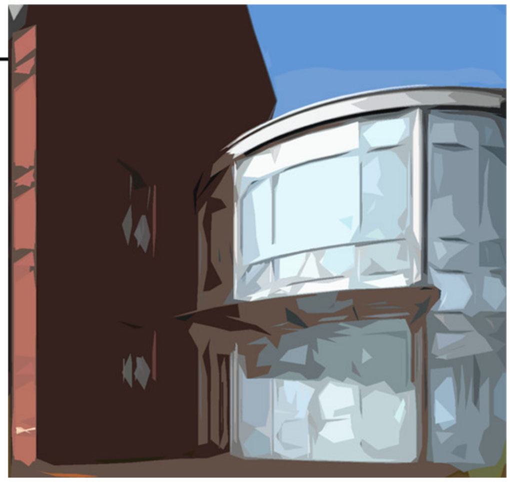
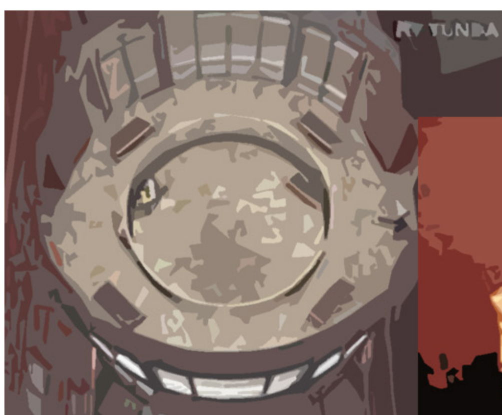


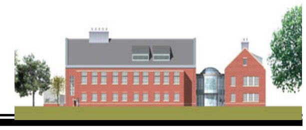
Jack E. Nill III

Construction Management
Thesis - Spring 2005

Episcopal High School New Science Facility
Alexandria, VA



Department of Architectural Engineering
The Pennsylvania State University



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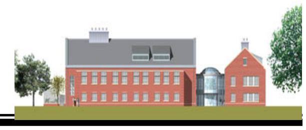

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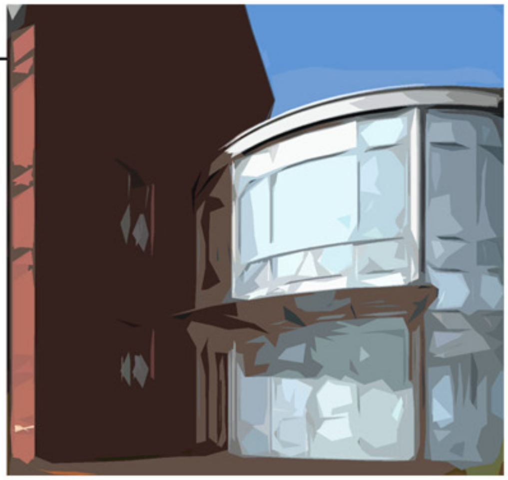
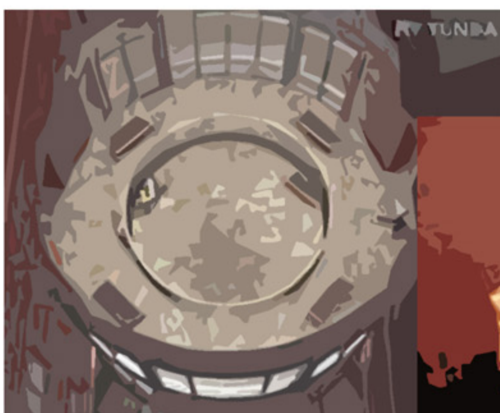
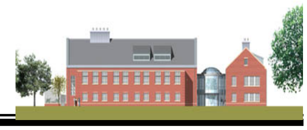


Executive Summary





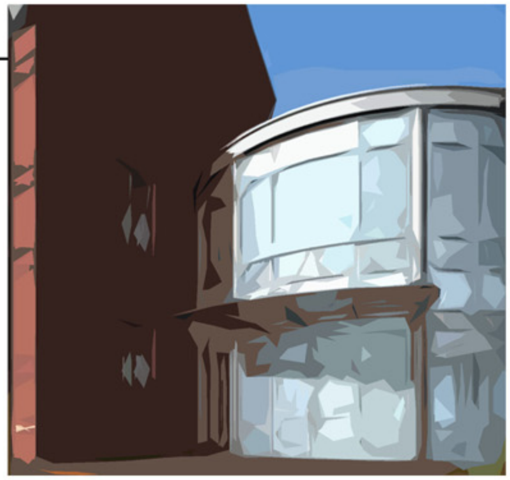
Executive Summary

The following senior thesis is the result of an analysis of the Episcopal High School New Science Facility. It focuses on various methods for improving the design and construction of this building as well as research in the emerging industry market of Storm water Reclamation Systems for green construction. The following report is broken into four sections. The first section will provide a project background. The second section is and analysis of the existing building envelope and impacts of implementing an alternate system. The third section looks at an upgrade to the building's mechanical system. The final section is an analysis of Storm water Reclaim Systems and their emergence in the green construction industry.

One of the primary focuses of green buildings is to obtain the highest efficiency building feasible. The analysis of the building envelope and wall system was performed to determine the appropriateness of implementing a Zero Percent Air Infiltration system. This system will have many impacts on the project that must be analyzed and compared to determine its feasibility such as initial cost, schedule impacts, constructability, and energy savings. Significant energy savings may result in the reduction of mechanical equipment size.

Along the same lines as the first analysis, mechanical systems are a primary part of high performance buildings. Four sustainable upgrades are considered for the existing mechanical system. An energy cost model was run to determine the energy cost savings per year for the upgraded system. These savings are then compared to the initial cost of the upgraded system. The significant construction management concerns are also factored in, and the feasibility of the upgraded system is determined.

The conservation of our natural resources is always found at the core of green building design and motives. The water efficiency portion of the New Science facility is perhaps its most innovative and interesting designs. Other projects have realized the importance of striving for a water efficient design. Three projects utilizing different types of Storm water Reclamation systems were studied and analyzed to better understand the barriers and conflicts when dealing with this new building market. Advantages and disadvantages of each system as well as an analysis of ways to mitigate onsite conflicts or issues are documented for future research of these types of systems.



Proposal

Proposal

Introduction

The core focus of this thesis research will revolve around the emerging industry market of high performance sustainable buildings as we discussed at the PACE Roundtable. Green building and LEED rated buildings have become increasingly popular in recent years and is now a powerful emerging market in the industry. Due to its intense and often complex requirements for both design and construction, many industry members struggle with this new type of building. It is important as students that we use the tools and knowledge on these systems available to us to learn as much as we can while still in school, so that we can bring this knowledge with us to the industry when we graduate. Green buildings focus on sustainable construction and high performance systems that increase the efficiency of the building, make it more environmentally friendly and reduce the life cycle energy requirements and cost of the building. For these reasons green design impacts every part of the building from the high performance mechanical systems to the location materials are procured to the way waste is disposed of on a site.

The Episcopal High School New Science Facility is a Green building design attempting to achieve a Silver LEED rating. Many unique features of this building have been designed to help achieve this rating. Many of these features are extremely new to contractors and have the potential to cause many conflicts on a project. Familiarity with the LEED credit system and how it applies to this particular project is a vital portion of the analysis. The three particular aspects of this project the research will focus on are as follows:

- Wall System: Zero Percent Air Infiltration
- HVAC Analysis/Upgrade
- Storm Water Reclamation System Analysis

Figure 1: The weight matrix located at the end of this proposal gives the breakdown of how this thesis will focus the research and analysis efforts as well as which areas of investigation each system will cover.

Analysis I: Zero Percent Air Infiltration

First, the research will focus on the redesign of the exterior wall system. This redesign is a switch from the existing brick veneer w/ metal stud back up to a "Zero Percent Air Infiltration System." The zero percent air infiltration (ZPAI) system is a new type of construction that was originally developed in Canada for buildings in extreme climates; however, this system to could be a very useful component that will aid buildings in achieving sustainability and high performance construction standards. A system such as this can dramatically reduce the heat loads, increase energy efficiency and reduce life cycle cost for a building.

In researching the new system each of the areas of investigation will be touched on in one respect or another as well as tie into the required breadth work. One of the most critical areas requiring considered will be the constructability of the new system. A new system that proposes to decrease the air infiltration through the wall will require extremely high quality construction processes and new types of wall components. These changes will impact the contractor in terms of both cost and schedule. Each of these impacts must be reviewed and analyzed to understand the overall benefits of such a system.

The first portion of the research will be to become familiar with components, applications and properties of this unique wall system. The primary means used to do this will be personal interviews of manufacturers, architects and engineers who have experience with this system. To complete the research several industry members will be contacted to obtain their expertise with such systems as well as an extensive literary review on the particular system will be conducted. These industry members include architects, mechanical engineers as well as general contractors. Each member interviewed will be asked a series of questions found attached in Appendix A, as well as their professional opinion on the practicality of implementing such a system. The research will then be compiled and analyzed. Each system will be compared against one another and the cost verses benefit chart will be documented for others to use in their consideration of this type of system in the future.

Analysis II: HVAC System Analysis

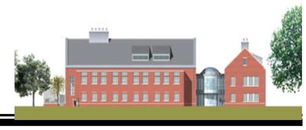
By proposing a change in the outside air infiltration properties of the building, the mechanical loads required will be impacted. If the impacts on the required loads are significant it will result in a redesign of the mechanical system to better suit the lower loads that are now required.

Building on my primary research topic I will analyze the existing HVAC system for the building and redesign/upgrade the system to meet the new load requirements as well as achieve a higher performance system. This will cover areas of investigation such as Value Engineering ideas as well as possible schedule impacts with an alternate system. This system analysis will also cover the breadth requirements for the thesis research.

Using the help of the mechanical engineers I will analyze the impacts of this type of system. Recalculation of the heating and cooling loads using the new air infiltration properties will need to be performed and applied. These loads will possibly induce a resizing of the mechanical equipment. Upgrades to the existing system will also be analyzed and compared to the current design to try to obtain the most efficient design. The new equipment could also be potentially smaller reducing upfront cost as well as long term cost benefits. This redesign will require a life cycle cost comparison using DOE II software from the department of energy. This comparison will then be analyzed to determine the appropriateness for using this alternate HVAC system.

Analysis III: Storm Water Reclamation System

One of the most unique aspects of this project is the Storm Water Reclaim system, also known as a Rainwater Catchment System. This is a system that gathers all the storm runoff water and channels it into a 20,000 gallon fiberglass storage tank located beneath grade. This water is then pumped out of the tank as needed to a filter structure that treats the water with chemicals

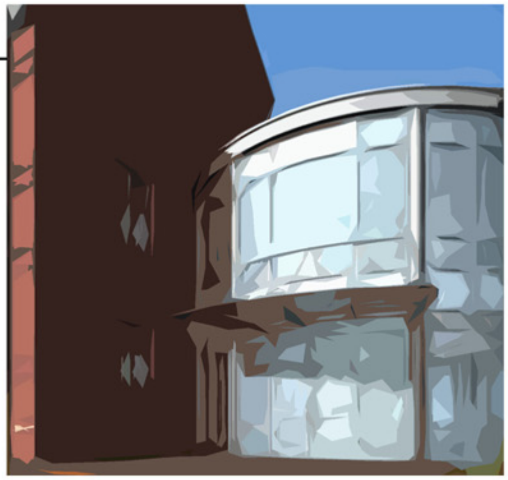


and filters it to be reused in the building. The water is then pumped back into the building to be reused for all non potable applications.

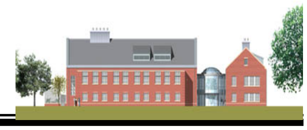
The contractor has run into many issues with this system in terms or warranties and coordination due to its unique nature. Issues such as keeping heavy equipment off the soil located above the tank, roughing in the control systems and plumbing connections before the pump vault and tank are back filled are all new issues the contractor must be aware of when using this type of system. By contacting multiple manufactures of this type of system and reviewing projects where similar systems were used, information regarding typical process and requirements needed to purchase and install this type of system will be evaluated. It will then be documented for contractors to follow in the future to avoid these types of issues and conflicts.

Figure 1: Weight Matrix

Description	Research	Value Eng.	Constructability	Schedule Red.	Total
ZPAI	30%		10%	5%	50%
Mechanical		25%		5%	30%
SWR	10%	5%	15%		20%
Total	45%	30%	25%	10%	100%



Project Background



Project Background

Project Systems Design

Architecture

Graham Gund Architects' design for The New Science Facility is intended to mach the existing buildings of Episcopal High School's campus while still giving the building an identity of its own in the large campus. The façade is a red brick veneer with white precast sills, cornice and stringers matching the campus. The most significant architectural feature of the building is the architectural rotunda connecting the two wings of the building. It contains an anodized aluminum frame with spandrel and vision glass curtain wall and a spherical glass roof. This feature was designed into the building as a geographical tie to the Washington, D.C. area. The rotunda design is inspired by the Jefferson Memorial's circular layout and spherical dome roof.

Structural

The structure is a two story Structural Steel Frame with moment connections and lateral bracing. The Floors consist if composite slab on metal deck. Foundations are cast-in-place spread footings. One 80 ton mobile hydraulic crane will be used to erect the steel. The erection sequence will consist of three pods and will work its way from the north end of the structure to the south end.

Mechanical/Plumbing

The mechanical rooms are located at the south end of the building on each floor. The attic space used as primary mechanical rooms. There is a Split-System A/C system w/ VAV and Constant Volume boxes. 194 ton Air cooled Rotary Screw Chiller. There are three AHU, one servicing the north wing and two servicing the south (labs). Hot water Fin Tube radiators and cabinet unit heaters complement the primary system. The sprinkler system is a wet pipe system.

Lighting/Electrical

The supply is typically 1200 Amps, 480Y/277 Volt, 3 Phase, 4W 60Hz Service and a battery back-up system (still in design due to elimination of generator as VE item). The lighting is typically 277V, recessed fluorescent T8 fixtures throughout the building. The Rotunda is typically 277V recessed down lighting. The greenhouse contains special 120V grow lights with 750W MH lamps.

Special Systems: Storm Water Management

There is a 20,000 gallon Storm Water Reclamation tank located beneath grade. The pump vault for this system is located beneath the slab on grade due to warranty issues. This system is used to store storm water captured by the building, filter it and recycle it throughout the building and landscape reducing the amount of water needed to be brought in from the city supply.

Project Delivery/Contractor Selection

Since this project is under a private owner a very unique delivery system is possible. Forrester and a competitor were chosen by the owner via qualifications and an interview to participate in pre-construction simultaneously. Both firms provided the owner with a price, value engineering ideas and constructability reviews for the period of 50% design through the completion of the bid set of documents. Each firm then submitted a lump sum Fees and general conditions to the owner. Episcopal then selected the contractor based on the cost of those two items and performance during the preconstruction phase. This delivery is very similar to a Design-Build method where the contractor works with the owner, engineers and architect early in the design to achieve a higher quality more constructible project. Forrester Construction Company won the competitive contract bid and holds a guaranteed maximum price (GMP) with Episcopal.

Episcopal is an experienced owner; however they chose to hire Advanced Project Management, Inc. (APM) as a construction manager to manage the general contractor. APM is used much like a CM agency. Each decision made by the general contractor must be approved first by APM, yet they do not hold any contracts with subcontractors to actually perform the work.

Project Cost Evaluation

Actual Building Construction Cost (not including land, site work or permitting)

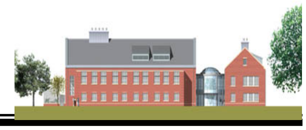
Total Cost = $8,732,625
Cost/SF=$214.90

Total Project Cost

Total Cost = $9,130,625
TC/SF = $244.70

Building Systems Cost

System	Total Cost ($)	Cost/SF	% of TC
Masonry	497,020	12.23	5.69
Cast in Place Concrete	305,500	7.52	3.50
Structural Steel	711,820	17.52	8.15
Mechanical	2,199,200	54.12	25.18
Electrical	1,137,003	27.98	13.02
Lab Case work	577,054	14.20	6.61
Storefront, Glass and Glazing	307,659	7.57	3.52



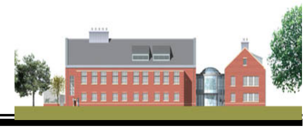
Design Cost

Total Cost = $490,000
DC/CC (%) = 5.6%

D4 cost Estimate Summary

Episcopal High School New Science Facility				
Code	**Division Name**	**%**	**SF Cost**	**Division Projected Cost**
00	Bidding Requirements	1.77	3.56	171,049
01	General Requirements	5.23	10.56	506,753
02	Site Work	4.71	9.51	456,564
03	Concrete	15.11	30.50	1,463,826
04	Masonry	7.50	15.14	726,850
05	Metals	5.57	11.25	539,882
06	Wood & Plastics	1.83	3.69	176,952
07	Thermal & Moisture Protection	5.57	11.23	539,036
08	Doors & Windows	5.67	11.44	548,903
09	Finishes	7.97	16.07	771,518
10	Specialties	1.66	3.35	160,823
11	Equipment	4.54	9.16	439,671
12	Furnishings	1.49	3.00	143,889
13	Special Construction	0.67	1.36	65,372
14	Conveying Systems	0.96	1.94	93,346
15	Mechanical	20.56	41.49	1,991,331
16	Electrical	9.19	18.55	890,225
	Total Building Costs	100.00	201.79	9,685,989

The projected cost obtained by the D4 estimate is very close to the actual project cost. This estimate was projected using 5 projects of similar nature to mine. Each project used in the averaging was a technical science facility with square footages ranging from 25,000 SF to 77,700 SF. Many of the projects used in the D4 estimate were high end college science facilities. The EHS Science facility is a high school building with less technical equipment requirements. Another reason for the difference in cost could be the budget. The actual cost of the project before VE was close to $10 million. The strict budget of the privately funded high school brought the cost of the building to under $9.5 million.



R.S. Means Estimate

<u>Assumptions:</u> 1. Building Type: Colleges – Science, Engineering, Laboratories

2. Cost Per Square Foot based on 45,000 SF : $128.90

3. Location Adjustment = 0.928 (weighted average)

4. No adjustment was taken for time

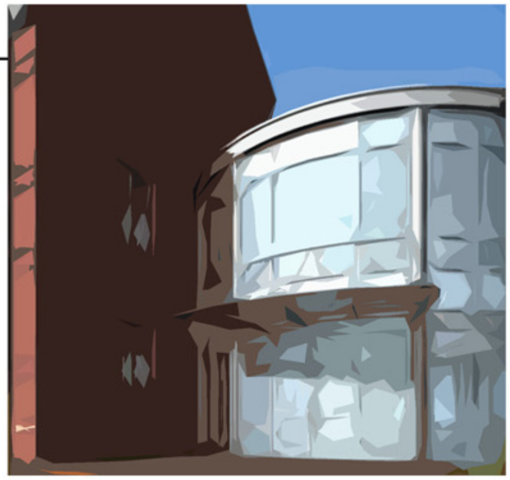
5. Perimeter Adjustment $2.05 per 100LF

6. No story height adjustment taken

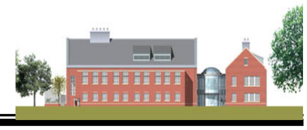
Calculations:

Colleges - Science, Engineering, Laboratories		
	Unit Cost	Total Cost
Cost per SF		$128.90
Perimeter Adj.	-2.05 per LF	-$6.05
Cost per SF		$122.85
Building Cost		$4,992,009.75
Lab Hoods	+$40,750.00	$5,032,759.75
Auditorium Seating	+$32,050.00	$5,064,809.75
Lab Sinks	+$29,325.00	$5,094,134.75
Location Adjustment		$4,727,357.05
Total		$4,727,357.05

The R.S Means estimate came out extremely low when compared to the actual cost of the building. This is largely due to the fact that the Means book estimate is based on a 1 story building. The EHS New Science Facility is not a typical science laboratory; however, this was the closest related building type available to estimate from. Other factors attributing to the differences could also be due to the stringent LEED requirements of this project, specialized equipment for the numerous labs in the facility, the architectural rotunda and greenhouse as well as the advanced storm water reclamation system.



Project Team



Project Team

Owner Profile

The owner of the New Science Facility is Episcopal High School. Episcopal is a very prestigious private college preparatory school. Episcopal was founded in 1839 and is the oldest high school in Virginia. Many of the countries most respected and well known leaders throughout history have attended Episcopal. The primary source of funding for the school is wealthy alumni and charitable donations.

Episcopal has grown considerably over the years to include over 420 students many of whom reside on campus. The increased enrolment necessitates the need for expansion. To attract new students Episcopal must keep up with the changing times and advancements in science and research facilities. The emergence of a strong science program strengthens Episcopal's position as one of the finest boarding schools in the nation and enhances students' academic experience

Due to the private funding of all buildings on campus Episcopal must follow a strict budget which is the driving force in this project. The initial estimate for the project came in close to $500,000 over budget. Many value engineering ideas have since been explored and implemented to get the project under budget.

Construction of this project spans during the entire 2004-2005 school year. The safety of the kids and inconvenience to staff as well as wealthy alumni all play major roles in the planning of this project. Proper signage directing students and visitors safely around campus is critical. The appeal of the campus is critical to attracting new students to the high school, thus appearance of the site becomes a primary concern to the owner. One example is the demand that all construction trucks use the side entrance to the campus off of West Braddock Road and not the main entrance off North Quaker Lane. Discrete egress routes for construction vehicles as well as protection of the exiting roads and curbs from damage will be necessary considerations for this project. The schedule is also very critical to the owner. The scheduled completion date for this building is August 30, 2005. This is just in time for the beginning of the new school year. It is crucial to the owner that the building be operational in time for the school year.

Perhaps the most challenging requirement to meet the owner's requirements is the LEED rating and sustainability requirements for this project. This project is designed for a silver LEED rating and contains many sustainability features. LEED buildings bring many new challenges to a GC such as disposal of waste, erosion control and stringent material requirements.

Contracts

Contracts held between Owner and GC

The GMP contract held between the owner and the GC, as indicated in Figure 1, is currently being negotiated and has not yet been signed due to redesign of specific systems. The terms of the contract therefore can not be disclosed at this time; however, the draft being considered is based on the standard AIA Document A201. According to the senior project manager who is currently negotiating the GMP with the owner there are several unique terms being incorporated into this project.

First is there is a shared savings clause with the owner. Any savings to the GMP are shared 75-25 for the owner and contractor respectively. Secondly, there is a liquidated damages clause of $500/day for late completion. Third, is the dominant role of the owner's CM agency (APM) defined by the contract. Lastly, is the unique LEED requirement of the contractor to ensure that the proper documentation is filed to provide a certified building.

Contracts held between GC and Subcontractors

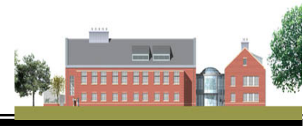
Contracts held between the GC and the subcontractors are Lump Sum contracts, as indicated in the chart above. This is due to the requirement in the contract with the owner that the design must be 100% complete before the bid process can begin. A subcontractor is selected based on the lowest bid number given to the contractor as well as their reputation for work with that owner. If a contractor has the lowest number they may not get the contract since they must be approved by the owner as well as the Vice President of the GC. The subcontractors are required to furnish payment and performance bonds by a surety acceptable by Forrester Construction. Forrester also reserves the right to issue change orders with out prior notice to the subcontractor's bonding company. If a dispute or discrepancy arises Forrester shall be notified immediately in writing and the most stringent requirements shall apply. Payment requisition for partial work must be in by the 25th day of each month. Payment to the subcontractor occurs only with payment to the contractor by the owner as a precedent. Full payment will be made to the subcontractor for complete scope of work will be made within 30 days of full approval of the owner. The subcontractor will provide at least one person with at least 10 years experience. The foreman is required to complete weekly safety meetings and submit a copy of the minutes with attendance records. All employees are required to wear hard hats and eye protection on site at all times. Insurance requirements for the subcontractor are as follows: Comprehensive General Liability, Workers Compensation, Auto Liability, Excess Umbrella ($1 million).

Bonds and Insurance Required

The contract with the GC has with the owner requires the GC to have all of the following insurance and bonds:

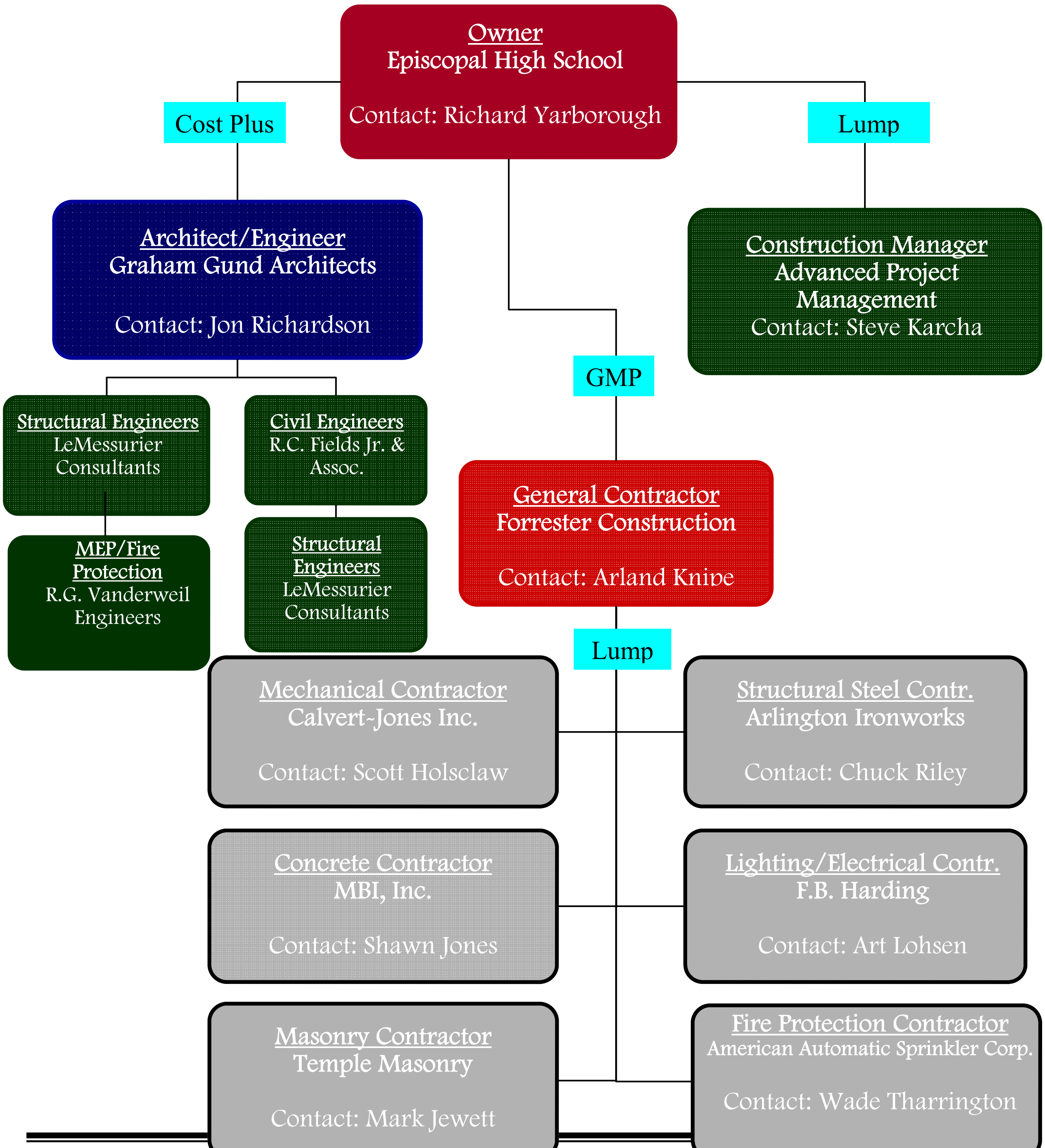
- Workers Compensation: Provide compensation to the maximum statutory limits in accordance with State requirements
- General Compensation:
  - Bodily Injury ($5 million)
  - Property Damage ($5 million)
  - Personal Injury with employment exclusion deleted
- Umbrella Excess Liability: $5 million over original insurance

- Automobile : condensed single limit of $1 million
  - Bodily injury
  - Property Damage



Forrester was not required to provide either a payment and performance bond or builder's risk insurance. The firm's reputation alleviated the owner's feelings for requiring this bond, and the owner is paying for the builder's risk insurance.

Figure 2: Project Organizational Chart



Existing Conditions

Existing Site/Soil Conditions

The site for the New Science Facility is located on the south eastern portion of Episcopal High School's 130 acre campus. The site is an undeveloped relatively flat grass field formally used for sports and recreation. It is located directly next to a brand new state-of-the-art composite track on the west side of the building and an existing gymnasium on the north end of the site. The soil on site is largely compacted clays with small deposits of silty-sands and limestone rock. The topsoil depth ranged from 4" to 8" below the existing surface.

Local Market Conditions

Episcopal High School is located in Alexandria, VA on the corner of North Quaker Lane and West Braddock Rd. The private campus isolates the site from any traffic or hazards of trespassers; however, construction will be going on during school and consideration of the students and their safety is of the highest priority.

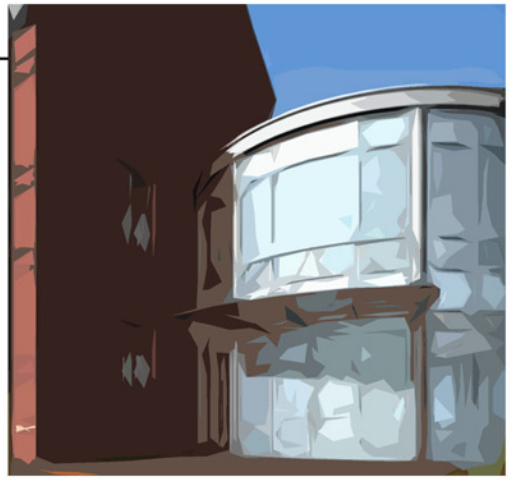
Figure 3: Arial view of Episcopal High School

Alexandria, VA is located directly across the Potomac River from Washington, D.C. and is only a 10 minute drive to the city center. The Washington D.C. market is an extremely large and prosperous market; however, at the moment labor is very hard to find. There are an extraordinary amount of projects under construction in the area and a full competent work force is very hard to find. Virginia is a "Right to Work" state; therefore no union labor is required on this job. Subcontractors are over booked, and it is highly important both when scheduling and estimating to consider this. Scheduling must be done many months in advance in many cases and contractors are largely at the mercy of the subs when it comes to cost due to the high demand for work.

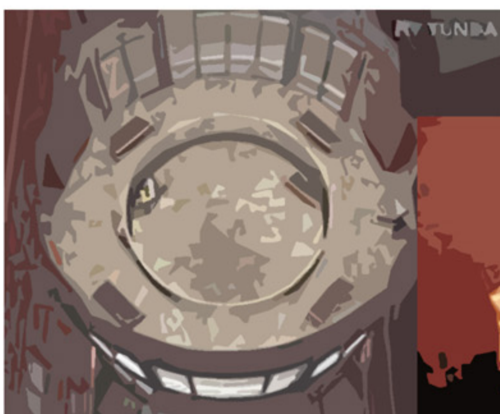
It is also important to consider the material costs of the area. Due to the world market right now steel is excessively expensive which highly affects this project due to its steel frame. This is one of the reasons fiber reinforcement was chosen in lieu of rebar for the slab on grade. The D.C. area is largely a concrete construction market and concrete is able to purchased quickly and cheaply.

Existing Site Plan

The site plan provided in Appendix A displays the site conditions as they exist before construction is to begin. As shown in the plan the site is not much larger than the building footprint. This will require careful coordination between the trades to ensure that a productive and safe environment is maintained throughout the duration of the project.



Existing Conditions



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Local Market Conditions

Episcopal High School is located in Alexandria, VA on the corner of North Quaker Lane and West Braddock Rd. The private campus isolates the site from any traffic or hazards of trespassers; however, construction will be going on during school and consideration of the students and their safety is of the highest priority.

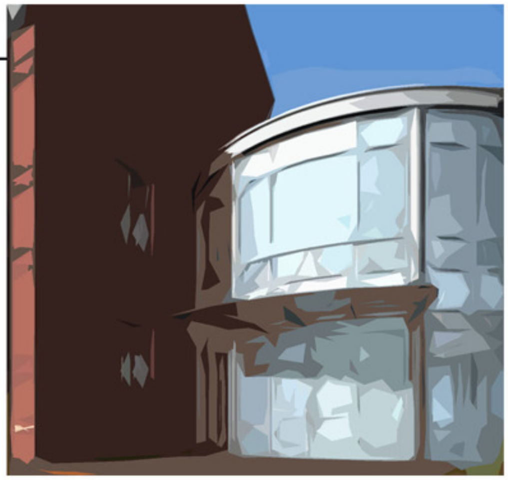
Alexandria, VA is located directly across the Potomac River from Washington, D.C. and is only a 10 minute drive to the city center. The Washington D.C. market is an extremely large and prosperous market; however, at the moment labor is very hard to find. There are an extraordinary amount of projects under construction in the area and a full competent work force is very hard to find. Virginia is a "Right to Work" state; therefore no union labor is required on this job. Subcontractors are over booked, and it is highly important both when scheduling and estimating to consider this. Scheduling must be done many months in advance in many cases and contractors are largely at the mercy of the subs when it comes to cost due to the high demand for work.

Figure 3: Arial view of Episcopal High School

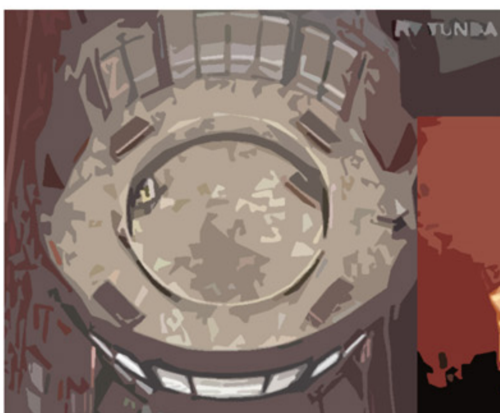
It is also important to consider the material costs of the area. Due to the world market right now steel is excessively expensive which highly affects this project due to its steel frame. This is one of the reasons fiber reinforcement was chosen in lieu of rebar for the slab on grade. The D.C. area is largely a concrete construction market and concrete is able to purchased quickly and cheaply.

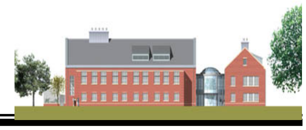
Existing Site Plan

The site plan provided in Appendix A displays the site conditions as they exist before construction is to begin. As shown in the plan the site is not much larger than the building footprint. This will require careful coordination between the trades to ensure that a productive and safe environment is maintained throughout the duration of the project.



Project Execution





Project Execution

Project Schedule Summary

The Schedule Summary depicted in Appendix A shows the basic sequencing discussed below. Since the design phase is complete before the procurement of construction services begins it allows for complete accurate bids to take place. This allows the GC to give the owner a more accurate number on the actual cost of the entire project and work out any differences in the budget and the cost early in the project.

The foundation of this building consists of cast in place spread footings and foundation wall. This process includes excavation of the spread footings, placing of rebar, placement of the spread footings, cure time for the footings and form, reinforce, place and cure of the foundation walls. The slab on grade was not included in the foundation phase because structural steel columns will have to be put in place before the slab can be formed and poured. Since there is no reinforcement to be used in the slab on grade the time needed to complete this process will be reduced significantly.

The structural system consists of a steel frame with moment connections and lateral bracing. Metal decking with a composite cast in place slab will compose the floor system. The structure will be erected in 3 sequences moving from north to south on the building. The structure will require temporary bracing during the erection of the other sequences. Miscellaneous connections and final plumb and alignment of the structure have been included in the duration for this phase of the project. It will be critical to get the foundations and structural systems in place on time to ensure the building is enclosed before the heart of winter sets in around late December.

MEP rough-in and equipment installation will begin to be put in place simultaneously to the construction of the exterior skin of the building. This overlap of trades will allow for an acceleration of schedule but will require close coordination with various trades to ensure the site does not become over crowded with materials, deliveries and personnel. Once the building is enclosed the finishes can begin. Finishes require a conditioned space; therefore, require an enclosed structure as well as functional mechanical and electrical systems. Finishes include drywall, painting, sealing of penetrations, termination of electrical systems, light fixtures installation, millwork installation, accessories, plumbing fixtures, drop ceilings and flooring.

Project Cash Flow

Figure 4: Monthly Gross Billing Summary

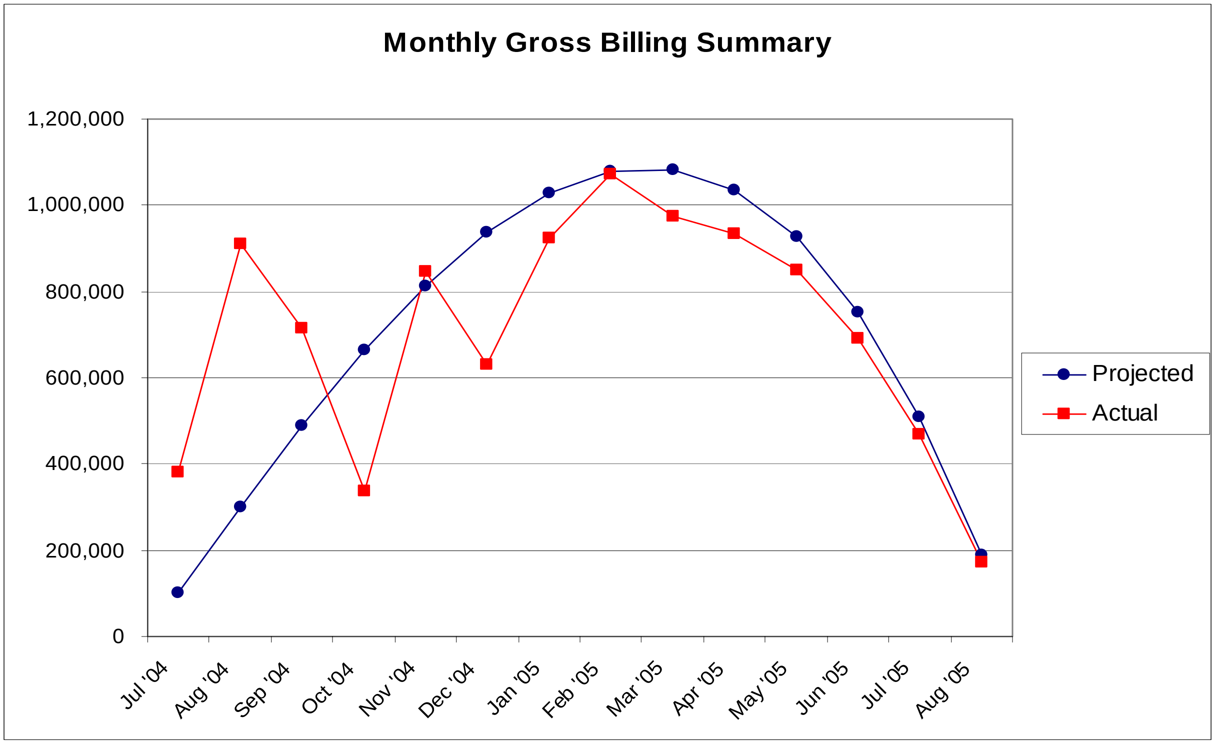
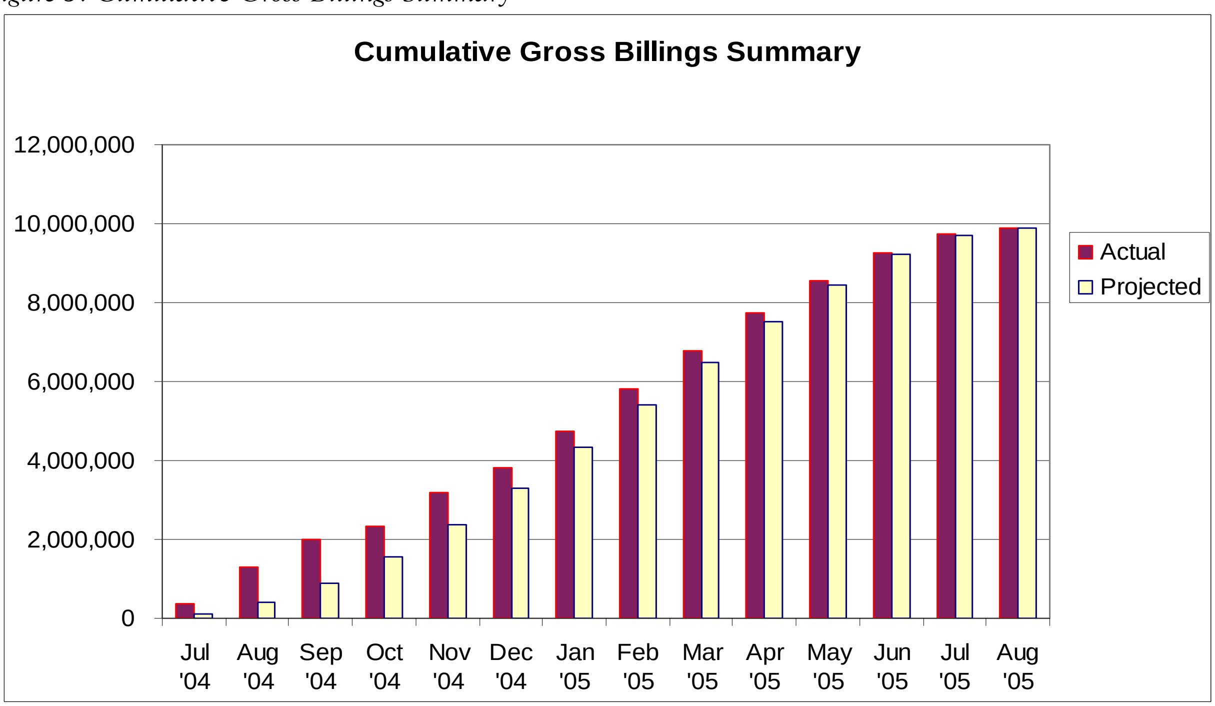
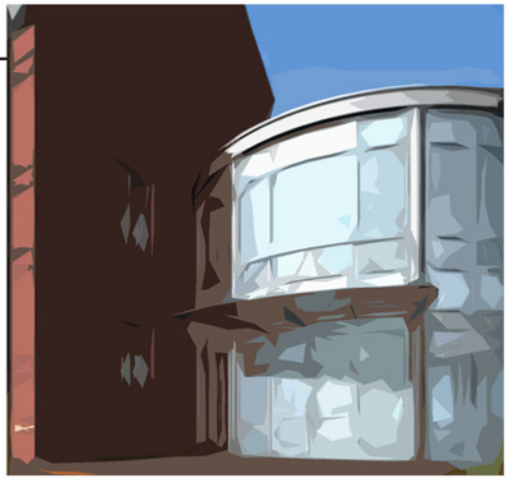
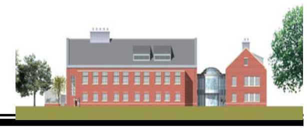


Figure 5: Cumulative Gross Billings Summary





LEED Accreditation Summary



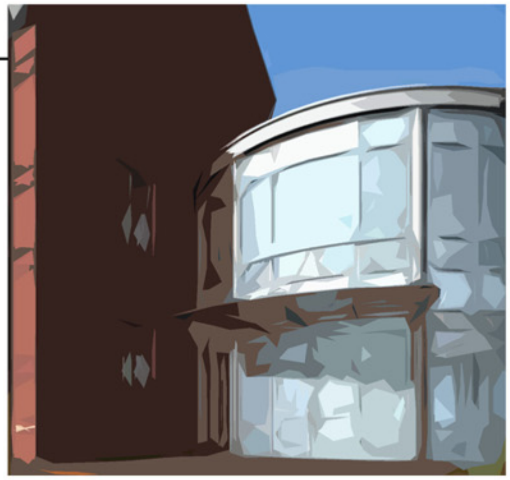
LEED Accreditation Summary

The U.S. Green Building Council (USGBC) has established a set of credentials for sustainable and high performance construction. A building is awarded credits for each credential it meets or exceeds. The points are tallied and a Leadership in Energy and Environmental Design (LEED) rating is given to the building. The Episcopal High School New Science Facility is currently projected to achieve a Silver LEED rating (33-38 points) for green construction as dictated by the USGBC. The primary focus for this thesis is in the LEED credits of Energy and Atmosphere, Innovation and Design Process and Water Efficiency sections.

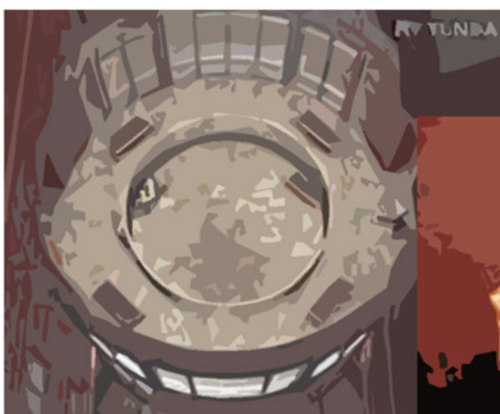
Analyses I and II fall within the Energy and Atmosphere section. More specifically EA Prerequisite 2 and Credit 1: Minimum Energy Performance and Optimize Energy Performance 15%+. In order to obtain these credits the design must meet the stricter of the ASHRAE/IESNA 90.1-1999 or local building code. Credit 1 the can be achieved by surpassing the minimum energy performance by 15+% less without reducing the comfort level of the occupants. More points can also be obtained for ever additional 5% improvement up to 60%. The current design does not exceed the Prerequisite by 5% and therefore does not achieve any points for the system. One of focuses of Analyses I and II is to possibly surpass the minimum requirements enough to achieve points for the LEED rating.

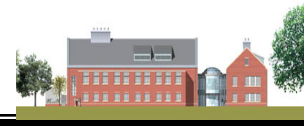
Analysis III falls under the Water Efficiency as well as the Innovation and Design Process sections. The unique Storm Water Reclaim system implemented in this project is achieving five out of five Water Efficiency credits as well as three additional credits for Innovation and Design Process for exceeding the requirements by 100%. Water Efficiency is broken up into three credits. The first credit is for water efficient landscaping. One point can be achieved by using high-efficiency irrigation technology or use captured rain or recycled site water to reduce potable water consumption for irrigation by 50% over conventional means. A second point can then be obtained by using only captured rain or recycled site water to eliminate all potable water use for site irrigation (except for initial watering to establish plants), or do not install permanent landscape irrigation systems. The second credit is for Innovative Waste Water Technologies. One point can be acquired by reducing the use of municipally provided potable water for building sewage conveyance by a minimum of 50%, or treat 100% of wastewater on site to tertiary standards. The third and final credit is for Water Use Reduction. One point can be achieved by employing strategies that in aggregate use 20% less water than the water use baseline calculated for the building (not including irrigation) after meeting the Energy Policy Act of 1992 fixture performance requirements. An additional point can then be acquired by increasing credit 3.1 to 30% less water.

The Innovation and Design Process credits are then awarded to provide design teams and projects the opportunity to be rewarded for exceptional performance above the requirements set by the LEED Green Building Rating System. The SWR system on this project reduces the water usage in the building by 60% which is a 100% improvement on the required 30%.



Analysis I: Wall System





Analysis I: Wall System Analysis and Redesign

Background

Green design and Sustainable Construction has become one of the most prominent and researched areas in the industry today. The primary focus of this analysis is the optimization of energy usage through a well designed and constructed efficient building envelope. The type of system proposed is a 100 percent Air Barrier wall system. This means that by carefully installing a specific building wrap and sealant into the building envelope the air infiltration from the outside into the building is eliminated.

There are four factors that induce the movement of air into and out of a building through the building envelope: the stack effect, chimneys, wind, and forced hot-air heating systems. The stack effect is when stratified temperatures cause pressure differentials in the building. The hot air rises to the top of the spaces and tries to escape through the envelope, while the cold air tries to infiltrate the envelope near the bottom. Chimneys act as an exhaust fan. Air can exhaust through the chimneys creating a low pressure inside the building inducing infiltration. Wind around the building creates pressure differentials around the wall assembly. On the side of impact there is a positive pressure created and a negative pressure created on the inside. This differential drives the air thought the building envelope causing both infiltration and ex-filtration. The last factor is the forced hot-air heating systems. Differing locations of supply and return ducts can lead to pressure differences which in turn cause infiltration and exfiltration though the building envelope.

Air Barriers have been applied to several projects in the industry recently and have even been incorporated into state codes as a minimum standard product. The state of Massachusetts recently underwent a complete revision of the energy conservation requirements for new commercial buildings taking effect July 1, 2001. The revised code includes elements from ANSI/ASHRAE/IESNA Standard 90.1-1999 and the 2000 International Energy Conservation Code (IECC), as well as several requirements that are unique to Massachusetts. This code is projected to save over 14 trillion BTU's of energy over the next 20 years which is currently about $120 million. The projected payback period for these standards is on average less than 2 years.

Problem Statement

One of the most significant ways to cut energy costs in the reduction of the mechanical loads on a building. According to studies done by both the Air Barrier Association of America (ABAA) and the North American Insulation Manufacturers Association (NAIMA), up to 40 percent of energy consumed heat or cool a building is due to air leakage through the building envelope. With increasing concern of energy consumption there has been extensive research to determine ways to mitigate the excess usage of energy through building construction methods and components.

Proposal/Design Criteria

One solution to this problem of air infiltration through the building envelope is the concept discussed above of an Air Barrier product that is installed into the envelope system. The Air Barrier product is installed in place of the typical building paper. The specific air barrier chosen for this analysis was a Grace Construction product called Perm-A-Barrier Wall Membrane. It is a self adhesive, rubberized asphalt/polyethylene waterproofing membrane. This membrane exceeds the CCMC requirements for air barrier membranes and complies with Massachusetts state energy code. The continuity of the membrane is ensured due to its self adhesive nature and it is cold applied in temperatures ranging from -4° C and above. Perm-A-Barrier wall membranes have a multitude of advantages:

- Prevent premature deterioration of the building envelope.
- Enhance thermal performance of the structure and save energy costs.
- Improve comfort for the building occupants.
- Decreased moisture infiltration into wall cavity, lowering probability of mold issues within the building envelope.

Construction Detail

The components of a Perm-A-Barrier wall membrane are not that different from a typical wall system building paper. Figure 6 shows the construction of membrane system. The primary differences between the current wall design and the proposed membrane is the different membrane material, the special joint sealant, the horizontal reinforcing needed for the Perm-A-Barrier wall membrane and the installation detail at window openings (Figure 7, 8 &9) and foundation wall junctions (Figure 10). The building paper that is currently designed for the building requires an adhesive; however that is eliminated by using the self adhering Perm-A-Barrier. A bituthene mastic is used at all penetrations of the membrane to ensure the system is 100 percent sealed. The following figures display the differences between the current wall system design and the proposed system with the Perm-A-Barrier Wall membrane.

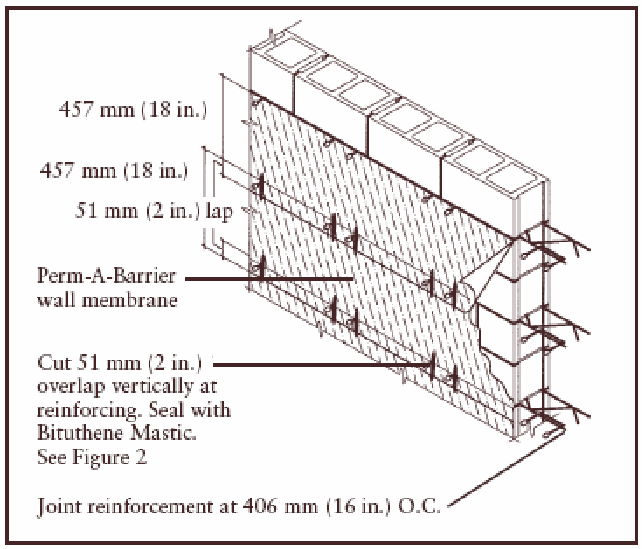


Figure 6: Perm-A-Barrier detail for CMU back-up

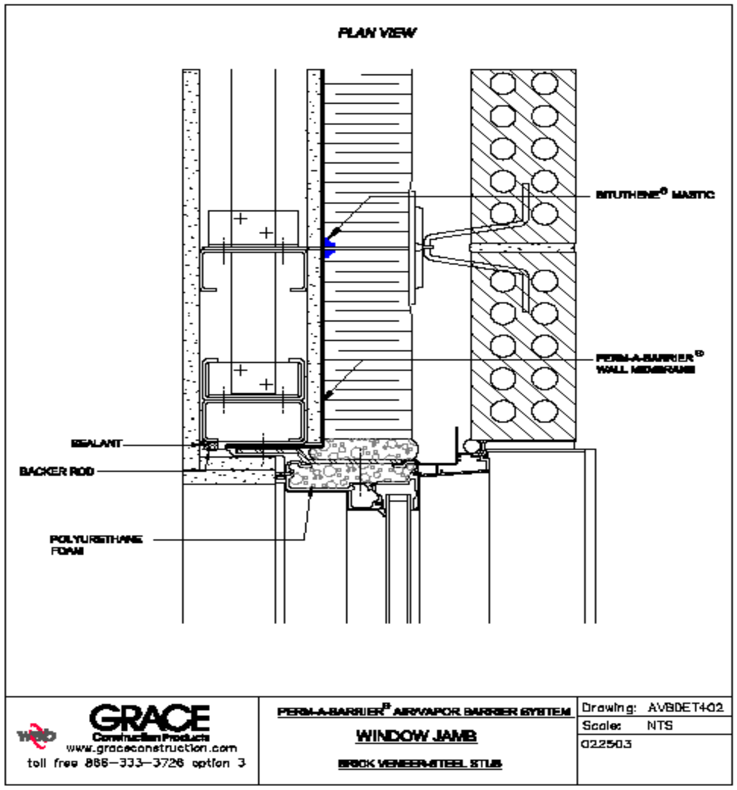


Figure 7: Pema-A-Barrier Window Jamb Detail

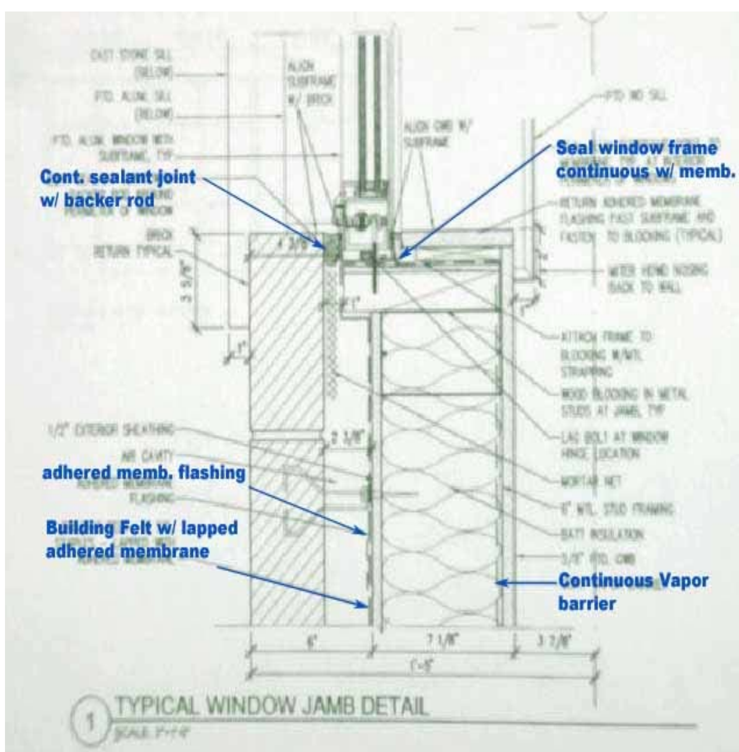
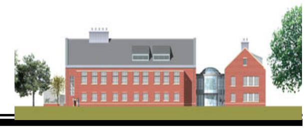


Figure 8: Current Window Jamb Detail



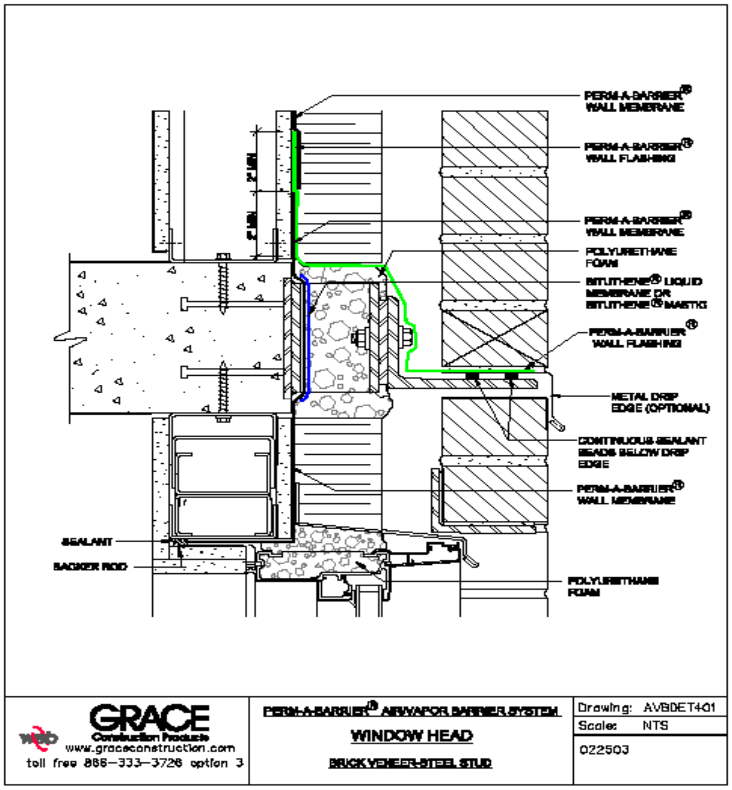


Figure 9: Perm-A-Barrier Window Head Detail

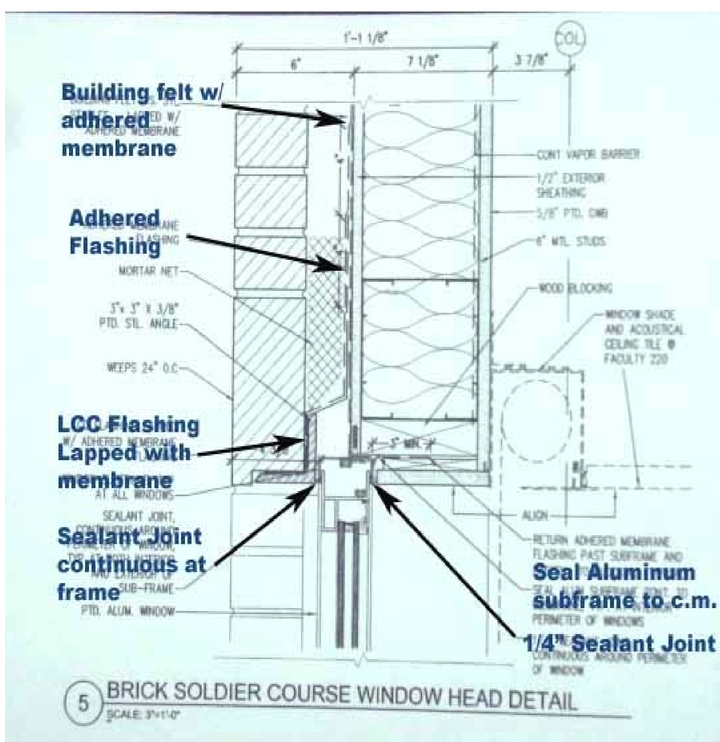
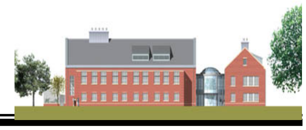


Figure 10: Current Window Head Detail



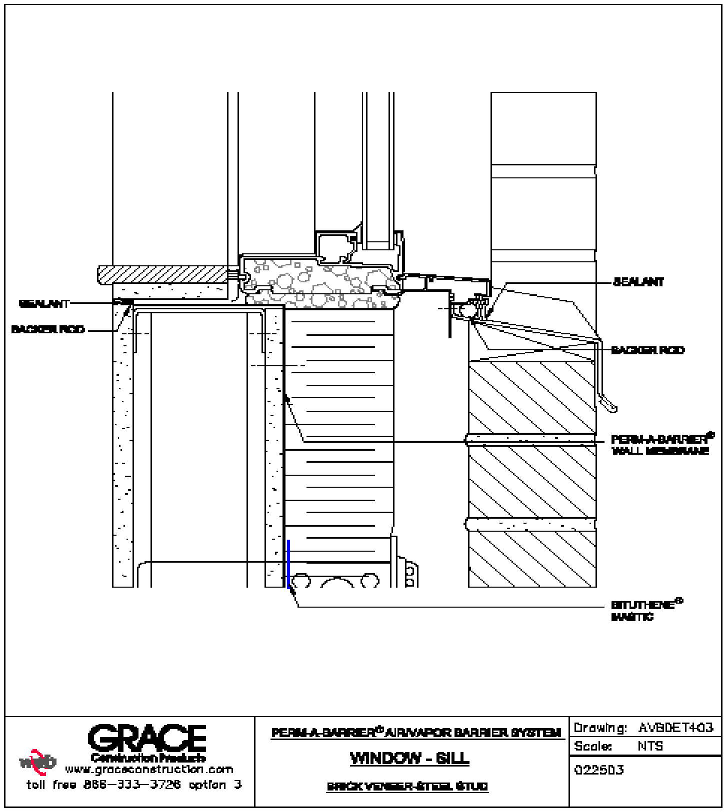


Figure 11: Perm-A-Barrier Window Sill Detail

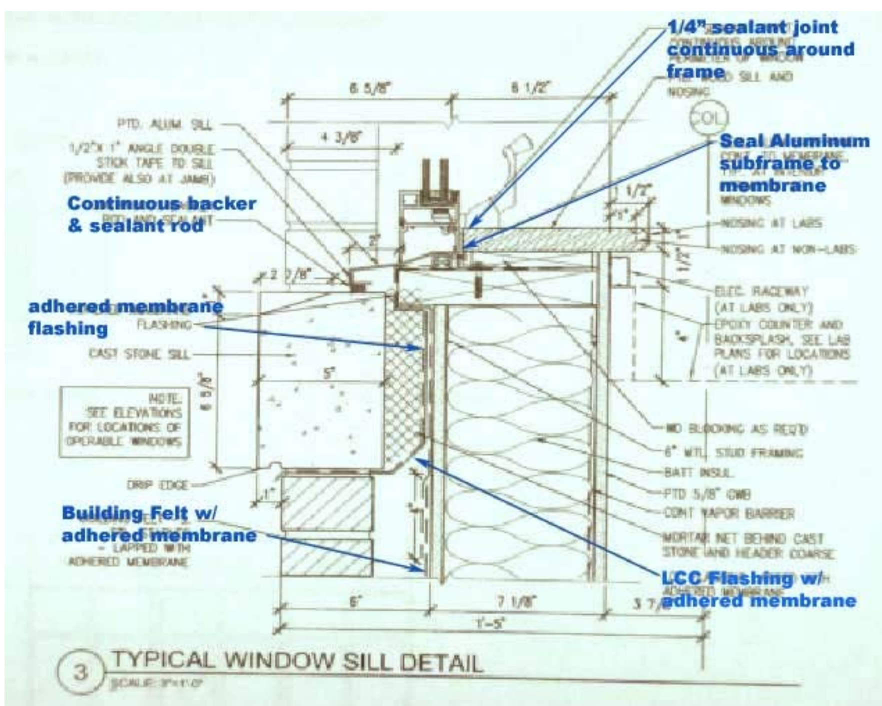


Figure 12: Current Window Sill Detail

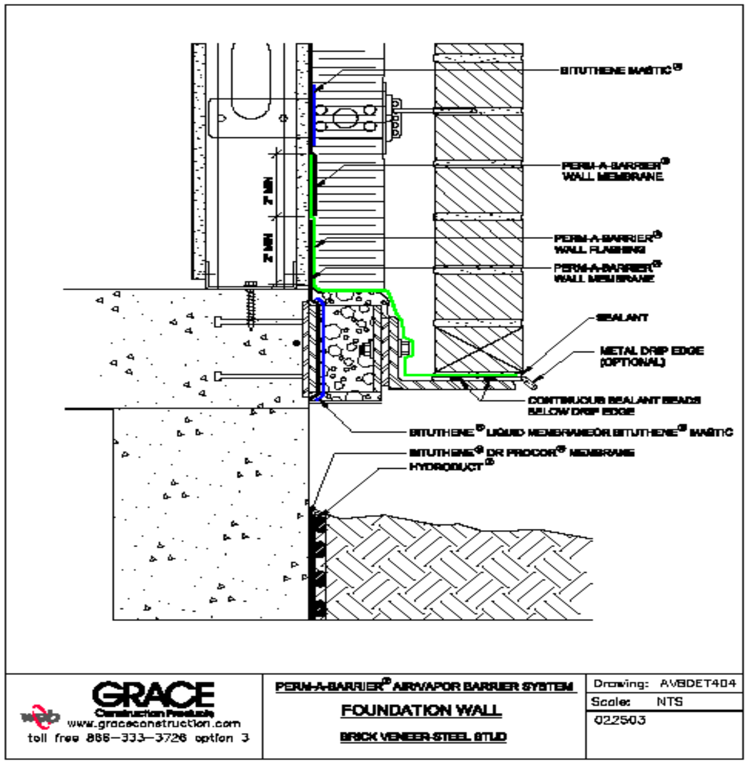


Figure 13: Perm-A-Barrier Wall Base Detail

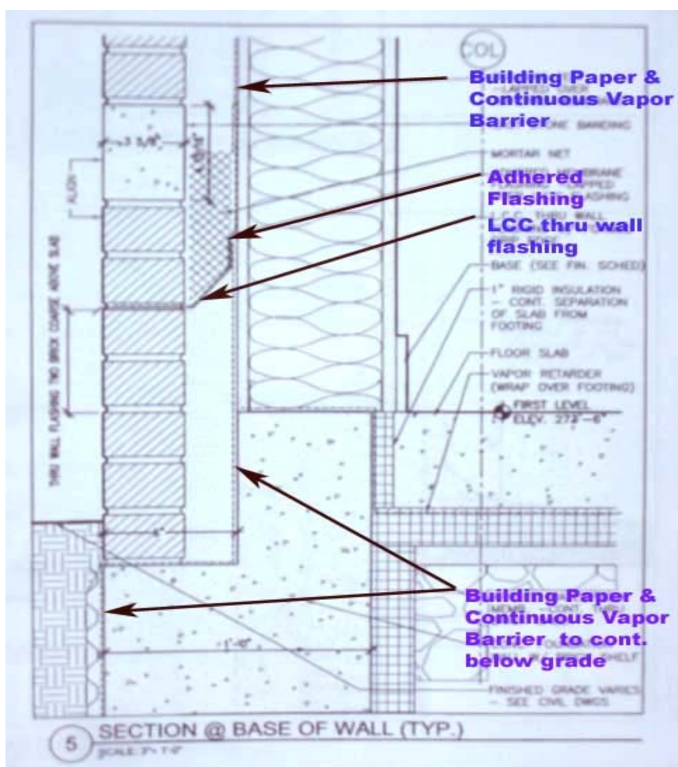


Figure 14: Current Wall Base Detail

Results

CM Issues and Concerns

The Perm-A-Barrier wall membrane is very similar to typical building paper except for its exceptional performance qualities. The membrane is installed similar to a typical building paper and can be done by normal envelope tradesmen. There are, however, some critical CM concerns associated with this special product that requires extra attention and care. In order for the product to work properly, the quality of construction must be closely monitored. All joints must be sealed properly and adequately to ensure no air leakage or moisture infiltration occurs. This will require special attention from the CM as well as extra care by the tradesmen during the installation process. Quality of construction, however, should always be a top priority on a project and should not impact the cost or time of construction too significantly. Fortunately for this particular project this activity is not on the critical path and the extra seven days required to implement the Perm-A-Barrier system to ensure the envelope is sealed properly; however, it does not impact the overall duration of the project since it is not on the critical path.

Coordination with the other components and trades of the building envelop becomes a critical issue when using this air barrier wall membrane. In order for the membrane to work properly it must be coordinated and tied into the roof system, window frames and any penetrations of the wall system with the proper care and sealants. The membrane must be wrapped back into the window frame and then properly sealed once the window is installed. Figure 9 shows a detail of the system at a typical window head for the upgraded wall construction type. The membrane must also properly tie into the roofing system and sealed properly to ensure no air leakage occurs at this seam. The sequencing for the envelope construction is not affected due to the ability to have the roofer, window installer or membrane installer seal the system at the time of the systems are completed. When contacted Arland Knipe, the Project Manager for the Episcopal High School New Science Facility, noted that this coordination is extremely necessary for this quality based construction system and would typically be done extremely early in the project to ensure the system is properly installed to achieve its intended purpose.

The final consideration of this system is the cost. As discussed earlier, there should be minimal to no extra cost incurred due to extra coordination or sequencing issues. The Grace product itself however does come at a premium. Figure 15 below shows a breakdown of cost and schedule comparison between the current wall system and the proposed system. Full systems estimates can be found in Appendix C.

Figure 15: Wall System Cost Summary

Wall System	Total Cost ($)	Cost ($/SFSA)	Schedule Impact (days)
Typical Building Paper	$665,160.08	$27.95	
Grace Perm-A-Barrier	$698,718.08	$29.36	+7
Difference	$33,558.00	$1.41	

Note: Cost and Schedule info taken from Cost Works 2004 and Forrester Construction Estimating Dept.

Infiltration Impacts

The air permeance value for the Grace Perm-A-Barrier membrane is 4e-6 cfm/sf. The total infiltration value of the new wall system is small enough to be designed at 0 cfm/sf. Using Trane Trace software the loads were calculated for the design case and the air barrier case. The air barrier resulted in a reduction in space conditioning demand of .3716 W/sf. Heating loads were reduced by 8% while cooling loads were reduced by only 6% of the total load. These impacts translate to an approximate energy cost savings of 1% or $1,180/year.

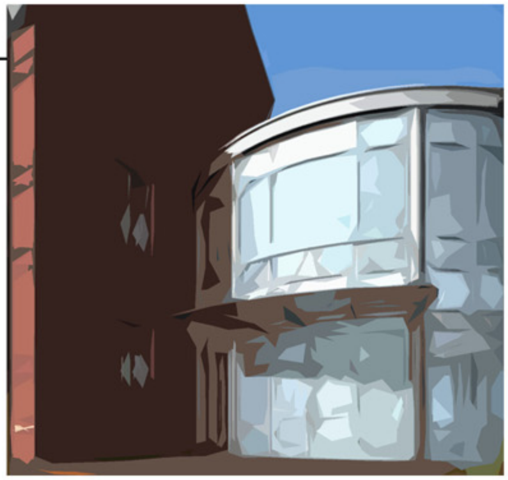
Conclusions

The goal of this analysis was to analyze the impacts of using a ZPAI system from both cost savings and construction management standpoint, and to determine the practicality of using this type of system in for this particular project.

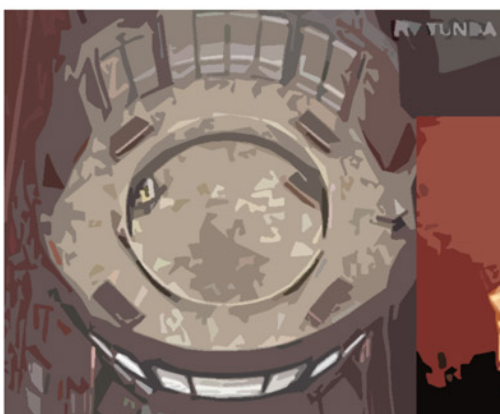
From a cost savings standpoint the system was not very effective. With a savings of only $1,180/year, the return on investment to the owner would be over 28 years. This is not very feasible from a value engineering standpoint.

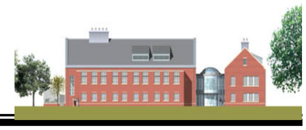
The system proved to be quite feasible in terms of constructability and schedule impact. The primary construction management concern was the quality of construction of the Perm-A-Barrier membrane. The schedule was only stretched by seven days which had no overall impact on the overall building schedule. The load reductions were approximately 8%, and were not significant enough to warrant a resizing of the mechanical equipment.

In other case studies and applications the ZPAI system has proven to be a feasible and cost effective solution to air leakage. ZPAI systems tend to work more effectively in environments with subjected to extreme weather conditions. This particular application does not warrant the usage of this type of system from a cost savings standpoint, primarily due to the large initial cost of the materials used.



Analysis II: Mechanical System





Analysis II: Mechanical System Upgrade and Analysis

Background

Energy costs can have a significant impact on an owner's decision to utilize high performance HVAC systems and sustainable upgrades to mechanical equipment. Two important factors as to why a Mechanical system upgrade and analysis was performed for this thesis are the fume hoods in certain laboratory classrooms and the recent adoption by the state of Virginia of the 2000 version of the ICC International Energy Conservation Code.

The utilization of fume hoods in the New Science Facility has a significant impact on the HVAC requirements due to the high degree of required outside air supply and exhaust and the corresponding high energy consumption. For this reason aggressive energy conservation options were explored to reduce the energy consumption for the entire year. In combination with the high performance air barrier wall system proposed in the previous analysis multiple sustainable upgrades were evaluated for effectiveness as well as financial feasibility.

Problem Statement

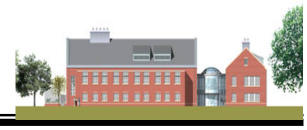
This analysis is based on the same issues existing in the industry as the first analysis. With the ever increasing energy crisis and rising cost of building systems operations it is important to explore new ways to increase energy efficiency without compromising occupant comfort levels.

Proposal/Design Criteria

Using simulation modeling as well as cost estimating the following sustainable upgrades to the mechanical system were analyzed:

1. Variable air volume with variable frequency drives
2. Heat Recovery on AHU 3
3. Water Cooled Chiller vs. Air Cooled Chiller
4. CO_2 monitors

Each upgrade will be analyzed using DOE 2.2 energy cost simulation software to determine its energy performance. The overall feasibility of the upgrades can then be determined by comparing the total cost of the upgraded system to the overall energy cost savings. A return on investment will also be calculated for the upgrade case in order to show the owner that they are not just spending money to obtain another LEED credit.



VFD's

Variable frequency drives accomplish part load control by varying electric motor speed, significantly reducing energy waste. Many electric motor-driven devices operate at full speed even when the loads they are serving are less than their capacity. To match the output of the device to the load, some sort of part load control is in use for the majority of their life. A monitor in the space relays an output signal to the VFD controlling the fans or pump. The VFD then controls the speed of the device based on the demand for conditioned air. Energy required to run a fan at half of its capacity is generally around 13% of the energy required to run the fan at full capacity. This results in significant energy savings and ultimately cost savings. For this analysis Siemens VFD's were chosen. The product data sheet can be found in Appendix B.

Heat Recovery

For further energy savings a fixed plate heat exchanger is designed into AHU 3. Ventilation air first enters the air to air, fixed-plate heat exchanger; there, the air is pre-cooled below the outdoor-air dew point, reducing the latent load on the coil. The ventilation air then goes through the cooling coil where it is cooled to the desired supply-air dew point. Finally, it is reheated to room-neutral temperature as it flows through the heat exchanger again. This is shown in Figure 16 to the right. The product data sheet for this heat exchanger can be found in Appendix B.

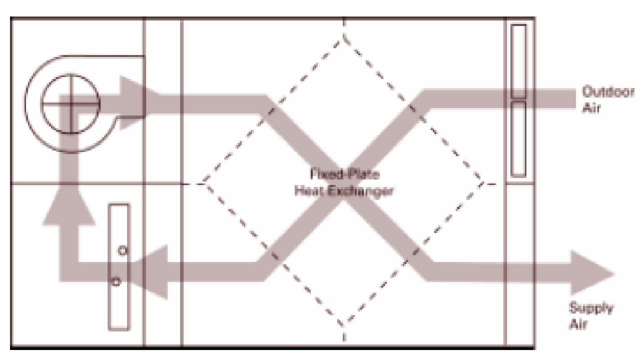


Figure 16: Air to air, fixed plate heat exchanger

Water Cooled Chiller

A water cooled chiller uses a plant water supply source (tower water, city water, or well water) to dissipate process heat. Water cooled chillers tend to be more efficient than air cooled chillers; however, they come at a greater initial cost. For this analysis a 250 ton premium efficiency Trane centrifugal water cooled chiller was chosen to take the place of the air-cooled chiller in the current design. Product data can be found in Appendix B.

Carbon Dioxide Monitors

Carbon Dioxide monitors can be installed in each space to monitor occupancy and further cut energy waste. Vaisala GMW20 CO_2 monitors were selected to use in the proposed analysis. The product data sheet can be found in Appendix B. CO_2 sensors monitor the level of CO_2 in a given space and relay a signal to the VFD's to alter the speed of the fans and pumps to meet the demand of the space based on its occupancy level. The monitors ensure that the optimum air quality is achieved in a space and reduces energy waste normally used to condition an unoccupied space.

Figure 17: CO_2 monitor

Results

Energy Cost Simulation

Assumptions: 1) Electric Costs based on Virginia Electric and Power Company Schedules GS-3 with fuel charges of $0.01613/kWh
2) Gas costs based on Washington Gas
3) Two position hood control in both cases
4) Chiller performance based on performance info provided from Trane
5) Weather data averaged over 25 year records

The total energy savings experienced due to the sustainable upgrades implemented was approximately 15% or $18,879/year. Figure 18 below summarizes the comparison between the base and upgraded mechanical systems energy cost simulation. The DOE 2.2 output files can be found in Appendix D.

	Base System	***Upgrade System***
Electricity Used (kWh)	1,117,914	841,615
Gas Used (therms)	45, 703	48, 112
Energy Cost ($/year)	$117,994	$99, 115
Energy Cost/Net SF	$6.51	$5.74
Energy Savings (%)	0	16%

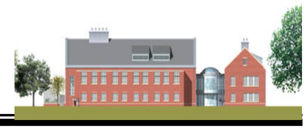
Note: Simulation does not include Perm-A-Barrier impacts

Figure 18: Energy Cost Simulation Summary

Once the Energy cost savings has been determined it is important to compare the amount of energy saved to the cost incurred due to the upgrades. Figures 18 and 19 show a break down of each upgrade's impact on the energy and cost savings, as well as the cost to implement each particular upgrade. The cost savings are then compared to the initial cost of the upgrade to obtain the Return on Investment (Equation 1) for the owner and contractor to analyze the feasibility of implementing such upgrades.

ROI (years) = Initial Cost ($) / Energy Cost Savings ($/year) (Equation 1)

As illustrated in Figure 19 the overall cost to upgrade the mechanical system is $82,800. The return on investment for the upgraded system is 4.43 years. This is a reasonable ROI for the owner to consider implementing this type of system.



Upgrade	Energy Savings (%)	Cost Savings ($/year)	Initial Cost ($)	Return On Investment (years)
VAV w/ VFD's	6%	$7,000	$46,500	6.64
Heat Recovery on AHU 3	4%	$5,900	$2,500	0.53
Water Cooled Chiller vs. Air Cooled Chiller	3%	$3,500	$24,000	6.86
CO_2 Monitors	3%	$3,500	$9,800	2.80
Total	16%	$19,900	$82,800	4.43

Notes: 1) Cost data taken from RS Means and courtesy of Good Heating and Air Conditioning
2) Dollar amounts rounded for simplicity
3) All costs include installation and wiring

Figure 19: Energy cost savings and return on investment per upgrade

CM issues and concerns

Although the upgraded system sounds like a great sustainable idea there are other issues that a construction manager must take into consideration when looking at implementing these upgrades. Figure 20 below gives a break down of many of these issues for each upgrade to the mechanical system.

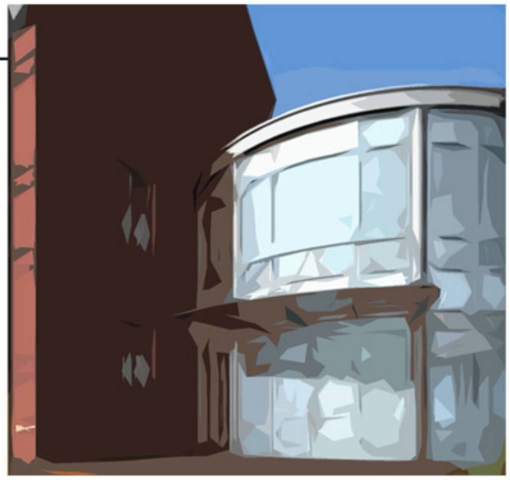
Upgrade	CM Issue or Concern
VAV w/ VFD's	1) Long lead time 2) Special controls and wiring requiring specialty tradesmen 3) Testing and Balancing 4) User/Operator Training
Heat Recovery on AHU3	1) Longer lead time on equipment 2) Slightly more space needed: both for the unit as well as extra piping
Water Cooled Chiller	1) Increased coordination amongst trades due to increased components 2) More space required 3) More installation time required 4) Proper sealant of connections 5) Delivery coordination with building enclosures to ensure it fits into the building
CO_2 Monitors	1) Long lead time 2) Special controls and wiring requiring specialty tradesmen 3) Testing and Balancing 4) User/Operator Training

Figure 20: CM Issues and Concerns for Mechanical Upgrades

Conclusions

The objective of this analysis was to optimize the energy efficiency of the mechanical system but implementing several sustainable upgrades. The system was then analyzed using an energy cost savings model called DOE 2.2 to determine the annual cost savings of the system. The annual cost savings were then compared against the initial cost of the upgrades and a return on investment was calculated. The upgrades yielded a 16% savings in energy usage which translates to an annual savings of $19,900/year according to the utility rates for Alexandria, VA. At an initial cost of $82,800 the upgraded system yields a return on investment of 4.34 years. An additional LEED credit is also obtained for the upgrade case. This is a highly desirable result and I recommend using the upgrade system over the original design.

The system was also analyzed from a construction management standpoint. There were considerable concerns with the upgrade case but nothing that was overbearing enough to negate the advantages of using the upgraded system. The most significant concerns were the long lead times and extensive control systems that accompany the VFD's and CO_2 monitors as well as increased coordination required amongst the trades to integrate the upgrades to the mechanical system.



Analysis III: Storm Water Reclaim System

Analysis III: Storm Water Reclaim System

Background

In the United States approximately 340 billion gallons of water are withdrawn from the sources available per day. The water deficit in the US is currently estimated to be 3,700 billion gallons per year. This has become an extremely critical topic in the industry in recent years. Many systems have been developed to attempt to recycle and reduce the use of water. One such system is a Storm Water Reclaim (SWR) system. Figure 18 shows the results of a recent survey in the industry about these types of systems. Industry members were asked if they felt that going beyond the code for water conservation measures is cost effective. Overwhelmingly 83% responded yes they feel it is cost effective.

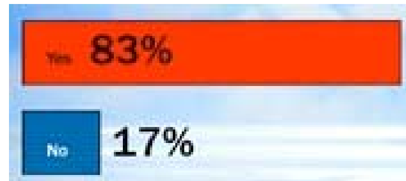


Figure 18: Do you feel going beyond the plumbing code with water conservation measures was cost-effective?

One of the most innovative approaches to the green design of the Episcopal High School New Science Facility is this type of Storm Water Reclaim system. The LEED accreditation program has influenced increased exploration of different types of SWR systems. The EHS New Science Facility is obtaining eight credits for this system, five for Water Efficiency and three for Innovation and Design Process. The Water Efficient Systems as well as Innovation and Design Process credits are detailed and broken down in the LEED accreditation portion of this report.

A SWR system collects rain water that would just be runoff of the site and stores it in a reclaim storage tank. The water is then pumped back into the building and treated if necessary for all non potable water needs, or is used to reduce the potable water used for irrigation purposes. Using a system like this can drastically reduce the amount of potable water required from the local water supply. This not only results in an environmentally friendly building system, but it also reduces utility costs to an owner and can save them money over time.

Problem Statement

SWR systems are still fairly new to the industry. Figure 18 shows the result of a survey conducted to find out how common SWR systems are in the industry today. Many contractors are inexperienced with these types of systems and often do not anticipate the issues or conflicts that may arise when installing them. These issues may range from coordination with the MEP systems to site layout planning.

Figure 18: Have you ever worked on a project or designed a SWR system?

Proposal

To study the conflicts and issues with implementing a SWR system on several projects and case studies in order to document the issues and concerns for construction managers. Several different types of this system will be analyzed for different projects on which they were implemented. They will each then be evaluated and compared to determine the critical concerns when implementing this type of system, as well as the advantages and disadvantages of each system. Each system will be reviewed for the following 3 CM Concerns:

1. Constructability
2. Coordination Issues
3. Schedule Impacts

This analysis will form a guide for construction managers to review when using a SWR system in order to avoid conflicts in the field that may impact schedule, cost or quality of construction.

Results/Design Criteria

Three projects utilizing different configurations of SWR systems were analyzed and compared for the four categories mentioned previously. The first type of system is the one found on this thesis project. There is a 20,000 gallon SWR tank located below grade just outside the building footprint. The initial design called for a pump vault to be cast sub-grade next to the tank to pump the water from the tank back to the building to be treated and distributed as needed. These pumps are necessary due the tank being located below the lowest level of the building. A schematic of this system can be found in Appendix E. The contractor ran into many conflicts in with this type of system that could have been avoided with proper knowledge of SWR systems. The table below illustrates the two primary concerns/issues experienced on this project and actions taken or looked at to mitigate the conflict.

Concern/Issue	Action Taken	Other Possible Actions
1. The pump warranty was voided due to the pump vault not located in a conditioned space.	1. Relocate the pump vault to a conditioned space inside the building footprint	1. Prior to purchasing look into submersible pumps that would save money vs. moving the entire pump vault.
2. The soil above the tank could not have any heavy machinery or load on it after the tank was installed. The tank is located right in the construction path next to the building footprint	2. Early coordination of scheduling trades with heavy machinery prior to installation and backfill of tank	2. Cover area over tank with supports to transfer heavy loads to soil with proper bearing capacity.

The second type of system analyzed was on the Chesapeake Bay Foundation Phillip Merrill Environmental Center building (CBFPMEC). This system is located above grade on the outside of the building footprint, as can be seen in the image to the right. Three tanks manufactured from recycled pickle barrels are located on the lower roof of the building. This allows for the elimination of pumps to boost the water back into the building. The system takes advantage of gravity to supply the water to its desired location. The table below illustrates the two primary concerns/issues experienced on this project and actions taken or looked at to mitigate the conflict.

Figure 19: SWR Tanks @ CBFPMEC

Concern/Issue	Action Taken	Other Possible Actions
1. The long lead time for the tanks to be manufactured	1. Tank connections and plumbing rough-in to point of quick connection when the tanks were delivered	1. Earlier involvement of the CM/GC with the design to realize this would be an issue
2. A crane with significant capacity was required to place the tanks on the roof significantly after the crane had left from the earlier phases.	2. Brought in another crane with capacity to lift tanks into place. This was costly and time consuming compared to earlier coordination of lifting capabilities. Primarily caused by unexpected long lead time.	2. Early sequencing coordination with the crane to ensure another crane will not need to be brought back on site. This can only be done by earlier purchasing of the tanks to coordinate delivery with availability of the crane on site.

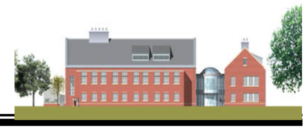
The final type of SWR system analyzed was on Penn State's SALA building. This system is similar to the first and second systems in that it is located partially sub-grade; however, it is not below the lowest level of the building and can still utilize gravity to supply the water to the desired location. The tanks are partially below grade and a stone wall built around them to make them aesthetically pleasing. The tanks were originally designed to eliminate all potable water needed for irrigation. The table below illustrates the primary concern/issue experienced on this project and actions taken or looked at to mitigate the conflict

Concern/Issue	Action Taken	Other Possible Actions
1. Utility cost savings analysis did not warrant the implementation of this system for irrigation control	1. One tank and the irrigation system were eliminated and the other was left to still obtain one LEED credit for storm water management. One credit was lost however	1. Use a more passive system that does not require pumps for the irrigation system. 2. Better research on Penn States maintenance and irrigation procedures

CM Concerns

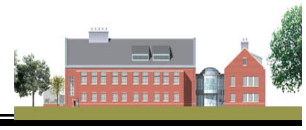
Based on the actual conflicts and issues experienced for each system on each site a list of CM concerns has been populated below to inform project teams of potential problems and issues associated with SWR systems.

Project/System Type	CM Concerns and Issues
EHS NSF Building	1. Extensive coordination with other trades to ensure rough-ins and connections are correct before backfilling. 2. Coordination with foundations systems to ensure pump vault is not in the way and is complete before slab on grade is pored. 3. Proper installation and connections insured before backfill. 4. Warranties from manufacturers are not compromised (for pumps and tanks). Is the pump submersible or does it require a conditioned space? 5. Surface above the tank is protected against heavy machinery (especially if close to the building footprint) 6. Delays will result in large schedule impacts since it is on the critical path.
CBFPMEC Building	1. Tanks are not in the way of construction 2. Aesthetics of tanks is not compromised during installation 3. Crane is onsite for placement of tanks 4. Rough-ins are completed prior to installation of tanks 5. Gravity lines have necessary drop to maintain flow 6. Long lead times for tanks
PSU SALA Building	1. Tanks are not in the way of construction 2. Rough-ins are completed and tested prior to tank installation and backfill 3. Gravity lines have necessary drop to maintain flow 4. Significant lead time for tanks



Advantages and Disadvantages of Each System

Project/System	Advantages	Disadvantages
EHS NSF Building	1. No site space required 2. Aesthetically pleasing 3. Freeze protected (if below the frost line) 4. Cheaper non aesthetic tanks allowed	1. Pumps required to allocate water into the building 2. Intense sequencing and coordination issues for installation 3. Critical to the schedule of the project due to sub-grade components 4. Difficult to detect leaks
CBFPMEC Building	1. Pumps to allocate water eliminated (gravity) 2. Sequencing not critical (can install and just hook into rough-in) 3. Coordination with other trades is less critical due to easy access to tanks 4. Easy to detect leaks	1. Aesthetic concerns 2. Exposed to the elements 3. More space required 4. Site Congestion
PSU SALA Building	1. Pumps to allocate water eliminated (gravity) 2. Aesthetically pleasing 3. Sequencing not critical (can install and just hook into rough-in) 4. Easy to detect leaks	1. Critical to coordination of trades (piping rough-in and control systems) 2. More Space Required 3. Site Congestion



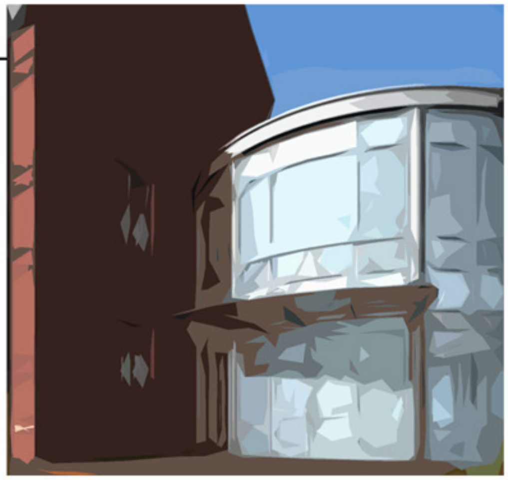
Conclusions

Stormwater Reclaim systems and Rainwater Catchment systems are becoming increasingly popular in the industry. Many concerns and conflicts still arise on projects that make these systems expensive to implement and intimidating to project teams.

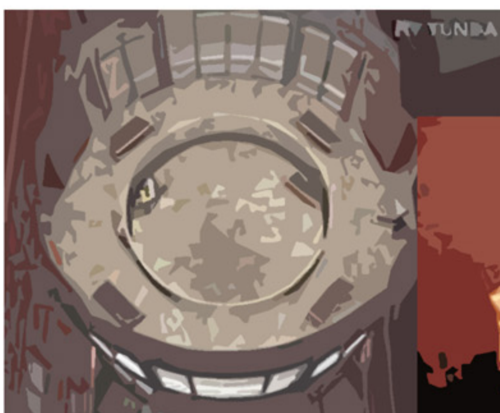
Each SWR system is unique to each project. System designs are determined by the following factors:

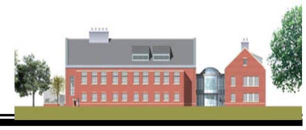
- budget
- objective of the system
- aesthetic requirements
- site layout and conditions
- local weather patterns (location)

Different conflicts or construction management issues arise on each project that are specific to that project; however, in each specific case there are actions that can be taken to mitigate the risk of conflict occurring in the field. In each case earlier involvement of the CM/GC to the design process would help to alleviate the risk of conflicts occurring in the field as well as reduce or eliminate over design issues for new SWR systems.



Summary & Conclusions



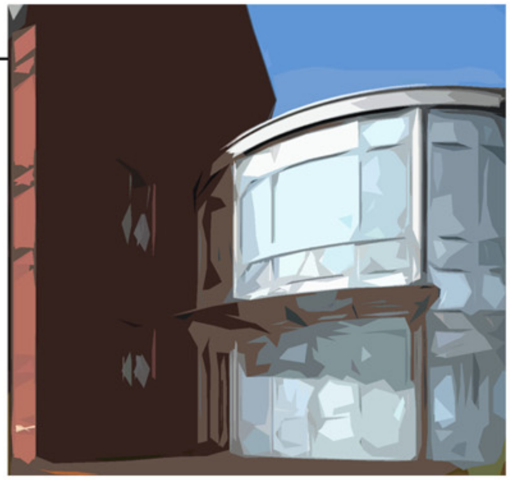


Summary & Conclusions

Green building design and high performance buildings are becoming an increasingly popular option in the industry today. Through the analysis of the Episcopal High School's New Science Facility, several different aspects of the design were analyzed from a sustainable and green approach. The feasibility of implementing a fairly new wall system with Zero Percent Air Infiltration for sustainable construction and high performance purposes was analyzed by looking at both initial cost as well as energy savings impacts. It was realized that for this project a ZPAI system would not be beneficial due to high initial cost and minimal energy savings.

The mechanical system accounts for a majority of the buildings total energy usage. By looking at high performance upgrades energy cost savings can be realized over the life of the building. Over time the upgrades payback their initial cost and eventually save the owner money on a yearly basis.

Lastly, water efficiency has taken large steps recently thanks to the LEED program. One of the most significant ways to reduce water usage on a project is to implement a Stormwater Reclaim System or Rainwater Catchment System. These systems are extremely new, however, and often times cause many conflicts on projects. These conflicts can be avoided with earlier involvement by the CM/GC with the design process, as well as more extensive and earlier coordination between the CM/GC and the trades involved with the SWR system.



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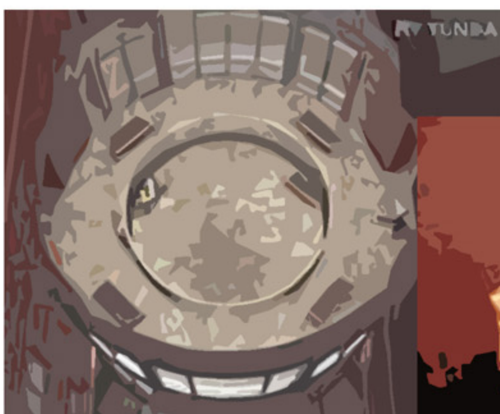

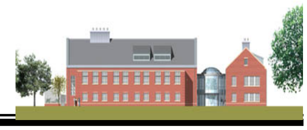

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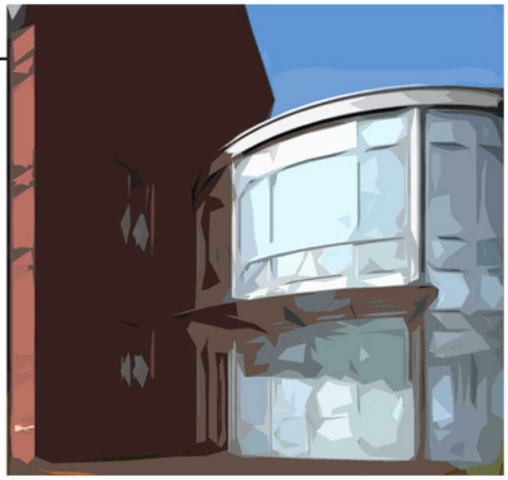

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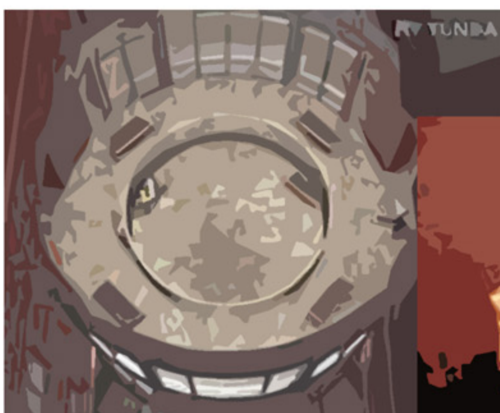

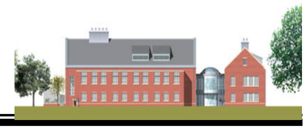

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- Steve Houff
- Rob Wenger
- Arland Knipe
- Jonathan McGee
- Jack Kwait-Blank
- Raissa Mallinger

Graham Gund Architects:

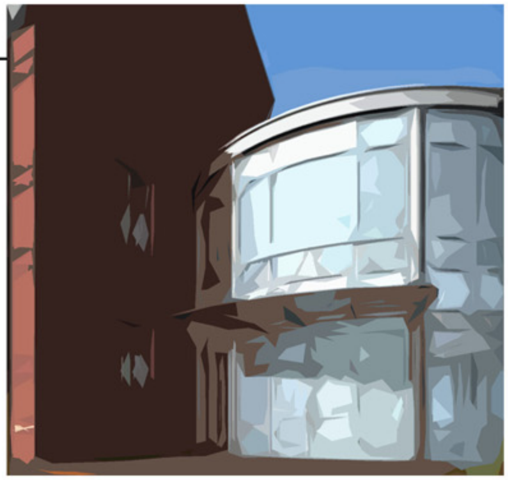
- Jon Richardson

R.G. Vanderweil Engineers, Inc. (Mechanical):

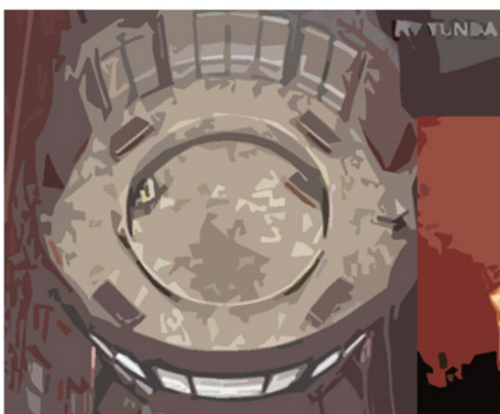
- Courtland Blake

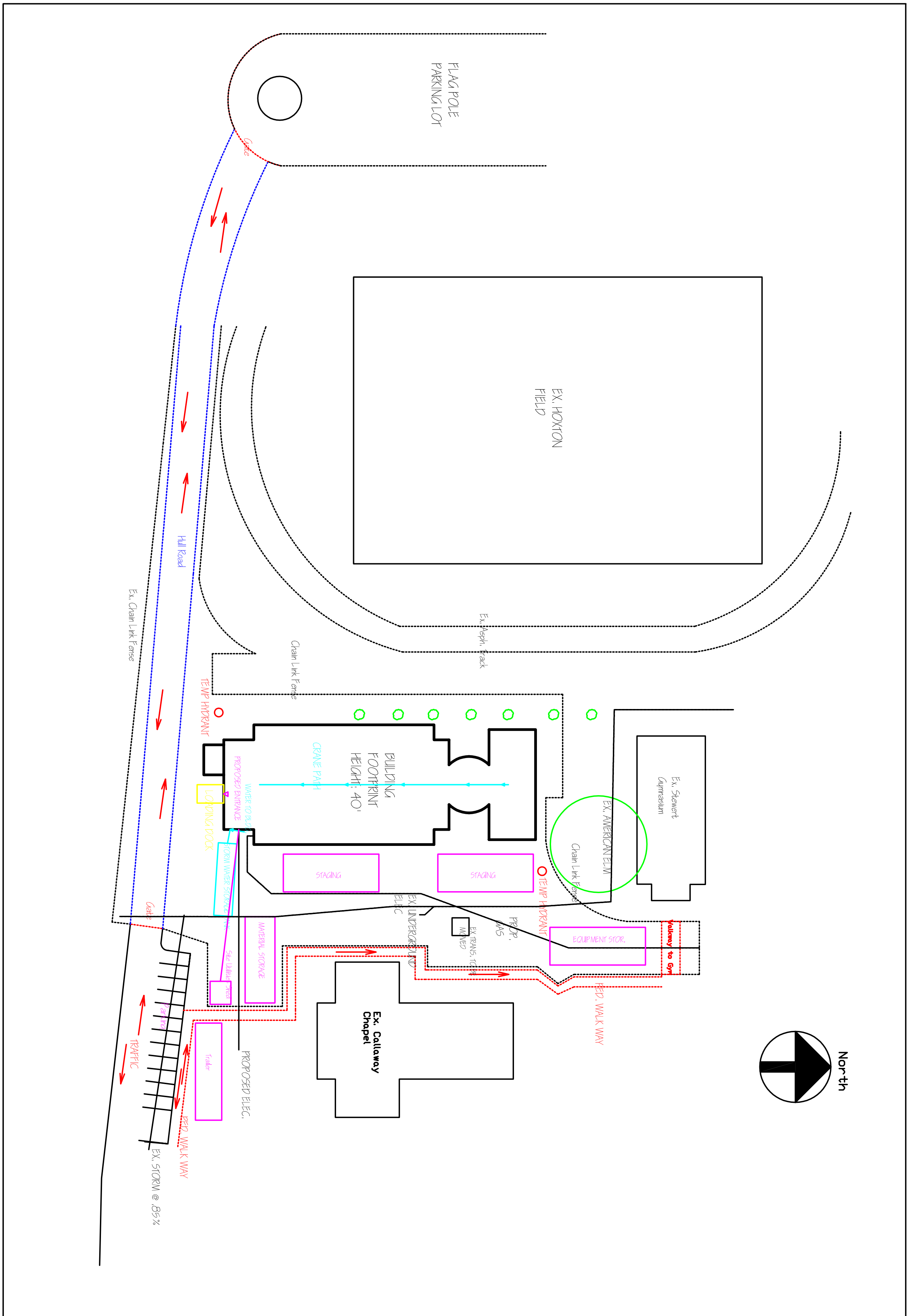
All of my family and friends for all of their support throughout my entire AE carrer, with out them this would not be possible. Especially:

- Mom and Dad
- All the AE students for the support and competition
- Nikkee Porcaro
- Larry Good (mechanical consultant)



Appendix A





EPISCOPAL HIGH SCHOOL

NEW SCIENCE FACILITY

1200 NORTH QUAKER LANE ALEXANDRIA, VA 22302

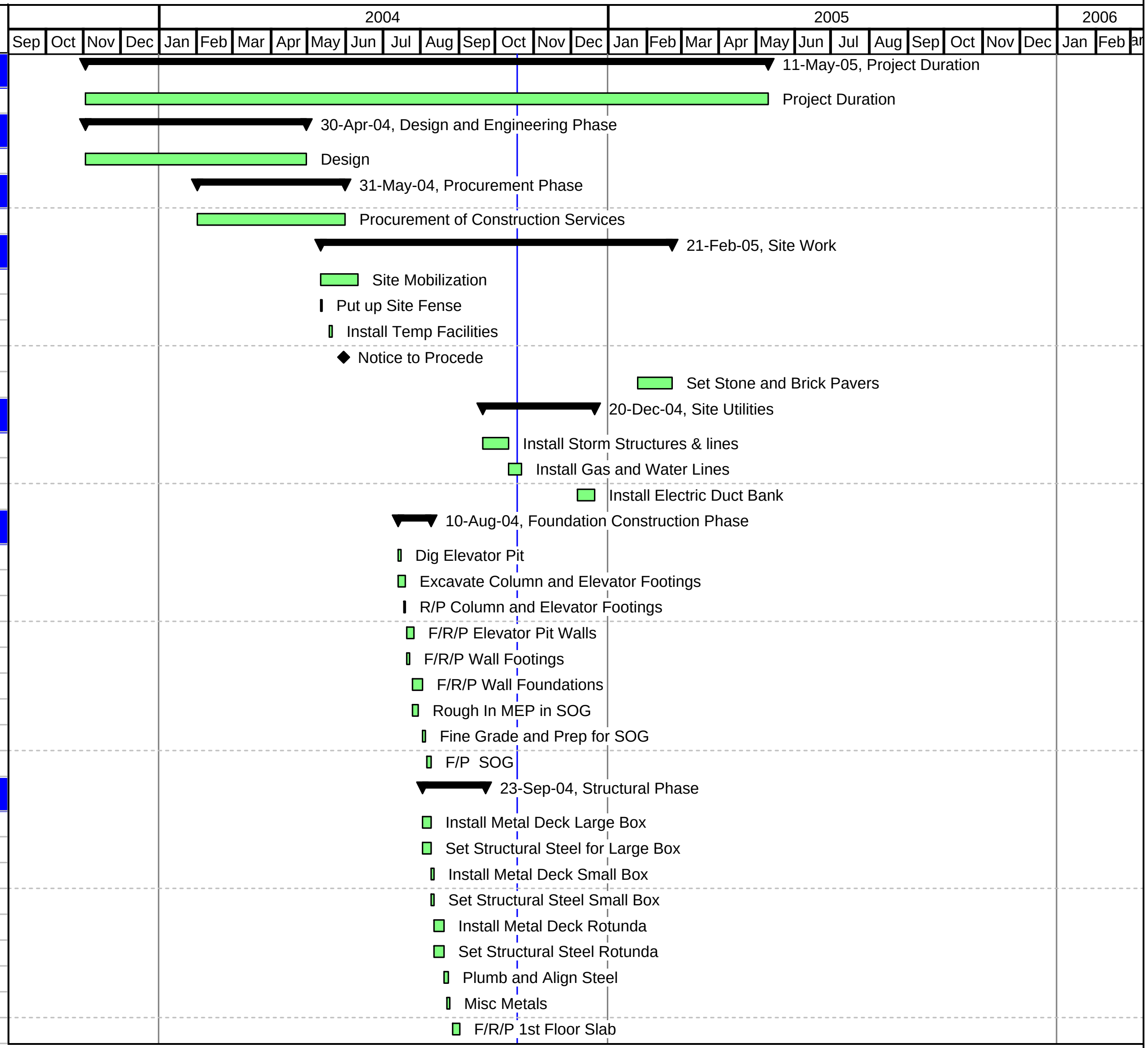
JACK NILL'S SENIOR THESIS
PENNSYLVANIA STATE UNIVERSITY
CONSTRUCTION MANAGEMENT
DR. MESSNER

EXITING CONDITIONS SITE PLAN

DATE: OCTOBER 4, 2004
SCALE: NTS
DRAWN BY: JACK NILL
REVISIONS:
SHEET NUMBER:

C1.0

Activity Name	Original Duration	Start	Finish
Project Duration	398	03-Nov-03	11-May-05
Project Duration	398	03-Nov-03*	11-May-05
Design and Engineering ...	130	03-Nov-03	30-Apr-04
Design	130	03-Nov-03*	30-Apr-04
Procurement Phase	86	02-Feb-04	31-May-04
Procurement of Construction Services	86	02-Feb-04	31-May-04
Site Work	204	12-May-04	21-Feb-05
Site Mobilization	23	12-May-04	11-Jun-04
Put up Site Fense	2	12-May-04	13-May-04
Install Temp Facilities	3	19-May-04	21-May-04
Notice to Procede	0	31-May-04	
Set Stone and Brick Pavers	20	25-Jan-05*	21-Feb-05
Site Utilities	65	21-Sep-04	20-Dec-04
Install Storm Structures & lines	15	21-Sep-04	11-Oct-04
Install Gas and Water Lines	9	12-Oct-04*	22-Oct-04
Install Electric Duct Bank	10	07-Dec-04*	20-Dec-04
Foundation Constructio...	20	14-Jul-04	10-Aug-04
Dig Elevator Pit	3	14-Jul-04	16-Jul-04
Excavate Column and Elevator Footi...	4	14-Jul-04	19-Jul-04
R/P Column and Elevator Footings	2	19-Jul-04	20-Jul-04
F/R/P Elevator Pit Walls	4	21-Jul-04	26-Jul-04
F/R/P Wall Footings	3	21-Jul-04	23-Jul-04
F/R/P Wall Foundations	6	26-Jul-04	02-Aug-04
Rough In MEP in SOG	5	26-Jul-04	30-Jul-04
Fine Grade and Prep for SOG	3	03-Aug-04	05-Aug-04
F/P SOG	3	06-Aug-04	10-Aug-04
Structural Phase	38	03-Aug-04	23-Sep-04
Install Metal Deck Large Box	6	03-Aug-04	10-Aug-04
Set Structural Steel for Large Box	6	03-Aug-04	10-Aug-04
Install Metal Deck Small Box	3	10-Aug-04	12-Aug-04
Set Structural Steel Small Box	3	10-Aug-04	12-Aug-04
Install Metal Deck Rotunda	7	12-Aug-04	20-Aug-04
Set Structural Steel Rotunda	7	12-Aug-04	20-Aug-04
Plumb and Align Steel	2	20-Aug-04	23-Aug-04
Misc Metals	3	23-Aug-04*	25-Aug-04
F/R/P 1st Floor Slab	5	27-Aug-04	02-Sep-04

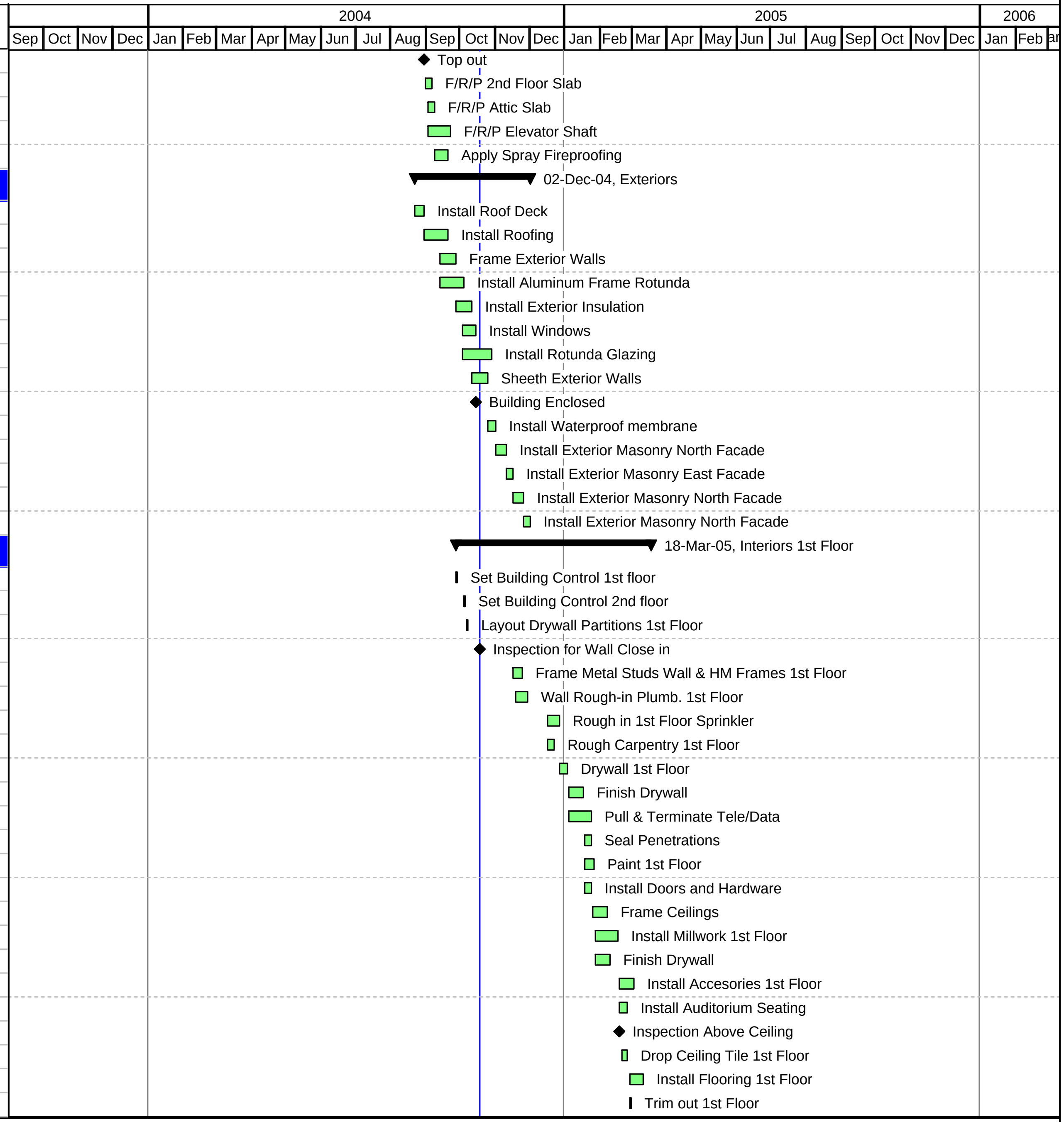


Actual Work
Remaining Work
Critical Remaining Work
Milestone
Summary

Jack Nill
Construction Management
Dr. Jon Messner

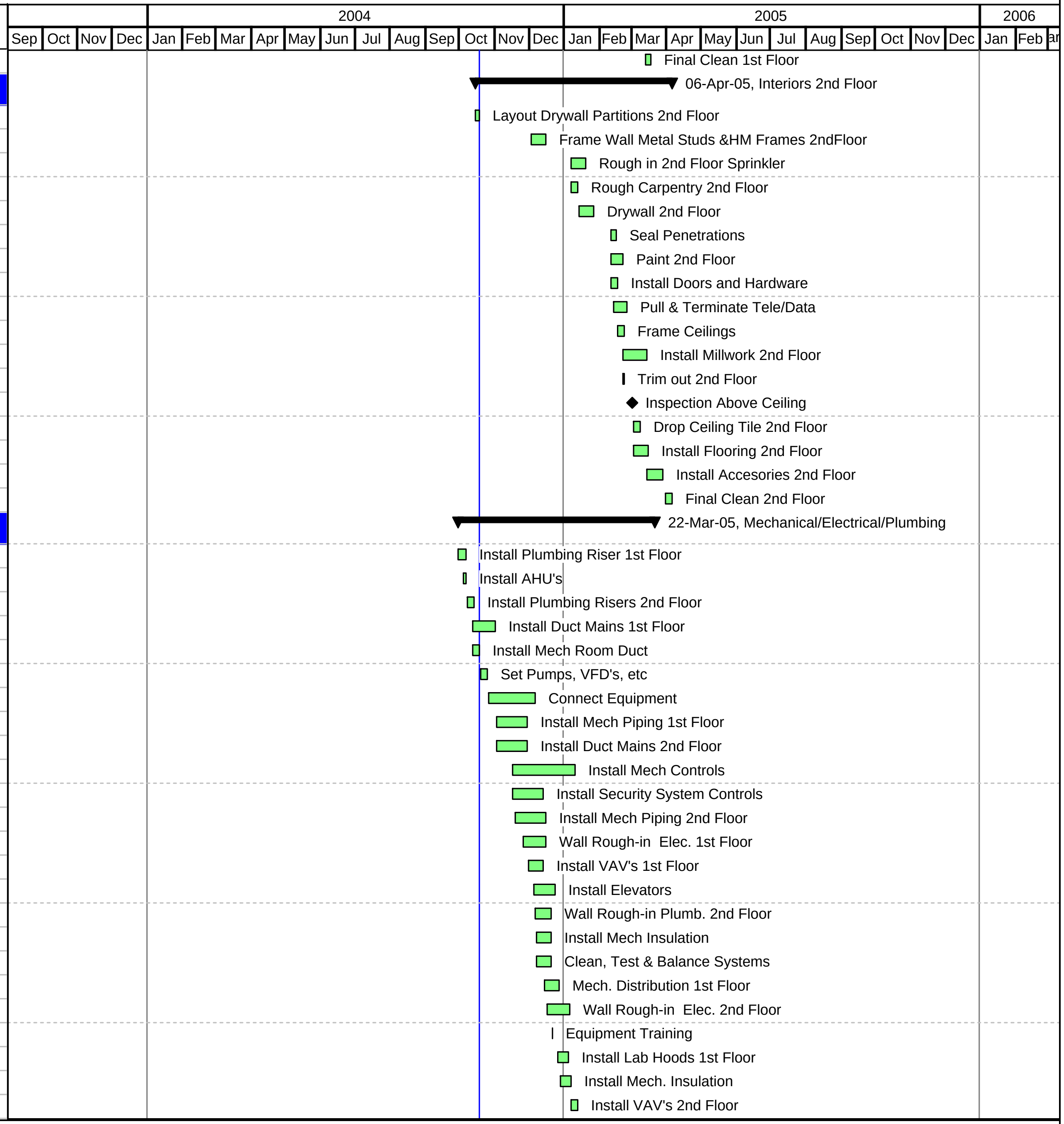
EHS New Scince Facility
Alexandria, VA

Activity Name	Original Duration	Start	Finish
Top out	0		31-Aug-04
F/R/P 2nd Floor Slab	5	01-Sep-04	07-Sep-04
F/R/P Attic Slab	5	03-Sep-04	09-Sep-04
F/R/P Elevator Shaft	15	03-Sep-04	23-Sep-04
Apply Spray Fireproofing	9	09-Sep-04	21-Sep-04
Exteriors	74	23-Aug-04	02-Dec-04
Install Roof Deck	7	23-Aug-04	31-Aug-04
Install Roofing	15	31-Aug-04	20-Sep-04
Frame Exterior Walls	11	14-Sep-04	28-Sep-04
Install Aluminum Frame Rotunda	15	14-Sep-04	04-Oct-04
Install Exterior Insulation	11	28-Sep-04	12-Oct-04
Install Windows	10	04-Oct-04*	15-Oct-04
Install Rotunda Glazing	20	04-Oct-04	29-Oct-04
Sheeth Exterior Walls	10	12-Oct-04	25-Oct-04
Building Enclosed	0		15-Oct-04
Install Waterproof membrane	5	26-Oct-04*	01-Nov-04
Install Exterior Masonry North Facade	8	02-Nov-04*	11-Nov-04
Install Exterior Masonry East Facade	5	11-Nov-04*	17-Nov-04
Install Exterior Masonry North Facade	8	17-Nov-04*	26-Nov-04
Install Exterior Masonry North Facade	5	26-Nov-04*	02-Dec-04
Interiors 1st Floor	124	28-Sep-04	18-Mar-05
Set Building Control 1st floor	2	28-Sep-04	29-Sep-04
Set Building Control 2nd floor	2	05-Oct-04	06-Oct-04
Layout Drywall Partitions 1st Floor	2	07-Oct-04	08-Oct-04
Inspection for Wall Close in	0		19-Oct-04
Frame Metal Studs Wall & HM Fram...	7	17-Nov-04*	25-Nov-04
Wall Rough-in Plumb. 1st Floor	8	19-Nov-04*	30-Nov-04
Rough in 1st Floor Sprinkler	7	17-Dec-04*	27-Dec-04
Rough Carpentry 1st Floor	5	17-Dec-04*	23-Dec-04
Drywall 1st Floor	6	28-Dec-04*	04-Jan-05
Finish Drywall	10	05-Jan-05*	18-Jan-05
Pull & Terminate Tele/Data	15	05-Jan-05*	25-Jan-05
Seal Penetrations	4	19-Jan-05*	24-Jan-05
Paint 1st Floor	7	19-Jan-05*	27-Jan-05
Install Doors and Hardware	5	19-Jan-05*	25-Jan-05
Frame Ceilings	10	26-Jan-05*	08-Feb-05
Install Millwork 1st Floor	15	28-Jan-05*	17-Feb-05
Finish Drywall	10	28-Jan-05*	10-Feb-05
Install Accesories 1st Floor	10	18-Feb-05*	03-Mar-05
Install Auditorium Seating	6	18-Feb-05*	25-Feb-05
Inspection Above Ceiling	0		18-Feb-05
Drop Ceiling Tile 1st Floor	5	21-Feb-05*	25-Feb-05
Install Flooring 1st Floor	10	28-Feb-05*	11-Mar-05
Trim out 1st Floor	2	28-Feb-05*	01-Mar-05



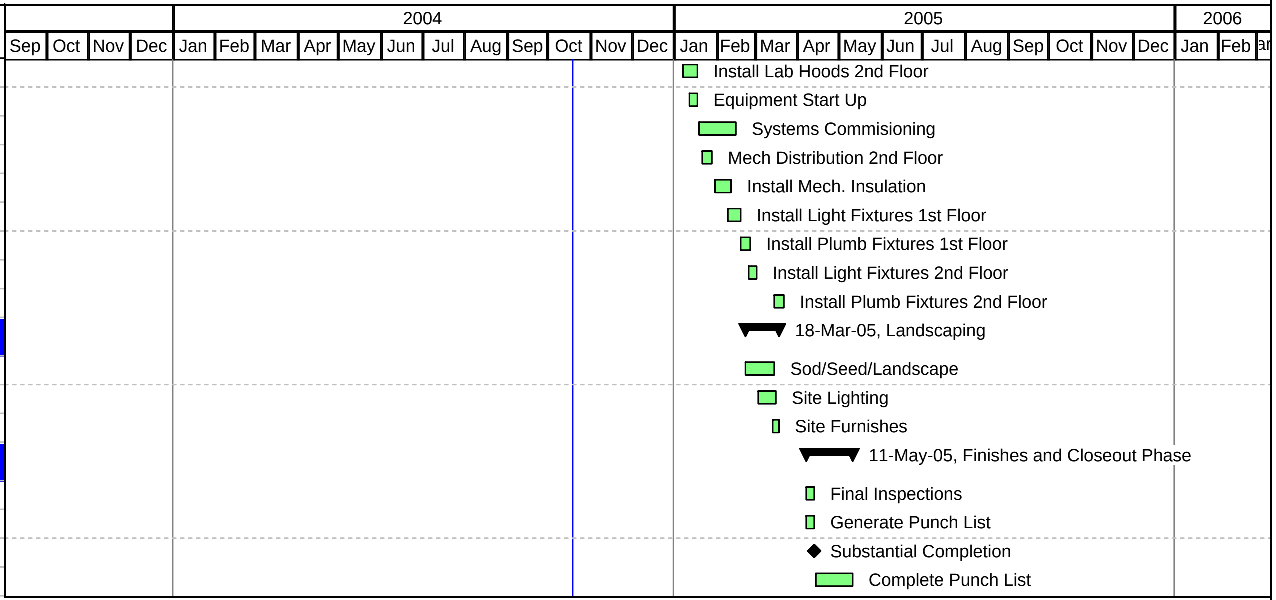
Jack Nill

Activity Name	Original Duration	Start	Finish
Final Clean 1st Floor	5	14-Mar-05*	18-Mar-05
Interiors 2nd Floor	124	15-Oct-04	06-Apr-05
Layout Drywall Partitions 2nd Floor	2	15-Oct-04	18-Oct-04
Frame Wall Metal Studs &HM Frame...	10	03-Dec-04*	16-Dec-04
Rough in 2nd Floor Sprinkler	10	07-Jan-05*	20-Jan-05
Rough Carpentry 2nd Floor	5	07-Jan-05*	13-Jan-05
Drywall 2nd Floor	10	14-Jan-05*	27-Jan-05
Seal Penetrations	4	11-Feb-05*	16-Feb-05
Paint 2nd Floor	7	11-Feb-05*	21-Feb-05
Install Doors and Hardware	5	11-Feb-05*	17-Feb-05
Pull & Terminate Tele/Data	10	14-Feb-05*	25-Feb-05
Frame Ceilings	5	17-Feb-05*	23-Feb-05
Install Millwork 2nd Floor	15	22-Feb-05*	14-Mar-05
Trim out 2nd Floor	2	22-Feb-05*	23-Feb-05
Inspection Above Ceiling	0		02-Mar-05
Drop Ceiling Tile 2nd Floor	5	03-Mar-05*	09-Mar-05
Install Flooring 2nd Floor	10	03-Mar-05*	16-Mar-05
Install Accesories 2nd Floor	10	15-Mar-05*	28-Mar-05
Final Clean 2nd Floor	5	31-Mar-05*	06-Apr-05
Mechanical/Electrical/Pl...	124	30-Sep-04	22-Mar-05
Install Plumbing Riser 1st Floor	6	30-Sep-04	07-Oct-04
Install AHU's	3	05-Oct-04	07-Oct-04
Install Plumbing Risers 2nd Floor	5	08-Oct-04	14-Oct-04
Install Duct Mains 1st Floor	15	13-Oct-04	02-Nov-04
Install Mech Room Duct	5	13-Oct-04	19-Oct-04
Set Pumps, VFD's, etc	5	20-Oct-04*	26-Oct-04
Connect Equipment	30	27-Oct-04*	07-Dec-04
Install Mech Piping 1st Floor	20	03-Nov-04*	30-Nov-04
Install Duct Mains 2nd Floor	20	03-Nov-04*	30-Nov-04
Install Mech Controls	40	17-Nov-04*	11-Jan-05
Install Security System Controls	20	17-Nov-04*	14-Dec-04
Install Mech Piping 2nd Floor	20	19-Nov-04*	16-Dec-04
Wall Rough-in Elec. 1st Floor	15	26-Nov-04*	16-Dec-04
Install VAV's 1st Floor	10	01-Dec-04*	14-Dec-04
Install Elevators	15	06-Dec-04*	24-Dec-04
Wall Rough-in Plumb. 2nd Floor	10	07-Dec-04*	20-Dec-04
Install Mech Insulation	10	08-Dec-04*	21-Dec-04
Clean, Test & Balance Systems	10	08-Dec-04*	21-Dec-04
Mech. Distribution 1st Floor	10	15-Dec-04*	28-Dec-04
Wall Rough-in Elec. 2nd Floor	15	17-Dec-04*	06-Jan-05
Equipment Training	1	22-Dec-04*	22-Dec-04
Install Lab Hoods 1st Floor	8	27-Dec-04*	05-Jan-05
Install Mech. Insulation	8	29-Dec-04*	07-Jan-05
Install VAV's 2nd Floor	5	07-Jan-05*	13-Jan-05



Jack Nill

Activity Name	Original Duration	Start	Finish
Install Lab Hoods 2nd Floor	8	07-Jan-05*	18-Jan-05
Equipment Start Up	5	12-Jan-05*	18-Jan-05
Systems Commisioning	20	19-Jan-05*	15-Feb-05
Mech Distribution 2nd Floor	6	21-Jan-05*	28-Jan-05
Install Mech. Insulation	10	31-Jan-05*	11-Feb-05
Install Light Fixtures 1st Floor	8	09-Feb-05*	18-Feb-05
Install Plumb Fixtures 1st Floor	6	18-Feb-05*	25-Feb-05
Install Light Fixtures 2nd Floor	5	24-Feb-05*	02-Mar-05
Install Plumb Fixtures 2nd Floor	6	15-Mar-05*	22-Mar-05
Landscaping	19	22-Feb-05	18-Mar-05
Sod/Seed/Landscape	15	22-Feb-05*	14-Mar-05
Site Lighting	10	03-Mar-05*	16-Mar-05
Site Furnishes	5	14-Mar-05*	18-Mar-05
Finishes and Closeout P...	25	07-Apr-05	11-May-05
Final Inspections	5	07-Apr-05*	13-Apr-05
Generate Punch List	5	07-Apr-05*	13-Apr-05
Substantial Completion	0		13-Apr-05
Complete Punch List	20	14-Apr-05*	11-May-05



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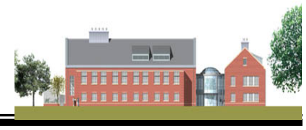


Interview Questions for each consultant (ZPAI)

Architect

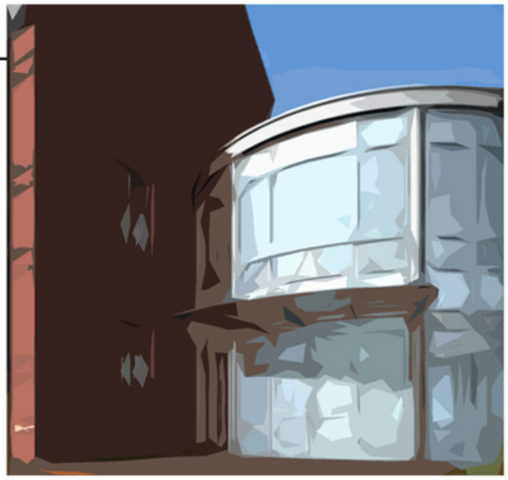
1. What makes a Zero Percent Air Infiltration (ZPAI) Wall System different from a typical exterior wall system?
2. Why was the (ZPAI) system developed?
3. Does the system cause any issues with indoor air quality since it eliminates the infiltration of fresh air from the outside?
4. What are the unique features of this system that are vital to a good design of this system?
5. Do you see the industry possibly using this system in high performance and sustainable construction?

Mechanical Engineers

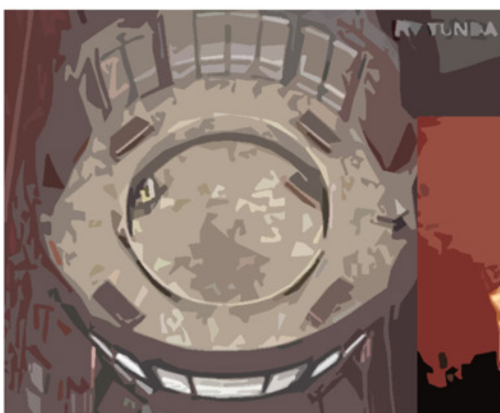
1. How much does a ZPAI system reduce the mechanical loads for a building?
2. How does a ZPAI wall system affect the sizing of the mechanical equipment for a particular project? (Thus the cost?)
3. What are some issues that must be taken into consideration when designing the mechanical systems for a ZPAI system such as IAQ or others?
4. How does the ZPAI system affect the life cycle cost of building?
5. Do you see the industry possibly using this system in high performance and sustainable construction?

Construction Managers

1. What are the critical constructability issues that arise when constructing a ZPAI system?
2. What are the initial costs incurred when incorporating this type of wall system?
3. How much extra coordination amongst trades if any is induced by using a ZPAI wall system?
4. Do you see the industry possibly using this system in high performance and sustainable construction?



Appendix B



Perm-A-Barrier® Wall Membrane

Self-adhesive, rubberized asphalt/polyethylene waterproofing membrane for air and vapor barrier applications

Advantages

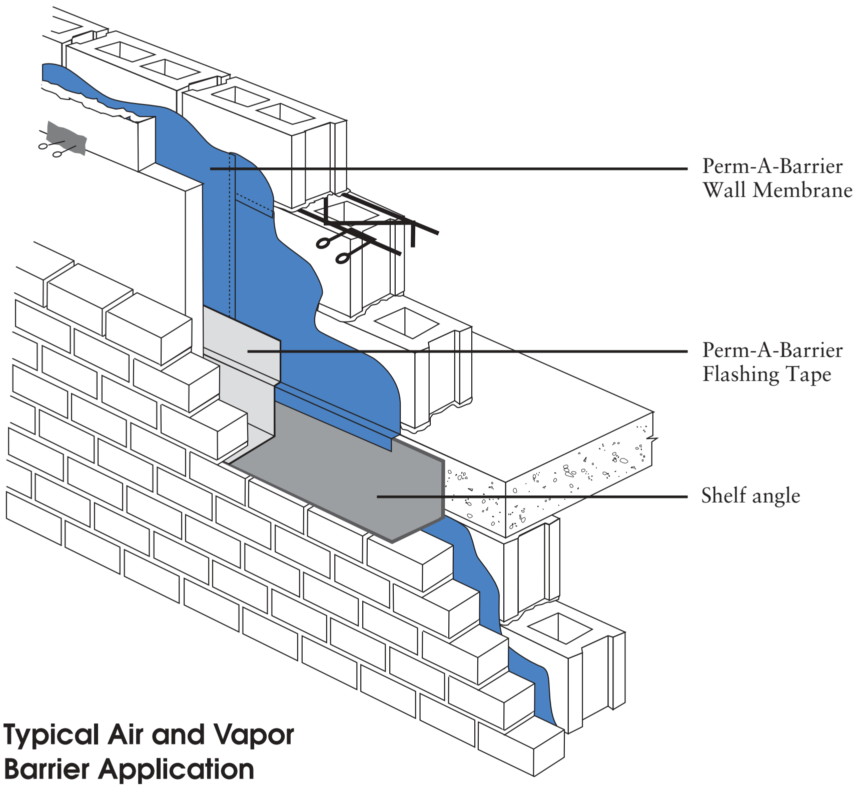
- **Fully bonded** – transmits wind loads directly to the substrate
- **Waterproof and virtually impermeable to moisture** – virtually impermeable to the passage of liquid water and vapor
- **Air tight** – exceeds CCMC requirements for air barrier membranes and complies with Massachusetts State Energy Code
- **Cross laminated film** – provides dimensional stability, high tear strength, puncture and impact resistance
- **Cold applied** – no flame hazard; self-adhesive overlaps ensure continuity
- **Flexible** – accommodates minor settlement and shrinkage movement
- **Controlled thickness** – factory made sheet ensures constant, non-variable site application
- **Aggressive, conformable adhesive** – allows self-sealing around mechanical fasteners
- **Wide application window** –
  - **Perm-A-Barrier® Wall Membrane** surface and ambient temperatures at 5°C (40°F) and above
  - **Perm-A-Barrier System 4000 Wall Membrane** surface and ambient temperatures at -4°C (25°F) and above
  - **Perm-A-Barrier Low Temperature Wall Membrane** surface and ambient temperatures between -4°C (25°F) and 16°C (60°F)

Description

Perm-A-Barrier wall membranes are ideal for protecting the building superstructure from the damaging effects of the elements.

By minimizing air and water vapor flow through the building exterior, Perm-A-Barrier wall membranes:

- Prevent premature deterioration of the building envelope
- Enhance thermal performance of the structure and save energy costs
- Improve comfort for the building occupants



Typical Air and Vapor Barrier Application

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System Components

- **Perm-A-Barrier System 4000 Wall Membrane –** extended temperature range system for use at all temperatures above -4°C (25°F), conveniently packaged with a unique water-based surface conditioner
- **Perm-A-Barrier Wall Membrane** – standard grade for use at temperatures above 5°C (40°F)
- **Perm-A-Barrier Low Temperature Wall Membrane –** low temperature grade for use at temperatures between -4°C (25°F) and 16°C (60°F)
- **Perm-A-Barrier Surface Conditioner –** water-based surface treatment for use with System 4000 on cementitious substrates
- **Perm-A-Barrier WB Primer –** high tack, water-based primer for use with Perm-A-Barrier Wall Membrane and Perm-A-Barrier Low Temperature Wall Membrane on cementitious and exterior gypsum wallboards
- **Bituthene® Primer B2 –** used to prime "green" concrete or damp substrates
- **Bituthene Mastic Trowel Grade** – rubberized asphalt mastic for sealing patches, terminations, brick ties, etc.

Installation

Safety

Perm-A-Barrier products must be handled properly. Vapors from the mastic and solvent-based primer are harmful and flammable. For these products, the best available information on safe handling, storage, personal protection, health and environmental considerations has been gathered. Refer to product label and Material Safety Data Sheet before use. All users should acquaint themselves with this information prior to working with the material. Carefully read detailed precaution statements on the product labels and MSDS before use. MSDSs can be obtained from our web site at www.graceconstruction.com or by contacting us toll free at 866-333-3SBM (3726).

Surface Preparation

Surface must be smooth, clean, dry and free of voids, spalled areas, loose aggregate, loose nails, sharp protrusions or other matter that will hinder the adhesion or regularity of the wall membrane installation. Clean loose dust or dirt from the surface to which the wall membrane is to be applied by wiping with a clean, dry cloth or brush.

If the substrate is damp, allow to dry or use Bituthene Primer B2 to prepare the area to receive the membrane.

Temperature

Perm-A-Barrier System 4000 Membrane and Bituthene Surface Conditioner may be applied only in dry weather when air and surface temperatures are above -4°C (25°F). Perm-A-Barrier Low Temperature Membrane may be applied only in dry weather when air and surface temperatures are between -4°C (25°F) and 16°C (60°F). Perm-A-Barrier Wall Membrane may be applied only in dry weather when air and surface temperatures are above 5°C (40°F).

Application

Conditioning and Priming:
Bituthene System 4000 Surface Conditioner is supplied ready to use. It should not be diluted with water or solvent. Mix and apply a light coating with a portable spray unit, brush or roller. Conditioner will cover 6-8 m^2/L (250-350 ft^2/gal) when applied with a low pressure, portable sprayer. Allow surface conditioner to dry completely before membrane application. The surface conditioner is considered dry when the substrate returns to its original color (minimum 1 hour). To test for dryness, rub small conditioned area by hand. Wet conditioner will ball up under the fingertips. Let dry until conditioner cannot be rubbed off. Condition only areas that can be covered the same day. Conditioned areas not covered the same day should be reconditioned.

Perm-A-Barrier WB Primer is a water-based primer which imparts an aggressive, high tack finish on the treated substrate. It is packaged ready to use and is specifically designed to facilitate tenacious adhesion of Perm-A-Barrier flashing tapes and wall membranes to glass mat surfaces and exterior gypsum boards such as Dens-Glass Gold®. Apply Perm-A-Barrier WB Primer by roller at a coverage rate of 6-8 m^2/L (250-350 ft^2 gal). Allow to dry for a minimum of 1 hour (longer at low temperatures).

Membrane Application

Cut membrane into easily handled lengths. Apply membrane horizontally or vertically to primed substrates receiving post-applied masonry anchors (ties), such as gypsum sheathing.

Apply wall membranes horizontally to the primed blockwork with projecting masonry anchors (ties), beginning at the base of the wall. Each length of the membrane must be installed so that the upper edge runs continuously along the underside of the line of masonry anchors (ties). Subsequent sheets applied above must overlap the sheet below by 51 mm (2 in.) immediately below the line of anchors (ties). Since the membrane width appropriate for this application of 457 mm (18 in.) is wider than the typical spacing between the lines of anchors (ties) 406 mm (16 in.), it will be necessary to cut the membrane at the location of the tie wires projecting from the wall to enable the sheet to be laid in place. End laps that occur in subsequent lengths that follow should maintain a minimum overlap of 51 mm (2 in.). See Figures 1 and 2.

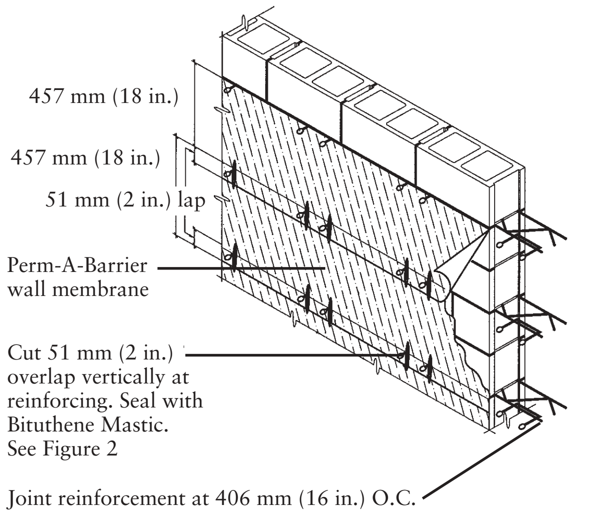

Figure 1: Membrane System Detail

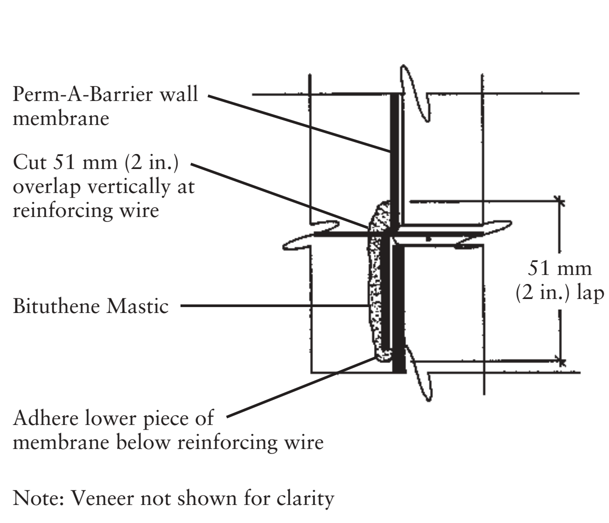

Figure 2: Horizontal Reinforcing

The membrane must be pressed firmly into place with a hand roller or the back of a utility knife as soon as possible, ensuring continuous and intimate contact with the substrate to prevent water from migrating under the membrane.

In certain applications such as on soffits, ceilings or substrates such as oriented strand board (OSB), backnail the membrane along the side lap prior to installing the next sheet of membrane to ensure positive contact to the substrate.

Apply Bituthene Mastic to seal around the tie wire projections. Fit the Perm-A-Barrier wall membrane tightly around all penetrations through the membrane and seal using Bituthene Mastic.

Continue the membrane into all openings in the wall area, such as windows, doors, etc., and terminate at points that will prevent interior visibility. The installation must be made continuous at all framed openings. Coordinate installation of the Perm-A-Barrier wall membrane with the roofing trade to ensure continuity with the roofing system at this critical transition area.

At the end of each working day, if the wall has been only partially covered, apply a bead of Bituthene Mastic along the top edge of the membrane at its termination to prevent vertical drainage of precipitation from penetrating the end and undermining the membrane adhesion. Tool the Bituthene Mastic to ensure it is worked into the surface. Inspect the membrane before covering and repair any punctures, damaged areas or inadequately lapped seams.

Membrane Repairs

Repairs must be made using Perm-A-Barrier wall membrane sized to extend 150 mm (6 in.) in all directions from the perimeter of the affected area. If repairs are required, carefully cut out affected areas and replace in similar procedure as outlined above. The repair piece must be pressed into place with a hand roller as soon as possible to ensure continuous and intimate contact with the substrate.

Membrane Protection

Perm-A-Barrier wall membranes must be protected from damage by other trades or construction materials.

Storage and Handling Information

All materials must be protected from rain and physical damage. Pallets of Perm-A-Barrier wall membrane must not be double stacked on the job site. Provide cover on top and all sides, allowing for adequate ventilation. Store membrane where temperatures will not exceed 32°C (90°F) for extended periods. All products must be stored in a dry area away from high heat, flames or sparks. Store only as much material at point of use as is required for each day's work.

Limitations

Perm-A-Barrier wall membrane systems must not be applied in areas where they will be permanently exposed to UV light and must be covered within a reasonable amount of time, not to exceed 30 days.

Warranty

Perm-A-Barrier products are warranted to be free of defects in manufacture for a period of 5 years. Material will be provided at no charge to replace any defective product.

Technical Service

Support is provided by full-time technically trained Grace field sales representatives and technical service personnel, backed by a central research and development technical services staff.

Supply

Product	Unit of Sale	Approximate Coverage	Weight	Palletization
Perm-A-Barrier System 4000 Wall Membrane (includes surface conditioner)	1 roll	20.9 m^2 (225 ft^2) per roll 0.9 x 25 m (3 x 75 ft) roll	73 lbs/roll	25 cartons (25 rolls) per pallet
Perm-A-Barrier Wall Membrane	1 roll	20.9 m^2 (225 ft^2) per roll 0.9 x 25 m (3 x 75 ft) roll	67 lbs/roll	25 cartons (25 rolls) per pallet
Perm-A-Barrier Low Temperature Wall Membrane	1 roll	20.9 m^2 (225 ft^2) per roll 0.9 x 25 m (3 x 75 ft) roll	67 lbs/roll	25 cartons (25 rolls) per pallet
Perm-A-Barrier Wall Flashing				
– 305 mm (12 in.)	3 rolls	75 linear ft per roll	25 lbs/roll	25 cartons (75 rolls) per pallet
– 457 mm (18 in.)	2 rolls	75 linear ft per roll	37.5 lbs/roll	25 cartons (50 rolls) per pallet
– 610 mm (24 in.)	1 roll	75 linear ft per roll	55 lbs/roll	35 cartons (35 rolls) per pallet
– 914 mm (36 in.)	1 roll	75 linear ft per roll	75 lbs/roll	25 cartons (25 rolls) per pallet
Bituthene Mastic – 5 gal pail	1 pail	approx. 120 ft^2 at 60 mils	54 lbs/pail	36 pails per pallet
Bituthene Mastic – 30 oz tube	12 tubes	approx. 30 lin. ft x ¼ in. bead	32 lbs/carton	72 cartons (864 tubes) per pallet
Perm-A-Barrier Surface Conditioner – 1 gal jug	4 jugs	6-8 m^2/L (250-350 ft^2/gal)	9 lbs/jug	36 cartons (144 jugs) per pallet
Perm-A-Barrier WB Primer – 5 gal pail	1 pail	6-8 m^2/L (250-350 ft^2/gal)	45 lbs/pail	24 pails per pallet
Bituthene Primer B2 – 5 gal pail	1 pail	6-8 m^2/L (250-350 ft^2/gal)	44 lbs/pail	48 pails per pallet

Physical Properties

Property and Test Method	Perm-A-Barrier System 4000	Perm-A-Barrier Wall Membrane	Perm-A-Barrier Low Temperature	Test Method
Thickness	1 mm (3⁄64 in.)	1 mm (3⁄64 in.)	1 mm (3⁄64 in.)	ASTM D3767 Method A
Minimum tensile strength, membranes	2.8 MPa (400 psi)	2.8 MPa (400 psi)	2.8 MPa (400 psi)	ASTM D412 Die C Modified
Minimum tensile strength, film	34.5 MPa (5000 psi)	34.5 MPa (5000 psi)	34.5 MPa (5000 psi)	ASTM D412 Die C Modified
Minimum elongation, to failure of rubberized asphalt	200%	200%	200%	ASTM D412 Die C Modified
Pliability, at 180° bend over 25 mm (1 in.) mandrel	Pass at -43°C (-45°F)	Pass at -32°C (-25°F)	Pass at -43°C (-45°F)	ASTM D1970
Crack cycling, 3.2 mm (1⁄8 in.) at -32°C (-25°F)	Unaffected	Unaffected	Unaffected	ASTM C836
Minimum puncture resistance, membrane	178 N (40 lbs)	178 N (40 lbs)	178 N (40 lbs)	ASTM E154
Lap peel adhesion at minimum application temperature	1100 N/m width (6.3 lbs/in.)	700 N/m width (4 lbs/in.)	875 N/m width (5 lbs/in.)	ASTM D1876 Modified
Maximum permeance to water vapor transmission	2.9 ng (0.05 perms/(Pa.s.m^2))	2.9 ng (0.05 perms/(Pa.s.m^2))	2.9 ng (0.05 perms/(Pa.s.m^2))	ASTM E96 Method B
Air permeance of in-place membrane[1]	8×10^{-5} L/s/m^2 (4×10^{-6} cf/min/ft^2)	1.7×10^{-4} L/s/m^2 (8.5×10^{-5} cf/min/ft^2)	1.7×10^{-4} L/s/m^2 (8.5×10^{-5} cf/min/ft^2)	ASTM E283
Air permeance of in-place membrane[2]	No change in air permeance value	No change in air permeance value	No change in air permeance value	ASTM E330
Water absorption (weight gain at 24 hours)	0.1%	0.1%	0.1%	ASTM D570

Footnote:
1. Air permeance measured at a pressure differential of 68 Pa (1⁄64 in.) Hg.
2. Air permeance measured at a pressure differential of 68 Pa (1⁄64 in.) Hg after wall being subjected to a negative 3014 Pa (57⁄64 in.) Hg pressure difference for 10 seconds.

For Technical Assistance call toll free at 866-333-3SBM (3726).

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Perm-A-Barrier® Wall Flashing

Self-adhesive, rubberized asphalt/polyethylene flashing tapes for cavity wall applications

Advantages

- **Fully bonded** – continuous adhesion to the substrate resists wind loads and prevents water tracking behind the tape
- **Waterproof and virtually impermeable to moisture** – virtually impermeable to the passage of liquid water and vapor
- **Cross laminated film** – provides dimensional stability, high tear strength, puncture and impact resistance
- **Cold applied** – no flame hazard; self-adhesive overlaps ensure continuity
- **Flexible** – accommodates minor settlement and shrinkage movement
- **Controlled thickness** – factory made sheet ensures constant, non-variable site application
- **Aggressive, conformable adhesive** – creates 100% watertight laps and allows self-sealing around mechanical fasteners
- **Unique green color and logo** – highly differentiated on the job site from other flashing types and enables easy identification of damage
- **RIPCORD™ "split release on demand"** – faster application in the straight-aways, ease of membrane positioning in detailed areas
- **Foldless release paper** – fewer edge catches, 180° pull-back, ease of membrane cutting (single cuts) and membrane positioning, quicker one-man installs

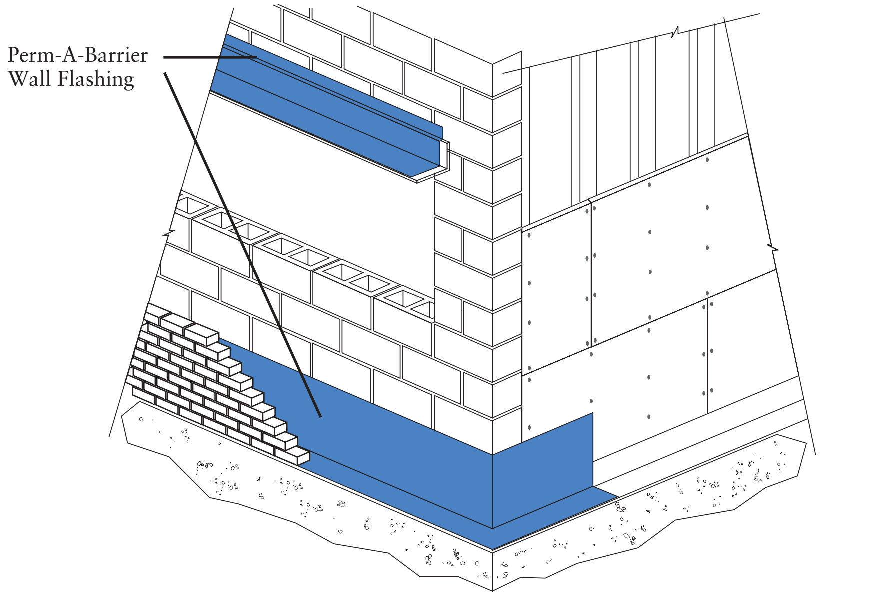
Description

Perm-A-Barrier® wall membranes are ideal for protecting the building superstructure from the damaging effects of the elements. By minimizing air and water vapor flow through the building exterior, Perm-A-Barrier wall membranes:

- Prevent premature deterioration of the building envelope
- Enhance thermal performance of the structure and save energy costs
- Improve comfort for the building occupants

System Components

- **Perm-A-Barrier Wall Flashing** – 1 mm (40 mil) total thickness self-adhesive, cold applied tape consisting of 0.8 mm (32 mils) of rubberized asphalt integrally bonded to a 0.2 mm (8 mil) high density, cross laminated polyethylene film. The rolls are interwound with disposable silicone-coated release sheet
- **Perm-A-Barrier Wall Membranes** – air and vapor barrier membranes for use in cavity wall applications
- **Perm-A-Barrier WB Primer** – high tack, water-based primer for use on exterior wallboards
- **Bituthene® Mastic Trowel Grade** – rubberized asphalt mastic for sealing around penetrations, terminations, brick ties, etc.



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Construction Products

Installation

Safety

Perm-A-Barrier products must be handled properly. Vapors from the mastic and solvent-based primer are harmful and flammable. For these products, the best available information on safe handling, storage, personal protection, health and environmental considerations has been gathered. Refer to product label and Material Safety Data Sheet before use. All users should acquaint themselves with this information prior to working with the material. Carefully read detailed precaution statements on the product labels and MSDS before use. MSDSs can be obtained from our web site at www.graceconstruction.com or by contacting us toll free at 866-333-3SBM (3726).

Preparatory Work

Apply Perm-A-Barrier Wall Flashing and accessories only in fair weather when air and surface temperatures are above -4°C (25°F).

Wherever wall flashing is to be applied, the surface must be smooth, clean, dry and free of voids, spalled areas, loose substrate, loose nails, sharp protrusions or other matter that will hinder the adhesion or uniformity of the wall flashing installation. Clean loose dust or dirt from the surface by wiping with a clean dry cloth or a brush.

Conditioning and Priming

Use Perm-A-Barrier WB Primer to enhance adhesion on dusty cementitious substrates. Perm-A-Barrier WB Primer is a water-based primer which imparts an aggressive, high tack finish on the treated substrate. It is specifically designed to facilitate tenacious adhesion of Perm-A-Barrier Wall Flashing, Perm-A-Barrier Wall Membrane, Grace underlayments and Grace Vycor® Self-Adhered Flashings to various substrates including Dens-Glass Gold® (refer to relevant product data sheets). It will cover approximately 6-8 m^2/L (250-350 ft^2/gal) when applied with a roller. A synthetic, 13 mm (½ in.) nap roller has been found to be very successful. A moderately thick coating should be applied and rolled out evenly. A properly applied coating will have uniform coverage and leave a tacky finish to the surface when dry.

Apply primer in dry weather with ambient and substrate temperatures above -4°C (25°F). Surface must be dry and clean, free from frost, dirt, grease, oil or other contaminants. Failure to remove excessive dust may result in compromised adhesion of the membrane. Allow primer to dry completely before application of the flashing.

In cooler or humid conditions, priming may be done in advance. If primed surface is exposed for more than 7 days, or if significant dust or dirt accumulates on the surface, re-prime with a thin coat of Perm-A-Barrier WB Primer.

The drying time could vary from 15 minutes (> 32°C (<90°F), windy, under the sun) to 3 hours (cold and no wind), depending on the weather condition. For 32°C (90°F) or greater, 45 minutes to one hour; 10°C (50°F) to 32°C (90°F), 1-3 hours; less than 10°C (50°F) 3 hours or more.

Bituthene Primer B2 is used to prime "green" concrete or damp substrates. Apply to clean surface at a coverage rate of 6-8 m^2/L (250-350 ft^2/gal). Allow primer to dry completely (approximately 1 hour dependent on weather condition) before application of wall flashing.

Flashing Application

Pre-cut Perm-A-Barrier Wall Flashing to easily handled lengths. Peel release paper from roll to expose rubberized asphalt and carefully position flashing against substrate. RIPCORD, a "split release on demand" feature embedded in the membrane, also makes Perm-A-Barrier Wall Flashing easy to position in detailed areas. Press firmly into place with a steel hand roller or the back of a utility knife as soon as possible, fully adhering the flashing to the substrate to prevent water from migrating under the Perm-A-Barrier Wall Flashing. Form end dams at horizontal flashing terminations to prevent water entry. Overlap adjacent pieces 51 mm (2 in.) and roll overlap with a steel hand roller.

Apply a bead of Bituthene Mastic along all laps, seams, top edges, cuts and penetrations and trowel into place. Lay or trim edges of Perm-A-Barrier Wall Flashing 13 mm (1/2 in.) back from the face of the masonry. No reglet is necessary when installing Perm-A-Barrier Wall Flashing to vertical surfaces. Complete installation instructions and details are available upon request.

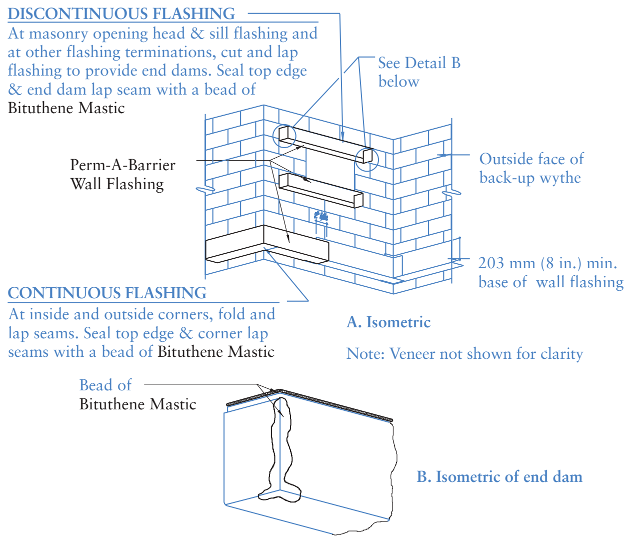
If wrinkles develop, carefully cut out affected area and replace in similar procedure outlined above. The repair piece must be pressed into place with a hand roller as soon as possible to ensure continuous and intimate contact with the substrate.

Protection

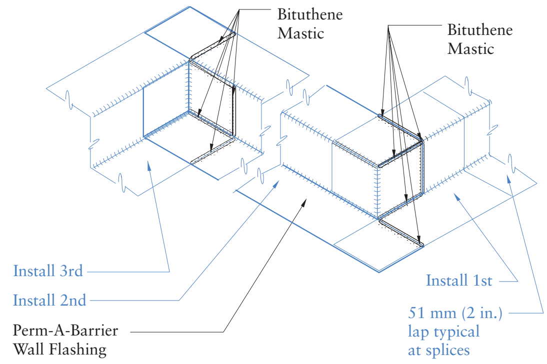
Perm-A-Barrier Wall Flashing must be protected from damage from other trades or construction materials.

Storage and Handling Information

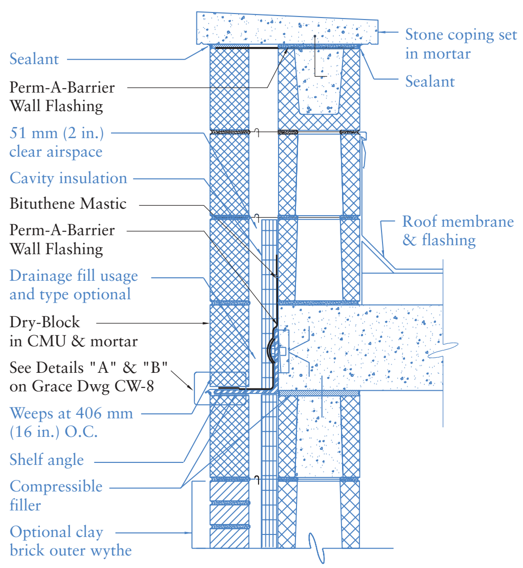
All materials must be protected from rain and physical damage. Pallets of Perm-A-Barrier Wall Flashing must not be double stacked on the job site. Provide cover on top and all sides, allowing for adequate ventilation. Store wall flashing where temperatures will not exceed 32°C (90°F) for extended periods. All products must be stored in a dry area away from high heat, flames or sparks. At point of use, store only as much material as is required for each day's work.



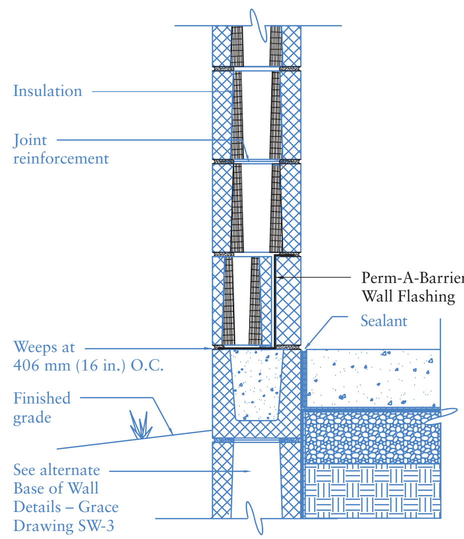
Through-wall Flashing Details



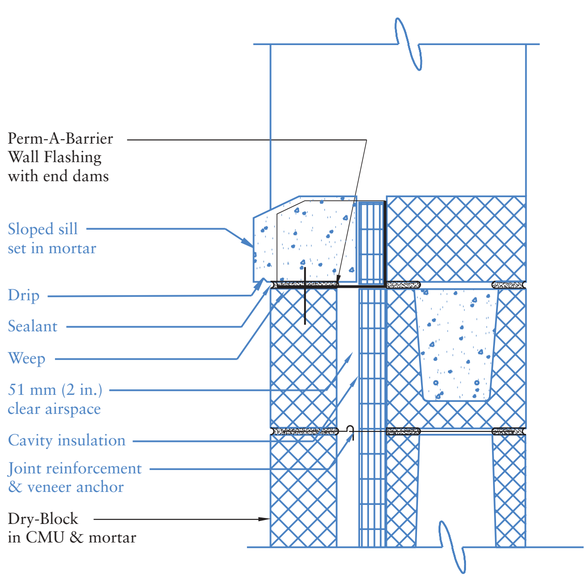
Perm-A-Barrier Flashing Details at Inside and Outside Corners



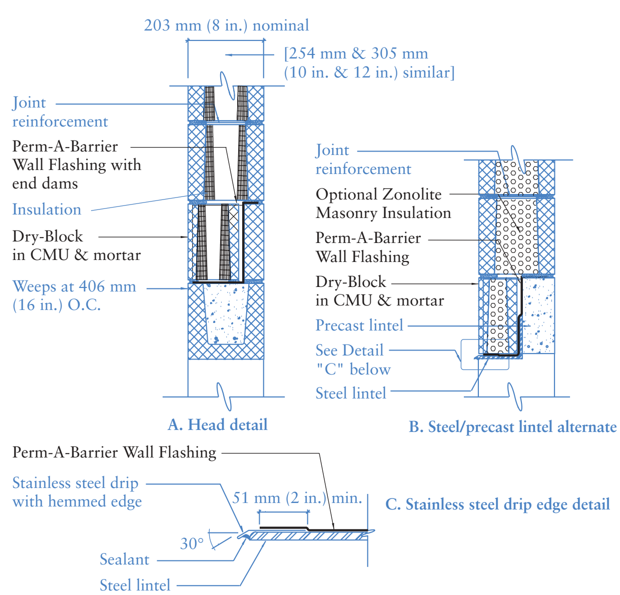
Parapet Detail



Base of Wall Detail



Sill Detail



Masonry Opening Head Flashing

Supply

Product	Unit of Sale	Approximate Coverage	Weight	Palletization
Perm-A-Barrier Wall Flashing				
– 305 mm (12 in.)	3 rolls	75 linear ft per roll	22.5 lbs/roll	25 cartons (75 rolls) per pallet
– 457 mm (18 in.)	2 rolls	75 linear ft per roll	33.7 lbs/roll	25 cartons (50 rolls) per pallet
– 610 mm (24 in.)	1 roll	75 linear ft per roll	49.7 lbs/roll	35 cartons (35 rolls) per pallet
– 914 mm (36 in.)	1 roll	75 linear ft per roll	67.7 lbs/roll	25 cartons (25 rolls) per pallet
Bituthene Mastic – 5 gal pail	1 pail	approx. 120 ft^2 at 60 mils	54 lbs/roll	36 pails per pallet
Bituthene Mastic – 30 oz tube	12 tubes	approx. 30 linear ft x ¼ in. bead	32 lbs/carton	72 cartons (864 tubes) per pallet
Perm-A-Barrier WB Primer – 5 gal pail	1 pail	6-8 m^2/L (250-350 ft^2/gal)	45 lbs/pail	24 pails per pallet

Physical Properties

Property	Typical Value	Test Method
Color	Green with repeated logo imprint	
Thickness	1 mm (40 mil)	ASTM D3767, Method A
Low temperature flexibility	Unaffected at -43°C (-45°F)	ASTM D1970
Tensile strength, membrane	8300 kPa (1200 psi) minimum	ASTM D412, Die C Modified
Elongation, ultimate failure of rubberized asphalt	200% minimum	ASTM D412
Lap adhesion at minimum application temperature	875 N/m (60 lbs/ft) width	ASTM D1876 Modified
Adhesion to concrete at minimum application temperature	875 N/m (60 lbs/ft) width	ASTM D903
Puncture resistance, membrane	178 N (40 lbs) minimum MD	ASTM D781
	356 N (80 lbs) minimum MD	ASTM E154
Tear resistance, initiation	58 N (13 lbs) minimum MD	ASTM D1004
Tear resistance, propagation	40 N (9 lbs) minimum MD	ASTM D1938
Permeance	2.9 ng/m^2sPa (0.05 perms) maximum	ASTM E96, Method B
Water absorption	0.1% maximum	ASTM D570

Limitations

Perm-A-Barrier Wall Flashing must not be applied in areas where it will be exposed to sunlight permanently and must be covered within a reasonable amount of time, not to exceed 30 days.

Warranty

Perm-A-Barrier products are warranted to be free of defects in manufacture for a period of 5 years. Material will be provided at no charge to replace any defective product.

Technical Services

Support is provided by full-time, technically trained Grace Construction Products representatives and technical service personnel, backed by a central research and development staff.

For Technical Assistance call toll free at 866-333-3SBM (3726).

Visit our web site at www.graceconstruction.com

printed on recycled paper

W. R. Grace & Co.-Conn. 62 Whittemore Avenue Cambridge, MA 02140

GRACE Construction Products

Perm-A-Barrier®

Surface Conditioner

Description

Perm-A-Barrier® Surface Conditioner is a water-based latex surface treatment that is specifically formulated to bind site dust and concrete efflorescence, thereby providing a suitable surface for the adhesion of Perm-A-Barrier Wall Flashing. The use of Perm-A-Barrier Surface Conditioner is required for dirty or dusty surfaces or surfaces having irregular or rough textures. Perm-A-Barrier Surface Conditioner imparts an aggressive high tack finish to the treated substrate.

Perm-A-Barrier Surface Conditioner prepares the substrate surface which promotes good initial adhesion and, more importantly, excellent permanent adhesion of the Perm-A-Barrier Wall Flashing.

Perm-A-Barrier Surface Conditioner complies with existing and anticipated Volatile Organic Compound (VOC) environment regulations.

Use

Perm-A-Barrier Surface Conditioner is used to condition all structural concrete, masonry or wood surfaces on which Perm-A-Barrier Wall Flashing is to be applied. Sufficient Surface Conditioner should be applied to condition the substrate to a dust-free state, suitable for the application of Perm-A-Barrier Wall Flashing.

Perm-A-Barrier Surface Conditioner can be used in vertical and horizontal applications above -4°C (25°F).

Application

Perm-A-Barrier Surface Conditioner is packaged ready-to-use and imparts an aggressive, high tack finish to the treated substrate. Perm-A-Barrier Surface Conditioner will cover approximately 7.2 m^2/L (300 ft^2/gal) when applied with a low pressure portable sprayer. Perm-A-Barrier Surface Conditioner may also be applied by brush or roller. Allow Perm-A-Barrier Surface Conditioner to dry completely (approximately 1 hour, dependent on weather conditions) before application of flashing. Excess surface conditioner will not improve the adhesion of the flashing. The Perm-A-Barrier Surface Conditioner is considered dry when the substrate returns to its original color.

Allow Perm-A-Barrier Surface Conditioner to dry one hour or until substrate returns to its original color. At low temperature or in high humidity conditions, drying time may be longer. Perm-A-Barrier Surface Conditioner is clear when dry. In general, conditioning should be limited to what can be covered within 24 hours. In circumstances where longer dry times may prevail, substrates may be conditioned in advance. Substrates should be reconditioned if significant dirt or dust accumulates.

Before Perm-A-Barrier Surface Conditioner dries, tools should be cleaned with water. After the surface conditioner dries, tools should be cleaned with mineral spirits. Mineral spirits is a combustible liquid which should be used in accordance with manufacturer's recommendations. Do not use solvents to clean hands or skin.

Safety, Storage and Handling

Perm-A-Barrier Surface Conditioner is non-flammable. Refer to product label and Material Safety Data Sheet before use. For further information, contact your local Grace representative.

Performance Properties

Property	Typical Value
Solvent Type	Water
Flash Point	>60°C (140°F)
VOC Content	Not to exceed 163 g/L
Application Temperature	-4°C (25°F) and above
Freeze-Thaw Stability	5 Cycles (Minimum)
Freezing Point (as packaged)	10°C (14°F)

For Technical Assistance call us toll free at 866-333-3SBM (3726).

W. R. Grace & Co.-Conn. 62 Whittemore Avenue Cambridge, MA 02140

GRACE Construction Products

SIEMENS

Submittal Sheet
Document No. 154-042
January, 23, 2004

SED2 Variable Frequency Drives

Description

The SED2 variable frequency drives are designed specifically for HVAC applications. The SED2 supports a wide variety of digital and analog I/O for diverse control capability. Built-in PID features control pumps and fans, and an integral system protocol can interface P1/N2 networks. Using the SED2 multi-level parameter access, operators can quickly pinpoint relevant data.

Product Numbers

Your Product Number:	S	E	D	2	-					/			X		
Example Product Number:	S	E	D	2	-	0	.	7	5	/	2	2	X		

Model:
SED2-

kW:
0.37, 0.55, 0.75, 1.1, 1.5, 2.2,
3, 4, 5.5, 7.5, 11, 15, 18.5,
22, 30, 37, 45, 55, 75, 90
(uses 2 to 4 spaces plus a divider "/")

Voltage:
2 = 200 to 240
3 = 380 to 480
4 = 500 to 600

NEMA:
2 (IP 20)
1 NEMA Type 1
5 NEMA Type 12 (IP 54) *

Other:
X include with all part #'s

(leave blank)

* Available with Voltage Codes 3 and 4.

Example shown:
SED2-0.75/22X =
SED2 only, 0.75 kW (1hp), 200V to 240V, open type IP20.

Features

- Built-in SBT P1 and JCI N2 (Metasys®) building automation system protocols for easy network integration
- LON Interface and Modbus Interface optional
- Low harmonics design reduces noises and interference eliminates need for filters/reactors in most installations
- Built-in PID for fast and accurate pressure control
- Pump staging for open loop, constant pressure, and constant flow-type applications
- Multi-level program access
- Belt failure detection with or without an external sensor
- Service mode for applications requiring continuous, uninterruptible operation
- Accepts a wide variety of digital and analog I/O types, including direct Ni 1000 RTD sensor level inputs
- One common interface throughout all power ranges
- Optional Advanced Operator Panel for uploading/downloading parameters
- Full form C relay contacts for digital outputs

Frame Sizes

SED2 IP20 and NEMA Type 1 frame sizes and power ranges are as follows:

HP	.5	.7	1	1.5	2	3	4	5	7.5	10	15	20	25	30	40	50	60	75	100	125
kW	.37	.5	.75	1.1	1.5	2.2	3	4	5.5	7.5	11	15	19	22	30	37	45	55	75	90
240V	A			B			C				D			E		F				
480V	A					B			C				D			E		F		
575V			C										D			E		F		

SED2 IP54/NEMA Type 12 frame sizes and power ranges are as follows:

HP	.5	.7	1	1.5	2	3	4	5	7.5	10	15	20	25	30	40	50	60	75	100	125
kW	.37	.5	.75	1.1	1.5	2.2	3	4	5.5	7.5	11	15	19	22	30	37	45	55	75	90
480V				B					C				D			E				
575V				C									D			E				

Technical Data

Table 1. Drive Specifications.

Drive Specifications	Description
Input voltage and power ranges (3-phase)	200V to 240V, 3 ac±10%. 1/2 hp to 60 hp
	380V to 480V, 3 ac ±10% 1/2 hp to 125 hp
	500V to 600V, 3 ac ±10% 1 hp to 125 hp
Input frequency	47 Hz to 63 Hz
Output frequency	0 Hz to 150 Hz
Power factor	≥0.9
VFD degree of efficiency	96% to 97%
Switch-on current	Less than nominal input current
Auxiliary supply 24V	Glavanically separated, unregulated auxiliary supply (18V to 32V) 100 mA
Overload capacity	110% for 60 seconds
Control method	Linear, parabolic and programmable V/f; and flux current control low-power mode
PWM frequency	2k Hz to 16k Hz (adjustable in 2k Hz increments)
Fixed frequencies	15 programmable
Skip frequency bands	4 programmable
Setpoint resolution	0.01 Hz digital
	0.01 Hz serial
	10 bit analog
Digital inputs (sink/source)	6: fully programmable and scalable isolated digital inputs, switchable
Analog inputs	2: 0 to 10 Vdc, 0/4 to 20 mA, can also be configured as digital inputs or Ni 1000 input
Relay outputs	2: configurable 30 Vdc/5A (resistive), 250 Vac/2A (inductive)
Analog outputs	2: programmable (0/4 mA to 20 mA, or 0 Vdc to 10 Vdc)
Serial interface	RS-485 transmission rate: Up to 38.4k baud Protocols: USS, P1 and N2
Protection level	IP20
	NEMA Type 1 with protective shield and gland plate installed
	IP54/NEMA Type 12
Temperature ranges	Operating: 14°F to 104°F (–10°C to 40°C)
	Storage: –40°F to 158°F (–40°C to 70°C)
Humidity	95% rh, non-condensing
Operational altitudes	Up to 3280 ft (1000m) above sea level without derating
Protection features	Under-voltage
	Over-voltage
	Overload
	Ground fault
	Short circuit
	Stall prevention
	Locked motor
	Motor overtemperature $I^2 t$, PTC
	Over-temperature
	Parameter PIN protection
Standards	UL, cUL, CE, C-tick
CE conformity	Conformity with EC Low Voltage Directive 73/23/EEC

Table 2. Output Ratings.

Voltage (±10%)	Product Number			Output Rating		Output Current Max (amps)	Frame Size
	IP20	NEMA Type 1	IP54/NEMA Type 12	HP	kW		
208V to 240V (3-Phase)	SED2-0.37/22X	SED2-0.37/21X	—	0.5	0.37	2.3	A
	SED2-0.55/22X	SED2-0.55/21X	—	0.75	0.55	3.0	A
	SED2-0.75/22X	SED2-0.75/21X	—	1.0	0.75	3.9	A
	SED2-1.1/22X	SED2-1.1/21X	—	1.5	1.1	5.5	B
	SED2-1.5/22X	SED2-1.5/21X	—	2.0	1.5	7.4	B
	SED2-2.2/22X	SED2-2.2/21X	—	3.0	2.2	10.4	B
	SED2-3/22X	SED2-3/21X	—	4.0	3.0	13.6	C
	SED2-4/22X	SED2-4/21X	—	5.0	4.0	17.5	C
	SED2-5.5/22X	SED2-5.5/21X	—	7.5	5.5	22.0	C
	SED2-7.5/22X	SED2-7.5/21X	—	10.0	7.5	28.0	C
	SED2-11/22X	SED2-11/21X	—	15.0	11.0	42.0	D
	SED2-15/22X	SED2-15/21X	—	20.0	15.0	54.0	D
	SED2-18.5/22X	SED2-18.5/21X	—	25.0	18.5	68.0	D
	SED2-22/22X	SED2-22/21X	—	30.0	22.0	80.0	E
	SED2-30/22X	SED2-30/21X	—	40.0	30.0	104.0	E
	SED2-37/22X	SED2-37/21X	—	50.0	37.0	130.0	F
	SED2-45/22X	SED2-45/21X	—	60.0	45.0	154.0	F
380V to 480V (3-Phase)	SED2-0.37/32X	SED2-0.37/31X	—	0.5	0.37	1.2	A
	SED2-0.55/32X	SED2-0.55/31X	—	0.75	0.55	1.6	A
	SED2-0.75/32X	SED2-0.75/31X	—	1.0	0.75	2.1	A
	SED2-1.1/32X	SED2-1.1/31X	SED2-1.1/35X	1.5	1.1	3.0	A *
	SED2-1.5/32X	SED2-1.5/31X	SED2-1.5/35X	2.0	1.5	4.0	A *
	SED2-2.2/32X	SED2-2.2/31X	SED2-2.2/35X	3.0	2.2	5.9	B
	SED2-3/32X	SED2-3/31X	SED2-3/35X	4.0	3.0	7.7	B
	SED2-4/32X	SED2-4/31X	SED2-4/35X	5.0	4.0	10.2	B
	SED2-5.5/32X	SED2-5.5/31X	SED2-5.5/35X	7.5	5.5	13.2	C
	SED2-7.5/32X	SED2-7.5/31X	SED2-7.5/35X	10.0	7.5	18.4	C
	SED2-11/32X	SED2-11/31X	SED2-11/35X	15.0	11.0	26.0	C
	SED2-15/32X	SED2-15/31X	SED2-15/35X	20.0	15.0	32.0	C
	SED2-18.5/32X	SED2-18.5/31X	SED2-18.5/35X	25.0	18.5	38.0	D
	SED2-22/32X	SED2-22/31X	SED2-22/35X	30.0	22.0	45.0	D
	SED2-30/32X	SED2-30/31X	SED2-30/35X	40.0	30.0	62.0	D
	SED2-37/32X	SED2-37/31X	SED2-37/35X	50.0	37.0	75.0	E
	SED2-45/32X	SED2-45/31X	SED2-45/35X	60.0	45.0	90.0	E
	SED2-55/32X	SED2-55/31X	SED2-55/35X	75.0	55.0	110.0	F
	SED2-75/32X	SED2-75/31X	SED2-75/35X	100.0	75.0	145.0	F
	SED2-90/32X	SED2-90/31X	SED2-90/35X	125.0	90.0	178.0	F
500V to 600V (3-Phase)	SED2-0.75/42X	SED2-0.75/41X	—	1.0	0.75	1.4	C
	SED2-1.1/42X	SED2-1.1/41X	SED2-1.1/45X	1.5	1.1	2.1	C
	SED2-1.5/42X	SED2-1.5/41X	SED2-1.5/45X	2.0	1.5	2.7	C
	SED2-2.2/42X	SED2-2.2/41X	SED2-2.2/45X	3.0	2.2	3.9	C
	SED2-3/42X	SED2-3/41X	SED2-3/45X	4.0	3.0	5.4	C
	SED2-4/42X	SED2-4/41X	SED2-4/45X	5.0	4.0	6.1	C
	SED2-5.5/42X	SED2-5.5/41X	SED2-5.5/45X	7.5	5.5	9.0	C
	SED2-7.5/42X	SED2-7.5/41X	SED2-7.5/45X	10.0	7.5	11.0	C
	SED2-11/42X	SED2-11/41X	SED2-11/45X	15.0	11.0	17.0	C
	SED2-15/42X	SED2-15/41X	SED2-15/45X	20.0	15.0	22.0	C
	SED2-18.5/42X	SED2-18.5/41X	SED2-18.5/45X	25.0	18.5	27.0	D
	SED2-22/42X	SED2-22/41X	SED2-22/45X	30.0	22.0	32.0	D
	SED2-30/42X	SED2-30/41X	SED2-30/45X	40.0	30.0	41.0	D
	SED2-37/42X	SED2-37/41X	SED2-37/45X	50.0	37.0	52.0	E
	SED2-45/42X	SED2-45/41X	SED2-45/45X	60.0	45.0	62.0	E
	SED2-55/42X	SED2-55/41X	SED2-55/45X	75.0	55.0	77.0	F
	SED2-75/42X	SED2-75/41X	SED2-75/45X	100.0	75.0	99.0	F
	SED2-90/42X	SED2-90/41X	SED2-90/45X	125.0	90.0	125.0	F

* IP54/NEMA Type 12 drives start at Frame Size B.

Accessories

Gland Plates (included with NEMA Type 1):

- ❑ SED2-GL-A Gland Plate, Frame A
- ❑ SED2-GL-B Gland Plate, Frame B
- ❑ SED2-GL-C Gland Plate, Frame C

Protection Shield (included with NEMA Type 1):

- ❑ SED2-PS-A Protection Shield, Frame A
- ❑ SED2-PS-B Protection Shield, Frame B
- ❑ SED2-PS-C Protection Shield, Frame C
- ❑ SED2-PS-DE Protection Shield, Frame D, E

Operator Panel:

- ❑ SED2-BOP1 Basic Operator Panel (included with all SED2s)
- ❑ SED2-AOP1 Advanced Operator Panel

BOP/AOP Door Mounting Kits:

- ❑ SED2-DOOR-KIT1 BOP/AOP Single Inverter Door Mounting Kit
- ❑ SED2-DOOR-KIT2 AOP Multi-Inverter Door Mounting Kit

LON Interface Option

- ❑ SED2-LONI/F

Modbus Interface Cable

- ❑ SED2-MODBUS1 Converts VFD's USS bus to Modbus RTU

Typical Specifications

SED2 shall provide control of fan and pump HVAC applications. A wide range of I/O allows for simple control solutions, with integral P1 and N2 protocols embedded for full control capabilities.

Dimensions

Table 3. Overall Dimensions for IP20 SED2 VFDs in Inches (Millimeters).

Frame Size	Height	Width	Depth	Weight lb (kg)
A	6.8 (173)	2.9 (73)	5.9 (149)	2.9 (1.3)
B	8.0 (202)	5.9 (149)	6.8 (172)	7.5 (3.4)
C	9.6 (245)	7.3 (185)	7.7 (195)	12 (5.5)
D	20.5 (520)	10.8 (275)	9.6 (245)	35 (16)
E	25.6 (650)	10.8 (275)	9.6 (245)	44 (20)
F	33.5 (850)	13. (350)	12.6 (320)	116 (53)

Table 4. Overall Dimensions for NEMA Type 1 SED2 VFDs Assembled with Protective Shield and Gland Plate in Inches (Millimeters).

Frame Size	Height	Width	Depth	Weight lb (kg)
A	9.1 (231)	2.9 (73)	5.9 (149)	3.2 (1.5)
B	11.8 (300)	5.9 (149)	6.8 (172)	8.3 (3.8)
C	13.8 (351)	7.3 (185)	7.7 (195)	13.6 (6.2)
D	24.6 (625)	10.8 (275)	9.6 (245)	37.5 (17)
E	29.7 (754)	10.8 (275)	9.6 (245)	46.4 (21)
F	54.5 (1384)	16.0 (406)	14.0 (356)	200 (91)

Table 5. Overall Dimensions for IP54/NEMA Type 12 SED2 VFDs in Inches (Millimeters).

Frame Size	Height	Width	Depth	Weight lb (kg)
B	15.2 (385)	10.6 (270)	10.6 (268)	10 (22)
C	23.9 (606)	13.8 (350)	11.2 (284)	42 (19)
D	27.0 (685)	14.2 (360)	13.9 (353)	77 (35)
E	34.8 (885)	14.2 (360)	17.8 (453)	105 (48)
F	45.3 (1150)	17.7 (450)	18.6 (473)	178 (81)

Wiring Diagrams

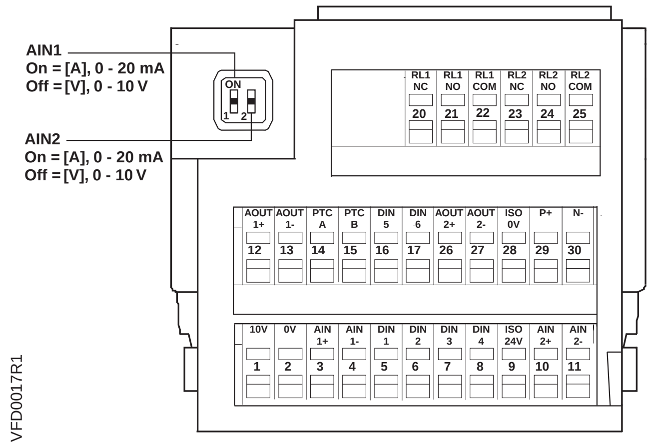


Figure 1. SED2 Control Terminals.

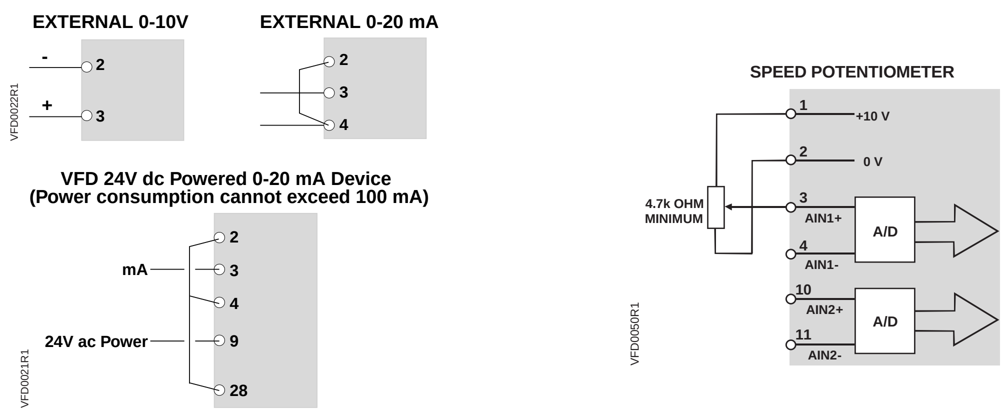


Figure 2. Typical Analog Inputs 1 and 2.

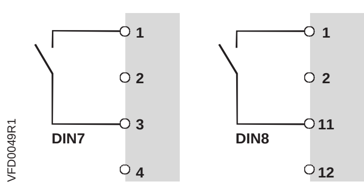


Figure 3. Typical Analog Inputs 1 and 2 as Digital Inputs 7 and 8.

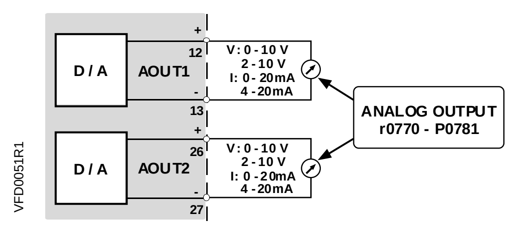


Figure 5. Typical Analog Outputs 1 and 2.

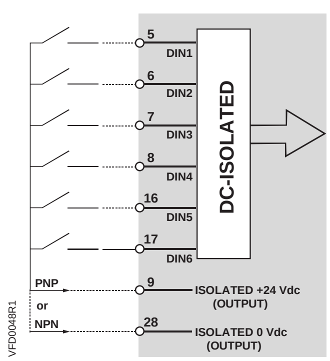


Figure 4. Typical Digital Inputs 1 through 6.

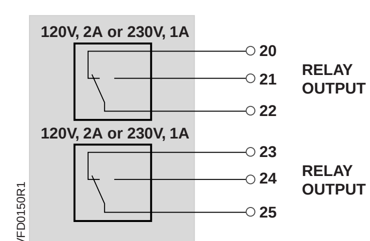


Figure 6. Typical Digital Outputs 1 and 2.

Table 6. Order Worksheet.

Item	Qty.	Designation	Part Number	Description

Siemens Building Technologies, Inc.
1000 Deerfield Parkway
Buffalo Grove, IL 60089-4513
U.S.A.

Your feedback is important to us. If you have comments about this document, please send them to **technical.editor@siemens.com**

M-Series Modules and Components

Modified Coils

Modified coils are ⅝-inch and 1-inch tube coils with reduced face areas. Use them with internal face-and-bypass dampers or in low-capacity applications.

Hot-Deck Coils

Hot-deck coils are used in the hot decks of multizone units and are available in all types of one-row and two-row heating coils with ⅝-inch and 1-inch tubes.

Air-to-Air, Fixed-Plate Heat Exchanger

An air-to-air, fixed-plate heat exchanger is used to reclaim exhaust-air energy as well as to provide dehumidified ventilation air to a space at room-neutral temperature. It is a sensible-energy-recovery device that consists of alternate layers of aluminum plates that are separated and sealed to form passages for the outdoor and exhaust air streams. This design minimizes cross-contamination and relies on thermal conduction to induce heat transfer. It is also easy to clean and service.

The fixed-plate surface is uniquely designed to equalize uneven entering airflow as the air travels through the heat exchanger. Air can enter the module on any side except the bottom, where there are drain pans to catch condensate.

An optional Trane frost-protection damper discourages icing, permitting exchanger operation at ambient temperatures as low as -20ºF. A factory-applied PVC (polyvinyl chloride) coating is available for high-temperature (140º–400ºF) or corrosive applications.

Application considerations:

- The heat exchanger module is available as a custom option for M-Series air handlers in 10 unit sizes ranging from 3 to 30. Two heat exchanger options per size and three plate-spacing options per heat exchanger for most unit sizes give substantial performance flexibility.
- Recovery is limited to primarily sensible energy; effectiveness typically ranges from 50 to 70 percent or about equal to an eight-row coil loop.
- The M-Series heat exchanger has a pressure drop of 0.6 to 1.0 in. wg per side.
- A frost-protection damper is required if the outdoor air drops below the frost formation point (typically around 20ºF, but possibly as high as 32ºF).
- Optional face-and-bypass dampers can bypass exhaust air through the exchanger to provide capacity control.
- The maximum pressure differential between the two air streams in the heat exchanger is 6 in. wg.
- Factory coatings are available for high temperature and/or corrosive air streams.
- If located directly downstream of a fan, put a 90-degree discharge plenum or diffuser module between the fan and the exchanger.
- Do *not* apply fixed-plate heat exchanger modules in systems where toxic or harmful gases must be isolated from the supply air stream.

Diffuser

A diffuser module consists of pressure-equalizing baffles that are designed to provide even airflow across components downstream of a fan. The diffuser module is typically used immediately downstream of a centrifugal fan in a blow-thru filter, coil, or silencer application.

Figure 39. Diffuser module

Discharge Plenum

Before leaving the air handler, supply air can be ducted to a discharge plenum module. The rapid air-stream expansion as it passes into the plenum reduces turbulence and creates an acoustical end reflection that dampens low-frequency sound. Two configurations enable supply-duct connections from any side:

- *Vertical-mounted* plenum modules mount atop an adjacent module. Openings can be factory- or field-cut.
- *Horizontal-mounted* plenum modules mount on the front of an adjacent module. Openings can be factory- or field-cut.

NOTE: All discharge plenum modules are available with 2-inch, insulated casing walls of solid or

Performance Data

Evaporator Flow Rates

Table 3. Minimum/maximum evaporator flow rates (GPM)

Shell	Bundle	One Pass			Two Pass			Three Pass		
Size	Size	SBCU	TECU	IECU	SBCU	TECU	IECU	SBCU	TECU	IECU
EVSZ	EVBS	Min / Max	Min / Max	Min / Max	Min / Max	Min / Max	Min / Max	Min / Max	Min / Max	Min / Max
032S	200	216 / 1187	230 / 1237	143 / 1050	108 / 593	115 / 618	72 / 525	72 / 396	77 / 412	48 / 350
032S	230	242 / 1331	258 / 1388	165 / 1212	121 / 666	129 / 694	83 / 606	81 / 444	86 / 463	55 / 404
032S	250	267 / 1465	284 / 1527	177 / 1293	134 / 733	142 / 764	88 / 646	89 / 488	95 / 509	59 / 431
032S/L	280	304 / 1672	324 / 1743	201 / 1474	152 / 836	162 / 871	101 / 737	102 / 557	108 / 581	67 / 491
032S/L	320	340 / 1868	362 / 1947	229 / 1676	170 / 934	181 / 973	115 / 838	114 / 623	121 / 649	76 / 559
032S/L	350	— / —	— / —	251 / 1838	— / —	— / —	126 / 919	— / —	— / —	84 / 613
050S	320	340 / 1868	362 / 1947	232 / 1696	170 / 934	181 / 973	116 / 848	114 / 623	121 / 649	77 / 565
050S	360	383 / 2105	399 / 2194	254 / 1858	192 / 1052	200 / 1097	127 / 929	128 / 702	133 / 731	85 / 619
050S	400	424 / 2332	442 / 2431	284 / 2080	212 / 1166	221 / 1215	142 / 1040	142 / 777	148 / 810	95 / 693
050S/L	450	482 / 2652	503 / 2764	322 / 2363	241 / 1326	252 / 1382	161 / 1181	161 / 884	108 / 921	108 / 788
050S/L	500	535 / 2941	558 / 3066	361 / 2646	268 / 1470	279 / 1533	181 / 1323	178 / 980	186 / 1022	121 / 882
050S/L	550	— / —	— / —	397 / 2908	— / —	— / —	198 / 1454	— / —	— / —	132 / 969
080S	500	535 / 2941	558 / 3066	361 / 2646	268 / 1470	279 / 1533	181 / 1323	178 / 980	186 / 1022	121 / 882
080S	560	602 / 3312	628 / 3453	400 / 2928	301 / 1656	314 / 1726	200 / 1464	201 / 1104	210 / 1151	133 / 976
080S	630	676 / 3715	704 / 3872	452 / 3312	338 / 1857	352 / 1936	226 / 1656	226 / 1238	235 / 1291	151 / 1104
080S/L	710	758 / 4169	790 / 4346	517 / 3756	379 / 2084	395 / 2173	259 / 1878	253 / 1390	264 / 1449	171 / 1252
080S/L	800	861 / 4736	898 / 4937	576 / 4221	431 / 2368	449 / 2469	288 / 2110	288 / 1579	300 / 1646	192 / 1407
080S/L	890	— / —	— / —	642 / 4706	— / —	— / —	321 / 2353	— / —	— / —	214 / 1569
142M/L	890	863 / 4746	900 / 4948	645 / 4726	432 / 2373	450 / 2474	323 / 2363	288 / 1582	300 / 1649	215 / 1575
142M/L	980	966 / 5314	1008 / 5540	716 / 5251	483 / 2657	504 / 2770	358 / 2625	322 / 1771	336 / 1847	239 / 1750
142M/L	1080	1075 / 5912	1121 / 6163	807 / 5917	538 / 2956	561 / 3082	404 / 2959	358 / 1971	374 / 2054	269 / 1972
142M/L/E	1220	1208 / 6645	1260 / 6927	895 / 6564	604 / 3323	630 / 3464	448 / 3282	403 / 2215	420 / 2309	299 / 2188
142M/L/E	1420	1345 / 7398	1402 / 7712	1041 / 7634	673 / 3699	701 / 3856	521 / 3817	449 / 2466	468 / 2571	347 / 2545
210L	1610	1318 / 7244	1373 / 7551	1146 / 8402	659 / 3622	687 / 3775	573 / 4201	440 / 2415	458 / 2517	382 / 2801
210L	1760	1471 / 8090	1534 / 8433	1286 / 9432	736 / 4045	767 / 4216	643 / 4716	490 / 2697	512 / 2811	429 / 3144
210L	1900	1634 / 8987	1704 / 9369	1421 / 10421	817 / 4494	852 / 4684	711 / 5211	545 / 2996	568 / 3123	474 / 3474
210L	2100	1802 / 9906	1878 / 10326	1509 / 11067	901 / 4953	939 / 5163	755 / 5534	601 / 3302	626 / 3442	503 / 3689
250E	2300	1948 / 10710	2030 / 11165	1640 / 11930	974 / 5355	1015 / 5583	820 / 5965	650 / 3570	677 / 3722	547 / 3977
250E	2500	2145 / 11794	2236 / 12295	1790 / 13060	1073 / 5897	1118 / 6147	895 / 6530	715 / 3931	746 / 4098	597 / 4353
210D	1610	1373 / 7550	1403 / 7719	1148 / 8421						
210D	1850	1623 / 8927	1659 / 9126	1311 / 9613		Not Applicable			Not Applicable	
210D	2100	1870 / 10282	1911 / 10511	1471 / 10784						
250D	2100	1877 / 10325	1919 / 10555	1471 / 10784						
250D	2300	2030 / 11164	2075 / 11413	1628 / 11935		Not Applicable			Not Applicable	
250D	2500	2235 / 12294	2285 / 12568	1782 / 13066						
250M	2100	1877 / 10325	1919 / 10555	1471 / 10784						
250M	2300	2030 / 11164	2075 / 11413	1628 / 11935		Not Applicable			Not Applicable	
250M	2500	2235 / 12294	2285 / 12568	1782 / 13066						
250X	2100	1877 / 10325	1919 / 10555	1471 / 10784						
250X	2300	2030 / 11164	2075 / 11413	1628 / 11935		Not Applicable			Not Applicable	
250X	2500	2235 / 12294	2285 / 12568	1782 / 13066						

Note: The minimum evaporator water velocity is 1.5 ft/sec for IECU tubes and 2.0 ft/sec for all other tubes. For a variable evaporator water flow system, the minimum GPME is generally not applicable at full load, and may be limited by other factors such as glycol. Confirm actual minimum and maximum flows for each selection before operating near flow boundaries.

Performance Data

Evaporator Flow Rates

Table 3 (Continued). Minimum/maximum evaporator flow rates (Liters/Second)

Shell	Bundle	One Pass			Two Pass			Three Pass		
Size	Size	SBCU	TECU	IECU	SBCU	TECU	IECU	SBCU	TECU	IECU
EVSZ	EVBS	Min / Max	Min / Max	Min / Max	Min / Max	Min / Max	Min / Max	Min / Max	Min / Max	Min / Max
032S	200	14 / 75	14 / 78	9 / 66	7 / 37	8 / 39	5 / 33	5 / 25	5 / 26	3 / 22
032S	230	16 / 84	16 / 88	11 / 76	8 / 42	8 / 44	5 / 38	6 / 28	6 / 29	4 / 25
032S	250	17 / 92	18 / 96	11 / 82	9 / 46	9 / 48	6 / 41	6 / 31	6 / 32	4 / 27
032S/L	280	20 / 105	20 / 110	13 / 93	10 / 53	10 / 55	7 / 47	7 / 35	7 / 37	4 / 31
032S/L	320	22 / 118	22 / 123	15 / 106	11 / 59	12 / 61	7 / 53	8 / 39	8 / 41	5 / 35
032S/L	350	— / —	— / —	16 / 116	— / —	— / —	8 / 58	— / —	— / —	6 / 39
050S	320	22 / 118	22 / 123	15 / 107	11 / 59	12 / 61	8 / 54	8 / 39	8 / 41	5 / 36
050S	360	24 / 133	26 / 138	16 / 117	12 / 66	13 / 69	8 / 59	8 / 44	9 / 46	6 / 39
050S	400	27 / 147	28 / 153	18 / 131	14 / 74	14 / 77	9 / 66	9 / 49	10 / 51	6 / 44
050S/L	450	31 / 167	32 / 174	22 / 149	16 / 84	16 / 87	10 / 75	10 / 56	11 / 58	7 / 50
050S/L	500	34 / 186	36 / 193	23 / 167	17 / 93	18 / 97	12 / 83	12 / 62	12 / 64	8 / 56
050S/L	550	— / —	— / —	25 / 183	— / —	— / —	13 / 92	— / —	— / —	9 / 61
080S	500	34 / 186	36 / 193	23 / 167	17 / 93	18 / 97	12 / 83	12 / 62	12 / 64	8 / 56
080S	560	38 / 209	40 / 218	25 / 185	19 / 104	20 / 109	13 / 92	13 / 70	14 / 73	9 / 62
080S	630	43 / 234	45 / 244	29 / 209	22 / 117	22 / 122	14 / 104	14 / 78	15 / 81	10 / 70
080S/L	710	48 / 263	50 / 274	33 / 237	24 / 131	25 / 137	16 / 118	16 / 88	17 / 91	11 / 79
080S/L	800	54 / 299	57 / 311	37 / 266	28 / 149	28 / 156	18 / 133	18 / 100	19 / 104	12 / 89
080S/L	890	— / —	— / —	41 / 297	— / —	— / —	20 / 148	— / —	— / —	14 / 99
142M/L	890	55 / 299	57 / 312	41 / 298	28 / 150	29 / 156	21 / 149	18 / 100	19 / 104	14 / 99
142M/L	980	61 / 335	63 / 349	45 / 331	31 / 168	32 / 175	23 / 166	20 / 112	22 / 116	15 / 110
142M/L	1080	68 / 373	71 / 389	51 / 373	34 / 186	36 / 194	26 / 187	23 / 124	24 / 130	17 / 124
142M/L/E	1220	76 / 419	80 / 437	57 / 414	38 / 210	40 / 218	28 / 207	26 / 140	27 / 146	19 / 138
142M/L/E	1420	85 / 467	89 / 487	66 / 482	43 / 233	44 / 243	33 / 241	28 / 156	30 / 162	22 / 161
210L	1610	84 / 457	87 / 476	73 / 530	42 / 228	44 / 238	36 / 265	28 / 152	29 / 159	24 / 177
210L	1760	86 / 510	97 / 532	81 / 595	47 / 255	49 / 266	41 / 297	31 / 170	32 / 177	27 / 198
210L	1900	104 / 567	108 / 591	90 / 657	52 / 283	54 / 296	45 / 329	35 / 189	36 / 197	30 / 219
210L	2100	114 / 625	119 / 651	95 / 698	57 / 312	60 / 326	48 / 349	38 / 208	40 / 217	32 / 233
250E	2300	123 / 676	128 / 704	104 / 752	62 / 338	64 / 352	52 / 376	41 / 235	43 / 235	35 / 250
250E	2500	136 / 744	142 / 776	113 / 824	68 / 372	71 / 388	57 / 411	46 / 248	48 / 259	38 / 274
210D	1610	87 / 476	89 / 487	72 / 531						
210D	1850	102 / 563	105 / 576	83 / 606		Not Applicable			Not Applicable	
210D	2100	118 / 649	121 / 663	93 / 680						
250D	2100	118 / 651	121 / 666	93 / 680						
250D	2300	128 / 704	131 / 720	103 / 753		Not Applicable			Not Applicable	
250D	2500	141 / 775	144 / 793	112 / 824						
250M	2100	118 / 651	121 / 666	93 / 680						
250M	2300	128 / 704	131 / 720	103 / 753		Not Applicable			Not Applicable	
250M	2500	141 / 775	144 / 793	112 / 824						
250X	2100	118 / 651	121 / 666	93 / 680						
250X	2300	128 / 704	131 / 720	103 / 753		Not Applicable			Not Applicable	
250X	2500	141 / 775	144 / 793	112 / 824						

Note: The minimum evaporator water velocity is 0.457 m/sec for IECU tubes and 0.610 m/sec for all other tubes. For a variable evaporator water flow system, the minimum GPME is generally not applicable at full load, and may be limited by other factors such as glycol. Confirm actual minimum and maximum flows for each selection before operating near flow boundaries.

Performance Data

Condenser Flow Rates

Table 4. Minimum/maximum condenser flow rates (GPM)

Shell	Bundle	Two Pass		
Size	Size	SBCU	TECU	IECU
CDSZ	CDBS	Min / Max	Min / Max	Min / Max
032S	230	214 / 784	209 / 767	218 / 798
032S/L	250	239 / 877	234 / 857	245 / 899
032S/L	280	267 / 980	261 / 958	273 / 1000
032S/L	320	295 / 1083	289 / 1059	306 / 1121
050S	360	336 / 1233	329 / 1205	347 / 1272
050S/L	400	378 / 1388	370 / 1357	391 / 1434
050S/L	450	426 / 1563	417 / 1528	441 / 1616
050S/L	500	473 / 1733	462 / 1695	490 / 1797
080S	500	473 / 1733	462 / 1695	490 / 1797
080S	560	529 / 1940	517 / 1896	548 / 2010
080S/L	630	595 / 2182	582 / 2133	614 / 2252
080S/L	710	673 / 2466	657 / 2411	689 / 2525
080S/L	800	756 / 2770	739 / 2708	774 / 2838
142L	890	853 / 3126	833 / 3056	876 / 3211
142L	980	948 / 3477	927 / 3399	975 / 3575
142L	1080	1060 / 3885	1036 / 3798	1091 / 3999
142L	1220	1185 / 4344	1158 / 4246	1217 / 4463
142L	1420	1335 / 4896	1305 / 4786	1407 / 5160
210L	1610	1331 / 4881	1301 / 4771	1495 / 5483
210L	1760	1473 / 5402	1440 / 5280	1655 / 6069
210L	1900	1615 / 5923	1579 / 5790	1812 / 6645
210L	2100	1760 / 6454	1721 / 6309	1964 / 7200
250L	2100	1760 / 6454	1721 / 6309	1950 / 7140
250L	2300	1935 / 7094	1891 / 6934	2140 / 7840
250L	2500	2113 / 7749	2066 / 7575	2330 / 8530
		One Pass		
210D	1610	2543 / 9324	2602 / 9541	2998 / 10991
210D	1760	2814 / 10320	2880 / 10560	3318 / 12165
210D	1900	3086 / 11315	3158 / 11578	3632 / 13319
210D	2100	3363 / 12330	3441 / 12617	3936 / 14432
250D	2100	3363 / 12330	3441 / 12617	3931 / 14412
250D	2300	3696 / 13552	3782 / 13868	4317 / 15829
250D	2500	4038 / 14804	4131 / 15149	4698 / 17226
250M	2100	3363 / 12330	3441 / 12617	3931 / 14412
250M	2300	3696 / 13552	3782 / 13868	4317 / 15829
250M	2500	4038 / 14804	4131 / 15149	4698 / 17226
250X	2100	3363 / 12330	3441 / 12617	3931 / 14412
250X	2300	3696 / 13552	3782 / 13868	4317 / 15829
250X	2500	4038 / 14804	4131 / 15149	4698 / 17226

Note: The minimum/maximum condenser water velocity is 3 / 11 ft/sec, and may be limited by other factors such as glycol. Confirm actual minimum and maximum flows for each selection before operating near flow boundaries.

Performance Data

Condenser Flow Rates

Table 4 (Continued). Minimum/maximum condenser flow rates (Liters/Second)

Shell Size CDSZ	Bundle Size CDBS	Two Pass SBCU Min / Max	TECU Min / Max	IECU Min / Max
032S	230	13 / 49	13 / 48	14 / 50
032S/L	250	15 / 55	15 / 54	15 / 57
032S/L	280	17 / 62	16 / 60	17 / 63
032S/L	320	19 / 68	18 / 67	19 / 71
050S	360	21 / 78	21 / 76	22 / 80
050S/L	400	24 / 88	23 / 86	25 / 90
050S/L	450	27 / 99	26 / 96	28 / 102
050S/L	500	30 / 109	29 / 107	31 / 113
080S	500	30 / 109	29 / 107	31 / 113
080S	560	33 / 122	33 / 120	35 / 127
080S/L	630	38 / 138	37 / 135	39 / 142
080S/L	710	42 / 156	41 / 152	43 / 159
080S/L	800	48 / 175	47 / 171	49 / 179
142L	890	54 / 197	53 / 193	55 / 203
142L	980	60 / 219	58 / 214	62 / 226
142L	1080	67 / 245	65 / 240	69 / 252
142L	1220	75 / 274	73 / 268	77 / 282
142L	1420	84 / 309	82 / 302	89 / 326
210L	1610	84 / 308	82 / 301	94 / 346
210L	1760	93 / 341	91 / 333	104 / 383
210L	1900	102 / 374	100 / 365	114 / 419
210L	2100	111 / 407	109 / 398	124 / 454
250L	2100	111 / 407	109 / 398	123 / 450
250L	2300	122 / 447	119 / 437	135 / 494
250L	2500	133 / 489	130 / 478	147 / 538
			One Pass	
210D	1610	160 / 588	164 / 602	189 / 693
210D	1760	178 / 651	182 / 666	209 / 767
210D	1900	195 / 714	199 / 730	229 / 840
210D	2100	212 / 778	217 / 796	248 / 910
250D	2100	212 / 778	217 / 796	248 / 909
250D	2300	233 / 855	239 / 875	272 / 998
250D	2500	255 / 934	261 / 956	296 / 1087
250M	2100	212 / 778	217 / 796	248 / 909
250M	2300	233 / 855	239 / 875	272 / 998
250M	2500	255 / 934	261 / 956	296 / 1087
250X	2100	212 / 778	217 / 796	248 / 909
250X	2300	233 / 855	239 / 875	272 / 998
250X	2500	255 / 934	261 / 956	296 / 1087

Note: The minimum/maximum condenser water velocity is 0.914/3.35 m/sec, and may be limited by other factors such as glycol. Confirm actual minimum and maximum flows for each selection before operating near flow boundaries.

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GMD/W20 Series Carbon Dioxide Transmitters for Demand Controlled Ventilation Applications

Vaisala CARBOCAP® Carbon Dioxide Transmitter Series GMD/W20 are designed for use in ventilation related applications.

Features/Benefits

- Versatile transmitters
- Duct and wall mount models
- Incorporates Vaisala CARBOCAP® Sensor - the silicon-based NDIR sensor
- Excellent long-term stability
- Negligible temperature dependence
- Ease of installation
- Five year recommended calibration interval

The duct mounted Vaisala CARBOCAP® Carbon Dioxide Transmitter Series GMD20 and wall mounted Vaisala CARBOCAP® Carbon Dioxide Transmitter Series GMW20 are specially designed for Demand Controlled Ventilation (DCV). They are easy to install and require almost no maintenance. The recommended calibration interval is five years.

Vaisala CARBOCAP® technology

The GMD/W20 Series Transmitters use the silicon-based Vaisala CARBOCAP® Sensor. The simple structure and reference measurement capabilities make this Single-Beam, Dual-Wavelength NDIR sensor extremely stable and reliable.

The temperature and flow dependence of Vaisala CARBOCAP® Sensor is negligible. In addition, the measurement accuracy of the sensor is not affected by dust, water vapor or most chemicals.

Versatile transmitters

The GMD/W20 series transmitters can be used independently, or they can be incorporated into building energy management systems. The series consists of duct mount units GMD20 and GMD20D and wall mount units GMW21/D and GMW22/D. Version D has a display. The variety of wall mount series sizes makes them easy to install for most standard junction boxes.

The duct units' compact sensor head design requires only a small hole in a ventilation duct, thereby minimizing the risk of leaking gaskets and measurement errors.

In addition to the standard 0...20 mA, 4...20 mA and 0...10 V outputs, there are three other options: two LonWorks® interfaces and a relay output. The relay output is standard with the display units.

Improve indoor air quality with minimum energy costs

The use of the GMD/W20 series transmitters ensures the best possible control of air quality and results in considerable savings in energy consumption, maintenance and recalibration costs.

Temperature option

The GMA20T temperature module, an option with the GMW21 wall mount unit, combines both CO_2 and temperature measurement into one transmitter. The GMA20T has an output of 0...10 V corresponding to a temperature range of 0...+50 °C (+32...122 °F).

Technical Data

Carbon dioxide

Measurement range	0...2000 ppm
	(nominal; can be calibrated for other ranges: 0...5000 ppm, 0...10,000 ppm, 0...20,000 ppm)
Accuracy at +25 °C (77 °F) against certified factory references	<± [30 ppm + 2.0% of reading] (incl. repeatability and calibration uncertainty)
Non-linearity	<±1 %FS
Temperature dependence of output (typical value)	0.15 %FS /°C
Long-term stability	<5 %FS /5 years
Response time (0 ...63% response)	1 minute

Temperature (optional with wall model)

Output signal	0...10V
Corresponding measurement range	0...+50 °C (32...+122 °F)
Accuracy (@+25 °C)	±0.5 °C (±0.9 °F)
Warm up time	30 min
Sensor	Semiconductor IC

General

Output signals	0...20 mA or 4...20 mA and 0..10 V
Resolution of analog outputs	0.5 %FS
Optional outputs	relay
	LonWorks® interface
	RS232 (with serial COM adapter for maintenance purposes)
Recommended external load:	
current output	max. 500 Ohm
voltage output	min. 1 kOhm
Power supply	nominal 24 VDC/VAC (18...30 VDC)
Power consumption	<2.5 W
Warm-up time	1 minute, 15 minutes full specification
Operating temperature range	-5...+45 °C (+23...113 °F)
Operating humidity range	0...85 %RH non-condensing
Air flow range (GMD20)	0...10m/s
Housing material	ABS plastic
Housing classification (electronics housing GMD20)	IP65 (NEMA 4)
Weight:	
GMD20 (D)	140 g (170 g)
GMW21 (D)	100 g (130 g)
GMW22 (D)	90 g (120 g)

Accessories and options

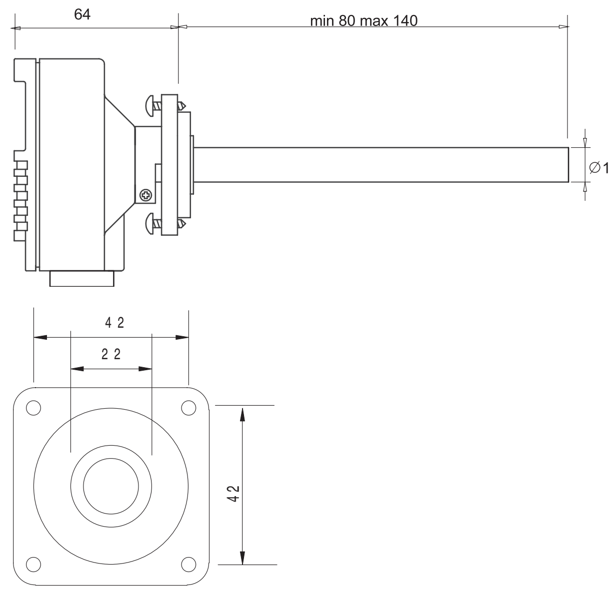
GMI21	display and relay option for GMD/W21/22
GMR20	relay output option
GML20	LonWorks® module with CO_2 signal (Not available when display option is added.)
GML20T	LonWorks® module with both CO_2 signal and temperature signals (Not available when display option is added.)
19222GM	calibration software kit (disk and serial COM adapter)
GMA20T	Analog temperature module for GMW21 (Not available when display option is added.)
GM70 w/pump option	hand-held CO_2 meter for field verification

The GMD/W20 Transmitters comply with EMC standard EN61326-1:1997 + Am1:1998 + Am2:2001; Generic Environment

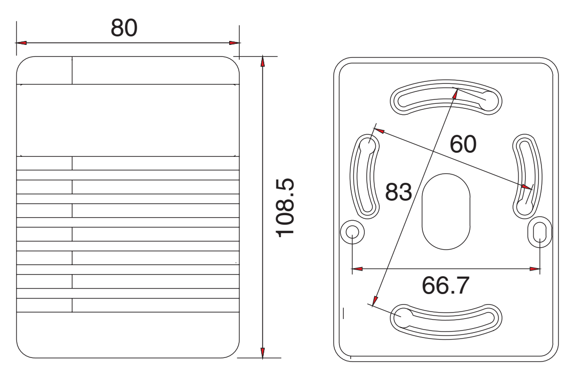
Dimensions

Dimensions in mm

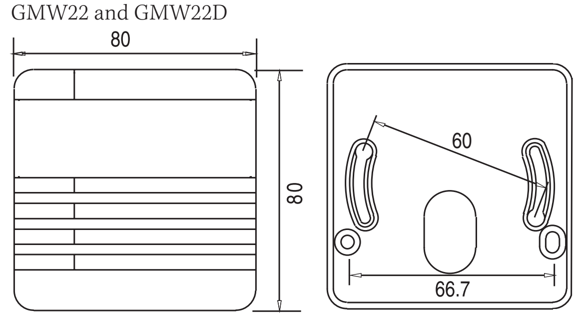
GMD20 and GMD20D



GMW21 and GMW21D



GMW22 and GMW22D



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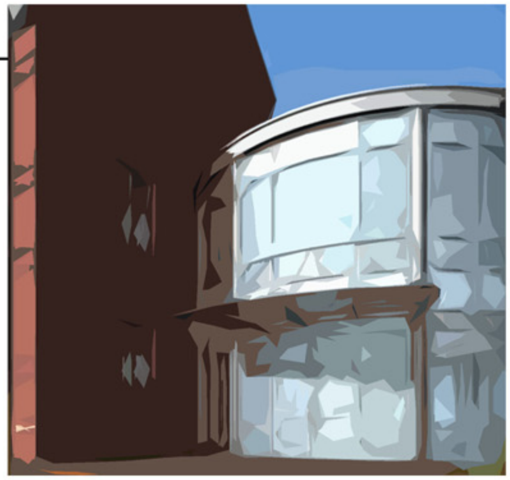
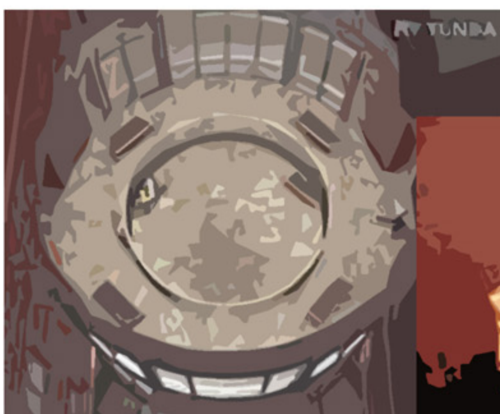
Specifications subject to change without prior notice.



Appendix C



REPORT- ES-A Annual Costs and Savings WEATHER FILE- TMY WASHINGTON, DC

	ENERGY ($)			OPERATIONS ($)					TOTAL
YEAR	ENERGY COST BASELINE	ENERGY COST THIS RUN	ENERGY COST SAVINGS	OPRNS COST BASELINE	OPRNS COST -- THIS RUN PLANT	BUILDING	TOTAL	OPRNS COST SAVINGS	SAVINGS- ENERGY PLUS OPRNS
1	0.	112337.	-112337.	0.	0.	0.	0.	0.	-112337.
2	0.	107230.	-107230.	0.	0.	0.	0.	0.	-107230.
3	0.	102356.	-102356.	0.	0.	0.	0.	0.	-102356.
4	0.	97704.	-97704.	0.	0.	0.	0.	0.	-97704.
5	0.	93263.	-93263.	0.	0.	0.	0.	0.	-93263.
6	0.	89023.	-89023.	0.	0.	0.	0.	0.	-89023.
7	0.	84977.	-84977.	0.	0.	0.	0.	0.	-84977.
8	0.	81114.	-81114.	0.	0.	0.	0.	0.	-81114.
9	0.	77427.	-77427.	0.	0.	0.	0.	0.	-77427.
10	0.	73908.	-73908.	0.	0.	0.	0.	0.	-73908.
11	0.	70548.	-70548.	0.	0.	0.	0.	0.	-70548.
12	0.	67342.	-67342.	0.	0.	0.	0.	0.	-67342.
13	0.	64281.	-64281.	0.	0.	0.	0.	0.	-64281.
14	0.	61359.	-61359.	0.	0.	0.	0.	0.	-61359.
15	0.	58570.	-58570.	0.	0.	0.	0.	0.	-58570.
16	0.	55908.	-55908.	0.	0.	0.	0.	0.	-55908.
17	0.	53366.	-53366.	0.	0.	0.	0.	0.	-53366.
18	0.	50941.	-50941.	0.	0.	0.	0.	0.	-50941.
19	0.	48625.	-48625.	0.	0.	0.	0.	0.	-48625.
20	0.	46415.	-46415.	0.	0.	0.	0.	0.	-46415.
21	0.	44305.	-44305.	0.	0.	0.	0.	0.	-44305.
22	0.	42291.	-42291.	0.	0.	0.	0.	0.	-42291.
23	0.	40369.	-40369.	0.	0.	0.	0.	0.	-40369.
24	0.	38534.	-38534.	0.	0.	0.	0.	0.	-38534.
25	0.	36782.	-36782.	0.	0.	0.	0.	0.	-36782.
TOTALS($)	0.	1698976.	-1698976.	0.	0.	0.	0.	0.	-1698976.

High School DOE-2.2-42 11/24/2003 13:14:20 BDL RUN 1

REPORT- ES-D Energy Cost Summary WEATHER FILE- TMY WASHINGTON, DC

UTILITY-RATE	RESOURCE	METERS	METERED ENERGY UNITS/YR	TOTAL CHARGE ($)	VIRTUAL RATE ($/UNIT)	RATE USED ALL YEAR?
Custom Elec Rate	ELECTRICITY	EM1	1117914. KWH	69765.	0.0624	YES
Custom Gas Rate	NATURAL-GAS	FM1	45703. THERM	42572.	0.9315	YES
				==========		
				112337.		

ENERGY COST/GROSS BLDG AREA: 6.51
ENERGY COST/NET BLDG AREA: 6.51

High School UPGRADE CASE DOE-2.2-42 11/24/2003 13:51:31 BDL RUN 1

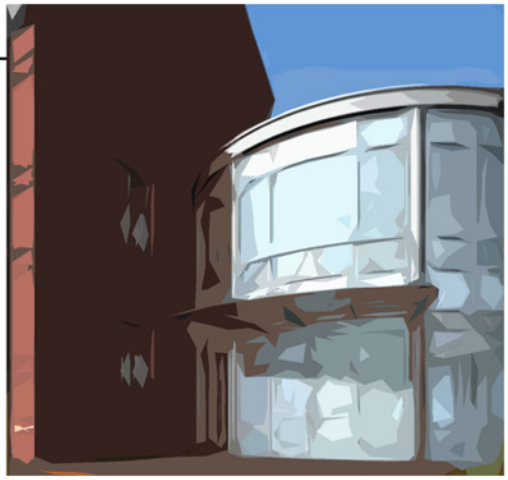
REPORT- ES-A Annual Costs and Savings WEATHER FILE- TMY WASHINGTON, DC

	ENERGY ($)			OPERATIONS ($)					TOTAL
					OPRNS COST -- THIS RUN				SAVINGS-
YEAR	ENERGY COST BASELINE	ENERGY COST THIS RUN	ENERGY COST SAVINGS	OPRNS COST BASELINE	PLANT	BUILDING	TOTAL	OPRNS COST SAVINGS	ENERGY PLUS OPRNS
1	0.	99115.	-99115.	0.	0.	0.	0.	0.	-99115.
2	0.	94610.	-94610.	0.	0.	0.	0.	0.	-94610.
3	0.	90310.	-90310.	0.	0.	0.	0.	0.	-90310.
4	0.	86205.	-86205.	0.	0.	0.	0.	0.	-86205.
5	0.	82286.	-82286.	0.	0.	0.	0.	0.	-82286.
6	0.	78546.	-78546.	0.	0.	0.	0.	0.	-78546.
7	0.	74976.	-74976.	0.	0.	0.	0.	0.	-74976.
8	0.	71568.	-71568.	0.	0.	0.	0.	0.	-71568.
9	0.	68315.	-68315.	0.	0.	0.	0.	0.	-68315.
10	0.	65209.	-65209.	0.	0.	0.	0.	0.	-65209.
11	0.	62245.	-62245.	0.	0.	0.	0.	0.	-62245.
12	0.	59416.	-59416.	0.	0.	0.	0.	0.	-59416.
13	0.	56715.	-56715.	0.	0.	0.	0.	0.	-56715.
14	0.	54137.	-54137.	0.	0.	0.	0.	0.	-54137.
15	0.	51677.	-51677.	0.	0.	0.	0.	0.	-51677.
16	0.	49328.	-49328.	0.	0.	0.	0.	0.	-49328.
17	0.	47085.	-47085.	0.	0.	0.	0.	0.	-47085.
18	0.	44945.	-44945.	0.	0.	0.	0.	0.	-44945.
19	0.	42902.	-42902.	0.	0.	0.	0.	0.	-42902.
20	0.	40952.	-40952.	0.	0.	0.	0.	0.	-40952.
21	0.	39091.	-39091.	0.	0.	0.	0.	0.	-39091.
22	0.	37314.	-37314.	0.	0.	0.	0.	0.	-37314.
23	0.	35618.	-35618.	0.	0.	0.	0.	0.	-35618.
24	0.	33999.	-33999.	0.	0.	0.	0.	0.	-33999.
25	0.	32453.	-32453.	0.	0.	0.	0.	0.	-32453.
TOTALS ($)	0.	1499018.	-1499018.	0.	0.	0.	0.	0.	-1499018.

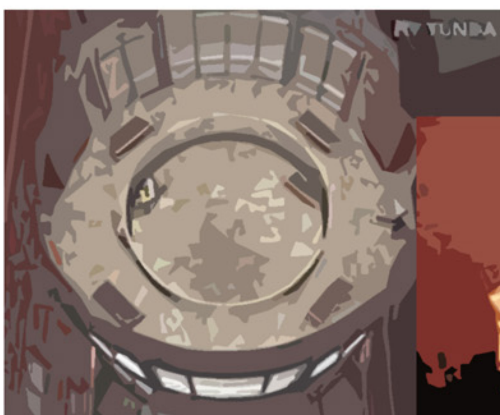
REPORT- ES-D Energy Cost Summary WEATHER FILE- TMY WASHINGTON, DC

UTILITY-RATE	RESOURCE	METERS	METERED ENERGY UNITS/YR	TOTAL CHARGE ($)	VIRTUAL RATE ($/UNIT)	RATE USED ALL YEAR?
Custom Elec Rate	ELECTRICITY	EM1	841615. KWH	54345.	0.0646	YES
Custom Gas Rate	NATURAL-GAS	FM1	48112. THERM	44770.	0.9305	YES
				========== 99115.		

ENERGY COST/GROSS BLDG AREA: 5.74
ENERGY COST/NET BLDG AREA: 5.74



Appendix D



CostWorks 2004 - Episcopal High School New Science Facility Base Wall System Estimate

Qty	Description	Unit	Bare Mat.	Bare Labor	Total
320	Precast window sill, concrete, 4" tapers to 3", 9" wide	L.F.	3,104.00	2,192.00	5,296.00
75	Mortar, portland cement and lime, 1:1:6 mix, 750 psi, type N	C.F.	255.75	107.25	363.00
2	Veneer wall ties, corrugated, galvanized, 24 ga., 7/8" x 7"	C	8.00	52.00	60.00
215	Red brick, veneer, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding	M	88,150.00	176,300.00	264,450.00
378	Precast concrete coping, stock units, 8" wall, 10" wide, 4" tapers to 3-1/2"	L.F.	6,633.90	2,419.20	9,053.10
378	Lintel angle, structural, unpainted, under 500 lb.	Lb.	185.22	189.00	374.22
660	Partition, galv LB studs, 18 ga x 6" W studs 24" O.C. x 10' H, incl galv top & bottom track, excl openings, headers, beams, bracing & bridging	L.F.	3,927.00	3,465.00	7,392.00
1	Miscellaneous wood blocking, to steel construction	M.B.F.	465.00	1,875.00	2,340.00
23,800	1/2" CDX plywood sheathing, on walls	S.F.	9,282.00	11,186.00	20,468.00
23,800	Building paper with continuous vapor barrier	S.F.	9,282.00	11,900.00	23,562.00
23,800	Fiberglass insulation, unfaced, batts or blankets for walls or ceilings, 6" thick, R19, 15" wide	S.F.	8,568.00	5,474.00	14,042.00
1,380	Lead coated copper flashing, fabric-backed, 5 ounce	S.F.	2,235.60	952.20	3,187.80
12	Caulking & Sealants, backer rod, polyethylene, 1" dia	C.L.F.	109.80	714.00	823.80
2	Frames, aluminum, door, entrance, clear finish, 6' x 10' opening, with 3' high transoms	Opng.	840.00	216.00	1,056.00
1	Doors & Frames, aluminum, entrance, narrow stile, clear finish, 3'-0" x 7'-0" opening, incl. standard hardware, excl. glass	Ea.	515.00	297.00	812.00
2,000	Windows, aluminum sash, stock, grade C, fixed casement, excl. glazing and trim	S.F.	21,200.00	5,940.00	27,140.00
2,000	Insulating Glass, double glazed, tinted, 1/4" float, for 1" thick unit, 30-70 SF	S.F.	28,600.00	13,700.00	42,300.00
3,046	Spandrel Glass, standard colors, 1/4" thick, up to 1,000 SF	S.F.	34,724.40	14,194.36	48,918.76
6,046	Curtain Wall, aluminum, stock, incl. glazing, minimum	S.F.	129,989.00	32,648.40	162,637.40
23,800	Gypsum wallboard, on walls, fire resistant, taped & finished (level 4 finish), 5/8" thick	S.F.	6,426.00	13,090.00	19,516.00
280	Louver, aluminum, extruded, with screen, mill finish, fixed blade, continuous line, stormproof	S.F.	8,260.00	3,108.00	11,368.00
	Totals		**$362,760.67**	**$300,019.41**	**$665,160.08**

CostWorks 2004 - Episcopal High School New Science Facility UPGRADE Wall System Estimate

Qty	Description	Unit	Bare Mat.	Bare Labor	Total
320	Precast window sill, concrete, 4" tapers to 3", 9" wide	L.F.	3,104.00	2,192.00	5,296.00
75	Mortar, portland cement and lime, 1:1:6 mix, 750 psi, type N	C.F.	255.75	107.25	363.00
2	Veneer wall ties, corrugated, galvanized, 24 ga., 7/8" x 7"	C	8.00	52.00	60.00
215	Red brick, veneer, running bond, T.L. lots, 6.75/S.F., 4" x 2-2/3" x 8", includes 3% brick and 25% mortar waste, excludes scaffolding	M	88,150.00	176,300.00	264,450.00
378	Precast concrete coping, stock units, 8" wall, 10" wide, 4" tapers to 3-1/2"	L.F.	6,633.90	2,419.20	9,053.10
378	Lintel angle, structural, unpainted, under 500 lb.	Lb.	185.22	189.00	374.22
660	Galv LB studs, 18 ga x 6" W studs 24" O.C. x 10' H, incl galv top & bottom track, excl openings, headers, beams, bracing & bridging	L.F.	3,927.00	3,465.00	7,392.00
1	Miscellaneous wood blocking, to steel construction	M.B.F.	465.00	1,875.00	2,340.00
23,800	1/2" CDX plywood sheathing, on walls	S.F.	9,282.00	11,186.00	20,468.00
23,800	Grace Perm-A-Barrier membrane, flashing, wall conditioner, bituthene mastic	S.F.	45,220.00	11,900.00	57,120.00
23,800	Fiberglass insulation, unfaced, batts or blankets for walls or ceilings, 6" thick, R19, 15" wide	S.F.	8,568.00	5,474.00	14,042.00
1,380	Lead coated copper flashing, fabric-backed, 5 ounce	S.F.	2,235.60	952.20	3,187.80
12	Caulking & Sealants, backer rod, polyethylene, 1" dia	C.L.F.	109.80	714.00	823.80
2	Frames, aluminum, door, entrance, clear finish, 6' x 10' opening, with 3' high transoms	Opng.	840.00	216.00	1,056.00
1	Doors & Frames, aluminum, entrance, narrow stile, clear finish, 3'-0" x 7'-0" opening, incl. standard hardware, excl. glass	Ea.	515.00	297.00	812.00
2,000	Windows, aluminum sash, stock, grade C, fixed casement, excl. glazing and trim	S.F.	21,200.00	5,940.00	27,140.00
2,000	Insulating Glass, double glazed, tinted, 1/4" float, for 1" thick unit, 30-70 SF	S.F.	28,600.00	13,700.00	42,300.00
3,046	Spandrel Glass, standard colors, 1/4" thick, up to 1,000 SF	S.F.	34,724.40	14,194.36	48,918.76
6,046	Curtain Wall, aluminum, stock, incl. glazing, minimum	S.F.	129,989.00	32,648.40	162,637.40
23,800	Gypsum wallboard, on walls, fire resistant, taped & finished (level 4 finish), 5/8" thick	S.F.	6,426.00	13,090.00	19,516.00
280	Louver, aluminum, extruded, with screen, mill finish, fixed blade, continuous line, stormproof	S.F.	8,260.00	3,108.00	11,368.00
	Totals		**$398,698.67**	**$300,019.41**	**$698,718.08**

ASSEMBLIES ESTIMATE

B201 EXTERIOR WALLS 130 BRICK VENEER / METAL STUD BACK UP

WALL TYPE 1

4" STANDARD FACE BRICK
AIR CAVITY
15 lb BUILDING FELT
½" EXT SHEETHING w/ LIQ MEM @ ALL SEAMS
BATT INSULATION
6" LIGHT GA CFM STUD FRAMING 24" O.C. (25 ga ASSUME LIGHT)
CONTINUOUS MEMBRANE VAPOR RETARDER
5/8" PTD. GWB
CONTROL JT @ 32'

USE
5100 (STD BRICK, 25 ga x 6" NLB, 24" OC, RUNNING)

COST PER S.F		
MAT	INST	TOT
4.67	12.30	16.97

PG. 168
R.S. MEANS ASSEMBLIES 2004
B201 130 1500

TAKE OFFS

PERIMETER
2(141') + (77'-8")2 + 2(70'-8") + 2(41'-4") = 661.33 L.F

WINDOWS (1st FLOOR)

20(5'-4") + 15(4-8") + 3(4') + 2(4'-4") = 197.33 L.F

PG. 202
B2020 100

(2nd FLOOR)
20(5'-8") + 18(4'-8") + 5(4') + 2(6') + 2(4'-4') = 238 L.F.

WINDOW TYPE

A (20)	A2 (4)	B (20)	C2 (1)	C3 (1)	D (11)	E (8)
60.44 SF	45.33	34.3	88.5	73.2	28	35.4
1208.8 SF	181.32 SF	686 SF	88.5 SF	73.2 SF	308 SF	283.2

F (6)	G (1)	H (1)	J (1)	K (1)	L (1)	M (1)	N (1)
32.67	75	65.625	101.39	93.3	54.1	123.3	107.33
196 SF	75 SF	65.7	101.4	93.3	54.1	123.3	107.3 SF

TOTAL = 3,645.12 SF

• CURTAIN WALL (WINDOWS A, A2, C2, C3) → 2093.3 SF

ROTUNDA (26.04 FT TALL)
16(3'-1½") + 4(1'-10¼") = 57.42'

PGS 206 & 207
B2020 210 & 220

1495.13 SF = TOTAL (CURTAIN WALL FOR ROTUNDA)

ROOF SLOPE

12
10

$\frac{10}{12} = \frac{52.17}{x}$

$x = 62.6$

$\frac{10}{12} = \frac{38.5}{x}$

$x = 46.2'$

SF TOTALS

BRICK

27.3' × 661.3' = 18,076.41 SF

2 × ½ (38.5 × 46.2') = 1778.70 SF

2 × (52.17 × 62.6) + 2(5' × 38.5') + 2(5' × 70.67') = 7623.4 SF

TOTAL = 27,478.5 SF
− 3,645.12 SF (WINDOWS + DOORS)

23,833.38 SF ✱

CURTAIN WALL (ANN ALUMINUM FRAME, INSULATED SPANDREL GLASS (GLAZED OUTSIDE), TEMPOR LAMINATED GLASS AT FLOOR LEVEL)

ROTUNDA

1495.13 SF

TOTAL = 3046.95 SF

WINDOWS (A, A2, C2, C3)

1551.82 SF

DOORS

101A	6-1" × 9'	(ALUM, TF GLAZING, CW ALUM)
101 B	6-1" × 9'	
105A	3' × 8'-10"	(ALUM, TF GLAZING, CM ALUM)
D1	3'-2" × 7'-2"	(STL, HM FRAME, HW SET 3)

TOTAL = 157.7 SF

PLUGED NUMBERS INTO COSTWORKS 2004 TO GET ESTIMATE

SEE SPEADSHEET IN REPORT FOR COST BREAKDOWN.

DETAILED ESTIMATE QTO

04 MASONRY

24 GA GALVANIZED WALL TIES 200 (E)

RED FACE BRICK STANDARD 4" 215 (M)

PRECAST STONE SILLS

PRECAST STONE COPING 378 LF

05 METALS

18 GA, 8" CFM STUDS @ 24" OC. 660 LF

PLAIN STEEL LINTELS UNDER 500 lbs 378 LF

06 WOODS & PLASTICS

TO STEEL CONST 2x4" WOOD BLOCKING @ ROOF 1 MBF

1/2" SHEETHING 23,800 SF

07 THERMAL & MOISTURE PROTECTION

CHANGE IN XCEL — 1 PLY CONTINOUS MEMBRANE VAPOR BARIER 23,800 SF

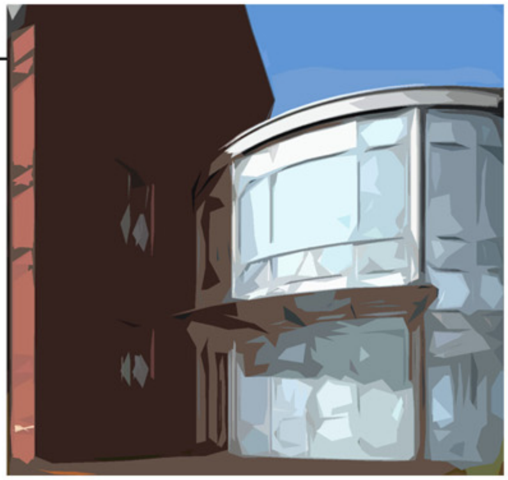
BATT INSULATION FIBERGLASS UNFACED 23,800 SF

L.L.C FLASHING 16.OZ. PER SF COLD ROLLED 1380 SF

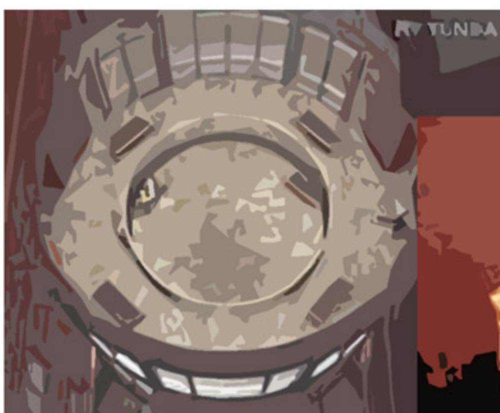
08 DOORS & WINDOWS

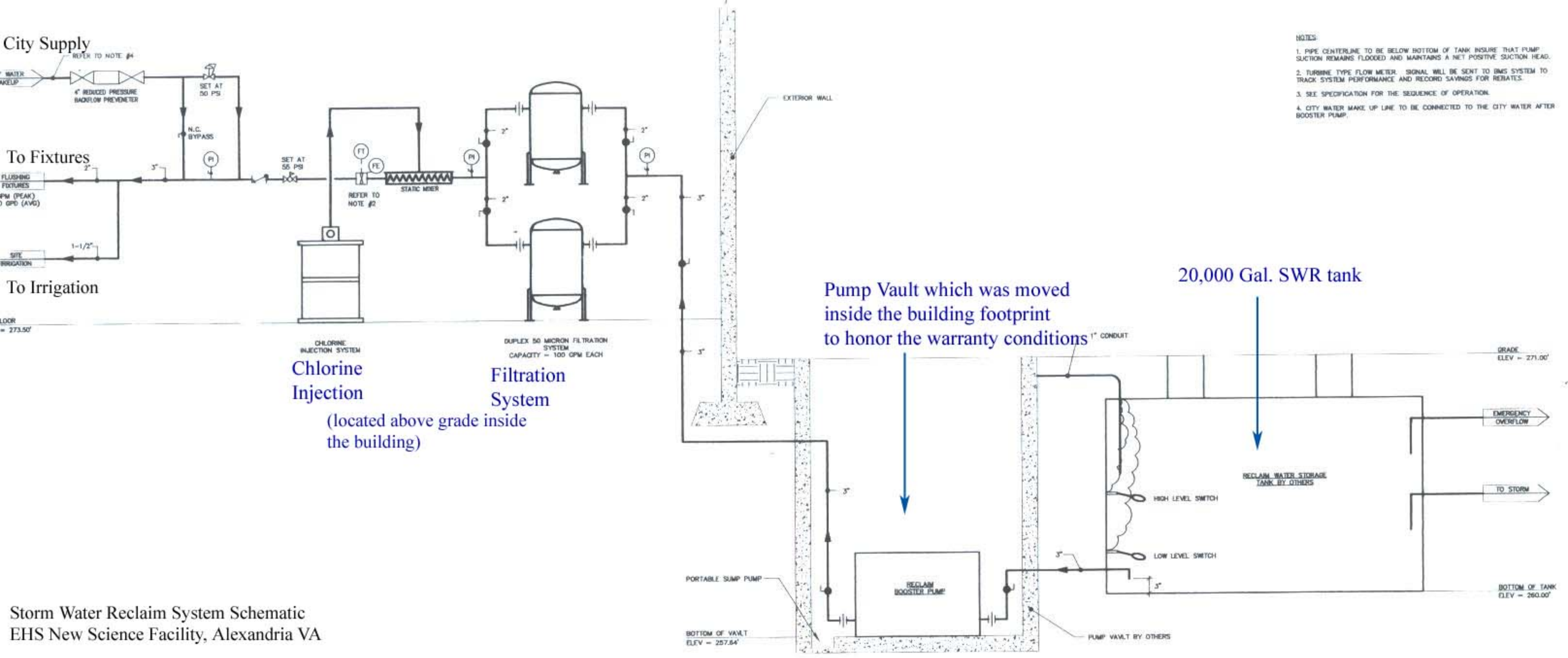
CURTAIN WALL SYSTEM ALUM FRAME 6,046 SF

SPANDREL GLASS 1/4" 3,046 SF



Appendix E





Storm Water Reclaim System Schematic
EHS New Science Facility, Alexandria VA