Technical Report One

ASHRAE Std 62.1 and Std 90.1 Analysis

APPELL LIFE SCIENCES

York College of Pennsylvania

York, PA

Joshua R Martz

Mechanical Option

10/4/2010

Dr. Srebric-Faculty Advisor

Table of Contents

Executive Summary

The purpose of this report is to determine the compliance of Appell Life Sciences building with ASHRAE Standards 62.1 and 90.1 2007.

Appell Life Sciences houses various laboratories in the field of biology, human anatomy, plant life, and archaeology. The building also houses administrative offices for the professors and regular lecture classrooms. The greenhouse building is part of the life sciences building and houses laboratories and five greenhouses on the top floor.

The ASHRAE 62.1 analysis showed that the building is largely compliant with these requirements. Section 5 showed that an outdoor air intake on the roof was not far enough away from exhaust fans from some of the laboratories. This could have been because of limited amount of roof space because of the many exhaust fans for the labs. Section 6 calculations showed that the AHU's were found compliant with the minimum amount of outdoor air they each provided for their spaces.

The ASHRAE 90.1 analysis showed that the building is mostly compliant with these requirements. Section 5 had some building envelope values that were not compliant most likely because this is an existing building and probably meets earlier standards requirements. Section 6 showed that most of the systems for the building are compliant. The exhaust fans for the labs do not meet the fan power requirements most likely because they are each 1 hp and must comply with different requirements. The lighting power density for the greenhouse building was twice the requirement for section 9 but this is most likely because the greenhouses have 400 watt lighting fixtures in them adding much more wattage to the building.

It was determined that Appell Life Sciences was closely compliant with the requirements set for these two ASHRAE standards.

System Description

The central plant in the basement of the life sciences building has a 400 ton chiller and 3 2640 MBH boilers supplying hot and cold water to the air handling units and fan coil units throughout the building. A primary pump system to supply this water has been set up in the basement in the life sciences. Because of space a secondary loop is located in the greenhouse building to service the fan coil units for that building.

There are five AHU's servicing the life sciences building. The first services the main floor office spaces with VAV boxes. The second services the main floor classrooms and labs with primary air and fan coil units. The third services the second and third floor office spaces with VAV boxes. The fourth services the second floor labs with primary air and fan coil units. The fifth services the third floor labs and classrooms with primary air and fan coil units. The AHU's for laboratory spaces are equipped with heat recovery wheels to recover energy from supplying the labs. Perimeter office spaces are conditioned with parallel fan powered VAV boxes and are connected to the hot water loop to reheat the air before it enters the space. Every other office space is conditioned using VAV reheat units. All air handlers will be equipped with airside economizers.

The greenhouse building is conditioned with fan coil units with outdoor air ducted from the outside. They will utilize waterside economizers. The actual greenhouses will be heated by wall hung hot water radiation units. Hot water horizontal unit heaters will also be provided for quicker pick up in space temperature if needed. The greenhouses will be cooled using a combination of natural ventilation, exhaust fans and evaporative coolers. Each greenhouse will be controlled separately with respect to temperature and humidity. The greenhouses will have separate misting systems to add humidity when required.

ASHRAE 62.1 Section 5

5.1 Natural Ventilation

The greenhouses use natural ventilation as part of cooling. There are 5 separate greenhouses ranging from 240-460 SF. They include motorized vents that are greater than 4% of these areas, therefore complying with these requirements.

5.2 Ventilation Air Distribution

All spaces meet ventilation requirements. The VAV system in the building is assumed to have a damper that does not allow less than the minimum ventilation air required.

5.3 Exhaust Duct Location

Exhaust from the toilet rooms and various laboratories are ducted and pressurized negatively through the spaces they pass, therefore complying with this requirement.

5.4 Ventilation System Control

Ventilation systems are run on DDC, direct digital control, to monitor airflow and maintain minimum outdoor airflow.

5.5 Airstream Surfaces

All airstream surfaces in equipment and ducts in the HVAC system are mold and erosion resistant, therefore complying with this requirement.

5.6 Outdoor Air Intakes

The following table shows the air intake minimum separation distance for outdoor intakes from potential outdoor contaminant sources.

TABLE 5-1 Air Intake Minimum Separation Distance			
Object	Minimum Distance (ft)	Distance (ft)	Complies
Significantly contaminated exhaust	15	NA	NA
Noxious/dangerous exhaust	30	22	No
Vents, chimneys, flues from combustion appliances and equipment	15	15	Yes
Garage entry, auto loading area, or drive-in queue	15	30	Yes
Truck loading area, bus parking/idling area	25	35	Yes
Driveway, street, or parking place	5	10	Yes
Thoroughfare w/ high traffic volume	25	30	Yes
Roof, landscaped grade, or other surfaces directly below intake	1	2	Yes
Garbage storage/pick-up area, dumpsters	15	NA	NA
Cooling tower intake or basin	15	22	Yes
Cooling tower exhaust	25	25	Yes

Although a few of the exhaust fans are close to the outdoor intake on the roof for the Tissue Lab the rest of the exhaust fans meet the minimum distance requirement away from the two AHU's on the roof. All openings for outdoor air intake will be provided with the proper bird screens.

5.7 Local Capture of Contaminants

All exhaust from the various labs and toilet rooms are ducted to exhaust fans on the roof.

5.8 Combustion Air

All combustion air from the boilers and emergency generator are directly exhausted to the outside of the building.

5.9 Particulate Matter Removal

All air handling units in the building will have MERV-7 or MERV-11 filters during occupancy. Fan coil units in the building will have MERV-7 filters.

5.10 Dehumidification Systems

When the relative humidity reaches above the setpoint of 60 % RH, the appropriate system will be set to dehumidification until the space reaches a RH of 55%.

5.11 Drain Pans

All drain pans for air handling units will slope in two planes to collect condensate and comply with the rest of the requirements. All drain pans for fan coil units will slope in all directions to collect condensate and comply with the rest of the requirements.

5.12 Finned-Tube Coils and Heat Exchangers

Fan coil units with finned-tube coils have an adequate drain pan as stated in 5.11. Finned-tube coils comply with these requirements. Heat exchanger with drip tray for condensate complies with 5.11.

5.13 Humidifiers and Water-Spray Systems

The fine mist atomizing foggers for the greenhouses comply with these requirements.

5.14 Access for Inspection, Cleaning, and Maintenance

Service doors shall be provided for all AHU's for the fan section, filter section, mixing box/damper section and access section with a minimum opening width of 18 inches.

Fan coil units and Air terminal units will have proper clearance or access for maintenance.

5.15 Building Envelope and Interior Surfaces

Proper vapor retarders and spray applied air/vapor barriers will be included in the wall and slab construction to prevent water liquid penetration. Proper insulation will be provided for interior ducts and piping to maintain temperature and prevent condensation build up on the surface.

5.16 Buildings with Attached Parking Garages

No parking structure is attached to the building; therefore this section does not apply.

5.17 Air Classification and Recirculation

The return air from offices, regular classrooms and computer labs is classified as class 1 air. Exhaust from the laboratories is classified as class 4. This air is directly exhausted through to the roof, avoiding recirculation. The toilet rooms are classified as class 2 air. This is also exhausted to the roof to avoid recirculation.

5.18 Requirements for Buildings Containing ETS Areas and ETS-Free Areas

Smoking is prohibited inside campus buildings but allowed 25 feet away from campus building entrances. These requirements should yield no challenge with ETS contamination.

ASHRAE 62.1 Section 6

The following procedure was used to calculate the minimum outdoor air for each zone. This procedure follows that which is in section 6 of ASHRAE Std. 62.1.

Ventilation Rate Procedure

Step 1: Calculate the Breathing Zone Outdoor Airflow (V_{bz}).

$$V_{bz}=R_p * P_z + R_a * A_z$$

A_z = zone floor area (ft^2)

P_z = zone population (Estimated from values in Table 6-1 of Section 6)

R_p = outdoor airflow rate required per person (Values found in Table 6-1 of Section 6)

R_a = outdoor airflow rate required per unit area (Values found in Table 6-1 of Section 6)

Step 2: Determine Zone Air Distribution Effectiveness (E_z) using Table 6-2 of Section 6.

Step 3: Calculate the Zone Outdoor Airflow (V_{oz}).

$$V_{oz} = V_{bz}/ E_z$$

Step 4: Calculate the Zone Primary Outdoor Air Fraction (Z_p).

$$Z_p = V_{oz}/V_{pz}$$

V_{pz} = zone primary airflow

Note: For VAV systems, V_{pz} is the minimum expected primary airflow for design purposes.

Step 5: Determine the System Ventilation Efficiency (E_v) using Table 6-3 of Section 6.

Step 6: Calculate the Uncorrected Outdoor Air Intake (V_{ou}).

$$V_{ou} = D\sum_{all\ zones} (R_p * P_z) + \sum_{all\ zones} (R_a * A_z)$$

D = diversity = $P_s/\sum_{all\ zones} (P_z)$

P_s = total population in the area served by the system

Step 7: Calculate the Outdoor Air Intake (V_{ot}).

$$V_{ot} = V_{ou}/ E_v$$

An alternate calculation is needed to determine E_z if the max Z_p is larger than 0.55. This happens in one instance in the Life Sciences building. Following is the alternate way to calculate for V_{ot}.

Step 1: Determine the Average Outdoor Air Fraction (X_s) from the following equation.

$$X_s = V_{ou}/V_{ps}$$

V_{ps} = systems primary airflow

Step 2: Determine the Zone Discharge Airflow (V_{dz}).

Step 3: Determine the Discharge Outdoor Air Fraction from the following equation.

$$Z_d = V_{oz}/V_{dz}$$

V_{dz} = the overall airflow provided to the zone

Step 4: Determine the System Ventilation Efficiency (E_{vz}) from the following equation.

$$E_{vz} = 1+X_s-Z_d$$

After these steps are completed the V_{ot} can be calculated using Step 7 from above.

Zone calculations for the previous two methods and the systems analyzed can be found in Appendix A.

Ventilation Assumptions

1. Student Lounges are assumed to be conference rooms the way they are laid out in architectural drawings.
2. Some indoor vestibules in the office spaces are assumed to be corridors as they are not connected to the exterior.
3. Elevator lobbies are assumed to be hotel lobbies.
4. Any type of prep room or storage for labs is assumed to be college labs.
5. Toilet rooms are assumed to be storage for ventilation purposes.

ASHRAE 62.1 Summary

Section 5

The HVAC design of the life sciences complies with all but one of the requirements for this section. The exhaust fans from some of the lab fume hoods are placed too close to the outdoor air intake for the tissue lab. This could be because there are so many fans and not enough roof space to comply with all the minimum distances from outdoor air intakes. However it seems great effort was put into the thought of good indoor air quality for the life sciences building.

Section 6

Each air handling unit for the life sciences building was analyzed for this section. AHU-1 was calculated to have 1151 cfm of outdoor air while the design value for this air handling unit is 1300 cfm. AHU-2 was calculated to have 5974 cfm of outdoor air while the design value for this air handling unit is 6900 cfm. AHU-3 was calculated to have 1632 cfm of outdoor air while the design value is 8000 cfm for this air handling unit. AHU-4 was calculated to have 4644 cfm of outdoor air while the design value is 8100 cfm for this air handling unit. AHU-5 was calculated to have 4196 cfm of outdoor air while the design value is 7550 cfm for this air handling unit. All five of the air handling units are found to be compliant with the requirements.

The greenhouse building is supplied by 100% outdoor air through fan coil units. Since this building is supplied with 100% outdoor air it meets the requirements for this standard. The greenhouses themselves use natural ventilation therefore meeting ventilation requirements from section 5.1.

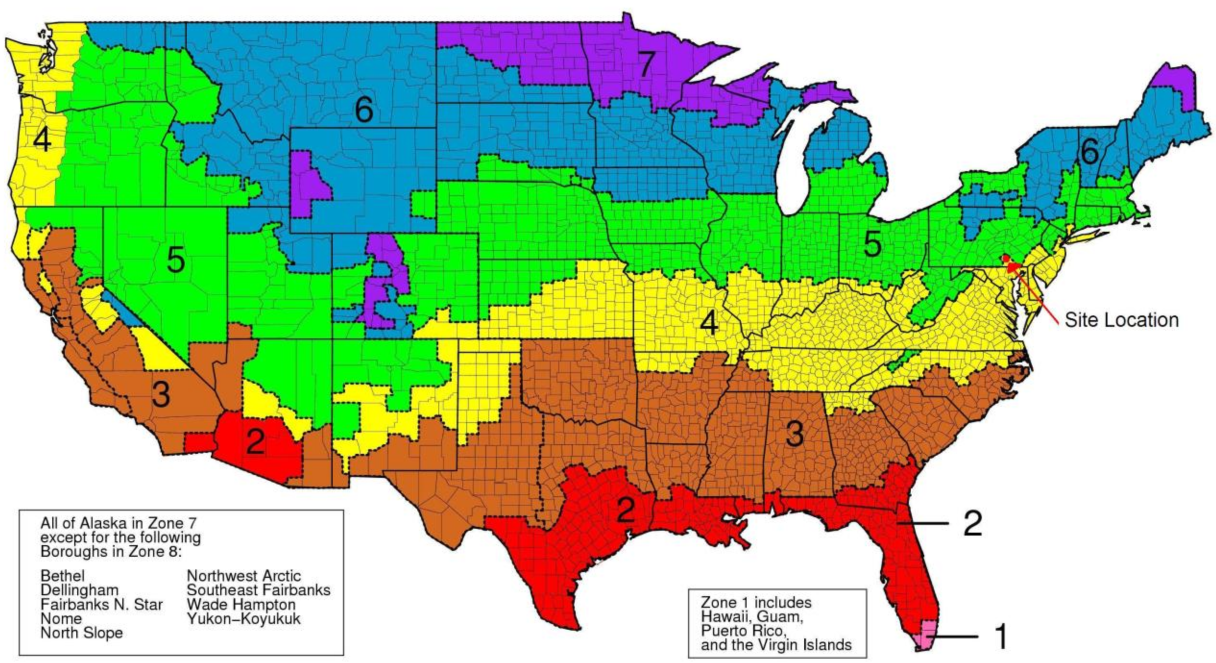
ASHRAE 90.1

Standard 90.1 mainly deals with the energy efficiency measures taken during the design of a building. These include building envelope, HVAC systems, service water heating, and lighting.

Section 5: Building Envelope

5.1.4 Climate

Life Sciences in York is in climate zone 4 and a non-residential building so therefore will have to comply with table 5.5-4. See the below figure for location in climate zone 4.



5.5 Prescriptive Building Envelope Option

Compliance with Envelope Requirements						
Element	Description	90.1 Specified Values		Life Sciences Values		Complies
		Max U-Value	Min R-Value	U-Value	R-Value	
Roof	Insulation Entirely Above Deck	0.048	20	0.023	42	Yes
Walls, Above-Grade	Mass	0.104	9.5	0.053	14	Yes
Walls, Below-Grade	Below-Grade Wall	1.14	NR	1.14	NR	Yes
Floors	Steel-Joist	0.038	8.3	0.05	NA	No
Slab-on-Grade Floors	Unheated	0.73	NR	0.7	5	Yes
Fenestration	Description	Max U-Value	SHGC	U-Value	SHGC	Complies
Vertical Glazing	Metal Framing (curtain wall)	0.5	0.4	0.29	0.34	Yes
Vertical Glazing	Metal Framing (entrance door)	0.85	0.4	0.61	0.65	No
Vertical Glazing	Metal Framing (all other)	0.55	0.4	0.4	0.435	No

Section 6: Heating, Ventilating, and Air Conditioning

6.4 Mandatory Provisions

Automatic temperature sensors will be placed in each zone to control the temperature of the spaces at the building owner's request. They will be accurate within 0.5 F. During the unoccupied period the controls will automatically set-back to minimum capacity for the systems.

All exhaust hoods, vents, and ventilators are equipped with motorized dampers that will automatically shut when the space is unoccupied. Ductwork insulation will comply with this requirement and consist of fibrous glass material.

6.5 Prescriptive Path

The air economizers supply 100% outdoor air. Air economizers are not required in this climate zone so they will only be used when the outdoor air conditions permit. The fan coil units used to condition lab spaces use waterside economizers. Again they are not required in this climate zone so they will only be used when the outdoor air conditions permit. The following chart checks the compliance of supply and exhaust fans for the AHU's and lab fume hoods.

Fan Power Limitation					
Unit	HP	CFM	CFM*0.0011	CFM*0.0015	Complies
Air Handling Units					
AHU-1 SF	7.5	4200		6.3	No
AHU-2 SF	15	6900	7.6		No
AHU-3 SF	15	8000		12.0	No
AHU-4 SF	15	8100	8.9		No
AHU-5 SF	15	7550	8.3		No
AHU-1 EF	2	3360		5.0	Yes
AHU-2 EF	7.5	6210	6.8		No
AHU-3 EF	5	6400		9.6	Yes
AHU-4 EF	5	7290	8.0		Yes
AHU-5 EF	5	6795	7.5		Yes
Exhaust Fans					
F-1	1	450	0.5		No
F-2	1	1800	2.0		Yes
F-3	1	280	0.3		No
F-4	1	370	0.4		No
F-5	1	450	0.5		No
F-6	1	100	0.1		No
F-7	1	750	0.8		No
F-8	1	900	1.0		Yes
F-9	1	400	0.4		No
F-10	1	8000	8.8		Yes
F-11	1	8000	8.8		Yes
F-12	1	2000	2.2		Yes
F-13	1	1000	1.1		Yes

VAV fan controls, (fan powered boxes), are powered by variable speed drive.

Energy recovery systems are used in AHU's 2, 4, and 5 which supply air to the laboratories in the life sciences building. They have an energy recovery effectiveness of greater than 50% meeting these requirements.

6.8 Minimum Efficiency

The elevator equipment room in the basement has a ductless split system air conditioner that has an efficiency of 12.3 EER meeting the requirements for this section. The centrifugal chiller of 400 tons has a COP of 6.17 and an IPLV of 0.362. The COP value is compliant with the minimum requirements however the IPLV value is significantly different from the standard. This could be because the chiller was made compliant to ARI 500/590 standards. The two cooling towers have axial fans with a performance of 70 gpm/hp which is greater than the required 38.2 gpm/hp.

Section 7: Service Water Heating

Hot service water for the systems is supplied by three 2640 MBH natural gas boilers. They have an efficiency of 88% exceeding the required 80% for compliance.

Section 9: Lighting

The building area method will be used to figure out the LPD of the Life Sciences Building. Since the Life Sciences building has a separate greenhouse building the LPD's will be calculated separately for these two buildings. The following tables show the building area method and the lighting power density for the two buildings.

Life Sciences

Lighting Power Density							
Fixture	Basement	1st Floor	2nd Floor	3rd Floor	Total	W/fixture	Total W
A3PR		96	167	109	372	120	44640
A	4	11	16	8	39	80	3120
A	4			2	6	120	720
C3P		20	7	6	33	80	2640
C3P		60	4	69	133	120	15960
C		25	18	31	74	80	5920
CE		31	20	24	75	120	9000
DFL		17	10	16	43	26	1118
DFLE		16	55	18	89	52	4628
G			1		1	40	40
G			1		1	80	80
I	5	1	5	5	16	80	1280
I	8				8	120	960
I	18		5	5	28	160	4480
PDI	12				12	80	960
PDIE	1				1	120	120
PUC		3	12	10	25	20	500
UC			8		8	17	136
UC			10		10	25	250
UC	2	4	31		37	32	1184
W		2	2	2	6	80	480
Total SF	11856	27783	26929	23670	90238		98216

W/ft^2	90.1 Value	Complies?
1.09	1.2	Yes

Greenhouse Building

Lighting Power Density						
Fixture	Basement	1st Floor	2nd Floor	Total	W/fixture	Total W
A3PR	2	6		8	120	960
C	10	4	2	16	80	1280
CE	7	6	1	14	120	1680
CFVT	4	6		10	26	260
GH			40	40	400	16000
I	8	12	2	22	80	1760
I	4	7	2	13	120	1560
PDI	14	14		28	80	2240
PDIE	1	1		2	120	240
UC	1	1		2	17	34
UC	5	23		28	32	896
VTE		1	5	6	120	720
VT		11	6	17	80	1360
Total SF	4590	4736	2523	11849		28990

W/ft^2	90.1 Value	Complies?
2.45	1.2	No

ASHRAE 90.1 Summary

The preceding calculations for sections 5, 6, 7, and 9 are done using the prescriptive method for building efficiency and the building met some of the requirements. In section 5 some of the building envelope values such as steel joist floors did not meet the requirements because they do not have insulation in them. Also fenestration values for windows and entrance doors do not meet the requirements. This could be due to the fact that this project was a renovation and addition to an existing building.

In section 6 the air system fans are higher horsepower than the prescribed values given for this requirement. This could be due to the larger pressure drop in the fans from the MERV 11 filters. As stated above most other systems meet the requirements. However the chiller IPLV value is much lower than the standard given. This could be because the specs state that the chiller should comply with ARI 500/590 standards which could be different than 90.1. The exhaust fans for the labs may not be compliant with the requirements of fan power because they are less than 1 hp each and must comply with different requirements.

In section 7 the boiler efficiency for service water supply meets the requirements of compliance.

In section 9 the LPD for the life sciences complies with the requirements of this section. However the LPD for the greenhouse building was much larger than the required value. This could be due to the fact that the actual greenhouses have high several high wattage lighting fixture in them. The wattage of these fixtures is 400 and there are 40 of them laid out in the greenhouses adding 16000 W to the greenhouse building.

References

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

ASHRAE, 2007, ANSI/ASHRAE, 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.

JDB Engineering. Mechanical Specifications. JDB Engineering, York, PA.

JDB Engineering. Mechanical Construction Documents. JDB Engineering, York, PA.

Reese, Lower, Patrick & Scott Architects, Ltd. Architectural Construction Documents.

RLPS Architects, Ltd., Lancaster, PA.

JDB Engineering. Electrical Construction Documents. JDB Engineering, York, PA.

Appendix A

Ventilation Rate Procedure Calculations

The following calculation was done for an Education Tech Lab on the first floor served by AHU-2. This particular space had the max Z_p value for AHU-2 of 0.51.

Step 1: Calculating V_{bz}

$A_z = 800$, $P_z = 26$, $R_p = 10$, $R_a = 0.18$

$V_{bz} = (26*10)+(800*0.18) = 404$ cfm

Step 2: $E_z = 1$

Step 3: $V_{oz} = V_{bz}/E_z = 404/1 = 404$ cfm

Step 4: $Z_p = V_{oz}/V_{pz}$

$V_{pz} = 800$ cfm $Z_p = 404/800 = 0.51$

Step 5: $E_v = 0.6$

Step 6: $V_{ou} = D(\sum(R_p*P_z)_{\text{all zones}} + (R_a*A_z)_{\text{all zones}})$

$V_{ou} = 1(2545+1040) = 3585$ cfm

Step 7: $V_{ot} = V_{ou}/E_v$

$V_{ot} = 3585/0.6 = 5974$ cfm for AHU-2

The following calculation was done for a General Lab that had a Zp value of 0.62. This space is served by AHU-4.

Step 1: Calculating V_{bz}

$A_z = 900$, $P_z = 21$, $R_p = 10$, $R_a = 0.18$

$V_{bz} = (21*10)+(900*0.18) = 372$ cfm

Step 2: $E_z = 1$

Step 3: $V_{oz} = V_{bz}/E_z = 372/1 = 372$ cfm

Step 4: $Z_p = V_{oz}/V_{pz}$

$V_{pz} = 600$ cfm $Z_p = 372/600 = 0.62$

Step 5: $X_s = V_{ou}/V_{ps}$

$V_{ps} = 8100$, $V_{ou} = 4180$, $X_s = 4180/8100 = 0.516$

Step 6: $V_{dz} = 600$ cfm

Step 7: $Z_d = V_{oz}/V_{dz}$

$Z_d = 372/600 = 0.62$

Step 8: $E_{vz} = 1 + X_s - Z_d$

$E_{vz} = 1 + 0.516 - 0.62 = 0.9$

Step 8: $V_{ot} = V_{ou}/E_{vz}$

$V_{ot} = 4180/0.9 = 4644$ cfm for AHU-4

Ventilation Rate Procedure Tables for AHU's 1-5

AHU-1	SA cfm=4200	Min. OA cfm=1300									
Room #	Room Name	Space Use	P_z (# of Occupants)	R_p (cfm/person)	A_z (area in SF)	R_a (cfm/SF)	V_{bz} (cfm)	E_z	V_{oz} (cfm)	V_{pz} (cfm)	Z_p
A106	Student Lounge	Conference	17	5	480	0.06	114	1	114	800	0.14
A105	Corridor	Corridor	0	0	858	0.06	51	1	51	150	0.34
A107	Toilet	Storage	0	0	60	0.12	7	0.8	9	75	0.12
A108	Toilet	Storage	0	0	60	0.12	7	0.8	9	75	0.12
A101	Vestibule	Entry Lobby	2	5	179	0.06	21	1	21	200	0.10
A102	Lobby	Entry Lobby	1	5	65	0.06	9	1	9	100	0.09
A110	Waiting	Reception	3	5	410	0.06	40	1	40	150	0.26
A111	Chairs Office	Office space	1	5	209	0.06	18	1	18	150	0.12
A112	Student Workstudy	Classroom	3	10	92	0.12	41	1	41	150	0.27
A113	AA	Reception	4	5	133	0.06	28	1	28	100	0.28
A119	Workroom/mail	Office space	4	5	195	0.06	32	1	32	300	0.11
A154	Office	Office space	1	5	160	0.06	15	1	15	150	0.10
A157	Office	Office space	1	5	160	0.06	15	1	15	150	0.10
A122	Master of Edu	Office space	1	5	178	0.06	16	1	16	300	0.05
A153	Office	Office space	1	5	109	0.06	12	1	12	80	0.14
A156	Office	Office space	1	5	109	0.06	12	1	12	80	0.14
A149	Office	Office space	1	5	160	0.06	15	1	15	150	0.10
A151	Office	Office space	1	5	160	0.06	15	1	15	150	0.10
A135	Office	Office space	1	5	160	0.06	15	1	15	200	0.07
A136	Office	Office space	1	5	133	0.06	13	1	13	200	0.06
A134	Biology Office	Office space	1	5	131	0.06	13	1	13	80	0.16
A138	Vestibule	Corridor	0	0	126	0.06	8	1	8	60	0.13
A133	Corridor	Corridor	0	0	290	0.06	17	1	17	60	0.29
A137	Office	Office space	1	5	117	0.06	12	1	12	58	0.21
A139	Receiving	Receiving	0	0	146	0.12	18	1	18	125	0.14
A115	Field Exp. Office	Office space	1	5	152	0.06	14	1	14	150	0.09
A120	Files	Storage	0	0	108	0.12	13	1	13	25	0.52
A121	Sp. Ed. Storage	Storage	0	0	105	0.12	13	1	13	25	0.50
A147	Office	Office space	1	5	109	0.06	12	1	12	80	0.14
A143	Office	Office space	1	5	109	0.06	12	1	12	80	0.14
A144	Office	Office space	1	5	160	0.06	15	1	15	150	0.10
A145	Office	Office space	1	5	160	0.06	15	1	15	150	0.10
A152	Office	Office space	1	5	109	0.06	12	1	12	80	0.14
A148	Office	Office space	1	5	109	0.06	12	1	12	80	0.14
A146	Hall	Corridor	0	0	91	0.06	5	1	5	40	0.14
A150	Hall	Corridor	0	0	91	0.06	5	1	5	40	0.14
A155	Hall	Corridor	0	0	91	0.06	5	1	5	40	0.14
									694		

AHU-2	SA cfm=6900	Min. OA cfm=6900								
Room #	Room Name	Space Use	P_z (# of Occupants)	R_p (cfm/person)	A_z (area in SF)	R_a (cfm/SF)	V_{bz} (cfm)	E_z	V_{oz} (cfm)	V_{pz} (cfm)	Z_p
A103	AA	Reception	9	5	293	0.06	63	1	63	400	0.16
A125	Classroom	Lecture Classroom	36	7.5	635	0.06	308	1	308	1000	0.31
A127	Classroom	Lecture Classroom	36	7.5	635	0.06	308	1	308	1000	0.31
A130	Classroom	Lecture Classroom	36	7.5	635	0.06	308	1	308	1000	0.31
A141	Preproom	College Lab	5	10	395	0.18	121	1	121	400	0.30
A142	Animal Lab	College Lab	21	10	1272	0.18	439	1	439	1200	0.37
A128	Classroom	Lecture Classroom	41	7.5	879	0.06	360	1	360	1000	0.36
A126	Classroom	Lecture Classroom	41	7.5	845	0.06	358	1	358	1000	0.36
A158	Ed. Tech lab	College Lab	26	10	800	0.18	404	1	404	800	0.51
A163	Corridor	Corridor	0	0	1015	0.06	61	1	61	200	0.30
A159	Ed. Tech lab	College Lab	26	10	800	0.18	404	1	404	800	0.51
A114	Observation	Classroom	8	10	230	0.06	94	1	94	200	0.47
A104	Observation	Classroom	2	10	66	0.06	24	1	24	150	0.16
A117	Reading Clinic	Classroom	13	10	380	0.06	153	1	153	600	0.25
A118	Conference	Conference	13	5	275	0.06	82	1	82	300	0.27
A109	Corridor	Corridor	0	0	507	0.06	30	1	30	200	0.15
A131	Toilet	Storage	0	0	142	0.12	17	0.8	21	300	0.07
A132	Toilet	Storage	0	0	170	0.12	20	0.8	26	300	0.09
A124	Corridor	Corridor	0	0	505	0.06	30	1	30	100	0.30
									3594		

AHU-3	SA cfm=8000	Min. OA cfm=8000									
Room #	Room Name	Space Use	P_z (# of Occupants)	R_p (cfm/person)	A_z (area in SF)	R_a (cfm/SF)	V_{bz} (cfm)	E_z	V_{oz} (cfm)	V_{pz} (cfm)	Z_p
A206	Chair's Office	Office Space	1	5	215	0.06	18	1	18	300	0.06
A208	Workroom/Mail	Office Space	4	5	215	0.06	33	1	33	275	0.12
A258	Corridor	Corridor	0	0	860	0.06	52	1	52	225	0.23
A210	Corridor	Corridor	0	0	231	0.06	14	1	14	100	0.14
A203	Waiting	Reception	5	5	180	0.06	36	1	36	80	0.45
A205	AA receptionist	Reception	13	5	265	0.06	81	1	81	225	0.36
A207	Student	Office Space	1	5	45	0.06	8	1	8	45	0.17
A375	Office	Office Space	1	5	105	0.06	11	1	11	100	0.11
A376	Office	Office Space	1	5	105	0.06	11	1	11	100	0.11
A362	Office	Office Space	1	5	110	0.06	12	1	12	150	0.08
A337	Office	Office Space	1	5	160	0.06	15	1	15	200	0.07
A338	Office	Office Space	1	5	133	0.06	13	1	13	200	0.06
A313	Office	Office Space	1	5	125	0.06	13	1	13	200	0.06
A315	Office	Office Space	1	5	130	0.06	13	1	13	200	0.06
A317	Office	Office Space	1	5	132	0.06	13	1	13	200	0.06
A217	Office	Office Space	1	5	125	0.06	13	1	13	150	0.08
A339	Office	Office Space	1	5	126	0.06	13	1	13	125	0.10
A340	Vestibule	Corridor	0	0	126	0.06	8	1	8	75	0.10
A334	Office	Office Space	1	5	127	0.06	13	1	13	150	0.08
A335	Office	Office Space	1	5	127	0.06	13	1	13	200	0.06
A336	Office	Office Space	1	5	116	0.06	12	1	12	150	0.08
A372	Office	Office Space	1	5	105	0.06	11	1	11	100	0.11
A373	Office	Office Space	1	5	105	0.06	11	1	11	100	0.11
A374	Office	Office Space	1	5	105	0.06	11	1	11	100	0.11
A332	Office	Office Space	1	5	127	0.06	13	1	13	100	0.13
A333	Corridor	Corridor	0	0	192	0.06	12	1	12	33	0.35
A324	Corridor	Corridor	0	0	154	0.06	9	1	9	33	0.28
A341	Corridor	Corridor	0	0	102	0.06	6	1	6	33	0.19
A231	Office	Office Space	1	5	160	0.06	15	1	15	200	0.07
A232	Office	Office Space	1	5	133	0.06	13	1	13	200	0.06
A229	Vestibule	Corridor	0	0	126	0.06	8	1	8	75	0.10
A230	Office	Office Space	1	5	131	0.06	13	1	13	125	0.10
A233	Office	Office Space	1	5	117	0.06	12	1	12	125	0.10
A234	Elev. Lobby	Hotel Lobby	4	7.5	146	0.06	39	1	39	125	0.31
A235	Storage	Storage	0	0	60	0.12	7	1	7	50	0.14
A328	Office	Office Space	1	5	117	0.06	12	1	12	125	0.10
A330	Elev. Lobby	Hotel Lobby	4	7.5	146	0.06	39	1	39	125	0.31
A331	Storage	Storage	0	0	60	0.12	7	1	7	50	0.14
A237	Office	Office Space	1	5	127	0.06	13	1	13	100	0.13
A236	Corridor	Corridor	0	0	191	0.06	11	1	11	33	0.35
A228	Corridor	Corridor	0	0	156	0.06	9	1	9	33	0.28
A240	Corridor	Corridor	0	0	102	0.06	6	1	6	33	0.19
A325	Work Study	Office Space	1	5	131	0.06	13	1	13	125	0.10
A329	Vestibule	Corridor	0	0	126	0.06	8	1	8	75	0.10
A238	Office	Office Space	1	5	127	0.06	13	1	13	150	0.08
A239	Office	Office Space	1	5	127	0.06	13	1	13	200	0.06
A242	Office	Office Space	1	5	116	0.06	12	1	12	150	0.08
A241	Vestibule	Corridor	0	0	126	0.06	8	1	8	75	0.10
A245	Office	Office Space	1	5	126	0.06	13	1	13	125	0.10
A243	Office	Office Space	1	5	160	0.06	15	1	15	200	0.07
A244	Office	Office Space	1	5	133	0.06	13	1	13	200	0.06
A353	Office	Office Space	1	5	93	0.06	11	1	11	100	0.11
A354	Office	Office Space	1	5	93	0.06	11	1	11	100	0.11
A326	Office	Office Space	1	5	160	0.06	15	1	15	200	0.07
A327	Applied Social Res.	Office Space	1	5	133	0.06	13	1	13	200	0.06
A304	Chair's Office	Office Space	1	5	215	0.06	18	1	18	300	0.06
A301	Waiting	Reception	5	5	180	0.06	36	1	36	100	0.36
A302	AA receptionist	Reception	8	5	265	0.06	56	1	56	332	0.17
A303	Student	Office Space	1	5	45	0.06	8	1	8	68	0.11
A305	Workroom/Mail	Office Space	4	5	215	0.06	33	1	33	300	0.11
A350	Office	Office Space	1	5	110	0.06	12	1	12	100	0.12
A351	Office	Office Space	1	5	100	0.06	11	1	11	100	0.11
A352	Office	Office Space	1	5	93	0.06	11	1	11	100	0.11
A309	Office	Office Space	1	5	130	0.06	13	1	13	230	0.06
A310	Office	Office Space	1	5	123	0.06	12	1	12	180	0.07
A377	Maintenance	Storage	0	0	320	0.12	38	1	38	190	0.20
A308	Office	Office Space	1	5	100	0.06	11	1	11	100	0.11
A311	Office	Office Space	1	5	100	0.06	11	1	11	100	0.11
A312	Office	Office Space	1	5	92	0.06	11	1	11	100	0.11
A316	Office	Office Space	1	5	92	0.06	11	1	11	100	0.11
A318	Office	Office Space	1	5	100	0.06	11	1	11	100	0.11
									1142		

AHU-4	SA cfm=8100	Min. OA cfm=8100									
Room #	Room Name	Space Use	P_z (# of Occupants)	R_p (cfm/person)	A_z (area in SF)	R_a (cfm/SF)	V_{bz} (cfm)	E_z	V_{oz} (cfm)	V_{pz} (cfm)	Z_p
A215	Preproom	College Lab	5	10	425	0.18	127	1	127	600	0.21
A216	Molecular Lab	College Lab	21	10	1160	0.18	419	1	419	1100	0.38
A223A	Preproom	College Lab	4	10	243	0.18	84	1	84	500	0.17
A221	Quiet Storage	College Lab	4	10	235	0.18	82	1	82	200	0.41
A223	Molecular Lab	College Lab	21	10	1160	0.18	419	1	419	1100	0.38
A219	Tissue Lab	College Lab	3	10	389	0.18	100	1	100	500	0.20
A224	Preproom	College Lab	5	10	408	0.18	123	1	123	400	0.31
A246	Human Anatomy Lab	College Lab	23	10	1230	0.18	451	1	451	1200	0.38
A247	Preproom	College Lab	4	10	403	0.18	113	1	113	300	0.38
A252	Preproom	College Lab	4	10	403	0.18	113	1	113	300	0.38
A253	Bio/plant Morph Lab	College Lab	21	10	1206	0.18	427	1	427	1000	0.43
A254	Dark Microscope Rm	College Lab	3	10	207	0.18	67	1	67	400	0.17
A255	Flour Microscope Rm	College Lab	3	10	334	0.18	90	1	90	500	0.18
A256	Micro-Biology Lab	College Lab	25	10	1420	0.18	506	1	506	1400	0.36
A257	Preproom	College Lab	4	10	474	0.18	125	1	125	600	0.21
A262	Autoclave	College Lab	2	10	160	0.18	49	1	49	500	0.10
A263	Preproom	College Lab	2	10	177	0.18	52	1	52	200	0.26
A260	Loud Science Storage	College Lab	3	10	137	0.18	55	1	55	250	0.22
A259	Hall	Corridor	0	0	180	0.06	11	1	11	50	0.22
A264	General Lab	College Lab	21	10	900	0.18	372	1	372	600	0.62
A251	Student Lounge	Conference	17	5	261	0.06	101	1	101	300	0.34
A214	Conference	Conference	24	5	363	0.06	142	1	142	400	0.35
A201	Corridor	Corridor	0	0	165	0.06	10	1	10	100	0.10
A220	Corridor	Corridor	0	0	631	0.06	38	1	38	100	0.38
A213	Corridor	Corridor	0	0	423	0.06	25	1	25	100	0.25
A249	Corridor	Corridor	0	0	443	0.06	27	1	27	300	0.09
A248	Toilet	Storage	0	0	170	0.12	20	0.8	26	300	0.09
A250	Toilet	Storage	0	0	142	0.12	17	0.8	21	300	0.07
A222	Corridor	Corridor	0	0	273	0.06	16	1	16	100	0.16
									4189		

AHU-5	SA cfm=7550	Min. OA cfm=7550									
Room #	Room Name	Space Use	P_z (# of Occupants)	R_p (cfm/person)	A_z (area in SF)	R_a (cfm/SF)	V_{bz} (cfm)	E_z	V_{oz} (cfm)	V_{pz} (cfm)	Z_p
A319	Psychology Lab	College Lab	7	10	275	0.18	120	1	120	600	0.20
A320	Computer Lab	Computer Lab	31	10	842	0.12	411	1	411	1800	0.23
A322	Classroom	Lecture Classroom	20	7.5	489	0.06	179	1	179	600	0.30
A357	Classroom	Lecture Classroom	36	7.5	878	0.06	323	1	323	1200	0.27
A358	Classroom	Lecture Classroom	36	7.5	830	0.06	320	1	320	1200	0.27
A360	Classroom	Lecture Classroom	16	7.5	435	0.06	146	1	146	800	0.18
A367	Classroom	Lecture Classroom	36	7.5	826	0.06	320	1	320	1150	0.28
A323	Corridor	Corridor	0	0	1165	0.06	70	1	70	350	0.20
A368	Classroom	Lecture Classroom	36	7.5	826	0.06	320	1	320	1200	0.27
A359	Corridor	Corridor	0	0	1215	0.06	73	1	73	350	0.21
A369	Corridor	Corridor	0	0	231	0.06	14	1	14	100	0.14
A365	Computer Classroom	Computer Lab	31	10	820	0.12	408	1	408	1100	0.37
A366	Corridor	Corridor	0	0	193	0.06	12	1	12	100	0.12
A361	Prep Room	College Lab	2	10	118	0.18	41	1	41	300	0.14
A364	Conference	Conference	18	5	437	0.06	116	1	116	400	0.29
A345	Toilet	Storage	0	0	170	0.12	20	0.8	26	300	0.09
A346	Toilet	Storage	0	0	142	0.12	17	0.8	21	300	0.07
A355	Corridor	Corridor	0	0	180	0.06	11	1	11	100	0.11
A356	Student Lounge	Conference	22	5	391	0.06	133	1	133	600	0.22
A363	Archaelogy Lab	College Lab	17	10	740	0.18	303	1	303	1000	0.30
									3366		

Yellow highlighted Z_p values are max values used to find the E_v value.

System Outdoor Air Comparison

System Outdoor Air								
Tag	V_{ou}	Max Z_p	E_v	D	P_s	V_{ot}	$\sum V_{oz}$	Design OA
AHU-1	691	0.52	0.6	1	53	1151	694	1300
AHU-2	3585	0.51	0.6	1	313	5974	3594	6900
AHU-3	1142	0.45	0.7	1	95	1632	1142	8000
AHU-4	4180	0.62	0.9	1	219	4644	4189	8100
AHU-5	3357	0.37	0.8	1	308	4196	3366	7550