DASCO Medical Office Building

Saint Joseph Medical Center

Towson, Maryland

Mechanical Technical Report 3

Mechanical System Existing Conditions Evaluation

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Mechanical Option

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Executive Summary

Technical Assignment 3 is written as a clear, succinct summary of the mechanical system of the DASCO Medical Office Building. Final design of a mechanical system is engineered after many factors are considered such as building use, external influences, control logic, and system configuration. These factors are chosen in order to meet requirements of building code and propose designs that will meet owner needs. This report discusses the various design goals and factors influencing design that the engineers needed to consider when choosing the mechanical system.

Overall mechanical system performance is discussed in this report. Original designer data for load and energy estimation and operating costs are compared to the estimated values used for the building model in a previous assignment. As with any client motivated project, the owner's desires for cost, maintainability, compatibility, etc. are usually the biggest influence on the design. Sometimes, engineers can propose different ideas to the owner through the conceptual design phase if energy savings or system longevity issues are explored. However, in this project, first cost played a major role in the mechanical system design. This was assumed since the owner does not occupy the building, and therefore initial cost should be kept at a minimum in order to try and maximize profit when leasing the rentable space. Another goal, since the building was designed as a shell and core, without knowledge of the space layout when the building is occupied, was to design an adaptable system. The fan powered VAV boxes can be moved or added depending on where larger loads occur, in the attempt to provide the most comfortable and healthy space for the occupants.

Ventilation was evaluated using AHSRAE Standard 62.1-2007. The calculations in Technical Assignment 1 proved that outdoor air requirements are met based on the 20% outdoor air each air handling unit is capable of providing. A building model was constructed for Technical Assignment 2 in order to estimate design heating and cooling loads. The model also allows for occupancy schedules and energy rates to be entered into the computer and then generates equipment performance data, operating costs, and building energy consumption. These items are also discussed in this report.

System operation and control logic are also discussed, although limited, since packaged units were used as the main mechanical components. The entire system is direct digital control, allowing for complete building automation. The AHUs operate within occupied/unoccupied modes that are adjustable through user interface control panels. Room thermostats modulate integral box controllers to adjust the amount of supply air and the need for reheat.

Overall the mechanical system works for its intended application. Without knowing occupancy makes it difficult to engineer the most efficient and optimized system. Continual fit-out projects created the need for added equipment, but the adaptability of the VAV system seems to make renovations and changing tenant needs easier to accommodate.

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 4 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 designed architecturally 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.

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. Appendix A contains condensed schedules of the major mechanical equipment in this building.

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

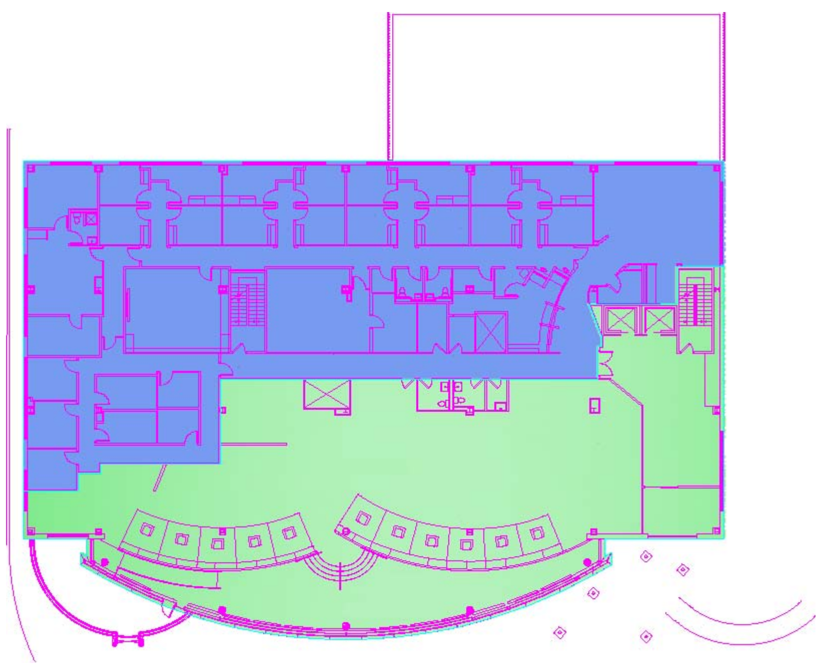

Figure 2 - First Floor

Air Handling Unit Space Breakdown

Figure 3 - Second Floor

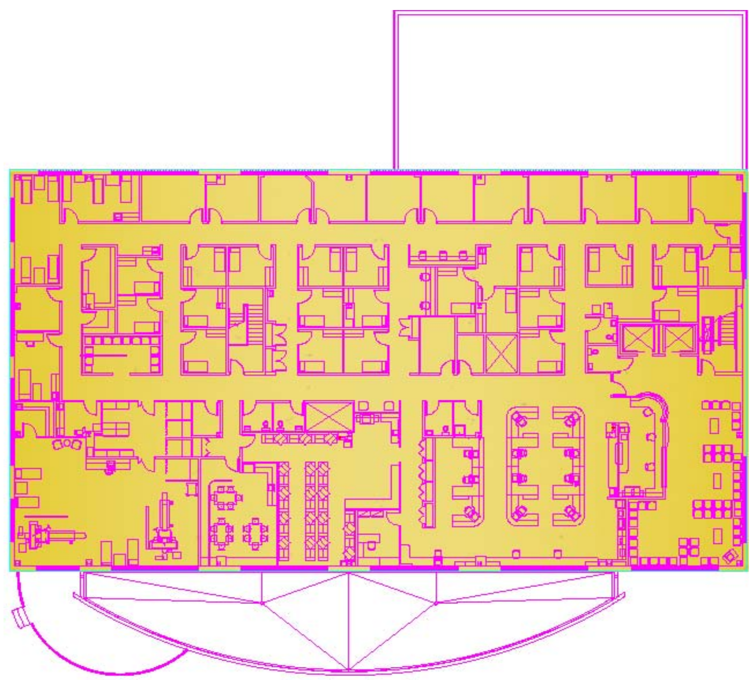

Figure 4 - Third Floor

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. The mechanical system first cost data for the DASCO Medical Office Building mechanical system 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. Any contract revisions based on the progress of construction as seen fit by the mechanical contractors are also included. 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.

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.

Table 2 - Summary of Results			
	design total supply air	desdign 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.

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 B contains tables detailing each air handler, the rooms served, and the design data from construction documents and the estimated loads from HAP.

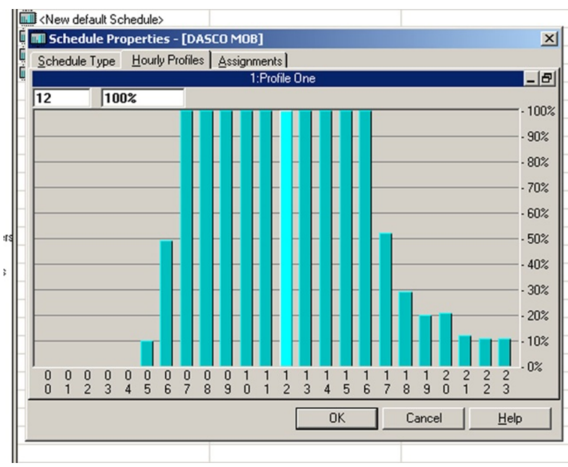

Figure 5 - Weekday Schedule

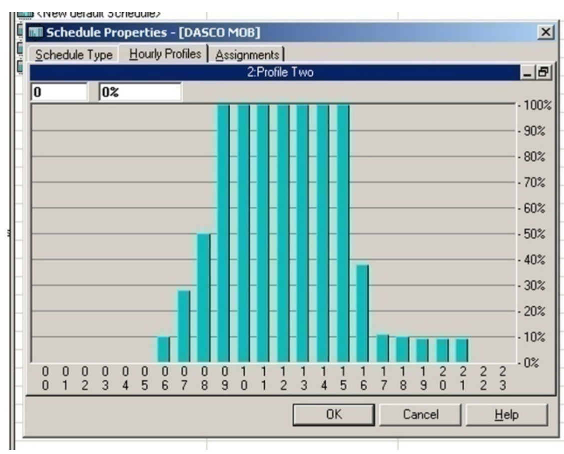

Figure 6 - Weekend Schedule

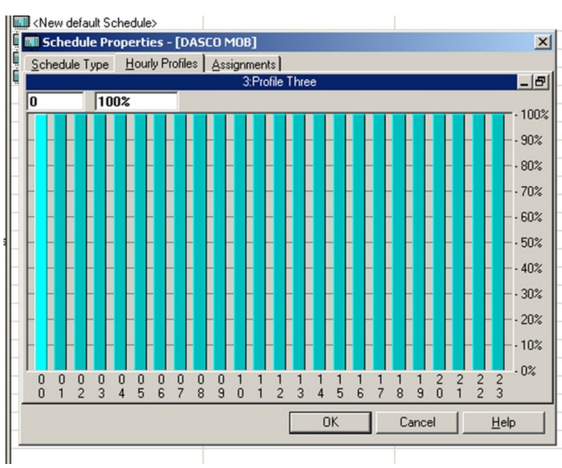

Figure 7 - Design Schedule

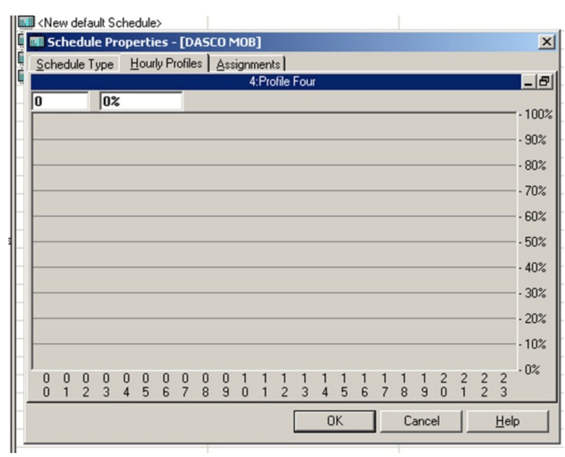

Figure 8 - Holiday Schedule

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

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 were unable to 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 8 below. Based on the information on BGE's website, there are certain categories, based on building type, that indicate the type of service. Table 8 lists the small, general service electric rates.

Table 8 - 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 9-14 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 9 - AHU Fan Performance Data				
	Supply Fan		Return Fan	
	Static Pressure	Efficiency	Static Pressure	Efficiency
AHU-1	7.75	54%	1.25	54%
AHU-2	7.75	54%	1.25	54%
AHU-3	2.82	54%	0.5	54%

Table 10 - Annual Energy Consumption		
	kWh	Annual Cost per Square Foot
HVAC - Components		
Electric	657,547	1.11
Non-HVAC Components		
Electric	253,181	0.433
Building Total	910,728	1.543

Table 11 - Annual Costs	
Component	Cost
Air System Fans	34,357
Cooling	1,139
Heating	28,524
Pumps	0
Cooling Tower Fans	0
HVAC Sub-Total	64,019
Lights	24,980
Electric Equipment	0
Misc. Electric	0
Misc. Fuel Use	0
Non-HVAC Sub-Total	24,980
Grand Total	89,000

Table 12 - Energy Consumption by System Component				
Component	Site Energy (kBTU)	Site Energy (kBTU/ft²)	Source Energy (kBTU)	Source Energy (kBTU/ft²)
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	0	0	0	0
Misc. Fuel Use	0	0	0	0
Non-HVAC Sub-Total	863,853	14.976	3,085,189	53.485
Grand Total	3,107,290	53.868	11,097,463	192.387

Table 13 - Annual Cost per Square Foot	
Component	Cost per Square Foot
Air System Fans	0.596
Cooling	0.02
Heating	0.495
Pumps	0
Cooling Tower Fans	0
HVAC Sub-Total	1.11
Lights	0.433
Electric Equipment	0
Misc. Electric	0
Misc. Fuel Use	0
Non-HVAC Sub-Total	0.433
Grand Total	1.543

Table 14 - Emissions Data		
	Generation Rate	Annual Emissions
CO_2	1.38 lb/kWh	1256771 lb
SO_2	3.42 g/kWh	3115 g
NOx	2.01 g/kWh	1831 g

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.

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 $89,000 annually; $64,019 is for the HVAC system. The biggest consumer of energy, as Table 12 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.

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.

Appendix A

Exhaust Fan Schedule								
Fan	Service	Air Flow Max (CFM)	Air Flow Min (CFM)	Total Static Pressure (IN WG)	Horsepower (BHP)	Wheel Diameter (inches)	Volts/Phase/Hertz	RPM
EF-1	General Exhaust	3,000	3,000	1.5	1.5 (1.31)	-	480/3/60	1450
EF-2	General Exhaust	3,000	3,000	1.5	1.5 (1.31)	-	480/3/60	1450
EF-3	Mold/Block	245	245	0.61	1/4 (0.18)	12	120/1/60	1775
EF-4	Hot Lab Exhaust	310	310	0.5	1/20 (0.06)	-	115/1/60	1550
EF-5	Pharmacy Exhaust	1,265	1,265	1.3	1.5 (1.29)	12	460/3/60	2591
EF-6	Isolation Exhaust	585	585	1	1/2 (0.48)	10	460/3/60	2593

Domestic Water Heater Schedule									
Water Heater	Location	Tank Type	Nominal Capacity	Entering Cold Water Temperature	Leaving Hot Water Temperature	Element Wattage	Volts/Phase/Hertz	FLA
DWH-1	Janitors Closet 006	Vertical Glass Lined	40	40	140	3000/3000	480/3/60	10.8/6.3
DWH-2	Janitors Closet 204	Vertical Glass Lined	40	40	140	3000/3000	480/3/60	10.8/6.3
DWH-3	Janitors Closet	Vertical Glass Lined	40	40	140	3000/3000	480/3/60	10.8/6.3
DWH-4	Janitors Closet	Vertical Glass Lined	40	40	140	3000/3000	480/3/60	10.8/6.3
DWH-5	Janitors Closet	Vertical Glass Lined	40	40	140	3000/3000	480/3/60	10.8/6.3
DWH-6	Janitors Closet	Vertical Glass Lined	40	40	140	3000/3000	480/3/60	10.8/6.3
DWH-7	Janitors Closet	Vertical Glass Lined	40	40	140	3000/3000	480/3/60	10.8/6.3
DWH-8	Janitors Closet	Vertical Glass Lined	40	40	140	3000/3000	480/3/60	10.8/6.3
DWH-9	Janitors Closet	Vertical Glass Lined	40	40	140	3000/3000	480/3/60	10.8/6.3

Appendix A

Chiller Schedule															
		Evaporator Perfromance				Compressor Perfromance			Pump				Electrical	
Chiller	Total Capacity (BTUH)	Operating Fluid	Leaving Fluid Temperature	Capacity (gallons)	Refrigerant	Quantity	Type	Motor Horsepower	Quantity	Horsepower	Maximum Flow Rate (gpm)	Discharge Pressure (psig)	Full Load Amps	Voltage/Phase/Hetrz
CH-1	85350	35% Propylene Glycol	68	95	R-507	1	Scroll	7.75	1	1/2	8	30	23	460/3/60
CH-2	85350	35% Propylene Glycol	68	95	R-507	1	Scroll	7.75	1	1/2	8	30	23	460/3/60
CH-3	-	35% Propylene Glycol	68	95	R-508	1	Scroll	-	1	-	-	-	-	-

Air Handling Unit Schedule																		
				Supply Air Fan				Relief Air Fan			Cooling Coil					Electrical	
Unit	Location	Total Supply Air (CFM)	Outdoor Air (CFM)	Quantity	Total Static Pressure (IN WG)	External Static Pressure (IN WG)	Horsepower	Quantity	Duct Static Pressure (IN WG)	Horsepower	Sensible (MBH)	Total (MBH)	EAT (DB/WB)	LAT (DB/WB)	Refrigerant	Volts	MCA
AHU-1	Roof	37,000	7,400	2	7.75	4.0	40	1	1.25	40	858	1488	95/78	58.28/55.8	R-22	480	400
AHU-2	Roof	36,000	7,200	2	7.75	4.0	40	1	1.25	30	848	1482	95/78	57.93/55.48	R-22	480	390
AHU-3	Roof	10,680	2,000	1	-	2.82	10	1	0.5	5	292	372	77.9/64.2	53.0/53.0	R-22	480	88

Appendix B

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 B

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 B

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 B

AHU-2

Room	Function	design cfm supply*	area (Az)*	Design Occupancy (Pz)*	Equipment Load (BTUh)*	Design Watts/ft²	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 B

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 B

AHU-3

Room	Function	design cfm supply*	area (Az)*	Design Occupancy (Pz)*	Equipment Load (BTUh)*	Design Watts/ft²	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

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