ASHRAE Standards 62.1 and 90.1 Evaluations

Technical Report One

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Nolan J. Amos, Mechanical Option
Dr. William Bahnfleth, Faculty Advisor

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Executive Summary:

The purpose of this technical assignment is to analyze the Early Learning Center's compliance with ASHRAE 62.1 – 2013 and ASHRAE 90.1 – 2013. On the campus of the Phoenixville Area School District, the new Phoenixville Early Learning Center and Elementary School is going to be built. Construction for the project will start in fall 2015 and last until fall 2017.

When comparing the design to ASHRAE 62.1, section five, the Early Learning Center responds very well to the code and often exceeds the minimum standards. Section five of ASHRAE 62.1 addresses the ventilation systems as well as equipment to push the air around. This group of standards attempts to prevent moisture build up within the building, stale air and air borne particulate health effects, as well as dehumidification and building envelope. After analyzing the building, unsurprisingly it came up fully compliant and had no issues.

Section six of ASHRAE 62.1 was then tested against the design of the Early Learning Center. In section six the ventilation system is compared to the ventilation standards. Outdoor air intakes were calculated to understand if there was enough fresh air and air movement throughout the building. Again, the building came up fully compliant and had no major design issues.

Within ASHRAE 90.1 Section five, the building's envelope is examined more in depth. This section looks for specific climate data according to various charts. It also examines the building envelope using u-values, and fenestration compliance. Similar to other sections the Early Learning Center is again compliant except for one small u-value. The u-value of the slab and piece of insulation is too high for ASHRAE standards.

The last section the Early Learning Center was analyzed against was ASHRAE 90.1 Section six. Section six is Heating, Ventilating, and Air Control. These sections discussed hydronic water pumps, energy recovery as well as lighting, and power. It was found the Early Learning Center is fully compliant with this section.

Building Overview:

The Phoenixville Early Learning Center and Elementary school is being built for a progressive school district who is looking to expand and address their growing student population. Phoenixville Early Learning Center is a 152,000 square foot educational building designed to hold 1,526 occupants.

The building is comprised of two stories above grade and will accommodate grades K-5. There are three wings to the building as well as one large common area and an outdoor learning amphitheater. Wings of the building, as shown in figure 1 below, are filled with learning

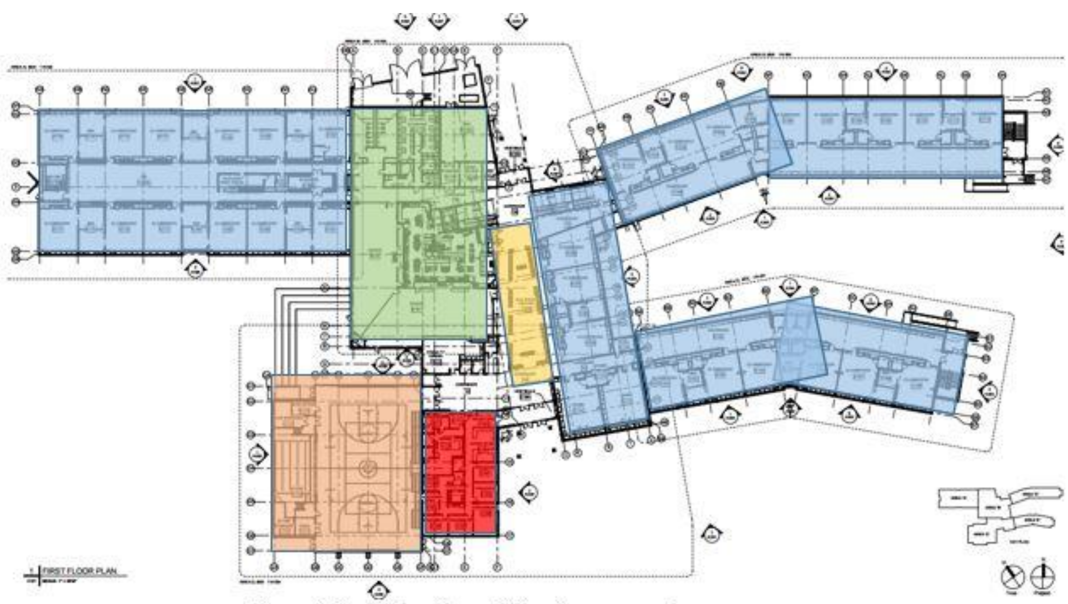

Figure 1: First Floor Plan with basic programming.

Legend:

- Learning Spaces –
- Gymnasium –
- Administrative –
- Kitchen and Dining -
- Media Center –

spaces comprised of group learning areas as well as learning studios. Within the large common area there are administration spaces, the learning resource center, support spaces, a media center as well as a full size gymnasium as displayed in figure 1 above.

Mechanical Systems Overview:

To provide an energy efficient and comfortable design the engineers decided to install water source heat pumps, energy recovery capability, condenser water pumps, a cooling tower and a high efficiency boiler plant. Heat pumps are located within small closet areas within close proximity to the space they are serving. Most of the large assembly spaces utilize equipment on the roof or in mechanical rooms. Ventilation is provided by energy recovery ventilator units (ERV) fitted with enthalpy heat wheels which are on the roof and ducted to heat pumps. Fans on the rooftop draw air out of the building and exhaust areas such as toilet rooms and locker rooms.

Hot water in the building is distributed via a central hot water plant within the mechanical room. Cold water originates from the roof and is run thru the cooling tower which extracts heat from the condenser loop. Electric trace heating cable is used throughout the building, to prevent piping from freezing in winter months.

Electric unit heaters will also be used in places without ceilings. These spaces using electric unit heaters are “back of house” spaces.

ASHRAE Standard 62.1 Evaluation

The comparison to ASHRAE Standard 62.1 is critical because it addresses important considerations such as energy usage, ventilation, and building envelope.

Section 5: Systems and Equipment

Within section five of ASHRAE 62.1 2013, the Early Learning Center will be compared to the rigorous standards presented by ASHRAE. These standards generally apply to the system selection, ensuring proper air distribution and construction of walls in response to eliminate moisture issues. Later in the section, indoor air quality is assessed with the classification of air to apply recirculation or exhaust compatibility. Section five is a broad overview of how air enters and exits the building.

5.1 | Ventilation Air Distribution

The Early Learning Center will be fully tested, including both Air Systems and Hydronic Systems, according to the Associated Air Balance Council, National Environmental Balancing Bureau and the Testing, Adjusting and Balancing Bureau for accuracy to the indicated design. Testing will be completed within 30 days of substantial completion by a certified Testing adjusting, and Balancing Engineer with certified equipment. In addition, all fans are to be run tested, statically and dynamically, at the factory before becoming Air Movement and Control Association (AMCA) certified. Plenums indicated on the drawings will be properly sealed before start of the system following Sheet Metal and Air Conditioning Contractors'' National Association (SMACNA), HVAC Duct construction Standards.

5.2 | Exhaust Duct Location

Exhaust Ducts within the building are strategically placed so contaminated spaces are negatively pressurized and will draw in contaminated air. The exhaust air ducts are run through positively pressurized rooms which will cause no leakage through the ducts, as the ducts are to be properly sealed and tested for leakage, ensuring adequate indoor air quality

5.4 | Airstream Surfaces

The air distribution in the Early Learning Center will be done with sheet metal ductwork and connected with metal fasteners. This type of ductwork is in compliance with 5.4.1 Resistance to mold growth and 5.4.2 Resistance to Erosion because sheet metal is an exception. Precautions are being taken with respect to dishwasher exhaust ductwork which will be fabricated in stainless steel only. Similarly, exterior ductwork will be installed as aluminum or stainless steel.

5.5 | Outdoor Air Intakes

Outdoor Air Intakes are critical to providing good indoor air quality. Plumbing vents that are exhausted on the roof comply with section 5.5, exhausting their air 36 inches above the level of the outdoor air intake. Additionally, all kitchen exhaust, is properly dispensed with a wide Air being exhausted is generally class one air, meaning it has a low contaminant concentration and is generally not going to harm another user. This air is transferred and recirculated throughout the building after going through an enthalpy wheel to extract the heat from the exhaust air to warm the supply air.

All air vents and exhausts are properly covered for protection against wind and snow. Bird screens are covering the vents of all mechanical equipment on the roof, including but not limited to centrifugal roof fans, gravity roof ventilators, and exhaust pipes.

5.6 | Local Capture of Contaminants

Kitchen and dishwasher exhaust fans will be turned on when in use. When the kitchen exhaust fan is turned on the energy recovery ventilator – 5 will be shut off to distribute air directly outside. Stainless steel hoods will be used in both applications.

5.7 | Combustion Air

Air from all combustible air sources are designed according to manufacturer's specifications on the ventilation of fuel sources from the area. These sources come from three high efficiency boilers. All boilers have specific compliance and separate flue ventilation pipes.

5.8 | Particulate Matter Removal

The Early Learning Center has seven rooftop water source heat pumps and ten energy recovery ventilators which all have Minimum Efficiency Reporting Value (MERV)-8 filters upstream of the units complying with section 5.8.

5.9 | Dehumidification Systems

The Building Automation System (BAS) is used to control the dehumidification mode on all of the eligible mechanical equipment. When instructed the water source heat pumps, as well as the rooftop water source heat pumps can switch to dehumidification mode. Within the dehumidification mode the humidity set point is adjustable, however specifications call for a 50% relative humidity, exceeding the 65% requirement.

Intake to the building exceeds the exhaust air positively pressurizing the building. This helps force exhaust air outside and complies with section 5.9.2, Exfiltration.

5.10 | Drain Pans

Drain Pans have been specified to comply with section 5.10. The drain pans will be installed on all condensation equipment. Drain Pans wall have adequate slope and sealing. The drain pan is to be properly sized independently for each instance where a drain pan is needed.

5.11 | Finned-Tube Coils and Heat Exchangers

As covered in section 5.10, drain pans will be installed at condensation equipment and dehumidifying assemblies. Drain pans are to be installed with easy to clean and remove solid aluminum plates.

5.12 | Humidifiers and Water-Spray Systems

No humidifiers or water-spray systems were used in the design of the Early Learning Center, so this section does not apply.

5.13 | Access for Inspection, Cleaning, and Maintenance

The water source heat pumps that are located within the classrooms have panels to be easily accessible for maintenance and cleaning. Rooftop units have excess room to perform maintenance and allow easy workability. Upon turnover, a recommended cleaning and maintenance manual will be left for the owner. Scheduled training will also occur for the owner before turnover.

5.14 | Building Envelope and Interior Surfaces

Exterior building envelope is a key component of the heating and cooling system in the building. This building’s envelope is compliant with section 5.14 of ASHRAE STD 62.1. The exterior walls have proper weather resistance. Weather resistance measures taken in the exterior walls include moisture barriers, vapor barriers, steel tubes against the structural steel for drainage, as well as cementitious siding for the exterior. Glazing materials used on the exterior of the building include a glazed storefront over the main entryway, a tempered insulated glazing on the windows and spandrel glazing also used on windows throughout. Throughout the building’s design, proper care was taken in the joints between wall materials to allow proper sealing.

5.15 | Buildings with Attached Parking Garages

The Early Learning Center does not have any attached parking garages so this section does not apply. Parking for the building will be in the front and back of the building.

5.16 | Air Classification and Recirculation

Rooms within the Early Learning Center are given air class ratings to ensure compliance with indoor air quality. Most rooms within the ELC are classrooms which is air class 1 which means the air has a low contaminant concentration, low odors and can be recirculated. Other air class 1 spaces within the building are support spaces, the learning resource center, and the media center. Another air class within the building is air class 2. This air class is still able to be recirculated within the building but has moderate contaminant concentration with mildy offensive odors. Some rooms within the building with air class 2 is the art room, cafeteria and gymnasium.

Other spaces with that are not class one or two air sources are exhausted directly outside. Examples of these other spaces would include bathrooms and kitchen exhaust.

5.17 | Requirements for Buildings Containing ETS and ETS-Free Areas

The Phoenixville Area School District promotes a smoke free campus, therefore, section 5.17 does not apply.

<u>Section 6: Ventilation Rate Procedure Analysis</u>

In section six, the Ventilation Rate Procedure is to be followed for indoor air quality testing. The purpose of section six is to make sure there is enough air going through the building for the amount of people. This procedure takes into account the outdoor airflow that is providing occupants with fresh air.

Ventilation Rate Procedure

The Ventilation Rate Procedure is a set of procedures to comply with outdoor ventilation standards. Outdoor air is important for keeping air fresh and the health of the building's occupants. Even though most of the time outside air is relatively clean and can be blown straight into the building there are different classes of air to determine the acceptable conditions of the air, outdoor air treatment may be required.

To find the rate of outdoor air that should be flowing into the building and different spaces the Breathing Zone Outdoor Air calculation from ASHRAE STD 62.1, section 6.2.2.1 should be followed. The formula for breathing zone outdoor airflow is;

$$V_{bz} = R_p \times P_z + R_a \times A_z$$

Where, A_z =Zone floor area or the net occupiable floor area of the ventilation zone, square feet

P_z = Zone population, the number of people in the ventilation zone during typical usage

R_p = Outdoor airflow rate required per person as specified in Table 6.2.2.1

R_a = Outdoor airflow rate required per unit area as specified in Table 6.2.2.1

(Definitions taken from ASHRAE STD 62.1 – 2013 Section 6.2.2.1)

This equation is comparing the air needed per person in the room with respect to occupancy, area, and activity type. Next, the Zone Air Distribution Effectiveness (E_z) needs to be determined based on how the air is distributed to the occupants. Table 6.2.2.2 in ASHRAE Standard 62.1 – 2013 shows the air distribution configurations with their respective effectiveness coefficients. When the Zone Air Distribution Effectiveness is determined the Zone Outdoor Air Flow (V_{oz}) can be calculated from the following equation:

$$V_{oz} = \frac{V_{bz}}{E_z}$$

Where, V_{oz} =Zone Outdoor Air Flow

V_{bz} = Breathing zone Outdoor Airflow

Ez = Zone Air Distribution Effectiveness

The design for outdoor air should be less than or equal to the sum of all design zone quantities. The final step to finding the required Outdoor Air Intake requires the knowledge of the mechanical systems to choose if the building is fit out with a 100 percent outdoor air system, a multiple-zone recirculating system, or a single-zone system. The Early Learning Center is fit out with ten energy recovery ventilator units (ERV) therefore, the procedure for a multiple-zone system will be constructed below.

To calculate the Primary Outdoor Air Fraction (Z_{pz}) we use the equation found in section 6.2.5.1 of ASHRAE Standard 62.1. The Primary Outdoor Air Fraction is the fraction of outdoor air needed in the zone to the total amount of airflow to the zone. The equation is the following:

$$Z_{pz} = \frac{V_{oz}}{V_{pz}}$$

Where, Z_{pz} = Primary Outdoor Air Fraction

V_{oz} = Zone Outdoor Air Flow

V_{pz} = Zone Primary Airflow, which included outdoor air as well as recirculated air

After finding the primary outdoor air fraction, refer to Table 6.2.5.2 of ASHRAE Standard 62.1 -2013 to find the System Ventilation Efficiency. Depending on the outdoor air fraction the ventilation efficiency will change. Now, knowing the Ventilation Efficiency the uncorrected outdoor intake (V_{ou}) can be calculated.

TABLE 6.2.5.2 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_{pz})" refers to the largest value of Z_{pz}, calculated using Equation 6.2.5.1, among all the ventilation zones served by the system.
2. For values of Max (Z_{pz}) between 0.15 and 0.55, the corresponding value of E_v may be determined 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 Normative Appendix A may yield more practical results.

Figure 3: System Ventilation Efficiency

Uncorrected outdoor intake is the amount of intake air that needs to be brought into the building, including all zones based on people, area and occupant diversity. The equation to calculate uncorrected outdoor intake and occupant diversity is the following:

$$V_{ou} = D \sum_{All\ Zones} R_p P_z + \sum_{All\ Zones} R_a A_z$$

And:

$$D = \frac{P_s}{\sum_{All\ zones} P_z}$$

Where, $D =$ Occupant Diversity

$P_s =$ System Population

Lastly, to calculate the Outdoor Air Intake (V_{ot}), the uncorrected outdoor intake is compared to the overall efficiency of the system to provide accurate airflow. A summary and description of the outcomes is described below.

System Evaluation

Within the Early Learning Center, there are ten ERV units that serve to distribute and condition air throughout the building. For the basis of my calculations I used information given by SCHRADERGROUP architecture, as well as Barton Associates. In performing the calculations, I combined similar spaces to have less zones and less complexity. Total occupancy in the building is calculated at 2685 occupants and to distribute air to these occupants a multi-zone system was used. Air distribution configurations used a ceiling supply of warm air and a floor return. According to Table 6.2.2.2 of ASHRAE Standard 62.1 – 2013 the effectiveness of this system is 100 percent effective, or, $E_z = 1$.

Details of the calculations including rooms included in the zones, zone square footage, primary airflow rates, as well as population values can be found in appendix A. All calculations were independently performed for this report but a procedure provided by Barton Associates was utilized. Primary airflow rates as well as areas for each room were taken from drawings provided by SCHRADERGROUP architecture and Barton Associates. Occupant diversity in the Early Learning Center was designed at 100%, therefore a diversity value of 100% was also used in these calculations.

ERV OUTDOOR VENTILATION ASHRAE STD 62.1 COMPLIANCE				
ERV	Zones Served	Required OA (CFM)	Design OA (CFM)	Compliance?
ERV-1	15, 16, 28,29	6085	8915	Yes
ERV-2	18, 19, 30, 31	5125	6480	Yes
ERV-3	3, 21, 22	5320	6155	Yes
ERV-4	1, 2, 20	5290	6125	Yes
ERV-5	7, 8, 25	5520	3775	No
ERV-6	13	3100	5000	Yes
ERV-7	12	480	600	Yes
ERV-8	14, 27	1204	600	No
ERV-9	4, 5, 6, 9, 23, 24	2356	3870	Yes
ERV-10	10, 24, 26	3090	4375	Yes
Total	31	37570	45895	
Notes				
1. When adding CFM values were rounded to the nearest factor of 5.				
2. Zone 24 was split evenly between zones served.				

Table 1: Summary of ERV Outdoor Ventilation Compliance

6.5 | Exhaust Ventilation:

A table of the exhaust ventilation calculations can be found in Appendix A. It was found all of the locations within the building to be exhausted met or, in most cases exceeded ASHRAE 62.1 standards, and fully complies with section 6.5.

Summary of ASHRAE Standard 62.1 Compliance

The Early Learning Center is fully compliant with Section Five of the ASHRAE Standard 62.1 – 2013. Each item in section five was carefully detailed within the specifications given by SCHRADERGROUP architecture. The building is designed to shed moisture and mold growth and provide clean ventilation to its occupants. Exhaust and contaminant collection systems were well designed and often times exceed standards.

In examination of Section Six of ASHRAE Standard 62.1 – 2013, it appears two EHV units are undersized. However, when totaling the design and required outside air ventilation the design ventilation is significantly higher than the amount of required outside air. This could most likely be because of the large generalizations of zones created while doing the calculations rather than going room by room. By creating the large zones it is a quicker but much rougher model to compare design considerations.

Through most sections there was shown a safety factor throughout most calculations and designers often exceeded standards.

ASHRAE Standard 90.1 Evaluation

The purpose of this section is to evaluate the mechanical systems and compare to ASHRAE Standard 90.1 – 2013. Primarily, Standard 90.1 is focused on minimum energy efficiency requirements.

Section Five: Building Envelope

Section 5.1: General

5.1.4 Climate

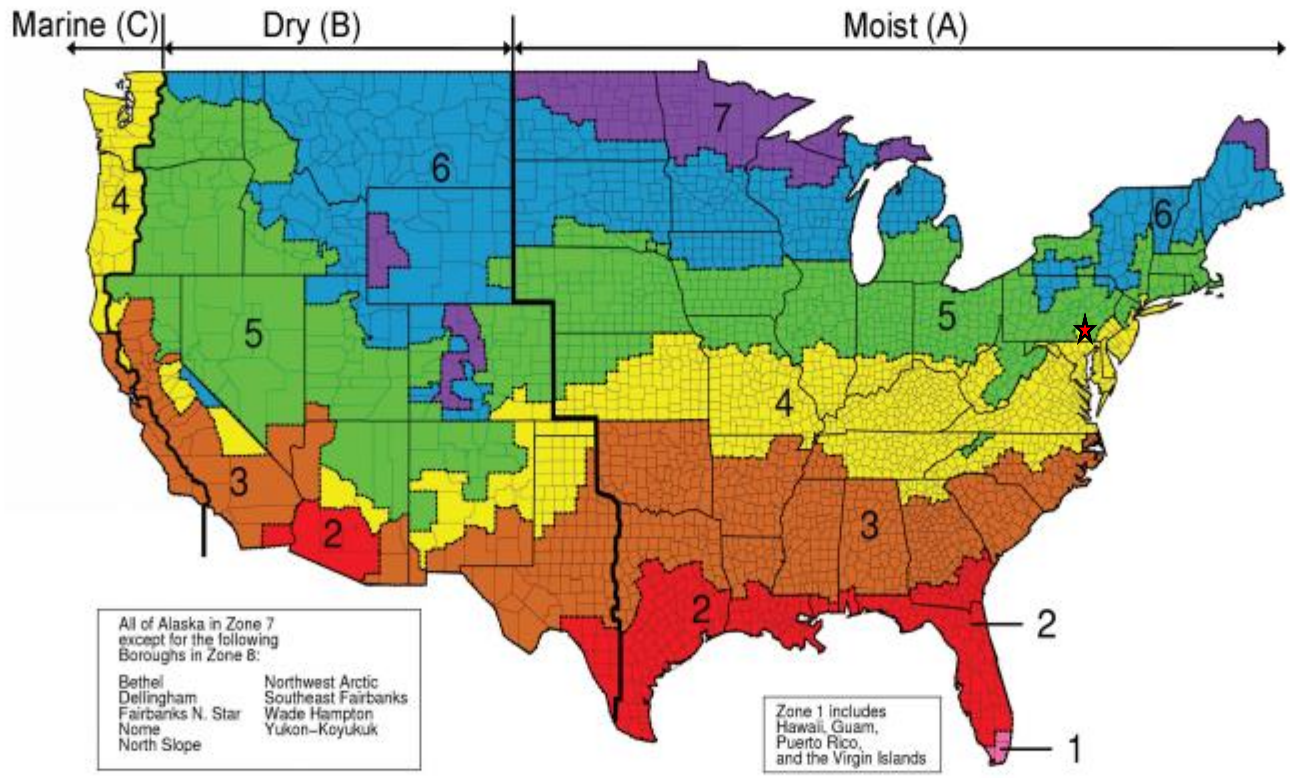

Figure 3: United States Climate Zone Map,
Taken from Figure B1-1, ASHRAE Standard 90.1 - 2013

From analyzing the United States Climate Zone Map, the Phoenixville Early Learning Center is in Zone 5A, indicated in Figure 3 by the star. Zone 4A categorizes the location as a warm and humid location. In Zone 4A most of the precipitation comes in the winter months and humid summers. The Zone generally has less than 4500 Cooling Degree Days and between 3600 and 5400 Heating Degree Days.

5.2 Compliance Paths:

The Prescriptive Building Envelope Option was chosen to show compliance of section 5. With this compliance path the Early Learning Center must comply with Section 5.1, 5.4, 5.5, 5.7, and 5.8.

5.4 Mandatory Provisions:

An air barrier has been constructed along the entirety of the exterior wall, controlling the interactions of air, as well as airborne particulates. There are two building entrances. Both building entrances have vestibules helping control air leakage within the building and maintaining the building pressurization.

5.5 Prescriptive Building Envelope:

The Early Learning Center complies with having less than 40% fenestration to wall ratio. As you can see in the table below the ELC takes advantage of the southern solar gain as well as the non-direct northern light.

Percent Fenstration					
	North	South	East	West	Roof
Surface Area (SF)	24295	17604	5618	10126	95007
Fenestration Area (SF)	6426	6567	793	2452	0
% Fenstration	26.4	37.3	14.1	24.2	0.0

Table 2: Percent Fenestration

The table below summarizes the building envelope requirements in Climate Zone 4A.

Building Construction: Climate Zone 4A				
Type	Description	Design U- Value	Required U-Value	Compliant?
Wall	Stacked Cementitious Siding Assembly	0.0526	0.06	Yes
Below-Grade Wall	12" Solid CMU Block with poured in place concrete footing	0.08	0.133	Yes
Roof	PVC Roofing with Aged R-30 Rigid Polyiso Insulation	0.0333	0.0333	Yes
Slab	5" Normal Weight Concrete, 2" Rigid Polysty Insulation	0.239	0.0667	No
Window	Venting Windows	0.29	0.5	Yes
Curtain Wall	Aluminum tube framing system with vision glass	0.19	0.16	Yes

Table 3: Building Construction: Climate Zone 4A

Section 6: Heating, Ventilating, and Air Conditioning

Section 6.2: Compliance Path

The Early Learning Center must comply with section 6.4, 6.5, as well as section 6.8. These different sections detail the mandatory provisions for the mechanical equipment as well as the prescriptive path for air travel and minimum equipment efficiency tables.

Section 6.4: Mandatory Provisions

The mandatory provisions outline the standard rating and operating conditions for all mechanical equipment. This information is show in in Tables 6.8.1-1 through 6.8.1-13 and must comply with the minimum requirements. The building automation system (BAS), is to be installed where the owner can have clear access to it. This system will be used to control all zones for usage by the building maintenance staff only. Walk in freezer complies with automatic door requirements and have all insulation materials needed. Furthermore, all ducts will be insulated in accordance with Tables 6.8.2-1 and 6.8.2-2. Piping throughout the building will also be insulated, minimizing the loss of heat through conduction.

Section 6.5: Prescriptive Path

The main form of heating and cooling within the Early Learning Center is through the use of hydronic heat pumps. There are 88 water source heat pumps as well as seven rooftop water source heat pumps. These heat pumps are very efficient and are able to recover energy as they circulate water. All water source heat pumps comply with section 6.5.2.2.3. This section details the controls for the heat pump temperature control as well as automatic valve shut offs.

When the building is operating at full design supply airflow rate the outdoor air intake is about one third of the total air that is being circulating around the building. Ventilation rates comply with Table 6.5.6.1-2, exhaust air energy recovery requirements, and recover energy over two thirds of return air.

Section 7: Service Water Heating

Section seven covers the service water heating requirements which includes efficiency, insulation, controls, servicing and types of heating equipment. With the building having 91 water source heat pumps this section was noted to pay close attention. All boilers specified have been given high efficiency rankings and meet all equipment efficiency requirements. Insulation is also to be strictly followed. The large amount of pipes need to see the least amount of heat loss as possible. Temperature maintenance controls will be provided to the owner upon turnover. These controls are contained within the building's BAS and given only access to maintenance personnel.

Section 8: Power

When the electricity comes into the building it first goes through a PECO Utility Transformer to drop the voltage to 277 and 408 volts. The electricity is then sent into the 2000 amp switchboard where it is distributed to panels across the building. Two other transformers are required to step the voltage down to 120/208 volts for usage in classrooms and offices.

Electrical drawings were configured to the detail of the National Electric Code, as well as the 2009 International Electrical Code and comply with all power requirements.

Section 9: Lighting

All lighting systems are to comply with sections 9.4, 9.5 and 9.7. These sections discuss controls, testing, lighting power densities, and submittals. Interior lighting controls are based on occupancy sensors with local manual overrides conserving energy when people are out of the space. Lighting power density levels comply with Table 9.5.1. As a school building, the lighting power density needed to be below 0.87 W/ft^2. The Early Learning Center complies with this code as most of their fixtures are florescent, which produces a very low lighting power density.

Section 10: Other Equipment

Section 10.4.1 addresses electric motors. ASHRAE sets standards on horsepower, usage, voltage to comply with the Energy Independence and Security Act of 2007. Within the specification, it is called out that all electric motors will comply with this act. Therefore, by providing this specification all motors installed in the building will be compliant with Section 10.4.1.

Summary of Compliance with ASHRAE 90.1-2013 Summary.

Overall, the Early Learning Center did very well with complying to ASHRAE 90.1 – 2013 standards. There was one instance where the U-value of the slab could have been more insulated. However, energy usage and energy recovery was designed very well within this building. The percentage of air that is taken through the enthalpy wheel is staggering and exciting for the owner of the building. The water source heat pumps perform very well, but do need a substantial amount of piping and pipe insulation. It could be a possibility to link up more water source heat pumps and reduce the amount of piping.

References:

SCHRADERGROUP architects. Architectural Construction Documents. SCHRADERGROUP architecture, Lancaster, PA

Barton Associates Inc. Mechanical, Electrical and Plumbing Construction Documents. Barton Associates, York, PA

ANSI/AHSRAE Standard 62.1 – 2013, Ventilation for Acceptable Indoor Air Quality. Atlanta, GA: American Society of Heating refrigeration and Air Conditioning Engineers, Inc.

ANSI/ASHRAE/IES Standard 90.1 – 2013, Energy Standard for Buildings Except Low-Rise Residential Buildings. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

Appendix 1A:

Job No. Tech 1	Subject		Sheet 1 of 1
Date Sep-15	ELC Building Loads	Minimum Ventilation & Exhaust Requirements	By NJA, Ckd By

System Type: Multi-zone system — System Ventilation Efficiency E_v 61.02 — Uncorrected Outdoor Intake V_{ou} 2209774 cfm

Total Zone Population 2685 people — Occupant Diversity 100.00 — Design AHU Outdoor Intake V_{ot} **36214 cfm**

Air Distribution Config. Ceiling or floor supply of warm air and floor return — Ez = 1

Space	Usage	V_z	P_z	A_z	$V_{z\ min}$	R_p	$R_p \times P_z$	R_a	$R_A \times A_z$	V_{bz}	V_{oz}	Z_p	E_{vz}	Exhaust
Zone 1	Classrooms (ages 5-8)	5220	162	7317	1566	10	1620	0.12	878.04	2498.04	2498.04	1.595	62.139	0
Zone 2	Corridors	2015	5	4910	605	0	0	0.06	294.6	294.6	294.6	0.487	63.247	0
Zone 3	Classrooms (ages 5-8)	5220	162	7383	1566	10	1620	0.12	885.96	2505.96	2505.96	1.600	62.134	0
Zone 4	Sports Locker Rooms	300	32	1597	90	0	0	0	0	0	0	0.000	63.734	798.5
Zone 5	Storage	300	3	2600	90	0	0	0.06	156	156	156	1.733	62.001	0
Zone 6	Corridors	1700	15	5228	510	0	0	0.06	313.68	313.68	313.68	0.615	63.119	0
Zone 7	Cafeteria / fast food	6360	500	5061	1908	7.5	3750	0.18	910.98	4660.98	4660.98	2.443	61.291	0
Zone 8	Kitchens (cooking)	1670	10	3034	501	0	0	0	0	0	0	0.000	63.734	2123.8
Zone 9	Media center	1245	50	2457	374	10	500	0.12	294.84	794.84	794.84	2.128	61.606	0
Zone 10	Classrooms (ages 5-8)	1395	81	2716	419	10	810	0.12	325.92	1135.92	1135.92	2.714	61.020	0
Zone 11	Corridors	1750	10	3221	525	0	0	0.06	193.26	193.26	193.26	0.368	63.366	0
Zone 12	Office space	2185	47	4064	656	5	235	0.06	243.84	478.84	478.84	0.730	63.004	0
Zone 13	Gym, stadium, arena (play area)	11100	1159	10321	3330	0	0	0.3	3096.3	3096.3	3096.3	0.930	62.804	0
Zone 14	Art classroom	1820	45	2473	546	10	450	0.18	445.14	895.14	895.14	1.639	62.095	1731.1
Zone 15	Classrooms (ages 5-8)	7010	220	8498	2103	10	2200	0.12	1019.76	3219.76	3219.76	1.531	62.203	0
Zone 16	Corridors	5270	5	3469	1581	0	0	0.06	208.14	208.14	208.14	0.132	63.602	0
Zone 17	Toilet Room - Public, Continuous	300	4	280	90	0	0	0	0	0	0	0.000	63.734	14000
Zone 18	Corridors	3355	5	4409	1007	0	0	0.06	264.54	264.54	264.54	0.263	63.471	0
Zone 19	Classrooms (ages 5-8)	4940	165	6317	1482	10	1650	0.12	758.04	2408.04	2408.04	1.625	62.109	0
Zone 20	Classrooms (ages 5-8)	5570	165	7000	1671	10	1650	0.12	840	2490	2490	1.490	62.244	0
Zone 21	Corridors	3970	5	5445	1191	0	0	0.06	326.7	326.7	326.7	0.274	63.460	0
Zone 22	Classrooms (ages 5-8)	5875	165	6965	1763	10	1650	0.12	835.8	2485.8	2485.8	1.410	62.324	0
Zone 23	Toilet Room - Public, Continuous	550	25	1000	165	0	0	0	0	0	0	0.000	63.734	50000
Zone 24	Reception areas	7080	300	11230	2124	5	1500	0.06	673.8	2173.8	2173.8	1.023	62.711	0
Zone 25	Art classroom	2915	50	2000	875	10	500	0.18	360	860	860	0.983	62.751	1400
Zone 26	Classrooms (ages 5-8)	1800	90	2825	540	10	900	0.12	339	1239	1239	2.294	61.440	0
Zone 27	Conference/meeting	3500	20	3400	1050	5	100	0.06	204	304	304	0.290	63.444	0
Zone 28	Classrooms (age 9 plus)	8000	140	8600	2400	10	1400	0.12	1032	2432	2432	1.013	62.721	0
Zone 29	Corridors	5000	10	5500	1500	0	0	0.06	330	330	330	0.220	63.514	0
Zone 30	Corridors	5000	10	3800	1500	0	0	0.06	228	228	228	0.152	63.582	0
Zone 31	Classrooms (age 9 plus)	5000	140	6800	1500	10	1400	0.12	816	2216	2216	1.477	62.257	0
		117415	**3800**		**35225**		**21935**		**16274.34**	**38209**	**38209**			**70053**