Final Report

CENTRAL HIGH SCHOOL MID-ATLANTIC REGION

ADAM BROWN

MECHANICAL OPTION

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Submitted 3/25/14

CENTRAL HIGH SCHOOL | MID-ATLANTIC REGION

Architecture

- Central courtyard for green space and daylight
- Curtain walls at main and rear entrance
- Red and slate colored exterior brick and CMU's
- Sustainable features such as low flow toilets

Mechanical

- 20 energy recovery units spaced throughout the building
- 4-pipe fan coil units service each zoned space
- 2 air cooled chillers creates chilled water for fan coil units
- 1 gas fired boiler creates hot water for fan coil units

Building Name: Central High School

Location and Site: Mid-Atlantic Region

Building Occupant Name: Confidential

Building Function: Higher Education

Size: 322,000 square feet

Height: 34 feet max but varies

Number of stories: 2 stories, 7 foot crawlspace below grade

Dates of construction: July 2010– December 2014

Project Cost: $84 million

Project delivery method: Multiple Primes

Electrical/Lighting

- Fluorescents for classrooms and labs
- Metal halides for auditorium and gymnasiums
- 277/480V stepped down to 120/208V
- 130kW natural gas backup generator

Structural

- Entire building is steel framed
- Masonry interior shear walls
- Concrete slab on metal deck for second floor
- Shallow foundations with square footings

Owner: Confidential

Construction Manager: Jacobs

Architect: SHW Group, LLP

Structural Engineer: Adtek Engineers, INC.

Mechanical and Electrical Engineers: SHW Group, LLP

Civil Engineers: Bowman Consulting

Kitchen Consultant: Nyikos Associates

Acoustical and Technology: Polysonics Corporation

Adam Brown | Mechanical Option | Senior Thesis Abstract
http://www.engr.psu.edu/ae/thesis/portfolios/2014/afb5065/index.html

Contents

Acknowledgments

I would like to thank everyone over the last five years who have helped me develop and grow. Without your help I could never have gotten through this without your support.

Thank you Dad, Mom, Billy, Andrea and Erik for always being there for me.

I would like to thank the AE faculty especially in the mechanical discipline and my thesis advisor for guiding me along this process the entire year.

I would also like to thank the Jacobs construction team and SHW Group for providing me all the information needed to complete this thesis.

Executive Summary

This report contains multiple analysis of Central High School that includes a GCHP depth analysis, acoustical breadth analysis and construction breadth analysis.

The first section was the sizing and layout of the GCHP system located at the soccer field next to the school. A total of 500 wells each at 400 feet deep would be used to satisfy peak cooling and heating loads. In case of breaks there are thirty eight rows of thirteen wells that can be individually shut off in the mechanical room.

To circulate the water throughout the system three Bell & Gossett variable speed, centrifugal pumps were selected. One of the pumps would be used for redundancy purposes while the other two would run to meet the pumping demand.

Vertical water source heat pumps from Carrier were selected with a typical range of one to three ton units. These would be placed in heat pump closets, which the feasibility of them was then further explored in another analysis.

Energy recovery units were the primary air movers in the building but the original design had a boiler and chillers supplying hot and chilled water. Therefore new packaged energy recovery units from Semco were selected that would utilize water-to-water source heat pumps.

It was found that by implementing a GCHP system the school would decrease their energy usage by 35% saving them $19074 annually. Also because of the energy reduction in the use of natural gas by not having a boiler emissions from the site decreased. However electrical usage increased by 45% which caused source emissions to rise.

The second section analyzed how a heat pump would affect the acoustics of a typical classroom. Going along the lines of ANSI S12.60 a wall of STC 60 would be implemented to negate immediate room noise from the heat pump. An additional analysis was done to see if noise would exceed an NC 30 value which it did not.

The third section analyzed the feasibility of installing a heat pump closet in comparison to installing it in the ceiling space. It was found that it was not feasible to install a heat pump closet based on cost, schedule and coordination issues.

The final recommendation of this report is to implement the GCHP system but to not build heat pump closets and install the heat pumps in the ceiling.

Building Overview

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. One interesting feature is the interior courtyard near the front of the building. More daylight comes into classrooms and corridors that surround the courtyard giving it a more open feeling. It is expected to be completed by February 2015.

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/

Existing Mechanical System

Ventilation System

Twenty dedicated outdoor air units located in the basement or mechanical rooms on the second floor bring in fresh outdoor air for ventilation purposes. Calculations were done in order to see if these units were compliant with ASHRAE 62.1-2010 ventilation rates. All but one unit meet and exceeded the minimum ventilation rate requirements. Outdoor air is provided to fan coil units that mix return air from the plenum to supply the occupants.

Hot and Chilled Water System

A single natural gas fired boiler serves dedicated outdoor air units, fan coil units, and unit heaters. Output of the boiler is at 7872 Mbh ensuring comfortable conditions for occupants on design days. After hot water is sent to the dedicated outdoor air units to condition the air it is sent to the fan coil units to handle the room load. Two pumps with variable frequency drive motors supply hot water at 1675 gpm per pump to these pieces of mechanical equipment.

Two air cooled chillers generate chilled water for the high school. These two chillers and a two cell cooling tower generate chilled water for the dedicated outdoor handling units and fan coil units. Chilled water is sent to the dedicated outdoor air units in order to decrease the latent load from the outdoor air. After this is done the chilled water is sent to the fan coil units were it will handle the room load. Two pumps at 1560 gpm per pump circulate condenser water from the cooling tower to the chillers while two more pumps at 2000 gpm per pump supply the chilled water to the dedicated outdoor air units and fan coil units. Variable frequency drive motors are attached to the pumps for better energy efficiency.

Energy Recovery

A unique feature to this project is the use of energy recovery wheels in the dedicated outdoor units. These were implemented because of financial incentives and to decrease energy usage. They utilize the heat from exhaust air to preheat or precool the outdoor during winter or summer time respectively. This decrease in demand on the heating and cooling coils decreases energy used by the building.

Energy Model Analysis

An energy model was run in Trane Trace 700 to find out the peak heating and cooling demands of the building, shown in Table 1 below. According to the model the high school is cooling dominated.

	Design	Model
Cooling [Tons]	505	934
Heating [Mbh]	11289	7772
Cooling [sf/ton]	634	342
Heating [Btuh/sf]	35	24
Supply [cfm/sf]	0.51	1.22
Ventilation [cfm/sf]	0.48	0.41

Table 1 – Design Calculations vs. Model Outputs

In addition to finding out the peak loads of the building the energy consumption, shown below in Table 2, and emissions, shown below in Table 3, were also examined.

Energy Consumption		
Building	18263	Btu/(ft^2-yr)
Source	35187	Btu/(ft^2-yr)
Floor Area	320000	ft^2

Table 2 – Energy Consumption

Environmental Impact Analysis		
CO2	1028013	lbm/yr
SO2	9257	gm/yr
NOX	1772	gm/yr

Table 3 – Emissions Report

Electricity is the dominate form of energy used in this building compared to the use of natural gas. This is due to the fact that the building is cooling dominated and must run the chillers to handle the cooling loads. The energy consumption report also shows the large amount of source energy that is required to create the energy needed at the site. This in turn shows up in the emissions report as how much emission the high school causes to be given off.

Proposed Mechanical Breadth

Ground Couple Heat Pump

The proposed redesign for the mechanical system was to convert the building over to a ground couple heat pump system. For most of the building's life a GCHP is a maintainable and simple system to take care of. The primary pieces of equipment are the few hydronic distribution pumps and heat pumps in each zone. This will also decrease the environmental impact the building has at the site by releasing fewer emissions from pieces of equipment such as the boiler.

As the high school has a lot of land for sport uses there is also room for expansion on a GCHP system by adding more wells. This is not so easily done with the original system with chillers and a boiler due to the mechanical room's size. A GCHP takes advantage of the relatively constant temperature of the earth year round compared to air cooled systems. This allows for better heat exchange between the fluid and the earth creating a more efficient mechanical system that deals with heating and cooling loads better.

Mechanical System Redesign

Sizing

To size the GCHP system a vertical well layout was chosen. Rules of thumb were used as the primary calculation methods as shown in Table 4.

Cooling Load [Tons]	Well Capacity [ft/Ton]	Depth of Well [ft]	Number of Wells
934	200	400	500

Table 4 – Well Calculation

A rule of thumb that for every two hundred feet of pipe a ton a cooling could be done was used to size the well at four hundred feet deep. This allowed the amount of wells to be cut down in half from 934 to 500. The system is oversized and well depth increased to also ensure there would be no need for a supplemental boiler or cooling tower. These are needed if the minimum and maximum temperature ranges the bore field is allowed to operate in are exceeded. The size of the bore field is shown below in table 5.

Well Coverage [ft^2]	Number of Wells	Total Coverage [ft^2]	Soccer Field Area [ft^2]
314	500	157080	202213

Table 5 - Bore Field Area Calculation

A separation of twenty feet between each well was chosen to give a coverage of 314 square feet per well. If separation of the wells were less than twenty feet this will lead to ground temperature rising and decrease of heat transfer efficiency. The total coverage of the system comes to 157080 square feet while the soccer field area is 202213 square feet which gives ample amount of room for the bore field.

Layout

The soccer fields will be where the bore field is laid out as shown below in Figure 1.   All supply and return pipes will connect in the mechanical room located in the basement of the building.

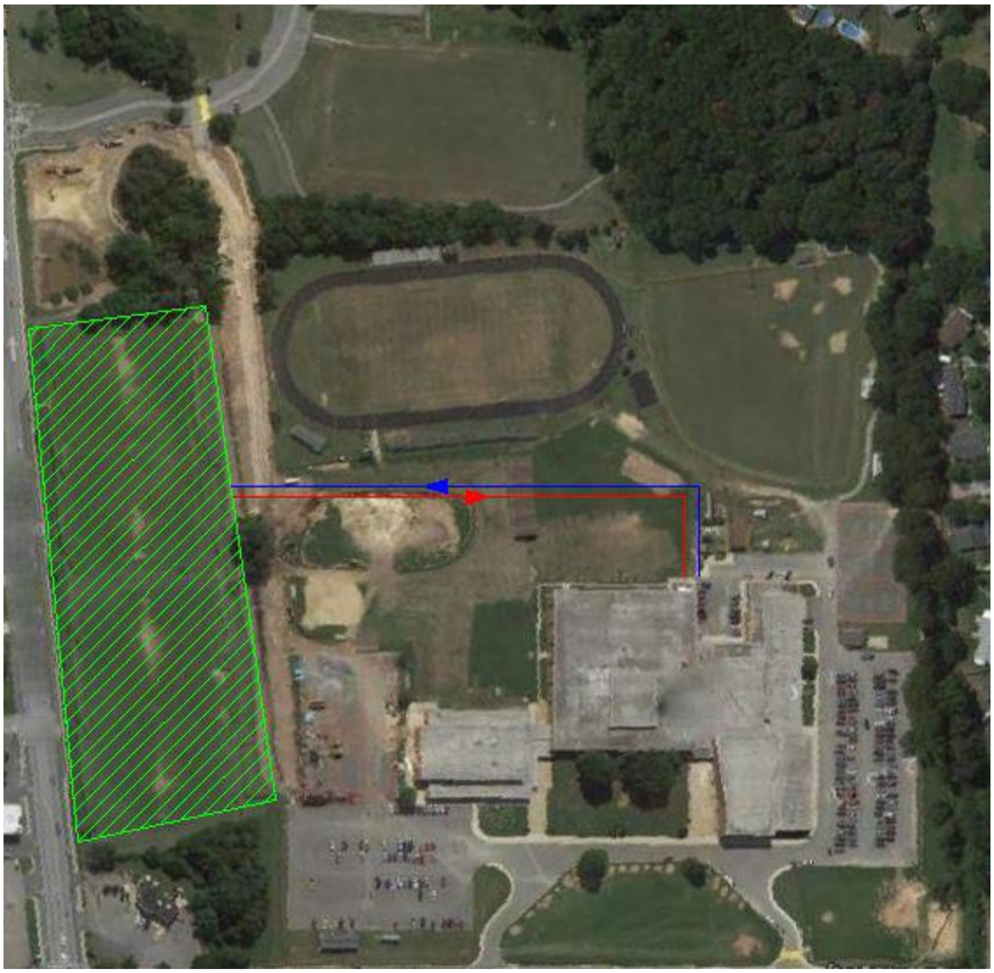

Figure 1 – Well Site

A total of thirty eight rows with thirteen wells in each row was selected as the final layout shown below in Figure 2. Each row has a reverse return piping layout that connects back in the building in the mechanical room. This reverse return layout allows for equal pressure across the wells since they would be hard to maintain being buried in the ground. If the entire system were connected to a single main pipe this would cause the shutdown of the entire system. Therefore each row is decoupled from one another by having its own supply and return back to the building. If a break occurs in one row then the shutoff valves located in the mechanical room would isolate it from the rest of the system.

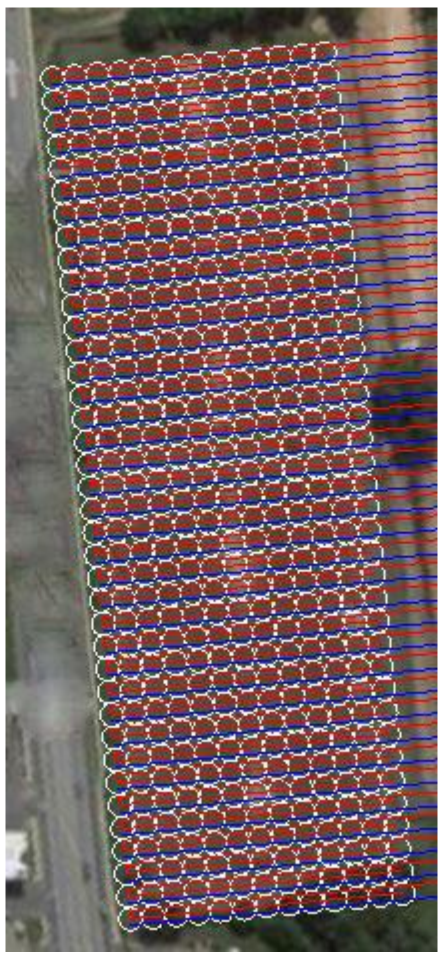

Figure 2 – Bore Field Layout

Below in Figure 3 the general layout for the mechanical room is shown. There are only three variable speed drive centrifugal pumps and it can be seen that there is enough room for them.

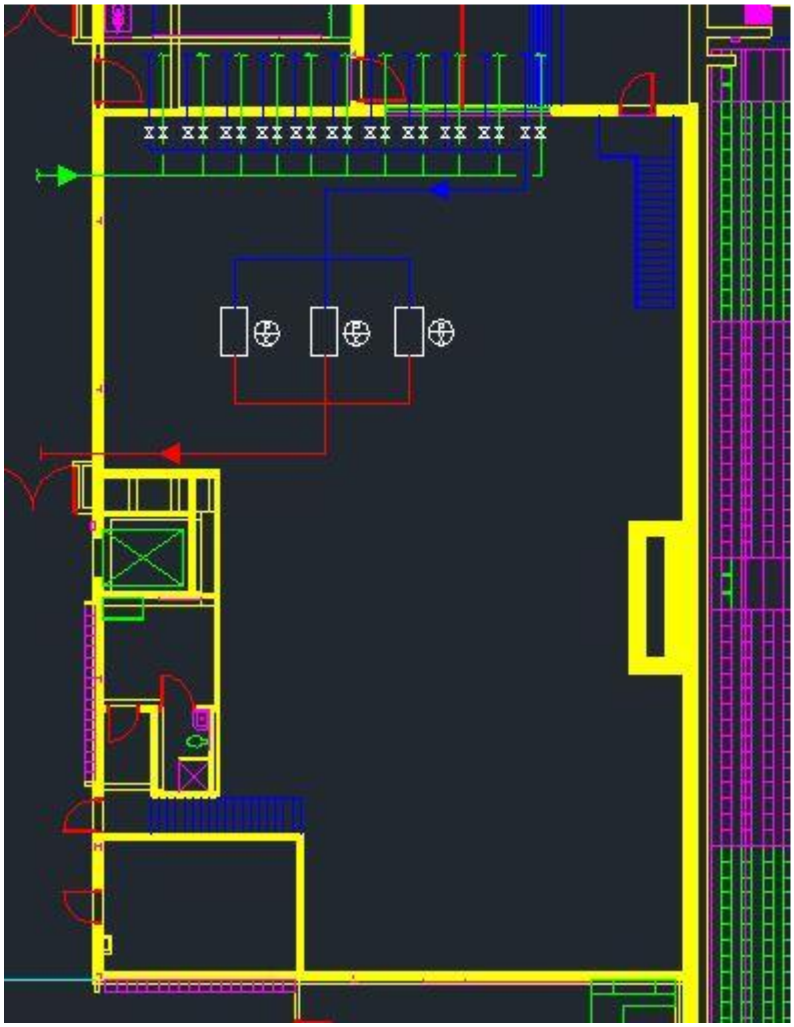

Figure 3 – Mechanical Room Layout

Equipment Selection

Pump Selection

To size the pumps calculations for head loss along with how much flow the system requires were done. Since the building is cooling load dominated the flow rate for the GCHP system was sized from that. Below in Table 6 the flow rate calculation is shown. A temperature differential of twelve degrees was used and a flow of 1868 GPM was found to be the required flow rate.

Load [Btu]	GPM	DELTA T
11208000	1868	12

Table 6 – Flow Rate Calculation

Below in Table 7 is the head loss calculation. A head loss of four feet for every one hundred feet was assumed along with the associated fittings factors. A total adjusted head loss for the system came to be 204 feet.

Run	Length [ft]	Head Loss [ft/100ft]	Total Head Loss [ft]	Fittings Factor	Adjusted Head Loss [ft]
Well Field	3000	4	120	1.1	132
Building	1200	4	48	1.5	72
Total					204

Table 7 – Head Loss Calculation

From these two pieces of information a pump from Bell & Gossett was selected. A base mounted centrifugal Series 1510 pump rated at 3550 RPM, 60 HP, and 1000 GPM was chosen. Two pumps of this type will be installed as the primary pumps with an additional pump for redundancy purposes. Charts from Bell & Gossett for sizing can be seen in Figures 6 and 7 of Appendix A.

Heat Pump Selection

Water source heat pumps will be placed in mechanical closets in each of the zones. Vertical units from Carrier were chosen that would be suited for commercial applications. A majority of these units will range from 1 – 3 tons for the classrooms and office spaces. Specifications for the heat pumps can be seen in Figures 8 and 9 of Appendix A.

Energy Recovery Unit Selection

The original energy recovery units received chilled water from chillers and hot water from a boiler. With these gone a new type of energy recovery unit was selected from SEMCO. These will be packaged energy recovery units feed from water to water source heat pumps. The energy recovery will consist of total and sensible only recovery wheels. Product information can be seen in Figure 11 of Appendix A.

Energy Model Comparison

The baseline model for the building was the original design while it was compared to the redesign in TRACE 700. By oversizing the system there was no need for a supplemental boiler or cooling tower to be added to the system. Table 8 shows the comparison of energy usage between the baseline and redesign. By implementing a GCHP system the use of energy goes down by 35% saving them $19074 annually.

	Baseline		Redesign	
	Energy (10^6 Btu/yr)	Cost/yr ($/yr)	Energy (10^6 Btu/yr)	Cost/yr ($/yr)
Electricity	2623	85793	3771	70516
Gas	3221.9	3797	0	0
Total	5845	89590	3771	70516

Table 8 – Energy & Cost Analysis

By reducing the amount of energy used by the building the site energy goes down yet the amount of source energy goes up. This is due to the fact that there is an increase in electricity by 45% even though consumption of gas was eliminated as shown in Table 9 below. The increase in electricity is reflected in Table 10 below by the increase in emissions.

	Baseline	Redesign
Electricity (kWh)	768528	1104826
Gas (kBtu)	3221945	0
Building (Btu/ft^2-yr)	18263	11782
Source (Btu/ft^2-yr)	35187	35350
Floor Area (ft^2)	320000	

Table 9 – Fuel Emissions

	Baseline	Redesign
CO_2 (lbm/yr)	1028013	1477859
SO_2 (gm/yr)	9257	13308
NO_X (gm/yr)	1772	2547

Table 10 – Building Emissions

Acoustical Breadth

Heat pump closets will be built in each space to allow for better access to the equipment and make it easier on the maintenance staff to maintain it. The walls that will be built around the heat pump must follow ANSI S12.60 standards. Following the guidelines set by ANSI S12.60 standards a wall of STC 60 was chosen based off of the criteria listed in Table 11 below. The last column in Table 11 shows that the minimum STC value between a mechanical room space and classroom must be at least 60.

Adjacent space			
Other enclosed or open-plan core learning space, therapy room, health care room and space requiring a high degree of acoustical privacy [a), b)]	**Common-use and public-use toilet room and bathing room [a)]**	**Corridor, staircase, office, or conference room [c), d)]**	**Music room, music performance space, auditorium, mechanical equipment room, [e)] cafeteria, gymnasium, or indoor swimming pool.**
50	53	45	60

[a)] These requirements do not apply to toilets opening only into the core learning space and used only by occupants of the core learning space.

[b)] A 20 cm (8") concrete masonry unit wall having a surface weight density of at least 180 kg/m^2 painted and sealed on both sides, acoustically sealed at the entire perimeter and extending from the floor slab to the structural deck above, is an acceptable alternate assembly that conforms to the intent of 5.4.2.1.

[c)] For corridor, office, or conference room walls containing doors, the basic wall, exclusive of the door, shall have an STC rating as shown in the appropriate column in this table. The entrance door shall conform to the requirements of 5.4.2.4.

[d)] When acoustical privacy is required, the minimum composite STC rating, including the effects of doors, of the partitions around an office or conference room, shall be increased to 50.

[e)] The isolation between core learning spaces and mechanical equipment rooms shall have a STC rating of 60 or greater unless it is shown that the sound level in the mechanical equipment room combined with a lower STC rating can achieve the required sound level in the core learning space. In no case shall the design STC between such spaces be less than 45.

Table 11 – Minimum STC Rating

A typical wall type has been chosen from the NRC-CNRC gypsum board walls manual shown in Figure 4 below. Table 12 below shows the materials and their thicknesses that make up this typical wall type.

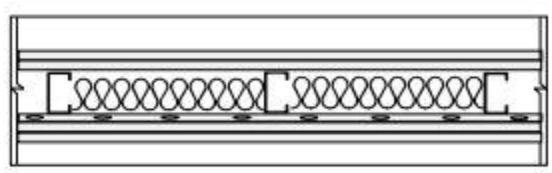

Figure 4 – Wall Section

NRC TL #	Description	STC
TL-94-020	1 single layer of 1/2 in gypsum board 1 single layer of 1/2 in gypsum board 3.5 in steel studs at 16 in o.c. 3.5 in glass fiber insulation resilient channels at 24 in o.c. 1 single layer of 1/2 in gypsum board 1 single layer of 1/2 in gypsum board	60

Table 12 – Wall Description

Having selected a wall that would mitigate the sound coming from the heat pump a scenario was run in Dynasonics AIM program to see if the NC value of the room was not exceeded. Table 13 shown below gives the path of the air that it would take from the heat pump to the diffusers in the classroom. The target NC was 30 which was exceeded by three to get an actual NC of 27. The lower frequencies is where heat pump's NC value is the largest and therefore this had to be mitigated to exceed the NC of 30 as shown below in Figure 5. Acoustical levels for the heat pump can be found in Figure 10 of Appendix A.

Typical Classroom

Calculation Summary

Element		Properties	NC	63	125	250	500	1K	2K	4K	dB(A)
				Octave Midband Frequency, Hz							
1	**Typical Classroom**	**Criteria: NC-30**	**27**	**53**	**45**	**22**	**0**	**0**	**0**	**0**	**31**
2	**Unassigned (1)**	**Criteria: NC-30**									
3	Air Terminal			72	72	70	64	65	56	52	
4	Rectangular Duct	18"x12"x17' (1")		-6	-6	-12	-30	-40	-40	-40	
5	Rectangular Duct	10"x10"x6' (1")		-2	-3	-6	-13	-27	-28	-19	
6	Circular Duct	8"x30' (1")		-10	-16	-27	-40	-40	-40	-40	
7	Room Correction (Normally Furnished)	30'x35'x9'		-1	-2	-3	-4	-5	-6	-7	
8	**SUM**		**27**	**53**	**45**	**22**	**0**	**0**	**0**	**0**	**31**

Table 13 – NC Calculation

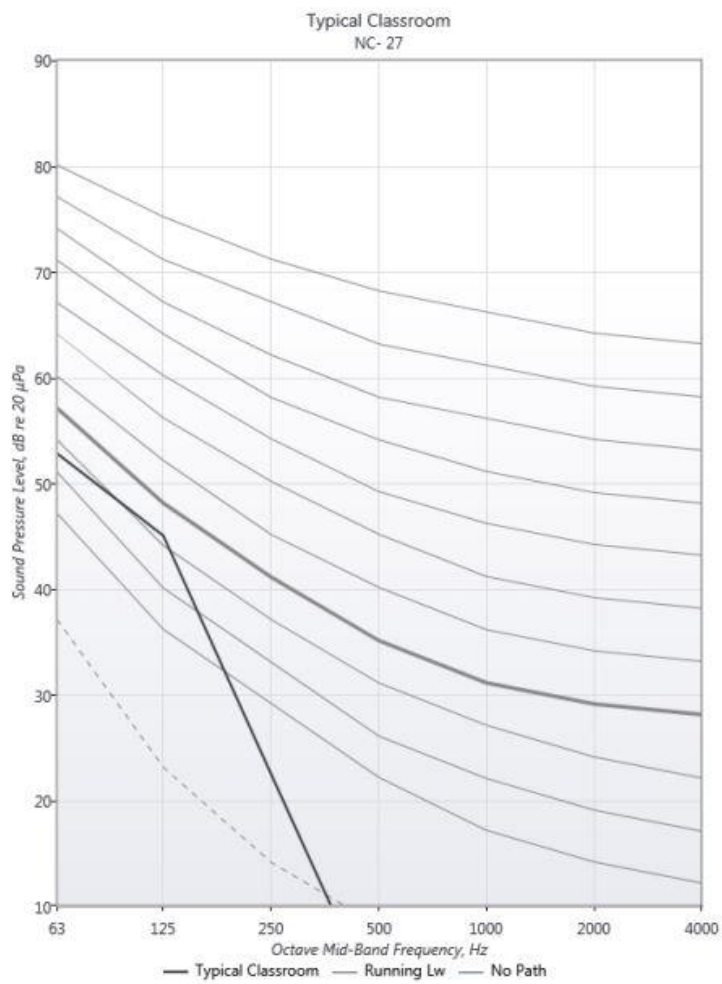

Figure 5 – NC Graph

Construction Breadth

Heat pump closets present multiple advantages over installing a heat pump in the ceiling. With aging maintenance staff at the building having a closet would allow them to have better access to the heat pumps in case of a malfunction or break. If there is a break the spill can be contained within the closet rather than drip down onto the occupants from the ceiling and damage the ceiling. Also with easier access the heat pump will be maintained more over time furthering the life span of the equipment.

A feasibility study was done to see if choosing to build the heat pump closets over installing the heat pump in the ceiling was more viable. The three main areas that were looked at are cost, schedule and coordination issues. The option that was most feasible was installing the heat pumps in the ceiling as shown below in Table 14. However as stated above there are other factors that go into choosing whether or not to build heat pumps.

	Cost [$]	Schedule [days]	Coordination Issues
Closet	63878.58	19	2
Ceiling	60234.69	17	4

Table 14 – Feasibility Matrix

Calculations for cost and schedule along with coordination issues are found in tables 15 – 25 in Appendix B.

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Faculty Consultations

Appendix A – Equipment Selection

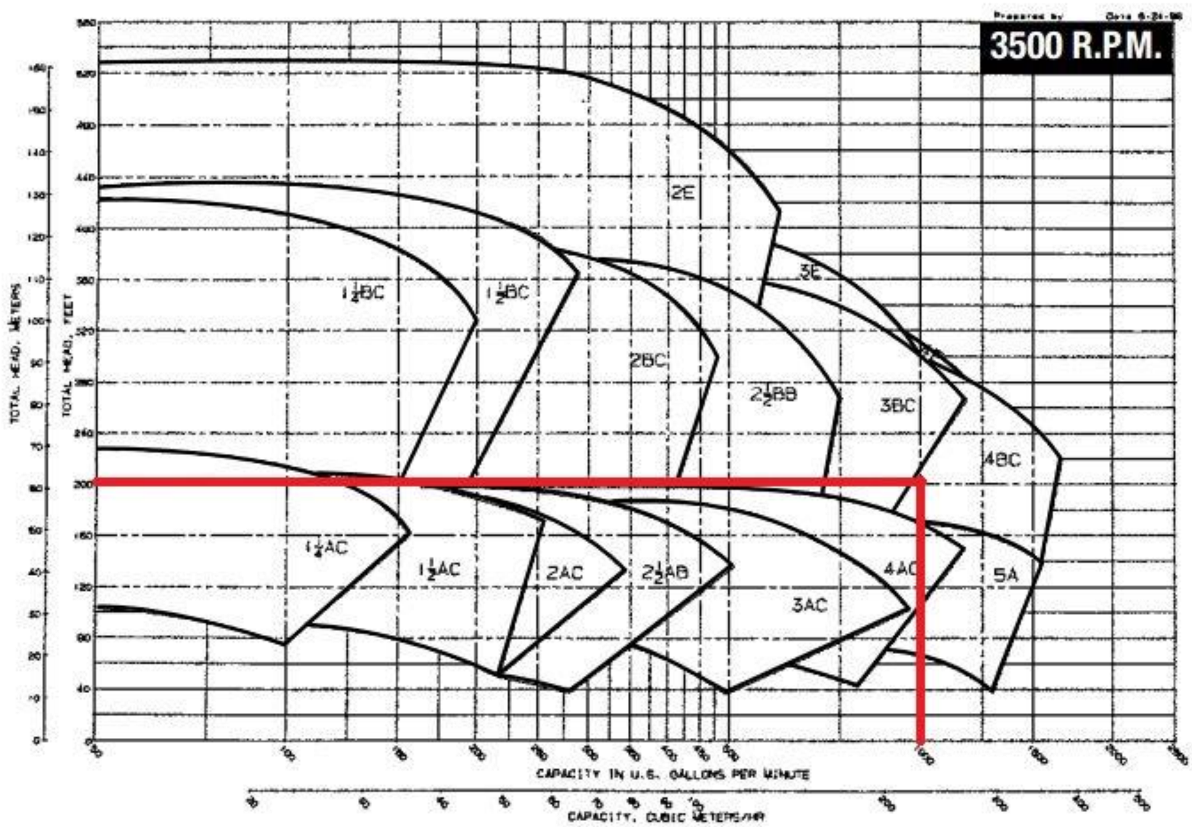


Figure 6 – Pump Selection Curves

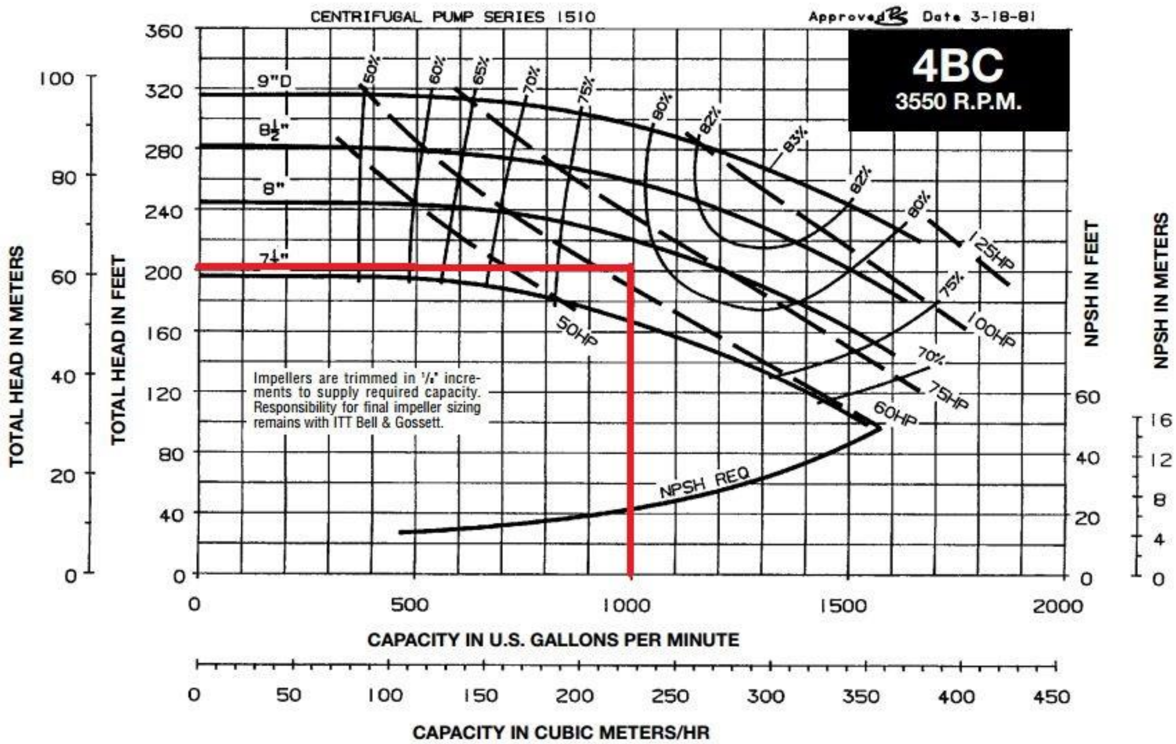


Figure 7 – Pump Performance Curve

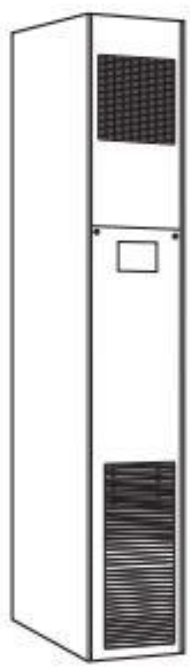
Carrier

Product Data

AQUAZONE™ 50VS Vertical Stack Water Source Heat Pump with PURON® (R-410A) Refrigerant

$^{3}/_{4}$ to 3 Nominal Tons

AQUAZONE™



ASHRAE 90.1 COMPLIANT

Well exceeds ASHRAE 90.1 and Energy Star Standards.

Puron®

the environmentally sound refrigerant

Single-package vertically stacked water source heat pumps with electronic controls offer:

- Puron non-ozone depleting R-410A refrigerant
- Compressor isolation
- Stainless steel drain pan
- 4-way compressor isolation for ultra-quiet operation
- Removable chassis and blower motor assembly
- Performance certified to ARI/ISO 13256-1:1998; sound tested to ARI 350-86
- Flexible and reliable controls include LON protocol and BACnet™ controls
- Cleanable pre-filter
- Multiple supply air discharge and riser piping location options

Features/Benefits

Carrier's Aquazone vertical stack water source heat pump with Puron (R-410A) refrigerant is a high quality, ultra-efficient solution for boiler/tower and geothermal design applications.

Operating efficiency

Carrier's vertical stack water source heat pumps are designed for quality and high performance over a lifetime of operation. All stack models with Puron (R-410A) refrigerant offer cooling EERs (Energy Efficiency Ratios) to 21.0 and heating COPs (Coefficiency of Performance) to 4.7.

Form 50VS-2PD

Figure 8 – Heat Pump Product

ARI/ISO capacity ratings

Carrier

50VS WATER LOOP AND GROUND WATER APPLICATIONS

UNIT	WATER LOOP HEAT PUMP				GROUND WATER HEAT PUMP				GROUND LOOP HEAT PUMP			
	Total Cooling at 86° F		Total Heating at 68° F		Total Cooling at 59° F		Total Heating at 50° F		Total Cooling at 77° F		Total Heating at 32° F	
	Capacity (Btuh)	EER (Btuh/W)	Capacity (Btuh)	COP	Capacity (Btuh)	EER (Btuh/W)	Capacity (Btuh)	COP	Capacity (Btuh)	EER (Btuh/W)	Capacity (Btuh)	COP
50VSA,B	9,200	13.5	12,500	4.7	11,200	21.0	10,500	4.1	9,700	15.6	8,100	3.4
50VSC,D	12,000	13.0	16,000	4.6	14,800	21.0	13,500	4.0	13,200	15.5	10,000	3.3
50VSE,F	16,500	13.0	21,500	4.5	19,500	20.0	18,500	3.9	18,000	15.0	15,000	3.2
50VSG,H	18,500	13.0	23,500	4.5	20,500	19.5	19,500	3.9	19,000	14.8	16,800	3.2
50VSI,J	22,500	13.0	29,500	4.7	26,800	20.0	24,500	4.2	24,000	15.0	19,000	3.3
50VSK,L	30,000	12.7	37,000	4.5	35,000	19.0	32,000	4.0	32,000	14.5	25,000	3.3
50VSM,N	34,000	13.0	41,000	4.5	38,000	19.0	35,000	4.0	36,000	15.0	27,000	3.2

LEGEND

COP — Coefficient Performance
db — Dry Bulb
EER — Energy Efficiency Ratio
wb — Wet Bulb

NOTES:
1. Cooling capacity based upon 80.6 F db, 66.2 F wb entering air temperature.
2. Heating capacity based upon 68 F db, 59 F wb entering air temperature.
3. All ratings based upon airflow at high speed and operation at lower voltage (208-vac) of dual voltage ratings.
4. Certified in accordance with the ARI/ISO Standard 13256-1:1998 Certification Program.

ARI PERFORMANCE CERTIFIED

Physical data

PHYSICAL DATA — 50VS UNIT

UNIT	50VSA,B	50VSC,D	50VSE,F	50VSG,H	50VSI,J	50VSK,L	50VSM,N
COOLING CAPACITY (Btuh)	9,200	11,700	16,500	18,000	22,500	28,500	32,700
HEATING CAPACITY (Btuh)	12,500	16,000	22,500	24,500	31,000	38,000	45,000
CABINET WEIGHT (lb)	120				170		
CHASSIS WEIGHT (lb)	99	105	119	122	187	198	205
COMPRESSOR (1 each)	Rotary						Scroll
High Side Pressure (psig)	550						
Low Side Pressure (psig)	170						
FACTORY REFRIGERANT CHARGE R-410A (oz)	27.5	27.5	38.7	41.6	49.4	63.5	61.8
FAN DATA							
Fan Motor Type/Speeds	PSC/2 speed						
Blower Wheel Size (Depth x Width) (in.) Std/High Static	7.08 x 6.89				9.21 x 9.99		
Airflow (cfm)	370	450	540	640	820	1120	1300
Static Pressure (in. wg)	0						
WATER/CONDENSATE SIDE DATA							
Flow Rate (gpm)	2.6	3.2	4.5	5.2	6.5	8.5	9.5
Water Connection Size (FPT) (in.)	1/2				3/4		
Water Side Pressure Drop (psi)	5.8	5.8	11.5	11.8	4.8	7.2	10.2
Condensate Connection Size (in.)	3/4						
AIR COIL DATA							
Total Face Area (sq ft)	1.48	1.48	1.81	1.48	1.48	1.81	1.48
Tube Size (in.)	3/8						
Fin Spacing (FPI)	12		14		10		
Number of Rows	2		3		2	3	
CABINET DATA							
Depth (in.)	18				24		
Height (in.)	88				88		
Width (in.)	18				24		
Standard Filter -- 1 in. Washable	14-1/4 x 18-1/2		14-1/4 x 22-1/2		19 x 28-3/4		

LEGEND

FPI — Fins Per Inch
PSC — Permanent Split Capacitor

Figure 9 – Heat Pump Specifications

50VS UNIT OCTAVE BAND SOUND POWER LEVEL (dB re 1pW)

UNIT	NOMINAL CAPACITY (TONS)	UNIT TEST OPERATION MODE	WITH SINGLE SUPPLY DOUBLE DEFLECTION GRILLE AND STANDARD PERIMETER BYPASS PANEL, OCTAVE BAND FREQUENCY, Hz						
			125	250	500	1000	2000	4000	8000
50VSA,B	3/4	Fan Only: Low Speed	52.3	50.5	46.0	41.1	33.6	32.1	31.0
		Fan Only: High Speed	52.9	51.0	47.4	41.5	33.9	32.8	31.1
		Cooling: Low Speed	53.5	51.5	47.6	41.7	34.4	32.9	31.1
		Cooling: High Speed	56.5	54.3	50.1	44.3	37.9	36.3	31.8
		Heating: Low Speed	53.9	51.0	48.4	42.4	34.9	33.2	33.1
		Heating: High Speed	56.2	53.8	50.2	44.2	37.5	36.3	32.8
50VSC,D	1	Fan Only: Low Speed	54.8	52.3	40.1	43.3	37.5	36.5	32.7
		Fan Only: High Speed	54.4	52.1	37.6	43.4	36.9	38.6	32.2
		Cooling: Low Speed	56.0	53.3	49.6	43.9	38.3	36.6	32.8
		Cooling: High Speed	58.0	55.4	41.7	46.2	40.9	39.2	34.2
		Heating: Low Speed	60.9	54.2	49.9	44.2	37.6	36.4	33.8
		Heating: High Speed	60.7	56.2	51.7	45.8	39.6	38.6	34.4
50VSE,F	1 1/4	Fan Only: Low Speed	58.9	57.8	54.0	51.5	45.0	43.7	38.4
		Fan Only: High Speed	59.2	59.1	54.3	52.6	45.2	44.7	41.3
		Cooling: Low Speed	60.1	58.8	55.6	52.1	45.8	44.5	38.6
		Cooling: High Speed	62.8	62.4	58.2	55.4	49.1	48.1	41.8
		Heating: Low Speed	61.3	59.3	56.4	52.3	45.4	44.1	39.1
		Heating: High Speed	63.8	62.3	58.1	55.2	48.4	47.7	41.7
50VSG,H	1 1/2	Fan Only: Low Speed	62.0	60.9	55.9	54.9	48.3	47.4	42.1
		Fan Only: High Speed	61.6	60.9	55.4	53.6	47.8	47.0	44.2
		Cooling: Low Speed	63.3	61.9	57.4	55.5	49.1	48.2	42.3
		Cooling: High Speed	65.1	64.1	59.4	57.5	51.3	50.5	44.8
		Heating: Low Speed	63.8	61.9	57.9	55.1	48.3	47.1	42.0
		Heating: High Speed	65.1	63.9	59.4	57.5	50.3	49.2	43.7
50VSI,J	2	Fan Only: Low Speed	60.7	58.6	54.1	48.3	42.3	38.4	35.7
		Fan Only: High Speed	59.6	58.7	54.8	49.2	43.1	39.2	36.9
		Cooling: Low Speed	61.9	59.6	55.7	48.9	43.1	39.2	35.9
		Cooling: High Speed	63.1	62.0	58.9	52.0	47.1	43.0	37.5
		Heating: Low Speed	63.7	60.8	57.9	51.1	44.8	40.5	38.4
		Heating: High Speed	65.7	63.2	59.4	52.3	48.7	44.1	39.6
50VSK,L	2 1/2	Fan Only: Low Speed	67.4	63.7	58.8	54.3	49.9	45.7	41.3
		Fan Only: High Speed	65.2	64.2	58.7	55.8	50.4	46.9	44.0
		Cooling: Low Speed	68.6	64.8	60.2	54.8	50.7	46.6	41.5
		Cooling: High Speed	68.8	67.4	63.0	58.5	54.2	50.3	44.5
		Heating: Low Speed	69.7	65.7	61.2	56.1	51.9	47.8	41.9
		Heating: High Speed	68.7	67.7	63.2	58.6	54.4	50.3	44.8
50VSM,N	3	Fan Only: Low Speed	70.2	68.0	62.1	59.1	56.6	50.1	45.1
		Fan Only: High Speed	70.3	68.1	63.2	65.3	56.6	50.3	46.8
		Cooling: Low Speed	71.4	69.6	62.1	59.4	56.7	50.4	45.2
		Cooling: High Speed	71.5	69.8	64.0	65.4	56.2	52.1	47.0
		Heating: Low Speed	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Heating: High Speed	70.5	69.6	64.0	60.9	58.8	53.0	47.7

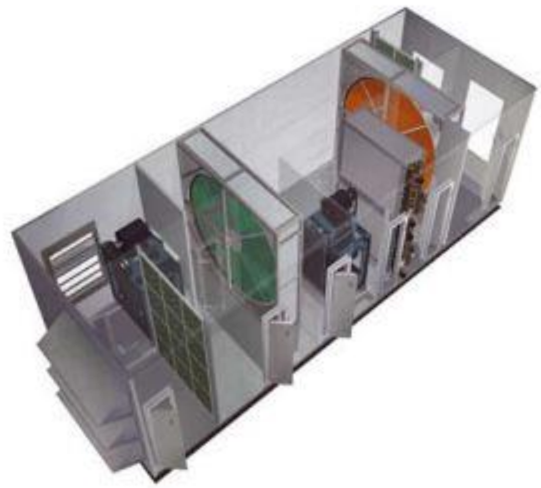
NOTES:
1. All performance is Sound Power Level in dB referenced to 1 picoWatt.
2. Data is based on sound measurements made in a reverberant room on representative units from each cabinet size in accordance with ARI Standard 350-86.

Figure 10 – Acoustical Data

Eliminate most of your building loads ... using less energy

Enthalpy wheel systems can save energy ranging from 40-50% of your required cooling tonnage and 50-100% of your heating capacity* associated with your ventilation load.

When supplemented with water source heat pump technology, the system becomes more than a pre-conditioner – it becomes a Dedicated Outside Air System (DOAS). The DOAS approach is utilized to decouple the ventilation load from your building, and through the use of hot gas reheat or a sensible energy recovery wheel, it can supply room neutral conditions to the space.



Go the next step

Going beyond mere decoupling the ventilation load, SEMCO's dual wheel systems go the next step by providing passive means to decouple the latent load of the space without the requirement of active regeneration. This system can discharge conditions as low as a 41 degree dewpoint regardless of the outdoor humidity content. SEMCO's Pinnacle System is an unparalleled DOAS that provides semi-neutral dry air without significantly increasing the cooling capacity over the more traditional single wheel approach.

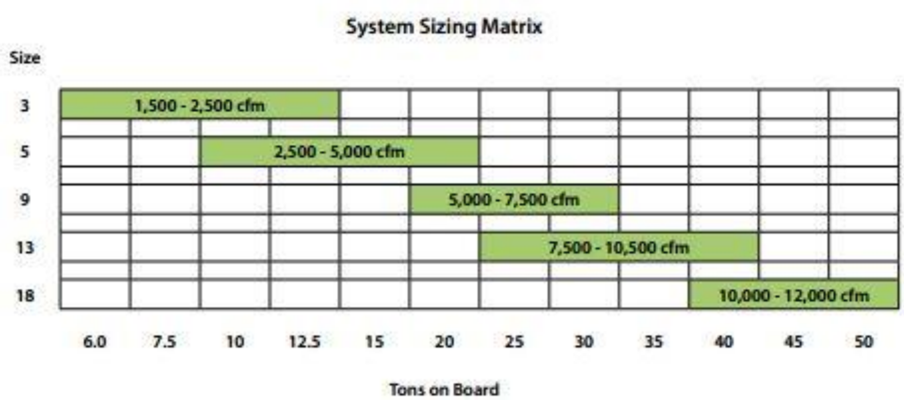


Figure 11 – SEMCO Energy Recovery Units

Appendix B – Construction Calculations

Ceiling Installation

Duct Type	Duct Size	Duct Length [ft]	Gauge	Weight [lb/ft]	Weight [lb]	Mat. [$/Unit]	Mat. Total [$]	Labor [$/Unit]	Labor Total [$]
SA	18 x 12	18	24	6.5	117	4.05	473.85	7	819
OA	20 x 8	5	24	6	30	4.05	121.5	7	210
	32 x 16	15	22	12	180	4.05	729	7	1260
	34 x 18	35	22	13	455	4.05	1842.75	7	3185
	38 x 18	40	22	14	560	2.95	1652	6.45	3612
	44 x 18	30	22	15.5	465	4.05	1883.25	7	3255
	58 x 20	30	20	22.6	678	2.95	2000.1	6.45	4373.1
Final Cost [$]	25416.55								

Table 15 – Ceiling Ductwork Takeoff & Cost

Pipe Type	Pipe Size [in]	Pipe Length [ft]	Mat. [$/Unit]	Mat. Total [$]	Labor [$/Unit]	Labor Total [$]
S	2	180	8.95	1611	12.95	2331
R	2	180	8.95	1611	12.95	2331
Final Cost [$]	7884					

Table 16 – Ceiling Piping Takeoff & Cost

Fitting Type	Amount	Mat. [$/Unit]	Mat. Total [$]	Labor [$/Unit]	Labor Total [$]
Duct Elbow	10	NA	NA	56	26074
Pipe Elbow	8	21.5	172	46	368
Final Cost [$]	26614				

Table 17 – Ceiling Fittings Takeoff & Cost

Ceiling Mount	Mat. [$/Unit]	Mat. Total [$]	Labor [$/Unit]	Labor Total [$]
Rods & Platform	75.04	75.04	245.1	245.1
Final Cost [$]	320.14			

Table 18 – Ceiling Assembly Takeoff & Cost

Note: Duct elbow labor [$/unit] is 56% of total labor cost

Activity Description	Qty.	Unit	Hours/Unit	Total Hours	Crew Size
Duct Installation	2485	Lb	0.137	340	1
Pipe Installation	180	LF	0.25	45	1
Pipe Connections	8	EA	0.889	7	1
Duct Connections	10	EA	0.137	1	1
Mounting Unit	1	EA	10	10	1
Total Duration [days]	17				

Table 19 – Ceiling Installation Duration

Closet Installation

Duct Type	Duct Size	Duct Length [ft]	Gauge	Weight [lb/ft]	Weight [lb]	Mat. [$/lb]	Mat. Total [$]	Labor [$/lb]	Labor Total [$]
SA	18 x 12	25	24	6.5	162.5	4.05	658.13	7	1137.5
OA	20 x 8	10	24	6	60	4.05	243	7	420
	32 x 16	20	22	12	240	4.05	972	7	1680
	34 x 18	35	22	13	455	4.05	1842.75	7	3185
	38 x 18	40	22	14	560	2.95	1652	6.45	3612
	44 x 18	30	22	15.5	465	4.05	1883.25	7	3255
	58 x 20	30	20	22.6	678	2.95	2000.1	6.45	4373.1
Final Cost [$]	26913.83								

Table 20 – Closet Ductwork Takeoff & Cost

Pipe Type	Pipe Size [in]	Pipe Length [ft]	Mat. [$/Unit]	Mat. Total [$]	Labor [$/Unit]	Labor Total [$]
S	2	190	8.95	1700.5	12.95	2460.5
R	2	190	8.95	1700.5	12.95	2460.5
Final Cost [$]	8322					

Table 21 – Closet Piping Takeoff & Cost

Fitting Type	Amount	Mat. [$/Unit]	Mat. Total [$]	Labor [$/Unit]	Labor Total [$]
Duct Elbow	11	NA	NA	56	27553.66
Pipe Elbow	9	21.5	193.5	46	414
Final Cost [$]	28161.16				

Table 22 – Closet Fittings Takeoff & Cost

Closet Assembly	Area [ft^2]	Mat. [$/SF]	Mat. Total [$]	Labor [$/Unit]	Labor Total [$]
Heat Pump Closet	80	1.99	159.2	4.03	322.4
Final Cost [$]	481.6				

Table 23 – Closet Assembly Takeoff & Cost

Note: Duct elbow labor [$/unit] is 56% of total labor cost

Activity Description	Qty.	Unit	Hours/Unit	Total Hours	Crew Size
Duct Installation	2620	Lb	0.137	359	1
Pipe Installation	190	LF	0.25	48	1
Pipe Connections	9	EA	0.889	8	1
Duct Connections	11	EA	0.137	2	1
Closet Assembly	80	SF	0.5	40	1
Total Duration [days]	19				

Table 24 – Closet Installation Duration

Coordination Issues

Ceiling Installation Coordination Issues

- Pre-installed hangars for supporting heat pump must be coordinated with slab pour
- Clearance height for heat pump between bottom of top slab and top of ceiling
- Pre-coordinate location of equipment due to congestion of other trades in ceiling
- Pre-coordinate with ceiling installers to install heat pump before ceiling installed

Closet Installation Coordination Issues

- Coordinate piping and ductwork to run in and out of heat pump closet space
- Coordinate with drywall and framing contractors to install closet

Table 25 – Coordination Issues