ASCE Charles Pankow Foundation
Annual Architectural Engineering
Student Competition

AEI
ASCE
ARCHITECTURAL ENGINEERING INSTITUTE

Mechanical Systems

Team No. 03-2013

contents

studio VI

Building Fast Facts

Three-Story Elementary School
87,000 Sq. Ft.
$19.7 Million

Building Systems Summary

Hybrid Geothermal System
Steel Frame w/ Shear Walls & Braced Frames
Brick & Aluminum Panel Façade
Add-Alternates:
- Separate Natatorium
- Hardened First Floor Envelope
- Existing School Usage

Location Fast Facts

Reading, PA
Southeast Pennsylvania
Urban Site
88,000 residents
Poorest City in America*
One of the Highest Crime Rates in America*
District is in Bottom 10% for Academic Performance in PA*
Highest Poverty Rate of School Districts in PA*
31.5 % High School Dropout Rate*
6.7% of Reading Residents have a Bachelor's Degree or Higher*

**Refer to 'Building Systems Integration Supporting Documents' Bibliography*

introduction

Project Overview. This proposal is for a new elementary school for the Reading School District in Reading, PA (**Figure 1** on next page). The enclosed design is a high-performance building that integrates energy conservation, environment, safety, security, durability, accessibility, cost-benefit, productivity, sustainability, functionality, and operational considerations.

The building is three stories and approximately 87,000 Sq. Ft. Some of the room areas have been modified from the original architectural design for constructability concerns and overall design enhancement. In addition, a 15,000 Sq. Ft. natatorium design is included as an add-alternate for the owner's review. The proposed building site is located on N. 13th Street and Robeson Street which will provide the necessary access and utilities for the project.

Owner Profile. After reviewing the competition guidelines and researching the Reading area, the project team assembled a typical owner profile for the Reading School District School Board:

- Cost is important, but not the only driving factor
- Open to innovative ideas
- Long-lasting and durable building
- Willing to spend upfront to achieve lifecycle savings.
    - Lifecycle savings will be reinvested in curriculum
- Prefers construction of new building affect existing operations for only one school year

Owner Goals:

- Improve student performance
- Student and teacher satisfaction & comfort
- School as a center of the community
- Future-proof facility
- Safety and security of students
- Sustainable

Project Goals. For the assumed owner profile, the project team was able to develop a set of goals to guide the design of this project. These goals are not meant to add cost, but instead provide additional value to the school district and building occupants.

- Promote active learning through effective design
- Maximize indoor environmental quality
- Create a community center without impacting student learning
- Create a secure environment for learning
- Flexible design for future adaptability and change
- Sustainable school as a teaching tool

Mechanical Goals:

- Deliver good indoor air quality
- Provide thermal comfort for occupants, (e.g. students in classrooms; community members at a summer event in the multipurpose room)
- Minimize noise disruptions from mechanical equipment
- Design an energy efficient and sustainable system while keeping in mind budget constraints

Executive Summary. The following pages serve as a narrative describing the mechanical systems design for the Reading Elementary School. This submittal includes a description of the intent of design, the calculations and reasoning behind the selection of systems. In addition, this submittal includes an appendix containing the supporting documentation of detail calculations, floor plans, sections, elevations, equipment data and references.

The mechanical team has decided to use a Hybrid Ground Source Heat Pump System with a Cooling Tower and 3 rooftop units to condition the main teaching areas. This decision was reached after conducting a load analysis with TRACE700 and finding out that the cooling load is 170 tons, while the heating load is 110 tons, or about two-thirds of the cooling load. With an imbalance of loads, the mechanical team decided it would be more energy efficient to add a cooling tower to handle the extra cooling load, and sizing the geothermal field for the heating load. The estimated cost for the proposed mechanical system, as coordinated with the construction management team, was found to be approximately $2,730,000. Although this is a higher first cost than what a traditional mechanical system with a boiler and chiller would be, the hybrid system has a payback period of 8 years.

Because the school is a center for the community, the first floor of the school is mechanically designed to be conditioned year-round. Therefore, the clinic, the administration area, and the classrooms located at the core of the building, each have their own Indoor Air Handling Unit. In addition, the multipurpose room and the kitchen will have an alternative fuel source for their mechanical equipment since their design requirements differ greatly from the overall school. The multipurpose room will have two VAV rooftop units, one servicing the side that converts into the cafeteria and the other unit servicing the rest of the gym area. The kitchen will have its own make-up air unit located on the roof at the east end of the school; three floors directly above of the kitchen to minimize the fire rated ductwork run.

After much research of elementary schools, the mechanical team acknowledges the importance of the mechanical system's role in the learning environment of students. As mentioned in ASHRAE's *Advanced Energy Design Guide for k-12 School buildings*, indoor air quality is specially important in schools for keeping kids healthy and reducing absentee rates from both students and staff[1]. The team used ASHRAE Standard 62.1 to do the baseline ventilation calculations, then added 30% more fresh air to achieve good indoor air quality. Dedicated Outdoor Air units are used in the team's design to deliver the fresh air. In order to use exposed ceilings in the classrooms to make the building act as a teaching tool, closets for the vertical heat pumps were added to the classrooms to minimize noise, while the rest of the spaces will have horizontal heat pumps located above the drop ceilings.

Because communication is a key factor in the learning process, the mechanical team designed a system to minimize noise disruptions to the learning environment. When selecting equipment, the project team looked at noise criteria as well as placement of the equipment to minimize noise. Coincidentally, quieter systems are also more energy efficient, which is another design element for this project. The school district wishes to achieve LEED certification for this project, therefore the project team has proposed a design meant to achieve LEED Silver. The mechanical team contributed 21 out of 54 credits for the whole project.

Production Side. After conducting load analysis and calculations, the mechanical team discovered that the building requires about 1/3 more cooling than heating (**Table 1**). Usually, when using a geothermal system, it is ideal to have a balanced load for both settings. If the geothermal field is oversized during the cooling mode, thermal comfort is compromised In the building because of humidity problems. Fortunately, if the equipment were to oversize, the system would not be oversized for cooling, it would be oversized for heating. Because of the load imbalance, the team decided that the best option is to size the geothermal field for the heating load, and use a cooling tower to take care of the additional cooling load needed in the warmer months. With this hybrid system, the area of the geothermal system is reduced and will be placed underneath the baseball field. You can find the construction sequence of the geothermal field in the *Construction Management* submittal, which outlines that the baseball season will not be disrupting by constructing the geother-

Table 1 Geothermal Field Size Cooling vs. Heating

	Q_o—Building Design Block Load (BTU/h)	Required Length (Linear ft.)	# of Boreholes (300ft Deep)	Field Area (ft^2)
Cooling	2,024,300	52,382	87	30,400
Heating	1,320,300	31,821	55	18,100

Figure 1 Exterior Rendering (North Façade)

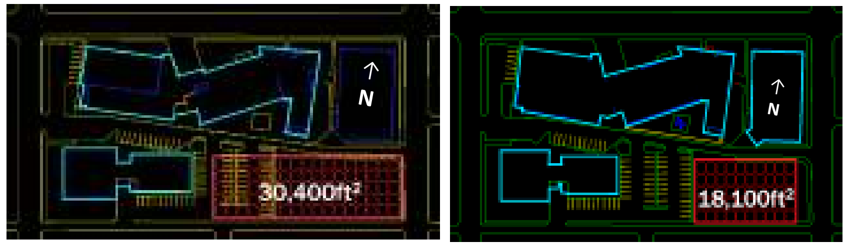


Figure 2 Geothermal Field Size for 170 tons (left). 110 tons. (right)

mal field in the winter months. Because of the reduction in field size by sizing it to heating, the parking lot area provided for the existing school also does not have to be disrupted.

After using Chapter 34 of ASHRAE Applications 2011, the mechanical team was able to determine that for a load of 110 tons, approximately 31,800 linear feet of piping will be needed. Using 1" diameter U-tube piping, there will be 55 boreholes, 300 feet deep, 20 feet apart. (**Table 1,** previous page, compares cooling vs. heating. *Detailed calculations may be found in the supporting documentation*).

If the field is sized for the full cooling load of 170 tons, then it would need approximately 30,400 ft^2 of area (**Figure 2**). But because the field is sized to the heating load, it only needs 18,100 ft^2 of land. By using this hybrid system the project team is able to greatly decrease the size of the field. (**Figure 2**) Another advantage of decreasing the field size, is decreasing the excavation cost for the field, which is one of the most expensive parts for this alternative. After discussing with the construction management team, who consulted *Nittany Geothermal*, the project team has an approximate cost of $10,000 per ton. If the field is sized to the full load, the cost would be $1,700,000. But by sizing the field to the heating load, the cost is reduced to $1,100,000 or a 35% decrease in cost. In addition, the typical cost for a cooling tower is $215 per ton[2]. With a 60 ton cooling tower, the additional cost would be $12,900 which is only 2% of what it would cost to condition 60 extra tons through the geothermal field. Therefore, not only is using a hybrid system beneficial for space restrains but also helps the design team have a reasonable budget.

Below is the schematic drawing of the hybrid ground source heat pump system with the cooling tower (**Figure 3**). Because the cooling tower was added to the design, the mechanical team had to coordinate with the other disciplines to figure out a place to put the cooling tower. One of the options was to put the cooling tower on the roof. After consulting with faculty, the project team was advised not to place the tower on the roof due to aesthetic reasons. Therefore, the project team decided to place the cooling tower on the ground near the southeast end of the building (**Figure 4**). In order to minimize the noise, as well as hide the cooling tower from plain site view, the project team enclosed the tower within the same façade as the rest of school building but still providing enough clearances for the tower to function properly.

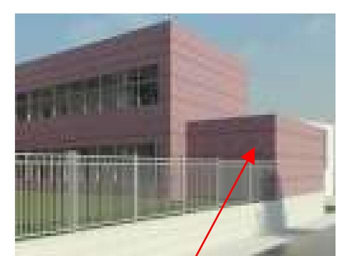
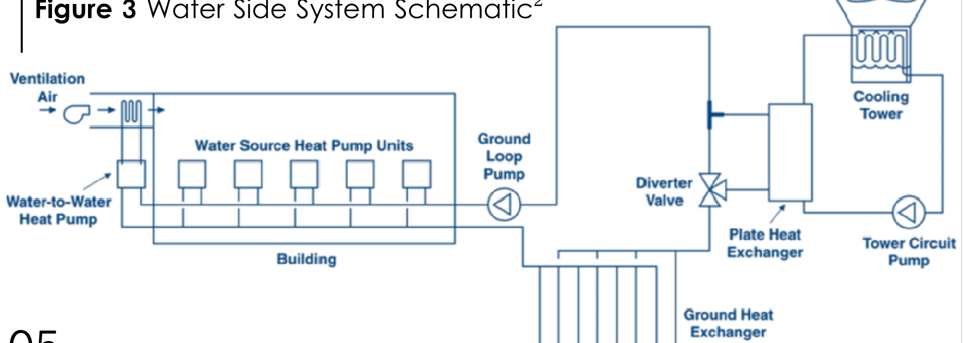


Figure 4—Cooling Tower Hidden from outside

Although the mechanical team sized the geothermal field according to the peak heating load, the team still built a boiler connection into the common chilled water loop in case, in the future, the ground temperature shifts and does not have the capacity to provide enough heating for the winter time (**Figure 5**).

Figure 3 Water Side System Schematic[2]



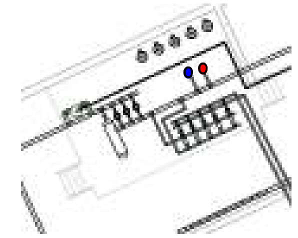


Figure 5—Boiler Connection

Because the gym and the kitchen design requirements are much different than the overall school, the mechanical team has decided that these zones will have an alternative fuel source for the mechanical equipment. For these areas, the project team will be using natural gas coming from the main utility lines located on 13th street.

Distribution Side. The entire first floor, minus the east wing (dark green **Figure 6a**) will be conditioned all year long so that community members can use a well conditioned spaced even during the summer months. The east wing, second and third floors of the building will not be utilized during the summer to decrease energy consumption during this time. The project team foresees the classrooms on the first floor along with the multipurpose room are sufficient space for any extra-curricular activities that may take place during the summer. Because the project team proposes the natatorium as an add alternative, the natatorium is not included in the zoning of the main building; the natatorium will be a separate building, with its own mechanical system. For a breakdown of all the zones see **Figure 6a-c, Table 2**. (**Basement not conditioned, therefore not included in zoning*). Natatorium is separate building, thereby a separate zone, more on the natatorium can be found on page 11 of this report.

Figure 6a First Floor Zones*

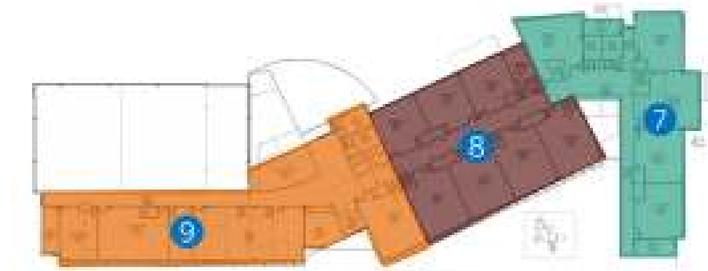


Figure 6b Second Floor Zones*

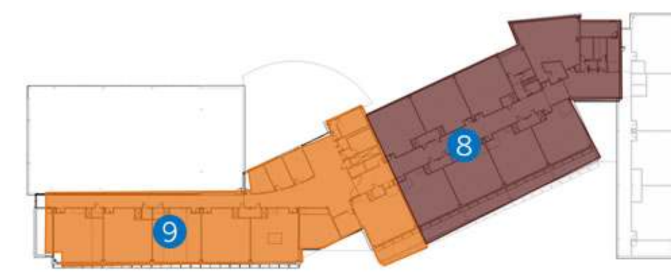


Figure 6c Third Floor Zones*

Zone	Serving Area	Size (Ton)	O.A. CFM	Required O.A.	30% Compliance
1	Multipurpose Room RTU1– Cafeteria Side	25 ton	18,200	14,000	YES
2	Multipurpose Room RTU2—Gym Side	15 ton	5,200	4,000	YES
3	Kitchen Make-up Air/Exhaust Unit	2.5 ton	495	380	YES
4	Clinic– Indoor AHU1	1.5 ton	435	335	YES
5	Administration & Offices– Indoor AHU2	2 ton	415	320	YES
6	1st Floor Classrooms– Indoor AHU3	13 ton	4,284	3,295	YES
7	1st & 2nd Floor– RTU1	14 ton	5,079	3,907	YES
8	2nd & 3rd Floor– RTU2	27 ton	18,400	14,150	YES
9	2nd & 3rd Floor– RTU3	11.5 ton	4,870	3,746	YES

Table 2— Equipment Data

The zones are not only broken down for energy consumption reasons, but as well as for smoke control. Double doors have been added to the main hallways on all three floors in order to provide different smoke zones to isolate specific areas in case of any fire.

For the distribution side of the system, the mechanical team chose heat pumps to take care of the cooling/heating load for the classrooms, library and administration. In addition, rooftop units will provide conditioned outdoor air for the 100 percent ventilation requirement and it will also take care of most of the latent load, which also helps downsize all the heat pumps. From here, the 100 percent outdoor air is mixed with the return air at the zone level, and then the air is delivered to the ground source heat pumps. This mixed air is then conditioned to the supply temperature by the R-(-) vapor compression cycle within the heat pumps, rejecting heat to or absorbing heat from the ground loop water.

Air is primarily exhausted to the roof top units, where it provides supplemental conditioning to the intake air through both sensible and enthalpy wheels within the unit.

Design Conditions. The elementary school is located in Reading, PA. It falls into Climate Zone 5 according to ASHRAE Standard 90.1. (**Table 3**)

In order to calculate the required outdoor air, ASHRAE Standard 62.1, Chapter 6 was used to calculate the ventilation requirements. The following equation, as well as Table 6-1 from ASHRAE was used for every space.

Outdoor Design Conditions	
Location	Reading, PA
Summer Dry Bulb (°F)	87.9
Summer Wet Bulb (°F)	72.1
Winter Dry Bulb (°F)	9

Table 3— Outdoor Design Air Conditions

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

R_p—Outdoor airflow rate per person as determined from Table 6-1
P_z—Zone population
R_a—Outdoor airflow rate per unit area as determined from Table 6-1
A_z—Zone Floor Area (ft2)

For more detail calculations refer to Mechanical Supporting Documentation.

Water heater selection was based on section 7 of ASHRAE Standard 90.1-2010 which specifies minimum efficiencies for water heating equipment as being 80%.

Teaching Area. After the project team studied the architectural plans provided by AEI committee, the project team decided to provide heat pumps for each classroom coupled with a dedicated outdoor air system to provide fresh air to meet ASHRAE 62.1 requirement. You can see **Figure 7** for the changes in room layouts to accommodate for the heat pump closets. A further insight on how this change in room layout benefited the project team's goals in design, can be found in the *Building systems Integration* Submittal.




Figure 7 Design Comparison: Bridging Docs (left), New Design (right)

The mechanical team configured the classroom supply and return air as high supply and low return, which promotes a good thermal comfort and eliminates stratification. The design conditions for rooms can be found in **Table 4**.

Room Design Conditions	
Cooling Dry Bulb (°F)	75
Heating Dry Bulb (°F)	72
Relative Humidity (%)	50
Cooling Driftpoint (°F)	77
Heating Driftpoint (°F)	70

Table 4—Room Design temperature conditions

With this design, and using Mcquay vertical heat pumps, the project team can control the acoustics of the classrooms to provide the desired learning environment for students. As noted by the Mcquay specifications for the heat pumps, the heat pumps have a 46dBA. In ASHRAE Handbook Chapter 48 *Noise and Vibration Control* there are guidelines for good acoustical design for different spaces (**Table 5**). Since a good acoustical design for classrooms is 35dB noise, any common partition wall assembly will provide sufficient transmission loss to eliminate the noise of the heat pumps through the closet wall. In addition, 10 ft. of the initial duct run will have 1" lining, thereby providing enough acoustical attenuation to reduce the noise through the duct. (**Figure 8**) The project team designed the classrooms with this additional investment in order to enhance the productivity of the students by enhancing the learning environment conditions. As you can read in the *structural submittal*, the structural design provides ample space in the corridors for the main branch of the duct to supply the outdoor air. From then, every classroom has its own branch which leads into the heat pump closets connected to the mixing air box which will supply the fully mixed and conditioned air to the classroom.

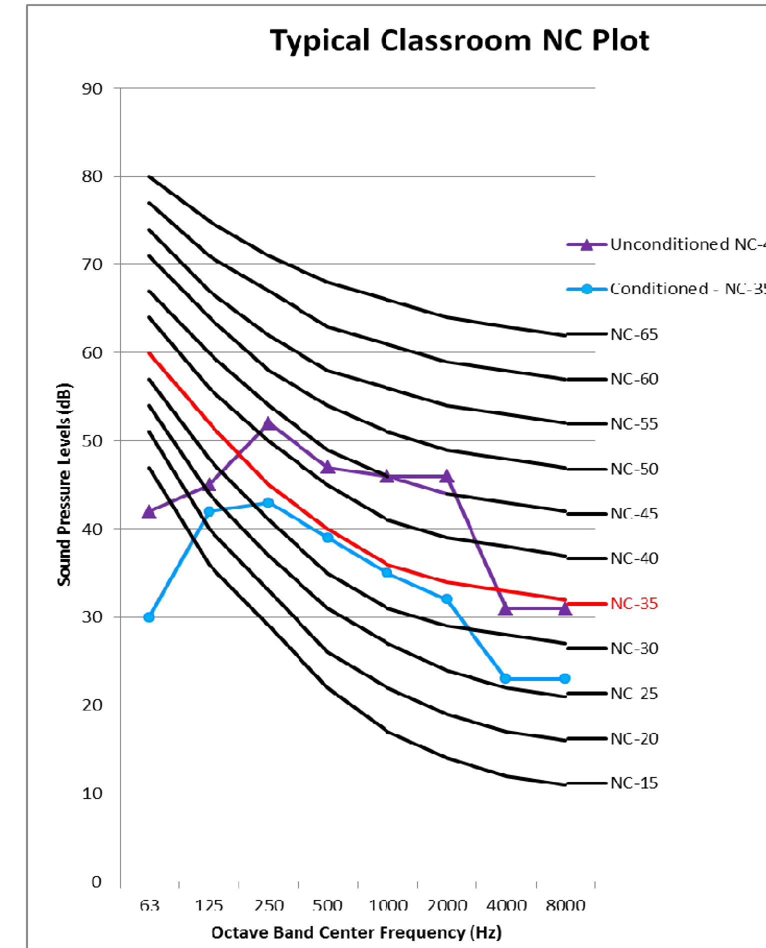


Figure 8 NC curves for classrooms with 1" lining

The classrooms will have exposed ceilings which will help with the design idea of using the building as a teaching tool. The

Space	A – Sound Levels dB	Desired NC (Noise Criteria)
Libraries, classrooms	35-45	30-40
Laboratories, shops	40-50	35-45
Gyms, multipurpose, corridors	40-55	35-50
Kitchens	45-55	40-55

Table 5 Noise Criteria for different zones.

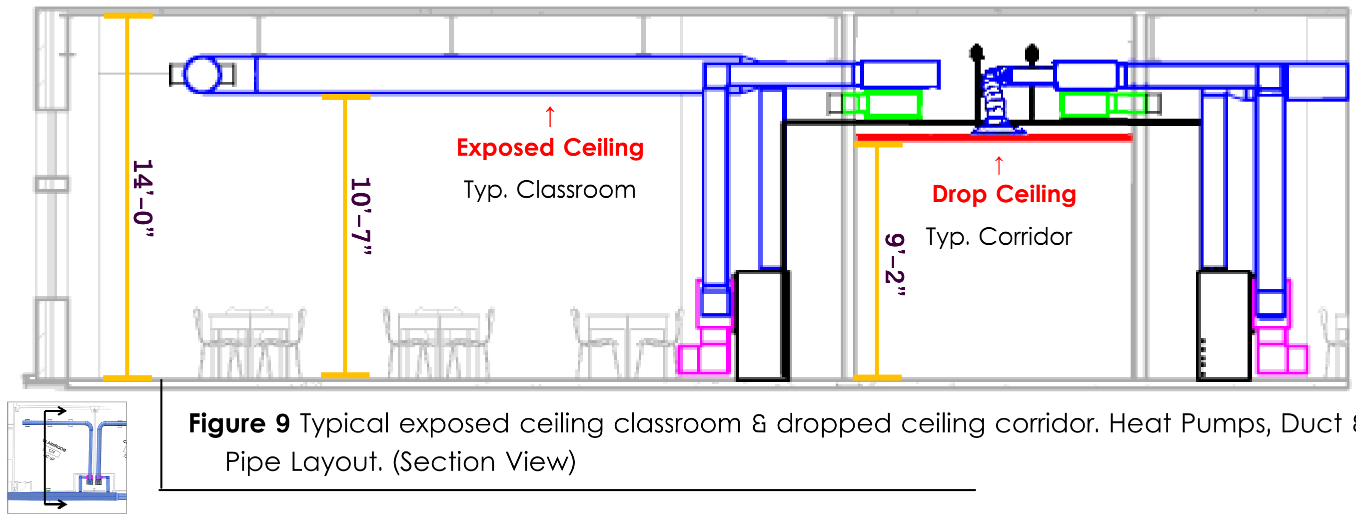
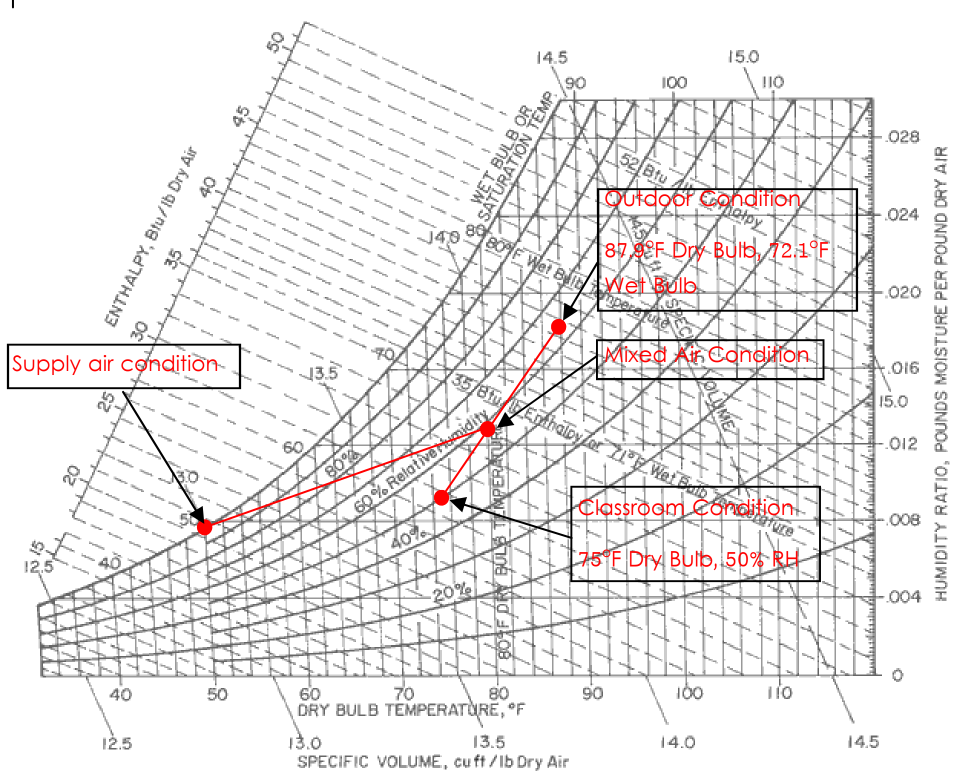


Figure 9 Typical exposed ceiling classroom & dropped ceiling corridor. Heat Pumps, Duct & Pipe Layout. (Section View)

project team is able to provide exposed ceilings because after coordinating with the structural design team, between the structure and the ductwork the project team still can provide a ceiling of ten and a half feet which is still tall enough to use exposed ceilings (**Figure 9**).

As mentioned before, there are 3 roof top units to bring conditioned fresh outdoor air to each space,

Figure 10 Psychometric Chart for classrooms



then the outdoor air is mixed with return air in the heat pumps, then the heat pumps further condition the mixed air to desired supply temperature as you can see in **Figure 10**. The mechanical equipment selection is compliant with section 6 of ASHRAE Standard 90.1 based on section 6.4, Mandatory Provisions, and section 6.5, Prescriptive Path. Section 6.3, Simplified Approach Option for HVAC systems was neglected, as the school is over two stories in height and has a gross floor area over 25,000 ft^2.

Multipurpose room. After the mechanical team finished the energy modeling, the team found that a separate system for the multipurpose room has lower electricity consumption than adding the space to the HGSHP system. The GSHP is not a hot enough source for heating the gym and kitchen area, so the mechanical team placed two roof top units independent of the ground water loop on top of the stage area.

Each RTU will serve half of the multipurpose space. The multipurpose room has a movable partition wall in the middle of the room, enabling the school to use only one half of the space. Therefore, the team would like to provide the school the ability to condition only one side of the space when the other side is not in session. The left side serves as a cafeteria which will be serving approximately 220 students during lunch time. The cafeteria side will have a 25 ton RTU while the other half used as a gym will have a 15 ton RTU. Because the gym has a height of 28 feet, there were no issues with structural for the placement of ductwork. The ceiling will be exposed in the gym so that the students may have another area of opportunity to see the building systems at work. See **Figure 11** for RTU location and duct distribution.

When the project team had to decide on

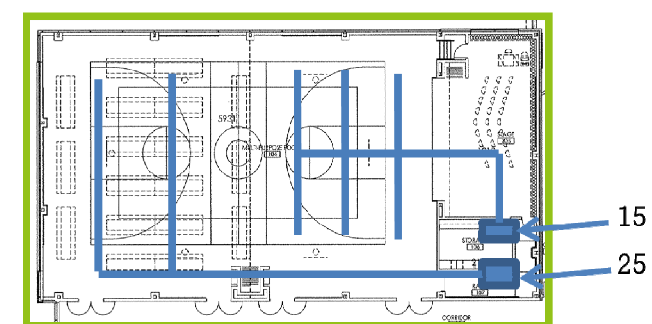
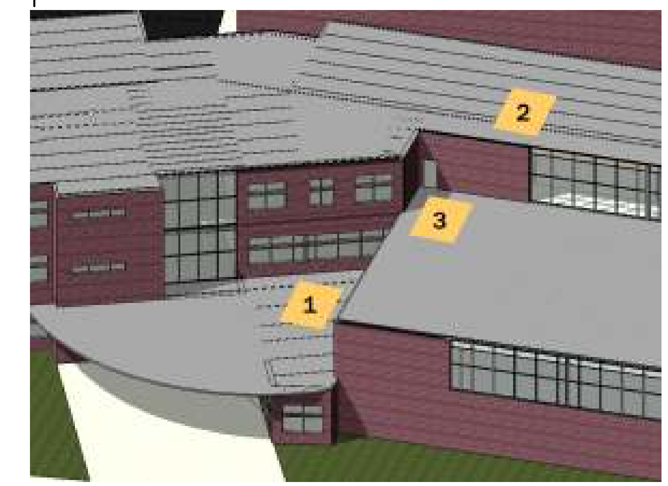


Figure 11 RTUs for multi-purpose room.

where to put the rooftop units for the gym, several options where considered. As you can see in **Figure 12**, the team came up with three possible solutions. The first option was to put the RTUs on top of the main entrance right next to the multipurpose room. This option was eliminated because as a team, we all felt that this would not be a suitable option in terms of it being aesthetically pleasing. If the rooftops where to be put there, everyone entering through the main entrance would have a view of the units. The second option was to put them on top of the third floor. But we ruled out this idea because, after speaking with the construction managers, this location added constructability problems, and in addition, the cost would be higher to run the

Figure 12 RTU location options



duct work extra full height of the third floor. We would have had to taken up corridor space to provide a chase for the ductwork as well. And so, as a team we decided that the best option for the location of the rooftop units would be right above the stage area of the multipurpose room (***Square 3*, Fig. 12**). By locating the units in this area, the equipment would not be as visible from the ground level and we were also able to provide an easy access for maintenance by providing a door through the third floor level.

In order to provide sound attenuation for the multipurpose room, the team proposes to hang panels from the ceiling with acoustical properties to minimize the reverberation time in the space and enhance the acoustics for performances, the cafeteria and any other use of the space. You can find in the *Integration Report Supporting Documentation* an example of AlphaEnviro Hangling Baffles which could be used for this area. They are available in different shapes, sizes and colors which would be perfect for an elementary school.

Administration & Clinic. Because the administration has a different occupancy schedule than the rest of the building, this area will have its own Air handling unit to provide the dedicated

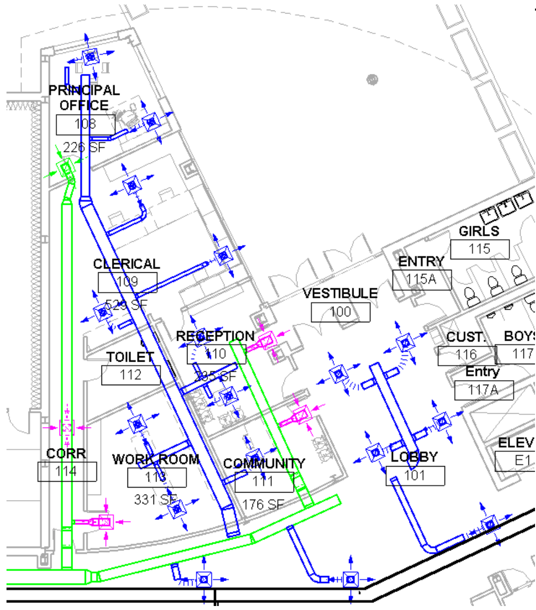


Figure 13 Admin. ductwork layout

outdoor air space (**Figure 13**). Also, after coordinating with the other disciplines, the administration will not have exposed ceilings, the mechanical team will be placing the McQuay horizontal heat pumps in the plenum above the ceiling.. This decision was made because after sizing and placing all the ductwork in the ceiling, the lowest point was around nine and a half feet which would be too low for the ceilings to portray the feeling the project team had for using exposed ceilings in the first place. In addition, most students do not spend time in this area therefore there was no need to expose ceilings for the purpose of using it as a teaching tool. With the heat pumps in the ceiling the mechanical team does not need to add addition space for heat pump closets on the floor plans. As for the clinic, due to the nature of clinics, 100% outdoor air system promotes excellent indoor air quality which is required by the clinic area. With that being said, the mechanical team will use indoor air handling units for each space to handle all the cooling and heating.

Kitchen. The kitchen area will have a Greenheck gas fired make-up air unit which will provide both the required conditioned air for the space and the exhaust for the area. In addition the mechanical team placed the make-up unit directly above the kitchen, having the duct work go through a fired-rated chase both through 3rd floor classroom and the 2nd floor art classroom. As you can see in **Figure 14,** the mechanical team needed to minimize the duct turns and runs because it would be very costly to have fire-rated duct making a lot of turns through the building.

By provided 100% outdoor air, the mechanical team is able to prevent the odor generated by food processing going back into the supply air in the kitchen area. Also to reduce energy consumption, the unit can be shut down in the afternoon for cleaning purposes.

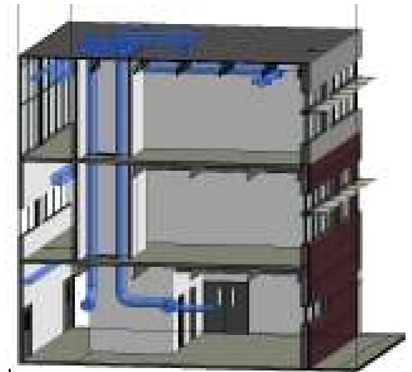


Figure 14 Kitchen exhaust and supply ductwork

Natatorium. The natatorium design is provided as an add-alternative for the School District. The natatorium is designed as a 6 lane, 25 meter indoor pool facility. The natatorium is a separate zone from the rest of the elementary school and will not be connected to the geothermal field, but to the main utility lines located on 13th street for its fuel source.

When designing the natatorium, the biggest concern is the humidity control for the space. When designing the mechanical system, the team looked into the evaporation rate of the pool, the room pressure control and the water chemistry. Humidity can cause several issues, specially mold and reduce the quality of indoor air, therefore the mechanical team will be providing the natatorium with a 100% dedicated outdoor air system which will provide adequate ventilation as well as help reduce some of the latent load. Because the mechanical team is using 100% outside air, a heat recovery unit is included to decrease the energy consumption of the system, therefore reusing some of the energy. To start sizing the dehumidification system the mechanical team first had to look into the conditions that will be used for the space. Since this natatorium will be mostly used by the community for recreation and competition purposes, the mechanical team design the water temperature for the pool to be 80°F. **(Table 6)** With a water temperature of 80°F the mechanical team designed for an air temperature of 82°F. This is because in order to reduce the evaporation rate of the water from the pool, the change in temperature between the pool and the air needs to be decrease. Therefore, by using a ΔT of 2°F, this can be accomplished. Since the natatorium will be used by the school and the public, a Use Factor of 0.9 was used. The mechanical team will also use a 60% relative humidity ratio. Again, the humidity can not be too high because air quality would be poor, the environment would be uncomfortable and health problems with mold would occur. But the humidity ratio does need to be somewhat over 50% so that the evaporation rate can be reduced as well. With these design criteria in mind, and using ASHRAE applications equation for the water evaporation (**Table 7**), plus the internal humidity and the outdoor air humidity the total load is 140 lbs/hr, The mechanical team will provide 20 ton dehumidifier with 4,500 CFM capacity. More on the equipment data can be found the *Mechanical Supporting Documentation*. Because the dehumidifier unit takes up a large floor area, the project team designed a mechanical room big enough to house all the equipment. Detail floor plans of the natatorium can be found in the *Building Integration Report* on page 14.

Type of Pool	Air Temp. °F	RH %	Water Temp. °F
Recreational	75 to 85	50 to 60	75 to 85
Therapeutic	80 to 85	50 to 60	85 to 95
Competition	78 to 85	50 to 60	76 to 82
Diving	80 to 85	50 to 60	80 to 90
Whirlpool Spa	80 to 85	50 to 60	97 to 104

Table 6— Pool Design Options

Pool Load Calculation		
Load= 0.1*pool area* vapor pressure * use factor		
Water Temp.	80	F
Air Temp.	82	F
RH	60	%
Pool Area	3680	ft^2
Use Factor	0.9	
Water Vapor Pressure	1.033	In. Hg
Air Vapor Pressure	0.62	In. Hg
delta vapor pressure	0.413	In. Hg
Pool load	**136.8**	**lbs/hr**

Table 7— Pool Load Calculation (Internal Humidity & Outdoor Air Humidity calculations in *Mechanical Supporting Documentation*).

Building Envelope. The mechanical team used ASHRAE Standard 90.1-2010 Section 5—*Building Envelope* to guide the design of the building envelope. The elementary school is a nonresidential building located in zone 5 as specified by section 5.1.2.1 and

	Min. Roof Insulation R-Value	Min. Wall Insulation R-Value	Fenestration Assembly Max. U-Value	Fenestration Max. SHGC	Non-Heated Slab on Grade Floor Min. Insulation
Required	R-20	R-13	0.45	0.4	NR
Designed	R-20	R-13	0.45	0.4	NR
Compliance	Achieved	Achieved	Achieved	Achieved	Achieved

Table 8— Building Envelope Material

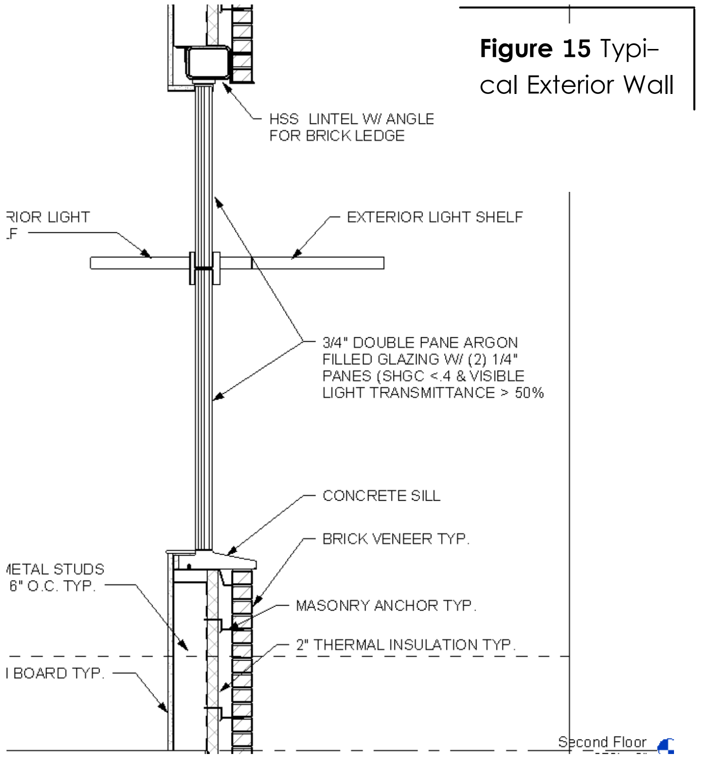


Figure 15 Typical Exterior Wall

Table B-1 of ASHRAE Standard 90.1-2010. The building façade is brick veneer with aluminum paneling to accent the architecture of the building. The placement of the aluminum paneling can be seen in *Building Systems Integration Supporting Documents*, **Table 8** (previous page), shows the elementary schools compliance with the requirements of Table 5.5-4. The project team has also provided an add alternative that would make the entire first floor bullet resistant rather than only the entrances, as specified in detail in the *Building Systems Integration Report*, pg. 08. Not only would this add alternative provide added security to the building, but it would lower the energy consumption of the mechanical system by increasing the thickness of both brick and glass therefore minimizing infiltration. Although strengthening the façade has many advantages, the biggest disadvantage would be the added cost. You can find more information on the cost analysis in the *Construction Management Report*. **Figure 15** shows a section detail view of a typical exterior wall for the building. By using the ASHRAE standard, the mechanical team was able to minimize infiltration and there by reducing the internal loads.

Energy Analysis. The overall energy consumption for the ground source heat pump is lower than conventional VAV with reheat. **Table 9** shows the energy break down on parts for the heating and cooling system (Trane TRACE data can be found in the *Mechanical Supporting Documentation).*

Energy Consumption (kWh)		
	Baseline	Proposed
Primary heating	58,656	13,675
Cooling Compressor	114,781	54,561
Other Cooling Accessories	—	31
Pumps	—	14,199
Lighting	58,5269	585,269
Receptacles	23,615	23,615
Total	782,260	691,350

Table 9— Energy Consumption Breakdown

By comparing the total energy consumption, ground source heat pump consumes 14% less energy than the baseline model. In addition for a typical mechanical system vs. the designed hybrid geothermal system[3], the cost comparison for maintenance is $12,000 for the Baseline model compared to the proposed hybrid geothermal of $8,100. With the decreased energy consumption and the lower maintenance cost per year, the initial cost for the proposed hybrid geothermal system is $2,730,000. The initial cost for the baseline system is $2,120,000. If an owner where to look at this cost first they would not want to use the hybrid geothermal system, but by showing the payback (**Table 10,** previous page)**,** the system in the end is a more economical solution for our project. The simple payback is 8 years. This analysis does not include the add-alternative for the natatorium, as it will not be fueled by the geothermal system.

Snapshot of first 10 out of 25 years for the mechanical system payback period			
Year	Baseline NPV	Design NPV	Design Savings
0	$2,132,000.00	$2,738,100.00	-$606,100.00
1	$2,357,752.38	$2,872,376.19	-$514,623.81
2	$2,570,650.34	$2,999,015.65	-$428,365.31
3	$2,771,406.20	$3,118,441.19	-$347,035.00
4	$2,962,602.25	$3,232,179.81	-$269,577.56
5	$3,144,693.73	$3,340,502.30	-$195,808.57
6	$3,319,845.41	$3,444,688.90	-$124,843.49
7	$3,488,305.31	$3,544,887.86	-$56,582.54
8	$3,651,883.85	$3,642,169.98	$9,713.87
9	$3,809,168.43	$3,735,702.73	$73,465.69
10	$3,961,811.82	$3,826,463.67	$135,348.15

Table 10— Simple Payback

A more in depth analysis of the payback calculations can be found in the *Building Systems Integration Supporting Documentation.*

LEED. The project team has decided to achieve Silver LEED status. In order to do so, the mechanical team has designed a mechanical system which first and for most provides quality and comfort for the student learning environment, but this design has also enabled the team to gain LEED credit. For example by using a hybrid geothermal system compared to the ASHRAE baseline model, the project team was able to achieve energy savings of 14% which provided LEED points under the energy and atmosphere criteria. The mechanical team also obtain LEED points by design a system with 30 percent more ventilation than the ASHRAE standard. Also with this design, LEED points for thermal comfort and acoustics can obtain . As mentioned before all classrooms have been designed so that the acoustics are below 35NC rating, which is good acoustic design for a learning environment. In addition, hanging baffles would be placed in the multipurpose room to decrease reverberation time, specially when half of the room is used as a cafeteria. These baffles not only provide LEED credit for acoustic control but also under the Materials and Resources category because of their recycled content and coming from regional materials. Overall the project team has proposed a design meant to achieve LEED Silver. The mechanical team contributed 21 out of 54 credits for the whole project (**Table 11**).

For complete scorecard please refer to the *Building Integration Supporting Documentation.*

Table 11 Sample of scorecard points pertaining to mechanical design

6		5	**Water Efficiency**		Possible Points: 11
Y			Prereq 1	Water Use Reduction—20% Reduction	
4			Credit 1	Water Efficient Landscaping	2 to 4
		2	Credit 2	Innovative Wastewater Technologies	2
2		2	Credit 3	Water Use Reduction	2 to 4
		1	Credit 3	Process Water Use Reduction	1
4		26	**Energy and Atmosphere**		Possible Points: 33
Y			Prereq 1	Fundamental Commissioning of Building Energy Systems	
Y			Prereq 2	Minimum Energy Performance	
Y			Prereq 3	Fundamental Refrigerant Management	
2		17	Credit 1	Optimize Energy Performance	1 to 19
		7	Credit 2	On-Site Renewable Energy	1 to 7
			Credit 3	Enhanced Commissioning	2
			Credit 4	Enhanced Refrigerant Management	1
2			Credit 5	Measurement and Verification	2
		2	Credit 6	Green Power	2
13		4	**Indoor Environmental Quality**		Possible Points: 19
Y			Prereq 1	Minimum Indoor Air Quality Performance	
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	
Y			Prereq 3	Minimum Acoustical Performance	
1			Credit 1	Outdoor Air Delivery Monitoring	1
1			Credit 2	Increased Ventilation	1
1			Credit 3.1	Construction IAQ Management Plan—During Construction	1
1			Credit 3.2	Construction IAQ Management Plan—Before Occupancy	1
4			Credit 4	Low-Emitting Materials	1 to 4
		1	Credit 5	Indoor Chemical and Pollutant Source Control	1
1			Credit 6.1	Controllability of Systems—Lighting	1
1			Credit 6.2	Controllability of Systems—Thermal Comfort	1
			Credit 7.1	Thermal Comfort—Design	1
			Credit 7.2	Thermal Comfort—Verification	1
1		2	Credit 8.1	Daylight and Views—Daylight	1 to 3
1			Credit 8.2	Daylight and Views—Views	1
1			Credit 9	Enhanced Acoustical Performance	1
		1	Credit 10	Mold Prevention	1

Conclusions. The mechanical design team set out to provide the School District of Reading with an elementary school (**Figure 16**) that promotes active learning, maximizes environmental quality to improve learning, and is a sustainable school that can act as a teaching tool so that students, employees, and the entire community can be proud of. The mechanical team's goals for this project were to:

◊ Deliver good **indoor air quality**
◊ Provide **thermal comfort** for occupants
◊ **Minimize noise disruptions** from mechanical equipment
◊ Design an **energy efficient** and **sustainable** system while keeping in mind **budget** constraints

By increasing the minimum ventilation rates obtained from ASHRAE Standard 62.1, more fresh air, delivered through the Dedicated Outdoor Air Units, is supplied to the occupants thereby increasing the indoor air quality and in turn increase the productivity of students.

With heat pumps serving every space, the mechanical team was able to provide conditioned air to all spaces. In addition, the first floor of the school is conditioned year-long thereby meeting the project goal of providing a place for the community.

Through the use of quieter heat pumps, adding attenuation to the classrooms, and providing baffles in the multipurpose room, the mechanical team achieved the goal of providing the school with an enhanced learning environment undisrupted by noise.

By using a Hybrid Ground Source Heat Pump System the mechanical team was able to provide an innovative sustainable design with a payback cycle of 8 years. The geothermal field was sized to accommodate the heating load of 110 tons and the cooling tower takes care of the addition 60 tons of cooling load. With this hybrid system the project team is able to provide a design that is projected to last 50 years with a lower maintenance and energy consumption cost of 35% less than with a typical packaged VAV boiler and chiller system. Furthermore, by using the geothermal system, the team was able to gain LEED credits under Energy and Atmosphere Category by optimizing energy performance. The mechanical team was able to contribute 21 out of the 54 credits the project team set out to achieve LEED Silver.

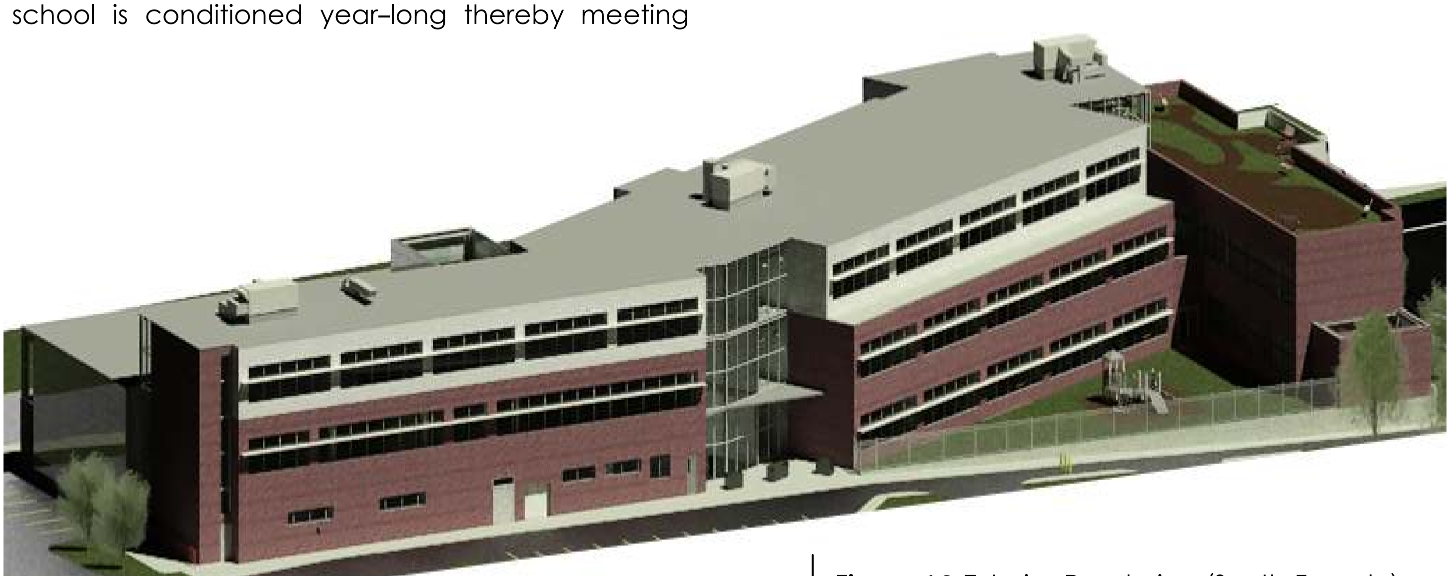


Figure 16 Exterior Rendering (South Façade)

ASCE Charles Pankow Foundation
Annual Architectural Engineering
Student Competition

ARCHITECTURAL ENGINEERING INSTITUTE

Mechanical Systems

Supporting Documentation

Team No. 03-2013

contents

studio VI

Company Profile

Studio VI

A/E/C Firm

Specialize in Educational Facilities

0.54 EMR

ENR Top Lists 2012

- #14 Green Contractor
- #23 General Contractor
- #28 Design Firm
- #12 Green Design Firm

Building Fast Facts

Three-Story Elementary School

Reading, PA

87,000 SF, $18.6 Million

Building Systems Summary

Hybrid Geothermal System

Steel Frame w/ Shear Walls & Braced Frames

Brick & Aluminum Panel Façade

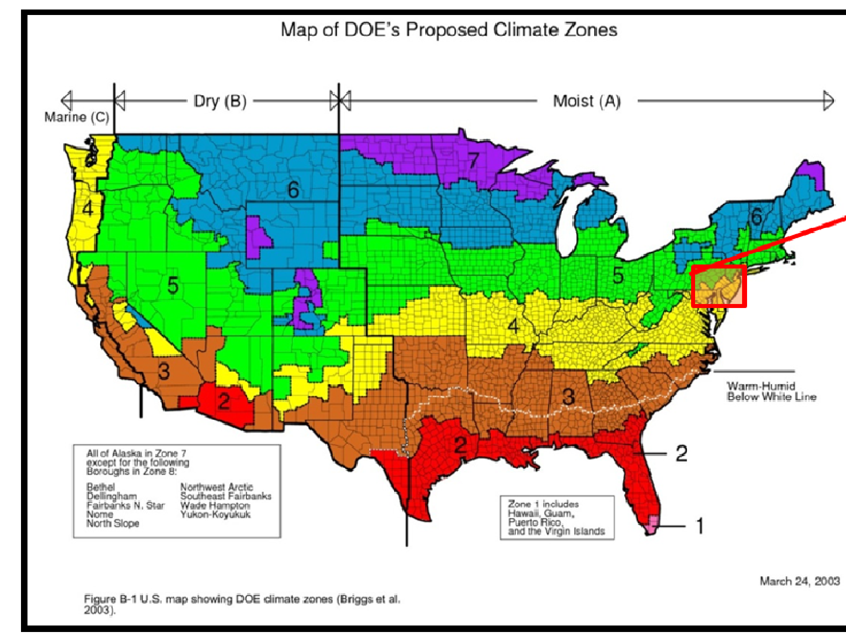
Add-Alternates:

- Separate Pool
- Hardened First Floor Envelope
- Existing School Usage

appendix a

Design Considerations. In order to begin the design of the systems, the mechanical team first had to research the locale conditions of Reading, PA in order to figure out a feasible solution.

Reading, PA Weather Data: After looking at ASHRAE 90.1 Standard we found that Reading, PA is located in Climate Zone 5A. (**Figure 17**)



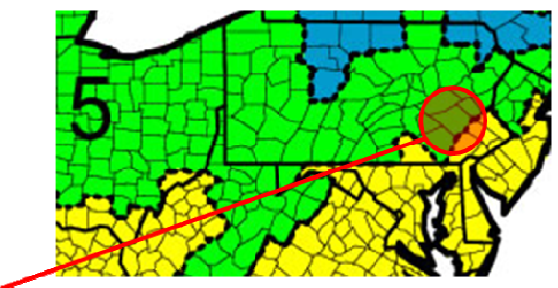


Figure 17 Climate Weather

With this information we were able to input into Trane TRACE the design temperatures and start finding the cooling and heating loads, which as noted in the Mechanical Report ended up being 170 tons and 110 tons respectively.

Weather Data for Zone 5A Reading, PA		
	Heating at 99.6 %	Cooling at 1%
Dry Bulb	9.4 °F	89.6 °F
Wet Bulb	—	73 °F

Table 11 Reading PA weather Data

appendix b

Design Considerations. Once the project team was able to come up with a reasonable load for the building, the next step was to find the conditions for the geothermal field. In order to do so, the mechanical team looked into the 2011 ASHRAE Applications book, Chapter 34 to begin the calculations of the geothermal field. In the map below (**Figure 18**) , one can see that the ground temperature for Reading, PA is approximately between 50 °F and 55 °F. The mechanical team assumed the temperature to be 52 °F.

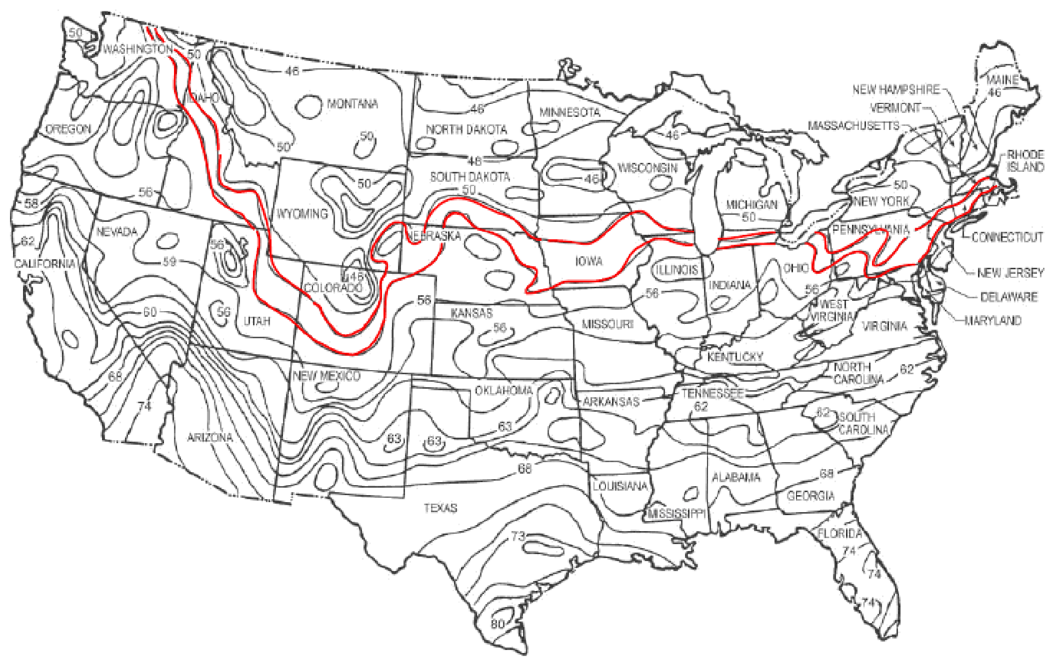


Figure 18 Ground Temperature

ASHRAE Baseline model. In order to compare the proposed hybrid geothermal system, the mechanical team had to look at ASHRAE 90.1 to create a baseline model (**Figure 19**). The table below was used to choose the specifications that would make up the baseline model which we would compare our system to.

TABLE G3.1.1A Baseline HVAC System Types

Building Type	Fossil Fuel, Fossil/Electric Hybrid, and Purchased Heat	Electric and Other
Residential	System 1—PTAC	System 2—PTHP
Nonresidential and 3 Floors or Less and <25,000 ft^2	System 3—PSZ-AC	System 4—PSZ-HP
Nonresidential and 4 or 5 Floors and <25,000 ft^2 or 5 Floors or Less and 25,000 ft^2 to 150,000 ft^2	System 5—Packaged VAV with Reheat	System 6—Packaged VAV with PFP Boxes
Nonresidential and More than 5 Floors or >150,000 ft^2	System 7—VAV with Reheat	System 8—VAV with PFP Boxes
Heated Only Storage	System 9—Heating and Ventilation	System 10—Heating and Ventilation

Figure 19 ASHRAE Baseline guidelines

- Packaged VAV with Reheat
  - Heating: Hot-Water fossil fuel boiler
  - Cooling: Direct Expansion

Geothermal Well Calculation. The following is a table containing the data input for the calculations of the geothermal pipe length needed for our building load. Chapter 34 of the ASHRAE 2011 Handbook-HVAC Applications was used.

Geothermal vertical loop input data			
Short-circuit heat loss factor	(F_{sc})	1.04	-
Part-load factor during design months	(PLF_{m})	1	Btu/h
Net annual average heat transfer to ground	(q_{a})	3344600	Btu/h
Building design Cooling block load	(q_{lc})	2024300	Btu/h
Building design heating block load	(q_{lh})	1320300	Btu/h
Effective thermal resistance of ground (annually)	(R_{ga})	0.257	Ft*h*°F/Btu
Effective thermal resistance of ground (daily)	(R_{gd})	0.157	Ft*h*°F/Btu
Effective thermal resistance of ground (monthly)	(R_{gm})	0.2429	Ft*h*°F/Btu
Thermal Resistance of bore	(R_{b})	0.1	Ft*h*°F/Btu
Undisturbed ground temperature	(t_{g})	52	°F
Temperature penalty for interference of adjacent bore	(t_{p})	3.4	°F
Liquid temperature at heat pump inlet (cooling)	(t_{wic})	77	°F
Liquid temperature at heat pump inlet (heating)	(t_{wih})	42	°F
Liquid temperature at heat pump outlet (cooling)	(t_{woc})	87	°F
Liquid temperature at heat pump outlet (heating)	(t_{woh})	32	°F
power input at design cooling load	W_c	81190	W
power input at design heating load	W_h	103051	W
Required length for cooling	L_c	52382	Ft
Required length for heating	L_h	31821	Ft

Table 12 Geothermal loop input data

$$L_h = \frac{q_a R_{ga} + (q_{lc} - 3.14W_c)(R_b + PLF_m R_{gm} + R_{gd} F_{sc})}{t_g - \frac{t_{wi} + t_{wo}}{2} - t_p}$$

Equation 1 Finds linear feet of pipe needed for the geothermal field

$$\#boreholes = \frac{L_h}{300} \div 2$$

Equation 2 Finds the necessary number of 300ft deep boreholes needed for the geothermal field

Ventilation Calculations. In order to find the necessary outdoor air for the building, the mechanical team used ASHRAE Standard 62.1 Chapter 6 to find the ventilation rates. The following tables were used to calculate the ventilation information.

Zone	Number	Type	Zone Floor Area	Zone Population	People OA Rate	Area OA Rate	Breathing Zone OA	Zone Air Distribution Effectiveness	Zone Outdoor Airflow
			Az (sq. ft.)	**Pz** (people)	Rp*Pz (CFM)	Ra*Az (CFM)	**Vbz**=Rp*Pz + Ra*Az (CFM)	**Ez**	**Voz**=Vbz/Ez (CFM)
Totals			**70,330**	**1497**	**12677.5**	**6926**	**19604**		**24505**
Multi-purpose Room	104_1	30	3,164	220	1100	190	1290	0.8	1612
Multi-purpose Room	104_2	30	4,311	110	550	259	809	0.8	1011
Principal Office	108	31	178	1	5	11	16	0.8	20
Clerical 109	109	31	756	3	15	45	60	0.8	75
Reception	110	32	233	1	5	14	19	0.8	24
Community Office	111	31	176	1	5	11	16	0.8	19
Working Room	113	22	335	5	25	20	45	0.8	56
Vestibule	100	49	94	0	0	6	6	0.8	7
Cust	116	24	46	0	0	6	6	0.8	7
Lobby	101	49	1,380	0	0	83	83	0.8	104
Corridor	103	23	866	0	0	52	52	0.8	65
M.D.F	118	13	124	0	0	15	15	0.8	19
Classroom	134	6	806	27	270	97	367	0.8	458
Classroom	135	6	789	27	270	95	365	0.8	456
Classroom	136	6	791	27	270	95	365	0.8	456
Instruct. Storage	137	24	182	0	0	22	22	0.8	27
Corridor	139	23	58	0	0	3	3	0.8	4
Cust	147	24	49	0	0	6	6	0.8	7
Cooridor	149	23	1,315	0	0	79	79	0.8	99
Special Education	140	6	964	25	250	116	366	0.8	457
Corridor	150	23	636	0	0	38	38	0.8	48
Cooridor	153	23	200	0	0	12	12	0.8	15
Cooridor	154	23	743	0	0	45	45	0.8	56
Classroom	155	6	903	26	260	108	368	0.8	460
Vestibule	156	49	147	0	0	9	9	0.8	11
Maintenance	157	24	276	0	0	33	33	0.8	41
I.D.F	158	13	90	0	0	11	11	0.8	14
Classroom	159	6	856	26	260	103	363	0.8	453
Classroom	160	6	856	26	260	103	363	0.8	453
Conference	161	22	160	5	25	10	35	0.8	43
Security	152	36	114	1	5	7	12	0.8	15
Conference	151	22	188	8	40	11	51	0.8	64
Classroom	141	6	1,074	27	270	129	399	0.8	499
Classroom	142	6	1,092	27	270	131	401	0.8	501
Classroom	143	6	1,092	27	270	131	401	0.8	501
Classroom	144	6	1,107	27	270	133	403	0.8	504
SGI/Comm. Room	145	22	1,100	36	180	66	246	0.8	308
Vestibule	102	49	190	0	0	11	11	0.8	14
Treating/Waiting	119	20	440	3	15	26	41	0.8	52
Office	120	31	96	2	10	6	16	0.8	20
Exam	121	31	111	1	5	7	12	0.8	15
COTS	122	31	226	3	15	14	29	0.8	36
P.E. Office/Storage	124	31	391	1	5	23	28	0.8	36
Corridor	128	23	208	0	0	12	12	0.8	16
Office	129	31	69	1	5	4	9	0.8	11
Storage	130	24	153	0	0	18	18	0.8	23
Kitchen	132	18	1,710	5	37.5	308	345	0.8	432
Table/Chair Storage	133	24	422	0	0	51	51	0.8	63

Table 13 Ventilation Data (Cont'd on next page)

Lobby	200	29	1,315	0	0	79	79	0.8	99
Corridor	201	23	862	0	0	52	52	0.8	65
Planning/Conference	202	22	669	8	40	40	80	0.8	100
Cust	204	24	47	0	0	6	6	0.8	7
I.D.F	206	13	67	0	0	8	8	0.8	10
Classroom	216	6	761	27	270	91	361	0.8	452
Classroom	217	6	760	27	270	91	361	0.8	452
Classroom	218	6	773	27	270	93	363	0.8	453
Teacher Workroom	219	31	214	2	10	13	23	0.8	29
Corridor	214	23	1,415	0	0	85	85	0.8	106
Corridor	220	23	52	0	0	3	3	0.8	4
Special Education	222	6	970	18	180	116	296	0.8	371
Corridor	215	23	568	0	0	34	34	0.8	43
Cust	229	24	49	0	0	6	6	0.8	7
Corridor	231	23	193	0	0	12	12	0.8	14
Classroom	233	6	877	26	260	105	365	0.8	457
Classroom	234	6	1,084	26	260	130	390	0.8	488
Classroom	235	6	821	26	260	99	359	0.8	448
Classroom	236	6	820	26	260	98	358	0.8	448
Corridor	232	23	685	0	0	41	41	0.8	51
Classroom	223	6	970	27	270	116	386	0.8	483
Classroom	224	6	985	27	270	118	388	0.8	485
Classroom	225	6	985	27	270	118	388	0.8	485
Classroom	226	6	985	27	270	118	388	0.8	485
Classroom	227	6	1,008	27	270	121	391	0.8	489
Assistant Principal	207	31	161	1	5	10	15	0.8	18
Library	208	48	1,949	25	125	234	359	0.8	449
Library Support	209	48	369	2	10	44	54	0.8	68
Art Classroom	211, 212	10	1,222	26	260	220	480	0.8	600
Faculty Dining	213	17	657	20	150	118	268	0.8	335
Corridor	301	23	862	0	0	52	52	0.8	65
Psych Office	302	31	220	1	5	13	18	0.8	23
Conference	303	22	203	4	20	12	32	0.8	40
I.S.T	304	13	237	1	10	28	38	0.8	48
Lobby	300	49	1,312	0	0	79	79	0.8	98
Cust	306	24	47	0	0	6	6	0.8	7
I.D.F	308	13	67	0	0	8	8	0.8	10
Corridor	315	23	1,417	0	0	85	85	0.8	106
Classroom	317	6	761	27	270	91	361	0.8	452
Classroom	318	6	760	27	270	91	361	0.8	452
Classroom	319	6	772	27	270	93	363	0.8	453
Instruct. Storage	320	24	167	0	0	20	20	0.8	25
Corridor	323	23	67	0	0	4	4	0.8	5
Special Education	324	6	972	18	180	117	297	0.8	371
Cust	331	24	23	0	0	3	3	0.8	3
Corridor	316	23	442	0	0	27	27	0.8	33
Corridor	333	23	104	0	0	6	6	0.8	8
Classroom	325	6	784	27	270	94	364	0.8	455
Classroom	326	6	798	27	270	96	366	0.8	457
Classroom	327	6	797	27	270	96	366	0.8	457
Special Education	328	6	798	27	270	96	366	0.8	457
Classroom	329	6	818	27	270	98	368	0.8	460
Guidance	309	31	162	1	5	10	15	0.8	18
Classroom	310	6	832	27	270	100	370	0.8	462
Classroom	311	6	837	27	270	100	370	0.8	463
Classroom	312	6	836	27	270	100	370	0.8	463
Classroom	313	6	816	27	270	98	368	0.8	460
Classroom	314	6	859	27	270	103	373	0.8	466

TRACE Results. Screen Shots of Trane TRACE 700 results for the baseline and the proposed model.

ENERGY CONSUMPTION SUMMARY
By ACADEMIC

	Elect Cons. (kWh)	% of Total Building Energy	Total Building Energy (kBtu/yr)	Total Source Energy* (kBtu/yr)
Alternative 1				
Primary heating				
Primary heating	55,656	7.1 %	189,956	569,924
Other Htg Accessories		0.0 %	0	0
Heating Subtotal	**55,656**	**7.1 %**	**189,956**	**569,924**
Primary cooling				
Cooling Compressor	101,923	13.1 %	347,862	1,043,689
Tower/Cond Fans	12,680	1.6 %	43,276	129,841
Condenser Pump		0.0 %	0	0
Other Clg Accessories	178	0.0 %	609	1,826
Cooling Subtotal....	**114,781**	**14.7 %**	**391,746**	**1,175,356**
Auxiliary				
Supply Fans		0.0 %	0	0
Pumps		0.0 %	0	0
Stand-alone Base Utilities		0.0 %	0	0
Aux Subtotal....		0.0 %	0	0
Lighting				
Lighting	585,269	75.1 %	1,997,522	5,993,165
Receptacle				
Receptacles	23,651	3.0 %	80,721	242,186
Cogeneration				
Cogeneration		0.0 %	0	0
Totals				
Totals**	**779,357**	**100.0 %**	**2,659,944**	**7,980,630**

* Note: Resource Utilization factors are included in the Total Source Energy value.
** Note: This report can display a maximum of 7 utilities. If additional utilities are used, they will be included in the total.

Project Name:
Dataset Name: correct.trc

TRACE® 700 v6.2.9 calculated at 04:12 PM on 11/10/2012
Alternative - 1 Energy Consumption Summary report page 1

Figure 20 Baseline Model Energy Consumption Summary

ENERGY CONSUMPTION SUMMARY
By ACADEMIC

	Elect Cons. (kWh)	% of Total Building Energy	Total Building Energy (kBtu/yr)	Total Source Energy* (kBtu/yr)
Alternative 3				
Primary heating				
Primary heating	13,669	2.0 %	46,652	139,969
Other Htg Accessories	6	0.0 %	20	61
Heating Subtotal	**13,675**	**2.0 %**	**46,672**	**140,030**
Primary cooling				
Cooling Compressor	54,561	7.9 %	186,218	558,709
Tower/Cond Fans		0.0 %	0	0
Condenser Pump		0.0 %	0	0
Other Clg Accessories	31	0.0 %	107	321
Cooling Subtotal....	**54,593**	**7.9 %**	**186,325**	**559,030**
Auxiliary				
Supply Fans		0.0 %	0	0
Pumps	14,199	2.1 %	48,461	145,398
Stand-alone Base Utilities		0.0 %	0	0
Aux Subtotal....	14,199	2.1 %	48,461	145,398
Lighting				
Lighting	585,269	84.7 %	1,997,522	5,993,165
Receptacle				
Receptacles	23,651	3.4 %	80,721	242,186
Cogeneration				
Cogeneration		0.0 %	0	0
Totals				
Totals**	**691,386**	**100.0 %**	**2,359,700**	**7,079,809**

* Note: Resource Utilization factors are included in the Total Source Energy value.
** Note: This report can display a maximum of 7 utilities. If additional utilities are used, they will be included in the total.

Project Name:
Dataset Name: correct.trc

TRACE® 700 v6.2.9 calculated at 04:12 PM on 11/10/2012
Alternative - 3 Energy Consumption Summary report page 1

Figure 21 Hybrid Geothermal System Consumption Summary

Load Calculations. The following tables show in detail the different zones for the building and their load requirements.

3. Kitchen Make-up Air Unit		Vpz	Vdz	Total	Latent Load	Sensible Load	DOAS Load		DOAS Airflow	Heat Pump Load		Heat Pump
		CFM	CFM	Btu/h	Btu/h	Btu/h	Btu/h	Ton	CFM	Btu/h	Ton	CFM
Kitchen	132	493	908	28017	7489	20528	15221	1.2684	493	12796	1.0664	415
						Total:	9549	1.3	493	12796	1.1	880

4. clinic		Vpz	Vdz	Total	Latent Load	Sensible Load	DOAS Load		DOAS Airflow	Heat Pump Load		Heat Pump Airflow
		CFM	CFM	Btu/h	Btu/h	Btu/h	Btu/h	Ton	CFM	Btu/h	Ton	CFM
Treating/Waiting	119	60	240	6346	1379	4967	1587	0.1322	60	4760	0.3966	180
Office	120	25	130	3396	238	3158	653	0.0544	25	2743	0.2286	105
Exam	121	20	149	3727	246	3481	500	0.0417	20	3227	0.2689	129
COTS	122	40	66	3357	1149	2208	2035	0.1695	40	1322	0.1102	26
						Total:	4774	0.40	145	12052	1.00	440

5. Admin. Ahu2		Vpz	Vdz	Total	Latent Load	Sensible Load	DOAS Load		DOAS Airflow	Heat Pump Load		Heat Pump Airflow
		CFM	CFM	Btu/h	Btu/h	Btu/h	Btu/h	Ton	CFM	Btu/h	Ton	CFM
Principal Office	108	30	335	6140	1175	4965	1191	0.0993	65	4949	0.4124	270
Clerical 109	109	90	2045	33084	1561	31523	1618	0.1348	100	31466	2.6222	1945
Reception	110	30	255	5037	502	4535	593	0.0494	30	4444	0.3704	225
Community Office	111	25	50	1799	501	1298	900	0.0750	25	900	0.0750	25
Working Room	113	65	100	5315	1867	3448	3455	0.2879	65	1860	0.1550	35
Cust	116	10	10	254	81	173	254	0.0212	10	0	0.0000	0
Corridor	103	74	322	8641	1073	7568	1992	0.1660	74	6649	0.5541	248
P.E. Office/Storage	124	36	195	5235	527	4708	966	0.0805	36	4269	0.3557	159
Corridor	128	18	52	1478	345	1133	507	0.0422	18	971	0.0809	34
Office	129	13	19	1077	376	701	740	0.0617	13	337	0.0281	6
Storage	130	20	20	844	270	574	844	0.0703	20	0	0.0000	0
Table/Chair Storage	133	50	63	3374	1149	2225	2678	0.2231	50	696	0.0580	13
Lobby	101	120	190	6856	1891	4965	4330	0.3608	120	2526	0.2105	70
						Total:	12340	1.67	415	46145	3.85	2570

6. 1st fl AHU3		Vpz	Vdz	Total	Latent Load	Sensible Load	DOAS Load		DOAS Airflow	Heat Pump Load		Heat Pump Airflow
		CFM	CFM	Btu/h	Btu/h	Btu/h	Btu/h	Ton	CFM	Btu/h	Ton	CFM
M.D.F	118	15	21	1021	337	684	972	0.0810	20	49	0.0041	1
Classroom	134	525	738	31485	12441	19044	22355	1.8629	524	9130	0.7608	214
Classroom	135	525	738	31485	12440	19045	22398	1.8665	525	9087	0.7573	213
Classroom	136	525	742	31560	12445	19115	22330	1.8608	525	9230	0.7692	217
Instruct. Storage	137	35	35	1784	648	1136	1784	0.1487	35	0	0.0000	0
Corridor	139	5	5	54	6	48	54	0.0045	5	0	0.0000	0
Classroom	141	575	1107	38099	14781	23318	19789	1.6491	575	18310	1.5258	532
Classroom	142	575	1140	38612	14889	23723	19475	1.6229	575	19137	1.5947	565
Classroom	143	575	1140	38611	14888	23723	19475	1.6229	575	19136	1.5947	565
Classroom	144	575	1143	38766	14938	23828	19518	1.6265	575	19248	1.6040	568
SGI/ Community Room	145	350	1206	44822	16458	28364	13008	1.0840	350	31814	2.6512	856
						Total:	161160	13	4284	135139	11	3731

7. 1st 2nd RTU1		Vpz	Vdz	Total	Latent Load	Sensible Load	DOAS Load		DOAS Airflow	Heat Pump Load		Heat Pump Airflow
		CFM	CFM	Btu/h	Btu/h	Btu/h	Btu/h	Ton	CFM	Btu/h	Ton	CFM
Special Education	140	525	989	36262	12015	24247	19249	1.6041	525	17013	1.4177	464
Cust	147	6	6	271	87	184	271	0.0226	6	0	0	0
Cooridor	149	79	79	1143	94	1049	1143	0.0953	79	0	0	0
Corridor	150	38	38	554	46	508	554	0.0462	38	0	0	0
Cooridor	153	17	94	2508	306	2202	454	0.0378	17	2054	0.1712	77
Cooridor	154	64	1398	33218	1186	32032	1521	0.1267	64	31697	2.6414	1334
Classroom	155	526	1176	38784	11063	27721	17347	1.4456	526	21437	1.7864	650
Maintenance	157	47	60	2703	739	1964	2117	0.1764	47	586	0.0488	13
I.D.F	158	15	15	734	243	491	734	0.0612	15	0	0.0000	0
Classroom	159	518	1151	37357	10973	26384	16812	1.4010	518	20545	1.7121	633
Classroom	160	518	1129	36981	10971	26010	16967	1.4139	518	20014	1.6678	611
Conference	161	35	55	4138	1666	2472	2633	0.2194	35	1505	0.1254	20
Security	152	17	34	1455	441	1014	728	0.0606	17	728	0.0606	17
Conference	151	50	73	6247	2602	3645	4279	0.3566	50	1968	0.1640	23
						Total:	65560	7	2455	117546	10	3842

Table 14 Room by Room Air Breakdown Loads (Cont'd on next page)

7. 1st 2nd RTU1		Vpz	Vdz	Total	Latent Load	Sensible Load	DOAS Load		DOAS Airflow	Heat Pump Load		Heat Pump Airflow
		CFM	CFM	Btu/h	Btu/h	Btu/h	Btu/h	Ton	CFM	Btu/h	Ton	CFM
Special Education	222	423	980	30842	9287	21555	13326	1.1105	423	17516	1.4597	557
Cust	229	6	6	271	87	184	271	0.0226	6	0	0	0
Corridor	215	25	1461	31510	437	31073	539	0.0449	25	30971	2.5809	1436
Corridor	231	17	91	2935	294	2641	534	0.0445	17	2401	0.2001	74
Corridor	232	50	2243	53030	966	52064	1182	0.0985	50	51848	4.3207	2193
Classroom	233	522	1222	39865	11014	28851	17022	1.4185	522	22843	1.9036	700
Classroom	234	557	1362	42862	11409	31453	17537	1.4614	557	25325	2.1104	805
Classroom	235	512	1197	38050	10906	27144	16281	1.3567	512	21769	1.8141	685
Classroom	236	512	1138	38197	10904	27293	17185	1.4321	512	21012	1.7510	626
						Total:	70550	7.0	2624	193686	16.1	7076

8. 2nd & 3rd-RTU2		Vpz	Vdz	Total	Latent Load	Sensible Load	DOAS Load		DOAS Airflow	Heat Pump Load		Heat Pump Airflow
		CFM	CFM	Btu/h	Btu/h	Btu/h	Btu/h	Ton	CFM	Btu/h	Ton	CFM
Classroom	216	516	731	31255	12375	18880	22070	1.8391	516	9185	0.7654	215
Classroom	217	516	731	31239	12371	18868	22051	1.8376	516	9188	0.7657	215
Classroom	218	518	737	31412	12403	19009	22088	1.8406	518	9324	0.7770	219
Teacher Workroom	219	33	78	2908	841	2067	1216	0.1014	33	1692	0.1410	45
Corridor	214	85	85	1230	101	1129	1230	0.1025	85	0	0.0000	0
Classroom	223	552	1159	37586	12672	24914	17901	1.4918	552	19685	1.6404	607
Classroom	224	555	1123	38177	14477	23700	18853	1.5711	555	19324	1.6103	568
Classroom	225	555	1123	38176	14476	23700	18852	1.5710	555	19324	1.6103	568
Classroom	226	555	1123	38176	14476	23700	18852	1.5710	555	19324	1.6103	568
Classroom	227	559	1182	37706	12758	24948	17817	1.4847	559	19889	1.6574	623
						Total:	160960	13.4	4445	126954	10.6	3632

8. 2nd & 3rd-RTU2		Vpz	Vdz	Total	Latent Load	Sensible Load	DOAS Load		DOAS Airflow	Heat Pump Load		Heat Pump Airflow
		CFM	CFM	Btu/h	Btu/h	Btu/h	Btu/h	Ton	CFM	Btu/h	Ton	CFM
Corridor	315	85	85	4929	101	4828	4929	0.4108	85	0	0.0000	0
Classroom	317	516	803	33270	12375	20895	21386	1.7822	516	11884	0.9903	287
Classroom	318	516	803	33261	12372	20889	21373	1.7811	516	11888	0.9907	287
Classroom	319	518	760	33363	12400	20963	22742	1.8952	518	10621	0.8851	242
Instruct. Storage	320	20	28	1760	461	1299	1257	0.1048	20	503	0.0419	8
Electrical Closet	321	5	5	309	77	232	307	0.0256	5	2	0.0001	0
Corridor	323	5	5	237	6	231	237	0.0198	5	0	0.0000	0
Special Education	324	424	1065	33318	9280	24038	13257	1.1048	424	20061	1.6717	641
Cust	331	5	5	183	40	143	183	0.0153	5	0	0.0000	0
Corridor	316	38	1533	34116	29	34087	843	0.0703	38	33273	2.7727	1495
Corridor	333	5	961	21407	179	21228	223	0.0186	10	21184	1.7654	951
Classroom	325	520	1157	37301	12251	25050	16768	1.3973	520	20533	1.7111	637
Classroom	326	523	1251	36406	12284	24122	15206	1.2672	523	21200	1.7667	728
Classroom	327	522	1248	36385	12281	24104	15229	1.2691	522	21156	1.7630	726
Special Education	328	523	1248	36395	12282	24113	15238	1.2698	523	21157	1.7631	725
Classroom	329	526	1187	37489	12328	25161	16611	1.3842	526	20878	1.7398	661
						Total:	165790	13.8	4755	214339	17.9	7389

9. 2nd 8 3rd -RTU3		Vpz	Vdz	Total	Latent Load	Sensible Load	DOAS Load		DOAS Airflow	Heat Pump Load		Heat Pump Airflow
		CFM	CFM	Btu/h	Btu/h	Btu/h	Btu/h	Ton	CFM	Btu/h	Ton	CFM
Lobby	200	113	688	17798	1784	16014	2916	0.2430	113	14882	1.2402	575
Planning/Conference	202	114	849	18317	2696	15621	2697	0.2247	125	15620	1.3017	724
Corridor	201	74	406	10431	1086	9345	1898	0.1582	74	8533	0.7111	332
Cust	204	6	6	259	83	176	259	0.0216	6	0	0.0000	0
I.D.F	206	8	12	555	183	372	555	0.0463	12	0	0.0000	0
Assistant Principal	207	21	735	16016	70	15946	456	0.0380	21	15560	1.2966	714
Library	208	513	2107	53530	6640	46890	13025	1.0854	513	40505	3.3754	1594
Library Support	209	78	362	8588	621	7967	1840	0.1533	78	6748	0.5624	284
Art Classroom	211, 212	686	1315	29012	601	28411	15127	1.2606	686	13885	1.1571	629
Faculty Dining	213	268	741	26431	11439	14992	9559	0.7966	268	16872	1.4060	473
						Total:	48333	4.0	1894	132604	11.1	5327

9. 2nd 8 3rd -RTU3		Vpz	Vdz	Total	Latent Load	Sensible Load	DOAS Load		DOAS Airflow	Heat Pump Load		Heat Pump Airflow
		CFM	CFM	Btu/h	Btu/h	Btu/h	Btu/h	Ton	CFM	Btu/h	Ton	CFM
Corridor	301	74	1556	38417	1248	37169	1824	0.1520	74	36593	3.0494	1482
Psych Office	302	26	261	5233	440	4793	521	0.0434	26	4712	0.3926	235
Conference	303	46	177	5602	1241	4361	1455	0.1212	46	4147	0.3456	131
I.S.T	304	38	163	4795	594	4201	1118	0.0932	38	3677	0.3064	125
Lobby	300	112	784	20184	1792	18392	2895	0.2413	112	17289	1.4407	672
Cust	306	6	6	381	83	298	381	0.0318	6	0	0.0000	0
I.D.F	308	8	12	729	183	546	486	0.0405	8	243	0.0203	4
Guidance	309	21	735	16059	297	15762	459	0.0383	21	15600	1.3000	714
Classroom	310	528	1254	37928	12540	25388	15980	1.3317	528	21948	1.8290	726
Classroom	311	529	1282	37966	12372	25594	15672	1.3060	529	22294	1.8578	753
Classroom	312	529	1281	37946	12368	25578	15671	1.3059	529	22275	1.8563	752
Classroom	313	526	1273	37735	12324	25411	15580	1.2983	526	22155	1.8462	747
Classroom	314	533	1275	38272	12602	25670	15998	1.3332	533	22274	1.8561	742
						Total:	88042	7.3	2976	193205	16.1	7083

Heat Pump Sizing. In order to select pumps for the system, we calculated the total flow rate in the common water loop by applying the equation below.

$$Q=500*GPM*\Delta T$$

1 ton=12000Btu/h

Building Peak: 168.7 ton = 2024400 Btu/h

ΔT= 15 °F

GPM= 269.92

Based on the GPM we calculated, we plotted the gpm and total head on the Scot 57 series pump curve which lead us to the final pump size which is a 20 HP with a 5.88 inch impeller.

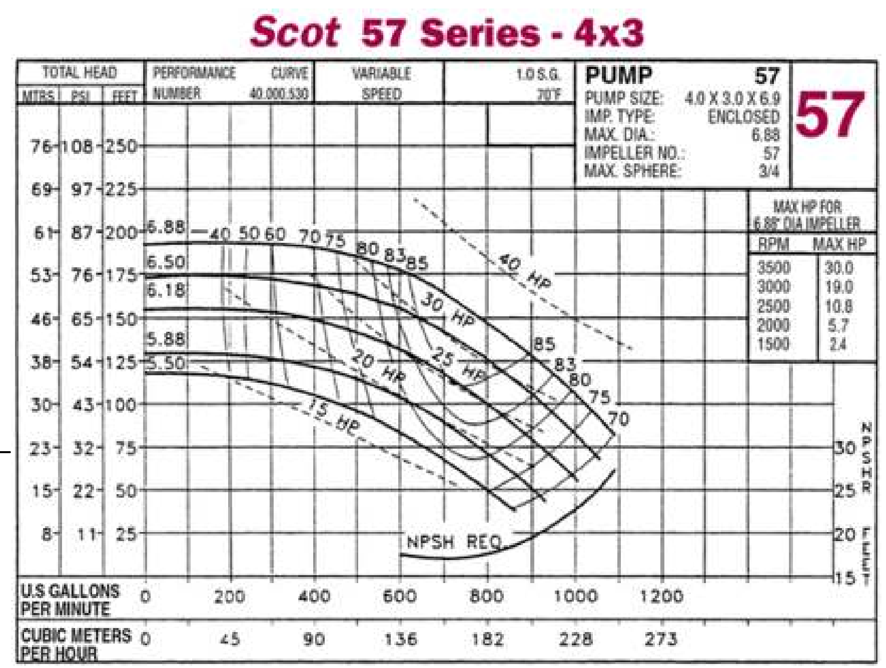


Figure 22 Pump Curve

Heat Pump Schedule Example

SmartSource Heat Pump																		
(V) or (H)	Stage(1) or (2)	Unit size		EWT	GPM	WPD: PSI	WPD: FT of W.C.	EAT (°F)	Cooling: tot. (Btu/hr)	Cooling: sen. (Btu/hr)	Cooling: Pwr In. (kW)	Cooling: THR (Btu/hr)	Cooling: EER	Heating: Tot. (Btu/hr)	Heating: Pwr In. (kW)	Heating: THA (Btu/hr)	Heating: LAT(°F)	Heating: COP
H	1	024	2	80	6	2.1	4.9	80/67	27200	19000	1.432	32100	19	31900	1.737	26000	117	5.38
SmartSource Heat Pump																		
(V) or (H)	Stage(1) or (2)	Unit size		EWT	GPM	WPD: PSI	WPD: FT of W.C.	EAT (°F)	Cooling: tot. (Btu/hr)	Cooling: sen. (Btu/hr)	Cooling: Pwr In. (kW)	Cooling: THR (Btu/hr)	Cooling: EER	Heating: Tot. (Btu/hr)	Heating: Pwr In. (kW)	Heating: THA (Btu/hr)	Heating: LAT(°F)	Heating: COP
H	1	012	1	80	3	4	9.1	80/67	13100	9400	0.799	15800	16.4	17200	0.989	13800	120	5.09
H	1	049	4.083333333	80	12	2.6	5.9	80/67	52000	36900	3.001	62200	17.3	63700	3.951	50200	117	4.72
SmartSource Heat Pump																		
(V) or (H)	Stage(1) or (2)	Unit size		EWT	GPM	WPD: PSI	WPD: FT of W.C.	EAT (°F)	Cooling: tot.(Btu/hr)	Cooling: sen. (Btu/hr)	Cooling: Pwr In. (kW)	Cooling: THR(Btu/hr)	Cooling: EER	Heating: Tot. (Btu/hr)	Heating: Pwr In. (kW)	Heating: THA(Btu/hr)	Heating: LAT(°F)	Heating: COP
V	1	009		80	2.3	2.6	5.8	80/67	11100	8100	0.551	13000	20.1	12400	0.739	9900	113	4.91
V	1	009		80	2.3	2.6	5.8	80/67	11100	8100	0.551	13000	20.1	12400	0.739	9900	113	4.91
V	1	009	3/4	80	2.3	2.6	5.8	80/67	11100	8100	0.551	13000	20.1	12400	0.739	9900	113	4.91
V	1	019	1.6	80	4.5	3.4	7.7	80/67	18200	13300	1.024	21700	17.8	25300	1.42	20500	119	5.22
V	1	019	1.6	80	4.5	3.4	7.7	80/67	18200	13300	1.024	21700	17.8	25300	1.42	20500	119	5.22
V	1	019	1.6	80	4.5	3.4	7.7	80/67	18200	13300	1.024	21700	17.8	25300	1.42	20500	119	5.22
V	1	019	1.6	80	4.5	3.4	7.7	80/67	18200	13300	1.024	21700	17.8	25300	1.42	20500	119	5.22
H	2	032	2.7	80	7.5	3.2	7.3	80/67	33200	23300	2.003	40000	16.6	40700	2.42	32400	117	4.92

Table 15 Heat Pump Sample Schedule

Cooling Tower Calculations. The cooling tower we've selected was an open cooling tower that is counterflow induced draft with fill which increase the thermal efficiency .

According to ASHRAE the summer design wet bulb for Reading, PA is 72.1°F. Base on many cooling tower manufacturers recommendation , the entering and leaving water temperatures were set at 95 F and 85 , so the cooling range is 95 F – 85 F = 10 F.

The approach temperature (the difference between the exiting fluid temperature of the cooling tower and the design wet bulb temperature) is 85F – 72 F =13 F

The fluid flow is calculated based on the equation below

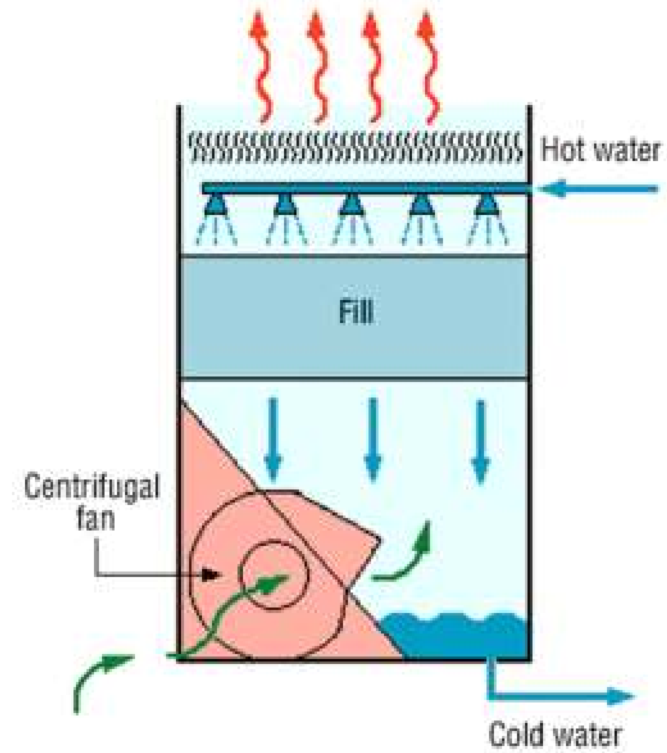


Figure 23 Cooling tower Schematic

$$\dot{m}_{H20} = \frac{\dot{q}}{Cp * \Delta T_{cooling\ range}}$$

Where:

m = the flow of the fluid to and from the cooling tower [gpm]

q = the cooling tower capacity [BTU/hr]

Cp = specific heat [BTU/lbm-F]

ΔT = cooling range

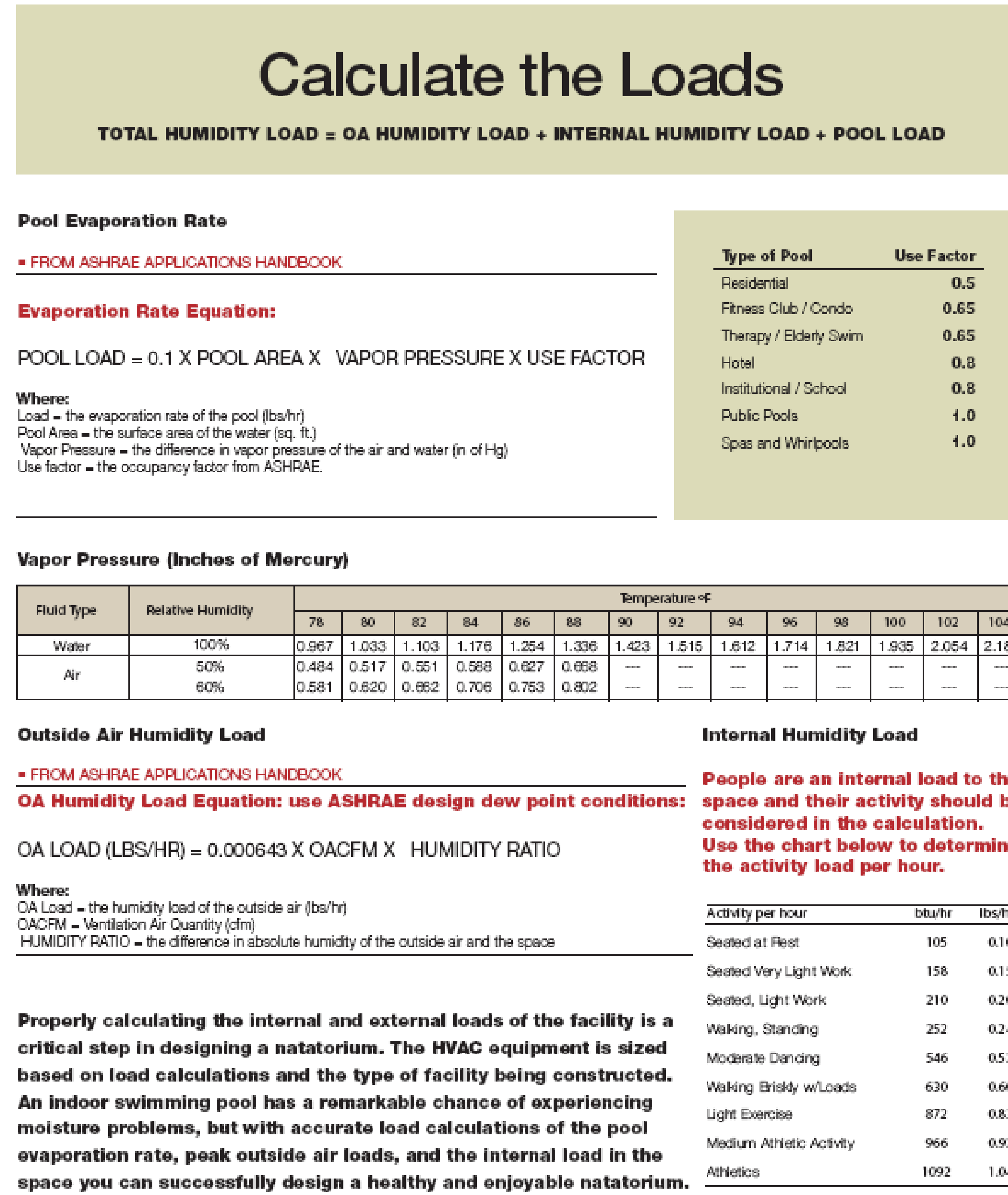
Tower Size	Required Flow [GPM]
60 Ton	144.5

Exhaust Rates. The following are areas that need to have exhaust air. Again, ASHRAE Standard 62.1 was used in order to determine the air changes per hour and find the cfm for each of the spaces.

Room	Area (sq ft)	Height (ft)	ACH	CFM	Rounded
112 Toilet	89	10	2	30	30
115 Girl/Entry	235	10	2	78	80
117 Boy/Entry	235	10	2	78	80
123 Toilet	75	10	2	25	25
132 Kitchen	1710	10		1197	1200
138 Toilet	47	10	2	16	20
140A Toilet	123	10	2	41	40
146 Boys/Entry	166	10	2	55	55
148 Girls/Entry	166	10	2	55	55
203 Girls/Entry	238	10	2	79	80
205 Boys/Entry	238	10	2	79	80
221 Toilet	47	10	2	16	15
222A Toilet	123	10	2	41	40
223A Toilet	123	10	2	41	40
224A Toilet	123	10	2	41	40
225A Toilet	123	10	2	41	40
226A Toilet	123	10	2	41	40
227A Toilet	123	10	2	41	40
228 Boys/Entry	166	10	2	55	55
230 Boys/Entry	166	10	2	55	55
234A Toilet	59	10	2	20	20
305 Girls/Entry	238	10	2	79	80
307Boys/Entry	238	10	2	79	80
322 Toilet	49	10	2	16	15
324A Toilet	123	10	2	41	40
330 Boys/Entry	125	10	2	42	40
332 Girls/Entry	125	10	2	42	40

Table 16 Rooms that need to be exhausted

Pool Calculations. As mentioned in the Mechanical Report, the most important thing to consider when designing the pool, is to look at the humidity load. The following data was used to calculate the humidity load.



Calculate the Loads

TOTAL HUMIDITY LOAD = OA HUMIDITY LOAD + INTERNAL HUMIDITY LOAD + POOL LOAD

Pool Evaporation Rate

▪ FROM ASHRAE APPLICATIONS HANDBOOK

Evaporation Rate Equation:

POOL LOAD = 0.1 X POOL AREA X VAPOR PRESSURE X USE FACTOR

Where:
Load = the evaporation rate of the pool (lbs/hr)
Pool Area = the surface area of the water (sq. ft.)
Vapor Pressure = the difference in vapor pressure of the air and water (in of Hg)
Use factor = the occupancy factor from ASHRAE.

Type of Pool	Use Factor
Residential	0.5
Fitness Club / Condo	0.65
Therapy / Elderly Swim	0.65
Hotel	0.8
Institutional / School	0.8
Public Pools	1.0
Spas and Whirlpools	1.0

Vapor Pressure (Inches of Mercury)

Fluid Type	Relative Humidity	Temperature °F													
		78	80	82	84	86	88	90	92	94	96	98	100	102	104
Water	100%	0.967	1.033	1.103	1.176	1.254	1.336	1.423	1.515	1.612	1.714	1.821	1.935	2.054	2.180
Air	50%	0.484	0.517	0.551	0.588	0.627	0.668	---	---	---	---	---	---	---	---
	60%	0.581	0.620	0.662	0.706	0.753	0.802	---	---	---	---	---	---	---	---

Outside Air Humidity Load

▪ FROM ASHRAE APPLICATIONS HANDBOOK

OA Humidity Load Equation: use ASHRAE design dew point conditions:

OA LOAD (LBS/HR) = 0.000643 X OACFM X HUMIDITY RATIO

Where:
OA Load = the humidity load of the outside air (lbs/hr)
OACFM = Ventilation Air Quantity (cfm)
HUMIDITY RATIO = the difference in absolute humidity of the outside air and the space

Properly calculating the internal and external loads of the facility is a critical step in designing a natatorium. The HVAC equipment is sized based on load calculations and the type of facility being constructed. An indoor swimming pool has a remarkable chance of experiencing moisture problems, but with accurate load calculations of the pool evaporation rate, peak outside air loads, and the internal load in the space you can successfully design a healthy and enjoyable natatorium.

Internal Humidity Load

People are an internal load to the space and their activity should be considered in the calculation. Use the chart below to determine the activity load per hour.

Activity per hour	btu/hr	lbs/hr
Seated at Rest	105	0.10
Seated Very Light Work	158	0.15
Seated, Light Work	210	0.20
Walking, Standing	252	0.24
Moderate Dancing	546	0.52
Walking Briskly w/Loads	630	0.60
Light Exercise	872	0.83
Medium Athletic Activity	966	0.92
Athletics	1092	1.04

Figure 24 Information used to calculate pool humidification

Pool Calculation Continued. ASHRAE 62.1 was used to find the outside air humidity load. The pool load was calculated using the table found in the Mechanical Systems report, below is the addition of the pool load, the outside air humidity load and the internal load. The water vapor pressure and air vapor pressure were found by following the guidelines from the previous page for water that is 80F and the air vapor pressure was found by using air temperature of 82F and a humidity ration of 60%. With these specifications, the water and air vapor pressure are 1.033In. Hg and 0.62 In. Hg respectively. In addition, the Internal Humidity Load was found by using the table on the previous page. Since the humidity internal load for a school is 0.8 and the humidity internal load for public use is 1.0, the mechanical team assumed an internal humidity load of 0.9. Finally the Outside Air Humidity Load was found using ASHRAE 62.1 to get the information for the pool area and the spectator section which is by the bleachers.

a) Pool Load Calculation		
Load= 0.1*pool area* vapor pressure * use factor		
Water Temp.	80	F
Air Temp.	82	F
RH	60	%
Pool Area	3680	ft^2
Use Factor	0.9	
Water Vapor Pressure	1.033	In. Hg
Air Vapor Pressure	0.62	In. Hg
delta vapor pressure	0.413	In. Hg
Pool load	136.8	lbs/hr

Tables 17a, 17b, 17c Pool Calculation Information

b) Outside Air Humidity Load Calculation			
	Area (ft^2)	Area Outdoor Air Rate (From ASHRAE 62.1)	Ventilation (CFM)
Pool & Deck	6403	0.48	3073
Spectator	2625	0.06	158
		Total=	3231

c) Total Load		
Pool Load	136.8	Lbs/hr
Internal Humidity Load	0.9	lbs/hr
Outside Air Humidity Load	2.1	lbs/hr
Total Humidity Load	**140**	**lbs/hr**

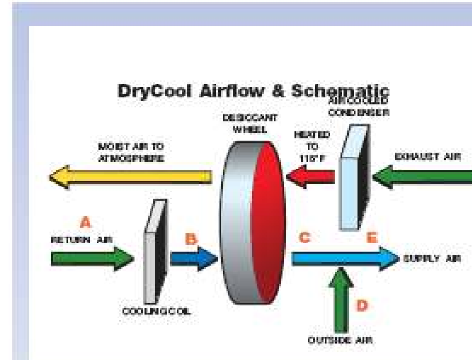
appendix c

Equipment Data: Pool

DryCool Pool

Product Description

The DryCool Pool dehumidifier provides energy efficient dehumidification in a small packaged product at low cost. Condenser heat is recovered from the direct expansion refrigeration system to provide the reactivation energy for the desiccant dehumidification process. The cooling energy of the refrigeration system is used to cool and dehumidify the air prior to entering the desiccant wheel. The hybrid refrigerantdesiccant system provides an efficient dehumidifier by eliminating the overcooling required with a refrigeration only based dehumidifier. The system uses the reactivation fan as the exhaust air fan to maintain negative pressure in the space while further enhancing efficiency and minimizing the unit footprint and cost.



State		Summer			Winter		
Point		CFM	°F	gr/hr	CFM	°F	gr/hr
A	Return	6,000	82	100	6,000	82	100
B	Post Cooling Coil	6,000	51	56	6,000	82	100
C	Post Desiccant Wheel	6,000	69	34	6,000	82	100
D	Outside Air	4,000	95	120	4,000	20	10
E	Supply Air	10,000	79	68	10,000	90	64

Product Features

- Foam injected 2" double wall casing
- Desiccant enhanced process for lower connected tonnage and lower operating cost
- Packaged DX, split system DX, water cooled DX and chilled water options
- Coated cooling coils and other critical components
- DDC microprocessor controls
- Option for 100% outside air during purge mode
- Stainless steel drain pans
- ETL listed

DryCool Pool Capacity

Unit	Maximum CFM			Minimum Exhaust	Maximum Exhaust	Tons	Dehumid lbs/hr	Dimensions L x W x H	Weight Pounds
	OA	Return	Total						
HCU-N 1005	1,000	1,200	2,200	250	1,200	5	40 lbs/hr	58 x 43 x 61	900
HCUc-2410	1,350	2,400	3,750	500	1,500	10	70 lbs/hr	178 x 65 x 57	3,500
HCUc-3412	2,250	3,400	4,000	833	2,500	12	90 lbs/hr	178 x 65 x 57	3,500
HCUc-3415	2,700	3,400	4,000	1,000	3,000	15	105 lbs/hr	178 x 65 x 57	3,500
HCUc-4015	2,700	4,000	4,500	1,000	3,000	15	115 lbs/hr	193 x 65 x 72	4,250
HCUc-6020	3,600	6,000	10,000	1,333	4,000	20	160 lbs/hr	226 x 86 x 70	5,250
HCUc-6030	5,400	6,000	10,000	2,000	6,000	30	225 lbs/hr	226 x 86 x 70	5,250
HCUc-8030	5,400	8,000	14,000	2,000	6,000	30	240 lbs/hr	249 x 96 x 86	7,850
HCUc-8040	7,200	8,000	14,000	2,667	8,000	40	315 lbs/hr	249 x 96 x 86	7,850

Capacity based on 82F 60% RH space condition

Natatorium Application & Product Guide 7

Equipment Data: Cooling Tower. With the information explain before, the mechanical team chose Marley MCW Series 62 town cooling tower.

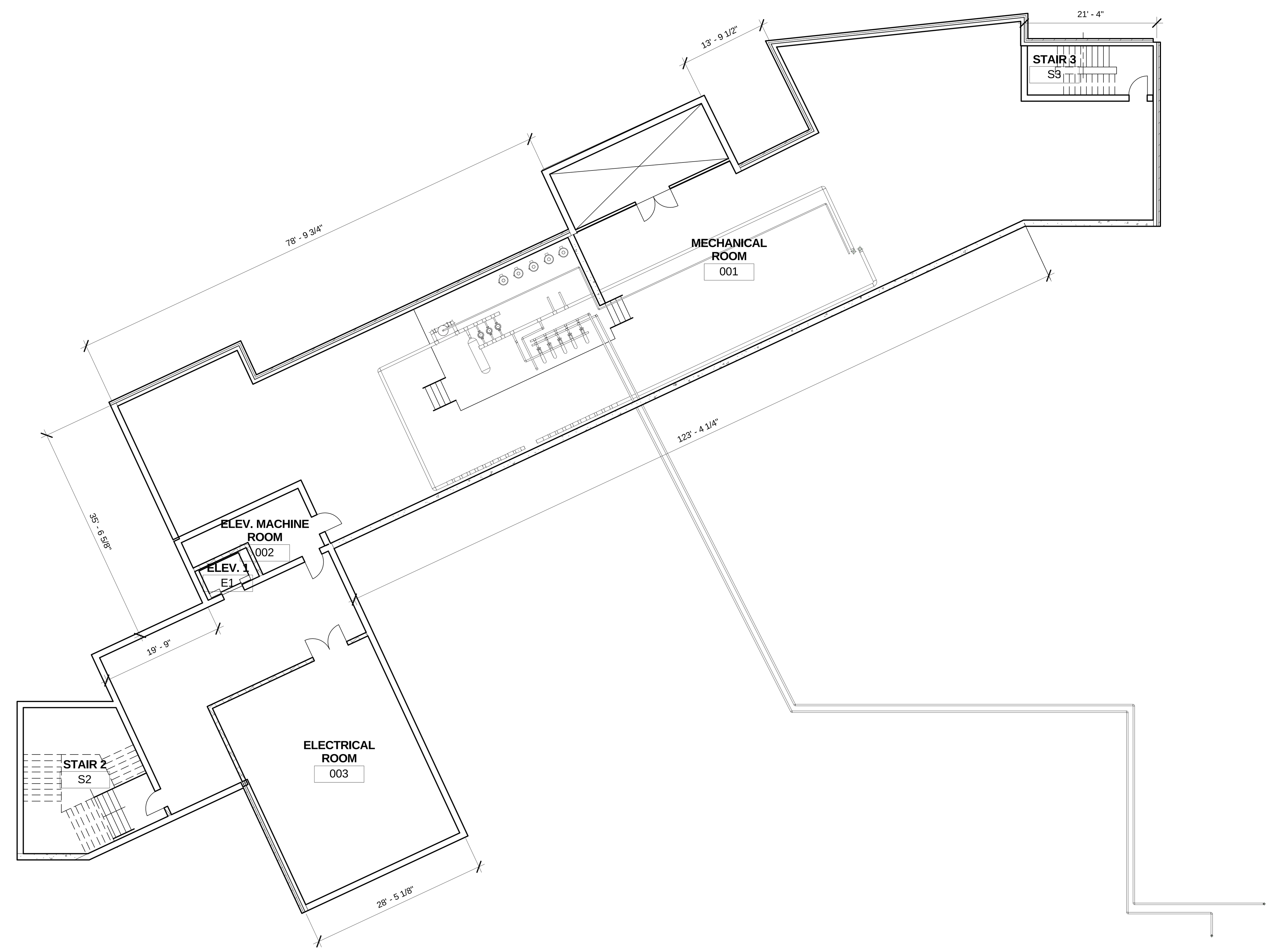
Model note 2	Nominal Tons note 3	Motor hp	Dimensions C	Dimensions H	Dimensions M	Dimensions Inlet / Outlet dia	Design Operating Weight lb	Shipping Weight lb Weight/Cell	Shipping Weight lb Heaviest Section
901116B-1	18	1.5	7'-6"	8'-4⅝"	9⅝"	2½"	1616	1279	741
901116C-1	20	2	7'-6"	8'-4⅝"	9⅝"	2½"			
901116D-1	23	3	7'-6"	8'-4⅝"	9⅝"	2½"			
901117D-1	26	3	8'-5⅝"	9'-4⅝"	9⅝"	2½"			
901117F-1	31	5	8'-5⅝"	9'-4⅝"	9⅝"	2½"			
901126F-1	45	5	7'-4⅝"	8'-4⅝"	9⅝"	3"	2548	1843	1005
901126H-1	50	7.5	7'-4⅝"	8'-4⅝"	9⅝"	3"			
901127H-1	57	7.5	8'-4⅝"	9'-4⅝"	9⅝"	3"			
901127J-1	62	10	8'-4⅝"	9'-4⅝"	9⅝"	3"			
901136H-1	66	7.5	7'-5⅝"	8'-4⅝"	1'-11⅝"	4"	3466	2410	1270
901136J-1	75	10	7'-5⅝"	8'-4⅝"	1'-11⅝"	4"			
9011137H-1	75	7.5	8'-5⅝"	9'-4⅝"	1'-11⅝"	4"			
9011137J-1	85	10	8'-5⅝"	9'-4⅝"	1'-11⅝"	4"			
9011137K-1	93	15	8'-5⅝"	9'-4⅝"	1'-11⅝"	4"			

Equipment Data: Heat Pumps. The mechanical team chose DAIKIN McQUAY vertical and horizontal Water Source Heat Pumps

Bibliography

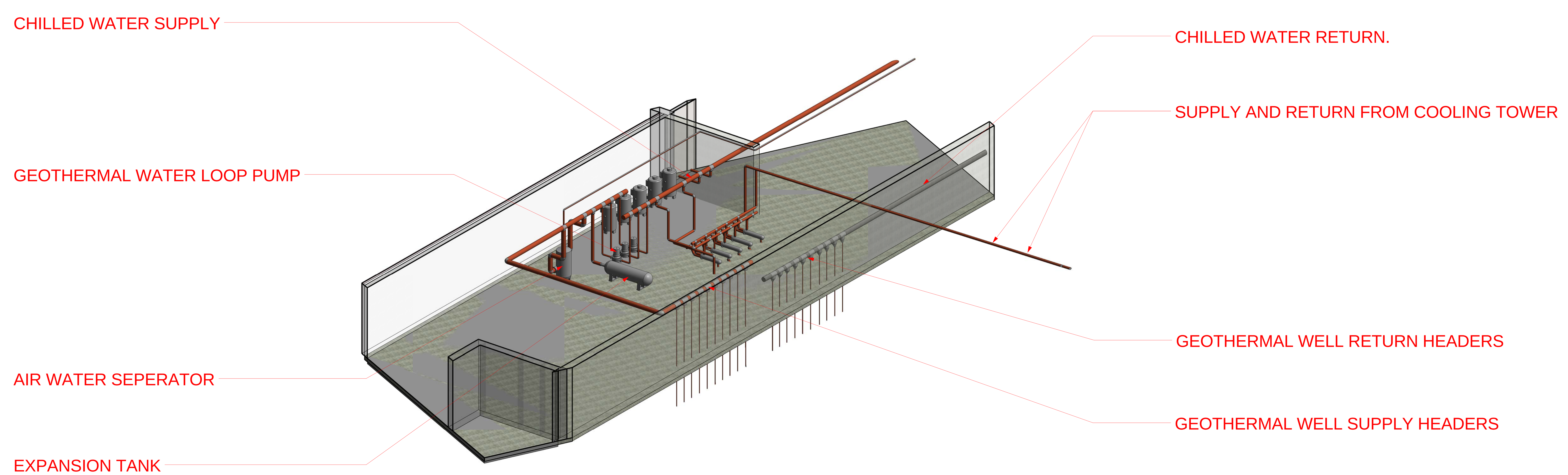
1. Pless, Shanti D. *Advanced Energy Design Guide for K-12 School Buildings: Achieving 50% Energy Savings toward a Net Zero Energy Building*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning, 2011. Print.
2. "Assessment of Hybrid Geothermal Heat Pump Systems" www1.eere.energy.gov. Web 03 Oct. 2012
3. "Mechanical Solutions." Mechanical Solution Inc. Web. 04 Jan 2013
4. Kavanaugh, S. and Rafferty, K. (1997) *Design of Geothermal Systems for Commercial and Institutional Buildings*. ASHRAE, Atlanta, Georgia.
5. A*SHRAE Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings*. American Society of Heating, Refrigerating and Air-Conditioning, 2010. Print.
6. A*SHRAE Standard 62.1 Ventilation for Acceptable Indoor Air Quality*. American Society of Heating, Refrigerating and Air-Conditioning, 2010. Print.
7. A*SHRAE Applications, Chapter 34, Geothermal Energy.* American Society of Heating, Refrigerating and Air-Conditioning, 2011. Print.
8. A*SHRAE Handbook, Chapter 48, Noise and Vibration Control.* American Society of Heating, Refrigerating and Air-Conditioning, 2011. Print.
9. "Green America's Schools; Cost and Benefits". Gregory Kats. Web. 17 Dec. 2012
10. "Lancaster, PA School Achieves Outstanding Savings and Comfort", Geothermal Heat Pump Consortium, Inc. Web 20 Oct. 2012
11. "Geothermal Heating and Cooling Fundamentals" Gipe Associates, Inc. Web. 19 Oct. 2012
12. "Design, Construct and Operate to Control Indoor Humidity". Munters. Web. 20 Oct. 2012

TEAM NO. 03-2013



BASEMENT MECHANICAL PLAN

SCALE: 3/32"=1'-0"

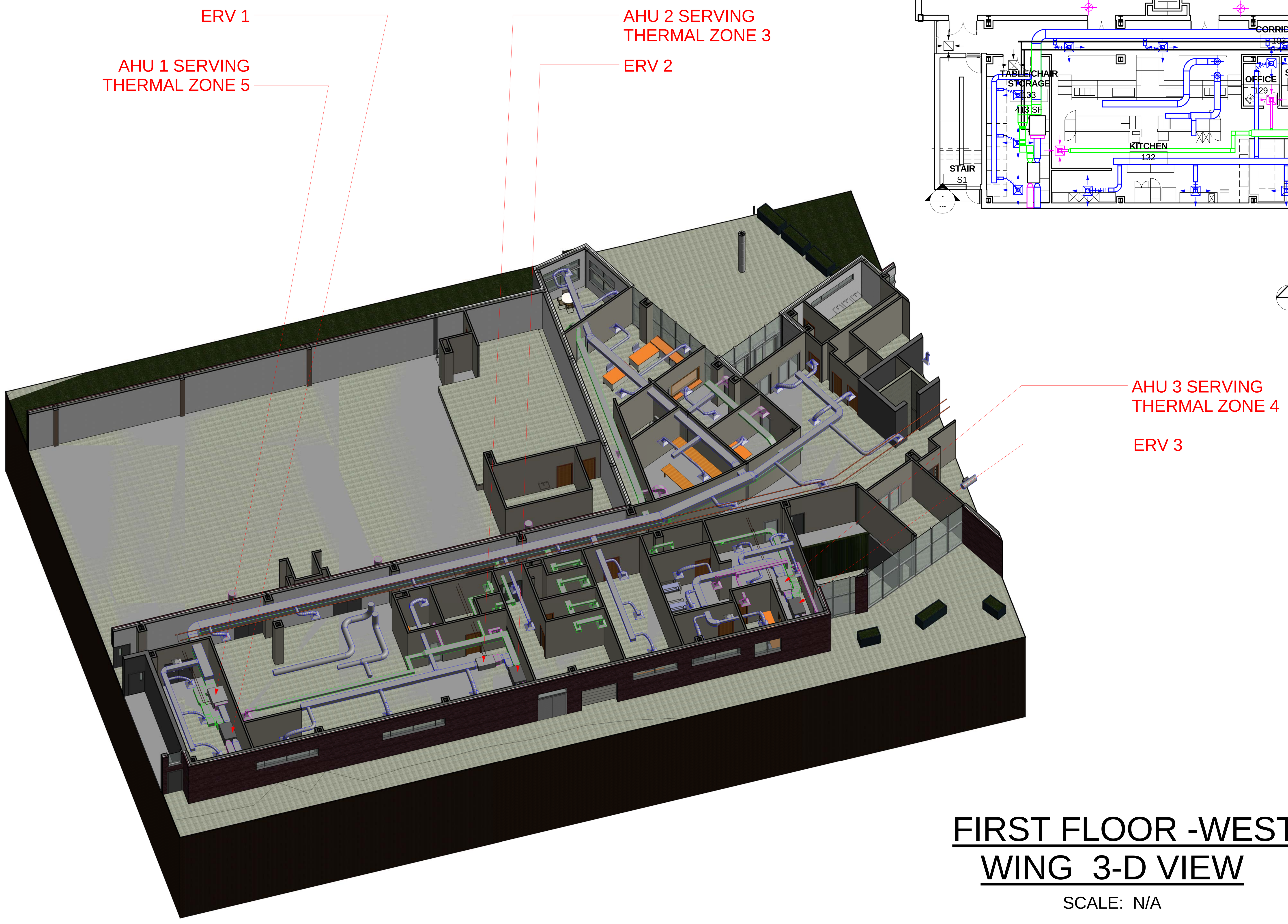


BASEMENT 3-D VIEW

SCALE: N/A

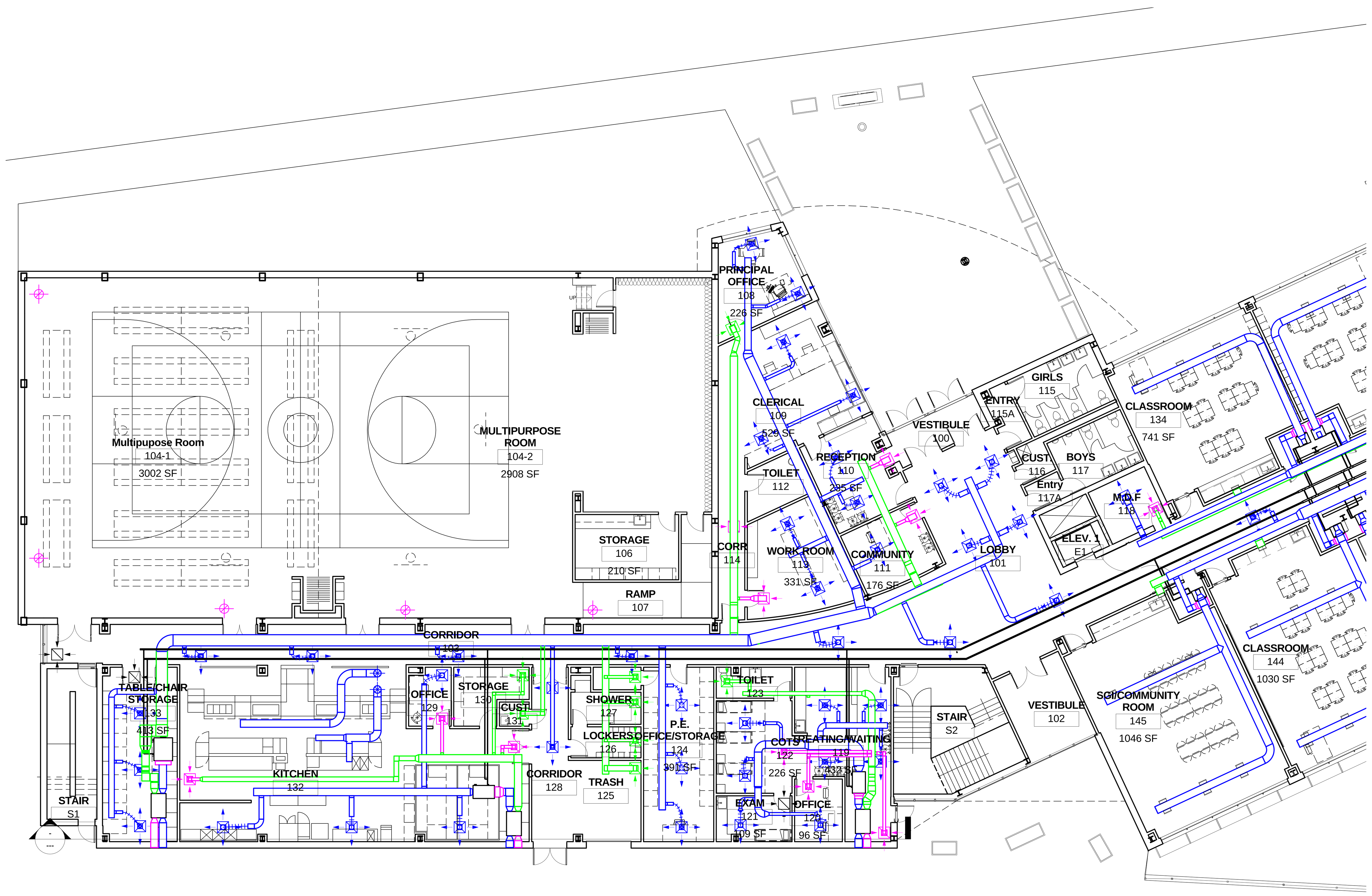
M100

TEAM NO. 03-2013



FIRST FLOOR -WEST WING 3-D VIEW

SCALE: N/A

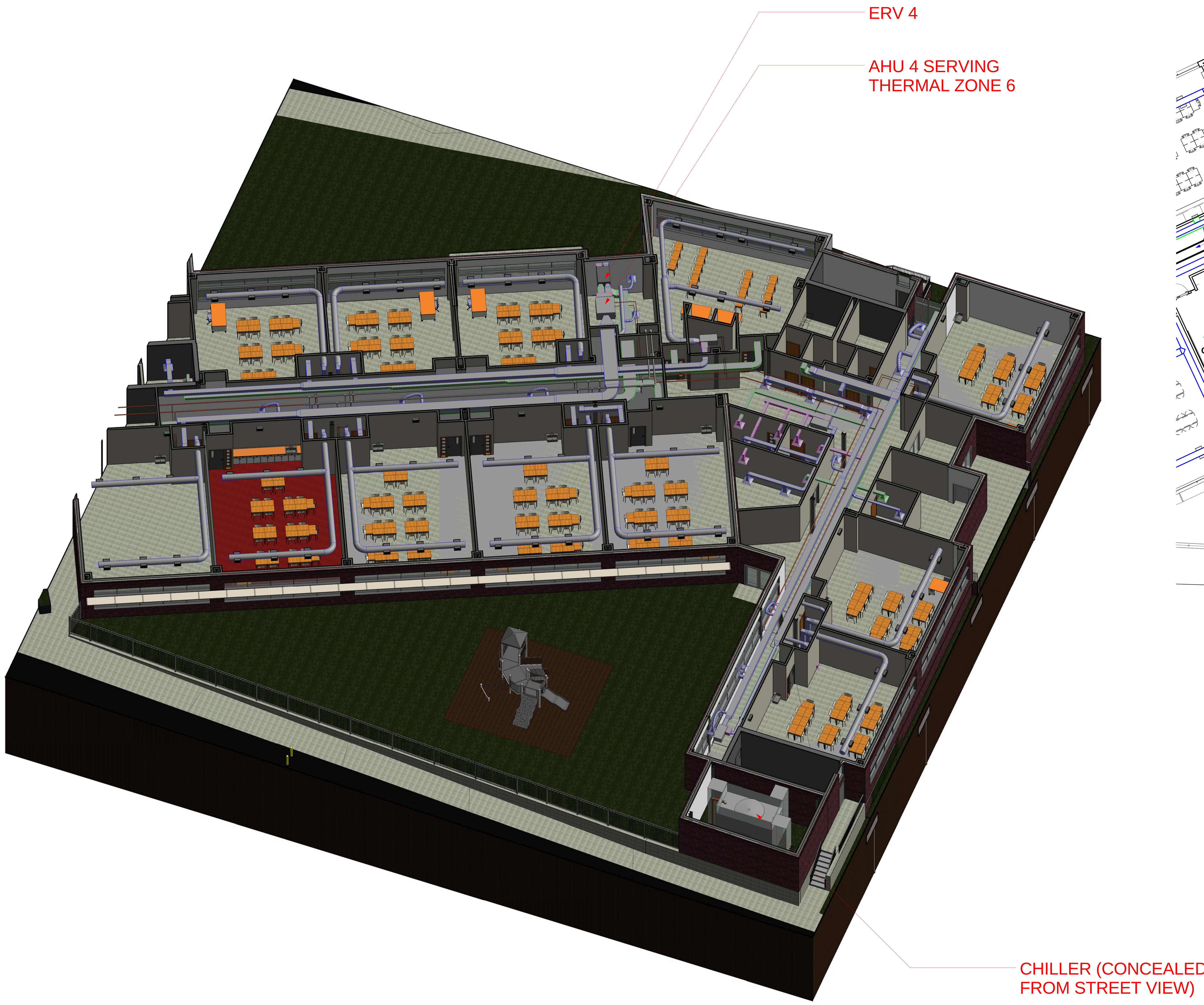


FIRST FLOOR - EAST WING

SCALE: 3/32"=1'-0"

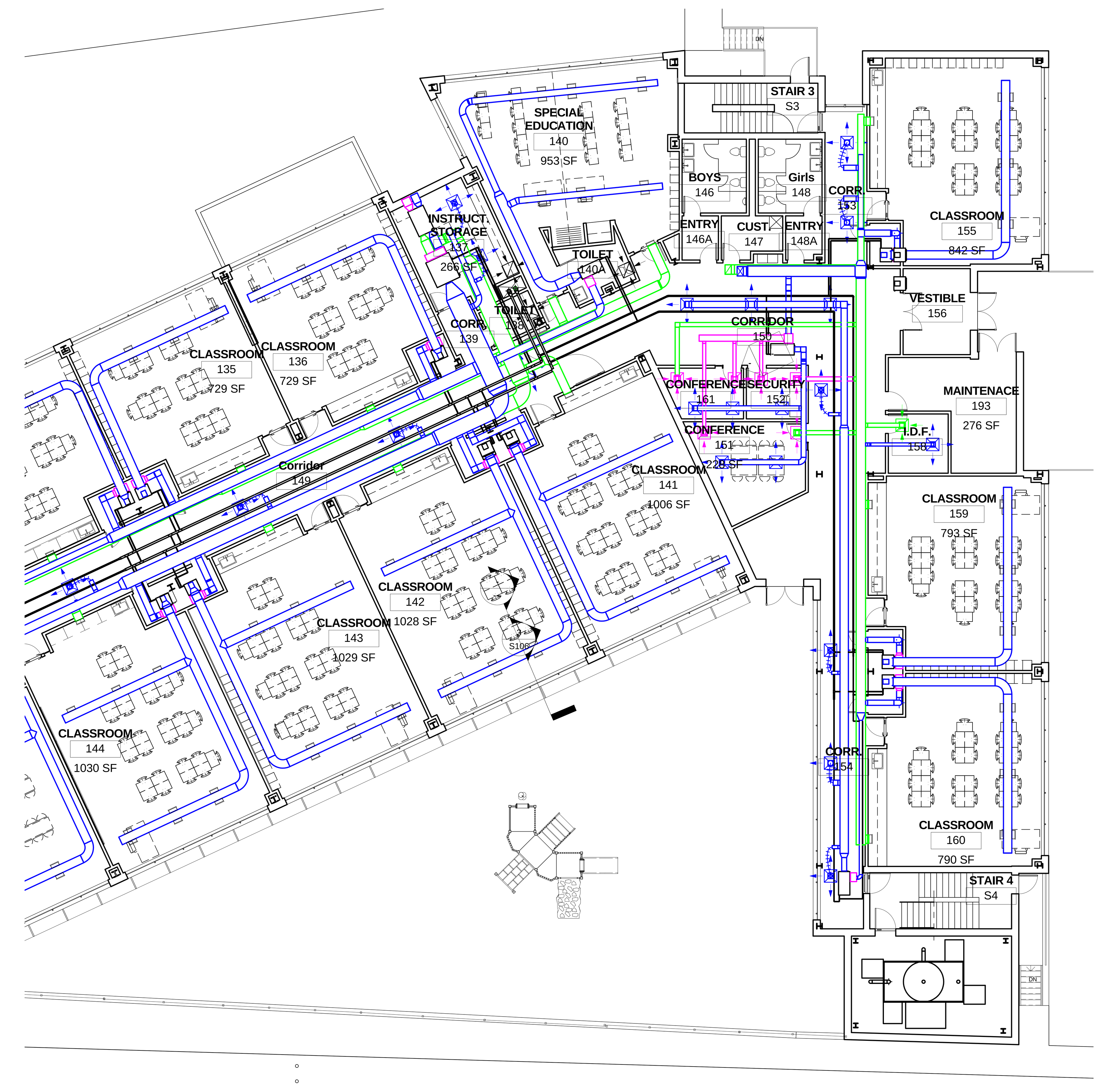
M101-01

TEAM NO. 03-2013



FIRST FLOOR -EAST WING 3-D VIEW

SCALE: N/A

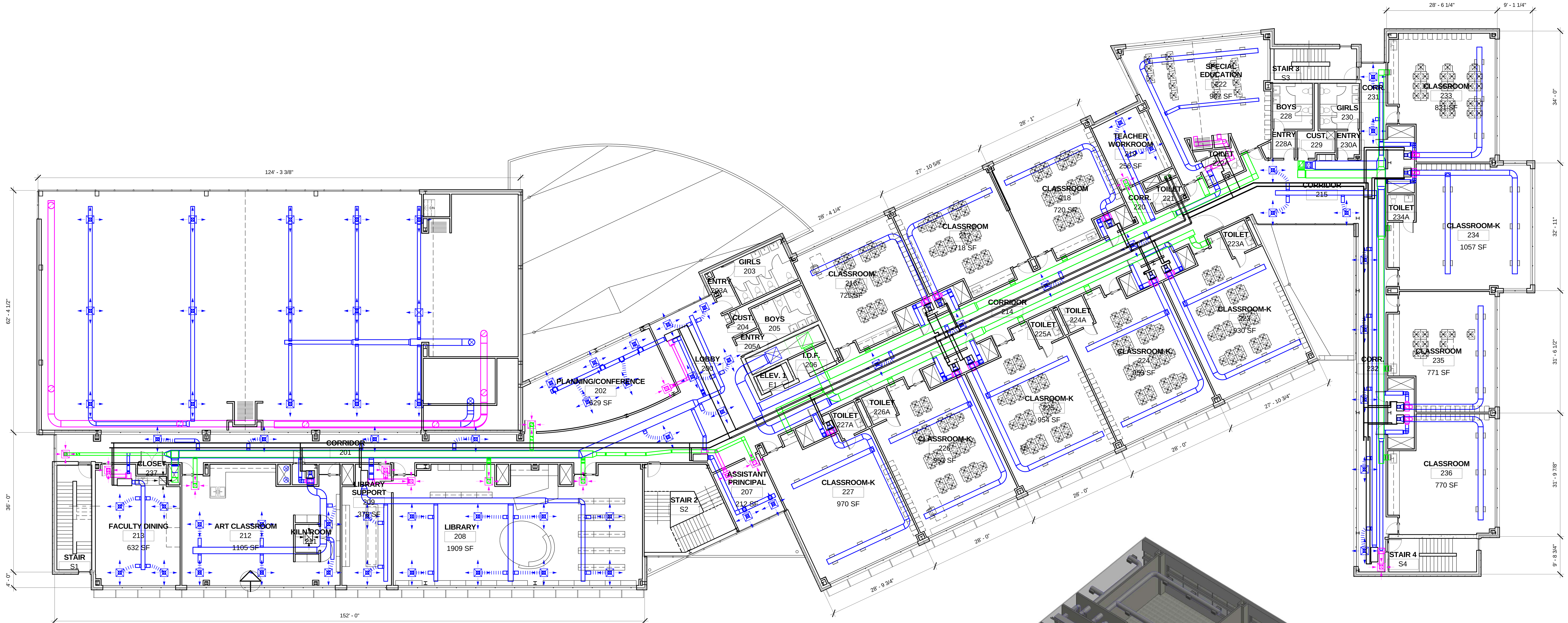


FIRST FLOOR - WEST WING

SCALE: 3/32"=1'-0"

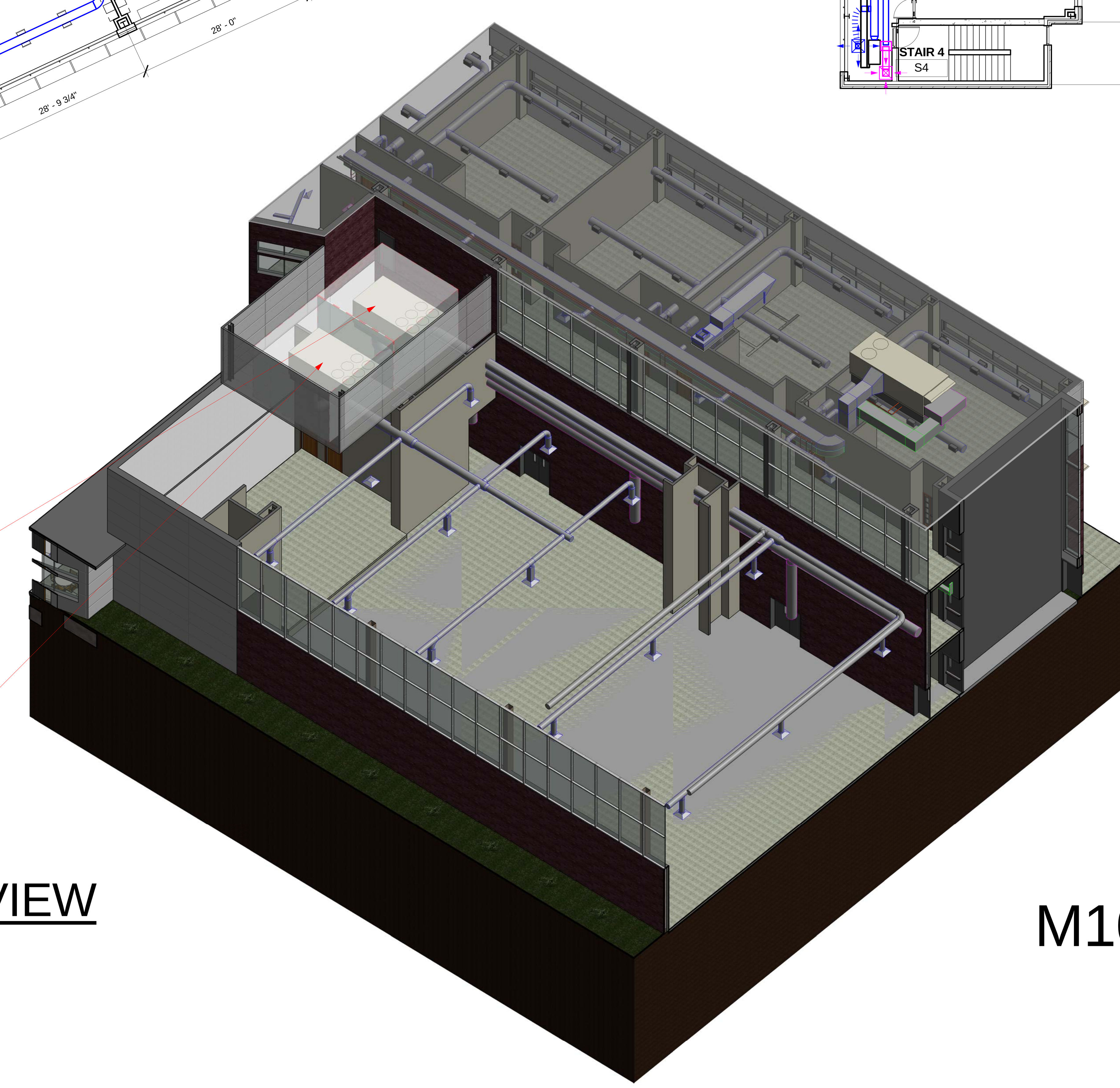
M101-02

TEAM NO. 03-2013



SECOND FLOOR

SCALE: 3/32"=1'-0"

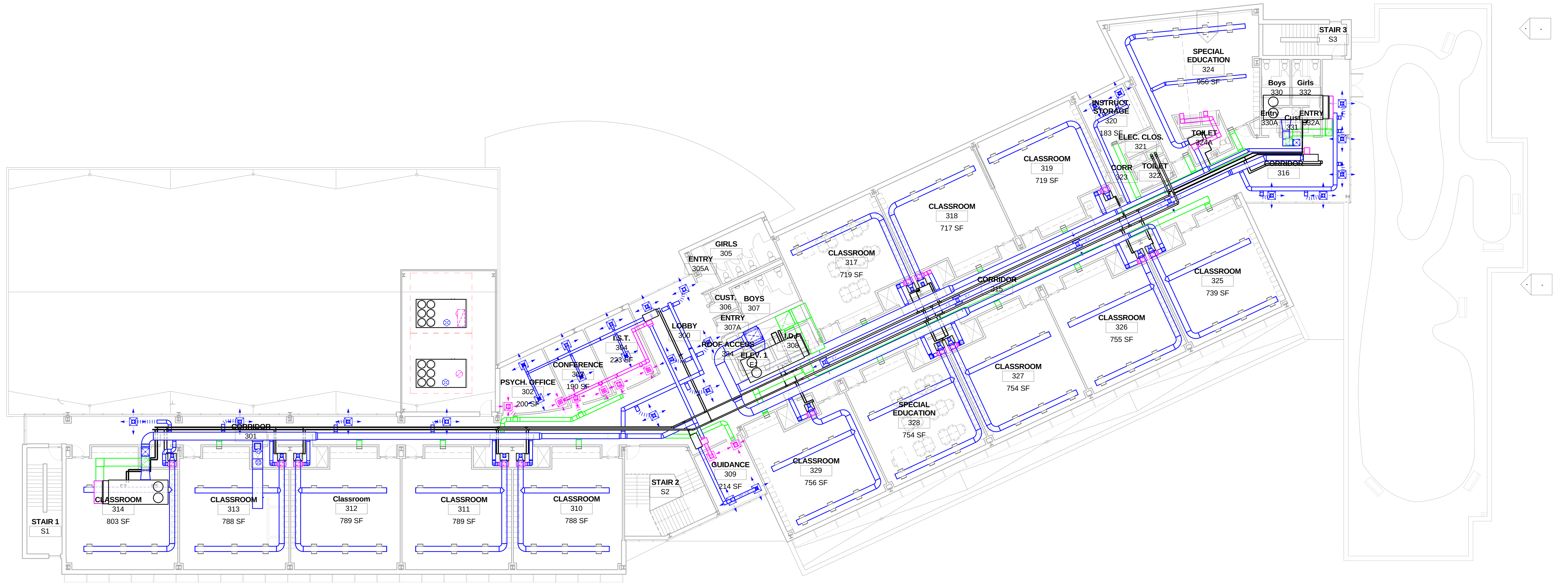


GYMNASIUM 3-D VIEW

SCALE: N/A

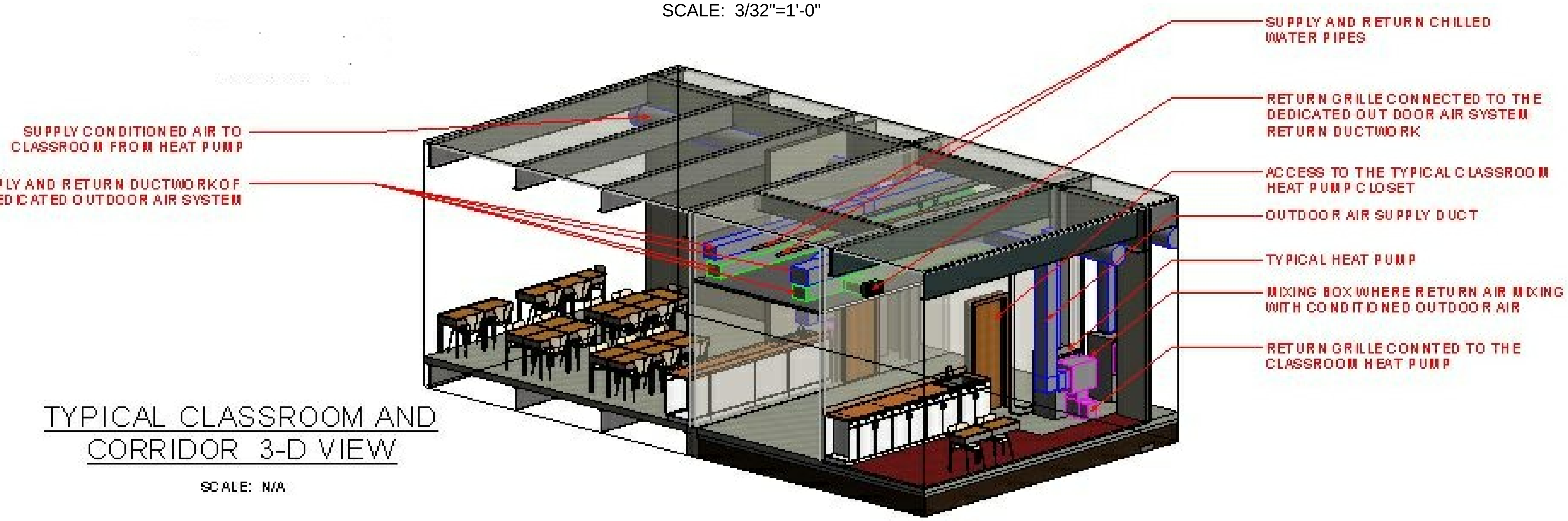
M102

TEAM NO. 03-2013



MECH. THIRD FLOOR PLAN

SCALE: 3/32"=1'-0"

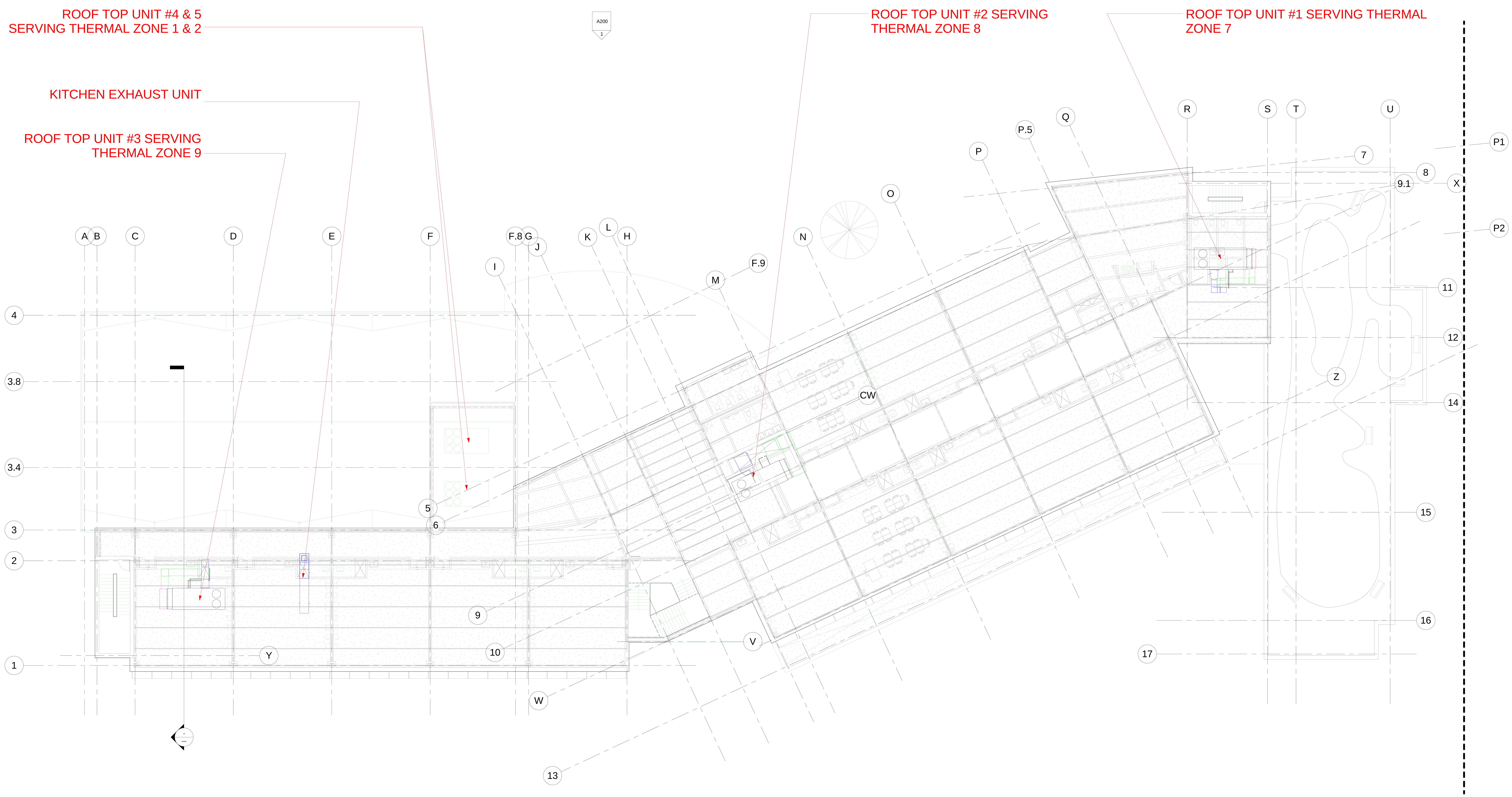


TYPICAL CLASSROOM AND CORRIDOR 3-D VIEW

SCALE: N/A

M103

TEAM NO. 03-2013

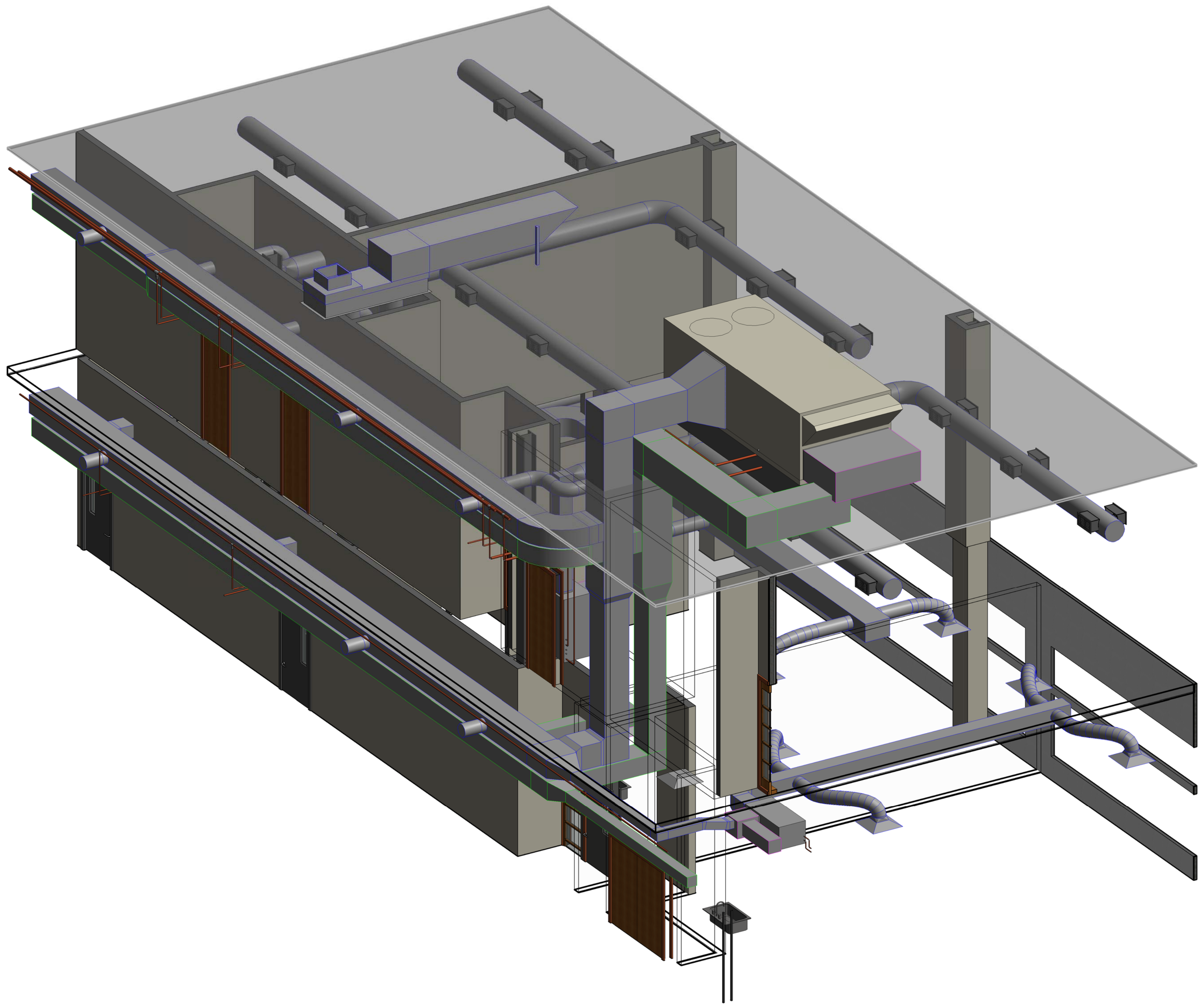


ROOF PLAN

SCALE: 3/32"=1'-0"

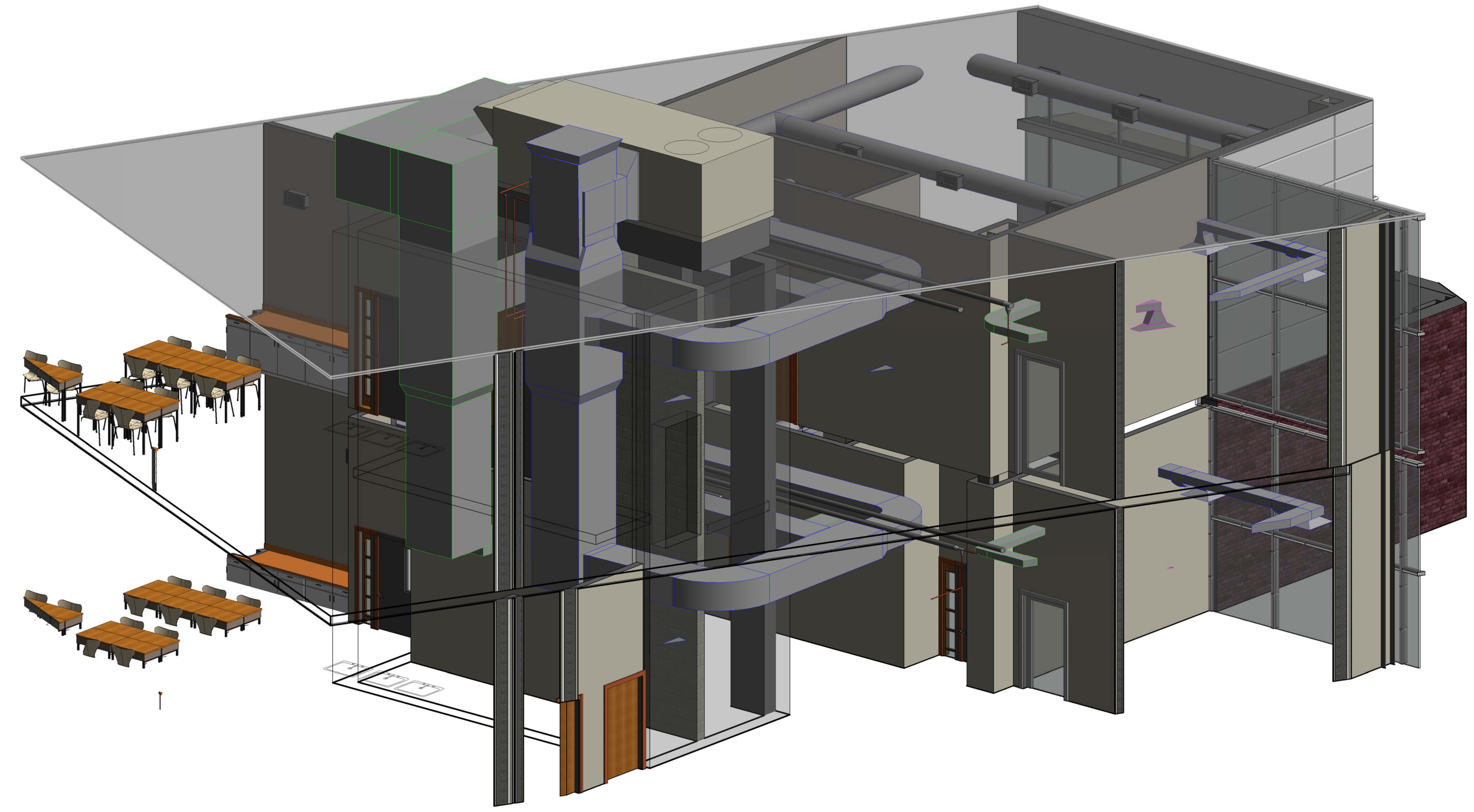
M104

TEAM NO. 03-2013



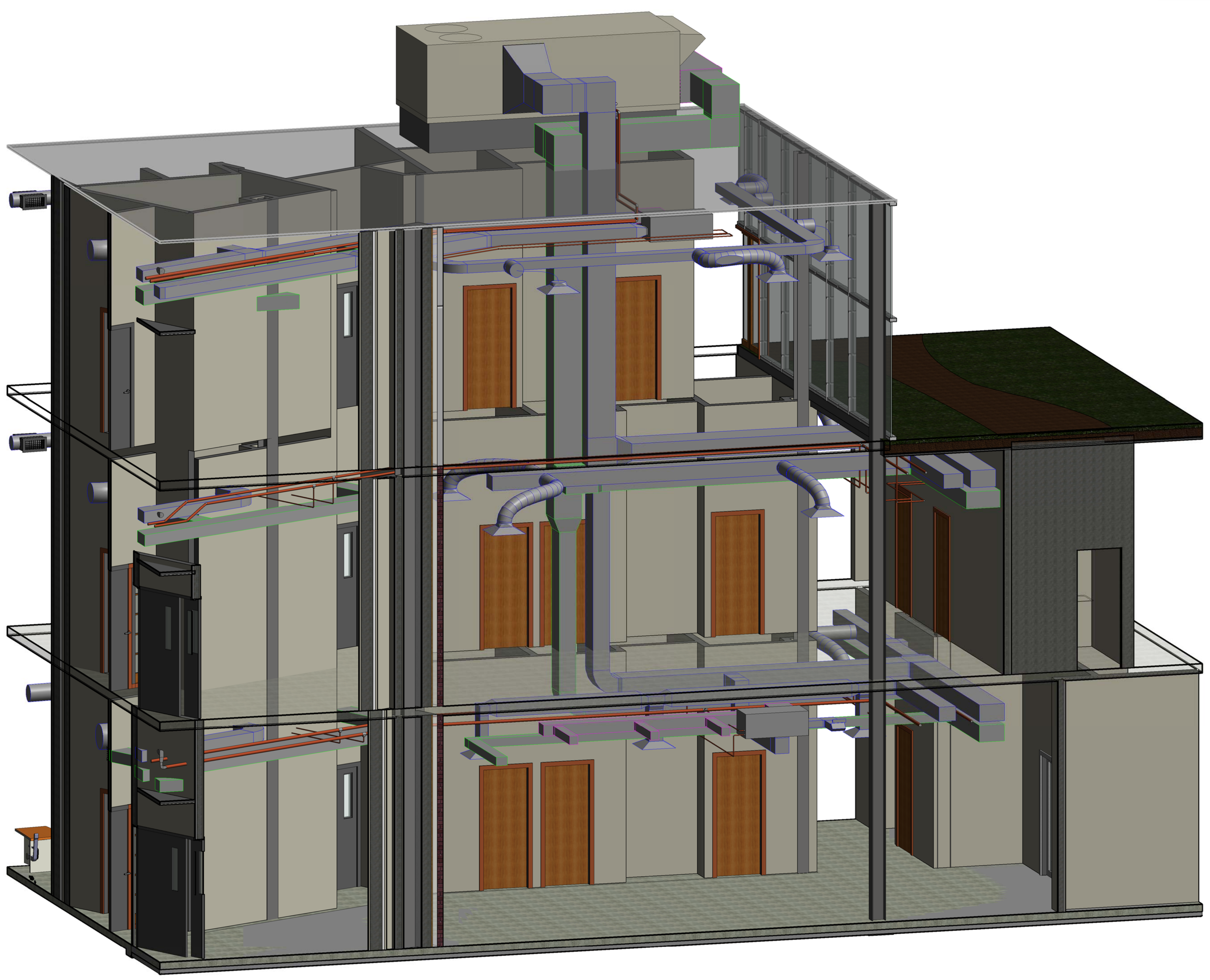
ROOF TOP UNIT 1
3-D SECTION VIEW

SCALE: N/A



ROOF TOP UNIT 2
3-D SECTION VIEW

SCALE: N/A

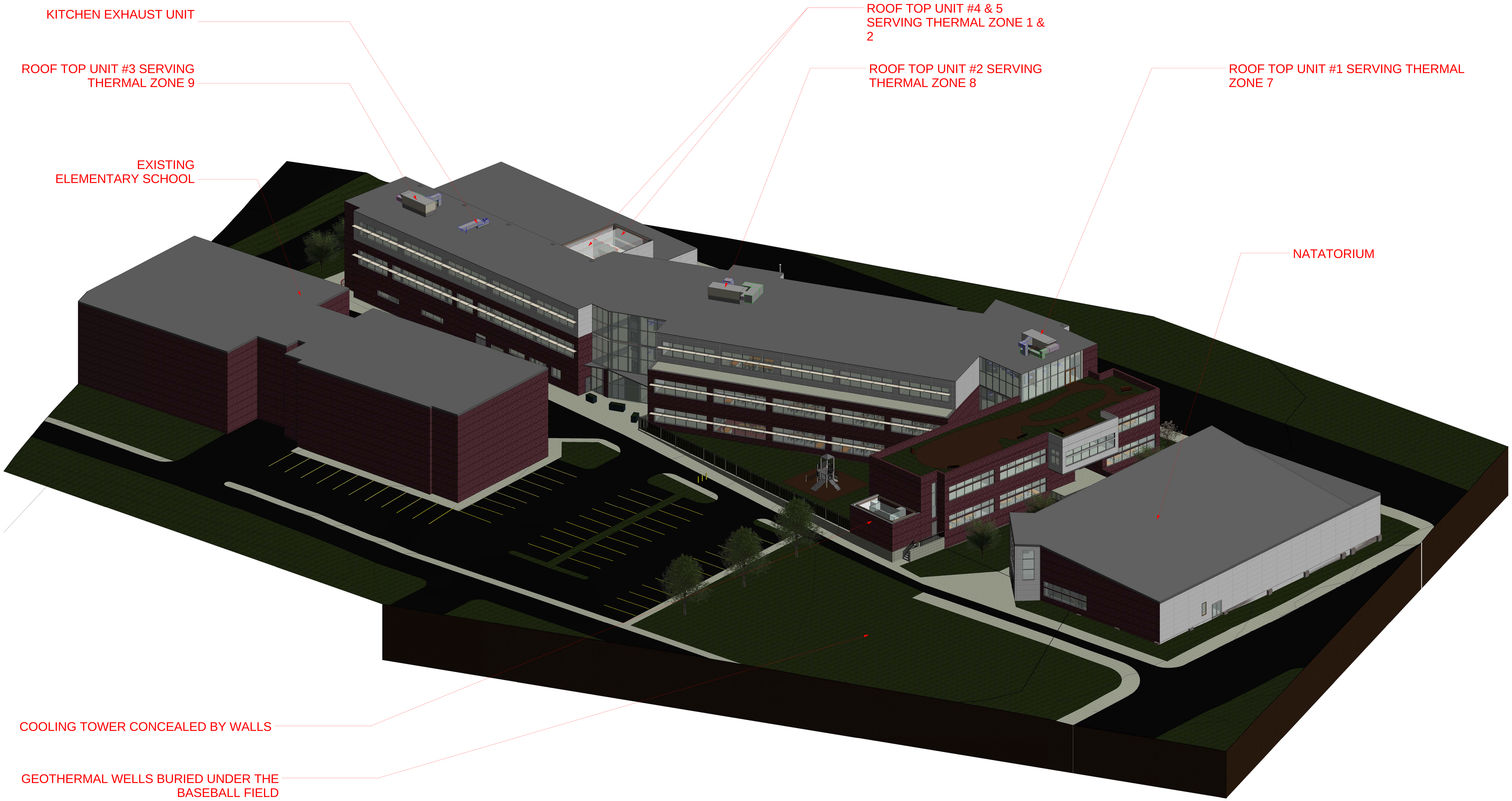


ROOF TOP UNIT 3
3-D SECTION VIEW

SCALE: N/A

M105

TEAM NO. 03-2013



SITE 3-D VIEW

SCALE: N/A

M106