FINAL REPORT

C-5 Fuel Cell Facility

167th Airlift Wing

Martinsburg, WV

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Construction Management

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Dr. Magent

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EXECUTIVE SUMMARY

This document is a comprehensive collection of the technical analyses which have been performed on the C-5 Fuel Cell Facility project in Martinsburg, WV as part of the Penn State AE Senior Thesis assignment. Its contents include background information to the project such as: client information, local conditions, an explanation of the project delivery method that was used, project costs, and the project schedule among other items. Also included are the four topics of analysis which have been researched and developed over the past semester, as well as two topics of breadth study outside of the construction management option. Each of these analyses is directed at studying productivity on a construction project with respect to alternative methods and design options.

The first analysis that is discussed is the installation of a solar collection system to the roof of the C-5 Fuel Cell Facility. Specifically, the system produced by Solyndra, Inc. has been analyzed in order to determine the electrical output that could be expected from such an addition and then compared to the expected total power usage of the building. The second analysis involves changing all CMU walls on the project to precast concrete or prefabricated walls. The exterior façade is examined primarily on the basis of a quality finished product and the interior load-bearing walls are analyzed based on structural design. In both instances, cost and schedule impacts are discussed, as well as site congestion. The third area of analysis focuses on finding the most efficient sequence for constructing the slab on grade in the hangar area. The expectation of producing a quality product while maintaining high productivity is the key measurement, along with cost and schedule impact. The fourth analysis explores the affect that using the design-build delivery method has on project productivity, specifically on the management and design side of the project.

The breadth topics that will be discussed in this document focus on the electrical and structural options of Architectural Engineering. The breadth in electrical will come from the analysis of the solar collection system by calculating the approximate quantity of energy that could be produced and then determining the building's overall power usage. The structural breadth analysis will be part of the study on changing the interior load-bearing CMU walls to a precast concrete system. Design of a concrete wall structure based on the current loads will be completed.

PROJECT BACKGROUND

CLIENT INFORMATION

The Owner and future occupant of the C-5 Fuel Cell Facility is the 167th Airlift Wing of the West Virginia Air National Guard. This unit is responsible for the flight and maintenance of the C-5 Galaxy aircraft. The Fuel Cell Facility is part of the overall C-5 Conversion project at the Martinsburg base which consists of major renovations to the West Virginia Eastern Regional Airport. Some of the other individual projects that have been completed as part of the Conversion project include complete reconstruction and expansion of the runways at the airport, construction of the Maintenance Hangar which is located to the immediate east of the Fuel Cell Facility, and a new control tower.

Cost expectations for this project are slightly different than private construction projects. As with all parts of the public sector, federal funding is set by a budget and the money must be spent or the budget will most likely be decreased in the future. Of course, this does not mean that there is unlimited funding and the project is still expected to be completed for budgeted cost. Completion of the project by the scheduled date is of importance to the owner mainly because of a desire to occupy the building as soon as possible. While the owner is not looking to make a profit from the final product as in commercial projects, the completion of this building means that the overall Conversion project is one step closer to being complete. Also, there are no plans for any phased occupancy of the building, so the Airlift Wing cannot move in to the building until completion.

Safety is of utmost importance to the Owner but has not been an issue on the Fuel Cell Facility project. This is due in large part to the safety program in place by Kinsley Construction which includes training of all individuals who are to work on the site, as well as safety inspections by company safety officials. The Contracting Officer, a Lt. Col. in the Airlift Wing, has discussed some of the discrepancies he has had in the past with contractors concerning safety issues, and expressed that he has no problems with kicking somebody off the site for violations.

With regards to the quality of the project, the Lt. Col. has also repeatedly explained, through examples of the two similar hangars on the base, what he expects as a result for the Fuel Cell Facility. While there are no high-end finishes in the hangar, the details that are present are expected to be just right. One item that has been specifically addressed is the jointing in the slab for the hangar area. The Lt. Col. has shown the two existing hangars and specified the parts in each that he likes best.

SITE CONDITIONS

SITE LOCATION

- Project located at West Virginia Eastern Regional Airport in Martinsburg, WV
- Part of base for 167th Airlift Wing of West Virginia Air National Guard

NEIGHBORING STRUCTURES

- North- Access road into and out of the base
- East- Maintenance Hangar for C-5 aircraft; almost identical to the proposed Fuel Cell Facility
- South- Taxiway and runway for C-5 aircrafts
- West- Fire department for the Airlift Wing

SPECIAL CONDITIONS

- As a military base, access is restricted
- Security of the runway is of extreme importance- painted lines on concrete of taxiway denote that contractors may not cross
- After blasting procedures, a survey was required to check for any stones that may have flown on to the taxiway
- Dust from construction activities is required to be minimized for sake of operation of aircrafts at the airport- site needs to be watered down
- All structures at the airport need to be lit at night as well as flagged during the day- this includes the building itself as well as the cranes being used on site
- Construction activities can be stopped at any time by Contracting Officer when under a security warning

See Appendix A for Site Plans

LOCAL CONDITIONS

PREFERRED METHODS OF CONSTRUCTION

The Martinsburg, WV region is one in which a particular structural system is not necessarily preferred over the other. That is, there are buildings with concrete structures as well as those with steel structures. For the Fuel Cell Facility though, it is obvious that a steel structural system is required due to the incredibly long spans that are required. Such a building could not be done as a concrete structure. All other parts of the project stay fairly close to the typical construction methods of the region such as slabs on grade and CMU exterior walls. The architectural features of the building, while not typical for any buildings outside of the base, match perfectly with the existing structures on the base.

CONSTRUCTION PARKING AVAILABILITY

The site for the Fuel Cell Facility is such that construction parking is very convenient. There is a large gravel covered area between the building footprint and the access road to the north which is used for job trailers, office trailers, and material laydown, as well as parking for the project.

RECYCLING AND TIPPING FEES

Disposal of all debris and construction waste is to be done off the base and is the responsibility of the contractor. The cost of this service is approximately $650 per month.

SOIL AND GROUNDWATER CONDITIONS

According to the Geotechnical Report, the subsurface stratification is divided into two strata: (1)residual soils with sands, silts and rock fragments, and (2)rock which is primarily shale. From the borings that were completed, it was found that the condition of the shale for bearing ranged from being very poor to good. It was suggested in the report that drilled shaft foundations be used in order to have bearing on competent rock, hence the use of caissons. The report also stated that no groundwater was found during the borings, but noted that it may become present depending on the fracture structure of the shale. This information was based on the construction of the Maintenance Hangar to the east of the Fuel Cell Facility; no groundwater was found during borings for that building, but it was encountered when holes for caissons were drilled. Submersible pumps were used to dewater the drilled holes for the caissons when necessary, but subsurface water was minimal.

BUILDING DESIGN BACKGROUND

ARCHITECTURE

This project is primarily a functional building and does not display many outstanding aesthetic features. However, as mentioned in the *Client Information* section, the occupant is still interested in a quality product. The hangar features an extremely large door assembly on the Southeast façade which opens to the taxiway of the existing airport. Within the hangar there are adjoining offices and support rooms to the Northwest which will be primarily divided with CMU partition walls.

BUILDING ENCLOSURE

Building Façades: The exterior of the Fuel Cell Facility consists of courses of split-face CMU for the first 10’ above finished floor level with an accent course at approximately 3’ above finished floor, and insulated metal panels for the majority of the remainder of the wall areas. As mentioned previously, the Southeast face of the building is taken up mainly by the door assembly which is a polyester material. Insulated translucent sandwich panels are the means by which natural light enters the structure.

Roofing: A standing seam metal roof system is being used for this building, attached to 3.3” of rigid roof insulation which is fastened to 1.5” metal deck.

STRUCTURAL

The structural system for the Fuel Cell Facility is a structural steel system with a drilled caisson foundation. There are 3’ and 6’ diameter caissons that are located along the exterior edges of the building at varying spacing. These caissons are laid out symmetrically about the centerline of the building and vary in depth from 12’ to 25’. Pier caps with cross sections ranging from 4’ x 4’6” to 14’ x 5’6” are made with 3000 psi, reinforced concrete. Wide flange and hollow structural steel shapes are used for the columns of the building, with sizes of W33x291 to W40x593 and HSS6x4x1/2 to HSS 16x8x1/2.

Above the support areas of the building, there are W24x94 beams with 27’ spans supporting 18K4 joists and W36x393 girders with 30’ spans supporting 24LH joists. In the hangar area of the building the

structural steel is broken into two parts, the portions that will cover the wings of the plane and the portion that covers the fuselage, or the center of the building, which is much taller. At the interface of these two portions, on both sides, there is a steel truss configuration which spans approximately 219 feet. The trusses consist of W14x500 and W14x605 beams to form the top and bottom chords with interior members varying in size between W14x99 to W14x283. On the wings of the building, a grid of W12x65 and W24x94 beams make up the typical structural system. The center of the building has a grid of W12x87 and W16x67 beams typically.

Governing Codes: Load calculations per ASCE 7-02

Concrete design and placing per ACI 318 and 301

ELECTRICAL

A new service transformer, on the North side of the building, will convert the utility distribution of 12.47 kV (delta) to the building utilization of 480Y/277V. Service for the building is provided from 200A load break junctions coming from an electrical cabinet in the electrical room. In the hangar area, 400Hz receptacles are provided as well as three 480V electrical and air compressor connection points. Connection points for 400Hz generators are located within the electrical room.

LIGHTING

In the support spaces of the building, artificial light is provided by a variety of styles of luminaires, some recessed and some pendant. All of these luminaires use 277V fluorescent T8 lamps. The hangar area is lit by 277V metal halide pendant luminaires, each providing 1000W of light. Outside of the building, 277V high pressure sodium luminaires are wall mounted, as well as 120V LED lamps which are mounted along the roof lines as obstruction lights. Emergency lighting is provided within the building by 277V LED lamps.

MECHANICAL

The Fuel Cell Facility mechanical system, like every other system, is different for the hangar than that of the support areas. The hangar area, due to the sheer volume and enormous doors, has a heating system and a ventilation system, but no cooling system. The heating is provided by 13 vented infrared radiant heaters which provide 300MBH each and are suspended from the structural steel. Ventilation comes from two 15,000 CFM make-up air units which are located, one each, in the two mechanical rooms. Inline centrifugal exhaust fans also support the ventilation system. For the support areas, the HVAC system consists of two 300GPM boilers, a 4,000 CFM air handling unit which connects to 4 VAV boxes, and 3 energy recovery units which average 1400 CFM each.

Governing Code: Per ASHRAE 90.1

FIRE PROTECTION

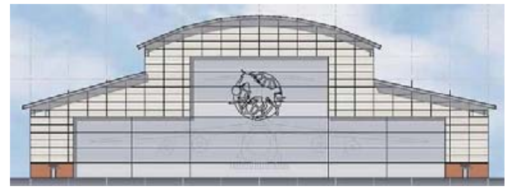
A wet pipe automatic fire sprinkler system provides fire protection for the entire building. The water for this system is supplied from an existing fire pump house near the site. In the hangar area of the Fuel Cell Facility, a low-level high expansion foam system is also provided in addition to the wet pipe system.

Governing Codes: Design of wet pipe for support areas per NFPA 13

Design of wet pipe for hangar area per NFPA 13 with stringent modifications

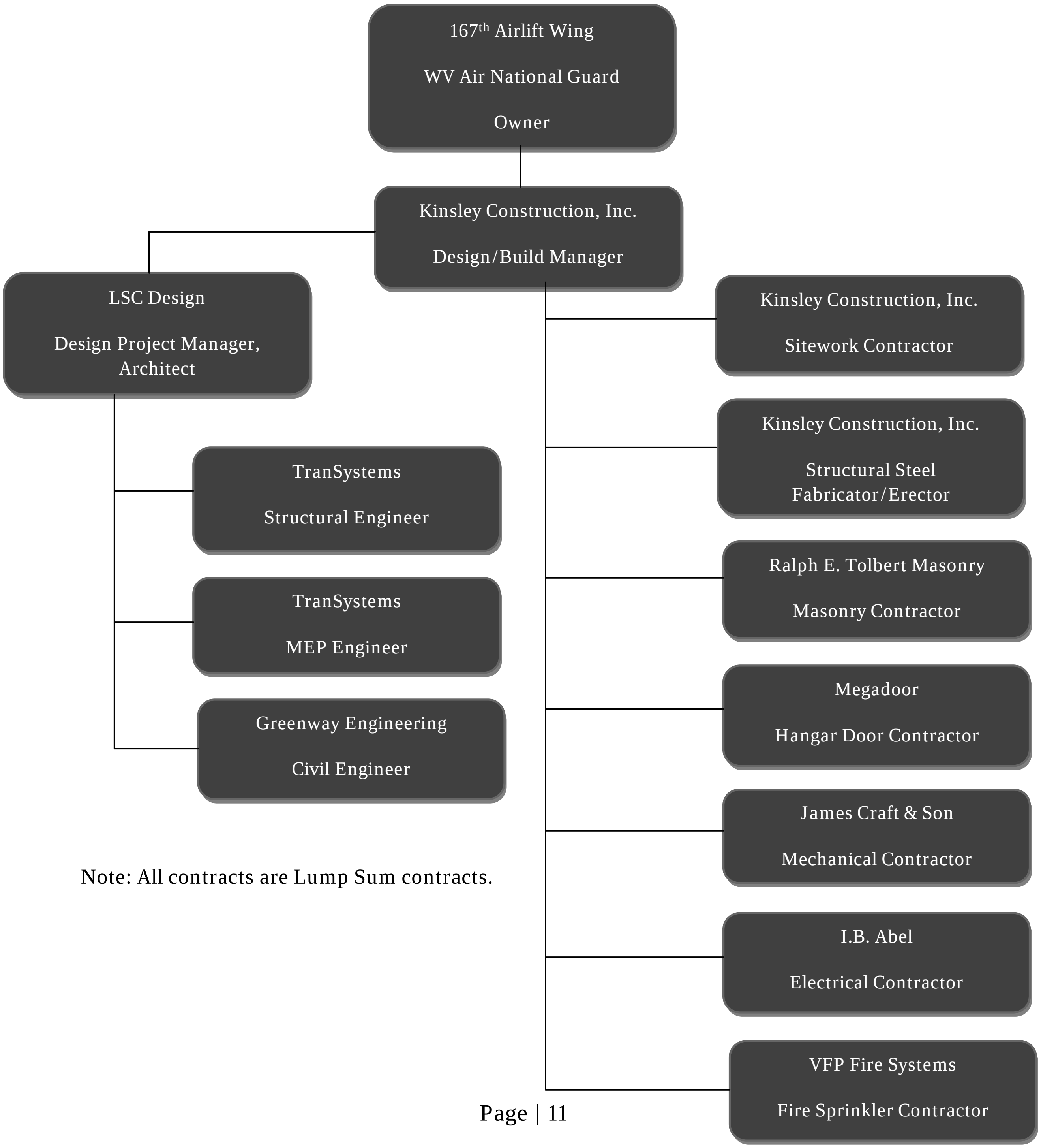
Design of HEF per ANG-ETL 02-15 Fire Protection Engineering Criteria

Installation per NFPA 72 and NFPA 70



PROJECT ORANIZATION

PROJECT DELIVERY SYSTEM



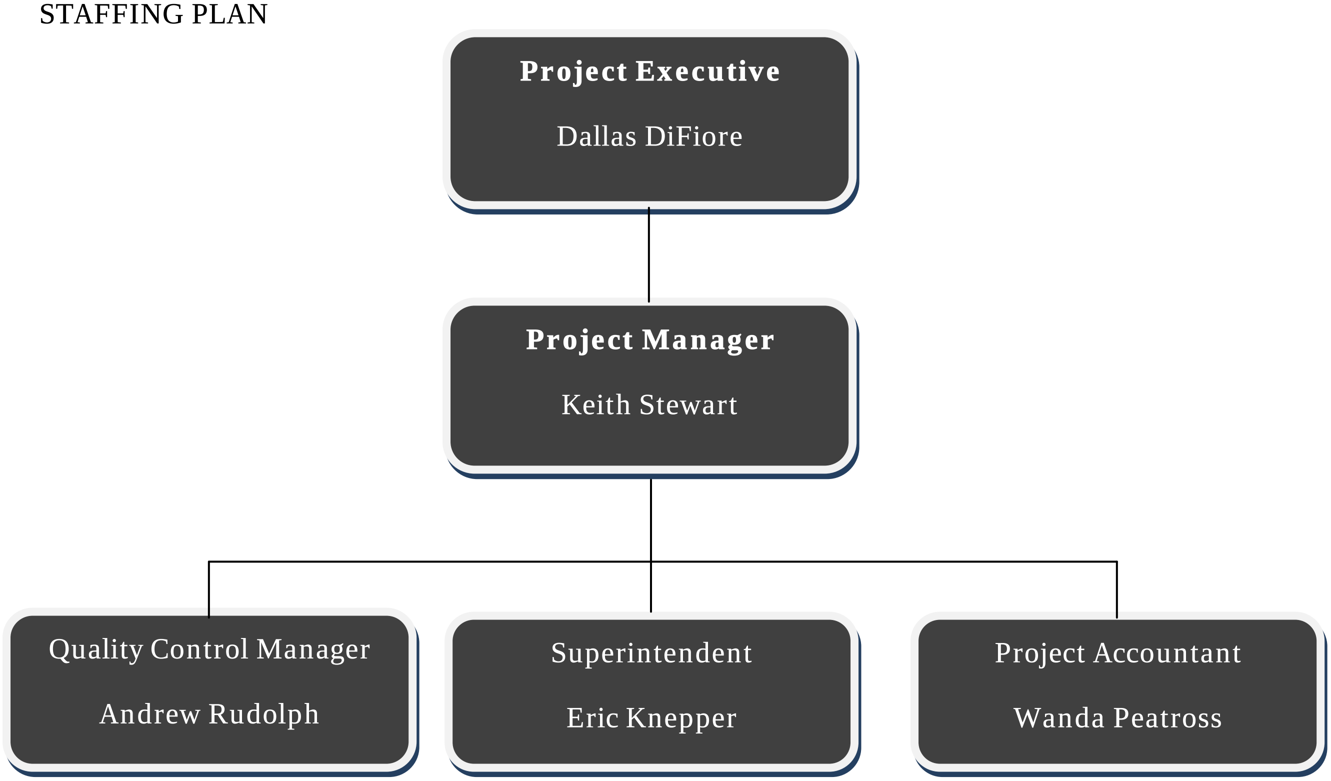
Note: All contracts are Lump Sum contracts.

The C-5 Fuel Cell Facility project has a unique organizational structure, as seen in the chart above. This abnormal structure has been used because a design-build delivery system was chosen for this project. The decision to use this project delivery method was determined based on the requirements of the funding for the project. As a federally funded project, the government was able to be selective in how this project was delivered. In some cases, this would cause projects to be bid as small business set-asides, but due to the size of this project that was not an option and so the design-build was the second option.

Kinsley Construction was selected to be the Design-Build Contractor and Project Manager based on a Lump Sum bid which was created from the preliminary project documents provided in the Request for Proposal. Acting as the Design-Build Manager and a general contractor, Kinsley was required to provide payment and performance bonds for the total value of the project. Kinsley Construction was also required to purchase Builder's Risk Insurance.

LSC Design was selected as the Design Project Manager for the project as it is an entity in the Kinsley family of companies. The contract between Kinsley and LSC is set up as a subcontract though, as are all of the contracts between LSC and the engineering firms that were selected. All of these contracts are based on a lump sum as noted above in the organizational chart. Subcontractors were selected based on lump sum bids to Kinsley Construction for the project and therefore the contracts are based on those lump sums. It can be seen in the organizational chart that Kinsley Construction opted to self-perform the sitework as well as the steel fabrication and erection.

STAFFING PLAN



The Project Executive's role in the project is to oversee the project as a whole and was primarily involved during the design phase of the project by coordinating with the Design Project Manager. He spends most of his time away from the site as he is also involved with other projects currently being worked on by the company. The Project Manager spends much more time on site and his duties include: cost control; working with the safety director; coordination with the Superintendent about manpower and materials; managing contractual arrangements with subcontractors; maintaining good working relations between Owner, Contractor, and Designer. The Project Manager also oversees all tasks completed by the QCM, Superintendent, and the Accountant relevant to the project.

The Quality Control Manager is on the site at all times and is responsible for the following: inspection of work put in place for compliance with design documents; reporting any deficiencies; field correspondence; review of plans and specifications for accuracy. Management of on-site activities is the responsibility of the Superintendent. He is in charge of: ordering and scheduling material deliveries; assigning crews; monitoring the deficiencies list created by the QCM; enforcing security on the site. The Project Accountant is responsible for tracking all costs and expenditures for the project.

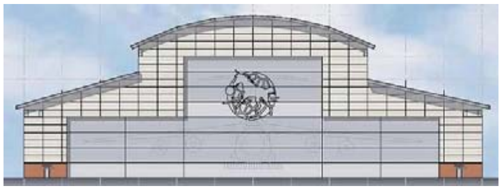
SITE LAYOUT PLANNING

The site for the C-5 Fuel Cell Facility is fairly accommodating as far as space on the North side, but is fairly restricted on the other three sides. Unfortunately, Kinsley Construction, Inc. was unable to provide any site layout plans for me to analyze. Based on my visits to the site though, it seems that they were successful in locating items on the site effectively. Located in Appendix B, are site layout plans for three major phases of the Fuel Cell Facility project, excavation and foundations, steel erection, and building enclosure.

EXCAVATION/FOUNDATIONS

The excavation phase of this project consisted of blasting a large portion of the site in order to aid in lowering the grade to the design elevation. As can be seen on the Excavation and Foundation Site Layout Plan in Appendix B, the excess spoils of excavation were stockpiled near the center of the site, in an area which has no caissons. In doing this, the entire site did not need to be cleared of the excess spoils prior to foundation work, but instead they could be done simultaneously. The caissons were drilled with a drilling rig, the steel reinforcing cages were set, and then the concrete was placed. In some cases, dewatering pumps were needed to remove water from the bottom of the holes, but this issue was minimal. After the caissons were completed, the pier caps and grade beams were constructed, following the same direction of progression.

As mentioned previously, space on the project was not a major issue, with the entire North side of the project site being available for placement of office and storage trailers, as well as parking for all employees working on site. This area also allowed space for easy loading and unloading of excavation equipment at the times when it was required. It should be noted that this Northern portion of the site is at a higher grade than the portion in which the Fuel Cell Facility is located; this portion did not require mass excavation like the Southern part did. Due to this, a ramp was created during the excavation phase for easy access between the upper staging and office area, and the lower area in which the construction is taking place. The ramp is to be removed at a later date when construction of the new service road begins.



STEEL ERECTION

Steel erection for the Fuel Cell Facility is one of the most important phases of the project. For that reason, as will be discussed in the *Detailed Project Schedule* section, there were eight phases created in which the steel would be set; these phases can be seen on the sketches in Appendix D. Erection began with a single, 250 ton crawler crane setting columns in the Southwest corner and moving North along the West side of the proposed building. Meanwhile, two more crawler cranes were being constructed in the upper parking area. Two of the cranes worked simultaneously to set the transverse trusses which run approximately North to South, and the third was then used to hold the truss in place with the aid of temporary shoring towers. This set up was maintained until the apex trusses from the exterior wall to the truss were set.

Once the West side steel was erected, the process repeated itself on the East side. After all of the East side steel was erected, the high roof area steel in the center of the building was set. The most important part of this activity was the setting of the B-line truss which extends from the transverse truss on one side to the other transverse truss, creating the frame for the main hangar door. The setting of this truss required the use of all three crawler cranes, a feat that requires a great deal of communication and teamwork as well as planning. Temporary shoring was used to hold this truss in place until all other steel was set for the building.

BUILDING ENCLOSURE

The enclosure of the Fuel Cell Facility building consists of four major parts: CMU around the bottom of the building, insulated metal wall panels, standing seam metal roofing, and the main hangar door. The first three of these activities take place around the building in the same sequence as the steel erection. Roof deck was first set in the Southwest corner once the steel was erected and followed the erection process. The CMU walls were then constructed and the insulated wall panels followed behind. The main hangar door was installed at a later date. The installation of the roof panels, wall panels, and hangar door was completed with the use of platform and articulated boom lifts. On the upper level, the panels were set simply with manpower and scaffolding which was erected on the lower roof.

PROJECT SCHEDULE AND COSTS

DETAILED PROJECT SCHEDULE

As a design-build project, the early portion of the schedule for the C-5 Fuel Cell Facility is slightly different than a project built using a traditional design-bid-build system. As can be seen on the *Detailed Project Schedule* in Appendix C, the project begins with the bidding and selection period, with the design phase beginning after the awarding of the project and the Notice to Proceed. When the design is nearing completion, work on the structural steel shop drawings commences as the design, fabrication, and erection of the steel are the major driving activities to keep the project on schedule.

It may be noted when comparing the *Project Summary Schedule* from Technical Assignment #1, also in Appendix C, to the *Detailed Project Schedule* that the duration for the structural shop drawings was increased, thus pushing back the fabrication of the steel. These issues in the steel design forced the entire construction schedule to be modified in order to maintain the original completion date. The schedules have been included in their differing states to illustrate the necessity of compression of activities later in the overall project schedule.

The construction of most exterior portions of the building revolves around the major steel erection sequences that were employed for the project. These sequences, as can be seen in Appendix D, break the building into eight sections with 1A through 2C covering all of the low-roof areas of the building and 3A through 3C covering the high-roof areas. Once the building is completely enclosed, the interior finishing process begins. All interior work, as can be seen on the schedule, has been broken into two separate portions, the hangar area and the administrative area, with many of the activities in the two areas being completed simultaneously. As the installation of the MEP systems is completed, testing and balancing of the systems begins, taking up the majority of the last month of the project schedule. Final inspection takes place immediately following the conclusion of all testing and building occupancy begins the following day.

PROJECT COST EVALUATION

COST SUMMARY FOR C-5 FUEL CELL FACILITY

Construction Cost:	$23,551,204	$298.78 per SF

Note: Construction Cost includes all costs except sitework, permits, and design fees

Total Project Cost:	$26,757,781	$339.46 per SF

BUILDING SYSTEMS COSTS

Mechanical System:	$3,419,475	$43.38 per SF

Note: includes HVAC and fire sprinkler

Electrical System:	$1,706,783	$21.65 per SF

Steel:	$7,768,880	$98.56 per SF

Note: includes structural steel and misc. metals

Structural Concrete:	$1,598,316	$20.28 per SF

Note: includes foundations and slab on grade

Sitework:	$1,650,799	$20.94 per SF

Note: does not include building earthwork, that is included in Construction Cost

GENERAL CONDITIONS ESTIMATE

The general conditions estimate for the C-5 Fuel Cell Facility was developed using a combination of RS Means Building Construction Cost Data 2009 and historical estimating data provided by Kinsley Construction, Inc. RS Means contained information concerning a majority of the reimbursable general conditions for the project, but for some items it was much more accurate to use the historical data from Kinsley due to deviations from the typical cost information. For example, it was necessary to use the historical data for estimating the cost of temporary storage trailers since many of these trailers are owned by Kinsley Construction. The costs in RS Means are based on rental of the trailers, but the cost to Kinsley for the trailers is much less since they have already been used on multiple past projects and paid for themselves.

General Conditions Estimate Summary

Description	Total Cost
Project Supervision	$746,700
Field Office and Equipment	$63,163
Mobilization	$78,500
Temporary Utilities	$1,430
Winter Protection	$81,500
Bonding	$240,821
Testing	$106,000
Safety Supervisor and Training	$159,500
Cleanup	$56,000
GRAND TOTAL	**$1,746,717**

Note: Grand Total includes extra costs beyond those listed.

The summary estimate shown above for the general conditions provides some of the major reimbursable costs for the project as well as the Grand Total. As noted, the grand total includes other costs that are not included in the table; it is included for comparison between individual components and the total. For example, it can be calculated from the listed values that *Project Supervision* makes up

approximately 43% of the total general conditions cost. Other important costs included above that should be noted are *Bonding*, *Testing*, and *Safety*. Specifically, the cost of safety on this project may seem high but it should be noted that this cost includes a safety supervisor, an expense that could also be included in the project supervision category. However, upon inspection of the *Staffing Plan*, one would notice that a safety supervisor is not included. This is because Kinsley Construction handles all safety personnel through a separate division of the company.

See Appendix E for detailed General Conditions Estimate

DETAILED STRUCTURAL SYSTEM ESTIMATE

The structural systems estimate for the C-5 Fuel Cell Facility was developed through a hand takeoff of all structural concrete, steel, and load-bearing masonry. The quantities that were found were then entered into the online CostWorks program offered by RS Means, which provides cost estimates for 2009 and also allows a location factor to be entered. The unfortunate part of the RS Means software, as with the books from the same company, is that there is a limited amount of information available. For example, when looking at structural steel members for pricing, the maximum size for a wide flange member is a W18x106. This is most likely not an issue for most common buildings, however the structural steel for the Fuel Cell Facility is anything but common with columns as large as W40x593 and truss members as large as W14x605.

To combat this lack of information, the majority of the steel was estimated based on tonnage. All open-web joists were found within the RS Means charts and were priced accordingly, as well as the metal roof deck, but all hollow structural steel and wide flange members were totaled by tonnage. This limits the ability to break down the different parts of the structure, but as can be seen in Appendix D, there has been some differentiation made between portions of the system. Below is a summary of the structural estimate.

Structural Systems Estimate Summary

CONCRETE	
Foundations	$236,441.80
Slab on Grade	$591,272.22
MASONRY	
CMU Walls	$55,046.70
STEEL	
Metal Deck	$243,222.40
Open-Web Joists	$218,099.68
Wide Flange and Hollow Members	$8,110,373.44
TOTAL	**$9,454,456.23**

ASSUMPTIONS/METHODS

- Open shop labor used for all parts
- “Concrete in place” category was used to include all formwork, reinforcement, placement, and finishing as one cost
- No overhead or profit is included in this estimate
- CostWorks from RS Means 2009 employed to create the estimate

See Appendix F for detailed Structural Systems Estimate