The Eberly Campus Community Center
Uniontown, PA

Building Ventilation Analysis: ASHRAE 62.1-2004 Compliance

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Executive Summary

To an engineer specializing in building mechanical systems, a fundamental requirement of any design is the correct supply of ventilation air. However, the correct amount of ventilation air to be used in a system is a matter of much debate. A standard design practice is the solution to the debate, and the American Society of Heating, Refrigerating, and Air-conditioning Engineers publishes its Standard 62.1-2004 to guide the building industry in this issue. The standard is a key to a healthy, well ventilated mechanical system. With air quality excellence in mind, the Eberly Campus Community Center has been analyzed for compliance with the most recent ASHRAE Standard 62.1.

Because the Eberly Campus Community Center is a relatively small building, the entire building area is represented in the analysis. The building area encompasses a wide variety of spaces, creating the necessity for many small single zone systems (one air system per space), and several smaller multi-zone systems (several spaces attached to one air system). Systems evaluated in this analysis have been subjected to a pre-scripted calculation process involving a summary of spaces, a calculation of the outdoor ventilation air required per space, and the impact of combining the space or spaces into a single system. The results include the proper design amount of ventilation air for the building and the results are then compared with the original design airflows to discover compliance with the ASHRAE Standard 62.1-2004.

During the comparison of calculated and designed air flows, the analysis proves the required building outdoor airflow to be several thousand cubic feet per minute higher than the design values. While this is an interesting development, the results of the two would match closely if several of the large, infrequently used spaces are analyzed with a time averaged occupancy rate. Therefore, even though a straightforward analysis places the current outdoor air flow below standard, considering a diversity of occupancy over periods of time could prove the design to be adequate.

Terms and Definitions

AHU: Air handling unit. Mechanical airside system used for conditioning and supplying air at desired flow rates and temperatures.

Airside: Any system dealing primarily with the condition of the air in the occupied space.

Breathing Zone: Region of occupied space within a zone consisting of volume between 3” and 72” above floor and 2’ away from all walls or fixed air conditioning equipment.

CFM: Cubic feet per minute. Unit of measurement in the English units system representing volumetric flow rate, generally of air or an air/water mixture.

Diversity: The result of different occupancy schedules and the redistribution of building occupants over time. As occupants move and shift location, the actual occupancy of the building does not change; however, the maximum design occupancy for any one space could be due to a combination of people who accumulate from other spaces. Taking this redistribution into account results in lower and more realistic load and ventilation rate calculations.

OA: Outdoor ventilation air supplied by the mechanical system in question.

Primary Air Flow: The conditioned air supplied directly to the zone or space. This air contains a predetermined mixture of outdoor and recirculated air provided at a temperature and speed calculated to correctly offset the loads within the space without providing an unpleasant draft or warm areas within the space.

RA: Return or recirculated air. Air that is pulled from the occupied space, reconditioned and mixed with outdoor air, then returned to the space.

SA: Supply air. Conditioned air consisting of either treated outdoor air or a mix of outdoor and recirculated air, heated to a predetermined temperature and injected into the space.

Space: An area defined by a certain use. Usually separated into rooms, though can be marked only by a difference in intended use of the occupants.

System: One air handling unit or other device providing outdoor air and conditioning serving either one or a multitude of spaces.

Transfer air: Air pulled from one zone to ventilate and condition a neighboring zone that receives no supply air.

Zone: A distinct area defined by a specific intended use. See space.

Building Data

Currently two years old, the Eberly Campus Community Center is a small conglomerate of widely different use groups. For an overview of the space, see Figure 1 on the following page. The building includes in its 52,000 square feet the following:

- 2000 seat basketball arena
- Auxiliary gymnasium, also used for banquets
- 450 seat auditorium complete with stage, green room, and orchestra pit
- Office and conference space
- Fitness center
- (2) racquetball courts
- A full service commercial kitchen
- 250 seat dining area
- Training and locker facilities.

These spaces are served with a variety of mechanical systems depending upon their use. The largest space, the 2000 seat arena, is served by four identical air handling units providing 2815 cfm of OA and 7500 cfm of SA per unit. Immediately beside the main arena lies the auxiliary gymnasium, served by one air handling unit using 2000 cfm outdoor air, 6000 cfm supply air. The 450 seat auditorium and stage area are served by two identical air handlers with 1600 and 5500 cfm of OA and SA, respectively. Office and conference spaces are served by individual fan coil units that allow for personal occupant temperature control. A single AHU serves the fitness center with 840 cfm OA and 3500 cfm SA to cover the loads involved.

Within the same mechanical room as the fitness center AHU, another AHU serves the two racquetball courts with 560 cfm OA and 2250 cfm SA. The full service commercial kitchen requires a large unit ventilator, several specialized exhaust hoods, and various transfer air ducts. Another AHU serves the 250 seat dining area as well as several other zones with 4400 cfm OA and 12700 cfm SA. Finally, all training rooms, locker facilities, and restrooms are provided with exhaust and sometimes transfer air, as well as radiant heat sources (radiant panels and radiators) to make up for the lack of conditioned supply air. All of the above mentioned systems incorporate the main air conditioning, handling, and ventilating systems.

To support the mechanical airside systems, the source of the heating and cooling media must be considered. The Eberly Campus Community Center does not tap into central heating or cooling plants. It provides its own hot and chilled water for the air handling units and the unit ventilator. Consequently, the center comes equipped with a nominal 225 ton air cooled screw type water chiller to handle the cooling loads, as well as two identical cast iron sectional boilers with a rated output of 2498 MBH per boiler.

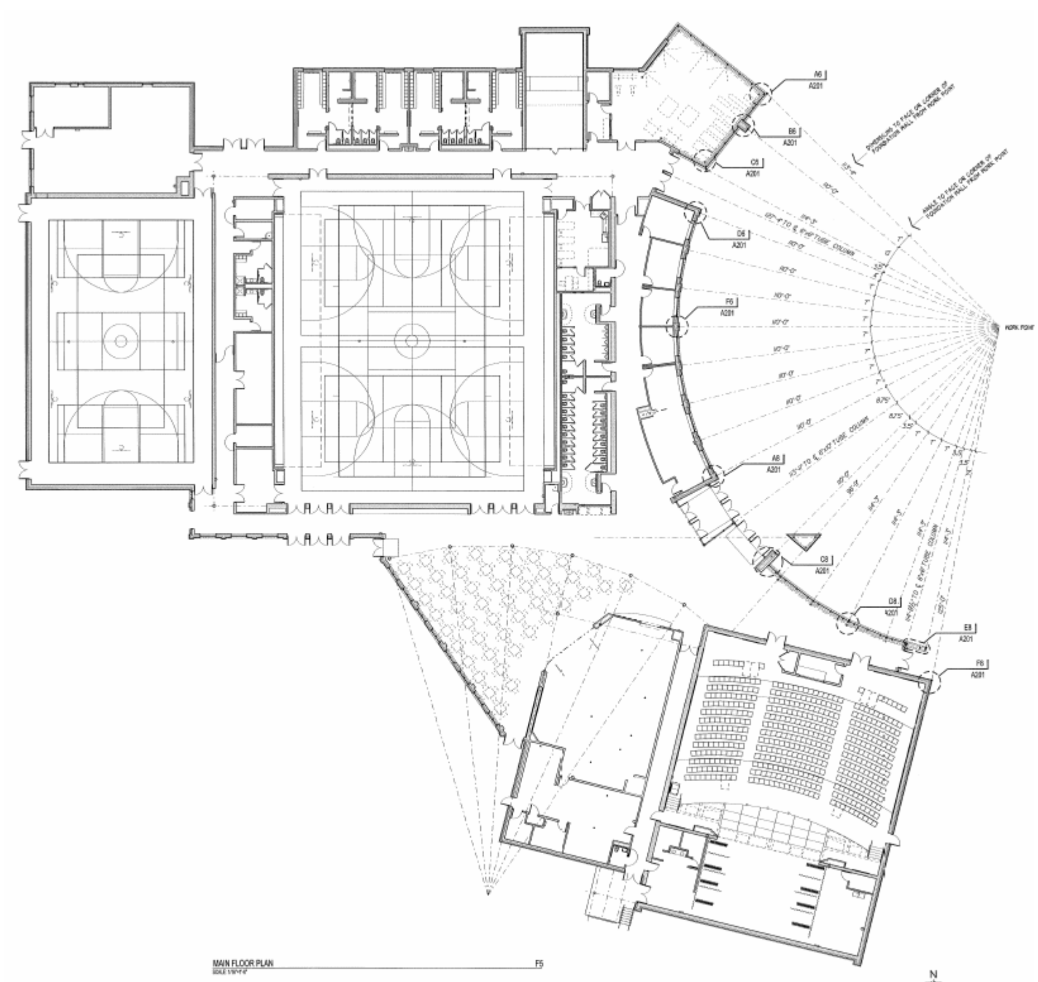

Fig. 1

Assumptions

- Design occupancies are the same as listed by the owner and/or shown by seating arrangements on the architectural plans. No time average of occupancy has been employed.
- Installed systems match the bid documents produced by Burt Hill and issued on February 17, 2003.
- Outdoor air is of a quality sufficient for use within the system. Intakes are not located near exhaust grilles.
- Unoccupied spaces served by transfer ducts do not add to the outdoor air load placed upon the air handling unit of the adjacent zone.
- Unoccupied, marginally occupied, or transitorily receive ventilation through transfer ducts or simple random motion of air.
- The zone air distribution effectiveness, Ez, is (1).
- The diversity factor of the occupants is also (1) due to the specific nature of the spaces. Occupants are unlikely wander to different spaces once the specific task is finished.
- Substitutions for occupied spaces to approximate use according to ASHRAE:
    - The racquetball courts 115 and 116 can be modeled as health club/aerobics rooms due to the high intensity and heat generated by the sport.
    - The main arena can be broken into two use groups – spectators (arena), and sporting arena – play area due to the high volume of expected spectators.
    - The training room 114 can be defined as stage/studio space as the activity involved will most likely be some form of light, relaxed exercise.
    - Room 102, the Kitchen, can be treated as science laboratory space as extra use becomes extra ventilation per person.
    - By the same token, the Dish Wash area can be treated the same way.

  - o The set building area beside the stage can be viewed as a high school Wood/metal shop due to the construction activities of the stage crew.
  - o Dressing rooms can be modeled as retail sales spaces due to a similarity in actual use and occupancy.
- The zone primary air fraction can be calculated from design (calculated) values combined with the actual supply air values used in the original design.
  - o Loads do not change between the time of original calculation and the time of this analysis, therefore supply air need not be varied to meet the loads.

Calculation: Single Zone System, Total Outside Air Ventilation

1. Find the net occupiable floor area (square feet) and maximum number of people expected to occupy the zone to be calculated.

   Az = Area Zone [sq. ft.]
   Pz = Design Occupancy of Zone [People]

2. From Table 6-1, Minimum Ventilation Rates in Breathing Zone, ASHRAE Std. 62.1-2004, find Rp and Ra for the intended use of the zone.

   Rp = Outdoor air flow rate per person from Table 6-1. [cfm/person]
   Ra = Outdoor air flow rate per unit of area from Table 6-1. [cfm/sq. ft.]

3. Breathing Zone Outdoor Air Flow is the outdoor air required to supply adequate ventilation to the breathing zone of a particular space.

   Vbz = RpPz + RaAz [cfm]

4. Zone Air Distribution Effectiveness, Ez, has been assumed to be (1). To determine the value of Ez, use Table 6-2 of ASHRAE Std. 62.1-2004.

5. Zone Outdoor Airflow is the amount of outdoor air flow required to provide proper ventilation to the zone as determined by ASHRAE Std. 62.1-2004.

   Voz = Vbz/Ez [cfm]

6. For single zone systems, the Zone Outdoor Intake Air Flow is equal to the calculated Zone Outdoor Airflow.

   Vot = Voz [cfm]

Calculation: Multiple Zone System, Total Outside Air Ventilation

1. Find the net occupiable floor area and maximum number of expected occupants per zone for every zone in the system.

   Az, for every zone
   Pz, for ever zone

   Usually it is easier to organize this sudden mass of information in a spreadsheet, table, database, or other program of the user's choice.

2. From Table 6-1, Minimum Ventilation Rates in Breathing Zone, ASHRAE Std. 62.1-2004, find Rp and Ra for the intended use of the zone.

   Complete this step for every zone in the system before continuing to the next step.

3. Breathing Zone Outdoor Air Flow is the outdoor air required to supply adequate ventilation to the breathing zone of a particular space. Again, complete this calculation using the values found above for each system until values of Vbz have been found for each zone in the system under analysis.

   Vbz = RpPz + RaAz [cfm]

4. Zone Air Distribution Effectiveness, Ez, has been assumed to be (1). The spaces uniformly fit with the requirements for an Ez of 1. However, to determine the value of Ez for any space, use Table 6-2 of ASHRAE Std. 62.1-2004.

5. Zone Outdoor Airflow is the amount of outdoor air flow required to provide proper ventilation to the zone as determined by ASHRAE Std. 62.1-2004. This value should be included for every zone being analyzed for the system.

Voz = Vbz/Ez [cfm]

6. Find the primary air flow to each zone and record. The primary air flow includes both the outdoor and recirculated air provided as supply conditioned air to the zone.

   Vpz = primary air flow per zone.

7. The zone primary outdoor air fraction should then be calculated for every zone. This value is a ratio of the outdoor air required to the total air supplied to a space.

   Zp = Zone primary outdoor air fraction
   Zp = Voz / Vpz

8. Compare the values of Zp found for all of the zones. The highest value of Zp labels that particular zone as the critical space, as the space with the highest Zp requires the most outdoor air supplied per supplied cfm of primary air flow.

9. Using the calculated maximum value of Zp and Table 6-3 of ASHRAE Std. 62.1-2004, find the system ventilation efficiency. Keep this number in the spreadsheet or other chosen calculation method while other variables are determined in the next few steps.

   Ev = System Ventilation Efficiency

10. Find the system population, the total population occupying the area served by the system.

    Ps = System Population

11. With the newly calculated Ps, use this value as well as the values for Pz for all of the zones served by the system to calculate the system diversity. This accounts for the fact that a set number of people occupy the same spaces and will redistribute the population over time, so that not all spaces are at 100% load at all times.

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

12. The diversity factor can now be used in an equation to find the system uncorrected outdoor air intake.

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

13. Finally, the uncorrected outdoor air intake has been calculated to include diversity, but still has yet to incorporate system ventilation efficiency. The calculation of the final outdoor air intake involves both the uncorrected outdoor air intake as well as the system ventilation efficiency.

$$Vot = Vou / Ev$$

Analysis Calculations: Eberly Campus Community Center

As stated previously, the Eberly Campus Community Center is a small building with an eclectic combination of different use groups. Its air systems consist of a large number of very small single zone systems, some larger single zone systems, and four small multi-zone systems. The unoccupied and low occupancy spaces are ventilated with a system of transfer ducts and exhaust. Thus, the ventilation analysis of the community center includes single and multi-zone calculations as shown above as well as verification calculations that the exhaust rates in the toilets, lockers, and other low occupancy spaces meet the exhaust air requirements introduced in Table 6-4 of ASHRAE Std. 62.1-2004, Minimum Exhaust Rates.

The results of the calculations are stored in a series of spreadsheets included in the appendix of this report. Appendix A includes a spreadsheet of the various spaces, their square footage, their use, and their design occupancy. The contents of Appendix B introduce the ventilation requirements for individual zones, as well as the zone Zp value per zone. The actual outdoor air intake calculations per system are located on the spreadsheet in Appendix C. Also located in Appendix C is the comparison of the entire building zone required outdoor air flows and the entire building calculated outdoor air intake. The final calculations, the exhaust compliance calculations, reside in the spreadsheet displayed in Appendix D.

After the calculation of the systems' outdoor air flows and outdoor air intakes, a summary of the total building required flows reveals noticeable differences in the required air flows. A simple summary of the systems' required outdoor air flow provides a building outdoor air flow rate of 26,034 cfm while the building outdoor air intake is calculated at 28,136 cfm. A several thousand cfm gap is quite noticeable. The gap is caused solely by the multi-zone systems providing lower ventilation efficiency, and therefore needing more outdoor air intake to compensate. If only four out of twenty-one systems are multi-zone, and the effects of decreased ventilation efficiency are already showing an eight percent increase in the outdoor air intake, imagine the effects upon a building-wide multi-zone system design. The comparison of single and multi-zone systems gives a pause for thought and will certainly result in some consideration in future designs.

While comparing the outdoor air flows and the outdoor air intakes, a comparison is drawn against the original system design building outdoor air intake. The final product of the analysis calculations is 28,136 cfm. The design building outdoor air intake is 23,475 cfm. This difference in calculated results is drastic, and could be caused by several measures. If the original designer had used a time averaged occupancy for the large occupancy, infrequently used spaces, then there would be a noticeable difference in the design air flows. For instance, if this method were to be used on the main arena, it could potentially cut the cfm required by one third to one half. Looking back at a comparison of the design and calculated air flows for this space, all four zones of the required air flow in the original design are between one third to one half smaller than the air flows calculated in this analysis.

Another possible explanation for the difference in outdoor air flows could be if the original designer had used an energy modeling program to find the required outdoor air flows for the spaces. Sometimes a slight change in input or selection of space use group can cause a significant difference in the calculation of the outdoor air flow rate with energy modeling programs. For future design, a closer look at possible time averaged occupancy for the main arena, at least, will be feasible and could save some cost both in the selection of equipment and in operation energy as the smaller units would only handle a smaller design air stream.

Ventilation Rate Procedure and Indoor Air Quality Procedure

ASHRAE Standard 62.1-2004 includes several methods to control ventilation and indoor air quality in buildings. The balance of this report has used the simplest procedure, the ventilation rate procedure. However, the standard covers several other methods as well. The procedure most applicable for commercial, industrial, and hospital buildings is the indoor air quality procedure. The ventilation rate procedure and the indoor air quality procedure both share a common problem which they aim to solve. It is the solution of the common problem that causes the difference between the indoor air quality procedure and the ventilation rate procedure.

As is shown throughout this report, the ventilation rate procedure is a clearly delineated step-by-step process that instructs the designer upon the amount of outdoor air to be provided to each space. Certain arbitrary amounts of flow rate are assigned to different use groups, based upon the probability of the occupants of different metabolic rates, exercise level, clothing level, and other factors that would affect the need to supply fresh outdoor air. ASHRAE has done all of the hard work: all that is left to the designer is to plug in numbers easily found to find a design outdoor air flow rate. The process is simple, the designer must only understand the reasoning and process to effectively pick the correct numbers. The ventilation rate procedure is a solid, reliable, and relatively easy process to getting a design outdoor air flow rate.

In direct contrast to the ventilation rate procedure, the indoor air quality procedure works more as a challenge thrown at the skills and comprehension of the designer. With this process, the building ventilation system is designed based upon the contaminant concentrations within the building. There are several methods to designing a properly functioning system through the indoor air quality procedure. First, for any of the procedures, the contaminant sources and strengths must be identified. Then, an upper allowable concentration limit is chosen. With this groundwork out of the way, the designer can choose the outdoor air provision method. The options include developing a mass balance approach, basing the design off of a previously developed, working design, contaminant monitoring approaches, and finally, using the ventilation rate procedure to find design outdoor air flows and dealing with the contaminants through different measures. The indoor air quality procedure presents itself as a bit more work than the ventilation rate procedure, yet both of these design procedures are efficient in certain situations.

Though the two different design options seem to be disparate, they do have some similarities. They both originated to control the indoor environmental spaces of buildings, and they both use an outdoor air based approach to dispersing unwanted contaminants. Several types of applications also can work well with both applications. Hospitals, schools, and large public spaces are all good examples. While the ventilation rate procedure can give adequate information about all off these different use groups, the indoor air quality procedure could easily be applied for these as well. All of these use groups have a good chance for concentrations of contaminants to build within, so the application of the indoor air quality procedure would effectively limit the amounts of contaminants within the spaces while providing the necessary ventilation.

However, as both options differ widely in the manner of their approach and execution, there are some glaring differences between the two processes. Ventilation rate procedure will give excellent figures and design criteria for the use groups and spaces included within its scope. Unfortunately, there is a limit to all tables and charts, and therefore, for most spaces the ventilation rate procedure becomes an art of educated guesswork and assumptions. The indoor air quality procedure is time consuming and may not be worth the effort for those types of spaces that are most commonly found under the tables for the ventilation rate procedure. There are many other spaces in the building industry, though, that involve large amounts of contaminants. It is with these spaces that the indoor air quality procedure becomes worthwhile. Spaces with high concentrations or probability for contaminants that need specific controls are not covered by the ventilation rate procedure. The indoor air quality procedure creates a very accurate method of determining where and when air flow would be necessary and provides other options to deal with more aggressive contaminants that would hopelessly overwhelm the ventilation rate procedure. Therefore, while both methods are trying to accomplish the same goal, their means to that end provide a great difference between the two.

While these two analysis systems have many similarities, they are two very different ways of attaining necessary results and each has a niche in the building industry. Simple spaces that require little thought are easily modeled by the ventilation rate procedure. More complex spaces with high contaminant risk can be accurately analyzed and resolved through the application of the indoor air quality procedure. Therefore, though both systems coexist within the same ASHRAE standard and accomplish the same broad objective, each has individualized strengths and weaknesses that act as a balance to the other procedure.

Appendices

Appendix A

Spaces Summary

Spaces and Use Summary				
Room Number	Room Name	Use	Sq. Ft.	Design Occupancy
P121	Electrical Room	Equipment	448	0
M121	Mechanical Room	Equipment	1,760	0
126	Auxiliary Gym	Mixed use	6,760	200
F103	Entry	Corridor	544	0
Q105	Corridor	Corridor	357	0
Q106	Corridor	Corridor	322	0
T122	Data/Telecom	Equipment	112	0
J122	Janitor	Janitor	91	0
122	Faculty Locker	Locker	208	2
123	Faculty Locker	Locker	208	2
124	Storage	Storage	416	0
P125	Electrical Closet	Equipment	104	0
125	Storage	Storage	319	0
120	Locker Room	Locker	270	2
120A	Toilet	Toilet	208	0
119A	Toilet	Toilet	208	0
119	Locker Room	Locker	270	2
118	Locker Room	Locker	270	2
118A	Toilet	Toilet	208	0
117A	Toilet	Toilet	208	0
117	Locker Room	Locker	270	2
115	Racquetball Court	Gym	810	2
116	Racquetball Court	Gym	810	2
113A	Office	Office	126	1
113B	Equipment	Equipment	99	0
113	Fitness Center	Gym	2,652	20
Q104	Corridor	Corridor	952	0
F102	Entry	Corridor	475	0
J105	Janitor	Janitor	50	0
105	Main Arena	Gym	11,045	2000
114B	Closet	Closet	32	0
T114	Data/Telecom	Equipment	28	0
114	Training Room	Gym	424	5
114A	Office	Office	117	1
110	Toilet	Toilet	42	0
R108	Men	Toilet	540	0
R106	Women	Toilet	810	0
Q103	Corridor	Corridor	1,063	0
112	Office	Office	238	1
111	Office	Office	213	1
109	Office	Office	162	1
108	Office	Office	156	1
107	Office	Office	206	1
106	Multi-purpose Room	Conference	462	24
	Vestibule	Corridor	221	0
F104	Entry	Corridor	255	0
Q107	Corridor	Corridor	1401	0
104	Dining	Dining	2780	250

103	Servery	Cafeteria	2203	6
102	Kitchen	Kitchen	462	6
	Refrigerators	Refrigerators	192	0
R102	Toilet	Toilet	48	0
102A	Dry Storage	Storage	123	0
102B	Office	Office	90	1
J102	Janitor	Janitor	18	0
102C	Dish Wash	Dish Wash	520	2
Q102	Corridor	Corridor	637	0
101	Auditorium	Auditorium	5230	450
	Stage	Gym	1260	20
	Set Building	Gym	422	5
101B	A/V Storage	Storage	54	0
101C	Dressing Room	Toilet	96	1
101D	Dressing Room	Toilet	108	1
101E	Green Room	Gym	280	20
101A	Control Room	Office	128	2
T101	Data/Telecom	Equipment	32	0
F101	Lobby	Corridor	1630.5	5
Q101	Auditorium Lobby	Corridor	970.3	50
M105A	Mechanical Room	Equipment	276	0
M105B	Mechanical Room	Equipment	276	0
M105C	Mechanical Room	Equipment	276	0
M105D	Mechanical Room	Equipment	276	0
M113	Mechanical Room	Equipment	468	0
M101A	Mechanical Room	Equipment	462	0
M101B	Mechanical Room	Equipment	476	0
M101C	Mechanical Room	Equipment	1115	0

Appendix B

Ventilation Requirements Per Zone

Ventilation Requirement per Zone											
Room Number	Room Name	Sq. Ft.	Design Occ.	cfm/ person	cfm/ ft^2	RpPz	RaAz	V_bz	V_oz	V_pz	Z_p
P121	Electrical Room	448	0			0	0	0	0	0	
M121	Mech. Rm	1,760	0			0	0	0	0	0	
126	Auxiliary Gym	6,760	200	7.5	0.06	1500	406	1906	1906	6000	0.32
F103	Entry	544	0	5	0.06	0	32.6	33	33	0	
Q105	Corridor	357	0		0.06	0	21.4	21	21	0	
Q106	Corridor	322	0		0.06	0	19.3	19	19	0	
T122	Data/Telecom	112	0		0.12	0	13.4	13	13	0	
J122	Janitor	91	0			0	0	0	0	0	
122	Faculty Locker	208	2			0	0	0	0	0	
123	Faculty Locker	208	2			0	0	0	0	0	
124	Storage	416	0		0.12	0	49.9	50	50	0	
P125	Electrical Closet	104	0			0	0	0	0	0	
125	Storage	319	0		0.12	0	38.3	38	38	0	
120	Locker Room	270	2			0	0	0	0	0	
120A	Toilet	208	0			0	0	0	0	0	
119A	Toilet	208	0			0	0	0	0	0	
119	Locker Room	270	2			0	0	0	0	0	
118	Locker Room	270	2			0	0	0	0	0	
118A	Toilet	208	0			0	0	0	0	0	
117A	Toilet	208	0			0	0	0	0	0	
117	Locker Room	270	2			0	0	0	0	0	
115	Racquetball Court	810	2	20	0.06	40	48.6	89	89	1125	0.08
116	Racquetball Court	810	2	20	0.06	40	48.6	89	89	1125	0.08
113A	Office	126	1	5	0.06	5	7.56	13	13	180	0.07
113B	Equipment	99	0			0	0	0	0	0	
113	Fitness Center	2,652	20	20	0.06	400	159	559	559	3500	0.16
Q104	Corridor	952	0		0.06	0	57.1	57	57	0	
F102	Entry	475	0	5	0.06	0	28.5	29	29	0	
J105	Janitor	50	0			0	0	0	0	0	
105	Main Arena-seating	6,408	2000	7.5	0.06	15000	384	15384	15384	7500	0.56 **
	Main Arena-court	4,636	20		0.3	0	1391	1391	1391		
114B	Closet	32	0			0	0	0	0	0	
T114	Data/Telecom	28	0			0	0	0	0	0	
114	Training Room	424	5	10	0.03	50	12.7	63	63	0	
114A	Office	117	1	5	0.06	5	7.02	12	12	180	0.07

110	Toilet	42	0			0	0	0	0	0		
R108	Men	540	0			0	0	0	0	0		
R106	Women	810	0			0	0	0	0	0		
Q103	Corridor	1,063	0		0.06	0	63.8	64	64	400	0.16	
112	Office	238	1	5	0.06	5	14.3	19	19	380	0.05	
111	Office	213	1	5	0.06	5	12.8	18	18	380	0.05	
109	Office	162	1	5	0.06	5	9.72	15	15	380	0.04	
108	Office	156	1	5	0.06	5	9.36	14	14	380	0.04	
107	Office	206	1	5	0.06	5	12.4	17	17	380	0.05	
106	Multi-purpose Room	462	24	5	0.06	120	27.7	148	148	380	0.39	
	Vestibule	221	0	5	0.06	0	13.3	13	13	0		
F104	Entry	255	0	5	0.06	0	15.3	15	15	250	0.06	
Q107	Corridor	1401	0		0.06	0	84.1	84	84	850	0.10	
104	Dining	2780	250	7.5	0.18	1875	500	2375	2375	5300	0.45	
103	Servery	2203	6	7.5	0.18	45	397	442	442	3600	0.12	
102	Kitchen	462	6	10	0.18	60	83.2	143	143	1275	0.11	
	Refrigerators	192	0			0	0	0	0	0		
R102	Toilet	48	0			0	0	0	0	0		
102A	Dry Storage	123	0		0.12	0	14.8	15	15	0		
102B	Office	90	1	5	0.06	5	5.4	10	10	180	0.06	
J102	Janitor	18	0			0	0	0	0	0		
102C	Dish Wash	520	2	10	0.18	20	93.6	114	114	475	0.24	
Q102	Corridor	637	0		0.06	0	38.2	38	38	0		
101	Auditorium	5230	450	5	0.06	2250	314	2564	2564	4600	0.28	*
	Stage	1260	20	10	0.06	200	75.6	276	276	900	0.15	*
	Set Building	422	5	10	0.18	50	76	126	126	0		
101B	A/V Storage	54	0		0.12	0	6.48	6	6	0		
101C	Dressing Room	96	1	7.5	0.12	7.5	11.5	19	19	0		
101D	Dressing Room	108	1	7.5	0.12	7.5	13	20	20	0		
101E	Green Room	280	10	5	0.06	50	16.8	67	67	0		
101A	Control Room	128	2	5	0.06	10	7.68	18	18	100	0.18	
T101	Data/Telecom	32	0			0	0	0	0	0		
F101	Lobby	1631	5	5	0.06	25	97.8	123	123	0		
Q101	Auditorium Lobby	970.3	50	5	0.06	250	58.2	308	308	1900	0.16	
M105A	Mechanical Room	276	0			0	0	0	0	0		
M105B	Mechanical Room	276	0			0	0	0	0	0		
M105C	Mechanical Room	276	0			0	0	0	0	0		
M105D	Mechanical Room	276	0			0	0	0	0	0		

M113	Mechanical Room	468	0			0	0	0	0	0	
M101A	Mechanical Room	462	0			0	0	0	0	0	
M101B	Mechanical Room	476	0			0	0	0	0	0	
M101C	Mechanical Room	1115	0			0	0	0	0	0	

NOTES:
1. The * Z_p of these spaces were calculated with one half of the V_oz, because there are two systems serving the space
2. The ** Z_p of this space was calculated with one fourth of the V_oz, as there are four systems serving the space

Appendix C

System Information | Outdoor Air Intakes

Zone and system information													
Zone (system)	Zones Served	V_bz, zone	Supplied OA	P_s	D	E_z	V_oz	Z_p max	RpPz	RaAz	V_ou	E_v	V_ot
AHU 1	Auxiliary Gym	1,906	2000	200	1	1	1906	N/A	1500	406	1906		1906
AHU 2	Arena	4,194	2815	500	1	1	4194	N/A	3750	444	4194		4194
AHU 3	Arena	4,194	2815	500	1	1	4194	N/A	3750	444	4194		4194
AHU 4	Arena	4,194	2815	500	1	1	4194	N/A	3750	444	4194		4194
AHU 5	Arena	4,194	2815	500	1	1	4194	N/A	3750	444	4194		4194
AHU 6	Fitness	559	840	20	1	1	559	N/A	400	159	559		559
AHU 7A	Racquetball 115, 116	177	560	4	1	1	177	0.08	80	97	177	1.00	177
AHU 8	104, Q101, F104, Q107, Q103, 103, F101	3,236	4440	256	1	1	3236	0.45	2020	1216	3236	0.70	4623
AHU 9	Auditorium, Stage	1,420	1800	235	1	1	1420	0.28	1225	195	1420	0.80	1775
AHU 10	Auditorium, Stage, Control Rm	1,437	1800	237	1	1	1437	0.28	1235	202	1437	0.80	1797
FC 2	Office 102B	10	20	1	1	1	10	N/A	5	5	10		10
FC 2	Office 113A	13	20	1	1	1	13	N/A	5	8	13		13
FC 2	Office 114A	12	20	1	1	1	12	N/A	5	7	12		12
FC 1	Multipurpose 106	74	40	12	1	1	74	N/A	60	14	74		74
FC 1	Multipurpose 106	74	40	12	1	1	74	N/A	60	14	74		74
FC 1	Office 107	17	40	1	1	1	17	N/A	5	12	17		17
FC 1	Office 108	14	40	1	1	1	14	N/A	5	9	14		14
FC 1	Office 109	15	40	1	1	1	15	N/A	5	10	15		15
FC 1	Office 111	18	40	1	1	1	18	N/A	5	13	18		18
FC 1	Office 112	19	40	1	1	1	19	N/A	5	14	19		19
UV1	Kitchen, dish wash	257	435	8	1	1	257	N/A	80	177	257		257

V_oz, entire building (calculated)	26,034
V_ot, entire building (calculated)	28,136
Total supplied OA (design)	23,475

Appendix D

Exhaust Rate Compliance

Exhaust Rates											
Room Number	Room Name	Use	Sq. Ft.	ASHRAE Use Group (Exhaust needs)	Exhaust (cfm/ft^2)*	Units (Toilets)	Actual exhaust (cfm)	Transfer Air	Pressurized?	ASHAE Req. cfm	Complies with ASHRAE?
P121	Electrical Room	Equipment	448								
M121	Mechanical Room	Equipment	1,760								
126	Auxiliary Gym	Mixed use	6,760								
F103	Entry	Corridor	544								
Q105	Corridor	Corridor	357								
Q106	Corridor	Corridor	322								
T122	Data/Telecom	Equipment	112								
J122	Janitor	Janitor	91	Janitor	1		125		Y	91	Y
122	Faculty Locker	Locker	208	Locker	0.5		250	250	N	104	Y
123	Faculty Locker	Locker	208	Locker	0.5		250	250	N	104	Y
124	Storage	Storage	416								
P125	Electrical Closet	Equipment	104								
125	Storage	Storage	319								
120	Locker Room	Locker	270	Locker	0.5		300	750	N	135	Y
120A	Toilet	Toilet	208	Toilets - public	70*	2	450		N	140	Y
119A	Toilet	Toilet	208	Toilets - public	70*	3	450		N	210	Y
119	Locker Room	Locker	270	Locker	0.5		300	750	N	135	Y
118	Locker Room	Locker	270	Locker	0.5		300	750	N	135	Y
118A	Toilet	Toilet	208	Toilets - public	70*	3	450		N	210	Y
117A	Toilet	Toilet	208	Toilets - public	70*	2	450		N	140	Y
117	Locker Room	Locker	270	Locker	0.5		300	750	N	135	Y
115	Racquetball Court	Gym	810								
116	Racquetball Court	Gym	810								
113A	Office	Office	126								
113B	Equipment	Equipment	99								
113	Fitness Center	Gym	2,652								
Q104	Corridor	Corridor	952								
F102	Entry	Corridor	475								
J105	Janitor	Janitor	50	Janitor	1		100		Y	50	Y
105	Main Arena	Gym	11,045	Arena	0.5			-6000		5522.5	Y
114B	Closet	Closet	32								
T114	Data/Telecom	Equipment	28								
114	Training Room	Gym	424								
114A	Office	Office	117								
110	Toilet	Toilet	42	Toilets - public	70*	1	75		Y	70	Y
R108	Men	Toilet	540	Toilets - public	70*	10	750	750	N	700	Y
R106	Women	Toilet	810	Toilets - public	70*	20	1500	1500	N	1400	Y
Q103	Corridor	Corridor	1,063								
112	Office	Office	238								
111	Office	Office	213								
109	Office	Office	162								
108	Office	Office	156								
107	Office	Office	206								
106	Multi-purpose Room	Conference	462								
	Vestibule	Corridor	221								

F104	Entry	Corridor	255								
Q107	Corridor	Corridor	1401								
104	Dining	Dining	2780								
103	Servery	Cafeteria	2203								
102	Kitchen	Kitchen	462	Kitchen-commercial	0.7		1700	875	Y	323.4	Y
	Refrigerators	Refrigerators	192								
R102	Toilet	Toilet	48	Toilets - public	70*	1	75		Y	70	Y
102A	Dry Storage	Storage	123								
102B	Office	Office	90								
J102	Janitor	Janitor	18	Janitor	1		75		Y	18	Y
102C	Dish Wash	Dish Wash	520	Kitchen-commercial	0.7		500			364	Y
Q102	Corridor	Corridor	637								
101	Auditorium	Auditorium	5230								
	Stage	Gym	1260								
	Set Building	Gym	422	Woodwork shop	0.5		300			211	Y
101B	A/V Storage	Storage	54								
101C	Dressing Room	Toilet	96	Dressing	0.25		125		Y	24	Y
101D	Dressing Room	Toilet	108	Dressing	0.25		125		Y	27	Y
101E	Green Room	Gym	280								
101A	Control Room	Office	128								
T101	Data/Telecom	Equipment	32								
F101	Lobby	Corridor	1630.5								
Q101	Auditorium Lobby	Corridor	970.3								
M105A	Mechanical Room	Equipment	276								
M105B	Mechanical Room	Equipment	276								
M105C	Mechanical Room	Equipment	276								
M105D	Mechanical Room	Equipment	276								
M113	Mechanical Room	Equipment	468								
M101A	Mechanical Room	Equipment	462								
M101B	Mechanical Room	Equipment	476								
M101C	Mechanical Room	Equipment	1115								

NOTE:
1. Exhaust rates with the * symbol are in units of cfm/unit.