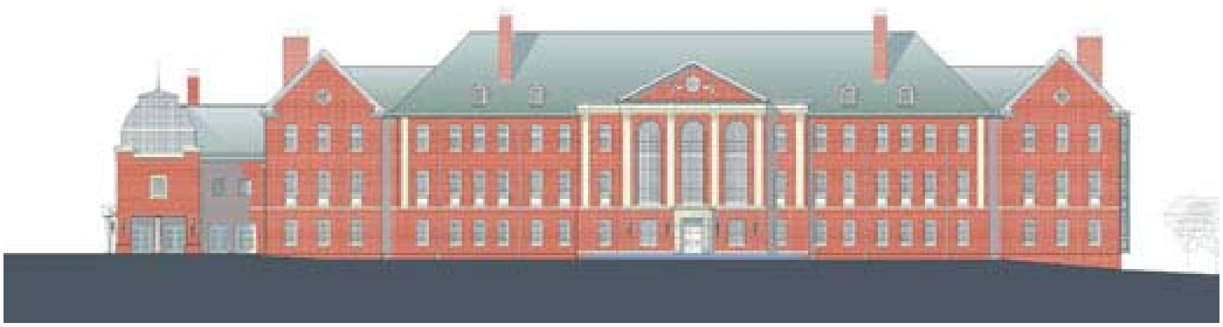
TECHNICAL REPORT 1

ASHRAE Standard 62.1-2007: Ventilation Compliance



Ann & Richard Barshinger Life Science & Philosophy Building

Franklin & Marshall College
Lancaster, PA

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Executive Summary

The Barshinger Life Science & Philosophy Building (LS&P) at Franklin & Marshall College (F&M) in Lancaster, PA has been evaluated for compliance with ASHRAE Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality. The evaluation procedure follows Chapter 6 in the standard and is based on floor area, room/space uses, occupancy, and ventilation system type.

This building is F&M's new laboratory, office, and classroom facility for the Biology, Psychology, and Philosophy departments and their associated education spaces. It is a 3-story building plus basement. This steel braced-frame structure encompasses 108,000 square feet.

The air distribution system for the main section of the building (floors 1-3) is a VAV system with hydronic reheat coils, fed by two air handlers on the roof (AHU-1 and AHU-2). These two units provide a great deal of outdoor air to the building to compensate for large amounts of exhaust air removed from the lab exhaust hoods. They serve a multitude of occupancy spaces, from faculty offices to anatomy/biology labs. These units are both sized at 50,000 cfm nominal.

The basement is home to the vivarium for animal housing and observation. This area is served by AHU-3, a 100% Outdoor Air unit located in the basement mechanical room. This unit provides 7,500-15,000 cfm of fresh conditioned air to the spaces 24/7 to keep the animals healthy.

Only AHU-3 is fully compliant with Standard 62.1-2007; the other two units do not provide enough outdoor air to fully and properly ventilate all the served spaces year round. AHU-1 can provide up to 50,000 cfm of outdoor air; 326,000 cfm is needed to properly ventilate the spaces. AHU-2 is not as far out of compliance, only needing to supply 77,800 cfm of outdoor air to meet the standard. Still, it can only provide 50,000 cfm total, so under-ventilation remains a problem for these two units.

Section 5 of the standard covers a plethora of issues regarding air quality and overall system design, and very few issues came up there. One issue was the proximity of a chemical storage area exhaust fan to the OA intake on AHU-1. The required distance between these two is 30 feet, and only 12 feet is provided. Other than this, no major problems exist in the application of section 5.

ASHRAE 62.1 Section 5 Compliance Study

5.1 – Natural Ventilation

None of the windows in the building are operable, save the greenhouse (3rd floor South), so the building has no natural ventilation, as intended by designers.

5.2 – Ventilation Distribution

Ventilation air (OA) is designed by 62.1, and analysis shows that these requirements are not fully met, although most spaces technically meet the requirements. Design intent to meet these requirements is shown, but VAV box selection does not allow for full ventilation air flow.

5.3 – Exhaust

The building has enormous exhaust air requirements from the numerous labs. All exhaust fans are located on the roof, and all exhaust ductwork is negatively pressurized, preventing any contamination of indoor air from leaking ductwork.

5.4 – Ventilation Controls

A fully-automated Building Controls System (Automated Logic) is provided to operate all equipment, and is tied to central plant and building controls. Overrides are also provided for testing and emergency situations (environmental threats, chemical spills, etc.). The system is designed to operate as 100% OA if required, and matches the undersized ventilation system design ventilation values.

5.5 – Airstream Surfaces

All ductwork is sheet metal with duct silencers; no duct lining is contained in the building. This prevents moisture entrainment and mold growth. Filter change schedules are specified once every 6-12 (max.) months, and are monitored by differential pressure gauges, alarms provided. Sheet metal surfaces are excepted from the flaking and erosion criteria, and as such, meet that requirement.

5.6 – Outdoor Air Intake

All three exhaust air handlers serving the building, located on the roof, may at some point contain air taken from laboratory fume hoods. This automatically gives a 30' minimum distance from those sources from which to take air into the building. The return fans are provided with relief dampers, and that air is driven out of the Air Handlers 11' from the OA intake louvers, and is separated by the exhaust and return ductwork, preventing the two airstreams from mixing. The only dangerous contaminator of the OA stream is an exhaust fan located on the roof dedicated to a chemical storage room on the 3rd floor North. It is merely 12' from the nearest point of the OA intake louver, with no separation or barrier. This presents a clear danger if there were ever to be a spill of chemicals in the storage room. Air handler 1 is not fully in compliance with section 5 of Standard 62.1; AHU-2 and AHU-3 are fully compliant with all minimum distances listed in Table 5-1.

All intake louvers are provided with sloped drains and settling areas for rain and snow. These areas are accessible by a 18"x60" door for cleaning and maintenance. Bird screens (1/4" wire screen) are provided at the inner edge of louver blades.

5.7 – Local Contaminant Capture

All local exhaust devices (hoods, mortuary tables, etc.) are directly ducted to the exterior through the main exhaust air units. Units in highly contaminated streams are provided with local filters to trap contaminants deemed dangerous by the F&M maintenance staff.

5.8 – Combustion Air

The only source of combustion exhaust in the building is the summer boiler located in the mechanical room on the roof. This exhaust stack is directed up through a chimney to 8' above the sloped architectural roof's peak. It is 42' from any the nearest air intake. A 4 square foot louver is provided for more-than-adequate ventilation during operation.

5.9 – Particulate Matter

All three AHUs are provided with filters rated as MERV-8 at the air intake to the AHU. There are no Return Air filters, but all air must pass through the cartridge filters before any conditioning occurs in the supply air stream.

5.10 – Dehumidification

The chilled water coils in each AHU provide all sensible and latent cooling for the building. RH requirements of this standard are limited to 65% maximum. Design standards required a maximum RH in the spaces of 60%, except the aquatics labs. These labs are provided with condensation-rated stainless steel environmental enclosures to prevent rust and bacterial growth. The design accounts for lower-than-required latent cooling, with controls maintaining positive building pressurization at all times throughout the year.

5.11 – Drains

All OA intakes, cooling coils, Air Handling Units, and AHU enclosures contain drains and/or pans for accumulated water. All surfaces have a minimum slope of 1/8" per foot, and drains have traps to prevent airflow through drain lines. The cooling coil pans (2 per AHU) are sized to prevent water spills to the AHU interior floor. Also specified are chemical tabs to prevent bacterial growth in these pans.

5.12 – Finned-Tube Coils and Heat Exchangers

All active sections in the built-up air handlers are separated by more than 24", 6" greater than required by Section 5.

5.13 – Humidification

Water is provided to the steam humidifiers from the domestic cold water supply after filtration through replaceable cartridge filters and water softeners. Ample absorption distance is provided before air exits the air handling units, and additional straight runs of duct are provided for safety.

5.14 – Equipment Access

All equipment requiring access for maintenance, inspection, and cleaning (except main ductwork) is located in the main AHUs. These active sections are separated by greater than 18" on each side (upstream and downstream) to allow for access. Main ductwork contains access doors on the downstream side of all fire dampers and other flow-control devices for maintenance and cleaning.

5.15 – Building Envelope / Interior Surfaces

The face brick facade allows some moisture penetration, but a weather barrier (30# building paper) and 1” airspace is provided behind this brick to prevent further moisture penetration. Drains and vents are provided at the bottom and top of each section of brick to allow accumulated moisture to escape. All expansion joints are caulked and filled with backer rod to fill gaps and prevent infiltration/exfiltration.

All domestic hot water lines require 1” minimum insulation for energy savings, and the same insulation was provided on all cold water lines to prevent condensation. All refrigerant suction lines (from environmental chambers throughout the building) are insulated to prevent condensation during operation. All ductwork is insulated both inside and outside the building envelope to control the air supply temperature, preventing condensation outside the ductwork simultaneously.

5.16 – Attached Parking Structures

Not Applicable – surface parking only at site.

5.17 – Air Classification and Recirculation

Return Air is Class 1; it is taken only from office, classroom, and lecture spaces not containing any chemical hazards, offensive odors, or biological agents. This is the only air possible to recirculate in the system. Almost all other air in the building is class 4 air, to be directly exhausted by the exhaust fans. The only process this air passes through is a simple runaround glycol energy recovery coil. The air is directly exhausted through this energy recovery device, never mixed or transferred to be recirculated in the building.

5.18 – Environmental Tobacco Smoke Management

The entire Franklin & Marshall campus has been designated a smoke-free campus. Smokers must travel off campus to smoke. All college facilities are ETS-free, and are marked as such. Signage is provided at each building entrance/exit, and in outdoor public gathering areas (such as the garden/patio south of the building). This eliminates all ETS-required ventilation for this building located in the central area of the F&M campus.

ASHRAE 62.1 Section 6 – Ventilation Calculations & Procedures

The ventilation rate procedure was used as a basis for calculations as specified in the report requirements for Tech Report 1, and was taken from Standard 62.1-2007 chapter 6 – Procedures. The VRP is a prescriptive procedure, and is designed to provide minimum outdoor ventilation air at all times. This was applied to the entire LS&P Building because of the nature of the systems. All supply ductwork is interconnected, making full building analysis necessary. The applications, formulas, and methods are covered in section 6.2 of Standard 62.1, and are outlined below.

Breathing Zone Outdoor Airflow (V_{bz}):

$V_{bz} = (R_p)(P_z) + (R_a)(A_z)$ (eq. 6-1)

where R_p = Outdoor Airflow rate per person (taken from Table 6-1)
P_z = Population of Zone (taken from design values in Table 6-1)
R_a = Outdoor Airflow rate per square foot (taken from Table 6-1)
A_z = Zone floor area, square feet

Zone Air Distribution Effectiveness (E_z):
All supply diffusers/grilles supply cool air from the ceiling to each zone. From table 6-2:

$E_z = 1.0$ for all zones (Table 6-2)

Zone Outdoor Airflow (V_{oz}):
$V_{oz} = V_{bz} / E_z = V_{bz}$ (eq. 6-2)

Zone Primary Outdoor Air Fraction (Z_p):
$Z_p = V_{oz} / V_{pz}$ (eq. 6-5)

where V_{pz} = Zone Primary Airflow (i.e. maximum airflow from AHU)

Uncorrected Outdoor Air Intake (V_{ou}):
$V_{ou} = (D)(\Sigma_{\text{all zones}}(R_p * P_z)) + (\Sigma_{\text{all zones}}(R_a * A_z))$ (eq. 6-6)

Outdoor Air Intake (V_{ot}):
$V_{ot} = V_{ou} / E_v$ (eq. 6-8)

where E_v = System Ventilation Efficiency (calculated using Appendix A)
such that E_v = minimum (E_{vz})
where E_{vz} = Zone Ventilation Efficiency (calculated using eq. A-1)
$E_{vz} = 1 + X_s – Z_d$ (eq. A-1)

where X_s = Average Outdoor Air Fraction = V_{ou} / V_{ps}
and Z_d = Discharge Outdoor Air Fraction = V_{oz} / V_{dz}
where V_{dz} = Zone Discharge Airflow = (VAV systems only) minimum expected primary airflow

For AHU-3 (100% Outdoor Air unit)

<u>*Outdoor Air Intake Flow*</u> (V_{ot}):

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

<u>Assumptions Used in Analysis</u>

Minimum Ventilation Rates in Breathing Zone

The minimum rates taken from Table 6-1 in Standard 62.1-2007 are based on space classifications. In some instances, these were assumed and taken as a closest-possible-match to the intended use of the space. Most often, the University Laboratories classification was used due to the nature of the labs. Assumptions were made as follows:

- Teaching Labs were considered Classrooms (9+) because of the teaching nature of these rooms. They are not used as chemically active or intensive laboratories.
- Student Lounges were treated as Classrooms (9+) because of the occupant densities shown on floor plans.
- Discussion Areas were considered as Office Spaces; all are ancillary spaces to faculty and staff offices.
- Corridors, Telecom closets, and Electrical closets, ventilated collectively, were treated with the most stringent of the standards as corridor areas.
- Restrooms, kitchen, and other "break-intended" spaces were considered Break Rooms

<u>Included Spaces</u>

All areas of the building were included except for elevator cars, elevator shafts, janitorial closets, fire escape stairwells, and entry/exit vestibules. These areas did not require supply of ventilation air, or only required exhausting, with requirements met across the board for exhaust in required spaces.

<u>Zone Population</u>

All populations were calculated based on the default occupant density values given in Table 6-1, usually being slightly higher than the intended population given on the floor plans.

<u>Supply, Return, and Exhaust Airflows</u>

Airflow rates were taken from the ductwork plans and VAV box schedules considering the maximum and minimum values given.

<u>Diversity</u>

The diversity for the entire building was considered as D=1.0. All classrooms may be occupied at once during any time in the day. There is no limit to total building occupancy to allow for application of population diversity.

Discussion / Conclusions

The table summarizing compliance of the main Air Handling Units is below. Neither of the two main AHUs comply with the 62.1-2007 Standard for two primary reasons. First, spaces served by those units do not individually meet ventilation criteria, and second, the remainder of spaces served by these two units, even excluding the individual under-ventilated spaces, do not meet the standard collectively because of the inefficiencies of ventilation throughout the system, and VAV box minimum flows set far below the minimum airflow required for ventilation for each space.

	Calculated OA	Minimum OA	Supply Minimum	Supply Maximum	62.1-2007 compliance
AHU-1	326,590	15,000	20,000	50,000	NO
AHU-2	77,880	15,000	20,000	50,000	NO
AHU-3	2,448	7,500	7,500	15,000	YES

AHU-3 (100% OA) is compliant. Since there is no re-circulated air, and ventilation rates are exceeded by a factor of nearly 3, even at minimum flow, the space is adequately ventilated.

One very odd thing about these calculations is that because of the poor performance of the ventilation air distribution system, the required outdoor air at the air handler is greater than the maximum supply airflow possible, especially for AHU-1. What is believed to have caused this is the design engineers assumed that minimum flow would always occur during periods when the building was not occupied. If this is the case, the minimum airflow is more than sufficient to ventilate the building. However, if this minimum flow condition (based purely on the T-stat for that zone) would occur during occupied times, the under-ventilation problem can swing wildly out of control, and many contaminant levels in the spaces can become quite high.

The Aquatics Suites on the 3rd floor and the Lecture Hall on the 1st floor are the critical and most offensive zones for both AHU-1 and AHU-2. Since these areas are greatly under-ventilated, they were excluded from further calculations, making the AHU-1 critical zone the Neuro Teaching Lab (rm. 245) and AHU-2 the Plant & Bio Teaching Lab (rm. 370, suite).

One opportunity that this issue presents is that it opens many options for solutions during later sections of the Thesis process. Demand-controlled ventilation, dedicated OA units, and possible re-sizing of the VAV boxes are all possibilities for problem solutions, and those will be discussed after further review in the Thesis Proposal.

Analysis

This section contains all charts for each Air Handling Unit and its ventilated spaces. AHU-1 and AHU-2 are both VAV units with supply and return fans, relief dampers at the return fan, and have the designed capacity to modulate to full outdoor air (100% OA) units if necessary, usually during periods of high exhaust. AHU-3 is a 100% OA unit serving the basement vivarium, and is operated 24/7 to ensure the proper environment for animal housing and observation.

Zones highlighted in pink do not meet 62.1 outright; their VAV box minimum flows are below the design OA values and zone ventilation efficiencies are below zero, and are excluded from further calculations. Grey highlights show the minimum (critical) zone ventilation efficiency. Yellow areas indicate an assumption of 10% leakage at the VAV box, as specified in the schedules as the maximum allowable leakage.

Appendices

Table 1 – AHU – 1 Summary & Calculations
Table 2 – AHU – 2 Summary & Calculations
Table 3 – AHU – 3 Summary & Calculations

References

ANSI/ASHRAE, 2007, Standard 62.1 – 2007, Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta, GA, 2007.

AHU-1

ROOM #	USE / NAME	Az	62.1 class	occ Density	Rp	Ra	Pz	Rp*Pz	Ra*Az	Vbz = Voz	Vpz	Zp	Vdz	Zd	Evz
302	micro/dev teaching lab	1070	Univ. Lab	25	10	0.18	27	268	193	460	1650	0.2788	725	0.6346	0.5739
308	digital imaging lab	575	Univ. Lab	25	10	0.18	14	144	104	247	900	0.2747	450	0.5494	0.6591
312	discussion/study alcove	100	Classroom (9+)	35	10	0.12	4	35	12	47	400	0.1175	200	0.2350	0.9735
311 suite	offices, student lounge	1000	Office Space	5	5	0.06	5	25	60	85	950	0.0895	475	0.1789	1.0296
328, 330, 322	Bio Labs, Write-up	1600	Univ. Lab	25	10	0.18	40	400	288	688	2660	0.2586	1060	0.6491	0.5595
306	media (glassware) prep	280	Univ. Lab	25	10	0.18	7	70	50	120	650	0.1852	250	0.4816	0.7269
304	Chemical Storage	200	Univ. Lab	25	10	0.18	5	50	36	86	300	0.2867	300	0.2867	0.9218
336	3rd floor restrooms	500	Break Room	25	5	0.06	13	63	30	93	700	0.1321	700	0.1321	1.0764
323, 325, 327	Bio Labs, Write-up	1600	Univ. Lab	25	10	0.18	40	400	288	688	2760	0.2493	1110	0.6198	0.5887
341	Bio/Chem Teaching Lab	1000	Classroom (9+)	35	10	0.12	35	350	120	470	1600	0.2938	425	1.1059	0.1026
3C-C	central 3rd fl. hall/stair	1100	corridors	0	0	0.06	0	0	66	66	1500	0.0440	750	0.0880	1.1205
3C-N, M324, M326	corridors, elec. Telecom	1325	corridors, elec. Telecom	0	0	0.06	0	0	80	80	800	0.0994	800	0.0994	1.1091
202	Intro Bio Teaching Lab	1200	Classroom (9+)	35	10	0.12	42	420	144	564	2000	0.2820	550	1.0255	0.1831
206	Instrument & Prep	750	Univ. Lab	25	10	0.18	19	188	135	323	550	0.5864	275	1.1727	0.0358
208	Intro Bio Teaching Lab	1150	Classroom (9+)	35	10	0.12	40	403	138	541	1800	0.3003	550	0.9827	0.2258
210	Anatomy Teaching Lab	1050	Univ. Lab	25	10	0.18	26	263	189	452	3510	0.1286	450	1.0033	0.2052
236	2nd floor restrooms	500	Break Room	25	5	0.06	13	63	30	93	700	0.1321	700	0.1321	1.0764
212	discussion/study alcove	100	Classroom (9+)	35	10	0.12	4	35	12	47	400	0.1175	200	0.2350	0.9735
211 suite	offices, student lounge	900	Office Space	5	5	0.06	5	23	54	77	900	0.0850	450	0.1700	1.0385
223, 225, 227	Bio Labs, Write-up	1900	Univ. Lab	25	10	0.18	48	475	342	817	2910	0.2808	1185	0.6895	0.5191
241	fresh aquatics suite	625	Univ. Lab	25	10	0.18	16	156	113	269	400	0.6719	200	1.3438	-0.1352
245	Neuro Teaching Lab	1150	Classroom (9+)	35	10	0.12	40	403	138	541	1500	0.3603	460	1.1750	0.0335
2C-C	central 2nd fl. hall/stair	1100	corridors	0	0	0.06	0	0	66	66	1500	0.0440	750	0.0880	1.1205
2C-N, M234, M236	corridors, elec. Telecom	1220	corridors, elec. Telecom	0	0	0.06	0	0	73	73	1200	0.0610	280	0.2614	0.9471
102 suite	Psych Dept Offices	2825	Office Space	5	5	0.06	14	71	170	240	2250	0.1067	1125	0.2134	0.9951
104	Large Seminar Room	675	Classroom (9+)	35	10	0.12	24	236	81	317	1000	0.3173	500	0.6345	0.5740
106	Psych Dept Lounge	600	Classroom (9+)	35	10	0.12	21	210	72	282	700	0.4029	350	0.8057	0.4028
112	discussion/study alcove	100	Classroom (9+)	35	10	0.12	4	35	12	47	400	0.1175	200	0.2350	0.9735
111 suite	offices, student lounge	1000	Office Space	5	5	0.06	5	25	60	85	950	0.0895	475	0.1789	1.0296
123	classroom - GP	725	Classroom (9+)	35	10	0.12	25	254	87	341	1000	0.3408	500	0.6815	0.5270
127 suite	Psychophysics Lab	975	Univ. Lab	25	10	0.18	24	244	176	419	1150	0.3646	600	0.6988	0.5098
145	Bio Dept. Offices	350	Office Space	5	5	0.06	2	9	21	30	350	0.0850	350	0.0850	1.1235
149	Lecture Hall	1175	Lecture-fixed	150	7.5	0.06	176	1322	71	1392	2000	0.6962	1000	1.3924	-0.1839
100	Atrium - N	1150	Main Entry Lobbies	10	5	0.06	12	58	69	127	1800	0.0703	900	0.1406	1.0680
1C-C	central 1st fl. Hall/stair	1200	corridors	0	0	0.06	0	0	72	72	1950	0.0369	975	0.0738	1.1347
1C-N, M134, M136	corridors, elec. Telecom	1000	corridors, elec. Telecom	0	0	0.06	0	0	60	60	800	0.0750	800	0.0750	1.1335
141	Advanced Statistics	375	Classroom (9+)	35	10	0.12	13	131	45	176	550	0.3205	275	0.6409	0.5676
M004, M011	main elec rm, fire rm	1150	electrical equip room	0	0	0.06	0	0	69	69	3200	0.0216	3200	0.0216	1.1870
21	field work suite	400	shipping/receiving	0	0	0.12	0	0	48	48	300	0.1600	300	0.1600	1.0485
27, 25	receiving/loading dock	620	shipping/receiving	0	0	0.12	0	0	74	74	575	0.1294	575	0.1294	1.0791
23	autoclave	300	Univ. Lab	25	10	0.18	8	75	54	129	275	0.4691	275	0.4691	0.7394
0C-N	corridors	775	corridors	0	0	0.06	0	0	47	47	1000	0.0465	500	0.0930	1.1155
								6899	4046	10945	52490				

Vou	10945
Vps=ΣVpz	52490
Xs=Vou/Vps	0.2085
Ev=min(Evz)	0.0335
Vot=Vou/Ev	326585

Table 1

AHU-2

ROOM #	USE / NAME	Az	62.1 class	occ Density	Rp	Ra	Pz	Rp*Pz	Ra*Az	Vbz = Voz	Vpz	Zp	Vdz	Zd	Evz
395	Animal Housing	180	Univ. Lab	25	10	0.18	5	45	32	77	500	0.1548	50	1.5480	-0.3120
380, 386, 376	Potting & Storage Area	832	Univ. Lab	25	10	0.18	21	208	150	358	1600	0.2236	800	0.4472	0.7888
371 suite	offices, student lounge	1070	Office Space	5	5	0.06	5	27	64	91	950	0.0957	575	0.1582	1.0779
374, 372, 3C-8, 3C-7	offices, corridors	580	Office Space	5	5	0.06	3	15	35	49	625	0.0789	325	0.1517	1.0843
370 suite	Plant Bio Teaching Lab	1200	Classroom (9+)	35	10	0.12	42	420	144	564	1625	0.3471	525	1.0743	0.1617
358, 360, 362	Bio Labs & Write-up	1700	Univ. Lab	25	10	0.18	43	425	306	731	2260	0.3235	1060	0.6896	0.5464
364	Biology Lounge	560	Classroom (9+)	35	10	0.12	20	196	67	263	700	0.3760	350	0.7520	0.4840
350	faculty office	150	Office Space	5	5	0.06	1	4	9	13	150	0.0850	75	0.1700	1.0660
357, 355, 353, 349	Bio Labs & Write-up	1800	Univ. Lab	25	10	0.18	45	450	324	774	2860	0.2706	1210	0.6397	0.5964
349, 341A	Cell/Molecular Bio Lab	1280	Univ. Lab	25	10	0.18	32	320	230	550	2175	0.2531	700	0.7863	0.4497
341B	Equipment Room	155	Univ. Lab	25	10	0.18	4	39	28	67	275	0.2424	150	0.4443	0.7917
3C-S, M352, M354	corridors, elec. Telecom	975	corridors, elec, telecom	0	0	0.06	0	0	59	59	800	0.0731	800	0.0731	1.1629
281	Bio Seminar Room	570	Classroom (9+)	35	10	0.12	20	200	68	268	900	0.2977	450	0.5953	0.6407
282	Classroom	960	Classroom (9+)	35	10	0.12	34	336	115	451	1400	0.3223	700	0.6446	0.5915
286	Seminar Room	570	Classroom (9+)	35	10	0.12	20	200	68	268	900	0.2977	450	0.5953	0.6407
284	Study / Discussion	250	Classroom (9+)	35	10	0.12	9	88	30	118	600	0.1958	600	0.1958	1.0402
270	Psych Lab and Observ	800	Univ. Lab	25	10	0.18	20	200	144	344	1350	0.2548	675	0.5096	0.7264
262 suite	Quant Psych Labs	850	Univ. Lab	25	10	0.18	21	213	153	366	1550	0.2358	525	0.6962	0.5398
258 suite	Intro Psych Teaching Lab	1350	Classroom (9+)	35	10	0.12	47	473	162	635	2100	0.3021	1050	0.6043	0.6317
266 suite	Breakout Session rooms	650	Classroom (9+)	35	10	0.12	23	228	78	306	800	0.3819	400	0.7638	0.4723
250	Bio Storage	150	Storage Rooms	0	0	0.12	0	0	18	18	150	0.1200	75	0.2400	0.9960
280	Loeb Gallery	850	Classroom (9+)	35	10	0.12	30	298	102	400	1200	0.3329	600	0.6658	0.5702
271 suite	offices, student lounge	1070	Office Space	5	5	0.06	5	27	64	91	1000	0.0910	500	0.1819	1.0541
257, 255, 253, 251	Bio Labs & Write-up	1800	Univ. Lab	25	10	0.18	45	450	324	774	3800	0.2037	1325	0.5842	0.6519
249	Salt Aquatics Suite	750	Univ. Lab	25	10	0.18	19	188	135	323	500	0.6450	250	1.2900	-0.0540
2C-S, M252, M254	corridors, elec. Telecom	1000	corridors, elec, telecom	0	0	0.06	0	0	60	60	1200	0.0500	1000	0.0600	1.1760
191	Humanities Common Rm	1200	Classroom (9+)	35	10	0.12	42	420	144	564	2150	0.2623	1075	0.5247	0.7114
172 suite	Faculty, Department Ofc.	2800	Office Space	5	5	0.06	14	70	168	238	2250	0.1058	1125	0.2116	1.0245
170	Phil Dept Lounge	480	Office Space	5	5	0.06	2	12	29	41	300	0.1360	150	0.2720	0.9640
164 suite	Office and support	775	Office Space	5	5	0.06	4	19	47	66	900	0.0732	490	0.1344	1.1016
166	Tech Office	100	Office Space	5	5	0.06	1	3	6	9	150	0.0567	75	0.1133	1.1227
162	Control Room	175	Office Space	5	5	0.06	1	4	11	15	200	0.0744	100	0.1488	1.0873
171 suite	interview/work offices	2300	Classroom (9+)	35	10	0.12	81	805	276	1081	2800	0.3861	1400	0.7721	0.4639
151 suite	testing area	850	Classroom (9+)	35	10	0.12	30	298	102	400	900	0.4439	450	0.8878	0.3482
150	Café support	150	Break Room	25	5	0.06	4	19	9	28	150	0.1850	75	0.3700	0.8660
149	Lecture Hall	1175	Lecture-fixed	150	7.5	0.06	176	1322	71	1392	2000	0.6962	1000	1.3924	-0.1563
141	Advanced Statistics	375	Classroom (9+)	35	10	0.12	13	131	45	176	550	0.3205	275	0.6409	0.5951
100	Atrium - S	1150	Main Entry Lobbies	10	5	0.06	12	58	69	127	1800	0.0703	900	0.1406	1.0955
1C-S, M152/154, caterer prep, storage	corridors, elec. Telecom	1900	corridors, elec, telecom	0	0	0.06	0	0	114	114	2800	0.0407	2800	0.0407	1.1953
M069	Bsmt Mech Room	1750	electrical equip rooms	0	0	0.06	0	0	105	105	1600	0.0656	1600	0.0656	1.1704
67	storage	330	Storage Rooms	0	0	0.12	0	0	40	40	150	0.2640	75	0.5280	0.7080
063, 061	M/W restrooms	600	Break Room	25	5	0.06	15	75	36	111	700	0.1586	350	0.3171	0.9189
0C-S	corridors	1120	Corridors	0	0	0.06	0	0	67	67	1000	0.0672	500	0.1344	1.1016
M056	elevator Mech room	80	elevator machine room	0	0	0.12	0	0	10	10	1000	0.0096	100	0.0960	1.1400
								8280	4317	12597	53370				

Vou	12597
Vps=ΣVpz	53370
Xs=Vou/Vps	0.2360
Ev=min(Evz)	0.1617
Vot=Vou/Ev	77882

Table 2

AHU-3

ROOM #	USE / NAME	Az	62.1 class	occ Density	Rp	Ra	Pz	Rp*Pz	Ra*Az	Vbz = Voz	Vpz	Zp
16	Animal Teaching Lab	700	Univ. Lab	25	10	0.18	18	175	126	301	1600	0.1881
14	Jan. Closet, Storage	115	Storage Rooms	0	0	0.12	0	0	14	14	175	0.0789
18	Cage Wash	475	Univ. Lab	25	10	0.18	12	119	86	204	1600	0.1277
28A, 28B	Animal Housing	190	Univ. Lab	25	10	0.18	5	48	34	82	450	0.1816
28C, 28D	Animal Housing	190	Univ. Lab	25	10	0.18	5	48	34	82	450	0.1816
28E, 28F	Animal Housing	190	Univ. Lab	25	10	0.18	5	48	34	82	450	0.1816
044A	Animal Housing	230	Univ. Lab	25	10	0.18	6	58	41	99	525	0.1884
44B	Animal Housing	250	Univ. Lab	25	10	0.18	6	63	45	108	600	0.1792
44C	Observation & Support	250	Univ. Lab	25	10	0.18	6	63	45	108	400	0.2688
44D	Animal Housing	310	Univ. Lab	25	10	0.18	8	78	56	133	700	0.1904
44E	Animal Housing	320	Univ. Lab	25	10	0.18	8	80	58	138	750	0.1835
54	Showers/Lockers	210	Univ. Lab	25	10	0.18	5	53	38	90	325	0.2778
50	Kitchen	100	Univ. Lab	25	10	0.18	3	25	18	43	175	0.2457
52	Medical/Procedure	190	Univ. Lab	25	10	0.18	5	48	34	82	450	0.1816
46 suite	Animal Housing	360	Univ. Lab	25	10	0.18	9	90	65	155	850	0.1821
36	Animal Housing	90	Univ. Lab	25	10	0.18	2	23	16	39	225	0.1720
34	Wrire-up	100	Office Space	5	5	0.06	1	3	6	9	150	0.0567
32C	Animal Housing	190	Univ. Lab	25	10	0.18	5	48	34	82	450	0.1816
32B	Animal Housing	190	Univ. Lab	25	10	0.18	5	48	34	82	450	0.1816
32A	Animal Housing	200	Univ. Lab	25	10	0.18	5	50	36	86	450	0.1911
30 suite	Animal Housing, halls	640	Univ. Lab	25	10	0.18	16	160	115	275	900	0.3058
24	Office	100	Office Space	5	5	0.06	1	3	6	9	175	0.0486
26	Feed/Bed Storage	110	Univ. Lab	25	10	0.18	3	28	20	47	225	0.2102
22	Quarantine	110	Univ. Lab	25	10	0.18	3	28	20	47	225	0.2102
0C-V	Vivarium Corridors	900	corridors	0	0	0.06	0	0	54	54	450	0.1200
								1379	1069	2448	13200	

$V_{ot}=\Sigma V_{oz}$	2448
$V_{ps}=\Sigma V_{pz}$	13200

Table 3