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Mechanical Option
"Mechanical Technical Report #1"

The Montgomery County Conference Center and Hotel (MCCCH), Rockville, MD

Architectural renderings compliments of RTKL Associates

Mechanical Technical Report #1

ASHRAE Standard 62: "Ventilation Compliance Evaluation"

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October 6, 2004

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1.0 Executive Summary:

The purpose of this report is to determine whether or not the Montgomery County Conference Center and Hotel in Rockville, MD, meets the minimum outdoor air (OA) requirements set forth by the first draft of ASHRAE Standard 62-2001, Addendum 62n. The overall size of the Montgomery County Conference Center and Hotel is approximately 240,000 square feet. The conference center portion, with its two stories extending into the hotel main and lower level, comprises about 100,000 square feet of this total. The hotel makes up the remaining square footage with its nine stories of guestrooms. For this report, only the ventilation requirements of the conference center and hotel's main and lower levels will be analyzed and compared.

Nine of eleven air handling units serve this area of the building with design supply airflow rates ranging from 1,400 to 50,000 cfm, for a total supply cfm of 146,725. The draft addendum ventilation specification consists of both a floor area component and an occupant component, unlike the 1989 version, which had an occupant component only. The cfm per person for the addendum is around 5-7 cfm/person compared to the 15-20 cfm per person for the 1989 version. As a result, previously critical small spaces like conference rooms are no longer critical since the floor component is almost insignificant.

Overall, it was found that the use of Addendum 62n resulted in a minimum building OA requirement of 68,729 cfm or, approximately 3% less OA than required with the original design based upon the '89 standard. Ventilation effectiveness values, Ev, ranged from 0.31 to 1.0. This large span is due to MCCCH having very large, high occupancy spaces served by variable air volume as well as smaller, lower occupancy areas served by constant volume systems.

Architectural renderings compliments of RTKL Associates

2.0 Building Data:

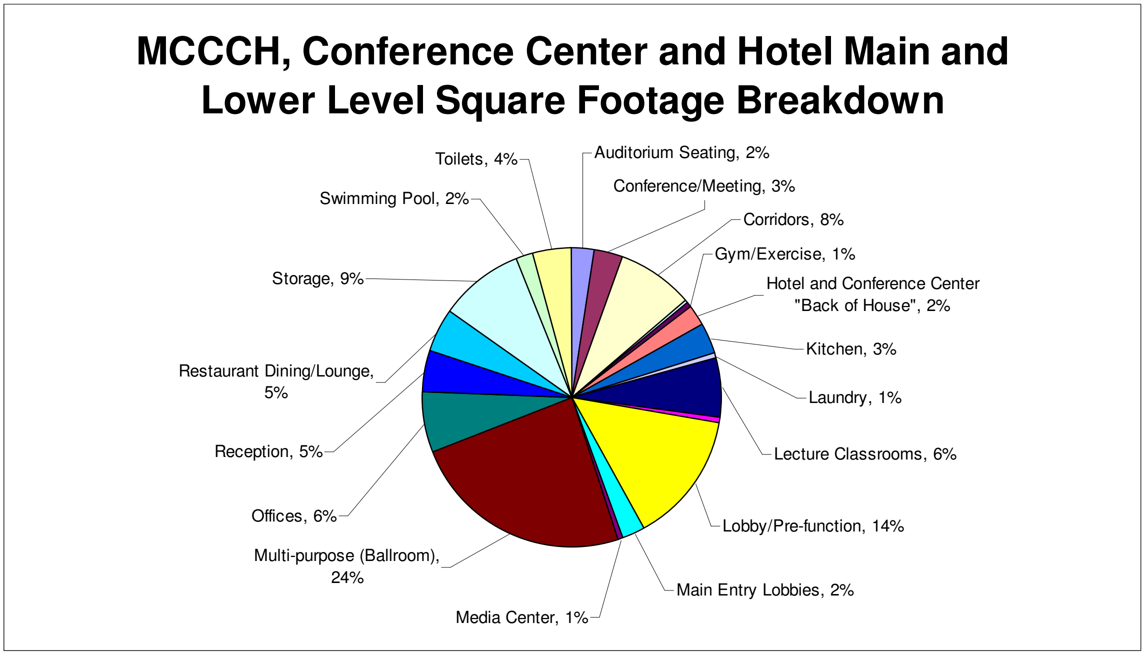
As stated previously, the 240,000 square foot Montgomery County Conference Center and Hotel consists of two major levels and a nine story hotel tower. This report will only focus on the two main levels of both the conference center and hotel, approximately 100,000 square feet of area. This section of the building contains twenty different types of spaces, which are listed/displayed below in Table 1/Graph 1. Areas not served by the air handlers in this portion of the building were not considered.

SPACE NAME	AREA (sq. ft.)	# ROOMS IN EACH SPACE
Auditorium Seating	2370	1
Conference/Meeting	3295	4
Corridors	8085	9
Electric/Telephone/Data Entry	320	10
Gym/Exercise	760	1
Hotel and Conference Center "Back of House"	2176	10
Kitchen	3116	1
Laundry	650	1
Lecture Classrooms	6465	8
Lobbies	380	1
Lobby/Pre-function	14369	12
Main Entry Lobbies	2275	4
Media Center	540	2
Multi-purpose (Ballroom)	24070	1
Offices	6480	20
Reception	4615	6
Restaurant Dining/Lounge	4740	2
Storage	8988	10
Swimming Pool	1860	1
Toilets	4270	12
Untreated	N/A	N/A
TOTALS	**99824**	**116**

** Error in measurement / untreated areas not accounted for cause total area < 100,000+ sq. ft. **

** only 101 zones exist on OA calculation spreadsheet due to some spaces being combined **

Table 1: Building Space Break Down



Graph 1: Building Space Break Down

The airside mechanical system for the Montgomery County Conference Center and Hotel consists of a combination of variable air volume and constant volume systems served by eleven different air handling units throughout the building. Eight of the air handling units are located in mechanical rooms throughout the building, two rest on the hotel roof, and one is ceiling mounted in a stairway area. (See Sketch 1 for all AHU locations.) Variable air volume boxes with electric reheat distribute air from the air handling units to all spaces in the two-story conference center, as well as, the restaurant and hotel first floor. Constant volume systems are used in the kitchen, exercise room, pool, and guest corridors/elevator areas on each hotel level. (Two of the three air handling units serving the kitchen area provide makeup air to the kitchen hoods, supplying 100% outdoor air.) The following is a list of MCCCH's air handling units/makeup air units and the components of their design.

Air Handling Units 1 and 2: are located in a mezzanine level mechanical room and serve all spaces in the conference center (Variable Volume), see Sketch 1, Section A. The contents of each AHU include min/max OA dampers, re-circulated air with a variable frequency drive fan, economizer, mixing box, filter (30% ASHRAE efficiency), pre-heat coil, cooling coil, heating coil, and a variable frequency drive supply fan all mounted on a 4" high housekeeping pad with ¼" thick neoprene pads. Both air handling units are balanced at a supply air cfm of 50,000, a max OA cfm of 50,000, and a minimum OA cfm of 30,000.

Air Handling Unit 3: is also located in the mezzanine level mechanical room. It serves the restaurant area on the main level between the conference center and hotel (Variable Volume), see Sketch 1, Section B. The contents of the AHU include min/max OA dampers, re-circulated air with a variable frequency drive fan, economizer, mixing box, filter (30% ASHRAE efficiency), cooling coil, heating coil, and a variable frequency drive supply fan all mounted on a 4" high housekeeping pad with ¼" thick neoprene pads. Air handling unit 3 is balanced at a supply air cfm of 12,500, a max OA cfm of 12,500, and a minimum OA cfm of 5,000.

Air Handling Unit 4: is located in the mezzanine level mechanical room. It serves the kitchen area on the main level between the conference center and hotel (Constant Volume), see Sketch 1, Section C. The contents of the AHU include min/max OA dampers, re-circulated air, economizer, mixing box, filter (30% ASHRAE efficiency), cooling coil, heating coil, and supply fan all mounted on a 4" high housekeeping pad with ¼" thick neoprene pads. Air handling unit 4 is balanced at a supply air cfm of 9,000, a max OA cfm of 9,000, and a minimum OA cfm of 2,250.

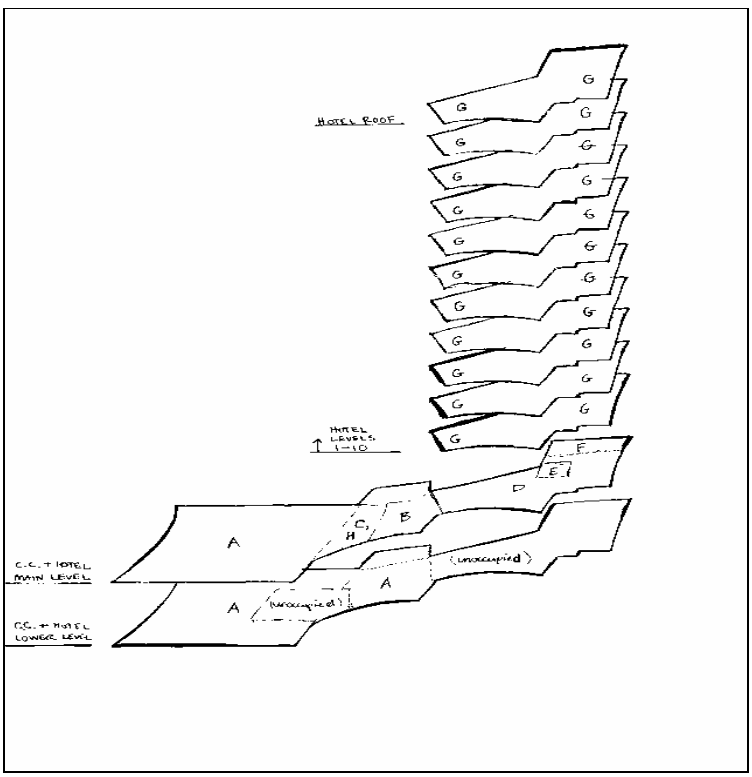
Air Handling Unit 5: is located in a mechanical room on the main hotel level, farthest from the conference center. It serves the hotel's first floor areas (Variable Volume), see Sketch 1, Section D. The contents of the AHU include min/max OA dampers, re-circulated air with a variable frequency drive fan, economizer, mixing box, filter (30% ASHRAE efficiency), cooling coil, heating coil, and a variable frequency drive supply fan all mounted on a 4" high housekeeping pad with ¼" thick neoprene pads. Air handling unit 5 is balanced at a supply air cfm of 9,000, a max OA cfm of 9,000, and a minimum OA cfm of 2,250.

Air Handling Unit 6: is also located in the mechanical room on the main hotel level, farthest from the conference center. It serves the exercise area on the hotel's main level (Constant Volume), see Sketch 1, Section E. The contents of the AHU include min/max OA dampers, re-circulated air, economizer, mixing box, filter (30% ASHRAE efficiency), cooling coil, heating coil, and supply fan all mounted on a 4" high housekeeping pad with ¼" thick neoprene pads. Air handling unit 6 is balanced at a supply air cfm of 1,400, a max OA cfm of 1,400, and a minimum OA cfm of 350.

Air Handling Unit 7: is ceiling mounted above a stairway near the pool area on the hotel's main level. It exists solely to provide air to the pool area (Constant Volume), see Sketch 1, Section F. The contents of the AHU include min/max OA dampers, re-circulated air, economizer, mixing box, filter (30% ASHRAE efficiency), preheat coil, cooling coil, heating coil, and supply fan. Additionally, the coils inside AHU 7 are coated with heresite to prevent corrosion. Air handling unit 7 is balanced at a supply air cfm of 3,200, a max OA cfm of 3,200, and a minimum OA cfm of 1,000.

Air Handling Units 8 and 9: are both located on the roof of the hotel tower. Each provide ventilation (100% OA) to the guest corridors and elevator lobbies on hotel levels 2 through 10 (Constant Volume), see Sketch 1, Section G. The contents of each AHU include an economizer, filter (30% ASHRAE efficiency), preheat coil, cooling coil, heating coil, and supply fan all mounted on a factory finished 18" high roof curb. Air handling unit 8 is balanced at a supply air cfm of 4,000, a max OA cfm of 4,000, and a minimum OA cfm of 4,000. Air handling unit 9 is balanced at a supply air cfm of 5,000, a max OA cfm of 5,000, and a minimum OA cfm of 5,000. (There are no AHUs that serve the individual hotel guestrooms. Each of these areas is provided for by an individual vertical fan coil unit.)

Makeup Air Units 10 and 11: are located in the mezzanine level mechanical room. They provide 100% outdoor air to the kitchen area in order to offset the kitchen exhaust hoods (Constant Volume), see Sketch 1, Section H. The contents of each AHU include an economizer, filter (30% ASHRAE efficiency), cooling coil, heating coil with face and bypass dampers, and supply fan all mounted on a 4" high housekeeping pad with ¼" thick neoprene pads. Makeup air unit 10 is balanced at a supply air cfm of 5,600, a max OA cfm of 5,600, and a minimum OA cfm of 5,600. Makeup air unit 11 is balanced at a supply air cfm of 6,025, a max OA cfm of 6,025, and a minimum OA cfm of 6,025.



Sketch 1: 3-D Sketch of AHU Serving Areas (Not to Scale)

Due to the overall size of the building and large number of air handling units, only the two main levels of the conference center and hotel will be analyzed for this report, leaving out the hotel's 2^{nd} – 10^{th} guestroom floors. Because of this simplification, AHUs 1-7 will be evaluated while AHUs 8 and 9 will not be analyzed. Makeup air units 10 and 11 will also not be studied due to their scheduling of 100% outdoor air to a single space for the sole purpose of offsetting the kitchen exhaust hoods. These MAUs (10 and 11) will not always be running and since their operation is intermittent, they are not a critical aspect of this ventilation study. (The exhaust ventilation portion of ASHRAE 6.2.7 and Table 6.4 will also not be considered in this analysis with the Ventilation Rate Procedure.)

The building's mechanical schedules and drawings, provided by the mechanical contractor, will be used to determine square footages, occupancy estimates, and design airflow rates for each space. All calculations will be based upon the summaries listed above.

3.0 Analysis and Assumptions:

ASHRAE Standard 62-2001 describes two different methods for analyzing the amount of outdoor air needed to meet a building's ventilation requirements. The two methods are "The Indoor Air Quality Procedure" and "The Ventilation Rate Procedure, VRP." The "Ventilation Rate Procedure", as modified by the first draft of Addendum 62n, is what will be used throughout this report. The "Indoor Air Quality Procedure" will not be used due to the lack of building information. However, both procedures will be discussed at the end of this report. (See section 6.0 of this report.)

The first draft of ASHRAE Standard 62-2001, Addendum 62n has a limited number of values for space occupancies and outdoor air ventilation requirements. Therefore, approximations and assumptions were made in order to estimate certain space requirements not listed in Addendum 62n, Table 6.1. These approximations were made with the help of faculty recommendations, industry contacts, past internship experience, and Addendum 62n space data comparisons. Table 2 contains a list of estimations made for this report. The data in Table 2 will be used throughout the remainder of the report and VRP calculations to compare the required amount of outdoor airflow to the actual design outdoor airflow. Section 4.0 will present the design outdoor airflow for the conference center and hotel's two main levels while Section 5.0 will illustrate how to calculate the required amount of outdoor ventilation needed in this portion of the building. Whether or not the building meets ASHRAE Standard 62 will be determined.

MCCCH Space Name		Equivalent ASHRAE Space used for Calculation		Occupancy (# people / 1000 sq. ft.)		People OA Rate (cfm/person)		Area OA Rate (cfm/sq. ft.)
Untreated		N/A		N/A		N/A		N/A
Projector Rooms/Translator Booths		Media Room		25		10		0.12
Elevator Machine Room		Storage Room (as far as ventilation)		0		0		0.12
Toilets		Storage Room (as far as ventilation)		0		0		0.12
Hotel and Conference Center "Back of House"		Wood/Metal Shop		20		10		0.18
Electric/Telephone		Telephone/Data Entry		5		5		0.06
Ballroom		Multi-Purpose Assembly		~112 or more		5		0.06
Kitchen Areas		Cafeteria		~45		7.5		0.18
Hotel Laundry Area		Warehouses (as far as ventilation)		10		0		0.06
Exercise Room		Health Club/Aerobics Room		40		20		0.06
Pool Area		Swimming (Pool&Deck)		35		0		0.48

Table 2: Occupancy and OA Requirement Assumptions

All other spaces mentioned throughout this report were listed in ASHRAE's Addendum 62n, Table 6.1. These areas include main entry lobbies, lobby/prefunction areas, reception areas, corridors, lecture classrooms, auditorium seating areas, conference/meeting rooms, storage rooms, office spaces, restaurant dining rooms, and bar/cocktail lounges. The occupancy (where needed) and ventilation values for these spaces were used as given in Addendum 62n, Table 6.1.

One last assumption made in preparing this report was that intermittent or variable occupancy throughout the conference center and hotel should not be considered. The tendency of the conference center and hotel spaces to be utilized at a semi-steady occupancy simultaneously, especially on the building's two main levels, is extremely likely. This type of situation for a conference center and hotel located in the Washington, D.C. metropolitan area would occur very frequently.

Therefore, a constant occupancy in all spaces, without fluctuation, must be used in order to determine the minimum outdoor airflow to each of MCCCH's many spaces. (Definite space occupancies were used where known, otherwise, ASHRAE default occupancy densities were used in estimating the number of people per space.)

4.0 Actual Design OA Flow Rates:

Once again, for practical reasons, this report is only focusing on the two main floors of the Montgomery County Conference Center and Hotel (~100,000+ sq. ft.). Exactly seven different air handling units serve this portion of the building. Two makeup air units are also incorporated into this section; however, they will not be analyzed for reasons stated previously in the report.

The areas served by each of the seven air handlers being studied for this report are presented in Sketch 1. The AHUs are labeled AHU 1-7 and the areas they provide ventilation to consist of the sections labeled A-F.

Since there are exactly seven AHUs that distribute air throughout the two main levels of the conference center and hotel, no calculation is required to find the total design OA flow rate(s). The OA cfms for each of the seven different air handlers can simply be extracted from the building's mechanical schedules. The overall design OA total is then just the sum of the seven individual OA cfms. Table 3 (below) lists the scheduled OA flow rates of interest.

The VRP laid out by ASHRAE Standard 62, Addendum 62n requires that each air handling unit and the area of which it serves be analyzed as a separate system. So, the individually scheduled design OA flows (from Table 3) will be utilized throughout the calculations presented in Section 5.0 of this report.

Design AHU	Serving Area/ Sketch 1 Section	Scheduled Supply CFM	Scheduled Max/Design OA CFM	Scheduled Min OA CFM
AHU-1	Conference Center/ Section A	50,000	50,000	30,000
AHU-2	Conference Center/ Section A	50,000	50,000	30,000
AHU-3	Restaurant/ Section B	12,500	12,500	5,000
AHU-4	Kitchen/Section C	9,000	9,000	2,250
AHU-5	Hotel First Floor/ Section D	9,000	9,000	2,250
AHU-6	Exercise Room/ Section E	1,400	1,400	350
AHU-7	Pool Area/Section F	3,200	3,200	1,000
	Total Flow:	**135,100**	**135,100**	**70,850**

Table 3: Individual AHU/Total Designed OA Flow Rates for the Two Main Levels of The Montgomery County Conference Center and Hotel

5.0 Determination of OA Flow Rates Required:

Now that the actual design outdoor airflow rates have been determined for each air handling unit serving the two main levels of MCCCH, they can be compared to the ventilation rate standard for acceptability or V_{ot} (outdoor air intake flow required). In order to calculate the minimum outdoor air required for ventilation to the two main levels of the conference center and hotel, the process outlined in the first draft of ASHRAE Standard 62-2001, Addendum 62n was applied to the building's data.

As stated before, Addendum 62n requires that every AHU serving the area of interest be evaluated separately for meeting OA requirements. Therefore, in this report, seven different air handling units are analyzed. Individual zones making up each AHU's total area served were determined by spaces monitored/served by VAV boxes or simply by CV spaces. All zones were chosen in accordance with Addendum 62n's Section 6.2.1.1 and 6.2.1.3.

Step 1: After the zones for each AHU are determined, one must find the *Breathing Zone Outdoor Airflow*, V_{bz}, for every zone corresponding to each AHU being studied. To do this, ASHRAE Equation 6-1 must be used.

$V_{bz} = (R_p*P_z) + (R_a*A_z)$ ASHRAE Equation 6-1

Where A_z = *zone floor area* or net occupiable floor area of the zone (ft^2).

P_z = *zone population* or the largest # of people expected to occupy the zone during typical usage. (This value was known for most zones but in some, it was estimated with the help of faculty/industry consultations and by using ASHRAE's Table 6.1 for occupancy densities.)

R_p = *outdoor airflow rate required per person* based on the values given in ASHRAE's Table 6.1.

R_a = *outdoor airflow rate required per unit area* based on the values given in ASHRAE's Table 6.1.

Step 2: Next, one must find the *Zone Air Distribution Effectiveness*, E_z, for every zone. To do this, ASHRAE Table 6.2 is used.

Throughout the two main levels of MCCCH, all cool and warm air supplied to the different zones is ceiling supplied. By using ASHRAE Table 6.2, it is easily found that all Zone Air Distribution Effectiveness values for MCCCH will be equal to one, $E_z = 1.0$.

Step 3: Each zone's outdoor airflow, V_{oz}, can now be solved for by using ASHRAE's Equation 6-2.

$V_{oz} = V_{bz} / E_z$ ASHRAE Equation 6-2

** Note: Where one air handler supplies a mixture of outdoor air and re-circulated air to only one zone, the V_{ot} for that particular AHU equals that zone's $V_{oz.}$ This will be illustrated later with the pool area in MCCCH.

Also, when one air handling unit supplies only outdoor air to one or more zones, the V_{ot} for that particular AHU equals the sum of its zones V_{oz} values. However, in this analysis, none of the air handlers (AHUs 1-7) supply only OA to the zones. If AHUs 8 and 9 and MAUs 10 and 11 were being analyzed for this building, this statement would apply as those four are all 100% OA units.

For multiple-zone re-circulating systems (like AHUs 1-7) where each air handler supplies both OA and re-circulated return air to more than one zone, the V_{ot} is determined by the following process, ASHRAE Section 6.2.4.1 – 6.2.4.4.**

Step 4: The next step is to determine each *zone primary OA fraction*, Z_p, and then, decide upon how to calculate the *system ventilation efficiency*, $E_{v,}$ for each AHU.

$Z_p = V_{oz} / V_{pzm}$ ASHRAE Equation 6-5

Where V_{pzm} = the minimum expected primary airflow to each zone.

The following tables (Tables 4-10 of this report) for air handling systems 1-7 of the Montgomery County Conference Center include a summary of values presented and calculated thus far in Section 5.0. The tables include OA requirements by zone for each AHU, as well as, a summary of Z_p values for each system.

AHU-1

	USE	AREA (sq. ft.)	DESIGN OCCUPANCY (# people)	OA REQUIREMENT (Voz, cfm)	Zp	MAX Zp
Zone 1	Main entry lobbies	270	5	41.2	0.055	
Zone 2	Reception areas	780	25	171.8	0.115	
Zone 3	Reception areas	210	3	27.6	0.084	
Zone 4	Corridors	1680	50	100.8	0.134	
Zone 5	Lecture Classroom	1000	50	435	0.806	
Zone 6	Media Center	340	5	90.8	0.275	

Zone 7	Auditorium seating area	790	42	257.4	0.572	
Zone 8	Reception areas	1000	50	310	0.207	
Zone 9	Conference / meeting	490	25	154.4	0.468	
Zone 10	Reception areas	350	30	171	0.190	
Zone 11	Media Center	200	2	44	0.326	
Zone 12	Auditorium seating area	790	42	257.4	0.572	
Zone 13	Storage rooms	6065	0	727.8	0.230	
Zone 14	Office space	725	10	93.5	0.283	
Zone 15	Office space	870	10	102.2	0.310	
Zone 16	Lecture Classroom	1000	50	435	0.806	
Zone 17	Lecture Classroom	1310	50	453.6	0.840	
Zone 18	Main entry lobbies	1015	10	110.9	0.148	
Zone 19	Reception areas	1015	30	210.9	0.281	
Zone 20	Main entry lobbies	850	10	101	0.067	
Zone 21	Reception areas	1260	50	325.6	0.217	
Zone 22	Lobbies/prefunction	1305	40	378.3	0.252	
Zone 23	Lobbies/prefunction	1160	35	332.1	0.221	
Zone 24	Lobbies/prefunction	1160	35	332.1	0.221	
Zone 25	Lobbies/prefunction	580	20	184.8	0.246	
Zone 26	Lobbies/prefunction	3000	30	405	0.540	
Zone 27	Corridors	2320	0	139.2	0.258	
Zone 28	Multi-purpose assembly	1885	213	1178.1	**0.873**	Max Zp
Zone 29	Multi-purpose assembly	1885	213	1178.1	**0.873**	Max Zp
Zone 30	Multi-purpose assembly	1885	213	1178.1	**0.873**	Max Zp
Zone 31	Multi-purpose assembly	1595	140	795.7	0.589	
Zone 32	Multi-purpose assembly	1595	140	795.7	0.589	
Zone 33	Multi-purpose assembly	1595	140	795.7	0.589	
Zone 34	Office space	1595	140	795.7	0.589	
	TOTALS	**43570**	**1908**	**13110.5**		

Table 4: AHU - 1 (consists of 34 different zones)

AHU-2

	USE	AREA (sq. ft.)	DESIGN OCCUPANCY (# people)	OA REQUIREMENT (Voz, cfm)	Zp	MAX Zp
Zone 35	Lecture Classroom	600	20	186	0.827	
Zone 36	Lecture Classroom	480	20	178.8	0.795	
Zone 37	Conference / meeting	845	42	260.7	0.483	
Zone 38	Lecture Classroom	465	20	177.9	0.791	
Zone 39	Lecture Classroom	480	20	178.8	0.795	
Zone 40	Lobbies/prefunction	2300	60	588	0.784	
Zone 41	Corridors	365	0	21.9	0.162	
Zone 42	Lecture Classroom	1130	50	442.8	0.820	
Zone 43	Corridors	3250	0	195	0.361	
Zone 44	Wood/metal shop	2800	10	604	0.805	
Zone 45	Corridors	1815	0	108.9	0.145	
Zone 46	Conference / meeting	650	32	199	0.603	
Zone 47	Lobbies/prefunction	2320	35	401.7	0.744	
Zone 48	Storage rooms	58	0	6.96	0.052	
Zone 49	Conference / meeting	1310	65	403.6	0.538	
Zone 50	Auditorium seating area	790	42	257.4	0.572	
Zone 51	Telephone/data entry	320	3	34.2	0.152	
Zone 52	Storage rooms	2060	10	247.2	0.330	
Zone 53	Multi-purpose assembly	1595	140	795.7	0.589	
Zone 54	Multi-purpose assembly	1595	140	795.7	0.589	
Zone 55	Multi-purpose assembly	1595	140	795.7	0.589	
Zone 56	Multi-purpose assembly	1595	140	795.7	0.589	
Zone 57	Multi-purpose assembly	1885	213	1178.1	**0.873**	Max Zp
Zone 58	Multi-purpose assembly	1885	213	1178.1	**0.873**	Max Zp
Zone 59	Multi-purpose assembly	1885	213	1178.1	**0.873**	Max Zp
	TOTALS	**34073**	**1628**	**11209.96**		

Table 5: AHU - 2 (consists of 25 different zones)

AHU-3

	USE	AREA (sq. ft.)	DESIGN OCCUPANCY (# people)	OA REQUIREMENT (Voz, cfm)	Zp	MAX Zp
Zone 60	Office space	1170	10	120.2	0.267	
Zone 61	Lobbies/prefunction	1070	45	401.7	0.446	
Zone 62	Lobbies/prefunction	700	30	267	0.178	
Zone 63	Restaurant dining rooms	870	40	456.6	0.609	
Zone 64	Restaurant dining rooms	870	40	456.6	0.609	
Zone 65	Lobbies/prefunction	550	25	220.5	0.147	
Zone 66	Restaurant dining rooms	1000	30	405	0.540	
Zone 67	Bars, cocktail lounges	2000	75	922.5	**0.615**	Max Zp
	TOTALS	**8230**	**295**	**3250.1**		

Table 6: AHU - 3 (consists of 8 different zones)

AHU-4

	USE	AREA (sq. ft.)	DESIGN OCCUPANCY (# people)	OA REQUIREMENT (Voz, cfm)	Zp	MAX Zp
Zone 68	Office space	60	2	13.6	0.170	
Zone 69	Storage rooms	140	0	16.8	0.105	
Zone 70	Corridors	230	0	13.8	0.036	
Zone 71	Cafeteria / fast food dining	400	5	109.5	0.219	
Zone 72	Cafeteria / fast food dining	250	3	67.5	0.135	
Zone 73	Corridors	200	0	12	0.024	
Zone 74	Cafeteria / fast food dining	60	5	48.3	0.097	
Zone 75	Cafeteria / fast food dining	380	6	113.4	0.095	
Zone 76	Storage rooms	80	0	9.6	0.024	
Zone 77	Cafeteria / fast food dining	145	2	41.1	0.103	
Zone 78	Cafeteria / fast food dining	90	2	31.2	0.078	
Zone 79	Office space	60	2	13.6	0.136	
Zone 80	Cafeteria / fast food dining	200	5	73.5	0.184	

Zone 81	Cafeteria / fast food dining	200	5	73.5	0.184	
Zone 82	Cafeteria / fast food dining	160	3	51.3	0.103	
Zone 83	Cafeteria / fast food dining	385	8	129.3	**0.404**	Max Zp
Zone 84	Cafeteria / fast food dining	186	3	55.98	0.140	
Zone 85	Cafeteria / fast food dining	220	3	62.1	0.124	
Zone 86	Cafeteria / fast food dining	220	3	62.1	0.155	
Zone 87	Cafeteria / fast food dining	220	3	62.1	0.155	
Zone 88	Storage rooms	365	2	43.8	0.110	
	TOTAL	**4251**	**62**	**1104.08**		

Table 7: AHU - 4 (consists of 21 different zones)

AHU-5

	USE	AREA (sq. ft.)	DESIGN OCCUPANCY (# people)	OA REQUIREMENT (Voz, cfm)	Zp	MAX Zp
Zone 89	Office space	235	5	39.1	0.290	
Zone 90	Corridors	125	0	7.5	0.056	
Zone 91	Warehouses	650	5	39	0.289	
Zone 92	Main entry lobbies	140	10	58.4	0.078	
Zone 93	Office space	2200	30	282	0.376	
Zone 94	Lobbies/prefunction	700	35	304.5	0.203	
Zone 95	Lobbies/prefunction	1090	15	177.9	0.119	
Zone 96	Office space	1160	15	144.6	0.321	
Zone 97	Lobbies	380	10	72.8	**0.539**	Max Zp
	TOTAL	**6680**	**125**	**1125.8**		

Table 8: AHU - 5 (consists of 9 different zones)

AHU-6

	USE	AREA (sq. ft.)	DESIGN OCCUPANCY (# people)	OA REQUIREMENT (Voz, cfm)	Zp	MAX Zp
Zone 98	Storage rooms	270	5	32.4	0.068	
Zone 99	Corridors	130	0	7.8	0.078	
Zone 100	Health club/aerobics room	760	10	245.6	**0.307**	Max Zp
	TOTAL	**1160**	**15**	**285.8**		

Table 9: AHU - 6 (consists of 3 different zones)

AHU-7

	USE	AREA (sq. ft.)	DESIGN OCCUPANCY (# people)	OA REQUIREMENT (Voz, cfm)	Zp	MAX Zp
Zone 101	Swimming (pool & deck)	1860	50	892.8	**0.279**	MAX Zp
	TOTAL	**1860**	**50**	**892.8**		

Table 10: AHU - 7 (consists of 1 different zone)

Once all Z_p's are known, ASHRAE Addendum 62n provides two different ways to find the value for E_v. ASHRAE Table 6.3 can be used along with the primary OA fractions to find E_v but, for certain zone criteria, Z_p's > 0.55, Table 6.3 cannot be used and therefore, references Appendix G.

Appendix G outlines a more precise way of calculating the *system ventilation efficiency* by setting E_v equal to the lowest calculated value of *zone ventilation efficiency*, $E_{vz.}$ The process laid out by Appendix G involves a bit more calculation but produces a more accurate E_v value by taking into account each individual zone.

Due to a large number of my Z_p's being greater than 0.55, I chose to use Appendix G to calculate all E_v values for this report. Also, by using Appendix G for every zone, my overall calculation will be more precise.

Step 5: Since Appendix G was chosen to be used for this report, certain variables needed for the overall calculation change. Instead of using V_{pz} (primary airflow to each zone) and V_{pzm} (defined above), V_{pz}, V_{dz}, and V_{dzm} are used; where V_{dz} is the supply/discharge to each zone and V_{dzm} is the minimum supply/discharge to each zone. However, for all of the zones being analyzed in MCCCH, $V_{pz} = V_{dz}$, and V_{dzm} is the minimum scheduled cfm for each zone (if VAV, minimum cfm is scheduled and if CV, $V_{dzm} = V_{pz} = V_{dz}$).

Also, Z_p becomes Z_d, the outdoor air fraction required in air discharged to zone, V_{oz}/V_{dzm}.

Step 6: Next, the *primary air fraction to each zone*, $E_p = V_{pz}/V_{dz}$ (=1 for single duct and single zone systems) can be calculated along with the *fraction of secondary re-circulated air to each zone*, E_r, which is representative of the system average. E_r only applies if E_p is less than 1. For plenum return $E_r = 0$ and for duct return with local secondary re-circulation $E_r = 1$. For all zones being analyzed in this report, E_p and E_r equal 1 and 0.

Step 7: The *fraction of supply air to each zone from sources outside the zone*, $F_a = E_p + (1-E_p)*E_r$, can now be calculated. The *fraction of supply air to each zone from fully mixed primary air*, $F_b = E_p = V_{pz}/V_{dz}$, can also be found. Finally, the *fraction of outdoor air to each zone from sources outside the zone*, $F_c = 1 - (1-E_z) * (1-E_r) * (1-E_p)$, can be evaluated.

In this analysis of the two main levels of MCCCH, all zone's value of F_a, F_b**,** and F_c was equal to 1.

Step 8: Now, one needs to estimate the P_s, *system population* or the maximum simultaneous number of occupants per total area served by each AHU. This value can most definitely differ from the simple sum of each AHU's zone populations due to the fact that all zones may not be fully occupied all at the same time.

Using the system populations, one can find the *occupant diversity*, D, for each of the seven AHUs being studied. Occupant diversity is the ratio of each system's peak occupancy to the sum of its peak space occupancies, $D = P_s/(\sum P_z)$, (ASHRAE Equation 6-7).

Step 9: The *uncorrected OA intake* (cfm) for each air handling unit can now be calculated by using ASHRAE's Equation 6-6,

$$V_{ou} = D*\sum R_p*P_z + \sum R_a*A_z$$

From here, the V_{ps} or *total system primary flow* from each AHU to its zones must be calculated. This value is the $\sum V_{pz}$ for CV systems, while in VAV systems, V_{ps} is equal to each AHU's fan airflow. MCCCH contains both CV and VAV, therefore, V_{ps} will be found accordingly.

Step 10: At Last**,** the *mixing ratio*, X_s, of the uncorrected outdoor air intake to each air handler system's primary flow can be found by V_{ou}/V_{ps}**.**

From this, the *zone ventilation efficiency*, E_{vs}, can be calculated for every individual zone by $(F_a + X_s*F_b - Z_d*F_c)/F_a$. Each AHU's E_v, or *system ventilation effectiveness,* is then set equal to that system's smallest zone value of $E_{vs.}$

Each individual air handling unit's V_{ot}, or minimum outdoor air intake (cfm), can be found by taking V_{ou}/E_v. The percentage (%) of OA intake is then simply $V_{ot}/V_{ps}*10$.

The entire process described above was used to calculate the required ventilation for each of MCCCH's seven air handling units being studied in this report. The final calculation results for AHUs 1-7 are summarized below. Full calculations for each of the air handling units can be found in Appendix A of this report. (The full calculations were performed using the ASHRAE published excel file for Addendum 62n, VRP.xls)

AHU-1

RESULTS		
Vot	Minimum outdoor air intake, Vou/Ev, cfm	29762
	Percent outdoor air intake, Vot/Vps	60%
Ev	System ventilation efficiency	0.31
ΣVoz	Sum of the AHU's individual zone req. OA flows, cfm	13111

The sum of AHU 1's individual zone required OA flows, ΣVoz, is 13,111 cfm, which is much less than the minimum OA intake required of 29,762 cfm. This is mainly due to the very low system ventilation efficiency, Ev, calculated for air handler #1. Ev could be that low due to the fact that AHU 1 serves many large conference center spaces that contain very large amounts of people all at one time.

However, from the results, the minimum amount of fresh air (OA) required for the zones served by AHU 1 is 29,792 cfm. The minimum amount of OA scheduled for AHU 1 (Table 3) is 30,000 cfm. Therefore,

AHU 1
OA Flow > OA Required by ASHRAE Std. 62, Addendum 62n
ASHRAE Standard 62 (Addendum 62n) is met by AHU 1

AHU-2

RESULTS		
Vot	Minimum outdoor air intake, Vou/Ev, cfm	29179
	Percent outdoor air intake, Vot/Vps	58%
Ev	System ventilation efficiency	0.31
ΣVoz	Sum of the AHU's individual zone req. OA flows, cfm	11210

The sum of AHU 2's individual zone required OA flows, ΣVoz, is 11,210 cfm, which is much less than the minimum OA intake required of 29,179 cfm. This is mainly due to the very low system ventilation efficiency, Ev, calculated for air handler #2. Ev could be that low due to the fact that AHU 2 also serves many large conference center spaces that contain very large amounts of people all at one time. (the same situation as AHU 1)

However, from the results, the minimum amount of fresh air (OA) required for the zones served by AHU 2 is 29,179 cfm. The minimum amount of OA scheduled for AHU 2 (Table 3) is 30,000 cfm. Therefore,

AHU 2
OA Flow > OA Required by ASHRAE Std. 62, Addendum 62n
ASHRAE Standard 62 (Addendum 62n) is met by AHU 2

AHU-3

RESULTS		
Vot	Minimum outdoor air intake, Vou/Ev, cfm	4827
	Percent outdoor air intake, Vot/Vps	39%
Ev	System ventilation efficiency	0.63
ΣVoz	Sum of the AHU's individual zone req. OA flows, cfm	3250

The sum of AHU 3's individual zone required OA flows, ΣVoz, is 3,250 cfm, which is just a bit less than the minimum OA intake required of 4,827 cfm. The smaller difference between the two airflows is due to the higher Ev value of 63%.

From the results, the minimum amount of fresh air (OA) required for the zones served by AHU 3 is 4,827 cfm. The minimum amount of OA scheduled for AHU 3 (Table 3) is 5,000 cfm. Therefore,

AHU 3
OA Flow > OA Required by ASHRAE Std. 62, Addendum 62n
ASHRAE Standard 62 (Addendum 62n) is met by AHU 3

AHU-4

RESULTS		
Vot	Minimum outdoor air intake, Vou/Ev, cfm	1828
	Percent outdoor air intake, Vot/Vps	21%
Ev	System ventilation efficiency	0.75
ΣVoz	Sum of the AHU's individual zone req. OA flows, cfm	1110

The sum of AHU 4's individual zone required OA flows, ΣVoz, is 1,110 cfm, which is just a bit less than the minimum OA intake required of 1,828 cfm. The smaller difference between the two airflows is due to the higher Ev value of 75%. AHU 4 is also a constant volume system which helps to further raise the ventilation efficiency value.

From the results, the minimum amount of fresh air (OA) required for the zones served by AHU 4 is 1,828 cfm. The minimum amount of OA scheduled for AHU 4 (Table 3) is 2,250 cfm. Therefore,

AHU 4
OA Flow > OA Required by ASHRAE Std. 62, Addendum 62n
ASHRAE Standard 62 (Addendum 62n) is met by AHU 4

AHU-5

RESULTS		
Vot	Minimum outdoor air intake, Vou/Ev, cfm	1922
	Percent outdoor air intake, Vot/Vps	21%
Ev	System ventilation efficiency	0.59
ΣVoz	Sum of the AHU's individual zone req. OA flows, cfm	1126

The sum of AHU 5's individual zone required OA flows, ΣVoz, is 1,126 cfm, which is just a bit less than the minimum OA intake required of 1,922 cfm. The smaller difference between the two airflows is due to the higher Ev value of 59%.

From the results, the minimum amount of fresh air (OA) required for the zones served by AHU 5 is 1,922 cfm. The minimum amount of OA scheduled for AHU 3 (Table 3) is 2,250 cfm. Therefore,

AHU 5
OA Flow > OA Required by ASHRAE Std. 62, Addendum 62n
ASHRAE Standard 62 (Addendum 62n) is met by AHU 5

AHU-6

RESULTS		
Vot	Minimum outdoor air intake, Vou/Ev, cfm	318
	Percent outdoor air intake, Vot/Vps	23%
Ev	System ventilation efficiency	0.90
ΣVoz	Sum of the AHU's individual zone req. OA flows, cfm	286

The sum of AHU 6's individual zone required OA flows, ΣVoz, is 286 cfm, which is just a bit less than the minimum OA intake required of 318 cfm. The smaller difference between the two airflows is due to the higher Ev value of 90%. AHU 6 is also a constant volume system which helps to further raise the ventilation efficiency value.

From the results, the minimum amount of fresh air (OA) required for the zones served by AHU 6 is 318 cfm. The minimum amount of OA scheduled for AHU 4 (Table 3) is 350 cfm. Therefore,

AHU 6
OA Flow > OA Required by ASHRAE Std. 62, Addendum 62n
ASHRAE Standard 62 (Addendum 62n) is met by AHU 6

AHU-7

RESULTS		
Vot	Minimum outdoor air intake, Vou/Ev, cfm	893
	Percent outdoor air intake, Vot/Vps	28%
Ev	System ventilation efficiency	1.00
ΣVoz	Sum of the AHU's individual zone req. OA flows, cfm	893

The sum of AHU 7's individual zone required OA flows, ΣVoz, is 893 cfm, which is the same as the minimum OA intake required. This is due to the Ev value being 100%. AHU 7 is also a constant volume system which serves only one zone.

From the results, the minimum amount of fresh air (OA) required for the zones served by AHU 7 is 893 cfm. The minimum amount of OA scheduled for AHU 7 (Table 3) is 1,000 cfm. Therefore,

AHU 7
OA Flow > OA Required by ASHRAE Std. 62, Addendum 62n
ASHRAE Standard 62 (Addendum 62n) is met by AHU 7

Finally, from the grand total of all of the results listed above, the minimum amount of fresh air (OA) required for MCCCH, the sum of all seven AHU's Vot's, is 68,729 cfm. The minimum amount of OA scheduled for the building (Table 3) is 70,850 cfm. Therefore,

The two main levels of the Montgomery County Conference Center and Hotel
OA Flow > OA Required by ASHRAE Std. 62, Addendum 62n
ASHRAE Standard 62 (Addendum 62n) is met by the entire building

This means that mechanical systems serving the two main levels of The Montgomery County Conference Center and Hotel can effectively dilute contaminants within the building/system(s).

6.0 Discussion:

For this report, ASHRAE Standard 62-2001, Addendum 62n was used to determine an acceptable OA flow to the two main levels of MCCCH. The

"Ventilation Rate Procedure, VRP" was the exact method of analysis utilized. In this process, the OA required for a building mechanical system is calculated based on building zone usage, size, and occupancy with an underlying effort to maintain CO2 levels below 700 ppm (the indoor air quality comfort zone for most people).

The "VRP" method is the prescriptive method for achieving acceptable indoor air quality. It requires minimum ventilation rates for varying spaces and occupancies thereby controlling indoor contaminant levels. By using the "VRP" method, the need to monitor indoor air contaminants like biological aerosols, volatile organic compounds, and particulates is eliminated. The minimum ventilation rates used to satisfy CO2 levels end up successfully diluting most other contaminants of concern.

The "Indoor Air Quality Procedure, IAQP" is another process set forth by ASHRAE that could have been used to determine the ventilation needed in MCCCH for this report. The "IAQP" deals with indoor air contamination factors throughout different building spaces. It takes into consideration the possible contamination of outdoor and re-circulated air as well as the evaluation of odor levels.

The "IAQP" is mainly a performance based method for guaranteeing good indoor air quality. The method helps one calculate the possible amounts of contamination within individual building zones. It then suggests certain ventilation rates in order to meet the "IAQP" limits for specified air contaminants. The "IAQP" also provides solutions to any contaminant build-up not taken care of by the prescribed ventilation levels. These solutions involve the monitoring and cleansing of all building supply air, ultimately leading to very high levels of indoor air quality.

However, the "Indoor Air Quality Procedure" can be very hard to use. ASHRAE Standard 62 is extremely limited in the amount of data/information available for use with the "IAQP". Most types of buildings/building criteria are not sufficiently outlined and the continued monitoring of all building zones throughout the life of the building is crucial. The "VRP", if used instead of the "IAQP", requires no monitoring or lifelong follow-up for a building. This is why the "VRP" is more commonly used in design practice and therefore, why it was implemented for this report.

7.0 References:

1. ASHRAE Standard 62-2001, Section 6, as modified by Addendum 62n, *Ventilation for Acceptable Indoor Air Quality*.
2. ASHRAE Standard 62-2001, as modified by Addendum 62n, *excel spreadsheet, VRP.xls*
3. The Pennsylvania State University Architectural Engineering Department, Thesis Advisor - Technical Assignment #1: Dr. Jelena Srebric.
4. Past Thesis Technical Assignments/Reports, E-thesis Archives, 2004
5. RTKL Associates, Engineering Design Group, and Southland Industries, Mechanical Drawings and Specifications.

8.0 Appendix A – ASHRAE Standard 62 Calculation Spreadsheets

RESULTS - AHU 1		
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**29762**
	Percent outdoor air intake, Vot/Vps	**60%**
Ev	**System ventilation efficiency**	**0.31**

ZONE LEVEL

	Zones served by system	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**	**Zone 5**	**Zone 6**	**Zone 7**	**Zone 8**	**Zone 9**	**Zone 10**	**Zone 11**	**Zone 12**	**Zone 13**	**Zone 14**	**Zone 15**
	Space type (select from pull-down list)	Main entry lobbies	Reception areas	Reception areas	Corridors	Lecture Classroom	Media Center	Auditorium seating	Reception areas	Conference / meeting	Reception areas	Media Center	Auditorium seating	Storage rooms	Office space	Office space
Az	Floor area of zone, ft2	270	780	210	1680	1000	340	790	1000	490	350	200	790	6065	725	870
Pz	Zone population, largest # of people expected to occupy zone	5	25	3	50	50	5	42	50	25	30	2	42	0	10	10
Rp	Area outdoor air rate from Table 6.1, cfm/ft2	5	5	5	0	7.5	10	5	5	5	5	10	5	0	5	5
Ra	People outdoor air rate from Table 6.1, cfm/person	0.06	0.06	0.06	0.06	0.06	0.12	0.06	0.06	0.06	0.06	0.12	0.06	0.12	0.06	0.06
Pz*Rp		25	125	15	0	375	50	210	250	125	150	20	210	0	50	50
Az*Ra		16.2	46.8	12.6	100.8	60	40.8	47.4	60	29.4	21	24	47.4	727.8	43.5	52.2
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	41.2	171.8	27.6	100.8	435	90.8	257.4	310	154.4	171	44	257.4	727.8	93.5	102.2
Vpz	Primary airflow to zone from air handler (intake plus recirculated air, but not local recirculation such as at mixing boxes), cfm. **In VAV systems, use the design**	1500	2800	820	1400	1620	900	1335	2800	675	1750	400	1335	3450	950	975
Vdz	Supply/discharge to zone including primary air Vpz and locally recirculated air, cfm. **In VAV systems, use the design value.**	1500	2800	820	1400	1620	900	1335	2800	675	1750	400	1335	3450	950	975
Vdzm	Minimum supply/discharge to zone used to calculate Ev, cfm. **In CAV systems, Vdzm = Vdz. In VAV systems, Vdzm is the minimum expected value of Vdz.**	750	1500	330	750	540	330	450	1500	330	900	135	450	3135	330	330
Zd	Outdoor air fraction required in air discharged to zone, = Voz/Vdzm	0.05	0.11	0.08	0.13	0.81	0.28	0.57	0.21	0.47	0.19	0.33	0.57	0.23	0.28	0.31
Ep	Primary air fraction to zone, = Vpz/Vdz (=1 for single duct and single zone systems)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Er	Fraction of secondary recirc to zone representative of system average, only applies if Ep<1. For plenum return =0. For duct return with local secondary recirc =1.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ez	Zone air distribution effectiveness, Table 6.2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fa	Fraction of supply air to zone from sources outside zone, = Ep + (1-Ep)*Er	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fb	Fraction of supply air to zone from full mixed primary air, = Ep = Vpz/Vdz	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fc	Fraction of outdoor air to zone from sources outside zone, = 1 - (1-Ez) * (1-Er) * (1-Ep)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

SYSTEM LEVEL

Ps	System population, maximum simultaneous # of occupants of space served by system	1200
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	0.63
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz +ΣRa*Az,	9363
Vps	Total system primary flow to all zones, Σ Vpz, cfm	50000
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.19

Note: In VAV systems, Vps is equal to the fan airflow, and the formula in cell c40 needs to be replaced by this value.

SYSTEM EFFICIENCY

		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12	Zone 13	Zone 14	Zone 15
Evs	Zone ventilation efficiency, (Fa +Xs*Fb - Z*Fc)/Fa	1.13	1.07	1.10	1.05	0.38	0.91	0.62	0.98	0.72	1.00	0.86	0.62	0.96	0.90	0.88
Ev	System ventilation efficiency, min(Evs)	0.31														

			Percent outdoor air intake
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**29762**	**60%** = Vot/Vps

Zone 16	Zone 17	Zone 18	Zone 19	Zone 20	Zone 21	Zone 22	Zone 23	Zone 24	Zone 25	Zone 26	Zone 27	Zone 28	Zone 29	Zone 30	Zone 31	Zone 32	Zone 33	Zone 34
Lecture Classroom	Lecture Classroom	Main entry lobbies	Reception areas	Main entry lobbies	Reception areas	Lobbies/prefunction	Lobbies/prefunction	Lobbies/prefunction	Lobbies/prefunction	Lobbies/prefunction	Corridors	Multi-purpose	Multi-purpose	Multi-purpose	Multi-purpose	Multi-purpose	Multi-purpose	Office space
1000	1310	1015	1015	850	1260	1305	1160	1160	580	3000	2320	1885	1885	1885	1595	1595	1595	1595
50	50	10	30	10	50	40	35	35	20	30	0	213	213	213	140	140	140	140
7.5	7.5	5	5	5	5	7.5	7.5	7.5	7.5	7.5	0	5	5	5	5	5	5	5
0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
375	375	50	150	50	250	300	262.5	262.5	150	225	0	1065	1065	1065	700	700	700	700
60	78.6	60.9	60.9	51	75.6	78.3	69.6	69.6	34.8	180	139.2	113.1	113.1	113.1	95.7	95.7	95.7	95.7
435	453.6	110.9	210.9	101	325.6	378.3	332.1	332.1	184.8	405	139.2	1178.1	1178.1	1178.1	795.7	795.7	795.7	795.7
1620	1560	1380	1200	2400	2400	2400	2400	2400	1200	1760	1600	4480	4480	4480	3640	3640	3640	3640
1620	1560	1380	1200	2400	2400	2400	2400	2400	1200	1760	1600	4480	4480	4480	3640	3640	3640	3640
540	540	750	750	1500	1500	1500	1500	1500	750	750	540	1350	1350	1350	1350	1350	1350	1350
0.81	0.84	0.15	0.28	0.07	0.22	0.25	0.22	0.22	0.25	0.54	0.26	0.87	0.87	0.87	0.59	0.59	0.59	0.59
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.38	0.35	1.04	0.91	1.12	0.97	0.94	0.97	0.97	0.94	0.65	0.93	0.31	0.31	0.31	0.60	0.60	0.60	0.60

RESULTS - AHU 2		
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**29179**
	Percent outdoor air intake, Vot/Vps	**58%**
Ev	**System ventilation efficiency**	**0.31**

ZONE LEVEL

	Zones served by system	Zone 35	Zone 36	Zone 37	Zone 38	Zone 39	Zone 40	Zone 41	Zone 42	Zone 43	Zone 44	Zone 45
	Space type (select from pull-down list)	Lecture Classroom	Lecture Classroom	Conference / meeting	Lecture Classroom	Lecture Classroom	Lobbies/prefunction	Corridors	Lecture Classroom	Corridors	Wood/metal shop	Corridors
Az	Floor area of zone, ft2	600	480	845	465	480	2300	365	1130	3250	2800	1815
Pz	Zone population, largest # of people expected to occupy zone	20	20	42	20	20	60	0	50	0	10	0
Rp	Area outdoor air rate from Table 6.1, cfm/ft2	7.5	7.5	5	7.5	7.5	7.5	0	7.5	0	10	0
Ra	People outdoor air rate from Table 6.1, cfm/person	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.18	0.06
Pz*Rp		150	150	210	150	150	450	0	375	0	100	0
Az*Ra		36	28.8	50.7	27.9	28.8	138	21.9	67.8	195	504	108.9
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	186	178.8	260.7	177.9	178.8	588	21.9	442.8	195	604	108.9
Vpz	Primary airflow to zone from air handler (intake plus recirculated air, but not local recirculation such as at mixing boxes), cfm. **In VAV systems, use the design value.**	720	675	1800	680	680	2350	300	1650	1500	2000	2500
Vdz	Supply/discharge to zone including primary air Vpz and locally recirculated air, cfm. **In VAV systems, use the design value.**	720	675	1800	680	680	2350	300	1650	1500	2000	2500
Vdzm	Minimum supply/discharge to zone used to calculate Ev, cfm. **In CAV systems, Vdzm = Vdz. In VAV systems, Vdzm is the minimum expected value of Vdz.**	225	225	540	225	225	750	135	540	540	750	750
Zd	Outdoor air fraction required in air discharged to zone, = Voz/Vdzm	0.83	0.79	0.48	0.79	0.79	0.78	0.16	0.82	0.36	0.81	0.15
Ep	Primary air fraction to zone, = Vpz/Vdz (=1 for single duct and single zone systems)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Er	Fraction of secondary recirc to zone representative of system average, only applies if Ep<1. For plenum return =0. For duct return with local secondary recirc =1.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ez	Zone air distribution effectiveness, Table 6.2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fa	Fraction of supply air to zone from sources outside zone, = Ep + (1-Ep)*Er	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fb	Fraction of supply air to zone from full mixed primary air, = Ep = Vpz/Vdz	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fc	Fraction of outdoor air to zone from sources outside zone, = 1 - (1-Ez) * (1-Er) * (1-Ep)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

SYSTEM LEVEL

Ps	System population, maximum simultaneous # of occupants of space served by system	1200
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	0.74
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz +ΣRa*Az, cfm	8922
Vps	Total system primary flow to all zones, Σ Vpz, cfm	50000
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.18

Note: In VAV systems, Vps is equal to the fan airflow, and the formula in cell c40 needs to be replaced by this value.

SYSTEM EFFICIENCY

		Zone 35	Zone 36	Zone 37	Zone 38	Zone 39	Zone 40	Zone 41	Zone 42	Zone 43	Zone 44	Zone 45
Evs	Zone ventilation efficiency, (Fa +Xs*Fb - Z*Fc)/Fa	0.35	0.38	0.70	0.39	0.38	0.39	1.02	0.36	0.82	0.37	1.03
Ev	System ventilation efficiency, min(Evs)	0.31										

Vot **Minimum outdoor air intake, Vou/Ev, cfm** **29179**

Percent outdoor air intake
58% = Vot/Vps

Zone 46	Zone 47	Zone 48	Zone 49	Zone 50	Zone 51	Zone 52	Zone 53	Zone 54	Zone 55	Zone 56	Zone 57	Zone 58	Zone 59
Conference / meeting	Lobbies/prefunction	Storage rooms	Conference / meeting	Auditorium seating a	Telephone/data entry	Storage rooms	Multi-purpose a	Multi-purpose a	Multi-purpose	Multi-purpose a	Multi-purpose	Multi-purpose	Multi-purpose a
650	2320	58	1310	790	320	2060	1595	1595	1595	1595	1885	1885	1885
32	35	0	65	42	3	10	140	140	140	140	213	213	213
5	7.5	0	5	5	5	0	5	5	5	5	5	5	5
0.06	0.06	0.12	0.06	0.06	0.06	0.12	0.06	0.06	0.06	0.06	0.06	0.06	0.06
160	262.5	0	325	210	15	0	700	700	700	700	1065	1065	1065
39	139.2	6.96	78.6	47.4	19.2	247.2	95.7	95.7	95.7	95.7	113.1	113.1	113.1
199	401.7	6.96	403.6	257.4	34.2	247.2	795.7	795.7	795.7	795.7	1178.1	1178.1	1178.1
955	1750	400	1950	1335	750	1960	3640	3640	3640	3640	4480	4480	4480
955	1750	400	1950	1335	750	1960	3640	3640	3640	3640	4480	4480	4480
330	540	135	750	450	225	750	1350	1350	1350	1350	1350	1350	1350
0.60	0.74	0.05	0.54	0.57	0.15	0.33	0.59	0.59	0.59	0.59	0.87	0.87	0.87
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0.58	0.43	1.13	0.64	0.61	1.03	0.85	0.59	0.59	0.59	0.59	0.31	0.31	0.31

RESULTS - AHU 3		
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**4827**
	Percent outdoor air intake, Vot/Vps	**39%**
Ev	**System ventilation efficiency**	**0.63**

ZONE LEVEL

	Zones served by system	**Zone 60**	**Zone 61**	**Zone 62**	**Zone 63**	**Zone 64**	**Zone 65**	**Zone 66**	**Zone 67**
	Space type (select from pull-down list)	Office space	Lobbies/prefunction	Lobbies/prefunction	Restaurant dining rooms	Restaurant dining rooms	Lobbies/prefunction	Restaurant dining rooms	Bars, cocktail lounges
Az	Floor area of zone, ft2	1170	1070	700	870	870	550	1000	2000
Pz	Zone population, largest # of people expected to occupy zone	10	45	30	40	40	25	30	75
Rp	Area outdoor air rate from Table 6.1, cfm/ft2	5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Ra	People outdoor air rate from Table 6.1, cfm/person	0.06	0.06	0.06	0.18	0.18	0.06	0.18	0.18
Pz*Rp		50	337.5	225	300	300	187.5	225	562.5
Az*Ra		70.2	64.2	42	156.6	156.6	33	180	360
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	120.2	401.7	267	456.6	456.6	220.5	405	922.5
Vpz	Primary airflow to zone from air handler (intake plus recirculated air, but not local recirculation such as at mixing boxes), cfm. **In VAV systems, use the design**	1420	1800	2900	2500	2500	3000	2500	2900
Vdz	Supply/discharge to zone including primary air Vpz and locally recirculated air, cfm. **In VAV systems, use the design value.**	1420	1800	2900	2500	2500	3000	2500	2900
Vdzm	Minimum supply/discharge to zone used to calculate Ev, cfm. **In CAV systems, Vdzm = Vdz. In VAV systems, Vdzm is the minimum expected value of Vdz.**	450	900	1500	750	750	1500	750	1500
Zd	Outdoor air fraction required in air discharged to zone, = Voz/Vdzm	0.27	0.45	0.18	0.61	0.61	0.15	0.54	0.62
Ep	Primary air fraction to zone, = Vpz/Vdz (=1 for single duct and single zone systems)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Er	Fraction of secondary recirc to zone representative of system average, only applies if Ep<1. For plenum return =0. For duct return with local secondary recirc =1.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ez	Zone air distribution effectiveness, Table 6.2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fa	Fraction of supply air to zone from sources outside zone, = Ep + (1-Ep)*Er	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fb	Fraction of supply air to zone from full mixed primary air, = Ep = Vpz/Vdz	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fc	Fraction of outdoor air to zone from sources outside zone, = 1 - (1-Ez) * (1-Er) * (1-Ep)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

SYSTEM LEVEL

Ps	System population, maximum simultaneous # of occupants of space served by system	265
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	0.90
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz +ΣRa*Az, cfm	3028
Vps	Total system primary flow to all zones, Σ Vpz, cfm	12500
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.24

Note: In VAV systems, Vps is equal to the fan airflow, and the formula in cell c40 needs to be replaced by this value.

SYSTEM EFFICIENCY

		Zone 60	Zone 61	Zone 62	Zone 63	Zone 64	Zone 65	Zone 66	Zone 67
Evs	Zone ventilation efficiency, (Fa +Xs*Fb - Z*Fc)/Fa	0.98	0.80	1.06	0.63	0.63	1.10	0.70	0.63
Ev	System ventilation efficiency, min(Evs)	0.63							

Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**4827**	**Percent outdoor air intake** **39%**	= Vot/Vps

RESULTS - AHU 4

Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**1828**
	Percent outdoor air intake, Vot/Vps	**21%**
Ev	**System ventilation efficiency**	**0.75**

ZONE LEVEL

	Zones served by system	**Zone 68**	**Zone 69**	**Zone 70**	**Zone 71**	**Zone 72**	**Zone 73**	**Zone 74**	**Zone 75**	**Zone 76**	**Zone 77**	**Zone 78**	**Zone 79**	**Zone 80**	**Zone 81**	**Zone 82**	**Zone 83**	**Zone 84**	**Zone 85**	**Zone 86**	**Zone 87**	**Zone 88**
	Space type (select from pull-down list)	Office space	Storage rooms	Corridors	Cafeteria	Cafeteria	Corridors	Cafeteria	Cafeteria	Storage rooms	Cafeteria	Cafeteria	Office space	Cafeteria	Cafeteria	Cafeteria	Cafeteria	Cafeteria	Cafeteria	Cafeteria	Cafeteria	Storage rooms
Az	Floor area of zone, ft2	60	140	230	400	250	200	60	380	80	145	90	60	200	200	160	385	186	220	220	220	365
Pz	Zone population, largest # of people expected to occupy zone	2	0	0	5	3	0	5	6	0	2	2	2	5	5	3	8	3	3	3	3	2
Rp	Area outdoor air rate from Table 6.1, cfm/ft2	5	0	0	7.5	7.5	0	7.5	7.5	0	7.5	7.5	5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	0
Ra	People outdoor air rate from Table 6.1, cfm/person	0.06	0.12	0.06	0.18	0.18	0.06	0.18	0.18	0.12	0.18	0.18	0.06	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.12
Pz*Rp		10	0	0	37.5	22.5	0	37.5	45	0	15	15	10	37.5	37.5	22.5	60	22.5	22.5	22.5	22.5	0
Az*Ra		3.6	16.8	13.8	72	45	12	10.8	68.4	9.6	26.1	16.2	3.6	36	36	28.8	69.3	33.48	39.6	39.6	39.6	43.8
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	13.6	16.8	13.8	109.5	67.5	12	48.3	113.4	9.6	41.1	31.2	13.6	73.5	73.5	51.3	129.3	55.98	62.1	62.1	62.1	43.8
Vpz	Primary airflow to zone from air handler (intake plus recirculated air, but not local recirculation such as at mixing boxes), cfm. **In VAV systems, use the design**	80	160	380	500	500	500	500	1200	400	400	400	100	400	400	500	320	400	500	400	400	400
Vdz	Supply/discharge to zone including primary air Vpz and locally recirculated air, cfm. **In VAV systems, use the design value.**	80	160	380	500	500	500	500	1200	400	400	400	100	400	400	500	320	400	500	400	400	400
Vdzm	Minimum supply/discharge to zone used to calculate Ev, cfm. **In CAV systems, Vdzm = Vdz. In VAV systems, Vdzm is the minimum expected value of Vdz.**	80	160	380	500	500	500	500	1200	400	400	400	100	400	400	500	320	400	500	400	400	400
Zd	Outdoor air fraction required in air discharged to zone, = Voz/Vdzm	0.17	0.11	0.04	0.22	0.14	0.02	0.10	0.09	0.02	0.10	0.08	0.14	0.18	0.18	0.10	0.40	0.14	0.12	0.16	0.16	0.11
Ep	Primary air fraction to zone, = Vpz/Vdz (=1 for single duct and single zone systems)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Er	Fraction of secondary recirc to zone representative of system average, only applies if Ep<1. For plenum return =0. For duct return with local secondary recirc =1.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ez	Zone air distribution effectiveness, Table 6.2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fa	Fraction of supply air to zone from sources outside zone, = Ep + (1-Ep)*Er	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fb	Fraction of supply air to zone from full mixed primary air, = Ep = Vpz/Vdz	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fc	Fraction of outdoor air to zone from sources outside zone, = 1 - (1-Ez) * (1-Er) * (1-Ep)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

SYSTEM LEVEL

Ps	System population, maximum simultaneous # of occupants of space served by system	100
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	1.61
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz +ΣRa*Az, cfm	1374
Vps	Total system primary flow to all zones, Σ Vpz, cfm	8840
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.16

Note: In VAV systems, Vps is equal to the fan airflow, and the formula in cell c40 needs to be replaced by this value.

SYSTEM EFFICIENCY

		Zone 68	Zone 69	Zone 70	Zone 71	Zone 72	Zone 73	Zone 74	Zone 75	Zone 76	Zone 77	Zone 78	Zone 79	Zone 80	Zone 81	Zone 82	Zone 83	Zone 84	Zone 85	Zone 86	Zone 87	Zone 88
Evs	Zone ventilation efficiency, (Fa +Xs*Fb - Z*Fc)/Fa	0.99	1.05	1.12	0.94	1.02	1.13	1.06	1.06	1.13	1.05	1.08	1.02	0.97	0.97	1.05	0.75	1.02	1.03	1.00	1.00	1.05
Ev	System ventilation efficiency, min(Evs)	0.75																				

Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**1828**	**Percent outdoor air intake** **21%** = Vot/Vps

RESULTS - AHU 5		
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**1922**
	Percent outdoor air intake, Vot/Vps	**21%**
Ev	**System ventilation efficiency**	**0.59**

ZONE LEVEL

	Zones served by system	**Zone 89**	**Zone 90**	**Zone 91**	**Zone 92**	**Zone 93**	**Zone 94**	**Zone 95**	**Zone 96**	**Zone 97**
	Space type (select from pull-down list)	Office space	Corridors	Warehouses	Main entry	Office space	Lobbies/prefunction	Lobbies/prefunction	Office space	Lobbies
Az	Floor area of zone, ft2	235	125	650	140	2200	700	1090	1160	380
Pz	Zone population, largest # of people expected to occupy zone	5	0	5	10	30	35	15	15	10
Rp	Area outdoor air rate from Table 6.1, cfm/ft2	5	0	0	5	5	7.5	7.5	5	5
Ra	People outdoor air rate from Table 6.1, cfm/person	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Pz*Rp		25	0	0	50	150	262.5	112.5	75	50
Az*Ra		14.1	7.5	39	8.4	132	42	65.4	69.6	22.8
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	39.1	7.5	39	58.4	282	304.5	177.9	144.6	72.8
Vpz	Primary airflow to zone from air handler (intake plus recirculated air, but not local recirculation such as at mixing boxes), cfm. **In VAV systems, use the design**	220	200	350	1500	1990	2800	2800	1425	350
Vdz	Supply/discharge to zone including primary air Vpz and locally recirculated air, cfm. **In VAV systems, use the design value.**	220	200	350	1500	1990	2800	2800	1425	350
Vdzm	Minimum supply/discharge to zone used to calculate Ev, cfm. **In CAV systems, Vdzm = Vdz. In VAV systems, Vdzm is the minimum expected value of Vdz.**	135	135	135	750	750	1500	1500	450	135
Zd	Outdoor air fraction required in air discharged to zone, = Voz/Vdzm	0.29	0.06	0.29	0.08	0.38	0.20	0.12	0.32	0.54
Ep	Primary air fraction to zone, = Vpz/Vdz (=1 for single duct and single zone systems)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Er	Fraction of secondary recirc to zone representative of system average, only applies if Ep<1. For plenum return =0. For duct return with local secondary recirc =1.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ez	Zone air distribution effectiveness, Table 6.2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fa	Fraction of supply air to zone from sources outside zone, = Ep + (1-Ep)*Er	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fb	Fraction of supply air to zone from full mixed primary air, = Ep = Vpz/Vdz	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fc	Fraction of outdoor air to zone from sources outside zone, = 1 - (1-Ez) * (1-Er) * (1-Ep)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

SYSTEM LEVEL

Ps	System population, maximum simultaneous # of occupants of space served by system	125	
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	1.00	
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz +ΣRa*Az, cfm	1126	
Vps	Total system primary flow to all zones, Σ Vpz, cfm	9000	**Note: In VAV systems, Vps is equal to the fan airflow, and the formula in cell c40 needs to be replaced by this value.**
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.13	

SYSTEM EFFICIENCY

		Zone 89	Zone 90	Zone 91	Zone 92	Zone 93	Zone 94	Zone 95	Zone 96	Zone 97
Evs	Zone ventilation efficiency, (Fa +Xs*Fb - Z*Fc)/Fa	0.84	1.07	0.84	1.05	0.75	0.92	1.01	0.80	0.59
Ev	System ventilation efficiency, min(Evs)	0.59								

Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**1922**	**Percent outdoor air intake** **21%** = Vot/Vps

RESULTS - AHU 6		
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**318**
	Percent outdoor air intake, Vot/Vps	**23%**
Ev	**System ventilation efficiency**	**0.90**

ZONE LEVEL

	Zones served by system	**Zone 98**	**Zone 99**	**Zone 100**
	Space type (select from pull-down list)	Storage rooms	Corridors	Health club/aerobics room
Az	Floor area of zone, ft2	270	130	760
Pz	Zone population, largest # of people expected to occupy zone	5	0	10
Rp	Area outdoor air rate from Table 6.1, cfm/ft2	0	0	20
Ra	People outdoor air rate from Table 6.1, cfm/person	0.12	0.06	0.06
Pz*Rp		0	0	200
Az*Ra		32.4	7.8	45.6
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	32.4	7.8	245.6
Vpz	Primary airflow to zone from air handler (intake plus recirculated air, but not local recirculation such as at mixing boxes), cfm. **In VAV systems, use the design**	480	100	800
Vdz	Supply/discharge to zone including primary air Vpz and locally recirculated air, cfm. **In VAV systems, use the design value.**	480	100	800
Vdzm	Minimum supply/discharge to zone used to calculate Ev, cfm. **In CAV systems, Vdzm = Vdz. In VAV systems, Vdzm is the minimum expected value of Vdz.**	480	100	800
Zd	Outdoor air fraction required in air discharged to zone, = Voz/Vdzm	0.07	0.08	0.31
Ep	Primary air fraction to zone, = Vpz/Vdz (=1 for single duct and single zone systems)	1.00	1.00	1.00
Er	Fraction of secondary recirc to zone representative of system average, only applies if Ep<1. For plenum return =0. For duct return with local secondary recirc =1.	0.00	0.00	0.00
Ez	Zone air distribution effectiveness, Table 6.2	1.00	1.00	1.00
Fa	Fraction of supply air to zone from sources outside zone, = Ep + (1-Ep)*Er	1.00	1.00	1.00
Fb	Fraction of supply air to zone from full mixed primary air, = Ep = Vpz/Vdz	1.00	1.00	1.00
Fc	Fraction of outdoor air to zone from sources outside zone, = 1 - (1-Ez) * (1-Er) * (1-Ep)	1.00	1.00	1.00

SYSTEM LEVEL

Ps	System population, maximum simultaneous # of occupants of space served by system	15	
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	1.00	
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz +ΣRa*Az, cfm	286	
Vps	Total system primary flow to all zones, Σ Vpz, cfm	1380	**Note: In VAV systems, Vps is equal to the fan airflow, and the formula in cell c40 needs to be replaced by this value.**
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.21	

SYSTEM EFFICIENCY

Evs	Zone ventilation efficiency, (Fa +Xs*Fb - Z*Fc)/Fa	1.14	1.13	0.90	
Ev	System ventilation efficiency, min(Evs)	0.90			
				Percent outdoor air intake	
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**318**		**23%**	= Vot/Vps

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Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**893**
	Percent outdoor air intake, Vot/Vps	**28%**
Ev	**System ventilation efficiency**	**1.00**

ZONE LEVEL

	Zones served by system	**Zone 101**
	Space type (select from pull-down list)	Swimming (pool & deck)
Az	Floor area of zone, ft2	1860
Pz	Zone population, largest # of people expected to occupy zone	50
Rp	Area outdoor air rate from Table 6.1, cfm/ft2	0
Ra	People outdoor air rate from Table 6.1, cfm/person	0.48
Pz*Rp		0
Az*Ra		892.8
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	892.8
Vpz	Primary airflow to zone from air handler (intake plus recirculated air, but not local recirculation such as at mixing boxes), cfm. **In VAV systems, use the design**	3200
Vdz	Supply/discharge to zone including primary air Vpz and locally recirculated air, cfm. **In VAV systems, use the design value.**	3200
Vdzm	Minimum supply/discharge to zone used to calculate Ev, cfm. **In CAV systems, Vdzm = Vdz. In VAV systems, Vdzm is the minimum expected value of Vdz.**	3200
Zd	Outdoor air fraction required in air discharged to zone, = Voz/Vdzm	0.28
Ep	Primary air fraction to zone, = Vpz/Vdz (=1 for single duct and single zone systems)	1.00
Er	Fraction of secondary recirc to zone representative of system average, only applies if Ep<1. For plenum return =0. For duct return with local secondary recirc =1.	0.00
Ez	Zone air distribution effectiveness, Table 6.2	1.00
Fa	Fraction of supply air to zone from sources outside zone, = Ep + (1-Ep)*Er	1.00
Fb	Fraction of supply air to zone from full mixed primary air, = Ep = Vpz/Vdz	1.00
Fc	Fraction of outdoor air to zone from sources outside zone, = 1 - (1-Ez) * (1-Er) * (1-Ep)	1.00

SYSTEM LEVEL

Ps	System population, maximum simultaneous # of occupants of space served by system	60	
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	1.20	
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz +ΣRa*Az, cfm	893	
Vps	Total system primary flow to all zones, Σ Vpz, cfm	3200	**Note: In VAV systems, Vps is equal to the fan airflow, and the formula in cell c40 needs to be replaced by this value.**
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.28	

SYSTEM EFFICIENCY

Evs	Zone ventilation efficiency, (Fa +Xs*Fb - Z*Fc)/Fa	1.00		
Ev	System ventilation efficiency, min(Evs)	1.00	**Percent outdoor air intake**	
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**893**	**28%**	= Vot/Vps