

**Compliance Evaluation:
ASHRAE Standard 62.1-2001
Ventilation for Acceptable Indoor Air Quality**

Photo rendering courtesy of [Hooper Shiles Architects](#)



**Philadelphia School District
Administration Headquarters
440 North Broad Street, Philadelphia, PA**

**Prepared for
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Wednesday, October 5, 2005**

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 Technical Assignment #1

Executive Summary

Philadelphia School District Administration Headquarters was evaluated by air handling unit to determine compliance with ASHRAE Standard 62.1 Addendum N. In a zone evaluation it was found that all air handling units complied except for AHU4.1. However, this is not due to a design fault as the design of this system was done previous to the Addendum N approval (January 8, 2004). The following chart gives a brief summary of the results found from the analysis:

AHU Summary							
	Zone Outdoor Airflow	Zone Primary Airflow (Minimum Design Flow Rate)	Zone Primary Outdoor Air Fraction	Outdoor Air Intake Flow Required	Supplied Outdoor Air Fraction	Outdoor Air Supplied	Complies with Std 62.1?
Equation Designation	$V_{oz} = V_{bzm}/E_z$	V_{pz}	$Z_p = V_{oz}/V_{pz}$	$V_{ot} = V_{ou}/E_v$			
Units	cfm	cfm		cfm		cfm	
AHU1.1	2425.0	28000.0	0.09	2425.0	0.10	2800.0	Yes
AHU1.2	2425.0	28000.0	0.09	2425.0	0.10	2800.0	Yes
AHU1.3	2500.0	28000.0	0.09	2500.0	0.10	2800.0	Yes
AHU1.4	2500.0	28000.0	0.09	2500.0	0.10	2800.0	Yes
AHU1.5	2687.5	28000.0	0.10	2687.5	0.10	2800.0	Yes
AHU2.1	2800.0	31500.0	0.09	2800.0	0.10	3150.0	Yes
AHU2.2	2800.0	31500.0	0.09	2800.0	0.10	3150.0	Yes
AHU2.3	2800.0	31500.0	0.09	2800.0	0.10	3150.0	Yes
AHU2.4	2800.0	31500.0	0.09	2800.0	0.10	3150.0	Yes
AHU3.1	2800.0	35000.0	0.08	2800.0	0.10	3500.0	Yes
AHU3.2	2800.0	35000.0	0.08	2800.0	0.10	3500.0	Yes
AHU3.3	2800.0	35000.0	0.08	2800.0	0.10	3500.0	Yes
AHU3.4	2800.0	35000.0	0.08	2800.0	0.10	3500.0	Yes
AHU3.5	2725.0	32000.0	0.09	2725.0	0.10	3200.0	Yes
AHU4.1	4750.0	35000.0	0.14	4750.0	0.10	3500.0	No
AHU5.1	2068.8	28000.0	0.07	2068.8	0.10	2800.0	Yes
AHU5.2	2068.8	28000.0	0.07	2068.8	0.10	2800.0	Yes

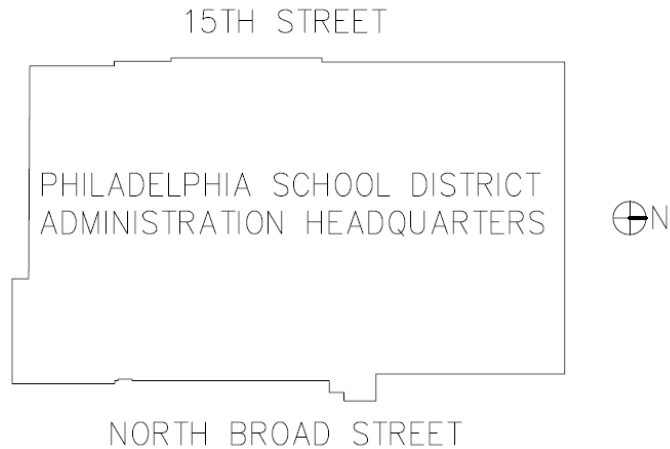
ASHRAE Standard 62.1 Addendum N Summary

ASHRAE Standard 62.1 establishes minimum requirements for outside ventilation air in buildings. This standard's purpose is to create acceptable indoor air quality for human occupants in the spaces of buildings. In Addendum N of the standard, a different procedure for calculating ventilation air is provided. The previous method only considered occupancy level. The new procedure is different in that it considers the spaces' floor area as well as the occupancy of the space.

In the previous method, outdoor air (OA) ventilation was calculated based on a number of people in a space and the amount of contaminants they produce. By considering floor area as well, it is admitted that building components also contribute to contaminant concentration. The method considers a certain amount of chemical, physical, and biological contaminants. A high concentration of contaminants such as these can greatly affect indoor air quality. If left unaddressed, occupants will be more likely to feel uncomfortable or 'sick' while spending time in the building. Acceptable indoor air quality occurs when there are no harmful concentrations of contaminants and when 80 percent or more of the occupants do not express displeasure.

Building AHU Systems Overview

The Administration building has a total **footprint area** of **161,000 square feet (SF)** with a total **gross area** of **848,000 SF**.

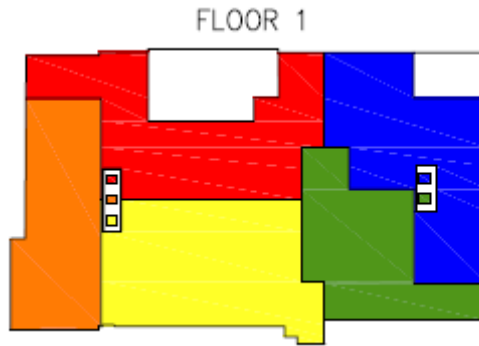


The building has a parallel fan-powered VAV system and is supplied by 17 new air handling units (AHUs) with supply air totaling 529,000 cubic feet per minute (CFM). Individual units are contained in mechanical rooms on the floor it is supplying. An example of an AHU's schedule number is 1.4, where 1 is the floor number and 4 is the unit's number on that floor. The following is a color-coded schedule of the unit layout by floor:

- AHU 1
- AHU 2
- AHU 3
- AHU 4
- AHU 5

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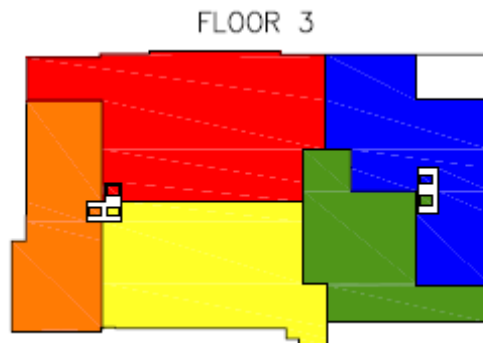
Floors 1 through 3 are broken up by a north half and a south half, each with its own mechanical room. The **first floor** has 5 AHUs, two serving the south half, two serving the north half and one serving the south tenant space (a double height space). The later AHU rises through a shaft to serve the space from the second floor ceiling.



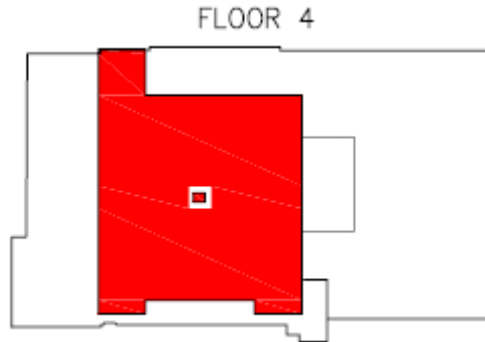
Four AHUs serve the **second floor**: two serving the south half and two serving the north half.



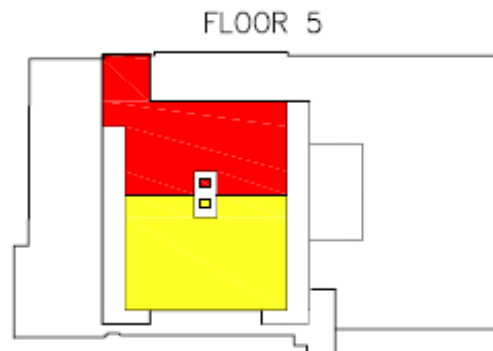
The **third floor** has 4 AHUs, two serving the south half, two serving the north half and one serving the south tenant space (above the tenant space on the first floor).



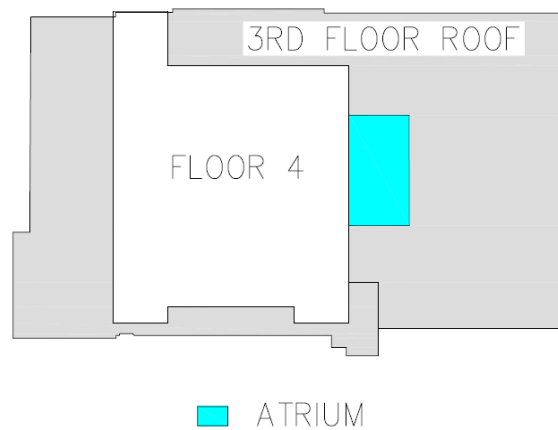
One AHU serves the entire **fourth floor**.



The **fifth floor** has 2 AHUs, one serving the east half and one serving the west half.



A new architectural feature in the building is the **three story atrium** between floors 1 and 3. This space is served by AHU 4 on each floor (1, 2, and 3). It receives 15,000 CFM in total from these three air handling units.



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A summary of the air handling unit schedule can be found below:

AHU Schedule					
AHU	Zone Served	SA (CFM)	OA (CFM)	Area (SF)	Occupancy (people)
1.1	s mer	28000	2800	24000	100
1.2	s mer	28000	2800	24000	100
1.3	n mer	28000	2800	25000	100
1.4	n mer	28000	2800	25000	100
1.5	tenant	28000	2800	27500	100
<i>Floor Total</i>		<i>140000</i>	<i>14000</i>	<i>125500</i>	<i>500</i>
2.1	s mer	31500	3150	29000	100
2.2	s mer	31500	3150	29000	100
2.3	n mer	31500	3150	29000	100
2.4	n mer	31500	3150	29000	100
<i>Floor Total</i>		<i>126000</i>	<i>12600</i>	<i>116000</i>	<i>400</i>
3.1	s mer	35000	3500	29000	100
3.2	s mer	35000	3500	29000	100
3.3	n mer	35000	3500	29000	100
3.4	n mer	35000	3500	29000	100
3.5	tenant	32000	3200	28000	100
<i>Floor Total</i>		<i>172000</i>	<i>17200</i>	<i>144000</i>	<i>500</i>
4.1	mer	35000	3500	50000	160
<i>Floor Total</i>		<i>35000</i>	<i>3500</i>	<i>50000</i>	<i>160</i>
5.1	mer	28000	2800	19250	100
5.2	mer	28000	2800	19250	100
<i>Floor Total</i>		<i>56000</i>	<i>5600</i>	<i>38500</i>	<i>200</i>
		529000	52900	474000	1720

Basis of Analysis: Assumptions

Occupancy Levels

Because this project was a "Shell and Core Renovation," the design team did not base building load calculations on specific architectural floor layouts. They based supply airflow on total area of each floor and solar loads using Trane's Trace program. Outdoor airflow design was based on maximum occupancy level which was assumed to be about 2700 people for the entire building. Occupancy breakdown per floor was assumed by using the architectural plans provided after shell and core renovations were designed: 500 people on floor 1, 400 people on floor 2, 500 people on floor 3, 160 people on floor 4 and 5.

Space Utilization

These architectural floorplan layouts were used to approximate the use of the space in the building. Because Philadelphia is using this facility as its School District Administration Headquarters, most of the space is used as open office with some perimeter private offices and conference rooms.

Short Term Conditions

The building is used during normal working office hours, approximately 8:00am to 5:00pm. Most office space will be occupied during that entire time, however, conference rooms will be used for only a portion of the day. This is considered for when designing for outdoor air quantity supplied to the space.

Diversity

Diversity in the entire building is assumed to be 1.0 except for conference spaces where diversity is considered by the time modified factor explained above.

Method of Analysis: Two Parts

I broke my analysis into two parts:

I. Overall Air Handling Unit Analysis:

Each air handling unit serves approximately one quarter of the space on each floor from floors 1 through 3. Using the occupancy level and area assumed by the engineer, the required outdoor air intake was calculated using the Ventilation Rate Procedure from ASHRAE Standard 62.1.

II. Architectural Floorplan Layout Analysis:

The architectural plans were used to find out if there would be enough outdoor air for the spaces once the building has been retrofitted. Because the fit-out occurred after the design of the mechanical building system, OA quantity may not comply with Standard 62.1.

Method of Analysis: Calculation Procedure

Part I: Compare required Outdoor Air to Outdoor Air provided by each air handler.

1. Assign **Zone Area (A_z)** for each air handler by that which was assigned by the engineer.
2. **Zone Population (P_z)** was assumed using the engineers' assumption of 2700 people in the entire building and floor layouts provided by the architect.
3. The **Outdoor Air Per Person (R_p)** was found using Table 6-1.
4. The **Outdoor Air Per Unit Area (R_a)** was found using Table 6-1.
5. **Breathing Zone Outdoor Airflow** was found using the following equation:

$$V_{bz} = R_p \times P_z + R_a \times A_z$$

6. **Zone Air Distribution Effectiveness (E_z)** was assumed to be 0.8 (by Table 6-2).
7. **Zone Outdoor Airflow** was calculated using the following equation:

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

8. **Zone Primary Airflow (V_{pz})** was found using the engineers' load calculations per AHU.
9. **Zone Primary Outdoor Air Fraction (Z_p)** was calculated using the following equation:

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

10. **System Ventilation Efficiency (E_v)** was found using Table 6-3.
11. **Outdoor Air Intake Flow (V_{ot})** was calculated using the following equation:

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

Method of Analysis: Calculation Procedure

Part II

1. *Zone designations* were inferred using mechanical and architectural floorplans provided by the project engineers and architect.
2. The **Floor Area** per space (A_z) was found using the architectural floorplans.
3. **Zone Population** (P_z) was assumed using the engineers' assumption of 2700 people in the entire building and floor layouts provided by the architect.
4. For necessary spaces, such as conference rooms, a *modified zone population* (P_{zm}) was used by calculating the modified time the space is occupied.
5. The **Outdoor Air Per Person** (R_p) was found using Table 6-2.
6. The **Outdoor Air Per Unit Area** (R_a) was found using Table 6-1.
7. **Breathing Zone Outdoor Airflow** was found using the following equation:

$$V_{bz} = R_p \times P_z + R_a \times A_z$$

This was done for the *design occupancy* (V_{bz}) and the *modified occupancy* (V_{bzm}).

8. **Zone Air Distribution Effectiveness** (E_z) was assumed to be 0.8 (by Table 6-2).
9. **Zone Outdoor Airflow** was calculated using the following equation:

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

10. By using the engineers' 10% outdoor air design **Zone Primary Airflow** (V_{pz}) was found by multiplying V_{oz} by 10.
11. **Zone Primary Outdoor Air Fraction** was calculated using the following equation:

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

12. **System Ventilation Efficiency** (E_v) was found using Table 6-3.
13. **Outdoor Air Intake Flow** (V_{ot}) was calculated by dividing the total **Zone Outdoor Airflow** by the **System Ventilation Efficiency**. See the following equation:

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

14. Comparing the calculated required total Outdoor Air and Supply Air to the actual Outdoor Air and Supply Air provided by the air handler will conclude if there is enough air to supply 10% outdoor air to spaces laid out by the architect for the fit-out.

Ventilation Rate Procedure vs. Indoor Air Quality Procedure

Indoor Air Quality (IAQ) Procedure is a performance based method for ensuring acceptable IAQ in a building. Monitoring contaminant levels and matching ventilation to suit ventilation needs is how this is done. The building system can monitor contaminant levels and adjust outdoor air ventilation based on the levels.

Ventilation Rate Procedure is a prescriptive method for maintaining IAQ in buildings. This rate is based on occupancy, area, and other special cases. Ventilations rates can remain constant at design value or be varied based on varying occupancy or CO₂ based estimation. This method is relatively simple and commonly used to establish ventilation rates to achieve acceptable IAQ.

Because Indoor Air Quality Procedure is performance based is superior to Ventilation Rate Procedure. However for most building applications results of both methods are almost identical. Since there are such close similarities in results of both procedures, Ventilation Rate is more practical because its simplicity minimized the chance of error.

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Conclusion of Analysis: Summary

Part I

Comparing the outdoor air required (as a function of the assumed occupancy and the area of each space designated to an air handler) to the outdoor air provided by the system proved that all but one air handler provides more than enough outside ventilation air. Most outdoor air required as a percentage of the air supplied by the air handler was calculated to be between 8% and 9% as can be seen in the following adjusted AHU schedule.

The fourth floor is where the OA percentage is not enough. This is because ASHRAE Standard 62.1 was used before Addendum N was added. The assumed number of people in the space is 160 by taking 3500 CFM divided by 20 CFM / person (an assumption by the engineer). The noncompliance is not due to any fault of the design team.

AHU Summary											
Equation Designation	Zone	Space	Occupancy Type	Zone Population	Floor Area	Zone Outdoor Airflow	Zone Primary Airflow (Minimum Design Flow Rate)	Zone Primary Outdoor Air Fraction	Outdoor Air Intake Flow Required	Outdoor Air Supplied	Complies with Std 62.1?
Units				P _z	A _z	$V_{oz} = V_{bzm} / E_z$	V _{pz}	Z _p = V _{oz} /V _{pz}	V _{ot} = V _{ou} / E _v		
				people	ft^2	cfm	cfm		cfm	cfm	
AHU1.1	1	123	open office	100.0	24000.0	2425.0	28000.0	0.09	2425.0	2800.0	Yes
AHU1.2	1	123	open office	100.0	24000.0	2425.0	28000.0	0.09	2425.0	2800.0	Yes
AHU1.3	1	104	open office	100.0	25000.0	2500.0	28000.0	0.09	2500.0	2800.0	Yes
AHU1.4	1	104	open office	100.0	25000.0	2500.0	28000.0	0.09	2500.0	2800.0	Yes
AHU1.5	1	119	open office	100.0	27500.0	2687.5	28000.0	0.10	2687.5	2800.0	Yes
AHU2.1	1	219	open office	100.0	29000.0	2800.0	31500.0	0.09	2800.0	3150.0	Yes
AHU2.2	1	219	open office	100.0	29000.0	2800.0	31500.0	0.09	2800.0	3150.0	Yes
AHU2.3	1	204	open office	100.0	29000.0	2800.0	31500.0	0.09	2800.0	3150.0	Yes
AHU2.4	1	204	open office	100.0	29000.0	2800.0	31500.0	0.09	2800.0	3150.0	Yes
AHU3.1	1	319	open office	100.0	29000.0	2800.0	35000.0	0.08	2800.0	3500.0	Yes
AHU3.2	1	319	open office	100.0	29000.0	2800.0	35000.0	0.08	2800.0	3500.0	Yes
AHU3.3	1	304	open office	100.0	29000.0	2800.0	35000.0	0.08	2800.0	3500.0	Yes
AHU3.4	1	304	open office	100.0	29000.0	2800.0	35000.0	0.08	2800.0	3500.0	Yes
AHU3.5	1	314	open office	100.0	28000.0	2725.0	32000.0	0.09	2725.0	3200.0	Yes
AHU4.1	1	404	open office	160.0	50000.0	4750.0	35000.0	0.14	4750.0	3500.0	No
AHU5.1	1	504	open office	100.0	19250.0	2068.8	28000.0	0.07	2068.8	2800.0	Yes
AHU5.2	1	504	open office	100.0	19250.0	2068.8	28000.0	0.07	2068.8	2800.0	Yes

As can be seen by this chart, V_{oz} and V_{ot} are equal because the System Ventilation Efficiency (E_v) turned out to be 1.0 for all AHUs. E_v has a value of 1.0 when Z_p (Zone Primary Outdoor Air Fraction) is between 0 and 0.15.

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Conclusion of Analysis: Summary

Part II

Although the results of Part II are not necessary for compliance, the By using space layouts from the architect to find out if 10% outside air can be supplied to individual spaces, it can be seen from the following summary chart that even after space is laid out, 10% outdoor air can be supplied to all but one floor.

The fourth floor does not comply but because the outdoor air intake was calculated before Addendum N was added to Standard 62.1 it is not a fault of the design team.

AHU Summary										
	Zone	Space	Zone Population	Floor Area	Zone Outdoor Airflow	Zone Primary Airflow (Minimum Design Flow Rate)	Zone Primary Outdoor Air Fraction	Outdoor Air Intake Flow Required	Outdoor Air Supplied	Complies with Std 62.1?
Equation Designation			P_z	A_z	$V_{oz} = V_{bzm}/E_z$	V_{pz}	$Z_p = V_{oz}/V_{pz}$	$V_{ot} = V_{ou}/E_v$		
Units			people	ft ²	cfm	cfm		cfm	cfm	
AHU1.1	1	123	100.0	24000.0	2425.0	28000.0	0.09	2113.4	2800.0	Yes
AHU1.2	1	123	100.0	24000.0	2425.0	28000.0	0.09	2062.3	2800.0	Yes
AHU1.3	1	104	100.0	25000.0	2500.0	28000.0	0.09	2213.5	2800.0	Yes
AHU1.4	1	104	100.0	25000.0	2500.0	28000.0	0.09	2598.8	2800.0	Yes
AHU1.5	1	119	100.0	27500.0	2687.5	28000.0	0.10	2687.5	2800.0	Yes
AHU2.1	1	219	100.0	29000.0	2800.0	31500.0	0.09	2690.0	3150.0	Yes
AHU2.2	1	219	100.0	29000.0	2800.0	31500.0	0.09	2467.5	3150.0	Yes
AHU2.3	1	204	100.0	29000.0	2800.0	31500.0	0.09	2700.1	3150.0	Yes
AHU2.4	1	204	100.0	29000.0	2800.0	31500.0	0.09	3137.2	3150.0	Yes
AHU3.1	1	319	100.0	29000.0	2800.0	35000.0	0.08	2690.0	3500.0	Yes
AHU3.2	1	319	100.0	29000.0	2800.0	35000.0	0.08	2467.5	3500.0	Yes
AHU3.3	1	304	100.0	29000.0	2800.0	35000.0	0.08	2700.1	3500.0	Yes
AHU3.4	1	304	100.0	29000.0	2800.0	35000.0	0.08	3137.2	3500.0	Yes
AHU3.5	1	314	100.0	28000.0	2725.0	32000.0	0.09	2725.0	3200.0	Yes
AHU4.1	1	404	160.0	50000.0	4750.0	35000.0	0.14	4513.6	3500.0	No
AHU5.1	1	504	100.0	19250.0	2068.8	28000.0	0.07	1831.0	2800.0	Yes
AHU5.2	1	504	100.0	19250.0	2068.8	28000.0	0.07	1967.5	2800.0	Yes

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Extra

By following CannonDesign's OA rate (20 CFM/person), the following chart has been provided to show that all actual supplied outdoor air by each air handling unit is greater than what was designed for, leaving more than enough room for growth.

AHU Summary									
Equation Designation	Zone	Space	Occupancy Type	Zone Population	Design OA 20CFM/person	Zone Primary Airflow (Minimum Design Flow Rate)	Outdoor Air Supplied	Zone Primary Outdoor Air Fraction	% Extra OA > Design
				P_z	$V_{ot} = V_{ou}/E_v$	V_{pz}		$Z_p = V_{oz}/V_{pz}$	
Units				people	cfm	cfm	cfm		%
AHU1.1	1	123	open office	100.0	2000.0	28000.0	2800.0	0.10	40.0
AHU1.2	1	123	open office	100.0	2000.0	28000.0	2800.0	0.10	40.0
AHU1.3	1	104	open office	100.0	2000.0	28000.0	2800.0	0.10	40.0
AHU1.4	1	104	open office	100.0	2000.0	28000.0	2800.0	0.10	40.0
AHU1.5	1	119	open office	100.0	2000.0	28000.0	2800.0	0.10	40.0
AHU2.1	1	219	open office	100.0	2000.0	31500.0	3150.0	0.10	57.5
AHU2.2	1	219	open office	100.0	2000.0	31500.0	3150.0	0.10	57.5
AHU2.3	1	204	open office	100.0	2000.0	31500.0	3150.0	0.10	57.5
AHU2.4	1	204	open office	100.0	2000.0	31500.0	3150.0	0.10	57.5
AHU3.1	1	319	open office	100.0	2000.0	35000.0	3500.0	0.10	75.0
AHU3.2	1	319	open office	100.0	2000.0	35000.0	3500.0	0.10	75.0
AHU3.3	1	304	open office	100.0	2000.0	35000.0	3500.0	0.10	75.0
AHU3.4	1	304	open office	100.0	2000.0	35000.0	3500.0	0.10	75.0
AHU3.5	1	314	open office	100.0	2000.0	32000.0	3200.0	0.10	60.0
AHU4.1	1	404	open office	160.0	3200.0	35000.0	3500.0	0.10	9.4
AHU5.1	1	504	open office	100.0	2000.0	28000.0	2800.0	0.10	40.0
AHU5.2	1	504	open office	100.0	2000.0	28000.0	2800.0	0.10	40.0

References

ASHRAE Standard 62.1-2001

ASHRAE Standard 62.1-2001 Addendum N

The Pennsylvania State University Department of Architectural Engineering Faculty Advisors

CannonDesign, Documents for Philadelphia School District Administration Headquarters.

Hooper Shiles Architects, Documents and rendering for Philadelphia School District Administration Headquarters.

Past Penn State AE Thesis Technical Reports

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Appendix A

AHU1.1																		
Table Where Found Equation Designation Units	Zone	Space	Occupancy Type	Modified Time Occupied	Zone Population		Outdoor Airflow Rate Per Person 6-1 Rp	Floor Area Az ft ²	Volume v ft ³	Outdoor Airflow Rate Per Unit Area 6-1 Ra cfm/ft ²	Breathing Zone Outdoor Airflow		Zone Air Distribution Effectiveness 6-2 Ez	Zone Outdoor Airflow Voz = Vozm/Ez cfm	Zone Primary Airflow (Minimum Design Flow Rate) Vpz cfm	Zone Primary Outdoor Air Fraction Zp = Voz/Vpz	System Ventilation Efficiency 6-3 Ev	Outdoor Air Intake Flow Vot = Vow/Ev cfm
					Zone	Modified					Zone	Modified						
Space Total	1	123	open office		37.0	37.0	5.0	13000.0	130000.0	0.06	965.0	965.0	0.8	1206.3	12062.5	0.10		
Space Total	2	102	e lobby		25.0	25.0	5.0	5000.0	50000.0	0.06	425.0	425.0	0.8	531.3	5312.5	0.10		
Space Total	3	123	ext private office		14.0	14.0	5.0	1800.0	18000.0	0.06	178.0	178.0	0.8	222.5	2225.0	0.10		
Space Total	4	123	hallway		0.0	0.0	5.0	800.0	8000.0	0.06	48.0	48.0	0.8	60.0	600.0	0.10		
	5	123	conference	2.2	12.0	5.6	5.0	350.0	3500.0	0.06	81.0	48.8	0.8	61.0	609.6	0.10		
	5	123	conference	2.2	12.0	5.6	5.0	350.0	3500.0	0.06	81.0	48.8	0.8	61.0	609.6	0.10		
Space Total					24.0			700.0						121.9	1219.3			
Space Total	6	101	electric		0.0	0.0	5.0	420.0	4200.0	0.06	25.2	25.2	0.8	31.5	315.0	0.10		
					100.0			20920.0						2113.4	21134.3	0.10	1.0	2113.4

AHU1.2																		
Table Where Found Equation Designation Units	Zone	Space	Occupancy Type	Modified Time Occupied	Zone Population		Outdoor Airflow Rate Per Person 6-1 Rp	Floor Area Az ft ²	Volume v ft ³	Outdoor Airflow Rate Per Unit Area 6-1 Ra cfm/ft ²	Breathing Zone Outdoor Airflow		Zone Air Distribution Effectiveness 6-2 Ez	Zone Outdoor Airflow Voz = Vozm/Ez cfm	Zone Primary Airflow (Minimum Design Flow Rate) Vpz cfm	Zone Primary Outdoor Air Fraction Zp = Voz/Vpz	System Ventilation Efficiency 6-3 Ev	Outdoor Air Intake Flow Vot = Vow/Ev cfm
					Zone	Modified					Zone	Modified						
Space Total	1	123	open office		50.0	50.0	5.0	17000.0	170000.0	0.06	1270.0	1270.0	0.8	1587.5	15875.0	0.10		
Space Total	2	123	w lobby		20.0	20.0	5.0	5000.0	50000.0	0.06	400.0	400.0	0.8	500.0	5000.0	0.10		
Space Total	3	123	int private office		5.0	5.0	5.0	900.0	9000.0	0.06	79.0	79.0	0.8	98.8	987.5	0.10		
Space Total	4	123	ext private office		15.0	15.0	5.0	2400.0	24000.0	0.06	219.0	219.0	0.8	273.8	2737.5	0.10		
Space Total	5	123	conference	2.0	10.0	5.0	5.0	264.0	2640.0	0.06	65.8	40.8	0.8	51.0	509.7	0.10		
Space Total	6	111	electric		0.0	0.0	5.0	268.0	2680.0	0.06	16.1	16.1	0.8	20.1	350.0	0.06		
					100.0			25832.0						2531.1	25459.7	0.10	1.0	2531.1

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Appendix B

AHU1.3																		
Table Where Found	Zone	Space	Occupancy Type	Modified Time Occupied	Zone Population		Outdoor Airflow Rate Per Person	Floor Area	Volume	Outdoor Airflow Rate Per Unit Area	Breathing Zone Outdoor Airflow		Zone Air Distribution Effectiveness	Zone Outdoor Airflow	Zone Primary Airflow (Minimum Design Flow Rate)	Zone Primary Outdoor Air Fraction	System Ventilation Efficiency	Outdoor Air Intake Flow
					6-1	Modified					6-1	6-2						
Equation Designation					P _z	P _{zm}	R _p	A _z	v	R _a	V _{bz}	V _{bz,m}	E _z	V _{oz} = V _{bz,m} /E _z	V _{pz}	Z _p = V _{oz} /V _{pz}	E _v	V _{ot} = V _{oa} /E _v
Units				hr	people	people	cfm/person	ft ²	ft ³	cfm/ft ²	cfm	cfm		cfm	cfm			cfm
Space Total	1	104	open office		22.0	22.0	5.0	13500.0	135000.0	0.06	920.0	920.0	0.8	1150.0	11500.0	0.10		
Space Total	2	104	int private office		10.0	10.0	5.0	1450.0	14500.0	0.06	137.0	137.0	0.8	171.3	1712.5	0.10		
Space Total	3	104	ext private office		22.0	22.0	5.0	4450.0	44500.0	0.06	377.0	377.0	0.8	471.3	4712.5	0.10		
Space Total	4	104	hallway		0.0	0.0	5.0	1600.0	16000.0	0.06	96.0	96.0	0.8	120.0	1200.0	0.10		
Space Total	5	104	conference	2.3	30.0	12.8	5.0	975.0	9750.0	0.06	208.5	122.7	0.8	153.3	1533.2	0.10		
Space Total	6	104	copy/fax		2.0	2.0	5.0	475.0	4750.0	0.06	38.5	38.5	0.8	48.1	481.3	0.10		
Space Total	7	104	kitchen		4.0	4.0	5.0	342.0	3420.0	0.06	40.5	40.5	0.8	50.7	506.5	0.10		
Space Total	8	104	reception		10.0	10.0	5.0	460.0	4600.0	0.06	77.6	77.6	0.8	97.0	970.0	0.10		
					100.0			23252.0						2261.6	22615.9	0.10	1.0	2261.6

AHU1.4																		
Table Where Found	Zone	Space	Occupancy Type	Modified Time Occupied	Zone Population		Outdoor Airflow Rate Per Person	Floor Area	Volume	Outdoor Airflow Rate Per Unit Area	Breathing Zone Outdoor Airflow		Zone Air Distribution Effectiveness	Zone Outdoor Airflow	Zone Primary Airflow (Minimum Design Flow Rate)	Zone Primary Outdoor Air Fraction	System Ventilation Efficiency	Outdoor Air Intake Flow
					6-1	Modified					6-1	6-2						
Equation Designation					P _z	P _{zm}	R _p	A _z	v	R _a	V _{bz}	V _{bz,m}	E _z	V _{oz} = V _{bz,m} /E _z	V _{pz}	Z _p = V _{oz} /V _{pz}	E _v	V _{ot} = V _{oa} /E _v
Units				hr	people	people	cfm/person	ft ²	ft ³	cfm/ft ²	cfm	cfm		cfm	cfm			cfm
Space Total	1	124	atrium		20.0	20.0	11.0	7000.0	70000.0	0.06	640.0	640.0	0.8	800.0	8000.0	0.10		
Space Total	2	104	open office		20.0	20.0	5.0	4000.0	40000.0	0.06	340.0	340.0	0.8	425.0	4250.0	0.10		
Space Total	3	104	int private office		32.0	32.0	5.0	9000.0	90000.0	0.06	700.0	700.0	0.8	875.0	8750.0	0.10		
Space Total	4	104	ext private office		16.0	16.0	5.0	4500.0	45000.0	0.06	350.0	350.0	0.8	437.5	4375.0	0.10		
Space Total	5	104	conference	2.0	12.0	6.1	5.0	310.0	3100.0	0.06	78.6	49.0	0.8	61.3	612.8	0.10		
					100.0			24810.0						2598.8	25987.8	0.10	1.0	2598.8

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Appendix D

AHU2.1																		
Table Where Found Equation Designation Units	Zone	Space	Occupancy Type	Modified Time Occupied	Zone Population		Outdoor Airflow Rate Per Person 6-1 R _p	Floor Area A _z ft ²	Volume v ft ³	Outdoor Airflow Rate Per Unit Area 6-1 R _a cfm/ft ²	Breathing Zone Outdoor Airflow		Zone Air Distribution Effectiveness 6-2 E _z	Zone Outdoor Airflow V _{oz} = V _{ozm} /E _z cfm	Zone Primary Airflow (Minimum Design Flow Rate) V _{pz} cfm	Zone Primary Outdoor Air Fraction Z _p = V _{oz} /V _{pz}	System Ventilation Efficiency 6-3 E _v	Outdoor Air Intake Flow V _{oz} = V _{ozm} /E _v cfm
					Zone P _z people	Modified P _{zm} people					Zone V _{bz} cfm	Modified V _{bzsm} cfm						
Space Total	1	219	open office		67.0	67.0	5.0	24000.0	240000.0	0.06	1775.0	1775.0	0.8	2218.8	22187.5	0.10	2800.0	
Space Total	2	219	int private office		5.0	5.0	5.0	1000.0	10000.0	0.06	85.0	85.0	0.8	106.3	1062.5	0.10	2800.0	
Space Total	4	219	ext private office		16.0	16.0	5.0	2300.0	23000.0	0.06	218.0	218.0	0.8	272.5	2725.0	0.10	2800.0	
Space Total	6	219	hallway		0.0	0.0	5.0	800.0	8000.0	0.06	48.0	48.0	0.8	60.0	600.0	0.10	2800.0	
Space Total	7	219	conference	2.2	12.0	5.6	5.0	350.0	3500.0	0.06	81.0	48.8	0.8	61.0	609.6	0.10	2800.0	
Space Total	12	219	electric		0.0	0.0	5.0	420.0	4200.0	0.06	25.2	25.2	0.8	31.5	315.0	0.10	2800.0	
					100.0			28870.0						2750.0	27499.6	0.10	1.0	2750.0

AHU2.2																		
Table Where Found Equation Designation Units	Zone	Space	Occupancy Type	Modified Time Occupied	Zone Population		Outdoor Airflow Rate Per Person 6-1 R _p	Floor Area A _z ft ²	Volume v ft ³	Outdoor Airflow Rate Per Unit Area 6-1 R _a cfm/ft ²	Breathing Zone Outdoor Airflow		Zone Air Distribution Effectiveness 6-2 E _z	Zone Outdoor Airflow V _{oz} = V _{ozm} /E _z cfm	Zone Primary Airflow (Minimum Design Flow Rate) V _{pz} cfm	Zone Primary Outdoor Air Fraction Z _p = V _{oz} /V _{pz}	System Ventilation Efficiency 6-3 E _v	Outdoor Air Intake Flow V _{oz} = V _{ozm} /E _v cfm
					Zone P _z people	Modified P _{zm} people					Zone V _{bz} cfm	Modified V _{bzsm} cfm						
Space Total	1	219	open office		65.0	65.0	5.0	19000.0	190000.0	0.06	1465.0	1465.0	0.8	1831.3	18312.5	0.10		
Space Total	2	219	int private office		5.0	5.0	5.0	900.0	9000.0	0.06	79.0	79.0	0.8	98.8	987.5	0.10		
Space Total	25	219	ext private office		12.0	12.0	5.0	2400.0	24000.0	0.06	204.0	204.0	0.8	255.0	2550.0	0.10		
Space Total	27	202	east lobby		8.0	8.0	5.0	2000.0	20000.0	0.06	160.0	160.0	0.8	200.0	2000.0	0.10		
Space Total	3	219	conference	2.0	10.0	5.0	5.0	264.0	2640.0	0.06	65.8	40.8	0.8	51.0	509.7	0.10		
Space Total	29	201	electric		0.0	0.0		420.0	4200.0	0.06	25.2	25.2	0.8	31.5	350.0	0.09		
					100.0			24984.0						2467.5	24709.7	0.10	1.0	2467.5

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Appendix E

AHU2.3																		
Table Where Found Equation Designation Units	Zone	Space	Occupancy Type	Modified Time Occupied	Zone Population		Outdoor Airflow Rate	Floor Area	Volume	Outdoor Airflow Rate	Breathing Zone Outdoor Airflow		Zone Air Distribution Effectiveness	Zone Outdoor Airflow	Zone Primary Airflow (Minimum Design Flow Rate)	Zone Primary Outdoor Air Fraction	System Ventilation Efficiency	Outdoor Air Intake Flow
					Zone	Modified	6-1 R _p			6-1 R _a	Zone	Modified	6-2 E _z	Zone	Modified	6-3 E _v		
				hr	P _z people	P _{zm} people	R _p cfm/person	A _z ft ²	v ft ³	R _a cfm/ft ²	V _{bz} cfm	V _{bzm} cfm	E _z	V _{oz} = V _{bzm} /E _z cfm	V _{pz} cfm	Z _p = V _{oz} /V _{pz}	E _v	V _{ot} = V _{oz} /E _v cfm
Space Total	1	204	open office		22.0	22.0	5.0	19160.0	191600.0	0.06	1259.6	1259.6	0.8	1574.5	15745.0	0.10		
Space Total	2	204	int private office		10.0	10.0	5.0	1550.0	15500.0	0.06	143.0	143.0	0.8	178.8	1787.5	0.10		
Space Total	3	204	ext private office		22.0	22.0	5.0	4950.0	49500.0	0.06	407.0	407.0	0.8	508.8	5087.5	0.10		
Space Total	4	204	hallway		0.0	0.0	5.0	1800.0	18000.0	0.06	108.0	108.0	0.8	135.0	1350.0	0.10		
Space Total	5	204	conference	2.5	30.0	12.0	5.0	1075.0	10750.0	0.06	214.5	124.4	0.8	155.5	1554.5	0.10		
Space Total	6	204	copy/fax		2.0	2.0	5.0	475.0	4750.0	0.06	38.5	38.5	0.8	48.1	481.3	0.10		
Space Total	7	204	kitchen		4.0	4.0	5.0	342.0	3420.0	0.06	40.5	40.5	0.8	50.7	506.5	0.10		
Space Total	8	204	reception		10.0	10.0	5.0	460.0	4600.0	0.06	77.6	77.6	0.8	97.0	970.0	0.10		
					100.0			29812.0						2748.2	27482.3	0.10	1.0	2748.2

AHU2.4																		
Table Where Found Equation Designation Units	Zone	Space	Occupancy Type	Modified Time Occupied	Zone Population		Outdoor Airflow Rate	Floor Area	Volume	Outdoor Airflow Rate	Breathing Zone Outdoor Airflow		Zone Air Distribution Effectiveness	Zone Outdoor Airflow	Zone Primary Airflow (Minimum Design Flow Rate)	Zone Primary Outdoor Air Fraction	System Ventilation Efficiency	Outdoor Air Intake Flow
					Zone	Modified	6-1 R _p			6-1 R _a	Zone	Modified	6-2 E _z	Zone	Modified	6-3 E _v		
				hr	P _z people	P _{zm} people	R _p cfm/person	A _z ft ²	v ft ³	R _a cfm/ft ²	V _{bz} cfm	V _{bzm} cfm	E _z	V _{oz} = V _{bzm} /E _z cfm	V _{pz} cfm	Z _p = V _{oz} /V _{pz}	E _v	V _{ot} = V _{oz} /E _v cfm
Space Total	1	204	atrium		20.0	20.0	11.0	7000.0	70000.0	0.06	640.0	640.0	0.8	800.0	8000.0	0.10		
Space Total	2	204	open office		25.0	25.0	5.0	10250.0	102500.0	0.06	740.0	740.0	0.8	925.0	9250.0	0.10		
Space Total	3	204.0	int private office		30.0	30.0	5.0	9500.0	95000.0	0.06	720.0	720.0	0.8	900.0	9000.0	0.10		
Space Total	4	204.0	ext private office		15.0	15.0	5.0	4900.0	49000.0	0.06	369.0	369.0	0.8	461.3	4612.5	0.10		
Space Total	5	204	conference	2.3	10.0	4.4	5.0	310.0	3100.0	0.06	68.6	40.7	0.8	50.9	509.1	0.10		
					100.0			31960.0						3137.2	31371.6	0.10	1.0	3137.2

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Appendix F

AHU3.1																		
Table Where Found	Zone	Space	Occupancy Type	Modified Time Occupied	Zone Population		Outdoor Airflow Rate Per Person	Floor Area	Volume	Outdoor Airflow Rate Per Unit Area	Breathing Zone Outdoor Airflow		Zone Air Distribution Effectiveness	Zone Outdoor Airflow	Zone Primary Airflow (Minimum Design Flow Rate)	Zone Primary Outdoor Air Fraction	System Ventilation Efficiency	Outdoor Air Intake Flow
					Zone	Modified					Zone	Modified						
Equation Designation					Pz	Pzm	Rp	Az	v	6-1	6-1	6-2	Ez	Voz = Vozm/Ez	Vpz	Zp = Voz/Vpz	6-3	Vot = Vot/Ev
Units				hr	people	people	cfm/person	ft²	ft³	cfm/ft²	cfm	cfm		cfm	cfm			cfm
Space Total	1	219	open office		67.0	67.0	5.0	24000.0	240000.0	0.06	1775.0	1775.0	0.8	2218.8	22187.5	0.10	2800.0	
Space Total	2	219	int private office		5.0	5.0	5.0	1000.0	10000.0	0.06	85.0	85.0	0.8	106.3	1062.5	0.10	2800.0	
Space Total	3	219	ext private office		16.0	16.0	5.0	2300.0	23000.0	0.06	218.0	218.0	0.8	272.5	2725.0	0.10	2800.0	
Space Total	4	219	hallway		0.0	0.0	5.0	800.0	8000.0	0.06	48.0	48.0	0.8	60.0	600.0	0.10	2800.0	
Space Total	5	219	conference	2.2	12.0	5.6	5.0	350.0	3500.0	0.06	81.0	48.8	0.8	61.0	609.6	0.10	2800.0	
Space Total	6	219	electric		0.0	0.0	5.0	420.0	4200.0	0.06	25.2	25.2	0.8	31.5	315.0	0.10	2800.0	
					100.0			28870.0						2750.0	27499.6	0.10	1.0	2750.0

Table Where Found	Zone	Space	Occupancy Type	Modified Time Occupied	Zone Population		Outdoor Airflow Rate Per Person	Floor Area	Volume	Outdoor Airflow Rate Per Unit Area	Breathing Zone Outdoor Airflow		Zone Air Distribution Effectiveness	Zone Outdoor Airflow	Zone Primary Airflow (Minimum Design Flow Rate)	Zone Primary Outdoor Air Fraction	System Ventilation Efficiency	Outdoor Air Intake Flow
					Zone	Modified					Zone	Modified						
Equation Designation					Pz	Pzm	Rp	Az	v	6-1	6-1	6-2	Ez	Voz = Vozm/Ez	Vpz	Zp = Voz/Vpz	6-3	Vot = Vot/Ev
Units				hr	people	people	cfm/person	ft²	ft³	cfm/ft²	cfm	cfm		cfm	cfm			cfm
Space Total	1	319	open office		65.0	65.0	5.0	19000.0	190000.0	0.06	1465.0	1465.0	0.8	1831.3	18312.5	0.10		
Space Total	2	319	int private office		5.0	5.0	5.0	900.0	9000.0	0.06	79.0	79.0	0.8	98.8	987.5	0.10		
Space Total	3	319	ext private office		12.0	12.0	5.0	2400.0	24000.0	0.06	204.0	204.0	0.8	255.0	2550.0	0.10		
Space Total	4	302	east lobby		8.0	8.0	5.0	2000.0	20000.0	0.06	160.0	160.0	0.8	200.0	2000.0	0.10		
Space Total	5	319	conference	2.0	10.0	5.0	5.0	264.0	2640.0	0.06	65.8	40.8	0.8	51.0	509.7	0.10		
Space Total	6	301	electric		0.0	0.0		420.0	4200.0	0.06	25.2	25.2	0.8	31.5	350.0	0.09		
					100.0			24984.0						2467.5	24709.7	0.10	1.0	2467.5

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Appendix G

AHU3.3																		
Table Where Found	Zone	Space	Occupancy Type	Modified Time Occupied	Zone Population		Outdoor Airflow Rate Per Person	Floor Area	Volume	Outdoor Airflow Rate Per Unit Area	Breathing Zone Outdoor Airflow		Zone Air Distribution Effectiveness	Zone Outdoor Airflow	Zone Primary Airflow (Minimum Design Flow Rate)	Zone Primary Outdoor Air Fraction	System Ventilation Efficiency	Outdoor Air Intake Flow
					Zone	Modified					Zone	Modified						
Equation Designation					Pz	Pzm	Rp	Az	v	Ra	Vbz	Vbz _m	Ez	Voz = Vbz _m /Ez	Vpz	Zp = Voz/Vpz	Ev	Vot = Vot _{in} /Ev
Units				hr	people	people	cfm/person	ft ²	ft ³	cfm/ft ²	cfm	cfm		cfm	cfm			cfm
Space Total	1	304	open office		22.0	22.0	5.0	19160.0	191600.0	0.06	1259.6	1259.6	0.8	1574.5	15745.0	0.10		
Space Total	2	304	int private office		10.0	10.0	5.0	1550.0	15500.0	0.06	143.0	143.0	0.8	178.8	1787.5	0.10		
Space Total	3	304	ext private office		22.0	22.0	5.0	4950.0	49500.0	0.06	407.0	407.0	0.8	508.8	5087.5	0.10		
Space Total	4	304	hallway		0.0	0.0	5.0	1800.0	18000.0	0.06	108.0	108.0	0.8	135.0	1350.0	0.10		
Space Total	5	304	conference	2.5	30.0	12.0	5.0	1075.0	10750.0	0.06	214.5	124.4	0.8	155.5	1554.5	0.10		
Space Total	6	304	copy/fax		2.0	2.0	5.0	475.0	4750.0	0.06	38.5	38.5	0.8	48.1	481.3	0.10		
Space Total	7	304	kitchen		4.0	4.0	5.0	342.0	3420.0	0.06	40.5	40.5	0.8	50.7	506.5	0.10		
Space Total	8	304	reception		10.0	10.0	5.0	460.0	4600.0	0.06	77.6	77.6	0.8	97.0	970.0	0.10		
					100.0			29812.0						2748.2	27482.3	0.10	1.0	2748.2

AHU3.4																		
Table Where Found	Zone	Space	Occupancy Type	Modified Time Occupied	Zone Population		Outdoor Airflow Rate Per Person	Floor Area	Volume	Outdoor Airflow Rate Per Unit Area	Breathing Zone Outdoor Airflow		Zone Air Distribution Effectiveness	Zone Outdoor Airflow	Zone Primary Airflow (Minimum Design Flow Rate)	Zone Primary Outdoor Air Fraction	System Ventilation Efficiency	Outdoor Air Intake Flow
					Zone	Modified					Zone	Modified						
Equation Designation					Pz	Pzm	Rp	Az	v	Ra	Vbz	Vbz _m	Ez	Voz = Vbz _m /Ez	Vpz	Zp = Voz/Vpz	Ev	Vot = Vot _{in} /Ev
Units				hr	people	people	cfm/person	ft ²	ft ³	cfm/ft ²	cfm	cfm		cfm	cfm			cfm
Space Total	1	304	atrium		20.0	20.0	11.0	7000.0	70000.0	0.06	640.0	640.0	0.8	800.0	8000.0	0.10		
Space Total	2	304	open office		25.0	25.0	5.0	10250.0	102500.0	0.06	740.0	740.0	0.8	925.0	9250.0	0.10		
Space Total	3	304	int private office		30.0	30.0	5.0	9500.0	95000.0	0.06	720.0	720.0	0.8	900.0	9000.0	0.10		
Space Total	4	304	ext private office		15.0	15.0	5.0	4900.0	49000.0	0.06	369.0	369.0	0.8	461.3	4612.5	0.10		
Space Total	5	304	conference	2.3	10.0	4.4	5.0	310.0	3100.0	0.06	68.6	40.7	0.8	50.9	509.1	0.10		
					100.0			31960.0						3137.2	31371.6	0.10	1.0	3137.2

