Gallaudet University
Sorenson Language and Communication Center

TECHNICAL REPORT I

ASHRAE STANDARD 62.1 VENTILATION COMPLIANCE

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Senior Thesis

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EXECUTIVE SUMMARY

ANSI/ASHRAE Standard 62.1-2004, *Ventilation for Acceptable Indoor Air Quality* sets forth minimum ventilation rates for typical spaces. Its goal is to provide acceptable indoor air quality for human occupants and "to minimize the potential for adverse health effects." The purpose of this report is to evaluate the Gallaudet University Sorenson Language and Communication Center (SLCC) in Washington, DC for its compliance with this standard.

The SLCC is an 83,000 SF education facility on the campus of Gallaudet University in the heart of Washington, DC. The building is served by six (6) Trane M-Series Climate Changer Air Handing Units. Each unit serves a distinct zone within the facility that is unique in use and occupation schedule. The spaces served include classrooms, offices, conference rooms, computer labs, media studios, therapy rooms, audiology labs, and typical support spaces. In total, the AHUs are designed to provide 72,875 CFM of conditioned air to 142 terminal VAV units. 21,360 CFM – or about 30% – of this supply is outdoor air.

The ventilation rate procedure explained in ASHRAE Std. 62.1 Section 6.2 was used to evaluate the HVAC design of the SLCC. This procedure is intended to reduce contaminants to acceptable levels based on space function, size and occupant density. Design calculations were based on a standard CFM/Person rate for typical spaces, while evaluation calculations included CFM/SF rates. Assumptions correlating the space function to those provided in Table 6-1 of ASHRAE Standard 62.1 were made with the specific program for each space unknown. Input numbers were derived from mechanical drawings, narratives, and calculations provided by the primary MEP engineers.

The calculations performed in this report show that the design for the SLCC does not meet ASHRAE Std. 62.1 requirements. Overall, the HVAC system provides 30.6% less outdoor air than is necessary. Five (5) of the six (6) AHUs do not meet minimum outdoor air requirements, while the sixth exceeds them by 24%. Much of this difference between design and calculations may be accounted for in the assumptions made, and their impact on the system ventilation efficiency.

All assumptions, procedures, calculations, analyses and conclusions regarding the design of the SLCC ventilation system may be found within this report.

ASSUMPTIONS

DESIGN OUTDOOR AIR RATES

Because of the unique functions of this one-of-a-kind facility, several assumptions were made relating design spaces to those included in Table 6-1, *Minimum Ventilation Rates in Breathing Zone*. These assumptions include:

- The atrium is equivalent to a "main entry lobby" of an office building.
- Media studio/control and video lab spaces are equivalent to "media centers" and "computer labs" in educational facilities.
- Therapy and observation spaces, as well as audio booths are equivalent to offices.
- Workrooms are equivalent to offices.
- While the functions within labs are not known, for safety those spaces are treated as science labs.
- Some calculated outdoor air intake values may be less than or equal to 10 CFM. While they may not realistically be provided to the space in practice, for the purpose of this report they are included in all calculations.
- In spaces where the calculated OA exceeds Design Minimum SA, a Z_p of 1.0 is assumed.
- All calculated total outdoor air intake rates are rounded up to the nearest multiple of 5 CFM.

DESIGN SUPPLY AIR RATES

Since thermal load calculations have not yet been performed as a part of this thesis, supply air rates from the design are used in calculations of the primary outdoor air fraction (Z_p).

DIVERSITY FACTOR

The diversity factor was assumed to be what was used in design calculations specific to each AHU.

OCCUPANCY

The design occupancy of each space was taken from the design calculations.

OUTDOOR AIR QUALITY

While the facility is located in a large metropolitan area (Washington, DC), air intake is removed from streets, parking lots, and exhaust. Also, on most days of the year the Air Quality Index (AQI) is below "unhealthy" levels. Also, it is assumed that filtration of outdoor air and mixed air is sufficient for proper Indoor Air Quality (IAQ) management.

INDOOR AIR QUALITY

Smoking is not allowed in the building. Toilet rooms, dryers, and rooms with large format copiers are exhausted.

SPACES NOT INCLUDED

Spaces not included in this evaluation include, but are not limited to mechanical spaces, closets, elevator shafts, and all stairs except feature stairs. Any other spaces not served by the AHUs are not included.

VARIABLES AND FORMULAS

VARIABLE NAME	VARIABLE	ASSOCIATED EQUATION(S)
Breathing Zone Outdoor Air Flow	V_{bz}	$V_{bz} = R_pP_z + R_aA_z$ (6-1)
People Outdoor Airflow Rate	R_p	Per Table 6-1
Area Outdoor Airflow Rate	R_a	Per Table 6-1
Zone Population	P_z	Per design
Zone Floor Area	A_z	Per design
Zone Air Distribution Effectiveness	E_z	Per Table 6-2
Zone Outdoor Airflow	V_{oz}	$V_{oz} = V_{bz} / E_z$ (6-2)
Primary Outdoor Air Fraction	Z_p	$Z_p = V_{oz} / V_{pz}$ (6-5)
Zone Primary Airflow	V_{pz}	Minimum SA in VAV system
Uncorrected Outdoor Air Intake	V_{ou}	$V_{ou} = D\Sigma_{allzones}R_pP_z + \Sigma_{allzones}R_aA_z$ (6-6)
Occupancy Diversity	D	$D = Pz / \Sigma_{allzones}P_z$ (6-7)
System Ventilation Efficiency	E_v	Per Table 6-3, or $E_v = 1 + X_s – Z_d$ (if $Z_p < 0.55$)
Average Outdoor Air Fraction	X_s	$X_s = V_{ou} / V_{ps}$ (Appendix A)
System Primary Airflow	V_{ps}	$V_{ps} = \Sigma V_{pz}$ (Appendix A)
Discharge Outdoor Air Fraction	Z_d	$Z_d = Z_p$ (for VAV)(Appendix A)
Outdoor Air Intake	V_{ot}	$V_{ot} = V_{ou} / E_v$ (6-8)

SAMPLE SINGLE ZONE CALCULATION

This calculation is for Research Laboratory 1230, served by AHU – 4.

STEP ONE

Determine breathing zone outdoor air flow (V_{bz}) for space:

$V_{bz} = R_pP_z + R_aA_z$ (6-1)

Where: R_p = 10 CFM/Person; R_a = 0.12 CFM/SF (Per Table 6-1)
P_z = 2 Persons; A_z = 166 SF (Per design)

V_{bz} = (10)(2) + (0.12)(166) = 49.9 CFM

STEP TWO

Determine zone air distribution effectiveness (E_z):

E_z = 1.0 (Ceiling supply of cool air) (Per Table 6-2)

STEP THREE

Determine zone outdoor airflow (V_{oz}):

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

V_{oz} = 49.9 / 1.0 = 49.9 CFM

STEP FOUR

Determine the primary outdoor air fraction (Z_p):

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

Z_p = 49.9 / 45 = 1.11 ⟶ 1.0 (Zp can not exceed 1.0)

SAMPLE CRITICAL ZONE CALCULATION

STEP ONE

Determine Uncorrected Outdoor Air Intake (V_{ou}):

$V_{ou} = D\Sigma_{allzones}R_pP_z + \Sigma_{allzones}R_aA_z$ (6-6)

$V_{ou} = (0.92)(1964) + (1523) =$ <u>3487 CFM</u>

STEP TWO

Determine E_v based on Z_p:

E_v must be derived from Appendix A because $Z_p > 0.55$ (Per Table 6-3)

$E_v = 1 + X_s – Z_d = 1 + (V_{ou} / \Sigma V_{pz}) – (Z_p)$

$E_v = 1 + (3487 / 7485) – 1.00 =$ <u>0.47</u>

STEP THREE

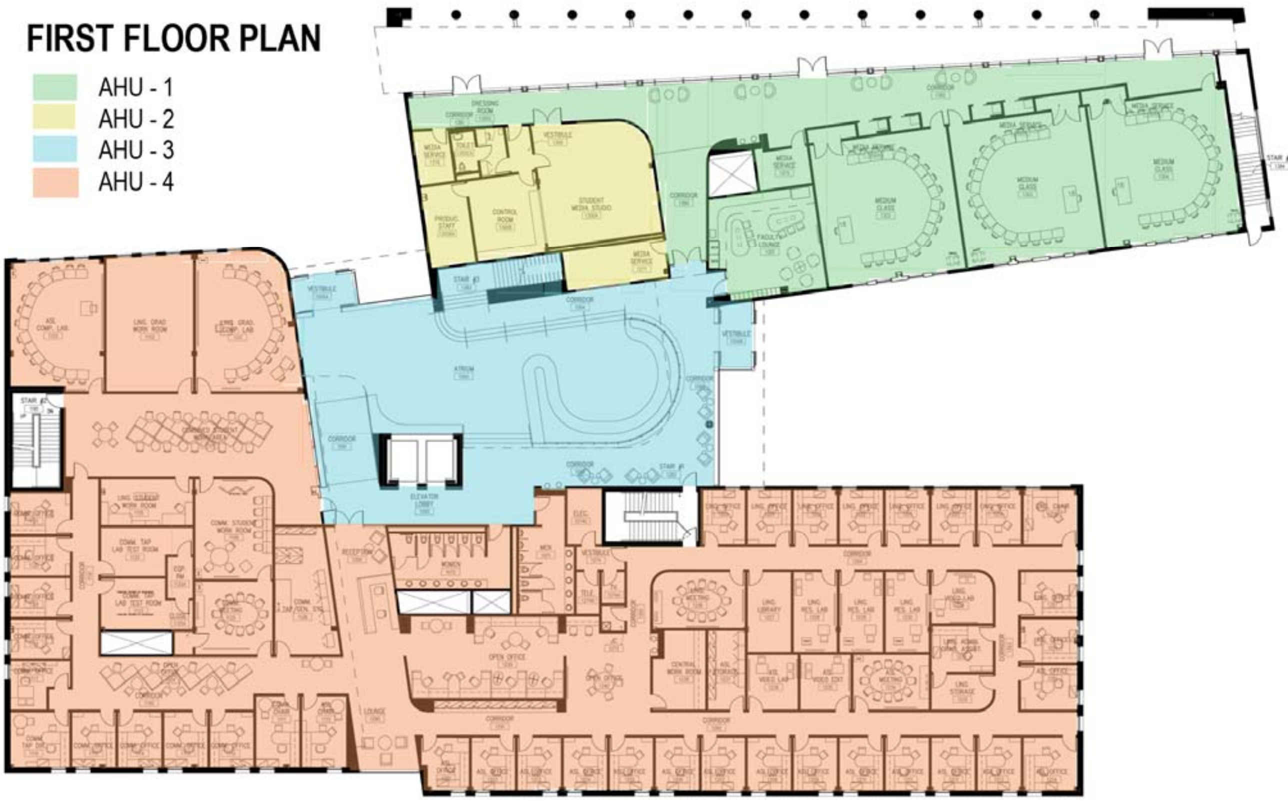
Determine total outdoor air intake (V_{ot}):

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

$V_{ot} = 3487 / 0.47 = 105.4 \longrightarrow$ <u>7485 CFM</u> (For the entire AHU-4 System)

Note that because Research Lab 1230 is the critical space, the minimum fraction of outdoor air must be delivered to this space at all times. As a result, other spaces served by AHU – 4 receive a proportional amount of outdoor air greater than that calculated with ASHRAE Std. 62.1.

BUILDING ZONES



BUILDING ZONES

BUILDING ZONES

RESULTS

These are the values used in the following calculations from ASHRAE Std. 62.1:

ASHRAE Std. 62.1-2004 Table 6-1					
	ROOM TYPE	R_p [CFM/PERSON]	R_a [CFM/SF]	CFM/UNIT	COMBINED (CFM/PERSON)
1	ATRIUM	5	0.06	-	11
2	CLASSROOM	7.5	0.06	-	8
3	CONFERENCE	5	0.06	-	6
4	COPY	0	0.50	-	0
5	CORRIDOR	0	0.06	-	0
6	LABS	10	0.18	-	17
7	LIBRARY	5	0.12	-	17
8	LOUNGE	5	0.06	-	11
9	COMP. LAB	10	0.12	-	15
10	OFFICE	5	0.06	-	17
11	RECEPTION	5	0.06	-	7
12	STORAGE	0	0.12	-	0
13	WC	70	0.00	70	0
14	JC	0	1.00		0

ASHRAE Std. 62.1-2004 Table 6-3	
Max Z_p	E_v
≤ 0.15	1
≤ 0.25	0.9
≤ 0.35	0.8
≤ 0.45	0.7
≤ 0.55	0.6
> 0.55	LOOK UP IN APPENDIX A

AHU-1:

Location: B200 E_v = 0.75

Design SA: 17400 D = 1.00

V_{ot} [CFM] = 3320 V_{ou} = 2500 CFM X_s = 0.19

CALCULATIONS									DESIGN		
Room No.	Room Type	Zone	Area A_z [SF]	P_z [#]	V_{bz} [CFM]	Rounded V_{oz} [CFM]	Unocc. Min OA $V_{bz,min}$ [CFM]	Z_p	$V_{ot, actual}$ [CFM]	MAX $V_{max, actual}$ [CFM]	MIN $V_{min, actual}$ [CFM]
B202	HOUSEKEEP	28	225	0	225.0	225	225	0.000	0	0	0
B290-292	CORRIDOR	28	979	0	58.7	60	60	0.29	100	260	210
B203	STORAGE	28	484	0	58.1	60	60	0.00	0	60	60
B274	TELECOM	28	141	0	16.9	20	20	0.20	0	100	100
1375	AV CLOSET	31	95	0	11.4	15	15	0.20	0	170	75
1302A	AV CLOSET	31	30	0	3.6	5	5	0.07	0	160	70
1303A	AV CLOSET	31	28	0	3.4	5	5	0.07	0	160	70
1304A	AV CLOSET	31	28	0	3.4	5	5	0.07	0	160	70
1304	CLASSROOM	44	916	20	205.0	205	55	0.52	300	890	395
1303	CLASSROOM	45	932	21	213.4	215	60	0.54	320	910	400
1302	CLASSROOM	46	932	21	213.4	215	60	0.54	320	910	400
1301	LOUNGE	4	504	18	120.2	125	35	0.19	360	650	650
1392	CORRIDOR	48A,B,C	1913	0	114.8	115	115	0.06	200	4090	1800
2300BA	AV CLOSET	69	55	0	6.6	10	10	0.14	0	160	70
2300AA	STORAGE	69	99	0	11.9	15	15	0.000	0	0	0
2375	AV CLOSET	85	95	0	11.4	15	15	0.20	0	170	75
2302A	AV CLOSET	85	38	0	4.6	5	5	0.07	0	160	70
2303A	AV CLOSET	85	28	0	3.4	5	5	0.07	0	160	70
2304A	AV CLOSET	85	28	0	3.4	5	5	0.07	0	160	70
2304	CLASSROOM	94	926	21	213.1	215	60	0.55	320	880	390
2303	CLASSROOM	95	934	21	213.5	215	60	0.54	320	900	400
2302	CLASSROOM	96	934	21	213.5	215	60	0.54	320	900	400
2301	CLASSROOM	97	508	11	113.0	115	35	0.50	170	520	230
2391	CORRIDOR	98A,B	1384	0	83.0	85	85	0.06	140	3160	1390
2300B	CONFERENCE	99	440	29	171.4	175	30	0.50	580	790	350
2300A	CONFERENCE	100	509	34	200.5	205	35	0.51	680	920	405
TOTALS:			13185	217		2550	1140		4130	17400	8220

AHU-2:

Location:	B200	E_v =	1.00			
Design SA:	2230	D =	1.00			
V_{ot} [CFM] =	**470**	V_{ou} =	470	CFM	X_s =	0.21

CALCULATIONS									DESIGN		
Room No.	**Room Type**	**Zone**	**Area A_z [SF]**	**P_z [#]**	**V_{bz} [CFM]**	**Rounded V_{oz} [CFM]**	**Unocc. Min OA $V_{bz,min}$ [CFM]**	**Z_p**	**$V_{ot, actual}$ [CFM]**	**MAX $V_{max,}$ actual [CFM]**	**MIN $V_{min,}$ actual [CFM]**
1300A	MEDIA STUDIO	49	636	13	206.3	210	80	0.16	200	1330	1330
1300B	MEDIA CONTRI	50	265	5	81.8	85	35	0.15	100	550	550
1376	AV CLOSET	51	82	0	9.8	10	10	0.06	0	160	160
1300BA	OFFICE	51	173	3	25.4	30	15	0.16	60	190	190
1300C	WC	51	62	1	70.0	70	0	0.00	0	0	0
1300	CORRIDOR	-	50	0	3.0	5	5	0.00	0	0	0
1300CA	WC	-	43	1	70.0	70	0	0.00	0	0	0
TOTALS:			1311	23		480	145		360	2230	2230

AHU-3:

Location:	B200	E_v =	0.33			
Design SA:	13070	D =	0.91			
V_{ot} [CFM] =	**3550**	V_{ou} =	1175	CFM	X_s =	0.27

CALCULATIONS									DESIGN		
Room No.	**Room Type**	**Zone**	**Area A_z [SF]**	**P_z [#]**	**V_{bz} [CFM]**	**Rounded V_{oz} [CFM]**	**Unocc. Min OA $V_{bz,min}$ [CFM]**	**Z_p**	**$V_{ot, actual}$ [CFM]**	**MAX $V_{max,}$ actual [CFM]**	**MIN $V_{min,}$ actual [CFM]**
1000	ATRIUM	-	4271	85	681.3	685	260	0.07	1280	9460	9460
2390	CORRIDOR	-	1018	0	61.1	65	65	0.07	110	920	920
2090	CORRIDOR	-	791	0	47.5	50	50	0.24	80	210	210
2091	LOUNGE	-	191	11	66.5	70	15	0.30	220	230	230
2092	LOUNGE	-	240	14	84.4	85	15	0.11	280	800	800
2390	LOUNGE	-	318	19	114.1	115	20	0.22	380	520	520
3090	CORRIDOR	-	784	0	47.0	50	50	0.24	80	210	210
3091	LOUNGE	-	113	7	41.8	45	10	0.32	140	140	140
3092	LOUNGE	-	264	16	95.8	100	20	0.17	320	580	580
TOTALS:			7990	152		1265	505		2890	13070	13070

AHU-4:

Location: B200
Design SA: 14080
V_{ot} [CFM] = 7485

E_v = 0.47
D = 0.92
V_{ou} = 3490 CFM

X_s = 0.53

CALCULATIONS									DESIGN		
Room No.	Room Type	Zone	Area A_z [SF]	P_z [#]	V_{bz} [CFM]	Rounded V_{oz} [CFM]	Unocc. Min OA $V_{bz,min}$ [CFM]	Z_p	$V_{ot, actual}$ [CFM]	MAX $V_{max, actual}$ [CFM]	MIN $V_{min, actual}$ [CFM]
1121	OFFICE	1	118	2	17.1	20	10	0.24	40	120	85
1120	OFFICE	1	111	2	16.7	20	10	0.24	40	120	85
1119	OFFICE	1	111	2	16.7	20	10	0.24	40	120	85
1118	OFFICE	2	110	2	16.6	20	10	0.24	40	120	85
1117	OFFICE	2	113	2	16.8	20	10	0.24	40	120	85
1116	OFFICE	3	154	4	29.2	30	10	0.18	80	180	170
1115	OFFICE	4	113	2	16.8	20	10	0.24	40	130	85
1114	OFFICE	4	114	2	16.8	20	10	0.24	40	130	85
1113	OFFICE	5	114	2	16.8	20	10	0.24	40	130	85
1112	OFFICE	5	114	2	16.8	20	10	0.24	40	130	85
1111	OFFICE	6	146	2	18.8	20	10	0.24	40	150	85
1110	OFFICE	7	150	3	24.0	25	10	0.20	60	150	125
1200	RECEPTION	8	478	4	48.7	50	30	0.91	60	160	55
1290	LOUNGE	8	218	3	28.1	30	15	0.12	60	760	255
1201	OFFICE	9	112	2	16.7	20	10	0.24	40	130	85
1202	OFFICE	10	109	2	16.5	20	10	0.24	40	130	85
1203	OFFICE	10	109	2	16.5	20	10	0.24	40	130	85
1204	OFFICE	10	109	2	16.5	20	10	0.24	40	130	85
1205	OFFICE	11	109	2	16.5	20	10	0.24	40	130	85
1206	OFFICE	11	109	2	16.5	20	10	0.24	40	130	85
1207	OFFICE	11	109	2	16.5	20	10	0.24	40	130	85
1208	OFFICE	12	109	2	16.5	20	10	0.24	40	130	85
1209	OFFICE	12	109	2	16.5	20	10	0.24	40	130	85
1210	OFFICE	12	109	2	16.5	20	10	0.24	40	130	85
1211	OFFICE	13	109	2	16.5	20	10	0.24	40	130	85
1212	OFFICE	13	109	2	16.5	20	10	0.24	40	130	85
1213	OFFICE	13	109	2	16.5	20	10	0.24	40	130	85
1214	OFFICE	14	135	2	18.1	20	10	0.24	40	140	85
1215	OFFICE	15	121	2	17.3	20	10	0.24	40	100	85
1216	OFFICE	15	116	2	17.0	20	10	0.24	40	130	85
1217	OFFICE	15	121	2	17.3	20	10	0.24	40	110	85
1293	CORRIDOR	15	333	0	20.0	20	20	0.24	40	160	85
1218	OFFICE	16	139	2	18.3	20	10	0.24	40	180	85
1219	OFFICE	17	113	2	16.8	20	10	0.24	40	150	85
1220	OFFICE	17	113	2	16.8	20	10	0.24	40	150	85
1221	OFFICE	17	113	2	16.8	20	10	0.24	40	150	85
1222	OFFICE	18	113	2	16.8	20	10	0.24	40	150	85
1223	OFFICE	18	113	2	16.8	20	10	0.24	40	150	85
1224	OFFICE	19	113	2	16.8	20	10	0.24	40	130	85
1225	OFFICE	19	110	2	16.6	20	10	0.24	40	90	85
1101	COMP LAB	20	635	19	266.2	270	80	0.34	380	900	795

AHU-4: Continued

Location: B200 E_v = 0.47

Design SA: 14080 D = 0.92

V_{ot} [CFM] = 7485 V_{ou} = 3490 CFM X_s = 0.53

CALCULATIONS									DESIGN		
Room No.	Room Type	Zone	Area A_z [SF]	P_z [#]	V_{bz} [CFM]	Rounded V_{oz} [CFM]	Unocc. Min OA $V_{bz,min}$ [CFM]	Z_p	$V_{ot, actual}$ [CFM]	MAX $V_{max, actual}$ [CFM]	MIN $V_{min, actual}$ [CFM]
1102	WORKROOM	21	556	8	73.4	75	35	0.22	160	820	335
1103	COMP LAB	22	559	17	237.1	240	70	0.34	340	1050	715
1126	STORAGE	23	344	0	41.3	45	45	2.25	0	60	20
1104	WORKROOM	23	1034	14	132.0	135	65	0.47	280	880	290
1105	WORKROOM	24	200	4	32.0	35	15	0.39	80	200	90
1106	WORKROOM	25	367	5	47.0	50	25	0.33	100	370	150
1125	CONFERENCE	26	252	8	55.1	60	20	0.71	160	250	85
1191	CORRIDOR	27	215	0	12.9	15	15	0.60	30	60	25
1124	OFFICE	27	632	10	87.9	90	40	0.72	200	330	125
1240	OFFICE	29	630	10	87.8	90	40	0.82	200	330	110
1292	CORRIDOR	30	1205	0	72.3	75	75	0.68	130	320	110
1239	OFFICE	30	254	5	40.2	45	20	0.90	100	150	50
1226	CONFERENCE	32	243	8	54.6	55	15	0.65	160	250	85
1227	LIBRARY	33	166	3	34.9	35	20	0.64	50	160	55
1228	RESEARCH LAB	34	166	2	49.9	50	30	1.00	40	120	45
1229	RESEARCH LAB	35	166	2	49.9	50	30	1.00	40	120	45
1230	RESEARCH LAB	36	166	2	49.9	50	30	1.00	40	120	45
1231	VIDEO LAB	37	148	3	148.0	150	150	1.00	60	120	45
1232	OFFICE	38	134	2	18.0	20	10	0.24	40	160	85
1234	CONFERENCE	39	198	8	51.9	55	15	0.65	160	250	85
1235	VIDEO LAB	40	132	3	132.0	135	135	1.00	60	110	45
1236	VIDEO LAB	41	132	3	132.0	135	135	1.00	60	110	45
1237	STORAGE	42	140	0	16.8	20	20	0.80	0	60	25
1238	WORKROOM	42	172	2	20.3	25	15	0.38	40	170	65
1122	TAP LAB	43	185	1	43.3	45	35	0.56	20	240	80
1123	TAP LAB	52	193	1	44.7	45	35	0.56	20	240	80
1122A	STORAGE	53	50	0	6.0	10	10	0.22	0	70	45
1233	STORAGE	54	102	0	12.2	15	15	0.33	0	60	45
1273	JC	-	28	1	28.0	30	30	0.00	0	0	0
1072	WC	-	312	6	420.0	420	0	0.00	0	0	0
1071	WC	-	232	6	420.0	420	0	0.00	0	0	0
TOTALS:			15285	237		3845	1710		4650	14080	7485

AHU-5:

Location: B200 E_{vz} = 0.45
Total CFM: 11965 D = 0.90
V_{ot} [CFM] = 6785 V_{ou} = 3025 CFM X_s = 0.57

CALCULATIONS									DESIGN		
Room No.	Room Type	Zone	Area A_z [SF]	P_z [#]	V_{bz} [CFM]	Rounded V_{oz} [CFM]	Unocc. Min OA $V_{bz,min}$ [CFM]	Z_p	$V_{ot, actual}$ [CFM]	MAX $V_{max, actual}$ [CFM]	MIN $V_{min, actual}$ [CFM]
2113	OBSERVATION	55	92	2	15.5	20	10	0.25	40	110	80
2112	THERAPY	55	92	2	15.5	20	10	0.33	30	90	60
2115	THERAPY	55	92	2	15.5	20	10	0.33	30	90	60
2118	OBSERVATION	56	92	2	15.5	20	10	0.25	40	110	80
2117	THERAPY	56	92	2	15.5	20	10	0.33	30	90	60
2119	THERAPY	56	92	2	15.5	20	10	0.33	30	90	60
2120	OFFICE	57	168	3	25.1	30	15	0.24	60	250	125
2121	THERAPY	58	395	4	43.7	45	25	0.36	60	220	125
2123A	THERAPY	59	184	2	21.0	25	15	0.42	30	160	60
2123D	THERAPY	59	236	3	29.2	30	15	0.29	50	130	105
2201	RECEPTION	60	346	10	70.8	75	25	0.25	150	800	305
2202	RECEPTION	61	492	16	109.5	110	30	0.28	240	390	390
2203	THERAPY	62	86	2	15.2	20	10	0.25	40	90	80
2204	WORKROOM	62	86	2	15.2	20	10	0.25	40	90	80
2205	WORKROOM	62	114	1	11.8	15	10	0.38	20	80	40
2206	CONFERENCE	63	145	5	33.7	35	10	0.17	100	220	205
2207	LAB	64	109	3	49.6	50	20	0.45	60	110	110
2208	LAB	64	109	3	49.6	50	20	0.45	60	110	110
2209	OFFICE	65	109	2	16.5	20	10	0.25	40	130	80
2210	OFFICE	65	109	2	16.5	20	10	0.25	40	130	80
2211	OFFICE	65	109	2	16.5	20	10	0.25	40	130	80
2212	OFFICE	66	109	2	16.5	20	10	0.25	40	130	80
2213	OFFICE	66	109	2	16.5	20	10	0.25	40	130	80
2214	OFFICE	66	109	2	16.5	20	10	0.25	40	130	80
2215	OFFICE	67	109	2	16.5	20	10	0.25	40	130	80
2216	OFFICE	67	109	2	16.5	20	10	0.25	40	130	80
2217	OFFICE	68	135	2	18.1	20	10	0.25	40	130	80
2293	CORRIDOR	68	226	0	13.6	15	15	0.19	30	140	80
2218	OFFICE	70	140	2	18.4	20	10	0.25	40	270	80
2219	OFFICE	71	114	2	16.8	20	10	0.25	40	160	80
2220	OFFICE	71	114	2	16.8	20	10	0.25	40	140	80
2221	OFFICE	71	114	2	16.8	20	10	0.25	40	140	80
2222	OFFICE	72	114	2	16.8	20	10	0.25	40	140	80
2223	OFFICE	72	114	2	16.8	20	10	0.25	40	140	80
2224	OFFICE	73	114	2	16.8	20	10	0.25	40	120	80
2225	OFFICE	73	109	2	16.5	20	10	0.25	40	90	80
2104	CONFERENCE	74	449	20	126.9	130	30	0.59	400	660	220
2106	THERAPY	75	336	4	40.2	45	25	0.36	60	340	125
2107	OBSERVATION	76	114	3	21.8	25	10	0.20	60	170	125
2108A	STORAGE	76	23	0	2.8	5	5	1.00	0	10	5
2106D	STORAGE	76	23	0	2.8	5	5	1.00	0	10	5

AHU-5: Continued

Location: B200 | E_{vz} = 0.45
Total CFM: 11965 | D = 0.90
V_{ot} [CFM] = 6785 | V_{ou} = 3025 CFM | X_s = 0.57

CALCULATIONS									DESIGN		
Room No.	Room Type	Zone	Area A_z [SF]	P_z [#]	V_{bz} [CFM]	Rounded V_{oz} [CFM]	Unocc. Min OA $V_{bz,min}$ [CFM]	Z_p	$V_{ot, actual}$ [CFM]	MAX $V_{max, actual}$ [CFM]	MIN $V_{min, actual}$ [CFM]
2108	THERAPY	77	238	14	84.3	85	15	0.59	210	440	145
2191	CORRIDOR	78	925	0	55.5	60	60	0.48	100	330	125
2105	STORAGE	78	217	0	26.0	30	30	1.20	0	60	25
2110	OBSERVATION	79	117	3	22.0	25	10	0.36	60	140	70
2109	THERAPY	79	155	2	19.3	20	10	0.57	30	70	35
2111	THERAPY	79	154	2	19.2	20	10	0.57	30	70	35
2114	OBSERVATION	80	104	3	21.2	25	10	0.42	60	120	60
2116	THERAPY	80	155	2	19.3	20	10	0.57	30	70	35
2123	CORRIDOR	81	188	0	11.3	15	15	0.60	20	50	25
2192	CORRIDOR	81	552	0	33.1	35	35	0.47	60	150	75
2122	OBSERVATION	81	75	2	14.5	15	5	0.33	40	90	45
2123C	OBSERVATION	81	73	2	14.4	15	5	0.33	40	90	45
2124	WORKROOM	82	535	8	72.1	75	35	0.83	160	265	90
2125	RECEPTION	83	209	2	22.5	25	15	0.63	30	80	40
2200	RECEPTION	83	480	10	78.8	80	30	0.73	150	220	110
2102	OBSERVATION	84	90	2	15.4	20	10	0.36	40	110	55
2103	THERAPY	8	92	2	15.5	20	10	0.57	30	70	35
2101	THERAPY	84	92	2	15.5	20	10	0.57	30	70	35
2226	AUDIO BOOTH	86	92	1	10.5	15	10	0.60	20	50	25
2226A	OBSERVATION	86	83	2	15.0	15	5	0.30	40	100	50
2227	AUDIO BOOTH	87	92	1	10.5	15	10	0.60	20	50	25
2227A	OBSERVATION	87	83	2	15.0	15	5	0.30	40	100	50
2228	AUDIO BOOTH	88	92	1	10.5	15	10	0.60	20	50	25
2228A	OBSERVATION	88	83	2	15.0	15	5	0.30	40	100	50
2229	AUDIO BOOTH	89	92	1	10.5	15	10	0.60	20	50	25
2229A	OBSERVATION	8	83	2	15.0	15	5	0.30	40	100	50
2233	WORKROOM	90	696	14	111.8	115	45	0.20	280	730	565
2295	CORRIDOR	90	1641	0	98.5	100	100	0.29	170	430	345
2232	COMP LAB	91	438	15	202.6	205	55	1.00	300	520	172
2231	STORAGE	92	143	0	17.2	20	20	0.33	0	60	60
2230	LAB	93	193	5	84.7	85	35	0.43	100	200	200
2273	JC	-	28	1	28.0	30	30	0.00	0	0	0
2106B	WC	-	50	1	70.0	70	0	0.00	0	0	0
2123B	WC	-	44	1	70.0	70	0	0.00	0	0	0
2072	WC	-	312	6	420.0	420	0	0.00	0	0	0
2071	WC	-	232	6	420.0	420	0	0.00	0	0	0
TOTALS:			15061	244		3450	1195		4550	11965	6782

AHU-6:

Location: B200 E_v = 0.35

Total CFM: 14130 D = 0.91

V_{ot} [CFM] = 9550 V_{ou} = 3315 CFM X_s = 0.68

CALCULATIONS									DESIGN		
Room No.	Room Type	Zone	Area A_z [SF]	P_z [#]	V_{bz} [CFM]	Rounded V_{oz} [CFM]	Unocc. Min OA $V_{bz,min}$ [CFM]	Z_p	$V_{ot, actual}$ [CFM]	MAX $V_{max,}$ actual [CFM]	MIN $V_{min,}$ actual [CFM]
3120	OFFICE	101	109	2	16.5	20	10	0.24	40	150	85
3119	OFFICE	101	109	2	16.5	20	10	0.24	40	150	85
3118	OFFICE	102	109	2	16.5	20	10	0.24	40	150	85
3117	OFFICE	102	132	2	17.9	20	10	0.24	40	180	85
3116	OFFICE	103	112	2	16.7	20	10	0.24	40	220	85
3115	OFFICE	104	109	2	16.5	20	10	0.24	40	130	85
3114	OFFICE	104	109	2	16.5	20	10	0.24	40	130	85
3113	OFFICE	104	109	2	16.5	20	10	0.24	40	130	85
3112	OFFICE	105	109	2	16.5	20	10	0.24	40	130	85
3111	OFFICE	105	109	2	16.5	20	10	0.24	40	130	85
3110	OFFICE	106	160	3	24.6	25	10	0.29	60	150	85
3290	LOUNGE	107	166	4	30.0	30	10	0.24	80	730	125
3200	RECEPTION	107	530	4	51.8	55	35	0.18	60	190	305
3201	OFFICE	108	153	3	24.2	25	10	0.20	60	150	125
3202	OFFICE	109	152	3	24.1	25	10	0.20	60	150	125
3203	OFFICE	110	147	3	23.8	25	10	0.20	60	150	125
3204	OFFICE	111	109	2	16.5	20	10	0.24	40	130	85
3205	OFFICE	111	109	2	16.5	20	10	0.24	40	130	85
3206	OFFICE	111	109	2	16.5	20	10	0.24	40	130	85
3207	OFFICE	112	109	2	16.5	20	10	0.24	40	130	85
3208	OFFICE	112	109	2	16.5	20	10	0.24	40	130	85
3209	OFFICE	112	109	2	16.5	20	10	0.24	40	130	85
3210	OFFICE	113	224	4	33.4	35	15	0.21	80	250	165
3211	OFFICE	114	109	2	16.5	20	10	0.24	40	130	85
3212	OFFICE	114	109	2	16.5	20	10	0.24	40	130	85
3213	OFFICE	115	135	2	18.1	20	10	0.24	40	140	85
3293	CORRIDOR	116	272	0	16.3	20	20	0.13	30	280	160
3214	WORKROOM	116	186	5	36.2	40	15	0.32	100	190	125
3215	OFFICE	117	135	2	18.1	20	10	0.24	40	190	85
3216	OFFICE	118	118	2	17.1	20	10	0.24	40	150	85
3217	OFFICE	118	113	2	16.8	20	10	0.24	40	140	85
3218	OFFICE	118	113	2	16.8	20	10	0.24	40	140	85
3219	OFFICE	119	113	2	16.8	20	10	0.24	40	140	85
3220	OFFICE	119	113	2	16.8	20	10	0.24	40	140	85
3221	OFFICE	120	113	2	16.8	20	10	0.24	40	120	85
3222	OFFICE	120	108	2	16.5	20	10	0.24	40	90	85
3102	WORKROOM	121	1787	45	332.2	335	110	0.18	900	2240	1855
3103	COMP LAB	122	562	17	237.4	240	70	0.71	340	1020	340
3121	LAB	123	302	9	144.4	145	55	1.00	180	290	100
3122B	LAB	124	92	1	26.6	30	20	0.86	20	70	35
3122C	LAB	124	86	1	25.5	30	20	0.86	20	70	35

AHU-6: Continued

Location: B200 E_v = 0.35

Total CFM: 14130 D = 0.91

V_{ot} [CFM] = 9550 V_{ou} = 3315 CFM X_s = 0.68

CALCULATIONS									DESIGN		
Room No.	Room Type	Zone	Area A_z [SF]	P_z [#]	V_{bz} [CFM]	Rounded V_{oz} [CFM]	Unocc. Min OA $V_{bz,min}$ [CFM]	Z_p	$V_{ot, actual}$ [CFM]	MAX $V_{max,}$ actual [CFM]	MIN $V_{min,}$ actual [CFM]
3122A	LAB	124	124	1	32.3	35	25	0.78	20	90	45
3122E	AUDIO BOOTH	125	59	1	8.5	10	5	0.40	20	50	25
3122F	AUDIO BOOTH	125	54	1	8.2	10	5	0.40	20	50	25
3122	LAB	125	580	12	224.4	225	105	1.15	240	390	195
3122L	LAB	126	89	1	26.0	30	20	0.67	20	70	45
3122K	LAB	126	90	1	26.2	30	20	0.67	20	70	45
3122J	LAB	127	82	1	24.8	25	15	0.56	20	70	45
3122I	LAB	127	90	1	26.2	30	20	0.67	20	70	45
3122G	AUDIO BOOTH	128	75	1	9.5	10	5	0.33	20	50	30
3122H	LAB	128	90	1	26.2	30	20	0.67	20	70	45
3101	CONFERNCE	129	290	8	57.4	60	20	0.21	160	290	290
3122D	AUDIO BOOTH	130	14	1	5.8	10	5	0.20	0	50	50
3122D	AUDIO BOOTH	130	14	1	5.8	10	5	0.20	0	50	50
3122D	LAB	130	147	1	36.5	40	30	0.89	20	110	45
3235	WORKROOM	132	626	16	117.6	120	40	0.19	320	630	630
3292-3296	CORRIDOR	133	1642	0	98.5	100	100	0.20	170	500	500
3233-3234	OFFICE	133	290	14	87.4	90	20	0.35	280	260	260
3232	STORAGE	135	189	1	22.7	25	25	0.42	20	60	60
3223	WORKROOM	135	239	6	44.3	45	15	0.19	120	240	240
3225	WORKROOM	136	184	3	26.0	30	15	0.24	60	190	125
3226	CONFERNCE	137	259	8	55.5	60	20	0.22	160	270	270
3228	LAB	138	126	3	52.7	55	25	0.50	60	110	110
3231	STORAGE	139	107	0	12.8	15	15	0.60	0	50	25
3229	STORAGE	139	199	0	23.9	25	25	1.00	0	50	25
3227	STORAGE	139	141	1	16.9	20	20	0.80	0	50	25
3232	STORAGE	139	189	0	22.7	25	25	1.00	0	50	25
3230	WORKROOM	140	144	2	18.6	20	10	0.24	40	150	85
3190-3191	CORRIDOR	141	824	2	49.4	50	50	0.26	90	320	190
	JC	-	28	0	28.0	30	30	0.00	0	0	0
3072	WC	-	31	6	420.0	420	0	0.00	0	0	0
3071	WC	-	262	6	420.0	420	0	0.00	0	0	0
TOTALS:			15146	256		3705	1415		5050	14130	9550

SUMMARY									
AHU	# Zones / VAVs	Area Served [SF]	Design OA [CFM]	Design SA [CFM]	Capacity [CFM]	Unit Size*	V_{ot} [CFM]	% Above V_{ot}	Max Z_p
1	19	13185	4130	17400	17700	40	3320	24.4	0.55
2	3	1311	360	2230	2500	6	470	-23.4	0.15
3	0	7990	2890	13070	13800	35	3550	-18.6	0.32
4	44	15285	4650	14080	13300	30	7485	-37.9	1.00
5	37	15061	4550	11965	11200	30	6785	-32.9	1.00
6	39	15146	5050	14130	13400	30	9550	-47.1	1.00
TOTALS	**142**	**67978**	**21630**	**72875**	**71900**		**31160**	**-30.6**	

* Unit Size for TRANE M-Series Climate Changer AHU

CONCLUSION

The calculations in this report find that five of the six AHUs serving the SLCC do not meet the minimum requirements of ASHRAE Std. 62.1. AHU – 1 provides approximately 24% excess outdoor air to the spaces it serves. Overall, however, the designed HVAC system provides more than 30% less outdoor air than is necessary per Std. 62.1. Specific findings may be reviewed in the “Summary” spreadsheet.

The design of the SLCC HVAC system was based on a standard CFM/Occupant airflow rate, with standards for water closets and support spaces based on rules of thumb. The calculations in this report, however, followed the prescriptive Ventilation Rate Procedure and included both occupancy and floor area airflow rate coefficients.

This discrepancy is predominantly due to the system ventilation efficiency. Critical spaces force the design outdoor air intake rate to be overcompensated. An individual space that requires a high outdoor air fraction governs all other spaces. The minimum requirements from Std. 62.1 must be met at all times for this space, thus forcing the design to condition a proportionally larger amount of outdoor air for the entire system.

In order to complete these calculations, certain assumptions were made that had notable impacts on this system ventilation efficiency calculation. Among them was the correlation between the functions of the individual spaces and those described in Table 6-1. Also, design minimum supply air rates were assumed to be equivalent to the system primary airflow. In cases where the minimum calculated outdoor airflow rate exceeded the minimum supply airflow, the primary outdoor air fraction was assumed to be 1.0. These assumptions are the source of the greatest differential between design and calculated airflows.

VENTILATION RATE vs. INDOOR AIR QUALITY PROCEDURE

The Ventilation Rate (VR) Procedure laid out in section 6.2 of ASHRAE Standard 62.1-2004 is a "prescriptive procedure" in which outdoor air intake rates are determined based on space function, space floor area, and occupancy. It is intended to provide designers with the acceptable ventilation rates acceptable to human occupants and to minimize negative health effects due to poor air quality. This procedure is a relatively simple calculation and can be performed with basic assumptions. Calculations can even be performed prior to the complete design of subject spaces, and are flexible to changes throughout the design process. However these assumptions, as demonstrated in this report, can lead to large variations in calculated outdoor air intake rates. Also, these assumptions do not take specific space functions into account. Rather, ventilation rates provided in Table 6-1 are for general spaces. With regard to the Gallaudet University SLCC this is evident in the functions of the research laboratories. The exact program, equipment, and procedures performed in these spaces are unknown to the designer. As a result, it is likely that these spaces are over-ventilated because of the assumption that they are traditional laboratories. Similar over- or under-ventilation can occur because of these assumptions in many building designs. The result is potential wasting of energy or less-than-acceptable indoor air quality.

Another procedure described in ASHRAE Standard 62.1 is the Indoor Air Quality (IAQ) Procedure. This method is based on the analysis of air contaminant sources, containment targets, and acceptability targets. It is tailored to the specific materials and functions within the space calculated. Credit is given for higher efficiency air cleaning/filtration and the use of low-VOC-emitting materials. It is possible that calculations using this procedure can produce outdoor air intake rates lower than those calculated with the VR Procedure, thus saving energy. However, it is a somewhat complex computation and does not allow for the flexibility or assumptions made with the VR Procedure. While the design of the air filtration, and even the space itself, can be influenced by this method it can not be determined as early in the design process. Also, because the IAQ Procedure is so space specific, it is not as easily repeatable from space to space. Instead, the IAQ Procedure is best applied in certain situations where energy use and/or air quality are a premium.

The benefits of the ease of calculation must be weighed with the potential errors resulting from assumptions. For most building designs in the United States, standard assumptions are acceptable and speedy design and construction are paramount. This is why the Ventilation Rate Procedure is arguably the most used method for calculating minimum outdoor air intake rates. However, specific sensitive spaces may require greater depth and understanding for this calculation. Here, the Indoor Air Quality Procedure may be worth the extra time and effort involved. In either case, the designer should always remember that the health and productivity of occupants are of the utmost importance.

RESOURCES

2005 ASHRAE Handbook – *HVAC Applications*. ASHRAE, Ind. Atlanta, GA. 2005.

ANSI/ASHRAE Standard 62.1-2004 – *Ventilation for Acceptable Indoor Air Quality*. ASHRAE, Inc. Atlanta, GA. 2004.