SHA HEADQUARTERS

707 N. Calvert St. | Baltimore, MD

Technical Report One

ASHRAE Standard 62.1 Ventilation

ASHRAE Standard 90.1 Energy Design

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

Dr. Bahnfleth | October 4, 2010

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Executive Summary

Technical Report I's objective is to determine the compliance or non-compliance of the Maryland State Highway Administration (SHA) Headquarters – 707 Systems Renovations with ASHRAE Standards 62.1 and 90.1. The SHA Headquarters is located in downtown Baltimore and occupies two office buildings, 707 and 211, which were both originally built in 1959. A connector between both buildings was built across Hunter Street in 2000, as seen below in Figure 1.

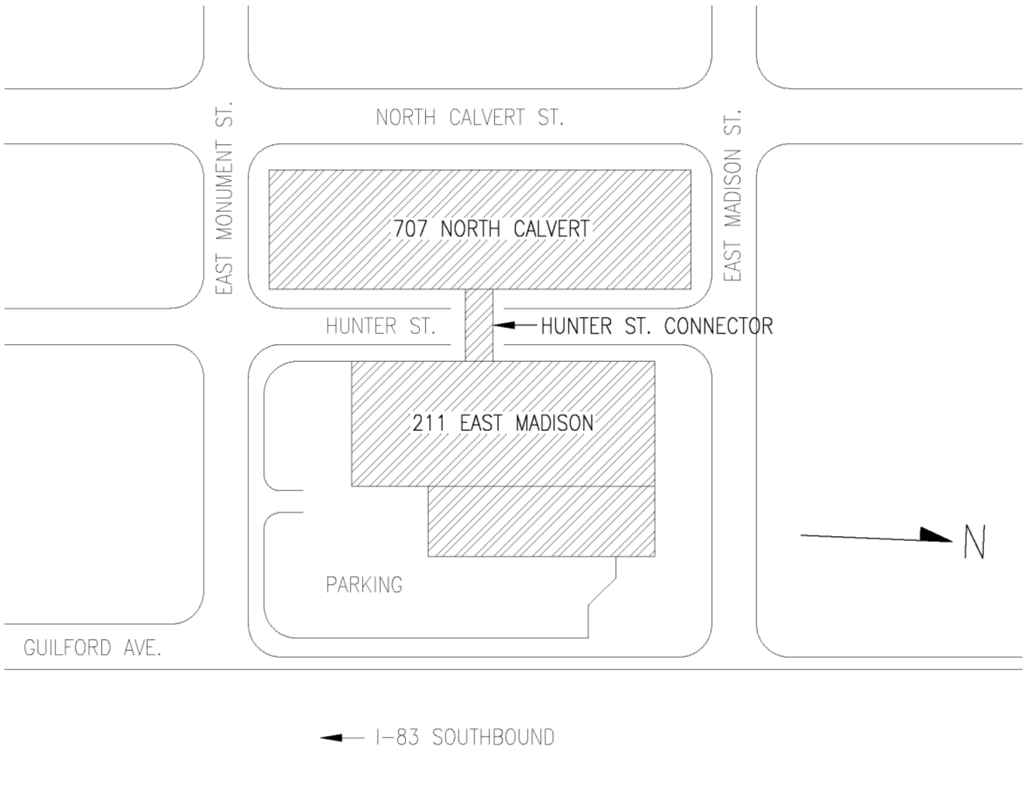

Figure 1: Site Layout

This report's focus is on the 707 N. Calvert Street building which has recently undergone significant renovations including building façade renovation, glazing replacement, roofing replacement, chiller/cooling tower replacement, branch electrical panel replacement, and air distribution ductwork (horizontal) replacement. The 707 building is a 6 story office building with two levels of parking in the Basement and Subbasement; the Basement level also includes a print shop and some office space. Each floor is approximately 29,000 square feet.

Ventilation for Acceptable Indoor Air Quality, ASHRAE Standard 62.1 – 2007, was evaluated first for building compliance. This standard describes means and methods to achieve acceptable indoor air quality within the building. A Section 5 study was executed for the 707 building. This analysis revealed semi-compliance with the constraints for acceptable indoor air quality, which takes into account outdoor air intake requirements, filtration, and building air classification. Most HVAC requirements that were examined within Section 5 were determined to be compliant. Section 6 of ASHRAE Standard 62.1 describes the necessities for the minimum ventilation rates supplied to space types so that adequate indoor air quality can be maintained. 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.

Energy Standard for Buildings Except Low Rise Residential Buildings, ASHRAE Standard 90.1-2007, was then analyzed to ascertain the 707 building's conformity with the minimum equipment efficiencies and building insulation values. Due to recent renovations, the building's façade and glazing materials met the minimum insulation values set forth within Section 5 – Building Envelope. Power distribution and lighting power densities were also found to be in compliance with the requirements set forth in Sections 8 and 9.

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.

Mechanical System Overview

Boiler Plant

The 707 building presently has two boilers in operation. One 250 HP gas fired, steam boiler was installed when the building was originally constructed in 1959; the second boiler (of 125 HP) was fitted in 1997. In 1995, when the area was renovated from a cafeteria to open office space, the steam radiators and the ACU in the Northwest corner were replaced with electric convection heaters.

Chiller Plant

After multiple renovations, the current chiller includes a dual compressor, single condenser, single evaporator chiller, and the existing primary chilled water pump was moved and piped in parallel with the latest primary chilled water pump. Furthermore, the cooling tower was exchanged with a new induced draft cooling tower and the remaining condenser water pump was relocated and piped in parallel with a new condenser water pump. A centrifugal separator was inserted, after the condenser pumps and before the condenser, in the condenser water loop.

Air Handling Units (AHU's)

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.

Heating and Ventilating Units (H&V's)

There are two H&V's, H&V-1 and 2, serving parts of the building. H&V-1 supplies the print shop and has a hot water heating coil. H&V-2 serves Archeology and the Basement lobby and has a steam heating coil.

Figure 2: H&V-1 (courtesy of JMT)

Terminal Units

Fan Coil Units: Currently, there are 8 Fan Coil Units (FCU's) in the Basement level.

Induction Units: The 707 building has the original 534 induction units running along the perimeter of the 6 office levels. These obtain high pressure air from AHU-S1 and dual temperature tempering water from the penthouse.

VAV Boxes: In 1996, 18 single duct VAV damper boxes, that serve individual areas, were installed.

Perimeter Electric Heat: As stated in the Boiler Plant section, electric convection heaters were installed in 1996, along the perimeter of the Northwest corner of the first office floor, when the area was converted from cafeteria to open office space.

Infrastructure

The current 707 building infrastructure includes ductwork and two hydronic piping systems, heating water and secondary water, dual temperature, heating/chilled, water. For each internal AHU, the 707 building has two central supply air chases. There is also one common central return air chase that provides return air to all of the AHU's.

Heating Water

H&V-1 and the 8 FCU's on the Basement level are served by the heating water system. Heating water is supplied to the building by a single supply main that is pumped through a steam-to-water heat exchanger by two heating water pumps (only one of which is active) which are piped in parallel. The functioning pump draws return from the active heating units and pumps through the steam-to-water heat exchanger.

Secondary Water

The secondary water system serves the 534 induction units and is either heated as it runs through the steam-to-water heat exchanger in the penthouse, or cooled as it is directed through the chiller. The secondary water always passes through the secondary water heat exchanger. The secondary water is circulated by a constant speed 20 HP pump with a bypass valve, located past the steam-to-water heat exchanger. When cooling, the chilled water first passes through AHU coils before it's circulated to the building.

Miscellaneous Equipment

The 707 building also contains some miscellaneous equipment. These include individual CU's on the roof for each of the following: two computer room units on the 6th floor, an Elevator Machine room unit (in the penthouse), and an ACU on 4th floor. There are CU's on the Basement level in the garage for both the computer room unit on 2nd floor, and the AHU serving 1st floor IT room. A Print Shop ACU has a CU in the Subbasement and there are three through-wall AC units along the east side of the Basement level.

ASHRAE Standard 62.1 Evaluation

Section 5 Compliance

5.1 Natural Ventilation

The 707 building takes advantage of the mild Baltimore climate by utilizing operable windows to allow natural ventilation to exist.

5.2 Ventilation Air Distribution

Air balancing and plenum systems are the emphasis of this section. The air handling and distribution systems must be adjusted to obtain minimum ventilation requirements for all specified spaces within the building. The ventilation air distribution system can be adjusted to achieve these minimum ventilation airflows under any load condition as required by ASHRAE Standard 62.1 – Section 6; a complete analysis of Section 6 is included later in this report.

5.3 Exhaust Duct Location

All exhaust ducts that carry potentially harmful contaminants are required to be negatively pressurized to prevent contamination of supply, return, and/or outdoor air ducts or plenums. The 707 building's duct system has gathered dirt and debris over the past 51 years.

5.4 Ventilation System Controls

The building automation system offers control and observation of the mechanical systems in both the 707 and 211 buildings. The existing controls system allows time scheduling and setpoint adjustment. The outdated system has approximately 1,000 points and is about 3 generations old. The existing system uses proprietary communications and is not directly compatible with or upgradable to non-proprietary communications protocol.

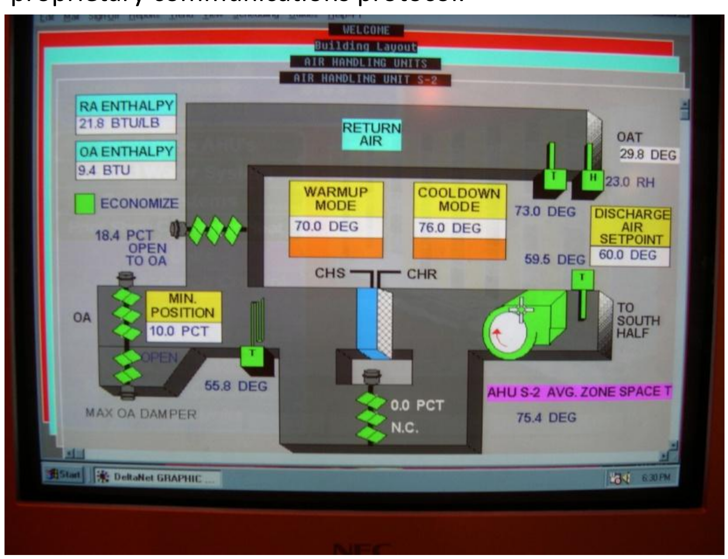

Figure 3: Control System program (courtesy of JMT).

5.5 Airstream Surfaces

According to this section, all surfaces in equipment and ducts are required to be resistant to mold growth and erosion. During a site visit, both AHU-S1 & S2 were found to have rusty coils and deteriorating interior insulation as seen in Figure 2. The original duct system and induction units have collected dirt and debris over the past 51 years of operation.

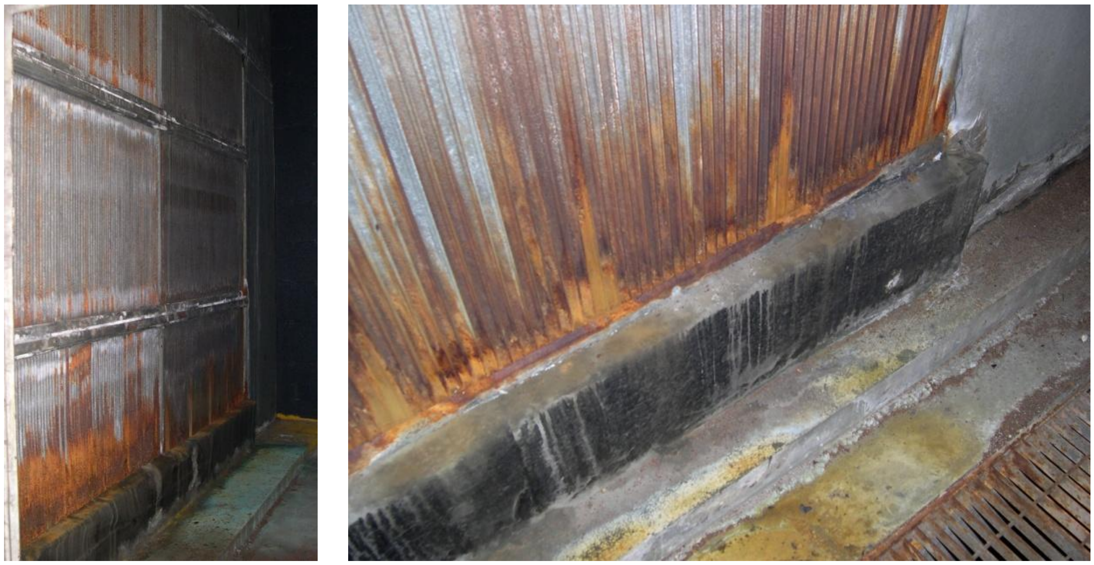

Figure 4-a and b: AHU-S1 and S2 cooling coils, respectively (courtesy of JMT)

5.6 Outdoor Air Intakes

All of the outdoor air intakes for 707 (including operable windows) are located so that the shortest distance from the intake to any potential outdoor contaminant source is greater than the minimum distance listed in Table 1 below, which is Table 5-1 of ASHRAE Standard 62.1

Table 1: Minimum Distances between Building Intakes as Pollutant Sources

Object	Minimum Distance, ft (m)
Significantly contaminated exhaust (Note 1)	15 (5)
Noxious or dangerous exhaust (Notes 2 and 3)	30 (10)
Vents, chimneys, and flues from combustion appliances and equipment (Note 4)	15 (5)
Garage entry, automobile loading area, or drive-in queue (Note 5)	15 (5)
Truck loading area or dock, bus parking/idling area (Note 5)	25 (7.5)
Driveway, street, or parking place (Note 5)	5 (1.5)
Thoroughfare with high traffic volume	25 (7.5)
Roof, landscaped grade, or other surface directly below intake (Notes 6 and 7)	1 (0.30)
Garbage storage/pick-up area, dumpsters	15 (5)
Cooling tower intake or basin	15 (5)
Cooling tower exhaust	25 (7.5)

Note 1: Significantly contaminated exhaust is exhaust air with significant contaminant concentration, significant sensory-irritation intensity, or offensive odor.
Note 2: Laboratory fume hood exhaust air outlets shall be in compliance with NFPA 45-1991[3] and ANSI/AIHA Z9.5-1992.[4]
Note 3: Noxious or dangerous exhaust is exhaust air with highly objectionable fumes or gases and/or exhaust air with potentially dangerous particles, bioaerosols, or gases at concentrations high enough to be considered harmful. Information on separation criteria for industrial environments can be found in the ACGIH Industrial Ventilation Manual [5] and in the *ASHRAE Handbook—HVAC Applications*.[6]
Note 4: Shorter separation distances are permitted when determined in accordance with (a) Chapter 7 of ANSI Z223.1/NFPA 54-2002[7] for fuel gas burning appliances and equipment, (b) Chapter 6 of NFPA 31-2001[8] for oil burning appliances and equipment, or (c) Chapter 7 of NFPA 211-2003[9] for other combustion appliances and equipment.
Note 5: Distance measured to closest place that vehicle exhaust is likely to be located.
Note 6: No minimum separation distance applies to surfaces that are sloped more than 45 degrees from horizontal or that are less than 1 in. (3 cm) wide.
Note 7: Where snow accumulation is expected, distance listed shall be increased by the expected average snow depth.

5.7 Local Capture of Contaminants

707 does not have any non-combustion equipment that produces contaminants, therefore section 5.7 is inapplicable.

5.8 Combustion Air

In compliance with section 5.8, all combustion producing processes are designed to expend the proper amount of combustion air, and are vented directly outdoors.

5.9 Particulate Matter Removal

Filters are required to be rated 6 or above to be placed upstream of all cooling coils and wetted surfaces. Unslightly filters in 707 have been retrofitted where applicable.

5.10 Dehumidification Systems

There is no direct dehumidification system in 707, therefore section 5.10 does not apply.

5.11 Drain Pans

In accordance with section 5.11, 707's drain pans are sealed, sloped, and have outlets at the lowest location.

5.12 Finned-Tube Coils and Heat Exchangers

Drain pans have been provided and correctly placed beneath all condensate-producing heat exchangers. Coils are required to be 18" from the access areas.

5.13 Humidifiers and Water-Spray Systems

There is no direct dehumidification system in 707, therefore section 5.10 does not apply.

5.14 Access for Inspection, Cleaning, and Maintenance

The access doors and clearances must ensure clear access for inspection, cleaning, and routine maintenance for all related equipment in accordance with 5.14. All of the access doors are sized and located suitably, and all of the appropriate equipment clearances have been met.

5.15 Building Envelope and Interior Surfaces

The building must be water-tight to prevent any liquid water infiltration and all pipes, ducts, etc… must be insulated to avoid condensation from developing. Debris from some of the induction units exists.

5.16 Buildings with Attached Parking Garages

The garage in the Subbasement level must be kept at a lower pressure than surrounding spaces to reduce the amount of vehicle exhaust from entering the occupied areas.

5.17 Air Classifications for Recirculation

Being an office building, 707 is categorized as Class 1 air classification for recirculation - air can be recirculated or transferred to any space because it has a low contaminant concentration, low sensory-irritation intensity, and inoffensive odor.

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.

Section 6 Compliance

Ventilation Rate Procedure Analysis

The following equations, from Standard 62.1 – 2007, were used to analyze the existing system to ensure that the minimum ventilation rates were met. The ASHRAE Standard 62.1 User's Manual contains a spreadsheet, in Appendix A, that calculates Section 6 compliance. The spreadsheet was used for these calculations based upon floor area, occupancy, zones, and supply air volume.

Equation: **Standard 62.1 Location:**

Breathing Zone Outdoor Airflow (V_{bz}):

$$V_{bz} = R_p * P_z + R_a * A_z$$ **(Equation 6-1)**

Where: V_{bz} = breathing zone outdoor airflow (cfm)
A_z = zone floor area (ft^2)
P_z = zone population (people)
R_p = outdoor air flow rate (cfm/person)
R_a = outdoor air flow rate (cfm/ft^2)

Zone Air Distribution Effectiveness (E_z):

$$E_z = 1.0$$ **(Table 6-2)**

Zone Outdoor Airflow (V_{oz}):

$$V_{oz} = \frac{V_{bz}}{E_z}$$ **(Equation 6-2)**

Primary Outdoor Air Fraction (Z_p):

$$Z_p = \frac{V_{oz}}{V_{pz}}$$ **(Equation 6-5)**

Where: Z_p = zone primary air fraction
V_{oz} = zone outdoor airflow
V_{pz} = zone primary airflow

System Ventilation Efficiency (E_v):

$$E_v = 1.07$$ **(Table 6-3)**

Where: E_v = system ventilation efficiency where $E_v = minE_{vz}$

E_{vz} = 1+ Vsystem

Occupant Diversity (D):

$$D = \frac{P_s}{\sum_{allzones} * P_z}$$ **(Equation 6-7)**

Where: P_s = system population

ASHRAE Standard 62.1 Summary

It is clear that some improvements can be made based on Section 5 compliance – mainly the ductwork, AHUs, and control system. The original ductwork has collected dirt and debris over the past 51 years of operation. Both AHU-S1 & S2 have rusty coils and deteriorating interior insulation. The outdated control system has approximately 1,000 points and is about 3 generations old. The existing system uses proprietary communications and is not directly compatible with or upgradable to non-proprietary communications protocol.

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. AHU-S1 is low on OA, which is reasonable because the minimum OA damper and pre-heat coil are boarded-up. Overall, the ventilated environment within the 707 office building meets the standards set forth by ASHRAE Standard 62.1.

ASHRAE Standard 90.1 Evaluation

Section 5 – Building Envelope

5.4.1 Climate Zone

Zone 4-A is the climate zone for Baltimore, Maryland where the Maryland State Highway Administration (SHA) Headquarters is located. This region is classified by having mixed weather conditions that can have phases of high humidity. The climate zone was determined by using Figure 5 below from section 5 of Standard 90.1-2007.

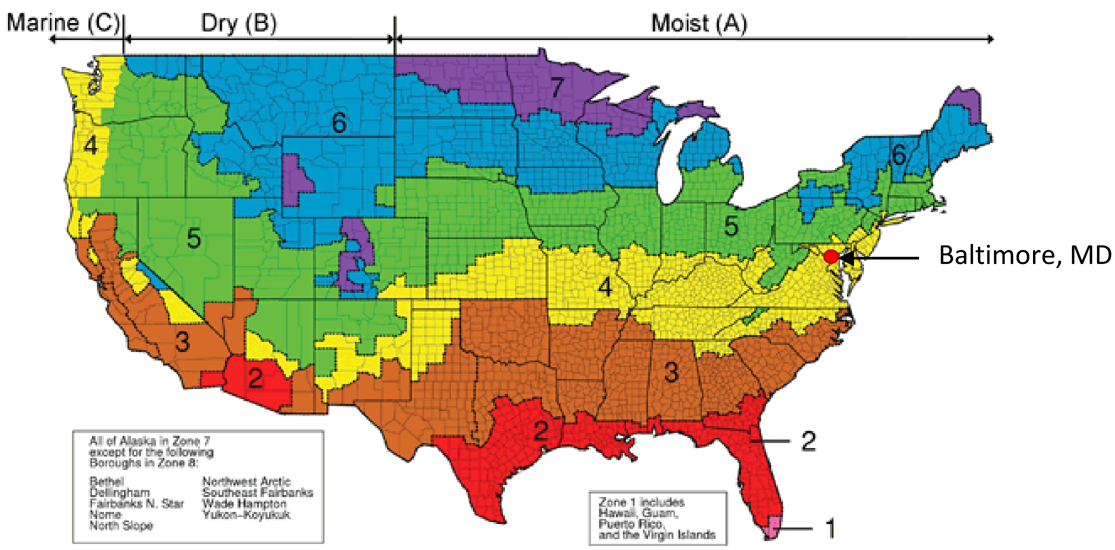

Figure 5: Climate Zones (courtesy of ASHRAE Standard 90.1-2007)

5.5 Prescriptive Building Envelope Option

To analyze the building envelope requirements, the Prescriptive Building Envelope Option was utilized. The requirements for construction in climate zone 4-A is located in Standard 90.1 – 2007, Table 5.5-4 (which is located in this report in Appendix B). As seen in Table 2-a below, the 707 building complies with the maximum vertical fenestration allowable, 40%, in zone 4-A. Table 2-b outlines the minimum building material insulation and minimum glazing information for the 707 building.

Table 2-a: Total Building Glazing Area

Glazing Area (ft^2)	Wall Area (ft^2)	Percentage Glazing	Compliance (Y/N)
16,364	63,094	26%	Y

Table 2-b: Building/Glazing Material Properties

Area	Maximum U-Value	Actual U-Value	Compliance (Y/N)
Roof	U-0.048	U-0.046	Y
Walls Above Grade	U-0.104	U-0.10	Y
Windows	U-0.55	U-0.34	Y
Floors	U-0.087	U-0.08	Y

Section 6 – Heating, Ventilating, and Air Conditioning

6.2 Compliance Path

Two options are available to evaluate the efficiency of the HVAC system in a building, the simplified approach and the prescriptive path. Since the 707 building surpassed both the 25,000ft^2 maximum size limit and two story maximum height limit of the simplified approach, the prescriptive path was chosen.

6.4 Mandatory Provisions

All HVAC load calculations are completed based on the requirements from section 6.4.2. Maximum damper leakage falls within the allowable percentages set forth by Table 6.4.3.4.4. Leakage for the AHU's and H&V's were calculated by JMT. The results, seen in Table 3 below, reveal that a large amount of leakage happens on the floors in the horizontal distribution ductwork; less than 20% of the combined leakage comes from the existing supply duct shafts.

Table 3: Air Leakage Testing (courtesy of JMT)

Unit	OA Position	Airflow (CFM)			Leakage	
		SA	OA	Outlet	CFM	%
AHU-S1	0%	24189	2559	--	--	--
AHU-S2	10%	35111	9175	29984	5127	15%
AHU-S3	10%	42033	7884	36728	5305	13%
H&V-1	20%	2763	151	2623	140	5%
H&V-2	10%	8534	2962	8671	-137	-2%

6.5.2.2 Hydronic System Controls

The heating water is supplied by two heating water pumps that are piped in parallel, which meets the Two-Pipe Changeover System requirements (6.5.2.2.2). Hydronic Heat Pump Systems, in section 6.5.2.2.3, demands that the loop have controls capable of a 20°F deadband for the supply water temperature. Located in Table 6.8.1F, Gas-Fired Boilers greater than 300 MBH, at maximum capacity should have a minimum efficiency of 75%.

Section 7 – Service Water Heating

All water heating meets the requirements from Table 7.8 in ASHRAE 90.1 – 2007. The current natural gas boiler is rated at 8,368,750 Btu/hr and has a minimum thermal efficiency of 90%.

Heating Water

The heating water system serves H&V-1 and the 8 FCU's on the Basement level. Heating water is supplied to the building by a single supply main that is pumped through a steam-to-water heat exchanger by two heating water pumps (only one of which is active) which are piped in parallel. The functioning pump draws return from the active heating units and pumps through the steam-to-water heat exchanger.

Secondary Water

The secondary water system serves the 534 induction units and is heated as it runs through the steam-to-water heat exchanger in the penthouse. The secondary water always passes through the secondary water heat exchanger. The secondary water is circulated by a constant speed 20 HP pump with a bypass valve, located past the steam-to-water heat exchanger.

Section 8 – Power

In terms of voltage drop, all feeders are sized for a maximum voltage drop of 2% at design load. Also, branch circuits are sized for a maximum voltage drop of 3% at design load.

Section 9 – Lighting

The requirements for lighting systems within buildings are explained in Section 9. Since the 707 is an office building, according to Table 9.5.1, the maximum lighting power density is 1.0 W/ft^2. The building interior lighting is mainly 2x4 fluorescent light fixtures. The lighting control system uses low voltage momentary push-button control station for central lighting control; each floor is controlled separately. This station is located in the lobby on the first floor.

Section 10 – Other Equipment

All motors met the criteria set forth in Table 10.8 of ASHRAE 90.1 – 2007, "Minimum Nominal Efficiency for General Purpose Design A and Design B Motors."

Section 11 – Energy Cost Budget Method

Section 11 describes how to use building modeling to determine if the structure meets the energy cost budget. The Technical II Assignment will illustrate this in further detail.

ASHRAE Standard 90.1 Summary

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. Explanations for non-conformity could be due to human error in calculations and/or errors with equipment specifications. All inaccuracies will be determined in Technical Report II, which will include energy modeling for the entire building.

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.

ANSI/ASHRAE (2007), Standard 90.1-2007, Energy Standard for Buildings Except Low-Rise Residential Buildings. American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta, GA, 2007.

Johnson, Mirmiran & Thompson (JMT) Engineering Reports and Images

Appendix A

	Name	Units		Formula / Note	System						
Building:	SHA Headquarters – 707										
System Tag/Name:	S-1 Perimeter AHU Zone Loads										
Operating Condition Description:	COOLING										
Units (select from pull-down list)	IP										
Inputs for System	**Name**	**Units**			**System**						
Floor area served by system	As	sf			164976						
Population of area served by system (including diversity)	Ps	P	100%	diversity	1,002						
Design primary supply fan airflow rate	Vpsd	cfm			109,347						
OA req'd per unit area for system (Weighted average)	Ras	cfm/sf			0.06						
OA req'd per person for system area (Weighted average)	Rps	cfm/p			5.0						
Inputs for Potentially Critical zones											
Zone Name				*Zone title turns purple italic for critical zone(s)*		1st Floor N	1st Floor NE	1st Floor NW	1st Floor S	*1st Floor SE*	1st Floor SW
Zone Tag						1st Floor N	1st Floor NE	1st Floor NW	1st Floor S	*1st Floor SE*	1st Floor SW
Space type		Select from pull-down list				Office	Office	Office	Office	Office	Office
Floor Area of zone	Az	sf				892	2076	1860	974	1928	1668.5
Design population of zone	Pz	P		(default value listed; may be overridden)		7	15	14	9	17	10
Design total supply to zone (primary plus local recirculated)	Vdzd	cfm				1,217	3734	2849	2216	2614	3763
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A				ITU	ITU	ITU	ITU	ITU	ITU
Local recirc. air % representative of ave system return air	Er					75%	75%	75%	75%	75%	75%
Inputs for Operating Condition Analyzed											
Percent of total design airflow rate at conditioned analyzed	Ds	%			46%	100%	100%	100%	100%	100%	100%
Air distribution type at conditioned analyzed		Select from pull-down list				CSCRW	CSCRW	CSCRW	CSCRW	CSCRW	CSCRW
Zone air distribution effectiveness at conditioned analyzed	Ez			Show codes for Ez		1.00	1.00	1.00	1.00	1.00	1.00
Primary air fraction of supply air at conditioned analyzed	Ep					100%	100%	100%	100%	100%	100%
Results											
Ventilation System Efficiency	Ev				**1.00**						
Outdoor air intake required for system	Vot	cfm			**12210**						
Outdoor air per unit floor area	Vot/As	cfm/sf			**0.07**						
Outdoor air per person served by system (including diversity	Vot/Ps	cfm/p			**12.2**						
Outdoor air as a % of design primary supply air	Ypd	cfm			**11%**						
Detailed Calculations											
Initial Calculations for the System as a whole											
Primary supply air flow to system at conditioned analyzed	Vps	cfm	=	VpdDs	50068						
UncorrectedOA requirement for system	Vou	cfm	=	Rps Ps + Ras As	14909						
Uncorrected OA req'd as a fraction of primary SA	Xs		=	Vou / Vps	0.30						
Initial Calculations for individual zones											
OA rate per unit area for zone	Raz	cfm/sf				0.06	0.06	0.06	0.06	0.06	0.06
OA rate per person	Rpz	cfm/p				5.00	5.00	5.00	5.00	5.00	5.00
Total supply air to zone (at condition being analyzed)	Vdz	cfm				1217	3734	2849	2216	2614	3763
Unused OA req'd to breathing zone	Vbz	cfm	=	Rpz Pz + Raz Az		88.5	199.6	181.6	103.4	200.7	150.1
Unused OA requirement for zone	Voz	cfm	=	Vbz/Ez		89	200	182	103	201	150
Fraction of zone supply not directly recirc. from zone	Fa		=	Ep + (1-Ep)Er		1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone supply from fully mixed primary air	Fb		=	Ep		1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone OA not directly recirc. from zone	Fc		=	1-(1-Ez)(1-Ep)(1-Er)		1.00	1.00	1.00	1.00	1.00	1.00
Unused OA fraction required in supply air to zone	Zd		=	Voz / Vdz		0.07	0.05	0.06	0.05	0.08	0.04
Unused OA fraction required in primary air to zone	Zp		=	Voz / Vpz		0.07	0.05	0.06	0.05	0.08	0.04
System Ventilation Efficiency											
Zone Ventilation Efficiency (App A Method)	Evz		=	(Fa + FbXs - FcZ) / Fa		1.23	1.24	1.23	1.25	1.22	1.26
System Ventilation Efficiency (App A Method)	Ev		=	min (Evz)	**1.22**						
Ventilation System Efficiency (Table 6.3 Method)	Ev		=	Value from Table 6.3	1.07						
Minimum outdoor air intake airflow											
Outdoor Air Intake Flow required to System	Vot	cfm	=	Vou / Ev	**12210**						
OA intake req'd as a fraction of primary SA	Y		=	Vot / Vps	**0.24**						
Outdoor Air Intake Flow required to System (Table 6.3 Metho	Vot	cfm	=	Vou / Ev	13891						
OA intake req'd as a fraction of primary SA (Table 6.3 Metho	Y		=	Vot / Vps	0.28						
OA Temp at which Min OA provides all cooling											
OAT below which OA Intake flow is @ minimum		Deg F	=	{(Tp-dTsf)-(1-Y)*(Tr+d'	2						

Item	Name	Units	Equation / Notes	System	3rd Floor SW	4th Floor N	4th Floor NE	4th Floor NW	4thFloor S	4th Floor SE	4th Floor SW
Building:	SHA Headquarters - 707										
System Tag/Name:	S-1 Perimeter AHU Zone Loads										
Operating Condition Description:	COOLING										
Units (select from pull-down list)	IP										
Inputs for System	**Name**	**Units**		**System**							
Floor area served by system	As	sf		164976							
Population of area served by system (including diversity)	Ps	P	100% diversity	1,002							
Design primary supply fan airflow rate	Vpsd	cfm		109,347							
OA req'd per unit area for system (Weighted average)	Ras	cfm/sf		0.06							
OA req'd per person for system area (Weighted average)	Rps	cfm/p		5.0							
Inputs for Potentially Critical zones											
Zone Name			*Zone title turns purple italic for critical zone(s)*		3rd Floor SW	4th Floor N	4th Floor NE	4th Floor NW	4thFloor S	4th Floor SE	4th Floor SW
Zone Tag					3rd Floor SW	4th Floor N	4th Floor NE	4th Floor NW	4thFloor S	4th Floor SE	4th Floor SW
Space type		Select from pull-down list			Office	Office	Office	Office	Office	Office	Office
Floor Area of zone	Az	sf			2,001	877	2037	1823	916	1825	2017
Design population of zone	Pz	P	(default value listed; may be overridden)		14	5	9	6	6	13	14
Design total supply to zone (primary plus local recirculated)	Vdzd	cfm			4,159	1102	3408	3527	2040	3246	4163
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?		Select from pull-down list or leave blank if N/A			ITU	ITU	ITU	ITU	ITU	ITU	ITU
Local recirc. air % representative of ave system return air	Er				75%	75%	75%	75%	75%	75%	75%
Inputs for Operating Condition Analyzed											
Percent of total design airflow rate at conditioned analyzed	Ds	%		46%	100%	100%	100%	100%	100%	100%	100%
Air distribution type at conditioned analyzed		Select from pull-down list	Show codes for Ez		CSCRW	CSCRW	CSCRW	CSCRW	CSCRW	CSCRW	CSCRW
Zone air distribution effectiveness at conditioned analyzed	Ez				1.00	1.00	1.00	1.00	1.00	1.00	1.00
Primary air fraction of supply air at conditioned analyzed	Ep				100%	100%	100%	100%	100%	100%	100%
Results											
Ventilation System Efficiency	Ev			**1.00**							
Outdoor air intake required for system	Vot	cfm		**12217**							
Outdoor air per unit floor area	Vot/As	cfm/sf		**0.07**							
Outdoor air per person served by system (including diversity)	Vot/Ps	cfm/p		**12.2**							
Outdoor air as a % of design primary supply air	Ypd	cfm		**11%**							
Detailed Calculations											
Initial Calculations for the System as a whole											
Primary supply air flow to system at conditioned analyzed	Vps	cfm	= VpdDs =	50830							
UncorrectedOA requirement for system	Vou	cfm	= Rps Ps + Ras As =	14909							
Uncorrected OA req'd as a fraction of primary SA	Xs		= Vou / Vps =	0.29							
Initial Calculations for individual zones											
OA rate per unit area for zone	Raz	cfm/sf			0.06	0.06	0.06	0.06	0.06	0.06	0.06
OA rate per person	Rpz	cfm/p			5.00	5.00	5.00	5.00	5.00	5.00	5.00
Total supply air to zone (at condition being analyzed)	Vdz	cfm			4159	1102	3408	3527	2040	3246	4163
Unused OA req'd to breathing zone	Vbz	cfm	= Rpz Pz + Raz Az =		190.1	77.6	167.2	139.4	85.0	174.5	191.0
Unused OA requirement for zone	Voz	cfm	= Vbz/Ez =		190	78	167	139	85	175	191
Fraction of zone supply not directly recirc. from zone	Fa		= Ep + (1-Ep)Er =		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone supply from fully mixed primary air	Fb		= Ep =		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone OA not directly recirc. from zone	Fc		= 1-(1-Ez)(1-Ep)(1-Er) =		1.00	1.00	1.00	1.00	1.00	1.00	1.00
Unused OA fraction required in supply air to zone	Zd		= Voz / Vdz =		0.05	0.07	0.05	0.04	0.04	0.05	0.05
Unused OA fraction required in primary air to zone	Zp		= Voz / Vpz =		0.05	0.07	0.05	0.04	0.04	0.05	0.05
System Ventilation Efficiency											
Zone Ventilation Efficiency (App A Method)	Evz		= (Fa + FbXs - FcZ) / Fa =		1.25	1.22	1.24	1.25	1.25	1.24	1.25
System Ventilation Efficiency (App A Method)	Ev		= min (Evz) =	**1.22**							
Ventilation System Efficiency (Table 6.3 Method)	Ev		= Value from Table 6.3 =	1.08							
Minimum outdoor air intake airflow											
Outdoor Air Intake Flow required to System	Vot	cfm	= Vou / Ev =	**12217**							
OA intake req'd as a fraction of primary SA	Y		= Vot / Vps =	**0.24**							
Outdoor Air Intake Flow required to System (Table 6.3 Methc	Vot	cfm	= Vou / Ev =	13843							
OA intake req'd as a fraction of primary SA (Table 6.3 Metho	Y		= Vot / Vps =	0.27							
OA Temp at which Min OA provides all cooling											
OAT below which OA Intake flow is @ minimum		Deg F	= {(Tp-dTsf)-(1-Y)*(Tr+d' =	1							

Building:										
System Tag/Name:										
Operating Condition Description:										
Units (select from pull-down list)										
Delete Zone										
Add Zone										
Inputs for System										
Floor area served by system										
Population of area served by system (including diversity)										
Design primary supply fan airflow rate										
OA req'd per unit area for system (Weighted average)										
OA req'd per person for system area (Weighted average)										
Inputs for Potentially Critical zones	**Potentially Critical Zones**									
Zone Name	*5th Floor N*	5th Floor NE	5th Floor NW	5th Floor S	2nd Floor SW	5th Floor SW	6th Floor N	6th Floor NE	6th Floor NW	6th Floor S
Zone Tag (Show Values per Zone)	*5th Floor N*	5th Floor NE	5th Floor NW	5th Floor S	2nd Floor SW	5th Floor SW	6th Floor N	6th Floor NE	6th Floor NW	6th Floor S
Space type	Office	Office	Office	Office	Office	Office	Office	Office	Office	Office
Floor Area of zone	885	2075	1855	1064	953	1984	893	1972	1833	90
Design population of zone	6	16	14	6	16	14	7	12	10	12
Design total supply to zone (primary plus local recirculated)	1138	3667	3820	2085	3081	4162	1393	4083	3265	249
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan	ITU	ITU	ITU	ITU	ITU	ITU	ITU	ITU	ITU	ITU
Local recirc. air % representative of ave system return air	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%
Inputs for Operating Condition Analyzed										
Percent of total design airflow rate at conditioned analyzed	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Air distribution type at conditioned analyzed	CSCRW	CSCRW	CSCRW	CSCRW	CSCRW	CSCRW	CSCRW	CSCRW	CSCRW	CSCRW
Zone air distribution effectiveness at conditioned analyzed	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0
Primary air fraction of supply air at conditioned analyzed	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Results										
Ventilation System Efficiency										
Outdoor air intake required for system										
Outdoor air per unit floor area										
Outdoor air per person served by system (including diversity										
Outdoor air as a % of design primary supply air										
Detailed Calculations										
Initial Calculations for the System as a whole										
Primary supply air flow to system at conditioned analyzed										
UncorrectedOA requirement for system										
Uncorrected OA req'd as a fraction of primary SA										
Initial Calculations for individual zones										
OA rate per unit area for zone	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
OA rate per person	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Total supply air to zone (at condition being analyzed)	1138	3667	3820	2085	3081	4162	1393	4083	3265	249
Unused OA req'd to breathing zone	83.1	204.5	181.3	93.8	137.2	189.0	88.6	178.3	160.0	114.
Unused OA requirement for zone	83	205	181	94	137	189	89	178	160	114
Fraction of zone supply not directly recirc. from zone	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone supply from fully mixed primary air	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone OA not directly recirc. from zone	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Unused OA fraction required in supply air to zone	0.07	0.06	0.05	0.05	0.04	0.05	0.06	0.04	0.05	0.05
Unused OA fraction required in primary air to zone	0.07	0.06	0.05	0.05	0.04	0.05	0.06	0.04	0.05	0.05
System Ventilation Efficiency										
Zone Ventilation Efficiency (App A Method)	1.22	1.24	1.25	1.25	1.25	1.25	1.23	1.25	1.24	1.25
System Ventilation Efficiency (App A Method)										
Ventilation System Efficiency (Table 6.3 Method)										
Minimum outdoor air intake airflow										
Outdoor Air Intake Flow required to System										
OA intake req'd as a fraction of primary SA										
Outdoor Air Intake Flow required to System (Table 6.3 Metho										
OA intake req'd as a fraction of primary SA (Table 6.3 Metho										
OA Temp at which Min OA provides all cooling										
OAT below which OA Intake flow is @ minimum										

Building:	SHA Headquarters – 707									
System Tag/Name:	S-2 South Core AHU Zone Loads									
Operating Condition Description:										
Units (select from pull-down list)	IP									
Delete Zone / Add Zone										
Inputs for System	**Name**	**Units**		**System**						
Floor area served by system	As	sf		54999						
Population of area served by system (including diversity)	Ps	P	100% diversity	288						
Design primary supply fan airflow rate	Vpsd	cfm		29,806						
OA req'd per unit area for system (Weighted average)	Ras	cfm/sf		0.06						
OA req'd per person for system area (Weighted average)	Rps	cfm/p		5.0						
Inputs for Potentially Critical zones					**Potentially Critical Zones**					
Zone Name			*Zone title turns purple italic for critical zone(s)*		*1st Floor S*	2nd Floor	3rd Floor S	4th Floor S	5th Floor S	6th Floor S
Zone Tag (Show Values per Zone)					1st Floor S	2nd Floor	3rd Floor S	4th Floor S	5th Floor S	6th Floor S
Space type			Select from pull-down list		Office	Office	Office	Office	Office	Office
Floor Area of zone	Az	sf			9,025	9011	8995	9109	9825	9034
Design population of zone	Pz	P	(default value listed; may be overridden)		35	59	46	40	50	58
Design total supply to zone (primary plus local recirculated)	Vdzd	cfm			4,098	4938	4482	4305	4878	7105
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?			Select from pull-down list or leave blank if N/A							
Local recirc. air % representative of ave system return air	Er									
Inputs for Operating Condition Analyzed										
Percent of total design airflow rate at conditioned analyzed	Ds	%		100%	100%	100%	100%	100%	100%	100%
Air distribution type at conditioned analyzed			Select from pull-down list		CS	CS	CS	CS	CS	CS
Zone air distribution effectiveness at conditioned analyzed	Ez		Show codes for Ez		1.00	1.00	1.00	1.00	1.00	1.00
Primary air fraction of supply air at conditioned analyzed	Ep									
Results										
Ventilation System Efficiency	Ev			**0.98**						
Outdoor air intake required for system	Vot	cfm		**4816**						
Outdoor air per unit floor area	Vot/As	cfm/sf		**0.09**						
Outdoor air per person served by system (including diversity)	Vot/Ps	cfm/p		**16.7**						
Outdoor air as a % of design primary supply air	Ypd	cfm		**16%**						
Detailed Calculations										
Initial Calculations for the System as a whole										
Primary supply air flow to system at conditioned analyzed	Vps	cfm	= VpdDs =	29806						
UncorrectedOA requirement for system	Vou	cfm	= Rps Ps + Ras As =	4740						
Uncorrected OA req'd as a fraction of primary SA	Xs		= Vou / Vps =	0.16						
Initial Calculations for individual zones										
OA rate per unit area for zone	Raz	cfm/sf			0.06	0.06	0.06	0.06	0.06	0.06
OA rate per person	Rpz	cfm/p			5.00	5.00	5.00	5.00	5.00	5.00
Total supply air to zone (at condition being analyzed)	Vdz	cfm			4098	4938	4482	4305	4878	7105
Unused OA req'd to breathing zone	Vbz	cfm	= Rpz Pz + Raz Az =		716.5	835.7	769.7	746.5	839.5	832.0
Unused OA requirement for zone	Voz	cfm	= Vbz/Ez =		717	836	770	747	840	832
Fraction of zone supply not directly recirc. from zone	Fa		= Ep + (1-Ep)Er =		1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone supply from fully mixed primary air	Fb		= Ep =		1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone OA not directly recirc. from zone	Fc		= 1-(1-Ez)(1-Ep)(1-Er) =		1.00	1.00	1.00	1.00	1.00	1.00
Unused OA fraction required in supply air to zone	Zd		= Voz / Vdz =		0.17	0.17	0.17	0.17	0.17	0.12
Unused OA fraction required in primary air to zone	Zp		= Voz / Vpz =		0.17	0.17	0.17	0.17	0.17	0.12
System Ventilation Efficiency										
Zone Ventilation Efficiency (App A Method)	Evz		= (Fa + FbXs - FcZ) / Fa =		0.98	0.99	0.99	0.99	0.99	1.04
System Ventilation Efficiency (App A Method)	Ev		= min (Evz) =	**0.98**						
Ventilation System Efficiency (Table 6.3 Method)	Ev		= Value from Table 6.3 =	0.98						
Minimum outdoor air intake airflow										
Outdoor Air Intake Flow required to System	Vot	cfm	= Vou / Ev =	**4816**						
OA intake req'd as a fraction of primary SA	Y		= Vot / Vps =	**0.16**						
Outdoor Air Intake Flow required to System (Table 6.3 Metho	Vot	cfm	= Vou / Ev =	4861						
OA intake req'd as a fraction of primary SA (Table 6.3 Metho	Y		= Vot / Vps =	0.16						
OA Temp at which Min OA provides all cooling										
OAT below which OA Intake flow is @ minimum		Deg F	= {(Tp-dTsf)-(1-Y)*(Tr+d' =	-33						

Building:			SHA Headquarters – 707							
System Tag/Name:			S-3 North Core AHU Zone Loads							
Operating Condition Description:										
Units (select from pull-down list)			IP							
Inputs for System	**Name**	**Units**		**System**						
Floor area served by system	As	sf		53804						
Population of area served by system (including diversity)	Ps	P	100% diversity	297						
Design primary supply fan airflow rate	Vpsd	cfm		29,681						
OA req'd per unit area for system (Weighted average)	Ras	cfm/sf		0.06						
OA req'd per person for system area (Weighted average)	Rps	cfm/p		5.0						
Inputs for Potentially Critical zones					**Potentially Critical Zones**					
Zone Name			*Zone title turns purple italic for critical zone(s)*		1st Floor N	2nd Floor	3rd Floor N	*4th Floor*	5th Floor N	6th Floor N
Zone Tag					1st Floor N	2nd Floor	3rd Floor N	4th Floor N	5th Floor N	6th Floor N
Space type			Select from pull-down list		Office	Office	Office	Office	Office	Office
Floor Area of zone	Az	sf			8,887	8955	8950	8979	8941	9092
Design population of zone	Pz	P	(default value listed; may be overridden)		46	56	50	34	56	55
Design total supply to zone (primary plus local recirculated)	Vdzd	cfm			4,449	4821	4608	4053	4814	6936
Induction Terminal Unit, Dual Fan Dual Duct or Transfer Fan?			Select from pull-down list or leave blank if N/A							
Local recirc. air % representative of ave system return air	Er									
Inputs for Operating Condition Analyzed										
Percent of total design airflow rate at conditioned analyzed	Ds	%		100%	100%	100%	100%	100%	100%	100%
Air distribution type at conditioned analyzed			Select from pull-down list		CS	CS	CS	CS	CS	CS
Zone air distribution effectiveness at conditioned analyzed	Ez		Show codes for Ez		1.00	1.00	1.00	1.00	1.00	1.00
Primary air fraction of supply air at conditioned analyzed	Ep									
Results										
Ventilation System Efficiency	Ev			**0.98**						
Outdoor air intake required for system	Vot	cfm		**4790**						
Outdoor air per unit floor area	Vot/As	cfm/sf		**0.09**						
Outdoor air per person served by system (including diversity)	Vot/Ps	cfm/p		**16.1**						
Outdoor air as a % of design primary supply air	Ypd	cfm		**16%**						
Detailed Calculations										
Initial Calculations for the System as a whole										
Primary supply air flow to system at conditioned analyzed	Vps	cfm	= VpdDs =	29681						
UncorrectedOA requirement for system	Vou	cfm	= Rps Ps + Ras As =	4713						
Uncorrected OA req'd as a fraction of primary SA	Xs		= Vou / Vps =	0.16						
Initial Calculations for individual zones										
OA rate per unit area for zone	Raz	cfm/sf			0.06	0.06	0.06	0.06	0.06	0.06
OA rate per person	Rpz	cfm/p			5.00	5.00	5.00	5.00	5.00	5.00
Total supply air to zone (at condition being analyzed)	Vdz	cfm			4449	4821	4608	4053	4814	6936
Unused OA req'd to breathing zone	Vbz	cfm	= Rpz Pz + Raz Az =		763.2	817.3	787.0	708.7	816.5	820.5
Unused OA requirement for zone	Voz	cfm	= Vbz/Ez =		763	817	787	709	816	821
Fraction of zone supply not directly recirc. from zone	Fa		= Ep + (1-Ep)Er =		1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone supply from fully mixed primary air	Fb		= Ep =		1.00	1.00	1.00	1.00	1.00	1.00
Fraction of zone OA not directly recirc. from zone	Fc		= 1-(1-Ez)(1-Ep)(1-Er) =		1.00	1.00	1.00	1.00	1.00	1.00
Unused OA fraction required in supply air to zone	Zd		= Voz / Vdz =		0.17	0.17	0.17	0.17	0.17	0.12
Unused OA fraction required in primary air to zone	Zp		= Voz / Vpz =		0.17	0.17	0.17	0.17	0.17	0.12
System Ventilation Efficiency										
Zone Ventilation Efficiency (App A Method)	Evz		= (Fa + FbXs - FcZ) / Fa =		0.99	0.99	0.99	0.98	0.99	1.04
System Ventilation Efficiency (App A Method)	Ev		= min (Evz) =	**0.98**						
Ventilation System Efficiency (Table 6.3 Method)	Ev		= Value from Table 6.3 =	0.98						
Minimum outdoor air intake airflow										
Outdoor Air Intake Flow required to System	Vot	cfm	= Vou / Ev =	**4790**						
OA intake req'd as a fraction of primary SA	Y		= Vot / Vps =	**0.16**						
Outdoor Air Intake Flow required to System (Table 6.3 Metho	Vot	cfm	= Vou / Ev =	4833						
OA intake req'd as a fraction of primary SA (Table 6.3 Metho	Y		= Vot / Vps =	0.16						
OA Temp at which Min OA provides all cooling										
OAT below which OA Intake flow is @ minimum		Deg F	= {(Tp-dTsf)-(1-Y)*(Tr+d' =	-33						

Appendix B

TABLE 5.5-4 Building Envelope Requirements For Climate Zone 4 (A, B, C)[a]

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.	U-0.173	R-5.0 c.i.
Metal Building	U-0.065	R-19.0	U-0.065	R-19.0	U-0.097	R-10.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0	U-0.053	R-19.0
Walls, Above-Grade						
Mass	U-0.104	R-9.5 c.i.	U-0.090	R-11.4 c.i.	U-0.580	NR
Metal Building	U-0.113	R-13.0	U-0.113	R-13.0	U-0.134	R-10.0
Steel-Framed	U-0.064	R-13.0 + R-7.5 c.i.	U-0.064	R-13.0 + R-7.5 c.i.	U-0.124	R-13.0
Wood-Framed and Other	U-0.089	R-13.0	U-0.064	R-13.0 + R-3.8 c.i.	U-0.089	R-13.0
Walls, Below-Grade						
Below-Grade Wall	C-1.140	NR	C-0.119	R-7.5 c.i.	C-1.140	NR
Floors						
Mass	U-0.087	R-8.3 c.i.	U-0.074	R-10.4 c.i.	U-0.137	R-4.2 c.i.
Steel-Joist	U-0.038	R-30.0	U-0.038	R-30.0	U-0.069	R-13.0
Wood-Framed and Other	U-0.033	R-30.0	U-0.033	R-30.0	U-0.066	R-13.0
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.540	R-10 for 24 in.	F-0.730	NR
Heated	F-0.860	R-15 for 24 in.	F-0.860	R-15 for 24in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.700		U-0.700	
Nonswinging	U-1.500		U-0.500		U-1.450	
Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[b]	U-0.40	SHGC-0.40 all	U-0.40	SHGC-0.40 all	U-1.20	SHGC-NR all
Metal framing (curtainwall/storefront)[c]	U-0.50		U-0.50		U-1.20	
Metal framing (entrance door)[c]	U-0.85		U-0.85		U-1.20	
Metal framing (all other)[c]	U-0.55		U-0.55		U-1.20	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}-1.17	$SHGC_{all}$-0.49	U_{all}-0.98	$SHGC_{all}$-0.36	U_{all}-1.98	$SHGC_{all}$-NR
2.1%–5.0%	U_{all}-1.17	$SHGC_{all}$-0.39	U_{all}-0.98	$SHGC_{all}$-0.19	U_{all}-1.98	$SHGC_{all}$-NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}-1.30	$SHGC_{all}$-0.65	U_{all}-1.30	$SHGC_{all}$-0.62	U_{all}-1.90	$SHGC_{all}$-NR
2.1%–5.0%	U_{all}-1.30	$SHGC_{all}$-0.34	U_{all}-1.30	$SHGC_{all}$-0.27	U_{all}-1.90	$SHGC_{all}$-NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}-0.69	$SHGC_{all}$-0.49	U_{all}-0.58	$SHGC_{all}$-0.36	U_{all}-1.36	$SHGC_{all}$-NR
2.1%–5.0%	U_{all}-0.69	$SHGC_{all}$-0.39	U_{all}-0.58	$SHGC_{all}$-0.19	U_{all}-1.36	$SHGC_{all}$-NR

[a] The following definitions apply: c.i. = continuous insulation (see Section 3.2), NR = no (insulation) requirement.
[b] Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.
[c] Metal framing includes metal framing with or without thermal break. The "all other" subcategory includes operable windows, fixed windows, and non-entrance doors.