The Palestra Building
London, England

Architectural Renderings compliments of Alsop Architects

Ventilation Report

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I. Executive Summary

The purpose of this report is to use ASHRAE Standard 62-2001 regarding building ventilation requirements to verify the size and proportions of outdoor air provided to the Palestra Building are appropriate. The Palestra Building was designed to meet all British Codes set forth in the Building Regulations 2000 issued by the Office of the Deputy Prime Minister. Therefore in addition to meeting the minimum ASHRAE standards, this report also investigates the differences between Standard 62-2001 from ASHRAE and Approved Document F from the British Standards.

The Palestra Building is currently the largest speculative office building under construction in London, England at over 37,000m^2. Located across the street from the Southwark tube station, and just minutes from the Tate Modern museum as well as Waterloo Station, Palestra was destined to be a high-profile building. The location only enhances the 'quirky' design of the architect, Will Alsop from Alsop Architects.

Because this iconic building is located in such close proximity to the high traffic flow of the Underground as well as the neighboring structures, it was virtually impossible to achieve the necessary levels of high quality outdoor air to meet the natural ventilation requirements. Therefore, the Palestra Building is one of the few offices in London that is vented through a fully mechanical system.

Maximum versatility of the building's spaces was one of the primary design objectives in order to increase revenue and the rent ability of the space. Thus over 31,000 m^2 is open place office space. With the rest of the area accounted for by water closets, corridors, and reception areas. This versatility was designed into all the building's systems, including the ventilation scheme to the office areas. In order to ensure the satisfaction of all future tenants and possible office space layouts, a minimum number of fan coil units have been placed on a grid system allowing for additional units to be strategically placed maximizing personalized comfort. The system's capacity was also sized to allow for this future growth as well as changes in the building's population density.

The system consists of seven Air Handling Units ranging from 1026 L/s (2173.97 cfm) to 18857 L/s (39955.72 cfm). Overall, it was concluded that the while the British Standards had a high population density suggested per unit area, and a higher minimum fresh air supply per occupant, these 'rules of thumbs' are proportional to those listed in Table 6-2 of ASHRAE Std 62-2001. Therefore, the air handling units included in this study comply the ventilation standards set forth in ASHRAE Standard 62-2001 and Approved Document F.

II. Building Data

As stated in the Executive Summary, the Palestra Building is a twelve story office building in central London. Over 31,000m^2 of the 37,000m^2 design is open plan office space, designed for maximum versatility and growth. Therefore, while the ventilation scheme is fairly straight forward, it also had to account for any possible layouts and additions that the future tenants would require including storage and kitchen areas.

There are seven air handling units in the Palestra Building. Two of the air handling units are located in the Basement Plant Room, four on the roof, and one on the Ground Floor servicing all of the office spaces, water closets, plant room, boiler room, and ground level reception/lobby.

Table 1.1 is a breakdown of the spaces and predicted occupancy served by the Air Handling Unit in the Building. These predicted occupancy levels are assumed under good design practices for British Standards. For a more detailed view of the space usage see Appendix A.

Table 1.1 Space and Occupancy Design Loads

Space	Area, m^2	Occupancy	AHU #
Office Space	31606	2202	1,2
Water Closets	1125	0	3,4
Reception	772	129	7
Sprinkler Plant	406	0	5
Boiler Rooms	273	0	6
Corridors	608	0	1,2
TOTAL	**34790**	**2333**	

*NOTE: The total area serviced by the Air Handling Units is less than the Total Building area due to the space exclusions noted in Section III Assumptions for Analysis.

Air Handling Units 1 and 2 are located on the roof and supply air to 16107m^2 of open plan office space disbursed evenly throughout the twelve levels (variable volume). Each AHU maintains a negative pressure of 400 Pa, and includes a heat exchanger in the form of a heat wheel, a cooling coil, a heating coil, a panel filter of grade G4, and a variable frequency drive supply and extract fan.

Air Handling Units 3 and 4 service the building's water closets and are also located in the roof ventilation plant. Unit 3 supplies air to 498m2 of toilets on the west side of the building, and Unit 4 supplies ventilation to 627m2 of toilet space on the east side. These are constant volume systems, and each includes a frost coil, cooling coil, heating coil, as well as supply and extract fans.

Air Handling Units 5 and 6 are located in the basement plant room. Unit 5 services the sprinkler plant and includes only a panel filter of grade G4, a cooling coil, and a heating coil. Unit 6 services the boiler rooms and also includes a panel filter of grade G4, a cooling coil, and a heating coil. Units 5 and 6 were designed to provide adequate smoke clearance to these vital mechanical spaces. Approved Document F requires a minimum of 12 m/s face velocity for ventilation extract in the case of fire. Because Units 5 and 6 do not service occupied spaces, nor do they carry any of the daily load they will be excluded from this study.

Air Handling Unit 7 is located in the Ground Floor mechanical room and solely supplies air to the reception area, 772m2, at a constant volume. This unit contains a heating coil, cooling coil, a panel filter of grade G4, as well as, supply and extract fans.

III. Assumptions for Analysis

- AHU 5 and 6 servicing the Sprinkler Plant and Boiler Rooms are used for smoke clearance. Because Units 5 and 6 do not service occupied spaces, nor do they carry any of the daily load they will be excluded from this study.
- The Predicted Population Density/m2 recommended by CIBSE are almost two times higher than those suggested by ASHRAE. Because the system was designed to British Standards, the same population predictions were used to maintain continuity between the two calculations. However, the differences in the density guidelines will be discussed further in the section V.
- There are several hundred square meters of space on the ground level reserved for use as retail space. However, the entire fit-out for the space including ventilation schemes will be designed to the tenant specifications. Currently there is no tenant and thus no specifications. This retail space will be excluded from the analysis.
- The current design documents only list Flow Rate values for one of the two AHUs servicing the water closets. Flow Rates for the unknown unit, AHU-3, will calculated proportionally to the known unit, AHU-4.
- While there is not enough high quality outdoor available for a naturally ventilated design, it is assumed there is sufficient fresh air available to meet the minimum standards set forth by ASHRAE and the Approved Document F.
- Ventilation Effectiveness (Ez) = 1.0 following ASHRAE standards for ceiling supply of warm air, and ceiling return providing that the warm air is less than 15°F above space temperature and that the supply jet reaches within 4.5 feet of the floor.
- Ventilation for all mechanical shafts, electrical risers, storage provisions (including janitor cupboards), stairwell shafts, and elevator shafts will be excluded from excluded from this study. Air circulation in these areas can be accounted for through the pressurization of adjacent spaces (corridors, lobbies).
- It is assumed that there are no significant sources of contaminations that will need to be account for in the building.

IV. ASHRAE Standard 62 Analysis

ASHRAE Standard 62 describes two different methods to for calculating the minimum amount of outdoor air needed to meet the building's ventilation needs: Indoor Air Quality Procedure (IAQ) and Ventilation Rate Procedure (VRP). This analysis will be completed using the Ventilation Rate Procedure. VRP was chosen over the IAQ method because IAQ is described as a performance-based design approach that requires a great level of knowledge about the concentration levels of contaminates in the building in order to maintain the appropriate levels. This is not information currently available for the Palestra Building.

a. Actual Design OA Flow Rates

Table 4.1 shows the OA Flow Rates provided in the mechanical design scheme following Approved Document F.

Table 4.1 Actual Design Outdoor Air Flow Rate

	Space Served	Scheduled Supply Air (L/s)	Scheduled Max OA (L/s)	Scheduled Min OA (L/s)
AHU - 1	Office Space/Corridors	18857	18857	7457.5
AHU - 2	Office Space/Corridors	18346	18346	7457.5
AHU - 3	Water Closets	2333	2333	1384
AHU - 4	Water Closets	3204	3204	1633
AHU - 7	Reception Area/Lobby	1026	1026	926

b. Determination of OA Flow Rates Required

After gathering all of the design conditions for each of the Air Handling Units included in this study, the calculation of the minimum outdoor air flow rate according to the Ventilation Rate Procedure listed in Standard 62 can be determined. The zones served by each AHU can also be noted in Appendix A.

Step 1: Calculate the *Breathing Zone Outdoor Airflow (Vbz)*

$$Vbz = Rp*Pz + Ra*Az$$

The design outdoor airflow required in the breathing zone of occupiable spaces or zones.

Step 2: Determine the *Zone Air Distribution Effectiveness (Ez)*

Reference Table 6-2 in ASHRAE Std. 62-2001

It was assumed that Ez=1.0 for all spaces in the Palestra Building as noted in section III.

Step 3: Calculate the *Zone Outdoor Airflow (Voz)*

$$Voz = Vbz/Ez$$

The outdoor airflow that must be provided to the zone by the air distribution system.

NOTE: The following steps are followed in accordance with 6.2.5 of ASHRAE Standard 62-2001 for Multiple Zone Recalculating Systems.

Step 4: Calculate the *Primary Outdoor Fraction (Zp)*

$$Zp = Voz/Vpz$$

The ratio of the zone outdoor airflow divided by the expected primary airflow for the zone.

Step 5: Determine the *System Ventilation Efficiency (Ev)*

Reference Table 6-3 in ASHRAE Std. 62-2001.

Step 6: Calculate the *Occupant Diversity (D)*

$$D = Ps/\Sigma_{\text{all zones}} Pz$$

This diversity accounts for variations in occupancy within each zone in a system.

Step 7: Calculate the *Uncorrected Outdoor Air Intake (Vou)*

$$Vou = D*\Sigma_{\text{all zones}} Rp*Pz + \Sigma_{\text{all zones}} Ra*Az$$

This new outdoor air intake value continues to now take into account the population diversity factor.

Step 8: Calculate the *Outdoor Air Intake (Vot)*

$$Vot = Vou/Ev$$

The Outdoor Air Intake is now appropriately calculated for a multi-zone system.

Variable Definitions:

- Az = zone floor area
- Pz = zone population
- Rp = outdoor airflow rate required per person, Table 6-1
- Ra = outdoor airflow rate required per unit area, Table 6-1
- Ez = zone air distribution effectiveness, Table 6-2
- Voz = zone outdoor airflow
- Zp = zone primary outdoor air fraction
- Vpz = zone primary airflow
- Ev = system ventilation efficiency, Table 6-3
- Ps = system population
- Vou = uncorrected outdoor air intake
- Vot = outdoor air intake flow

V. Discussion

a. Results of ASHRAE Std 62 Analysis

The results of the ventilation rate calculations described in section IV are summarized in the tables below as well as Appendixes B-F.

AHU - 1 RESULTS		
Ez	1.00	
D	0.47	
ΣVou	5351.29	
Ev	**0.7**	
Vot (L/s)	**7644.70**	Min OA Intake Needed
ΣVpzm (L/s)	**18977.00**	Supply Air Rate
	40.28%	Percentage Supply Air is OA
Σ Voz (L/s)	**6594.95**	

Air Handling Unit 1 has an uncorrected minimum outdoor airflow of 6594.95 L/s. This minimum value is increased with the system ventilation efficiency of 0.7 determined from Table 6-3 of the ASHRAE 62-2001 standard. The system efficiency could be low due to the large office spaces AHU – 1 serves with variable occupancy levels.

The calculated minimum outdoor airflow rate according to ASHRAE standards is 7644.7 L/s > 7457.5 L/s designed according to Approved Document Part F. Thus, AHU – 1 meets the ventilation criteria for both AHSRAE 62-2001 and Approved Document F.

AHU - 2 RESULTS		
Ez	1.00	
Ps	2331	
ΣPz	1101	
D = Ps/ΣPz	0.47	
ΣVou	5320.09	
Ev	**0.7**	
Vot (L/s)	**7600.12**	Min OA Intake Needed
ΣVpzm (L/s)	**18346.00**	Supply Air Rate
	41.43%	Percentage Supply Air is OA
Σ Voz (L/s)	**6772.5**	

Air Handling Unit 2 has an uncorrected minimum outdoor airflow of 6772.5 L/s. This minimum value is increased with the system ventilation efficiency of 0.7 determined from Table 6-3 of the ASHRAE 62-2001 standard. The system efficiency could be low due to the large office spaces AHU – 2 serves with variable occupancy levels.

The calculated minimum outdoor airflow rate according to ASHRAE standards is 7600.12 L/s > 7457.5 L/s designed according to Approved Document Part F. Thus, AHU – 2 meets the ventilation criteria for both AHSRAE 62-2001 and Approved Document F.

AHU - 3 RESULTS		
Ez	1.00	
ΣVou	237.6	
Ev	**1.00**	
Vot (L/s)	**237.60**	Min OA Intake Needed
ΣVpzm (L/s)	**2332.77**	Supply Air Rate
	10.19%	Percentage Supply Air is OA
Σ Voz (L/s)	**237.6**	

Air Handling Unit 3 has an uncorrected minimum outdoor airflow of 237.6 L/s. This minimum value remains constant with the system ventilation efficiency of 1.0 determined from Table 6-3 of the ASHRAE 62-2001 standard.

The calculated minimum outdoor airflow rate according to ASHRAE standards is 237.60 L/s < 1384 L/s designed according to Approved Document F. The minimum outdoor airflow required is much less than the minimum supplied by the AHU. Because the building systems were design for maximum versatility for the tenants, including the addition of many additional fan coil units, that additional capacity for growth was placed on Units 3 and 4. The minimum amount of Outdoor Air needed will increase as more FCUs and other equipment are added to the system. If the timeline proceeds as expected, the additional loads for this AHU will be added before the building becomes fully functional. And the new required minimum values should meet the minimum supply rates provided by Unit 3. AHU – 3 does not meet the ventilation criteria for AHSRAE 62-2001 as currently designed.

AHU - 4 RESULTS		
D	1.00	
Ez	1.00	
ΣVou	280.8	
Ev	**1.00**	
Vot (L/s)	**280.80**	Min OA Intake Needed
ΣVpzm (L/s)	**3204.00**	Supply Air Rate
	8.76%	Percentage Supply Air is OA
Σ Voz (L/s)	**280.8**	

Air Handling Unit 4 has an uncorrected minimum outdoor airflow of 280.8 L/s. This minimum value remains constant with the correction of the system ventilation efficiency of 1.0 determined from Table 6-3 of the ASHRAE 62-2001 standard.

The calculated minimum outdoor airflow rate according to ASHRAE standards is 280.8 L/s < 1633 L/s designed according to Approved Document F. Similar to Unit 3, Unit 4 has also been sized to account for additional load capacity that may be needed as the tenants move in and begin to fit out their office spaces to meet their needs. Thus there is a large deviation between the minimum required value and the minimum outdoor air provided by the unit. The likelihood that the Unit will ever have to supply only 280.8 L/s is rare, since the additional loads will be added before the building becomes fully operational. AHU – 4 does not meet the ventilation criteria for both AHSRAE 62-2001 as currently designed.

AHU - 7 RESULTS		
Ez	1.00	
Ps	2331	
D	1.00	
ΣVou	554.1	
Ev	**0.6**	
Vot (L/s)	**923.50**	Min OA Intake Needed
ΣVpzm (L/s)	**1026.00**	Supply Air Rate
	90.01%	Percentage Supply Air is OA
Σ Voz (L/s)	**554.1**	

Air Handling Unit 7 has an uncorrected minimum outdoor airflow of 923.5 L/s. This minimum value is increased with the system ventilation efficiency of 0.6 determined from Table 6-3 of the ASHRAE 62-2001 standard. The system efficiency could be low due to the large lobby and reception area with highly variable occupancy loads which AHU – 7 serves.

The calculated minimum outdoor airflow rate according to ASHRAE standards is 923.5 L/s < 926 L/s designed according to Approved Document F. The calculated values based on ASHRAE standards is less than 3 L/s less than the minimum flow rate from the AHU. Thus, the minor difference can be accounted for through calculation and error in assumptions and therefore AHU – 7 is considered to meet the ventilation criteria for both AHSRAE 62-2001 and Approved Document F.

b. Comparison of ASHRAE Std 62 with Approved Document F

In discussing the results of the fresh air rates required by ASHRAE, it is important to compare the assumptions assumed when the designing following the Approved Document F versus those assumptions made by ASHRAE. One of the most notable assumptions was with the determination of the occupancy loads. Under the American Standards for office space the density is assumed to be 5 people per 100 m^2, while the British Standards assume 1 person per every 12 m^2. That is a 60% increase in the population assumption. For ease of comparison and continuity the same population densities were used for both calculations.

Another significant difference is in the area outdoor air rate per unit area. British standards suggested 1.33 L/s*m^2 while ASHRAE suggests 0.3 L/s*m^2. However, because the British assumptions are consistently and proportionally larger than the American load assumptions, it allows both calculations to come to one conclusion on the appropriate about of fresh air required in these spaces.

This is a continuing topic of interest and research, and I am currently in the process of compiling associated documents and 'rules of thumb' for good building practice. As this topic continues to be investigated this report will be elaborated on and updated to account correctly for the variances between the code calculations.

c. Comparison of ASHRAE's Ventilation Rate Procedure and Indoor Air Quality Procedure

ASHRAE Standard 62-2001 describes two methods for calculating the minimum quantity of outdoor air that needs to be supplied to a specified room: the Ventilation Rate Procedure (VRP) and the Indoor Air Quality Procedure (IAQ). The Ventilation Rate Procedure is a prescriptive process, where if you follow the guidelines set out by ASHRAE concerning the flow rates to your zones then you are guaranteed to have sufficient mixing with the fresh air supply to dilute any dangerous contaminants to safe levels. Thus, the only system maintenance required is to ensure that the appropriate air flow rates to each space is continued.

On the other hand, you have the option of following a more performance-based methodology under the IAQ procedure. The IAQ procedure is based around the process of controlling the levels of contaminants in each zone independently. For this method you must be much more knowledgeable about the possible sources of contaminants within the building, how to contain those sources, and dilute the concentration levels to those safe for all occupants. With this process you must be able to carefully measure the concentration levels throughout the building, and be notified if there is ever a build up contaminants in one location.

There are benefits and drawbacks to both procedures, but it is best to choose a method based on the specifics of the building or design in question. For example, if you have a science building with lab spaces, each containing their own possible contaminant sources, it could be advantageous to be able to control each space separately through a building monitoring system. Where trying to dilute one zone using the VRP approach would cause you to severely over-ventilate the rest of the building in order to lower the contaminant concentration in one room.

VI. References

1. ASHRAE Standard 62-2001, Section 6, as modified by Addendum 62n, *Ventilation for Acceptable Indoor Air Quality.*
2. The Pennsylvania State University Architectural Engineering Department, Thesis Advisor – Technical Assignment 1: Dr. Jelena Srebric.
3. Past Thesis Technical Assignments/Reports, E-Thesis Archives, 2005.
4. Buro Happold Engineers Ltd, Mechanical Drawings and Specifications.
5. Skanska, Ventilation Schematics.
6. Approved Document F: Ventilation, The Building Regulations 2000. Office of the Deputy Prime Minister.

Appendix A

	Space Use	Area, sq. m.	Occupancy
Level 0			
Zone 1	Open Office	441.5	37
Zone 2	Open Office	441.5	37
Zone 3	WC West	36	0
Zone 4	Corridor West	48	0
Zone 5	WC East	39	0
Zone 6	Corridor East	16	0
Zone 7	Reception	772	129
Level 1			
Zone 8	Open Office	754.5	63
Zone 9	Open Office	754.5	63
Zone 10	Corridor West	48	0
Zone 11	WC East	39	0
Zone 12	Corridor East	16	0
Level 2			
Zone 13	Open Office	1235.5	103
Zone 14	Open Office	1235.5	103
Zone 15	WC West	36	0
Zone 16	Corridor West	20	0
Zone 17	WC East	39	0
Zone 18	Corridor East	16	0
Level 3			
Zone 19	Open Office	1235.5	103
Zone 20	Open Office	1235.5	103
Zone 21	WC West	36	0
Zone 22	Corridor West	20	0
Zone 23	WC East	39	0
Zone 24	Corridor East	16	0
Level 4			
Zone 25	Open Office	1235.5	103
Zone 26	Open Office	1235.5	103
Zone 27	WC West	36	0
Zone 28	Corridor West	20	0
Zone 29	WC East	39	0
Zone 30	Corridor East	16	0
Level 5			
Zone 31	Open Office	1235.5	103
Zone 32	Open Office	1235.5	103
Zone 33	WC West	36	0
Zone 34	Corridor West	20	0
Zone 35	WC East	39	0
Zone 36	Corridor East	16	0

Level 6			
Zone 37	Open Office	1235.5	103
Zone 38	Open Office	1235.5	103
Zone 39	WC West	36	0
Zone 40	Corridor West	20	0
Zone 41	WC East	39	0
Zone 42	Corridor East	16	0
Level 7			
Zone 43	Open Office	1002.5	83.5
Zone 43	Open Office	1002.5	83.5
Zone 45	WC West	36	0
Zone 46	Corridor West	20	0
Zone 47	WC East	39	0
Zone 48	Corridor East	16	0
Level 8			
Zone 49	Open Office	888.5	74
Zone 50	Open Office	888.5	74
Zone 51	WC West	36	0
Zone 52	Corridor West	20	0
Zone 53	WC East	39	0
Zone 54	Corridor East	16	0
Level 9			
Zone 55	Open Office	1314.5	109.5
Zone 56	Open Office	1314.5	109.5
Zone 57	WC West	36	0
Zone 58	Corridor West	20	0
Zone 59	WC East	39	0
Zone 60	Corridor East	16	0
Level 10			
Zone 61	Open Office	1314.5	109.5
Zone 62	Open Office	1314.5	109.5
Zone 63	WC West	36	0
Zone 64	Corridor West	20	0
Zone 65	WC East	39	0
Zone 66	Corridor East	16	0
Level 11			
Zone 67	Open Office	1314.5	109.5
Zone 68	Open Office	1314.5	109.5
Zone 69	WC West	36	0
Zone 70	Corridor West	20	0
Zone 71	WC East	39	0
Zone 72	Corridor East	16	0

APPENDIX B: AHU – 1

A	B	C	D	E	F	G	H	I	J	K	L	M	N
AHU-1													
Level		Space Use	Area sq. m., Az	Occupancy, Pz		Rp (L/s*person)	Ra (L/s*m^2)	Vou	Vbz (L/s)	OA Requirement (Voz, L/s)	Vpzm (L/s)	Zp	MAX Zp
0	Zone 1	Open Office	441.5	37	22.1	2.5	0.3	176.140476	224.95	224.95	1296	0.174	
0	Zone 4	Corridor West	48	0		-	0.3	14.4	14.4	14.4	55	0.262	
1	Zone 8	Open Office	754.5	63	37.7	2.5	0.3	300.741892	383.85	383.85	1006	**0.382**	MAX Zp
1	Zone 10	Corridor West	48	0		-	0.3	14.4	14.4	14.4	55	0.262	
2	Zone 13	Open Office	1235.5	103	61.8	2.5	0.3	492.274839	628.15	628.15	1647	0.381	
2	Zone 16	Corridor West	20	0		-	0.3	6	6	6	55	0.109	
3	Zone 19	Open Office	1235.5	103	61.8	2.5	0.3	492.274839	628.15	628.15	1648	0.381	
3	Zone 22	Corridor West	20	0		-	0.3	6	6	6	55	0.109	
4	Zone 25	Open Office	1235.5	103	61.8	2.5	0.3	492.274839	628.15	628.15	1648	0.381	
4	Zone 28	Corridor West	20	0		-	0.3	6	6	6	55	0.109	
5	Zone 31	Open Office	1235.5	103	61.8	2.5	0.3	492.274839	628.15	628.15	1646	**0.382**	Max Zp
5	Zone 34	Corridor West	20	0		-	0.3	6	6	6	55	0.109	
6	Zone 37	Open Office	1235.5	103	61.8	2.5	0.3	492.274839	628.15	628.15	1648	0.381	
6	Zone 40	Corridor West	20	0		-	0.3	6	6	6	55	0.109	
7	Zone 43	Open Office	1002.5	83.5	50.12	2.5	0.3	399.348777	300.75	300.75	1337	0.225	
7	Zone 46	Corridor West	20	0		-	0.3	6	6	6	55	0.109	
8	Zone 49	Open Office	888.5	74	44.43	2.5	0.3	353.930952	451.55	451.55	1185	0.381	
8	Zone 52	Corridor West	20	0		-	0.3	6	6	6	55	0.109	
9	Zone 55	Open Office	1314.5	109.5	65.73	2.5	0.3	523.650193	668.1	668.1	1752	0.381	
9	Zone 58	Corridor West	20	0		-	0.3	6	6	6	55	0.109	
10	Zone 61	Open Office	1314.5	109.5	65.73	2.5	0.3	523.650193	668.1	668.1	1752	0.381	
10	Zone 64	Corridor West	20	0		-	0.3	6	6	6	55	0.109	
11	Zone 67	Open Office	1314.5	109.5	65.73	2.5	0.3	523.650193	668.1	668.1	1752	0.381	
11	Zone 70	Corridor West	20	0		-	0.3	6	6	6	55	0.109	

AHU - 1 RESULTS		
Ez	1.00	
D	0.47	
ΣVou	5351.29	
Ev	**0.7**	
Vot (L/s)	**7644.70**	Min OA Intake Needed
ΣVpzm (L/	**18977.00**	Supply Air Rate
	40.28%	Percentage Supply Air is OA

APPENDIX C: AHU – 2

AHU - 2

Level		Space Use	Area sq. m.	Occupancy	Rp (L/s*person)	Ra (L/s*m^2)		Vbz (L/s)	OA Requirement (Voz, L/s)	Vpzm (L/s)	Zp	MAX Zp
0	Zone 2	Open Office	441.5	37	2.5	0.3	176.1405	224.95	224.95	782	0.288	
0	Zone 6	Corridor East	16	0	-	0.3	4.8	4.8	4.8	45	0.107	
1	Zone 9	Open Office	754.5	63	2.5	0.3	300.7419	383.85	383.85	1006	**0.382**	MAX Zp
1	Zone 12	Corridor East	16	0	-	0.3	4.8	4.8	4.8	45	0.107	
2	Zone 14	Open Office	1235.5	103	2.5	0.3	492.2748	628.15	628.15	1648	0.381	
2	Zone 18	Corridor East	16	0	-	0.3	4.8	4.8	4.8	45	0.107	
3	Zone 20	Open Office	1235.5	103	2.5	0.3	492.2748	628.15	628.15	1648	0.381	
3	Zone 24	Corridor East	16	0	-	0.3	4.8	4.8	4.8	45	0.107	
4	Zone 26	Open Office	1235.5	103	2.5	0.3	492.2748	628.15	628.15	1648	0.381	
4	Zone 30	Corridor East	16	0	-	0.3	4.8	4.8	4.8	45	0.107	
5	Zone 32	Open Office	1235.5	103	2.5	0.3	492.2748	628.15	628.15	1646	**0.382**	
5	Zone 36	Corridor East	16	0	-	0.3	4.8	4.8	4.8	45	0.107	
6	Zone 38	Open Office	1235.5	103	2.5	0.3	492.2748	628.15	628.15	1648	0.381	
6	Zone 42	Corridor East	16	0	-	0.3	4.8	4.8	4.8	45	0.107	
7	Zone 43	Open Office	1002.5	83.5	2.5	0.3	399.3488	509.5	509.5	1338	0.381	
7	Zone 48	Corridor East	16	0	-	0.3	4.8	4.8	4.8	45	0.107	
8	Zone 50	Open Office	888.5	74	2.5	0.3	353.931	451.55	451.55	1184	0.381	
8	Zone 54	Corridor East	16	0	-	0.3	4.8	4.8	4.8	45	0.107	
9	Zone 56	Open Office	1314.5	109.5	2.5	0.3	523.6502	668.1	668.1	1752	0.381	
9	Zone 60	Corridor East	16	0	-	0.3	4.8	4.8	4.8	45	0.107	
10	Zone 62	Open Office	1314.5	109.5	2.5	0.3	523.6502	668.1	668.1	1752	0.381	
10	Zone 66	Corridor East	16	0	-	0.3	4.8	4.8	4.8	45	0.107	
11	Zone 68	Open Office	1314.5	109.5	2.5	0.3	523.6502	668.1	668.1	1754	0.381	
11	Zone 72	Corridor East	16	0	-	0.3	4.8	4.8	4.8	45	0.107	

AHU - 2 RESULTS		
Ez	1.00	
Ps	2331	
ΣPz	1101	
D = Ps/ΣPz	0.47	
ΣVou	5320.09	
Ev	**0.7**	
Vot (L/s)	**7600.12**	Min OA Intake Needed
ΣVpzm (L/	**18346.00**	Supply Air Rate
	41.43%	Percentage Supply Air is OA
Σ Voz (L/s)	**6772.5**	

APPENDIX D: AHU – 3

AHU - 3											
Level		Space Use	Area sq. m.	Occupancy	Rp (L/s*person)	Ra (L/s*m^2)	Vbz (L/s)	OA Requirement (Voz, L/s)	Vpzm (L/s)	Zp	MAX Zp
0	Zone 3	WC West	36	0	-	0.6	21.6	21.6	212.07	**0.102**	MAX Zp
2	Zone 15	WC West	36	0	-	0.6	21.6	21.6	212.07	**0.102**	
3	Zone 21	WC West	36	0	-	0.6	21.6	21.6	212.07	**0.102**	
4	Zone 27	WC West	36	0	-	0.6	21.6	21.6	212.07	**0.102**	
5	Zone 33	WC West	36	0	-	0.6	21.6	21.6	212.07	**0.102**	
6	Zone 39	WC West	36	0	-	0.6	21.6	21.6	212.07	**0.102**	
7	Zone 45	WC West	36	0	-	0.6	21.6	21.6	212.07	**0.102**	
8	Zone 51	WC West	36	0	-	0.6	21.6	21.6	212.07	**0.102**	
9	Zone 57	WC West	36	0	-	0.6	21.6	21.6	212.07	**0.102**	
10	Zone 63	WC West	36	0	-	0.6	21.6	21.6	212.07	**0.102**	
11	Zone 69	WC West	36	0	-	0.6	21.6	21.6	212.07	**0.102**	

AHU - 3 RESULTS		
Ez	1.00	
ΣVou	237.6	
Ev	**1.00**	
Vot (L/s)	**237.60**	Min OA Intake Needed
ΣVpzm (L/s)	**2332.77**	Supply Air Rate
	10.19%	Percentage Supply Air is OA
Σ Voz (L/s)	**237.6**	

APPENDIX E: AHU – 4

AHU - 4											
Level		Space Use	Area sq. m.	Occupancy	Rp (L/s*person)	Ra (L/s*m^2)	Vbz (L/s)	OA Requirement (Voz, L/s)	Vpzm (L/s)	Zp	MAX Zp
0	Zone 5	WC East	39	0	-	0.6	23.4	23.4	267	**0.088**	MAX Zp
1	Zone 11	WC East	39	0	-	0.6	23.4	23.4	267	0.088	
2	Zone 17	WC East	39	0	-	0.6	23.4	23.4	267	0.088	
3	Zone 23	WC East	39	0	-	0.6	23.4	23.4	267	0.088	
4	Zone 29	WC East	39	0	-	0.6	23.4	23.4	267	0.088	
5	Zone 35	WC East	39	0	-	0.6	23.4	23.4	267	0.088	
6	Zone 41	WC East	39	0	-	0.6	23.4	23.4	267	0.088	
7	Zone 47	WC East	39	0	-	0.6	23.4	23.4	267	0.088	
8	Zone 53	WC East	39	0	-	0.6	23.4	23.4	267	0.088	
9	Zone 59	WC East	39	0	-	0.6	23.4	23.4	267	0.088	
10	Zone 65	WC East	39	0	-	0.6	23.4	23.4	267	0.088	
11	Zone 71	WC East	39	0	-	0.6	23.4	23.4	267	0.088	

AHU - 4 RESULTS		
D	1.00	
Ez	1.00	
ΣVou	280.8	
Ev	**1.00**	
Vot (L/s)	**280.80**	Min OA Intake Needed
ΣVpzm (L/s)	**3204.00**	Supply Air Rate
	8.76%	Percentage Supply Air is OA
Σ Voz (L/s)	**280.8**	

APPENDIX F: AHU – 7

AHU - 7

Level		Space Use	Area sq. m.	Occupancy	Rp (L/s*person)	Ra (L/s*m^2)		Vbz (L/s)	OA Requirement (Voz, L/s)	Vpzm (L/s)	Zp	MAX Zp
0	Zone 7	Reception	772	129	2.5	0.3	231.6	554.1	554.1	1026	**0.540**	**MAX Zp**

AHU - 7 RESULTS		
Ez	1.00	
Ps	2331	
D	1.00	
ΣVou	231.6	
Ev	0.6	
Vot (L/s)	**386.00**	Min OA Intake Needed
ΣVpzm (L/s)	**1026.00**	Supply Air Rate
	37.62%	Percentage Supply Air is OA
Σ Voz (L/s)	554.1	