DASCO Medical Office Building

Saint Joseph Medical Center

Towson, Maryland

Final Report

Mechanical System Redesign

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Mechanical Option

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DASCO Medical Office Building
Saint Joseph Medical Center
Towson, Maryland

Building Information:

4 story, 64,000 sq. ft. Medical Office Building located on the Saint Joseph Medical Center campus.

Owner: DASCO Companies
General Contractor/Construction Manager: Whiting-Turner
Architect: Cochran, Stephenson & Donkervoet, Incorporated Architects
Mechanical/Electrical: Leach Wallace Associates, Inc.
Structural: Morabito Consultants, Inc.
Civil: Site Resources, Inc.

Construction:

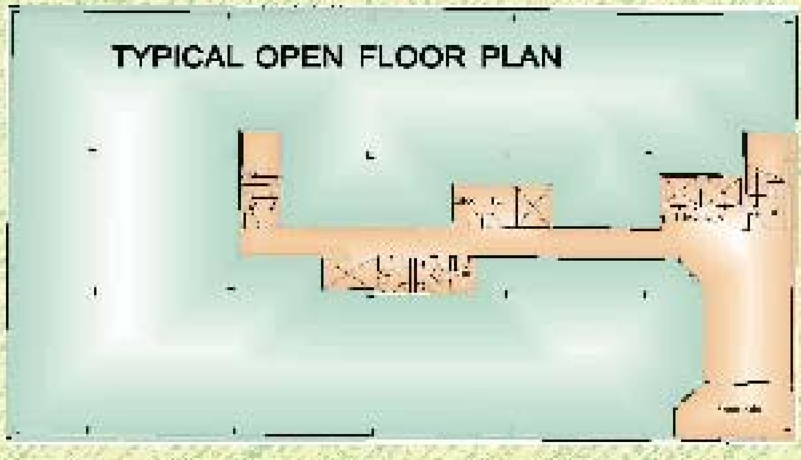
- Shell and core: October 10, 2005 to November 16, 2006
- Expansion and final build out: tentative completion November 2007
- AIA 111 guarenteed cost plus fee

Structural System:

- Spread concrete footings
- Wide flange beams and columns
- 3-1/2" concrete slab on a 3", 18 gauge composite metal deck

Mechanical System:

- 3 high efficiency direct expansion packaged roof top air handling units, 20% outdoor air
- Each serves fan powered variable air volume control boxes with electric reheat coils
- Ceiling plenum return



Electrical System:

- 1500 KVA transformer, utility
- 480Y/277V, 2500 amp main switchboard serves 2 AHUs and 4 xfmrs
- 150 KVA, 3F, 480VD x 208Y/120 xfmr, each floor (4 total)
- 2x2, 3 bulb F17T8 flourescent lighting fixtures

Chris Nicolais

Mechanical

CPEP address – http://www.engr.psu.edu/ae/thesis/portfolios/2008/can165

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Executive Summary

The final product of two semesters of work studying the engineered systems of the four story, 64,000 square foot DASCO Medical Office Building is contained in this document. A description and evaluation of the existing mechanical system is included as pieces of the three different technical assignments written in the fall 2007 semester. Ventilation calculations, energy standards and performance, as well as an existing conditions report all aided in presenting areas that can be improved upon in a system redesign. Knowledge of the performance of this system is essential in understanding the mechanical system redesign proposal, and is detailed in the body of this report.

The existing system is comprised of three direct expansion packaged roof top units that serve fan powered VAV boxes with individual electric reheat. The building design allowed for adequate ventilation and overall system energy performance as written by the American Society of Heating, Refrigerating and Air-Conditioning Engineers. However, the current system consumes only electricity, which in mass quantities is generated through the environmentally unfriendly process of coal burning. Redesign goals were to increase system efficiency, reduce energy costs, and cut down on emissions. The idea explored over the course of the spring 2008 semester was to create a chilled water plant dedicated to the cooling load of the DASCO building. Also to eliminate electrically run system components, a boiler was sized for both domestic hot water and space heating requirements. Equipment sizing and selection methods are elaborated upon in the discussion of the redesigned system. Most components are based on the building model created using Carrier's Hourly Analysis Program. Overall redesigned system performance reduces emissions, costs less to operate each year and eliminates a percentage of consumed electricity.

In addition to studying the mechanical system, efforts were made to evaluate other areas of the engineered systems and building construction effected by the proposed redesign. An emergency generator was sized to handle power loads based on sizing criteria found in the National Electric Code. This was done since the current shell and core building had no emergency power system previously. Another aspect of redesign was the impact a new mechanical system will have on the cost and schedule of construction. RS Means construction cost data was used to determine the labor cost and daily output of equipment installation. Both systems are comparable so that neither one has a vast effect on construction.

Overall, a redesigned system would improve many aspects of the building.

Building Description

The DASCO Medical Office Building was constructed by the DASCO Companies on the campus of Saint Joseph Medical Center in Towson, Maryland. DASCO Companies plays the role of owner and operator of this project.

Initially the building was designed as a four story, 64,000 square foot shell and core facility. Each open floor plan has approximately 12,700 square feet of leasable space. Mechanical shafts, two private toilets, two elevators, a main corridor and electrical rooms comprise the core which is the remaining 3,300 square feet of each floor. Inside spaces were designed to maximize floor space, thus allowing for a maximum rentable square footage. A two story addition to the shell of the building facing the driveway and patient drop-off added 2,200 square feet to the first floor creating space for infusion bays. Each fit-out was architecturally designed for the needs of the leasing tenant. Office spaces, conference rooms, labs, and storage among other types of spaces were built into the shell of the building.

The mechanical system for the DASCO Medical Office Building was initially engineered for the shell and core building phase with the knowledge that the building would be fit-out to accommodate tenant needs in the future. Designers understood the building to be a medical office building and not a hospital, so that any future spaces requiring hospital quality fit-outs such as diagnostic imaging and laboratories would be evaluated individually. This is evident since additional HVAC equipment has been added to the building since the shell and core construction.

Mechanical design for the shell and core building, engineered with the intent of future fit-outs, is an all air variable air volume (VAV) system. There are two 130 ton Trane Intellipak high efficiency direct expansion rooftop air handling units designed for approximately 20% outdoor air. AHU-1 has a 37,000 cubic feet per minute (cfm) capacity (7,400 cfm outdoor air) intended to serve the ground and first floor; while AHU-2 has a 36,000 cfm capacity (7,200 cfm outdoor air) intended to serve the second and third floors. Each is equipped with a 0-100% economizer section with proportional dampers allowing for 0-100% outside air. Both AHUs are located on the roof of the building, above the third floor. With the design of the first floor fit-out, which is a multi-disciplinary space; a third air handler was added to the project. This unit is a 30 ton Trane Intellipak high efficiency direct expansion rooftop air handling unit providing approximately 20% outdoor air. The location of the third unit is on the roof of the linear accelerator area with a capacity of 10,680 cfm (2,000 cfm outdoor air).

Each air handler serves parallel fan powered VAV boxes with electric reheat which provide the outdoor air to the spaces. Return air travels through a ceiling plenum to three separate return air ducts leading back to the three air handling units.

Existing System Analysis

Design Goals

Objectives for this engineering project were to meet the owner's requirements while designing a functioning HVAC system that complied with code and also was able to provide comfortable spaces for the occupants. Because the occupants were not known at the time of initial system design it is assumed that many safety factors were put into the calculations for outdoor supply air. Fan powered VAV boxes were selected to accommodate assumed loads based on a building model and the AHU capacities. This system is adaptable to future interior space layouts since the terminal units can be relocated without much effort to ensure that proper amounts of ventilation air are supplied to each room. Electric reheat was most likely chosen so that the future heating load, which was unknown or approximated for the shell and core design phase, can be adapted to individual zones as needed. Heating load is influenced by exposure, fenestration, occupancy, equipment, and lighting. Although electric reheat is not the optimal choice for minimizing energy consumption, the allowable adaptability for the potential relocation of terminal units may have proved to be the deciding factor in choosing this type of reheat. If hot water reheat had be specified, challenges would arise in relocating and adjusting hot water piping to accommodate potentially new locations of the terminal units, again based on the needs of each individual fit-out project.

Additional equipment was added as fit-out projects were designed to include a nuclear lab and clean rooms as well as imaging and cancer treatment rooms on various floors. The nuclear lab has two computer room air conditioning units providing direct cooling over the two machines located in the space. Fan powered HEPA ceiling modules were added to the clean and ante rooms of the first floor infusion center fit-out. Also due to the cooling demands of the two linear accelerators and the PET/CT scanner, located on the ground floor, each has a separate closed loop chilled glycol system running through individual chillers located outside of the linear accelerator bunker. Also domestic water heaters of the electric fuel type were added to the building as needed based on fit-out requirements for hot water, mostly supplying sinks located in the labs, toilets, and exam rooms.

Table 1 below gives the supply air and outside air for each air handling unit. The following figures are color coded to indicate which AHU serves the designated area. Figure 1 is a floor plan of the ground floor and served entirely by AHU-1. Figure 2 represents the first floor and is served by AHU-1 and AHU-3. Figures 3 and 4 are of the second and third floors respectively and both are served by AHU-2.

Table 1 - Air Handling Units			
No.	Total Supply Air	Outside Air	Color
AHU-1	37,000	7,400	(green)
AHU-2	36,000	7,200	(yellow)
AHU-3	10,680	2,000	(blue)

Air Handling Unit Space Breakdown

Figure 1 - Ground Floor

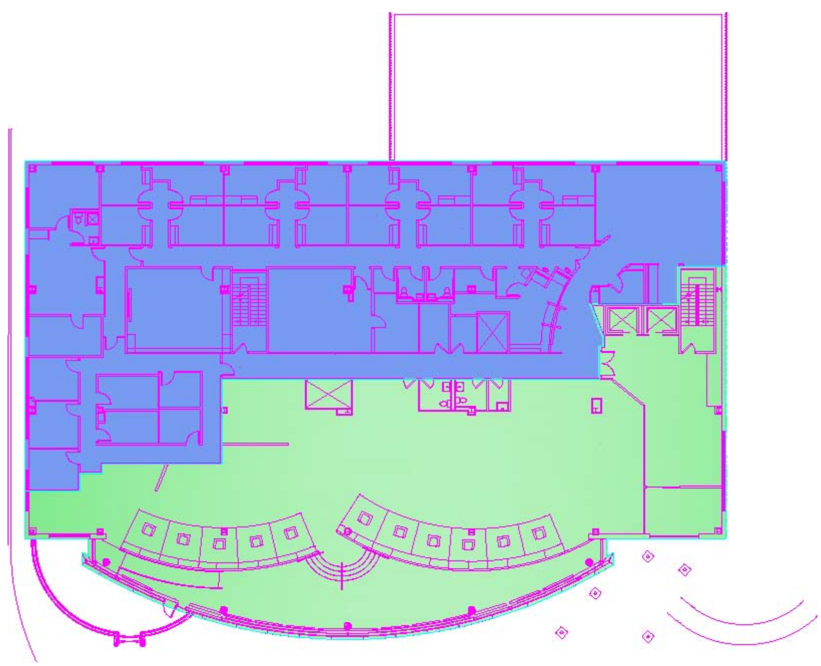

Figure 2 - First Floor

Air Handling Unit Space Breakdown

Figure 3 - Second Floor

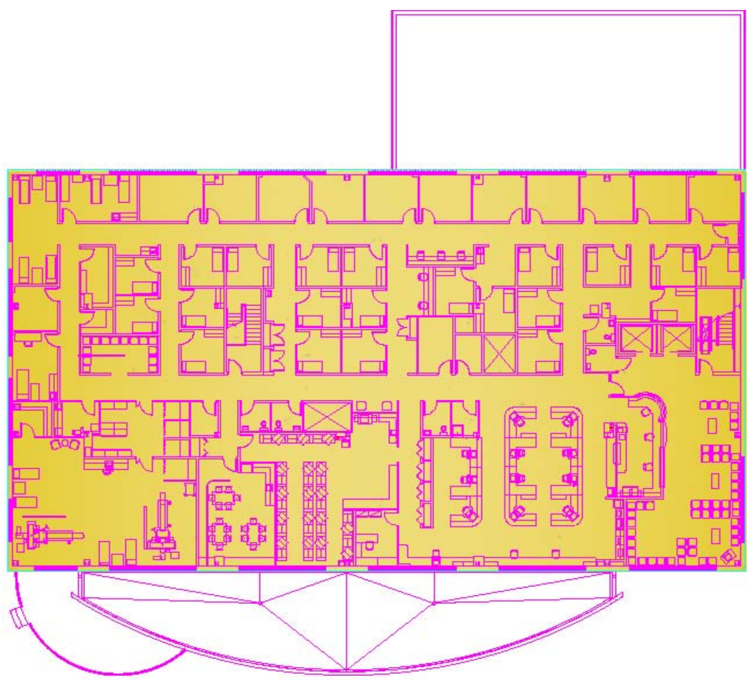

Figure 4 - Third Floor

Factors Influencing Design

Owner budget is often the main influence dictating what type of HVAC system to design for a building project. Certain types of systems can prove to be too costly, depending on the application, and therefore design hours are not spent exploring the possibilities of certain systems. The DASCO Companies own the medical office building; however they are not the tenants of any part of the four story building. Space within the building has been leased to various companies and their individual space needs were established in the fit-out process. Generally in building projects where the owner is not the occupant, most of the building operating cost is passed onto the leasing tenant. Usually there is no appeal for the owner to pay for the design of a high performance building when they will not be paying for its energy consumption and utility costs. Typically these types of projects are designed for the lowest possible first cost. Therefore the mechanical systems are simple with as inexpensive equipment costs as possible. System design is also made for ease of modulation especially in a shell and core project where final floor plans can be developed months or years later, once tenants are secured. It should also be noted that most typical office buildings are renovated on three to five year cycles in order to accommodate new tenants or upgrade the facility for the current occupants. Adaptability for a building without a finalized floor plan and aiming for a low initial cost factored into the design of this mechanical system. On this type of project there are no cost factors that may be found to influence public or government projects where strict budgets are in place because of the sensitivity of spending taxpayers' dollars for new construction.

Building cost and rentable space are important numbers to compare when designing a building of this nature. First cost from the owner's perspective must be less than the cost to lease each square foot of building area, thus making profit. System cost is analyzed later in this report.

Lost rentable space due to mechanical system equipment and vertical shafts provided for routing pipes and ductwork amounts to 930 square feet. The areas containing mechanical equipment are janitor's closets on each floor that house domestic water heaters. The other areas contributing to the lost rentable space are a 74 square foot and 65 square foot vertical mechanical shaft through each floor. All three AHUs are located on roof areas; also specialized chillers which provided cooling directly to each linear accelerator, and the PET/CT scanner located on the ground floor, are located outside of the linear accelerator bunker on the south side of the building. Only 1.3% of the building square footage is lost to mechanical needs.

Based on the information received from the engineers, no site factors influenced the design of the mechanical system for this building. Some of the rooms located on the ground floor are below grade and therefore have no outside exposure. This effects the load calculations for both heating and cooling, which does factor into the load totals for AHU-1. However, the main design for the mechanical system was not influenced by the site. The biggest contributing factors were the owner's requests, cost decisions, and suitability for a shell and core project where future fit-outs would require a somewhat adaptable system design.

Load and Energy Estimation

Ventilation Requirements

As Table 2 below shows, each air handling units has the ability to supply sufficient outdoor air to each space. It should be noted that the building was designed as a shell and core, so ventilation requirements may have been approximated based on knowledge of medical office building occupancy and space functions. Each AHU was designed for approximately 20% outdoor air, an assumption made by the engineers prior to fit-out design. This seems to be an adequate estimate of the ventilation requirements. The calculations shown in this report are based on the building and its final space breakdowns and occupancies. This may change in the future depending on tenant needs, but as for now the building mechanical system meets ASHRAE Standard 62.1-2007. Appendix B contains the spreadsheets used to calculate the required outdoor air for each space. Based on the Ventilation Rate Procedure, part of ASHRAE 62.1-2007 Section 6, the outside air required for each zone which was broken down per AHU, is summarized in Table 2 below. A detailed description of the calculation procedure as well as a list of the necessary variables can be found in Appendix A.

Table 2 - Summary of Results

	design total supply air	design outdoor air	outside air required per ASHRAE Std. 62.1-2007
AHU-1	37,000	7,400	3,822
AHU-2	36,000	7,200	6,935
AHU-3	10,680	2,000	1,810
Totals	83,680	16,600	12,567

One of the reasons AHU-1 may seem oversized for outdoor air is due to the fact that there was a two-story addition to the front of the building and a fit-out on the first floor. AHU-3 was added because the engineering team felt that AHU-1, which was originally designed to handle the ground and first floor, would not be sufficient after the occupancy and space functions were decided for that first floor fit-out. The other AHUs seem to be very close to the required outdoor air.

There has been no available history of how the mechanical system has been operating for the DASCO Medical Office Building to include in this report. However, according to Section 6 of Standard 62.1-2007, building must meet the exhaust airflow requirements outlined in Table 6-4 (ASHRAE 2007). Exhaust air can be a combination of outdoor air, re-circulated air, or transfer air. The primary rooms of concern are toilets, janitor closets, and soiled utility rooms. Table 45 in Appendix A details each space that requires ventilation compared to the minimum exhaust rates outlined in the standard.

Design Heating and Cooling Load

Estimating the design load required the use of Carrier's Hourly Analysis Program (HAP). Each of the 277 rooms was individually entered into the program. Data used for the model consisted of the outdoor air ventilation rates based on the design documents, lighting and equipment loads found on the drawings, and also the design occupancies based on the furniture plans. HAP also takes into consideration the floor to floor height, and whatever exposures rooms may have to the outside including window area. In order to simulate an accurate design day, occupancy schedules are made in the program, and can be found in Figures 5-8 below. These schedules were estimated based on a normal office building that operates from 8am to 5pm on weekdays, and from 10am to 4pm on the weekends. Any holidays throughout the year in which the building may not be open were entered into the computer and based on holidays that Baltimore Gas and Electric acknowledges as charged off-peak hours. Appendix C contains tables detailing each air handler, the rooms served, and the design data from construction documents and the estimated loads from HAP.

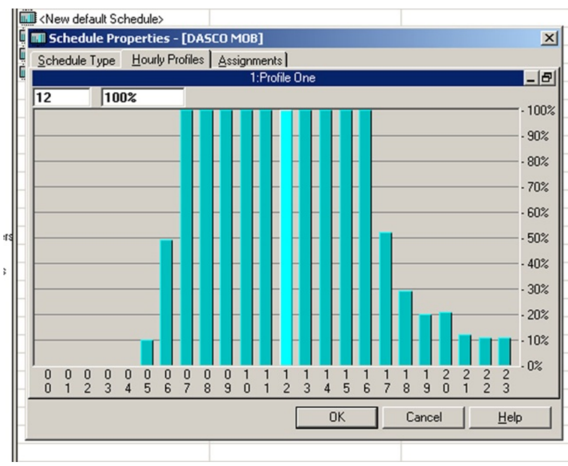

Figure 5 - Weekday Schedule

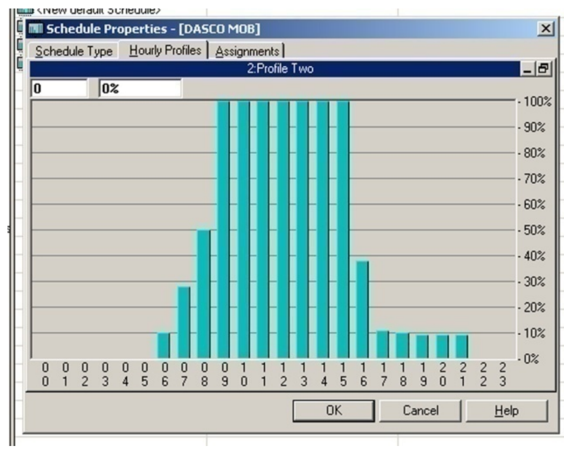

Figure 6 - Weekend Schedule

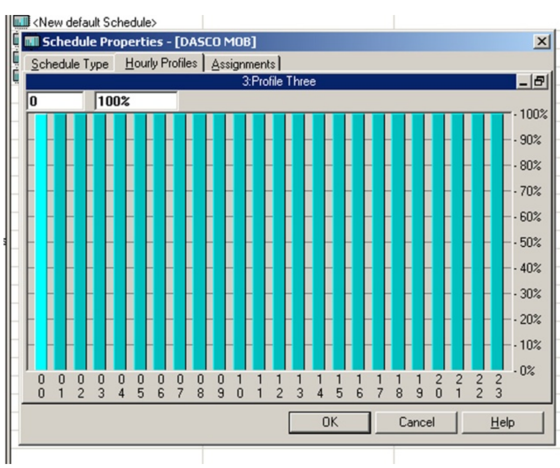

Figure 7 - Design Schedule

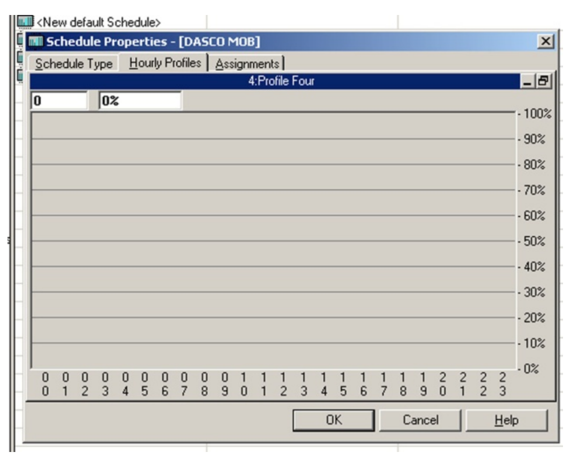

Figure 8 - Holiday Schedule

The outdoor air ventilation rate is 20% of the supply air. Tables 3 and 4 below detail the indoor and outdoor air design conditions from the engineer for the original design and the estimated temperatures programmed into HAP.

Table 3 - Indoor Air Design Conditions		
	Designer (°F)	Estimate (°F)
Cooling T-Stat, Occupied	72	75
Cooling T-Stat, Unoccupied	85	85
Heating T-Stat, Occupied	72	70
Heating T-Stat, Unoccupied	60	60

Table 4 - Outdoor Air Design Conditions		
	Designer (°F)	Estimate (°F)
Summer Design Dry Bulb	95	91
Summer Coincident Wet Bulb	78	74
Winter Design Dry Bulb	0	11
Winter Design Wet Bulb	0	8.6

The comparison of design conditions and computed loads using HAP are listed in Tables 5-7 below. The ventilation data is exactly the same because the building model was sized using outdoor air ventilation rates from the design documents. However, the cooling square feet per ton and supply cubic feet per minute per square foot data is different for all three air handlers. This is because each air handler has a maximum cooling capacity in tons as listed in the design schedules. However, when the computer models each space, only the design day loads are important. Because of building orientation, occupancy schedules, time of day, and weather data, the building's mechanical equipment capacity is hardly ever used to its full potential. This is evident in the computed load row of Tables 5-7 below. Each air handler has more capacity than HAP modeled as necessary to cool the building on the design day. Again, it should be noted that the engineers selected AHU-1 and AHU-2 prior to the building having floor plans suiting each tenant. Some type of approximation as to how the space would be used, and how many people would occupy each space was added to the shell and core loads of the building for initial design.

Table 5 - Design and Computed Loads AHU-1			
	cooling ft^2/ton	supply cfm/ft^2	ventilation supply cfm/ft^2
Design	190.2	1.69	0.34
Computed	300.9	1.03	0.33
Percent Difference	58.2	-39.1	-2.9

Table 6 - Design and Computed Loads AHU-2			
	cooling ft^2/ton	supply cfm/ft^2	ventilation supply cfm/ft^2
Design	218.9	1.36	0.27
Computed	383.3	0.59	0.28
Percent Difference	75.1	-56.6	3.7

Table 7 - Design and Computed Loads AHU-3			
	cooling ft^2/ton	supply cfm/ft^2	ventilation supply cfm/ft^2
Design	228.7	1.49	0.30
Computed	369.8	0.74	0.30
Percent Difference	61.7	-50.3	0

ASHRAE Standard 90.1-2004

This standard establishes design criteria which provide minimum requirements for the energy efficient design of new buildings. The standard has six main provisions which help engineers achieve energy efficient system design for the building envelope, HVAC system, service water heating, power, lighting, and other equipment.

Building Envelope

ASHRAE Standard 90.1-2004 provides building compliance criteria for the building envelope, HVAC systems, service water heating, power, lighting, and other equipment. It is necessary to determine some of the criteria for which this building must follow in order to be in compliance with Standard 90.1. The building location determines its climate zone, which is used to break down many of the categories found in this standard. Towson, Maryland is in climate zone 4A, which is a mixed-humid environment. It is suggested that buildings be designed for a cooling dry bulb temperature of 91°F, cooling wet bulb of 74°F, and a winter design condition of 11°F for the Baltimore area.

Building envelope requirements for climate zone 4A are highlighted in Table 8 below. This shows that the assemblies comply with the maximum U-values and achieve better performance than the required minimum R-values. Assembly values came from HAP as the modeled walls and roof were based on design documents. Each material was input into the program and the U-value feedback from the program is listed in the table below. The glazing, or vertical fenestration, as prescribed in Standard 90.1, should be no more than 50% of the gross wall area. Based on the building elevations, the vertical fenestration is calculated to be 16% of the gross wall area, which is well within the allotted amount. Also, based on the design documents, the type of clear anodized aluminum storefront windows are specified as having 1/8" clear float glass inboard, a 3/8" airspace, and 1/8" low "e" float glass outboard. This data was input into HAP and the program generated an assembly U-value of 0.563 and Solar Heat Gain Coefficient of 0.37. Both of these values comply with Standard 90.1.

Table 8 - Nonresidential Building Envelope Requirements

	Assembly Maximum	Insulation Minimum	Actual Assembly	Actual Insulation
Roofs	U-0.063	R-15	U-0.061	R-15
Walls, Above Grade	U-0.124	R-13	U-0.042	R-19
Walls, Below Grade	C-1.140	None Required	C-0.104	R-7 board insulation
	Assembly Maximum	**Solar Heat Gain Coefficient**	**Actual Assembly**	**Actual SHGC**
Vertical Glazing, % of Wall (10.1-20.0%)	fixed U-0.57	SHGC-0.39 all	U-0.563	SHGC-0.37
		SGHC-0.49 north		SHGC-0.37

Heating, Ventilating, and Air Conditioning

The HVAC system for this building is a variable air volume with parallel fan-powered boxes with supply air conditioned through packaged roof top units. The packaged roof top units are direct expansion cooling type. Heating is accomplished through electric resistance in each fan-powered VAV box. According to Standard 90.1 Table 6.5.1, no economizer is required for climate zone 4A; however the building specifications indicate that each AHU has a 0-100% economizer to allow for “free” cooling when outdoor air conditions are suitable.

The fan power limitations prescribed by Standard 90.1 are based on the supply fan airflow rate at design conditions. Design conditions used in this compliance check were generated from the system model from HAP. Table 9 below shows the evaluation of the fan power compliance with what is written in Standard 90.1. As the table shows, the calculated motor power for AHU-1 and AHU-2 is much greater than the limitation set by AHSRAE. AHU-3 is close to the limitation, however still exceeds the performance requirement. The excessive motor horsepower may be due to the fact that both AHU-1 and AHU-2 were designed as part of the shell and core phase of this building. Therefore both AHUs were selected for an estimated load, and may have complied with Standard 90.1 prior to each fit-out phase of the building construction. Now that the building is complete and final occupancy is reflected in the HAP model, the AHUs are oversized for the ventilation and cooling load they must provide to the spaces. AHU-3 was added to the project during one fit-out phase in which the engineers analyzed the current air handling capabilities, and felt that AHU-1 and AHU-2 did not have enough capacity. Therefore a third AHU was added to the project. This unit was designed for the spaces which it supplies, and is much closer to the limitation value set by ASHRAE.

Table 9 - Fan Power Limitation Variable Volume System

	Design supply (cfm)	Fan Horsepower	Allowable Nameplate Motor Power (ASHRAE 90.1-2004)	Calculated Motor Power
AHU-1	25070	2 @ 40 hp	1.5 hp/1000 cfm	3.2 hp/1000 cfm
AHU-2	15915	2 @ 40 hp	1.5 hp/1000 cfm	5.1 hp/1000 cfm
AHU-3	5278	1 @ 10 hp	1.7 hp/1000 cfm	1.9 hp/1000 cfm

Pipe and duct minimum insulation values are also listed in the HVAC section. Table 6.8.3 of ASHRAE Standard 90.1-2004 lists the minimum thickness of pipe insulation based on fluid design temperature and nominal pipe size. For the domestic water system, hot water is designated as 140°F leaving water temperature. Based on reading the table, the insulation conductivity range can fall between 0.22 to 0.28 for fluid design temperatures between 105°F and 140°F. The mechanical specifications list pipe insulation conductivity valves are to fall between 0.23 and 0.27. As specified, the pipe insulation complies with Standard 90.1. Duct insulation values are listed in Table 6.8.2A in AHSRAE Standard 90.1-2004. The only ducted air distribution is through cooling only ducts. All return air travels through a ceiling plenum. For climate zone 4 the minimum duct insulation R-value for ducts located in unconditioned space is

R-1.9. The mechanical specifications call for 2" rigid insulation on supply ducts. This is equivalent to an R-value of 8, which well exceeds the requirement.

Service Water Heating

The basis of design for the domestic water heaters is the A.O. Smith Dura-Power Model DEL-40. As indicated on the manufacturer specification sheet for this product, each electric water heater meets or exceeds the requirements of ASHRAE Standard 90.1-1999 for energy efficiencies. According to ASHRAE Standard 90.1-2004, electric water heaters using less than 12kW input and are rated for greater than 20 gallons, have a required performance of 0.93-0.00132V EF. Because no data could be located referencing the 1999 Standard, it is assumed that the water heaters also comply with the 2004 Standard.

Power

The power requirements described in ASHRAE Standard 90.1-2004 state that the maximum voltage drop for feeders must be no more than 2%. Also the maximum voltage drop for branch circuits must not exceed 3%.

Lighting

ASHRAE Standard 90.1-2004 details two methods for determining lighting power densities. The more general building area method gives specific values for building area types listed as hospital, office, retail, etc. The space-by-space method is more detailed in that the table gives lighting power densities for each room type based on room usage. The lighting power density requirement for a health care-clinic building is 1.0 Watts per square foot. Table 10 provides a summary of evaluated square footage for the building spaces and the designed lighting based on building construction drawings. Each room was reviewed to find the total number of fixtures and the total wattage was summed for all spaces based on the lighting fixture schedules.

Table 10 - Lighting Power Density, Building Area Method			
ASHRAE Standard 90.1-2004, Health care-clinic (1.0 W/ft^2)			
	ft^2	Watts	Watts/ft^2
DASCO MOB	57,703	104,275	1.81

Table 10 above shows that based on the building area method, the DASCO Medical Office Building exceeds the lighting power density prescribed in Standard 90.1. Another way to evaluate the lighting power density is to use the space-by-space method. Table 11 shows a breakdown of how the spaces lighting was entered into the HAP model. This information was also used to evaluate the buildings compliance using the space-by-space method.

Table 11 - Lighting Power Densities, Space-by-Space	
Common Space Type	LPD (W/ft^2)
Office	1.1
Conference	1.3
Lobby	1.3
Laboratory	1.4
Restrooms	0.9
Corridor	0.5
Nurse Station	1.0
Exam/Treatment	1.5
Medical Supply	1.4
Radiology	0.4
Equipment	1.2
Control	0.5
Electrical/Mechanical	1.5
Stairs	0.6
Library, Reading	1.2
Active Storage	0.8
Lounge	1.2

A detailed space-by-space breakdown, which lists each room and its compliance with Table 11 above, is provided in Appendix D. The DASCO Medical Office Building has very few rooms that actually comply with this standard. Most rooms are over the Watts per square foot requirements.

Mechanical System First Cost

The DASCO Medical Office Building mechanical system first cost data is based on the payment sheet for each phase of work completed by Southern Mechanical Inc., mechanical contractors. Equipment cost of piping, plumbing fixtures, water heaters, air handlers, sheet metal, ATC controls, and insulation are included along with balancing coordinated drawings and any contract revisions based on the progress of construction as seen fit by the mechanical contractors. First cost data for the building totaled $678,784.79. This is equivalent to $9.73 per square foot for mechanical equipment in the building.

Annual Energy Consumption and Operating Costs

The DASCO Medical Office Building was designed as an electricity consuming building. Three direct expansion rooftop air handling units send conditioned air to parallel fan powered VAV boxes with electric reheat supplying each room. Return air is sent through a ceiling plenum that blows through three return fans, one for each AHU. All of the systems, including the lighting and other normal equipment that can be found in an office type building, with the addition of certain specialized medical equipment, consume energy in the form of generated electricity.

Yearly utilization data, meter data, or utility bills could not be obtained for this building. Therefore in order to calculate energy consumption, the utility rates from Baltimore Gas and Electric Company (BGE) were taken from the company website and summarized in Table 12 below. Based on the information on BGE's website, there are certain categories, based on building type, that indicate the type of service. Table 12 lists the small, general service electric rates.

Table 12 - Baltimore Gas and Electric Company, Electric Rates		
General Service Small - Electric (cents per kWh)		
	Summer	Non-Summer
Peak	15.173	11.817
Intermediate-Peak	9.177	10.109
Off-Peak	7.254	7.984

Carrier's Hourly Analysis Program (HAP) was used to generate a yearly energy simulation for this building. The rating period used in the computer model is as follows: Peak hours between 10am and 8pm on weekdays, Intermediate hours are 7am to 10am and 8pm to 11pm on weekdays, and Off-Peak hours are weekends and national holidays which are listed on the BGE rate plan. Summer hours are charged between the months of June through September, winter billing months are October through May.

The information provided in Tables 13-19 below was generated using HAP building simulation. Performance data was taken from the design documents, and some was part of default equipment selection from the HAP database. The loads are for the three packaged roof top air handling units which all operate using electricity. There is no central chiller plant utilized in this project, nor are there any types of boilers or steam generators. Heating is accomplished by electric resistance in each parallel fan powered VAV box.

There was no energy model completed by the engineers for this building. Perhaps this is because the building was constructed and fit-out in phases, which would make developing a complete and accurate model difficult.

Table 13 - Annual Energy Consumption		
	kWh	Annual Cost ($) per Square Foot
HVAC - Components		
Electric	657,547	1.121
Non-HVAC Components		
Electric	360,393	0.623
Building Total	1,017,940	1.743

Table 14 - Annual Costs	
Component	Cost ($)
Air System Fans	34,718
Cooling	1,153
Heating	28,758
Pumps	0
Cooling Tower Fans	0
HVAC Sub-Total	64,629
Lights	25,241
Electric Equipment	0
Misc. Electric	10,689
Misc. Fuel Use	0
Non-HVAC Sub-Total	35,930
Grand Total	100,559

Table 15 - Energy Consumption by System Component				
Component	Site Energy (kBTU)	Site Energy (kBTU/ft^2)	Source Energy (kBTU)	Source Energy (kBTU/ft^2)
Air System Fans	1,186,868	20.576	4,238,812	73.485
Cooling	38,102	0.661	136,080	2.359
Heating	1,018,467	17.656	3,637,383	63.058
Pumps	0	0	0	0
Cooling Towers	0	0	0	0
HVAC Sub-Total	2,243,437	38.893	8,012,275	138.902
Lights	863,853	14.976	3,085,189	53.485
Electric Equipment	0	0	0	0
Misc. Electric	365,803	6.342	1,306,438	22.649
Misc. Fuel Use	0	0	0	0
Non-HVAC Sub-Total	1,229,656	21.318	4,391,627	76.134
Grand Total	3,473,093	60.21	12,403,901	215.036

Table 16 - Annual Cost per Square Foot	
Component	Cost per Square Foot
Air System Fans	0.602
Cooling	0.02
Heating	0.499
Pumps	0
Cooling Tower Fans	0
HVAC Sub-Total	1.121
Lights	0.438
Electric Equipment	0
Misc. Electric	0.185
Misc. Fuel Use	0
Non-HVAC Sub-Total	0.623
Grand Total	1.743

Table 17 - Emissions Data		
	Generation Rate	Annual Emissions
CO_2	1.38 lb/kWh	1,404,722 lb
SO_2	3.42 g/kWh	3,481 g
NOx	2.01 g/kWh	2,046 g

Table 18 - Energy Consumption by Energy Source				
Component	Site Energy (kBTU)	Site Energy (kBTU/ft²)	Source Energy (kBTU)	Source Energy (kBTU/ft²)
Electric	2,243,550	38.895	8,012,678	138.909
Natural Gas	0	0	0	0
HVAC Sub-Total	2,243,550	38.895	8,012,678	138.909
Electric	1,229,660	21.318	4,391,643	76.134
Natural Gas	0	0	0	0
Non-HVAC Sub-Total	1,229,660	21.318	4,391,643	76.134
Grand Total	3,473,210	60.212	12,404,321	215.043

Table 19 - Annual Coil Loads		
	Load (kBTU)	$kBTU/ft^2$
Cooling Coil	3,006,371	52.119
Heating Coil	1,018,509	17.657
Total	4,024,880	69.776

System Operation

Each air handling unit operates through its associated user interface control panel to maintain supply air temperature set points of 55°F summer and 65°F winter. Both set points are adjustable and the supply air temperature reset is based on the outside air temperature and is available through the AHU controls. All safety interlocks are hard wired through the fan controllers to be operable whenever the fan is in either “auto” or “hand” positions. Exhaust fans EF-1 and EF-2 are interlocked with the AHU occupied/unoccupied modes. During occupied modes both fans start and run continuously, conversely during unoccupied mode both exhaust fans are off.

The fan powered supply air terminals for variable volume applications are controlled so that on a fall in space temperature, the space temperature transmitter modulates the integral box controller to its respective minimum setting. Upon a further fall in space temperature, the fan will run and the space temperature transmitter will modulate the reheat coil through an internal step controller in order to maintain space temperature. On a rise in space temperature the reverse occurs.

Control system

The complete control system is of direct digital temperature, building automation, and automatic temperature control of the digital/electronic type. Direct digital control (DDC) logic controllers are able to perform through the use of application specific controllers (ASC), which all operate as stand-alone controllers capable of performing its specified control responsibilities independently of other controllers on the network. Terminal equipment controllers are application specific and are provided for VAV boxes. The specification states that factory mounted direct digital controllers having digital/electronic thermostats are user programmable for each VAV box. Each controller has three specified modes: occupied/unoccupied, night setback, and normal. The terminal equipment controllers for VAV boxes must have 50% of point outputs as universal type, allowing for additional system flexibility. This means that half of the outputs on each controller can be used as either modulating or two-stage. Analog outputs shall produce industry standard signals such as 24V floating control, which allows for interface to a variety of modulating actuators. Each controller performing space temperature control shall be provided with a matching room temperature sensor of the RTD or thermistor type providing the following minimum performance requirements:

Accuracy:	±1°F
Operating Range:	35°F to 115°F
Set Point Adjustment Range:	55°F to 95°F
Set Point Modes:	Independent Heating Cooling Night Setback-Heating Night Setback-Cooling

Room thermostats shall be 2-pipe pneumatic type, proportioned single output, and single set point with an operating range of 50°F to 100°F with an accuracy of ±1 ° F. Fire and smoke detection devices are installed as required by NFPA Standards 96 and 90A in accordance with Division 16. Smoke detectors are capable of detecting visible and invisible products of combustion through the resistance of an ionized field within the device. A building evacuation alarm is established whenever any of the following alarm signal initiating devices are activated: manual stations, sprinkler flow alarm switches, smoke detectors, thermal fire detectors, or duct detectors. All heat detectors, ionization smoke detectors, photoelectric smoke detectors, and duct detectors shall be addressable by the control system.

Existing System Critique

The engineered mechanical system for the DASCO Medical Office Building was designed for a shell and core project. DASCO Companies is a medical real estate development, acquisition, and management firm who owns the building on the Saint Joseph Medical Center campus. Recognizing that no floor plans were available to the engineers detailing the number and size of individual rooms, occupancies, and usage, the mechanical system meets the outdoor air requirements of ASHRAE Standard 62.1-2007 as Table 2 shows. Although the initial project incorporated two roof top AHUs, a third, smaller unit was added to the building to ensure outdoor air supply was still acceptable after an addition and fit-out project adding many patient exam rooms and physician offices to the first floor. The type of AHU chosen, direct expansion packaged unit, has a 0-100% economizer section which helps reduce energy consumption if outdoor air conditions are ideal. The use of refrigerant, in this case R-22, is not the best for the environment or global warming. Generally in green building practice refrigerants should not be used in mechanical systems, and R-22 is eventually going to be phased out of the industry.

Initial shell space indoor air design conditions were achieved by a system of parallel fan powered VAV units with electric reheat. These units are ducted to the supply side of the AHUs and return air travels through a ceiling plenum to the return air side of the AHUs. A ceiling plenum was most likely chosen because the location of return grilles was not known. It also allows for the mixing of conditioned air and fresh supply air, 55°F in summer and 65°F in winter, within the ceiling. This reduces the amount of reheat needed in the winter months. Many more VAV boxes have been added to the building since the first shell and core design for different fit-outs. The heating load is addressed by electric reheat coils within each terminal unit. Since the building was a shell and core, choosing hot water reheat coils as the method of heating at the terminal units may not have been practical. It would have been difficult to create a piping system to deliver hot water to each terminal unit since the locations of every VAV box were not known at initial design, and many were added later.

Energy consumption for this building is all electric. HAP approximated the system operation to cost $100,559 annually; $64,629 is for the HVAC system. The biggest consumer of energy, as Table 15 shows are the fans and the electric reheat. This proves that heating the building is a large majority of the HVAC operation costs.

The cost of installing the mechanical system totaled $678,784.79. This is about 12% of the final cost of the shell and core and is equivalent to $9.73 per square foot for mechanical equipment in the building. Only 1.3% of the floor area is lost as rentable space due to the mechanical system. This small percentage only helps to increase the maximum leasable area, which is what any owner would want as a design goal. It should be noted that the total leasable area is 50,800 square feet which was determined by subtracting the total built floor area (64,000 square feet) from the core space (13,200 square feet). This amounts to 80 percent of the building space which can be leased and is generally the main design criteria to optimize from a real estate development perspective.

Given the circumstances surrounding the design of a mechanical system for a shell and core building such as; the owner not occupying the building, and not knowing the final layout, which prevents accurate internal loads to be used for the sizing of the AHUs, the system at least provides adequate outdoor air. It is also capable of maintaining comfortable indoor air conditions for the occupants. However, electric reheat is a very costly method of maintaining temperatures inside during the winter months. The adaptability of this system for each fit-out seems to be one of the deciding factors which led to this system. Although, owner requirements and keeping first costs low, while maximizing rentable space is clearly the reason why this system was designed for this building.

Redesign Topics

Proposed Redesign

Redesign goals are to increase the efficiency of the mechanical system by making changes to the equipment installed in the building. However, this must be done with sensitivity to the cost of the mechanical equipment. Also, reducing the energy costs, specifically with electricity consumption, will help bring down annual energy bills and reduce emissions. In order to achieve these goals the mechanical system redesign will involve the sizing of a chilled water plant solely dedicated to the cooling load for the DASCO building. This new plant will also incorporate a gas fired hot water boiler for space heating and domestic water heating.

The chilled water will be integrated with an air handler mounted on the roof that will provide supply air to each space. In order to reduce the amount of fan energy consumed by the current system, it will prove beneficial to select standard VAV boxes instead of parallel fan powered boxes. The supply air fan, as part of the air handler, can be sized to overcome the static pressure requirements of the longest duct run. This will limit the amount of electricity used to provide the air throughout the building.

Another way to reduce electricity use is to eliminate the electric reheat coils from the VAV boxes which create a need to design a different system that will provide heating to the spaces. Using the gas fired boiler to generate hot water can reduce electricity consumption, and also provide the service hot water which is currently supplied by domestic water heaters. The hot water can be pumped through the building to perimeter fin tube radiators. Based on the current building model created in HAP, the only areas that have a heating load are those along the perimeter of the building. Supplying heat at the window, along the perimeter, will reduce the amount of energy lost to the outdoor environment, thus increasing the overall efficiency of the building envelope.

System cost may rise due to the increase in mechanical equipment with the redesigned system. However, most of this may be offset by reducing the cost of each VAV box, since fans are eliminated and electric reheat coils are not used. Although the cost of installing fin tube baseboard heating to be integrated with a hot water gas fired boiler can be expensive, heating costs will decrease since the amount of consumed electricity is reduced. Also, each of the nine domestic water heaters are not needed since hot water produced from the boiler can be supplied to sinks and other service hot water applications within the building. The operating cost of the building should be greatly reduced, which may not have been an initial concern by the owner for the original design. Electricity use can be limited to normal receptacle service, lighting and any other medical equipment requiring electricity. In addition to existing electricity consumers, fan power and additional pumps for the supply of chilled water from the plant and hot water from the boiler will also consume electricity.

Part of making a better built environment is to reduce the amount of natural resources used in the construction process. One way to do this is by designing a system which incorporates existing forms of cooling production, thus eliminating the need to build new equipment. Purchasing new equipment also adds to the project cost, which in this case was an area of design that was to be kept to a minimum. Thus, exploring the capacity of the campus chilled water plant is an alternate design route that will be taken into consideration for this project. In order to utilize the central chilled water plant currently used for the hospital buildings only, it must have the capacity to provide the cooling load for the DASCO building. Exploring the capacity of the four chiller plant will be based on operating conditions provided by the engineer. Information in this case is from the building maintenance operation system monitoring the chiller plant. Using this plant eliminates the need to design and purchase a separate chiller and cooling tower for the DASCO building. However the boiler, fin tube radiators, and replacement VAV boxes will still be used. Therefore it is necessary to generate a cost per ton of cooling that the DASCO building owner or tenants will pay for chilled water production from Saint Joseph Medical Center.

The maintainability of a new system design utilizing the central chilled water plant will most likely improve. Since the hospital employs building engineers that regularly check and service the central chilled water plant, the separate service calls to fix problems with the current packaged roof top units can be eliminated. Other than the cleaning of coils and filters, the other maintenance required arises with each VAV box that would need to be addressed on a case by case basis if a problem occurs.

Breadth Topics

In addition to studying the in-depth redesign of the mechanical system, there are two other areas to be explored. The first is the fact that the building currently has no emergency power system. Initial proposals for the design of the shell and core engineering did not include the fees to design emergency power. Utility company power can at times be unreliable or endure outages. Since this is a medical office building with important medical equipment for the treatment of cancer and for diagnostic imaging, an emergency power generation system is very essential. Sizing an emergency power system for this building incorporates various medical imaging and treatment equipment, as well as normal office receptacle loads and lighting. The second breadth study will be to determine and compare the labor cost of installing the new equipment with the installation of the old equipment. RS Means 2008 will be used to determine and compare the amount of time mechanical system installation will cost. This will have an impact on the completion of the shell and core building prior to fit-out construction.

Mechanical System Depth Study

Mechanical system redesign ideas were developed based on the main goals of decreasing energy consumption, more specifically electrical energy, and reducing the annual operating cost of the mechanical system. Reducing energy consumption will also lead to a reduction in emissions from the generation of utility power. The existing mechanical system is an all electric type with three main components that run on electricity. All three AHU's run on electricity, specifically the direct expansion coils which are the means of cooling supply air. The building service water is heated in nine different domestic water tanks each containing two 3,000 watt heating elements. The supply air is distributed throughout the building via fan powered VAV boxes and when heating is required in winter months, each VAV box is equipped with an electric reheat coil. Many of the components selected for the redesigned mechanical system are intended to reduce the dependency on electric power.

In order to begin sizing alternate equipment for a new mechanical system, the design loads must be collected. In this case building simulation data and load information was taken from a model created using Carrier's Hourly Analysis Program (HAP) of the DASCO building which was also used for the analyses of past technical assignments. Included in the building model are design parameters such as weather data, design temperatures, and any other variables or factors associated with using design software which will be uniform form both the existing case and the redesign case. Most of this information is mentioned in earlier sections of this report.

To accomplish the task of reducing electrical dependency, the three direct expansion AHUs can be eliminated and replaced by a chilled water air handling unit (CWAHU). Chilled water, in this application, is used as the refrigerant instead of the environmentally hazardous refrigerant R-22 used in the direct expansion coils. HAP is able to model the air system and provide a sizing summary for the cooling coil and the supply air. To determine an AHU design, HAP was used to model one CWAHU for the entire building, and as a second option, model two AHU's, one serving the ground and first floor and the second serving the second and third floors. The simulation data for both scenarios is listed in Table 20 below. Based on research through the CoolTools™ Chilled Water Plant Design and Specification Guide, which was used as the primary source of information for design, one AHU was assumed to slightly simplify controls and therefore chosen as the redesign option.

Table 20 - Air Handling Unit Sizing Data

		Two CWAHU option	
Unit	One CWAHU option	Ground, First floors	Second, Third floors
Cooling Coil (tons)	125.4	70.9	57.3
Supply Air (cfm)	45,488	29,726	18,668

The basis for design is a Carrier AERO™ Outdoor Air Handler ranging from 26,000 to 60,000 nominal cubic feet per minute (cfm). This packaged unit is manufactured as a central station with several configurations. Because the AHU is being used for cooling only with a single duct

VAV supply network, a horizontal draw-thru unit is the ideal configuration type. The recommended face velocity based on Carrier's Product Data sheets for a cooling coil ranges between 440 to 550 feet per minute (fpm). With a supply air volume of approximately 46,000 cfm, the coil face area is determined to be 96 square feet based on Equation 1 below.

Equation 1: Face Velocity (fpm) = Air Volume (cfm) / Coil Face Area (sq ft)

Figure 9 below is from the product data sheets as an alternate way to size the AHU and proves the proper size for the coil is 96 square feet.

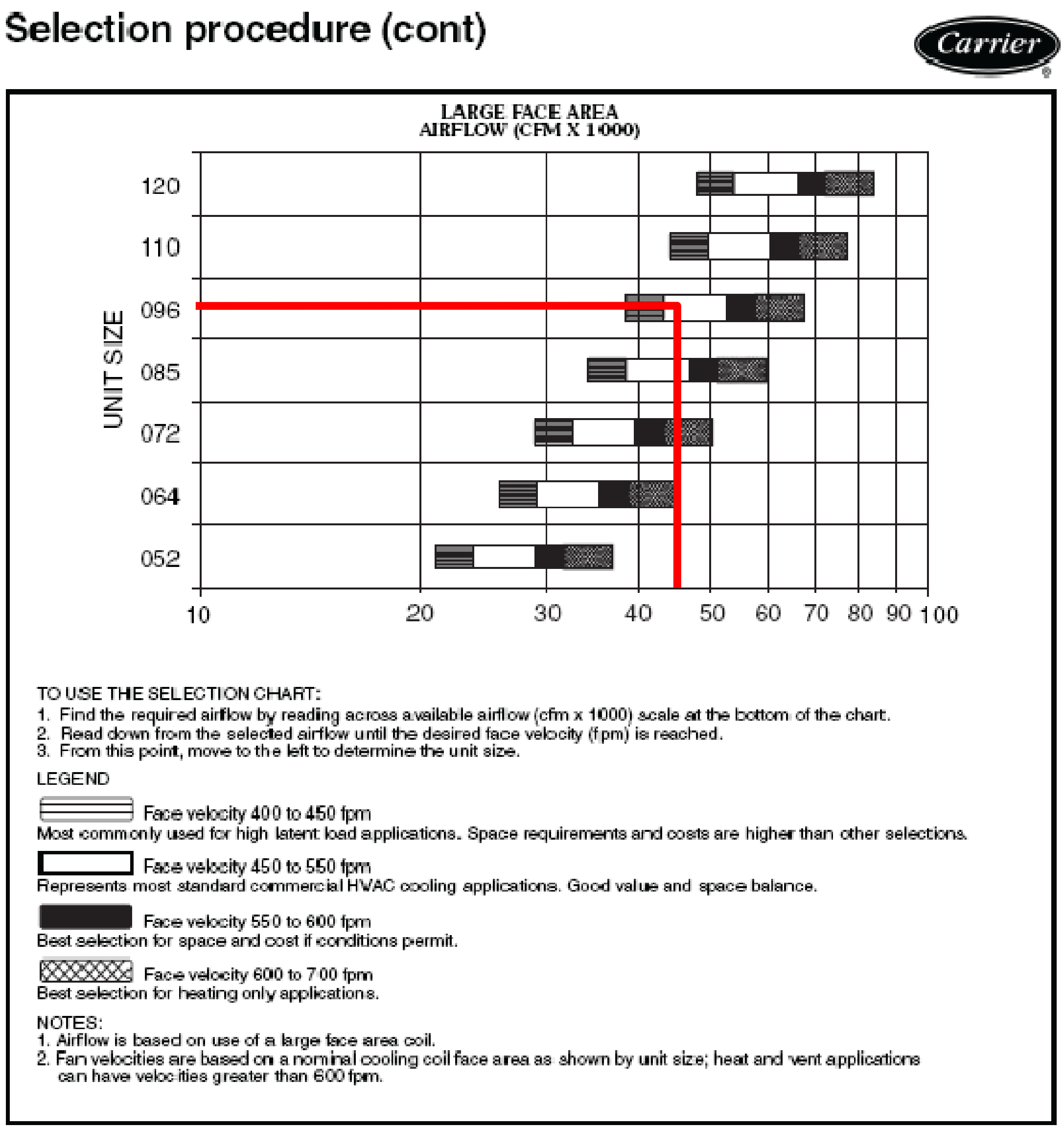

Figure 9 – Chilled Water AHU Selection Chart

With the CWAHU sized to the building cooling load and designed supply air, the necessary chilled water production equipment must be sized and selected. Based on the cooling coil sizing data, the chiller must be capable of producing 125.4 tons of cooling capacity. There are many different types of chillers that run on various fuel types and operate at different efficiencies and are suited for different applications. The CoolTools™ literature suggests that screw chillers can be more efficient than reciprocating chillers since they incorporate refrigerant economizers. Screw chillers are ideal when sized between 70 to 400 tons which can provide a coefficient of performance (COP) of 4.9-5.8. These chillers also prove to be less expensive than other chiller types; the cost can be approximated as $225 to $275 per ton of cooling production. Chiller selection from the Carrier website led to an indoor packaged water cooled screw chiller that uses R-134a refrigerant, which is chlorine free, and thus a better choice for the environment. This chiller operates on electricity; therefore its integration in to the current power distribution system will not require other utility connections. A 136.5 ton chiller was selected, which allows for a 10% safety factor above the simulated building coil load. A schedule provided in Table 21 below details the chiller performance data provided by Carrier.

Table 21 - Chiller Perfromance Data

Unit Design Basis	Unit Size	Entering Water Temperature (°F)	Leaving Chilled Water Temperature (°F)	Capacity	Cooler Flow Rate (gpm)	Condenser Flow Rate (gpm)
Carrier 30HXC	136	85	44	136.0	326.0	389.4

The chilled water distribution best suited for a single chiller, single load is a constant flow, primary pump only system with no control valves. Not only does this allow for a simpler design of reliable heat transfer but it can also improve chiller performance. In order to have a constant flow system, a certain volume of water must be maintained in the pipes at all times. The rule of thumb is 2.4 gallons per ton, which in this case is equal to 326.4 gallons. Figure 10 below shows a typical constant flow piping arrangement taken from CoolTools™ Chilled Water Plant Design and Specification Guide.

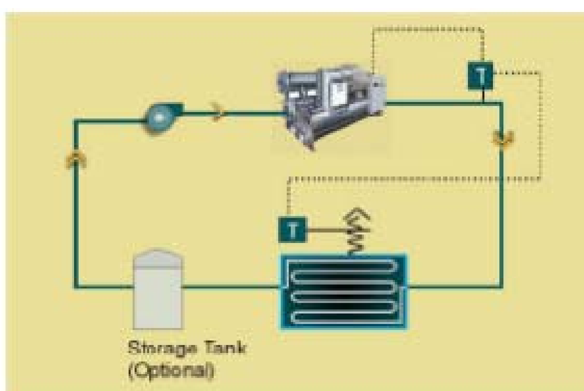

Figure 10 – Constant flow piping, single chiller, single coil

A chiller plant must have a method of heat rejection. This is accomplished through the incorporation of a cooling tower into the system. Cooling towers are sized around the need for three gallons per minute per ton. This case requires a 409.5 ton cooling tower which was selected from Baltimore Air Coil. An induced draft, crossflow type was chosen because of its wide industry use and its efficiency. The operating conditions allow for a 10°F temperature difference between the entering water temperature of 95°F and the leaving water temperature 85°F. A schematic of the entire chilled water plant is shown in Figure 11 below and again with corresponding water temperatures in Figure 12 below.

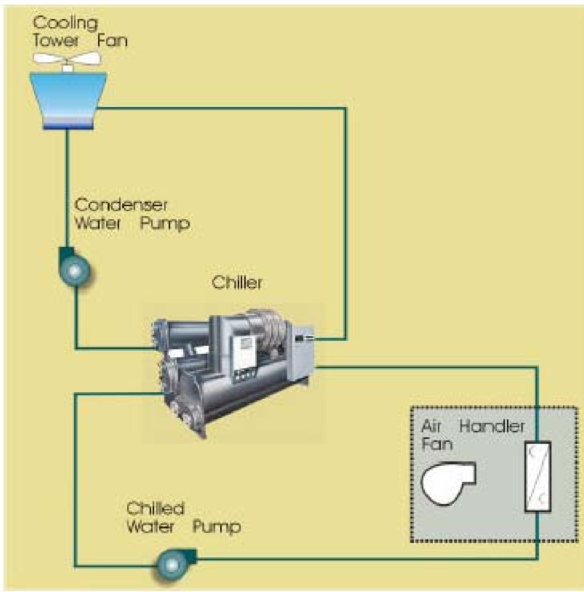

Figure 11 – Chiller plant schematic

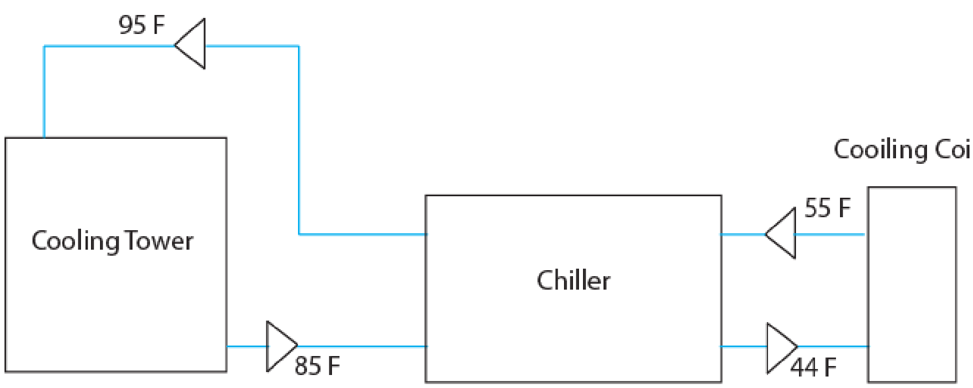

Figure 12 – Chilled water flow diagram

After the cooling system is designed, means of producing heat must be explored since they are separate from the cooling system. The design loads were taken from the HAP building model. The space heating load was simulated to be 368,400 BTU per hour. Also incorporated in the heating system is the service hot water demand which will be stored in a hot water tank containing a water to water heat exchanger that will be tied into the boiler water. Based on information found in the ASHRAE Applications Handbook under the Service Water Heating section, a boiler being sized for heating requirements as well as service hot water heating must have a rated capacity based calculations shown below. Equation 2 determines the hot water requirement from entering and leaving temperatures as well as the thermal efficiency of the boiler. All the subsequent information from ASHRAE is based on a typical office building.

Equation 2:
Q = (service water gallons per hour)(8.4 lbm/gallon)(1 BTU/lbm °F)(T_h – T_c) / Thermal Efficiency

The first step is to determine the service hot water load to be supplied at 120°F. Table 22 below shows the basis of design capacity for this number.

Table 22 - Service Hot Water		
Fixture	Number	Required Flow (gallons per hour)
Basin, Private Lav	30	2
Service Sink	4	20
Shower	1	30
Wash Sink	65	10
Total		820

Solving Equation 2 above for the service hot water requirements yields 598,957 BTU per hour at a thermal efficiency of 92%. This thermal efficiency is based on a model manufactured by Patterson Kelley Boilers, and will be the basis of design for this system. A ratio of hot water heating load to space heating load is used order to determine the additional boiler capacity above that required to meet the heating load. This ratio is calculated to have a value of 1.63 which is plotted on a graph provided in the ASHRAE Handbook giving a reducing factor to be multiplied by the water heating load determined above. The graph results in a factor of 0.83 which reduces the hot water heating load to 497,134 BTU per hour. Thus, the boiler capacity must be the sum of the reduced hot water heating load and the space heating load taken from the HAP model which results in an 865,534 BTU per hour boiler. The hot water storage tank capacity is based on the 820 gallons per hour (gph) and then reduced based on typical building demand factors for hot water use. The possible maximum demand factor is 0.3 and thus the probable maximum demand is 0.3 * 820 gph which equals 246 gph. The storage capacity is twice this amount, which results in the needs for a 492 gallon hot water storage tank. The storage tank selected from Patterson Kelley is based on the Series 500 Control-Flo® Water Heater which has a built in heat exchanger utilizing the produced boiler water. Figure 13 below is a diagram of the water tank and heat exchanger taken from the Patterson Kelley water heater brochure. Figure 14 below shows a flow diagram of the boiler system.

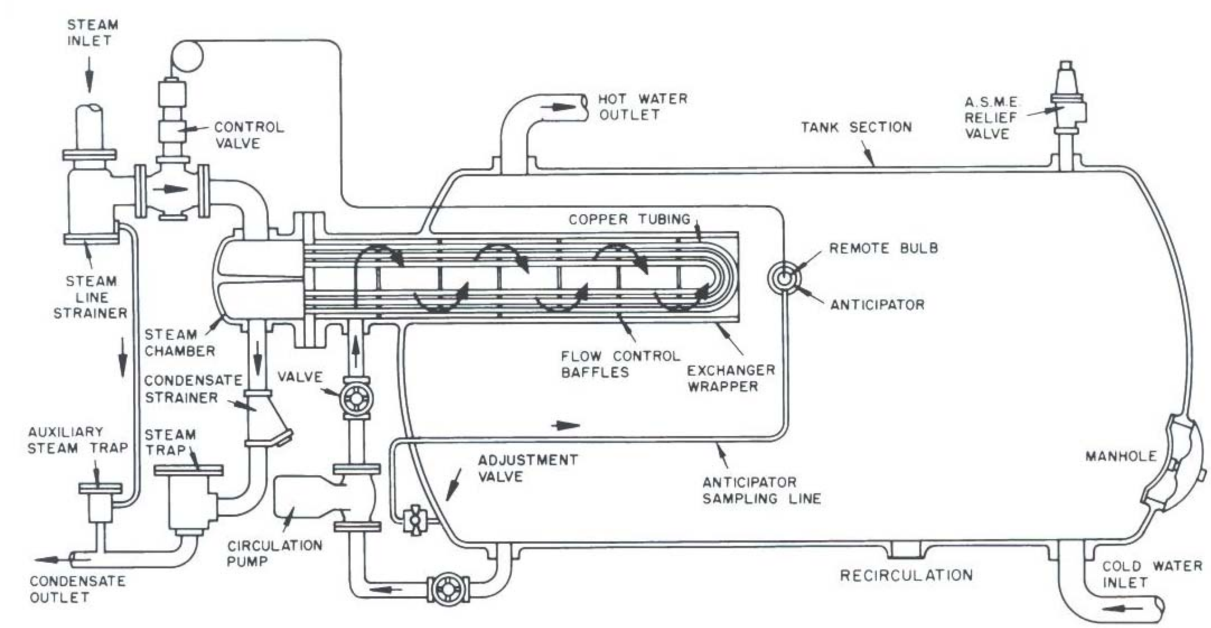

Figure 13 – Standard flow schematic

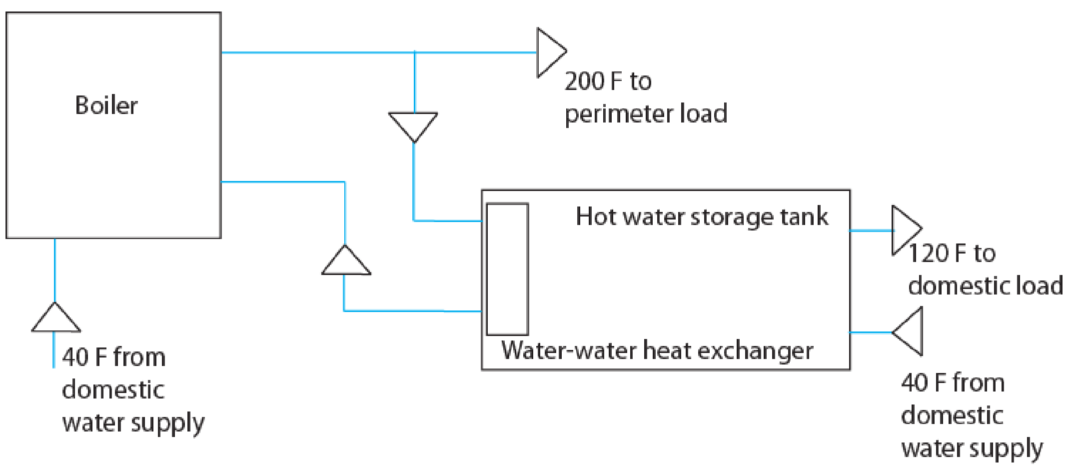

Figure 14 – Boiler hot water distribution

The remaining mechanical system component needed to be designed is the equipment for space heating. For this building it is suitable, based on the HAP model, to heat only perimeter spaces. Since reducing electricity consumption is a design goal and a boiler has been designed to provide hot water at 200°F, fin-tube radiators based on Slant/Fin Multi/Pak 90 design will be selected for this building. The system will operate through a two pipe reverse return system to minimize heating capacity losses of the water, thus ensuring that each radiator has approximately the same entering water temperature. Design parameters for this system are based on a three feet per second flow rate at one gallon per minute. Physically, the fin-tube size is a one inch copper pipe with 4-1/4 inch aluminum fins spaces at 40 fins per foot. The heating capabilities of each radiator depend on the average temperature in the tube and range from

860 BTU per hour per foot for an average temperature of 150°F to 2048 BTU per hour per foot for an average temperature of 220°F. The necessary lengths for each room are listed in Appendix E. As shown in Appendix E, the total length of fin-tube assembly is 406.5 feet.

Water systems in closed piping circuits that exchange heat create the need for an expansion tank. This is due to the physical properties of water, specifically the change in volume when the temperature changes significantly. Amtrol expansion tanks are sized based on Equation 3 below.

Equation 3: $V_t = (0.00041*T - 0.0466) * V / (1 - P_f / P_o)$

The system volume (V) is calculated based on the boiler capacity, heat exchanger pipe length, fin-tube length, and length of distribution piping for the fin-tube system. The estimated volume is based on a four gallon heat exchanger, an approximated four inch distribution pipe at 200 feet holding 125 gallons, the boiler capacity of 7.3 gallons, and the 406.5 feet of one inch copper fin-tube yields 17.5 gallons. The total system volume is added to be 153.8 gallons of water. The temperature of the water is 200°F, the minimum operating pressure (P_f) is 24 pounds per square inch (psig) and the maximum operating pressure at the boiler is 60 psig. Therefore based on Equation 3 above the total volume needed for an expansion tank is 11.29 gallons, which can be selected as an Amtrol Extrol® AX-60.

After sizing and selecting equipment, a new building model was created using the existing base building model in HAP. All the mechanical equipment used to provide evaluations in previous technical assignments was deleted. Each new piece of equipment was entered into the program as accurately as possible keeping within the limitations of modeling software. The chiller, cooling tower, CWAHU and boiler were modeled based on performance data provided on manufacturer specification sheets. Other equipment such as VAV boxes and fin-tube radiators were entered as default systems, and any information that was able to be altered was done so based on manufacturer data. After modeling through the HAP program, final system design can be summarized as follows:

A roof mounted chilled water air handling unit with a 48,000 cubic feet per minute supply air capacity is supplied chilled water produced by a packaged water cooled screw chiller. Chilled water is distributed through a constant flow primary only system. The AHU serves variable air volume terminal units in a ducted supply, plenum return arrangement. The chiller, rated for 136 tons of cooling, has an entering water temperature of 85°F and a leaving chilled water temperature of 44°F. A 409.5 ton induced draft, crossflow cooling tower rejects heat to the environment which lowers the water temperature by 10°F. Heating is accomplished through 406.5 feet of fin-tube radiators in the perimeter spaces of the building. Hot water supplied to the radiators is produced at 200°F by a natural gas condensing boiler capable of producing 987,000 BTU per hour operating at 105 gallons per minute with a 20°F temperature difference. The boiler also provides hot water to heat the domestic supply water from approximately 40°F to 120°F through a water to water heat exchanger built inside a 492 gallon service water storage tank.

In order to run building simulations with the redesigned mechanical system described above, a natural gas utility rate must be input into the building model so that annual operating costs and emission data can be calculated. Baltimore Gas and Electric offers a general service gas rate where the customer charge is listed in Table 23 below. The electric service rate from the existing building model was used in the redesign simulation. Values for these utility services are summarized in Table 24 below.

Table 23 - Baltimore Gas and Electric Company, Gas Rates	
General Service - Gas (cost per therm)	
Therms	Price ($)
First 10,000	0.1975
All Over	0.0948

Table 24 - Emissions Data		
	Generation Rate (Coal)	Generation Rate (Natural Gas)
CO_2	1.38 lb/kWh	39.27 lb/Therm
SO_2	3.42 g/kWh	0.18 g/Therm
NOx	2.01 g/kWh	33.77 g/Therm

The annual cost and annual energy consumption data provided by HAP upon simulation of the DASCO building with the redesigned mechanical system is shown in Tables 25-32 below.

Table 25 - Annual Energy Consumption		
	Energy	Annual Cost ($) per Square Foot
HVAC - Components		
Electric (kWh)	560,860	0.994
Natural Gas (Therm)	7,506	0.033
Non-HVAC Components		
Electric (kWh)	253,182	0.445
Natural Gas (Therm)	0	0
Building Total	-	1.472
Electric (kWh)	814,043	
Natural Gas (Therm)	7,506	

Table 26 - Annual Costs	
Component	Cost ($)
Air System Fans	35,623
Cooling	13,859
Heating	1,924
Pumps	1,560
Cooling Tower Fans	6,258
HVAC Sub-Total	59,224
Lights	25,681
Electric Equipment	0
Misc. Electric	0
Misc. Fuel Use	0
Non-HVAC Sub-Total	25,681
Grand Total	84,905

Table 27 - Annual Coil Loads		
	Load (kBTU)	kBTU/ft^2
Cooling Coil	2,578,020	44.693
Heating Coil	713,852	12.375
Total	3,291,872	57.068

Table 28 - Energy Consumption by System Component				
Component	Site Energy (kBTU)	Site Energy (kBTU/ft^2)	Source Energy (kBTU)	Source Energy (kBTU/ft^2)
Air System Fans	1,197,851	20.766	4,278,039	74.165
Cooling	456,595	7.916	1,630,697	28.27
Heating	751,351	13.026	753,232	13.058
Pumps	51,918	0.9	185,422	3.215
Cooling Towers	206,543	3.581	737,653	12.788
HVAC Sub-Total	2,664,258	46.188	7,585,043	131.495
Lights	863,858	14.976	3,085,207	53.486
Electric Equipmen	0	0	0	0
Misc. Electric	0	0	0	0
Misc. Fuel Use	0	0	0	0
Non-HVAC Sub-To	863,858	14.976	3,085,207	53.486
Grand Total	3,528,116	61.164	10,670,251	184.981

Table 29 - Annual Cost per Square Foot	
Component	Cost per Square Foot
Air System Fans	0.618
Cooling	0.24
Heating	0.033
Pumps	0.027
Cooling Tower Fans	0.109
HVAC Sub-Total	1.027
Lights	0.445
Electric Equipment	0
Misc. Electric	0
Misc. Fuel Use	0
Non-HVAC Sub-Total	0.445
Grand Total	1.472

Table 30 - Energy Consumption by Energy Source				
Component	Site Energy (kBTU)	Site Energy (kBTU/ft²)	Source Energy (kBTU)	Source Energy (kBTU/ft²)
Electric	1,913,656	33.175	6,834,485	118.484
Natural Gas	750,619	13.013	750,619	13.013
HVAC Sub-Total	2,664,275	46.188	7,585,103	131.496
Electric	863,858	14.976	3,085,207	53.486
Natural Gas	0	0	0	0
Non-HVAC Sub-Total	863,858	14.976	3,085,207	53.486
Grand Total	3,528,133	61.164	10,670,311	184.982

Table 31 - Emissions Data			
	Generation Rate (Coal)	Generation Rate (Natural Gas)	Annual Emissions
CO_2	1.38 lb/kWh	39.27 lb/Therm	1,418,149 lb
SO_2	3.42 g/kWh	0.18 g/Therm	2,785 g
NOx	2.01 g/kWh	33.77 g/Therm	1,890 g

Table 32 - Monthly Plant Simulation							
Month	Cooling Coil Load (kBTU)	Plant Load (kBTU)	Chiller Output (kBTU)	Chiller Input (kWh)	Primary Chilled Water Pump (kWh)	Condenser Water Pump (kWh)	Cooling Tower Fan (kWh)
January	4,537	4,669	4,669	233	41	24	65
February	2,134	2,198	2,198	110	20	12	22
March	39,091	39,683	39,683	1,936	185	174	1,109
April	69,825	71,252	71,252	3,522	445	345	1,532
May	252,492	254,765	254,765	12,388	708	884	6,826
June	464,066	466,490	466,490	23,932	756	1,172	10,877
July	582,022	584,526	584,526	31,320	781	1,258	11,954
August	574,379	576,883	576,883	31,507	781	1,244	11,729
September	339,353	341,729	341,729	16,565	741	1,074	9,490
October	172,701	174,543	174,543	8,476	574	659	4,795
November	75,031	76,152	76,152	3,708	349	309	2,082
December	2,388	2,462	2,462	123	23	13	51
Total	2,578,020	2,595,351	2,595,351	133,820	5,404	7,168	60,534

Comparison of the design goals between the existing building mechanical system and the redesigned mechanical system can be done with the summarization of three main simulation results: annual energy consumption, annual operating cost, and annual emissions. These data are compared in Table 33-below.

Table 33 - Annual Energy Consumption				
	Existing System		Redesigned System	
	Energy	Annual Cost ($) per Square Foot	Energy	Annual Cost ($) per Square Foot
HVAC - Components				
Electric (kWh)	657,547	1.121	560,860	0.994
Natural Gas (Therm)	0	0	7,506	0.033
Non-HVAC Components				
Electric (kWh)	360,393	0.623	253,182	0.445
Natural Gas (Therm)	0	0	0	0
Building Total	1,017,940	1.743	-	1.472
Electric (kWh)	-		814,043	
Natural Gas (Therm)	-		7,506	

Table 34 - Energy Consumption by Energy Source				
Component	Existing Site Energy (kBTU)	Redesign Site Energy (kBTU)	Percent Difference	
Electric	2,243,550	1,913,656	15.87	decrease
Natural Gas	0	750,619	200.00	increase
HVAC Sub-Total	2,243,550	2,664,275	17.15	increase
Electric	1,229,660	863,858	34.95	decrease
Natural Gas	0	0	0	
Non-HVAC Sub-Total	1,229,660	863,858	34.95	decrease
Grand Total	3,473,210	3,528,133	1.57	increase

Table 35 - Annual Costs				
	Cost ($)			
Component	Existing	Redesign	Percent Difference	
Air System Fans	34,718	35,623	2.57	increase
Cooling	1,153	13,859	169.28	increase
Heating	28,758	1,924	174.92	decrease
Pumps	0	1,560	200.00	increase
Cooling Tower Fans	0	6,258	200.00	increase
HVAC Sub-Total	64,629	59,224	8.73	decrease
Lights	25,241	25,681	1.73	increase
Electric Equipment	0	0	0.00	
Misc. Electric	10,689	0	200.00	decrease
Misc. Fuel Use	0	0	0.00	
Non-HVAC Sub-Total	35,930	25,681	33.27	decrease
Grand Total	100,559	84,905	16.88	decrease

Table 36 - Emissions Data				
	Annual Emissions			
	Existing	Redesign	Percent Difference	
CO_2 (lb)	1,404,722	1,418,149	0.95	increase
SO_2 (g)	3,481	2,785	22.22	decrease
No_x (g)	2,046	1,890	7.93	decrease

As the tables above summarize, the mechanical system actually consumes 1.57% more energy than the existing building system. Even though the electricity needs are decreased in both the HVAC components as well as the non-HVAC components, the amount of natural gas needed to fuel the boiler pushes the redesigned mechanical system site energy consumption above the existing mechanical system. The redesign allows a 17% decrease in the annual operating cost of the entire building. This savings will most likely be a better marketing point for the owners when trying to lease out space in the DASCO building. Both the SO_2 and NO_x emissions are reduced significantly due to the major reduction in electricity consumption. However, CO_2 emissions increase about 1% which does not represent a major difference between systems.

One of the design conditions most important to building owners is the cost of mechanical system equipment. This represents a significant portion of new building construction and in many cases is engineered to be a lower first cost. Low first cost can be especially significant in building projects that are not constructed with the intent of being occupied by the developers. As shown in Table 37 below, the mechanical equipment cost actually decreases by $14,047 even though there are many more pieces of equipment in the redesigned system. The most significant source of high cost is found in the price of the VAV boxes. Fan powered boxes with reheat are an average of $859 dollars more than standard VAV terminal units.

Table 37 - Mechanical Equipment Cost

Existing			Redesign		
Item	Cost ($) 2008	Cost ($) 2006	Item	Cost ($) 2008	Cost ($) 2006
Domestic Water Heaters*	-	3,350	Boiler	10,412	9,746
Air Handlers*	-	202,900	Hot Water Storage Tank	8,518	7,973
Fan Powered VAV, w/ reheat	140,448	131,459	Water-Water Heat Exchanger	136	127
			Air Handler	196,050	183,503
			Chiller	59,096	55,314
			Cooling Tower	15,205	14,232
			Expansion Tank	740	693
			Fin-Tube Radiators	11,396	10,667
			VAV Boxes	44,240	41,409
Total System First Cost		337,709			323,662

*Price based on mechanical contractor payment document

Note: All other prices were found using RS Means 2008 Mechanical Cost Data

An alternate option to the design and expense of building a new chiller plant dedicated to the DASCO building would be to purchase chilled water from the Saint Joseph Medical Center chiller plant. This option can eliminate the cost of a purchasing a new chiller and cooling tower, which costs $69,536 as shown in Table 37 above, which amounts to 21.5% of the first cost. Although this may seem cost effective, the chilled water would still need to be purchased from the hospital. In addition to this there is also cost associated with piping and regulating the flow from the location of the campus chiller plant and the location of the DASCO building. Figure 15 below shows a map of the hospital campus, detailing the locations of the DASCO building and the mechanical equipment which generates the chilled water. The red line connecting the two buildings represents the probable routing of the hydronic distribution pipe.

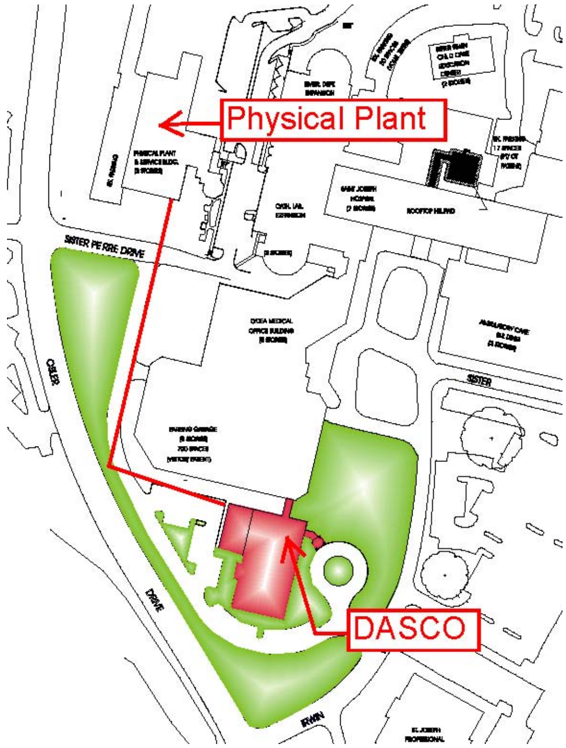

Figure 15 – Saint Joseph Medical Center – Campus Map

The required length of black steel service pipe routed underground as shown in Figure 15 above is approximately 680 feet at five inch diameter. Pipe size was determined by using a System Syzer® Calculator. This calculator gives a necessary pipe size based on a normally used design range for piping friction loss per 100 feet of pipe aligned with the flow rate through the pipe. Design parameters for this system are 330 gpm which results in a five inch iron pipe. This is closely approximated to the steel priced in Table 38 below estimated using RS Means 2008 Plumbing Cost Data. Site earthwork and underground hydronic energy distribution piping values found are listed below in Table 38.

Table 38 - Cost data associated with hydronic distribution

Item	Untis	Amount	Material Cost ($)	Labor Cost ($)	Total Cost ($)	Total Cost ($) 2006
Site Earthwork	Per linear foot	680	0.74	0.56	884.00	827.42
Black Steel Service Pipe	Per linear foot	680	109.00	37.50	99,620.00	93,244.32
Venturi Flow Measuring Device	Each	1	835.00	264.00	1,099.00	1,028.66
Total					101,603.00	95,100.41

Also included in Table 38 is the cost of a utility flow meter which will need to be installed in the piping system to determine how much chilled water the DASCO building uses. Readings from this meter will allow the hospital to bill the DASCO tenants at a rate of $0.10 per ton. Based on simulation output from the HAP model the screw chiller designed for the DASCO building has a 2,595,351 kBTU per year output. In order to consider using the campus chiller plant as an alternative, the chiller capacity in the physical plant must meet this load in addition to all others loads required by the current hospital buildings using the plant for cooling. The kBTU output can be converted to 216,280 tons of cooling per year. In order to determine an appropriate cost to charge for each ton of cooling Table 39 below was used to figure out the simulated cost of operating the chiller plant designed for the DASCO building. The total tons of cooling divided by the operating cost of $21,677 per year results in the $0.10 per ton.

Table 39 - Annual Costs	
Component	Cost ($)
Air System Fans	35,623
Cooling	13,859
Heating	1,924
Pumps	1,560
Cooling Tower Fans	6,258
HVAC Sub-Total	59,224
Lights	25,681
Electric Equipment	0
Misc. Electric	0
Misc. Fuel Use	0
Non-HVAC Sub-Total	25,681
Grand Total	84,905

This alternate method is determined to cost more upfront due to the relatively high cost of the hydronic distribution pipe and therefore would not be suggested as a design alternative. The price to purchase cooling from the central plant was determined based on the annual cost of operating a dedicated chiller plant. Building operation would cost the same as purchasing cooling at $0.10 per ton from the hospital; therefore the operating cost is no factor in this alternative design. Other reasons for the dismissal of this approach are the various complications involved with connecting buildings of this nature. Because the building types are different, one being an office building and therefore considered non-healthcare and the other is a central plant that does serve hospital buildings with patient care, different electrical codes, specifically healthcare electrical codes would need to be applied to the DASCO building. Also, from an owner perspective, the standalone building that is the DASCO medical office space can potentially be sold in the future. A system integrated with a central plant may be a tough selling point to potential buyers. One other reason for caution is that the hospital has the possibility to expand in the future and would not want to have the extra cooling capacity originally designed into the central plant for redundancy or expansion purposes to be unavailable. This would then cause problems if the hospital were to reclaim their cooling production; so most likely the hospital will not agree to sell cooling to the DASCO building.

One remaining concern dealing with the redesigned mechanical system is the needed mechanical space for the installation of the additional equipment involved in the new system. The existing system components were located on the roof. Any indoor equipment was located in janitor closets in the core of each floor. Therefore there is not enough room with the current layout to install the equipment on the ground floor inside the walls of the building. A general guideline for medical office buildings is to allow for 80 percent of the floor area to be leasable. The current building core consumes approximately 13,000 square feet totaled from all four floors. Based on a 64,000 square foot building, this leaves 51,000 square feet of open leasable area amounting to 79.7 percent of the entire building. This is very close to the guideline of 80 percent, and this does not include area needed to house the mechanical equipment selected in the redesign.

The redesigned system requires sheltering of the chiller, boiler, hot water storage tank and the emergency generator. Based on the equipment sizes and recommended service clearance space the required floor area for mechanical equipment is estimated to be 205 square feet. Since leasable space is a considerable factor for the owner, as mentioned previously and there is no room in the current floor plans to add a mechanical room. A separate structure would need to be built next to the building. This mechanical room can easily be constructed without taking up valuable landscape on the back side of the building near the linear accelerator bunker. Figure 16 below shows the probable location of this structure in green hatching.

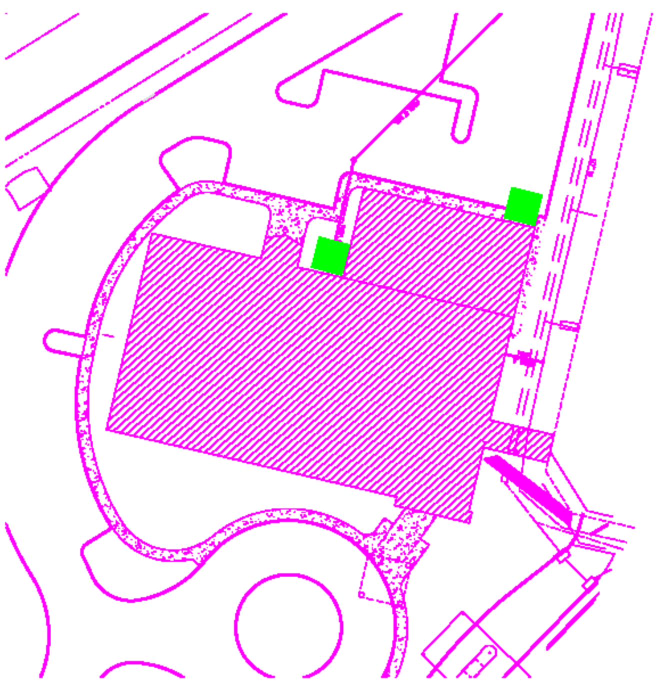

Figure 16 – Proposed Locations for Mechanical Equipment Housing

RS Means 2008 Square Foot Cost Data was used to price the construction material and labor cost to build a mechanical equipment shelter. Base design is a nine foot high cinder block building priced as a slab on grade, six inch thick, reinforced heavy industrial base with brick face composite walls and a roof composed of steel joists and deck on bearing walls. Service entrance to the shelter is accomplished by installing two, 18 gauge steel doors allowing for a five foot maximum opening. Cost data is listed in Table 40 below.

Table 40 - Mechanical Room Construction Cost

Item	Material and Labor ($/ft^2)	Total (2008)	Total(2006)
Slab on Grade	12.06	2,472.30	2,314.07
Roof	3.16	647.80	606.34
Brick Face Composite Walls	27.1	14,634.00	13,697.42
Steel Doors	-	3,450.00	3,229.20
Total		21,204.10	19,847.04

The cost of building a separate structure would add about $20,000 to the first cost of redesign. Including this construction cost would make the redesign mechanical system first cost greater than the existing system cost by approximately $5,500. This is assumed to be a negligible amount compared with the total construction cost. In addition to this assumption, allowing for an additional 205 square feet on the ground floor to be dedicated as a mechanical room will only reduce the leasable area by 0.4 percent. Because system integration would improve and the amount of leasable space sacrificed is so small, the owner and engineer should be able to agree on this compromise.

Redesign Conclusion

Evaluating the redesigned mechanical system requires a comparison of the performance generated by the computer building model to the intended goals of the proposal. System efficiency, when comparing the amount of energy consumed each year, did not improve over the existing system. However, the amount of electricity consumed decreased significantly in both HVAC and non-HVAC system components. Because of the decrease in electrical energy needed, both the SO_2 and NO_x emissions were reduced by a significant percentage compared to the existing building. Annual operating cost decreased by over 16 percent, a savings that can be divided among the tenants. System equipment first cost is approximately equal to that of the existing system; therefore there is no real advantage from a first cost perspective. One of the unique aspects of this buildings design is that it was built as a shell and core. The engineering of a mechanical system for an open floor plan with an assumed occupancy makes optimizing design difficult. If the building were designed as it stands now with all the floors occupied, perhaps a chiller plant system would have been a design option for the engineers.

Emergency Power System Breadth Study

The National Electric Code (NEC 2005) establishes the standard for emergency power system sizing. Article 700 of this standard has basic requirements established for minimum life safety. The sources of emergency power must be located within a space fully protected by approved automatic fire suppression systems or in a space with a one hour fire rating. Also the equipment generating the electricity supply must be of adequate capacity so that power is available for exit lights, emergency and egress lighting and the operation of elevators. The International Building Code (IBC 2006) is the reference which lists the standard minimum lighting supply needed for egress. The IBC states that initial light levels must be one foot-candle, which is equivalent to one lumen per square foot for all areas leading to exits or stairwells. Light must be provided for a full 90 minutes from the time of the power loss. The fixtures used for emergency power cannot produce light levels below 0.6 foot-candles near the end of the 90 minutes. Most lights on emergency circuits are attached to battery packs which have a capacity to store enough power to run the lights for the duration of the 90 minutes. These batteries charge during normal building operation via the main electrical supply.

Elevator operation standards for emergency situations are written in the National Fire Protection Agency (NFPA) Standard 101. Elevators must be able to switch to emergency power within 60 seconds of power failure. The motors must return each elevator to a designated floor, usually the ground floor, where any occupants can exit to the outside. In the case where two elevators run simultaneously, as in the DASCO building, one elevator must remain operational for fire department use to evacuate physically impaired individuals. Any other receptacles, HVAC system components, and/or miscellaneous equipment can be made operational as long as the emergency power system is sized accordingly to include the power requirements of the essential egress lighting and elevators as well as the additional loads.

The DASCO Medical Office Building contains medical imaging equipment and also cancer treatment equipment. This equipment is usually operated for certain brief periods throughout the day as patients are scheduled for treatment. The operation of this equipment consumes great amounts of power during its relatively short operational periods. Because of this, each piece of equipment is put on its own separate source of electricity. This is due to power quality concerns for both the equipment and the rest of the building. During an emergency power failure, the medical equipment would not be necessary to have operational. Since power requirements for any building during an emergency lasts only 90 minutes, vacating the building is of most concern. Therefore HVAC system operation is not necessary during an emergency; especially during a fire, the HVAC system would be shut down as to limit the spread of the fire and associated smoke to other parts of the building. Certain exhaust systems may run during a fire of emergency but are designed for the purpose of evacuating smoke or other contaminants. Since the construction of the ventilation system is not designed for emergency operation, the loads associated with exhaust fans will not be included in the emergency power calculation.

The total loads associated with the emergency power system sizing are decided by the engineer and the building owner. In this case the system will be sized for the operation of elevators, egress lighting load, and the fire pump associated with the fire suppression system. Based on design documents the two elevators have a capacity of 3500 pounds operating up to 150 feet per minute. Listed in the specification, both elevators are controlled by a 50 horsepower motor. The fire suppression system operates on a separate electrical service just like the large medical equipment and is sized for a 475 gallon per minute flow rate. Using the sizing program found on the website of A-C Fire Pump Systems, a 20 horsepower motor is needed to handle this calculated water flow rate to ensure adequate performance of the sprinklers during a fire. Both motors require a much larger amount of power at start-up than is needed to run at full load. The required starting watts for each motor and the total wattage required for emergency lighting can be found in Table 41 below. The elevator motor and fire pump starting capacities are based on the extrapolation of Table 42 below. Based on the electrical drawings provided by the engineers, emergency lighting fixtures are designated throughout the means of egress. Each drawing from the shell and core construction to the final fit-out was examined to determine the wattage provided in emergency situations. There are four floors to the building and two stairwells, each having one twelve watt fixture on each floor totaling 96 watts. The rest of the building requires 7,953 Watts of emergency egress lighting.

Table 41 - Emergency Power Load

Load Type	Watts
Lighting	8,049
Elevators	164,000
Fire Pump	68,000
Total	240,049

Table 42 - Starting and Running Requirements for Commonly Used 60-Cycle, Single-Phase Motors

Motor Rating (HP)	Watts required to start	Watts required to run full load
1/6	-	215
1/4	1200	300
1/3	1600	400
1/2	2300	575
3/4	3345	835
1	4000	1000
1-1/2	6000	1500
2	8000	2000
3	12000	3000
5	18000	4500
37438	28000	7000
10	36000	9000

The total required power to supply the loads determined to rely on emergency power is 204 kilowatts. The appropriate system would be a natural gas generator since uninterrupted power supply is not necessary in a medical office building. Kohler manufactures a 400 kilowatt natural gas generator that has the capacity to provide power for the emergency loads.

Building code requires the installation of an adequately sized transfer switch for any system that has both normal power and a standby or emergency system. A transfer switch is a device that transfers the building electrical supply from normal utility to generator supply in an emergency situation. The transfer switch can be either automatic or manual depending on the desired response time between power outage and backup power startup. In either case the National Electric Code requires that the transfer switch be mechanically held as opposed to electronically held for safety reasons. The size of a transfer switch must meet the buildings current normal volt amperage even if the emergency load provided is a significantly lower percentage of the total building load. This ensures that in case of a malfunction or surge in power from the utility, the transfer switch can handle the current and prevent a fire. Existing electrical supply is through a main transformer sized at 1500 kilo volt-amperes. The main switchboard distribution panel is rated for 2500 amperes; therefore an automatic transfer switch must also have a rated capacity of 2500 amperes. Figure 17 below shows a typical wiring diagram for normal utility and the integration of an emergency generator.

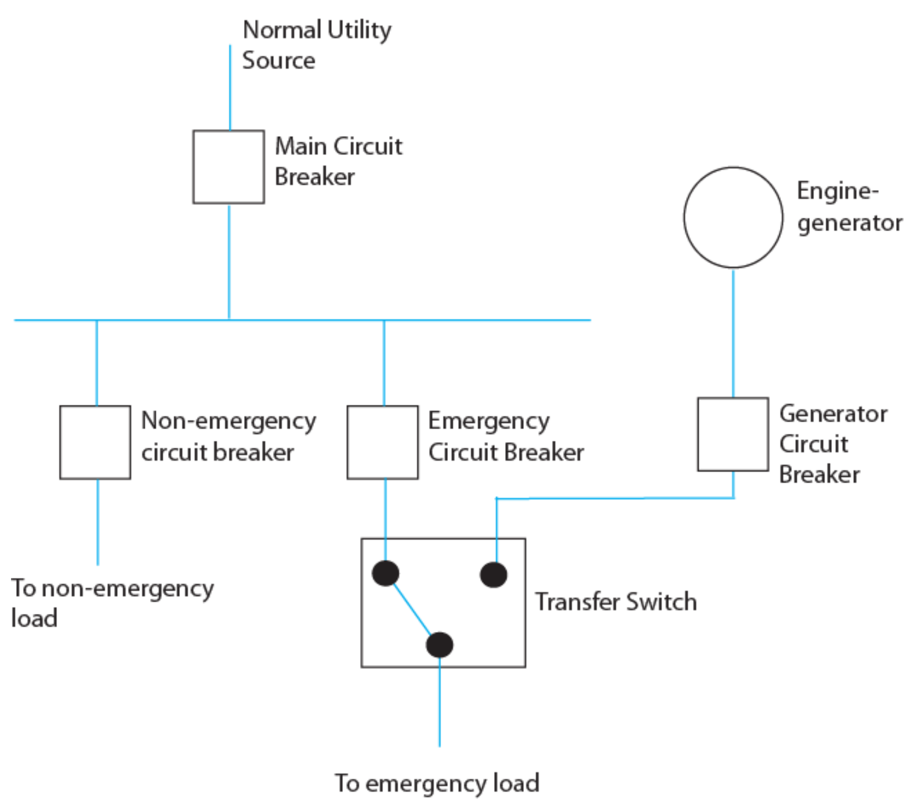

Figure 17 – Emergency engine-generator system with transfer switch

Mechanical Equipment Installation Breadth Study

Aside from building a habitable space, every construction project has two main goals for its delivery. The first goal is that the completion of construction happens on time so that occupants can use and function in the space. The second goal is to have the total building construction cost end at or below the projected budget. In the case of the DASCO building construction cost and timing were very important to the building owners. The investment made in many tenant occupied facilities that are constructed by an owner that does not use space in the building is best returned with a short construction time and a relatively low construction cost. Part of redesign is to evaluate the impact of changing engineered parts of a building, in this case the mechanical system, to determine is the design has a positive or negative effect on the construction period and labor cost. RS Means 2008 Mechanical Cost Data includes the industry costs of labor for the installation of every part of a building including the mechanical equipment. The data found in the pricing books also gives a daily output rate based on standard labor crews performing tasks associated with the installation of equipment and construction of systems. From this data a construction manager can determine an accurate approximation of the amount of time labor crews will be on the job site and how much it should cost the building owners for the construction of each piece of the building.

The length of installation and cost of labor for the existing system equipment is determined in Table 43 below. One discrepancy with RS Means AHU data was that it only listed daily output for units up to 60 tons. Two AHUs at 124 ton are part of the engineered system which led to extrapolation procedure to obtain usable values. In doing the extrapolation, negative daily output resulted and therefore the number was approximated to half the daily output of a 60 ton unit.

Table 43 - Existing Mechanical System Equipment Construction Costs

Item	Amount	Daily Output (items per day)	Labor Cost ($ per item)	Total Installation Time (days)	Total Labor Cost ($) base	Total Labor Cost ($) Baltimore
31 ton AHU	1	0.497	2,825	2.01	2,825	2,494
124 ton AHU*	2	0.125	11,730	16.00	23,460	20,715
Domestic Water Heaters	9	2.60	345	3.46	3,103	2,740
Fan Powered VAV Boxes w/ reheat	112	6.94	106	16.14	11,823	10,440
Total				37.62	41,211	36,389

*Assumed value for daily output based on negative extrapolation from RS Means

As shown above, installation time is about 40 days with the assumption that the contractor had only one crew for each task each day. Labor cost was totaled and then reduced to 88.3% of the base value to represent the labor cost in Baltimore.

Redesigned installation time and labor cost are shown in Table 44 below. As expressed by the total values installation time is reduced by about 5 days however cost increases by about

$6,000. This can be caused by the increased complexity of the networks of piping associated with the new systems.

Table 44 - Redesigned Mechanical System Equipment Construction Costs						
Item	Amount	Daily Output (items per day)	Labor Cost ($ per item)	Total Installation Time (days)	Total Labor Cost ($) base	Total Labor Cost ($) Baltimore
AHU	1	0.077	17,940.00	12.99	17,940	15,841
Chiller	1	0.133	10,660.00	7.53	10,660	9,413
Cooling Tower*	136	121.900	8.67	1.12	1,179	1,041
VAV Boxes	112	8.330	81.33	13.45	9,109	8,043
Boiler	1	0.419	3,459.29	2.39	3,459	3,055
Hot Water Storage Tank	1	3.080	219.52	0.32	220	194
Expansion Tank	1	17.000	40.00	0.06	40	35
Fin-Tube Radiators**	308	38.000	17.85	8.11	5,498	4,855
Total				35.08	48,105	42,476
*Cooling Tower Units in Tons						
**Fin-Tube Radiator Units in Linear Feet						

Based on this evaluation the cost of construction and job site labor time are about equal for either system.

Appendix A

Table 45 - ASHRAE 62.1-2007 Standard 6, Exhaust Requirements							
		design cfm		Exhaust req.		exhaust	exhaust
Room	Function		area	cfm/unit	cfm/sq. ft.	needed	provided
129	hc toilet	50	53	25		25	125
105	hc toilet	50	39	25		25	125
139	hc toilet	50	48	25		25	125
117	dirty	0	18	0	1	18	50
100-10	patient toilet	50	52	25		25	75
100-05	staff toilet	50	52	25		25	75
i-124	toilet	0	53	25		25	80
i-125	toilet	0	53	25		25	80
i-134a	toilet	50	50	25		25	85
105	jan clos.	0	37	0	1	37	75
106	mens toilet	0	57	25		25	75
107	womens toilet	0	57	25		25	75
s-204	jan. clos.	0	37	0	1	37	75
s-205	mens toilet	0	57	25		25	75
s-206	womens toilet	0	57	25		25	75
210	toilet/shower	50	80	25		25	125
234	hc toilet	50	48	25		25	125
a-211	patient toilet	0	46	25		25	75
a-215	staff toilet	0	51	25		25	75
a-236	patient toilet	0	52	25		25	75
a-239	staff toilet	0	52	25		25	75
a-246	public toilet	0	52	25		25	75
310	staff toilet	50	51	25		25	125
311	janitor	0	47	0	1	47	75
314	patient toilet	50	47	25		25	125
315	patient toilet	50	47	25		25	125
345	patient toilet	50	42	25		25	125
346	patient toilet	50	43	25		25	125
128a	toilet	0	52	25		25	75
101	patient toilet	0	76	25		25	100
116	soiled utility	0	33	0	1	33	100
111	staff toilet	0	50	25		25	75
110	patient toilet	0	50	25		25	75

Appendix A

Ventilation Rate Procedure

Table 46 - ASHRAE Standard 62.1-2007, Section 6, Variables	
Az	Zone Floor Area
Pz	Zone Population
Rp	Outdoor airflow rate required per person
Rz	Outdoor airflow rate required per square foot
Ez	Zone air distribution effectiveness
Voz	Design zone outdoor airflow
Zp	Zone promary outdoor air fraction
Vbz	Breathing zone outdoor airflow
Vpz	Zone primary airflow
Vou	Uncorrected outdoor air intake
D	Occupant diversity
Ps	System population
Vot	Outdoor air intake flow

Table 47 - ASHRAE Standard 62.1-2004 Section 6, Equations	
1	Vbz=(Pz*Rp+Az*Ra)
2	Voz=Vbz/Ev
3	Zp=Voz/Vpz
4	D=Ps/ΣPz
5	Vou=D*Σ(Rp*Pz)+Σ(Ra*Az)
6	Vot=Vou/Ev

Appendix A

Variables described below are listed in Table 46 in Appendix A.

Equations described below are referenced by number in Table 47 in Appendix A.

Step 1:

- Find each room area in square feet (Az)
- Determine the zone population (Pz)
- Using Table 6-1 (ASHRAE 2007) determine the outdoor airflow rate per person (Rp)
- Using Table 6-1 (ASHRAE 2007) determine the outdoor airflow rate per area (Ra)
- Insert these values into equation 1 to determine breathing zone airflow (Vbz)

Step 2:

- The zone air distribution effectiveness (Ez) is one (1) based on Table 6-2 (ASHRAE 2007)
- Therefore, zone outdoor airflow (Voz) as determined by equation 2 is equal to Vbz

Step 3:

- Each rooms' primary outdoor airflow (Vpz) is determined from the drawings
- Then, equation 3 is used resulting in the primary outdoor air fraction (Zp)

Step 4:

- The occupant diversity is found using equation 4 (Ps=Pz for each AHU)

Step 5:

- Equation 5 is used to find the uncorrected outdoor air intake (Vou)
- This number is a summation of each Vbz determined earlier for each zone

Step 6:

- Use Zp and Table 6-3 (ASHRAE 2007) to find the system ventilation efficiency (Ev)
- Then determine the outdoor air intake (Vot) using equation 6

Appendix B

AHU-1

Room	Function	design cfm supply	exhaust	area (Az)	Design Occupancy (Pz)	OA required (ASHRAE 2007) cfm/person (Rp)	OA required (ASHRAE 2007) cfm/sq. ft. (Ra)	Vbz	Vpz	Zp
003	corridor	315		1480	0	0	0.06	89	315	0.282
003a	link	495		304	0	0	0.06	18	495	0.037
008	electrical room	50		84	0	0	0.06	5	50	0.101
009	telephone	380		55	0	0	0	0	380	0.000
014	elec. Room	1000		185	0	0	0.06	11	1000	0.011
126	director	395		140	1	5	0.06	12	395	0.030
125	chief tech	195		85	1	5	0.06	10	195	0.052
124	physicist	305		85	1	5	0.06	10	305	0.033
123	treatment planning	570		120	1	5	0.06	10	570	0.018
122	dressing	65		29	1	5	0.06	7	65	0.104
121	dressing	50		29	1	5	0.06	7	50	0.135
127	corridor	160		265	0	0	0.06	16	160	0.099
143	corridor	75		179	0	0	0.06	11	75	0.143
128	office	245		123	1	5	0.06	10	245	0.043
129	hc toilet	50	125	53	0	0	0	0	50	0.000
131	chart storage	85		213	0	0	0.12	26	85	0.301
132	file serv/phone/stor	145		70	0	0	0.12	8	145	0.058
136	exam	120		108	2	5	0.06	16	120	0.137
135	exam	105		90	2	5	0.06	15	105	0.147
134	exam	105		90	2	5	0.06	15	105	0.147
144	storage	50		89	0	0	0.12	11	50	0.214
146	mold block	145	245	100	0	5	0.06	6	145	0.041
145	corridor	100		100	0	0	0.06	6	100	0.060
147	staff lounge	185		122	3	5	0.06	23	185	0.122
148	chart storage	170		159	0	0	0.12	19	170	0.112
150	rad/oncogolgy stor	60		188	0	0	0.12	23	60	0.376
149	chart storage	50		127	0	0	0.12	15	50	0.305
#	shell space	2000		2075	10	5	0.06	176	2000	0.088
112	linacc	1365		789	2	15	0.06	77	1365	0.057
111	linacc	1485		789	2	15	0.06	77	1485	0.052
108	mech room	165		76	0	5	0.06	5	165	0.028
110	control	785		209	2	5	0.06	23	785	0.029
113	control	785		219	2	5	0.06	23	785	0.029
107	control room	460		126	2	5	0.06	18	460	0.038
106	ct simulator	1050		287	2	15	0.06	47	1050	0.045
105	hc toilet	50	125	39	0	0	0	0	50	0.000
104	ofc mgr	185		120	2	5	0.06	17	185	0.093
115	view boxes	100		168	0	5	0.06	10	100	0.101
139	hc toilet	50	125	48	0	0	0	0	50	0.000
117	dirty	0	50	18	0	0	0.06	1	0	-
118	clean	50		18	0	5	0.06	1	50	0.022
114	dark room	130		54	1	5	0.12	11	130	0.088
119	dressing	50		44	1	5	0.06	8	50	0.153
120	sub-waiting	135		154	5	5	0.06	32	135	0.240
137	nursing	175		79	1	5	0.06	10	175	0.056
138	stretcher	50		81	1	5	0.06	10	50	0.197
116	corridor	0		133	0	0	0.06	8	0	-
103	storage	50		67	0	0	0.12	8	50	0.161
102	reception	305		135	4	5	0.06	28	305	0.093
140	conference	800		182	9	5	0.06	56	800	0.071
141	exam	105		90	2	5	0.06	15	105	0.147
142	med storage	50		58	0	0	0.12	7	50	0.139
101	waiting	1350		415	12	5	0.06	87	1350	0.065
100-04	prep/injection	105		92	1	5	0.06	11	105	0.100
100-06	prep/injection	105		92	1	5	0.06	11	105	0.100
100-08	prep/injection	105		92	1	5	0.06	11	105	0.100
100-10	patient toilet	50	75	52	0	0	0	0	50	0.000
100-12	hot lab	105		90	1	10	0.18	26	105	0.250
100-01	corridor	105		322	0	0	0.06	19	105	0.184
100-00	waiting	170		184	6	5	0.06	41	170	0.241
100-03	reg/techs	250		163	2	5	0.06	20	250	0.079
100-05	staff toilet	50	75	52	0	0	0	0	50	0.000
100-07	control	500		124	1	5	0.06	12	500	0.025
100-09	pet/ct scan	1015		374	2	15	0.06	52	1015	0.052

Appendix B

AHU-1

Room	Function	design cfm supply	exhaust	area (Az)	Design Occupancy (Pz)	OA required (ASHRAE 2007) cfm/person (Rp)	cfm/sq. ft. (Ra)	Vbz	Vpz	Zp
100-11	equip	0		92	0	0	0.06	6	0	-
r-005	social work/diet	165		126	1	5	0.06	13	165	0.076
r-007	nurses	165		120	1	5	0.06	12	165	0.074
r-008	phd	115		108	1	5	0.06	11	115	0.100
r-004	registry/research	1105		800	16	5	0.06	128	1105	0.116
r-003	research nurses	325		118	1	5	0.06	12	325	0.037
r-002	office	150		91	1	5	0.06	10	150	0.070
r-006	genetics pastoral	165		137	1	5	0.06	13	165	0.080
r-001	recep/waiting	825		433	13	7.5	0.06	123	825	0.150
c-11	corridor	55		107	0	0	0.06	6	55	0.117
e101	elevator lobby	570		738	7	5	0.06	81	570	0.142
i-117	phlebotomy	140		140	1	10	0.18	35	140	0.251
i-118	pharmacy	160		92	2	5	0.18	27	160	0.166
i-118a	work room	265		112	1	5	0.06	12	265	0.044
i-118b	ante room	565		71	1	10	0.06	14	565	0.025
i-118c	clean room	750		112	0	5	0.06	7	750	0.009
i-119	reception	190		202	6	5	0.06	42	190	0.223
i-120	waiting	834		742	25	7.5	0.06	232	834	0.278
i-121a	front office	295		223	3	5	0.06	28	295	0.096
i-123	soiled utility	50		86	0	0	0	0	50	0.000
i-124	toilet	0	80	53	0	0	0	0	0	-
i-125	toilet	0	80	53	0	0	0	0	0	-
i-126	hall	200		334	0	0	0.06	20	200	0.100
i-128	consult	130		91	5	5	0.06	30	130	0.234
i-130	triage	130		72	1	25	0.06	29	130	0.226
i-131	clean utility	185		245	0	5	0.06	15	185	0.079
i-132a	infusion bay 2	10985		4205	16	5	0.06	332	10985	0.030
i-134	private office	375		152	0	5	0.06	9	375	0.024
i-134a	toilet	50	85	50	0	0	0	0	50	0.000
i-136	break room	225		139	4	5	0.06	28	225	0.126
i-138	it closet	0		8	0	0	0	0	0	-
c-10	corridor	300		550	0	0	0.06	33	300	0.110
103	telephone	380		55	0	0	0	0	380	0.000
104	electrical room	50		84	0	0	0.06	5	50	0.101
105	jan clos.	0	75	37	0	0	0	0	0	-
106	mens toilet	0	75	57	0	0	0	0	0	-
107	womens toilet	0	75	57	0	0	0	0	0	-

Max Zp	0.376
Pz(total)	198
Vou	2675
D	1
Ev	0.7
Vot	3822

Appendix B

AHU-2

Room	Function	design cfm supply	exhaust	area (Az)	Design Occupancy (Pz)	OA required (ASHRAE 2007) cfm/person (Rp)	cfm/ft (Ra)	Vbz	Vpz	Zp
s-202	telephone	380		55	0	0	0	0	380	0
s-203	elec. Room	50		84	0	0	0.06	5	50	0.101
s-204	jan. clos.	0	75	37	0	0	0	0	0	-
s-205	mens toilet	0	75	57	0	0	0	0	0	-
s-206	womens toilet	0	75	57	0	0	0	0	0	-
200	waiting	1110		520	20	7.5	0.06	181	1110	0.163
201	reception	410		470	4	5	0.06	48	410	0.118
202	corridor	345		1141	0	0	0.06	68	345	0.198
204	exam	95		108	1	5	0.06	11	95	0.121
205	exam	95		108	1	5	0.06	11	95	0.121
206	phone room	180		44	0	0	0	0	180	0.000
207	break room	295		239	12	5	0.06	74	295	0.252
208	meds closet	50		64	0	0	0.12	8	50	0.154
209	supply closet	0		35	0	0	0.12	4	0	-
210	toilet/shower	50	125	80	0	0	0	0	50	0.000
211	surgeon's office	340		254	3	5	0.06	30	340	0.089
212	surgeon's office	340		159	3	5	0.06	25	340	0.072
213	surgeon's office	395		157	3	5	0.06	24	395	0.062
214	pa office	110		129	3	5	0.06	23	110	0.207
215	physicans office	210		120	3	5	0.06	22	210	0.106
216	physicans office	395		120	3	5	0.06	22	395	0.056
217	exam	95		100	1	5	0.06	11	95	0.116
218	physicans office	210		114	3	5	0.06	22	210	0.104
219	physicans office	210		112	3	5	0.06	22	210	0.103
220	managers office	290		91	3	5	0.06	20	290	0.071
221	private office 1	195		92	3	5	0.06	21	195	0.105
222	private office 2	195		88	3	5	0.06	20	195	0.104
223	private office 3	295		96	3	5	0.06	21	295	0.070
224	private office 4	195		97	3	5	0.06	21	195	0.107
225	private office 5	195		91	3	5	0.06	20	195	0.105
226	private office 6	295		96	3	5	0.06	21	295	0.070
227	private office 7	195		101	3	5	0.06	21	195	0.108
228	private office 8	195		92	3	5	0.06	21	195	0.105
229	private office 9	295		95	3	5	0.06	21	295	0.070
230	private office 10	300		158	5	5	0.06	34	300	0.115
231	research office	205		166	2	5	0.06	20	205	0.097
232	research supply	85		253	0	0	0.12	30	85	0.357
233	open area	625		728	8	7.5	0.06	104	625	0.166
234	hc toilet	50	125	48	0	0	0	0	50	0.000
235	research supply	85		273	0	0	0.12	33	85	0.385
a-202	front office	140		154	1	5	0.06	14	140	0.102
a-203	reading	175		275	1	5	0.06	22	175	0.123
a-205	us 1	300		153	1	5	0.06	14	300	0.047
a-206	hallway	120		321	0	0	0.06	19	120	0.161
a-207	mammo 1	395		146	1	5	0.06	14	395	0.035
a-208	mammo 2	480		143	1	5	0.06	14	480	0.028
a-209	us 2/mammo 3	420		147	1	5	0.06	14	420	0.033
a-210	storage	50		59	0	0	0.12	7	50	0.142
a-211	patient toilet	0	75	46	0	0	0	0	0	-
a-212	dressing	180		199	5	5	0.06	37	180	0.205
a-213	tech work area	270		90	1	5	0.06	10	270	0.039
a-215	staff toilet	0	75	51	0	0	0	0	0	-
a-216	dexa	205		94	2	5	0.06	16	205	0.076
a-217	manager	105		96	2	5	0.06	16	105	0.150
a-218	imaging registration	175		60	2	5	0.06	14	175	0.078
a-219	shared waiting	1330		1152	44	7.5	0.06	399	1330	0.300
a-220	check in	155		136	2	5	0.06	18	155	0.117
a-221	manager office	90		82	1	5	0.06	10	90	0.110
a-222	check out	130		76	2	5	0.06	15	130	0.112
a-224	conference room	260		184	6	5	0.06	41	260	0.158
a-225	exam 6	285		120	1	5	0.06	12	285	0.043
a-226	exam 1	285		133	1	5	0.06	13	285	0.046
a-227	sterilization	410	460	120	2	5	0.06	17	410	0.042
a-228	exam 5	285		121	1	5	0.06	12	285	0.043

Appendix B

AHU-2

Room	Function	design cfm supply	exhaust	area (Az)	Design Occupancy (Pz)	OA required (ASHRAE 2007) cfm/person (Rp)	cfm/ft (Ra)	Vbz	Vpz	Zp
a-230	exam 3	320		135	1	5	0.06	13	320	0.041
a-231	exam 4	285		120	1	5	0.06	12	285	0.043
a-232	office	370		193	7	5	0.06	47	370	0.126
a-233	office	290		125	3	5	0.06	23	290	0.078
a-234	hallway	335		638	0	0	0.06	38	335	0.114
a-235	bbc	675		274	3	5	0.06	31	675	0.047
a-236	patient toilet	0	75	52	0	0	0	0	0	-
a-238	exam 2	285		135	1	5	0.06	13	285	0.046
a-239	staff toilet	0	75	52	0	0	0	0	0	-
a-242	storage	50		68	0	0	0.12	8	50	0.163
a-244	kitchen	215		40	0	5	0.06	2	215	0.011
a-245	med rec	305		274	6	5	0.06	46	305	0.152
a-246	public toilet	0	75	52	0	0	0	0	0	-
s-302	telephone	380		54	0	0	0	0	380	0.000
300	waiting	2400		1075	44	7.5	0.06	395	2400	0.164
301	reception	285		247	2	5	0.06	25	285	0.087
302	charts	2050		1630	14	5	0.06	168	2050	0.082
304	office manager	285		127	1	5	0.06	13	285	0.044
305	corridor	1605		2696	0	0	0.06	162	1605	0.101
310	staff toilet	50	125	51	0	0	0	0	50	0.000
311	janitor	0	75	47	0	0	0	0	0	-
313	file room	830		835	2	5	0.06	60	830	0.072
314	patient toilet	50	125	47	0	0	0	0	50	0.000
315	patient toilet	50	125	47	0	0	0	0	50	0.000
316	break room	685		431	18	5	0.06	116	685	0.169
318	server	195		50	0	5	0.06	3	195	0.015
319	file area	300		270	2	5	0.06	26	300	0.087
319a	dress	0		0	0	0	0	0	0	-
319b	dress	0		0	0	0	0	0	0	-
319c	dress	0		0	0	0	0	0	0	-
320	nuclear lab	600		1145	8	15	0.18	326	600	0.544
320a	hc dress	0		0	0	0	0	0	0	-
321	hot lab	210		73	2	10	0.18	33	210	0.158
322	blood lab	115		80	2	10	0.18	34	115	0.299
323	echo	390		168	2	10	0.18	50	390	0.129
324	research office	350		110	2	5	0.06	17	350	0.047
325	stress test	650		270	4	15	0.06	76	650	0.117
326	echo	445		198	3	10	0.18	66	445	0.148
327	pa office	405		161	1	5	0.06	15	405	0.036
328	physicans office	240		123	1	5	0.06	12	240	0.052
329	physicans office	330		130	1	5	0.06	13	330	0.039
330	physicans office	240		133	1	5	0.06	13	240	0.054
331	physicans office	330		132	1	5	0.06	13	330	0.039
332	physicans office	330		132	1	5	0.06	13	330	0.039
333	physicans office	240		132	1	5	0.06	13	240	0.054
334	physicans office	425		132	1	5	0.06	13	425	0.030
335	physicans office	150		132	1	5	0.06	13	150	0.086
336	physicans office	425		132	1	5	0.06	13	425	0.030
337	physicans office	440		132	1	5	0.06	13	440	0.029
339	exam 1	150		93	2	5	0.06	16	150	0.104
340	exam 3	90		91	2	5	0.06	15	90	0.172
341	exam 2	90		80	2	5	0.06	15	90	0.164
344	exam 4	90		90	2	5	0.06	15	90	0.171
345	patient toilet	50	125	42	0	0	0	0	50	0.000
346	patient toilet	50	125	43	0	0	0	0	50	0.000
347	exam 5	90		102	2	5	0.06	16	90	0.179
348	exam 6	90		92	2	5	0.06	16	90	0.172
349	exam 7	90		92	2	5	0.06	16	90	0.172
350	sink area	50		88	1	5	0.06	10	50	0.206
351	exam 8	90		92	2	5	0.06	16	90	0.172
352	exam 9	90		101	2	5	0.06	16	90	0.178
353	techs	115		73	3	5	0.06	19	115	0.169
354	techs	115		72	2	5	0.06	14	115	0.125
356	ekg area	120		84	1	10	0.18	25	120	0.209

Appendix B

AHU-2

Room	Function	design cfm supply	exhaust	area (Az)	Design Occupancy (Pz)	OA required (ASHRAE 2007) cfm/person (Rp)	cfm/ft (Ra)	Vbz	Vpz	Zp
357	exam 10	90		102	2	5	0.06	16	90	0.179
358	exam 11	90		93	2	5	0.06	16	90	0.173
359	exam 12	90		92	2	5	0.06	16	90	0.172
360	exam 15	90		92	2	5	0.06	16	90	0.172
361	exam 14	90		93	2	5	0.06	16	90	0.173
362	exam 13	90		102	2	5	0.06	16	90	0.179
366	exam 16	90		98	2	5	0.06	16	90	0.176
367	exam 17	90		92	2	5	0.06	16	90	0.172
368	exam 18	90		92	2	5	0.06	16	90	0.172
369	exam 19	90		102	2	5	0.06	16	90	0.179
370	sub-waiting	350		156	10	7.5	0.06	84	350	0.241
371	exam 21	90		88	2	5	0.06	15	90	0.170
372	exam 20	90		87	2	5	0.06	15	90	0.169
374	research files	60		97	0	5	0.06	6	60	0.097
375	supply closet	50		42	0	0	0.12	5	50	0.101

Max Zp	0.544
Pz(total)	384
Vou	4226
D	1
Ev	0.6
Vot	7044

Appendix B

AHU-3

		design cfm			Design	OA required (ASHRAE 2007)				
Room	Function	supply	exhaust	area (Az)	Occupancy (Pz)	cfm/person (Rp)	cfm/sq. ft. (Ra)	Vbz	Vpz	Zp
129	office	550		230	5	5	0.06	39	550	0.071
128a	toilet	0	75	52	0	0	0	0	0	-
127	exam room	160		115	3	5	0.06	22	160	0.137
126	exam room	265		113	3	5	0.06	22	265	0.082
125	treatment room	470		141	3	10	0.12	47	470	0.100
124	exam room	160		122	3	5	0.06	22	160	0.140
122	exam room	160		122	3	5	0.06	22	160	0.140
121	treatment room	470		141	3	10	0.12	47	470	0.100
128	exec reception	665		338	7	5	0.06	55	665	0.083
131	conference/library	955		518	42	5	0.12	272	955	0.285
120	exam room	265		112	3	5	0.06	22	265	0.082
119	exam room	160		115	3	5	0.06	22	160	0.137
115	exam room	160		115	3	5	0.06	22	160	0.137
114	exam room	265		112	3	5	0.06	22	265	0.082
113	exam room	470		141	3	5	0.06	23	470	0.050
112	exam room	160		122	3	5	0.06	22	160	0.140
106	exam room	160		122	3	5	0.06	22	160	0.140
105	exam room	265		112	3	5	0.06	22	265	0.082
104	exam room	470		141	3	5	0.06	23	470	0.050
103	exam room	160		122	3	5	0.06	22	160	0.140
102	waiting room	1595		808	40	7.5	0.06	348	1595	0.218
101	patient toilet	0	100	76	0	0	0	0	0	-
116	soiled utility	0	100	33	0	0	0	0	0	-
111	staff toilet	0	75	50	0	0	0	0	0	-
110	patient toilet	0	75	50	0	0	0	0	0	-
108	clean utility	100		56	0	0	0.06	3	100	0.034
107	front office	365		320	6	5	0.06	49	365	0.135
100	entry vestibule	150		245	2	5	0.06	25	150	0.165
130	office	270		170	5	5	0.06	35	270	0.130
132	office	360		124	3	5	0.06	22	360	0.062
133	office	270		132	3	5	0.06	23	270	0.085
134	office	240		118	3	5	0.06	22	240	0.092
140	md mgr office	95		85	1	5	0.06	10	95	0.106
139	office	130		115	3	5	0.06	22	130	0.168
138	office	130		112	3	5	0.06	22	130	0.167
137	inf mgr office	95		85	1	5	0.06	10	95	0.106
c-7	corridor	105		488	0	0	0.06	29	105	0.279
c-1	corridor	290		918	0	0	0.06	55	290	0.190

Max Zp	0.285
Pz(total)	172
Vou	1448
D	1
Ev	0.8
Vot	1810

Appendix C

AHU-1

Room	Function	design cfm supply*	area (Az)*	Design Occupancy (Pz)*	Equipment Load (BTUh)*	Design Watts/ft^2	Heating Load (MBH)**	Cooling Load (MBH)**	Required Outdoor Air (cfm)**
003	corridor	315	1480	0	-	1.07	0	1.8	63
003a	link	495	304	0	-	1.03	4.3	4.3	99
008	electrical room	50	84	0	-	0.76	0	0.3	10
009	telephone	380	55	0	-	1.16	0	0.2	76
014	elec. Room	1000	185	0	-	0.35	2.1	1	200
126	director	395	140	1	500	1.09	1.5	2.7	79
125	chief tech	195	85	1	500	1.20	0.8	1.9	39
124	physicist	305	85	1	500	1.20	1.5	3.2	61
123	treatment planning	570	120	1	500	1.60	1.6	3.1	114
122	dressing	65	29	1	-	1.76	0.2	0.5	13
121	dressing	50	29	1	-	1.76	0	0.3	10
127	corridor	160	265	0	-	2.17	0	0.3	32
143	corridor	75	179	0	-	1.61	0	0.2	15
128	office	245	123	1	500	0.83	0	1.1	49
129	hc toilet	50	53	0	-	0.96	0	0.1	10
131	chart storage	85	213	0	-	1.80	0	0.4	17
132	file serv/phone/stor	145	70	0	-	1.83	0	0.1	29
136	exam	120	108	2	-	1.78	0	0.9	24
135	exam	105	90	2	-	2.13	0	0.8	21
134	exam	105	90	2	-	2.13	0	0.8	21
144	storage	50	89	0	-	1.15	0	0.2	10
146	mold block	145	100	0	-	1.92	0	0.4	29
145	corridor	100	100	0	-	1.92	0	0.1	20
147	staff lounge	185	122	3	3420	1.57	0	4.5	37
148	chart storage	170	159	0	-	1.61	1.9	0.9	34
150	rad/oncogolgy stor	60	188	0	-	1.53	1.2	0.7	12
149	chart storage	50	127	0	-	1.51	0	0.2	10
#	shell space	2000	2075	10	-	0.25	11.7	11	400
112	linacc	1365	789	2	10000	2.39	13.4	17.5	273
111	linacc	1485	789	2	10000	2.14	13.4	16.1	297
108	mech room	165	76	0	-	0.84	0	0.3	33
110	control	785	209	2	1000	1.41	0	1.7	157
113	control	785	219	2	1000	1.11	0	1.8	157
107	control room	460	126	2	1000	3.11	0	2.6	92
106	ct simulator	1050	287	2	15800	2.69	0	17.3	210
105	hc toilet	50	39	0	-	1.31	0	0.1	10
104	ofc mgr	185	120	2	500	1.60	0	1.3	37
115	view boxes	100	168	0	-	0.88	0	0.2	20
139	hc toilet	50	48	0	-	2.71	0	0.1	10
117	dirty	0	18	0	-	2.83	0	0	0
118	clean	50	18	0	-	2.83	0	0	10
114	dark room	130	54	1	-	4.26	0	0.4	26
119	dressing	50	44	1	-	1.16	0	0.4	10
120	sub-waiting	135	154	5	-	1.25	0	1.6	27
137	nursing	175	79	1	500	2.43	0	0.9	35
138	stretcher	50	81	1	-	1.19	0	0.4	10
116	corridor	0	133	0	-	1.44	0	0.1	0
103	storage	50	67	0	-	1.91	0	0.1	10
102	reception	305	135	4	1000	1.42	0	2.3	61
140	conference	800	182	9	585	1.58	0	3.2	160
141	exam	105	90	2	-	2.13	0	0.8	21
142	med storage	50	58	0	-	2.21	0	0.1	10
101	waiting	1350	415	12	-	0.82	0	4	270
100-04	prep/injection	105	92	1	-	2.26	0	0.6	21
100-06	prep/injection	105	92	1	-	2.26	0	0.6	21
100-08	prep/injection	105	92	1	-	2.26	0	0.6	21
100-10	patient toilet	50	52	0	-	1.96	0	0.1	10
100-12	hot lab	105	90	1	600	1.51	0.9	1.3	21

*Data taken from design documents

**Data collected from Carrier's Hourly Analysis Program

Appendix C

AHU-1

Room	Function	design cfm supply*	area (Az)*	Design Occupancy (Pz)*	Equipment Load (BTUh)*	Design Watts/ft^2	Heating Load (MBH)**	Cooling Load (MBH)**	Required Outdoor Air (cfm)**
100-01	corridor	105	322	0	-	1.45	0.8	0.5	21
100-00	waiting	170	184	6	-	1.41	0	2	34
100-03	reg/techs	250	163	2	2100	1.25	1.3	3.4	50
100-05	staff toilet	50	52	0	-	1.96	0.8	0.4	10
100-07	control	500	124	1	4011	2.35	1	4.7	100
100-09	pet/ct scan	1015	374	2	15000	1.93	2.3	17.7	203
r-005	social work/diet	165	126	1	500	1.52	0	1.1	33
r-007	nurses	165	120	1	1000	1.60	0	1.5	33
r-008	phd	115	108	1	500	1.78	0.8	1.3	23
r-004	registry/research	1105	800	16	10000	1.80	2.2	14.5	221
r-003	research nurses	325	118	1	1000	1.63	1.4	3.7	65
r-002	office	150	91	1	500	2.11	0	1	30
r-006	genetics pastoral	165	137	1	1000	2.10	0	1.6	33
r-001	recep/waiting	825	433	13	-	2.00	3.9	8.8	165
c-11	corridor	55	107	0	-	1.79	0	0.1	11
e101	elevator lobby	570	738	7	-	1.75	3	5.4	114
i-117	phlebotomy	140	140	1	500	1.46	0	1.2	28
i-118	pharmacy	160	92	2	1240	4.17	0	2	32
i-118a	work room	265	112	1	500	3.43	0	1	53
i-118b	ante room	565	71	1	-	2.70	0	0.4	113
i-118c	clean room	750	112	0	-	2.43	0	0.3	150
i-119	reception	190	202	6	-	1.54	0	2	38
i-120	waiting	834	742	25	-	1.82	0.2	8.2	166.8
i-121a	front office	295	223	3	1500	1.61	0	2.8	59
i-123	soiled utility	50	86	0	-	2.23	0	0.2	10
i-124	toilet	0	53	0	-	1.45	0	0.1	0
i-125	toilet	0	53	0	-	1.45	0	0.4	0
i-126	hall	200	334	0	-	1.38	0	0.4	40
i-128	consult	130	91	5	500	1.68	0	2	26
i-130	triage	130	72	1	-	2.67	0	0.5	26
i-131	clean utility	185	245	0	-	1.96	0	0.5	37
i-132a	infusion bay 2	10985	4205	16	2000	2.48	110	327.1	2197
i-134	private office	375	152	0	500	1.89	0	1.1	75
i-134a	toilet	50	50	0	-	1.66	1	1.5	10
i-136	break room	225	139	4	1340	2.30	0	4.8	45
i-138	it closet	0	8	0	-	0.00	0	0	0
c-10	corridor	300	550	0	-	1.02	0	0.7	60
103	telephone	380	55	0	-	0.93	0	0.2	76
104	electrical room	50	84	0	-	0.61	0	0.3	10
105	jan clos.	0	37	0	-	1.38	0	0.1	0
106	mens toilet	0	57	0	-	0.89	0	0.1	0
107	womens toilet	0	57	0	-	0.89	0	0.1	0

*Data taken from design documents

**Data collected from Carrier's Hourly Analysis Program

Appendix C

AHU-2

Room	Function	design cfm supply*	area (Az)*	Design Occupancy (Pz)*	Equipment Load (BTUh)*	Design Watts/ft^2	Heating Load (MBH)**	Cooling Load (MBH)**	Required Outdoor Air (cfm)**
s-202	telephone	380	55	0	-	1.16	0	0.2	76
s-203	elec. Room	50	84	0	-	0.76	0	0.3	10
s-204	jan. clos.	0	37	0	-	1.73	0	0.1	0
s-205	mens toilet	0	57	0	-	0.89	0	0.1	0
s-206	womens toilet	0	57	0	-	0.89	0	0.1	0
200	waiting	1110	520	20	-	1.66	0	6.2	222
201	reception	410	470	4	3300	1.63	0	5.5	82
202	corridor	345	1141	0	-	2.19	0	1.4	69
204	exam	95	108	1	-	1.78	0	0.6	19
205	exam	95	108	1	-	1.78	0	0.6	19
206	phone room	180	44	0	-	2.18	0	0.2	36
207	break room	295	239	12	3420	2.41	0	7	59
208	meds closet	50	64	0	-	1.50	0	0.1	10
209	supply closet	0	35	0	-	2.74	0	0.1	0
210	toilet/shower	50	80	0	-	5.85	0	0.2	10
211	surgeon's office	340	254	3	500	1.13	1.8	4.8	68
212	surgeon's office	340	159	3	500	1.81	1.6	4.1	68
213	surgeon's office	395	157	3	500	1.83	2.7	4.9	79
214	pa office	110	129	3	500	1.49	0	1.6	22
215	physicans office	210	120	3	500	1.60	1	3	42
216	physicans office	395	120	3	500	1.60	2.3	5.8	79
217	exam	95	100	1	-	1.92	0	0.6	19
218	physicans office	210	114	3	500	1.68	0.9	3	42
219	physicans office	210	112	3	500	1.71	0.9	3	42
220	managers office	290	91	3	500	2.11	1.5	4.3	58
221	private office 1	195	92	3	500	2.09	1	3	39
222	private office 2	195	88	3	500	2.18	0.9	2.9	39
223	private office 3	295	96	3	500	2.00	1.5	4.3	59
224	private office 4	195	97	3	500	1.98	0.9	3	39
225	private office 5	195	91	3	500	2.11	0.9	2.9	39
226	private office 6	295	96	3	500	2.00	1.5	4.3	59
227	private office 7	195	101	3	500	1.90	0.9	3	39
228	private office 8	195	92	3	500	2.09	0.9	2.9	39
229	private office 9	295	95	3	500	2.02	1.5	4.3	59
230	private office 10	300	158	5	500	2.43	2.7	4.4	60
231	research office	205	166	2	1250	2.31	1.6	3	41
232	research supply	85	253	0	-	1.52	0	0.5	17
233	open area	625	728	8	5100	1.32	0	9	125
234	hc toilet	50	48	0	-	8.25	0	0.1	10
235	research supply	85	273	0	-	1.76	0	0.5	17
a-202	front office	140	154	1	750	1.95	0	1.4	28
a-203	reading	175	275	1	500	1.13	0	1.5	35
a-205	us 1	300	153	1	-	2.82	0	0.6	60
a-206	hallway	120	321	0	-	1.43	0	0.4	24
a-207	mammo 1	395	146	1	-	2.96	0.4	0.9	79
a-208	mammo 2	480	143	1	-	3.02	1.9	1.7	96
a-209	us 2/mammo 3	420	147	1	-	2.80	2.4	2.4	84
a-210	storage	50	59	0	-	1.63	1.1	1.8	10
a-211	patient toilet	0	46	0	-	3.35	0	0.1	0
a-212	dressing	180	199	5	-	2.59	1.3	3.7	36
a-213	tech work area	270	90	1	2000	8.30	0	2.5	54
a-215	staff toilet	0	51	0	-	3.02	0	0.1	0
a-216	dexa	205	94	2	-	2.04	0	0.7	41
a-217	manager	105	96	2	1000	2.00	0	1.7	21
a-218	imaging registration	175	60	2	1000	1.70	0	1.6	35
a-219	shared waiting	1330	1152	44	-	1.94	0	13.7	266
a-220	check in	155	136	2	1000	3.75	0	1.8	31
a-221	manager office	90	82	1	500	2.34	0	1	18

*Data taken from design documents

**Data collected from Carrier's Hourly Analysis Program

Appendix C

AHU-2

Room	Function	design cfm supply*	area (Az)*	Design Occupancy (Pz)*	Equipment Load (BTUh)*	Design Watts/ft^2	Heating Load (MBH)**	Cooling Load (MBH)**	Required Outdoor Air (cfm)**
a-222	check out	130	76	2	1000	5.34	0	1.7	26
a-224	conference room	260	184	6	-	1.67	0	2	52
a-225	exam 6	285	120	1	-	2.47	0	0.7	57
a-226	exam 1	285	133	1	-	2.23	0	0.7	57
a-227	sterilization	410	120	2	500	0.43	0	1.3	82
a-228	exam 5	285	121	1	-	2.45	0.4	0.8	57
a-230	exam 3	320	135	1	-	1.81	0.5	0.8	64
a-231	exam 4	285	120	1	-	2.47	0.4	0.8	57
a-232	office	370	193	7	750	2.39	3.4	5.9	74
a-233	office	290	125	3	1000	1.54	1.4	3.4	58
a-234	hallway	335	638	0	-	1.44	2.3	1.3	67
a-235	bbc	675	274	3	-	2.70	4.2	6.7	135
a-236	patient toilet	0	52	0	-	2.96	0.2	0.2	0
a-238	exam 2	285	135	1	-	3.85	0.5	0.8	57
a-239	staff toilet	0	52	0	-	2.96	0.2	0.2	0
a-242	storage	50	68	0	-	1.41	0.2	0.2	10
a-244	kitchen	215	40	0	3420	2.40	0.1	3.6	43
a-245	med rec	305	274	6	1250	2.10	1	3.7	61
a-246	public toilet	0	52	0	-	0.98	0.2	0.2	0
s-302	telephone	380	54	0	-	1.19	0.2	0.2	76
300	waiting	2400	1075	44	-	1.66	11.7	20.5	480
301	reception	285	247	2	2100	1.94	0.9	3.4	57
302	charts	2050	1630	14	6450	1.47	11.5	22.6	410
304	office manager	285	127	1	500	3.02	1.6	2.8	57
305	corridor	1605	2696	0	-	1.57	9.7	5.4	321
310	staff toilet	50	51	0	-	2.55	0.2	0.2	10
311	janitor	0	47	0	-	2.04	0.2	0.2	0
313	file room	830	835	2	1050	1.95	4.9	6.5	166
314	patient toilet	50	47	0	-	2.77	0.2	0.1	10
315	patient toilet	50	47	0	-	2.77	0.2	0.1	10
316	break room	685	431	18	3420	1.78	3.2	11.5	137
318	server	195	50	0	-	1.92	0.2	0.1	39
319	file area	300	270	2	-	2.00	1	1.4	300
320	nuclear lab	600	1145	8	12500	1.72	12	27.5	120
321	hot lab	210	73	2	-	1.32	1.5	2.8	42
322	blood lab	115	80	2	-	1.20	0.3	0.8	23
323	echo	390	168	2	-	1.71	2.3	3.7	78
324	research office	350	110	2	1000	1.75	1.9	4.4	70
325	stress test	650	270	4	-	2.13	4.4	6.1	130
326	echo	445	198	3	-	1.72	2.8	5	89
327	pa office	405	161	1	5000	1.19	2.6	5	81
328	physicans office	240	123	1	5000	1.56	1.4	2.6	48
329	physicans office	330	130	1	5000	1.48	2	4	66
330	physicans office	240	133	1	5000	1.44	1.5	2.7	48
331	physicans office	330	132	1	5000	1.45	2	4	66
332	physicans office	330	132	1	5000	1.45	2.1	4	66
333	physicans office	240	132	1	5000	1.45	1.4	2.7	48
334	physicans office	425	132	1	5000	1.45	2.8	5.4	85
335	physicans office	150	132	1	5000	1.45	0.8	1.4	30
336	physicans office	425	132	1	5000	1.45	2.8	5.4	85
337	physicans office	440	132	1	5000	1.45	2.7	3.2	88
339	exam 1	150	93	2	-	2.06	1.6	1.6	30
340	exam 3	90	91	2	-	2.11	0.3	0.9	18
341	exam 2	90	80	2	-	2.40	0.3	0.8	18
344	exam 4	90	90	2	-	2.13	0.3	0.9	18
345	patient toilet	50	42	0	-	3.10	0.2	0.1	10
346	patient toilet	50	43	0	-	3.02	0.2	0.1	10
347	exam 5	90	102	2	-	1.88	0.4	0.9	18

*Data taken from design documents

**Data collected from Carrier's Hourly Analysis Program

Appendix C

AHU-2

Room	Function	design cfm supply*	area (Az)*	Design Occupancy (Pz)*	Equipment Load (BTUh)*	Design Watts/ft^2	Heating Load (MBH)**	Cooling Load (MBH)**	Required Outdoor Air (cfm)**
348	exam 6	90	92	2	-	2.09	0.3	0.9	18
349	exam 7	90	92	2	-	2.09	0.3	0.9	18
350	sink area	50	88	1	-	2.18	0.3	0.5	10
351	exam 8	90	92	2	-	2.09	0.3	0.9	18
352	exam 9	90	101	2	-	1.90	0.4	0.9	18
353	techs	115	73	3	1500	2.63	0.3	2.5	23
354	techs	115	72	2	500	2.67	0.3	1.7	23
356	ekg area	120	84	1	-	1.14	0.3	0.5	24
357	exam 10	90	102	2	-	1.88	0.4	0.9	18
358	exam 11	90	93	2	-	2.06	0.3	0.9	18
359	exam 12	90	92	2	-	2.09	0.3	0.9	18
360	exam 15	90	92	2	-	2.09	0.3	0.9	18
361	exam 14	90	93	2	-	2.06	0.3	0.9	18
362	exam 13	90	102	2	-	1.88	0.3	0.9	18
366	exam 16	90	98	2	-	1.96	0.3	0.9	18
367	exam 17	90	92	2	-	2.09	0.3	0.9	18
368	exam 18	90	92	2	-	2.09	0.3	0.9	18
369	exam 19	90	102	2	-	1.88	0.4	0.9	18
370	sub-waiting	350	156	10	-	1.85	0.6	2.9	70
371	exam 21	90	88	2	-	2.18	0.3	0.9	18
372	exam 20	90	87	2	-	2.21	0.3	0.9	18
374	research files	60	97	0	-	1.98	0.3	0.3	12
375	supply closet	50	42	0	-	2.29	0.2	0.1	10

*Data taken from design documents
**Data collected from Carrier's Hourly Analysis Program

Appendix C

AHU-3

Room	Function	design cfm supply*	area (Az)*	Design Occupancy (Pz)*	Equipment Load (BTUh)*	Design Watts/ft^2	Heating Load (MBH)**	Cooling Load (MBH)**	Required Outdoor Air (cfm)**
129	office	550	230	5	750	1.67	3.7	7	110
128a	toilet	0	52	0	-	1.96	0	0.1	0
127	exam room	160	115	3	-	1.67	0	1.1	32
126	exam room	265	113	3	-	1.70	0.9	2.6	53
125	treatment room	470	141	3	-	1.36	2.5	5.5	94
124	exam room	160	122	3	-	1.57	0	1.2	32
122	exam room	160	122	3	-	1.57	0	1.2	32
121	treatment room	470	141	3	-	1.36	2.5	5.5	94
128	exec reception	665	338	7	1000	2.27	2.6	7.7	133
131	conference/library	955	518	42	-	1.13	0	11.1	191
120	exam room	265	112	3	-	1.71	1	2.6	53
119	exam room	160	115	3	-	1.67	0	1.1	32
115	exam room	160	115	3	-	1.67	0	1.1	32
114	exam room	265	112	3	-	1.71	1	2.6	53
113	exam room	470	141	3	-	1.36	2.5	5.5	94
112	exam room	160	122	3	-	1.57	0	1.2	32
106	exam room	160	122	3	-	1.57	0	1.2	32
105	exam room	265	112	3	-	1.71	1	2.6	53
104	exam room	470	141	3	-	1.36	2.5	5.5	94
103	exam room	160	122	3	-	1.57	0	1.2	32
102	waiting room	1595	808	40	-	1.48	6.9	19	319
101	patient toilet	0	76	0	-	1.34	0	0.2	0
116	soiled utility	0	33	0	-	2.91	0	0.1	0
111	staff toilet	0	50	0	-	2.04	0	0.1	0
110	patient toilet	0	50	0	-	2.04	0	0.1	0
108	clean utility	100	56	0	-	1.71	0	0.1	20
107	front office	365	320	6	3400	2.41	0	5.9	73
100	entry vestibule	150	245	2	-	2.61	0	1.1	30
130	office	270	170	5	750	2.26	0.9	3.8	54
132	office	360	124	3	750	2.06	1.6	4.5	72
133	office	270	132	3	750	1.94	1.6	4.5	54
134	office	240	118	3	750	2.17	0.9	3.2	48
140	md mgr office	95	85	1	750	3.01	0	1.2	19
139	office	130	115	3	750	2.23	0	1.8	26
138	office	130	112	3	750	2.29	0	1.8	26
137	inf mgr office	95	85	1	750	3.01	0	1.2	19
c-7	corridor	105	488	0	-	1.81	0	0.6	21
c-1	corridor	290	918	0	-	2.29	0	1.1	58

*Data taken from design documents
**Data collected from Carrier's Hourly Analysis Program

Appendix D

AHU-1

Room	Function	design cfm supply	area (Az)	Design Occupancy (Pz)	Equipment Load (BTUh)	Lighting Load (ASHRAE 90.1-2004)	Lighting Design (W)	Watts/ft^2	Complies
003	corridor	315	1480	0	-	0.5	1589	1.07	no
003a	link	495	304	0	-	0.5	312	1.03	no
008	electrical room	50	84	0	-	1.5	64	0.76	yes
009	telephone	380	55	0	-	1.5	64	1.16	yes
014	elec. Room	1000	185	0	-	1.5	64	0.35	yes
126	director	395	140	1	500	1.1	153	1.09	yes
125	chief tech	195	85	1	500	1.1	102	1.20	no
124	physicist	305	85	1	500	1.1	102	1.20	no
123	treatment planning	570	120	1	500	1.1	192	1.60	no
122	dressing	65	29	1	-	1.1	51	1.76	no
121	dressing	50	29	1	-	1.1	51	1.76	no
127	corridor	160	265	0	-	0.5	576	2.17	no
143	corridor	75	179	0	-	0.5	288	1.61	no
128	office	245	123	1	500	1.1	102	0.83	yes
129	hc toilet	50	53	0	-	0.9	51	0.96	no
131	chart storage	85	213	0	-	0.8	384	1.80	no
132	file serv/phone/stor	145	70	0	-	0.8	128	1.83	no
136	exam	120	108	2	-	1.5	192	1.78	no
135	exam	105	90	2	-	1.5	192	2.13	no
134	exam	105	90	2	-	1.5	192	2.13	no
144	storage	50	89	0	-	0.8	102	1.15	no
146	mold block	145	100	0	-	1.5	192	1.92	no
145	corridor	100	100	0	-	0.5	192	1.92	no
147	staff lounge	185	122	3	3420	1.2	192	1.57	no
148	chart storage	170	159	0	-	0.8	256	1.61	no
150	rad/oncogolgy stor	60	188	0	-	0.8	288	1.53	no
149	chart storage	50	127	0	-	0.8	192	1.51	no
#	shell space	2000	2075	10	-	1.1	512	0.25	yes
112	linacc	1365	789	2	10000	1.5	1888	2.39	no
111	linacc	1485	789	2	10000	1.5	1688	2.14	no
108	mech room	165	76	0	-	1.5	64	0.84	yes
110	control	785	209	2	1000	0.5	294	1.41	no
113	control	785	219	2	1000	0.5	243	1.11	no
107	control room	460	126	2	1000	0.5	392	3.11	no
106	ct simulator	1050	287	2	15800	1.5	772	2.69	no
105	hc toilet	50	39	0	-	0.9	51	1.31	no
104	ofc mgr	185	120	2	500	1.1	192	1.60	no
115	view boxes	100	168	0	-	0.5	147	0.88	no
139	hc toilet	50	48	0	-	0.9	130	2.71	no
117	dirty	0	18	0	-	0.8	51	2.83	no
118	clean	50	18	0	-	0.8	51	2.83	no
114	dark room	130	54	1	-	1.2	230	4.26	no
119	dressing	50	44	1	-	1.1	51	1.16	no
120	sub-waiting	135	154	5	-	1.1	192	1.25	no
137	nursing	175	79	1	500	1.0	192	2.43	no
138	stretcher	50	81	1	-	0.8	96	1.19	no
116	corridor	0	133	0	-	0.5	192	1.44	no
103	storage	50	67	0	-	0.8	128	1.91	no
102	reception	305	135	4	1000	1.1	192	1.42	no
140	conference	800	182	9	585	1.3	288	1.58	no
141	exam	105	90	2	-	1.5	192	2.13	no
142	med storage	50	58	0	-	0.8	128	2.21	no
101	waiting	1350	415	12	-	1.3	340	0.82	yes
100-04	prep/injection	105	92	1	-	1.5	208	2.26	no
100-06	prep/injection	105	92	1	-	1.5	208	2.26	no
100-08	prep/injection	105	92	1	-	1.5	208	2.26	no
100-10	patient toilet	50	52	0	-	0.9	102	1.96	no
100-12	hot lab	105	90	1	600	1.4	136	1.51	no

Appendix D

AHU-1

Room	Function	design cfm supply	area (Az)	Design Occupancy (Pz)	Equipment Load (BTUh)	Lighting Load (ASHRAE 90.1-2004)	Lighting Design (W)	Watts/ft^2	Complies
100-01	corridor	105	322	0	-	0.5	468	1.45	no
100-00	waiting	170	184	6	-	1.3	260	1.41	no
100-03	reg/techs	250	163	2	2100	1.1	204	1.25	no
100-05	staff toilet	50	52	0	-	0.9	102	1.96	no
100-07	control	500	124	1	4011	1.5	292	2.35	no
100-09	pet/ct scan	1015	374	2	15000	1.5	720	1.93	no
r-005	social work/diet	165	126	1	500	1.1	192	1.52	no
r-007	nurses	165	120	1	1000	1.0	192	1.60	no
r-008	phd	115	108	1	500	1.1	192	1.78	no
r-004	registry/research	1105	800	16	10000	1.2	1440	1.80	no
r-003	research nurses	325	118	1	1000	1.0	192	1.63	no
r-002	office	150	91	1	500	1.1	192	2.11	no
r-006	genetics pastoral	165	137	1	1000	1.1	288	2.10	no
r-001	recep/waiting	825	433	13	-	1.3	864	2.00	no
c-11	corridor	55	107	0	-	0.5	192	1.79	no
e101	elevator lobby	570	738	7	-	1.3	1294	1.75	no
i-117	phlebotomy	140	140	1	500	1.4	204	1.46	no
i-118	pharmacy	160	92	2	1240	1.4	384	4.17	no
i-118a	work room	265	112	1	500	1.1	384	3.43	no
i-118b	ante room	565	71	1	-	1.1	192	2.70	no
i-118c	clean room	750	112	0	-	1.1	272	2.43	no
i-119	reception	190	202	6	-	1.1	312	1.54	no
i-120	waiting	834	742	25	-	1.3	1349	1.82	no
i-121a	front office	295	223	3	1500	1.1	359	1.61	no
i-123	soiled utility	50	86	0	-	0.8	192	2.23	no
i-124	toilet	0	53	0	-	0.9	77	1.45	no
i-125	toilet	0	53	0	-	0.9	77	1.45	no
i-126	hall	200	334	0	-	0.5	460	1.38	no
i-128	consult	130	91	5	500	1.1	153	1.68	no
i-130	triage	130	72	1	-	1.5	192	2.67	no
i-131	clean utility	185	245	0	-	0.8	480	1.96	no
i-132a	infusion bay 2	10985	4205	16	2000	1.5	10446	2.48	no
i-134	private office	375	152	0	500	1.1	287	1.89	no
i-134a	toilet	50	50	0	-	0.9	83	1.66	no
i-136	break room	225	139	4	1340	1.2	320	2.30	no
i-138	it closet	0	8	0	-	0.8	0	0.00	yes
c-10	corridor	300	550	0	-	0.5	561	1.02	no
103	telephone	380	55	0	-	1.5	51	0.93	yes
104	electrical room	50	84	0	-	1.5	51	0.61	yes
105	jan clos.	0	37	0	-	1.5	51	1.38	yes
106	mens toilet	0	57	0	-	0.9	51	0.89	yes
107	womens toilet	0	57	0	-	0.9	51	0.89	yes

Appendix D

AHU-2

Room	Function	design cfm supply	area (Az)	Design Occupancy (Pz)	Equipment Load (BTUh)	Lighting Load (ASHRAE 90.1-2004)	Lighting Design (W)	Watts/ft^2	Complies
s-202	telephone	380	55	0	-	1.5	64	1.16	yes
s-203	elec. Room	50	84	0	-	1.5	64	0.76	yes
s-204	jan. clos.	0	37	0	-	1.5	64	1.73	no
s-205	mens toilet	0	57	0	-	0.9	51	0.89	yes
s-206	womens toilet	0	57	0	-	0.9	51	0.89	yes
200	waiting	1110	520	20	-	1.3	864	1.66	no
201	reception	410	470	4	3300	1.1	768	1.63	no
202	corridor	345	1141	0	-	0.5	2496	2.19	no
204	exam	95	108	1	-	1.5	192	1.78	no
205	exam	95	108	1	-	1.5	192	1.78	no
206	phone room	180	44	0	-	1.5	96	2.18	no
207	break room	295	239	12	3420	1.2	576	2.41	no
208	meds closet	50	64	0	-	0.8	96	1.50	no
209	supply closet	0	35	0	-	0.8	96	2.74	no
210	toilet/shower	50	80	0	-	0.9	468	5.85	no
211	surgeon's office	340	254	3	500	1.1	288	1.13	no
212	surgeon's office	340	159	3	500	1.1	288	1.81	no
213	surgeon's office	395	157	3	500	1.1	288	1.83	no
214	pa office	110	129	3	500	1.1	192	1.49	no
215	physicans office	210	120	3	500	1.1	192	1.60	no
216	physicans office	395	120	3	500	1.1	192	1.60	no
217	exam	95	100	1	-	1.5	192	1.92	no
218	physicans office	210	114	3	500	1.1	192	1.68	no
219	physicans office	210	112	3	500	1.1	192	1.71	no
220	managers office	290	91	3	500	1.1	192	2.11	no
221	private office 1	195	92	3	500	1.1	192	2.09	no
222	private office 2	195	88	3	500	1.1	192	2.18	no
223	private office 3	295	96	3	500	1.1	192	2.00	no
224	private office 4	195	97	3	500	1.1	192	1.98	no
225	private office 5	195	91	3	500	1.1	192	2.11	no
226	private office 6	295	96	3	500	1.1	192	2.00	no
227	private office 7	195	101	3	500	1.1	192	1.90	no
228	private office 8	195	92	3	500	1.1	192	2.09	no
229	private office 9	295	95	3	500	1.1	192	2.02	no
230	private office 10	300	158	5	500	1.1	384	2.43	no
231	research office	205	166	2	1250	1.1	384	2.31	no
232	research supply	85	253	0	-	0.8	384	1.52	no
233	open area	625	728	8	5100	1.1	960	1.32	no
234	hc toilet	50	48	0	-	0.9	396	8.25	no
235	research supply	85	273	0	-	0.8	480	1.76	no
a-202	front office	140	154	1	750	1.1	300	1.95	no
a-203	reading	175	275	1	500	1.1	310	1.13	no
a-205	us 1	300	153	1	-	1.1	432	2.82	no
a-206	hallway	120	321	0	-	0.5	459	1.43	no
a-207	mammo 1	395	146	1	-	1.5	432	2.96	no
a-208	mammo 2	480	143	1	-	1.5	432	3.02	no
a-209	us 2/mammo 3	420	147	1	-	1.5	412	2.80	no
a-210	storage	50	59	0	-	0.8	96	1.63	no
a-211	patient toilet	0	46	0	-	0.9	154	3.35	no
a-212	dressing	180	199	5	-	1.1	515	2.59	no
a-213	tech work area	270	90	1	2000	1.1	747	8.30	no
a-215	staff toilet	0	51	0	-	0.9	154	3.02	no
a-216	dexa	205	94	2	-	1.1	192	2.04	no
a-217	manager	105	96	2	1000	1.1	192	2.00	no
a-218	imaging registration	175	60	2	1000	1.1	102	1.70	no
a-219	shared waiting	1330	1152	44	-	1.3	2236	1.94	no
a-220	check in	155	136	2	1000	1.1	510	3.75	no
a-221	manager office	90	82	1	500	1.1	192	2.34	no

Appendix D

AHU-2

Room	Function	design cfm supply	area (Az)	Design Occupancy (Pz)	Equipment Load (BTUh)	Lighting Load (ASHRAE 90.1-2004)	Lighting Design (W)	Watts/ft^2	Complies
a-222	check out	130	76	2	1000	1.1	406	5.34	no
a-224	conference room	260	184	6	-	1.3	308	1.67	no
a-225	exam 6	285	120	1	-	1.5	296	2.47	no
a-226	exam 1	285	133	1	-	1.5	296	2.23	no
a-227	sterilization	410	120	2	500	1.0	51	0.43	yes
a-228	exam 5	285	121	1	-	1.5	296	2.45	no
a-230	exam 3	320	135	1	-	1.5	244	1.81	no
a-231	exam 4	285	120	1	-	1.5	296	2.47	no
a-232	office	370	193	7	750	1.1	462	2.39	no
a-233	office	290	125	3	1000	1.1	192	1.54	no
a-234	hallway	335	638	0	-	0.5	918	1.44	no
a-235	bbc	675	274	3	-	1.1	740	2.70	no
a-236	patient toilet	0	52	0	-	0.9	154	2.96	no
a-238	exam 2	285	135	1	-	1.5	520	3.85	no
a-239	staff toilet	0	52	0	-	0.9	154	2.96	no
a-242	storage	50	68	0	-	0.8	96	1.41	no
a-244	kitchen	215	40	0	3420	1.2	96	2.40	no
a-245	med rec	305	274	6	1250	1.1	576	2.10	no
a-246	public toilet	0	52	0	-	0.9	51	0.98	no
s-302	telephone	380	54	0	-	1.5	64	1.19	yes
300	waiting	2400	1075	44	-	1.3	1788	1.66	no
301	reception	285	247	2	2100	1.1	480	1.94	no
302	charts	2050	1630	14	6450	1.1	2400	1.47	no
304	office manager	285	127	1	500	1.1	384	3.02	no
305	corridor	1605	2696	0	-	0.5	4224	1.57	no
310	staff toilet	50	51	0	-	0.9	130	2.55	no
311	janitor	0	47	0	-	1.5	96	2.04	no
313	file room	830	835	2	1050	1	1632	1.95	no
314	patient toilet	50	47	0	-	0.9	130	2.77	no
315	patient toilet	50	47	0	-	0.9	130	2.77	no
316	break room	685	431	18	3420	1.2	768	1.78	no
318	server	195	50	0	-	0.8	96	1.92	no
319	file area	300	270	2	-	1	540	2.00	no
320	nuclear lab	600	1145	8	12500	1.5	1972	1.72	no
321	hot lab	210	73	2	-	1.4	96	1.32	yes
322	blood lab	115	80	2	-	1.4	96	1.20	yes
323	echo	390	168	2	-	1.4	288	1.71	no
324	research office	350	110	2	1000	1.1	192	1.75	no
325	stress test	650	270	4	-	1.5	576	2.13	no
326	echo	445	198	3	-	1.4	340	1.72	no
327	pa office	405	161	1	5000	1.1	192	1.19	no
328	physicans office	240	123	1	5000	1.1	192	1.56	no
329	physicans office	330	130	1	5000	1.1	192	1.48	no
330	physicans office	240	133	1	5000	1.1	192	1.44	no
331	physicans office	330	132	1	5000	1.1	192	1.45	no
332	physicans office	330	132	1	5000	1.1	192	1.45	no
333	physicans office	240	132	1	5000	1.1	192	1.45	no
334	physicans office	425	132	1	5000	1.1	192	1.45	no
335	physicans office	150	132	1	5000	1.1	192	1.45	no
336	physicans office	425	132	1	5000	1.1	192	1.45	no
337	physicans office	440	132	1	5000	1.1	192	1.45	no
339	exam 1	150	93	2	-	1.5	192	2.06	no
340	exam 3	90	91	2	-	1.5	192	2.11	no
341	exam 2	90	80	2	-	1.5	192	2.40	no
344	exam 4	90	90	2	-	1.5	192	2.13	no
345	patient toilet	50	42	0	-	0.9	130	3.10	no
346	patient toilet	50	43	0	-	0.9	130	3.02	no
347	exam 5	90	102	2	-	1.5	192	1.88	no

Appendix D

AHU-2

Room	Function	design cfm supply	area (Az)	Design Occupancy (Pz)	Equipment Load (BTUh)	Lighting Load (ASHRAE 90.1-2004)	Lighting Design (W)	Watts/ft^2	Complies
348	exam 6	90	92	2	-	1.5	192	2.09	no
349	exam 7	90	92	2	-	1.5	192	2.09	no
350	sink area	50	88	1	-	1.0	192	2.18	no
351	exam 8	90	92	2	-	1.5	192	2.09	no
352	exam 9	90	101	2	-	1.5	192	1.90	no
353	techs	115	73	3	1500	1.1	192	2.63	no
354	techs	115	72	2	500	1.1	192	2.67	no
356	ekg area	120	84	1	-	1.1	96	1.14	no
357	exam 10	90	102	2	-	1.5	192	1.88	no
358	exam 11	90	93	2	-	1.5	192	2.06	no
359	exam 12	90	92	2	-	1.5	192	2.09	no
360	exam 15	90	92	2	-	1.5	192	2.09	no
361	exam 14	90	93	2	-	1.5	192	2.06	no
362	exam 13	90	102	2	-	1.5	192	1.88	no
366	exam 16	90	98	2	-	1.5	192	1.96	no
367	exam 17	90	92	2	-	1.5	192	2.09	no
368	exam 18	90	92	2	-	1.5	192	2.09	no
369	exam 19	90	102	2	-	1.5	192	1.88	no
370	sub-waiting	350	156	10	-	1.3	288	1.85	no
371	exam 21	90	88	2	-	1.5	192	2.18	no
372	exam 20	90	87	2	-	1.5	192	2.21	no
374	research files	60	97	0	-	1.0	192	1.98	no
375	supply closet	50	42	0	-	0.8	96	2.29	no

Appendix D

AHU-3

Room	Function	design cfm supply	area (Az)	Design Occupancy (Pz)	Equipment Load (BTUh)	Lighting Load (ASHRAE 90.1-2004)	Lighting Design (W)	Watts/ft^2	Complies
129	office	550	230	5	750	1.1	384	1.67	no
128a	toilet	0	52	0	-	0.9	102	1.96	no
127	exam room	160	115	3	-	1.5	192	1.67	no
126	exam room	265	113	3	-	1.5	192	1.70	no
125	treatment room	470	141	3	-	1.5	192	1.36	yes
124	exam room	160	122	3	-	1.5	192	1.57	no
122	exam room	160	122	3	-	1.5	192	1.57	no
121	treatment room	470	141	3	-	1.5	192	1.36	yes
128	exec reception	665	338	7	1000	1.5	768	2.27	no
131	conference/library	955	518	42	-	1.5	584	1.13	yes
120	exam room	265	112	3	-	1.5	192	1.71	no
119	exam room	160	115	3	-	1.5	192	1.67	no
115	exam room	160	115	3	-	1.5	192	1.67	no
114	exam room	265	112	3	-	1.5	192	1.71	no
113	exam room	470	141	3	-	1.5	192	1.36	yes
112	exam room	160	122	3	-	1.5	192	1.57	no
106	exam room	160	122	3	-	1.5	192	1.57	no
105	exam room	265	112	3	-	1.5	192	1.71	no
104	exam room	470	141	3	-	1.5	192	1.36	yes
103	exam room	160	122	3	-	1.5	192	1.57	no
102	waiting room	1595	808	40	-	1.3	1196	1.48	no
101	patient toilet	0	76	0	-	0.9	102	1.34	no
116	soiled utility	0	33	0	-	0.8	96	2.91	no
111	staff toilet	0	50	0	-	0.9	102	2.04	no
110	patient toilet	0	50	0	-	0.8	102	2.04	no
108	clean utility	100	56	0	-	1.1	96	1.71	no
107	front office	365	320	6	3400	1.3	772	2.41	no
100	entry vestibule	150	245	2	-	1.1	640	2.61	no
130	office	270	170	5	750	1.1	384	2.26	no
132	office	360	124	3	750	1.1	256	2.06	no
133	office	270	132	3	750	1.1	256	1.94	no
134	office	240	118	3	750	1.1	256	2.17	no
140	md mgr office	95	85	1	750	1.1	256	3.01	no
139	office	130	115	3	750	1.1	256	2.23	no
138	office	130	112	3	750	1.1	256	2.29	no
137	inf mgr office	95	85	1	750	1.1	256	3.01	no
c-7	corridor	105	488	0	-	0.5	884	1.81	no
c-1	corridor	290	918	0	-	0.5	2100	2.29	no

Appendix E

Fin-Tube Length Calculations

Room	Function	Heating Load (MBH)*	T(leaving), T(entering) = 200	T(average) = (T(entering)+T(leaving))/2	BTU/Hr/Ft**	Length needed	Fin-Tube Length (ft)	
003a	link	4.3	191	196	1614.6	2.7	3	
014	elec. Room	2.1	196	198	1645.8	1.3	2	
126	director	1.5	197	199	1661.4	0.9	2	
125	chief tech	0.8	198	199	1661.4	0.5	2	
124	physicist	1.5	197	199	1661.4	0.9	2	
123	treatment planning	1.6	197	198	1645.8	1.0	2	
122	dressing	0.2	200	200	1677	0.1	2	
148	chart storage	1.9	196	198	1645.8	1.2	2	
150	rad/oncogolgy stor	1.2	198	199	1661.4	0.7	2	
#	shell space	11.7	177	188	1486	7.9	8	
112	linacc	13.4	173	187	1468.5	9.1	-	2@5
111	linacc	13.4	173	187	1468.5	9.1	-	2@5
100-12	hot lab	0.9	198	199	1661.4	0.5	2	
100-01	corridor	0.8	198	199	1661.4	0.5	2	
100-03	reg/techs	1.3	197	199	1661.4	0.8	2	
100-05	staff toilet	0.8	198	199	1661.4	0.5	2	
100-07	control	1	198	199	1661.4	0.6	2	
100-09	pet/ct scan	2.3	195	198	1645.8	1.4	2	
r-008	phd	0.8	198	199	1661.4	0.5	2	
r-004	registry/research	2.2	196	198	1645.8	1.3	2	
r-003	research nurses	1.4	197	199	1661.4	0.8	2	
r-001	recep/waiting	3.9	192	196	1614.6	2.4	3	
e101	elevator lobby	3	194	197	1630.2	1.8	2	
i-120	waiting	0.2	200	200	1677	0.1	2	
i-132a	infusion bay 2	110	-20	90	1521	72.3	-	5@8, 5@7
i-134a	toilet	1	198	199	1661.4	0.6	2	
211	surgeon's office	1.8	196	198	1645.8	1.1	2	
212	surgeon's office	1.6	197	198	1645.8	1.0	2	
213	surgeon's office	2.7	195	197	1630.2	1.7	2	
215	physicans office	1	198	199	1661.4	0.6	2	
216	physicans office	2.3	195	198	1645.8	1.4	2	
218	physicans office	0.9	198	199	1661.4	0.5	2	
219	physicans office	0.9	198	199	1661.4	0.5	2	
220	managers office	1.5	197	199	1661.4	0.9	2	
221	private office 1	1	198	199	1661.4	0.6	2	
222	private office 2	0.9	198	199	1661.4	0.5	2	
223	private office 3	1.5	197	199	1661.4	0.9	2	
224	private office 4	0.9	198	199	1661.4	0.5	2	
225	private office 5	0.9	198	199	1661.4	0.5	2	
226	private office 6	1.5	197	199	1661.4	0.9	2	
227	private office 7	0.9	198	199	1661.4	0.5	2	
228	private office 8	0.9	198	199	1661.4	0.5	2	
229	private office 9	1.5	197	199	1661.4	0.9	2	
230	private office 10	2.7	195	197	1630.2	1.7	2	
231	research office	1.6	197	198	1645.8	1.0	2	
a-207	mammo 1	0.4	199	200	1677	0.2	2	
a-208	mammo 2	1.9	196	198	1645.8	1.2	2	
a-209	us 2/mammo 3	2.4	195	198	1645.8	1.5	2	
a-210	storage	1.1	198	199	1661.4	0.7	2	
a-212	dressing	1.3	197	199	1661.4	0.8	2	
a-228	exam 5	0.4	199	200	1677	0.2	2	
a-230	exam 3	0.5	199	200	1677	0.3	2	
a-231	exam 4	0.4	199	200	1677	0.2	2	
a-232	office	3.4	193	197	1630.2	2.1	3	
a-233	office	1.4	197	199	1661.4	0.8	2	
a-234	hallway	2.3	195	198	1645.8	1.4	2	

Appendix E

Fin-Tube Length Calculations

Room	Function	Heating Load (MBH)*	T(leaving), T(entering) = 200	T(average) = (T(entering)+T(leaving))/2	BTU/Hr/Ft**	Length needed	Fin-Tube Length (ft)	
a-235	bbc	4.2	192	196	1614.6	2.6	3	
a-236	patient toilet	0.2	200	200	1677	0.1	2	
a-238	exam 2	0.5	199	200	1677	0.3	2	
a-239	staff toilet	0.2	200	200	1677	0.1	2	
a-242	storage	0.2	200	200	1677	0.1	2	
a-244	kitchen	0.1	200	200	1677	0.1	2	
a-245	med rec	1	198	199	1661.4	0.6	2	
a-246	public toilet	0.2	200	200	1677	0.1	2	
s-302	telephone	0.2	200	200	1677	0.1	2	
300	waiting	11.7	177	188	1486	7.9	8	
301	reception	0.9	198	199	1661.4	0.5	2	
302	charts	11.5	177	189	1503.5	7.6	8	
304	office manager	1.6	197	198	1645.8	1.0	2	
305	corridor	9.7	181	190	1521	6.4	7	
310	staff toilet	0.2	200	200	1677	0.1	2	
311	janitor	0.2	200	200	1677	0.1	2	
313	file room	4.9	190	195	1599	3.1	3.5	
314	patient toilet	0.2	200	200	1677	0.1	2	
315	patient toilet	0.2	200	200	1677	0.1	2	
316	break room	3.2	194	197	1630.2	2.0	2	
318	server	0.2	200	200	1677	0.1	2	
319	file area	1	198	199	1661.4	0.6	2	
320	nuclear lab	12	176	188	1486	8.1	-	1@4,1@5
321	hot lab	1.5	197	199	1661.4	0.9	2	
322	blood lab	0.3	199	200	1677	0.2	2	
323	echo	2.3	195	198	1645.8	1.4	2	
324	research office	1.9	196	198	1645.8	1.2	2	
325	stress test	4.4	191	196	1614.6	2.7	3	
326	echo	2.8	194	197	1630.2	1.7	2	
327	pa office	2.6	195	197	1630.2	1.6	2	
328	physicans office	1.4	197	199	1661.4	0.8	2	
329	physicans office	2	196	198	1645.8	1.2	2	
330	physicans office	1.5	197	199	1661.4	0.9	2	
331	physicans office	2	196	198	1645.8	1.2	2	
332	physicans office	2.1	196	198	1645.8	1.3	2	
333	physicans office	1.4	197	199	1661.4	0.8	2	
334	physicans office	2.8	194	197	1630.2	1.7	2	
335	physicans office	0.8	198	199	1661.4	0.5	2	
336	physicans office	2.8	194	197	1630.2	1.7	2	
337	physicans office	2.7	195	197	1630.2	1.7	2	
339	exam 1	1.6	197	198	1645.8	1.0	2	
340	exam 3	0.3	199	200	1677	0.2	2	
341	exam 2	0.3	199	200	1677	0.2	2	
344	exam 4	0.3	199	200	1677	0.2	2	
345	patient toilet	0.2	200	200	1677	0.1	2	
346	patient toilet	0.2	200	200	1677	0.1	2	
347	exam 5	0.4	199	200	1677	0.2	2	
348	exam 6	0.3	199	200	1677	0.2	2	
349	exam 7	0.3	199	200	1677	0.2	2	
350	sink area	0.3	199	200	1677	0.2	2	
351	exam 8	0.3	199	200	1677	0.2	2	
352	exam 9	0.4	199	200	1677	0.2	2	
353	techs	0.3	199	200	1677	0.2	2	
354	techs	0.3	199	200	1677	0.2	2	
356	ekg area	0.3	199	200	1677	0.2	2	
357	exam 10	0.4	199	200	1677	0.2	2	

Appendix E

Fin-Tube Length Calculations

Room	Function	Heating Load (MBH)*	T(leaving), T(entering) = 200	T(average) = (T(entering)+T(leaving))/2	BTU/Hr/Ft**	Length needed	Fin-Tube Length (ft)	
358	exam 11	0.3	199	200	1677	0.2	2	
359	exam 12	0.3	199	200	1677	0.2	2	
360	exam 15	0.3	199	200	1677	0.2	2	
361	exam 14	0.3	199	200	1677	0.2	2	
362	exam 13	0.3	199	200	1677	0.2	2	
366	exam 16	0.3	199	200	1677	0.2	2	
367	exam 17	0.3	199	200	1677	0.2	2	
368	exam 18	0.3	199	200	1677	0.2	2	
369	exam 19	0.4	199	200	1677	0.2	2	
370	sub-waiting	0.6	199	199	1661.4	0.4	2	
371	exam 21	0.3	199	200	1677	0.2	2	
372	exam 20	0.3	199	200	1677	0.2	2	
374	research files	0.3	199	200	1677	0.2	2	
375	supply closet	0.2	200	200	1677	0.1	2	
129	office	3.7	193	196	1614.6	2.3	3	
126	exam room	0.9	198	199	1661.4	0.5	2	
125	treatment room	2.5	195	198	1645.8	1.5	2	
121	treatment room	2.5	195	198	1645.8	1.5	2	
128	exec reception	2.6	195	197	1630.2	1.6	2	
120	exam room	1	198	199	1661.4	0.6	2	
114	exam room	1	198	199	1661.4	0.6	2	
113	exam room	2.5	195	198	1645.8	1.5	2	
105	exam room	1	198	199	1661.4	0.6	2	
104	exam room	2.5	195	198	1645.8	1.5	2	
102	waiting room	6.9	186	193	1567.8	4.4	5	
130	office	0.9	198	199	1661.4	0.5	2	
132	office	1.6	197	198	1645.8	1.0	2	
133	office	1.6	197	198	1645.8	1.0	2	
134	office	0.9	198	199	1661.4	0.5	2	
Sub Total							307.5	99
Total		368.1						406.5

* Heating load values from HAP model

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