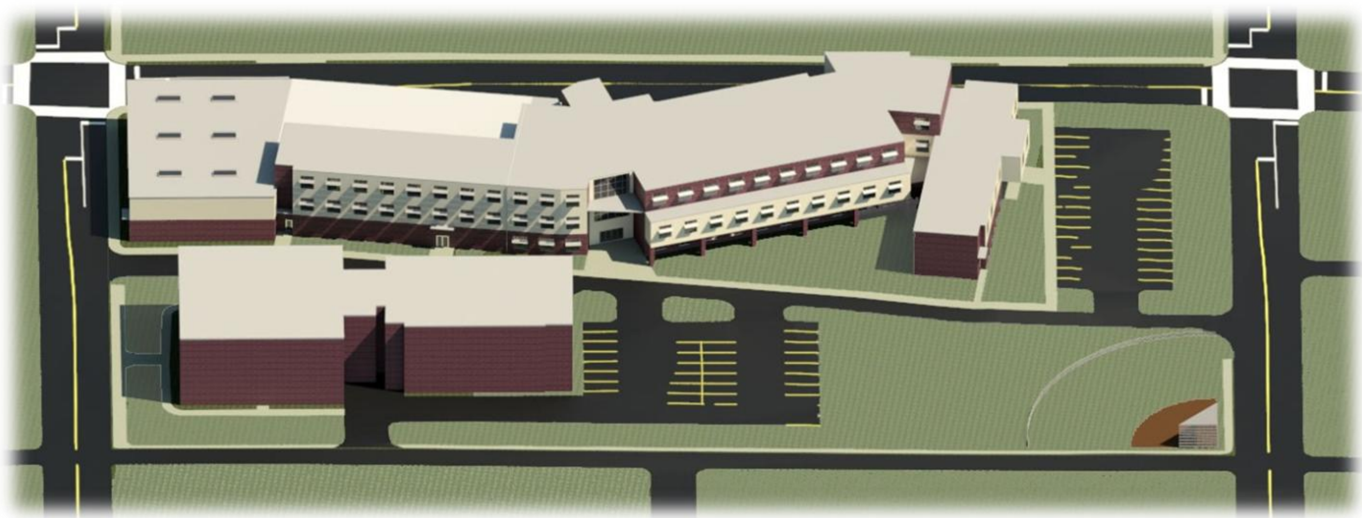
6 February 2013

TEAM NEXUS



Mechanical Systems

Team Registration Number: 02-2013

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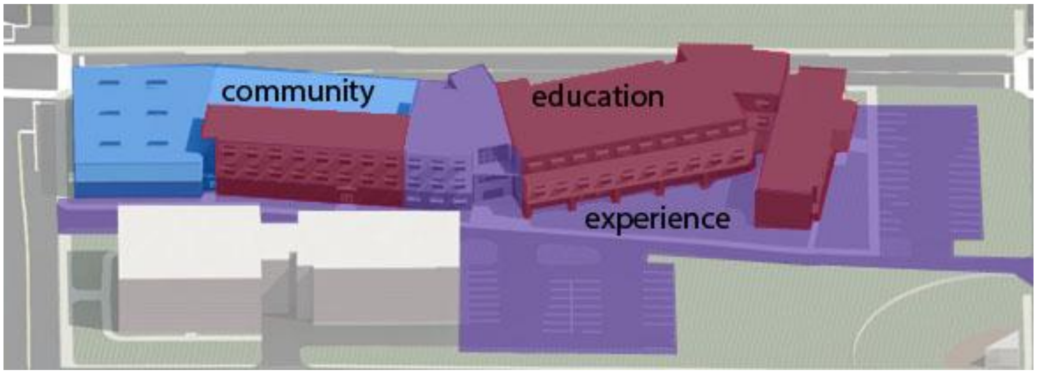


The requirements of a typical elementary school, in conjunction with the socioeconomic conditions of the Reading School District necessitated unique design decisions and innovative solution. To achieve this, a set of categories was created to define the purpose of each space in the school. It was determined that the three major functions of the building included **Experience**, **Community**, & **Education** spaces. The function of these three unique aspects dictated the integrated design of the various building systems. This too, became a manner of dividing the building in terms of system types and discipline coordination. As such, these will be the key aspects of discussion and integration in the following content.

1. Executive Summary:

1.1 Introduction

In designing a mechanical system for the Reading Elementary School many socioeconomic, constructability, and sustainability factors were taken into consideration. The preliminary/baseline calculations presented us with a 70,000 cfm and 190 ton load requirement for the building. The mechanical design criteria to **reduce, recover,** and **reuse**, in conjunction with the objectives of the other design disciplines, were met through the implementation of an integrated façade, a unique lateral duct configuration, in addition to an innovative Ethylene Glycol run-around system. The integrated façade will maximize interior daylighting while minimizing infiltration and solar heat gain by 15%. The unique lateral ducting configuration will allow for a 30% increase in outdoor air ventilation to be introduced to the classrooms while minimizing initial installation costs and eliminating conflicts with the other design disciplines. Finally, the implementation of the Ethylene Glycol recovery system will reduce the total building load by 50% through a maximum heat recovery rate of 65%. These savings will allow for a cost effective building in both upfront and lifecycle costs; both of which are of the utmost importance to the owner and Team Nexus. This design and integration of the mechanical system with the other disciplines will ultimately enhance the overall building **experience** to provide a top-of-the-line facility for education and the **community**.

1.2 System Summary

The recovery system manufactured by Konvekta was used in the determining the efficiency and cost analysis of this system as it was found to be the most efficient form of recovery at 65% recovery with the addition of the pool and 60% without the pool. This allows for drastic energy savings in short and long run cost analysis. Although there will be an increase in mechanical upfront cost of about 20-30%, this increase will be offset by a 3-5 year payback period due to the system efficiency. Additionally it is a packaged system that does not impact construction schedule and allows for a flexible layout. The system too, will be a 100% outdoor air system to allow for maximized ventilation rates and an overall improved internal environment. This will earn the LEED Credit for 30% increase in the ASHRAE baseline ventilation requirements.

The largest design challenge is undoubtedly the pool as it is specified as an alternate phase to the owner. This requires an HVAC system with the capacity and flexibility to allow the addition the pool at a later date while still maintaining a maximized rate of recovery and efficiency. The system also incorporates a dehumidification loop to recover latent heat to be reintroduced or removed during the preconditioning of the outdoor air. The product has a guaranteed success rate of implementation by Konvekta as well; this proves to the owner that the investment in this technology will be beneficial over the building's lifecycle.

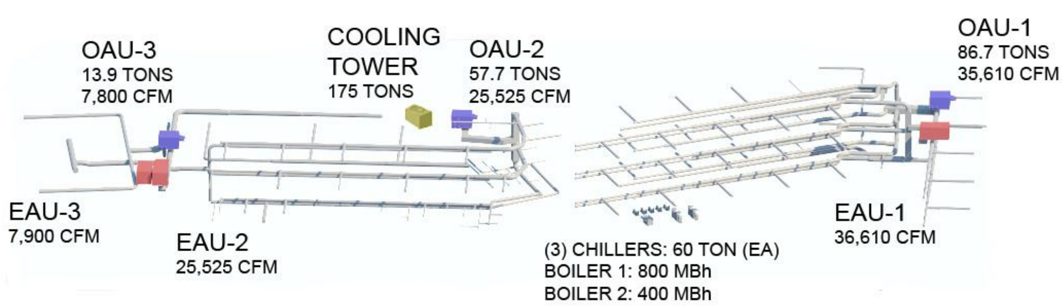


Figure 1: Revit Rendering of HVAC System (Piping not shown for clarity)

1.3 Mechanical Design Goals

The biggest challenge for selecting and designing a mechanical system became finding a balance between initial cost and lifecycle return. As a team, Nexus developed three main goals to use in achieving these design criteria; all three of which are visible the design decisions of the other disciplines and ultimate comprise one of the overall Team Nexus design goals:

reduce, recover, reuse

Reduce: *Loads-* To reduce up front and lifecycle cost the building need first require less energy to be conditioned appropriately. The implementation of these systems reduces annual building load by about 50%; thus not only decreasing annual energy use but also allowing savings in a 50% reduction of boiler size.

Construction Schedule- This system will not impede construction sequencing as the 18 weeks required for manufacturing will allow the units to be ready prior to their scheduled date; additionally allowing time for delays and mishaps.

Maintenance/ Lifecycle Costs- After the initial payback period of 4.3 years for the implementation of the HVAC system alone, the Konvekta system specified will only undergo routine coil maintenance bi-annually. This maintenance cost will be minimal in comparison to the savings due to the high system efficiency.

Recover: *Energy*- To further reduce the cost associated with energy waste, the Ethylene Glycol system will recover the thermal energy being exhausted by the HVAC system during both the heating and cooling seasons. This is done to retain a percentage of the energy spent conditioning the air for the respective building loads.

Reuse: *Energy*- This obviously plays directly into the aforementioned goal of recovery. By recovering the thermal energy being lost through the exhaust system and reimplementing it as preconditioning for the incoming outdoor air, will greatly impact the building's lifecycle cost. This will be done at an efficiency between 40 and 65%; the latter occurring during the heating season when the school is mostly in operation.

2. Passive Mechanical Solutions

2.1.1 Building Envelope

The first step in the mechanical design process was to create a mass model and analyze the site conditions to generate a basic energy model (as shown in Figure 2). This was done using Project Vasari, and allowed us to develop static mechanical designs to optimize the envelope of our building with considerations to specific to our site layout.

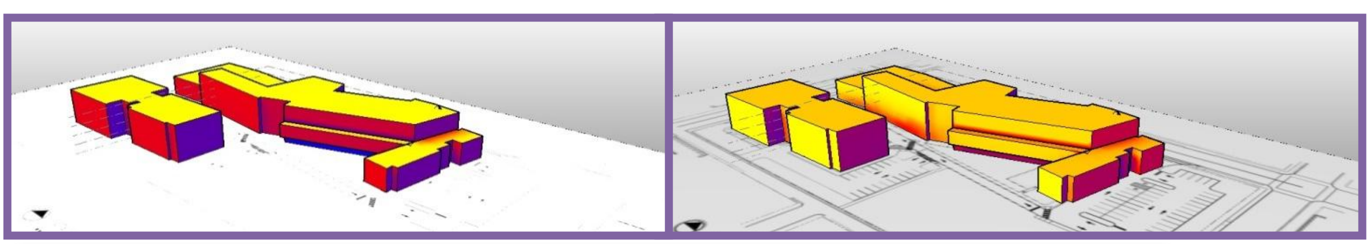


Figure 2: Vasari Model showing solar radiation on building envelope in summer (left) & Winter (right)

Using these modeling outputs in cohesion with the ASHRAE 2010 design criteria, it was determined that an ICF (Insulated Concrete Form) exterior wall construction be implemented. This system provides an R value of 24 and greatly decreases the rate of infiltration of thermal conditioning to the environment as this façade system provides a tighter seal than most. The ICF system too, greatly surpasses the ASHRAE minimum R-Value for Climate zone 5 by almost 20%. Special considerations were also taken into the glazing design for the building. The design goals of the Lighting/Electrical Engineer required that the building utilize as much natural daylighting as possible. In working with the lighting designer a standardized window system was developed with a U-value of 0.28. It too should be noted that this glazing configuration comprises less than 30% of the entire exterior surface area which is well under the ASHRAE 2010 maximum design criteria of 40%. Additionally, the south facing glazing will utilize a three- foot louver that will shield the rooms from direct glare but also excessive solar heat gain during the cooling season. The iteration to the original roofing design was the replacement of the standard black roofing material with white roof on insulated decking. This will prevent the “heat-island-effect” which will allow for additional energy savings especially during the cooling season.

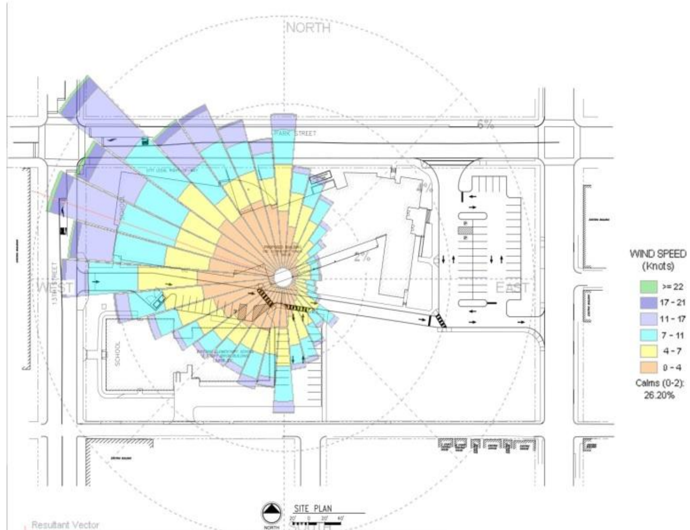


Figure 3: Wind rose overlay on site

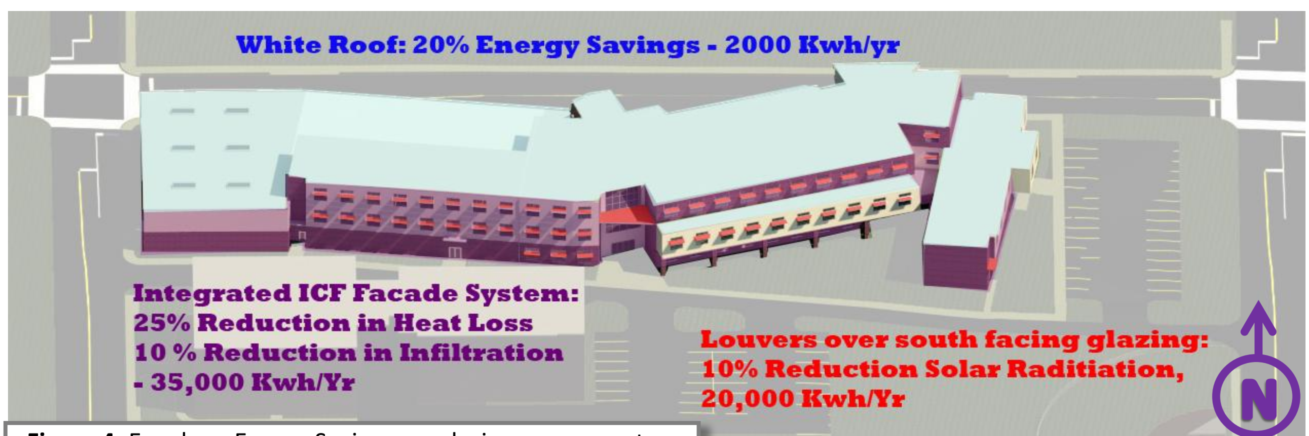


Figure 4: Envelope Energy Savings per design component

2.1.2 Rationale

In comparing the initial baseline energy model (which calculated building loads and energy requirements utilizing all minimum envelope requirements as per ASHRAE 2010) to the current model; taking into account only the change in the envelope design, the proposed building uses 8% less energy. The baseline model graphic shown in Figure 4 shows the breakdown of these savings by Façade, Glazing, and Roofing materials.

The white roof will be constructed using an insulated acoustic metal decking as its main source of support. This decking includes an additional layer of insulation to ensure that there an R-Value of 20 is met as per the ASHRAE 2010 minimum design standard. The overall design of the envelope also allows for a change in the required airflows needed to condition the building. The baseline model provided an 111,000 cfm building with a

306 ton cooling load. With the implementation of the new envelope system alone, the building loads decreased to about 285 tons.

2.2 Acoustic Design

Due to the exposed nature of the discipline systems, (as greatly demonstrated in the Team Nexus Integration Documentation) there were primary concerns with the acoustical integrity of not only the classrooms but the lobby, gymnasium and pools as well. To ensure that these spaces met the necessary acoustic criteria, acoustical analyses were done to calculate the reverberation time of each space which guided the selection process of materials based on their reflective and absorption properties. In integrating these considerations with the structural design team, it was decided that a 3VLPA Insulated Composite Acoustical Metal Deck will be used in the construction of the building so that the open ceiling concept could be carried out through the majority of the building. Particularly in the classrooms, it was found that utilizing this system alone allowed reduced our reverberation time from over 1 second to approximately half a second for the 1000 Hz octave band in comparison to a normal metal deck. A reverberation time between 0.6 seconds and 0.8 seconds is desired for a classroom setting. A classroom section and acoustical analysis breakdown can be seen in Figure 5. For the entire classroom acoustic analysis, see Appendix pages 31-32.

Additionally, the ICF wall system being used for the exterior façade facilitates many acoustical benefits in the building due to the two-inch interior foam insulation; upon which the drywall will be supplied. This system provides an STC rating of 48 which will not only be beneficial in sound attenuation within the space but will also prevent noise from the exterior urban setting from causing distractions to the in students and teachers within the building. The two other spaces where the most considerations are made to improve their acoustical integrity are the lobby and the multipurpose room.

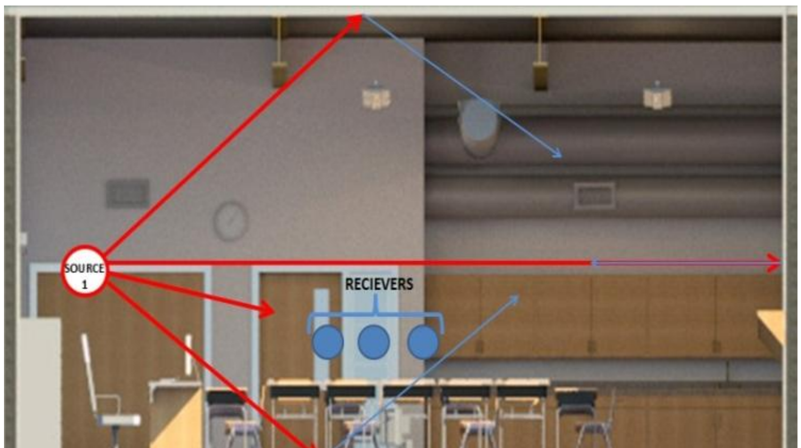


Figure 5: Classroom Acoustical Analysis Breakdown

The main concern with the lobby space is a result of the three-story atrium that was created in the redesign of the building's entrance. Because of this atrium space the main concern lies with the reverberation of sound between the levels of the building via the adjacent hallways. As such, it was decided that the lobby utilize a standard acoustic ceiling tile in order to create some attenuation within the atrium. The multipurpose room too creates an interesting environment in terms of its acoustical properties due to its many different uses. In this design, the criterion that holds the most consideration is the use of this room as an auditorium. The same acoustical metal deck being used in the rest of the building will provide some attenuation, but as the volume in the space is the largest out of the entire building; slotted CMU's will be used in the construction of the interior multipurpose room wall. This will reduce the reverberation time of the space by approximately half a second while adding minimal cost to the design.

3. Mechanical System Solutions

3.1 Heating Ventilation and Air Conditioning

The building will be conditioned by a Constant Volume 100% Outdoor Air system. The decision was made to use 100% outdoor air primarily to enhance the indoor environment of the classrooms. Studies done by the

Environmental Protection Agency have shown that increased ventilation rates help improve teacher and student performance. The increased ventilation rates will earn 1 LEED credit for a 30% improvement over the ASHRAE baseline minimum. The system too will be integrated into one control hub via the centralized Konvekta control system. This will be able to monitor the electric lighting system based on daylighting levels as well as control the mechanical system based on occupancy and CO2 levels.

Initial prices have been determined using RS Means for all system components and specific units that will be utilized in the mechanical system for this project. An initial price tag of 990,935.00 was calculated should the system be implemented in conjunction with the pool. Should the pool not be included in the building scope, the price will drop to $863,210.00, which is a difference of nearly $130,000. A full system summary and breakdown of this pricing calculation can be found in the Appendix on page 25.

3.2 Rooftop Equipment & Zoning

To more accurately analyze the loads in our building, an in-depth energy model was done using Trane Trace 700. Trane Trace 700 software is a complete load, system, energy, and economic analysis program. This building was zoned vertically because all three floor plans are practically identical. These zones were derived with the thought that each zone would have its own Outdoor Intake and Exhaust air handler. This will allow the mechanical system to condition the zones separately. This is important during the summer months when students will not be in the building. These six air handlers will all be placed on the roof of the second story. This will allow for easy access from the third floor for any maintenance that may occur in the future. This layout can be shown in Figure 6.

Figure 6: Air handler Layout on Second Floor Roof

Each of these air handlers will be connected to and controlled by the centralized control system. This will modulate airflow based on the varying load requirements. The building was broken up into three zones: Academic (right wing), Community (left wing), and Pool (as shown in Figures 7-9 below). This building was zoned vertically because all three floor plans are practically identical. These zones were derived with the thought that each zone would have its own pair of outdoor air and exhaust air handlers. This will allow the mechanical system to condition the zones independently of one another. This is important during the summer months when students will not be in the building. This configuration will allow us to condition these public spaces while not wasting energy conditioning the classrooms when no students are present. Additionally the system is configured so that the community zone can run independently on emergency power, as this zone houses the multipurpose room that will act as a community shelter in the event of an emergency.

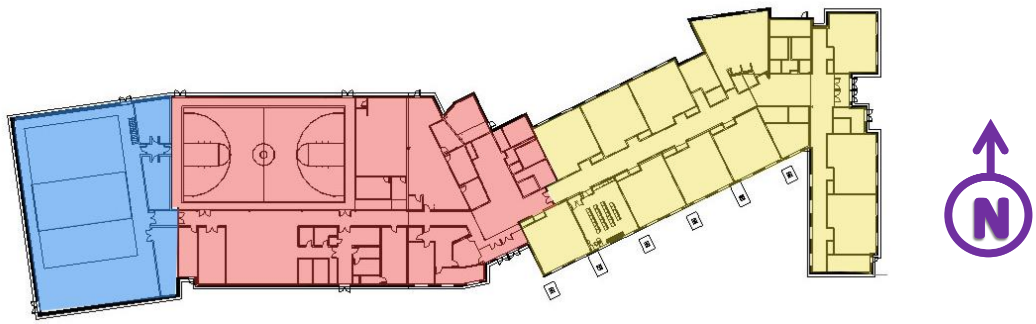


Figure 7: First Floor Plan: Zone Diagram: Pool (Blue), Community (Red), Classrooms (Yellow)

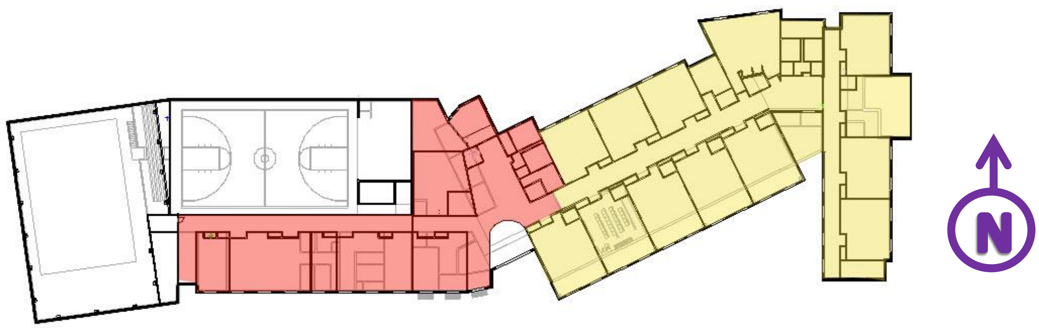


Figure 8: Second Floor Plan: Zone Diagram: Community (Red), Classrooms (Yellow)

Figure 9: Third Floor Plan: Zone Diagram: Community (Red), Classrooms (Yellow)

Table 1 shows a breakdown of peak building loads per each of the three pairs of air handlers conditioning our three zones. Additional Zone Loads that are broken down by load sources can be seen in the Appendix on pages 23-24. The third zone in this configuration consists of the pool alternate that is being proposed. The mechanical design took into strong consideration this aspect of the design by developing a system that allowed the addition of the pool at a later date while still allowing it to function seamlessly with preexisting system. Additionally, due to the airborne chemicals being used to exhaust this space, the coils and inner workings of the pools air handling systems will be coated with a protective polymer that will prevent any corrosion of the unit during the building's lifecycle.

Table 1: Building Peak Load Summary – Trane TRACE700 Outputs

Building Loads				
Zone		**Cooling Capacity [TONS]**	**Heating Capacity [TONS]**	**Airflow [CFM]**
1	Academic	86.7	64.2	35,610
2	Community	57.7	39.6	25,525
3	Pool	13.9	28.3	7,800
	TOTAL	158.3	132.1	68,935

The selection of three outdoor air units and three exhaust units placed along the entire length of building was done to minimize the size and length of ductwork required to condition the spaces. Additionally, due to the type of heat recovery system being utilized for this application, having fewer units helps maximize the run-around heat recovery efficiency.

3.3 Heat Recovery

As stated in the aforementioned mechanical goals, recovering lost energy is considered one of the most important design criteria. Therefore and Ethylene Glycol runaround system was selected to be the best system to handle our building needs. The system specified by our design is one made by Konvekta and started being used in applications in the United States for the past 5 years. The system works in the manner of a traditional runaround system by capturing thermal energy from the exhaust air and reintroducing it to precondition incoming outdoor air (as shown in Figure 10). Not only is this system the largest means of energy recovery and reimplementation; but it is also our main determinate in overall building load reduction. This is determined using energy model analysis with DOEII (Ecotect) and TraneTRACE700 to determine the efficiency of the system in this particular application. It was found that utilizing this configuration of the Ethylene Glycol allowed us to downsize the equipment on the heating side of the building's mechanical systems by 50% which is not only an incredible savings in upfront cost; but lifecycle costs as well.

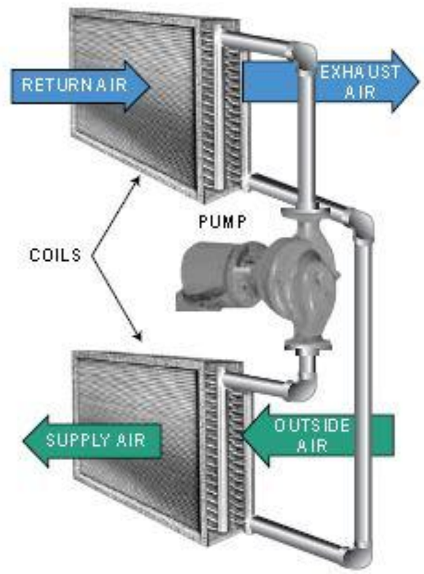


Figure 10: Traditional Runaround System
http://www.dac-hvac.com/blog/page/3/

The graphic below (Figure 11) shows a schematic layout of how the runaround loop will work for this building. As you can see, the entire mechanical system functions as one entity to optimize system efficiency and energy recovery. The image below represents the function of the system during the heating season; during which 12.9F outdoor air is being preheated to 61.5F solely through the recovery and reuse of thermal energy being exhausted on the left. This is done at an efficiency of 65% which is a drastic energy savings. The blue lines represent the “cooled” ethylene glycol solution leaving the incoming outdoor air handler as it makes its way to the exhaust air handlers. The red lines represent the “heating” of ethylene glycol solution through the absorption of heat being captured in the exhaust air. This then moves to the centralized hydronic unit where it is then pumped to the outdoor air units to precondition the incoming 12.9F air. The hydronic unit will be located in the basement of the building and piping will be run to and from the air handlers such that it will not be visible or exposed in public areas. This decision was made in contrast with the Team Nexus overall goals to expose all architectural systems as to further develop the building as a “learning tool”. A hybrid geothermal system was also considered in the early phases of the mechanical design. After some rough cost and construction sequencing analyses, it was determined that the hybrid geothermal system would be much more expensive in upfront costs. The geothermal system too does not meet the same efficiency and recovery level of the runaround system being only 40-60% efficient. Lastly the geothermal system was omitted as it left no opportunity to incorporate the vast demand of the pool into the ground loop system should the pool be built at a later date.

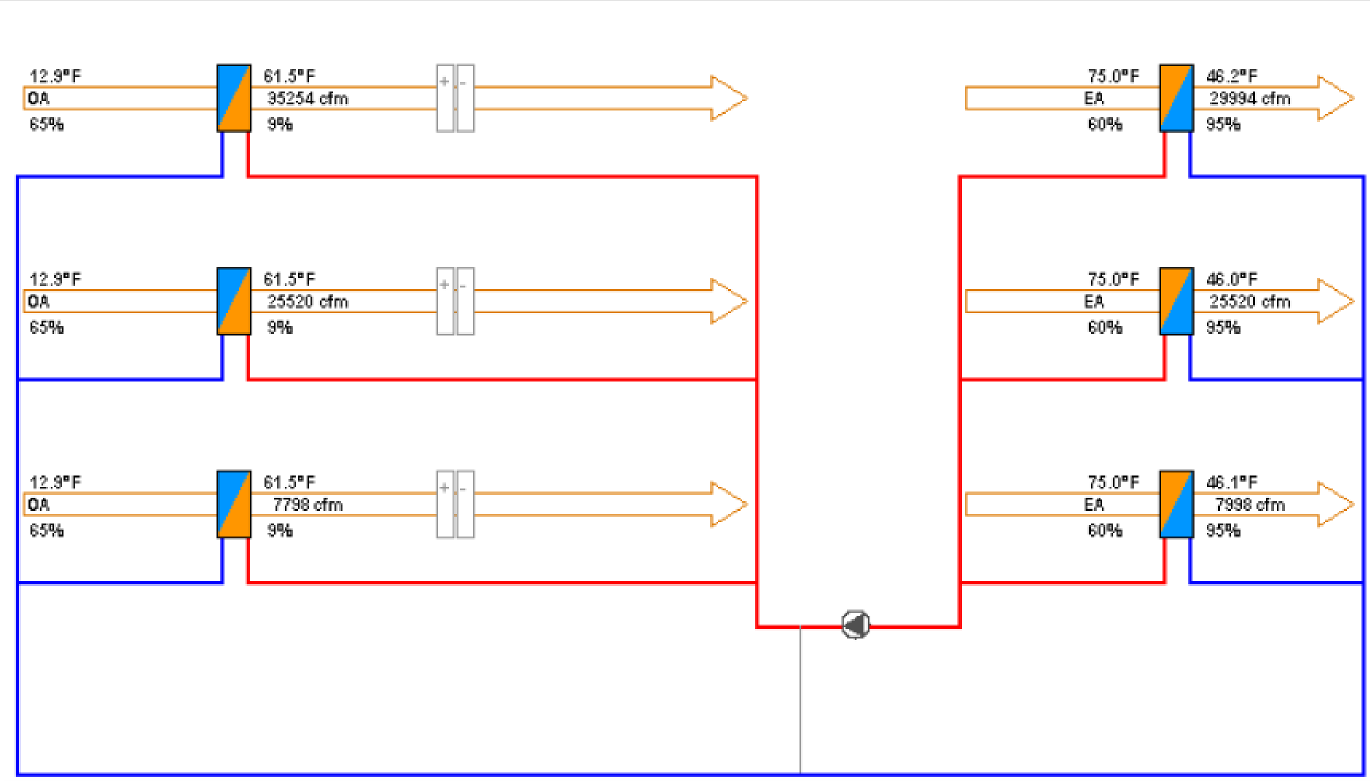


Figure 11: Air handler Runaround configuration at 100% Air Volumes – showing a 65% efficiency during heating season.

There are three components of the Konvekta run-around system that make it more 20-30 % more efficient than a typical run-around recovery system. This allows Konvekta's system to recover 60 – 90% of energy that escapes the building in exhaust. This differs greatly from the 40-60% of energy recovered via a traditional runaround system. These three differentiating components are as follows:

Figure 12: Konvekta Counter flow Coil www.dac-hvac.com/blog/

1) **Coil Array:**
   - Traditional systems use water with some form of an anti-freezing agent as the medium in which they transfer thermal energy. These additives diminish the water's heat transfer capabilities to around 40-50%. Utilizing the ethylene glycol solution improves this transfer capability by about 20%.
   - The coil array is 10% more efficient than a typical flat plate heat exchanger. The array utilizes a double header, thick, wide-spaced, fin design that maximizes counter flow. It also offers a small air-glycol approach temperature to maximize heat transfer. (Figure 12)
   - From a maintenance perspective the entire depth of the coil is accessible for ease of cleaning**.**

2) **Piping/Flow Configuration**
   - Traditional runaround uses 1 or two units on the loop with constant flow of heat transfer fluid

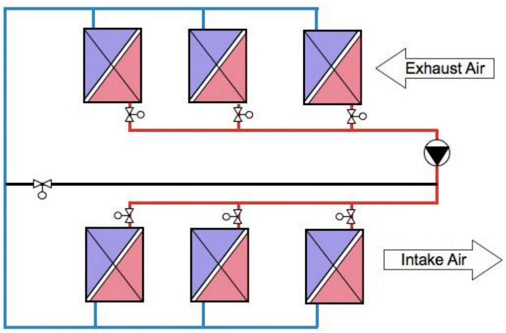


Figure 13: Konvekta "Gang" Configuration
www.konvekta.ch

- This uses a **gang system** (Figure 13) that allows multiple exhaust units on one loop with control valves at each unit. This allows for variable flow to optimize heat transfer between exhaust and glycol solution. The centralized pumping system then takes all of this pretreated solution and distributes it to the OA units for preheating/cooling in the same manner.

Control System

- These controls match delta T between OA and EA with the variable flow valves at each unit in order to optimize heat transfer performance and partial load efficiency with glycol solution.
- Integrates with air handler controls for variable air flow across coils as well in order to match ventilation requirements.
- Assesses real time energy savings in addition to having pressure drop alert systems for potential leakages etc. (Ethylene glycol has less chances of leaking due to its viscosity and surface tension)

Overall this system allows for a heating energy recovery of about 65% (with the pool, 60% without). As the school is primarily being used in the heating season, this will provide tremendous savings to the owner and community in lifecycle costs. The system will too utilize an economizer cycle that will stop the pumping of ethylene glycol for the necessary units when the outdoor air temperature is close to that of the set point; saving additional energy cost.

3.4 Humidification/Dehumidification

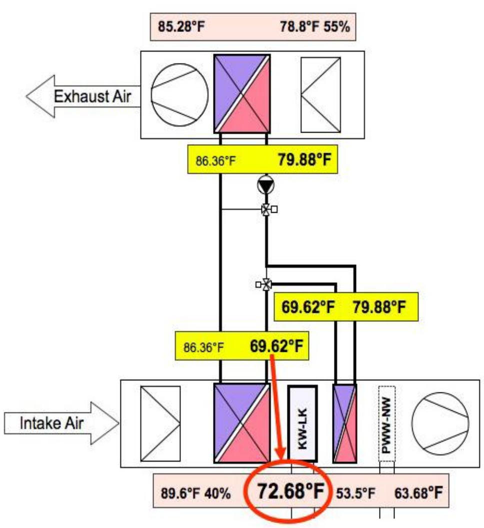


Figure 14: Konvekta Dehumidification Loop
www.konvekta.ch

In designing our system and speaking with industry professionals we found that the high humidity in the exhaust air allows a high heat recovery rate without the need to excessively cool the exhaust air. This will cause some condensation in the exhaust air coils so they will implement an epoxy coating. The other aspect that makes this system very efficient is its efficiency at partial load supply. This is a result of the reduced airflow which allows the maximum transfer of thermal energy to precondition the outdoor air. In continuing with the pool the Konvekta system also utilizes a dehumidification "loop" that will allow the system to handle the high latent loads being produced by the evaporative effects of the pool, as shown in Figure 14.

The heat exchanger on the intake side has two parts, the first will cool the intake air, thus dehumidifying it and the second part will be reheated using the runaround loop to bring it up to the required supply temperature. This allows for a reduction in the peak cooling load of the chiller and will require smaller chillers that will consume less energy as they will operate at a higher level of efficiency.

3.5 Specialized Zone Considerations/Coordination

3.5.1 Pool

The pool is one of the most, if not the most difficult zone included in the mechanical design of the building. First and foremost, the uncertainty of pool's construction date (if one) presented the unique challenge of designing a system. The system designed meets the goals of reduction, recovery, and reuse while allowing a drastically demanding load/zone to be incorporated to the system at a later date (or not at all). This is one of the main reasons an ethylene glycol runaround system is implemented as it allows for the pool zone to be incorporated into the existing "gang system" created by the 2 pairs of air handlers conditioning the education and lobby/community wings. Additionally the high latent loads created and exhausted from the pool will improve the overall efficiency of the heat recovery system by about 3-5% annually.

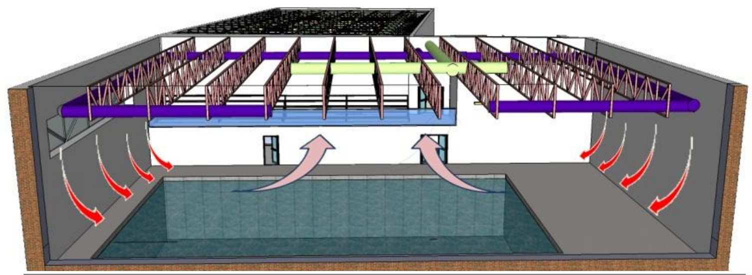


Figure 15: Sketchup Model of Schematic Duct Layout in Pool

As per the ASHRAE design criteria the pool air temperature will be heated between 82-84 degrees; roughly 2 degrees warmer than the water temperature. Special consideration is made to ensure that the tri-chloramine vapors evaporating from the water's surface are immediately exhausted as these vapors can attribute to throat and eye irritation of occupants. As such, the mechanical layout is designed such that air is supplied around the perimeter of the pool to not only prevent condensation on the windows and the walls, but to also create a centripetal motion of air over the pool. At this centralized location (above the pool) air and vapors are removed through the negatively pressured exhaust system. This system utilizes a special coating to prevent corrosion of the system due to the chemical vapors. Although this adds about a 10% cost to this particular exhaust unit, the cost is drastically offset by the absorption and reuse of this 82-84 F air by the ethylene glycol system. A packaged pool unit was also considered in the design of this particular zone. Although this option was cheaper; the payback associated with the 3-5% in annual energy savings (due to this unit's integration into the ethylene glycol loop) will be about 3.8 years. There will also be a small mechanical room located within the pool zone. This will house all the necessary pumping, heating, and filtering equipment necessary for pool maintenance. (See Integrated Report for more detail).

Figure 16: Rendering of Pool Ceiling: Integration of Structure, Daylighting, & Ductwork

3.5.2 Lobby, Gym, Kitchen, Healthcare

The largest challenge with this zone is the variation in conditioning requirements of each space within the zone. Due to the large volume of air being supplied for the pool, lobby, admin, and kitchen, an 8'x8' vertical chase was devised in conjunction with the structural engineers in the early stages of design to accommodate the 3'x3' supply

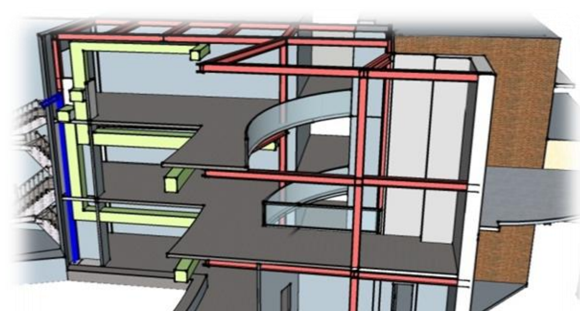


Figure 17: Sketch up Model of vertical chase in lobby

ductwork required to condition these spaces (see Figures 17 &18). This chase additionally holds all the piping running from the basement mechanical room for the ethylene glycol and domestic hot/cold water for the unit's coils.

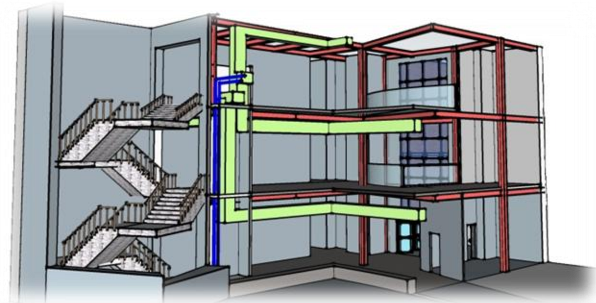


Figure 18: Sketch up Model of vertical chase in lobby

In the lobby, special consideration was taken into conditioning the new atrium space; the challenge for this space was the large south facing curtain wall and the three story open atrium connected to the hallways of the adjacent floors. Much of the summer solar radiation is nullified due to the large architectural canopy above the main entrance of the school. However, this space is the most prone to heat transfer (to interior and exterior) via this two-story curtain wall. As such the atrium is supplied with 5000 cfm (1670 cfm at each floor) at the edge of each floor with a throw of 24 feet to reach the curtain wall. The space will be exhausted from the acoustic drop ceiling located solely in the lobby of the building.

Figure 19: Rendering of Multipurpose Room Ceiling: Integration of Structure & Ductwork

This vertical chase also feeds directly into the multipurpose room. This was the most challenging space for this zone as it serves many different purposes during the school day while also acting as the emergency shelter for the community. Therefore, this set of air handlers will be connected to a generator located in the basement. This generator will serve the lighting, conditioning (to include heat recovery, 1 boiler, and 1 small chiller), and health center loads, providing power to the shelter in the event of a natural disaster. The actual HVAC design for this space will meet the requirements for a gymnasium, auditorium, and cafeteria. The schematic design phase found that the cafeteria requirements were the most astringent therefor the system is designed using these ASHRAE criteria of 7.5 per person; thus resulting in an airflow of 4700 cfm. The duct layout is much like that of the pool, fitting seamlessly under the flange of the K-series structural joists supporting the roof structure (as seen in Figure 19). The multipurpose space also has a set of lockerrooms that connect to the adjacent pool. These lockers will be exhausted by the gymnasium exhaust system.

Lastly, in the general duct layout of the space the decision was made to supply from one end of this zone and exhaust from the other as to allow space for the large duct work. Due to this configuration where the supply ductwork is large (on the lobby side by the vertical chase) the exhaust ductwork is at its smallest. Visa versa, at the end of the zone closest to the pool, where the exhaust unit is located, the supply duct work is smallest, having only to condition small office spaces. This can be seen more clearly in Figure 20, which shows how the ductwork for this zone was able to run to each space without conflicting with other discipline systems.

Figure 20: Section Rendering of West Wing Classrooms/Office Showing Configuration of Supply (Blue) & Exhaust (Green) Duct

3.5.3 Classrooms

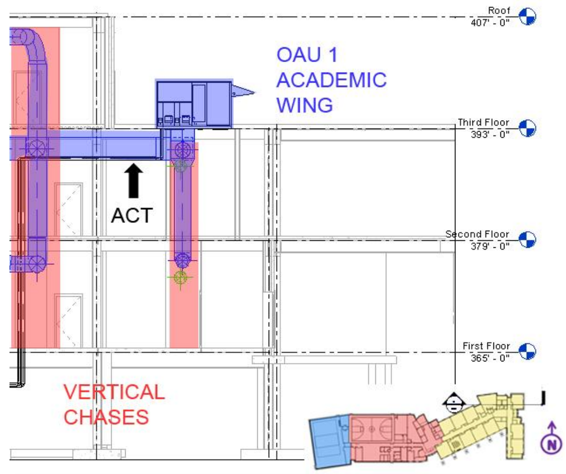


Figure 21: Vertical chase section for education

The classroom wing of the building too presented some challenges in determining the most effective manner of conditioning the spaces. Due to the modularization of the structural bay size (as detailed in the Team Nexus Integration Report) each classroom in this wing is roughly the same size, with the same occupant density. This is ideal as it allows a standardized method of conditioning each of these classrooms. As was done in the lobby, a vertical chase was also created to house the large ductwork leaving the air handler to reach each of the three floors. There will also be some acoustical ceiling tile located in the farthest corner of the second level hallway as to prevent sound attenuation from the rooftop unit as well as allow room for the large rectangular ductwork leaving the unit (as shown in Figure 21). There is an additional vertical chase created from existing closet space outside of each classroom. One of these closets is now used as a vertical chase from the basement to supply the chilled / hot water to the air handler. This to keeps the ethylene glycol piping obscured while still allowing access at each floor; should any future maintenance be required.

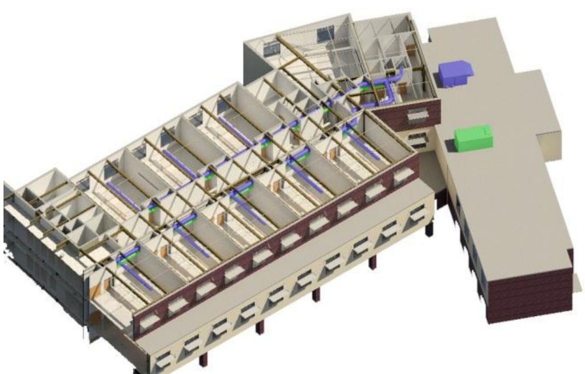


Figure 22: Building System Integration in Education Wing

In addition to these vertical chases created to house the required air handler piping, this particular wing of the building required the innovation of a lateral duct chase superimposed within the corridor wall and structural system of the wing. As it is a Nexus goal to leave the engineering systems exposed within the building as to make the school itself a learning tool; a unique duct layout was designed to meet the necessary load requirements without conflicting with the other discipline systems and maintaining the desired architectural aesthetic. As such, the round ductwork for the classrooms runs mostly exposed along the classroom side of the corridor wall (as shown in Figure 22). The decision was made to use round ductwork as it is easier to install, cheaper to manufacture, and is more visually attractive than traditional rectangular ductwork. This too allowed savings by eliminating the need to enclose the ductwork within a bulkhead. The rooms are conditioned by a supply duct running perpendicular from the lateral (hallway adjacent) main along the ceiling of each classroom between the structural steel joists. The rooms on the south side of the wing will receive 980 cfm each, which is slightly more than those on the north receiving 700 cfm each. As previously mentioned, the ductwork is sized slightly smaller as the building utilizes a 100% outdoor air system. Each room will then be exhausted from two return grilles located in the exhaust main along the hallway side of the room, directly under the supply main (as shown in Figure 23). These classrooms will also be equipped with CO2 sensors that tie into the central control system discussed previously as to regulate air handler and ethylene glycol performance to maintain an outdoor ventilation level 30% greater than the minimum ASHRAE recommendation.


Figure 23: Teacher classroom perspective rendering with exposed ductwork

3.6 Mechanical Equipment & Room Layout

Figure 24: Site plan with the mechanical room access

To maintain the constructability as well as a lifecycle maintenance integrity of the mechanical system an exterior access/opening is located on the Park Avenue side of the building (see Figure 24). Due to the restrictions of the site in terms of its relatively level grade; this was deemed the only cost effective and appropriate solution for the replacement or addition of new equipment to the basement mechanical room.

Table 2: Equipment Load Summary

Equipment Loads	
Equipment	**Capacity**
Chiller-1	60 Tons
Chiller-2	60 Tons
Chiller-3	60 Tons
Cooling Tower	175 Tons
Boiler-1	800 MBh
Boiler-2	400 MBh
OAU-1	38,000 CFM
OAU-2	27,000 CFM
OAU-3	8,000 CFM
EAU-1	34,500 CFM
EAU-2	24,500 CFM
EAU-3	9,000 CFM

In selecting the other equipment (i.e.: boilers, chillers, cooling tower, etc.) several energy analyses were done in determining the efficiency of our system configuration. The implementation of the ethylene glycol recovery system allows for an annual load reduction of roughly 50% year round. This allows the boilers to be downsized by 50% which is a great upfront cost savings. Two boilers will be utilized as to account for the add-alternate of the pool. Should the owner design they want the pool in the first phase of the project; there will be one boiler large enough to accommodate the loads of the three combined zones. The chillers however were not able to be downsized as there was a minimal difference in the year round cooling capacities. This is because the delta T between set point temperature and exterior summer temperature is very small in comparison to that in the winter. As such, there is not as much energy being recovered by the run around system to justify a decrease in chiller sizing. This not an issue in the design of the building as it was determined that three chillers be used to optimize the efficiency of the chiller configuration. Table 2 shows our Equipment breakdown with the respective capacities. See the Mechanical Room Layout in Appendix page 25.

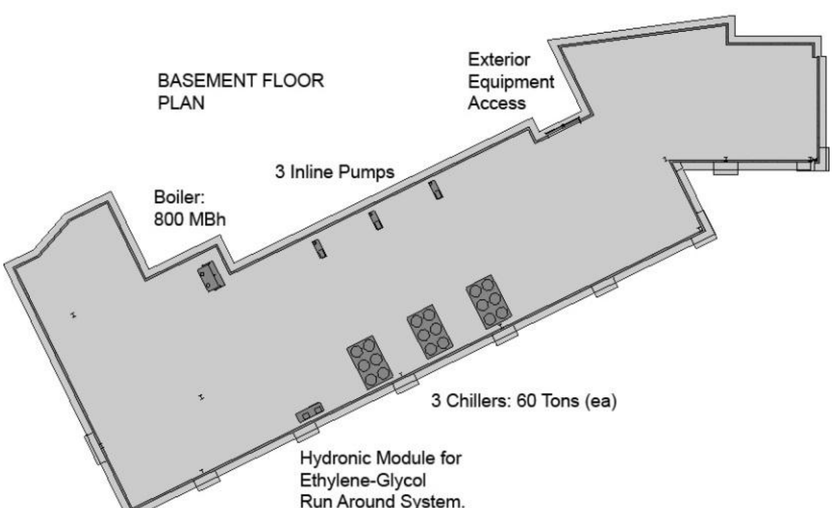


Figure 25: Basement Floor Plan: Mechanical Room Layout

The chillers were selected based on the information included in the Appendix on pages 26-28. It was decided to use 3 chillers based on our cooling load profiles calculated via Trane Trace. When breaking down these profiles by a month-month analysis it was shown that the building cooling loads differ by 3 conditioning seasons. Therefore, one chiller will run at full capacity for four months out of the year, two chillers will run at full capacity for four months out of the year, and all three will run at full capacity for the remaining four. This will ensure that the chillers are constantly operating at their optimal capacity to ensure efficient use of this equipment and the elimination of unnecessary energy use.

4. Sustainability Analysis

Through the implementation of all passive and mechanical design considerations the Nexus design team successfully reduced the overall building loads and was able to recover and reuse waste energy to such a degree that the building will sustain a minimal consumption of energy use over the course of its lifecycle. As is shown in Tables 3-4, the Nexus building design greatly surpasses the energy use and load consumption of minimum values mandated by the ASHRAE standard. Nexus' design for the Reading Elementary school utilizes 50-65% less energy than that of the minimum requirements for this type of building.

Table 3: Baseline Building Peak Load Summary – Trane TRACE700 Outputs

Baseline Building Loads				
Zone		**Cooling Capacity [TONS]**	**Heating Capacity [TONS]**	**Airflow [CFM]**
1	Academic	165.2	85.3	42,120
2	Community	127.4	48.7	28,735
3	Pool	14.1	36.4	9,100
	TOTAL	306.7	170.4	79,955

VS

Table 4: NEXUS Building Peak Load Summary – Trane TRACE700 Outputs

Building Loads				
Zone		**Cooling Capacity [TONS]**	**Heating Capacity [TONS]**	**Airflow [CFM]**
1	Academic	86.7	64.2	35,610
2	Community	57.7	39.6	25,525
3	Pool	13.9	28.3	7,800
	TOTAL	158.3	132.1	68,935

This is achieved, as previously stated, through the implementation of the Ethylene Glycol Run Around system that functions concurrently with efficient envelope design. However, the implementation of the Ethylene Glycol is the largest cost consideration in the design of this mechanical system. In electing to use this form of heat recovery, there was an added cost of approximately $295,000 for the technology and packaged coils for each unit. The second largest cost consideration is the chiller configuration. As discussed above, three chillers will be used to provide cooling. Each unit costs about $55,000 and in saving roughly $30,000 through the downsizing of the boilers, the decision was made to include the third chiller to maintain peak performance during operation. Additionally, having the third chiller allows for an extra degree of redundancy that will ensure the building remains functional should one fail.

As previously stated, taking all of these factors into consideration, an initial price tag of 990,935.00 was calculated should the Ethylene Glycol system be implemented in conjunction with the pool. Should the pool not be included in the building scope, the price will drop to $863,210.00, which is a difference of nearly $130,000. In calculating the basic payback of this system, including the reduction of annual energy consumption of 50%, a payback period of 4.3 years was calculated. This clearly justifies the use of this system over one functioning under the ASHRAE baseline standards. Therefore, the use of this system will provide a tremendous value to the owner through the continued savings accrued throughout the longevity of the building.

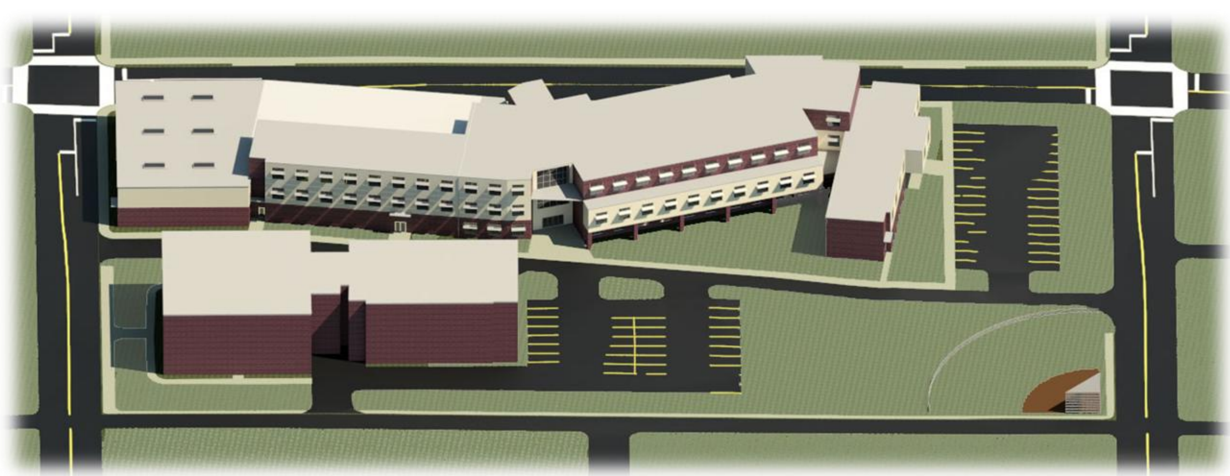
5. Conclusion

In designing a system with the three criteria of Experience, Community, and Education in mind, Team Nexus has created a mechanical system that meets all the needs of these unique spaces while providing an improved environment to the building's occupants. The three mechanical goals of reduction, recovery, and reuse have a bearing effect on the function of the building and the integrity of its lifecycle efficiency. By reducing the building's conditioning load by over 48% through the integrated Nexus Façade, Daylighting system, and Heat recovery, we were able to downsize equipment (In some cases up to 50%) and save drastically on initial and long term energy costs. The implementation of these packaged units too will reduce construction time considerably in comparison to alternative methods of conditioning.

Through the recovery of up to 65% of the thermal energy leaving the building via the exhaust system and reintroducing it to precondition the outdoor air; this mechanical design reduces HVAC annual energy costs by 50% of that of a typical ASHRAE Baseline building. This has a profound result on the sustainability of the building as the community of Reading will be less burdened by operation cost and maintenance. The implementation of the Ethylene Glycol Run Around system is the leading contributor to the long-term energy savings with this design. The additional 30% ($295,000) spent on this system over a typical heat recovery system (i.e. Recovery wheels, flat plate heat exchangers, etc….) is well worth the investment as the system's superior efficiency will allow for a payback period of 4.3 years atop these alternative, less effective methods. This is nothing in comparison to the longevity of the building. This system alone will continue to provide value to the owner in the decades to come as it continues to save on energy and operation costs.

Lastly the methodology of implementing this system will continue to form the building as a learning tool for the students. In facilitating a balance between system exposure and effectiveness, this mechanical design will inevitably evoke a curiosity within the students. Students will be able to see and follow the systems as they move throughout the building, slowly gaining an understanding of that which comprises their educational environment. Through the use of a centralized control system students will see the effect of their own energy use and hopefully draw the parallel between their consumption in the classroom and their lives at home. The seamless integration of these mechanical design considerations with the designs of the three other disciplines that comprise Team Nexus will ultimately create a superior learning environment to facilitate the education of the Reading District youth.

reduce, recover, reuse



6. APPENDIX

6.1 ZONE LOAD CALCULATIONS – EXPORTS FROM TRACE700

Zone Checksums

By ACADEMIC

Academic Zone

COOLING COIL PEAK — Peaked at Time: Mo/Hr: 7 / 12; Outside Air: OADB/WB/HR: 84 / 70 / 91

CLG SPACE PEAK — Mo/Hr: 9 / 12; OADB: 77

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	17,197	0	17,197	2	11,571	2
Glass Solar	303,680	0	303,680	29	382,399	51
Glass/Door Cond	8,463	0	8,463	1	-5,648	-1
Wall Cond	6,280	0	6,280	1	2,584	0
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	18,847		18,847	2	-1,675	0
Sub Total ==>	354,467	0	354,467	34	389,231	52
Internal Loads						
Lights	148,154	3,315	151,469	15	148,154	20
People	349,800	0	349,800	34	187,890	25
Misc	21,791	0	21,791	2	21,791	3
Sub Total ==>	519,745	3,315	523,060	50	357,835	48
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	126,077	12	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	944		944	0	944	0
Exhaust Heat		-708	-708	0		
Sup. Fan Heat			36,107	3		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	875,155	2,607	1,039,946	100.00	748,009	100.00

HEATING COIL PEAK — Mo/Hr: Heating Design; OADB: 9

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	-26,169	-26,169	4.90
Glass Solar	0	0	0.00
Glass/Door Cond	-94,709	-94,709	17.72
Wall Cond	-32,217	-32,217	6.03
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	-54,679	-54,679	10.23
Sub Total ==>	-207,775	-207,775	38.87
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		0	0.00
OA Preheat Diff.		-242,377	45.34
RA Preheat Diff.		-84,424	15.79
Additional Reheat		0	0.00
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-207,774	-534,575	100.00

TEMPERATURES

	Cooling	Heating
SADB	54.9	75.6
Ra Plenum	75.0	70.0
Return	75.1	70.0
Ret/OA	76.0	70.0
Fn MtrTD	0.1	0.0
Fn BldTD	0.2	0.0
Fn Frict	0.7	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	33,850	33,850
Terminal	33,850	33,850
Main Fan	33,850	33,850
Sec Fan	0	0
Nom Vent	8,391	0
AHU Vent	8,391	0
Infil	815	815
MinStop/Rh	0	0
Return	34,666	34,666
Exhaust	9,207	815
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	27.2	0.0
cfm/ft²	0.92	0.92
cfm/ton	390.60	
ft²/ton	424.23	
Btu/hr-ft²	28.29	-20.95
No. People	872	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB/WB/HR °F	Enter °F	Enter gr/lb	Leave DB/WB/HR °F	Leave °F	Leave gr/lb
Main Clg	86.7	1,040.0	765.6	33,850	76.1	63.1	66.7	54.2	52.5	57.1
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	86.7	1,040.0								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	36,765		
Part	0		
Int Door	0		
ExFlr	0		
Roof	13,000	0	0
Wall	19,551	5,496	28
Ext Door	42	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-770.4	33,850	54.9	75.6
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-770.4			

Project Name: Elementary School
Dataset Name: READING ELEM EQ.TRC

TRACE® 700 v6.2.8 calculated at 01:24 PM on 12/13/2012
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Zone Checksums

By ACADEMIC

Community Zone

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 15; Outside Air: OADB/WB/HR: 88 / 72 / 94

CLG Space Peak — Mo/Hr: 9 / 14; OADB: 81

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	21,396	0	21,396	3	14,903	3
Glass Solar	202,257	0	202,257	29	248,940	48
Glass/Door Cond	3,609	0	3,609	1	-8,693	-2
Wall Cond	2,931	0	2,931	0	249	0
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	9,821		9,821	1	-3,488	-1
Sub Total ==>	240,014	0	240,014	35	251,910	49
Internal Loads						
Lights	111,632	6,483	118,115	17	111,632	22
People	239,060	0	239,060	35	118,410	23
Misc	32,812	0	32,812	5	32,812	6
Sub Total ==>	383,504	6,483	389,987	56	262,854	51
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	63,290	9	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	931		931	0	931	0
Exhaust Heat		-1,341	-1,341	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	624,450	5,142	692,882	100.00	515,696	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 9

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	-28,504	-28,504	12.75
Glass Solar	0	0	0.00
Glass/Door Cond	-46,259	-46,259	20.69
Wall Cond	-19,029	-19,029	8.51
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	-32,368	-32,368	14.48
Sub Total ==>	-126,161	-126,161	56.42
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	1	1	0.00
Exhaust Heat		0	0.00
OA Preheat Diff.		-124,228	55.56
RA Preheat Diff.		26,787	-11.98
Additional Reheat		0	0.00
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-126,159	-223,600	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	75.1
Ra Plenum	75.0	70.0
Return	75.3	70.0
Ret/OA	76.5	70.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	23,398	19,319
Terminal	23,398	19,319
Main Fan	23,398	19,319
Sec Fan	0	0
Nom Vent	5,205	0
AHU Vent	5,205	0
Infil	483	483
MinStop/Rh	0	0
Return	23,768	19,769
Exhaust	5,575	450
Rm Exh	112	32
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	22.5	0.0
cfm/ft²	0.73	0.60
cfm/ton	405.23	
ft²/ton	554.12	
Btu/hr-ft²	21.66	-14.85
No. People	451	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB/WB/HR °F	Enter °F	Enter gr/lb	Leave DB/WB/HR °F	Leave °F	Leave gr/lb
Main Clg	57.7	692.9	522.7	23,398	76.0	62.9	66.1	55.0	52.7	56.7
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	57.7	692.9								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	31,995		
Part	0		
Int Door	0		
ExFlr	0		
Roof	14,160	0	0
Wall	10,941	2,639	24
Ext Door	84	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-475.2	19,319	53.6	75.9
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-475.2			

Project Name: Elementary School
Dataset Name: READING ELEM EQ.TRC

TRACE® 700 v6.2.8 calculated at 01:24 PM on 12/13/2012
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Zone Checksums

By ACADEMIC

Pool Zone

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 15; Outside Air: OADB/WB/HR: 88 / 72 / 94

Clg Space Peak — Mo/Hr: 7 / 15; OADB: 88

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	34,519	0	34,519	21	34,519	30
Skylite Cond	355	0	355	0	355	0
Roof Cond	9,527	0	9,527	6	9,527	8
Glass Solar	3,143	0	3,143	2	3,143	3
Glass/Door Cond	227	0	227	0	227	0
Wall Cond	1,691	0	1,691	1	1,691	1
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	21,258		21,258	13	10,170	9
Sub Total ==>	70,721	0	70,721	42	59,633	52
Internal Loads						
Lights	28,387	426	28,813	17	28,387	25
People	35,250	0	35,250	21	16,650	14
Misc	11,118	0	11,118	7	11,118	10
Sub Total ==>	74,754	426	75,180	45	56,154	48
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	14,745	9	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		0	0	0		
Sup. Fan Heat			6,307	4		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	145,475	426	166,953	100.00	115,788	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 9

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	-6,153	-6,153	3.50
Roof Cond	-14,972	-14,972	8.52
Glass Solar	0	0	0.00
Glass/Door Cond	-3,938	-3,938	2.24
Wall Cond	-17,826	-17,826	10.15
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	-122,658	-122,658	69.83
Sub Total ==>	-165,547	-165,547	94.24
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		1,269	-0.72
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		-11,384	6.48
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-165,547	-175,661	100.00

TEMPERATURES

	Cooling	Heating
SADB	63.6	106.7
Ra Plenum	75.0	70.0
Return	81.8	81.2
Ret/OA	82.4	81.2
Fn MtrTD	0.1	0.0
Fn BldTD	0.2	0.0
Fn Frict	0.7	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	5,913	5,913
Terminal	5,913	5,913
Main Fan	5,913	5,913
Sec Fan	0	0
Nom Vent	1,378	0
AHU Vent	1,378	0
Infil	1,530	1,530
MinStop/Rh	5,913	5,913
Return	7,275	7,433
Exhaust	2,740	1,520
Rm Exh	168	10
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	23.3	0.0
cfm/ft²	0.81	0.81
cfm/ton	424.98	
ft²/ton	524.34	
Btu/hr-ft²	22.89	-64.10
No. People	54	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	13.9	167.0	128.2	5,913	82.7	68.8	84.8	63.0	60.4	75.5
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	13.9	167.0								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	7,295		
Part	0		
Int Door	0		
ExFlr	0		
Roof	6,515	300	5
Wall	6,734	192	3
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-340.4	5,913	54.4	106.7
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Reheat	-176.1	5,913	54.4	81.4
Humidif	-127.2	6,122	1.8	31.8
Opt Vent	0.0	0	0.0	0.0
Total	-467.6			

Project Name: Elementary School
Dataset Name: READING ELEM EQ.TRC

TRACE® 700 v6.2.8 calculated at 01:24 PM on 12/13/2012
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6.2 AIRFLOW CALCULATIONS

Reading Elementary School - Reading, PA
ASHRAE 62.1 2007 Minimum Ventilation Calculations
AEI Team 5

AHU	Capacity cfm	Percent OA	OA cfm
RTU-1	7800	100.0%	7800

System Population, Ps	50
Zone Population, Pz	26
Occupant Diversity, D = (Pz-Ps)/Pz	52%

b a =a/b

Room Name	Room Number	Occupancy Category	Area (SF)	People O.A. Rate (cfm/person)	Area O.A. Rate (cfm/SF)	# of Occupants Furniture	Occupant Density	Breathing Zone O.A. Flow Required Vbz	Table 6-2 Zone Air Dist. Eff.	Zone outdoor airflow	Primary O.A. fraction	Table 6.3 System Vent. Eff.	Uncorrected O.A. Intake	Design O.A. Intake	Zone Primary Air Flow Set Point (cfm)	Percent OA	Actual O.A. Flow	% Above Min OA	Meets Standard?	Meets LEED 30%?
			Az	Rp	Ra	Pz,f		Vbz = Rp*Pz + Ra*Az	Ez	Voz = Vbz / Ez	Zp = Voz / Vpz	Ev	Vou = D*∑(Rp*Pz) + ∑(Ra*Az)	Vot = Vou / Ev	Vpz		OA = % * Vpz	=(OA/Vot) -1		
RTU-1										**3654.0**	**0.47**	**0.6**	**3424**	**5706**	**7800**	**100.0%**	**7800**	**37%**	**Yes**	**Yes**
Pool	162	Pool	6515	0	0.48	26	3.99	3127.2	1.0	3127.2	0.46	0.6	3127.2	5212.0	6800		6800.0	30%	Yes	Yes
Girl's Locker Room	163	Locker Room	440	20	0.06	12	27.27	266.4	1.0	266.4	0.53	0.6	151.2	252.0	500		500.0	98%	Yes	Yes
Boy's Locker Room	164	Locker Room	340	20	0.06	12	35.29	260.4	1.0	260.4	0.52	0.6	145.2	242.0	500		500.0	107%	Yes	Yes

Maximum Zp	0.53

Reading Elementary School - Reading, PA
ASHRAE 62.1 2007 Minimum Ventilation Calculations
AEI Team 5

AHU	Capacity cfm	Percent OA	OA cfm
RTU-2	18533	100.0%	18533

System Population, Ps	220
Zone Population, Pz	220
Occupant Diversity, D = (Pz-Ps)/Pz	100%

b a =a/b

Room Name	Room Number	Occupancy Category	Area (SF)	People O.A. Rate (cfm/person)	Area O.A. Rate (cfm/SF)	# of Occupants Furniture	Occupant Density	Breathing Zone O.A. Flow Required Vbz (cfm)	Table 6-2 Zone Air Dist. Eff.	Zone outdoor airflow	Primary O.A. fraction	Table 6.3 System Vent. Eff.	Uncorrected O.A. Intake	Design O.A. Intake	Zone Primary Air Flow Set Point (cfm)	Percent OA	Actual O.A. Flow	% Above Min OA	Meets Standard?	Meets LEED 30%?
			Az	Rp	Ra	Pz,f		Vbz = Rp*Pz + Ra*Az	Ez	Voz = Vbz / Ez	Zp = Voz / Vpz	Ev	Vou = D*∑(Rp*Pz) + ∑(Ra*Az)	Vot = Vou / Ev	Vpz		OA = % * Vpz	=(OA/Vot) -1		
RTU-2										**2823.6**	**0.15**	**0.7**	**2032**	**3386**	**18533**	**100.0%**	**18533**	**447%**	**Yes**	**Yes**
Vestibule	100	Vestibule	140	0	0.06	0	0.00	8.4	1.0	8.4	0.01	0.6	8.4	14.0	850		850.0	5971%	Yes	Yes
Multi-Purpose Room	104	Gym/Cafeteria	5980	7.5	0.18	220	36.79	2726.4	1.0	2726.4	0.15	0.6	1934.4	3224.0	18308		18308.0	468%	Yes	Yes
Stage	105	Stage	1020	10	0.06	0	0.00	61.2	1.0	61.2	0.44	0.6	61.2	102.0	140		140.0	37%	Yes	Yes
Storage	106	Storage	200	0	0.12	0	0.00	24.0	1.0	24.0	0.44	0.6	24.0	40.0	55		55.0	38%	Yes	Yes
Ramp	107	Corridor	200	0	0.06	0	0.00	12.0	1.0	12.0	0.40	0.6	12.0	20.0	30		30.0	50%	Yes	Yes

Maximum Zp	0.44

Reading Elementary School - Reading, PA
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AEI Team 5

AHU	Capacity cfm	Percent OA	OA cfm
RTU-3	19302	100.0%	19302

System Population, Ps	227
Zone Population, Pz	227
Occupant Diversity, D = (Pz-Ps)/Pz	100%

b a =a/b

Room Name	Room Number	Occupancy Category	Area (SF)	People O.A. Rate (cfm/person)	Area O.A. Rate (cfm/SF)	# of Occupants Furniture	Occupant Density	Breathing Zone O.A. Flow Required Vbz	Table 6-2 Zone Air Dist. Eff.	Zone outdoor airflow	Primary O.A. fraction	Table 6.3 System Vent. Eff.	Uncorrected O.A. Intake	Design O.A. Intake	Zone Primary Air Flow Set Point (cfm)	Percent OA	Actual O.A. Flow	% Above Min OA	Meets Standard?	Meets LEED 30%?
			Az	Rp	Ra	Pz,f		Vbz = Rp*Pz + Ra*Az	Ez	Voz = Vbz / Ez	Zp = Voz / Vpz	Ev	Vou = D*∑(Rp*Pz) + ∑(Ra*Az)	Vot = Vou / Ev	Vpz		OA = % * Vpz	=(OA/Vot) -1		
RTU-3										**4419.1**	**0.23**	**0.6**	**4419**	**7365**	**19302**	**100.0%**	**19302**	**162%**	**Yes**	**Yes**
Vestibule	100	Vestibule	140	0	0.06	0	0.00	8.4	1.0	8.4	0.01	0.6	8.4	14.0	850		850.0	5971%	Yes	Yes
Lobby	101	Lobby	1710	0	0.06	0	0.00	102.6	1.0	102.6	0.22	0.6	102.6	171.0	475		475.0	178%	Yes	Yes
Corridor	103	Corridor	980	0	0.06	0	0.00	58.8	1.0	58.8	0.45	0.6	58.8	98.0	130		130.0	33%	Yes	Yes
Principal Office	108	Office	250	5	0.06	1	4.00	20.0	1.0	20.0	0.03	0.6	20.0	33.3	591		591.0	1673%	Yes	Yes
Clerical	109	Office	330	5	0.06	1	3.03	24.8	1.0	24.8	0.24	0.6	24.8	41.3	104		104.0	152%	Yes	Yes
Reception	110	Office	285	5	0.06	2	7.02	27.1	1.0	27.1	0.07	0.6	27.1	45.2	367		367.0	713%	Yes	Yes
Community Office	111	Office	150	5	0.06	1	6.67	14.0	1.0	14.0	0.24	0.6	14.0	23.3	59		59.0	153%	Yes	Yes
Work Room	113	Office	290	5	0.06	2	6.90	27.4	1.0	27.4	0.27	0.6	27.4	45.7	100		100.0	119%	Yes	Yes
Custodial	116	Storage	60	0	0.12	0	0.00	7.2	1.0	7.2	0.36	0.6	7.2	12.0	20		20.0	67%	Yes	Yes
Storage	118	Storage	105	0	0.12	0	0.00	12.6	1.0	12.6	0.42	0.6	12.6	21.0	30		30.0	43%	Yes	Yes
Nurse	119/122	Pharmacy	1000	5	0.18	2	2.00	190.0	1.0	190.0	0.42	0.6	190.0	316.7	450		450.0	42%	Yes	Yes
Nurse's Office	120	Office	115	5	0.06	1	8.70	11.9	1.0	11.9	0.24	0.6	11.9	19.8	50		50.0	152%	Yes	Yes
Nurse's Exam Room	121	Pharmacy	160	5	0.18	2	12.50	38.8	1.0	38.8	0.39	0.6	38.8	64.7	100		100.0	55%	Yes	Yes
Storage	124	Storage	400	0	0.12	0	0.00	48.0	1.0	48.0	0.16	0.6	48.0	80.0	300		300.0	275%	Yes	Yes
Storage	125	Storage	140	0	0.12	0	0.00	16.8	1.0	16.8	0.42	0.6	16.8	28.0	40		40.0	43%	Yes	Yes
Locker Room	126	Locker Room	80	20	0.06	1	12.50	24.8	1.0	24.8	0.41	0.6	24.8	41.3	60		60.0	45%	Yes	Yes
Corridor	128	Corridor	210	0	0.06	0	0.00	12.6	1.0	12.6	0.21	0.6	12.6	21.0	61		61.0	190%	Yes	Yes
Office	129	Office	75	5	0.06	1	13.33	9.5	1.0	9.5	0.26	0.6	9.5	15.8	36		36.0	127%	Yes	Yes
Storage	130/131	Storage	120	0	0.12	0	0.00	14.4	1.0	14.4	0.36	0.6	14.4	24.0	40		40.0	67%	Yes	Yes
Kitchen	132	Kitchen	1640	7.5	0.18	6	3.66	340.2	1.0	340.2	0.45	0.6	340.2	567.0	750		750.0	32%	Yes	Yes
Storage	133	Storage	410	0	0.12	0	0.00	49.2	1.0	49.2	0.16	0.6	49.2	82.0	313		313.0	282%	Yes	Yes
Lobby	200	Lobby	2430	0	0.06	0	0.00	145.8	1.0	145.8	0.08	0.6	145.8	243.0	1800		1800.0	641%	Yes	Yes
Corridor	201	Corridor	980	0	0.06	0	0.00	58.8	1.0	58.8	0.45	0.6	58.8	98.0	130		130.0	33%	Yes	Yes
Conference	202	Conference	770	5	0.06	12	15.58	106.2	1.0	106.2	0.38	0.6	106.2	177.0	279		279.0	58%	Yes	Yes
Custodial	204	Storage	60	0	0.12	0	0.00	7.2	1.0	7.2	0.36	0.6	7.2	12.0	20		20.0	67%	Yes	Yes
Storage	206	Storage	105	0	0.12	0	0.00	12.6	1.0	12.6	0.42	0.6	12.6	21.0	30		30.0	43%	Yes	Yes
Assistant Principal	207	Office	250	5	0.06	1	4.00	20.0	1.0	20.0	0.13	0.6	20.0	33.3	150		150.0	350%	Yes	Yes
Library	208	Library	1960	5	0.12	26	13.27	365.2	1.0	365.2	0.17	0.6	365.2	608.7	2097		2097.0	245%	Yes	Yes
Library Support	209	Library	390	5	0.12	0	0.00	46.8	1.0	46.8	0.15	0.6	46.8	78.0	311		311.0	299%	Yes	Yes
Art Classroom	211/212	Art Classroom	1140	10	0.18	26	22.81	465.2	1.0	465.2	0.34	0.6	465.2	775.3	1350		1350.0	74%	Yes	Yes
Faculty Dining	213	Break Room	500	5	0.06	6	12.00	60.0	1.0	60.0	0.13	0.6	60.0	100.0	472		472.0	372%	Yes	Yes
Lobby	300	Lobby	2430	0	0.06	0	0.00	145.8	1.0	145.8	0.08	0.6	145.8	243.0	1837		1837.0	656%	Yes	Yes
Corridor	301	Corridor	980	0	0.06	0	0.00	58.8	1.0	58.8	0.15	0.6	58.8	98.0	380		380.0	288%	Yes	Yes
Psych Office	302	Office	130	5	0.06	2	15.38	17.8	1.0	17.8	0.12	0.6	17.8	29.7	150		150.0	406%	Yes	Yes
Conference	303	Conference	200	5	0.06	2	10.00	22.0	1.0	22.0	0.23	0.6	22.0	36.7	95		95.0	159%	Yes	Yes
IST	304	Storage	250	0	0.12	0	0.00	30.0	1.0	30.0	0.40	0.6	30.0	50.0	75		75.0	50%	Yes	Yes
Custodial	306	Storage	60	0	0.12	0	0.00	7.2	1.0	7.2	0.36	0.6	7.2	12.0	20		20.0	67%	Yes	Yes
Storage	308	Storage	105	0	0.12	0	0.00	12.6	1.0	12.6	0.42	0.6	12.6	21.0	30		30.0	43%	Yes	Yes
Guidance	309	Office	250	5	0.06	2	8.00	25.0	1.0	25.0	0.17	0.6	25.0	41.7	150		150.0	260%	Yes	Yes
Classroom	310	Classroom	755	10	0.12	26	34.44	350.6	1.0	350.6	0.35	0.6	350.6	584.3	1000		1000.0	71%	Yes	Yes
Classroom	311	Classroom	755	10	0.12	26	34.44	350.6	1.0	350.6	0.35	0.6	350.6	584.3	1000		1000.0	71%	Yes	Yes
Classroom	312	Classroom	755	10	0.12	26	34.44	350.6	1.0	350.6	0.35	0.6	350.6	584.3	1000		1000.0	71%	Yes	Yes
Classroom	313	Classroom	755	10	0.12	26	34.44	350.6	1.0	350.6	0.35	0.6	350.6	584.3	1000		1000.0	71%	Yes	Yes
Classroom	314	Classroom	755	10	0.12	26	34.44	350.6	1.0	350.6	0.35	0.6	350.6	584.3	1000		1000.0	71%	Yes	Yes

Maximum Zp	0.45

Reading Elementary School - Reading, PA
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AEI Team 5

AHU	Capacity cfm	Percent OA	OA cfm
RTU-4	22699	60.0%	13619.4

System Population, Ps	463
Zone Population, Pz	463
Occupant Diversity, D = (Pz-Ps)/Pz	100%

Room Name	Room Number	Occupancy Category	Area (SF)	People O.A. Rate (cfm/person)	Area O.A. Rate (cfm/SF)	# of Occupants Furniture	Occupant Density	Breathing Zone O.A. Flow Required Vbz	Table 6-2 Zone Air Dist. Eff.	Zone outdoor airflow	Primary O.A. fraction	Table 6.3 System Vent. Eff.	Uncorrected O.A. Intake	Design O.A. Intake	Zone Primary Air Flow Set Point (cfm)	Percent OA	Actual O.A. Flow	% Above Min OA	Meets Standard?	Meets LEED 30%?
												b	a	=a/b						
			Az	Rp	Ra	Pz,f		Vbz = Rp*Pz + Ra*Az	Ez	Voz = Vbz / Ez	Zp = Voz / Vpz	Ev	Vou = D*∑(Rp*Pz) + ∑(Ra*Az)	Vot = Vou / Ev	Vpz		OA = % * Vpz	=(OA/Vot) -1		
RTU-4										**6794.1**	**0.30**	**0.8**	**6787**	**8483**	**22699**	**60.0%**	**13619**	**61%**	**Yes**	**Yes**
Classroom	134	Classroom	815	10	0.12	26	31.90	357.8	1.0	357.8	0.30	0.8	357.8	447.3	1200		720.0	61%	Yes	Yes
Classroom	135	Classroom	815	10	0.12	26	31.90	357.8	1.0	357.8	0.30	0.8	357.8	447.3	1200		720.0	61%	Yes	Yes
Classroom	136	Classroom	815	10	0.12	26	31.90	357.8	1.0	357.8	0.30	0.8	357.8	447.3	1200		720.0	61%	Yes	Yes
Instructor Storage	137	Storage	245	0	0.12	0	0.00	29.4	0.8	36.8	0.27	0.8	29.4	36.8	135		81.0	120%	Yes	Yes
Special Education	140	Classroom	970	10	0.12	18	18.56	296.4	1.0	296.4	0.30	0.8	296.4	370.5	1000		600.0	62%	Yes	Yes
Classroom	141	Classroom	790	10	0.12	26	32.91	354.8	1.0	354.8	0.30	0.8	354.8	443.5	1200		720.0	62%	Yes	Yes
Classroom	142	Classroom	790	10	0.12	26	32.91	354.8	1.0	354.8	0.30	0.8	354.8	443.5	1200		720.0	62%	Yes	Yes
Classroom	143	Classroom	790	10	0.12	26	32.91	354.8	1.0	354.8	0.30	0.8	354.8	443.5	1200		720.0	62%	Yes	Yes
Classroom	144	Classroom	790	10	0.12	26	32.91	354.8	1.0	354.8	0.30	0.8	354.8	443.5	1200		720.0	62%	Yes	Yes
Classroom	145	Classroom	790	10	0.12	26	32.91	354.8	1.0	354.8	0.30	0.8	354.8	443.5	1200		720.0	62%	Yes	Yes
Custodial	147	Storage	55	0	0.12	0	0.00	6.6	1.0	6.6	0.33	0.8	6.6	8.3	20		12.0	45%	Yes	Yes
Corridor	149/150	Corridor	1670	0	0.06	0	0.00	100.2	1.0	100.2	0.29	0.8	100.2	125.3	350		210.0	68%	Yes	Yes
Conference	151	Conference	220	10	0.12	8	36.36	106.4	1.0	106.4	0.27	0.8	106.4	133.0	397		238.2	79%	Yes	Yes
Security	152	Office	65	5	0.06	1	15.38	8.9	1.0	8.9	0.27	0.8	8.9	11.1	33		19.8	78%	Yes	Yes
Conference	161	Conference	85	5	0.06	2	23.53	15.1	1.0	15.1	0.30	0.8	15.1	18.9	50		30.0	59%	Yes	Yes
Corridor	214/215	Corridor	1670	0	0.06	0	0.00	100.2	1.0	100.2	0.29	0.8	100.2	125.3	350		210.0	68%	Yes	Yes
Classroom	216	Classroom	815	10	0.12	26	31.90	357.8	1.0	357.8	0.30	0.8	357.8	447.3	1200		720.0	61%	Yes	Yes
Classroom	217	Classroom	815	10	0.12	26	31.90	357.8	1.0	357.8	0.30	0.8	357.8	447.3	1200		720.0	61%	Yes	Yes
Classroom	218	Classroom	815	10	0.12	26	31.90	357.8	1.0	357.8	0.30	0.8	357.8	447.3	1200		720.0	61%	Yes	Yes
Teacher Workroom	219	Office	245	5	0.06	0	0.00	14.7	1.0	14.7	0.11	0.8	14.7	18.4	135		81.0	341%	Yes	Yes
Special Education	222	Classroom	970	10	0.12	18	18.56	296.4	1.0	296.4	0.30	0.8	296.4	370.5	1000		600.0	62%	Yes	Yes
Classroom	223	Classroom	975	10	0.12	26	26.67	377.0	1.0	377.0	0.31	0.8	377.0	471.3	1200		720.0	53%	Yes	Yes
Classroom	224	Classroom	975	10	0.12	26	26.67	377.0	1.0	377.0	0.31	0.8	377.0	471.3	1200		720.0	53%	Yes	Yes
Classroom	225	Classroom	975	10	0.12	26	26.67	377.0	1.0	377.0	0.31	0.8	377.0	471.3	1200		720.0	53%	Yes	Yes
Classroom	226	Classroom	975	10	0.12	26	26.67	377.0	1.0	377.0	0.31	0.8	377.0	471.3	1200		720.0	53%	Yes	Yes
Classroom	227	Classroom	975	10	0.12	26	26.67	377.0	1.0	377.0	0.31	0.8	377.0	471.3	1209		725.4	54%	Yes	Yes
Custodial	229	Storage	55	0	0.12	0	0.00	6.6	1.0	6.6	0.33	0.8	6.6	8.3	20		12.0	45%	Yes	Yes
Corridor	315/316	Corridor	1430	0	0.06	0	0.00	85.8	1.0	85.8	0.25	0.8	85.8	107.3	350		210.0	96%	Yes	Yes
Classroom	317	Classroom	815	10	0.12	26	31.90	357.8	1.0	357.8	0.30	0.8	357.8	447.3	1200		720.0	61%	Yes	Yes
Classroom	318	Classroom	815	10	0.12	26	31.90	357.8	1.0	357.8	0.30	0.8	357.8	447.3	1200		720.0	61%	Yes	Yes
Classroom	319	Classroom	815	10	0.12	26	31.90	357.8	1.0	357.8	0.30	0.8	357.8	447.3	1200		720.0	61%	Yes	Yes
Instructor Storage	320	Storage	245	0	0.12	0	0.00	29.4	1.0	29.4	0.22	0.8	29.4	36.8	135		81.0	120%	Yes	Yes
Special Education	324	Classroom	970	10	0.12	18	18.56	296.4	1.0	296.4	0.30	0.8	296.4	370.5	1000		600.0	62%	Yes	Yes
Classroom	325	Classroom	750	10	0.12	26	34.67	350.0	1.0	350.0	0.29	0.8	350.0	437.5	1200		720.0	65%	Yes	Yes
Classroom	326	Classroom	750	10	0.12	26	34.67	350.0	1.0	350.0	0.29	0.8	350.0	437.5	1200		720.0	65%	Yes	Yes
Classroom	327	Classroom	750	10	0.12	26	34.67	350.0	1.0	350.0	0.29	0.8	350.0	437.5	1200		720.0	65%	Yes	Yes
Classroom	328	Classroom	750	10	0.12	26	34.67	350.0	1.0	350.0	0.29	0.8	350.0	437.5	1200		720.0	65%	Yes	Yes
Classroom	329	Classroom	750	10	0.12	26	34.67	350.0	1.0	350.0	0.29	0.8	350.0	437.5	1200		720.0	65%	Yes	Yes
Custodial	331	Storage	55	0	0.12	0	0.00	6.6	1.0	6.6	0.33	0.8	6.6	8.3	20		12.0	45%	Yes	Yes

Maximum Zp	0.33

Reading Elementary School - Reading, PA
ASHRAE 62.1 2007 Minimum Ventilation Calculations
AEI Team 5

AHU	Capacity cfm	Percent OA	OA cfm
RTU-5	8562	60.0%	5137.2

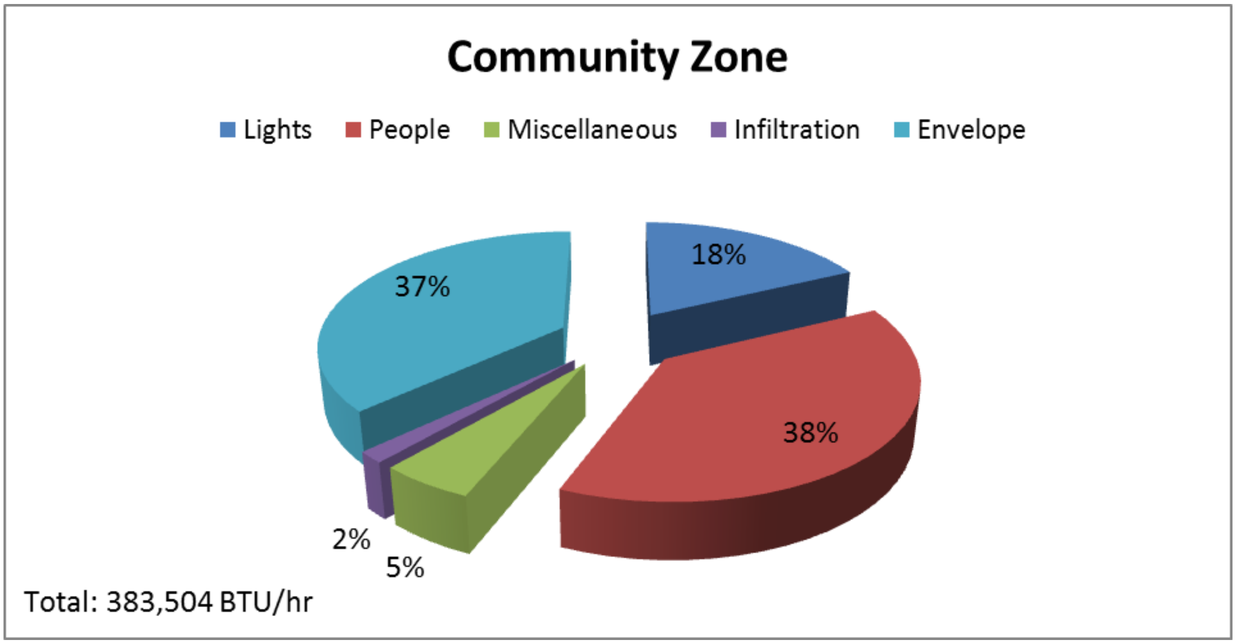
System Population, Ps	182
Zone Population, Pz	182
Occupant Diversity, D = (Pz-Ps)/Pz	100%

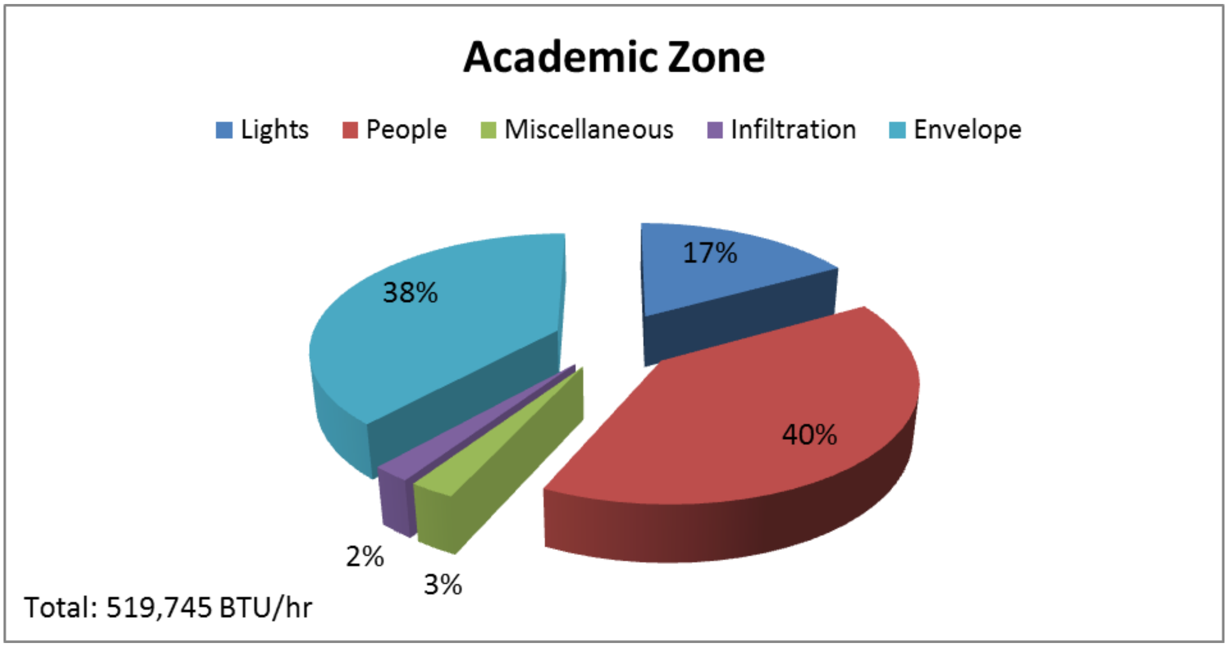
b a =a/b

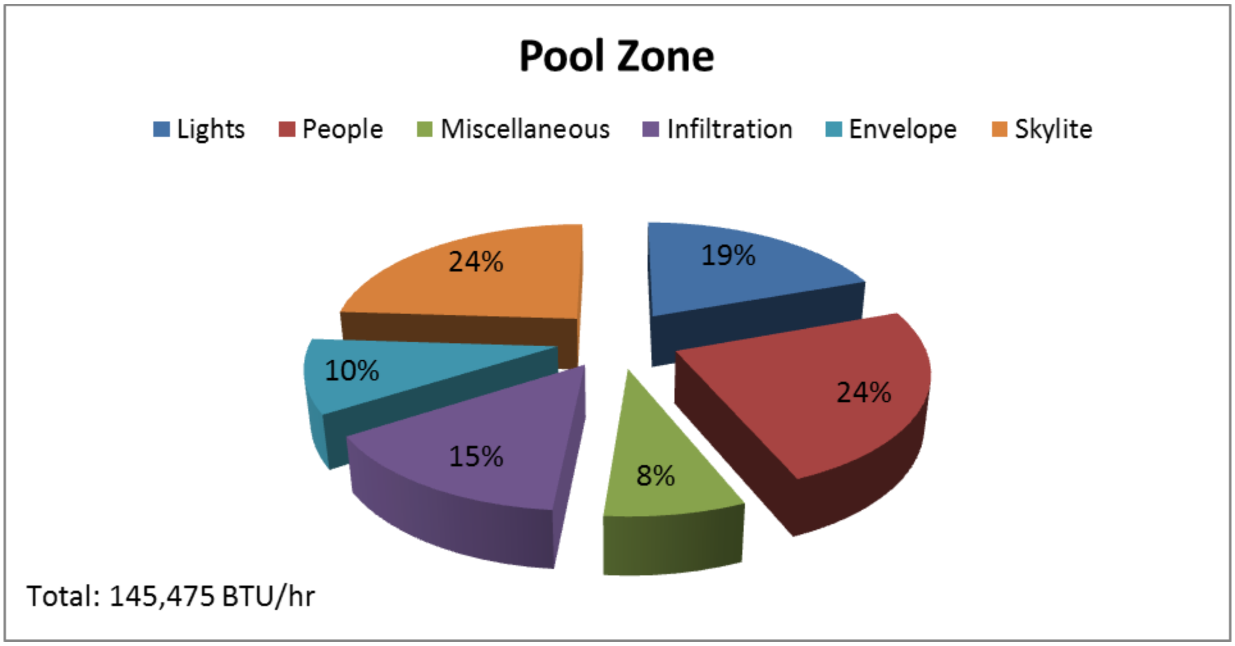
Room Name	Room Number	Occupancy Category	Area (SF)	People O.A. Rate (cfm/person)	Area O.A. Rate (cfm/SF)	# of Occupants Furniture	Occupant Density	Breathing Zone O.A. Flow Required Vbz	Table 6-2 Zone Air Dist. Eff.	Zone outdoor airflow	Primary O.A. fraction	Table 6.3 System Vent. Eff.	Uncorrected O.A. Intake	Design O.A. Intake	Zone Primary Air Flow Set Point (cfm)	Percent OA	Actual O.A. Flow	% Above Min OA	Meets Standard?	Meets LEED 30%?
			Az	Rp	Ra	Pz,f		Vbz = Rp*Pz + Ra*Az	Ez	Voz = Vbz / Ez	Zp = Voz / Vpz	Ev	Vou = D*∑(Rp*Pz) + ∑(Ra*Az)	Vot = Vou / Ev	Vpz		OA = % * Vpz	=(OA/Vot) -1		
RTU-5										**2667.2**	**0.31**	**0.8**	**2667**	**3334**	**8562**	**60.0%**	**5137**	**54%**	**Yes**	**Yes**
Corridor	153/154	Corridor	1085	0	0.06	0	0.00	65.1	1.0	65.1	0.33	0.8	65.1	81.4	200		120.0	47%	Yes	Yes
Classroom	155	Classroom	780	10	0.12	26	33.33	353.6	1.0	353.6	0.34	0.8	353.6	442.0	1050		630.0	43%	Yes	Yes
Vestibule	156	Vestibule	100	0	0.06	0	0.00	6.0	1.0	6.0	0.01	0.8	6.0	7.5	762		457.2	5996%	Yes	Yes
Maintenance	157/158	Storage	275	0	0.12	0	0.00	33.0	1.0	33.0	0.33	0.8	33.0	41.3	100		60.0	45%	Yes	Yes
Classroom	159	Classroom	780	10	0.12	26	33.33	353.6	1.0	353.6	0.35	0.8	353.6	442.0	1000		600.0	36%	Yes	Yes
Classroom	160	Classroom	780	10	0.12	26	33.33	353.6	1.0	353.6	0.35	0.8	353.6	442.0	1000		600.0	36%	Yes	Yes
Corridor	231/232	Corridor	1085	0	0.06	0	0.00	65.1	1.0	65.1	0.33	0.8	65.1	81.4	200		120.0	47%	Yes	Yes
Classroom	233	Classroom	730	10	0.12	26	35.62	347.6	1.0	347.6	0.33	0.8	347.6	434.5	1050		630.0	45%	Yes	Yes
Classroom	234	Classroom	1020	10	0.12	26	25.49	382.4	1.0	382.4	0.32	0.8	382.4	478.0	1200		720.0	51%	Yes	Yes
Classroom	235	Classroom	780	10	0.12	26	33.33	353.6	1.0	353.6	0.35	0.8	353.6	442.0	1000		600.0	36%	Yes	Yes
Classroom	236	Classroom	780	10	0.12	26	33.33	353.6	1.0	353.6	0.35	0.8	353.6	442.0	1000		600.0	36%	Yes	Yes

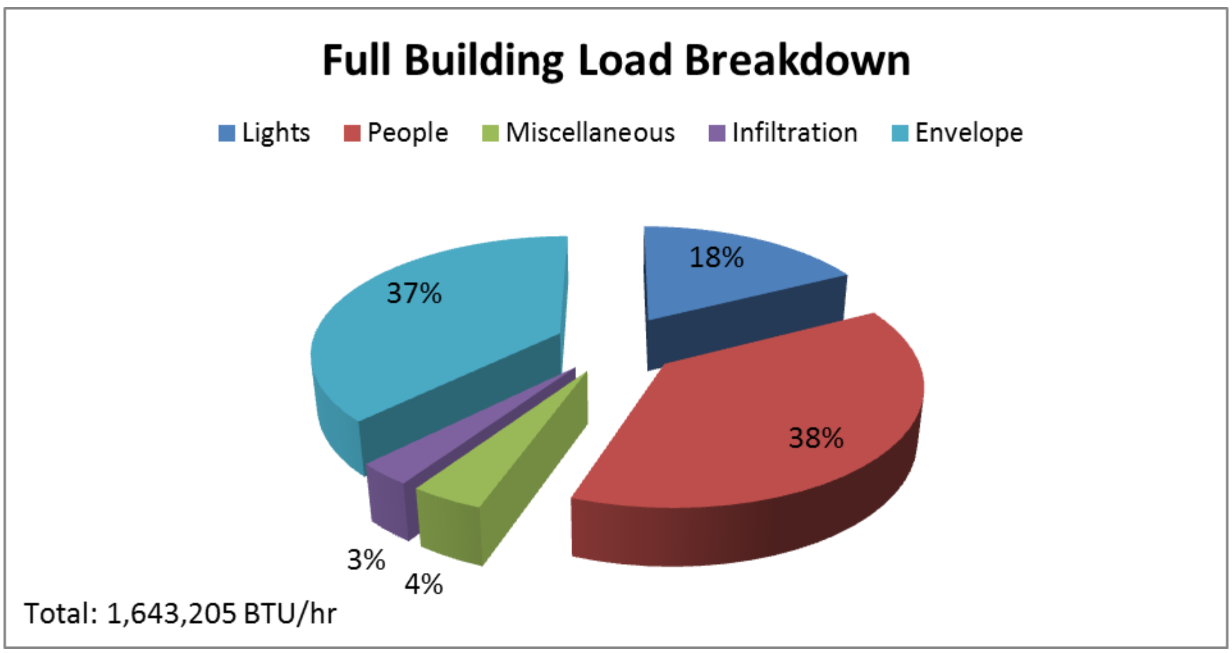
Maximum Zp	0.35

6.3 LOAD PROFILES AND BREAKDOWNS

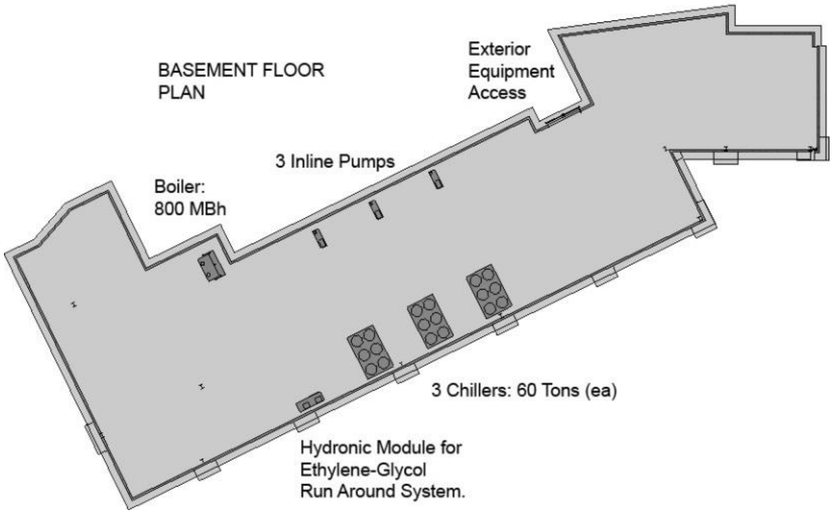





Pool Zone
Lights
People
Miscellaneous
Infiltration
Envelope
Skylite
24%
19%
10%
24%
15%
8%
Total: 145,475 BTU/hr


Full Building Load Breakdown
Lights
People
Miscellaneous
Infiltration
Envelope
18%
37%
38%
3%
4%
Total: 1,643,205 BTU/hr

6.4 MECHANICAL ROOM LAYOUT

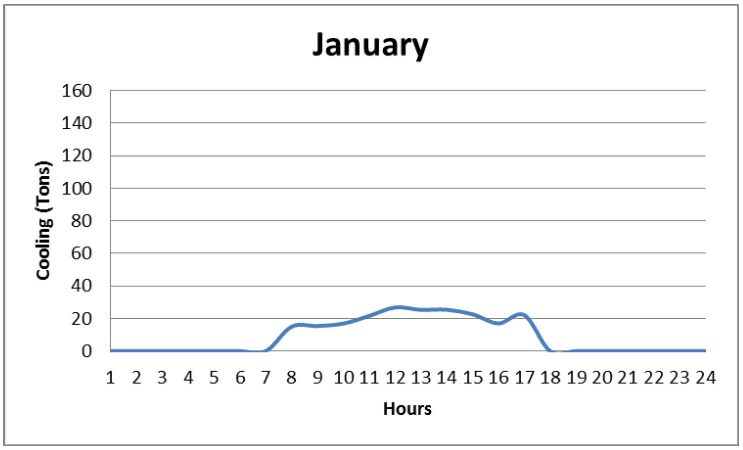


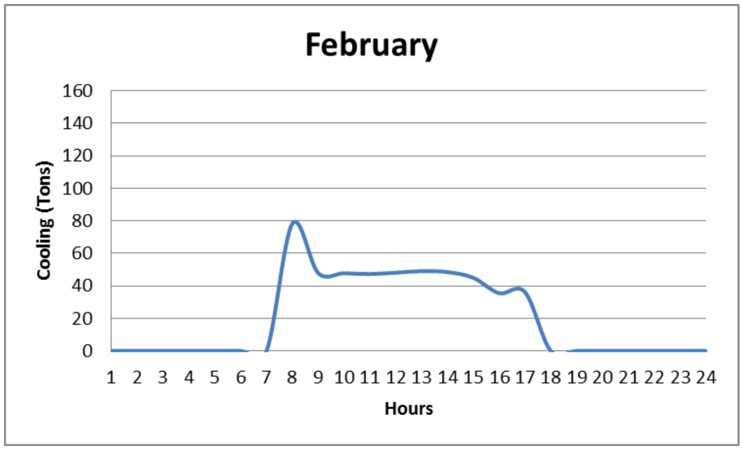
The majority of the mechanical equipment will be housed in the basement. There are three chillers placed 10 feet apart and 3 inline pumps across from the chillers. The main boiler will be located in the upper left hand corner and the hydronic module for the ethylene glycol system is located in the bottom left. This room will be accessible from the exterior of the building for maintenance purposes from an exterior access panel located along one wall.

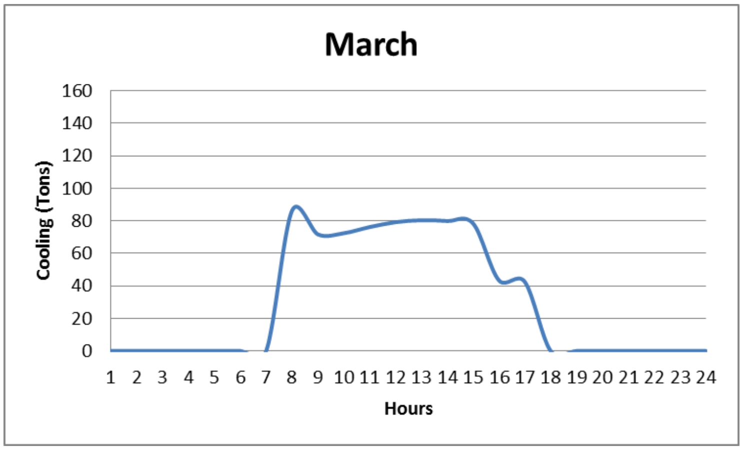
6.5 MECHANICAL EQUIPMENT SUMMARY

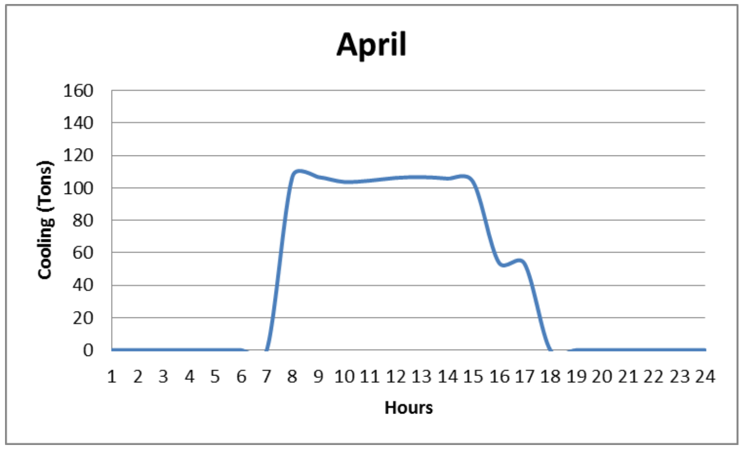
Equipment Breakdown			
Equipment	**Description**	**Capacity**	**Price**
Chiller-1	Rotary-Screw Water Chillers	60 Tons	$ 55,300.00
Chiller-2	Rotary-Screw Water Chillers	60 Tons	$ 55,300.00
Chiller-3	Rotary-Screw Water Chillers	60 Tons	$ 55,300.00
Cooling Tower	Axial Fan, Induced Draft	175 Tons	$ 27,375.00
Boiler-1	Gas-Fired Boiler	800 MBh	$ 16,475.00
Boiler-2	Gas-Fired Boiler	350 MBh	$ 7,725.00
OAU-1	Dedicated Outdoor Air	38,000 CFM	$ 172,400.00
OAU-2	Dedicated Outdoor Air	27,000 CFM	$ 163,200.00
OAU-3	Dedicated Outdoor Air	8,000 CFM	$ 54,400.00
EAU-1	Exhaust Air Unit	34,500 CFM	$ 12,320.00
EAU-2	Exhaust Air Unit	24,500 CFM	$ 10,540.00
EAU-3	Exhaust Air Unit	9,000 CFM	$ 5,600.00
Ethylene-Glycol System	Without Pool	65,000 CFM	$ 295,000.00
Ethylene-Glycol System	With Pool	8,000 CFM	$ 355,000.00
Total	**Without Pool**		**$ 863,210.00**
Total	**With Pool**		**$ 990,935.00**

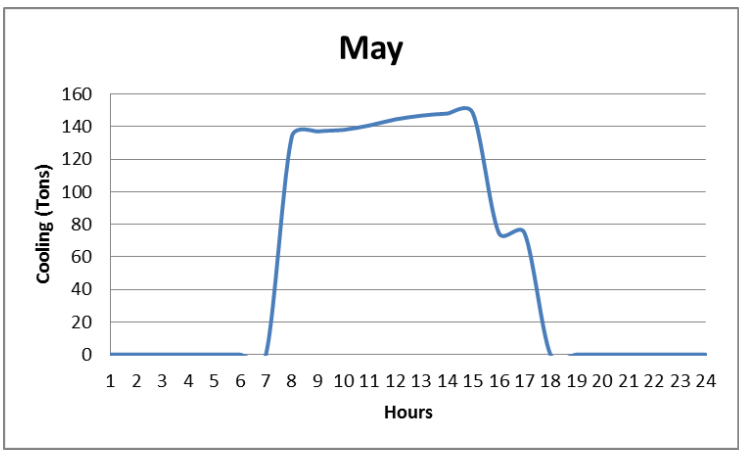
6.6 CHILLER COOLING DEMAND PROFILES

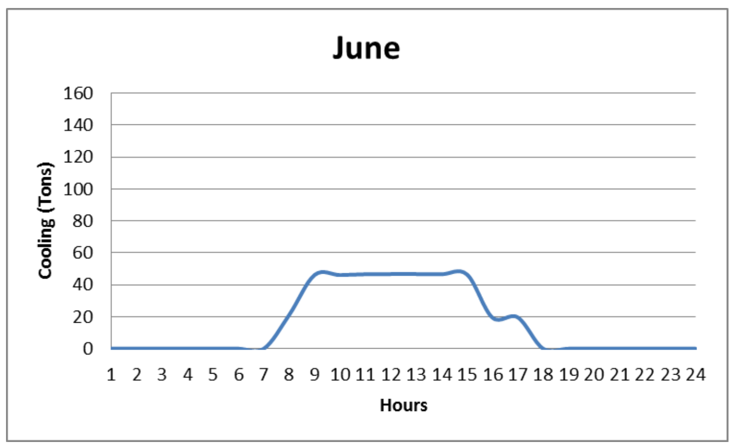


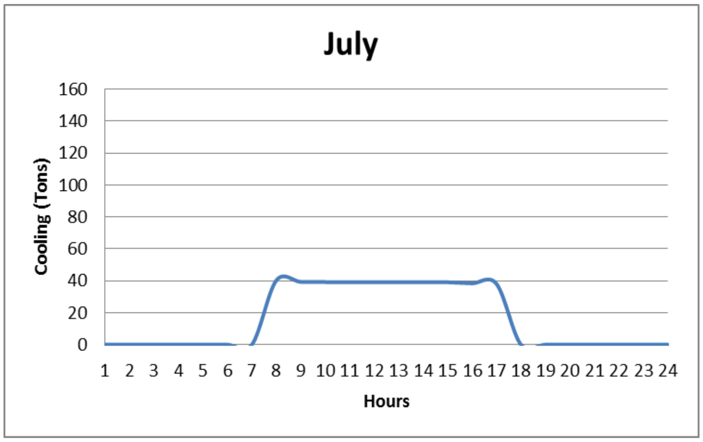


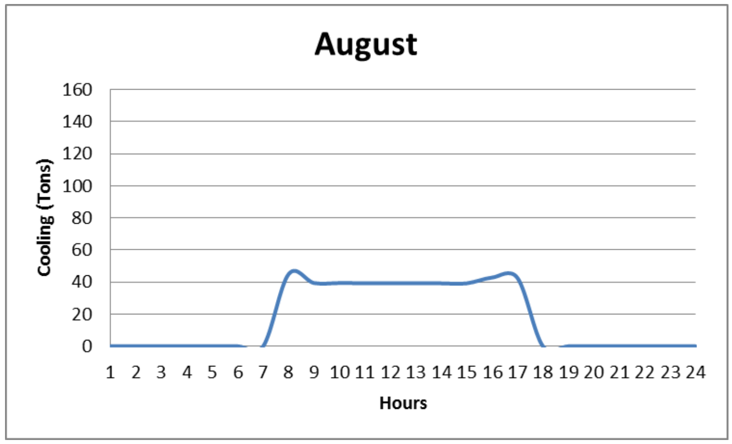


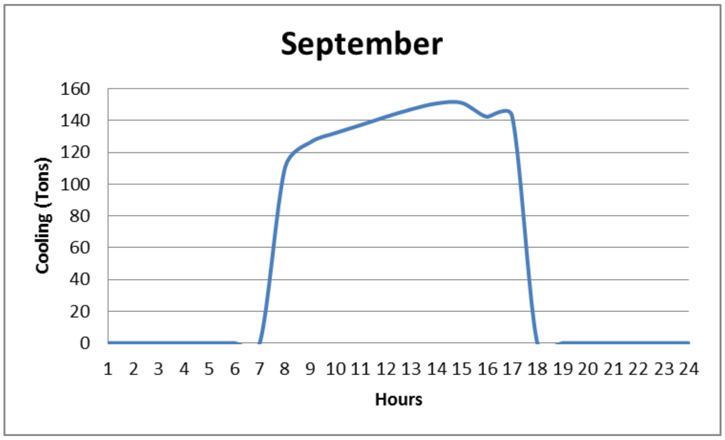


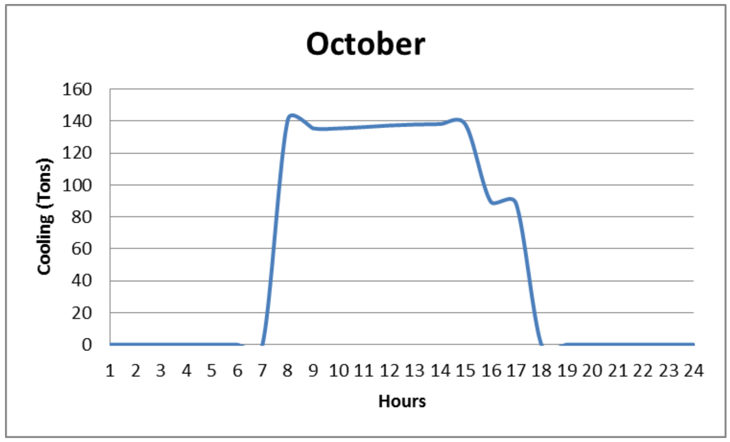


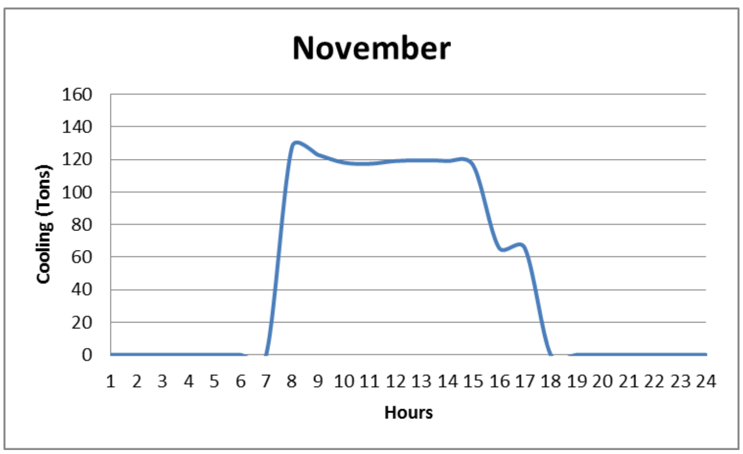


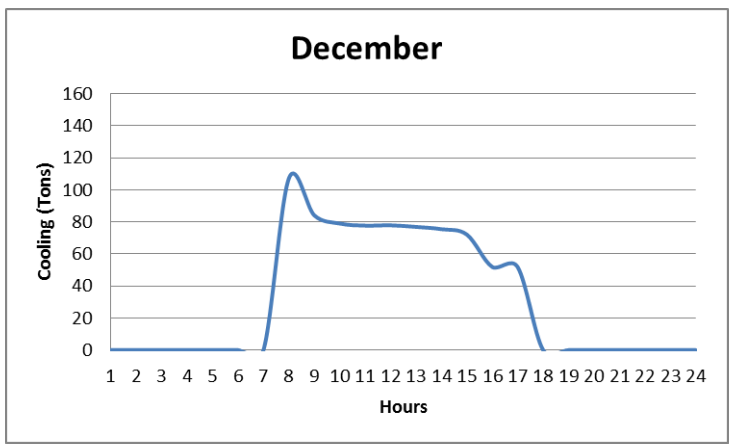

July
Cooling (Tons)
160
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours


August
Cooling (Tons)
160
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours

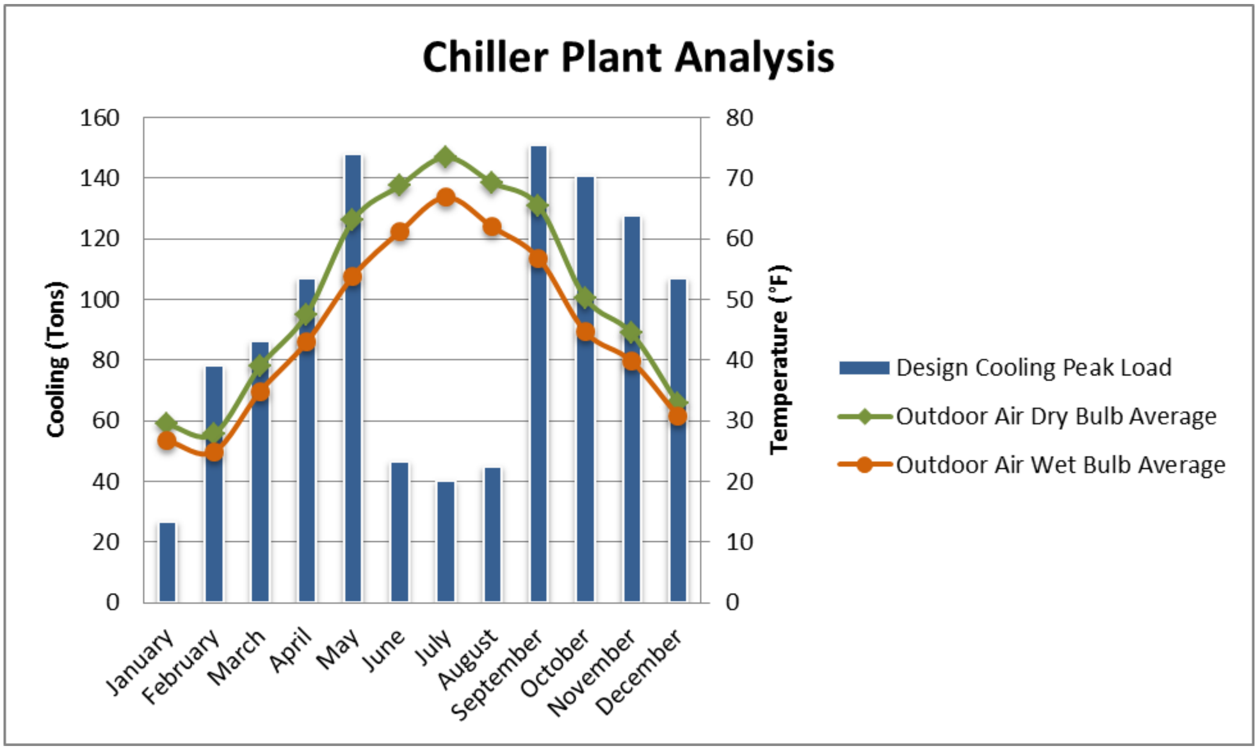

September
Cooling (Tons)
160
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours


October
Cooling (Tons)
160
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours


November
Cooling (Tons)
160
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours


December
Cooling (Tons)
160
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours

6.7 CHILLER PLANT ANALYSIS



6.8 FIN DATA FOR HEAT EXCHANGER

		SHRC AHU 1	SHRC AHU 2	SHRC AHU 3
Quantity		2	2	1
Design				
type	(fin spacing - mm)	3.0	3.0	3.0
height	(inch)	49.4	41.5	47.4
length	(inch)	145.7	126.0	70.9
installed depth	(inch)	16.3	15.9	15.9
weight (dry)	(lb)	2x 2249	2x 1632	1058
water capacity	(gal)	2x 64.2	2x 45.5	30.6
corrosion protection		KO31	KO31	KO31
materials				
tubes		copper	copper	copper
fins (suitable for hp cleaning 2600 psi)		alu (0.0157inch)	alu (0.0157inch)	alu (0.0157inch)
collectors		steel	steel	steel
Rating data air side				
Media		AIR	AIR	AIR
volume flow	(cfm)	2x 17627	2x 12760	7799
intake	(°F/%r.h.)	30.0/ 65	30.0/ 65	30.0/ 65
outlet	(°F/%r.h.)	64.9/ 17	64.9/ 17	64.9/ 17
pressure drop	(inch H2O)	0.551	0.551	0.512
Rating data water side				
Media		ETH-GLY 30 %w	ETH-GLY 30 %w	ETH-GLY 30 %w
volume flow	(gpm)	2x 48.11	2x 34.83	21.29
intake / outlet	(°F)	71.6/ 41.6	71.6/ 41.6	71.6/ 41.6
pressure drop	(ft H2O)	97	97	101
Performance	**(Btu/h)**	2x 682508	2x 494128	301739

		EHRC EAHU 1	EHRC EAHU 2	EHRC EAHU 3
Quantity		2	2	1
Design				
type	(fin spacing - mm)	3.0	3.0	3.0
height	(inch)	45.5	41.5	47.4
length	(inch)	135.8	126.0	70.9
installed depth	(inch)	16.3	15.9	15.9
weight (dry)	(lb)	2x 1940	2x 1632	1058
water capacity	(gal)	2x 55.6	2x 45.5	30.6
corrosion protection		KO32	KO31	KO31
materials				
tubes		copper	copper	copper
fins (suitable for hp cleaning 2600 psi)		alu coated (0.4)	alu (0.0157inch)	alu (0.0157inch)
collectors		steel	steel	steel
Rating data air side				
Media		AIR	AIR	AIR
volume flow	(cfm)	2x 14997	2x 12760	7999
intake	(°F/%r.h.)	75.0/ 60	75.0/ 60	75.0/ 60
outlet	(°F/%r.h.)	52.5/ 96	52.3/ 96	52.4/ 96
pressure drop	(inch H2O)	0.669	0.669	0.669
Rating data water side				
Media		ETH-GLY 30 %w	ETH-GLY 30 %w	ETH-GLY 30 %w
volume flow	(gpm)	2x 44.20	2x 37.60	23.58
intake / outlet	(°F)	41.4/ 71.5	41.4/ 71.8	41.4/ 71.6
pressure drop	(ft H2O)	92	92	89
Performance	**(Btu/h)**	2x 627702	2x 539711	336822

6.9 ETHYLENE GLYCOL ENERGY COMPARISONS

Energy/Financial Comparison: Pennsylvania State AEI

OAU-1/2, EAHU-1/2

SUMMARY		Without E Recovery	Konvekta System
Winter			
Heating Energy Requirement	kWh/a	856,050	402,000
Effectiveness Heating			0.53
Summer			
Cooling Energy Requirement	kWh/a	194,610	178,410
Effectiveness Cooling/Reheat			0.08
Year			
Heating Energy	kWh/a	856,050	402,000
Cooling Energy	kWh/a	194,610	178,410
Electricity (Δ Fans, Pumps)	kWh/a	0	14,503
Total Energy Consumption	kWh/a	1,050,660	594,913
Effectiveness			43%
Peak Demand			
Cooling	kW	1,525	1,355
	tons	433	385
Heat	kW	1,340	535
	MBTU/h	4,572	1,825

Energy/Financial Comparison: Pennsylvania State AEI

OAU-1/2/3, EAHU-1/2/3

SUMMARY		Without E Recovery	Konvekta System
Winter			
Heating Energy Requirement	kWh/a	965,900	407,500
Effectiveness Heating			0.58
Summer			
Cooling Energy Requirement	kWh/a	219,660	200,460
Effectiveness Cooling/Reheat			0.09
Year			
Heating Energy	kWh/a	965,900	407,500
Cooling Energy	kWh/a	219,660	200,460
Electricity (Δ Fans, Pumps)	kWh/a	0	16,514
Total Energy Consumption	kWh/a	1,185,560	624,474
Effectiveness			47%
Peak Demand			
Cooling	kW	1,722	1,522
	tons	489	432
Heat	kW	1,512	411
	MBTU/h	5,159	1,402

6.10 ACOUSTIC ANALYSIS

Acoustic Analysis

Classrooms without Acoustic Metal Deck

Recommended T60 Time: 0.4 - 0.8 s

Dimensions		
Height	13	ft
Width	30	ft
Length	28	ft
Volume	10,920	cf
Window		
Height	8	ft
Width	7	ft
AREA	112	sf

	Material	Composition	Area /Quanity		Absorptivity (α) 125	250	500	1000	2000	4000	A*α 125	250	500	1000	2000	4000
Walls	Gyp	1/2" Thick on 2x4 metal stud 16" O.C.	1396	sf	0.29	0.1	0.05	0.04	0.07	0.09	404.8	139.6	69.8	55.8	97.7	125.6
Ceiling	Acoustic Metal Deck	3VLPA w/Insulation	840	sf	0.33	0.31	0.3	0.14	0.09	0.01	277.2	260.4	252.0	117.6	75.6	8.4
Flooring	Carpet	Carpet, Heavy Tile on Concrete	840	sf	0.02	0.06	0.14	0.37	0.06	0.065	16.8	50.4	117.6	310.8	50.4	54.6
Window	Glass	Double Pane Argon B_ITCH	112	sf	0.3	0.2	0.2	0.1	0.07	0.04	33.6	22.4	22.4	11.2	7.8	4.5
Occupant	Student's Informally Dressed seated in Tablet Arm Chairs		29	per	0.3	0.41	0.49	0.84	0.87	0.84	8.7	11.9	14.2	24.4	25.2	24.4
Treatment	N/A															

	Sound Pressure Level (dB) 125	250	500	1000	2000	4000
Classroom	66	72	77	74	68	60

$$T_{60} = 0.05V/A$$

V	10,920
A_{125}	741.1
A_{250}	484.7
A_{500}	476.0
A_{1000}	519.8
A_{2000}	256.8
A_{4000}	217.5

Frequency	$T_{60\,(s)}$
125 Hz	0.7367029
250 Hz	1.1264932
500 Hz	1.1470347
1000 Hz	1.050404
2000 Hz	2.126251
4000 Hz	2.5105757

Acoustic Analysis

Classrooms with Acoustic Metal Deck

Recommended T60 Time: 0.4 - 0.8 s

Dimensions		
Height	13	ft
Width	30	ft
Length	28	ft
Volume	10,920	cf
Window		
Height	8	ft
Width	7	ft
AREA	112	sf

	Material	Composition	Area /Quanity		Absorptivity (α) 125	250	500	1000	2000	4000	A*α 125	250	500	1000	2000	4000
Walls	Gyp	1/2" Thick on 2x4 metal stud 16" O.C.	1396	sf	0.29	0.1	0.05	0.04	0.07	0.09	404.8	139.6	69.8	55.8	97.7	125.6
Ceiling	Acoustic Metal Deck	3VLPA w/Insulation	840	sf	0.4	0.56	1.07	0.78	0.57	0.35	336.0	470.4	898.8	655.2	478.8	294.0
Flooring	Carpet	Carpet, Heavy Tile on Concrete	840	sf	0.02	0.06	0.14	0.37	0.06	0.065	16.8	50.4	117.6	310.8	50.4	54.6
Window	Glass	Double Pane Argon B_ITCH	112	sf	0.3	0.2	0.2	0.1	0.07	0.04	33.6	22.4	22.4	11.2	7.8	4.5
Occupant	Student's Informally Dressed seated in Tablet Arm Chairs		29	per	0.3	0.41	0.49	0.84	0.87	0.84	8.7	11.9	14.2	24.4	25.2	24.4
Treatment	N/A															

	Sound Pressure Level (dB) 125	250	500	1000	2000	4000
Classroom	66	72	77	74	68	60

$$T_{60} = 0.05V/A$$

V	10,920
A_{125}	799.9
A_{250}	694.7
A_{500}	1122.8
A_{1000}	1057.4
A_{2000}	660.0
A_{4000}	503.1

Frequency	$T_{60\,(s)}$
125 Hz	0.6825512
250 Hz	0.7859621
500 Hz	0.48628
1000 Hz	0.5163609
2000 Hz	0.8272853
4000 Hz	1.0853145

TYPICAL CLASSROOM ACOUSTIC ANALYSIS

Room Dimensions
Height: 13 ft
Width: 30 ft
Length: 28 ft
Volume: 10,920 cf

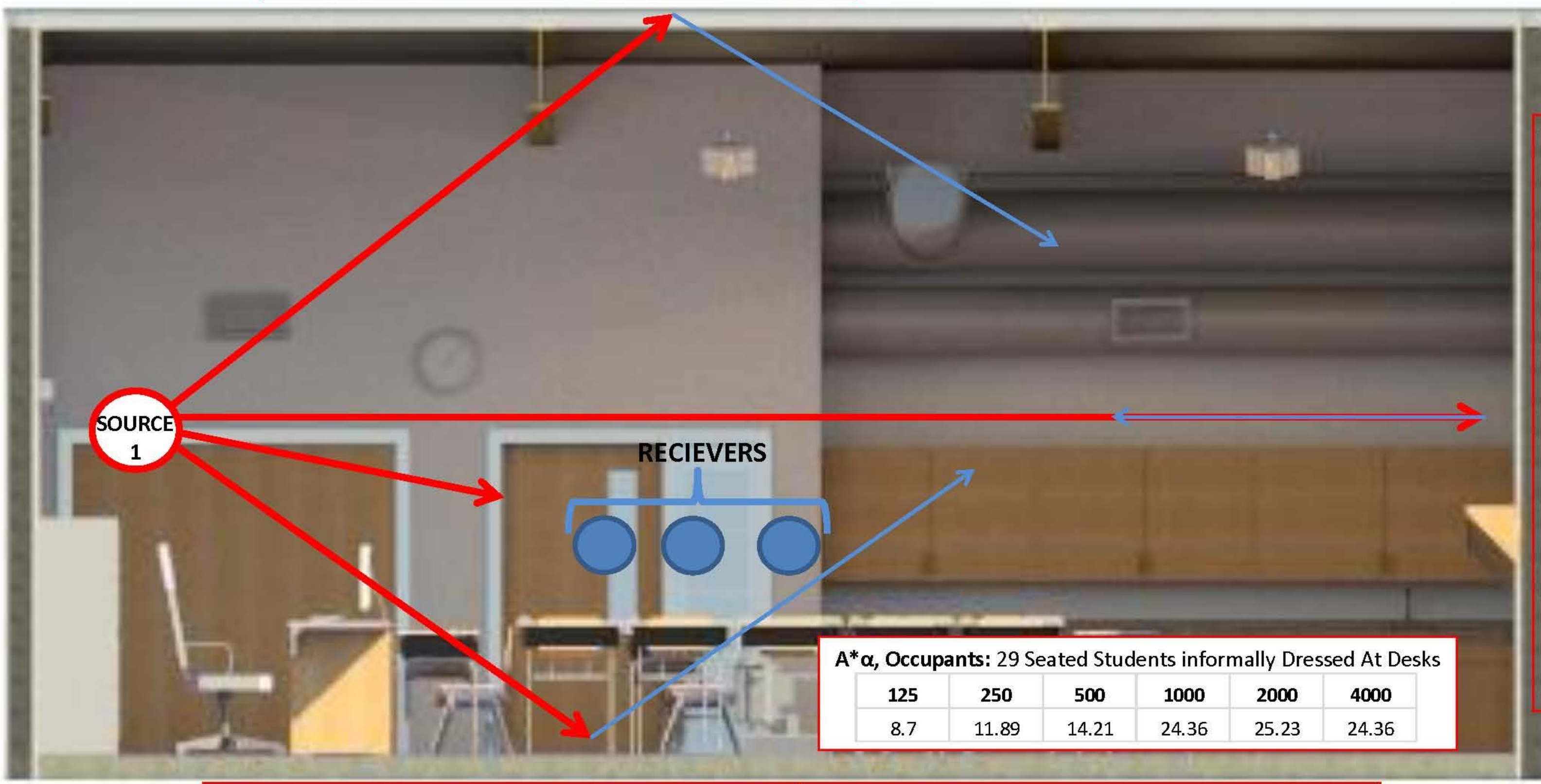
$T_{60}(Reverb\ Time) = 0.05V/A$

Recommended Time For Elementary School Classrooms: 0.6-0.8 seconds

Frequency (Hz)	125	250	500	1000	2000	4000
Room T_{60} (s)	0.682551	0.785962	0.48628	0.516361	0.827285	1.085314

A*α, Ceiling: 3VLPA Metal Deck w/Insulation- 840 sf

125	250	500	1000	2000	4000
336	470.4	898.8	655.2	478.8	294



A*α, Walls: 1/2" Thick on 2x4 metal stud 16" O.C.- 1396 sf

125	250	500	1000	2000	4000
404.84	139.6	69.8	55.84	97.72	125.64

A*α, Occupants: 29 Seated Students informally Dressed At Desks

125	250	500	1000	2000	4000
8.7	11.89	14.21	24.36	25.23	24.36

A*α, Flooring: Heavy Traffic Carpet Tile on Concrete- 840 sf

125	250	500	1000	2000	4000
16.8	50.4	117.6	310.8	50.4	54.6

A*α, Glazing: Double Pane Argon – 122sf

125	250	500	1000	2000	4000
33.6	22.4	22.4	11.2	7.8	4.5

6.11 MSDS REPORT

Health	1
Fire	1
Reactivity	0
Personal Protection	C

Material Safety Data Sheet
Ethylene glycol MSDS

Section 1: Chemical Product and Company Identification

Product Name: Ethylene glycol

Catalog Codes: SLE1072

CAS#: 107-21-1

RTECS: KW2975000

TSCA: TSCA 8(b) inventory: Ethylene glycol

CI#: Not available.

Synonym: 1,2-Dihydroxyethane; 1,2-Ethanediol; 1,2-Ethandiol; Ethylene dihydrate; Glycol alcohol; Monoethylene glycol; Tescol

Chemical Name: Ethylene Glycol

Chemical Formula: HOCH2CH2OH

Contact Information:

Sciencelab.com, Inc.
14025 Smith Rd.
Houston, Texas 77396

US Sales: **1-800-901-7247**
International Sales: **1-281-441-4400**

Order Online: ScienceLab.com

CHEMTREC (24HR Emergency Telephone), call:
1-800-424-9300

International CHEMTREC, call: 1-703-527-3887

For non-emergency assistance, call: 1-281-441-4400

Section 2: Composition and Information on Ingredients

Composition:

Name	CAS #	% by Weight
Ethylene glycol	107-21-1	100

Toxicological Data on Ingredients: Ethylene glycol: ORAL (LD50): Acute: 4700 mg/kg [Rat]. 5500 mg/kg [Mouse]. 6610 mg/kg [Guinea pig]. VAPOR (LC50): Acute: >200 mg/m 4 hours [Rat].

Section 3: Hazards Identification

Potential Acute Health Effects:
Hazardous in case of ingestion. Slightly hazardous in case of skin contact (irritant, permeator), of eye contact (irritant), of inhalation. Severe over-exposure can result in death.

Potential Chronic Health Effects:
CARCINOGENIC EFFECTS: A4 (Not classifiable for human or animal.) by ACGIH. MUTAGENIC EFFECTS: Mutagenic for mammalian somatic cells. Non-mutagenic for bacteria and/or yeast. TERATOGENIC EFFECTS: Not available. DEVELOPMENTAL TOXICITY: Not available. The substance may be toxic to kidneys, liver, central nervous system (CNS). Repeated or prolonged exposure to the substance can produce target organs damage. Repeated exposure to a highly toxic material may produce general deterioration of health by an accumulation in one or many human organs.

Section 4: First Aid Measures

6.12 ECONOMIC SUMMARY- TRANE TRACE700

Economic Summary

Project Information

Location	Reading, PA	Study Life:	20 years
Project Name	Elementary School	Cost of Capital:	10 %
User		Alternative 1:	Reading Elementary School
Company			
Comments			

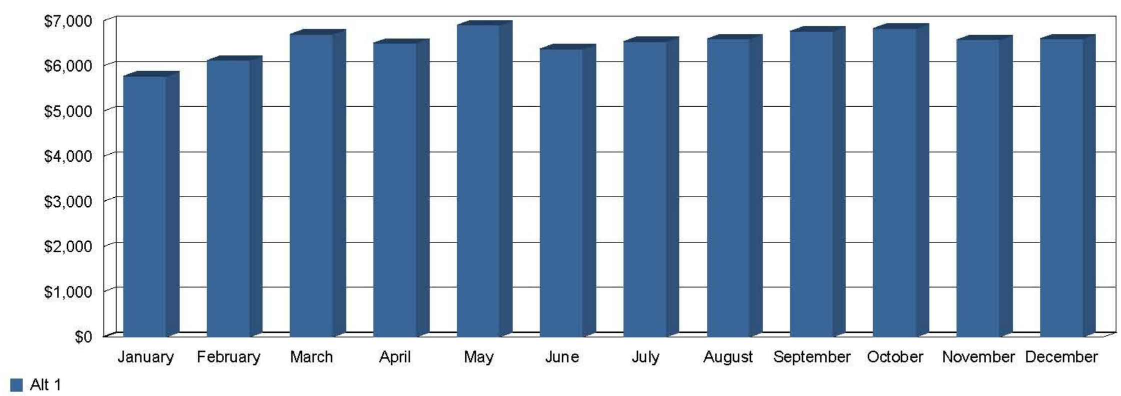
Economic Comparison of Alternatives

Yearly Savings ($)	First Cost Difference ($)	Cumulative Cash Flow Difference ($)	Simple Payback (yrs.)	Net Present Value ($)	Life Cycle Payback (yrs.)	Internal Rate of Return (%)	Life Cycle Cost

Annual Operating Costs

Yearly Total Operating Cost ($)	Yearly Utility Cost ($)	Yearly Maintenance Cost ($)	Plant kWh/ton-hr

Monthly Utility Costs



Project Name:	Elementary School		TRACE 700 6.2.8
Dataset Name:	READING ELEM EQ.TRC		calculated at 01:24 PM on 12/13/2012