STENGEL HALL – ACADEMIC CENTER FOR EXCELLENCE

Linden Hall School for Girls
Lititz, Pennsylvania

TECHNICAL REPORT 1

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The Stengel Hall Academic Center for Excellence is a 39,000 square foot renovation and addition to the growing Linden Hall School for Girls campus. The renovation and addition will provide modern more effective learning space for the students. The purpose of this report is to investigate Stengel Hall's compliance to ASHRAE Standard 62.1-2007: Ventilation for Acceptable Indoor Air Quality and ASHRAE Standard 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings.

Stengel Hall's designed ventilation system was the focus of the evaluation with Standard 62.1. The specific sections evaluated were Section 5: Systems and Equipment and Section 6: Ventilation Rate Procedure. The Section 5 evaluation shows that the ventilation equipment and systems are mostly in compliance with the requirements ASHRAE has set. In cases where there is little information, and compliance could not be directly determined it has been cautiously assumed to be non-compliant. It should be noted that compliance may be met within the current submittal phase of the project. A complete ventilation rate analysis has been conducted to evaluate Stengel Hall's compliance with Section 6 of Standard 62.1. Ventilation and exhaust rates have been determined to be compliant with required outside airflow and exhaust rates outlined in this section.

Many components of the entire building design were evaluated in the analysis of Standard 90.1. The broad analysis conducted determined majority of the building envelope and equipment performance characteristics met and exceed the requirements established in this section.

Through this analysis it is determined that the Stengel Hall Academic Center for Excellence is satisfactory in providing the occupants proper ventilation rates which contributes to suitable indoor air quality. It is also evident that measures and considerations were taken to provide the Linden Hall School with an energy efficient building.

The unique heating, ventilating, and air-conditioning design of Stengel Hall is able to overcome many limitations and provide acceptable airflow to its occupants. The mechanical system is comprised of four outdoor split-system units, four boilers, twenty-eight air handling units, and eleven energy recovery ventilators. The energy recovery ventilators primarily serve air supplied to and returned from classroom spaces. There are very few office spaces that are supplied air from the ERVs. The majority of this equipment is either located in the basement or attic. However, a few of the air handlers have been incorporated on the second and third levels in mechanical closets.

The mechanical equipment located in the basement provides air distribution at the ceiling level for occupied spaces in the basement as well as floor distribution to many of the offices on the first level in the existing portion of Stengel Hall. The first level of the addition portion is also served by the equipment located in basement but air is distributed from the ceiling rather than the floor.

The majority of the air supply to the second and third levels is routed from equipment located in the attic. These levels have a ceiling supply as well as high or low return which depend on the space. The air handlers located within the occupied floor plan distribute air to both the second and third level. Outdoor air is supplied from the attic fresh air intake to these air handlers.

The mechanical equipment is located in two different areas due to the many size limitations of Stengel Hall. The existing portion of Stengel Hall has extremely low ceilings, which is understandable since it was built in 1748, and running ductwork within these areas is extremely difficult.

Section 5.0 – Systems & Equipment Summary

The Stengel Hall – Academic Center for Excellences is compliant with most requirements of ASHRAE Standard 62.1 Section 5.0. Bird screens and ventilation controls have been considered non-compliant for the purposes of this report because they are not specified on the drawings, however may be part of the current submittal phase. Another area that has not been addressed in any supporting documents is the humidification or dehumidification requirements and capabilities of controlling the latent load with the mechanical system design. Below you will find a brief summary of each of the sub-sections compliance or non-compliance with the requirements of Section 5.0.

5.1 – Natural Ventilation

The building is comprised of operable double-hung windows which could provide natural ventilation at the discretion of the building occupants. There are no other noteworthy natural ventilation features.

5.2 – Ventilation Air Distribution

The ventilation air distribution for this project meets and exceeds the minimum outdoor air requirements outlined in Standard 62.1 Section 6. Further discussion on the specific ventilation air requirements can be found on page 7 of this report.

5.3 – Exhaust Duct Location

Air is exhausted from the restrooms throughout this building and, as per this section; the exhaust ductwork does not run through any conditioned spaces which could potentially contaminate the air. The exhaust ductwork runs directly from the restrooms, through mechanical shafts and other unoccupied spaces to reach the exterior of the building.

5.4 – Ventilation System Controls

Controls have not been specified for the ventilation system.

5.5 – Airstream Surfaces

The ductwork which is specified for the heating, ventilation, and air-conditioning system is galvanized sheet-metal with exterior fiberglass duct wrap. This material meets all requirements established by this section to to resist mold growth and erosion.

5.6 – Outdoor Air Intakes

The outdoor air intakes for this building are located at the basement and attic levels. They are located away from areas of heavy vehicle traffic that could potentially contaminate the fresh air. The blades for the louvers are designed to manage rain entrainment with stationary-drainable blades at a 38 degree tilt. Bird and insect screening is not specified and is considered unsatisfactory for the purposes of this report.

5.7 – Local Capture of Contaminants

This section is not applicable to equipment specified in this building

5.8 – Combustion Air

The contaminants produced from the boilers located in the basement are vented directly to the attic by a single, pipe chase within a mechanical shaft. This direct ventilation pathway complies with this section.

5.9 – Particulate Matter Removal

Outside air is first filtered through (2) 1" pleated, 30% efficient filter in the energy recovery units. It is then filtered again by a 2" Pleated Throw-Away filter with the air handling units which is also rated with an average dust spot efficiency of 35-40%.

5.10 – Dehumidification Systems

There is no dehumidification system specified.

5.11 – Drain Pans

A non-corrosive polymer drip pan is specified to be used in conjunction with the air-handling units. The pan is double-sloped with the drain at the lowest point. This complies with the requirements specified with this section.

5.12 – Finned-Tube Coils & Heat Exchangers

The drip pan noted above, which complies with Section 5.11, is to be provided beneath the condensing cooling in all air handling units.

5.13 – Humidifiers & Water Spray Systems

This section does not apply to Stengel Hall.

5.14 – Access for Inspection

All manufacturer-required equipment clearances have been noted in equipment submittals from the mechanical engineer for the Stengel Hall renovation. The clearances allow access to the equipment for maintenance and filter replacement which complies with this section.

5.15 – Building Envelope & Interior Surfaces

To prevent moisture damage all joints, windows, doorways are specified to be sealed with compatible air-seal spray insulation. Also, painted mold and mildew resistant gypsum wall board is specified to be used on all interior wall surfaces. The design is compliant in providing protection against liquid water penetration.

5.16 – Buildings with Attached Parking Garages

This section does not apply to Stengel Hall.

5.17 – Air Classification & Recirculation

The air in all areas of the Academic Center for Excellence is classified as Type 1 except for toilet facilities. The exhaust air from the toilet facilities is directly exhausted to the exterior as previously mention in Section 5.3. There are no other spaces in this building that require special consideration because Type 1 air may be transferred and recirculated to any space without concern.

5.18 – Requirements for Buildings Containing ETS Areas & ETS-Free Areas

This section does not apply to Stengel Hall.

Ventilation Rate Procedure Analysis (Section 6.0)

All spaces were used in the ventilation rate analysis of Stengel Hall. The space limitations in the existing Stengel Hall are influential in the mechanical design of many small capacity energy recovery units and air handling units. Each piece of equipment is sized specifically for the spaces in which it will serve. Due to this lack of repetition and varying load sizes within the building the entire building was chosen for analysis.

Figure 1, in the Appendix, outlines pertinent information for every room, existing and new, that is a part of the Stengel Hall - Academic Center for Excellence. Room occupancies were determined by the architect and noted on the architectural floor plans. The outdoor air rates were determined using Table 6-1 the Minimum Ventilation Rates in Breathing Zone which is found in ASHRAE Standard 62.1. The breathing zone outdoor airflow was calculated using the following equation (the coefficients can be determined from Figure-1):

$$V_{bz} = R_p*P_z + R_a*A_z$$

Figure 2 organizes the rooms by the air handling unit that serves them as well as the energy recovery ventilators if applicable. For the sake of this analysis zones were established by the area in which each air handler services. So, each air handling unit is considered a single-zone system.

As per the ventilation rate procedure, the zone distribution effectiveness evaluates how effective the supply and exhaust locations are for each zone. This table is included in the appendix and is labeled as Figure-2. In some areas of Stengel Hall there is floor supply and floor return of both warm and cool air. This configuration is not an option in Figure-2 and was conservatively estimated in this analysis as 0.8 due to poor air mixing capabilities of this configuration.

The zone outdoor airflow, V_{oz}, is determined by the following equation: $V_{oz} = E_z*V_{bz}$

When comparing the zone outdoor airflow, as determined from the above procedure to the designed outdoor airflow for the Stengel Hall renovation one will notice some significant differences (values seen in Figure-4). The outdoor airflow determined in this analysis was on average 22% lower than the designed outdoor airflow. The largest difference occurs with AHU-305 where there is a 77% difference in the required outdoor airflow versus the designed airflow. The differences seen in this comparison could be due to a number of reasons. First, and foremost, the mechanical engineer may have increased the design values as per their own practices and procedures. However, the large differences may be due to other space requirements not noted on the drawing or future planning. The designer may have also designated larger amounts of outside air to spaces where the indoor air quality should be better than average, such as the headmaster's office, board room, and day lounge.

In another case Figure-4 depicts that the design is lacking in outdoor airflow for AHU-209. However, while AHU-209 is lacking outdoor air by 16%, AHU-208 exceeds outdoor air requirements by 16%. Both of these air handlers supply air to the learning center and work room and the total combined ventilation air satisfies the requirements of the space. Lastly, because many of the air handling units supply air in conjunction with an energy recovery ventilator, it may be more beneficial to supply a greater outdoor airflow in order to operate the ERV's effectively.

Figure-4 also includes the primary outdoor air fraction which was calculated based on the designed airflow rates for Stengel Hall. The primary air fraction, Z_p, is calculated with the following equation:

$$Z_p = V_{oz}/V_{pz}$$

The primary outdoor air fraction is significantly higher for classroom spaces compared to other Stengel hall spaces. This is due to the larger air rate required per person in such spaces.

Overall, the Stengel Hall – Academic Center for Excellence mostly complies with the ventilation rates required by ASHRAE Standard 62.1. In addition, the average of the system ventilation efficiencies is 80%.

ASHRAE Standard 90.1 has established the minimum design requirements that must be met in order to achieve an energy-efficient building. With the information and supporting documents provided this analysis found that the Stengel Hall renovation and addition have fulfilled most of these requirements. Very few conclusions were able to be made about the control systems for the mechanical design of this building. This is one area that there is currently very little information is provided. A detailed summary of the compliance and non-compliance with Standard 90.1 can be found below.

Section 5 – Building Envelope

5.1 – General

The climate zone, based on location, is determined to be 5A – Cool, Humid. This climate zone location can be seen in the Climate Zone Map (Figure 5) in the appendix.

5.2 – Compliance Paths

The Stengel Hall project falls under the prescriptive building option because the glazing is less than 40% of the gross wall area and there is no skylight fenestration.

5.4 – Mandatory Provisions

The fenestration and door sealing is specified in the drawings to provide an air tight seal, as noted in Section 5 analysis. There is not any information provided relating to leakage rates. Vestibules protect the conditioned space from the unconditioned space in all but one area of Stengel Hall. On the third level, the entrance from the outdoor classroom to the library there is no vestibule area. However, this door can be classified as an exception because it is opening from a space less than 3000 square feet. Therefore compliance with the requirements of this section is met.

5.5 – Prescriptive Building Envelope Option (See summary Figure-6)

The roof assemblies specified for the Stengel Hall – Academic Center for Excellence meet the minimum R-values specified in this section. The attic roof, constructed of light gauge framing, includes rigid insulation (R-10 min.) as well as batt insulation (R-19). Another roof assembly is a low-sloped roof which is specified to maintain a minimum of R-20 which meets the requirement of R-19.

The exterior walls both above and below grade are constructed of 12” concrete block with 2” Styrofoam which is specified to be rated at a minimum of R-11.9. Smaller sections of the addition are constructed of 6” metal studs with R-19 batt insulation which also meet requirements for steel framed buildings.

All floors are 4” concrete slab configurations, slab-on-grade and slab-deck configuration. There are no set requirements for unheated slab-on-grade in this climate zone. The attic floor is specified to have R-38 batt insulation which meets requirements for floor and attic alike.

The fenestration specified for Stengel Hall complies with the prescriptive building envelope requirements. The windows specified are double-pane low-e glazing with argon.

Section 6 – Heating, Ventilating, and Air Conditioning

6.4 – Mandatory Provisions

Minimum Equipment Efficiencies

Split systems which provide 135,000-240,000 Btu/h must have an EER of at least 11.0. The split system units of this size in Stengel Hall have an EER of 12.5 which meets these requirements. Stengel Hall also has a split system that has cooling performance characteristics of ≥240,000 and < 760,000 Btu/hr with an EER of 12.0. The EER of equipment of this size require a minimum EER of 10.0.

Labeling

The submittals include the necessary labeling which is to be produced by the manufacturer.

Load Calculations

It is evident that heating and cooling design loads were calculated for this project to determine proper sizing of equipment.

Zone Thermostatic Controls

Thermostats for each zone are noted in the mechanical drawings for the basement and first floor, but there are very few noted for the upper levels of the building. Currently there is very little information pertaining to controls for this project. This section does not currently comply based on the supporting documents received.

Ventilation System Controls

The design includes fire dampers intended to seal fire-rated stair ways, elevators, and elevator equipment. Fire dampers are not included for non-fire-rated stairways. Motorized dampers are not noted in the mechanical drawings. The fans specified do not require automatic shut-off because they are only ½ hp. High occupancy controls are not necessary for any spaces within the building.

Insulation

All rectangular ducts are indoors and are specified to have 1- ½” thick, Fiberglass duct wrap. This meets the minimum duct insulation criterion which requires an R-value of R-3.5 in unconditioned spaces. Spiral ducts are not specified to be insulated. They are also not required to be insulated because they are located in conditioned spaces.

Pipes are specified to have ½” fiberglass insulation when <1.25” in diameter and 2” fiberglass insulation if larger than 1.25” in diameter. This meets requirements set as the HWS temperatures are not specified to exceed 140 degrees.

6.5 Prescriptive Path

6.5.1 – Economizers

Economizers are not required for the Stengel hall addition because heat recovery systems are utilized.

6.5.2 – Simultaneous Heating and Cooling Limitations

The refrigerant piping loop and hot water piping loop are completely independent of one another. Therefore, the system controls required by this section do not apply because there is no immediate reheating or re-cooling in the cycle.

6.5.3 – Air System Design and Control

The fan power limitation does not apply because the largest fan in any AHU for this project is ½ hp.

6.5.6 – Energy Recovery

The energy recover systems used in this project are less than 5000cfm-does not apply

6.57 – Kitchen Hoods

This section does not apply to Stengel Hall.

6.5.8 – Radiant Heating Systems

This section does not apply to Stengel Hall.

6.5.9 – Hot Gas Bypass Limitation

This section does not apply to Stengel Hall.

Section 7 – Service Water Heating

Stengel Hall utilizes boilers to for hot water supply to air handling units. The piping, no greater than 1”, is specified to be wrapped with ½” insulation which meets the requirements set by this section.

Hot water heaters for potable water have not been specified.

Section 8 – Power

The electrical distribution system in the Stengel Hall renovation complies with the 2009 International Electric Code (IEC). The power requirements set by this standard allow for a maximum feeder voltage drop of 2% and a maximum branch circuit voltage drop of 3%. These requirements are higher than that of the IEC and it can therefore be assumed that the project is in compliance with this section.

Section 9 – Lighting

The Stengel Hall lighting design incorporates many energy saving features which comply with this section. Occupancy sensors are implemented in spaces where they are practically useful. New exterior lighting is controlled by photocell. The lighting power density for a school/university is not to exceed 1.2 watts per square foot. In a preliminary analysis of the power density of Stengel Hall, by the building area method, it has been determined that the lighting power density is between 0.70 and 1.2 and is compliant with this section.

Figure 1 – Stengel Hall Rooms by Level

ROOM INFORMATION				OUTDOOR AIR RATE		BREATHING ZONE OUTDOOR AIRFLOW, V_{bz}	EXHAUST RATE REQUIREMENT (cfm/person)
ROOM NAME	ROOM #	OCCUPANCY, P_z	AREA, R_a (Sq. Ft.)	PEOPLE, R_p (cfm/person)	AREA, R_a (cfm/sq.ft.)		
BASEMENT							
Corridor	1		387		0.06	23	
Corridor	2		226		0.06	14	
Testing/Lecture	3	65	1304	7.5	0.06	566	
Storage	3A		75		0.12	9	
Elev. Equipment	4		60		0.12	7	
Elev. Lobby	5		215		0.06	13	
Corridor	6		277		0.06	17	
Day Lounge	7	35	1375	5	0.06	258	
E. Mech/Elec	8		743		0.06	45	
Unisex R. Rm.	9	1	52			0	50
Unisex R. Rm.	10	1	52			0	50
Mech/Boiler/Elec	11	4	963		0.06	58	
Mech/Elec	12	2	587		0.06	35	
FIRST LEVEL							
North Entry	101		250	5	0.06	15	
Centre Lobby	102	19	718	5	0.06	138	
Receptionist	103	1	116	5	0.06	12	
South Entry	104		193	5	0.06	12	
Corridor	105		491		0.06	29	
Vestibule	106		228	5	0.06	14	
Cot	107	1	77	5	0.06	10	
Toilet	107A	1	60			0	50
Work Room	108	1	148	5	0.06	14	
Faculty Work Room	109	4	258	5	0.06	35	
Faculty	110	4	254	5	0.06	35	
Men	111	2	135			0	140
Women	112	2	138			0	140
Conference	113	4	94	5	0.06	26	
Passage	114		125		0.06	8	
Display	115	2	94	5	0.06	16	
Corridor	116		211		0.06	13	
Corridor	117		355		0.06	21	
Administrative Assistant	118	4	280	5	0.06	37	
Director of Admissions	119	1	250	5	0.06	20	
Asst. Director of Admissions	120	1	150	5	0.06	14	
Manager	121	1	161	5	0.06	15	
Janitor	122		47			0	
Mechanical	123		37			0	
Corridor	124		138		0.06	8	
Passage	125		144		0.06	9	
Advancement Office	126	1	209	5	0.06	18	
Director of Advancement	127	1	256	5	0.06	20	
Existing Passage	128		204		0.06	12	
Business Manager	129	1	214	5	0.06	18	
Business Assistant	130	1	223	5	0.06	18	
Existing Passage	131		270		0.06	16	

Figure 1 (cont.) – Stengel Hall Rooms by Level

ROOM INFORMATION				OUTDOOR AIR RATE		BREATHING ZONE OUTDOOR AIRFLOW, V_{bz}	EXHAUST RATE REQUIREMENT (cfm/person)
ROOM NAME	ROOM #	OCCUPANCY, P_z	AREA, R_a (Sq. Ft.)	PEOPLE, R_p (cfm/person)	AREA, R_a (cfm/sq.ft.)		
Conference	132	5	250	5	0.06	40	
Mechanical/Storage	133	1	170		0.12	20	
Existing Entry	134		168	5	0.06	10	
Headmaster	135	1	350	5	0.06	26	
Board Room	136	32	718	5	0.06	203	
Existing Passage	137		324		0.06	19	
SECOND LEVEL							
Classroom	201	23	627	10	0.12	305.24	
Learning Center	202	20	720	5	0.12	186.4	
Conference	203	12	216	5	0.06	72.96	
Learning center	204	21	495	5	0.12	164.4	
Conference	205	5	108	5	0.06	31.48	
Work Room	206	1	85	5	0.06	10.1	
Library Office Work Room	207	1	150	5	0.06	14	
Bookshelves	208	6	476	5	0.12	87.12	
Passage	209		290		0.06	17.4	
Toilet	210	1	53			0	50
Passage	211		227		0.06	13.62	
Toilet	212	1	53			0	50
College Counseling	213	4	169	5	0.06	30.14	
Office	214	1	110	5	0.06	11.6	
Office	215	1	110	5	0.06	11.6	
Corridor	216		200		0.06	12	
Mechanical	216A		24			0	
Classroom	217	16	434	10	0.12	212.08	
Corridor	218		169		0.06	10.14	
Academic Dean	219	1	250	5	0.06	20	
Corridor	220		279		0.06	16.74	
Assistant	221	1	188	5	0.06	16.28	
Tech Office/Server	222	2	182	5	0.06	20.92	
Computer Lab	223	8	345	10	0.12	121.4	
Assistant Head	224	1	154	5	0.06	14.24	
Conference	225	6	185	5	0.06	41.1	
Passage	226		345		0.06	20.7	
Classroom	227	15	479	10	0.12	207.48	
Passage	228		118		0.06	7.08	
Passage	229		87		0.06	5.22	
Mechanical	230		53			0	
Classroom	231	13	239	10	0.12	158.68	
Mechanical	232		41			0	
THIRD LEVEL							
Classroom	301	26	625	10	0.12	335	
Corridor	302		363		0.06	21.78	
Mechanical	303		40			0	
Classroom	304	11	317	10	0.12	148.04	
Passage	305		66		0.06	3.96	
Mechanical	306		18			0	

Figure 1 (cont.) – Stengel Hall Rooms by Level

ROOM INFORMATION				OUTDOOR AIR RATE		BREATHING ZONE OUTDOOR AIRFLOW, V_{bz}	EXHAUST RATE REQUIREMENT (cfm/person)
ROOM NAME	ROOM #	OCCUPANCY, P_z	AREA, R_a (Sq. Ft.)	PEOPLE, R_p (cfm/person)	AREA, R_a (cfm/sq.ft.)		
Classroom	307	9	230	10	0.12	117.6	
Classroom	308	9	235	10	0.12	118.2	
Classroom	309	15	418	10	0.12	200.16	
Exterior Passage	310		281		0.06	16.86	
Mechanical	311		21			0	
Corridor	312		405		0.06	24.3	
Passage	313		228		0.06	13.68	
Toilet	314	1	53			0	50
Toilet	315	1	53			0	50
Corridor	316		190		0.06	11.4	
Mechanical	317		20			0	
Classroom	318	17	392	10	0.12	217.04	
Existing Classroom	319	11	387	10	0.12	156.44	
Existing Classroom	320	21	497	10	0.12	269.64	
Existing Classroom	321	23	568	10	0.12	298.16	
Corridor	322		252		0.06	15.12	
Existing Classroom	323	21	481	10	0.06	238.86	
Existing Work Room/Archives	324		176	5	0.12	21.12	
Passage	325		128		0.06	7.68	
Office	326	4	305	5	0.06	38.3	
Existing Storage	327		75		0.12	9	
ATTIC							
Mech/Elec	401	2	615				
Existing Unoccupied Attic	402						
Existing Unoccupied Attic	403						
Existing Unoccupied Attic	404						

Figure 2 – ASHRAE Table of Distribution Effectiveness

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 ANSI/ASHRAE Standard 129[16] for all air distribution configurations except unidirectional flow.

Figure 3 – ASHRAE Table of Ventilation Efficiency

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.

Figure 4 –AHU Zone Calculations

ERV (IF APPLICABLE)	AHU	ROOMS SERVED FROM AIR HANDLING UNITS	CALCULATED BREATHING ZONE OUTDOOR AIRFLOW, V_{bz} (CFM)	ZONE DISTRIBUTION EFFECTIVENESS, E_z	ZONE OUTDOOR AIRFLOW, V_{oz} (CFM)	DESIGNED OUTDOOR AIR (CFM)	DESIGNED TOTAL AIRFLOW, V_{pz} (CFM)	PRIMARY OUTDOOR AIR FRACTION, Z_p	SYSTEM VENTILATION EFFICIENCY, E_v
ERV-2	AHU-001	007-Day Lounge	258	1.0	258	600	1400	0.43	0.7
	AHU-002	002-Coridoor 005-Elevator Lobby 006-Coridoor	43	1.0	43	100	525	0.19	0.9
ERV-3	AHU-003	003-Testing/Lecture	566	1.0	566	710	1600	0.44	0.7
	AHU-101	134-Existing Entry 135-Headmaster	36.1	1.0	36	80	700	0.11	1.0
ERV-1	AHU-102	136-Existing Passage 137-Existing Passage	222.5	1.0	223	250	825	0.30	0.8
	AHU-103	129-Business Manager 130-Business Assistant 131-Existing Passage 132-Conference 133-Mech/Elec	112.8	1.0	113	150	1050	0.14	1.0
	AHU-104	121-Manager 124-Corridor 126-Advancement Office 127-Director of Advancement 128-Existing Passage	73.1	1.0	73	80	875	0.09	1.0
	AHU-105	101-North Entry 102-Centre Lobby 103-Receptionist 104-South Entry 106-Vestibule	190.3	0.8	238	380	1400	0.27	0.8
	AHU-106	118-Administrative Assistant 119-Director of Admissions 120-Assistant Director of Admissions	70.8	1.0	71	60	525	0.11	1.0
	AHU-107	105-Corridor 107-Cot 108-Work Room 109-Faculty Work Room 110-Faculty 113-Conference 115-Display 117-Corridor	186.3	0.8	233	180	1225	0.15	1.0

Figure 4 (cont.) –AHU Zone Calculations

ERV (IF APPLICABLE)	AHU	ROOMS SERVED FROM AIR HANDLING UNITS	CALCULATED BREATHING ZONE OUTDOOR AIRFLOW, V_{bz} (CFM)	ZONE DISTRIBUTION EFFECTIVENESS, E_z	ZONE OUTDOOR AIRFLOW, V_{oz} (CFM)	DESIGNED OUTDOOR AIR (CFM)	DESIGNED TOTAL AIRFLOW, V_{pz} (CFM)	PRIMARY OUTDOOR AIR FRACTION, Z_p	SYSTEM VENTILATION EFFICIENCY, E_v
	AHU-201	213-College Counseling 214-Offices 215-Offices 216-Corridor	65.3	1.0	65	60	525	0.11	1.0
ERV-4	AHU-202	217-Classroom	212.1	1.0	212	240	525	0.46	0.6
	AHU-203	218-Corridor 219-Academic Dean 220-Corridor 221-Assistant 224-Assistant Head 225-Conference 226-Passage	139.2	1.0	139	150	1400	0.11	1.0
	AHU-204	222-Tech Office/Server Room	20.9	1.0	21	40	525	0.08	1.0
	AHU-205	223-Conference	41.1	1.0	41	110	525	0.21	0.9
ERV-7	AHU-206	227-Classroom	207.5	1.0	207	300	700	0.43	0.7
ERV-9	AHU-207	201-Classroom 231-Classroom	463.9	1.0	464	465	875	0.53	0.6
	AHU-208	208-Bookshelves 206-Work Room 202-Learning Center	283.6	1.0	284	340	1225	0.28	0.8
ERV-10	AHU-209	202-Learning Center 206-Work Room 203-Conference 204-Learning Center 207-Library Office/Work Room	349.6	1.0	350	300	1050	0.29	0.8
	AHU-210	205-Conference 209-Passage 211-Passage 312-Corridor 313-Passage	100.5	1.0	100	240	875	0.27	0.8
ERV-4	AHU-301	316-Corridor 318-Classroom 319-Existing Classroom	384.9	1.0	385	500	1400	0.36	0.7
ERV-5	AHU-302	320-Existing Classroom	269.6	1.0	270	320	875	0.37	0.7
ERV-6	AHU-303	321-Existing Classroom	298.2	1.0	298	360	875	0.41	0.7
ERV-6	AHU-304	323-Existing Classroom	238.9	1.0	239	340	700	0.49	0.6

Figure-4 (cont.) –AHU Zone Calculations

ERV (IF APPLICABLE)	AHU	ROOMS SERVED FROM AIR HANDLING UNITS	CALCULATED BREATHING ZONE OUTDOOR AIRFLOW, V_{bz} (CFM)	ZONE DISTRIBUTION EFFECTIVENESS, E_z	ZONE OUTDOOR AIRFLOW, V_{oz} (CFM)	DESIGNED OUTDOOR AIR (CFM)	DESIGNED TOTAL AIRFLOW, V_{pz} (CFM)	PRIMARY OUTDOOR AIR FRACTION, Z_p	SYSTEM VENTILATION EFFICIENCY, E_v
ERV-7	AHU-305	324-Archives 326-Office 327-Existing Storage	68.4	1.0	68	300	875	0.34	0.8
ERV-8	AHU-306	301-Classroom 304-Classroom	483.0	1.0	483	625	1225	0.51	0.6
	AHU-307	302-Corridor 309-Classroom	221.9	1.0	222	300	700	0.43	0.7
	AHU-308	307-Classroom 309-Classroom	317.8	1.0	318	300	700	0.43	0.7

Figure-5 – Climate Zone Map

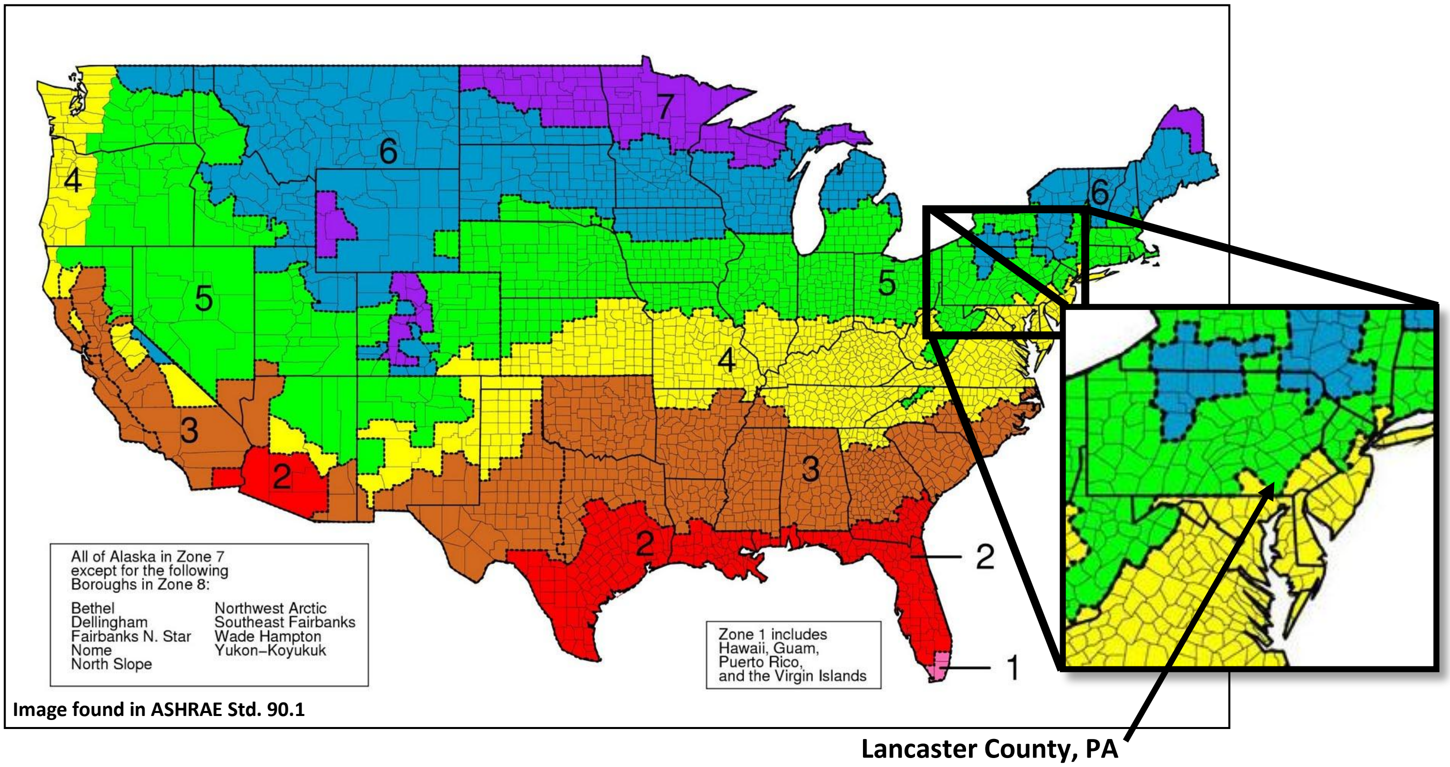

Figure 6 - Building Envelope Requirements for Climate Zone 5 (A, B, C)

		Nonresidential		
		Assembly Maximum	Insulation Min. R-value	Designed R-Value
Roofs				
	Metal Building	U-0.065	R-19.0	R-20
	Attic and Other	U-0.027	R-38.0	R-38.0
Walls, Above-Grade				
	Mass	U-0.09	R-11.4	R-11.9
	Steel-Framed	U-0.064	R-13.0 + R-7.5	R-19
Walls, Below-Grade				
	Below-Grade Wall	C-0.119	R-7.5	R-11.9
Slab-on-Grade Floors				
	Unheated	F-0.730	NR	-