Technical Report 3

Mechanical

Mechanical Systems Existing Conditions Evaluation

Author:
Tessa Bauman

technical consultant:
Laura Miller, Ph.D, P.E.

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Executive Summary

The purpose of this report is to analyze and give a general overview of the mechanical systems of Twin Rivers Elementary/Intermediate as they are designed and how they work. It is also a general theme through out the report to search for interesting solutions for problems that may arise within the design.

The design was done according to the correct codes and standards. There was no problems found in comparison to ASHRAE standards 62.1 and 90.1. The building can handle the appropriate loads. The robust thermal envelope negates loss of energy.

The building is aiming for LEED certification, Silver at the least. The building has many sustainable features that can influence and inspire the generation that will come to learn within those walls.

There is a possibility to further extract the site's energy sources, such as waste heat recovery, solar accessibility, and wind energy. There is also the acoustic problem that may come from a glass enclosed mechanical room to consider in future analysis of Twin Rivers.

Mechanical Systems Summary

The Twin Rivers Elementary/Intermediate School will house 800 students of the Mckeesport Area School District. It is a two story building of 127,000 sq. ft. The Mechanical system is designed to save 30% of energy when compared to ASHRAE standard 90.1-2007 requirements. ASHRAEs Advanced Energy Design Guide for K-12 School Buildings also had a major impact on the design. The building has many different rooms with different functions, including the following types of areas:

1. Cafeteria
2. Classroom
3. Computer Lab
4. Corridor
5. Gymnasium
6. Kitchen
7. Library
8. Mechanical & Electrical
9. Nurse's area
10. Offices
11. Water Closets

The main heating and cooling will come from a geothermal system. This will be an earth coupled water loop directly connected to water-to-air heat pumps. There will be 2 well fields located slightly north of the building's foundation. The earth coupled water loop will also be connected to a chiller, serving air handling units, variable volume reheat boxes, and radiant floor systems for the kindergarten, pre-school rooms, and library story room.

The ventilation system consists of 2 dedicated outside air systems (DOAS) which serve the classrooms and most of the building. The library, cafeteria, gymnasium, and offices each have individual air handling units (AHU). The library and office AHUs will have zone reheat coils. The gym and cafeteria AHUs will consist of just a single zone.

Mechanical Systems Design Requirements

Design Objectives

Twin Rivers Elementary/Intermediate was designed to be a state of the art educational building. It is to be a example for other school districts in the area to follow. LEED considerations heavily influenced the design. Once completed, the school is to be LEED Silver certified. The HVAC design references the following standards:ASHRAE 15-2010,62-2007,90.1-2007, and 55-2004,and uses ASHRAEs 2006 Advanced Energy Design Guide for K-12 School Building as a guideline.

Design Conditions

Twin Rivers Elementary/Intermediate is in Mckeesport, PA. This is less than 20 miles from downtown Pittsburgh, PA. This area is mostly a urban area. For this report, weather data is taken from Pittsburgh. The climate that the school is located in is zone 5A according to 90.1's table B-1. Type A is considered to be very humid in the summers, where the OA needs to be air conditioned to be considered comfortable. Table 1 is the Summer and Winter outdoor design condtions. This is for degree days 3323 and 5356 respectively. Table 2 demonstrates the necessary design conditions of the indoor air.

Exterior Weather Conditions		
Summer Design		Winter Design
db (F)	mcwb (F)	db (F)
87.4	71.1	4.3

Table 1: Design Exterior Temp

Space	Summer Design		Winter Design	
	db (deg F)	% RH Max	db (deg F)	% RH Max
Computer Labs/Classrooms	75	60	72	20
Offices	75	60	72	20
Library	75	60	72	40
Gymnasium	75	60	72	20
Cafeteria	75	60	72	20
Restrooms	78	60	70	20

Table 2: Design Interior Temp and Relative Humidity

Ventilation

Two DOAS's, four AHU's supply the building, one kitchen make-up air unit, and one fan coil unit provide the building with the appropriate ventilation as required by ASHREA Standard 62.1.

The DOAS's return air, including that from the restrooms and from the classrooms, is used within the DOAS for heat recovery. It is then exhausted out of the system near the outside air intake. Since restroom exhaust is considered a Class 2 exhaust, it is allowed to be recirculated into the system. The AHU supplying the cafeteria and support area is placed at least 18 feet away from the kitchen exhaust. This is more than the 15 feet required for a Class 3 exhaust.

The Kitchen will have specific exhausts to the rooftop. Because of this, there is a kitchen makeup air unit.

The DOASs will have disposable filters with MERV 13 minimum efficiency minimum as rated by ASHRAE Test Standard 52-76. The supply filter is upstream of the enthalpy wheel and the DX cooling coil. There is another filter on the exhaust side of the unit right before the enthalpy wheel. Both the supply and reactivation air stream shall be completely filtered. AHU-1,2,3, and 4 will have filters that are UL 900 listed, Class I or Class II. These must be approved by local authorities.

A ventilation calculation was performed in order to determine outdoor air intake flow for optimal ventilation system for breathing zone. The ventilation airflow rates depend on type of space, occupancy level, space orientation, and area of the space. In every room, more than enough outdoor air was introduced into the environment. The table 3 includes general areas and the required ventilation rates.

Table 3: Requirements for Ventilation Rates

Zone Type	Minimum Ventilation Rates (CFM/person)	Minimum Ventilation (cfm/SF)	Infiltration (ACH)
Cafeteria	7.5	0.18	13
Classroom	10	0.12	6
Computer Lab	10	0.12	10
Corridor	0	0.06	4
Gym	0	0.3	8
Kitchen	7.5	0.12	15
Library	5	0.12	4
Mech/Elec	0	0.06	4
Nurse	10	0.18	8
Office	5	0.06	4
Water Closet	20	0.06	10

The designed ventilation systems for Twin Rivers Elementary/Intermediate meet the requirements, as seen in table 4.

Table 4: Required Ventilation Rates vs. Designed Rates

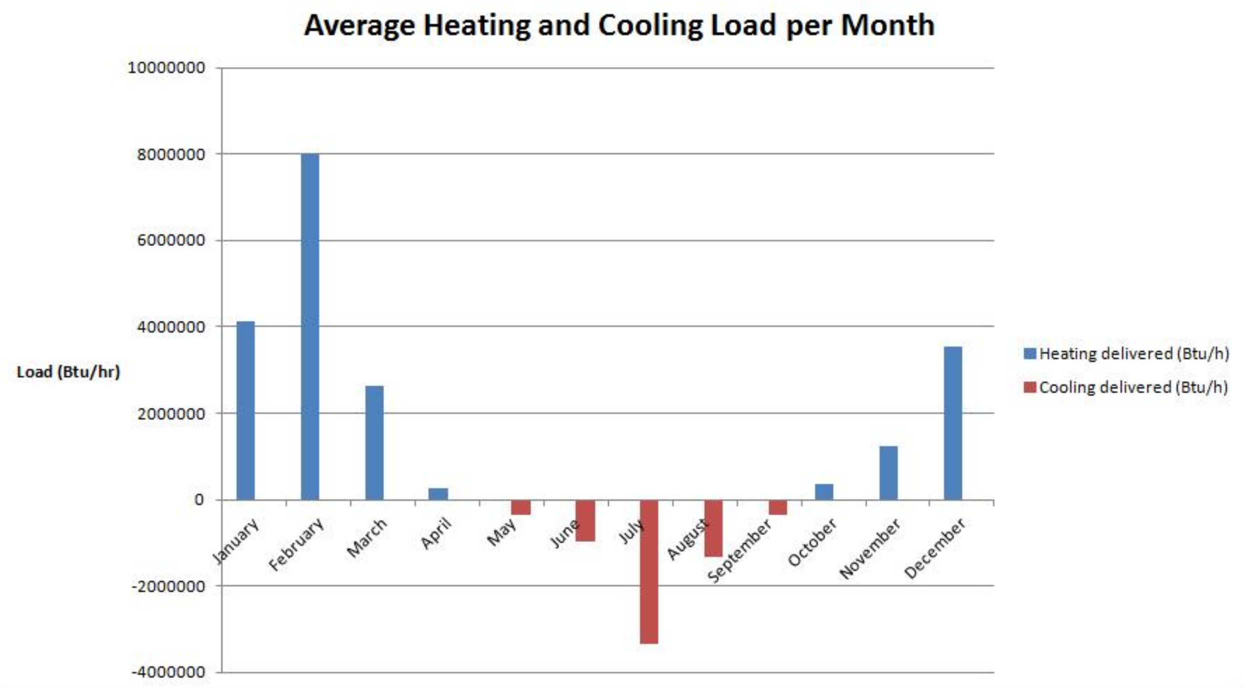
System	Calculated Ventilation Required (CFM)	Designed Ventialion (CFM)	Comply?
DOAS-1	10363.9	10370	Y
DOAS-2	14604.54	15380	Y
AHU-1 Cafeteria	6337.52	10500	Y
AHU-2 Library	2244.6	8350	Y
AHU-3 Gymnasium	2292.58	11250	Y
AHU-4 Offices	964.96	8650	Y

Heating and Cooling Loads

Twin Rivers Elementary/Intermediate is designed for 99.6% winter conditions due to the lack of occupancy during the summer months. This means that most of the load is for heating purposes.

A Load simulation was preformed in the TRANE Trace program. To do this, a block load energy analysis was applied. Similar areas were formed into blocks for the entire school. for example, a large grouping of classrooms are considered to be one block. Within Trace, templates for different zone types were created. A block load analysis is for simplicity and estimation. The mechanical engineers would create a more accurate model. However, The designer's load calculation is not available at this time.

The following graph is the load for each month of the year. February has the highest average load due to extreme winter conditions. December and January do not have a high load as it may be expected. This is because these months have school holidays that lessen the load needed during those times. The peak heating load is 10,998 MBh. This is typical for western Pennsylvania design conditions.



Annual Energy Consumption & Cost Information

Table 5 is the utility summary for the building. The annual cost for electricity and for gas is almost $50,000. The gas consumption is minimal so the main utility cost is from electricity. this is a normal estimate for a school building this size.

Table 5: Monthly Utility Costs

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
					------ Monthly Utility Costs ------							
Alternative 1												
Electric												
On-Pk Cons. ($)	2,316	2,075	2,133	1,096	1,118	1,294	1,376	1,254	1,084	1,128	1,312	1,756
Off-Pk Cons. ($)	3,952	3,340	2,993	2,309	1,525	1,755	2,123	1,759	1,675	2,085	2,407	3,316
Total ($):	6,268	5,414	5,126	3,406	2,643	3,049	3,499	3,013	2,759	3,213	3,719	5,072
Gas												
Off-Pk Cons. ($)	248	181	181	0	0	0	0	0	0	0	60	134
Monthly Total ($):	6,517	5,595	5,307	3,406	2,643	3,049	3,499	3,013	2,759	3,213	3,779	5,206

Building Area = 116,950 ft²

Utility Cost Per Area = 0.41 $/ft²

Each year $47,985 is paid for utilities. However, the market discount rate decreases the present value of future payments. If the payment for year 20, the final year of the life cycle cost analysis, were to be paid today the utility cost would only be $7,133. This is a difference of $40,852. View table 6 for more details.

Table 6: Annual Utility Costs

Alternative: 1

Life Cycle Cost: $408,519.02

Year	Utility Cost ($)	Maint. Cost ($)	Interest Cost ($)	Principal Cost ($)	Property Taxes ($)	Insurance Cost ($)	Revenue Penalty ($)	Replace. Expenses ($)	Deprec. Tax ($)	Cash Flow Effect ($)	Present Value ($)
0	0	0	0	0	0	0	0	0	0	0	0
1	47,984	0	0	0	0	0	0	0	0	47,984	43,622
2	47,984	0	0	0	0	0	0	0	0	47,984	39,657
3	47,984	0	0	0	0	0	0	0	0	47,984	36,051
4	47,984	0	0	0	0	0	0	0	0	47,984	32,774
5	47,984	0	0	0	0	0	0	0	0	47,984	29,795
6	47,984	0	0	0	0	0	0	0	0	47,984	27,086
7	47,984	0	0	0	0	0	0	0	0	47,984	24,624
8	47,984	0	0	0	0	0	0	0	0	47,984	22,385
9	47,984	0	0	0	0	0	0	0	0	47,984	20,350
10	47,984	0	0	0	0	0	0	0	0	47,984	18,500
11	47,984	0	0	0	0	0	0	0	0	47,984	16,818
12	47,984	0	0	0	0	0	0	0	0	47,984	15,289
13	47,984	0	0	0	0	0	0	0	0	47,984	13,899
14	47,984	0	0	0	0	0	0	0	0	47,984	12,636
15	47,984	0	0	0	0	0	0	0	0	47,984	11,487
16	47,984	0	0	0	0	0	0	0	0	47,984	10,443
17	47,984	0	0	0	0	0	0	0	0	47,984	9,493
18	47,984	0	0	0	0	0	0	0	0	47,984	8,630
19	47,984	0	0	0	0	0	0	0	0	47,984	7,846
20	47,984	0	0	0	0	0	0	0	0	47,984	7,133

Energy Sources

The Building uses available area around the school for a geothermal heat pump system. This allows for less dependency on other utilities such as gas or electric.

Twin Rivers also uses a grey water system and collects storm water.

Since this is a educational building, the architects decided to tap in to the mechanical system as a source of knowledge. The main mechanical room's walls are mainly windows so that students can educate themselves on the inner workings of the building.

There are a few energy sources that could possible be utilized. Wind turbines were in earlier designs of this building. There may also be a better solution than the auxiliary boiler. It may be possible to install a waste heat recovery system, thermal photovoltaic array, or return to the wind turbine preliminary design.

Mechanical Operation and Schematics

Water Side

Note: Water Temperature Measurement Device missing from diagrams, should be in next to flow monitoring system after each set of pumps.

Heat pump water return is circulated through the well field. The ground is either a heat source, for heating, or a heat sink, for cooling. These pipes are buried in the ground. These pipes then enter the mechanical room through the ground. The heat pump water supply then can go into a the condenser water system, continue on into the parallel heat pump water pumps, or a percentage of the water goes in either direction(as seen in figure 2).

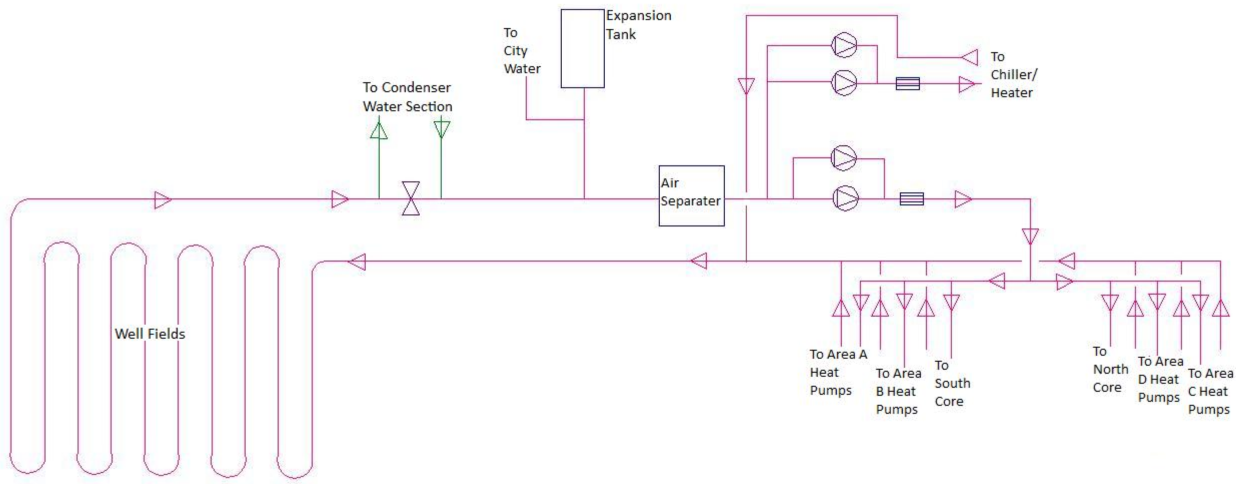


Figure 1: Heat Pump Water Supply and Return Flow Diagram

If the cooling load is high then some of that load can be helped with the condenser water system. The condenser water system (figure 3) begins with an heat exchange. This is due to the connection with the cooling towers. Since cooling towers are open to the environment, it is not suggested to mix the possibly contaminated evaporative fluid with the heat pump water.

If the heating load is high then some of that load can be helped with the condenser water system as well. The water will then go through an auxiliary boiler. If extra load needs to be met, either for heating or cooling, the by-pass valve adjusts accordingly(figure 1). If there is no extra load on the heat pump systems then the cooling tower is an closed water circuit and the condenser water pump (CDWP) with the lowest run time then energizes. All pumps in this building are coupled in parallel pairs with a flow monitoring system and temperature measuring device and a air separator . When either of the CDWP's are in operation then the 2 way valve from the HPWS will then open to allow flow through the heat exchanger.

The condenser water is a solution of 30% poly glycol and the rest water. This is maintained through the Glycol Fill Station. If the solution is below 65° the boiler is activated and by-pass valve is shut. If the temperature rises above 90 or drops below 60, an alarm will sound. The system monitors the flow and temperature after the CDWPs.

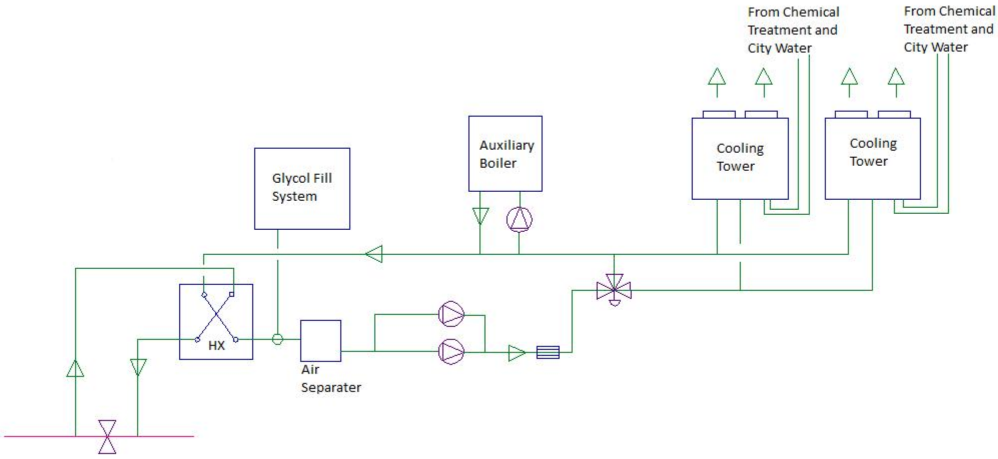


Figure 2: Condenser Water Supply and Return Flow Diagram

In figure 2, The HPWS can bypass the Condenser water system. It then goes into an air separater for equipment safety reasons. Two sets of two parallel water pumps are then in series. One set of pumps is leading to the heat pump units in the individual rooms.

The room heat pumps are vertical units, like shown in figure 3. these are controlled by zone thermostats. When the building is in unoccupied mode the unit will only cycle as necessary to maintain a night time temperature set point.

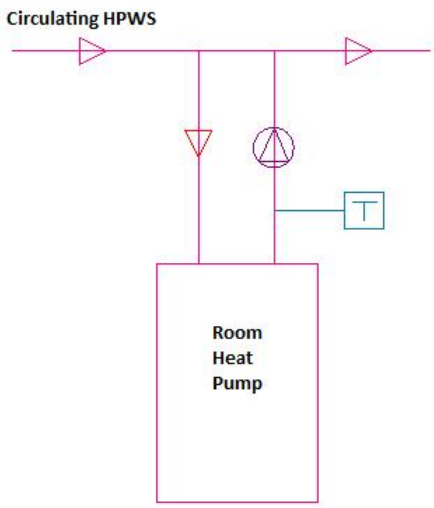


Figure 3: Typical Room Heat Pump

If the HPWS does not enter the room heat pump circulation, the water enters the chiller system (Figure 4). This also has flow and temperature monitored. The Chiller supplies both the hot water (HWS) and the chilled water (CHWS). These are to go to all of the AHUs' coils, all variable air volume reheat boxes in the office and library, and the radiant floor heating for the pre-school/kindergarten rooms and story room.

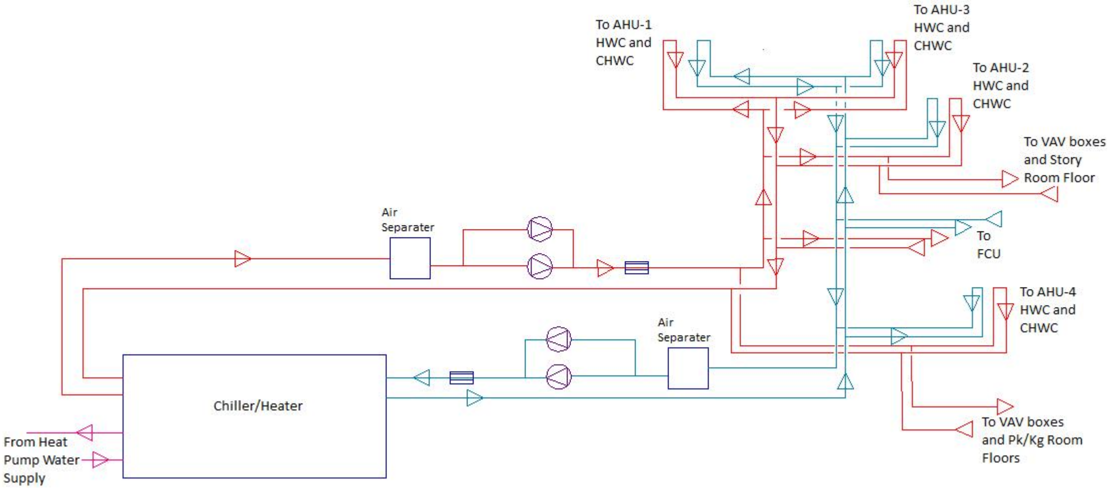


Figure 4: Chilled/ Hot Water Supply and Return Flow Diagram

Air Side

The majority of the building is ventilated with the two dedicated outside air systems (figure 5). These are controlled by multiple temperature sensors,thermal dispersion air-flow/temperature measurement device (ATMD), in both the exhaust and the supply paths.

The DOASs supply the classrooms and auxiliary spaces with proper ventilation. There are air flow dampers at each supply vent in the ceiling.

The AHU's (figure 6)supply one of the following areas: Cafeteria, Gymnasium, Library, or Offices. . The AHU for the cafeteria and the gymansium are constant volume systems. The AHUs for the library and the offices are variable air volumes with reheat boxes at individual zones. the variable speed drive controls how much is going to the two zones.

Both of these systems follow similar layout of ductwork (figure 7)

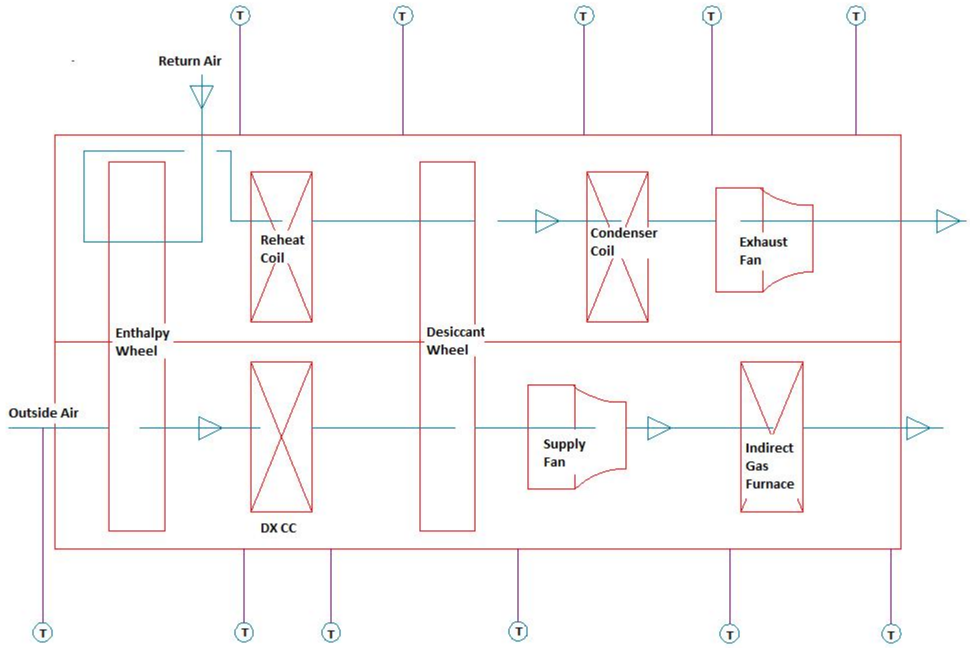


Figure 5: Typical DOAS Configuration

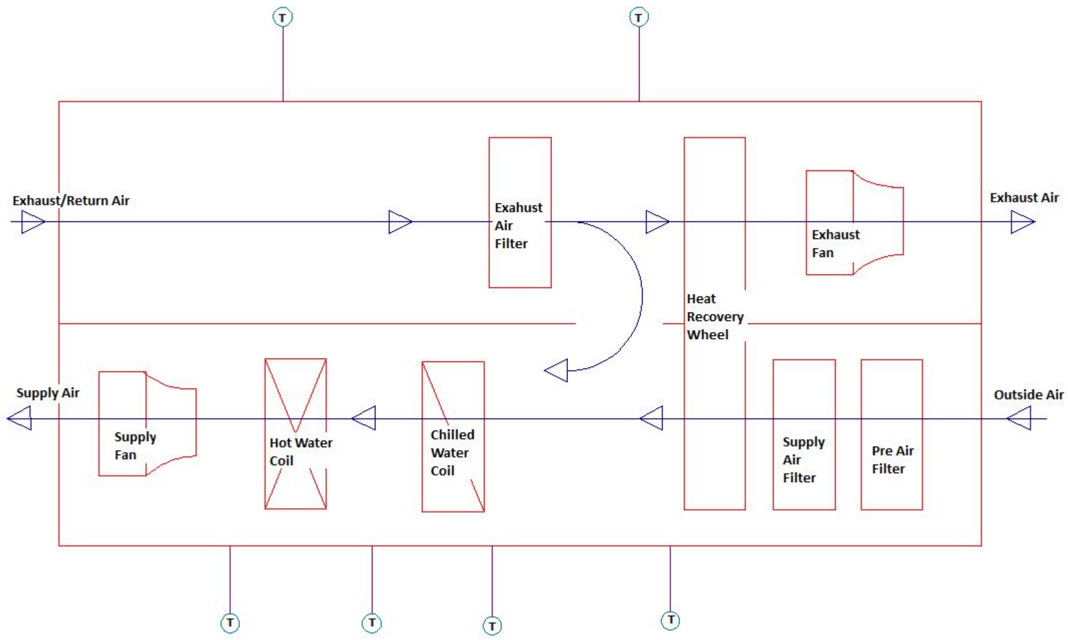


Figure 6: Typical AHU Configuration

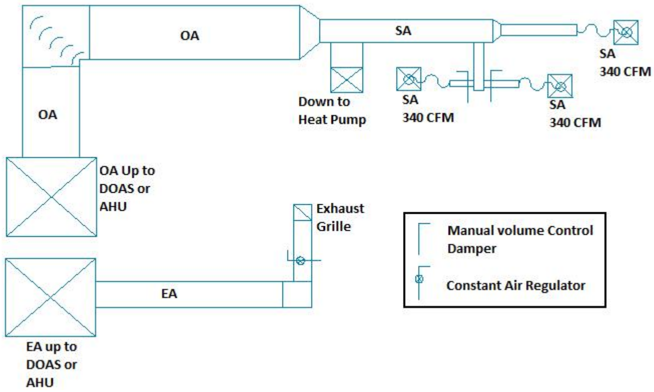


Figure 7: Typical Ventilation: Supply Air and Exhaust Air

Major Equipment Schedules

Table 7: Dedicated Outside Air System Schedule

DOAS Recovery Units											
		Fan Data			Heat Recovery			Cooling Coils, Reheat Coils/ Heating Section			
	location	Total CFM	RPM	HP	Type	CFM (Winter Design)	db (F) (Before/After)	CFM	Heat in MBH	Heat Out MBH	Refrig. Type
DOAS-1	Supply	10370	2055	20	Enthalpy	10870	2.00/53	10370	400	320	R-401a
	Exhaust	11150	1927	20	Desiccant	10650	70/19	NA			R-401a
DOAS-2	Supply	15380	1771	30	Enthalpy	16080	2.00/49	15380	600	480	R-401a
	Exhaust	15200	1597	30	Desiccant	14200	70/17	NA			R-401a

Table 8: Air Handling Unit Schedule

Air Handler with Heat Recovery Unit												
				Fan Data			Cooling Coil and Heat Recovery				Heating Coil Data	
	Serves	Description	Location	Total CFM	RPM	HP	Type	CFM	Total MBH	Sen. MBH	Type	CFM
AHU-1	Café	Recir/Ht. Recov.	Supply	10500	VFD	15	Coil	10500	460		HWC-1	4688
			Exhaust	10500	VFD	7.5	Heat Wheel	3710				
AHU-2	Library	Recir	Supply	8350	2618	15	Coil	8350	337.7	253.8	HWC-1	3695
			Exhaust	8350	2832	15						
AHU-3	Gym	Recir/Ht. Recov.	Supply	11250	VFD	15	Coil	11250	515		HWC-1	7175
			Exhaust	11250	VFD	10	Heat Wheel	4835				
AHU-4	Offices	Recir	Supply	8650	2653	15	Coil	8650	278.2	247.5	HWC-1	4022
			Exhaust	8650	2036	10						

Table 9: Heat Pump Schedule

Water Source Heat Pumps									
	Description	Fan Data High Speed CFM	Hp	Cooling Cap. Total MBH	Sens. MBH	Heating Cap. Total MBH	THA MBH	COP	Refrig. Type
HP-A	Vertical Cabinet	1000	1/3	25.9	22.8	22.3	18.4	4.9	R410a
HP-B	Vertical Cabinet	1100	1/2	34	25.2	31.3	25	4.4	R410a
HP-C	Vertical Cabinet	1300	1/2	37.5	29.6	35.2	28.2	3.8	R410a
HP-D	Vertical Cabinet	1500	3/4	38.9	35.1	41.9	33.5	3.5	R410a
HP-E	Vertical Cabinet	1800	3/4	55.9	46.1	60.5	48.4	4.1	R410a
HP-F	Horizontal Console	600	NA	15.1	11.7	14.5	10.5	3.6	R410a

Table 10: Chiller/Heater Schedule

Water-to Pater HP (Chiller/Heater)								
	Heating COP	MBTUH Heat	Cooling EER	Tons Cooling	Ground Loop Water GPM	DP FT	Building Water GPM Heat	GPM Cool.
CH-1	3.6	1167.9	14.1	121.7	452	17.7	250	350

Table 11: Heat Exchanger Schedule

Heat Exchanger						
	Descriptio	Cold Side GPM	DP FT	Hot Side GPM	PD FT	Heat exch MBH
HX-1	Plate and Frame	500	9.4	475	7	2378

Table 12: Evaporative Fluid Cooler Schedule

Evaporative Fluid Cooler						
	MBH	GPM	Coil DP FT	Spray pump GPM	Spray Pump HP	Sump HeaterType
EFC-1	1188	250	15	470	3	electric
EFC-2	1188	250	15	470	3	electric

Table 13: Auxiliary Boiler Schedule

Auxilary Hot Water Boiler					
	type	Input MBH	Output MBH	Max GPM	DP Feet
HWB-1	finned tube	1000	970	58	9.5

Table 14: Water Pump Schedule

Water Pumps						
	Descriptio	Solution	GPM	Head ft	Motor RPM	Motor HP
HPWP-1		Water	270	110	3525	15
HPWP-2		Water	270	110	3525	15
HPWP-3		Water	235	100	1750	15
HPWP-4		Water	235	100	1750	15
HWP-1		30% PG	250	65	1750	7.5
HWP-2		30% PG	250	65	1750	7.5
CHWP-1		30% PG	350	70	1750	15
CHWP-2		30% PG	350	70	1750	15
CDWP-1		30% PG	500	60	1750	15
CDWP-2		30% PG	500	60	1750	15
HPCP-A		Water	13	15	2750	0.08
HWCP-B		Water	3	12	3300	.4A

Mechanical System Space

The Mechanical System take 1,282 square feet of usable space. There is a total of 4,437 square feet of both mechanical and electrical space. Some of the mechanical systems pass through the electrical rooms.

However, since the main mechanical room is being presented educational for the students, it can be argued that the space is not completely lost to the occupant. The main mechanical room is viewable through the large curtain walls and LCD monitors are displayed outside of the room with information about the systems. This feature may possibly cause disruption if the room is not properly prepared acousticly.

LEED Analysis

The project is projected to get either LEED Silver or Gold certification. The following points are assumed to be obtained due to MEP systems once construction is completed early 2014.

- Water Use Reduction by 20%
- Grey Water Used for Irrigation
- Optimize energy Performance through geothermal source heat pump and well field
- Minimum IAQ Performance
- Direct-Digital HVAC control system provides optimum thermal comfort

Overall Evaluation

The Twin Rivers Elementary/Intermediate is a well thought out design. This particular type of HVAC design is becoming popular within the school sector of construction. Geothermal source heat pump systems seem to be the best system for the environment and also have a decently short time til the system starts to payback, 3-5 years. In comparison, a solar thermal system may take anywhere from 7 to 15 years to start paying back. The ventilation system seems to be efficient due to the lack of occupancy during months at a time. This allows for the AHU for the offices to run at full capacity but allow other systems to reduce the output.

References

ASHRAE. Standard 62.1-2007, . Atlanta, GA. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc

ASHRAE. Stanard 90.1-2007, Atlanta, GA. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

Design by J C Pierce, Architects with help from the following engineering firms

- Phillips & Associates, Inc
- Loftus Engineers
- American Geosciences, Inc.