University of Miami Interdisciplinary Laboratory

Mechanical Technical Report 1
ASHRAE Standard 62.1-2004 Study

Ben Burgoyne

October 5, 2006

Ben Burgoyne
University of Miami Interdisciplinary Laboratory
Miami, Florida
Mechanical Technical Report 1-Executive Summary
10/5/06

Executive Summary:

The University of Miami Interdisciplinary Laboratory is a 178,000 square foot animal laboratory building located on the campus of the University of Miami, Miami, Florida. All ten floors are above grade: the tenth floor is a mechanical penthouse, the 3rd through 9th floors contain laboratory space, and the 1st and 2nd floors contain animal vivarium space. Additionally, office spaces are grouped on the west end of the building on floors one through nine, and the first floor also contains generator, electrical, and telecommunication rooms, the boiler plant, and a delivery receiving area. The University of Miami Interdisciplinary Laboratory has two main air systems: a variable-air-volume system to the office spaces and a 100% outdoor air constant-air-volume system to the animal and laboratory spaces. The other spaces are served independently or by fan coil units. An analysis of ASHRAE Standard 62.1-2004 Section 6.2 covering the two main air systems has been conducted.

The animal and laboratory areas are served by AHU-P-1, 2, 3, and 4, each 51,000 cfm, with 100% outdoor air, for a total of 204,000 cfm outdoor air. The Standard is satisfied, which calls for 23,905 cfm.

The office area, a variable air volume system, is served by AHU-P-5 with 48,500 cfm, 23,000 of which is outdoor air. The Standard is satisfied, which calls for 6,660 cfm.

Of 15 exhaust fans serving several areas, all exceed the required ventilation cfm rate as stipulated by the Standard.

Indoor Air Quality techniques were used in design such as pressurized spaces, 100% outdoor air, distancing of intake and exhaust locations, and appropriate air change rates.

The University of Miami Interdisciplinary Laboratory meets or exceeds all the ventilation requirements as set by the ASHRAE Standard in this analysis. There is no doubt that this building is adequately designed to ensure proper ventilation and air quality for its intended use: the handling and study of delicate organic processes.

Ben Burgoyne
University of Miami Interdisciplinary Laboratory
Miami, Florida
Mechanical Technical Report 1
10/5/06

Building Information

The University of Miami Interdisciplinary Laboratory, hereafter referred to as UMIL, is a ten floor animal laboratory building located on the campus of the University of Miami, in Miami, Florida. Specifically, the site is located on the corner of N.W. 15th St. and N.W. 9th Ave. The first and second floors contain vivarium space, including animal holding rooms, cage handling areas, and procedure rooms. Additionally, on the first floor are found generator, electrical, and telecommunication rooms, the boiler plant, and delivery receiving area, there being no basement. The third through ninth floors are typical, including laboratory space and additional animal holding spaces. The tenth floor is a double heighted mechanical penthouse containing, among other equipment, seven air handling units and four energy recovery units. There is also office space, grouped on the west side of the building, located on the first through ninth floors. The total office space is variable-air-volume and is supplied by one 48,500 cfm air handling unit, the mechanical penthouse is supplied by two 4,000 cfm air handling units, and all the laboratory and animal related spaces are on a constant-air-volume, 100% outside air system, supplied by four 51,000 cfm air handling units. The first floor generator, electrical, and telecommunication rooms, boiler plant, and delivery receiving area have their own dedicated fan coil units and are not supplied by air handling units. Figure 1 illustrates the air handling unit coverage.

ASHRAE Standard 62.1-2004

The air movement in the UMIL is studied based on compliance to ASHRAE Standard 62.1-2004, Ventilation for Acceptable Indoor Air Quality, which is a standard adopted by many municipalities throughout the nation in their building codes. Analysis for this report is focused on Section 6, Procedures, which applies to buildings with non-natural ventilation systems, in which category the UMIL is found. Following is a breakdown of compliance to this section.

Section 6.2 Ventilation Rate Procedure

In order for a building space to maintain healthy air standards consistently, a certain amount of air supplied to that space must be brought directly from outside of the building. Outdoor air conditions generally foster cleaner air because of its opportunity to move freely through the atmosphere and take part in the ecosystem processes that the earth provides to naturally clean the air. Within enclosed building spaces, air is denied that natural cleansing, and it is subject to become contaminated by particulates, microorganisms, or chemicals given off by objects, animals, or people. Supplying outdoor air to such spaces helps in keeping this contamination to a minimum. This section is designed to ensure that the right amount of clean air is supplied to given spaces.

6.2.1 Outdoor Air Treatment

The outdoor air introduced to a space must be sufficiently clean in order to do any good. Following are checkpoints to ensure that the outdoor air is clean, and, if not, that it is treated properly.

-6.2.1.1

Miami, Florida, the site of the UMIL, is not included in the List of PM10 Nonattainment Areas per the EPA, http://www.epa.gov/air/oaqps/greenbk/pnc.html, and therefore particle filters are not required and not provided for outdoor air intake of the UMIL.

-6.2.1.2

Miami, Florida has had a green level ozone reading everyday so far in 2006, except for under 5 days when it was yellow, according to EPA AIRNow, http://airnow.gov/index.cfm?action=airnow.showlocal&CityID=140. This shows that air cleaning devices are not required and not provided for the outdoor air intake of the UMIL.

6.2.2 Zone Calculations

Table 62.1-6.2 pages 1 through 6 identify Rp, Pz (occupancy), Ra, Az (area), and Vbz for each space. (Note for all tables that rooms on the 3rd through 8th floors are identical to the 9th floor, and are accounted for in the totaling, or are left out to avoid redundancy). Occupancy for animal holding areas is assumed as one each. No human occupancy is planned for those areas, but, as they will contain animals which also require breathable air, this occupancy assumption will ensure that these animals are accounted for. The Multipurpose Room occupancy is determined by an occupancy density of 150/1000 s.f. for an auditorium space. Otherwise, occupancies are as given by the architect. Rp and Ra are values taken from Table 6-1 ASHRAE Standard 62.1-2004 Section 6.2. Exceptions to this are spaces that are viewed as hospital spaces, which give Rp and Ra values in Table E-1, Appendix E in ASHRAE Standard 62.1-2004. These spaces include the Necropsy Rooms 123 and 248 (Autopsy: 0.5 cfm/s.f.); the Operating Room 118 (30 cfm/person); Recovery Room 117 (15 cfm/person); and Procedure Rooms 138, 219, 225, 228, 230, 250, 256, and 261 (15 cfm/person). Az for each space is calculated using Equation 6-1, ASHRAE Standard 62.1-2004 Section 6.2.2.1. The Ez for all the zones is determined as 1.0 per Table 6-2, ASHRAE Standard 62.1-2004 Section 6.2. This value corresponds to all-ceiling supplied cool air.

At this point, the spaces are divided into two parts: those served by AHU-P-1 through 4, and those served by AHU-P-5. This is necessary because of the two different types of systems they supply. Further values for these separate systems are found on pages 7 through 12 of Table 62.1-6.2.

AHU-P-1, 2, 3 and 4 work together to supply the animal and laboratory spaces. They supply 100% outdoor air to a constant-air-volume system. The corresponding Voz for each space is calculated using Equation 6-2, and the Vot for the system is the sum of its Voz values (Equation 6-4). The system Vot is 23,905 cfm, given on Table 62.1-6.2 page 12. The available outdoor air from the air handling units is 204,000 cfm, so the requirement for this system is easily met. The reason for supplying so much extra outdoor air in the design is based on the nature of the activities in the spaces, which involve animals, and shall be discussed later.

The office spaces, supplied by AHU-P-5, serve a variable-air-volume system that includes recirculated return air, and so is governed by Section 6.2.5. On pages 7 through 12 of Table 62.1-6.2 under AHU-P-5, the Voz values from each space are consolidated by zones, each zone being served by one terminal unit. Vpz is determined by the minimum supply air, in cfms, through each terminal unit, and Zp is calculated based on these, using Equation 6-5. Corresponding Evz values are determined from Table 6-3, and it is seen that the Multipurpose Room (Zone S104 and S106 combined) has the maximum Evz value, and is so great that Appendix A must be used to calculate it. The new Evz for the Multipurpose Room is calculated using Equation A-1 from Xs (based on Vou and Vps) and Zd (based on Voz and Vdz). For Vou calculation, D is assumed to be 1.0, as there is no other indication of building occupancy than for each space given by the architect or deduced. Vot is then calculated as 6,660 cfm from Equation 6-8, which is easily met by AHU-P-5 which supplies 23,000 cfm outdoor air alone.

It is not known whether peak or off peak times exist with the use of the UMIL, and it is assumed that the outdoor air requirements are generally constant, so associated changes in the calculations are not made.

Finally within Section 6.2, exhaust requirements are detailed which must be met in order to ensure that certain spaces have the contaminated air removal, not just dilution, that they need. Table 6-4 identifies the spaces which require such exhaust and includes values per unit or per square foot. Pages 13 through 18 of Table 62.1-6.2 contain a breakdown per space of required exhaust cfm, the exhaust fans that serve those spaces, and the exhaust cfm those fans provide. F-M-1, 2, and 3 serve the fume hoods in the laboratory rooms; F-M-4, 5, and 6 are linked with the Exhaust Terminal Units that are located in the animal and laboratory spaces; F-P-1 serves the restrooms, kitchenettes, copy rooms, etc. in the office spaces; and other fans are used for individual exhaust needs as indicated on the table. In all the cases, the exhaust criteria are met. What does require more explanation is the partnership between F-M-1, 2, and 3, and F-M-4, 5, 6. The fume hood fans (1, 2, and 3) show cfm values which are based on the entire square footage of the laboratories they are found in, and these values are less than the required exhaust for those laboratories. This is not a problem, because those laboratories are also served by F-M-4, 5, and 6, which have a cfm surplus, and they indeed work with the fume hood fans, meeting the exhaust criteria.

6.3 Indoor Air Quality

It is especially important to take the space air quality in the UMIL under consideration during design. As a laboratory facility, experiments, specimens, etc. must not be contaminated by outside pollutants, or else findings and conclusions can become corrupted. Likewise, some activities within the laboratories may include harmful products that need to be isolated from filtering into the rest of the building. There are various techniques to ensure good air quality, many of which are used in the design of the UMIL, and shall now be discussed.

Using the amount of air supplied to different spaces, pressure differentials can be created to ensure that air flows in a specified direction when an opening between two spaces is created. These pressure differentials are in effect for the animal and laboratory spaces of the UMIL. See Pressurized Spaces Table for a breakdown of positively, negatively, and adjustably pressurized spaces along with reasoning for the pressurization decisions. Some areas need to be isolated from air coming in from other spaces, and other areas from inside air going out into other spaces.

Further, to ensure clean air supplied to the sensitive areas, 100% outdoor air is used for the AHU-P-1, 2, 3, and 4 system to the animal and laboratory areas. This system, unlike the office system served by AHU-P-5, does not recirculate air from the spaces into the supply air stream through the air handling units, but rather exhausts all the room air to the atmosphere and replaces it completely with clean outdoor air. This is why, as stated in the Ventilation Rate Procedure section, the required outdoor air rate for these spaces is so greatly exceeded; all the air supplied to the space is outdoor air.

Now, there are considerations that must be taken with a 100% outdoor air system. First, there is a large energy cost for conditioning complete outdoor air. The main reason for recirculating air in the first place is that, upon mixing with the outdoor air, the resulting supply air is closer to the design condition, and requires less energy to reach it. In order to ease the energy burden, four energy recovery units are included in the design. These take energy from outdoor air being drawn in and deposit it in the exhaust air, which helps lower the outdoor air properties to the design condition. These energy recovery units transfer the energy by means of water coils.

Another important consideration, especially with a 100% outdoor air system, is the placement of the air exhaust relative to the intake louvres. If they are too close, air exhausted from the building may be immediately drawn in again, and the purpose of all outdoor air is negated. The design of the UMIL system takes this principle into account. The intake louvres for AHU-P-1 through 5 are located side by side along the north wall of the tenth floor mechanical penthouse. The exhaust fans that are located close to the north side of the roof (fans F-M-1 through 6) are high-induction, with a minimum effective stack height of 36 ft. at 15 mph. This means that the undesirable air leaving these fans will be removed to 36 feet above the building before it has any chance to reenter through the intake louvres. All the other exhaust fans are located well away from the north side, and the chance of re-intake of that air is minimal.

Another purpose for exceeding by far the required outdoor air intake to the animal and laboratory spaces is to achieve certain desirable air changes, to ensure good consistent air quality within each space. Table AHU-P-1 through 4 contains a breakdown of air changes per hour for each space in the second to last column. The last column shows the required air changes per hour found in Table 3, ASHRAE HVAC Application 1999 7.5. This table contains information for hospital spaces and can be applied to the UMIL animal laboratory spaces because similar activities are carried out, just on different species. For the sake of satisfactory experimental and procedural results, and for the health and safety of the human workers and animals alike, the UMIL spaces are held to the same standard. The highlighted values for air changes correspond to a different recommended level. These are for the holding, procedure, and recovery rooms: the spaces that will likely contain animals on a consistent basis. For these standards, Table 16-1 is used from ASHRAE Laboratory Design Guide (McIntosh, Dorgan, and Dorgan, ASHRAE, 2001, page 187). This table recommends ten to fifteen air changes per hour for individual animals typically used in laboratories. It is not now known which specific animals will be used in each of the UMIL spaces, so the typical air change values fall in the fourteen to fifteen range.

There are innumerable tactics to ensure good air quality. Some of those, which are among the more significant, were addressed above. In the end, air cannot be too clean, so from a quality standpoint, there is no limit to applying such tactics to a building. However, budget, time constraint, and coordination make it impractical to incorporate every possibility for ensuring clean air into the design. Good judgment is required to determine how clean the air needs to be within the building to serve its purposes, to know the limitations in design, and to implement whatever air quality techniques that are feasible. Some of them don't require any extra time, effort, or money; they simply depend on having a clear awareness of the conditions.

Conclusion

Ventilation Rate Procedure and Indoor Air Quality can be described as the objective and the subjective, respectively, of the measure of air quality in buildings. VRP uses concrete values, equations, and constants in determining compliance. It is easy to see if a building is up to standard: the numbers tell the story. This is important for creating a fair based requirement that all can adhere to, and local ordinances can site this standard for that reason. VRP, however, only describes air volume. There are many more variables that come into play in terms of ensuring air quality, some of which can't be expressed in equations, or it is unfeasible to account for them all in series of equations. That is where IAQ becomes effective- it accounts for the "in-between" considerations that are equally important, but can't be covered by VRP. In this way, a fullness of air quality assurance is achieved, while feasibility is conserved to reasonably apply to real-life conditions.

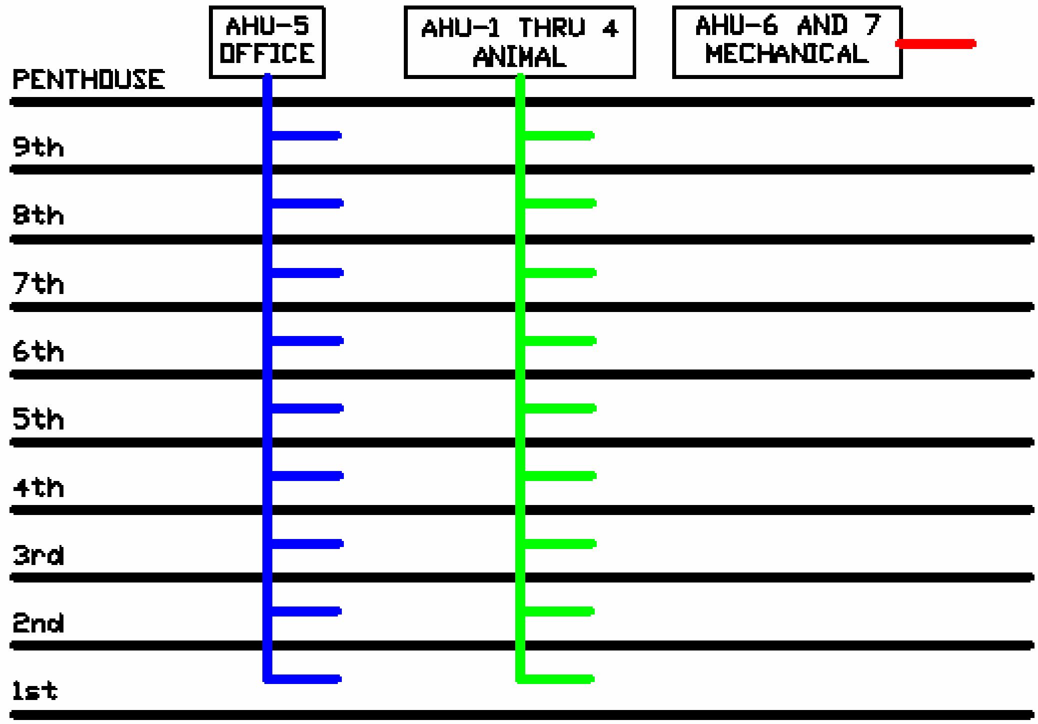
AHU-5
OFFICE
AHU-1 THRU 4
ANIMAL
AHU-6 AND 7
MECHANICAL
PENTHOUSE
9th
8th
7th
6th
5th
4th
3rd
2nd
1st

Figure 1

SPACE		Type	Length (ft)	Width (ft)	Area (sf)	Occupancy	Ra	Rp	Vbz
	3rd-9th Floors								
900.1	Alcove	Corridor	7	6	42	0	0.06	0	2.52
925	Auxiliary	Science Laboratory	21	15	315	0	0.18	10	56.7
927	Auxiliary	Science Laboratory	10.5	10.5	110.25	0	0.18	10	19.845
928	Auxiliary	Science Laboratory	10.5	11.5	120.75	0	0.18	10	21.735
930	Auxiliary	Science Laboratory	10	10	100	0	0.18	10	18
936	Cold Room	Science Laboratory	13	10	130	0	0.18	10	23.4
910	Conference	Conference	21	12.5	262.5	10	0.06	5	65.75
900	Corridor	Corridor	48	8	384	0	0.06	0	23.04
901	Corridor	Corridor	21	5	105	0	0.06	0	6.3
907	Corridor	Corridor	40	5	200	0	0.06	0	12
911	Corridor	Corridor	11	5	55	0	0.06	0	3.3
917	Corridor	Corridor	26	7.5	195	0	0.06	0	11.7
918	Corridor	Corridor	21	7.5	157.5	0	0.06	0	9.45
926	Corridor	Corridor	12.5	5	62.5	0	0.06	0	3.75
	East Elevator Lobby	Lobby	23	8.5	195.5	0	0.06	5	11.73
	Electrical	Storage	12.5	10	125	0	0.12	0	15
923	Equipment	Science Laboratory	23.5	10.5	246.75	0	0.18	10	44.415
929	Equipment	Science Laboratory	26	7.5	195	0	0.18	10	35.1
933	Equipment	Science Laboratory	23.5	10	235	0	0.18	10	42.3
931	Glasswash	Science Laboratory	13.5	10	135	2	0.18	10	44.3
	Janitor	Storage	11	5.5	60.5	0	0.12	0	7.26
906	Kitchenette		23	12	276	6	0.06	0	16.56
924	Laboratory	Science Laboratory	105	31.5	3307.5	40	0.18	10	995.35
941	Laboratory	Science Laboratory	105	31.5	3307.5	40	0.18	10	995.35
937	Linear Equipment Room	Science Laboratory	129	8	1032	0	0.18	10	185.76
	Men's WC		23	9	207	0	0.06	0	12.42
902	Office	Office	13	9	117	1	0.06	5	12.02
903	Office	Office	13	10	130	1	0.06	5	12.8
904	Office	Office	15.5	11.5	178.25	1	0.06	5	15.695
905	Office	Office	13	12.5	162.5	1	0.06	5	14.75
913	Office	Office	12	10	120	1	0.06	5	12.2
914	Office	Office	15	10.5	157.5	1	0.06	5	14.45
915	Office	Office	13	10	130	1	0.06	5	12.8
916	Office	Office	13	10	130	1	0.06	5	12.8
919	Office	Office	15.5	10.5	162.75	1	0.06	5	14.765

940	Office	Office	15.5	10.5	162.75	1	0.06	5	14.765
935	Radioisotope	Science Laboratory	10.5	10	105	1	0.18	10	28.9
900.2	Reception	Corridor	10	8	80	2	0.06	0	4.8
	Telecom	Storage	10.5	10	105	0	0.12	0	12.6
932	Tissue Culture	Science Laboratory	20.5	23.5	386.75	4	0.18	10	109.615
932.1	Tissue Culture	Science Laboratory	10	9.5	95	1	0.18	10	27.1
934	Tissue Culture	Science Laboratory	20.5	23.5	95	4	0.18	10	57.1
934.1	Tissue Culture	Science Laboratory	10	9.5	95	1	0.18	10	27.1
	Women's WC		23	9	207	0	0.06	0	12.42
908	Work Area	Office	11.5	9	103.5	2	0.06	5	16.21
909	Work Area	Office	11.5	9	103.5	2	0.06	5	16.21
912	Work Area,Copy	Office	10.5	8	84	0	0.06	5	5.04

Note: Floors 3 through 8 (identical to 9) are accounted for in the totaling.

SPACE		Type	Length (ft)	Width (ft)	Area (sf)	Occupancy	Ra	Rp	Vbz
	2nd Floor								
238	Anteroom	Science Laboratory	16	7.5	120	0	0.18	10	21.6
216	Break/Work	Office	18	14	252	6	0.06	5	45.12
245	Cage Stage	Science Laboratory	18	9	162	0	0.18	10	29.16
244	Clean Cage Storage	Science Laboratory	33	30	990	0	0.18	10	178.2
208	Copy	Storage	11	6	66	0	0.12	0	7.92
200	Corridor	Corridor	35	8	280	0	0.06	0	16.8
201	Corridor	Corridor	8.5	5	42.5	0	0.06	0	2.55
207	Corridor	Corridor	44	6	264	0	0.06	0	15.84
214	Corridor	Corridor	21	4.5	94.5	0	0.06	0	5.67
215	Corridor	Corridor	37	6	222	0	0.06	0	13.32
224	Corridor	Corridor	22	8	176	0	0.06	0	10.56
227	Corridor	Corridor	52.5	7	367.5	0	0.06	0	22.05
237	Corridor	Corridor	34	7	238	0	0.06	0	14.28
255	Corridor	Corridor	103	7	721	0	0.06	0	43.26
268	Corridor	Corridor	16	8	128	0	0.06	0	7.68
	East Elevator Lobby	Lobby	23	8.5	195.5	0	0.06	0	11.73
	Electrical	Storage	12.5	10	125	0	0.12	0	15
217	Holding	Science Laboratory	21	11.5	241.5	1	0.18	7.5	50.97
218	Holding	Science Laboratory	21	11.5	241.5	1	0.18	7.5	50.97
223	Holding	Science Laboratory	21.5	12	258	1	0.18	7.5	53.94
226	Holding	Science Laboratory	17	16	272	1	0.18	7.5	56.46
229	Holding	Science Laboratory	17	16	272	1	0.18	7.5	56.46
231	Holding	Science Laboratory	21.5	11	236.5	1	0.18	7.5	50.07
232	Holding	Science Laboratory	21.5	11	236.5	1	0.18	7.5	50.07
233	Holding	Science Laboratory	21.5	11	236.5	1	0.18	7.5	50.07
234	Holding	Science Laboratory	21.5	11	236.5	1	0.18	7.5	50.07
235	Holding	Science Laboratory	21.5	11	236.5	1	0.18	7.5	50.07
236	Holding	Science Laboratory	21.5	11	236.5	1	0.18	7.5	50.07
252	Holding	Science Laboratory	15	12	180	1	0.18	7.5	39.9
253	Holding	Science Laboratory	15	12	180	1	0.18	7.5	39.9
254	Holding	Science Laboratory	15	12	180	1	0.18	7.5	39.9
257	Holding	Science Laboratory	15	12	180	1	0.18	7.5	39.9
258	Holding	Science Laboratory	15	12	180	1	0.18	7.5	39.9

259	Holding	Science Laboratory	15	12	180	1	0.18	7.5	39.9
260	Holding	Science Laboratory	15	12	180	1	0.18	7.5	39.9
262	Holding	Science Laboratory	15	12	180	1	0.18	7.5	39.9
263	Holding	Science Laboratory	15	12	180	1	0.18	7.5	39.9
264	Holding	Science Laboratory	15	12	180	1	0.18	7.5	39.9
265	Holding	Science Laboratory	15	12	180	1	0.18	7.5	39.9
242	Iso. No. 1	Science Laboratory	9.5	9	85.5	1	0.18	10	25.39
241	Iso. No. 2	Science Laboratory	9.5	9	85.5	1	0.18	10	25.39
240	Iso. No. 3	Science Laboratory	9.5	9	85.5	1	0.18	10	25.39
239	Isolation	Science Laboratory	16.5	6.5	107.25	1	0.18	10	29.305
	Janitor	Storage	11	5.5	60.5	0	0.12	0	7.26
267	Laundry	Storage	12.5	12	150	0	0.12	0	18
247	Lobby	Lobby	29	9.5	275.5	2	0.06	5	26.53
	Men's WC		23	9	207	0	0.06	0	12.42
248	Necropsy	Science Laboratory	16	10.5	168	1	0.5	10	94
202	Office	Office	12	12	144	1	0.06	5	13.64
203	Office	Office	34.5	8.5	293.25	1	0.06	5	22.595
204	Office	Office	11	7.5	82.5	1	0.06	5	9.95
205	Office	Office	11	11.5	126.5	1	0.06	5	12.59
206	Office	Office	12.5	8	100	1	0.06	5	11
209	Office	Office	11	7.5	82.5	1	0.06	5	9.95
210	Office	Office	11	7.5	82.5	1	0.06	5	9.95
211	Office	Office	10.5	11.5	120.75	1	0.06	5	12.245
212	Office	Office	10.5	8.5	89.25	1	0.06	5	10.355
213	Office	Office	15.5	8.5	131.75	1	0.06	5	12.905
219	Procedure	Science Laboratory	34.5	19	397.5	1	0.18	15	86.55
225	Procedure	Science Laboratory	17	8.5	144.5	1	0.18	15	41.01
228	Procedure	Science Laboratory	17	8.5	144.5	1	0.18	15	41.01
230	Procedure	Science Laboratory	33	12.5	412.5	1	0.18	15	89.25
250	Procedure	Science Laboratory	24	11	264	1	0.18	15	62.52
256	Procedure	Science Laboratory	24	11	264	1	0.18	15	62.52
261	Procedure	Science Laboratory	24	11	264	1	0.18	15	62.52
251	Quarantine	Science Laboratory	15	12	180	1	0.18	15	47.4
200.1	Reception	Lobby	15	8	120	2	0.06	5	17.2
246	Storage/Food	Storage	16	13.5	216	0	0.12	0	25.92
	Telecom	Storage	10.5	10	105	0	0.12	0	12.6
266	Vestibule	Corridor	13	7	91	0	0.06	0	5.46
	Women's WC		23	9	207	0	0.06	0	12.42
243	Work Area	Science Laboratory	14.5	11	159.5	2	0.18	10	48.71

SPACE		Type	Length (ft)	Width (ft)	Area (sf)	Occupancy	Ra	Rp	Vbz
	1st Floor								
127	Animal Cold Room	Science Laboratory	17	10.5	178.5	0	0.18	10	32.13
139	Animal Prep	Science Laboratory	14	9.5	133	0	0.18	10	23.94
142	Bedding	Storage	17	13	214.5	0	0.12	0	25.74
129	Clean Cagewash Area	Science Laboratory	42	25	984	2	0.18	10	197.12
107	Copy/Work	Storage	10	10	100	0	0.12	0	12
100	Corridor	Corridor	58	8	784	0	0.06	0	47.04
C100	Corridor	Corridor	44	5.5	242	0	0.06	0	14.52
106	Corridor	Corridor	26	6.5	169	0	0.06	0	10.14
112	Corridor	Corridor	29	5.5	159.5	0	0.06	0	9.57
115	Corridor	Corridor	46.5	8	372	0	0.06	0	22.32
124	Corridor	Corridor	32.5	7	227.5	0	0.06	0	13.65
128	Corridor	Corridor	43	7	301	0	0.06	0	18.06
130	Corridor	Corridor	32	12	384	0	0.06	0	23.04
132	Corridor	Corridor	46.5	7.5	348.75	0	0.06	0	20.925
	Delivery	Shipping/Receiving	73	64	4672	0	0.12	0	560.64
131	Dirty Cagewash Area	Science Laboratory	65	32	1900	2	0.18	10	362
	East Elevator Lobby	Lobby	23	8.5	195.5	0	0.06	5	11.73
	Emergency Elec.		20	16	320	0			0
	Fire Pump Room		16	15	240	0			0
	Fireroom	Storage	11.5	10.5	120.75	0	0.12	0	14.49
143	Food	Science Laboratory	17	12.5	206.25	0	0.18	10	37.125
141	Food Cold Room	Science Laboratory	12.5	9	112.5	0	0.18	10	20.25
140	Food Storage	Storage	12	7	84	0	0.12	0	10.08
	FP&L Vault		32	19	608	0			0
	Generator Room		32	19	608	0			0
133	Holding	Science Laboratory	24	13.5	324	1	0.18	7.5	65.82
134	Holding	Science Laboratory	24	13.5	324	1	0.18	7.5	65.82
135	Holding	Science Laboratory	24	13.5	324	1	0.18	7.5	65.82
136	Holding	Science Laboratory	24	13.5	324	1	0.18	7.5	65.82
137	Holding	Science Laboratory	24	20	480	1	0.18	7.5	93.9
	Janitor	Storage	11	5.5	60.5	0	0.12	0	7.26
125	Laundry	Storage	11	6	66	0	0.12	0	7.92
	Main Elec.		24	14.5	348	0			0
	Main Telecom		14.5	12	174	0			0
114	Men's Bath		17	10.5	178.5	0	0.06	0	10.71

	Men's WC		23	9	207	0	0.06	0	12.42
101	Multi-Purpose	Auditorium	32	30	960	144	0.06	5	777.6
	N.E.Exit Corridor	Corridor	57	8	456	0	0.06	0	27.36
123	Necropsy	Science Laboratory	12	17.5	210	1	0.5	10	115
108	Office	Office	17	12	204	1	0.06	5	17.24
109	Office	Office	17.5	10.5	183.75	1	0.06	5	16.025
110	Office	Office	9	11	99	1	0.06	5	10.94
111	Office	Office	9	11	99	1	0.06	5	10.94
118	Operating Room	Science Laboratory	20	15.5	310	1	0.18	30	85.8
138	Procedure	Science Laboratory	21	8	168	1	0.18	15	45.24
117	Recovery	Science Laboratory	12	10	120	1	0.18	15	36.6
116	Scrub	Science Laboratory	10	8	76	0	0.18	10	13.68
100.2	Secretary	Corridor	12	12	144	1	0.06	0	8.64
119	Sterile	Science Laboratory	15	13	195	0	0.18	10	35.1
101.1	Storage	Storage	4	2.5	10	0	0.12	0	1.2
	Vivarium Receiving	Shipping/Receiving	34	12.5	425	0	0.12	0	51
113	Women's Bath		17	10.5	178.5	0	0.06	0	10.71
	Women's WC		23	9	207	0	0.06	0	12.42

	AHU-P-1 thru 4		AHU-P-5							
SPACE	Ez	Voz	Space Voz	Zone	Zone Voz	Vpz=Vdz	Zp=Zd	Evz	Rp*Pz	Ra*Az
3rd-9th										
900.1	1.0	2.52								
925	1.0	56.7								
927	1.0	19.845								
928	1.0	21.735								
930	1.0	18								
936	1.0	23.4								
910	1.0		65.75	S908	65.75	560	0.12	1.00	50	15.75
900	1.0		23.04	S902						
901	1.0	6.3								
907	1.0		12	S904						
911	1.0	3.3								
917	1.0		11.7	S912						
918	1.0		9.45	S913						
926	1.0	3.75								
	1.0	11.73								
	1.0	15								
923	1.0	44.415								
929	1.0	35.1								
933	1.0	42.3								
931	1.0	44.3								
	1.0	7.26								
906	1.0		16.56	S904	28.56	205	0.14	0.98	0	16.56
924	1.0	995.35								
941	1.0	995.35								
937	1.0	185.76								
	1.0		12.42	S901	12.42	50	0.25	0.87	0	12.42
902	1.0		12.02	S907	24.82	290	0.09	1.03	5	7.02
903	1.0		12.8	S907					5	7.8
904	1.0		15.695	S906	15.695	305	0.05	1.07	5	10.695
905	1.0		14.75	S905	14.75	220	0.07	1.05	5	9.75
913	1.0		12.2	S909	12.2	135	0.09	1.03	5	7.2
914	1.0		14.45	S911	14.45	210	0.07	1.05	5	9.45
915	1.0		12.8	S912	37.3	265	0.14	0.98	5	7.8
916	1.0		12.8	S912						
919	1.0		14.765	S913						

940	1.0		14.765	S913	38.98	150	0.26	0.86	5	9.765
935	1.0	28.9								
900.2	1.0		4.8	S902	27.84	285	0.10	1.02	0	4.8
	1.0	12.6								
932	1.0	109.615								
932.1	1.0	27.1								
934	1.0	57.1								
934.1	1.0	27.1								
	1.0		12.42	S901	12.42	50	0.25	0.87	0	12.42
908	1.0		16.21	S903	16.21	35	0.46	0.66	10	6.21
909	1.0		16.21	S903	16.21	35	0.46	0.66	10	6.21
912	1.0		5.04	S910	5.04	45	0.11	1.01	0	5.04
	Vot:	**2794.53**			**Total Vpz:**	**2840**		**Total:**	**110**	**148.89**
	x7 Floors	**19561.71**			**x7 Floors**	**19880**		**x7 Floors:**	**770**	**1042.23**

	AHU-P-1 thru 4		AHU-P-5								
SPACE	**Ez**	**Voz**	**Space Voz**	**Zone**	**Zone Voz**	**Vpz=Vdz**	**Zp=Zd**	**Evz**	**Rp*Pz**	**Ra*Az**
2nd										
238	1.0	21.6								
216	1.0		45.12	S212	58.44	195	0.30	0.82	30	15.12
245	1.0	29.16								
244	1.0	178.2								
208	1.0		7.92	S207	7.92	120	0.07	1.05	0	7.92
200	1.0		16.8	S209					0	16.8
201	1.0	2.55								
207	1.0		15.84	S206					0	15.84
214	1.0	5.67								
215	1.0		13.32	S212					0	13.32
224	1.0	10.56								
227	1.0	22.05								
237	1.0	14.28								
255	1.0	43.26								
268	1.0		7.68	S213	7.68	150	0.05	1.07	0	7.68
	1.0	11.73								
	1.0	15								
217	1.0	50.97								
218	1.0	50.97								
223	1.0	53.94								
226	1.0	56.46								
229	1.0	56.46								
231	1.0	50.07								
232	1.0	50.07								
233	1.0	50.07								
234	1.0	50.07								
235	1.0	50.07								
236	1.0	50.07								
252	1.0	39.9								
253	1.0	39.9								
254	1.0	39.9								
257	1.0	39.9								
258	1.0	39.9								

259	1.0	39.9								
260	1.0	39.9								
262	1.0	39.9								
263	1.0	39.9								
264	1.0	39.9								
265	1.0	39.9								
242	1.0	25.39								
241	1.0	25.39								
240	1.0	25.39								
239	1.0	29.305								
	1.0	7.26								
267	1.0		18	S203	18	50	0.36	0.76	0	18
247	1.0	26.53								
	1.0		12.42	S208	12.42	50	0.25	0.87	0	12.42
248	1.0	94								
202	1.0		13.64	S202	13.64	95	0.14	0.98	5	8.64
203	1.0		22.595	S201	22.595	465	0.05	1.07	5	17.595
204	1.0		9.95	S205	22.54	330	0.07	1.05	5	4.95
205	1.0		12.59	S205					5	7.59
206	1.0		11	S204	11	35	0.31	0.81	5	6
209	1.0		9.95	S206	35.74	290	0.12	1.00	5	4.95
210	1.0		9.95	S206					5	4.95
211	1.0		12.245	S210	22.6	275	0.08	1.04	5	7.245
212	1.0		10.355	S210					5	5.355
213	1.0		12.905	S211	12.905	180	0.07	1.05	5	7.905
219	1.0	86.55								
225	1.0	41.01								
228	1.0	41.01								
230	1.0	89.25								
250	1.0	62.52								
256	1.0	62.52								
261	1.0	62.52								
251	1.0	47.4								
200.1	1.0		17.2	S209	34	155	0.22	0.90	10	7.2
246	1.0	25.92								
	1.0	12.6								
266	1.0	5.46								
	1.0		12.42	S208	12.42	50	0.25	0.87	0	12.42
243	1.0	48.71								
	Vot:	**2180.915**			**Total Vpz:**	**2440**		**Total:**	**90**	**201.9**

	AHU-P-1 thru 4		AHU-P-5								
SPACE	Ez	Voz	Space Voz	Zone	Zone Voz	Vpz=Vdz	Zp=Zd	Evz	Rp*Pz	Ra*Az
1st										
127	1.0	32.13								
139	1.0	23.94								
142	1.0	25.74								
129	1.0	197.12								
107	1.0		12	S107	22.14	175	0.13	0.99	0	12
100	1.0		47.04	S103	47.04	635	0.07	1.05	0	47.04
C100	1.0		14.52	S106						
106	1.0		10.14	S107						
112	1.0		9.57	S111						
115	1.0	22.32								
124	1.0	13.65								
128	1.0	18.06								
130	1.0	23.04								
132	1.0	20.925								
	1.0	560.64								
131	1.0	362								
	1.0	11.73								
	1.0	0								
	1.0	0								
	1.0		14.49	S105	14.49	45	0.32	0.80	0	14.49
143	1.0	37.125								
141	1.0	20.25								
140	1.0	10.08								
	1.0	0								
	1.0	0								
133	1.0	65.82								
134	1.0	65.82								
135	1.0	65.82								
136	1.0	65.82								
137	1.0	93.9								
	1.0	7.26								
125	1.0	7.92								
	1.0	0								
	1.0	0								
114	1.0		10.71	S111	30.99	325	0.10	1.02	0	10.71

	1.0		12.42	S101	24.84	50	0.50	0.62	0	12.42
101	1.0		777.6	S104,S106	792.12	1195	0.66	0.46	720	57.6
	1.0	27.36								
123	1.0	115								
108	1.0		17.24	S108	17.24	240	0.07	1.05	5	12.24
109	1.0		16.025	S109	16.025	235	0.07	1.05	5	11.025
110	1.0		10.94	S110	21.88	125	0.18	0.94	5	5.94
111	1.0		10.94	S110						
118	1.0	85.8								
138	1.0	45.24								
117	1.0	36.6								
116	1.0	13.68								
100.2	1.0		8.64	S102	8.64	35	0.25	0.87	0	8.64
119	1.0	35.1								
101.1	1.0	1.2								
	1.0	51								
113	1.0		10.71	S111		50	0.00	1.12	0	10.71
	1.0		12.42	S101						
	Vot:	**2162.09**			**Total Vpz:**	**3110**		**Total:**	**735**	**202.815**
								Total:	**1,595**	**1,447**
									Vou:	**3,042**
									Vps:	**25,430**
									Xs:	**0.120**
									Ev:	**0.46**
	Total Vot (cfm):	**23,905**						**Total Vot (cfm):**		**6,660**
	AHU OA (cfm):	**204,000**						**AHU OA (cfm):**		**23,000**

	Exhaust Rate							
SPACE	cfm/unit	cfm/sf	Needed cfm	Exhaust Equipment	Available cfm	F-M-4,5,6	F-M-1,2,3	F-P-1
3rd-9th								
900.1								
925		1	315	F-M-4,5,6		315		
927		1	110.25	F-M-4,5,6		110		
928		1	120.75	F-M-4,5,6		121		
930		1	100	F-M-4,5,6		100		
936		1	130	F-M-4,5,6		130		
910								
900								
901								
907								
911								
917								
918								
926								
923		1	246.75	F-M-4,5,6		247		
929		1	195	F-M-4,5,6		195		
933		1	235	F-M-4,5,6		235		
931		1	135	F-M-4,5,6		135		
		1	60.5	F-M-10	75			
906		0.3	82.8	F-P-1				83
924		1	3307.5	F-M-1,2,3			3308	
941		1	3307.5	F-M-1,2,3			3308	
937		1	1032	F-M-4,5,6		1032		
	50		150	F-P-1				150
902								
903								
904								
905								
913								
914								
915								
916								
919								

940								
935		1	105	F-M-17	500			
900.2								
932		1	386.75	F-M-4,5,6		387		
932.1		1	95	F-M-1,2,3			95	
934		1	95	F-M-4,5,6		95		
934.1		1	95	F-M-1,2,3			95	
	50		150	F-P-1				150
908								
909								
912		0.5	42	F-P-1				42
					Total:	**2326**	**6805**	**425**
					x7 Floors:	**16279**	**47635**	**2974**

	Exhaust Rate							
SPACE	cfm/unit	cfm/sf	Needed cfm	Exhaust Equipment	Available cfm	F-M-4,5,6	F-M-1,2,3	F-P-1
2nd								
238		1	120	F-M-4,5,6		120		
216		0.3	75.6	F-P-1				76
245		1	162	F-M-8	6000			
244		1	990	F-M-8	6000			
208		0.5	33	F-P-1				33
200								
201								
207								
214								
215								
224								
227								
237								
255								
268								
217		0.9	217.35	F-M-4,5,6		217		
218		0.9	217.35	F-M-4,5,6		217		
223		0.9	232.2	F-M-4,5,6		232		
226		0.9	244.8	F-M-4,5,6		245		
229		0.9	244.8	F-M-4,5,6		245		
231		0.9	212.85	F-M-4,5,6		213		
232		0.9	212.85	F-M-4,5,6		213		
233		0.9	212.85	F-M-4,5,6		213		
234		0.9	212.85	F-M-4,5,6		213		
235		0.9	212.85	F-M-4,5,6		213		
236		0.9	212.85	F-M-4,5,6		213		
252		0.9	162	F-M-4,5,6		162		
253		0.9	162	F-M-4,5,6		162		
254		0.9	162	F-M-4,5,6		162		
257		0.9	162	F-M-4,5,6		162		
258		0.9	162	F-M-4,5,6		162		

259		0.9	162	F-M-4,5,6		162		
260		0.9	162	F-M-4,5,6		162		
262		0.9	162	F-M-4,5,6		162		
263		0.9	162	F-M-4,5,6		162		
264		0.9	162	F-M-4,5,6		162		
265		0.9	162	F-M-4,5,6		162		
242		0.9	76.95	F-M-4,5,6		77		
241		0.9	76.95	F-M-4,5,6		77		
240		0.9	76.95	F-M-4,5,6		77		
239		0.9	96.525	F-M-4,5,6		97		
		1	60.5	F-M-10	75			
267								
247								
	150		450	F-P-1				450
248		1	168	F-M-18	755			
202								
203								
204								
205								
206								
209								
210								
211								
212								
213								
219		1	397.5	F-M-4,5,6		398		
225		1	144.5	F-M-4,5,6		145		
228		1	144.5	F-M-4,5,6		145		
230		1	412.5	F-M-4,5,6		413		
250		1	264	F-M-4,5,6		264		
256		1	264	F-M-4,5,6		264		
261		1	264	F-M-4,5,6		264		
251		0.9	162	F-M-4,5,6		162		
200.1								
246								
266								
	50		150	F-P-1				150
243		1	159.5	F-M-4,5,6		160		
					Total:	**6755**	**0**	**709**

	Exhaust Rate							
SPACE	**cfm/unit**	**cfm/sf**	**Needed cfm**	**Exhaust Equipment**	**Available cfm**	**F-M-4,5,6**	**F-M-1,2,3**	**F-P-1**
1st								
127		1	178.5	F-M-4,5,6		179		
139		0.9	119.7	F-M-4,5,6		120		
142								
129		1	984	F-M-9	6000			
107		0.5	50	F-P-1				50
100								
C100								
106								
112								
115								
124								
128								
130								
132								
131		1	1900	F-M-9	6000			
143		1	206.25	F-M-4,5,6		206		
141		1	112.5	F-M-4,5,6		113		
140								
133		0.9	291.6	F-M-4,5,6		292		
134		0.9	291.6	F-M-4,5,6		292		
135		0.9	291.6	F-M-4,5,6		292		
136		0.9	291.6	F-M-4,5,6		292		
137		0.9	432	F-M-4,5,6		432		
		1	60.5	F-M-10	75			
125								
114		0.25	44.625	F-P-1				45

	50		150	F-P-1				150
101								
123		1	210	F-M-19	755			
108								
109								
110								
111								
118		1	310	F-M-4,5,6		310		
138		1	168	F-M-4,5,6		168		
117		0.9	108	F-M-4,5,6		108		
116		1	76	F-M-4,5,6		76		
100.2								
119		1	195	F-M-4,5,6		195		
101.1								
113		0.25	44.625	F-P-1				45
	50		150	F-P-1				150
					Total:	**2774**	**0**	**439**
					Needed cfm	**25,808**	**47,635**	**4,121**
					Available cfm	**38,220**	**36,400**	**10,200**

1) Fans F-M-8,9,10,17,18, & 19 are adequate for their given spaces. (Compare Available cfm column with Needed Rate cfm column.)

2) The FEV's, powered by F-M-1,2,3, are located in spaces that are also ventilated by ETU's powered by F-M-4,5,6. The excess F-M-4,5,6 capacity thus makes up for lacking capacity in F-M-1,2,3.

Positively Pressured Spaces	Space Type	Outgoing cfm	Comments
923	Equipment	250	Equipment stored here may be need to be kept sterile
934	Tissue Culture	200	Specimens handled here need to be kept unconaminated
933	Equipment	150	
932	Tissue Culture	200	
929	Equipment	350	
926	Corridor	350	May be used as a buffer zone, completely isolating spaces it is in contact with from each other
244	Clean Cage Storage	400	Cages need to be kept clean
246	Storage/Food	125	Food needs to be kept untainted
226	Holding	100	Animals here may be particulary sensitive to other germs or the scents of other animals
229	Holding	100	
140	Food Storage	50	
118	Operating Room	400	Needs to be kept sterile from any contaminants
143	Food	100	
142	Bedding	200	Bedding needs to be kept clean
129	Clean Cagewash Area	325	
129	Clean Cagewash Area	325	

Negatively Pressured Spaces	Space Type	Incoming cfm	Comments
941	Laboratory	60	Toxic or disturbing substances may be handled here and need to be kept away from the animals or occupants
935	Radioisotope	100	Harmful substances or energy here needs to be isolated
941	Laboratory	60	
934.1	Tissue Culture	100	Toxic or disturbing substances may be handled here and need to be kept away from the animals or occupants
932.1	Tissue Culture	100	
941	Laboratory	60	
931	Glasswash	100	Certain chemicals used in cleaning may need to be isolated from the animals
941	Laboratory	60	
930	Auxiliary	100	
927	Auxiliary	100	
928	Auxiliary	100	
925	Auxiliary	100	
924	Laboratory	80	
924	Laboratory	80	
924	Laboratory	80	
924	Laboratory	80	
924	Laboratory	80	
248	Necropsy	200	Chemicals and deceased animals here need to be isolated
225	Procedure	200	Toxic or disturbing substances may be handled here and need to be kept away from the animals or occupants
228	Procedure	200	
261	Procedure	100	
256	Procedure	100	
250	Procedure	300	
251	Quarantine	100	Animals with infectious diseases here may need to be isolated

133	Holding	100	Animals with infectious diseases here may need to be isolated
134	Holding	100	
135	Holding	100	
136	Holding	100	
137	Holding	150	
138	Procedure	50	
139	Animal Prep	200	
123	Necropsy	150	
125	Laundry	100	Certain chemicals used in cleaning may need to be isolated from the animals
131	Dirty Cagewash Area	250	Odors and contamination here may need to be isolated
131	Dirty Cagewash Area	250	
131	Dirty Cagewash Area	250	

Adjustably Pressured Spaces	Space Type	Changeable cfm	Comments
240	Iso. No. 3	100	These spaces have the ability to switch between negative and positive pressurization according to their uses at the time
235	Holding	100	
236	Holding	100	
239,243	Work Area,Isolation	400	
234	Holding	100	
241	Iso. No. 2	100	
230	Procedure	500	
242	Iso. No. 1	100	
232	Holding	100	
231	Holding	100	
223	Holding	100	
219	Procedure	400	
218	Holding	100	
217	Holding	100	
264	Holding	100	
265	Holding	100	
262	Holding	100	
263	Holding	100	
260	Holding	100	
259	Holding	100	
257	Holding	100	
258	Holding	100	
253	Holding	100	
254	Holding	100	
252	Holding	100	

1) Comment for repeated room types are referred back to the first room of that type listed in the section.
2) Pressurized spaces on the 3rd through 8th floors are identical to the 9th floor spaces shown in the table.
3) All of these spaces are served by AHU-P-1, 2, 3, and 4

ZONES	SUPPLY CFM MAX	MIN	Flow	SPACE	TYPE	Length	Width	Area	Ceiling Height	Volume	ACH	Needed ACH
3rd-9th												
S914	900	900	CV	941	Laboratory	105	31.5	661.5	9	5953.5	9	6
S915	1360	1360	CV	East Elevator Lobby		23	8.5	195.5	9	1759.5	46	
S916	470	470	CV	923	Equipment	23.5	10.5	246.75	9	2220.75	13	10
S917	350	350	CV	935	Radioisotope	10.5	10	105	9	945	22	15
S918	900	900	CV	941	Laboratory	105	31.5	661.5	9	5953.5	9	6
S919	850	850	CV	934.1	Tissue Culture	10	9.5	95	9	855	60	2
S920	900	900	CV	941	Laboratory	105	31.5	661.5	9	5953.5	9	6
S921	720	720	CV	934	Tissue Culture	20.5	23.5	386.75	9	3480.75	12	2
S922	470	470	CV	933	Equipment	23.5	10	235	9	2115	13	10
S923	850	850	CV	932.1	Tissue Culture	10	9.5	95	9	855	60	2
S924	900	900	CV	941	Laboratory	105	31.5	661.5	9	5953.5	9	6
S925	720	720	CV	932	Tissue Culture	20.5	23.5	386.75	9	3480.75	12	2
S926	650	650	CV	931	Glasswash	13.5	10	135	9	1215	32	10
S927	900	900	CV	941	Laboratory	105	31.5	661.5	9	5953.5	9	6
S928	150	0	W	Electrical		12.5	10	125	9	1125	8	
S929	470	470	CV	929	Equipment	23.5	10	235	9	2115	13	10
S930	450	0	W	Telecom		10.5	10	105	9	945	29	
S931	200	200	CV	930	Auxiliary	10	10	100	9	900	13	
S932	330	330	CV	926,927,928	Auxiliary,Corridor	21	16.5	346.5	9	3118.5	6	
S933	670	670	CV	925	Auxiliary	21	15	315	9	2835	14	
S934	1000	1000	CV	924	Laboratory	105	31.5	661.5	9	5953.5	10	6
S935	1000	1000	CV	924	Laboratory	105	31.5	661.5	9	5953.5	10	6
S936	1000	1000	CV	924	Laboratory	105	31.5	661.5	9	5953.5	10	6
S937	1000	1000	CV	924	Laboratory	105	31.5	661.5	9	5953.5	10	6
S938	1000	1000	CV	924	Laboratory	105	31.5	661.5	9	5953.5	10	6

ZONES	SUPPLY CFM MAX	SUPPLY CFM MIN	Flow	SPACE	TYPE	Length	Width	Area	Ceiling Height	Volume	ACH	Needed ACH
2nd												
S214	1840	1840	CV	244	Clean Cage Storage	37	31	1147	9	10323	11	2
S215	1360	1360	CV	East Elevator Lobby		23	8.5	195.5	9	1759.5	46	
S216	420	420	CV	246	Storage/Food	16	13.5	216	9	1944	13	
S217	190	190	CV	240	Iso. No. 3	9.5	9	85.5	9	769.5	15	15
S218	950	950	CV	238	Anteroom	16	7.5	120	9	1080	53	
S219	550	550	CV	248	Necropsy	16	10.5	168	9	1512	22	12
S220	520	520	CV	235	Holding	21.5	11	236.5	9	2128.5	15	10 to 15
S221	510	510	CV	236	Holding	21.5	11	236.5	9	2128.5	14	10 to 15
S222	2100	1500	W	239,243	Work Area,Isolation	28	14.5	286	9	2574	49	2
S223	530	530	CV	234	Holding	21.5	11	236.5	9	2128.5	15	10 to 15
S224	190	190	CV	241	Iso. No. 2	9.5	9	85.5	9	769.5	15	15
S225	950	950	CV	230	Procedure	33	12.5	412.5	9	3712.5	15	
S226	190	190	CV	242	Iso. No. 1	9.5	9	85.5	9	769.5	15	15
S227	530	530	CV	233	Holding	21.5	11	236.5	9	2128.5	15	10 to 15
S228	520	520	CV	232	Holding	21.5	11	236.5	9	2128.5	15	10 to 15
S229	510	510	CV	231	Holding	21.5	11	236.5	9	2128.5	14	10 to 15
S230	570	570	CV	223	Holding	21.5	12	258	9	2322	15	10 to 15
S231	870	870	CV	219	Procedure	34.5	19	397.5	9	3577.5	15	10 to 15
S232	530	530	CV	218	Holding	21	11.5	241.5	9	2173.5	15	10 to 15
S233	510	510	CV	217	Holding	21	11.5	241.5	9	2173.5	14	10 to 15
S234	320	320	CV	225	Procedure	17	8.5	144.5	9	1300.5	15	
S235	330	330	CV	228	Procedure	17	8.5	144.5	9	1300.5	15	
S236	150	0	W	Electrical		12.5	10	125	9	1125	8	
S237	720	720	CV	226	Holding	17	16	272	9	2448	18	10 to 15
S238	450	0	W	Telecom		10.5	10	105	9	945	29	
S239	720	720	CV	229	Holding	17	16	272	9	2448	18	10 to 15
S240	380	380	CV	264	Holding	15	12	180	9	1620	14	10 to 15
S241	390	390	CV	265	Holding	15	12	180	9	1620	14	10 to 15
S242	590	590	CV	261	Procedure	24	11	264	9	2376	15	
S243	390	390	CV	262	Holding	15	12	180	9	1620	14	10 to 15
S244	380	380	CV	263	Holding	15	12	180	9	1620	14	10 to 15
S245	390	390	CV	260	Holding	15	12	180	9	1620	14	10 to 15
S246	380	380	CV	259	Holding	15	12	180	9	1620	14	10 to 15
S247	590	590	CV	256	Procedure	24	11	264	9	2376	15	10 to 15
S248	380	380	CV	257	Holding	15	12	180	9	1620	14	10 to 15
S249	390	390	CV	258	Holding	15	12	180	9	1620	14	10 to 15

S250	380	380	CV	253	Holding	15	12	180	9	1620	14	10 to 15
S251	390	390	CV	254	Holding	15	12	180	9	1620	14	10 to 15
S252	590	590	CV	250	Procedure	24	11	264	9	2376	15	10 to 15
S253	380	380	CV	252	Holding	15	12	180	9	1620	14	10 to 15
S254	420	420	CV	251	Quarantine	15	12	180	9	1620	16	15

ZONES	SUPPLY CFM		Flow	SPACE	TYPE	Length	Width	Area	Ceiling Height	Volume	ACH	Needed ACH
	MAX	MIN										
1st												
S112	100	100	CV	140	Food Storage	12	7	84	9	756	8	
S113	750	750	CV	133	Holding	24	13.5	324	9	2916	15	10 to 15
S114	750	750	CV	134	Holding	24	13.5	324	9	2916	15	10 to 15
S115	750	750	CV	135	Holding	24	13.5	324	9	2916	15	10 to 15
S116	750	750	CV	136	Holding	24	13.5	324	9	2916	15	10 to 15
S117	1,140	1,140	CV	137	Holding	24	20	480	9	4320	16	10 to 15
S118	360	360	CV	138	Procedure	21	8	168	9	1512	14	10 to 15
S119	1,050	1,050	CV	119	Sterile	15	13	195	9	1755	36	2
S120	270	270	CV	139	Animal Prep	14	9.5	133	9	1197	14	
S121	240	240	CV	117	Recovery	12	10	120	9	1080	13	10 to 15
S122	90	90	CV	116	Scrub	10	8	76	9	684	8	2
S123	1,000	1,000	CV	123	Necropsy	12	17.5	210	9	1890	32	12
S124	800	800	CV	118	Operating Room	20	15.5	310	9	2790	17	15
S125	200	200	CV	125	Laundry	11	6	66	9	594	20	2
S126	220	220	CV	143	Food	17	12.5	206.25	9	1856.25	7	
S127	230	230	CV	142	Bedding	17	13	214.5	9	1930.5	7	
S128	1,990	1,990	CV	131	Dirty Cagewash Area	65	32	627	9	5643	21	2
S129	1,980	1,980	CV	131	Dirty Cagewash Area	65	32	2080	9	18720	6	2
S130	1,980	1,980	CV	131	Dirty Cagewash Area	65	32	2080	9	18720	6	2
S131	2,000	2,000	CV	129	Clean Cagewash Area	42	25	492	9	4428	27	2
S132	2,000	2,000	CV	129	Clean Cagewash Area	42	25	492	9	4428	27	2
S133	1,360	1,360	CV	East Elevator Lobby		23	8.5	195.5	9	1759.5	46	
S134	780	780	CV	N.E.Exit Corridor		57	8	456	9	4104	11	

Table 3 General Pressure Relationships and Ventilation of Certain Hospital Areas

Function Space	Pressure Relationship to Adjacent Areas[a]	Minimum Air Changes of Outdoor Air per Hour[b]	Minimum Total Air Changes per Hour[c]	All Air Exhausted Directly to Outdoors	Air Recirculated Within Room Units[d]
SURGERY AND CRITICAL CARE					
Operating room (all outdoor air system)	P	15[e]	15	Yes	No
(recirculating air system)	P	5	25	Optional	No
Delivery room (all outdoor air system)	P	15	15	Optional	No
(recirculating air system)	P	5	25	Optional	No
Recovery room	E	2	6	Optional	No
Nursery suite	P	5	12	Optional	No
Trauma room[f]	P	5	12	Optional	No
Anesthesia storage (see code requirements)	±	Optional	8	Yes	No
NURSING					
Patient room	±	2	4	Optional	Optional
Toilet room[g]	N	Optional	10	Yes	No
Intensive care	P	2	6	Optional	No
Protective isolation[i]	P	2	15	Yes	Optional
Infectious isolation[h]	±	2	6	Yes	No
Isolation alcove or anteroom	±	2	10	Yes	No
Labor/delivery/recovery/postpartum (LDRP)	E	2	4	Optional	Optional
Patient corridor	E	2	4	Optional	Optional
ANCILLARY					
Radiology X-ray (surgery and critical care)	P	3	15	Optional	No
X-ray (diagnostic and treatment)	±	2	6	Optional	Optional
Darkroom	N	2	10	Yes[j]	No
Laboratory, general	N	2	6	Yes	No
Laboratory, bacteriology	N	2	6	Yes	No
Laboratory, biochemistry	P	2	6	Optional	No
Laboratory, cytology	N	2	6	Yes	No
Laboratory, glasswashing	N	Optional	10	Yes	Optional
Laboratory, histology	N	2	6	Yes	No
Laboratory, nuclear medicine	N	2	6	Yes	No
Laboratory, pathology	N	2	6	Yes	No
Laboratory, serology	P	2	6	Optional	No
Laboratory, sterilizing	N	Optional	10	Yes	No
Laboratory, media transfer	P	2	4	Optional	No
Autopsy	N	2	12	Yes	No
Nonrefrigerated body-holding room[k]	N	Optional	10	Yes	No
Pharmacy	P	2	4	Optional	Optional
ADMINISTRATION					
Admitting and Waiting Rooms	N	2	6	Yes	Optional
DIAGNOSTIC AND TREATMENT					
Bronchoscopy, sputum collection, and pentamidine administration	N	2	10	Yes	Optional
Examination room	±	2	6	Optional	Optional
Medication room	P	2	4	Optional	Optional
Treatment room	±	2	6	Optional	Optional
Physical therapy and hydrotherapy	N	2	6	Optional	Optional
Soiled workroom or soiled holding	N	2	10	Yes	No
Clean workroom or clean holding	P	2	4	Optional	Optional
STERILIZING AND SUPPLY					
Sterilizer equipment room	N	Optional	10	Yes	No
Soiled or decontamination room	N	2	6	Yes	No
Clean workroom and sterile storage	P	2	4	Optional	Optional
Equipment storage	±	2 (Optional)	2	Optional	Optional
SERVICE					
Food preparation center[l]	±	2	10	Yes	No
Warewashing	N	Optional	10	Yes	No
Dietary day storage	±	Optional	2	Optional	No
Laundry, general	N	2	10	Yes	No
Soiled linen sorting and storage	N	Optional	10	Yes	No
Clean linen storage	P	2 (Optional)	2	Optional	Optional
Linen and trash chute room	N	Optional	10	Yes	No
Bedpan room	N	Optional	10	Yes	No
Bathroom	N	Optional	10	Optional[f]	No
Janitor's closet	N	Optional	10	Optional	No

P = Positive N = Negative E = Equal ± = Continuous directional control not required

[a] Where continuous directional control is not required, variations should be minimized, and in no case should a lack of directional control allow the spread of infection from one area to another. Boundaries between functional areas (wards or departments) should have directional control. Lewis (1988) describes methods for maintaining directional control by applying air-tracking controls.

[b] Ventilation in accordance with ASHRAE *Standard* 62, Ventilation for Acceptable Indoor Air Quality, should be used for areas for which specific ventilation rates are not given. Where a higher outdoor air requirement is called for in *Standard* 62 than in Table 3, the higher value should be used.

[c] Total air changes indicated should be either supplied or, where required, exhausted.

[d] Recirculating HEPA filter units used for infection control (without heating or cooling coils) are acceptable.

[e] For operating rooms, 100% outside air should be used only when codes require it and only if heat recovery devices are used.

[f] The term "trauma room" as used here is the first aid room and/or emergency room used for general initial treatment of accident victims. The operating room within the trauma center that is routinely used for emergency surgery should be treated as an operating room.

[g] See section on Patient Rooms for discussion on design of central toilet exhaust systems.

[h] The infectious isolation rooms described in this table are those that might be used for infectious patients in the average community hospital. The rooms are negatively pressurized. Some isolation rooms may have a separate anteroom. Refer to the discussion in the chapter for more detailed information. Where highly infectious respirable diseases such as tuberculosis are to be isolated, increased air change rates should be considered.

[i] Protective isolation rooms are those used for immunosuppressed patients. The room is positively pressurized to protect the patient. Anterooms are generally required and should be negatively pressurized with respect to the patient room.

[j] All air need not be exhausted if darkroom equipment has scavenging exhaust duct attached and meets ventilation standards of NIOSH, OSHA, and local employee exposure limits.

[k] The nonrefrigerated body-holding room is only for facilities that do not perform autopsies on-site and use the space for short periods while waiting for the body to be transferred.

[l] Food preparation centers should have an excess of air supply for positive pressure when hoods are not in operation. The number of air changes may be reduced or varied for odor control when the space is not in use. Minimum total air changes per hour should be that required to provide proper makeup air to kitchen exhaust systems. See Chapter 30, Kitchen Ventilation.

Recommended Temperature, Relative Humidity, and Ventilation for Common Laboratory Animals

Species	Temperature °F (°C)		Relative Humidity (%)		Minimum Room Air Exchange Rate (ACH)	
	ILAR*	CCAC**	ILAR	CCAC	ILAR	CCAC
Mouse	64.4 – 78.8 (18 – 26)	71.6 – 77.0 (22 – 25)	40 – 70	50 – 70	15	8 – 12
Rat	64.4 – 78.8 (18 – 26)	68.0 – 77.0 (20 – 25)	40 – 70	50 – 55	15	10 – 20
Hamster	64.4 – 78.8 (18 – 26)	69.8 – 75.2 (21 – 24)	40 – 70	45 – 65	15	6 – 10
Guinea pig	64.4 – 78.8 (18 – 26)	64.4 – 71.6 (18 – 22)	40 – 70	50 – 60	15	4 – 8
Rabbit	60.8 – 69.8 (16 – 21)	60.8 – 71.6 (16 – 22)	40 – 60	40 – 50	10	10 – 20
Cat	64.4 – 84.2 (18 – 29)	68.0 – 71.6 (20 – 22)	30 – 70	45 – 60	10	10 – 18
Dog	64.4 – 84.2 (18 – 29)	64.4 – 69.8 (18 – 21)	30 – 70	45 – 55	10	8 – 12
Nonhuman primate	64.4 – 84.2 (18 – 29)	69.8 – 78.8 (21 – 26)	30 – 70	45 – 60	10 – 15	12 – 16
Chicken	60.8 – 80.6 (16 – 27)	64.4 – 71.6 (18 – 22)	45 – 70	45 – 70	10 – 15	5 – 15

* Institute of Laboratory Animal Resources

** Canadian Council on Animal Care

5.17.3.3 Class 3 Air. Class 3 air may be recirculated within the space of origin. Class 3 air shall not be recirculated or transferred to any other space.

5.17.3.4 Class 4 Air. Class 4 air shall not be recirculated or transferred to any space nor recirculated within the space of origin.

5.17.4 Documentation. Design documentation shall indicate the justification for classification of air from any location not listed in Table 6-1, Table 5-2, or Table 5-3.

6. PROCEDURES

This section is not required for natural ventilation systems; natural ventilation systems shall be designed in accordance with Section 5.1.

6.1 General. Either the Ventilation Rate Procedure or the IAQ Procedure shall be used to design each ventilation system in a building, subject to the following considerations and restrictions.

6.1.1 Ventilation Rate Procedure. This is a prescriptive procedure in which outdoor air intake rates are determined based on space type/application, occupancy level, and floor area. **Note:** The Ventilation Rate Procedure minimum rates are based on contaminant sources and source strengths that are typical for the listed space types.

6.1.2 IAQ Procedure. This is a design procedure in which outdoor air intake rates and other system design parameters are based on an analysis of contaminant sources, contaminant concentration targets, and perceived acceptability targets. The IAQ Procedure allows credit to be taken for controls that remove contaminants (for example, air cleaning devices) or for other design techniques (for example, selection of materials with lower source strengths) that can be reliably demonstrated to result in indoor contaminant concentrations equal to or lower than those achieved using the Ventilation Rate Procedure. The IAQ Procedure may also be used where the design is intended to attain specific target contaminant concentrations or levels of acceptability of perceived indoor air quality.

6.2 Ventilation Rate Procedure

The design *outdoor air intake flow* (V_{ot}) for a ventilation system shall be determined in accordance with Sections 6.2.1 through 6.2.9.

Note: Additional explanation of terms used below is contained in Appendix A, along with a ventilation system schematic (Figure A.1).

6.2.1 Outdoor Air Treatment. If outdoor air is judged to be unacceptable in accordance with Section 4.1, each ventilation system that provides outdoor air through a supply fan shall comply with the following sections.

Exceptions: Systems supplying air for enclosed parking garages, warehouses, storage rooms, janitor's closets, trash rooms, recycling areas, shipping/receiving/distribution areas.

Note: Occupied spaces ventilated with outdoor air that is judged to be unacceptable are subject to reduced air quality when outdoor air is not cleaned prior to introduction to the occupied spaces.

6.2.1.1 Particulate Matter. When the building is located in an area where the national standard for PM10 is exceeded, particle filters or air cleaning devices shall be provided to clean the air at any location prior to its introduction to occupied spaces. Particulate matter filters or air cleaners shall have a Minimum Efficiency Reporting Value (MERV) of 6 or higher when rated in accordance with ASHRAE Standard 52.2-1999.[15]

6.2.1.2 Ozone. Air-cleaning devices for ozone shall be provided when the second-highest daily maximum one-hour average concentration exceeds 0.160 ppm (313 $\mu g/m^3$). The ozone concentration for design purposes shall be determined in accordance with Appendix H to subchapter C, 40 CFR 50,[1] or equivalent.

Note: Monitored values for historical one-hour average ozone concentrations are available for United States locations at the AIRData Web site, located under www.epa.gov.

Such air-cleaning devices shall have a minimum volumetric ozone removal efficiency of 40% when installed, operated, and maintained in accordance with manufacturer recommendations and shall be approved by the authority having jurisdiction. Such devices shall be operated whenever outdoor ozone levels are expected to exceed 0.160 ppm (313 $\mu g/m^3$).

Note: For United States locations, the one-hour average ozone concentration is expected to exceed the 0.160 ppm (313 $\mu g/m^3$) limit when the Air Quality Index forecast exceeds 151 (category red, purple, or maroon). This forecast is available in local media or at the AIRNow Web site, located under www.epa.gov.

Exceptions:

Air cleaning for ozone is not required when:

1. The minimum system design outdoor air intake flow results in 1.5 air changes per hour or less.
2. Controls are provided that sense outdoor ozone level and reduce intake airflow to result in 1.5 air changes per hour or less while complying with the outdoor airflow requirements of Section 6.
3. Outdoor air is brought into the building and heated by direct-fired, makeup air units.

6.2.1.3 Other Outdoor Contaminants. When the building is located in an area where the national standard for one or more contaminants not specifically addressed in Section 6.2.1 is exceeded, any design assumptions and/or calculations related to the impact on indoor air quality shall be included in the design documents.

6.2.2 Zone Calculations. *Zone* parameters shall be determined in accordance with Sections 6.2.2.1 through 6.2.2.3.

Note: In some cases it is acceptable to determine these parameters for only selected *zones* as outlined in Appendix A.

6.2.2.1 Breathing Zone Outdoor Airflow. The design outdoor airflow required in the *breathing zone* of the occupiable space or spaces in a *zone*, *i.e., the breathing zone outdoor airflow* (V_{bz}), shall be determined in accordance with Equation 6-1.

$$V_{bz} = R_p P_z + R_a A_z \qquad (6\text{-}1)$$

where:

A_z = *zone floor area*: the net occupiable floor area of the *zone* m^2, (ft^2).

P_z = *zone population*: the largest number of people expected to occupy the zone during typical usage. If the number of people expected to occupy the zone fluctuates, P_z may be estimated based on averaging approaches described in Section 6.2.6.2. **Note**: If P_z cannot be accurately predicted during design, it shall be an estimated value based on the zone floor area and the default occupant density listed in Table 6-1.

R_p = outdoor airflow rate required per person as determined from Table 6-1. **Note**: These values are based on adapted occupants.

R_a = outdoor airflow rate required per unit area as determined from Table 6-1.

Note: Equation 6-1 is the means of accounting for people-related sources and area-related sources for determining the outdoor air required at the *breathing zone*. The use of Equation 6-1 in the context of this standard does not necessarily imply that simple addition of sources can be applied to any other aspect of indoor air quality.

6.2.2.2 Zone Air Distribution Effectiveness. The *zone air distribution effectiveness* (E_z) shall be determined using Table 6-2.

6.2.2.3 Zone Outdoor Airflow. The design *zone outdoor airflow* (V_{oz}), i.e., the outdoor airflow that must be provided to the zone by the supply air distribution system, shall be determined in accordance with Equation 6-2.

$$V_{oz} = V_{bz}/E_z \qquad (6\text{-}2)$$

6.2.3 Single-Zone Systems. When one air handler supplies a mixture of outdoor air and recirculated air to only one zone, the *outdoor air intake flow* (V_{ot}) shall be determined in accordance with Equation 6-3.

$$V_{ot} = V_{oz} \qquad (6\text{-}3)$$

6.2.4 100% Outdoor Air Systems. When one air handler supplies only outdoor air to one or more zones, the *outdoor air intake flow* (V_{ot}) shall be determined in accordance with Equation 6-4.

$$V_{ot} = \Sigma_{all\ zones} V_{oz} \qquad (6\text{-}4)$$

6.2.5 Multiple-Zone Recirculating Systems. When one air handler supplies a mixture of outdoor air and recirculated return air to more than one zone, the *outdoor air intake flow* (V_{ot}) shall be determined in accordance with Sections 6.2.5.1 through 6.2.5.4.

6.2.5.1 Primary Outdoor Air Fraction. When Table 6-3 is used to determine system ventilation efficiency, the *zone primary outdoor air fraction* (Z_p) shall be determined in accordance with Equation 6-5.

$$Z_p = V_{oz}/V_{pz} \qquad (6\text{-}5)$$

where V_{pz} is the zone primary airflow, i.e., the primary airflow to the zone from the air handler including outdoor air and recirculated return air. **Note**: For VAV systems, V_{pz} is the minimum expected primary airflow for design purposes.

6.2.5.2 System Ventilation Efficiency. The *system ventilation efficiency* (E_v) shall be determined using Table 6-3 or Appendix A.

6.2.5.3 Uncorrected Outdoor Air Intake. The design *uncorrected outdoor air intake* (V_{ou}) shall be determined in accordance with Equation 6-6.

$$V_{ou} = D\ \Sigma_{all\ zones} R_p P_z + \Sigma_{all\ zones} R_a A_z \qquad (6\text{-}6)$$

The *occupant diversity*, *D*, may be used to account for variations in occupancy within the zones served by the system. The *occupancy diversity* is defined as

$$D = P_s/\Sigma_{all\ zones} P_z \qquad (6\text{-}7)$$

where the *system population* (P_s) is the total population in the area served by the system. Alternative methods may be used to account for population diversity when calculating V_{ou}, provided that the resulting value is no less than that determined by Equation 6-6.

Note: The *uncorrected outdoor air intake* (V_{ou}) is adjusted for diversity but uncorrected for ventilation efficiency.

6.2.5.4 Outdoor Air Intake. The design *outdoor air intake flow* (V_{ot}) shall be determined in accordance with Equation 6-8.

$$V_{ot} = V_{ou}/E_v \qquad (6\text{-}8)$$

6.2.6 Design for Varying Operating Conditions.

6.2.6.1 Variable Load Conditions. Ventilation systems shall be designed to be capable of providing the required ventilation rates in the breathing zone whenever the zones served by the system are occupied, including all full- and part-load conditions.

6.2.6.2 Short-Term Conditions. If it is known that peak occupancy will be of short duration and/or ventilation will be varied or interrupted for a short period of time, the design may be based on the average conditions over a time period *T* determined by Equation 6-9:

$$T = 3\ v\ /\ V_{bz} \qquad (6\text{-}9a)\ IP$$

$$T = 50\ v\ /\ V_{bz} \qquad (6\text{-}9b)\ SI$$

where:

T = averaging time period, (min).

v = the volume of the zone for which averaging is being applied, ft^3 (m^3).

V_{bz} = the *breathing zone outdoor airflow* calculated using Equation 6-1 and the design value of the zone population P_z, cfm (L/s).

Acceptable design adjustments based on this optional provision include the following:

1. Zones with fluctuating occupancy: The *zone population* (P_z) may be averaged over time *T*.
2. Zones with intermittent interruption of supply air: The average outdoor airflow supplied to the *breathing zone* over time *T* shall be no less than the *breathing zone outdoor airflow* (V_{bz}) calculated using Equation 6-1.
3. Systems with intermittent closure of the outdoor air intake: The average outdoor air intake over time *T* shall be no less than the *minimum outdoor air intake* (V_{ot}) calculated using Equation 6-3, 6-4, or 6-8 as appropriate.

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values			Air Class
						Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
	cfm/person	L/s•person	cfm/ft^2	L/s•m^2		#/1000 ft^2 or #/100 m^2	cfm/person	L/s•person	
Correctional Facilities									
Cell	5	2.5	0.12	0.6		25	10	4.9	2
Day room	5	2.5	0.06	0.3		30	7	3.5	1
Guard stations	5	2.5	0.06	0.3		15	9	4.5	1
Booking/waiting	7.5	3.8	0.06	0.3		50	9	4.4	2
Educational Facilities									
Daycare (through age 4)	10	5	0.18	0.9		25	17	8.6	2
Classrooms (ages 5-8)	10	5	0.12	0.6		25	15	7.4	1
Classrooms (age 9 plus)	10	5	0.12	0.6		35	13	6.7	1
Lecture classroom	7.5	3.8	0.06	0.3		65	8	4.3	1
Lecture hall (fixed seats)	7.5	3.8	0.06	0.3		150	8	4.0	1
Art classroom	10	5	0.18	0.9		20	19	9.5	2
Science laboratories	10	5	0.18	0.9	E	25	17	8.6	-
Wood/metal shop	10	5	0.18	0.9		20	19	9.5	2
Computer lab	10	5	0.12	0.6		25	15	7.4	1
Media center	10	5	0.12	0.6	A	25	15	7.4	1
Music/theater/dance	10	5	0.06	0.3		35	12	5.9	1
Multi-use assembly	7.5	3.8	0.06	0.3		100	8	4.1	1
Food and Beverage Service									
Restaurant dining rooms	7.5	3.8	0.18	0.9		70	10	5.1	2
Cafeteria/fast food dining	7.5	3.8	0.18	0.9		100	9	4.7	2
Bars, cocktail lounges	7.5	3.8	0.18	0.9		100	9	4.7	2
General									
Conference/meeting	5	2.5	0.06	0.3		50	6	3.1	1
Corridors	-	-	0.06	0.3		-			1
Storage rooms	-	-	0.12	0.6	B	-			1
Hotels, Motels, Resorts, Dormitories									
Bedroom/living Room	5	2.5	0.06	0.3		10	11	5.5	1
Barracks sleeping areas	5	2.5	0.06	0.3		20	8	4.0	1
Lobbies/prefunction	7.5	3.8	0.06	0.3		30	10	4.8	1
Multi-purpose assembly	5	2.5	0.06	0.3		120	6	2.8	1

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE *(Continued)*

(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values			Air Class
						Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
	cfm/person	L/s•person	cfm/ft^2	L/s•m^2		#/1000 ft^2 or #/100 m^2	cfm/person	L/s•person	
Office Buildings									
Office space	5	2.5	0.06	0.3		5	17	8.5	1
Reception areas	5	2.5	0.06	0.3		30	7	3.5	1
Telephone/data entry	5	2.5	0.06	0.3		60	6	3.0	1
Main entry lobbies	5	2.5	0.06	0.3		10	11	5.5	1
Miscellaneous Spaces									
Bank vaults/safe deposit	5	2.5	0.06	0.3		5	17	8.5	2
Computer (not printing)	5	2.5	0.06	0.3		4	20	10.0	1
Pharmacy (prep. area)	5	2.5	0.18	0.9		10	23	11.5	2
Photo studios	5	2.5	0.12	0.6		10	17	8.5	1
Shipping/receiving	-	-	0.12	0.6	B	-			1
Transportation waiting	7.5	3.8	0.06	0.3		100	8	4.1	1
Warehouses	-	-	0.06	0.3	B	-			2
Public Assembly Spaces									
Auditorium seating area	5	2.5	0.06	0.3		150	5	2.7	1
Places of religious workshop	5	2.5	0.06	0.3		120	6	2.8	1
Courtrooms	5	2.5	0.06	0.3		70	6	2.9	1
Legislative chambers	5	2.5	0.06	0.3		50	6	3.1	1
Libraries	5	2.5	0.12	0.6		10	17	8.5	1
Lobbies	5	2.5	0.06	0.3		150	5	2.7	1
Museums (children's)	7.5	3.8	0.12	0.6		40	11	5.3	1
Museums/galleries	7.5	3.8	0.06	0.3		40	9	4.6	1
Retail									
Sales (except as below)	7.5	3.8	0.12	0.6		15	16	7.8	2
Mall common areas	7.5	3.8	0.06	0.3		40	9	4.6	1
Barber shop	7.5	3.8	0.06	0.3		25	10	5.0	2
Beauty and nail salons	20	10	0.12	0.6		25	25	12.4	2
Pet shops (animal areas)	7.5	3.8	0.18	0.9		10	26	12.8	2
Supermarket	7.5	3.8	0.06	0.3		8	15	7.6	1
Coin-operated laundries	7.5	3.8	0.06	0.3		20	11	5.3	2

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE *(Continued)*
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values			Air Class
						Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
	cfm/person	L/s•person	cfm/ft^2	L/s•m^2		#/1000 ft^2 or #/100 m^2	cfm/person	L/s•person	
Sports and Entertainment									
Sports arena (play area)	-	-	0.30	1.5		-			1
Gym, stadium (play area)	-	-	0.30	1.5		30			2
Spectator areas	7.5	3.8	0.06	0.3		150	8	4.0	1
Swimming (pool & deck)	-	-	0.48	2.4	C	-			2
Disco/dance floors	20	10	0.06	0.3		100	21	10.3	1
Health club/aerobics room	20	10	0.06	0.3		40	22	10.8	2
Health club/weight rooms	20	10	0.06	0.3		10	26	13.0	2
Bowling alley (seating)	10	5	0.12	0.6		40	13	6.5	1
Gambling casinos	7.5	3.8	0.18	0.9		120	9	4.6	1
Game arcades	7.5	3.8	0.18	0.9		20	17	8.3	1
Stages, studios	10	5	0.06	0.3	D	70	11	5.4	1

GENERAL NOTES FOR TABLE 6-1

1 **Related Requirements:** The rates in this table are based on all other applicable requirements of this standard being met.

2 **Smoking:** This table applies to no-smoking areas. Rates for smoking-permitted spaces must be determined using other methods. See Section 6.2.9 for ventilation requirements in smoking areas.

3 **Air Density:** Volumetric airflow rates are based on an air density of 0.075 lb_{da}/ft^3 (1.2 kg_{da}/m^3), which corresponds to dry air at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 70°F (21°C). Rates may be adjusted for actual density but such adjustment is not required for compliance with this standard.

4 **Default Occupant Density**: The default occupant density shall be used when actual occupant density is not known.

5 **Default Combined Outdoor Air Rate (per person)**: This rate is based on the default occupant density.

6 **Unlisted Occupancies:** If the occupancy category for a proposed space or zone is not listed, the requirements for the listed occupancy category that is most similar in terms of occupant density, activities and building construction shall be used.

7 **Residential facilities, Healthcare facilities and Vehicles:** Rates shall be determined in accordance with Appendix E.

ITEM-SPECIFIC NOTES FOR TABLE 6-1

A For high school and college libraries, use values shown for Public Spaces – Library.

B Rate may not be sufficient when stored materials include those having potentially harmful emissions.

C Rate does not allow for humidity control. Additional ventilation or dehumidification may be required to remove moisture.

D Rate does not include special exhaust for stage effects, e.g., dry ice vapors, smoke.

E No class of air has been established for this occupancy category.

TABLE 6-2
Zone Air Distribution Effectiveness

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

1. "Cool air" is air cooler than space temperature.
2. "Warm air" is air warmer than space temperature.
3. "Ceiling" includes any point above the *breathing zone.*
4. "Floor" includes any point below the *breathing zone.*
5. As an alternative to using the above values, E_z may be regarded as equal to air change effectiveness determined in accordance with ASHRAE Standard 129[16] for all air distribution configurations except unidirectional flow.

6.2.7 Dynamic Reset. The system may be designed to reset the design *outdoor air intake flow* (V_{ot}) and/or space or zone airflow as operating conditions change. These conditions include but are not limited to:

1. Variations in occupancy or ventilation airflow in one or more individual zones for which ventilation airflow requirements will be reset. **Note**: Examples of measures for estimating such variations include: occupancy scheduled by time-of-day, a direct count of occupants, or an estimate of occupancy or ventilation rate per person using occupancy sensors such as those based on indoor CO_2 concentrations.
2. Variations in the efficiency with which outdoor air is distributed to the occupants under different ventilation system airflows and temperatures.
3. A higher fraction of outdoor air in the air supply due to intake of additional outdoor air for free cooling or exhaust air makeup.

6.2.8 Exhaust Ventilation. Exhaust airflow shall be provided in accordance with the requirements in Table 6-4. Exhaust makeup air may be any combination of outdoor air, recirculated air, and transfer air.

TABLE 6-3
System Ventilation Efficiency

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

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

6.2.9 Ventilation in Smoking Areas. Smoking areas shall have more ventilation and/or air cleaning than comparable no-smoking areas. Specific ventilation rate requirements cannot be determined until cognizant authorities determine the concentration of smoke that achieves an acceptable level of risk. Air from smoking areas shall not be recirculated or transferred to no-smoking areas.

6.3 Indoor Air Quality Procedure

The Indoor Air Quality (IAQ) Procedure is a performance-based design approach in which the building and its ventilation system are designed to maintain the concentrations of specific contaminants at or below certain limits identified during the building design and to achieve the design target level of perceived indoor air quality acceptability by building occupants and/or visitors. For the purposes of this procedure, acceptable perceived indoor air quality excludes dissatisfaction related to thermal comfort, noise and vibration, lighting, and psychological stressors.

6.3.1 Designs employing the Indoor Air Quality Procedure shall comply with the requirements in the following sections.

6.3.1.1 Contaminant Sources. Contaminants of concern for purposes of the design shall be identified. For each contaminant of concern, indoor and outdoor sources shall be identified, and the strength of each source shall be determined.

6.3.1.2 Contaminant Concentration. For each contaminant of concern, a target concentration limit and its corresponding exposure period and an appropriate reference to a cognizant authority shall be specified. (See Appendix B for some contaminant concentration guidelines.)

6.3.1.3 Perceived Indoor Air Quality. The criteria to achieve the design level of acceptability shall be specified in terms of the percentage of building occupants and/or visitors expressing satisfaction with perceived indoor air quality.

6.3.1.4 Design Approaches. Select one or a combination of the following design approaches to determine mini-

TABLE 6-4 Minimum Exhaust Rates

Occupancy Category	Exhaust Rate cfm/unit	Exhaust Rate cfm/ft^2	Notes	Exhaust Rate L/s-unit	Exhaust Rate L/s-m^2	Air Class
Art classrooms	-	0.70		-	3.5	2
Auto repair rooms	-	1.50	A,F	-	7.5	-
Barber shop	-	0.50		-	2.5	2
Beauty and nail salons	-	0.60		-	3.0	2
Cell with toilet	-	1.00		-	5.0	2
Darkrooms	-	1.00		-	5.0	2
Arena	-	0.50	B	-	2.5	-
Kitchen – commercial	-	0.70		--	3.5	2
Kitchenettes	-	0.30		--	1.5	2
Locker rooms	-	0.50		-	2.5	2
Locker/dressing rooms	-	0.25		-	1.25	2
Parking garages	-	0.75	C	--	3.7	2
Janitor, trash, recycle	-	1.00		-	5.0	3
Pet shops (animal areas)	-	0.90		-	4.5	2
Copy, printing rooms	-	0.50		-	2.5	2
Science lab classrooms	-	1.00	F	-	5.0	-
Toilets – public	50/70	-	D	25/35	-	2
Toilet – private	25/50	-	E	12.5/25	-	2
Woodwork shop/classroom	-	0.50		-	2.5	2

A Stands where engines are run shall have exhaust systems that directly connect to the engine exhaust and prevent escape of fumes.
B When combustion equipment is intended to be used on the playing surface additional dilution ventilation and/or source control shall be provided.
C Exhaust not required if two or more sides comprise walls that are at least 50% open to the outside.
D Rate is per water closet and/or urinal. Provide the higher rate where periods of heavy use are expected to occur, e.g., toilets in theatres, schools, and sports facilities. The lower rate may be used otherwise.
E Rate is for a toilet room intended to be occupied by one person at a time. For continuous system operation during normal hours of use, the lower rate may be used. Otherwise use the higher rate.
F No class of air has been established for this occupancy category.

mum space and system outdoor airflow rates and all other design parameters deemed relevant (e.g., air cleaning efficiencies and supply airflow rates).

(a) Mass balance analysis. The steady-state equations in Appendix D, which describe the impact of air cleaning on outdoor air and recirculation rates, may be used as part of a mass balance analysis for ventilation systems serving a single space.
(b) Design approaches that have proved successful in similar buildings.
(c) Approaches validated by contaminant monitoring and subjective occupant evaluations in the completed building. An acceptable approach to subjective evaluation is presented in Appendix B, which may be used to validate the acceptability of perceived air quality in the completed building.
(d) Application of one of the preceding design approaches (a, b, or c) to specific contaminants and the use of the Ventilation Rate Procedure to address the general aspects of indoor air quality in the space being designed. In this situation, the Ventilation Rate Procedure would be used to determine the design ventilation rate of the space and the IAQ Procedure would be used to address the control of the specific contaminants through air cleaning or some other means.

6.3.2 Documentation. When the IAQ Procedure is used, the following information shall be included in the design documentation: the contaminants of concern considered in the design process; the sources and source strengths of the contaminants of concern; the target concentration limits and exposure periods and the references for these limits; the design approach used to control the contaminants of concern; and the background or justification for this design approach. If the design is based on an approach that has proved successful for similar buildings, the documentation shall include the basis for concluding that the design approach was successful in the other buildings and the basis for concluding that the previous buildings are relevant to the new design. If contaminant monitoring and occupant evaluation are to be used to demonstrate compliance, then the monitoring and evaluation plans shall also be included in the documentation.

6.4 Design Documentation Procedures. Design criteria and assumptions shall be documented and should be made available for operation of the system within a reasonable time after installation. See Sections 4.3, 5.2.3, 5.17.4, and 6.3.2 regarding assumptions that should be detailed in the documentation.

7. CONSTRUCTION AND SYSTEM START-UP

7.1 Construction Phase

7.1.1 Application. The requirements of this section apply to ventilation systems and the spaces they serve in new buildings and additions to or alterations in existing buildings.

7.1.2 Filters. Systems designed with particle filters shall not be operated without filters in place.

7.1.3 Protection of Materials. When recommended by the manufacturer, building materials shall be protected from rain and other sources of moisture by appropriate in-transit and on-site procedures. Porous materials with visible microbial growth shall not be installed. Nonporous materials with visible microbial growth shall be decontaminated.

7.1.4 Protection of Occupied Areas

7.1.4.1 Application. The requirements of Section 7.1.4 apply when construction requires a building permit and entails sanding, cutting, grinding, or other activities that generate significant amounts of airborne particles or procedures that generate significant amounts of gaseous contaminants.

7.1.4.2 Protective Measures. Measures shall be employed to reduce the migration of construction-generated contaminants to occupied areas. Examples of acceptable measures include, but are not limited to, sealing the construction area using temporary walls or plastic sheathing, exhausting the construction area, and/or pressurizing contiguous occupied areas.

7.1.5 Air Duct System Construction. Air duct systems shall be constructed in accordance with the following standards, as applicable:

(a) the following sections of SMACNA's *HVAC Duct Construction Standards—Metal and Flexible*[17]
- Section S1.9j of Section 1.6, Duct Construction and Installation Standards
- Section 2.6, Installation Standards for Rectangular Ducts Using Flexible Liner
- Section 3.5, Duct Installation Standards
- Section 3.6, Specification for Joining and Attaching Flexible Duct
- Section 3.7, Specification for Supporting Flexible Duct
- Sections S6.1, S6.3, S6.4, and S6.5 of Section 6.1, Casing and Plenum Construction Standards

(b) all sections of SMACNA's *Fibrous Glass Duct Construction Standards*[18]

(c) NFPA 90A,[19] *Standard for the Installation of Air-Conditioning and Ventilating Systems*, and NFPA 90B,[20] *Standard for the Installation of Warm Air Heating and Air-Conditioning Systems*

7.2 System Start-Up

7.2.1 Application. The requirements of this section apply to the following ventilation systems:

(a) newly installed air-handling systems;

(b) existing air-handling systems undergoing supply air or outdoor air flow reduction—only the requirements of Section 7.2.2 shall apply to these altered systems; or

(c) existing air-handling distribution systems undergoing alterations affecting more than 25% of the floor area served by the systems—only the requirements of Section 7.2.2 shall apply to these altered systems.

7.2.2 Air Balancing. Ventilation systems shall be balanced in accordance with ASHRAE Standard 111,[21] SMACNA's *HVAC Systems—Testing, Adjusting and Balancing*,[22] or equivalent at least to the extent necessary to verify conformance with the total outdoor air flow and space supply air flow requirements of this standard.

7.2.3 Testing of Drain Pans. To minimize conditions of water stagnation that may result in microbial growth, drain pans shall be field tested under normal operating conditions to ensure proper drainage.

Exception to 7.2.3: Field testing of drain pans is not required if units with factory-installed drain pans have been certified (attested in writing) by the manufacturer for proper drainage when installed as recommended.

7.2.4 Ventilation System Start-Up. Ventilation air distribution systems shall be clean of dirt and debris.

7.2.5 Outdoor Air Dampers. Prior to occupancy, each ventilation system shall be tested to ensure that outdoor air dampers operate properly in accordance with the system design.

7.2.6 Documentation. The following ventilation system documentation shall be provided to the building owner or his/her designee, retained within the building, and made available to the building operating personnel:

(a) An operating and maintenance manual describing basic data relating to the operation and maintenance of ventilation systems and equipment as installed.

(b) HVAC controls information consisting of diagrams, schematics, control sequence narratives, and maintenance and/or calibration information.

(c) An air balance report documenting the work performed for Section 7.2.2.

(d) Construction drawings of record, control drawings, and final design drawings.

(e) Design criteria and assumptions.

Efficiency by Particle Size. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.

[16] *ANSI/ASHRAE 129-1997 (RA 02), Measuring Air Change Effectiveness.* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.

[17] *HVAC Duct Construction Standards--Metal and Flexible*, 2nd Edition, 1995. Sheet Metal and Air Conditioning Contractors' National Association, Inc. (SMACNA), Chantilly, VA.

[18] *Fibrous Glass Duct Construction Standards*, 6th Edition, 1992. Sheet Metal and Air Conditioning Contractors' National Association, Inc. (SMACNA), Chantilly, VA.

[19] *NFPA-90A-2002, Standard for the Installation of Air-Conditioning and Ventilating Systems.* National Fire Protection Association, Quincy, MA.

[20] *NFPA-90B-2002, Standard for the Installation of Warm Air Heating and Air-Conditioning Systems.* National Fire Protection Association, Quincy, MA.

[21] *ASHRAE Standard 111-1988, Practices for Measurement, Testing, Adjusting, and Balancing of Building, Heating, Ventilation, Air-Conditioning and Refrigeration Systems.* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.

[22] *HVAC Systems–Testing, Adjusting and Balancing*, 3rd Edition, 2002. Sheet Metal and Air Conditioning Contractors' National Association, Inc. (SMACNA), Chantilly, VA.

(This is a normative appendix and is part of the standard.)

APPENDIX A
MULTIPLE-ZONE SYSTEMS

This appendix presents an alternative procedure for calculating the *system ventilation efficiency* (E_v) that must be used when Table 6-3 values are not used. In this alternative procedure, E_v is equal to the lowest calculated value of the *zone ventilation efficiency* E_{vz} (see Equation A-3 below). Figure A.1 contains a ventilation system schematic depicting most of the quantities used in this appendix.

The *zone ventilation efficiency* E_{vz}, i.e., the efficiency with which a system distributes outdoor air from the intake to an individual *breathing zone*, shall be calculated using Equation A-1 or A-2.

Single Supply Systems $E_{vz} = 1 + X_s - Z_d$ (A-1)

Equation A-1 (or A-2) shall be used for "single supply" systems, where all the ventilation air is a mixture of outdoor air and recirculated air from a single location, e.g., Reheat, Single-Duct VAV, Single-Fan Dual-Duct, and Multizone.

General Case $E_{vz} = (F_a + X_s{*}F_b - Z_d{*}F_c)/F_a$ (A-2)

Equation A-2 shall be used for systems that provide all or part of their ventilation by recirculating air from other zones without directly mixing it with outdoor air, e.g., dual-fan dual-duct, fan-powered mixing box, and transfer fans for conference rooms.

The system ventilation efficiency shall be calculated using Equation A-3.

$E_v = minimum\ (E_{vz})$ (A-3)

Alternative Calculations

The above equations may be rearranged to calculate other design parameters of interest based on known parameters. This includes, but is not limited to, calculating minimum *zone discharge* (supply) *airflow* (V_{dz}) when the *outdoor air intake flow* V_{ot} is known.

Other mass or flow balance equations for multiple zone systems may also be used provided that they result in *outdoor air intake airflow* (V_{ot}) that is within 5% of the airflow value obtained using the *system ventilation efficiency* calculated using Equation A-3 or they more accurately represent a particular system configuration.

Design Process

The *system ventilation efficiency* and therefore the outdoor air intake for the system (V_{ot}) are determined as part of the design process based on the design and minimum supply flows to individual zones as well as the outdoor air requirements to the zones. In this process, the designer shall assume that the critical zone is at its minimum supply or discharge airflow in VAV systems. **Note**: The designer may increase the zone supply flows during the design process, particularly to the critical zones requiring the highest fraction of outdoor air, and thereby reduce the system outdoor air intake requirement determined in the calculation, sometimes dramatically.

Selecting Zones for Calculation

Since *system ventilation efficiency* E_v is determined by the minimum value of the *zone ventilation efficiency* ($E_{vz,}$) in accordance with Equation A-3, calculation of E_{vz} is required only for the *zone* with the minimum value of E_{vz} at ventilation design conditions. It is not required for any zone that clearly has an E_{vz} that is equal to or larger than that of the zone for which a calculation has been done. E_{vz} for a zone will have a larger (or equal) value if all of the following are true relative to the zone with minimum E_{vz}:

1. Floor area per occupant (A_z/P_z) is no lower
2. Minimum *zone discharge airflow* rate per unit area (V_{dz}/A_z) is no lower
3. Primary air fraction E_p is no lower
4. *Zone air distribution effectiveness* E_z is no lower
5. Area outdoor air rate R_a is no higher
6. People outdoor air rate R_p is no higher

If all of the above six parameters are the same for different spaces or areas, then those spaces or areas may be treated as a single zone for calculation of E_{vz}.

Example: In office buildings it is generally necessary to calculate E_{vz} for one typical interior zone. If overhead supply air is used to heat the perimeter, it is also necessary to calculate for the perimeter zone with the lowest supply airflow rate per unit area. No other calculations for E_{vz} are typically necessary, even if the building has 1,000 zones, provided the ventilation for any conference rooms is separately calculated.

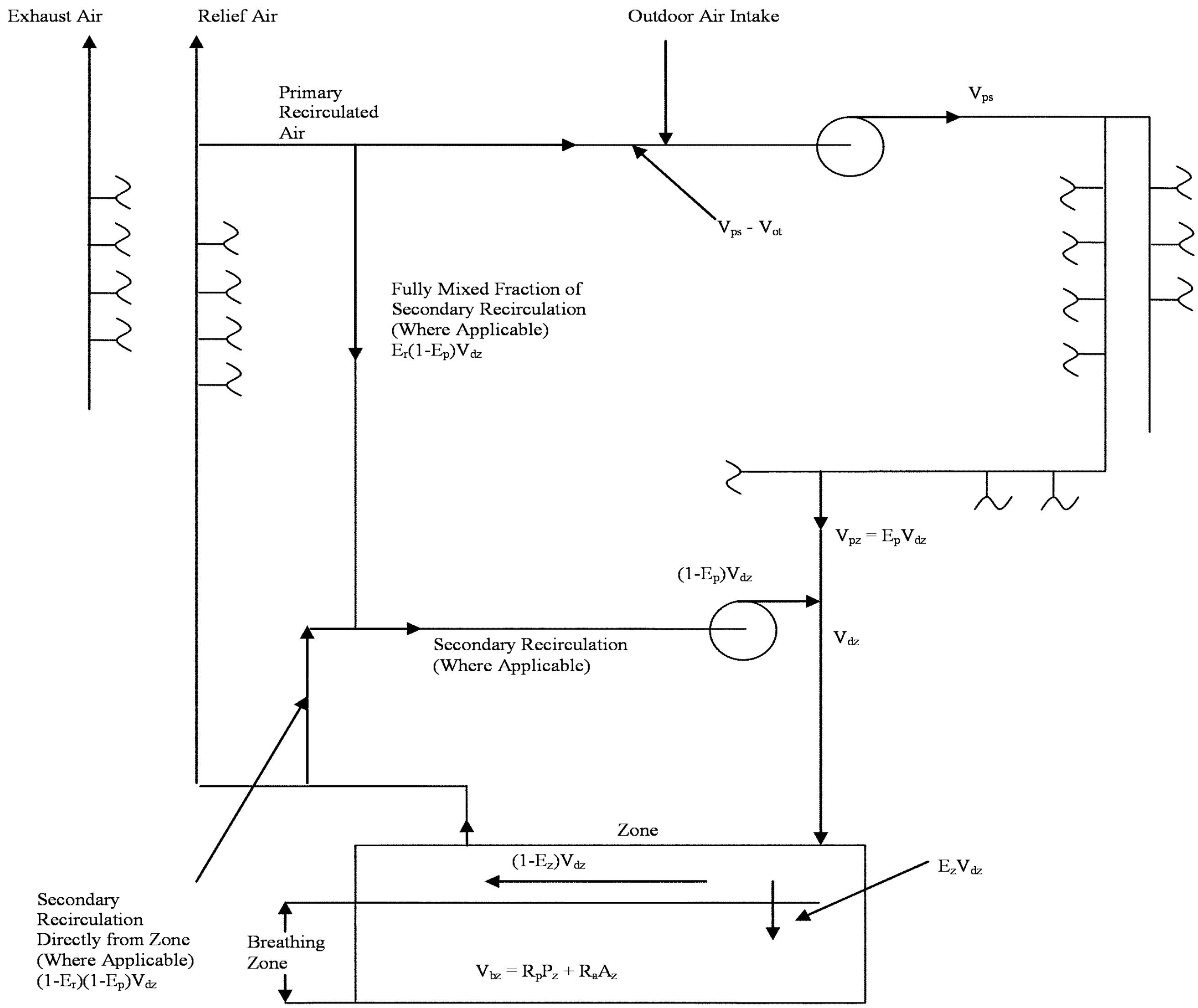

Figure A.1 Ventilation System Schematic

Definitions

A_z **Zone Floor Area:** the net occupiable floor area of the *zone* ft^2, (m^2).

D **Occupant Diversity:** the ratio of the *system population* to the sum of the *zone populations*: $D = P_s/\Sigma P_z$.

E_p Primary air fraction to the *zone*: $E_p = V_{pz}/V_{dz}$ (E_p = 1.0 for single-duct and single-*zone* systems).

E_r In systems with secondary recirculation of return air, fraction of secondary recirculated air to the zone that is representative of average system return air rather than air directly recirculated from the zone. **Note**: For plenum return systems with local secondary recirculation (e.g., fan-powered VAV with plenum return), $E_r \leq 1.0$. For ducted return systems with local secondary recirculation (e.g., fan-powered VAV with ducted return), typically $E_r = 0.0$.

E_v **System Ventilation Efficiency:** the efficiency with which the system distributes air from the outdoor air intake to the breathing zone in the ventilation-critical zone, which requires the largest fraction of outdoor air in the primary air stream. E_v is determined from Table 6-3 or Equation A-3.

E_{vz} **Zone Ventilation Efficiency:** the efficiency with which the system distributes air from the outdoor air intake to the breathing zone in a particular zone. E_{vz} is determined from Equations A-1 or A-2.

E_z **Zone Air Distribution Effectiveness (E_z):** a measure of how effectively the zone air distribution uses its supply air to maintain acceptable air quality in the *breathing zone*. E_z is determined from Table 6-2.

F_a Fraction of supply air to the *zone* from sources outside the *zone*: $F_a = E_p + (1 - E_p)*E_r$.

F_b Fraction of supply air to the *zone* from fully mixed primary air: $F_b = E_p$.

F_c Fraction of outdoor air to the *zone* from sources outside the *zone*: $F_c = 1 - (1 - E_z)*(1 - E_r)*(1 - E_p)$.

P_s **System Population**: the maximum simultaneous number of occupants in the area served by the system. Where population fluctuates, it may be averaged as described in Section 6.2.5.2.

P_z **Zone Population:** the largest number of people expected to occupy the zone during typical usage. If P_z is not known, it is determined from the default occupant densities listed in Table 6-1. Where population fluctuates, it may be averaged as described in Section 6.2.5.2.

R_a **Area Outdoor Air Rate**: the outdoor airflow rate per unit area to be provided in the breathing zone to dilute contaminants that are emitted at a rate that is related more to floor area than to population. The value of R_a for a zone is determined from Table 6-1.

R_p **People Outdoor Air Rate**: the outdoor airflow rate per person to be provided in the breathing zone to dilute contaminants that are emitted at a rate that is related more to population than to floor area. The value of R_p for a zone is determined from Table 6-1.

V_{bz} **Breathing Zone Outdoor Airflow:** the outdoor airflow required in the breathing zone of an occupiable space, $V_{bz} = R_pP_z + R_aA_z$.

V_{dz} **Zone Discharge Airflow:** The expected discharge (supply) airflow to the zone that includes primary airflow and locally recirculated airflow, cfm (L/s).

V_{ot} **Outdoor Air Intake Flow**: the design outdoor airflow required at the ventilation system outdoor air intake.

V_{ou} **Uncorrected Outdoor Air Intake**: The outdoor air intake flow required if the system ventilation efficiency E_v were 1.0. $V_{ou} = D*\Sigma R_p*P_z + \Sigma R_a*A_z$.

V_{oz} **Zone Outdoor Airflow:** the design outdoor airflow required in the zone, i.e., $V_{oz} = V_{bz}/E_z$.

V_{ps} **System Primary Airflow:** The total primary airflow supplied to all *zones* served by the system from the air-handling unit at which the outdoor air intake is located, $V_{ps} = \Sigma V_{pz}$, in cfm (L/s).

V_{pz} **Zone Primary Airflow:** The primary airflow supplied to the *zone* from the air-handling unit at which the outdoor air intake is located, L/s (cfm). It includes outdoor intake air and recirculated air from that air-handling unit but does not include air transferred or air recirculated to the zone by other means.

X_s **Average Outdoor Air Fraction**: At the primary air handler, the fraction of outdoor air intake flow in the system primary airflow, $X_s = V_{ou}/V_{ps}$.

Z_d **Discharge Outdoor Air Fraction:** The outdoor air fraction required in air discharged to the zone, $Z_d = V_{oz}/V_{dz}$. **Note:** For VAV systems, V_{dz} is the minimum expected discharge airflow for design purposes.

(This appendix is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and does not have ANSI approval.)

APPENDIX B
SUMMARY OF SELECTED AIR QUALITY GUIDELINES

If particular contaminants are of concern or if the Indoor Air Quality Procedure is to be used, acceptable indoor concentrations and exposures are needed for the particular contaminants. When using this procedure, these concentration and exposure values need to be documented and justified by reference to a cognizant authority as defined in the standard. Such guidelines or other limiting values can also be useful for diagnostic purposes. At present, no single organization develops acceptable concentrations or exposures for all indoor air contaminants, nor are values available for all contaminants of potential concern. A number of organizations offer guideline values for selected indoor air contaminants. These values have been developed primarily for ambient air, occupational settings, and, in some cases, for residential settings. They should be applied with an understanding of their basis and applicability to the indoor environment of concern. If an acceptable concentration or exposure has not been published for a contaminant of concern, a value may be derived through review of the toxicological and epidemiological evidence using appropriate consultation. However, the evidence with respect to health effects is likely to be insufficient for many contaminants. At present, there is no quantitative definition of acceptable indoor air quality that can necessarily be met by measuring one or more contaminants.

(This is a normative appendix and is part of the standard.)

APPENDIX E
VENTILATION RATES FOR HEALTH CARE FACILITIES, RESIDENTIAL BUILDINGS, AND VEHICLES

TABLE E-1*
Outdoor Air Requirements for Ventilation of Health Care Facilities (Hospitals, Nursing and Convalescent Homes)

Application	Estimated Maximum** Occupancy P/1000 ft^2 or 100 m^2	Outdoor Air Requirements cfm/person	L/s · person	cfm/ft^2	L/s · m^2	Comments
Patient rooms	10	25	13			Special requirements or codes and pressure relationships may determine minimum ventilation rates and filter efficiency. Procedures generating contaminants may require higher rates.
Medical procedure	20	15	8			
Operating rooms	20	30	15			
Recovery and ICU	20	15	8			
Autopsy rooms	20			0.50	2.50	Air shall not be recirculated into other spaces.
Physical therapy	20	15	8			

* Table E-1 prescribes supply rates of acceptable outdoor air required for acceptable indoor air quality. These values have been chosen to dilute human bioeffluents and other contaminants with an adequate margin of safety and to account for health variations among people and varied activity levels.

** Net occupiable space.

TABLE E-2 [a]
Outdoor Air Requirements for Ventilation of Residential Facilities (Private Dwellings, Single, Multiple)

Applications	Outdoor Requirements	Comments
Living areas	0.35 air changes per hour but not less than 15 cfm (7.5 L/s) per person	For calculating the air changes per hour, the volume of the living spaces shall include all areas within the conditioned space. The ventilation is normally satisfied by infiltration and natural ventilation. Dwellings with tight enclosures may require supplemental ventilation supply for fuel-burning appliances, including fireplaces and mechanically exhausted appliances. Occupant loading shall be based on the number of bedrooms as follows: first bedroom, two persons; each additional bedroom, one person. Where higher occupant loadings are known, they shall be used.
Kitchens [b]	100 cfm (50 L/s) intermittent or 25 cfm (12 L/s) continuous or openable windows	Installed mechanical exhaust capacity.[c] Climatic conditions may affect choice of the ventilation system.
Baths, Toilets [b]	50 cfm (25 L/s) intermittent or 20 cfm (10 L/s) continuous or openable windows	Installed mechanical exhaust capacity[c]
Garages: Separate for each dwelling unit	100 cfm (50 L/s) per car	Normally satisfied by infiltration or natural ventilation
Common for several units	1.5 cfm/ft^2 (7.5 L/s m^2)	See "Parking garages" in Table 6-4.

[a] In using this table, the outdoor air is assumed to be acceptable.

[b] Climatic conditions may affect choice of ventilation option chosen.

[c] The air exhausted from kitchens, bath, and toilet rooms may utilize air supplied through adjacent living areas to compensate for the air exhausted. The air supplied shall meet the requirements of exhaust systems as described in Section 5.8 and be of sufficient quantities to meet the requirements of this table.

TABLE E-3*
Outdoor Air Requirements for Ventilation of Vehicles

Application	Estimated Maximum** Occupancy P/1000 ft^2 or 100 m^2	Outdoor Air Requirements cfm/person	L/s · person	cfm/ft^2	L/s · m^2	Comments
Vehicles	150	15	8			Ventilation within vehicles may require special considerations.

* Table E-3 prescribes supply rates of acceptable outdoor air required for acceptable indoor air quality. These values have been chosen to dilute human bioeffluents and other contaminants with an adequate margin of safety and to account for health variations among people and varied activity levels.

** Net occupiable space.