Technical Assignment 3

Alternative Methods Analysis

November 21, 2008

Meghan Graber
Construction Management
Dr. Riley

Integrated Science Center

College of William & Mary

Williamsburg, Virginia

TABLE OF CONTENTS

I. Executive Summary

The following document is intended to provide an opportunity to begin to identify areas of the project that will form the basis of my final thesis proposal. The core thesis investigation areas to keep in mind during this assignment include critical issue research, value engineering topics, constructability challenges, and schedule acceleration scenarios. The ideas and information covered in this paper were developed through an in-person interview with the project manager of the job as well as my observations.

I was fortunate to have had the opportunity to visit and conduct an interview with Dan Hamilla, project manager for the Integrated Science Center job. The first three sections of this assignment, Constructability Challenges, Schedule Acceleration Scenarios, and Value Engineering Topics, were compiled based off my conversation with Dan. It was extremely beneficial to have had this interview because we discussed issues specifically for this project that I would not have identified on my own and it provided me with ideas for the Problem Identification section of this report.

The Constructability Challenges section describes three challenging constructability issues unique to the Integrated Science Center project and discusses the solutions the site team implemented to overcome these challenges. The issues discussed include the addition of 50 feet of piping to the Cryo venting system, moisture carry over at the air handler units, and the coordination and scheduling of the auditorium renovation.

The project's critical path is covered in the Schedule Acceleration Scenario section. The biggest risks to the schedule were proper sequencing of work, inspections, and controls work. The greatest potential for acceleration was with the ceiling MEP work. Giving the mechanical and electrical contractors free run on the floors for six weeks allowed partitions and rough-in be begin almost two months ahead of schedule. The cost for paying the premium portion of the overtime was approximately $68,000, taken from the project contingency.

The Value Engineering Topics section introduced the key areas of value engineering that were implemented on the project. For Phase II, the renovation of Rogers Hall, the original contract documents required to keep the existing windows and curtainwall systems. After evaluating the situation though, replacing the windows during demolition would be a beneficial alternative because it would improve efficiency, aesthetics, and quality.

The last two sections covered in this assignment include Problem Identification and Technical Analysis Methods. The Problem Identification portion listed problematic construction and design issues on my project that could be pursued through a detailed analysis. Four of these problem areas are developed in the Technical Analysis Methods section: the Geopier Intermediate Foundation System versus an alternative foundation system, Phase II existing windows versus replacement windows, moisture carry over at the AHUs, and vendor and material selection.

II. Construction Challenges:

Cryo Venting System

The College of William and Mary's Integrated Science Facility was constructed with a liquid nitrogen delivery system that was supposed to be capable of providing liquid nitrogen to all four levels (basement through 3rd floor) of the facility. The main nitrogen tank was located outside of the building at the loading dock. Unfortunately, the tank was mispositioned on the contract drawings and had to be relocated to accommodate the building structure. In doing so, an additional 50 feet of cryogenic piping was added. The additional piping, which was fiberglass insulated, caused massive head loss and evaporation of nitrogen in the system. After multiple meetings over the span of several months, the solution was determined to be as follows:

1. Utilize vacuum jacketed piping in lieu of fiberglass insulated piping.
2. Install an additional gas relief valve to disburse the additional nitrogen gas created when the liquid nitrogen in the system warms above its boiling point.

Implementation of these two suggestions resulted in the liquid nitrogen being delivered to the fill stations as designed.

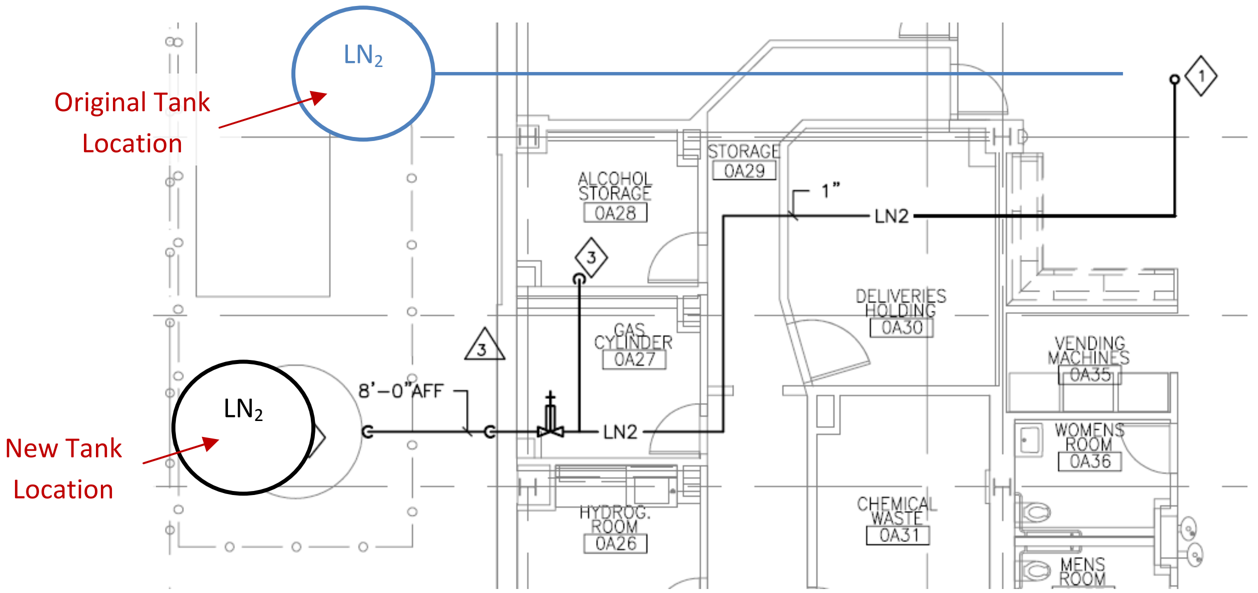


Figure 1.1 – Liquid Nitrogen Tank Relocation

Moisture Carry Over at AHU's
The Integrated Science Center is a state of the art facility which contains over 40 fume hoods. All of the ambient air in the building must be exchanged with external air several times per day. Recirculation of air is not permitted, as the fume hoods are integral to the building exhaust system. Unfortunately, the engineer who specified the air handler units did not take into consideration the massive amount of condensation that would form when operating the system at 100% external air exchange in the humid summer months, and as such, moisture began to overflow the small drain pans and flood the penthouse floor. After consulting with the design engineer, manufacturer, and mechanical contractor, the following measures were implemented.

1. Operate the system at less than maximum airflow. The system was designed for each unit to draw 43,000 CFM; however, they were originally operating at 48,000 CFM per the Owner's specifications. After additional modifications were made to the air distribution system, the airflow at each unit was lowered back to the 43,000 CFM, which helped to mitigate, but not eliminate the problem.
2. Addition of moisture eliminators and larger drain pans finally resolved this issue. The moisture eliminators effectively contained the excess moisture being blown off of the coils and deposited the condensation into the larger drain pans which were capable of handling the excess capacity. Please see Appendix A for moisture eliminator product sheet.

Figure 1.2 – Air Handler Unit

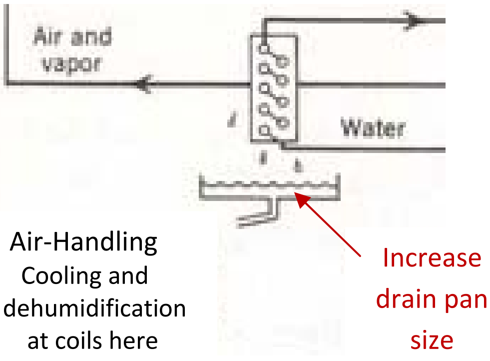


Figure 1.3 – Condensate Schematic

Auditorium Renovation

Demolition was scheduled to begin for Phase II on 06/01/08. The auditorium life safety system design had to be modified, approved, and constructed prior to 08/11/08. The auditorium was originally not scheduled to be operational during construction; however, a last minute decision forced the project team to make this happen. The team immediately met with the sprinkler and fire alarm contractor and reviewed the scope of work. The biggest challenge was revising the sprinkler to fit above the suspended drywall ceiling, as opposed to being exposed as originally designed. The drawings were produced, submitted, and approved prior to 06/20. Scaffolding of the room began on 6/23. Work was completed and tied into the existing systems on 7/30, tested and inspected on 8/4, and remedial finishes were completed on 8/8. The temporary walkway, handicap entrance, and revised lighting were also completed during this time frame. The auditorium was opened for fall semester classes on 8/11 as scheduled.

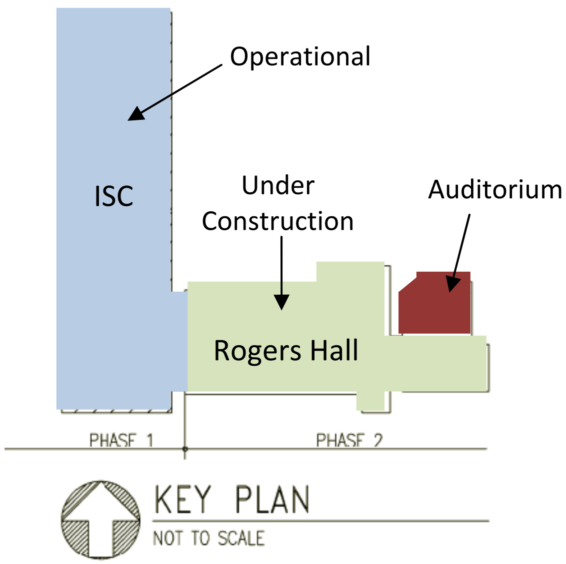


Figure 1.4 – Auditorium Location

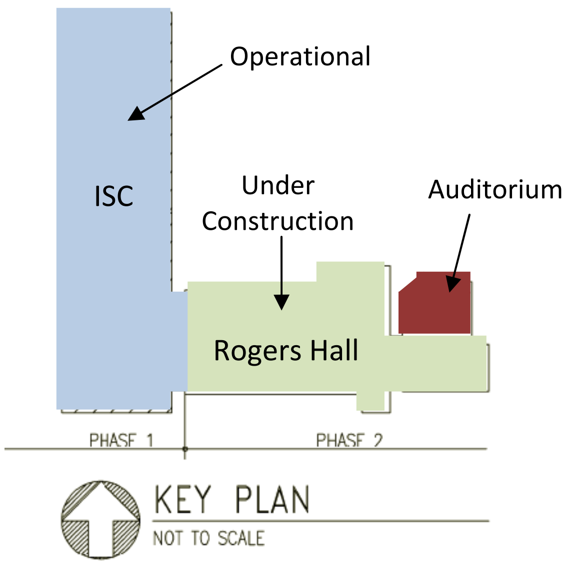
III. Schedule Acceleration Scenarios

The critical path of the project schedule revolves around the three key activities that are required to be completed prior to the issuance of the Certificate of Occupancy: installation of lab fume hoods, completion of above ceiling inspections, and completion of TAB. The College of William and Mary's Code Review Team was adamant that all above ceiling and in-wall MEP systems undergo a thorough three phase inspection process, which was noted in detail on the project schedule.

The biggest risks to the project schedule were:

1. **Proper sequencing of work** - allowing the major MEP above ceiling work to be installed and insulated prior to installation of most partitions is critical in maintaining the schedule. Installing all of the partitions, which the drywall contractor fights for and, on some projects, the superintendent may allow, will drastically impede the MEP contractor's above ceiling work progress.

Auditorium Renovation
Demolition was scheduled to begin for Phase II on 06/01/08. The auditorium life safety system design had to be modified, approved, and constructed prior to 08/11/08. The auditorium was originally not scheduled to be operational during construction; however, a last minute decision forced the project team to make this happen. The team immediately met with the sprinkler and fire alarm contractor and reviewed the scope of work. The biggest challenge was revising the sprinkler to fit above the suspended drywall ceiling, as opposed to being exposed as originally designed. The drawings were produced, submitted, and approved prior to 06/20. Scaffolding of the room began on 6/23. Work was completed and tied into the existing systems on 7/30, tested and inspected on 8/4, and remedial finishes were completed on 8/8. The temporary walkway, handicap entrance, and revised lighting were also completed during this time frame. The auditorium was opened for fall semester classes on 8/11 as scheduled.



III. Schedule Acceleration Scenarios

The critical path of the project schedule revolves around the three key activities that are required to be completed prior to the issuance of the Certificate of Occupancy: installation of lab fume hoods, completion of above ceiling inspections, and completion of TAB. The College of William and Mary's Code Review Team was adamant that all above ceiling and in-wall MEP systems undergo a thorough three phase inspection process, which was noted in detail on the project schedule.

The biggest risks to the project schedule were:

1. **Proper sequencing of work** - allowing the major MEP above ceiling work to be installed and insulated prior to installation of most partitions is critical in maintaining the schedule. Installing all of the partitions, which the drywall contractor fights for and, on some projects, the superintendent may allow, will drastically impede the MEP contractor's above ceiling work progress

2. **Inspections** - mandating that project quality control protocols were in place to ensure framing, in-wall, and above ceiling inspections passed the first time, with minimal re-inspections required. Re-work is the most costly endeavor in construction and can cripple a schedule if work in place must be removed and constructed properly.

3. **Controls work** - pushing the controls contractor and the fume hood valve contractor to complete their wiring and programming in time for TAB to begin. Note that while this work is independent of the above ceiling work, both the controls work and the above ceiling inspections must be completed simultaneously in order for TAB to begin.

The project team conducted a scheduling "card trick" meeting prior to major construction activities beginning to discuss the best way to map out the schedule logic. In order to complete the job 5 to 6 weeks ahead of schedule, the lab casework and fume hoods would have to be delivered on 11/05/08. They were required to have a dry building, finished interior shell space, and tempered air by that time. The lab casework contractor was instructed to begin fabrication for the 11/05 delivery date in June, whereupon the team set to work ensuring that the space would be ready. The greatest potential for acceleration was with the above ceiling MEP work. The team gave the mechanical and electrical contractors free run of the floors, after the partitions had been laid out and top track installed, with instructions to complete most of their major rough-in over a six week duration. This acceleration of a critical path activity allowed partitions and in-wall rough in to begin approximately two months ahead of the original schedule. Some additional money was spent accelerating the drywall contractor to finish the drywall once the in-wall inspections were passed, in order to get ceiling grid dropped ahead of schedule and subsequently the diffusers and permanent lights installed. The sprinkler and painting contractors, the other two main interior players, were able to keep pace without acceleration.

The additional time that was gained was used as float for the difficult TAB and commissioning activities that would follow. The team is currently tracking to complete the project five weeks ahead of the original substantial completion date. Total cost for paying the premium portion only of the overtime was approximately $68,000, money that was taken out of the project contingency but was well spent.

IV. Value Engineering Topics

Value engineering has two components: cost and quality. Sometimes, a value engineering option may actually cost slightly more than the design intent, but the quality of the implemented finished product or system may far surpass that of the intended design.

From the quality standpoint, I will focus on Phase II of the project, which consists primarily of the complete interior demolition and renovation of approximately 25,000 SF of lab space. The original contract documents required the existing window and curtainwall systems to remain protected and in place. However, after evaluating the situation, it became clear that replacing the windows during demolition would be a responsible option for the following reasons:

1. **Improved efficiency**: The original windows and curtainwall system consisted of unfinished aluminum frames holding single pane uninsulated glazing. The new system, which uses the now standard insulated double paned glazing filled with an inert gas, will drastically improve the thermal efficiency and consequently the operating costs of the building.

2. **Improved Aesthetics**: Exterior aesthetics were drastically improved due to this change, as the windows and curtainwall mullion configuration now precisely matches the windows in the façade of the newly constructed adjacent facility. The interior aesthetic changes were also appreciable. Each window was "framed" by CMU and a precast concrete lintel, which protruded approximately 8" away from the face of the exterior partition into the room. Elimination of the windows allowed the CMU "frame" and lintel to be eliminated, creating a flush surface on the perimeter walls. The new openings were then reinforced with heavy gauge metal framing, and the face of the window assembly was installed approximately 3" back from the front of the existing face brick veneer. This allowed the perimeter of the interior rooms to be framed with a uniform consistency and eliminated the necessity of framing around the original CMU window supports.

3. **Improved quality**: The windows will come with a 10 year warranty and will be water tested under a negative interior room pressure environment to ensure the façade is completely weather tight.

From an operational standpoint, the original design indicated that all mechanical work was to be installed above the 1st and 2nd floor ceilings. However, on the roof of the existing facility was a structural steel frame that supported several of the original exhaust fans. The structural steel framing was to be encapsulated with architectural louvers after the existing exhaust fans were eliminated.

However, it soon became clear that the main exhaust duct for the Phase II facility could not be installed above the 2nd floor ceiling with the inordinate amount of laboratory piping, electrical work and fume hood connections crammed into the space. Therefore, the main exhaust duct, along with many of the main chilled, hot water and steam condensate lines were relocated from above the 2nd floor ceiling to the now crowded roof chase and run to the new manifold which connected the exhaust to Phase I. The mechanical contractor saved a considerable amount of time and money, as the reconfiguration allowed personnel to work from the floor on this work as opposed to above ceiling work from ladders or lifts. Another benefit was the elimination of a large portion of work that would have come under above ceiling inspection scrutiny. Most importantly, the Owner agreed to the change as we proved that it saved enough time for the chilled and hot water piping work to be installed, tested, and inspected in order to operate the auditorium AHU for fall semester classes.

The cost of relocating this roofing piping and encapsulating the roof chase with EPDM roofing, metal studs, and light gauge metal panels was offset by the deletion of the custom architectural louvers, which had not yet been fabricated, and the elimination of heat trace wiring and exterior grade insulation.

V. Problem Identification:

This section identifies several problematic features of the Integrated Science Center project that are good candidates for research, alternative methods, value engineering, and schedule compression. Ultimately, proposal topics will be chosen for this list.

Site and Foundations:

- *Site Logistics*

  The Integrated Science Center project site was an island of chaotic congestion for much of the construction process. Bounded on the north by Landrum Road, to the south by university owned soccer fields (which were to be undisturbed), and to the east and west by existing buildings, the lack of space created a tense situation among the tradesmen. For example, the underground utility and masonry subcontractors were in conflict, as brick and mortar materials were stored where sewer lines were to be installed. Subcontractors, in order to be most productive, must have the space they need to operate without intrusion. Their work should be scheduled in carefully orchestrated stages.

Once the addition to the ISC was completed, people and equipment were transitioned into the new facility and the renovation of the existing Rogers Hall commenced. Once again, the lack of space for storage, delivery trucks, and worker vehicles created havoc on the jobsite. Perhaps if the site was coordinated and managed better for differing construction phases, there would be a positive effect on the project schedule.

- *Geopier Intermediate Foundation System Versus Alternative Foundation System*

  It was decided to reinforce the foundation soils on the Integrated Science Center site using the Geopier Intermediate Foundation System. This process involved the drilling and reoccupation of numerous 10 to 15 foot deep auger holes and an enormous amount of coordination with underground utility location. However, based on the geotechnical engineer's evaluation, the ISC addition could have been supported by a shallow foundation system in conjunction with ground replacement or ground reinforcement measures. Could a significant savings be realized by selecting this alternative foundation system?

Superstructure:

- *Steel Erection Sequence*

  For the steel erection of the Integrated Science Center, the structure was broken into two areas. The north end of the building was considered Area A and the south end was considered Area B. Floors one through four were erected in Area B, followed by floors one through four in Area A. Construction therefore moved from the south end to the north end. Perhaps the structure could have been erected by completing one floor before moving to the next. Would this have a positive influence on the project schedule? Crane usage and its related costs would also have to be considered.

Building Envelope:

- *Precast Panels Versus Masonry*

  The ISC building's exterior walls consist of a brick veneer on metal studs. An alternative to this masonry system could be the use of precast panels. Precast panels can be designed to have a similar brick appearance. The use of precast panels would result in decreased labor costs but they would be offset by an increased cost of material and crane rental. The major advantage of the precast panel system is its significant reduction in installation time compared to masonry. An acceleration of the project schedule might be of interest to the owner, but they would have the ultimate say on approving an alternative material.

- *Existing Windows Versus Replacing Windows for Phase II*

  As mentioned in the previous section, the original contract documents required the existing window and curtainwall systems to remain in place. After evaluating the situation, it was decided to replace the windows for improved efficiency, aesthetics, and quality. A thorough analysis of keeping the existing windows versus replacing them would show the effects the project schedule, construction costs, and building operation costs.

- *Existing Roof Versus Replacing Roof for Phase II*

  The existing Rogers Hall roof has sustained 35 years of weather. Although the current system is sufficient, the building is currently undergoing a major renovation. This is the time to consider replacing the current single-ply roofing membrane or upgrading to another option. A new roof would improve the building's thermal efficiency and therefore decrease mechanical system operational costs. At this time, the intention is to keep the existing roof.

MEP:

- *Moisture Carry Over at AHU*

  As discussed previously, the engineer who specified the AHUs did not take into consideration the massive amount of condensation that would form when operating the system at 100% external air exchange in the humid summer months. As a result, moisture began to overflow the drain pans and flood the penthouse floor. The system was designed for each unit to draw 43,000 CFM; however they were operating at 48,000 CFM per the Owner's specifications. To fix this problem, the airflow at each unit was lowered back to 43,000 CFM, moisture eliminators were added and larger drain pans were installed. This situation could have been avoided if the proper AHU was specified initially. With the help of mechanical professionals, a new AHU system could be proposed. What would be the difference in cost be compared to the original system?

- *MEP Coordination*

  The MEP coordination is crucial for a high-end laboratory. The implementation of a 4D model might have helped this project significantly due to the complexity of the facility. A 4D model would have identified many of the coordination issues before they occurred in the field. The initial time and costs to develop the model would be minimal compared to the time and money saved by using this technology.

Cost and Schedule:

- *Hitting Benchmark Dates*

  This project is a higher education building and therefore, the owner has requested certain dates to be met so not to interrupt the college's academic schedule. Hitting benchmark dates was a major concern and challenge for the team. Schedule acceleration techniques were used when necessary. Are there any alternative time saving methods that could have improved efficiency? After evaluating the schedule acceleration methods implemented for this project, other options could be proposed.

- *Subcontractor, Vendor, and Material Selection*

  Cost is obviously an important consideration for the owner, who selected Gilbane in part because of their competitive bid price. Gilbane, in most cases on this project, chose subcontractors who submitted the lowest bid. Unfortunately, the reliability and quality of work performed by several subcontractors was not completely acceptable. Selecting capable, reliable subcontractors is probably the most critical responsibility that a project manager assumes. Prior job experience, safety record, and financial strength should all be part of the vetting process. As a project manager gains experience, he/she will develop long-term relationships which will be beneficial on future projects. The more mutual trust in the relationship, the greater freedom the PM has to concentrate on other issues.

  Vendor and material selection is also a key component in a successful project. So often, the emphasis is on first cost, when it should be long-term value. For example, if the proper piping material had been specified for the liquid nitrogen distribution in the ISC, the costly replacement could have been avoided. Careful inspection of purchased materials to adhere to proper quality standards should be a standard procedure.

- *Completion of Commissioning and Punchlist Items*

  The completion of Phase I commissioning and punchlist has posed a major problem on this project. The original project schedule had these two activities completed by March 28, 2008 and both are still unfinished. Once Phase II commenced, crews began to focus on the bigger tasks as opposed to fixing up the little remaining items on Phase I. There are difficulties getting subcontractors to send one laborer for only a few small tasks. The college has also moved into the new facility so additional items that weren't on the original punchlist have been pointed out by the new owners. How could this situation been avoided? What needs to be enforced to get these items completed? I would propose a new way of tracking commissioning and punchlist items. They should be addressed promptly and the subcontractors responsible must be aware of their importance. Emphasize that payments are delayed when punchlist items are not completed.

- *Extra Work Claims*
  Subcontractors submitted numerous claims of "extra" work performed, expecting compensation for those items which are not part of the contract. To control these costs, which can significantly erode the profitability of a project, managers should negotiate terms and conditions when extra work is needed. Change orders should be agreed upon and signed by both parties before work commences.

- *Construction Waste*
  There was no recycling or reuse of materials on this project. If implemented, would there have been any cost savings? An investigation of reusing, reducing, and recycling materials on this project could prove cost effective. Even if a cost savings is not realized, an attempt to recycle or reuse construction materials sends a positive message to the owner and the local community that we strive to be environmentally friendly.

VI. Technical Analysis Methods

From the thirteen topics previously mentioned in the Problem Identification section, four of these have been chosen as possibilities for further development in my thesis studies. Below are the technical analysis methods that will be used to research each area.

Geopier Intermediate Foundation System Versus Alternative Foundation System
The Integrated Science Center site used the Geopier Intermediate Foundation System to reinforce the foundation soils. An in-depth look into an alternative foundation system may yield cost savings while maintaining the same or increased level of functionality and quality. The Geopier system is relatively quick to install depending on depth requirements but comparisons can be made regarding the schedule impacts of other systems.

To complete my analysis of alternative foundation systems, I will first need to develop a list of feasible systems that could replace the current Geopier system. Extensive research on each of the substitute options would then be conducted specifically focusing on cost, schedule, and constructability. With the assistance of Wayne Boy, the College of William and Mary's director of Facilities Planning, Design, and Construction, I plan to investigate the foundation systems of other campus buildings for ideas. Based on my research, I would select an alternative foundation system, develop an estimated cost and schedule for this system, and then compare these figures to the actual Geopier system. I would like to contact a geotechnical engineer, preferably a representative from Froehling & Robertson, Inc. who was the geotechnical firm on this project, to assist me in my foundations analysis.

Existing Windows Versus Replacing Windows for Phase II

One of the core thesis investigation areas to consider is possible value engineering ideas. A perfect example of this is the Phase II window controversy. The original contract documents required the existing window and curtainwall systems to remain in place. After evaluating the situation, the owner decided to replace the windows for improved efficiency, aesthetics, and quality. I would like to assess both alternatives and determine if installing new windows are cost effective.

The three main areas I will focus on are material and labor costs for the replacing window system, the variation in thermal efficiency between the old and new systems, and the estimated difference in building operation costs. The material and construction costs can be obtained from Gilbane's project manager. The College of William and Mary's construction and facilities team has been extremely helpful in answering questions related to my thesis and I should be able to acquire the previous Rogers Hall operation costs. Calculating the operating costs with the new system will require some extra research but a good estimate could be determined based on expected energy consumption. The thermal efficiency of each system is based on the different window designs. I can easily obtain the window data for the two systems and with the help of a professor or a professional, determine the difference in thermal efficiency, and thus compare the value of each option.

Moisture Carry Over at AHU

The Integrated Science Center is a state-of-the-art laboratory facility and it requires an elaborate mechanical system. The humid summer months caused an excessive amount of condensation to form when operating the system at 100% external air exchange. As a result, moisture began to overflow the drain pans and flood the penthouse floor. I would like to propose a new AHU system that could handle the building demands during Williamsburg's humid summers. The estimated new system cost could then be compared to current system plus the added expenses for larger drain pans and moisture eliminators.

The most challenging part of this analysis is determining a new air handling unit that can withstand the building loads. A mechanical professional at Facility Dynamics, the mechanical engineer for the ISC project, has agreed to provide assistance in proposing a new AHU system. Once the alternative system is selected, it can be priced from catalogs. The actual costs for the current system and the required repairs to this system can be obtained from the project manager. A comparative cost analysis can then be presented.

Subcontractor, Vendor, and Material Selection

Due to the owner's emphasis on cost, Gilbane, in most cases for this project, chose contractors who submitted the lowest bid. The reliability and work quality of several of these subcontractors was not completely satisfactory. Based on my summer internship experience and observations on this project, I believe that a significant amount of time, expense, and aggravation would have been saved if Gilbane had selected responsible and trustworthy subcontractors based on previous project relations.

To investigate my theory, I would begin by questioning Dan Hamilla, current project manager on this project, and ask him to identify the most problematic subcontractors. (Note: Mr. Hamilla was on the original project manager and did not select the subcontractors). After compiling his list, I would inquire about his preferred tradesman. Background information and evaluation of subcontractors based on previous projects, can be acquired (with permission) from Gilbane's records. On each Gilbane project, data regarding subcontractor manpower and work hours is recorded in Prolog. With the information I obtained and the assistance of the project manager, I should be able to point out areas in the schedule that could have been completed more timely.

APPENDIX

Appendix A – Product Data Sheet

WORLD LEADER IN AIR HANDLING UNITS

AHU COMPONENT - MOISTURE ELIMINATORS

Modular, flexible and made of different materials, the Arosio Moisture Eliminators represent the most effective system to remove humidity. Thanks to their blade profile made of polypropylene they ensure a constant efficiency.

The polypropylene-bladed moisture eliminators are specially designed to meet many requirements in air treatment. The screwed extruded aluminium frame is extremely solid and gives sturdiness to the whole system. Also available with/without bottom drains.

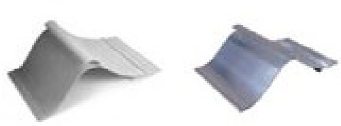
MATERIALS USED

- **BLADES** polypropylene + talc / extruded aluminium
- **DISTANCE-SETTING PROFILE** polypropylene, pitch 25 mm and 33 mm
- **VERTICAL CLOSING PROFILE** polypropylene
- **FRAME** extruded aluminium

TECHNICAL DATA AND APPLICATIONS

PSG10 (170mm blade)

- Polypropylene / Aluminium
- Air straightner, open-air intakes
- pitch 25 mm or 33 mm
- face velocity 2-6 m/sec
- temp -20℃ / 95℃



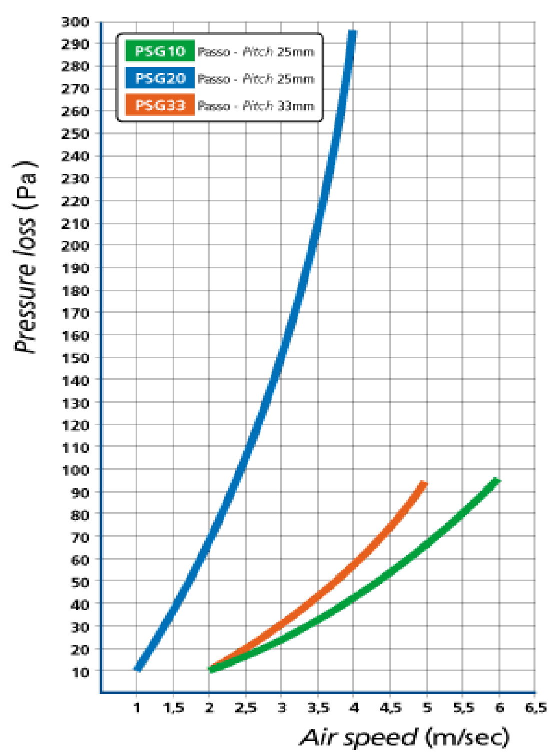
PSG20 (150mm blade)

- For large quantities of water in the air
- Polypropylene
- pitch 25 mm or 33 mm
- face velocity 1-4 m/sec
- temp -20℃ / 95℃

PSG33 (101mm blade)

- Polypropylene / Aluminium
- With cooling coils
- pitch 25 mm or 33 mm
- face velocity 2-5 m/sec
- temp -20℃ / 95℃

PRESSURE LOSS GRAPH



For further information and a quote to suit your application, please contact us

12-16 Catalano Road, Canning Vale, WA 6155
Telephone: +61 (08) 9456 0300 Facsimile: +61 (08) 9456 0388
Email: arosio@barclayeng.com.au Web: www.apsarosio.com