TECHNICAL REPORT 3

CENTRAL HIGH SCHOOL MID-ATLANTIC REGION

ADAM BROWN

MECHANICAL OPTION

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Contents

Executive Summary

This report contains the analysis of Central High School's existing mechanical system in place. Included are design objectives and its influences, energy usage, LEED analysis and cost of the system.

Primarily electricity and natural gas are used as the primary energy sources on site. Almost 1.2 million lbm/year of CO2 is produced primarily because of the boiler. This along with other air pollutants should be reduced for the safety and health for people and the environment.

As this building was not built with LEED in mind it has sustainable features. Energy recovery wheels in the energy recovery units are part of the sustainable design and give rebates to the school. Ventilation requirements have been meet and exceeded according to ASHRAE 62.1 standards. Also VFD pumps are used to circulate hot and chilled water throughout the building depending on the demand. LEED Certified is achievable by the mechanical system alone but short 4 points.

The mechanical system costs $51.89 per square foot of space in the building. Mechanical mezzanines take up the most space followed by the boiler room and mechanical shafts.

Building Overview

Building Description

Central High School is a newly renovated high school located in the Mid-Atlantic region. At roughly 320,000 square feet it is an impressive state of the art school with two levels the top one being the addition. The building has food and science labs, classrooms, offices, gyms and an auditorium to serve the learning needs of the occupants. It is expected to be completed by February 2015.

Mechanical System Overview

Twenty energy recovery units are located throughout the building that delivers outdoor air to fan coil units with recirculated air serving the zones. Along with that, two air cooled chillers and a boiler serve the energy recovery units and fan coil units.

Occupant and Project Team

Owner: Confidential

Construction Manager: Jacobs http://jacobs.com/

Architect: SHW Group, LLP http://www.shwgroup.com/

Structural Engineer: Adtek Engineers, INC. http://www.adtekengineers.com/

Mechanical and Electrical Engineers: SHW Group, LLP http://www.shwgroup.com/

Civil Engineers: Bowman Consulting http://www.bowmanconsulting.com/

Kitchen Consultant: Nyikos Associates http://nyikosassociates.com/

Acoustical and Technology: Polysonics Corporation http://www.polysonics-corp.com/

Design Objectives and Requirements

Mechanical System Design Objectives

The driving force behind the renovation and new construction was to bring Central High School up to date and make it a state of the art school. Even though LEED was not a target for this project creating a mechanical system that would sustain the building was. By doubling the size of the area of the building a central chiller and boiler plant was put in place so that they could handle the new loads on the building. Energy recovery units served from the central plants helped recover much of the energy from exhaust air. The total energy wheels within these units are designed to help keep energy consumption down as a whole for the entire system in place. Fan coil units were also added to help better handle the loads in each zone. Therefore the combination of all three components would hopefully help make Central High School a state of the art school.

Mechanical System Design Requirements

Currently the two main codes that are being followed are ASHRAE Standards 90.1 and 62.1. These two main codes are crucial for design as there are no zoning issues that are being taken into account at this time. Furthermore a stringent commissioning process is in place to make sure that after construction the building's mechanical systems are compliant and run as prescribed per specifications.

Site Energy Sources

The two main sources of energy are electricity and natural gas. Due to the site being so close to the Baltimore, Maryland area typical rates from there were used. Many energy source providers are present in and around the area but the two listed below in Table 1 are the lowest prices per unit. These factors do not include delivery cost, contract length and initial cost to the customer. However with natural gas if the customer goes over the 10,000 therms the cost become $.1303 per therm.

Source Type	Provider	Price
Electricity	ConEdison Solutions	8.15 cents/kWh
Natural Gas	BGE	$0.261/therm

Table 1 – Utility Rates

Site Factors

Central High School's mechanical system was renovated and updated with energy recovery units due to the fact that rebates were given if they were chosen to be used. Therefore the mechanical system was re-designed in this case with the idea of using these energy recovery units to receive the rebate.

Design Conditions

Closet to the site is Baltimore, Maryland whose outdoor design conditions are listed in Appendix A. Indoor conditions for the summer time are set to be at 55 degrees Fahrenheit. For winter design conditions the set point varies by each space by the energy recovery unit that serves it which is shown in Appendix A.

Design Ventilation Requirements

In Table 2 below the ventilation rates from the design engineer and calculated rates are compared. Ventilation was increased from the minimum compliance of ASHRAE 62.1 for every energy recovery unit in the building. Therefore the design engineer meet and exceeded the minimum rate required for each space.

Ventilation Compliance ASHRAE 62.1 -2010			
System	OA Minimum	OA Designed Minimum	OA Provided
ERU-1	5700	9060	11780
ERU-2A/B	1500	2010	3400
ERU- 3	3400	4504	6990
ERU- 4	950	1255	1655
ERU- 5	3410	3070	3500
ERU- 6	430	495	1535
ERU- 7	13235	14598	20130
ERU- 8	16000	21260	28360
ERU- 9	2900	3730	5570
ERU- 10	3070	3531	4700
ERU- 11	1900	2250	4500
ERU- 12/13	7155	15000	21540
ERU- 14	705	1250	2295
ERU- 15	7570	7440	10660
ERU- 16	2235	1800	2170
ERU- 17	2000	3012	4050
ERU- 18/19	11200	13620	18960
ERU- 20	1770	2171	2925

Table 2 – Ventilation Rates

Design Heating and Cooling

Table 3 shows the comparison between the design and calculated heating and cooling loads for the building. Trane TRACE 700 was the program used for the model. Information for the design part was taken from drawings and specifications since the energy model was not released for comparison. The model shows a difference of almost 1.3 and 1.1 times more cooling and heating, respectively, needed than what the building systems were designed to. Therefore factors such as equipment, lighting and shading were assumed and would account for the differences between the design and model load calculations.

	Design	Model
Cooling [tons]	505	678
Heating [MBH]	11289	13147
Cooling [sf/ton]	634	472
Heating [Btuh/sf]	35	41
Supply [cfm/sf]	0.51	1.22
Ventilation [cfm/sf]	0.48	0.41

Table 3 – Heating and Cooling Loads

Energy Usage

Also from the Trane TRACE 700 model is the energy usage for the building on a monthly basis for the year shown in Figure 1 below. Electric and natural gas use were broken down into on and off peak demand times to show how much was being used during those periods. No comparison could be made with the mechanical engineer's energy calculations for the building.

MONTHLY ENERGY CONSUMPTION

By ACADEMIC

------- Monthly Energy Consumption -------

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 1	**Central High School**												
Electric													
On-Pk Cons. (kWh)	63,134	56,815	69,836	69,075	101,159	65,924	74,500	71,221	99,198	75,626	69,947	61,678	878,111
On-Pk Demand (kW)	421	414	496	558	790	1,010	1,099	1,003	869	614	556	434	1,099
Off-Pk Demand (kW)	63	63	63	54	54	54	54	54	54	54	54	63	63
Mid-Pk Demand (kW)	330	330	339	397	649	839	975	894	711	456	384	339	975
Gas													
On-Pk Cons. (therms)	488	459	132	0	0	0	0	0	0	5	14	223	1,321
Off-Pk Cons. (therms)	570	499	42	0	0	0	0	0	0	0	30	298	1,440
Mid-Pk Cons. (therms)	3,008	2,644	2,172	969	1	0	0	0	2	1,345	1,726	2,308	14,176
On-Pk Demand (therms/hr)	18	18	7	0	0	0	0	0	0	1	2	12	18
Off-Pk Demand (therms/hr)	5	5	1	0	0	0	0	0	0	0	1	2	5
Mid-Pk Demand (therms/hr)	68	68	54	39	2	0	0	0	0	44	51	62	68

Energy Consumption		
Building	18,759	Btu/(ft2-year)
Source	43,092	Btu/(ft2-year)
Floor Area	250,039	ft2

Environmental Impact Analysis		
CO2	1,174,596	lbm/year
SO2	10,577	gm/year
NOX	2,024	gm/year

ACADEMIC USE ONLY

Figure 1 – Energy Usage

Mechanical Schematic – Water Side

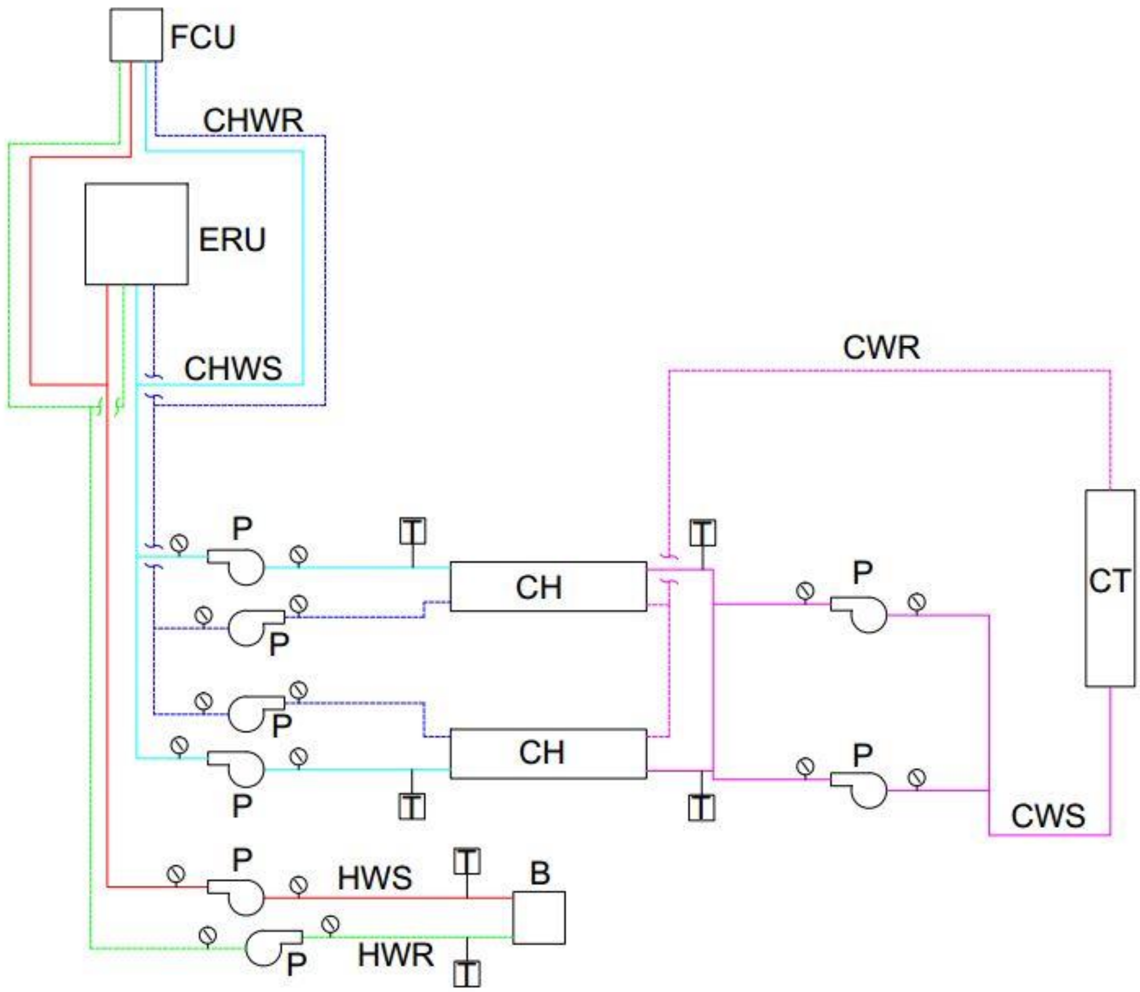

Figure 2 – Mechanical Schematic – Water Side

Central High School has a central plant for the water side of its mechanical system as laid out in Figure 2. Two chillers create chilled water that is pumped to the energy recovery units and fan coil units. After use the chilled water is then returned to the chillers where the heat is rejected to a refrigerant that rejects heat to a water loop. From there the heat is rejected to the outdoor air through the use of a cooling tower. For heating a natural gas boiler creates hot water for both the energy recovery units and fan coil units. After use the hot water is returned back to the boiler.

Mechanical Schematic – Air Side

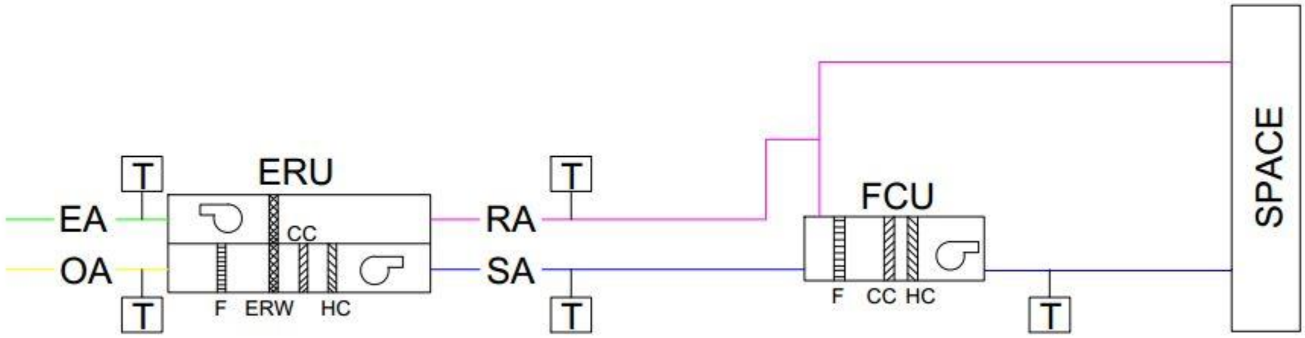

Figure 3 – Mechanical Schematic – Air Side

The two main pieces of mechanical equipment that deliver air to the space are energy recovery units and fan coil units as laid out in Figure 3. Outdoor air is pulled through the energy recovery unit and then pumped through the duct work to the fan coil unit. Return and outdoor air are mixed within the plenum and the fan coil unit then supplies this mixed air to the space. Afterwards some return is exhausted through the energy recovery unit to the outside of the building.

System Operation – Water Side

When the building requires cooling the chillers produce chilled water to meet this demand. Chilled water from the chillers is pumped by two VFD pumps that have pressure gauges on both the suction and discharge sides shown in Figure 2. This will tell the pumps how much flow the spaces need in order to satisfy the heating loads. Both the energy recovery units and fan coil units require chilled water to meet the load demand. After satisfying the loads water is returned by two VFD pumps to the chillers where the refrigerants R-134A and R-22 take the heat and reject it to a water loop. That water is then run through a cooling tower and the heat is rejected to the outdoor air. Two more VFD pumps then pump the now chilled water through the chillers to be distributed to the energy recovery units and fan coil units. Thermometers are set and calibrated on both the supply and return side of the chillers to make sure the correct temperature of chilled water is made depending on the demand of the loads.

System Operation – Air Side

Fresh outdoor air is pulled through the energy recovery unit that goes through a filter, energy recovery wheel, cooling coil and then a heating coil. The addition of the energy recovery wheel allows the heating coil to not work as hard especially when the outdoor air is at a freezing temperature. A thermostat is placed on both the outdoor, supply, return and exhaust ends of the energy recovery unit shown in Figure 3. This controls how much the air needs to be conditioned and if the energy recovery wheel needs to operate. Outdoor air is pumped through the ductwork to fan coil units where it mixes in the plenum space with return air. The amount of return air mixed with outdoor air to the fan coil unit and to what temperature is controlled by thermostats placed on the outdoor, return and supply sides. A carbon monoxide sensor system is in place to make sure the levels within the spaces does not exceed a certain amount that would be harmful to the occupants. Exhaust systems for labs, bathrooms, kitchens, and equipment rooms were omitted from this schematic.

Mechanical Systems Cost

Table 4 gives the total first cost of the mechanical system to be put into place for the building. It is above $16.6 million that is then spread out over an area of 320,000 square feet. This gives a cost per square foot for the entire mechanical system to be about $52. However the school is getting a rebate by using energy recovery units which has not been factored in for the initial cost.

Total First Cost	$16,604,704.00
Cost per sq. ft.	$51.89

Table 4 – Mechanical System Cost

Major Mechanical Equipment

Listed in Table 4 are the major pieces of mechanical equipment. This list includes heating and cooling equipment along with air distribution units.

Major Mechanical Equipment							
Tag	Equipment	Input/Output (MBH)		Max Pressure (lb)			
B-1	Cast Iron Boiler	9805/7872		40			
		Load/Source (GPM)					
HX-1	Heat Exchanger	500/540					
		Compressor (kW/Ton)		Evaporator Flow (GPM)			
CHL-3	Air Cooled Chiller	1.13		540			
CHL-4	Air Cooled Chiller	3.52		92			
		GPM	Head (ft)	HP	RPM	Efficiency (%)	
P-1A/B	VFD Pump - Boiler	1675	122	75	1750	84.8	
P-2A/B	VFD Pump - Chillers	1500	70	40	1750	83.2	
P-3A/B	VFD Pump - Chillers	2000	110	75	1750	82.7	
P-4A/B	VFD Pump - Chillers	1560	80	50	1750	85.3	
		Tank Volume (Gal)		Acceptance Volume (Gal)			
ET-1	Expansion Tank	300		300			
		GPM					
AS-1	Air Seperator	975					
AS-2	Air Seperator	540					
			Capacity (MBH)				
CU-1	Air Cooled Condensing Unit		18				
CU-2	Air Cooled Condensing Unit		12				
CU-3	Air Cooled Condensing Unit		36				
CU-4	Air Cooled Condensing Unit		48				
		Supply (CFM)	Exhaust (CFM)	Total GPM	Cooling (MBH)	Heating (MBH)	ER Wheel (HP)
ERU-1	Energy Recovery Unit	12100	10800	141.8	484.3	609.9	0.05
ERU-2A/B	Energy Recovery Unit	1700	1650	18.4	65.1	66.7	0.05
ERU-3	Energy Recovery Unit	6990	6790	61.9	166.6	313.5	0.05
ERU-4	Energy Recovery Unit	1655	1580	16.2	40.5	86.5	0.05
ERU-5	Energy Recovery Unit	6000	3500	66	222.9	329.3	0.05
ERU-6	Energy Recovery Unit	1535	1515	16.2	40.5	86.5	0.05
ERU-7	Energy Recovery Unit	20393	20130	174.6	840.7	339.1	0.50
ERU-8	Energy Recovery Unit	28655	28360	245.9	1160	480.7	0.50
ERU-9	Energy Recovery Unit	5570	5345	49.2	196.5	63.4	0.05
ERU-10	Energy Recovery Unit	4700	3400	42.3	171	57.7	0.05
ERU-11	Energy Recovery Unit	8480	4500	95.9	333.3	336.5	0.05
ERU-12	Energy Recovery Unit	10700	10700	118.5	395	590.6	0.05
ERU-13	Energy Recovery Unit	10700	10700	118.5	395	590.6	0.05
ERU-14	Energy Recovery Unit	2295	2175	19.9	50.7	97.3	0.05
ERU-15	Energy Recovery Unit	10660	10660	118.5	395	590.6	0.05
ERU-16	Energy Recovery Unit	4420	2170	49.7	154.4	244.1	0.05
ERU-17	Energy Recovery Unit	4050	3830	39.1	110.4	178.1	0.05
ERU-18	Energy Recovery Unit	9480	9000	114.6	385.4	576.1	0.05
ERU-19	Energy Recovery Unit	9480	9000	114.6	385.4	576.1	0.05
ERU-20	Energy Recovery Unit	2925	2475	28	71.1	131.6	0.05

Table 5 – Major Mechanical Equipment

Mechanical System Space Usage

The total amount of space usage by the mechanical system, listed in Table 5, is 9925 square feet. The majority of it is taken up by mechanical mezzanines where the energy recovery units sit. Chillers and boilers are in the boiler room and take up the second most amount of space. Shafts for the ducts take up the least amount of space in the building. Comparing the total amount of area the mechanical system takes up in comparison with the rest of the building comes out to be about 3 percent.

Mechanical Space	Area (sf)
Boiler Room	3847
Mechanical Mezzanines	5574
Shafts	504
Total	9925
Building	320000
Building Space Usage	3.10%

Table 6 – Mechanical Space Usage

LEED Rating

To make Central High School LEED certified is not a goal of the current project team or the owner. Sustainable features such as low flow toilets were put in place however. The point total for the mechanical system is 32 points making the building close to LEED Certified by 4 points. In Energy and Atmosphere the points came from the rigorous verification and commissioning process that is going to take place when the building is finished. Also optimizing energy performance with energy recovery units and state of the art controls on the chillers, boilers and pumps gave the assumed maximum amount of points possible. For Indoor Environmental Quality the design team put outdoor air monitoring devices on the energy recovery units along with increasing ventilation from ASHRAE standards. Controls for pollutants and chemicals are set up to ensure the best quality air is delivered to the occupants. Finally thermal comfort controls are in place and the curtain wall systems allow for daylight and views.

LEED 2009 for New Construction and Major Renovations

Project Checklist

Project Name

Date

Y	?	N			Points
			Sustainable Sites		**Possible Points: 26**
Y			Prereq 1	Construction Activity Pollution Prevention	
			Credit 1	Site Selection	1
			Credit 2	Development Density and Community Connectivity	5
			Credit 3	Brownfield Redevelopment	1
			Credit 4.1	Alternative Transportation—Public Transportation Access	6
			Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Roon	1
			Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Vehic	3
			Credit 4.4	Alternative Transportation—Parking Capacity	2
			Credit 5.1	Site Development—Protect or Restore Habitat	1
			Credit 5.2	Site Development—Maximize Open Space	1
			Credit 6.1	Stormwater Design—Quantity Control	1
			Credit 6.2	Stormwater Design—Quality Control	1
			Credit 7.1	Heat Island Effect—Non-roof	1
			Credit 7.2	Heat Island Effect—Roof	1
			Credit 8	Light Pollution Reduction	1
			Water Efficiency		**Possible Points: 10**
Y			Prereq 1	Water Use Reduction—20% Reduction	
			Credit 1	Water Efficient Landscaping	2 to 4
			Credit 2	Innovative Wastewater Technologies	2
			Credit 3	Water Use Reduction	2 to 4
			Energy and Atmosphere		**Possible Points: 35**
Y			Prereq 1	Fundamental Commissioning of Building Energy Systems	
Y			Prereq 2	Minimum Energy Performance	
Y			Prereq 3	Fundamental Refrigerant Management	
Y			Credit 1	Optimize Energy Performance	1 to 19
		N	Credit 2	On-Site Renewable Energy	1 to 7
Y			Credit 3	Enhanced Commissioning	2
		N	Credit 4	Enhanced Refrigerant Management	2
Y			Credit 5	Measurement and Verification	3
		N	Credit 6	Green Power	2
			Materials and Resources		**Possible Points: 14**
Y			Prereq 1	Storage and Collection of Recyclables	
			Credit 1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof	1 to 3
			Credit 1.2	Building Reuse—Maintain 50% of Interior Non-Structural Elements	1
			Credit 2	Construction Waste Management	1 to 2
			Credit 3	Materials Reuse	1 to 2

Y	?	N			Points
			Materials and Resources, Continued		
			Credit 4	Recycled Content	1 to 2
			Credit 5	Regional Materials	1 to 2
			Credit 6	Rapidly Renewable Materials	1
			Credit 7	Certified Wood	1
			Indoor Environmental Quality		**Possible Points: 15**
Y			Prereq 1	Minimum Indoor Air Quality Performance	
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	
Y			Credit 1	Outdoor Air Delivery Monitoring	1
Y			Credit 2	Increased Ventilation	1
	?		Credit 3.1	Construction IAQ Management Plan—During Construction	1
	?		Credit 3.2	Construction IAQ Management Plan—Before Occupancy	1
	?		Credit 4.1	Low-Emitting Materials—Adhesives and Sealants	1
	?		Credit 4.2	Low-Emitting Materials—Paints and Coatings	1
	?		Credit 4.3	Low-Emitting Materials—Flooring Systems	1
	?		Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Product	1
Y			Credit 5	Indoor Chemical and Pollutant Source Control	1
	?		Credit 6.1	Controllability of Systems—Lighting	1
Y			Credit 6.2	Controllability of Systems—Thermal Comfort	1
Y			Credit 7.1	Thermal Comfort—Design	1
Y			Credit 7.2	Thermal Comfort—Verification	1
Y			Credit 8.1	Daylight and Views—Daylight	1
Y			Credit 8.2	Daylight and Views—Views	1
			Innovation and Design Process		**Possible Points: 6**
			Credit 1.1	Innovation in Design: Specific Title	1
			Credit 1.2	Innovation in Design: Specific Title	1
			Credit 1.3	Innovation in Design: Specific Title	1
			Credit 1.4	Innovation in Design: Specific Title	1
			Credit 1.5	Innovation in Design: Specific Title	1
			Credit 2	LEED Accredited Professional	1
			Regional Priority Credits		**Possible Points: 4**
			Credit 1.1	Regional Priority: Specific Credit	1
			Credit 1.2	Regional Priority: Specific Credit	1
			Credit 1.3	Regional Priority: Specific Credit	1
			Credit 1.4	Regional Priority: Specific Credit	1
			Total		**Possible Points: 110**

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110

Figure 4 – LEED Checklist

Overall System Evaluation

The mechanical system at Central High School has done a good job for sustainability and energy efficiency. Through the use of energy recovery units the building is not only more efficient but will receive rebates for using them. At over 16.6 million dollars the project cost associated with the mechanical system will be reduced by utilizing these energy recovery units.

Since the high school is at 320,000 square feet it requires a large mechanical system to deal with heating and cooling loads. Two chillers and a natural gas fired boiler are the primary means of heating and cooling in the building. There is not much in the way of redundancy for heating but for cooling the extra chiller provides such a means for backup. Also the ventilation rates are well above that of the ASHRAE 62.1 standards minimum requirements.

A thorough and rigorous commissioning process is in place when the building is done with the renovation and addition. This will ensure that the mechanical system should function as well as it was designed to be. Along with this the maintenance will be easy since the energy recovery units are in mechanical mezzanines. The fan coil units are located above the spaces and therefore are easy to access in case problems occur with them.

References

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Appendix A

Baltimore, Maryland (Baltimore-Washington) outdoor design conditions.

Meaning of acronyms:
DB: Dry bulb temperature, °F   *WB: Wet bulb temperature, °F*
MCWB: Mean coincident wet bulb temperature, °F
Lat: Latitude, °
DP: Dew point temperature, °F
MCDB: Mean coincident dry bulb temperature, °F
Long: Longitude, °
HR: Humidity ratio, grains of moisture per lb of dry air
HDD and CDD 65: Annual heating and cooling degree-days, base 65°F, °F-day
Elev: Elevation, ft
WS: Wind speed, mph

Station	Lat	Long	Elev	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB				Dehumidification DP/HR/MCDB						Extreme Annual WS			Heat./Cool. Degree-Days	
						0.4%		1%		2%		0.4%		1%		0.4%			1%							
				99.6%	99%	DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	DP	HR	MCDB	DP	HR	MCDB	1%	2.5%	5%	HDD	CDD 65
TOPEKA/BILLARD MUNI	39.07N	95.63W	886	3.1	8.7	97.1	76.2	93.9	75.9	91.0	75.0	79.0	91.3	77.8	90.1	75.5	137.9	86.3	74.2	132.1	84.7	23.5	20.1	18.3	4902	1446
WICHITA/MID-CONTINE	37.65N	97.43W	1339	7.4	12.2	100.1	73.7	97.0	73.8	93.5	73.7	77.7	90.5	76.5	89.5	74.2	134.2	83.6	72.9	128.5	82.1	28.2	25.6	23.4	4464	1682
COL JAMES JABARA	37.75N	97.22W	1421	7.1	11.5	99.4	74.0	96.8	74.4	92.6	73.9	77.4	91.2	76.4	89.7	73.2	130.2	83.4	72.5	126.9	82.4	27.7	25.0	22.6	4495	1577
Kentucky																										*8 sites, 5 more on CD-ROM*
BOWLING GREEN WARRE	36.98N	86.44W	538	11.2	16.7	93.4	75.0	91.1	75.2	89.5	74.7	78.4	88.6	77.4	87.3	75.5	136.0	83.6	74.5	131.5	82.5	19.8	17.9	16.1	4063	1427
CINCINNATI/GREATER	39.04N	84.67W	883	5.4	11.3	91.4	74.2	89.2	73.5	86.7	72.5	77.4	87.1	76.1	85.0	74.5	133.1	82.3	73.2	127.6	80.7	21.8	19.1	17.2	4954	1107
FORT CAMPBELL (AAF)	36.67N	87.50W	571	12.3	18.1	93.3	76.0	91.0	76.0	89.8	75.8	79.6	87.6	78.4	86.5	77.3	145.3	83.0	76.6	141.8	82.4	20.1	17.7	15.7	3818	1548
HENDERSON CITY CO	37.81N	87.68W	387	8.8	14.2	93.2	76.4	91.1	76.0	90.0	75.4	79.4	91.0	78.1	89.0	75.5	135.4	86.9	74.6	131.3	85.8	21.0	18.7	16.7	4444	1384
LEXINGTON/BLUE GRAS	38.04N	84.61W	988	8.3	13.6	91.6	73.9	89.6	73.6	87.3	72.8	77.3	87.5	76.1	85.4	74.2	132.6	82.7	73.1	127.5	81.1	20.3	18.0	16.3	4567	1201
BOWMAN FLD	38.23N	85.66W	558	9.7	15.7	93.3	75.1	91.1	74.7	89.6	74.0	78.5	88.6	77.4	87.3	75.4	136.0	83.3	74.6	132.0	82.7	18.7	16.8	14.7	4201	1459
LOUISVILLE/STANDIFO	38.18N	85.73W	489	10.2	15.9	93.8	75.3	91.5	75.0	89.6	74.2	78.7	89.1	77.5	87.9	75.7	136.8	84.7	74.4	131.0	83.2	21.0	18.7	16.8	4109	1572
SOMERSET PULASKI CO	37.05N	84.60W	928	12.3	17.9	94.6	74.9	91.6	74.3	90.3	73.7	78.0	90.5	76.8	88.4	74.1	131.8	84.1	73.0	126.9	82.4	17.9	15.4	12.6	3866	1460
Louisiana																										*12 sites, 8 more on CD-ROM*
ESLER RGNL	31.40N	92.30W	118	26.6	28.3	97.8	76.7	95.3	77.2	93.0	76.7	80.3	89.7	79.5	89.6	78.3	147.8	83.8	77.1	141.8	83.3	16.5	13.8	12.0	2004	2485
ALEXANDRIA INT	31.34N	92.56W	79	27.4	29.9	97.2	77.1	94.7	77.3	92.8	76.8	80.7	89.5	79.8	89.4	78.9	150.3	84.4	77.3	142.3	84.0	18.6	16.5	14.1	1835	2621
BARKSDALE AFB	32.50N	93.66W	167	23.6	27.2	97.3	76.6	95.0	76.5	92.8	76.5	80.0	90.8	79.0	89.9	77.2	142.5	84.0	76.1	137.4	83.2	19.1	17.0	14.8	2291	2305
BATON ROUGE METRO R	30.54N	91.15W	75	28.5	31.8	94.6	77.6	93.1	77.3	91.5	76.9	80.4	89.0	79.8	88.2	78.5	148.3	83.8	77.5	143.5	83.2	18.7	16.7	15.0	1573	2709
LAFAYETTE RGNL	30.21N	91.99W	43	29.9	33.6	94.6	77.8	92.9	77.6	91.3	77.3	80.7	88.9	80.0	88.3	78.9	150.3	83.7	77.8	144.9	83.3	20.4	18.3	16.5	1463	2806
LAKE CHARLES MUNI	30.13N	93.23W	10	30.3	33.8	94.4	77.8	92.8	77.7	91.2	77.6	81.4	88.5	80.4	87.6	79.4	152.8	84.2	78.7	149.2	83.7	20.5	18.4	16.7	1453	2806
MONROE RGNL	32.51N	92.04W	82	25.2	28.1	97.5	77.8	95.2	77.7	93.1	77.0	81.0	91.4	80.1	90.6	78.5	148.2	85.4	77.3	142.6	84.6	19.0	17.0	15.0	2189	2462
NEW ORLEANS NAS JRB	29.83N	90.03W	0	30.7	34.2	92.8	78.1	91.2	77.8	90.2	77.6	81.9	87.5	80.6	86.6	80.4	157.8	84.6	79.2	151.3	83.6	18.1	16.0	13.6	1444	2626
NEW ORLEANS/MOISANT	29.99N	90.25W	20	33.1	36.3	93.8	78.1	92.2	77.7	90.8	77.5	80.9	88.9	80.2	88.0	79.0	150.6	84.4	78.2	146.5	83.8	20.7	18.7	17.0	1286	2925
LAKEFRONT	30.04N	90.03W	10	35.6	38.6	93.3	78.7	91.8	78.2	90.7	77.9	81.4	89.3	80.6	88.3	79.3	152.3	85.3	78.8	149.7	85.0	24.9	21.0	18.9	1138	3232
SHREVEPORT DOWNTOWN	32.54N	93.74W	180	26.9	29.6	99.2	76.6	96.9	76.5	93.5	76.2	79.6	91.3	78.8	90.2	76.9	141.0	83.1	75.5	134.3	82.7	18.8	16.7	14.9	2149	2628
SHREVEPORT REGIONAL	32.45N	93.82W	259	25.2	28.4	98.5	76.2	96.0	76.3	93.6	76.0	79.4	91.2	78.6	89.9	76.4	139.2	83.2	75.7	135.8	82.7	19.7	17.7	16.1	2117	2535
Maine																										*5 sites, 16 more on CD-ROM*
AUBURN LEWISTON MUNI	44.05N	70.28W	289	-6.2	-0.1	87.9	70.7	83.6	69.2	81.0	67.5	73.6	83.4	71.4	80.2	70.4	113.1	78.5	68.5	106.0	76.4	20.8	18.5	16.4	7632	308
BANGOR INTL	44.81N	68.82W	194	-7.3	-2.0	87.9	70.7	84.1	69.0	81.1	67.0	73.2	83.1	71.3	80.6	70.2	111.7	78.1	68.2	104.2	75.4	23.5	19.7	18.0	7665	355
BRUNSWICK (NAS)	43.90N	69.93W	75	-2.2	2.1	86.3	70.7	82.8	68.9	80.5	67.3	73.5	82.4	71.5	79.8	70.4	112.4	78.0	69.0	106.7	76.0	23.2	19.5	17.4	7202	367
PORTLAND/INTNL. JET	43.64N	70.30W	62	0.1	4.9	86.8	71.3	83.4	69.9	80.4	68.2	74.1	83.2	72.2	80.2	71.0	114.7	78.8	69.5	108.8	76.6	23.2	19.6	17.6	7023	370
SANFORD RGNL	43.39N	70.70W	243	-6.2	0.3	89.5	71.0	85.2	69.4	82.0	67.8	74.1	84.6	72.1	81.9	71.5	117.4	80.1	69.6	109.6	77.7	20.9	18.5	16.3	7470	350
Maryland																										*3 sites, 4 more on CD-ROM*
ANDREWS AFB/CAMP SP	38.82N	76.85W	289	15.6	18.4	92.6	74.1	90.2	73.4	87.9	72.8	77.6	86.6	76.3	84.9	75.1	133.1	80.4	73.4	125.3	79.2	24.7	20.7	18.3	4419	1199
BALTIMORE-WASHINGTO	39.17N	76.68W	154	14.0	17.9	94.0	74.9	91.3	74.1	88.7	73.1	78.1	88.6	76.8	86.6	75.3	133.2	82.1	74.1	127.8	80.7	22.3	19.1	17.1	4552	1261
THOMAS POINT	38.90N	76.43W	39	17.6	21.4	86.8	74.7	84.8	74.6	83.1	74.0	79.6	82.7	77.8	81.5	78.7	149.0	81.2	76.9	140.3	80.0	37.7	31.6	26.5	4196	1236
Massachusetts																										*11 sites, 10 more on CD-ROM*
BARNSTABLE MUNI BOA	41.67N	70.28W	52	9.9	15.6	84.0	73.0	81.5	71.5	79.3	70.2	75.5	81.3	74.2	78.9	73.3	124.1	77.6	72.7	121.5	77.0	24.7	21.2	19.2	5872	511
BOSTON/LOGAN INTL	42.36N	71.01W	30	8.1	13.0	90.6	72.7	87.6	71.7	84.2	70.2	75.9	85.7	74.3	83.0	72.8	122.0	80.6	71.5	116.3	78.6	26.9	24.2	20.9	5596	750
BUZZARDS BAY	41.38N	71.03W	56	12.4	16.7	76.0	N/A	74.4	N/A	73.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	43.8	38.3	34.0	5552	302
CHATHAM MUNI	41.69N	69.99W	69	11.7	17.1	82.1	72.3	80.7	71.6	78.1	70.5	75.1	80.2	73.9	78.2	73.2	123.5	77.6	72.5	120.5	76.7	21.7	18.7	16.7	5688	457
LAWRENCE MUNI	42.72N	71.12W	148	3.4	9.6	90.4	72.8	87.9	71.9	83.9	70.7	75.7	84.8	74.3	82.8	72.8	122.3	79.7	72.1	119.3	79.1	20.4	18.1	16.2	6091	652
MARTHAS VINEYARD	41.39N	70.62W	69	9.5	14.0	83.8	72.5	81.3	71.2	79.1	70.0	75.2	80.9	73.9	78.6	73.1	123.3	77.8	72.4	120.3	76.8	26.0	23.5	20.4	5886	429
NEW BEDFORD RGNL	41.68N	70.96W	79	8.7	12.1	88.2	73.2	84.1	71.7	81.7	70.1	75.8	83.7	74.4	80.9	73.1	123.4	78.7	72.4	120.4	77.8	23.1	19.9	17.9	5833	570
NORWOOD MEM	42.19N	71.17W	49	3.1	9.1	90.4	73.3	88.0	72.6	84.1	70.8	76.5	85.6	74.9	82.9	73.3	124.1	79.5	72.5	120.7	78.7	20.5	18.2	16.3	6233	581
PLYMOUTH MUNICIPAL	41.91N	70.73W	148	5.3	9.9	89.5	73.1	84.4	71.6	82.0	69.9	75.8	84.1	74.4	81.3	73.2	123.9	78.8	72.4	120.6	78.0	23.3	19.9	17.9	6154	553
SOUTH WEYMOUTH NAS	42.15N	70.93W	161	5.9	10.4	91.2	73.8	87.7	72.3	84.7	70.7	76.9	86.8	74.9	83.8	74.1	127.9	81.9	72.2	119.7	79.4	18.5	16.5	14.5	5832	646
WORCESTER REGIONAL ARPT	42.27N	71.88W	1017	1.9	6.7	85.7	71.2	83.0	69.7	80.7	68.1	74.0	81.7	72.3	79.4	71.7	121.5	77.8	70.1	115.1	76.1	25.9	22.9	19.7	6706	462
Michigan																										*15 sites, 44 more on CD-ROM*
DETROIT CITY	42.41N	83.01W	627	5.2	9.6	90.7	73.4	88.2	72.1	85.5	70.8	76.4	86.4	74.6	83.8	73.2	126.3	81.9	71.9	120.5	80.3	20.4	18.5	17.1	5989	884
DETROIT/METROPOLITA	42.22N	83.35W	663	2.9	8.0	90.4	73.8	87.6	72.6	84.7	71.1	76.9	86.4	75.0	83.4	73.8	129.2	82.3	72.3	122.7	80.2	25.3	22.2	19.5	6103	807
WILLOW RUN	42.24N	83.53W	715	0.8	6.3	90.3	74.0	87.8	72.5	84.3	70.8	76.7	86.3	74.8	83.6	73.3	127.3	81.3	72.2	122.2	80.0	24.7	21.5	19.0	6415	679
FLINT/BISHOP INTL	42.97N	83.75W	768	-0.2	4.5	89.7	73.8	86.7	72.0	83.9	70.3	76.3	85.3	74.4	82.9	73.3	127.4	81.9	71.7	120.4	79.3	23.8	20.4	18.5	6741	594
GRAND RAPIDS/KENT C	42.88N	85.52W	804	2.2	6.9	89.4	73.1	86.5	71.7	83.8	70.1	76.3	85.1	74.4	82.6	73.4	128.2	81.4	71.8	121.0	79.3	24.7	21.0	19.0	6615	639
GROSSE ILE MUNI	42.10N	83.17W	591	7.1	10.2	89.7	74.2	85.9	73.5	82.5	71.8	77.9	84.5	76.2	82.7	75.3	135.8	81.1	73.4	127.2	79.6	20.9	18.6	16.7	5804	863
TULIP CITY	42.75N	86.10W	689	7.2	10.1	88.4	73.3	85.7	72.0	82.3	70.3	76.1	84.2	74.4	82.2	73.1	126.0	80.9	72.2	122.3	79.5	25.7	22.1	19.2	6234	617
JACKSON CO REYNOLDS	42.26N	84.46W	1020	0.5	5.4	88.3	73.4	85.6	71.9	82.7	70.1	76.0	84.4	74.3	82.2	73.2	127.9	80.9	71.8	122.2	79.4	20.2	18.4	16.9	6619	565
KALAMAZOO BATTLE CR	42.24N	85.55W	873	2.8	8.6	90.0	72.8	87.7	71.8	83.9	70.4	75.9	84.6	74.4	82.8	72.8	125.9	81.0	72.0	122.4	79.9	21.7	19.0	17.2	6251	709

Energy Recovery Unit schedule.

ENERGY RECOVERY UNIT SCHEDULE

SYMBOL	DESIGN OUTSIDE ENT. AIR TEMP.		DESIGN EXHAUST ENT. AIR TEMP.		WHEEL LAT AT DESIGN		SUPPLY FAN				EXHAUST FAN			ER WHEEL
	SUMMER D.B./W.B.	WINTER D.B.	SUMMER D.B./W.B.	WINTER D.B.	SUMMER D.B./W.B.	WINTER D.B.	DESIGN CFM	OA CFM	E.S.P.	H P	DESIGN CFM	E.S.P.	H P	H P
ERU-1	91°F/76°F	11°F	76°F/67°F	70°F	79°F/67°F	55°F	12,100	11,780	1.3"	7.5	10,800	0.8"	3 (x2)	1/20
ERU-2A/B					80°F/67°F	49°F	1,700	1,700	1.3"	2	1,650	0.8"	1.5	
ERU-3					79°F/66°F	57°F	6,990	6,990	1.3"	5	6,790	0.8"	5	
ERU-4					79°F/66°F	57°F	1,655	1,655	1.3"	2	1,580	0.8"	1	
ERU-5					79°F/67°F	54°F	6,000	3,500	1.3"	7.5	3,500	0.8"	7.5	
ERU-6					78°F/65°F	58°F	1,535	1,535	1.3"	2	1,515	0.8"	1	
ERU-7					80°F/67°F	55°F	20,393	20,130	1.3"	40	20,130	0.8"	25	1/2
ERU-8					80°F/67°F	55°F	28,655	28,360	1.3"	60	28,360	0.8"	40	1/2
ERU-9					78°F/65°F	54°F	5,570	5,570	1.3"	7.5	5,345	0.8"	5	1/20
ERU-10					78°F/65°F	54°F	4,700	4,700	1.3"	7.5	3,400	0.8"	5	1/20
ERU-11					79°F/66°F	54°F	8,480	4,500	1.3"	10	4,500	0.8"	7.5	
ERU-12					79°F/66°F	53°F	10,700	10,700	1.3"	15	10,700	0.8"	10	
ERU-13					79°F/66°F	53°F	10,700	10,700	1.3"	15	10,700	0.8"	10	
ERU-14					79°F/66°F	53°F	2,295	2,295	1.3"	2	2,175	0.8"	1	
ERU-15					80°F/67°F	53°F	10,660	10,660	1.3"	15	10,660	0.8"	10	
ERU-16					79°F/66°F	55°F	4,420	2,170	1.3"	5	2,170	0.8"	5	
ERU-17					79°F/67°F	54°F	4,050	4,050	1.3"	5	3,830	0.8"	3	
ERU-18					79°F/67°F	52°F	9,480	9,480	1.3"	15	9,000	0.8"	7.5	
ERU-19					79°F/67°F	52°F	9,480	9,480	1.3"	15	9,000	0.8"	7.5	
ERU-20					79°F/67°F	54°F	2,925	2,925	1.3"	3	2,475	0.8"	1.5	

SYMBOL	COOLING COIL					HEATPIPE REHEAT		PREHEAT HEATING COIL				REHEAT HEATING COIL			
	TOTAL MBH	SENSIBLE MBH	LAT DB/WB	EWT	LWT	ROWS	LAT DB/WB	TOTAL MBH	LAT DB	EWT	LWT	TOTAL MBH	LAT DB	EWT	LWT
ERU-1	484.3	395.6	55°F/54°F	44°F	54°F	–	–	–	–	–	–	609.9	95°F	180°F	157°F
ERU-2A/B	65.1	45.5	55°F/54°F		54°F	–	–	–	–	–	–	66.7	95°F		155°F
ERU-3	166.6	151.0	55°F/54°F		54°F	3	66°F/59°F	–	–	–	–	313.5	98°F		158°F
ERU-4	40.5	36.2	55°F/54°F		54°F	3	66°F/59°F	–	–	–	–	86.5	99°F		158°F
ERU-5	222.9	158.2	55°F/54°F		54°F	–	–	–	–	–	–	329.3	104°F		152°F
ERU-6	40.5	36.2	55°F/54°F		54°F	3	66°F/59°F	–	–	–	–	86.5	99°F		158°F
ERU-7	840.7	574.4	55°F/54°F		54°F	4	66°F/58°F	1,535	70°F	180°F	160°F	339.1	70°F		150°F
ERU-8	1,160.0	799.6	55°F/54°F		54°F	4	66°F/58°F	2,263	70°F	180°F	150°F	480.7	70°F		150°F
ERU-9	196.5	145.0	55°F/54°F		54°F	4	65°F/58°F	573.5	95°F	180°F	160°F	63.4	65°F		150°F
ERU-10	171.0	125.1	55°F/54°F		54°F	4	65°F/58°F	573.5	95°F	180°F	150°F	57.7	65°F		150°F
ERU-11	333.3	233.2	55°F/54°F		54°F	–	–	–	–	–	–	336.5	95°F		155°F
ERU-12	395.0	273.5	55°F/54°F		54°F	–	–	–	–	–	–	590.6	107°F		155°F
ERU-13	395.0	273.5	55°F/54°F		54°F	–	–	–	–	–	–	590.6	107°F		155°F
ERU-14	50.7	43.6	55°F/54°F		54°F	3	66°F/59°F	–	–	–	–	97.3	96°F		160°F
ERU-15	395.0	273.5	55°F/54°F		54°F	–	–	–	–	–	–	590.6	107°F		155°F
ERU-16	154.4	112.6	55°F/54°F		54°F	–	–	–	–	–	–	244.1	105°F		155°F
ERU-17	110.4	95.6	55°F/54°F		54°F	3	64°F/58°F	–	–	–	–	178.1	95°F		**160°F**
ERU-18	385.4	263.1	55°F/54°F		54°F	–	–	–	–	–	–	576.1	108°F		155°F
ERU-19	385.4	263.1	55°F/54°F		54°F	–	–	–	–	–	–	576.1	108°F		155°F
ERU-20	71.1	56.3	55°F/54°F		54°F	3	66°F/59°F	–	–	–	–	131.6	95°F		**160°F**

BASIS OF DESIGN:
SEE SCHEDULE

WATER FLOW COOLING GPM	WATER FLOW COOLING WPD (PSI)	WATER FLOW PREHEAT GPM	WATER FLOW PREHEAT WPD (PSI)	WATER FLOW REHEAT GPM	WATER FLOW REHEAT WPD (PSI)	BRANCH PIPING SIZE CLG	BRANCH PIPING SIZE PREHEAT	BRANCH PIPING SIZE REHEAT	UNIT ELECTRICAL DATA MCA	UNIT ELECTRICAL DATA MOP	UNIT ELECTRICAL DATA VOLT/PHASE	MANUF.	MODEL	NOMINAL SIZE L" x W" x H"	MAX. OPERATING WEIGHT (LBS)	GENERAL LOCATION	SYMBOL
87.7	11.9'	–	–	54.1	13.1'	3"	–	2-1/2"	26.0	35	460V-3Ø	GREENHECK	APEX-200H-30	289"x98"x98"	12,000	CAFETERIA – ROOFTOP UNIT	ERU-1
11.2	3.6'	–	–	7.2	1.0'	1-1/2"	–	1-1/4"	8.0	15	460V-3Ø	GREENHECK	ERCH-20H-30	98"x56"x50"	1,800	STAGE – INDOOR UNIT	ERU-2A/B
32.4	1.1'	–	–	29.5	2.2'	2"	–	2"	18.5	25	460V-3Ø	GREENHECK	ERT-74H-30	199"x97"x91"	9,800	EAST CLRM. ADDITION – INDOOR UNIT	ERU-3
8.2	0.5'	–	–	8.0	1.0'	1-1/4"	–	1-1/4"	7.2	15	460V-3Ø	GREENHECK	ERT-52S-15	158"x69"x64"	4,500	CHILD DEV./CONF. – INDOOR UNIT	ERU-4
42.0	3.4'	–	–	24.0	3.2'	2-1/2"	–	2"	26.1	35	460V-3Ø	GREENHECK	ERCH-55H-30	117"x76"x70"	4,500	MEDIA CENTER – INDOOR UNIT	ERU-5
8.2	0.5'	–	–	8.0	1.0'	1-1/4"	–	1-1/4"	7.2	15	460V-3Ø	GREENHECK	ERT-52S-15	158"x69"x64"	4,500	MAIN LOBBY – ROOFTOP UNIT	ERU-6
152.2	9.5'	156.4	3.1'	22.4	1.0'	4"	4"	2"	105.2	175	460V-3Ø	AIR ENTERPRISES	CUSTOM UNIT	368"x315"x122"	–	1ST FLOOR EXISTING CLASSROOM CORE	ERU-7
214.4	12.6'	147.1	9.5'	31.5	1.0'	4"	4"	2"	150.0	225	460V-3Ø	AIR ENTERPRISES	CUSTOM UNIT	366"x315"x132"	–	2ND FLOOR EXISTING CLASSROOM CORE	ERU-8
37.7	14.2'	39.2	6.0'	11.5	1.0'	2-1/2"	2-1/2"	1-1/2"	27.8	35	460V-3Ø	AIR ENTERPRISES	CUSTOM UNIT	252"x98"x77"	–	ADMIN./PART. CR. ADD. – INDOOR UNIT	ERU-9
31.8	10.5'	39.2	6.0'	10.5	1.0'	2"	2-1/2"	1-1/4"	27.8	35	460V-3Ø	AIR ENTERPRISES	CUSTOM UNIT	252"x98"x77"	–	PART. CLRM. ADDITION – INDOOR UNIT	ERU-10
58.2	4.5'	–	–	37.7	3.3'	2-1/2"	–	2-1/2"	29.9	40	460V-3Ø	GREENHECK	ERCH-90H-30	130"x95"x85"	6,000	AUXILIARY GYM – INDOOR UNIT	ERU-11
71.9	6.5'	–	–	46.6	9.3'	3"	–	2-1/2"	41.6	60	460V-3Ø	GREENHECK	ERCH-90H-30	130"x95"x85"	6,000	NEW GYM – INDOOR UNIT	ERU-12
71.9	6.5'	–	–	46.6	9.3'	3"	–	2-1/2"	41.6	60	460V-3Ø	GREENHECK	ERCH-90H-30	130"x95"x85"	6,000	NEW GYM – INDOOR UNIT	ERU-13
10.2	0.5'	–	–	9.7	1.3'	1-1/4"	–	1-1/4"	7.2	15	460V-3Ø	GREENHECK	ERT-52S-15	158"x69"x64"	4,500	GYM LOBBY/OFFICES – INDOOR UNIT	ERU-14
71.9	6.5'	–	–	46.6	9.3'	3"	–	2-1/2"	41.6	60	460V-3Ø	GREENHECK	ERCH-90H-30	130"x95"x85"	6,000	TEAM/LOCKER AREA – INDOOR UNIT	ERU-15
30.1	2.2'	–	–	19.6	2.4'	2"	–	2"	17.9	25	460V-3Ø	GREENHECK	ERCH-45H-30	105"x65"x68"	3,500	FITNESS AREA – INDOOR UNIT	ERU-16
20.7	1.1'	–	–	18.4	2.2'	2"	–	2"	15.1	20	460V-3Ø	GREENHECK	ERT-52H-30	158"x69"x64"	4,500	EXTERIOR MUSIC AREA – INDOOR UNIT	ERU-17
69.4	6.1'	–	–	45.2	8.8'	3"	–	2-1/2"	38.6	50	460V-3Ø	GREENHECK	ERCH-90H-30	130"x95"x85"	6,000	AUDITORIUM – INDOOR UNIT	ERU-18
69.4	6.1'	–	–	45.2	8.8'	3"	–	2-1/2"	38.6	50	460V-3Ø	GREENHECK	ERCH-90H-30	130"x95"x85"	6,000	AUDITORIUM – INDOOR UNIT	ERU-19
14.4	0.5'	–	–	13.6	1.0'	1-1/2"	–	1-1/2"	9.8	15	460V-3Ø	GREENHECK	ERT-52S-15	158"x69"x64"	4,500	INTERIOR MUSIC AREA – INDOOR UNIT	ERU-20