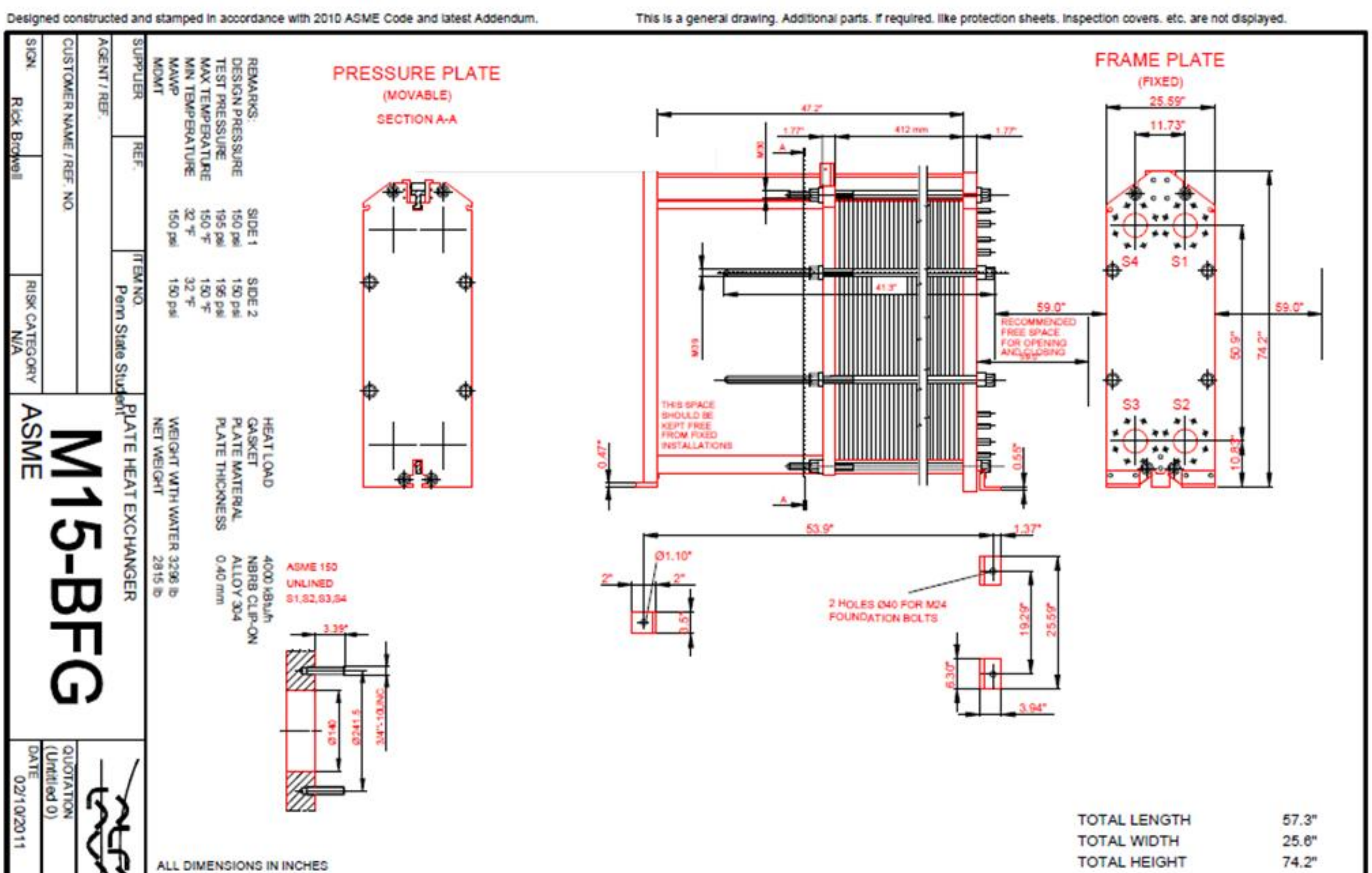
- Standard (start gable) 4.9"air duct connection
- Horizontal through start gable water connection
- Four pipe with standard capacity water coils
- Flow pattern diffuser with 15 degree increment adjustment
- Two mounting brackets per chilled beam for installation purposes
- Four braided flex hoses for water coil connections

Price (Freight Allowed to First US Destination).......... $71,313.00 (1st Half-12)

Total Price (Freight Allowed to First US Destination)................ $473,415.00 (1st Half-12)

1) Lead time is dependent upon production load at point of release to production.
2) Quote is valid for 30 days. Additional surcharges may apply if equipment is not shipped in specified pricing period.
3) All sales are subject to SEMCO Credit Dept. approval.
4) All sales orders are subject to State Sales Tax. If an order is tax exempt a Sales Tax Exemption Certificate must be included with the contract documents or an exemption certificate must be on file with SEMCO Incorporated. Taxes, if applicable, will be added to the invoice amount. Taxes are not included in the quoted prices.
5) Not responsible for freight on international shipments.

Appendix G: Heat Exchanger Quote & Specs



SIDE	MEDIA	INLET	TEMP.	OUTLET	TEMP.	FLOW RATE	PRESSURE DROP	LIQUID VOL.
1	Water	S1	65 °F	S2	57 °F	540 gpm	4.647 psi	3.885 ft³
2	Water	S3	55 °F	S4	62.2 °F	600 gpm	9.937 psi	3.94 ft³

To:	Matt Geary
Company:	Penn State University Student
Tel:	
Fax:	
From:	Rick Browell
Date:	2/10/2011
Project:	Butler Memorial Hospital
Pages:	5

Alfa Laval Inc.
5400 International Trade Drive
Richmond, VA 23231
USA
Tel: 724-942-3400
Fax: 724-942-3405
www.alfalaval.us

Dear Matt,

Based on the conditions specified, the following Alfa Laval plate heat exchanger is required. Please see the attached data sheet and dimensional drawing for detailed information.

Item	Qty	Description	RCPL Price
Plate/Frame Heat Exhanger	1	M15B-FG, with (142) ALLOY 304 plates with NBRB CLIP-ON gaskets.	$14,600.00

Quoted price is FOB Richmond, VA.
Quotes are valid for 30 days.
All orders are subject to the attached Alfa Laval Standard Terms and Conditions.

Thank you for the opportunity to provide a quotation on this project. Should you have any further questions, please contact me at 724-942-3400.

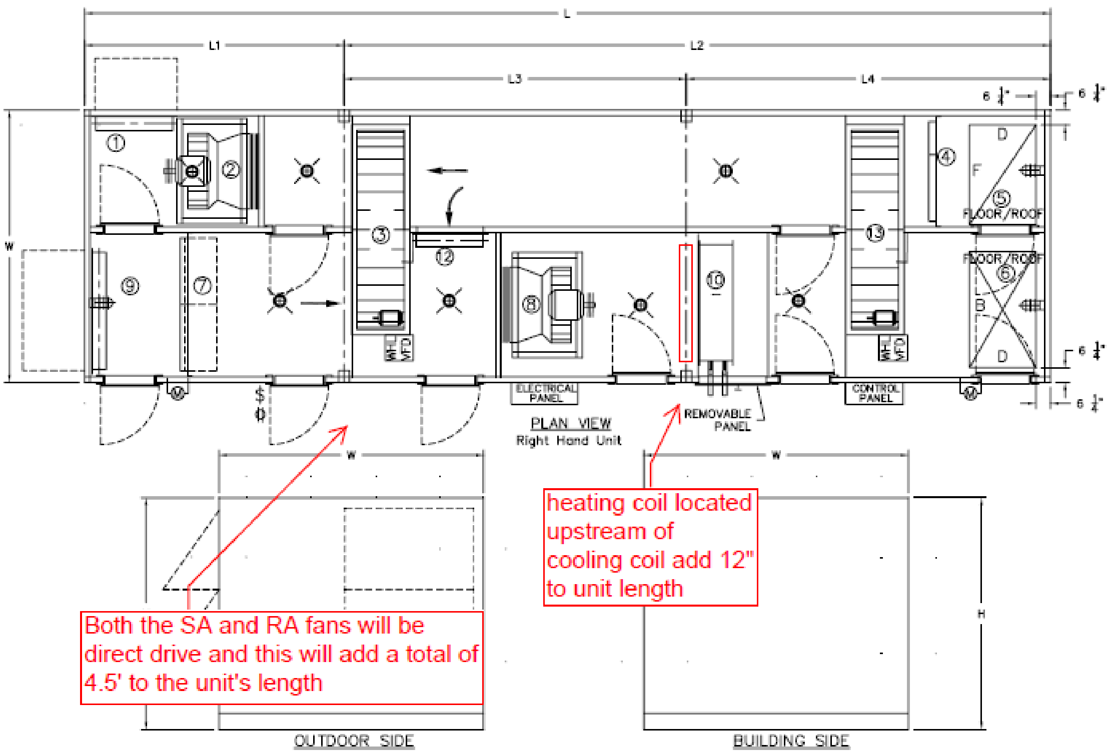
Best regards,

Rick Browell

Rick Browell

MISSION: To optimize the performance of our customers' processes. Time and time again.

Appendix H: Pinnacle Unit Quote & Specs



MODEL	W	H	A	B	C	D	E	F	G	WEIGHT MOD# 1	WEIGHT MOD# 2	WEIGHT MOD# 3	L	L1	L2	L3	L4
PVS–3	86.25	48.25	14.25	24	12.25	20	14.25	24	12.25	7,400#	0	0	288.5	0	0	0	0
PVS–5	86.25	60.25	15.25	34	14.25	20	20.25	24	14.25	8,700#	0	0	298.5	0	0	0	0
PVS–9	98.25	72.25	15.25	46	20.25	20	21.25	34	14.25	11,000#	0	0	304.375	0	0	0	0
PVS–13	98.25	86.25	23.25	46	17.25	26	29.25	34	11.25	4,400#	9,750#	0	333.125	99.625	233.5	0	0
PVS–18	122.25	98.25	23.25	58	23.25	26	29.25	46	17.25	5,800#	12,250#	0	348.875	107.5	241.375	0	0
PVS–24	122.25	110.25	29.25	58	20.25	32	35.25	46	14.25	6,700#	14,150#	0	364.625	115.375	249.25	0	0
PVS–28	146.25	122.25	29.25	70	26.25	32	35.25	58	20.25	8,050#	8,800#	9,950#	381.5	119.25	0	133	129.125
PVS–35	146.25	134.25	35.25	70	22.75	37	41.25	58	16.75	9,200#	9,950#	11,050#	401.125	129.125	0	137	135
PVS–43	182.25	146.25	29.25	94	32.25	44	41.25	70	20.25	11,800#	11,800#	13,650#	417	137	0	139	141

SYMBOLS

- MOTOR
- FILTER GUAGE
- 1 1/2" NPT DRAIN
- WHEEL PURGE
- AIRFLOW DIRECTION
- LIGHTS
- LIGHT SWITCH
- RECEPTACLE

LEGEND

1. EXHAUST AIR OPENING W/DAMPER
2. EXHAUST FAN
3. ENTHALPY WHEEL
4. RETURN AIR FILTER BANK
5. RETURN AIR OPENING
6. SUPPLY AIR OPENING
7. SUPPLY AIR FILTER BANK
8. SUPPLY FAN
9. OUTSIDE AIR OPENING W/DAMPER
10. COOLING COIL
11. HEATING COIL
12. RECIRCULATION DAMPER
13. PASSIVE DEHUMIDIFICATION WHEEL

13" WIDE DOORS FOR UNIT SIZE 3–9

18" WIDE DOORS FOR UNIT SIZE 13–43

REV	JOB NO:	BY	DATE	DESCRIPTION
0		JCR	3/28/06	ORIGINAL ISSUANCE

revised total unit length of 475"

INCORPORATED

TITLE: GENERAL ARRANGEMENT PVS DESIGN FAN MID PVS–03–43

PROTO TYPE: A4 | ASSY DWG.# | SCALE: NONE | ORDER # | DWG. NO.: GA–A24XX

SEMCO
A FLÄKT WOODS COMPANY

QUOTATION

To:

Company:

Fax:

Job Name: Butler Memorial Hospital

Location:

From:

Date: Thursday, 17 March, 2011

Based on specification # : BUDGET QUOTE

SEMCO proposes to furnish the materials described below for the above project in accordance with SEMCO's Standard Terms and Conditions of Sale (Form G SP 008 2M 023 S). SEMCO sales representative assumes responsibility for ensuring proper equipment is quoted to customer.

PVS-43 (Qty - 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 24 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.
- 40 hp, Premium Effciency, ODP supply fan motor in centrifugal plenum type fan.
- 40 hp, Premium Effciency, 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.
- 85%, Class 2, 12-inch high efficiency pleated filters.
- 30%, Class 2, 4-inch pleated filters in return airstream.

1800 East Pointe Drive - Columbia, MO 65201-3508 - Telephone: (573)443-1481 - Fax: (573)886-5408

- Exhaust air damper, galvanized steel frames and blades and two position electric actuators.
- Exhaust air damper spec would be the same as the outdoor air damper spec
- Outside air damper, galvanized steel frames and blades and modulating electric actuators.
- Re-circulation damper, galvanized steel frames and blades and modulating electric actuators.
- **WIRING ACROSS SHIPPING SPLITS BY OTHERS (NOT SEMCO)**
- 5 Year Service Contract
- 1' wider cooling coil
- heating coil upstream of cooling coil
- second SA fan motor
- second EA fan motor
- dual/stacked direct drive SA and RA fans
- unit DDC controls
- roof curb
- exterior paint

Price (Freight Allowed to First US Destination)........................... $272,859.00 (1st Half-12)

1-Day Field Service (Description - start up and owner training) (Qty - 2)
Price (Freight Allowed to First US Destination)........................... $5,045.00 (1st Half-12)

1) Lead time is dependent upon production load at point of release to production.
2) Quote is valid for 30 days. Additional surcharges may apply if equipment is not shipped in specified pricing period.
3) All sales are subject to SEMCO Credit Dept. approval.
4) All sales orders are subject to State Sales Tax. If an order is tax exempt a Sales Tax Exemption Certificate must be included with the contract documents or an exemption certificate must be on file with SEMCO Incorporated. Taxes, if applicable, will be added to the invoice amount.
5) Not responsible for freight on international shipments.

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Appendix I: AISC Steel Tables

Table 3–2 (continued) W Shapes Selection by Z_x

$F_y = 50$ ksi Z_x

Shape	Z_x	M_{px}/Ω_b	$\phi_b M_{px}$	M_{rx}/Ω_b	$\phi_b M_{rx}$	BF	BF	L_p	L_r	I_x	V_{nx}/Ω_v	$\phi_v V_{nx}$
		kip-ft	kip-ft	kip-ft	kip-ft	kips	kips				kips	kips
	in.^{3}	ASD	LRFD	ASD	LRFD	ASD	LRFD	ft	ft	in.^{4}	ASD	LRFD
W30×116	**378**	**943**	**1420**	**575**	**864**	**24.7**	**37.2**	**7.74**	**22.6**	**4930**	**339**	**509**
W21×147	373	931	1400	575	864	13.8	20.7	10.4	36.3	3630	318	476
W24×131	370	923	1390	575	864	16.3	24.5	10.5	31.9	4020	296	444
W18×158	356	888	1340	541	814	10.5	15.7	9.68	42.8	3060	319	479
W14×193	355	886	1330	541	814	5.27	7.92	14.3	79.7	2400	276	413
W12×210	348	868	1310	510	767	4.24	6.38	11.6	96.0	2140	347	521
W30×108	**346**	**863**	**1300**	**522**	**785**	**23.7**	**35.6**	**7.59**	**22.0**	**4470**	**325**	**488**
W27×114	343	856	1290	522	785	21.7	32.6	7.70	23.1	4080	311	467
W21×132	333	831	1250	515	774	18.3	20.0	10.3	34.1	3220	284	426
W24×117	327	816	1230	508	764	15.3	23.1	10.4	30.4	3540	267	400
W18×143	322	803	1210	493	740	10.4	15.6	9.61	39.6	2750	285	427
W14×176	320	798	1200	491	738	5.22	7.84	14.2	73.2	2140	253	379
W30×99	**312**	**778**	**1170**	**470**	**706**	**22.2**	**33.3**	**7.42**	**21.4**	**3990**	**308**	**463**
W12×190	311	776	1170	459	690	4.18	6.28	11.5	87.3	1890	305	457
W21×122	307	766	1150	477	717	12.9	19.4	10.3	32.7	2960	260	390
W27×102	305	761	1140	466	701	20.2	30.3	7.59	22.2	3620	279	419
W18×130	290	724	1090	447	672	10.2	15.3	9.54	36.7	2460	258	387
W24×104	289	721	1080	451	677	14.3	21.5	10.3	29.2	3100	241	361
W14×159	287	716	1080	444	667	5.18	7.79	14.1	66.7	1900	223	335
W30×90[v]	**283**	**706**	**1060**	**428**	**643**	**20.5**	**30.9**	**7.38**	**20.9**	**3610**	**249**	**375**
W24×103	280	699	1050	428	643	18.2	27.4	7.03	21.9	3000	270	405
W21×111	279	696	1050	435	654	12.4	18.7	10.2	31.3	2670	237	355
W27×94	278	694	1040	424	638	19.1	28.8	7.49	21.6	3270	264	396
W12×170	275	686	1030	410	617	4.11	6.18	11.4	78.5	1650	269	404
W18×119	262	654	983	403	606	10.1	15.2	9.50	34.3	2190	249	373
W14×145	260	649	975	405	609	5.11	7.68	14.1	61.7	1710	201	302
W24×94	254	634	953	388	583	17.3	26.0	6.99	21.2	2700	250	376
W21×101	253	631	949	396	596	11.8	17.7	10.2	30.1	2420	214	320
W27×84	**244**	**609**	**915**	**372**	**559**	**17.6**	**26.4**	**7.31**	**20.8**	**2850**	**246**	**369**
W12×152	243	606	911	365	549	4.07	6.11	11.3	70.6	1430	239	358
W14×132	234	584	878	365	549	5.13	7.70	13.3	56.0	1530	189	284
W18×106	230	574	863	356	536	9.70	14.6	9.40	31.8	1910	221	332

ASD	LRFD
$\Omega_b = 1.67$ $\Omega_v = 1.50$	$\phi_b = 0.90$ $\phi_v = 1.00$

[v] Shape does not meet the h/t_w limit for shear in Specification Section G2.1a with $F_y = 50$ ksi, $\Omega_v = 1.67$, $\phi_v = 0.90$.

Table 3–2 (continued) W Shapes Selection by Z_x

Z_x $F_y = 50$ ksi

Shape	Z_x	M_{px}/Ω_b	$\phi_b M_{px}$	M_{rx}/Ω_b	$\phi_b M_{rx}$	BF	BF	L_p	L_r	I_x	V_{nx}/Ω_v	$\phi_v V_{nx}$
		kip-ft	kip-ft	kip-ft	kip-ft	kips	kips				kips	kips
	in.^{3}	ASD	LRFD	ASD	LRFD	ASD	LRFD	ft	ft	in.^{4}	ASD	LRFD
W24×84	**224**	**559**	**840**	**342**	**515**	**16.2**	**24.3**	**6.89**	**20.3**	**2370**	**227**	**340**
W21×93	221	551	829	335	504	14.6	21.9	6.50	21.3	2070	251	376
W12×136	214	534	803	325	488	4.01	6.03	11.2	63.3	1240	212	318
W14×120	212	529	795	332	499	5.09	7.64	13.2	52.0	1380	171	256
W18×97	211	526	791	328	494	9.45	14.2	9.36	30.3	1750	199	298
W24×76	**200**	**499**	**750**	**307**	**462**	**15.0**	**22.5**	**6.78**	**19.6**	**2100**	**210**	**316**
W16×100	198	494	743	306	459	7.90	11.9	8.87	32.7	1490	199	298
W21×83	196	489	735	299	449	13.8	20.8	6.46	20.2	1830	221	331
W14×109	192	479	720	302	454	5.02	7.54	13.2	48.4	1240	150	226
W18×86	186	464	698	290	436	9.04	13.6	9.29	28.5	1070	177	265
W12×120	186	464	698	285	428	3.95	5.93	11.1	56.5	1530	186	279
W24×68	**177**	**442**	**664**	**269**	**404**	**14.1**	**21.2**	**6.61**	**18.8**	**1830**	**197**	**295**
W16×89	175	437	656	271	407	7.74	11.6	8.80	30.2	1300	176	264
W14×99[f]	173	430	646	274	412	4.89	7.35	13.5	45.3	1110	137	206
W21×73	172	429	645	264	396	12.9	19.4	6.39	19.2	1600	193	290
W12×106	164	409	615	253	381	3.93	5.90	11.0	50.7	933	157	236
W18×76	163	407	611	255	383	8.49	12.8	9.22	27.1	1330	155	232
W21×68	**160**	**399**	**600**	**245**	**368**	**12.5**	**18.8**	**6.36**	**18.7**	**1480**	**182**	**273**
W14×90[f]	157	382	573	250	375	4.80	7.22	15.2	42.6	999	123	185
W24x62	**153**	**382**	**574**	**229**	**344**	**16.0**	**24.1**	**4.87**	**14.4**	**1550**	**204**	**306**
W16×77	150	374	563	234	352	7.34	11.0	8.72	27.8	1110	150	225
W12×96	147	367	551	229	344	3.87	5.81	10.9	46.6	833	140	210
W10×112	147	367	551	220	331	2.68	4.02	9.47	64.3	716	172	257
W18×71	146	364	548	222	333	10.5	15.7	6.00	19.6	1170	183	274
W21×62	**144**	**359**	**540**	**222**	**333**	**11.6**	**17.4**	**6.25**	**18.1**	**1330**	**168**	**252**
W14×82	139	347	521	215	323	5.43	8.16	8.76	33.1	881	146	219
W24×55[v]	**134**	**334**	**503**	**199**	**299**	**14.8**	**22.2**	**4.73**	**13.9**	**1350**	**167**	**251**
W18×65	133	332	499	204	307	9.92	14.9	5.97	18.8	1070	165	248
W12×87	132	329	495	206	310	3.84	5.76	10.8	43.0	740	129	194
W16×67	130	324	488	204	307	6.91	10.4	8.69	26.1	954	129	194
W10×100	130	324	488	196	294	2.66	4.01	9.36	57.7	623	151	226
W21×57	129	322	484	194	291	13.4	20.1	4.77	14.3	1170	171	256

ASD	LRFD
$\Omega_b = 1.67$ $\Omega_v = 1.50$	$\phi_b = 0.90$ $\phi_v = 1.00$

[f] Shape exceeds compact limit for flexure with $F_y = 50$ ksi.
[v] Shape does not meet the h/t_w limit for shear in Specification Section G2.1a with $F_y = 50$ ksi, $\Omega_v = 1.67$, $\phi_v = 0.90$.

Table 3–2 (continued)
W Shapes
Selection by Z_x

$F_y = 50$ ksi

Shape	Z_x	M_{px}/Ω_b	$\phi_b M_{px}$	M_{rx}/Ω_b	$\phi_b M_{rx}$	BF	BF	L_p	L_r	I_x	V_{nx}/Ω_v	$\phi_v V_{nx}$
		kip-ft	kip-ft	kip-ft	kip-ft	kips	kips				kips	kips
	in.^{3}	ASD	LRFD	ASD	LRFD	ASD	LRFD	ft	ft	in.^{4}	ASD	LRFD
W21×55	**126**	314	**473**	192	**289**	10.8	**16.3**	**6.11**	**17.4**	**1140**	156	**234**
W14×74	126	314	473	196	294	5.34	8.03	8.76	31.0	795	128	191
W18×60	123	307	461	189	284	9.64	14.5	5.93	18.2	984	151	227
W12×79	119	297	446	187	281	3.77	5.67	10.8	39.9	662	116	175
W14×68	115	287	431	180	270	5.20	7.81	8.69	29.3	722	117	175
W10×88	113	282	424	172	259	2.63	3.95	9.29	51.1	534	131	197
W18×55	**112**	279	**420**	172	**258**	9.26	**13.9**	**5.90**	**17.5**	**890**	141	**212**
W21×50	**110**	274	**413**	165	**248**	12.2	**18.3**	**4.59**	**13.6**	**984**	158	**237**
W12×72	108	269	405	170	256	3.72	5.59	10.7	37.4	597	105	158
W21×48[f]	**107**	265	**398**	162	**244**	9.78	**14.7**	**6.09**	**16.6**	**959**	144	**217**
W16×57	105	262	394	161	242	7.98	12.0	5.65	18.3	758	141	212
W14×61	102	254	383	161	242	4.96	7.46	8.65	27.5	640	104	156
W18×50	101	252	379	155	233	8.69	13.1	5.83	17.0	800	128	192
W10×77	97.6	244	366	150	225	2.59	3.90	9.18	45.2	455	112	169
W12×65[f]	96.8	237	356	154	231	3.60	5.41	11.9	35.1	533	94.5	142
W21×44	**95.4**	238	**358**	143	**214**	11.2	**16.8**	**4.45**	**13.0**	**843**	145	**217**
W16×50	92.0	230	345	141	213	7.59	11.4	5.62	17.2	659	124	185
W18×46	90.7	226	340	138	207	9.71	14.6	4.56	13.7	712	130	195
W14×53	87.1	217	327	136	204	5.27	7.93	6.78	22.2	541	103	155
W12×58	86.4	216	324	136	205	3.76	5.66	8.87	29.9	475	87.8	132
W10×68	85.3	213	320	132	199	2.57	3.86	9.15	40.6	394	97.8	147
W16×45	82.3	205	309	127	191	7.16	10.8	5.55	16.5	586	111	167
W18×40	**78.4**	196	**294**	119	**180**	8.88	**13.3**	**4.49**	**13.1**	**612**	113	**169**
W14×48	78.4	196	294	123	184	5.10	7.66	6.75	21.1	484	93.8	141
W12×53	77.9	194	292	123	185	3.65	5.48	8.76	28.2	425	83.2	125
W10×60	74.6	186	280	116	175	2.53	3.80	9.08	36.6	341	85.8	129
W16×40	**73.0**	182	**274**	113	**170**	6.69	**10.1**	**5.55**	**15.9**	**518**	97.7	**146**
W12×50	71.9	179	270	112	169	3.97	5.97	6.92	23.9	391	90.2	135
W8×67	70.1	175	263	105	159	1.73	2.60	7.49	47.7	272	103	154
W14×43	69.6	174	261	109	164	4.82	7.24	6.68	20.0	428	83.3	125
W10×54	66.6	166	250	105	158	2.49	3.74	9.04	33.7	303	74.7	112

ASD	LRFD
$\Omega_b = 1.67$ $\Omega_v = 1.50$	$\phi_b = 0.90$ $\phi_v = 1.00$

[f] Shape exceeds compact limit for flexure with $F_y = 50$ ksi.

Table 3–2 (continued)
W Shapes
Selection by Z_x

$F_y = 50$ ksi

Shape	Z_x	M_{px}/Ω_b	$\phi_b M_{px}$	M_{rx}/Ω_b	$\phi_b M_{rx}$	BF	BF	L_p	L_r	I_x	V_{nx}/Ω_v	$\phi_v V_{nx}$
		kip-ft	kip-ft	kip-ft	kip-ft	kips	kips				kips	kips
	in.^{3}	ASD	LRFD	ASD	LRFD	ASD	LRFD	ft	ft	in.^{4}	ASD	LRFD
W18×35	**66.5**	166	**249**	101	**151**	8.07	**12.1**	**4.31**	**12.4**	**510**	106	**159**
W12×45	64.2	160	241	101	151	3.83	5.75	6.89	22.4	348	80.8	121
W16×36	64.0	160	240	98.7	148	6.19	9.31	5.37	15.2	448	93.6	140
W14×38	61.5	153	231	95.4	143	5.39	8.10	5.47	16.2	385	87.4	131
W10×49	60.4	151	227	95.4	143	2.44	3.67	8.97	31.6	272	68.0	102
W8×58	59.8	149	224	90.8	137	1.70	2.56	7.42	41.7	228	89.3	134
W12×40	57.0	142	214	89.9	135	3.66	5.50	6.85	21.1	307	70.4	106
W10×45	54.9	137	206	85.8	129	2.59	3.89	7.10	26.9	248	70.7	106
W14×34	**54.6**	136	**205**	84.9	**128**	5.05	**7.59**	**5.40**	**15.6**	**340**	79.7	**120**
W16×31	**54.0**	135	**203**	82.4	**124**	6.76	**10.2**	**4.13**	**11.9**	**375**	87.3	**131**
W12×35	51.2	128	192	79.6	120	4.28	6.43	5.44	16.7	285	75.0	113
W8×48	49.0	122	184	75.4	113	1.68	2.53	7.35	35.2	184	68.0	102
W14×30	**47.3**	118	**177**	73.4	**110**	4.65	**6.99**	**5.26**	**14.9**	**291**	74.7	**112**
W10×39	46.8	117	176	73.5	111	2.51	3.77	6.99	24.2	209	62.5	93.7
W16×26[v]	**44.2**	110	**166**	67.1	**101**	5.96	**8.96**	**3.96**	**11.2**	**301**	70.5	**106**
W12×30	43.1	108	162	67.4	101	3.92	5.89	5.37	15.6	238	64.2	96.3
W14×26	**40.2**	100	**151**	61.7	**92.7**	5.32	**7.99**	**3.81**	**11.1**	**245**	70.9	**106**
W8×40	39.8	99.3	149	62.0	93.2	1.64	2.47	7.21	29.9	146	59.4	89.1
W10×33	38.8	96.8	146	61.1	91.9	2.39	3.59	6.85	21.8	171	56.4	84.7
W12×26	**37.2**	92.8	**140**	58.3	**87.7**	3.61	**5.42**	**5.33**	**14.9**	**204**	56.2	**84.3**
W10×30	36.6	91.3	137	56.6	85.0	3.08	4.62	4.84	16.1	170	62.8	94.2
W8×35	34.7	86.6	130	54.5	81.9	1.62	2.43	7.17	27.0	127	50.3	75.5
W14×22	**33.2**	82.8	**125**	50.6	**76.1**	4.75	**7.14**	**3.67**	**10.4**	**199**	63.2	**94.8**
W10×26	31.3	78.1	117	48.7	73.2	2.90	4.36	4.80	14.9	144	53.7	80.6
W8×31[f]	30.4	75.8	114	48.0	72.2	1.58	2.37	7.18	24.8	110	45.6	68.4
W12×22	**29.3**	73.1	**110**	44.4	**66.7**	4.65	**6.99**	**3.00**	**9.17**	**156**	64.0	**96.0**
W8×28	27.2	67.9	102	42.4	63.8	1.66	2.50	5.72	21.0	98.0	45.9	68.9
W10×22	**26.0**	64.9	**97.5**	40.5	**60.9**	2.68	**4.02**	**4.70**	**13.8**	**118**	48.8	**73.2**
W12×19	**24.7**	61.6	**92.6**	37.2	**55.9**	4.27	**6.43**	**2.90**	**8.62**	**130**	57.2	**85.7**
W8×24	23.1	57.6	86.6	36.5	54.9	1.59	2.39	5.69	19.0	82.7	38.9	58.3
W10×19	**21.6**	53.9	**81.0**	32.8	**49.3**	3.17	**4.77**	**3.09**	**9.72**	**96.3**	51.2	**76.8**
W8×21	20.4	50.9	76.5	31.8	47.8	1.86	2.79	4.45	14.8	75.3	41.4	62.1

ASD	LRFD
$\Omega_b = 1.67$ $\Omega_v = 1.50$	$\phi_b = 0.90$ $\phi_v = 1.00$

[f] Shape exceeds compact limit for flexure with $F_y = 50$ ksi.
[v] Shape does not meet the h/t_w limit for shear in Specification Section G2.1a with $F_y = 50$ ksi, $\Omega_v = 1.67$, $\phi_v = 0.90$.

Appendix J: Steel Takeoff

Structural Steel Subtracted from Design						
Area	Column Line		Size	Length	Wt./foot	Weight
	Along	Spanning		(ft)	(lb/ft)	(lb)
AHU-1	D	2-3	W30x99	30	99	2,970.0
AHU-1	D.4	2-2.5	W14x30	15	30	450.0
AHU-1	D.6	2-2.5	W16x26	14.75	26	383.5
AHU-1	D.8	2.3-3	W12x16	22.5	16	360.0
AHU-1	D.8	2-2.3	W14x30	7.5	30	225.0
AHU-1	E	2-3	W30x99	30	99	2,970.0
AHU-1	E.3	2.75-3	W12x19	7.5	19	142.5
AHU-1	E.4	2.75-3	W12x19	7.5	19	142.5
AHU-1	E.5	2.3-3	W12x16	22.5	16	360.0
AHU-1	E.5	2-2.3	W14x30	7.5	30	225.0
AHU-1	E.6	2.75-3	W12x19	7.5	19	142.5
AHU-1	E.65	2.75-3	W12x19	7.5	19	142.5
AHU-1	E.7	2-2.5	W18x35	14.75	35	516.3
AHU-1	E.9	2-2.5	W16x26	14.75	26	383.5
AHU-1	F	2-3	W30x99	30	99	2,970.0
AHU-1	F.5	2-2.5	W14x30	13.75	30	412.5
AHU-1	F.7	2.25-2.75	W18x35	14.75	35	516.3
AHU-1	2	D-E	W24x55	30	55	1,650.0
AHU-1	2	E-F	W24x55	30	55	1,650.0
AHU-1	2.25	D-D.4	W12x16	9.25	16	148.0
AHU-1	2.25	D.6 - E	W14x22	13.4	22	294.8
AHU-1	2.25	E-E.7	W16x26	22.3	26	579.8
AHU-1	2.25	E.9-F	W14x22	2.7	22	59.4
AHU-1	2.25	F-F.7	W21x44	23.4	44	1,029.6
AHU-1	2.5	D-E	W24x55	30	55	1,650.0
AHU-1	2.5	E-F	W24x55	30	55	1,650.0
AHU-3	F.6	5.2-5.7	W12x19	13.3	19	252.7
AHU-3	F.8	5.2-5.7	W12x19	13.3	19	252.7
AHU-3	G	6-7	W24x55	14	55	770.0
AHU-3	G.2	5.5-6	W12x16	13.3	16	212.8
AHU-3	G.3	6-7	W16x26	14	26	364.0
AHU-3	G.8	5.5-6	W12x16	13.3	16	212.8
AHU-3	G.9	6-7	W16x26	14	26	364.0
AHU-3	H	6-7	W24x55	14	55	770.0
AHU-3	H.4	5.8-7	W12x16	17.2	16	275.2
AHU-3	H.5	6.6-7	W12x16	4	16	64.0
AHU-3	5.4	F.6-F.8	W12x19	4	19	76.0
AHU-3	5.6	F.6-F.8	W12x19	4	19	76.0
AHU-3	5.6	G.8-H	W12x16	5.6	16	89.6
AHU-3	5.9	F.7-G.2	W12x16	10.7	16	171.2
AHU-3	5.9	G.8-H	W12x16	6.2	16	99.2
AHU-3	5.9	H-J	W21x50	30	50	1,500.0
AHU-3	6	G-H	W21x44	30	44	1,320.0
AHU-3	6.5	G.2-G.8	W14x22	21.3	22	468.6
AHU-3	6.9	F.7-G	W12x16	6.2	16	99.2
AHU-3	6.9	G-H	W21x44	30	44	1,320.0
AHU-3	6.10	H-J	W21x44	30	44	1,320.0
Total						**32,101.6**

Structural Steel Added to Design						
Area	Column Line		Size	Length (ft)	Wt./foot (lb/ft)	Weight (lb)
	Along	Spanning				
AHU-1	D	2-3	W27x84	30	84	2,520.0
AHU-1	E	2-3	W27x84	30	84	2,520.0
AHU-1	F	2-3	W27x84	30	84	2,520.0
AHU-1	2	D-E	W18x40	30	40	1,200.0
AHU-1	2	E-F	W18x40	30	40	1,200.0
AHU-1	2.25	D-E	W18x40	30	40	1,200.0
AHU-1	2.25	E-F	W18x40	30	40	1,200.0
AHU-1	2.25	F-F.7	W16x36	23.2	36	835.2
AHU-1	2.5	D-E	W18x40	30	40	1,200.0
AHU-1	2.5	E-F	W18x40	30	40	1,200.0
AHU-3	G	6-7	W21x44	14	44	616.0
AHU-3	H	6-7	W21x44	14	44	616.0
AHU-3	6	G-H	W18x40	30	40	1,200.0
AHU-3	6.5	G-H	W18x40	30	40	1,200.0
Total						**19,227.2**

Appendix K: National Electric Code Tables

Table 430.250 Full-Load Current, Three-Phase Alternating-Current Motors

The following values of full-load currents are typical for motors running at speeds usual for belted motors and motors with normal torque characteristics.

The voltages listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 to 120, 220 to 240, 440 to 480, and 550 to 600 volts.

	Induction-Type Squirrel Cage and Wound Rotor (Amperes)							Synchronous-Type Unity Power Factor* (Amperes)			
Horsepower	115 Volts	200 Volts	208 Volts	230 Volts	460 Volts	575 Volts	2300 Volts	230 Volts	460 Volts	575 Volts	2300 Volts
½	4.4	2.5	2.4	2.2	1.1	0.9	—	—	—	—	—
¾	6.4	3.7	3.5	3.2	1.6	1.3	—	—	—	—	—
1	8.4	4.8	4.6	4.2	2.1	1.7	—	—	—	—	—
1½	12.0	6.9	6.6	6.0	3.0	2.4	—	—	—	—	—
2	13.6	7.8	7.5	6.8	3.4	2.7	—	—	—	—	—
3	—	11.0	10.6	9.6	4.8	3.9	—	—	—	—	—
5	—	17.5	16.7	15.2	7.6	6.1	—	—	—	—	—
7½	—	25.3	24.2	22	11	9	—	—	—	—	—
10	—	32.2	30.8	28	14	11	—	—	—	—	—
15	—	48.3	46.2	42	21	17	—	—	—	—	—
20	—	62.1	59.4	54	27	22	—	—	—	—	—
25	—	78.2	74.8	68	34	27	—	53	26	21	—
30	—	92	88	80	40	32	—	63	32	26	—
40	—	120	114	104	52	41	—	83	41	33	—
50	—	150	143	130	65	52	—	104	52	42	—
60	—	177	169	154	77	62	16	123	61	49	12
75	—	221	211	192	96	77	20	155	78	62	15
100	—	285	273	248	124	99	26	202	101	81	20
125	—	359	343	312	156	125	31	253	126	101	25
150	—	414	396	360	180	144	37	302	151	121	30
200	—	552	528	480	240	192	49	400	201	161	40
250	—	—	—	—	302	242	60	—	—	—	—
300	—	—	—	—	361	289	72	—	—	—	—
350	—	—	—	—	414	336	83	—	—	—	—
400	—	—	—	—	477	382	95	—	—	—	—
450	—	—	—	—	515	412	103	—	—	—	—
500	—	—	—	—	590	472	118	—	—	—	—

*For 90 and 80 percent power factor, the figures shall be multiplied by 1.1 and 1.25, respectively.

2008 Edition NATIONAL ELECTRICAL CODE 70–325

NEMA Size	Ampere Rating
00	9 Amps
0	18 Amps
1	27 Amps
2	45 Amps
3	90 Amps
4	135 Amps
5	270 Amps
6	540 Amps
7	810 Amps
8	1215 Amps
9	2250 Amps

Table 310.16 Allowable Ampacities of Insulated Conductors Rated 0 Through 2000 Volts, 60°C Through 90°C (194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Temperature of 30°C (86°F)

	Temperature Rating of Conductor [See Table 310.13(A).]					
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)
Size AWG or kcmil	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM		
18	—	—	14	—	—	—
16	—	—	18	—	—	—
14*	20	20	25	—	—	—
12*	25	25	30	20	20	25
10*	30	35	40	25	30	35
8	40	50	55	30	40	45
6	55	65	75	40	50	60
4	70	85	95	55	65	75
3	85	100	110	65	75	85
2	95	115	130	75	90	100
1	110	130	150	85	100	115
1/0	125	150	170	100	120	135
2/0	145	175	195	115	135	150
3/0	165	200	225	130	155	175
4/0	195	230	260	150	180	205
250	215	255	290	170	205	230
300	240	285	320	190	230	255
350	260	310	350	210	250	280
400	280	335	380	225	270	305
500	320	380	430	260	310	350
600	355	420	475	285	340	385
700	385	460	520	310	375	420
750	400	475	535	320	385	435
800	410	490	555	330	395	450
900	435	520	585	355	425	480
1000	455	545	615	375	445	500
1250	495	590	665	405	485	545
1500	520	625	705	435	520	585
1750	545	650	735	455	545	615
2000	560	665	750	470	560	630

Table C.1 Maximum Number of Conductors or Fixture Wires in Electrical Metallic Tubing (EMT) (*Based on Table 1, Chapter 9*)

CONDUCTORS											
	Conductor Size	Metric Designator (Trade Size)									
Type	(AWG kcmil)	16 (½)	21 (¾)	27 (1)	35 (1¼)	41 (1½)	53 (2)	63 (2½)	78 (3)	91 (3½)	103 (4)
RHH, RHW, RHW-2	14	4	7	11	20	27	46	80	120	157	201
	12	3	6	9	17	23	38	66	100	131	167
	10	2	5	8	13	18	30	53	81	105	135
	8	1	2	4	7	9	16	28	42	55	70
	6	1	1	3	5	8	13	22	34	44	56
	4	1	1	2	4	6	10	17	26	34	44
	3	1	1	1	4	5	9	15	23	30	38
	2	1	1	1	3	4	7	13	20	26	33
	1	0	1	1	1	3	5	9	13	17	22
	1/0	0	1	1	1	2	4	7	11	15	19
	2/0	0	1	1	1	2	4	6	10	13	17
	3/0	0	0	1	1	1	3	5	8	11	14
	4/0	0	0	1	1	1	3	5	7	9	12
	250	0	0	0	1	1	1	3	5	7	9
	300	0	0	0	1	1	1	3	5	6	8
	350	0	0	0	1	1	1	3	4	6	7
	400	0	0	0	1	1	1	2	4	5	7
	500	0	0	0	0	1	1	2	3	4	6
	600	0	0	0	0	1	1	1	3	4	5
	700	0	0	0	0	0	1	1	2	3	4
	750	0	0	0	0	0	1	1	2	3	4
	800	0	0	0	0	0	1	1	2	3	4
	900	0	0	0	0	0	1	1	1	3	3
	1000	0	0	0	0	0	1	1	1	2	3
	1250	0	0	0	0	0	0	1	1	1	2
	1500	0	0	0	0	0	0	1	1	1	1
	1750	0	0	0	0	0	0	1	1	1	1
	2000	0	0	0	0	0	0	1	1	1	1
TW	14	8	15	25	43	58	96	168	254	332	424
	12	6	11	19	33	45	74	129	195	255	326
	10	5	8	14	24	33	55	96	145	190	243
	8	2	5	8	13	18	30	53	81	105	135
RHH*, RHW*, RHW-2*, THHW, THW, THW-2	14	6	10	16	28	39	64	112	169	221	282
RHH*, RHW*, RHW-2*, THHW, THW	12	4	8	13	23	31	51	90	136	177	227
	10	3	6	10	18	24	40	70	106	138	177
RHH*, RHW*, RHW-2*, THHW, THW, THW-2	8	1	4	6	10	14	24	42	63	83	106

Table C.1 *Continued*

		CONDUCTORS									
	Conductor Size	Metric Designator (Trade Size)									
Type	(AWG kcmil)	16 (½)	21 (¾)	27 (1)	35 (1¼)	41 (1½)	53 (2)	63 (2½)	78 (3)	91 (3½)	103 (4)
RHH*, RHW*, RHW-2*, TW, THW, THHW, THW-2	6	1	3	4	8	11	18	32	48	63	81
	4	1	1	3	6	8	13	24	36	47	60
	3	1	1	3	5	7	12	20	31	40	52
	2	1	1	2	4	6	10	17	26	34	44
	1	1	1	1	3	4	7	12	18	24	31
	1/0	0	1	1	2	3	6	10	16	20	26
	2/0	0	1	1	1	3	5	9	13	17	22
	3/0	0	1	1	1	2	4	7	11	15	19
	4/0	0	0	1	1	1	3	6	9	12	16
	250	0	0	1	1	1	3	5	7	10	13
	300	0	0	1	1	1	2	4	6	8	11
	350	0	0	0	1	1	1	4	6	7	10
	400	0	0	0	1	1	1	3	5	7	9
	500	0	0	0	1	1	1	3	4	6	7
	600	0	0	0	1	1	1	2	3	4	6
	700	0	0	0	0	1	1	1	3	4	5
	750	0	0	0	0	1	1	1	3	4	5
	800	0	0	0	0	1	1	1	3	3	5
	900	0	0	0	0	0	1	1	2	3	4
	1000	0	0	0	0	0	1	1	2	3	4
	1250	0	0	0	0	0	1	1	1	2	3
	1500	0	0	0	0	0	1	1	1	1	2
	1750	0	0	0	0	0	0	1	1	1	2
	2000	0	0	0	0	0	0	1	1	1	1
THHN, THWN, THWN-2	14	12	22	35	61	84	138	241	364	476	608
	12	9	16	26	45	61	101	176	266	347	443
	10	5	10	16	28	38	63	111	167	219	279
	8	3	6	9	16	22	36	64	96	126	161
	6	2	4	7	12	16	26	46	69	91	116
	4	1	2	4	7	10	16	28	43	56	71
	3	1	1	3	6	8	13	24	36	47	60
	2	1	1	3	5	7	11	20	30	40	51
	1	1	1	1	4	5	8	15	22	29	37
	1/0	1	1	1	3	4	7	12	19	25	32
	2/0	0	1	1	2	3	6	10	16	20	26
	3/0	0	1	1	1	3	5	8	13	17	22
	4/0	0	1	1	1	2	4	7	11	14	18
	250	0	0	1	1	1	3	6	9	11	15
	300	0	0	1	1	1	3	5	7	10	13
	350	0	0	1	1	1	2	4	6	9	11
	400	0	0	0	1	1	1	4	6	8	10
	500	0	0	0	1	1	1	3	5	6	8
	600	0	0	0	1	1	1	2	4	5	7
	700	0	0	0	1	1	1	2	3	4	6
	750	0	0	0	0	1	1	1	3	4	5
	800	0	0	0	0	1	1	1	3	4	5
	900	0	0	0	0	1	1	1	3	3	4
	1000	0	0	0	0	1	1	1	2	3	4
FEP, FEPB, PFA, PFAH, TFE	14	12	21	34	60	81	134	234	354	462	590
	12	9	15	25	43	59	98	171	258	337	430
	10	6	11	18	31	42	70	122	185	241	309
	8	3	6	10	18	24	40	70	106	138	177
	6	2	4	7	12	17	28	50	75	98	126
	4	1	3	5	9	12	20	35	53	69	88
	3	1	2	4	7	10	16	29	44	57	73
	2	1	1	3	6	8	13	24	36	47	60

(Continues)

Appendix L: Panelboard Schedules

277/480 Volt, 3 Phase, 4 Wire, 900 A — **ORIGINAL NHP1-01** — Panel Location: Room 1A209

M.L.O. 35000 AIC Fully Rated, Surface Mounted

100% Rated Neutral, Door -in- Door Construction

Descriptions	Amps	Poles	CCT	Phase	CCT	Amps	Poles	Descriptions
Exterior Garden Lighting	20	3	1	A	2	20	1	S-7
Ground Floor Lighting	20	1	3	B	4	20	1	-----------5 HP-----------
First Floor Lighting	20	1	5	C	6	20	1	--------------------------
First Floor Lighting	20	1	7	A	8	20	1	R-7
First Floor Lighting	20	1	9	B	10	20	1	-----------1 HP-----------
Ground Floor Lighting	20	1	11	C	12	20	1	--------------------------
PCHWP-1	25	3	13	A	14	20	1	AD-1
-----------10 HP-----------	–	--	15	B	16	20	1	-----------(2) 1/2 HP------
--------------------------	–	--	17	C	18	20	1	--------------------------
PCHWP-2	25	3	19	A	20	20	1	AD-2
-----------10 HP-----------	–	--	21	B	22	20	1	-----------(2) 1/2 HP-----
--------------------------	–	--	23	C	24	20	1	--------------------------
SCHWP-1	70	3	25	A	26	80	3	CWP-2
-----------25 HP-----------	–	--	27	B	28	--	--	-----------30 HP-----------
--------------------------	–	--	29	C	30	--	--	--------------------------
SCHWP-2	70	3	31	A	32	20	1	PHWP-2
-----------25 HP-----------	–	--	33	B	34	20	1	-----------5 HP-----------
--------------------------	–	--	35	C	36	20	1	--------------------------
CWP-1	80	3	37	A	38	110	3	NT1-01/Panel NLP1-01
-----------30 HP-----------	–	--	39	B	40	--	--	-----------75 VA-----------
--------------------------	–	--	41	C	42	--	--	--------------------------

277/480 Volt, 3 Phase, 4 Wire, 800 A — **NEW NHP1-01** — Panel Location: Room 1A209

M.L.O. 35000 AIC Fully Rated, Surface Mounted

100% Rated Neutral, Door -in- Door Construction

Descriptions	Amps	Poles	CCT	Phase	CCT	Amps	Poles	Descriptions
Exterior Garden Lighting	20	3	1	A	2	20	1	S-7
Ground Floor Lighting	20	1	3	B	4	20	1	-----------5 HP-----------
First Floor Lighting	20	1	5	C	6	20	1	--------------------------
First Floor Lighting	20	1	7	A	8	20	1	R-7
First Floor Lighting	20	1	9	B	10	20	1	-----------1 HP-----------
Ground Floor Lighting	20	1	11	C	12	20	1	--------------------------
PCHWP-1	15	3	13	A	14	20	1	AD-1
-----------5 HP-----------	–	--	15	B	16	20	1	-----------(2) 1/2 HP------
--------------------------	–	--	17	C	18	20	1	--------------------------
PCHWP-2	25	3	19	A	20	20	1	AD-2
-----------7.5 HP-----------	–	--	21	B	22	20	1	-----------(2) 1/2 HP-----
--------------------------	–	--	23	C	24	20	1	--------------------------
SCHWP-1	40	3	25	A	26	40	3	CWP-2
-----------15 HP-----------	–	--	27	B	28	--	--	-----------15 HP-----------
--------------------------	–	--	29	C	30	--	--	--------------------------
SCHWP-2	80	3	31	A	32	20	1	PHWP-2
-----------25 HP-----------	–	--	33	B	34	20	1	-----------5 HP-----------
--------------------------	–	--	35	C	36	20	1	--------------------------
CWP-1	40	3	37	A	38	110	3	NT1-01/Panel NLP1-01
-----------15 HP-----------	–	--	39	B	40	--	--	-----------75 VA-----------
--------------------------	–	--	41	C	42	--	0	--------------------------

277/480 Volt, 3 Phase, 4 Wire, 225 A				ORIGINAL NHP1-02				Panel Location: Room 1A206
M.L.O. 65000 AIC Fully Rated, Surface Mounted								
100% Rated Neutral, Door -in- Door Construction								
Descriptions	Amps	Poles	CCT	Phase	CCT	Amps	Poles	Descriptions
Snow Melt - Stairs	20	3	1	A	2	60	3	SHWP-2
Snow Melt- West Entry	40	1	3	B	4	--	--	-----------20 HP------------
Ground Floor Lighting	20	1	5	C	6	--	--	----------------------------
First Floor Lighting	20	1	7	A	8	20	3	CP-1
Spare	20	1	9	B	10	--	--	----------1 1/2 HP---------
Spare	20	1	11	C	12	--	--	----------------------------
Spare	20	1	13	A	14	20	1	Spare
Spare	20	1	15	B	16	20	1	Spare
Spare	20	1	17	C	18	20	1	Spare
Spare	20	1	19	A	20	20	1	Spare
Spare	20	1	21	B	22	20	1	Spare
Spare	20	1	23	C	24	20	1	Spare
Spare	20	1	25	A	26	20	1	Spare
Spare	20	1	27	B	28	20	1	Spare
Spare	20	1	29	C	30	20	1	Spare
Spare	20	1	31	A	32	20	1	Spare
Spare	20	1	33	B	34	20	1	Spare
Spare	20	1	35	C	36	20	1	Spare
Spare	20	1	37	A	38	50	3	NT1-01
Spare	20	1	39	B	40	--	--	-----------30 KVA------------
Spare	20	1	41	C	42	--	--	------------------------------

277/480 Volt, 3 Phase, 4 Wire, 400 A				NEW NHP1-02				Panel Location: Room 1A206
M.L.O. 65000 AIC Fully Rated, Surface Mounted								
100% Rated Neutral, Door -in- Door Construction								
Descriptions	Amps	Poles	CCT	Phase	CCT	Amps	Poles	Descriptions
Snow Melt - Stairs	20	3	1	A	2	60	3	SHWP-2
Snow Melt- West Entry	40	1	3	B	4	--	--	-----------20 HP------------
Ground Floor Lighting	20	1	5	C	6	--	--	----------------------------
First Floor Lighting	20	1	7	A	8	20	3	CP-1
Spare	20	1	9	B	10	--	--	----------1 1/2 HP---------
Spare	20	1	11	C	12	--	--	----------------------------
PCHWP-3	25	3	13	A	14	20	1	Spare
-----------7.5 HP------------	–	--	15	B	16	20	1	Spare
------------------------------	–	--	17	C	18	20	1	Spare
SCHWP-3	80	3	19	A	20	20	1	Spare
-----------25 HP------------	–	--	21	B	22	20	1	Spare
------------------------------	–	--	23	C	24	20	1	Spare
Spare	20	1	25	A	26	20	1	Spare
Spare	20	1	27	B	28	20	1	Spare
Spare	20	1	29	C	30	20	1	Spare
Spare	20	1	31	A	32	20	1	Spare
Spare	20	1	33	B	34	20	1	Spare
Spare	20	1	35	C	36	20	1	Spare
Spare	20	1	37	A	38	50	3	NT1-01
Spare	20	1	39	B	40	--	--	-----------30 KVA------------
Spare	20	1	41	C	42	--	0	------------------------------

277/480 Volt, 3 Phase, 4 Wire, 1200 A		ORIGINAL EHQ7-01		
Location: 7A101A	M.L.O. 65000 AIC Fully Rated			
Grouind Bus, 100% Rated Neutral				
Descriptions	Amps	Poles	CCT	Phase
S-1	225	3	1	A
------------125 HP-------------	--	--		B
---------------------------------	--	--		C
S-2	225	3	2	A
------------125 HP-------------	--	--		B
---------------------------------	--	--		C
S-3	225	3	3	A
------------125 HP-------------	--	--		B
---------------------------------	--	--		C
R-1	100	3	4	A
------------50 HP-------------	--	--		B
---------------------------------	--	--		C
R-2	100	3	5	A
------------50 HP-------------	--	--		B
---------------------------------	--	--		C
R-3	100	3	6	A
------------50 HP-------------	--	--		B
---------------------------------	--	--		C
E-3	20	3	7	A
------------10 HP-------------	--	--		B
-------------------------------	--	--		C
MAU-3	20	1	8	A
--------5 HP----------------	--	--		B
-------------------------------	--	--		C
FC-1, FC-2	20	1	9	A
--------1 HP, 3/4 HP----------	--	--		B
-------------------------------	--	--		C
FC-3, FC-4	20	1	10	A
--------1 HP, 3/4 HP----------	--	--		B
-------------------------------	--	--		C
ELPQ7-01	20	1	11	A
---------XFMR ETQ&-01----------	--	--		B
-------------------------------	--	--		C

277/480 Volt, 3 Phase, 4 Wire, 800 A			NEW EHQ7-01	
Location: 7A101A	M.L.O. 65000 AIC Fully Rated			
Grouind Bus, 100% Rated Neutral				
Descriptions	Amps	Poles	CCT	Phase
S-1	225	3	1	A
------------75 HP-------------	--	--		B
---------------------------------	--	--		C
S-2	225	3	2	A
------------75 HP-------------	--	--		B
---------------------------------	--	--		C
Spare	--	3	3	A
---------------------------------	--	--		B
---------------------------------	--	--		C
R-1	100	3	4	A
------------40 HP-------------	--	--		B
---------------------------------	--	--		C
R-2	100	3	5	A
------------40 HP-------------	--	--		B
---------------------------------	--	--		C
Spare	--	3	6	A
---------------------------------	--	--		B
---------------------------------	--	--		C
E-3	20	3	7	A
------------10 HP-------------	--	--		B
-------------------------------	--	--		C
MAU-3	20	1	8	A
--------5 HP----------------	--	--		B
-------------------------------	--	--		C
FC-1, FC-2	20	1	9	A
--------1 HP, 3/4 HP----------	--	--		B
-------------------------------	--	--		C
FC-3, FC-4	20	1	10	A
--------1 HP, 3/4 HP----------	--	--		B
-------------------------------	--	--		C
ELPQ7-01	20	1	11	A
---------XFMR ETQ&-01----------	--	--		B
-------------------------------	--	--		C

277/480 VOLT, 3 PHASE, 4 WIRE, 5000A	ORIGINAL NSWB1-01 a									Panel Location: Room 1A206
5000A M.C.B., 65000 AIC, FULLY RATED, GROUND BUS, 100% RATED NEUTRAL,					LOADS (kVA)					
Descriptions	Amps	Poles	Circuit	Phase	Lighting	Recept.	Cont.	Heat/ Non-Cont.	Motors	Kitchen
CH-1	450	3	1	A					79.0	
---	---	---		B					79.0	
---	---	---		C					79.0	
CH-2	450	3	2	A					79.0	
---	---	---		B					79.0	
---	---	---		C					79.0	
NHP1-01	400	3	3	A	4.1	13.3	0.0	0.0	57.4	0.0
---	---	---		B	4.8	12.4	0.0	0.0	60.9	0.0
---	---	---		C	4.6	11.6	0.0	0.0	57.1	0.0
SPARE	150	3	4	A						
---	---	---		B						
---	---	---		C						
NHPPH-01	225	3	5	A	1.1	0.9	0.0	0.0	37.6	0.0
---	---	---		B	0.0	0.2	0.0	0.0	37.6	0.0
---	---	---		C	0.0	0.0	0.0	0.0	37.6	0.0
NHP7-01	225	3	6	A	7.2	13.7	0.0	0.0	0.0	0.0
---	---	---		B	5.0	15.6	0.0	0.0	0.0	0.0
---	---	---		C	5.0	15.0	1.0	0.0	0.0	0.0
NECB7-01	110	3	7	A	1.2	16.3	0.0	0.0	0.0	0.0
---	---	---		B	0.3	13.9	0.0	0.0	0.0	0.0
---	---	---		C	1.2	15.4	0.0	0.0	0.0	0.0
NHP6-01	225	3	8	A	8.3	15.6	0.0	0.0	0.0	0.0
---	---	---		B	4.6	16.9	0.0	0.0	0.0	0.0
---	---	---		C	4.4	14.9	0.0	0.0	0.3	0.0
NECB6-01	110	3	9	A	1.2	15.8	0.0	0.0	0.0	0.0
---	---	---		B	0.3	14.2	0.0	0.0	0.0	0.0
---	---	---		C	1.2	15.6	0.0	0.0	0.0	0.0
NHP5-01	225	3	10	A	9.5	18.8	0.0	0.0	2.2	0.0
---	---	---		B	5.4	13.9	1.0	0.0	3.8	0.0
---	---	---		C	4.6	15.3	0.0	0.0	3.8	0.0
NECB5-01	110	3	11	A	1.2	19.4	0.0	0.0	0.0	0.0
---	---	---		B	0.4	14.0	0.0	0.0	0.6	0.0
---	---	---		C	0.8	14.4	0.0	0.0	0.0	0.0
NHP3-01	225	3	12	A	8.5	#REF!	0.0	0.0	0.0	0.0
---	---	---		B	5.7	25.5	0.0	0.0	0.4	0.0
---	---	---		C	5.9	24.7	1.0	0.0	0.0	0.0
NECB3-01	110	3	13	A	0.1	20.0	0.0	0.0	0.0	0.0
---	---	---		B	0.0	15.0	0.0	0.0	0.0	0.0
---	---	---		C	0.0	16.8	0.0	0.0	0.0	0.0
NHP2-01	225	3	14	A	14.3	21.7	0.0	27.4	0.5	0.0
---	---	---		B	12.0	24.5	0.0	27.4	0.0	0.0
---	---	---		C	13.2	24.1	0.0	13.7	0.8	0.0
NECB2-01	110	3	15	A	3.3	9.6	1.0	0.0	0.5	0.0
---	---	---		B	3.2	5.2	0.0	0.0	0.0	0.0
---	---	---		C	3.2	6.8	0.0	0.0	0.9	0.0
					136.1	#REF!	3.0	68.5	774.4	0.0

277/480 VOLT, 3 PHASE, 4 WIRE, 5000A	NEW NSWB1-01 a				Panel Location: Room 1A206					
5000A M.C.B., 65000 AIC, FULLY RATED, GROUND BUS, 100% RATED NEUTRAL,					LOADS (kVA)					
Descriptions	Amps	Poles	Circuit	Phase	Lighting	Recept.	Cont.	Heat/ Non-Cont.	Motors	Kitchen
CH-1	350	3	1	A					42.3	
—	—	—		B					42.3	
—	—	—		C					42.3	
CH-2	350	3	2	A					42.3	
—	—	—		B					42.3	
—	—	—		C					42.3	
NHP1-01	400	3	3	A	4.1	13.3	0.0	0.0	57.4	0.0
—	—	—		B	4.8	12.4	0.0	0.0	60.9	0.0
—	—	—		C	4.6	11.6	0.0	0.0	57.1	0.0
CH-4	350	3	4	A					42.3	
—	—	—		B					42.3	
—	—	—		C					42.3	
NHPPH-01	225	3	5	A	1.1	0.9	0.0	0.0	37.6	0.0
—	—	—		B	0.0	0.2	0.0	0.0	37.6	0.0
—	—	—		C	0.0	0.0	0.0	0.0	37.6	0.0
NHP7-01	225	3	6	A	7.2	13.7	0.0	0.0	0.0	0.0
—	—	—		B	5.0	15.6	0.0	0.0	0.0	0.0
—	—	—		C	5.0	15.0	1.0	0.0	0.0	0.0
NECB7-01	110	3	7	A	1.2	16.3	0.0	0.0	0.0	0.0
—	—	—		B	0.3	13.9	0.0	0.0	0.0	0.0
—	—	—		C	1.2	15.4	0.0	0.0	0.0	0.0
NHP6-01	225	3	8	A	8.3	15.6	0.0	0.0	0.0	0.0
—	—	—		B	4.6	16.9	0.0	0.0	0.0	0.0
—	—	—		C	4.4	14.9	0.0	0.0	0.3	0.0
NECB6-01	110	3	9	A	1.2	15.8	0.0	0.0	0.0	0.0
—	—	—		B	0.3	14.2	0.0	0.0	0.0	0.0
—	—	—		C	1.2	15.6	0.0	0.0	0.0	0.0
NHP5-01	225	3	10	A	9.5	18.8	0.0	0.0	2.2	0.0
—	—	—		B	5.4	13.9	1.0	0.0	3.8	0.0
—	—	—		C	4.6	15.3	0.0	0.0	3.8	0.0
NECB5-01	110	3	11	A	1.2	19.4	0.0	0.0	0.0	0.0
—	—	—		B	0.4	14.0	0.0	0.0	0.6	0.0
—	—	—		C	0.8	14.4	0.0	0.0	0.0	0.0
NHP3-01	225	3	12	A	8.5	#REF!	0.0	0.0	0.0	0.0
—	—	—		B	5.7	25.5	0.0	0.0	0.4	0.0
—	—	—		C	5.9	24.7	1.0	0.0	0.0	0.0
NECB3-01	110	3	13	A	0.1	20.0	0.0	0.0	0.0	0.0
—	—	—		B	0.0	15.0	0.0	0.0	0.0	0.0
—	—	—		C	0.0	16.8	0.0	0.0	0.0	0.0
NHP2-01	225	3	14	A	14.3	21.7	0.0	27.4	0.5	0.0
—	—	—		B	12.0	24.5	0.0	27.4	0.0	0.0
—	—	—		C	13.2	24.1	0.0	13.7	0.8	0.0
NECB2-01	110	3	15	A	3.3	9.6	1.0	0.0	0.5	0.0
—	—	—		B	3.2	5.2	0.0	0.0	0.0	0.0
—	—	—		C	3.2	6.8	0.0	0.0	0.9	0.0
					136.1	#REF!	3.0	68.5	681.1	0.0

Appendix M: Zone Parameters

Ground Floor - Core							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Corridor	3380	0.88	0	1.20	1.05	0.50	0.44
Mechanical	471	0.12	0	1.40	0.17	50.00	6.12
	3851		0		1.22		6.55

First Floor - Core							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Corridor	5561	0.41	0	1.20	0.50	0.50	0.21
Lobby	2785	0.21	2	1.80	0.37	0.50	0.10
Mechanical	3464	0.26	1	1.40	0.36	6.00	1.54
Office	1455	0.11	7	1.70	0.18	2.00	0.22
Restroom	197	0.01	1	1.10	0.02	0.00	0.00
	13462		11		1.43		2.07

Second Floor - Core							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Corridor	6502	0.24	3	1.20	0.28	1.00	0.24
Lobby	13336	0.49	70	1.80	0.88	1.00	0.49
Mechanical	262	0.01	0	1.40	0.01	25.00	0.24
Office	4713	0.17	101	1.70	0.29	2.00	0.34
Restroom	2620	0.10	0	1.10	0.11	0.00	0.00
	27433		174		1.57		1.31

Second Floor - Exterior North							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Conference	4263	0.74	191	2.00	1.49	2.00	1.49
Corridor	304	0.05	1	1.20	0.06	1.00	0.05
Mechanical	178	0.03	1	1.40	0.04	2.50	0.08
Office	996	0.17	17	1.70	0.29	2.00	0.35
	5741		210		1.89		1.96

Second Floor - Exterior South							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Corridor	73	1.00	2	1.20	1.20	1.00	1.00
	73		0		1.20		1.00

Second Floor - Exterior East							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Lobby	413	1.00	2	1.80	1.80	1.00	1.00
	413		2		1.80		1.00

Second Floor - Exterior West							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Conference	1496	0.67	48	2.00	1.35	2.00	1.35
Corridor	95	0.04	0	1.20	0.05	1.00	0.04
Office	632	0.28	6	1.70	0.48	2.00	0.57
	2223		54		1.88		1.96

Third Floor - Core							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Corridor	11590	0.61	7	1.20	0.73	1.00	0.61
Mechanical	1077	0.06	0	1.40	0.08	22.00	1.24
Office	3389	0.18	35	1.70	0.30	2.00	0.36
Patient	1932	0.10	16	1.60	0.16	2.00	0.20
Restroom	1095	0.06	0	1.10	0.06	0.00	0.00
	19083		58		1.33		2.41

Third Floor - Core (Operating Rooms)							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Operating	8012	1.00	87	2.80	2.80	4.00	4.00
	8012		87		2.80		4.00

Third Floor - Exterior North							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Patient	1447	0.89	13	1.60	1.43	2.00	1.79
Mechanical	115	0.07	0	1.40	0.10	2.50	0.18
Restroom	58	0.04	0	1.10	0.04	0.00	0.00
	1620		13		1.57		1.96

Third Floor - Exterior South							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Corridor	136	0.14	0	1.20	0.17	1.00	0.14
Office	820	0.86	7	1.70	1.46	2.00	1.72
	956		7		1.63		1.86

Third Floor - Exterior East							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Lobby	1316	1.00	4	1.80	1.80	1.00	1.00
	1316		4		1.80		1.00

Third Floor - Exterior West							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Corridor	1458	0.47	0	1.20	0.56	1.00	0.47
Office	730	0.24	7	1.70	0.40	2.00	0.47
Patient	910	0.29	9	1.60	0.47	2.00	0.59
	3098		16		1.44		1.53

Fifth Floor - Core							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Corridor	6125	0.64	14	1.20	0.77	1.00	0.64
Mechanical	373	0.04	0	1.40	0.05	35.00	1.37
Office	2102	0.22	15	1.70	0.38	2.00	0.44
Restroom	915	0.10	0	1.10	0.11	0.00	0.00
	9515		29		1.31		2.46

Fifth Floor - Exterior North							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Corridor	1021	0.25	0	1.20	0.30	1.00	0.25
Patient	2472	0.61	20	1.60	0.97	2.00	1.21
Restroom	588	0.14	0	1.10	0.16	0.00	0.00
	4081		20		1.43		1.46

Fifth Floor - Exterior South							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Patient	1571	0.85	14	1.60	1.37	2.00	1.71
Restroom	270	0.15	0	1.10	0.16	0.00	0.00
	1841		14		1.53		1.71

Fifth Floor - Exterior East							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Corridor	325	0.12	0	1.20	0.14	1.00	0.12
Lobby	1373	0.51	46	1.80	0.91	1.00	0.51
Office	1003	0.37	9	1.70	0.63	2.00	0.74
	2701		55		1.69		1.37

Fifth Floor - Exterior West							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Patient	1640	1.00	14	1.60	1.60	2.00	2.00
	1640		**14**		**1.60**		**2.00**

Sixth Floor - Core							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Corridor	5562	0.65	9	1.20	0.78	1.00	0.65
Mechanical	445	0.05	1	1.40	0.07	30.00	1.55
Office	2098	0.24	13	1.70	0.41	2.00	0.49
Restroom	501	0.06	0	1.10	0.06	0.00	0.00
	8606		**23**		**1.33**		**2.69**

Sixth Floor - Exterior North							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Corridor	1021	0.25	0	1.20	0.30	1.00	0.25
Patient	2472	0.61	20	1.60	0.97	2.00	1.21
Restroom	588	0.14	0	1.10	0.16	0.00	0.00
	4081		**20**		**1.43**		**1.46**

Sixth - Exterior South							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Office	247	0.13	6	1.70	0.22	2.00	0.26
Patient	1298	0.69	12	1.60	1.11	2.00	1.39
Restroom	324	0.17	0	1.10	0.19	0.00	0.00
	1869		**18**		**1.53**		**1.65**

Sixth - Exterior East							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Corridor	325	0.12	0	1.20	0.14	1.00	0.12
Lobby	1373	0.49	46	1.80	0.89	1.00	0.49
Office	224	0.08	4	1.70	0.14	2.00	0.16
Patient	744	0.27	6	1.60	0.43	2.00	0.54
Restroom	108	0.04	0	1.10	0.04	0.00	0.00
	2774		**56**		**1.64**		**1.31**

Sixth Floor - Exterior West							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Patient	1640	0.81	14	1.60	1.30	2.00	1.63
Restroom	378	0.19	0	1.10	0.21	0.00	0.00
	2018		**14**		**1.51**		**1.63**

Seventh Floor - Core							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Corridor	5562	0.65	9	1.20	0.78	1.00	0.65
Mechanical	445	0.05	1	1.40	0.07	30.00	1.55
Office	2098	0.24	13	1.70	0.41	2.00	0.49
Restroom	501	0.06	0	1.10	0.06	0.00	0.00
	8606		**23**		**1.33**		**2.69**

Seventh Floor - Exterior North							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Corridor	1021	0.25	0	1.20	0.30	1.00	0.25
Patient	2472	0.61	20	1.60	0.97	2.00	1.21
Restroom	588	0.14	0	1.10	0.16	0.00	0.00
	4081		**20**		**1.43**		**1.46**

Seventh - Exterior South							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Office	247	0.13	6	1.70	0.22	2.00	0.26
Patient	1298	0.69	12	1.60	1.11	2.00	1.39
Restroom	324	0.17	0	1.10	0.19	0.00	0.00
	1869		**18**		**1.53**		**1.65**

Seventh - Exterior East							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Corridor	325	0.12	0	1.20	0.14	1.00	0.12
Lobby	1373	0.49	46	1.80	0.89	1.00	0.49
Office	224	0.08	4	1.70	0.14	2.00	0.16
Patient	744	0.27	6	1.60	0.43	2.00	0.54
Restroom	108	0.04	0	1.10	0.04	0.00	0.00
	2774		56		1.64		1.31

Seventh Floor - Exterior West							
Space Type	(sqft) Area	(%) Zone Area	(#) People	(W / sqft) Lighting Load	(W / sqft) Avg. Lighting Load	(W / sqft) Equip. Load	(W / sqft) Avg. Equip. Load
Patient	1640	0.81	14	1.60	1.30	2.00	1.63
Restroom	378	0.19	0	1.10	0.21	0.00	0.00
	2018		14		1.51		1.63

Internal People Loads				
Zone Type	Density	Activity	Sensible (Btu/hr)	Latent (Btu/hr)
Conference	Ref. Schedule	Hospital	250	200
Office	Ref. Schedule	Hospital	250	200
Operating Rooms	Ref. Schedule	Hospital	250	200
Patient Rooms	Ref. Schedule	Hospital	250	200
Lobby	Ref. Schedule	Lobby	250	200
Corridor	Ref. Schedule	Hospital	250	200
Mechanical Space	Ref. Schedule	Hospital	250	200
Restroom	Ref. Schedule	Hospital	250	200

Internal Lighting Loads		
Zone Type	Light Fixture	Energy Use (W/sqft)
Conference	Fluorescent, not vented, 80% to load	2.00
Office	Fluorescent, not vented, 80% to load	1.70
Operating Rooms	Fluorescent, not vented, 80% to load	2.80
Patient Rooms	Fluorescent, not vented, 80% to load	1.60
Lobby	Fluorescent, not vented, 80% to load	1.80
Corridor	Fluorescent, not vented, 80% to load	1.20
Mechanical Space	Fluorescent, not vented, 80% to load	1.40
Restroom	Fluorescent, not vented, 80% to load	1.10

Internal Equipment Loads		
Zone Type	Equipment Loads	Energy Use (W/sqft)
Conference	Projectors, Computers, Office Equip	2.00
Office	Computers, Office Equip, Desk Lights	2.00
Operating Rooms	Medical Equipment, Computers	4.00
Patient Rooms	Medical Equipment, Televisions	2.00
Lobby	Computers, Televisions	1.00
Corridor	Medical Equipment, Monitors	1.00
Mechanical Space	Heat load from equipment	Varies
Restroom	No equipment load	0.00

Ground Floor						
	(ft)	(ft)	(sqft)	(ft)	(ft)	(sqft)
Ext. Face	Wall Length	Wall Height	Wall Area	Window Length	Window Height	Window Area
North	0	14.75	0	0	0	0
South	0	14.75	0	0	0	0
East	0	14.75	0	0	0	0
West	109	14.75	1607.75	12	8	96
			1607.75			96

First Floor						
	(ft)	(ft)	(sqft)	(ft)	(ft)	(sqft)
Ext. Face	Wall Length	Wall Height	Wall Area	Window Length	Window Height	Window Area
North	38	14.75	560.5	0	0	0
South	0	14.75	0	0	0	0
East	0	14.75	0	0	0	0
West	140	14.75	2065	12	6	72
			2625.5			72

Second Floor						
	(ft)	(ft)	(sqft)	(ft)	(ft)	(sqft)
Ext. Face	Wall Length	Wall Height	Wall Area	Window Length	Window Height	Window Area
North	238	14.75	3510.5	59	8	472
South	44	14.75	649	12	6	72
East	55	14.75	811.25	53	2	106
West	154	14.75	2271.5	72	6	432
			7242.25			1082

Third Floor						
	(ft)	(ft)	(sqft)	(ft)	(ft)	(sqft)
Ext. Face	Wall Length	Wall Height	Wall Area	Window Length	Window Height	Window Area
North	238	14.75	3510.5	145	6	870
South	44	14.75	649	12	6	72
East	55	14.75	811.25	52	6	312
West	154	14.75	2271.5	69	6	414
			7242.25			1668

Fifth Floor						
	(ft)	(ft)	(sqft)	(ft)	(ft)	(sqft)
Ext. Face	Wall Length	Wall Height	Wall Area	Window Length	Window Height	Window Area
North	179	14.75	2640.25	119	6	714
South	137	14.75	2020.75	42	6	252
East	245	14.75	3613.75	98	6	588
West	154	14.75	2271.5	69	6	414
			10546.25			1968

Sixth Floor						
	(ft)	(ft)	(sqft)	(ft)	(ft)	(sqft)
Ext. Face	Wall Length	Wall Height	Wall Area	Window Length	Window Height	Window Area
North	179	14.75	2640.25	119	6	714
South	137	14.75	2020.75	42	6	252
East	245	14.75	3613.75	98	6	588
West	154	14.75	2271.5	69	6	414
			10546.25			1968

Seventh Floor						
	(ft)	(ft)	(sqft)	(ft)	(ft)	(sqft)
Ext. Face	Wall Length	Wall Height	Wall Area	Window Length	Window Height	Window Area
North	179	14.75	2640.25	128	6	768
South	137	14.75	2020.75	42	6	252
East	245	14.75	3613.75	103	6	618
West	154	14.75	2271.5	69	6	414
			10546.25			2052

Third Floor Roof						
	(ft)	(ft)	(sqft)	(ft)	(ft)	(sqft)
Zone	Roof Length	Roof Width	Roof Area	Skylight Length	Skylight Width	Skylight Area
Core	135	139	18765	88	18	1584
			18765			1584

Seventh Floor Roof			
	(ft)	(ft)	(sqft)
Ext. Face	Roof Length	Roof Width	Roof Area
Core	100	86.06	8606
North	179	22.7	4081
South	137	13.6	1869
East	245	11.3	2774
West	154	13.1	2018
			19348