Technical Assignment 1

ASHRAE Standard 62.1 Ventilation Compliance Evaluation

The Milton Hershey School New Supply Center
Hershey, Pennsylvania

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1.0 EXECUTIVE SUMMARY

The Ventilation Rate Procedure described in ASHRAE Standard 62.1 (ASHRAE 2004) is used as the basis for calculating the ventilation requirements for the Milton Hershey School New Supply Center. The Supply Center consists of 14 air handling units supplying conditioned air to every space by way of VAV and CAV systems. Ventilation calculations for the Supply Center prove whether or not each of the air handling units complies with Standard 62.1 (ASHRAE 2004).

The Milton Hershey School New Supply Center is an 110,000 square foot, single story building with four elevated mechanical mezzanine rooms housing the 14 AHUs. Approximately 48,000 square feet of the building consists of the food distribution center for the Milton Hershey School while the remainder of the building consists of a clothing shop, general offices, a mail distribution center, and storage for the supply center and the school. Ventilation rates set fourth by Standard 62.1 (ASHRAE 2004) are determined for each space based on the occupancy, use, and square footage of these areas.

Ventilation effectiveness is determined by using the primary outdoor air fraction to locate the critical space for each AHU. The required amount of outdoor air each AHU must intake is then increased to ensure all spaces are properly ventilated and this value is compared to what is actually being supplied.

Table 1 Standard 62.1 Compliance Summary

AHU	Min OA Req (cfm)	OA Supplied (cfm)	Complies with Std. 62.1	AHU	Min OA Req (cfm)	OA Supplied (cfm)	Complies with Std. 62.1
1	1124	1150	YES	**8**	335	7400	YES
2	795	1150	YES	**9**	1348	1000	NO
3	3215	3640	YES	**10**	1414	1125	NO
4	3008	5585	YES	**11**	394	1045	YES
5	1041	3000	YES	**12**	552	1250	YES
6	1416	13500	YES	**13**	996	3000	YES
7	686	3000	YES	**14**	647	800	YES

Table 1 summarizes the OA requirements for each AHU in the supply center as well as the amount of outdoor air each AHU is scheduled to intake according to the construction documents prepared by H. F. Lenz Company. The table illustrates that 12 of the 14 AHUs comply with Standard 62.1 (ASHRAE 2004) based on the assumptions that were made for this report. AHU-9 and AHU-10 are not scheduled to supply enough outdoor air to their spaces as proven by the ventilation calculations and therefore do not comply with ASHRAE Standard 62.1 (ASHRAE 2004).

2.0 BUILDING DESIGN BACKGROUND

The Milton Hershey School New Supply Center is a single story 110,000 square foot building with four elevated mechanical mezzanine rooms and contains a variety of spaces. The north and northwest sections of the building consists of general office spaces and conference rooms. Located in the center of the building is the food distribution center for the Milton Hershey School. This area contains large freezers, refrigerators, and temperature controlled storage areas, fifteen in all, totaling to 13,600 square feet to go along with its central food preparation spaces.

Aside from the food production section of the building, the New Supply Center also includes a central mail distribution center for the school and a clothing store with an alterations work area. Complementing the four mechanical mezzanine rooms that house the air handling units, a boiler and chiller plant is located on the north side of the building. The east side is mostly loading docks for deliveries, and the south side accommodates a variety of storage space. There are also two data rooms located in the center of the floor plan. Figure one, shown below, gives a breakdown of the space's location in the building as well as the portion of area each occupancy type consumes.

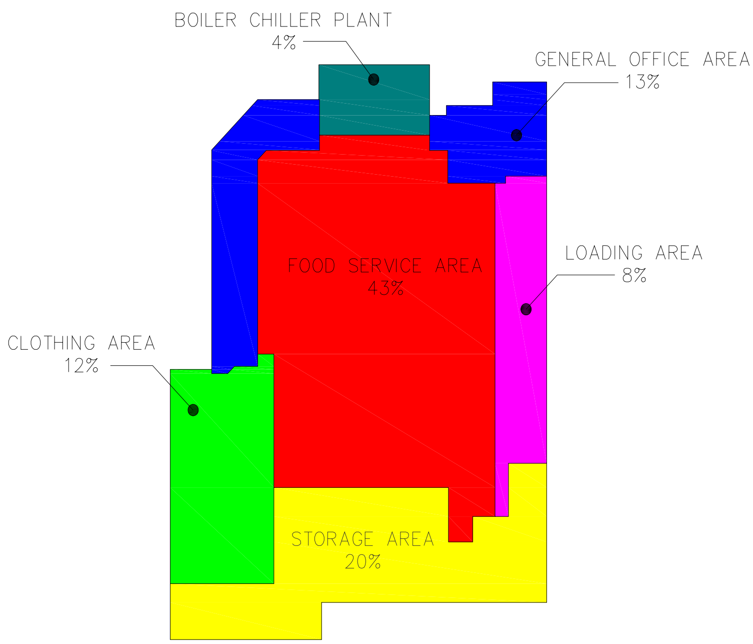

Figure 1 Space relationship and area breakdown

3.0 MECHANICAL SYSTEMS SUMMARY

The air side mechanical system for the supply center uses the fourteen air handling units that were mentioned in the previous section. All but two of the air handling units are controlled by variable frequency drives making these twelve air handlers part of variable volume systems. Four of the VAV air handlers serve the kitchen area, the loading dock, and the bakery. These four air handlers are demand based 100% outdoor air units that provide make-up air to these spaces. When the food service areas are not operating, the outdoor air intake is backed down to the minimum amount required. The trash area, not served by a VFD, is also a 100% outdoor air unit but a constant volume system.

The mail rooms, offices, break rooms, locker rooms, clothing store, and the clothing alterations sections of the building contain variable air volume boxes with hot water reheat for individual space conditioning control. The food service sections of the building do not use VAV boxes; instead these air handlers modulate the amount of air needed to meet both ventilation and thermal loads with variable frequency drives.

Aside from the air handling units, horizontal unit heaters and cabinet unit heaters are used in restrooms and entrance lobby areas. Ductless air cooled split system units are also used serving the two data rooms in the Supply Center.

The chiller plant consists of two (one duty one standby) 270 ton electric centrifugal water cooled chillers that produce 45˚F water. These chillers handle the building load and supply the chilled water to the fourteen air handling units. Along with the building load chillers, the plant also contains two electric (one duty one standby) water cooled brine chillers operating at 20˚F. These brine chillers are nominally 75 ton units when they produce 45 degree water, however, the chillers supply 20 degree water to serve fan coil units located in the walk-in coolers year round. Since these chillers operate at lower temperatures, the actual load the chiller handles is lowered from 75 tons to 35 tons. The brine chillers are separate from the water cooled condensing units serving the walk-in freezers. The chilled water system is variable flow with VFDs on the pumps.

Also included in the chiller plant are three heat exchangers. One heat exchanger is used in the winter time for water side “free” cooling. The centrifugal chillers that handle the building load also pick up rejected heat from the walk-in freezer’s water cooled condensing units through the other two heat exchangers.

The boiler plant includes three gas fired fire tube boilers, two 200 boiler horse power boilers and one 125 BHP boiler, producing 40 psig medium pressure steam to serve both the building load and process loads in the kitchen. The boilers have a gross out put of 6695 MBH for the two larger boilers and 4184 MBH for the smaller. Low pressure steam enters two heat exchangers (one duty one standby) which convert the steam to hot water which is used for space heating. The medium pressure steam, not converted to hot water, is used to serve the dishwashing equipment in the kitchen and bakery.

The New Supply Center's mechanical systems utilize energy saving techniques and these assist in the project's goal of LEED Certification (26-31 points).

4.0 SPACE VENTILATION ANALYSIS AND ASSUMPTIONS

ASHRAE Standard 62.1-2004 Table 6-1 (ASHRAE 2004) provides minimum ventilation rates for breathing zones and governs the design outdoor air requirements of the Supply Center. Table 6-1 (ASHRAE 2004) includes a list of occupancy categories and the required minimum outdoor air rates per person and per square foot for those spaces. However, certain room occupancies in the Supply Center differed from the categories found in the Standard; in this case assumptions were made and shown below:

- Restrooms: 0.5 cfm/ft^2
- Washing Area: 0.5 cfm/ft^2
- Recycling: 0.5 cfm/ft^2
- Alterations: 0.12 cfm/ft^2, 7.5 cfm/person
- Clothing: 0.12 cfm/ft^2, 7.5 cfm/person
- Locker Rooms: 0.5 cfm/ ft^2

When finding the supply air quantity to each space, the diffuser air quantities shown on the mechanical floor plans designed by H.F. Lenz Company are summed. In calculating the maximum outdoor air fraction (Zp), the minimum amount of supply air is needed. The construction drawings state that the minimum amount of supply air for the VAV systems is 50% of the maximum value for each space unless otherwise noted.

The following tables illustrate space characteristics including floor area, function, and design occupancy provided by H.F. Lenz Company, outside air requirements from Standard 62.1 (ASHRAE 2004), and the maximum supply air quantity for each space organized by the air handling unit that serves the spaces.

Table 2 AHU-1 Space Breakdown

Room	Area (sq ft)	Function	Design Occupancy	OA Reqd. (ASHRAE 2004)			Supply Air Quantity (max)
				cfm/person	cfm/ft²	Total (cfm)	
Kitchen Prep. Area	5910	Kitchen	8	7.5	0.18	1124	22,000

Table 3 AHU-2 Space Breakdown

Room	Area (sq ft)	Function	Design Occupancy	OA Reqd. (ASHRAE 2004)			Supply Air Quantity (max)
				cfm/person	cfm/ft²	Total (cfm)	
Dishwashing	405	Dishwashing	3	7.5	0.18	95	1370
Pot washing	383	Dishwashing	3	7.5	0.18	91	1380
Kitchen	2000	Kitchen	3	7.5	0.18	383	10990
Insulated Container Storage	1884	Storage	0	0	0.12	226	8260

AHU-1 and AHU-2 are demand based 100% outdoor air units. When the kitchen is not being operated, the outdoor air is backed down to the minimum amount required. When the kitchen is operating, the outdoor air is increased to the design value shown in the tables.

Table 4 AHU-3 Space Breakdown

Room	Area (sq ft)	Function	Design Occupancy	OA Reqd. (ASHRAE 2004)			Supply Air Quantity (max)
				cfm/person	cfm/ft²	Total (cfm)	
Dining	1212	Dining	100	7.5	0.18	968	1800
Decoration Storage	95	Storage	0	0	0.12	12	75
Women's Toilet	185	Toilet Room	0	0	0.5	93	200
Men's Toilet	172	Toilet Room	0	0	0.5	86	200
Storage	231	Storage	0	0	0.12	28	75
Office 108	174	Office	2	5	0.06	20	250
Office 110	150	Office	2	5	0.06	19	250
Work Area	315	Office	3	5	0.06	34	125
Work Room	133	Office	3	5	0.06	23	250
Waiting	161	Reception	3	5	0.06	24	225
Reception	160	Reception	2	5	0.06	20	250

Lobby	315	Lobbies	0	5	0.06	29	312
Waiting	170	Reception	3	5	0.06	25	100
Reception	160	Reception	2	5	0.06	20	250
Work Room	132	Office	2	5	0.06	18	250
Conference	243	Conference	10	5	0.06	65	450
Work Area	475	Office	3	5	0.06	46	250
Office 123	152	Office	2	5	0.06	19	250
Office 124	175	Office	2	5	0.06	21	250
Office 125	228	Office	2	5	0.06	24	250
Servery	884	Office	10	5	0.06	108	850
Training	574	Classroom	15	10	0.12	223	600
Entry	97	Corridors	0	0	0.06	6	75
Corridor	1445	Corridors	0	0	0.06	137	988
Storage	96	Storage	0	0	0.12	14	175
Office 144	96	Office	2	5	0.06	11	175
Office 145	96	Office	2	5	0.06	16	175

Table 5 AHU-4 Space Breakdown

Room	Area (sq ft)	Function	Design Occupancy	OA Reqd. (ASHRAE 2004)			Supply Air Quantity (max)
				cfm/person	cfm/ft^2	Total (cfm)	
Janitor/Storage	245	Storage	0	0	0.12	29	275
Laundry	166	Laundry	2	7.5	0.06	25	375
Catering Storage	381	Storage	4	0	0.12	46	235
Corridor	1060	Corridor	0	0	0.06	64	300
Custodial	726	Janitor	0	0	0.12	87	450
IT Room	305	IT Room	2	10	0.12	57	1680
Break Room	895	Cafeteria	12	7.5	0.18	251	900
Mail Room	1235	Office	6	5	0.06	104	930
Insulated Container Washing	950	Dish Washing	4	7.5	0.18	201	1500
Men's Locker Room	839	Locker Rm.	10	0	0.5	419	800
Women's Locker Room	817	Locker Rm.	12	0	0.5	408	800
Office 187	160	Office	2	5	0.06	20	210
Transportation Team Room	530	Classroom	6	7.5	0.06	77	800
Dispatcher	116	Office	2	5	0.06	17	200

Table 6 AHU-5 Space Breakdown

Room	Area (sq ft)	Function	Design Occupancy	OA Reqd. (ASHRAE 2004)			Supply Air Quantity (max)
				cfm/person	cfm/ft²	Total (cfm)	
Washing Area	110	Washing	0	0	0.5	55	250
Recycling	1556	Trash Room	0	0	0.5	778	3000

AHU-5 is a constant volume, 100% outdoor air system. Standard 62.1 Section 6 (ASHRAE 2004) states that exhaust makeup air can be any combination of outdoor air, re-circulated air, and transfer air. AHU-5's system operates such that all of the makeup air is outdoor air for these spaces and all 3,250 cfm of supply air is exhausted.

Table 7 AHU-6 Space Breakdown

Room	Area (sq ft)	Function	Design Occupancy	OA Reqd. (ASHRAE 2004)			Supply Air Quantity (max)
				cfm/person	cfm/ft²	Total (cfm)	
Delivery	9063	Loading	12	0	0.12	1088	13195
Storage 165	177	Storage	0	0	0.12	21	135
Storage 166	201	Storage	0	0	0.12	24	170

AHU-6 is a 100% demand based outdoor air system. When the delivery room is not occupied, AHU-6 decreases the outdoor air amount to the minimum. When the delivery room is occupied, the outdoor air rate is at the supply air design value.

Table 8 AHU-7 Space Breakdown

Room	Area (sq ft)	Function	Design Occupancy	OA Reqd. (ASHRAE 2004)			Supply Air Quantity (max)
				cfm/person	cfm/ft²	Total (cfm)	
Order Assembly and Storage	1350	Storage	4	0	0.12	162	1500
Corridor	3931	Corridor	0	0	0.06	236	2400
Catering/Staging	570	Kitchen	4	7.5	0.18	133	900
Passage	300	Corridor	0	0	.06	18	200

Table 9 AHU-8 Space Breakdown

Room	Area (sq ft)	Function	Design Occupancy	OA Reqd. (ASHRAE 2004)			Supply Air Quantity (max)
				cfm/person	cfm/ft²	Total (cfm)	
Bakery	1610	Kitchen / Food Production	6	7.5	0.18	335	7400

AHU-8 is a 100% demand based outdoor air system. When the Bakery is not occupied, AHU-8 decreases the outdoor air amount to the minimum. When the delivery room is occupied, the outdoor air rate is at the supply air design value.

Table 10 AHU-9 Space Breakdown

Room	Area (sq ft)	Function	Design Occupancy	OA Reqd. (ASHRAE 2004)			Supply Air Quantity (max)
				cfm/person	cfm/ft²	Total (cfm)	
Kitchen Dry Storage	890	Storage	4	0	0.12	107	1005
Dry Storage	6250	Storage	4	0	0.12	750	4545
Storage	721	Storage	0	0	0.12	87	450

Table 11 AHU-10 Space Breakdown

Room	Area (sq ft)	Function	Design Occupancy	OA Reqd. (ASHRAE 2004)			Supply Air Quantity (max)
				cfm/person	cfm/ft²	Total (cfm)	
Office 127	157	Office	2	5	0.06	19	175
Alterations	2535	Clothing Alterations	8	7.5	0.12	364	2680
Work Room	290	Office	6	5	0.06	47	350
Girls Fitting Room	100	Clothing Fitting Room	6	7.5	0.06	51	180
Boys Fitting Room	100	Clothing Fitting Room	6	7.5	0.06	51	180
Clothing	350	Clothing work room	4	7.5	0.12	72	1955
Clothing Shipping and Receiving	863	Clothing work room	6	7.5	0,12	149	1000
Used Clothing	350	Clothing work room	4	7.5	0.12	72	400
Corridor	385	Corridor	0	0	0.06	23	580

Table 12 AHU-11 Space Breakdown

Room	Area (sq ft)	Function	Design Occupancy	OA Reqd. (ASHRAE 2004)			Supply Air Quantity (max)
				cfm/person	cfm/ft²	Total (cfm)l	
IT Room	285	IT Room	2	10	0.12	53	1605
Year Round Experience	640	Classroom	4	7.5	0.06	68	600
Laundry	432	Laundry	2	7.5	0.06	41	900
Program Support Inventory	1064	Storage	4	0	0.12	128	2140
Corridor	1051	Corridor	0	0	0.06	63	900

Table 13 AHU-12 Space Breakdown

Room	Area (sq ft)	Function	Design Occupancy	OA Reqd. (ASHRAE 2004)			Supply Air Quantity (max)
				cfm/person	cfm/ft²	Total (cfm)	
Storage	1094	Storage	6	0	0.06	66	1500
Storage	7182	Storage	6	0	0.06	431	4820
Clothing Work Area	3266	Clothing work area	4	7.5	0.12	423	4530

Table 14 AHU-13 Space Breakdown

Room	Area (sq ft)	Function	Design Occupancy	OA Reqd. (ASHRAE 2004)			Supply Air Quantity (max)
				cfm/person	cfm/ft²	Total (cfm)	
Receiving	5810	Storage	6	0	0.12	698	5625
General Building Storage	1660	Storage	4	0	0.12	200	1875

Table 15 AHU-14 Space Breakdown

Room	Area (sq ft)	Function	Design Occupancy	OA Reqd. (ASHRAE 2004)			Supply Air Quantity (max)
				cfm/person	cfm/ft²	Total (cfm)	
Household Goods Storage	4850	Storage	2	0	0.12	582	6500

5.0 PROCEDURE

The Ventilation Rate Procedure found in Standard 62.1 Section 6.2 (ASHRAE 2004) is used in calculating the outdoor air requirements. The total outdoor air quantity listed in the previous tables are a minimum design values that each space needs to have supplied at design conditions in order to comply with Standard 62.1 (ASHRAE 2004). However, in the cases of air handling units supplying more than one space, such as AHU-3, corrections need to be configured into the calculations which will result in each AHU in-taking more outdoor air than what the summation of the minimum values describes.

According to Standard 62.1 (ASHRAE 2004), the corrected value of outdoor air that each AHU intakes will insure that the space that needs the most ventilation air (or the critical space) will receive the proper amount. Since most of the AHUs are part of variable air volume systems and not 100% outdoor air units, return air is mixed with outdoor air and the resulting supply air is sent to the spaces. The outdoor air is now part of a large mixture and is difficult to control the distribution so that the proper amount is sent to each individual space. Therefore, the Ventilation Rate Procedure is used to correct this problem. The calculations are described in Appendix B and taken from Standard 62.1 Section 6.2 (ASHRAE 2004), and spread sheet summaries of the ventilation calculations for the supply center are found in Appendix A.

6.0 DISCUSSION OF RESULTS

The results of the ventilation calculations for the Milton Hershey School New Supply Center show that 12 of the 14 air handling units comply with ASHRAE Standard 62.1 (ASHRAE 2004). Table 15 illustrates the maximum primary outdoor air fraction (Zp) for each space, the minimum amount of OA required by Standard 62.1 (ASHRAE 2004) for each AHU to intake, the amount of outdoor air that each AHU is actually in-taking according to the New Supply Center's schedule sheet, and whether or not the AHU complies with Standard 62.1 (ASHRAE 2004).

Table 16 Ventilation Compliance Summary

AHU	ΣVoz	Max Zp	Min OA Req. (Vot cfm)	OA Supplied (cfm)	Complies with Std. 62.1
1	1124	0.1	1124	1150	YES
2	795	0.14	795	1150	YES
3	1957	0.53	3215	3640	YES
4	1817	0.52	3008	5585	YES
5	833	0.26	1041	3000	YES
6	1133	0.30	1416	13500	YES
7	549	0.29	686	3000	YES
8	335	0.09	335	7400	YES
9	943	0.38	1348	1000	NO
10	849	0.51	1414	1125	NO
11	354	0.23	394	1045	YES
12	497	0.19	552	1250	YES
13	896	0.25	996	3000	YES
14	582	0.18	647	800	YES

Table 16 shows that AHU-9 and AHU-10 do not comply with ASHRAE Standard 62.1 (ASHRAE 2004). Possible reasons for these occurrences are that the assumptions made for the minimum amount of supply air to each space that is not typically found in the standard were different than the value used in the design of the supply center. Also, both AHUs were actually designed without using the minimum amount of outdoor supplied to each space when calculating Zp. This results in lower max Zp values which ultimately results in lower amounts of outdoor air required. The max Zp value found in this report for AHU 9 and 10 affected the outcome by determining the system ventilation efficiencies which are 0.7 and 0.6 respectively. These ventilation efficiencies result in each AHU requiring a higher amount of outdoor air (see Appendix A). Different assumptions and not using minimum primary air flow rates will result in different Zp values that could lower the required amount of outdoor air, but with the assumptions made in this case; AHU-9 and AHU-10 do not comply with the standard.

Table 16 also shows the affect of the primary outdoor fraction by comparing the nominal amount of outdoor air for each AHU to the required amount of outdoor air when system ventilation efficiency is taken into consideration. As it can be seen, the trend is that the critical primary outdoor air fraction determines that more outdoor air is needed for each AHU than what the nominal sum of outdoor air for each space in tells. The primary outdoor air fraction identifies the system ventilation efficiency which increases the amount of outdoor air that each AHU is to intake in order to ensure that the critical space receives the proper amount.

7.0 COMPARISON OF PROCEDURES

ASHRAE Standard 62.1 Section 6 (ASHRAE 2004) explains two procedures in which ventilation requirements for a building can be determined. The first is the Indoor Air Quality Procedure (IAQ) and the second is the procedure used and explained in this report, the Ventilation Rate Procedure.

The Ventilation Rate Procedure uses a series of equations in conjunction with tables found in Standard 62.1 (ASHRAE 2004) which calculate the amount of ventilation air required for each space based on the it's use, occupancy, and floor area. This procedure then calculates the amount of outdoor air required for each AHU to intake in order to ensure that each space receives at least the minimum amount of outdoor air.

The IAQ procedure determines the outdoor air intake rates based on analysis of contaminant sources, contaminant concentration targets, and perceived acceptability targets (ASHRAE 2004). Ventilation rates can be lowered, according to the IAQ procedure, if controls that remove contaminants, such as air cleaning devices, can prove to result in lower indoor contaminate concentrations levels than when the Ventilation Rate Procedure is used. If the design of a building's ventilation systems is to attain a specific target of contaminant concentrations or a level of accepted indoor air quality, the IAQ procedure is used over the ventilation rate procedure. The IAQ procedure is also used if the design of the building uses materials with lower contaminate source strengths.

The Ventilation Rate Procedure is a more straight forward procedure with basic equations and standard values that can be applied to most projects and used during early phases of design. The IAQ procedure requires more extensive analysis of each space in the building in order to determine the contaminate levels. The IAQ procedure also requires the knowledge of the building materials used to calculate contaminate source strengths and this may only be known at later times in the project. When space contaminate target levels are known, the IAQ procedure is acceptable, however, in other cases the Ventilation Rate Procedure proves to be a faster and effective way to determine the ventilation requirements for the building.

8.0 REFERENCES

ASHRAE. 2004, ANSI/ASHRAE, Standard 62.1 – 2004, Ventilation for Acceptable Indoor Air Quality. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc., Atlanta, GA. 2004.

H.F. Lenz Company. 2006, Mechanical Construction Documents. H.F. Lenz Company, Johnstown, PA. 2006.

APPENDIX A – Ventilation Calculations

AHU - 1	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Prep Area	5910	8	7.5	0.18	60	1063.8	1124	22000	22000	11000	0.10	1	1	1								
															8	1	1124	22000	0.05	0.10	1	1123.8

AHU - 2	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Dishwasher	405	3	7.5	0.18	22.5	72.9	95.4	1370	1370	685	0.14	1	1	1								
Pot Wash	383	3	7.5	0.18	22.5	68.9	91.4	1380	1380	690	0.13	1	1	1								
Storage	2000	3	7.5	0.18	22.5	360	383	10990	10990	5495	0.07	1	1	1								
Insulated Container Storage	1884	4	0	0.12	0	226	226	8260	8260	4130	0.05	1	1	1								
															13	1	795	22000	0.04	0.14	1	795

AHU - 3	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Dining	1213	100	7.5	0.18	750	218	968	1800	1800	1800	0.54	1	1	1								
Decoration Storage	96	0	0	0.12	0	11.5	11.5	75	75	40	0.29	1	1	1								
Women's Toilet	186	0	0	0.5	0	93	93	200	200	200	0.47	1	1	1								
Men's Toilet	172	0	0	0.5	0	86	86	200	200	200	0.43	1	1	1								
Storage	233	0	0	0.12	0	28	28	75	75	75	0.37	1	1	1								
Office 108	174	2	5	0.06	10	10.4	20.4	250	250	125	0.16	1	1	1								
Office 110	150	2	5	0.06	10	9	19	250	250	125	0.15	1	1	1								
Work Area 111	297	3	5	0.06	15	17.8	32.8	125	125	62.5	0.53	1	1	1								
Work Room 112	132	3	5	0.06	15	7.92	22.9	250	250	125	0.18	1	1	1								
Waiting 114	155	3	5	0.06	15	9.3	24.3	225	225	115	0.21	1	1	1								
Reception 113	160	2	5	0.06	10	9.6	19.6	250	250	125	0.16	1	1	1								
Lobby 115	315	2	5	0.06	10	18.9	28.9	312	312	156	0.19	1	1	1								
Waiting	169	3	5	0.06	15	10.1	25.1	100	100	75	0.34	1	1	1								
Reception	160	2	5	0.06	10	9.6	19.6	250	250	125	0.16	1	1	1								
Work Room	132	2	5	0.06	10	7.92	17.9	250	250	125	0.14	1	1	1								
Conference	244	10	5	0.06	50	14.6	64.6	450	450	225	0.29	1	1	1								
Work Area	516	3	5	0.06	15	31	46	250	250	125	0.37	1	1	1								
Office 123	152	2	5	0.06	10	9.12	19.1	250	250	125	0.15	1	1	1								
Office 124	175	2	5	0.06	10	10.5	20.5	250	250	125	0.16	1	1	1								
Office 125	228	2	5	0.06	10	13.7	23.7	250	250	125	0.19	1	1	1								
Servery	969	10	5	0.06	50	58.1	108	850	850	551	0.20	1	1	1								
Training	612	15	10	0.12	150	73.4	223	600	600	600	0.37	1	1	1								
Entry	105	0	0	0.06	0	6.3	6.3	75	75	50	0.13	1	1	1								
Corridor	2280	0	0	0.06	0	137	137	988	988	500	0.27	1	1	1								
Storage	114	0	0	0.12	0	13.7	13.7	175	175	90	0.15	1	1	1								
Office 144	96	1	5	0.06	5	5.76	10.8	175	175	90	0.12	1	1	1								
Office 145	96	2	5	0.06	10	5.76	15.8	175	175	90	0.18	1	1	1								
															171	1.00	1956.98	9100	0.22	0.53	0.6	3215

AHU - 4	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Janitor/Storage Storage	245	0	0	0.12	0	29.4	29.4	275	275	140	0.21	1	1	1								
Washer/Dryer Room	166	2	7.5	0.06	15	9.96	25	375	375	190	0.13	1	1	1								
Catering Storage	381	4	0	0.12	0	45.7	45.7	235	235	120	0.38	1	1	1								
Corridor	1060	0	0	0.06	0	63.6	63.6	300	300	150	0.42	1	1	1								
Custodial	726	0	0	0.12	0	87.1	87.1	450	450	225	0.39	1	1	1								
It	305	2	10	0.12	20	36.6	56.6	1680	1680	1680	0.03	1	1	1								
Break Room	895	12	7.5	0.18	90	161	251	900	900	500	0.50	1	1	1								
Mail Room	1235	6	5	0.06	30	74.1	104	930	930	465	0.22	1	1	1								
Insulated Container Washing	950	4	7.5	0.18	30	171	201	1500	1500	750	0.27	1	1	1								
Mens Locker Room	839	10	0	0.5	0	420	420	800	800	800	0.52	1	1	1								
Womens Locker Room	817	12	0	0.5	0	409	409	800	800	800	0.51	1	1	1								
Office	160	2	5	0.06	10	9.6	19.6	210	210	105	0.19	1	1	1								
Transportation Team Room	530	6	7.5	0.06	45	31.8	76.8	800	800	400	0.19	1	1	1								
Dispatcher	116	2	5	0.06	10	6.96	17	200	200	100	0.17	1	1	1								
															62	1.00	1817	9455	0.19	0.52	0.6	3008

AHU - 5	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Washing Area	110	1	0	0.5	0	55	55	250	250	250	0.22	1	1	1								
Recycling	1556	1	0	0.5	0	778	778	3000	3000	3000	0.26	1	1	1								
															2	1	833	3250	0.26	0.26	0.8	1041

AHU - 6	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Delivery	9063	12	0	0.12	0	1088	1088	13195	13195	6600	0.16	1	1	1								
Storage	177	0	0	0.12	0	21.2	21.2	135	135	70	0.30	1	1	1								
Storage	201	0	0	0.12	0	24.1	24.1	170	170	85	0.28	1	1	1								
															12	1	1133	13500	0.08	0.30	0.8	1416

AHU - 7	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Order Assembly/Storage	1351	4	0	0.12	0	162	162	1500	1500	750	0.22	1	1	1								
Corridor	3931	0	0	0.06	0	236	236	2400	2400	1200	0.20	1	1	1								
Catering/Storage	570	4	7.5	0.18	30	103	133	900	900	450	0.29	1	1	1								
Passage	300	0	0	0.06	0	18	18	200	200	100	0.18	1	1	1								
															8	1	549	5000	0.11	0.29	0.8	686

AHU - 8	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Bakery 169	1610	6	7.5	0.18	45	290	335	7400	7400	3700	0.09	1	1	1								
															6	1	335	7400	0.05	0.09	1	335

AHU - 9	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Kitchen Dry Storage	890	4	0	0.12	0	107	107	1005	1005	505	0.21	1	1	1								
Dry Storage	6250	4	0	0.12	0	750	750	4545	4545	2275	0.33	1	1	1								
Storage	721	0	0	0.12	0	86.5	86.5	450	450	225	0.38	1	1	1								
															8	1	943	6000	0.16	0.38	0.7	1348

AHU - 10	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Office 127	157	2	5	0.06	10	9.42	19.4	175	175	90	0.22	1	1	1								
Alterations	2535	8	7.5	0.12	60	304	364	2680	2680	1340	0.27	1	1	1								
Work Room	290	6	5	0.06	30	17.4	47.4	350	350	175	0.27	1	1	1								
Girls Fitting	100	6	7.5	0.06	45	6	51	180	180	100	0.51	1	1	1								
Boys Fitting	100	6	7.5	0.06	45	6	51	180	180	100	0.51	1	1	1								
Clothing	350	4	7.5	0.12	30	42	72	1955	1955	980	0.07	1	1	1								
Clothing Storage	863	6	7.5	0.12	45	104	149	1000	1000	500	0.30	1	1	1								
Used Clothing	350	4	7.5	0.12	30	42	72	400	400	200	0.36	1	1	1								
Corridor	385	0	0	0.06	0	23.1	23.1	580	580	290	0.08	1	1	1								
															42	1	849	7500	0.11	0.51	0.6	1414

AHU - 11	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
IT	285	2	10	0.12	20	34.2	54.2	1605	1605	805	0.07	1	1	1								
Year Round Experience	640	4	7.5	0.06	30	38.4	68.4	600	600	300	0.23	1	1	1								
Laundry	432	2	7.5	0.06	15	25.9	40.9	900	900	450	0.09	1	1	1								
Program Support Inventory	1064	4	0	0.12	0	128	128	2140	2140	1070	0.12	1	1	1								
Corridor	1051	0	0	0.06	0	63.1	63.1	900	900	450	0.14	1	1	1								
															12	1	354	6145	0.06	0.23	0.9	394

AHU - 12	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Storage	1094	6	0	0.06	0	65.6	65.6	1500	1500	750	0.09	1	1	1								
Mezzanine Storage	7182	6	0	0.06	0	431	431	4820	4820	2410	0.18	1	1	1								
Clothing	3266	4	7.5	0.12	30	392	422	4530	4530	2265	0.19	1	1	1								
															12	1	497	10850	0.05	0.19	0.9	552

AHU - 13	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Receiving	5810	6	0	0.12	0	697	697	5625	5625	2812	0.25	1.00	1.00	1								
General Building Storage	1660	4	0	0.12	0	199	199	1875	1875	938	0.21	1.00	1.00	1								
															10	1	896	7500	0.12	0.25	0.9	996

AHU - 14	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Household Goods Storage	4850	2	0	0.12	0	582	582	6500	6500	3250	0.18	1	1	1								
															2	1	582	6500	0.09	0.18	0.9	647

APPENDIX B – Ventilation Rate Procedure Calculation

The procedure is outlined in ASHREA Standard 62.1 (ASHRAE) and summarized in this appendix.

The Breathings Zone Outdoor Air Flow:
Vbz = RpPz + RaAz

- Az = Zone floor area
- Pz = The largest zone population expected to occupy the zone during typical usage.
- Rp = Outdoor airflow rate required per person as determined from Table 6-1.
- Ra = Outdoor airflow rate required per unit area as determined from Table 6-1.
- Vbz = The design outdoor air flow required in each space.

The Rp and Ra values used for each space are outlined in the Space Breakdown tables shown in section 4 of this report. Vbz for each space is the total cfm value in the tables.

Zone Outdoor Airflow:

The design outdoor airflow that must be provided to each space (Voz) by the AHU is determined by dividing breathing zone outdoor air flow, Vbz, by the Zone Air Distribution Effectiveness value.

Voz = Vbz/Ez

The Zone Air Distribution Effectiveness is found in Table 6-2 of Standard 62.1 (ASHRAE 2004). The value of Ez depends on how the air is distributed to the space. Figure 2 is Table 6-2 from the Standard (ASHRAE 2004) and illustrates different air distribution methods and their corresponding Ez value.

TABLE 6-2
Zone Air Distribution Effectiveness

Air Distribution Configuration	E_z
Ceiling supply of cool air	1.0
Ceiling supply of warm air and floor return	1.0
Ceiling supply of warm air 15°F (8°C) or more above space temperature and ceiling return.	0.8
Ceiling supply of warm air less than 15°F (8°C) above space temperature and ceiling return provided that the 150 fpm (0.8 m/s) supply air jet reaches to within 4.5 ft (1.4 m) of floor level. **Note:** For lower velocity supply air, E_z = 0.8.	1.0
Floor supply of cool air and ceiling return provided that the 150 fpm (0.8 m/s) supply jet reaches 4.5 ft (1.4 m) or more above the floor. **Note:** Most underfloor air distribution systems comply with this proviso.	1.0
Floor supply of cool air and ceiling return, provided low-velocity displacement ventilation achieves unidirectional flow and thermal stratification	1.2
Floor supply of warm air and floor return	1.0
Floor supply of warm air and ceiling return	0.7
Makeup supply drawn in on the opposite side of the room from the exhaust and/or return	0.8
Makeup supply drawn in near to the exhaust and/or return location	0.5

Figure 2 ASHRAE Standard 62.1 Table 6-2 (ASHRAE 2004)

Section 6.2.3, Single-Zone Systems, and Section 6.2.4, 100% Outdoor Air Systems, found in the Standard (ASHRAE 2004) apply to four of the AHUs. AHU-1, AHU-8, and AHU-14 apply to the single-zone system section of the standard, while AHU-5 applies to the 100% outdoor air system section (ASHRAE 2004).

Section 6.2.3 states that when one AHU supplies air to only one zone, the outdoor air intake flow to the AHU is found by (ASHRAE 2004):

Vot = Voz

Vot is the outdoor air intake flow into the air handler.

AHU-5 is a 100% outdoor air unit supplying outdoor air to two spaces. Other 100% outdoor air units, such as AHU-2, are demand based, and when spaces they are supplying are not in operation, the AHUs only supply the minimum amount of outdoor air. Therefore only AHU-5 can follow Section 6.2.4 of the Standard (ASHRAE 2004). The outdoor air intake flow is calculated for AHU-5 by:

Vot = Σall zonesVoz

Finding the outdoor air intake flow for the rest of the AHUs will require the rest of the calculations found in Section 6.2 of Standard 62.1 (ASHRAE 2004).

Outdoor Air Intake Flow For Multiple-Zone Recirculation Systems:

The Primary Outdoor Air Fraction (Zp) is used to determine the system ventilation efficiency. As stated earlier, corrections need to be made to the summations of the Zone Outdoor Air Flows (Voz) to ensure that the critical spaces receive the proper amount of outdoor air in multiple-zone recirculation systems. Finding Zp is the first step in this process:

Zp = Voz/Vpz

Vpz is the primary airflow to the zone from the AHU that includes outdoor air and recirculated air. Section 6.2.5.1 of the Standard (ASHRAE 2004) states that in VAV systems, Vpz is the minimum expected primary air flow to each space.

Once Zp is calculated, the System Ventilation Efficiency (Ev) is determined using Table 6-3 or Appendix A in the Standard (ASHRAE 2004). Figure three shows Table 6-3 of Standard 62.1 (ASHRAE 2004):

TABLE 6-3
System Ventilation Efficiency

Max (Z_p)	E_v
≤ 0.15	1.0
≤ 0.25	0.9
≤ 0.35	0.8
≤ 0.45	0.7
≤ 0.55	0.6
> 0.55	Use Appendix A

1. "Max Z_p" refers to the largest value of Z_p, calculated using Equation 6-5, among all the zones served by the system.
2. For values of Z_p between 0.15 and 0.55, one may determine the corresponding value of E_v by interpolating the values in the table.
3. The values of E_v in this table are based on a 0.15 *average* outdoor air fraction for the system (i.e., the ratio of the *uncorrected outdoor air intake* V_{ou} to the total *zone primary airflow* for all the zones served by the air handler). For systems with higher values of the average outdoor air fraction, this table may result in unrealistically low values of E_v and the use of Appendix A may yield more practical results.

Figure 3 ASHRAE Standard 62.1 Table 6-3 (ASHRAE 2004)

The System Ventilation Efficiency is used in the last step of the calculation to determine the outdoor intake required for each air handler for multi-zone recirculation systems. If the maximum Zp value is greater than 0.55 Appendix A must be used to find Ev. The calculations in Appendix A of this report show the Zp values for each individual space.

The next step in the calculation is to find the uncorrected outdoor air intake Vou (ASHRAE 2004).

$$Vou = D \sum_{all\ zones} RpPz + \sum_{all\ zones} RaAz$$

The variable D represents occupant diversity and is used to account for variations in occupancy within the zones served by the system (ASHRAE 2004).

$$D = Ps / \sum_{all\ zones} Pz.$$

- Ps = Total population in the area served by the system.

Finally, the outdoor air intake for the AHU is calculated using the uncorrected outdoor air intake value and dividing by the system ventilation efficiency.

$$Vot = Vou/Ev$$

Use of Appendix A (ASHRAE 2004)

Appendix A of Standard 62.1 (ASHRAE 2004) presents the procedure for calculating the system ventilation efficiency when Table 6-3 of the Standard can not be used. The zone ventilation efficiency (Evz) is calculated at each space and Ev is then equal to the minimum of the Evz's.

The equation for calculating Evz is as follows (ASHRAE 2004):

$$Evz = (Fa + Xs*Fb - Zd*Fc)/Fa$$

- Fa = Fraction of supply air to the zone from sources outside zone. If there are other sources supplying air to the zone other than the main AHU, then Fa is less than one. However, for the supply center, each zone is only supplied by one source.
- Xs = Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, Vou/Vps. Vps is the total primary air flow to all zones.
- Fb = Fraction of supply air to zone from full mixed primary air, Vpz/Vdz. Vdz is the total amount of air supplied to the zone including primary air from the AHU and locally recirculated air.
- Zd = Outdoor air fraction
- Fc = Fraction of outdoor air to zone from sources outside of the primary air system. However, for the supply center, each zone is only supplied outdoor air by one source.

The minimum of the Evz's for each AHU will equal the Ev value, and then the outdoor air intake is calculated.