Technical Report: Part One

Rendering courtesy of Devrouax & Purnell Architects

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Option: Mechanical

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Executive Summary

Technical Report One evaluated the compliance of Elementary School One with ASHRAE 2013 Standards 62.1 and 90.1. Elementary School One is a school located in Town, Maryland. The existing school building was renovated and an addition was built on the west side of the building. Elementary School One modernization finished in 2011 and was designed using a much older standards like IBC 2006. The purpose of this report is to see if the building complies with the newer standards.

ASHRAE 62.1 required the building systems and equipment to meet the standards. The systems must be designed to provide ventilation minimum, prevent mold growth, and control indoor air quality. ASHRAE 90.1 sets standards for systems and building envelope are energy efficiency. This assessment involved the evaluation of the building materials and power, water, lighting, and HVAC systems.

After assessing Elementary School One for compliance with the standards, the building meets the majority of the requirements. The ventilation rate for a couple spaces did not comply, but this may be due to the change in standards over the years. The existing building envelope will be imperfect due to its age. Even though most of the building meets the standards, the building systems can be improved. There are more efficient equipment and new technology now compared to when Elementary School One was built.

Building Overview

Building Name:	Elementary School One
Location and Site:	Town, Maryland
Dates of Construction:	2010 – August 2011
Size:	84,400 sq. ft.
Number of Stories:	3 above and 1 below grade

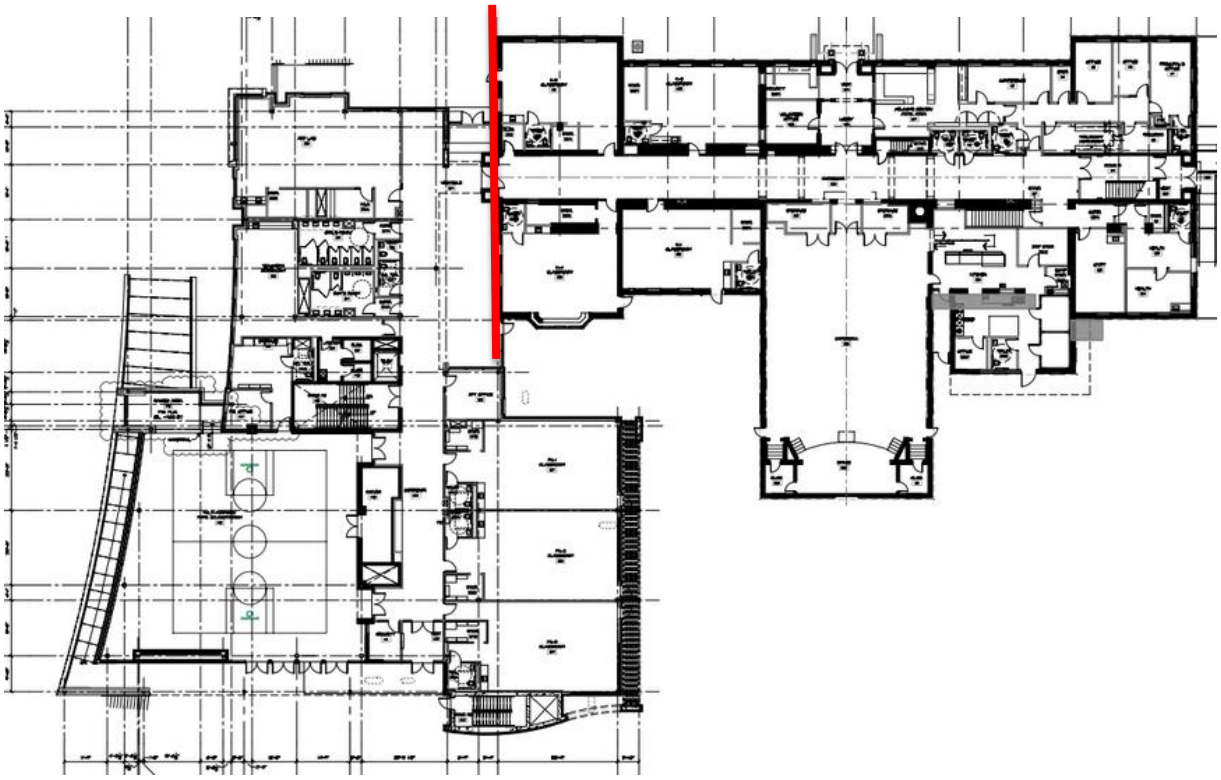

Figure 1: First Floor Plan.

The red line separates the existing building and the addition. The existing is on the right and the addition is on the left.

Mechanical Systems Summary

Elementary School One modernization involved a reinvasion of the existing building and adding an addition on the west side. All new mechanical systems were applied to both the existing and the addition. The mechanical system has three dedicated outside air RTUs that supply VAV boxes in each space. Each space then exhausts air back to the RTUs for heat wheel. There are three VRF systems that condition these spaces with dedicated outside area.

Two RTUs serve the cafeteria and two serve the multipurpose room. There are also base board radiators and cabinet heaters in some of the spaces near the exterior. In the administrative section of the existing building, an AHU conditions the spaces with its own outside air intake.

- RTU-1 and 2 serve cafeteria
- RTU-3 and 4 serve the existing building (heat wheel)
- RTU-5 serve the addition (heat wheel)
- RTU-6 and 7 serve the multipurpose room

ASHRAE 62.1 Evaluation

Section 5 – Systems and Equipment

5.1- Ventilation Air Distribution

Section 5.1.1 air balancing of the ventilation system must provide the means to adjust to achieve at least the minimum ventilation airflow required for the space. Most spaces are supplied a dedicated outside air system that reaches a VAV box for each space. The branches from the VAV box to the diffusers have a balancing damper, which both allow each space to get the appropriate OA flow. The RTUs that serve the cafeteria and multipurpose room have OA intake balancing within the unit. The administrative space that is served by its own AHU has a motorized damper to control the outside air intake to the unit.

Section 5.1.2 states when ceiling or floor plenum is used to reticulate return air and to distribute ventilation that the system must provide at least the minimum required ventilation airflow. This section does not apply to Elementary School One because the mechanical systems do not use a plenum.

Section 5.1.3 requires that air balance testing requirements to be documented. In specification 15950, states that all air systems must be balanced with accordance to Associated Air Balance Council (AABC), National Environmental

Balancing Bureau (NEBB), and Sheet Metal and Air Conditioning Contractor's National Association (SMACNA).

5.2- Exhaust Duct Location

Section 5.2 states that all harmful contaminants that are exhausted must be negatively pressured and not leak into any spaces that the duct passes through. All spaces that require exhaust such as bathrooms, storage, etc. have a negatively pressured duct that leads to an energy wheel and is not mixed with supply air.

5.3- Ventilation System Controls

Section 5.3 requires the ventilation system to be controlled manually or automatically to maintain at least the minimum outside air requirement. The mechanical ventilation system is controlled by VAV boxes, manual balancing dampers, air flow sensors and thermostats. The VAV boxes in each space have a minimum air flow setting and the airflow can be increased depending on the sensors' data sent to the RTUs. All controls are located on an interface with BAS and ATC.

5.4- Airstream Surfaces

Section 5.4 requires that all airstream surfaces must resist mold growth and erosion. In specification 15815, all ducts and airstream surfaces comply with ASTM, UL or SMACNA standards. All ducts are made of sheet metal and the duct accessories comply with the standards above.

5.5- Outdoor Air Intakes

Section 5.5 requires the outdoor air intakes to be a certain distance from potential outdoor contaminant sources. All outdoor air intakes meet the required distance and coverage from rain, snow and birds. All RTU's have parallel outside air intake and exhaust which are pointed away from the adjacent RTUs. This allows for the Class 4 air exhaust not to containment the supply air.

5.6- Local Capture of Contaminants

Section 5.6 states that non-combustion equipment discharge shall be directly ducted outdoors. The Elementary School does not have non-combustion equipment on site so this section does not apply.

5.7- Combustion Air

Section 5.7 requires fuel-burning appliances to be provided with sufficient air for combustion and if the appliance is vented that the vent goes directly outdoors. The fuel-burning appliances are the boilers in the basement and the generator on the roof. The mechanical room with boilers has exhaust that directly goes outside. The generator on the roof is open to the environment so no ventilation or exhaust required.

5.8- Particulate Matter Removal

Section 5.8 states that filters or air cleaners must have a rating of MERV of at least 8 and should be located upstream of coils or other devices that may have wet surfaces. Each RTU has a 2" thick pre-filter and a 4" thick MERV 13 filter. Having these filters in series exceeds the requirement for this section.

5.9- Dehumidification Systems

Section 5.9.1 requires occupied spaces to be 65% RH or less. The design supply air for the mechanical systems range from 48% to 53% RH and this meets the requirement.

Section 5.9.2 requires the outdoor air shall be equal to or greater than the exhaust airflow. From the air flow calculations given, the outside air equals the exhaust airflow. The fan speeds may have been changed by maintenance when installed to pressurize the building.

5.10- Drain Pans

Section 5.10 requires all drain pans for condensate producing equipment to have a slope at least 0.125 in/ft and the drain outlet at the lowest point. The specification 15738 states that drain pan installation must follow these requirements for the RTUs. Some of the units on the roof have drain pans with in the unit with an outlet at the lowest point which also complies. Condensate drain pans are installed by factory for the VRF units that connect into the storm water system.

5.11- Finned-Tube Coils and Heat Exchangers

Section 5.11.1 states that drain pans for cooling coils and heat exchangers that produce condensate must follow the drain pan requirements from section 5.10.

There is a heat exchanger in the mechanical room for the boilers and the heat exchanger has a drain pain that complies with section 5.10.

Section 5.11.2 requires certain spacing of finned-tube coils for cleaning. This section doesn't apply to this building.

5.12- Humidifiers and Water Spray Systems

Section 5.12 states that water in connect with ventilation air must be at least potable and obstructions must be downstream at the required distance. Elementary School One does not have humidifiers or water spray systems so this section does not apply.

5.13- Access for Inspection, Cleaning and Maintenance

Section 5.13 requires that all equipment must have enough space to access panels for maintenance and cleaning. Most of the dampers, controls, VAVs and VRFs are in spaces with drop down ceilings for easy access. The RTUs and other equipment are spaced appropriate to comply with this section. In specification 15183, install all VRF piping above accessible ceilings to allow sufficient space.

5.14- Building Envelope and Interior Surfaces

Section 5.14.1 requires the building envelope to have some water barrier or vapor retarder. The existing building is has load bearing brick which acts as a water barrier due to its thickness and ability to dry. The addition is a combination of glass curtain wall and face brick with vapor barrier and water proof sealants. Both of these types of envelope meet the requirements of this section.

Section 5.14.2 states that any duct or pipe on interior surface that may produce condensation needs to have insulation. All cold surfaces in the building have insulations so it complies.

5.15- Building with Attached parking Garages

Section 5.15 requires the attached parking garage to have a lower pressure that adjacent occupied space or an airlock vestibule between spaces. The school meets both requirements. There is a vestibule that separates the underground parking garage from the entrance into the building. The parking garage as direct exhaust and is open to the outside on the ramp going down to the garage.

5.16- Air Classification and Recirculation

Section 5.16 requires certain air classification can't be used again or recirculated to other spaces depending on that spaces air classification. Elementary School One ventilation system brings air into a space and exhausts it directly out. There is no mixing of air classification or reuse besides Class 4 air spaces like bathrooms are negatively pressured so hallway air will be pulled in which complies with this section.

5.17- Requirements for Building Containing ETS Areas and ETS-free Areas

There are no ETS areas in Elementary School One so the section does not apply.

Section 6 – Procedures

6.1- General

Section 6.1 requires the ventilation system must designed using Ventilation Rate Procedure, IAQ Procedure or Natural Ventilation Procedure. Elementary School One used the ventilation rate procedure to reach acceptable ventilation airflow.

6.2- Ventilation Rate Procedure

Section 6.2.11 and 6.2.12 require filtration system to be at least MERV of 6 and all AHUs exceed this requirement. The calculations for ventilation rate are described in this section. The calculation for ASHRAE 2013 compared to the designed values can be seen in Appendix A.

The design calculation were based on IMC 2006 and they were compared to ASHRAE 2013. Most of the design outside airflow complies with the newer standard except two spaces. The music room and science classroom both are not supplied with enough outside air. This may be due to the change in requirements of the years or classification of the space.

ASHRAE 62.1 Summary

Elementary School One complies with the majority of these standards and exceeds many of them. The only area that this building does not comply with the new code is the ventilation rate for two of the spaces. This may be due to the change of the standards through the years. Not many modifications with be needed to reach the modern standards, but the building can be improved.

ASHRAE 90.1 Evaluation

Section 5 – Building Envelope

5.1- General

Section 5.1.4 states how to determine the climate of the site. Elementary School One falls in climate zone 4A which can be seen in the image below. Zone 4A is an area what is middle temperature and moist. These factors affected the original design.

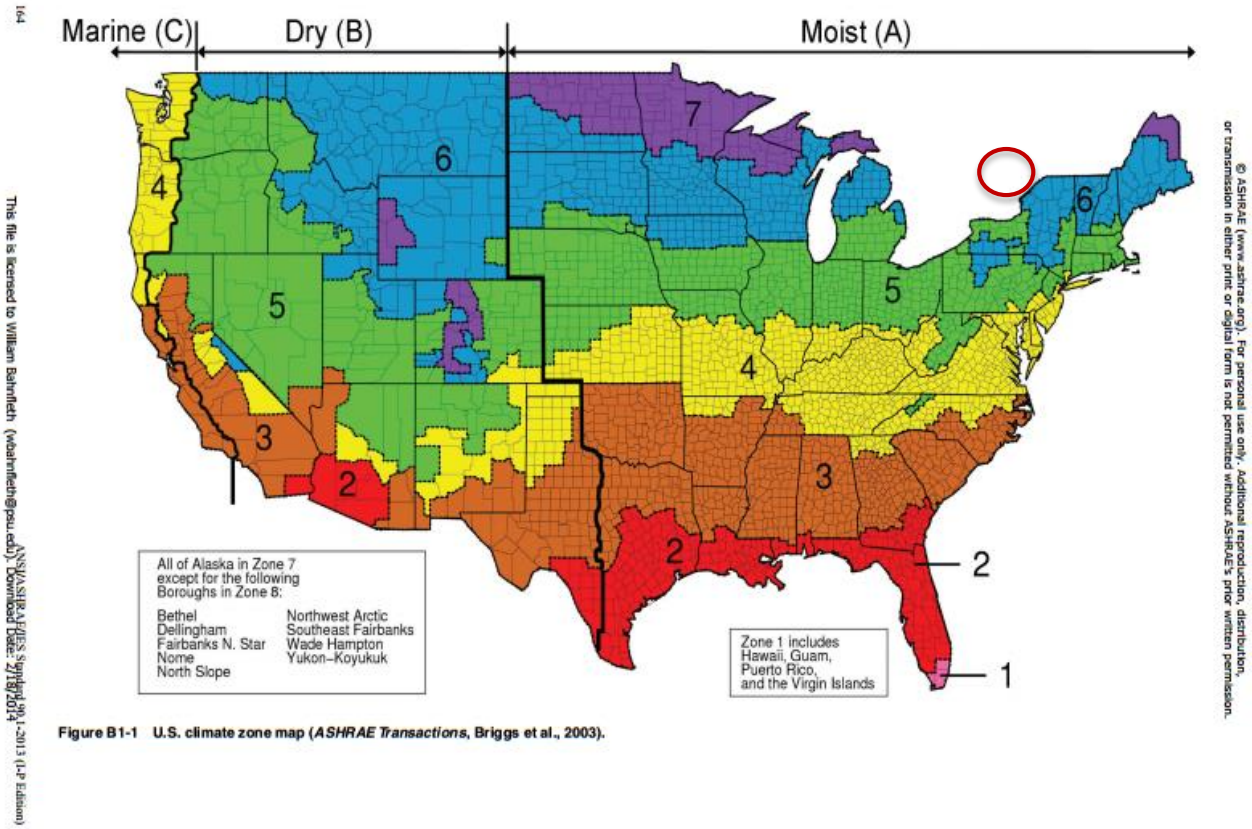

Figure B1-1 U.S. climate zone map (*ASHRAE Transactions*, Briggs et al., 2003).

Figure 2: The Climate Zone map from ASHRAE 90.1

5.2 Compliance Paths

The building construction complies with Section 5.5 by the method of Prescriptive Building Envelope Option. To comply, vertical fenestration area cannot exceed 40% of the gross wall area and the skylight fenestration does not exceed 5% of the gross roof area. Elementary School one meets both of these requires therefore can use this option.

5.4 Mandatory Provisions

Section 5.4.3 requires the building to have a continuous air barrier to prevent air leakage. The building meets this requirement.

5.5 Prescriptive Building Envelope Option

Elementary School one is nonresidential conditioned space and must comply with climate zone 4A requirements. They can be seen in the table to the right and the building meets the requirements.

Table 5.5-4 Building Envelope Re

Opaque Elements	Nonresidential Assembly Maximum	Nonresidential Insulation Min. R-Value
Roofs		
Insulation Entirely above Deck	U-0.032	R-30 c.i.
Metal Building[a]	U-0.037	R-19 + R-11 Ls or R-25 + R-8 Ls
Attic and Other	U-0.021	R-49
Walls, above Grade		
Mass	U-0.104	R-9.5 c.i.
Metal Building	U-0.060	R-0 + R-15.8 c.i.
Steel Framed	U-0.064	R-13 + R-7.5 c.i.
Wood Framed and Other	U-0.064	R-13 + R-3.8 c.i. or R-20
Wall, below Grade		
Below Grade Wall	C-0.119	R-7.5 c.i.
Floors		
Mass	U-0.057	R-14.6 c.i.
Steel Joist	U-0.038	R-30
Wood Framed and Other	U-0.033	R-30
Slab-on-Grade Floors		
Unheated	F-0.520	R-15 for 24 in.
Heated	F-0.843	R-20 for 24 in.
Opaque Doors		
Swinging	U-0.500	
Nonswinging	U-0.500	

Fenestration	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC
Vertical Fenestration, 0%–40% of Wall		(for all frame types)	
Nonmetal framing, all	U-0.35		
Metal framing, fixed	U-0.42		
Metal framing, operable	U-0.50	SHGC-0.40	1.10
Metal framing, entrance door	U-0.77		
Skylight, 0%–3% of Roof			
All types	U-0.50	SHGC-0.40	NR

Table 1: Building Envelope Requirements for climate zone 4 (A,B,C) from ASHRAE 90.1

Section 6– Heating, Ventilating, and Air Conditioning

6.1- General

The existing building modernization must comply with all parts in section 6.1.13 and the addition must comply with section 6.2. Elementary School One classifies as an addition and reinvasion. Some of the standards overlap, but must be treated separately.

6.2- Compliance Paths

Elementary School One uses the compliance path defined in section 6.4 (Mandatory provisions) and section 6.5 (Prescriptive Path).

6.4- Mandatory Provisions

The buildings equipment must met the minimum performance specified in the tables in Appendix B. Elementary School One complies with the requirements. Specification section 15088 complies with the pipe insulation and section 15086 meets the duct insulation requirement.

6.5- Prescriptive path

All cooling systems over 54,000 BTU/h must have an economizer. All RTUs have an economizer that serve Elementary School One. The dedicated outside air units utilize a heat wheel.

Section 7– Service Water Heating

The service water for heating is supplied from the five boilers in the mechanical room in the basement. There is a recirculation and heat exchanger to conserve energy. Complying with section 7.4.3, all equipment and piping are properly insulated. The water temperature is controlled by the building BAS interface.

Section 8– Power

Section 8.4.1 states the voltage drop for feeders must at a maximum of 2% and a maximum drop of 3% for branch circuits. Elementary School One power distribution complies with this section. There is an oil generator on the roof that can run the emergency lightning if needed.

Section 9– Lighting

Most lighting fixtures are recessed fluorescent in the school and compact fluorescent lamps are used in the multipurpose room. The lighting throughout the building is controlled by time switches, photoelectric switches, standalone daylight-harvesting switching controls and indoor occupancy sensors. These controls help save energy while meeting the lighting power density for the spaces. Elementary School One complies with the lighting power densities in table 9.5.1 which is 0.87 W/sf for schools.

ASHRAE 90.1 Summary

ASHRAE Standard 90.1 establishes minimum requirements for energy efficiency. The standard involves the building envelope and the systems. Elementary School One meet the new standards of ASHRAE 90.1. The existing building envelope will have imperfections because of its age. Elementary School One when it was modernized earned LEED Gold so the systems are energy efficacy. There is room for improvement because the design would not get LEED Gold on today standards and there is new technology that can be applied.

Appendix A

ASHRAE 62.1 Section 6 Ventilation Calculations

Existing Building

ASHRAE 62.1 2013 Section 6- Ventialtion Rate													
Existing Rooms		Designed Calculations			Ventilation Rate Factor								
Floor	Room	Area (sf)	# of People	Min OA (cfm)	Space Type	Rp	Occupant Density	Pz	Ra	Az	Required OA	Meets ASHRAE	Difference
1st	Cafeteria	3550	249	4980	Multiuse	7.5	100	355	0.06	3550	2876	YES	
1st	RM 123	210	2	40	Office	5	5	1	0.06	210	18	YES	
1st	RM 124	201	2	40	Office	5	5	1	0.06	201	17	YES	
1st	RM 101	780	30	450	Class	10	35	27	0.12	780	367	YES	
1st	RM 102	623	30	450	Class	10	35	22	0.12	623	293	YES	
1st	RM 125	294	3	60	Office	5	5	1	0.06	294	25	YES	
1st	CORR	1861	0	186	Corridor	0	0	0	0.06	1861	112	YES	
1st	RM 132	647	30	450	Class	10	35	23	0.12	647	304	YES	
1st	RM 133	688	30	450	Class	10	35	24	0.12	688	323	YES	
2nd	CONF	200	10	200	Conference	5	50	10	0.06	200	62	YES	
2nd	RM 201	706	30	450	Class	10	35	25	0.12	706	332	YES	
2nd	RM 202	706	30	450	Class	10	35	25	0.12	706	332	YES	
2nd	RM 203	494	4	80	Office	5	5	2	0.06	494	42	YES	
2nd	RM204	704	30	450	Class	10	35	25	0.12	704	331	YES	
2nd	RM 205	704	30	450	Class	10	35	25	0.12	704	331	YES	
2nd	CORR	1884	0	188	Corridor	0	0	0	0.06	1884	113	YES	
2nd	RM 208	704	30	450	Class	10	35	25	0.12	704	331	YES	
2nd	RM 209	704	30	450	Class	10	35	25	0.12	704	331	YES	
2nd	RM 211	707	30	450	Class	10	35	25	0.12	707	332	YES	
2nd	RM 212	706	30	450	Class	10	35	25	0.12	706	332	YES	
3rd	RM 301	706	30	450	Class	10	35	25	0.12	706	332	YES	
3rd	RM 302	708	30	450	Class	10	35	25	0.12	708	333	YES	
3rd	RM 303	940	30	450	Class	10	35	33	0.12	940	442	YES	
3rd	RM 304	703	30	450	Class	10	35	25	0.12	703	330	YES	
3rd	RM 305	704	30	450	Class	10	35	25	0.12	704	331	YES	
3rd	RM 307	700	30	450	Class	10	35	25	0.12	700	329	YES	
3rd	RM 308	705	30	450	Class	10	35	25	0.12	705	331	YES	
3rd	RM 309	707	30	450	Class	10	35	25	0.12	707	332	YES	
3rd	RM 310	706	30	450	Class	10	35	25	0.12	706	332	YES	
3rd	CORR	2004	0	200	Corridor	0	0	0	0.06	2004	120	YES	

Building Addition

ASHRAE 62.1 2013 Section 6- Ventialtion Rate													
Addition Rooms		Designed Calculations			Ventilation Rate Factor								
Floor	Room	Area (sf)	# of People	Min OA (cfm)	Space Type	Rp	Occupant Density	Pz	Ra	Az	Required OA	Meets ASHRAE	Difference
1st	AFT 136	203	2	40	Office	5	5	1	0.06	203	17	YES	
1st	ART LAB 135	1016	30	450	Art Class	10	20	20	0.18	1016	386	YES	
1st	CORR 144	2810	0	281	Corridor	0	0	0	0.06	2810	169	YES	
1st	PE OFFICE149	280	2	40	Office	5	5	1	0.06	280	24	YES	
1st	PK CLASS 137	1007	30	450	Class PK	10	25	25	0.12	1007	373	YES	
1st	PK CLASS 138	1007	30	450	Class PK	10	25	25	0.12	1007	373	YES	
1st	PK CLASS 139	1007	30	450	Class PK	10	25	25	0.12	1007	373	YES	
1st	STORAGE 147	128	0	19	Storage	5	2	0	0.06	128	9	YES	
1st	TEACHER 152	548	4	80	Office	5	5	3	0.06	548	47	YES	
1st	SECURITY 141	97	1	20	Office	5	5	0	0.06	97	8	YES	
1st	MULTIPURPOSE	4015	269	4035	Multiuse	7.5	100	402	0.06	4015	3252	YES	
2nd	SPEECH 230	132	1	20	Office	5	5	1	0.06	132	11	YES	
2nd	ASSIST 233	191	2	40	Office	5	5	1	0.06	191	16	YES	
2nd	CORR 216	940	0	94	Corridor	0	0	0	0.06	940	56	YES	
2nd	ESL 234	132	1	20	Office	5	5	1	0.06	132	11	YES	
2nd	PSYCH	156	2	40	Office	5	5	1	0.06	156	13	YES	
2nd	RES 213	263	2	40	Office	5	5	1	0.06	263	22	YES	
2nd	RES 214	251	2	40	Office	5	5	1	0.06	251	21	YES	
2nd	SOCIAL 229	135	1	20	Office	5	5	1	0.06	135	11	YES	
2nd	STAFF LOUGE 217	746	22	440	Breakroom	5	50	37	0.12	746	276	YES	
2nd	STUDENT SERV 23	350	3	60	Office	5	5	2	0.06	350	30	YES	
2nd	TEACHER 228	380	3	60	Office	5	5	2	0.06	380	32	YES	
3rd	BOOK STOR 314	501	0	75	Storage	5	2	1	0.06	501	35	YES	
3rd	CONF 326	150	8	160	Conference	5	50	8	0.06	150	47	YES	
3rd	CORR 327	935	0	94	Corridor	0	0	0	0.06	935	56	YES	
3rd	MUSIC 325	1240	30	450	Music	10	35	43	0.06	1240	508	NO	58.4
3rd	RES 312	251	2	40	Office	5	5	1	0.06	251	21	YES	
3rd	STORAGE 324	235	0	35	Storage	5	2	0	0.06	235	16	YES	
Basemen	AV CLOSET L17	198	2	40	Storage	5	2	0	0.06	198	14	YES	
Basemen	BOOK STOR L13	500	0	75	Storage	5	2	1	0.06	500	35	YES	
Basemen	CONF L20	180	6	120	Conference	5	50	9	0.06	180	56	YES	
Basemen	CONF L33	300	10	200	Conference	5	50	15	0.06	300	93	YES	
Basemen	CORR L07	1100	0	110	Corridor	0	0	0	0.06	1100	66	YES	
Basemen	CUST L31	337	3	45	Storage	5	2	1	0.06	337	24	YES	
Basemen	HEAD END L19	110	1	20	Storage	5	2	0	0.06	110	8	YES	
Basemen	MEDIA L18A	514	4	80	Office	5	5	3	0.06	514	44	YES	
Basemen	OFFICE L23	320	3	45	Office	5	5	2	0.06	320	27	YES	
Basemen	READING RM L21	3110	63	945	Libraries	5	10	31	0.12	3110	529	YES	
Basemen	STORAGE L32	303	0	45	Storage	5	2	1	0.06	303	21	YES	
Basemen	SCIENCE L01	1205	30	450	Class	10	35	42	0.12	1205	566	NO	116.35

Appendix B

TABLE 6.8.1-1 Electrically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure[a]
Air conditioners, air cooled	<65,000 Btu/h[b]	All	Split system	13.0 SEER	AHRI 210/240
			Single package	13.0 SEER (before 1/20/15) 14 SEER (as of 1/1/2015)	
Through the wall, air cooled	≤30,000 Btu/h[b]	All	Split system	12.0 SEER	
			Single package	12.0 SEER	
Small duct high velocity, air cooled	<65,000 Btu/h[b]	All	Split System	11.0 SEER	
Air conditioners, air cooled	≥65,000 Btu/h and <135,000 Btu/h	Electric resistance (or none)	Split system and single package	11.2 EER 11.4 IEER (before 1/1/2016) 12.9 IEER (as of 1/1/2016)	AHRI 340/360
		All other	Split system and single package	11.0 EER 11.2 IEER (before 1/1/2016) 12.7 IEER (as of 1/1/2016)	
	≥135,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	Split system and single package	11.0 EER 11.2 IEER (before 1/1/2016) 12.4 IEER (as of 1/1/2016)	
		All other	Split system and single package	10.8 EER 11.0 IEER (before 1/1/2016) 12.2 IEER (as of 1/1/2016)	
	≥240,000 Btu/h and <760,000 Btu/h	Electric resistance (or none)	Split system and single package	10.0 EER 10.1 IEER (before 1/1/2016) 11.6 IEER (as of 1/1/2016)	
		All other	Split system and single package	9.8 EER 9.9 IEER (before 1/1/2016) 11.4 IEER (as of 1/1/2016)	
	≥760,000 Btu/h	Electric resistance (or none)	Split system and single package	9.7 EER 9.8 IEER (before 1/1/2016) 11.2 IEER (as of 1/1/2016)	
		All other	Split system and single package	9.5 EER 9.6 IEER (before 1/1/2016) 11.0 IEER (as of 1/1/2016)	

a. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
b. Single-phase, air-cooled air conditioners <65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

TABLE 6.8.1-6 Gas- and Oil-Fired Boilers—Minimum Efficiency Requirements

Equipment Type[a]	Subcategory or Rating Condition	Size Category (Input)	Minimum Efficiency	Efficiency as of 3/2/2020	Test Procedure
Boilers, hot water	Gas fired	<300,000 Btu/h[f,g]	82% AFUE	82% AFUE	10 CFR Part 430
		≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	80% E_t	80% E_t	10 CFR Part 431
		>2,500,000 Btu/h[a]	82% E_c	82% E_c	
	Oil fired[e]	<300,000 Btu/h[g]	84% AFUE	84% AFUE	10 CFR Part 430
		≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	82% E_t	82% E_t	10 CFR Part 431
		>2,500,000 Btu/h[a]	84% E_c	84% E_c	
Boilers, steam	Gas fired	<300,000 Btu/h[f]	80% AFUE	80% AFUE	10 CFR Part 430
	Gas fired—all, except natural draft	≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	79% E_t	79% E_t	10 CFR Part 431
		>2,500,000 Btu/h[a]	79% E_t	79% E_t	
	Gas fired—natural draft	≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	77% E_t	79% E_t	
		>2,500,000 Btu/h[a]	77% E_t	79% E_t	
	Oil fired[e]	<300,000 Btu/h	82% AFUE	82% AFUE	10 CFR Part 430
		≥300,000 Btu/h and ≤2,500,000 Btu/h[d]	81% E_t	81% E_t	10 CFR Part 431
		>2,500,000 Btu/h[a]	81% E_t	81% E_t	

a. These requirements apply to boilers with rated input of 8,000,000 Btu/h or less that are not packaged boilers and to all packaged boilers. Minimum efficiency requirements for boilers cover all capacities of packaged boilers.
b. E_c = combustion efficiency (100% less flue losses). See reference document for detailed information.
c. E_t = thermal efficiency. See reference document for detailed information.
d. Maximum capacity—minimum and maximum ratings as provided for and allowed by the unit's controls.
e. Includes oil-fired (residual).
f. Boilers shall not be equipped with a constant burning pilot light.
g. A boiler not equipped with a tankless domestic water heating coil shall be equipped with an automatic means for adjusting the temperature of the water such that an incremental change in inferred heat load produces a corresponding incremental change in the temperature of the water supplied.

TABLE 6.8.1-9 Electrically Operated Variable-Refrigerant-Flow Air Conditioners—Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure
VRF air conditioners, air cooled	<65,000 Btu/h	All	VRF multisplit system	13.0 SEER	AHRI 1230
	≥65,000 Btu/h and <135,000 Btu/h	Electric resistance (or none)	VRF multisplit system	11.2 EER 12.5 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	VRF multisplit system	11.0 EER 12.3 IEER	
	≥240,000 Btu/h	Electric resistance (or none)	VRF multisplit system	10.0 EER 11.1 IEER	

TABLE 6.8.1-10 Electrically Operated Variable-Refrigerant-Flow Air-to-Air and Applied Heat Pumps—Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure
VRF air cooled (cooling mode)	<65,000 Btu/h	All	VRF multisplit system	13.0 SEER	AHRI 1230
	≥65,000 Btu/h and <135,000 Btu/h	Electric resistance (or none)	VRF multisplit system	11.0 EER 12.3 IEER	
	≥65,000 Btu/h and <135,000 Btu/h	Electric resistance (or none)	VRF multisplit system with heat recovery	10.8 EER 12.1 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	VRF multisplit system	10.6 EER 11.8 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	VRF multisplit system with heat recovery	10.4 EER 11.6 IEER	
	≥240,000 Btu/h	Electric resistance (or none)	VRF multisplit system	9.5 EER 10.6 IEER	
	≥240,000 Btu/h	Electric resistance (or none)	VRF multisplit system with heat recovery	9.3 EER 10.4 IEER	
VRF water source (cooling mode)	<65,000 Btu/h	All	VRF multisplit systems 86°F entering water	12.0 EER	AHRI 1230
	<65,000 Btu/h	All	VRF multisplit systems with heat recovery 86°F entering water	11.8 EER	
	≥65,000 Btu/h and <135,000 Btu/h	All	VRF multisplit system 86°F entering water	12.0 EER	
	≥65,000 Btu/h and <135,000 Btu/h	All	VRF multisplit system with heat recovery 86°F entering water	11.8 EER	
	≥135,000 Btu/h	All	VRF multisplit system 86°F entering water	10.0 EER	
	≥135,000 Btu/h	All	VRF multisplit system with heat recovery 86°F entering water	9.8 EER	
VRF groundwater source (cooling mode)	<135,000 Btu/h	All	VRF multisplit system 59°F entering water	16.2 EER	AHRI 1230
	<135,000 Btu/h	All	VRF multisplit system with heat recovery 59°F entering water	16.0 EER	
	≥135,000 Btu/h	All	VRF multisplit system 59°F entering water	13.8 EER	
	≥135,000 Btu/h	All	VRF multisplit system with heat recovery 59°F entering water	13.6 EER	

TABLE 6.8.2-2 Minimum Duct Insulation R-Value,[a]
Combined Heating and Cooling Supply Ducts and Return Ducts

Climate Zone	Duct Location						
	Exterior	Ventilated Attic	Unvented Attic Above Insulated Ceiling	Unvented Attic with Roof Insulation[a]	Unconditioned Space[b]	Indirectly Conditioned Space[c]	Buried
				Supply Ducts			
1	R-6	R-6	R-8	R-3.5	R-3.5	None	R-3.5
2	R-6	R-6	R-6	R-3.5	R-3.5	None	R-3.5
3	R-6	R-6	R-6	R-3.5	R-3.5	None	R-3.5
4	R-6	R-6	R-6	R-3.5	R-3.5	None	R-3.5
5	R-6	R-6	R-6	R-1.9	R-3.5	None	R-3.5
6	R-8	R-6	R-6	R-1.9	R-3.5	None	R-3.5
7	R-8	R-6	R-6	R-1.9	R-3.5	None	R-3.5
8	R-8	R-8	R-8	R-1.9	R-6	None	R-6
				Return Ducts			
1 to 8	R-3.5	R-3.5	R-3.5	None	None	None	None

a. Insulation R-values, measured in (h·ft^2·°F)/Btu, are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Where exterior walls are used as plenum walls, wall insulation shall be as required by the most restrictive condition of Section 6.4.4.2 or Section 5. Insulation resistance measured on a horizontal plane in accordance with ASTM C518 at a mean temperature of 75°F at the installed thickness.
b. Includes crawlspaces, both ventilated and nonventilated.
c. Includes return air plenums with or without exposed roofs above.

TABLE 6.8.3-1 Minimum Piping Insulation Thickness
Heating and Hot Water Systems[a,b,c,d,e]
(Steam, Steam Condensate, Hot Water Heating and Domestic Water Systems)

Fluid Operating Temperature Range(°F) and Usage	Insulation Conductivity		≥Nominal Pipe or Tube Size, in.				
	Conductivity, Btu·in./(h·ft^2·°F)	Mean Rating Temperature, °F	<1	1 to <1-1/2	1-1/2 to <4	4 to <8	≥8
			Insulation Thickness, in.				
>350°F	0.32–0.34	250	4.5	5.0	5.0	5.0	5.0
251°F–350°F	0.29–0.32	200	3.0	4.0	4.5	4.5	4.5
201°F–250°F	0.27–0.30	150	2.5	2.5	2.5	3.0	3.0
141°F–200°F	0.25–0.29	125	1.5	1.5	2.0	2.0	2.0
105°F–140°F	0.22–0.28	100	1.0	1.0	1.5	1.5	1.5

a. For insulation outside the stated conductivity range, the minimum thickness (T) shall be determined as follows: $T = r\{(1 + t/r)^{K/k} - 1\}$, where T = minimum insulation thickness (in.), r = actual outside radius of pipe (in.), t = insulation thickness listed in this table for applicable fluid temperature and pipe size, K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature (Btu·in./h·ft2·°F); and k = the upper value of the conductivity range listed in this table for the applicable fluid temperature.
b. These thicknesses are based on energy efficiency considerations only. Additional insulation is sometimes required relative to safety issues/surface temperature.
c. For piping smaller than 1.5 in. and located in partitions within conditioned spaces, reduction of these thicknesses by 1 in. shall be permitted (before thickness adjustment required in footnote [a]) but not to thicknesses below 1 in.
d. For direct-buried heating and hot-water system piping, reduction of these thicknesses by 1.5 in. shall be permitted (before thickness adjustment required in footnote [a]) but not to thicknesses below 1 in.
e. The table is based on steel pipe. Nonmetallic pipes schedule 80 thickness or less shall use the table values. For other nonmetallic pipes having thermal resistance greater than that of steel pipe, reduced insulation thicknesses are permitted if documentation is provided showing that the pipe with the proposed insulation has no more heat transfer per metre than a steel pipe of the same size with the insulation thickness shown in the table.

TABLE 6.8.3-2 Minimum Piping Insulation Thickness
Cooling Systems (Chilled Water, Brine, and Refrigerant)[a,b,c,d]

Fluid Operating Temperature Range (°F) and Usage	Insulation Conductivity		Nominal Pipe or Tube Size, in.				
	Conductivity, Btu·in./(h·ft^2·°F)	Mean Rating Temperature, °F	<1	1 to <1-1/2	1-1/2 to <4	4 to <8	≥8
			Insulation Thickness, in.				
40°F–60°F	0.21–0.27	75	0.5	0.5	1.0	1.0	1.0
<40°F	0.20–0.26	50	0.5	1.0	1.0	1.0	1.5

a. For insulation outside the stated conductivity range, the minimum thickness (T) shall be determined as follows: $T = r\{(1 + t/r)^{K/k} - 1\}$, where T = minimum insulation thickness (in.), r = actual outside radius of pipe (in.), t = insulation thickness listed in this table for applicable fluid temperature and pipe size, K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature (Btu·in./h·ft2·°F); and k = the upper value of the conductivity range listed in this table for the applicable fluid temperature.
b. These thicknesses are based on energy efficiency considerations only. Issues such as water vapor permeability or surface condensation sometimes require vapor retarders or additional insulation.
c. For direct-buried cooling system piping, insulation is not required.
d. The table is based on steel pipe. Nonmetallic pipes schedule 80 thickness or less shall use the table values. For other nonmetallic pipes having thermal resistance greater than that of steel pipe, reduced insulation thicknesses are permitted if documentation is provided showing that the pipe with the proposed insulation has no more heat transfer per foot than a steel pipe of the same size with the insulation thickness shown in the table.