SHA HEADQUARTERS

707 N. Calvert St. | Baltimore, MD

Technical Report Three

Existing Mechanical System Conditions Evaluation

Stephanie Kunkel | www.engr.psu.edu/ae/thesis/portfolios/2011/slk5061 | **Mechanical Option**

Dr. Bahnfleth | **November 29, 2010**

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EXECUTIVE SUMMARY

The Maryland State Highway Administration (SHA) Headquarters is located in downtown Baltimore and occupies two office buildings, 707 and 211, which were both originally built in 1959. This report's focus is on the 707 N. Calvert Street building, a 6 story office building with two levels of parking in the Basement and Subbasement; the Basement level also includes a print shop as well as some office space. With each floor approximately 29,000 square feet, the total renovation cost is $4,435,500.

The objective of Technical Report III is to analyze the existing conditions of the complete heating, ventilating, and air conditioning systems there were installed in the 707 Building. Each system was analyzed, including the two low pressure central station air handling units (AHUs) serving the central core of the building and one high pressure central station AHU serving the central core of the building. Another analysis, the Leadership in Energy and Environmental Design (LEED), a subsidiary of the United States Green Building Council (USGBC), was also performed in Technical Report III.

In Technical Report II, Trane TRACE 700 Version 6.2 was utilized to calculate the office building load data, as well as the yearly energy consumption, of the 707 building. TRACE inputs were selected from the building design specifications and drawings as well as additional information provided by the design engineer. The generated block load energy model for the 707 building calculated the total annual energy consumption for cooling and heating loads to be 44.305 MBtu/year. The annual utility cost, that was totaled in Technical Report II, for the consumed electricity and natural gas was $200,808 or 1.17 $/sf. In order to provide a redesigned mechanical system with reduced energy consumptions, the current features of the building's utility usage must be analyzed. The operating history of the 707 Building's system was not available. Therefore, it was not possible to obtain annual energy utilization data – electric power (kWh) and fossil fuel (therms of natural gas). As SHA receives one single energy bill for the entire state, which includes over 400 buildings, there is no way to compare the actual energy usage to the estimated values.

A ventilation estimation was performed in Technical Report I, and since 707 is solely an office building, the inputs for CFM per person and floor area were the same throughout. The building was analyzed using the ventilation rate procedure, and in the majority of cases, 707 exceeded the minimum ventilation rates required due to the overestimated occupancy.

MECHANICAL SYSTEM SUMMARY

The 707 building's mechanical system is comprised of two low pressure central station air handling units (AHUs) serving the central core of the building and one high pressure central station AHU serving the central core of the building. Cooling is provided by a chilled water plant, utilizing a centrifugal chiller and an updraft cooling tower, while heating is provided by two low pressure steam boilers and a steam-to-hot water heat exchanger. Overall, the components of the system include 3 constant volume built-up AHUs, 534 perimeter induction units with no operating fans on the 6 office levels, 18 VAV boxes that serve individual areas, a chilled water/hot water indoor unit, and a chilled water/steam indoor unit. An expansive description about the mechanical system design can be found in the following section.

MECHANICAL SYSTEM DESIGN

Design Objectives, Requirements & Influences

The intent of renovating the 707 Building is to improve system reliability, energy efficiency and occupant safety and comfort. The options for renovation were compared using the following criteria: disturbance to Operations (during construction), maintenance requirements of the proposed system, simplicity of the system control strategy, robustness (system resistance to failure – may be in conflict with maintainability). The winning bid for the following renovation plans totaled at $4,435,500, or about $18.90/sf.

Many options were considered for the HVAC renovation of the 707 Building. The current plan is to have nine total phases that will be performed so that work can be completed while maintaining building operations. Due to limited relocation space, a maximum of 20 people can be removed from their areas at a time during the renovation. The contractor will be responsible for submitting a phasing plan and coordinated schedule which will achieve this goal.

To prevent system failure and improve the current levels of building comfort, system reliability and operating efficiency, much of the outdated and dilapidated mechanical system will be replaced. This option is intended to improve comfort to occupants and system efficiency, and lessen maintenance costs as the equipment will be new.

Since much of the equipment at the 707 Building has exceeded its expected service life, it will be replaced to maintain reliable building operation. The following equipment should be replaced with similar equipment: AHU's, the original boiler and pumps. The new AHU's will be equipped with supply fan and return fan VFD's; adding return fans and VFD's will allow proper control of building pressurization and ventilation. The induction unit secondary water system will be modified to only provide reheat water. Also, the existing building automation system will be replaced. Once there are supply fan VFD's and a new controls system, zone dampers can be added for each half of a floor.

The current option for the perimeter spaces' replacement is for the 534 induction units to be replaced, in kind. This requires installation of new floor mounted induction units, cleaning the vertical ducts, adding new branch ducts from the existing verticals, and all new dual temp piping, control valves, and thermostats and tie into BAS. Advantages of this option include limited building operation disturbance, little architectural work needed, and increased system efficiency. The main disadvantage is that this option does not provide any increase in usable floor area. Other impacts of these interior improvements are the cause of the occupant relocation (2 weeks per floor), and system outages of approximately 1 week during equipment replacement.

Outdoor and Indoor Design Conditions

The weather data was taken from the 2009 ASHRAE Handbook of Fundamentals (HOF), and they represent the 0.4% and 99.6% values, respectively. Below, Table 1 shows these values used in the building analysis. Actual weather conditions that were used in TRACE are displayed in the TRACE schedules in Appendix C. The entire Baltimore, MD weather data from ASHRAE 2009 HOF can also be found in Appendix C.

Table 1: ASHRAE Weather Data – Baltimore, MD

ASHRAE Values	Summer Design Cooling (0.4%)	Winter Design Heating (99.6%)
OA Dry Bulb (°F)	93.9	12.9
OA Wet Bulb (°F)	78.1	-

Indoor design conditions, in Table 2 below, were assessed from ASHRAE 90.1. Other indoor design inputs such as "Typical Office Airflows" and "Typical Office Internal Loads" can be seen in Appendix A.

Table 2: Indoor Design Conditions

Thermostat Settings	
Cooling DB	5°F
Cooling Setback	0°F
Heating DB	0°F
Heating Setback	5°F
Relative Humidity	0%

Design Ventilation Requirements

The 707 building meets, and in some cases, exceeds the minimum ventilation requirements based upon Section 6. When determining the population density, the conference rooms were left empty so that the block load would be more accurate. The occupied floors had a combined occupancy of 1,099 people, which considerably surpasses both the current (833) and projected (930) number of occupants, even with the empty conference rooms. As shown in Table 3, AHU-S1 is low on OA, which is reasonable because the minimum OA damper and pre-heat coil are boarded-up. Airflow of the707 Building airflow was assessed by Whitman Requardt and Associates, LLP. Assuming a design Supply Air Temperature of 55 F (Increased to 57 by time entering space) for the AHU's and H&V's, the following was determined:

Table 3: Design Ventilation Measured vs TRACE Calculated (Courtesy of JMT)

Unit	Measured		TRACE Calculated		
	Total CFM	OA CFM	Total CFM	OA CFM	Tons
AHU-S1	24189	2559	89904	8520	162.8
AHU-S2	35111	9175	23001	6380	70.5
AHU-S3	42033	7884	24341	7080	76
H&V-1	2763	151	8159	280	11.9
H&V-2	8534	2962	7288	960	15.3
TOTAL	**112630**	**22731**	**152693**	**23220**	

Although there was a larger people load in the calculations, the total building block cooling load was less than 320 tons, meaning the 450 nominal ton existing chiller is sufficient. The initial AHU configuration remains - all 6 office floors are served by 3 built-up AHUs in the penthouse. One unit (AHU-S1) provides high pressure air to the perimeter induction units on the office levels and is a constant volume unit with preheat, cooling and reheat coils. The remaining units (AHU-S2 & S3) serve the north and south halves of the building respectively and are constant volume, cooling-only units that provide supply air to the core of all of the office floors. Calculations showed that Outdoor Air quantities for the internal AHU's (S2&S3) were also appropriate.

There are two Heating and Ventilating Units (H&V-1 and 2) serving parts of the building, and are the only means of ventilating the spaces they serve. H&V-1 supplies the print shop and has a hot water heating coil. The DX unit in the Print Shop (served by H&V-1) reduces the actual building block cooling load; however, H&V-1 is low on ventilation air. H&V-2 serves Archeology and the Basement lobby and has a steam heating coil. H&V-1&2 appear to be low on CFM because there is Unitary DX cooling equipment in the space served by H&V-1 and FCU's in the spaces served by H&V-2; therefore, H&V-1&2 do not see the full load of the spaces they serve. Figure 1 on the next page shows the layout of the AHU's S-1,2&3 and H&V-1&2.

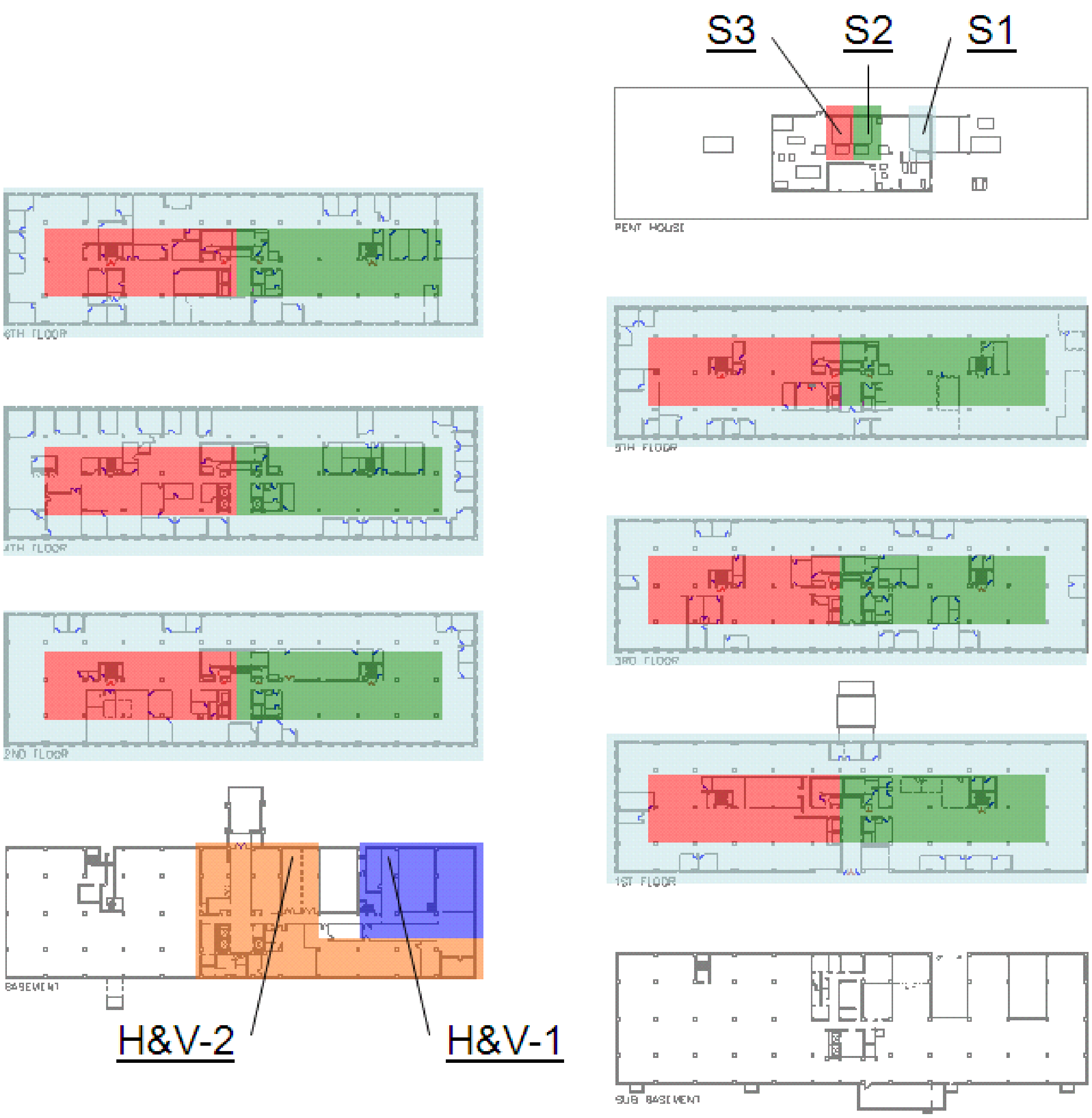

Figure 1: 707 Air Distribution System (Courtesy of JMT)

Design Heating and Cooling Loads

Below, Table 4 indicates cooling, heating, supply, and ventilation rates for the TRACE block load compared to the original loads calculated by the design engineer. The block load values are greater than those of the original calculations; this is most likely due to the simplified load estimations and assumptions of the block load. Specific information for every single room/space must be known and analyzed exactly to obtain the most accurate cooling and heating loads for 707. Nonetheless, even with the simplifications that were made for the block load, the findings show a plausible portrayal of the loads that the design engineer calculated.

Table 4: Block Loads vs. Original Loads and Ventilation

	Cooling (ft^2/ton)	Heating (Btu/h*ft^2)	Supply Air (cfm/ft^2)	Ventilation Air (cfm/ft^2)
707 Block Load	405.4	27.9	0.85	0.15
707 Original	535.2	21.6	0.37	0.14

SYSTEM ENERGY CONSUMPTION & OPERATING COSTS

During Technical Assignment II, a year-long energy simulation was composed by the Trane TRACE 700 model that was used to find the building design cooling and heating loads. Cooling is provided by a chilled water plant operated by electricity, while heating is provided by two low pressure steam boilers and a steam-to-hot water heat exchanger.

System Energy Classification

According to the energy analysis results from Technical Report II, the 707 building consumes 1,743,765 kWh of energy annually. The breakdown of this energy consumption is shown in both Table 5 and Figure 2 below. Typical for an office building in this region, space heating and lighting are large energy consumers. Since there are no fans within any of the 534 induction units for the cooling system, the amount of energy expended is reduced when compared to a standard office building.

Table 5: Energy Consumption Breakdown

	Energy (kBtu/yr)	Total Energy (%)
Lighting	2951.2	35
Space Heating	2533.5	30
Receptacles	1986.7	24
Space Cooling	566.2	7
Heat Rejection	310.4	4

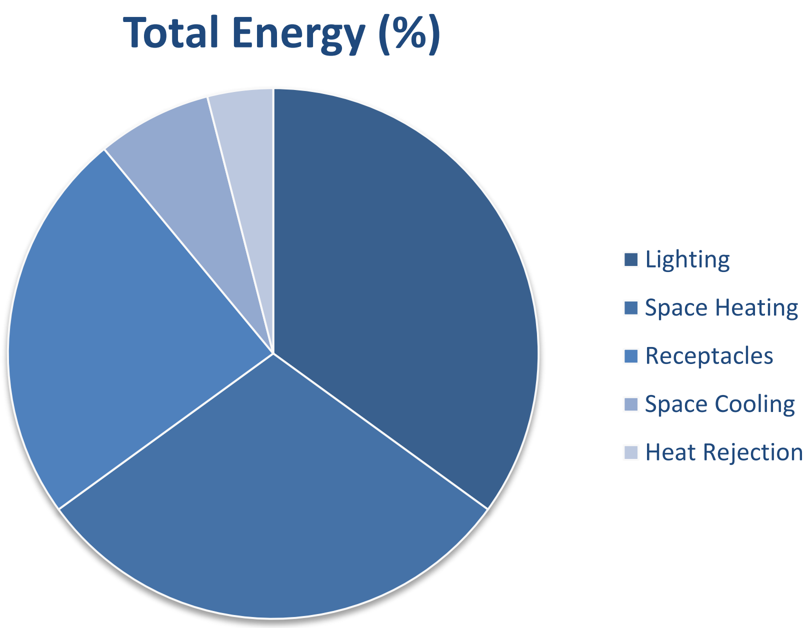

Figure 2: Energy Consumption Pie Chart

Building Energy Cost Analysis

Knowing the monthly energy usages, an annual building operating cost analysis was performed in Technical Report II. Tables 6 and 7 display the utility rates for both electricity and natural gas, respectively, from the Baltimore Gas and Electric Company (BGE) website. These values were manually inserted into TRACE in the form of utility schedules, so that the energy consumption could be calculated in a yearlong energy simulation.

Table 6: BGE Electric Rates

	Demand Charge ($/kW)	Peak ($/kWh)	Mid-Peak (cents/kWh)	Off-Peak (cents/kWh)
Electricity	3.95	0.1155	0.0927	0.0882

Table 7: BGE Natural Gas Rates

	Up to first 10,000 therms ($/therm)	Above 10,000 therms ($/therm)
Natural Gas	0.198	0.095

The total annual utility cost that was totaled for the consumed electricity and natural gas is $200,808 or 1.17 $/sf.

Building Energy and Cost Analysis Results

The generated block load energy model for the 707 building calculated the total annual energy consumption for cooling and heating loads to be 44.305 MBtu/year. The total load calculated by the design engineer was 42.232 MBtu/year, which indicates that the load energy consumptions are within 4.9% of each other. No energy cost analysis was run by the design engineer, therefore results could not be compared. As SHA receives one single energy bill for the entire state, which includes over 400 buildings, there is no way to compare the actual energy usage to the estimated values.

An estimated operating cost was determined by using individual utility consumptions. The total annual utility cost that was totaled for the consumed electricity and natural gas is $200,808 or 1.17 $/sf. The final operating cost per square foot will provide a unit of measurement that can be used to compare the building's energy performance to the redesign. The same combustion emissions analysis for the operation of the redesign will be performed in order to quantify the emissions footprint enhancements of the redesigned building.

SYSTEM OPERATION AND SCHEMATICS

Heating Water System

The heating system consists of two steam boilers which feed steam heating coils in the built-up air handler that serves the perimeter, a steam coil in a basement H&V unit, a steam unit heater in the penthouse, and two heat exchangers. One heat exchanger serves a heating water loop which serves a basement H&V and basement fan coil units; the other heat exchanger serves a secondary water loop which serves the perimeter induction units on the main office floors. The heating water system will be reconfigured to provide pumping redundancy and flow to all equipment.

The 707 basement is served solely by two H&V units, labeled AHU-4&5, and 8 fan coil units (FCU's). One H&V provides ventilation to the zones conditioned by FCU's. Both H&V units were at one point retrofitted with chilled water coils on their discharge. One H&V has a steam coil, while the other has a hot water coil. The Heating Water Schematics can be seen in Appendix B. All of the mechanical systems discussed can be seen in Appendix D.

Chilled Water System

The chilled water system consists of a chiller and cooling tower from 1997, served by redundant condenser and chilled water pumps. One of each set of pumps is original to the building and one pump was installed in 1997. There are three original, built-up air handlers in the penthouse: unit S1 serves the perimeter of floors 1 through 6; unit S2 serves the south interior area of floors 1 through 6; and unit S3 serves the north interior area of floors 1 through 6. All three of these AHU's, as well as the steam and chilled water coils will be replaced during the renovation. The Cooling Water Schematics can be seen in Appendix B. All of the mechanical systems discussed can be seen in Appendix D.

Mechanical System Space Requirements

The total space that was allocated for mechanical system components is outlined in Table 8, below. The 707 Building mechanical system renovation requires the replacement of 534 induction units, in kind. This involves the installation of new floor mounted induction units; the main disadvantage of this act is that it does not provide any increase in usable floor area. The area occupied by the VAV boxes and ceiling ductwork was not taken into account during this takeoff. Since most of the mechanical equipment is located in the Penthouse, usable floor area taken up by these systems is minimal for such a large building. Summing the information from the table below, the total square footage occupied by mechanical systems comes to be roughly 1,500 ft^2.

Table 8: Mechanical Space Requirements

	Area (ft^2)
Induction Units	1,112.5
Basement AHU's	130
Vertical Shafts	256

LEED® ANALYSIS

Within the past 10 years, the United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED®) system has become wildly popular as a comprehensive assessment of sustainable buildings. LEED was developed in order to address five areas of state-of-the-art strategies for building construction/renovation. The two strategies that are most relevant to the mechanical system design are Energy and Atmosphere and Indoor Environmental Quality. Originally built in 1959, the 707 Building is not LEED certified. The following LEED analysis only contains the relevant potential mechanical credits.

Energy and Atmosphere (EA)

EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems

Intent: "To verify that the buildings energy related systems are installed, calibrated, and perform according to the owner's projects requirements, basis of design, and construction documents"

707: The mechanical contractor, G.E. Tignal & Co., Inc., will be responsible for ensuring that the mechanical system in 707 is installed and adjusted as needed.

EA Prerequisite 2: Minimum Energy Performance

Intent: "To establish the minimum level of energy efficiency for the proposed building and systems"

707: The ASHRAE Standard 90.1-2007 analysis in Technical Report I showed that the 707 Building was mostly compatible with the minimum energy efficiency levels that must be met by the designed systems.

EA Prerequisite 3: Fundamental Refrigerant Management

Intent: "To reduce ozone depletion"

707: No chlorofluorocarbon-based refrigerants can be used in order to reduce contributions to stratospheric ozone depletion. JMT has discussed this in their plans.

EA Credit 1: Optimize Energy Performance

Intent: "To achieve increasing levels of energy performance beyond the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use"

707: The generated block load energy model for the 707 building calculated the total annual energy consumption for cooling and heating loads to be 44.305 MBtu/year. The total load calculated by the design engineer was 42.232 MBtu/year, which indicates that the load energy consumptions are within 4.9% of each other. The annual utility cost that was totaled for the consumed electricity and natural gas was $200,808 or 1.17 $/sf.

EA Credit 3: Enhanced Commissioning

Intent: "To begin the commissioning process early in the design process and execute additional activities after systems performance verification is completed"

707: An MEP firm, G.E. Tignal & Co., Inc., was hired by SHA for all of their commissioning needs. The result is that the renovation receives 2 points for this credit.

Indoor Environmental Quality (IEQ)

IEQ Prerequisite 1: Minimum Indoor Air Quality Performance

Intent: "To establish minimum indoor air quality (IAQ) performance to enhance IAQ in buildings, thus contributing to the comfort and well-being of the occupants"

707: As Technical Report I showed, Section 6 "Ventilation Rate Procedure Analysis" protocols in ASHRAE Standard 62.1-2007 were met. Overall, the ventilated environment within the 707 office building meets the standards set forth by ASHRAE Standard 62.1.

IEQ Prerequisite 2: Environmental Tobacco Smoke (ETS) Control

Intent: "To prevent or minimize exposure of building occupants, indoor surfaces and ventilation air distribution systems to environmental tobacco smoke (ETS)"

707: From Technical Report I, ASHRAE Standard 62.1 Section 5.18 "Requirements for Buildings Containing ETS Areas and ETS-Free Areas," the interior of the 707 building is smoke free. Smoking is permitted outdoors in the designated smoking areas which are a minimum distance away from the entrance and air intakes of the building.

IEQ Credit 1: Outdoor Air Delivery Monitoring

Intent: "To provide capacity for ventilation system monitoring to help promote occupant comfort and well-being"

707: Necessary CO2 sensors are placed throughout the building to measure the concentrations within the spaces.

IEQ Credit 2: Increased Ventilation

Intent: "To provide additional outdoor air ventilation to improve IAQ and promote occupant comfort, well-being and productivity"

707: During Technical Report I, the calculated airflow measurement of the 707 building meets, and in some cases, exceeds the minimum ventilation requirements based upon Section 6. The ventilation rates supplied to each occupied zone exceed the 30% increase over ASHRAE Standard 62.1-2007 as stated within this section.

IEQ Credit 3.1: Construction Indoor Air Quality Management Plan - During Construction
Intent: "To reduce IAQ problems resulting from construction or renovation and promote the comfort and well-being of construction workers and building occupants"

707: In order to reduce IAQ related problems resulting from the construction process, the design of the renovation will protect stored on-site and installed materials from moisture damage, and all filters will have appropriate MERV ratings.

IEQ Credit 4.1: Low-Emitting Materials Adhesives and Sealants
Intent: "To reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants"

707: To reduce the quantity of harmful contaminants, adhesives that will be installed in the 707 Building will meet the maximum VOC limits.

IEQ Credit 6.2: Controllability of Systems - Thermal Comfort
Intent: "To provide a high level of thermal comfort system control by individual occupants or groups in multi-occupant spaces and promote their productivity, comfort and well-being"

promote thermal comfort control for individual occupants.

707: Due to this zoning and operable windows, at least 50% of the occupants within the building should have access to individual temperature control systems.

IEQ Credit 7.1: Thermal Comfort - Design
Intent: "To provide a comfortable thermal environment that promotes occupant productivity and well-being"

707: In order to provide a thermally comfortable environment to help promote occupant well-being, the designed Heating Ventilation and Air Conditioning (HVAC) meet the criteria stated by ASHRAE Standard 55-2004.

IEQ Credit 7.2: Thermal Comfort - Verification
Intent: "To provide for the assessment of building occupant thermal comfort over time"

707: The MEP firm currently plans to provide this survey to asses that acceptable thermal comfort is achieved after occupancy. Per the requirements, the thermal comfort survey must be conducted 6 to 18 months after occupancy and result in less than 20% of the occupants being dissatisfied.

OVERALL SYSTEM EVALUATION

In this Technical Report, a complete system evaluation was performed. Evaluations of the existing and renovated design systems in the areas of construction cost, maintainability, operating cost, and mechanical space requirements, were made. With each floor approximately 29,000 square feet and the total usable square footage occupied by mechanical systems comes to be about 1,500 square feet, the total renovation cost is $4,435,500.

The 707 building meets, and in some cases, exceeds the minimum ventilation requirements based upon Section 6. When determining the population density, the conference rooms were left empty so that the block load would be more accurate. The 707 building was mostly compatible with Standard 90.1 – 2007. The non-compliant fields only make up a fraction of the total building system. ASHRAE Standards 62.1 and 90.1 are necessary items to improve upon when striving towards an energy efficient, healthy building. Overall, 707 should be evaluated as adequate, but definitely needs enhancement, in both Standards. Consistent with these Standards, through more renovations and efficient equipment choices, the 707 building could advance its current condition to one that features commendable indoor air quality and energy efficiency.

According to the energy analysis results from Technical Report II, the 707 building consumes 1,743,765 kWh of energy annually. Knowing the monthly energy usages, an annual building operating cost analysis was performed in Technical Report II. Utility rates for both electricity and natural gas, from the Baltimore Gas and Electric Company (BGE) website were manually inserted into TRACE in the form of utility schedules, so that the energy consumption could be calculated in a yearlong energy simulation. The total annual utility cost that was totaled for the consumed electricity and natural gas is $200,808 or 1.17 $/sf.

Areas of improvement may produce hefty savings in energy and renovation costs. From increasing building usable square footage, to quickening the construction schedule, there are many opportunities for improvement of this 51 year-old building. These, and more, design modifications will be studied during coming reports.

REFERENCES

ANSI/ASHRAE (2007), Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta, GA, 2007.

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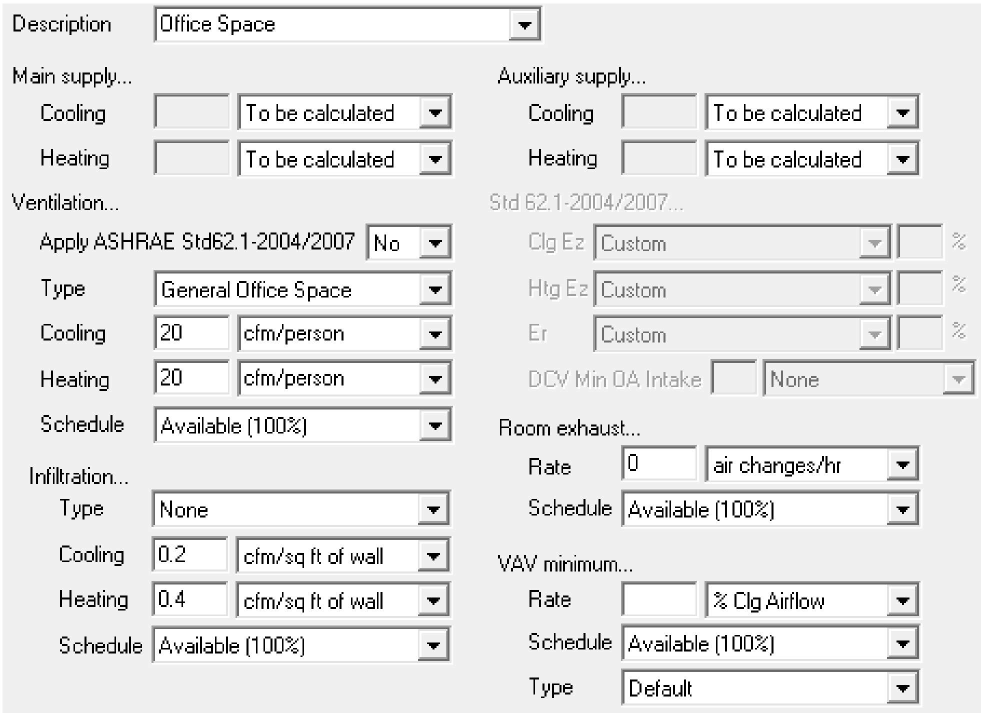
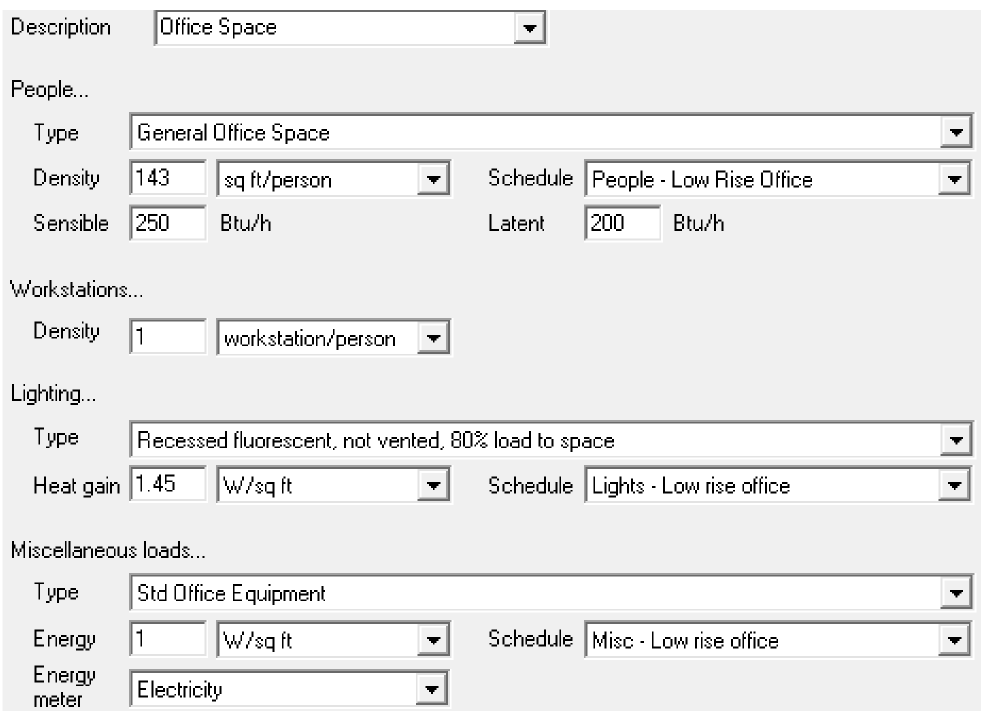
APPENDIX A – TRACE DATA TEMPLATES

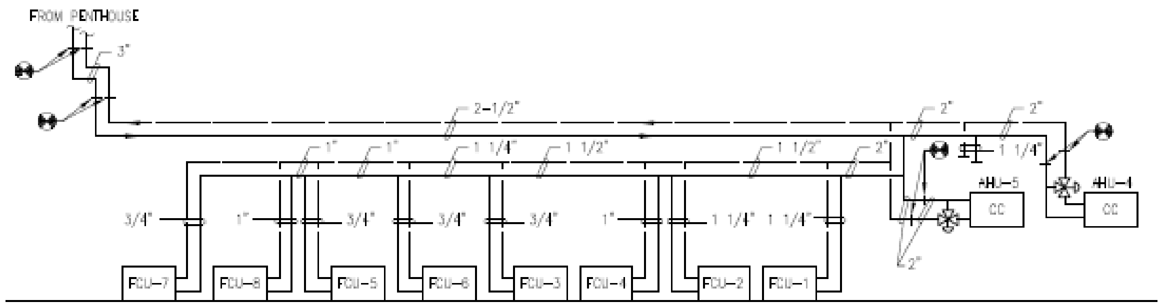


Typical Office Airflows

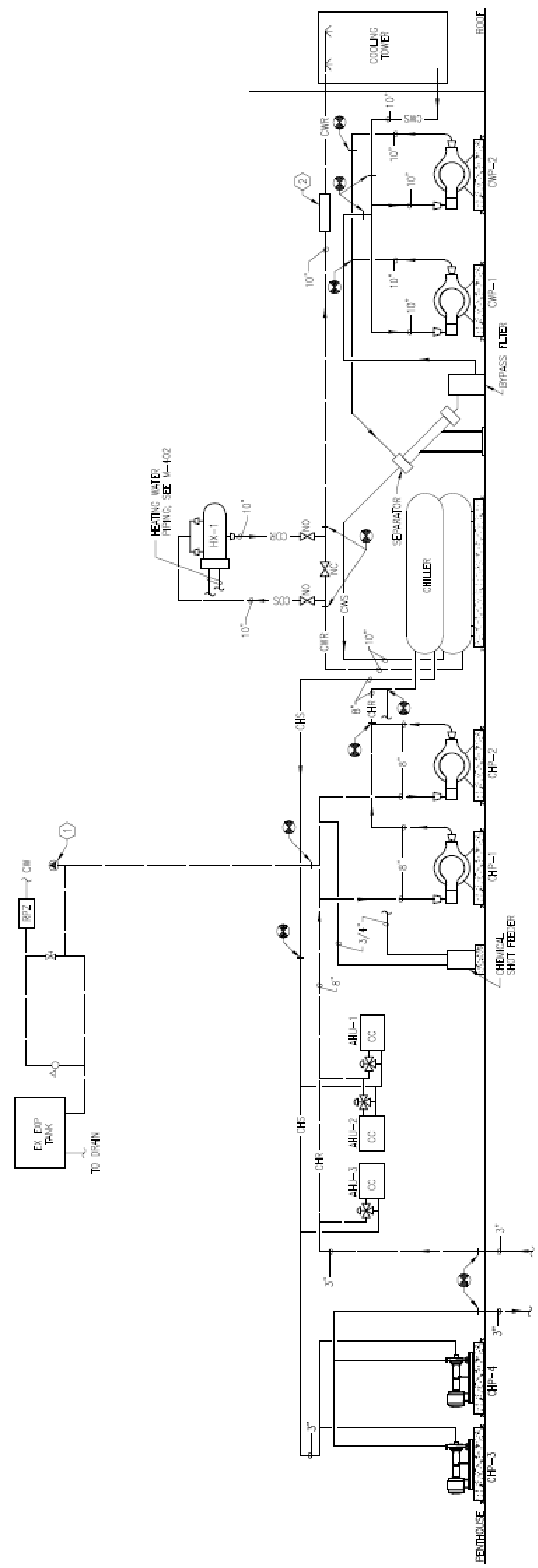


Typical Office Internal Loads

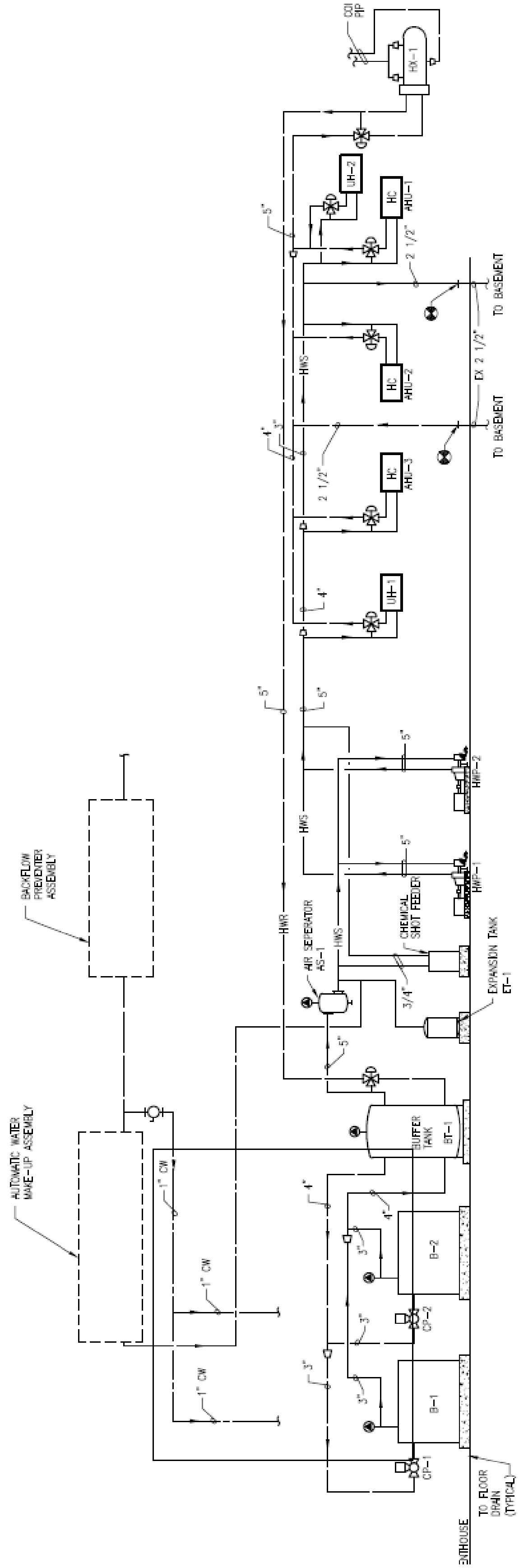
APPENDIX B – MECHANICAL SYSTEM SCHEMATIC



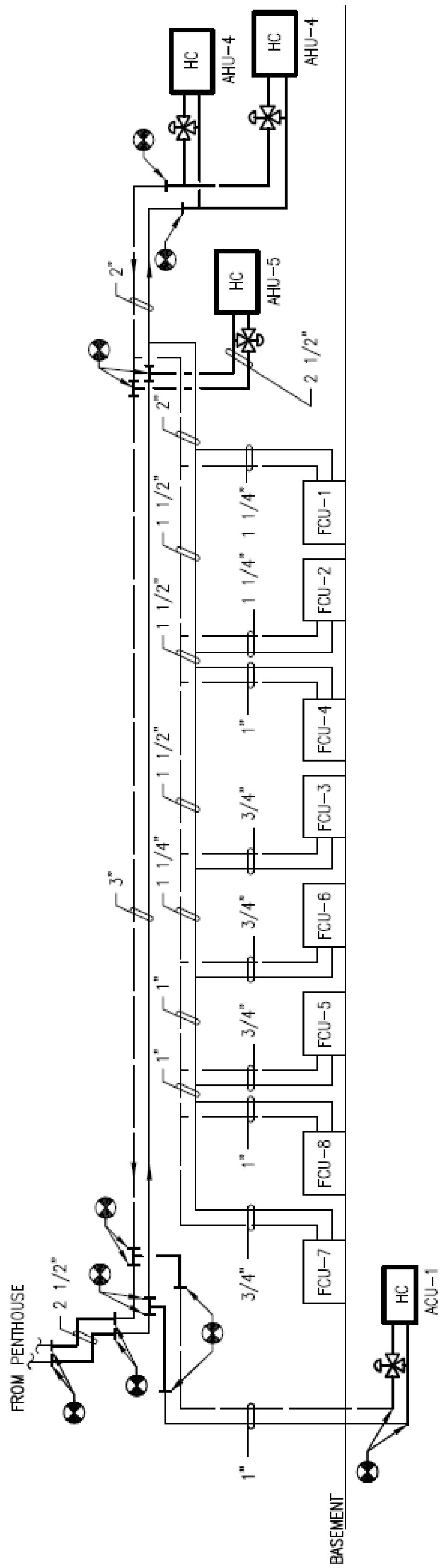
Basement Chilled and Condenser Water Schematic



Penthouse Chilled and Condenser Water Schematic

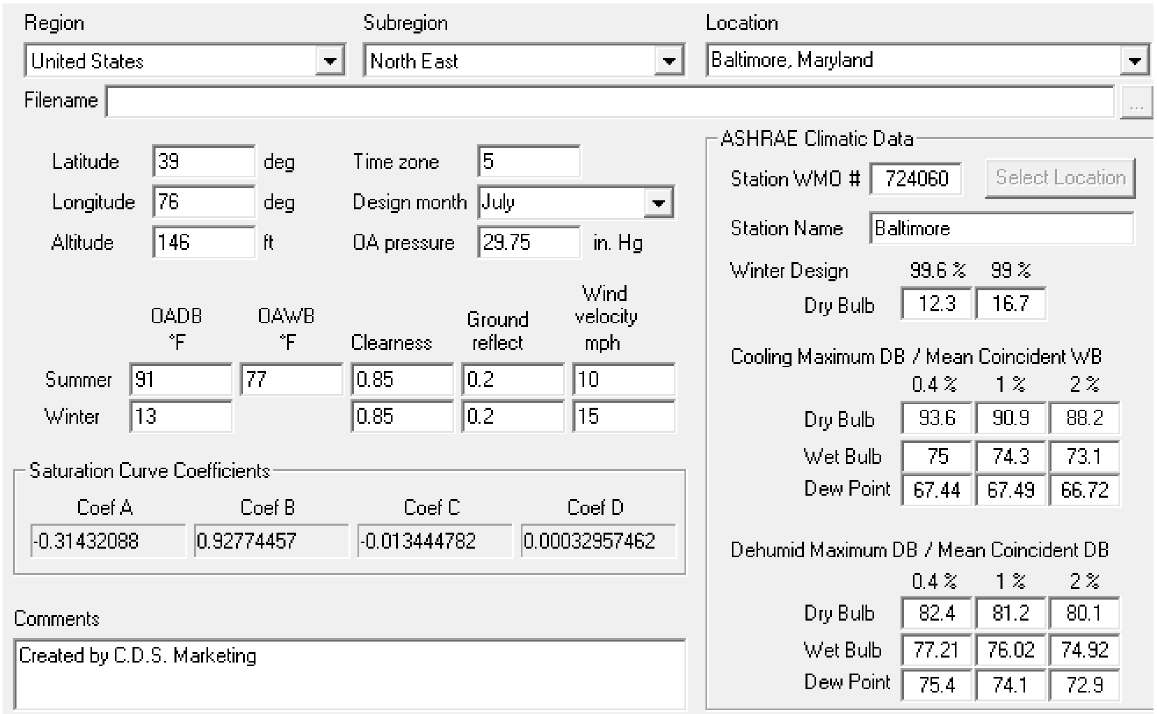


Penthouse Heating Water Schematic



Basement Heating Water Schematic

APPENDIX C – WEATHER INFORMATION



Region: United States
Subregion: North East
Location: Baltimore, Maryland
Filename:

Latitude: 39 deg
Longitude: 76 deg
Altitude: 146 ft
Time zone: 5
Design month: July
OA pressure: 29.75 in. Hg

	OADB °F	OAWB °F	Clearness	Ground reflect	Wind velocity mph
Summer	91	77	0.85	0.2	10
Winter	13		0.85	0.2	15

Saturation Curve Coefficients

Coef A	Coef B	Coef C	Coef D
-0.31432088	0.92774457	-0.013444782	0.00032957462

Comments
Created by C.D.S. Marketing

ASHRAE Climatic Data
Station WMO #: 724060 Select Location
Station Name: Baltimore

Winter Design	99.6 %	99 %
Dry Bulb	12.3	16.7

Cooling Maximum DB / Mean Coincident WB

	0.4 %	1 %	2 %
Dry Bulb	93.6	90.9	88.2
Wet Bulb	75	74.3	73.1
Dew Point	67.44	67.49	66.72

Dehumid Maximum DB / Mean Coincident DB

	0.4 %	1 %	2 %
Dry Bulb	82.4	81.2	80.1
Wet Bulb	77.21	76.02	74.92
Dew Point	75.4	74.1	72.9

Weather Conditions for Baltimore, MD

2009 ASHRAE Handbook - Fundamentals (IP)

BALTIMORE BLT-WASHNGTN INT'L, MD, USA

WMO#: 724060

Lat: 39.17N Long: 76.68W Elev: 154 StdP: 14.61 Time Zone: -5.00 (NAE) Period: 82-06 WBAN: 93721

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB	
			99.6%			99%			0.4%		1%			
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD
1	12.9	17.3	-3.3	4.6	17.8	1.3	5.9	22.1	26.2	31.6	24.2	32.1	8.7	290

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
7	18.7	93.9	74.9	91.2	74.2	88.5	73.1	78.1	88.6	76.8	86.5	75.6	84.3	10.2	280

Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Hours 8 to 4 & 55/69
0.4%			1%			2%			0.4%		1%		2%		
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	
75.3	133.3	82.1	74.1	127.9	80.8	73.0	123.1	79.8	41.5	89.1	40.2	86.5	39.1	84.5	723

Extreme Annual Design Conditions

Extreme Annual WS			Extreme Max WB	Extreme Annual DB				n-Year Return Period Values of Extreme DB							
				Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
22.4	19.2	17.3	84.6	5.1	98.0	6.3	3.3	0.6	100.3	-3.1	102.2	-6.7	104.0	-11.3	106.4

Monthly Climatic Design Conditions

			Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperatures, Degree-Days and Degree-Hours	Tavg		55.9	33.9	36.9	44.2	54.2	63.6	72.7	77.6	75.7	68.3	56.8	47.3	37.8
	Sd			10.07	8.67	9.29	8.30	7.49	6.31	5.08	5.20	6.95	7.72	8.51	9.29
	HDD50		1726	507	376	231	45	1	0	0	0	0	22	152	392
	HDD65		4567	964	787	649	339	119	12	0	2	45	275	532	843
	CDD50		3861	8	9	50	171	424	680	855	796	550	232	71	15
	CDD65		1228	0	0	4	15	77	242	390	333	145	21	1	0
	CDH74		11317	0	1	42	195	792	2240	3853	2963	1071	148	11	1
	CDH80		4315	0	0	8	57	267	849	1669	1125	317	23	0	0
Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4%	DB		65.2	69.3	80.0	86.9	90.9	94.6	98.0	96.9	92.6	83.2	75.3	68.5
		MCWB		57.7	56.2	62.2	66.7	71.5	74.5	76.5	75.9	72.8	68.9	63.6	60.2
	2%	DB		59.5	61.4	71.1	79.6	86.8	91.3	94.7	92.6	87.1	78.1	69.8	62.1
		MCWB		54.5	53.5	58.1	63.2	69.3	73.9	75.7	75.0	71.7	66.9	60.2	55.3
	5%	DB		53.0	55.5	64.7	74.1	82.6	88.2	91.8	89.2	83.4	74.0	65.3	56.4
		MCWB		46.8	47.5	54.1	60.3	67.9	73.0	74.9	73.8	70.1	64.3	58.7	51.0
	10%	DB		47.6	50.4	59.4	69.3	78.1	85.1	88.7	86.1	80.2	70.2	61.4	51.6
		MCWB		42.7	44.3	50.1	57.3	65.5	71.8	74.0	72.5	69.0	62.5	55.6	46.1
Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures	0.4%	WB		60.1	60.1	64.6	68.9	74.8	78.8	80.2	79.4	77.0	72.2	66.5	62.1
		MCDB		63.2	66.0	76.5	80.5	86.0	88.3	91.3	90.0	85.0	77.8	70.8	67.1
	2%	WB		55.0	53.7	60.2	65.7	72.1	76.5	78.4	77.5	75.0	69.8	63.5	57.2
		MCDB		58.6	58.7	68.8	75.7	82.8	85.9	89.4	88.0	82.1	75.5	67.9	61.0
	5%	WB		47.9	49.1	55.7	62.4	69.7	75.2	77.2	76.2	73.3	66.6	60.1	52.1
		MCDB		50.9	54.0	62.1	71.4	79.4	84.2	87.6	85.0	79.2	71.9	64.1	55.5
	10%	WB		43.3	45.1	51.5	59.3	67.4	73.7	76.0	74.9	71.7	63.8	56.7	47.0
		MCDB		47.2	50.2	58.5	67.2	75.4	81.7	85.2	82.5	77.2	68.8	60.6	50.6
Mean Daily Temperature Range		MDBR		15.5	16.7	18.4	20.3	20.2	19.6	18.7	18.3	18.6	19.8	18.6	16.0
	5% DB	MCDBR		22.7	24.8	26.8	27.7	26.2	23.2	22.4	21.7	22.1	23.8	23.5	22.7
		MCWBR		17.1	17.3	16.6	14.6	12.2	9.6	8.1	8.3	9.7	13.7	16.1	17.5
	5% WB	MCDBR		20.1	21.3	23.7	24.0	22.7	19.6	19.1	18.6	17.7	19.3	19.6	19.8
		MCWBR		17.2	17.0	16.5	14.0	11.7	9.2	8.2	8.2	9.1	12.5	16.2	17.4
Clear Sky Solar Irradiance	taub			0.319	0.353	0.411	0.417	0.474	0.546	0.552	0.580	0.421	0.370	0.342	0.317
	taud			2.373	2.188	1.997	2.036	1.892	1.746	1.769	1.681	2.164	2.286	2.350	2.446
	Ebn,noon			269	272	266	273	258	239	237	225	261	264	258	262
	Edh,noon			30	40	52	53	62	72	69	74	44	36	31	27

ASHRAE 2009 HOF Weather Data for Baltimore, MD

APPENDIX D – MAJOR MECHANICAL EQUIPMENT

Air Handling Unit Specifications

	Area Served	Airflow (CFM)	Motor (RPM)	LAT (°F)	EWT (°F)	LWT (°F)
AHU-S1	Induction Units	32,000	1800	55	45	55
AHU-S2	South 707	30,000	1800	55	45	55
AHU-S3	North 707	37,000	1800	55	45	55

Chiller Specifications

	GPM	EAT (°F)	Volts/ ϕ	Rated from (°F to °F)
Chiller	1080	85	460/3	54 to 44

Boiler Specifications

	Natural Gas (ft^3/hr)	Steam (psig)	BTU/ ft^3	lbs/hr	HP	BTU/hr
B-1959	10,420	15	1,030	-	250	8,368,750
B-1997	5250	15	-	4,312	125	-

Induced Draft Cooling Tower

	GPM	HP	Volts/ ϕ	Rated from (°F to °F)	OA Condition (°F/°F)
Cooling Tower	1350	30 two speed fan	460/3	95 to 85	95/87

Heating and Ventilating Units

	Airflow (CFM)	Fan Motor (HP)	Heating Coil (MBH)	Heating Coil (GPM)
H&V-1	2,200	3	141	14.0
H&V-2	2,200	7.5	141	14.0

Induction Unit Schedule

	CFM	Air Pressure (in w.g.)	Unit Size (in)
IU-A	90	1.20	40
IU-B	70	1.10	32
IU-C	60	1.28	32
IU-D	45	1.19	32

Pump Schedule

	Service	Type	GPM	Head (ft/H_2O)	RPM	HP
CHP-1	Chilled Water	Horiz. Split Case	1095	65	1780	25
CHP-2	Chilled Water	Horiz. Split Case	1095	65	1780	25
CHP-3	Chilled Water	End Suction	105	50	1750	3
CHP-4	Chilled Water	End Suction	105	50	1750	3
CWP-1	Condensing Water	Horiz. Split Case	1350	85	1780	40
CWP-2	Condensing Water	Horiz. Split Case	1350	85	1780	40
HWP-1	Heating Water	End Suction	315	45	1750	7.5
HWP-2	Heating Water	End Suction	315	45	1750	7.5
CP-1	Boiler	Inline Pump	120	20	1150	1.5
CP-2	Boiler	Inline Pump	120	20	1150	1.5