City Hospital Pennsylvania Phase I

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Executive Summary

City Hospital is a multi-phased research facility located in Southeast Pennsylvania. Phase I is an "L" shaped four-story composite building structure which will provide a research facility, an administrative space, a conference space, and a Central Utility Plant (C.U.P.). Phase II is an 8-floor steel frame building above grade that will be used for research in medicine, and Phase III is a proposed 22 floor future addition to Phase II. Once the building is completed to its full size, the site will accommodate underground parking, an imaging, and an ambulatory building with outpatient care facility, which will be an improved facility for patients, families and employees. City Hospital is seeking LEED® Silver Certification for New Construction. The project intends to earn 35 LEED® points in order to achieve a silver LEED® certification.

The first research topic is an issue that relates to the construction industry as discussed in the PACE Roundtable in October of 2007. This topic will identify the issue of Building Information Modeling- 3D modeling on the City Hospital Phase 1 project. The next two topics; medium voltage generators and LEED® Gold Certification execution are technical analyses that will also be breadth analyses for my proposal. The alternative methods chosen will be analyzed using different investigation areas such as constructability review, value engineering analysis, and schedule reduction.

This report contains information about the critical issues facing the construction industry; these same issues also face the City Hospital Phase 1 project. Also contained in this report are two breadth analyses that address some of the problems on the project, and a proposal of a solution with theoretical benefits.

I. Project Overview

The City Hospital is currently in the process of undergoing a huge expansion. The construction of the building, which is the focus of my research, is one of the many buildings affiliated with the hospital called the City Hospital. It is located in Southeast Pennsylvania. The Phase I of City Hospital currently exists only on the south side of the campus. This phase of the building will house research space, office space, and a central utility plant. Construction of this 266,000 square feet building began in March 2005 and will be completed in December 2007. The estimated cost of this 3.5-story facility is $156 million.

A. Project Team

The project team consists of:

Owner – City Hospital
Construction Manager – Turner Construction Company
Architect – Ballinger
Structural Engineer – LeMessurier Consultants
MEP Engineer – Bard Rao + Athanas
Civil Engineer – Pennoni Associates Inc

B. Client Information

The owner of this project is City Hospital. City Hospital has a team of professionals (user group) which include doctors, facility operators and advisors that direct and communicates the owner’s requirements to the engineers responsible. City Hospital is one of the leading research facilities in the world. The research project is part of a second part master plan that will span across about eight acres of land located directly across from the Hospital's current clinical and research facilities. Once completed, City Hospital will house a state-of-the-art translational research facility, translating basic science research into real-life treatments and cures, which will include and underground parking. The project consists of an “L” shaped development that is being constructed in three phases. The owner will award separate contracts for each phase. The total facility development is estimated at $1 billion and could total more than one million square feet which is double the size of the main hospital when complete. The hospital received about $5 M in research support and $6 M overall for patient care services. The hospital plans to renovate another 165,000 square foot. This all signifies that business is good for City hospital.

C. Project Delivery Method

City Hospital is following the format of a construction management at risk system. As seen on the project organizational chart shown in Figure 5.1, the hospital holds a contract with both the architect and the construction manager. Ballinger was selected as the architect by the owner to design the project. The hospital holds a cost plus fee contract with Ballinger. Turner Construction Company (TCCO) was selected as the construction manager and holds a guaranteed maximum price contract with the hospital. Turner was selected based on their past performance with City Hospital through prior work and the working relationship that they have established.

TCCO holds a lump sum contract with each of the subcontractors shown on the organization chart. These subcontractors were selected on the criteria of experience, price and scope of bid. Ballinger does not hold a contract with TCCO, however there is a line of communication between these two companies throughout the term of the project in order to meet the needs of the owner.

Ballinger contracted Bard Rao + Athanas to handle all MEP engineering for the building. They also contracted LeMessurier Consultants to design the structural system for the facility and Pennoni Associates Inc. as civil engineers. All players on this particular project hold lines of communication with each other.

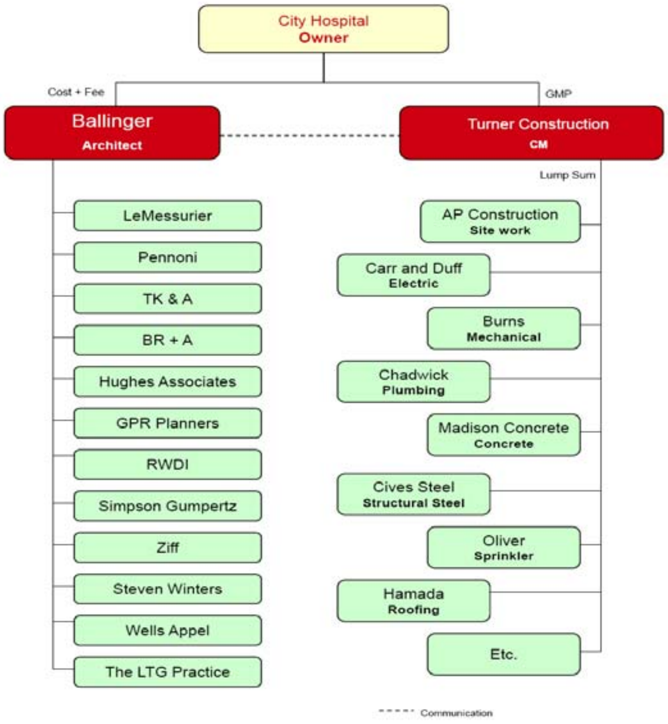


Figure 5.1: Project Delivery Method

D. Site Plan and Existing Conditions

The site plan of existing conditions for the project at City Hospital is located in Appendix A. The map shows neighboring buildings, parking locations, temporary facilities, utility lines, access roads, and pedestrian walkways around the site. The owner, City Hospital is currently located directly north of the project site. Directly to the east is a separate construction site for another research facility. Existing and new utilities are located at the perimeter of the building. The main water and electrical lines are located at the south side of the building. The plan provides a better idea of how the project fits into the existing structure of the campus.

Turner performed site demolition and excavation. Site work included grading, paving, new water, storm and sanitary laterals, new curbs and sidewalks. Due to the hardness of the solid mica schist encountered onsite, excavation required six months of rock blasting. There were a total of forty-two blasts removing 150,000 cubic yards of material. A sheeting and shoring system was used for the support of excavation. An existing north and south retaining wall was removed and replaced with a system capable of supporting the seventy foot open excavation. The new system included soldier piles behind the existing retaining wall. During the early phases of construction, there was a planned destruction of the Hall located to the west of the project site. The Hall was imploded which was a success and posed minimal risk to the surroundings and progress of the City Hospital project. Cast in place structures have been a typical construction practice in the surrounding area so they were better prepared for the blasting. The area is classified as a high density commercial area, mixed-use and residential developments are generally found in the area. There are various area and open space requirements. For example, public spaces must be equal to 30% of the lot and seating and landscaping must be provided.

This project is aiming for a LEED® Silver credit rating, so in their bid to attain credits all trash and garbage disposal is being provided by an independent waste removal company; there are separate dumpsters for materials such as wood, metal, concrete, paper (office), etc. to provide for onsite separation of recyclables. Turner keeps precise records and receipt of these transactions, for later submittal to the construction administrator.

E. Building Systems Summary

Construction:

City Hospital holds a lump sum contract with Ballinger Architects to design the structure and the building systems. The project construction is being coordinated by Turner Construction Company and constructed by its prime contractors. Turner acts as a construction manager at

risk and holds lump sum contracts with its prime contractors. City Hospital holds a guaranteed maximum price contract with Turner.

Phase I which is the crux of my thesis includes four levels below grade as shown in Figure 5.2.

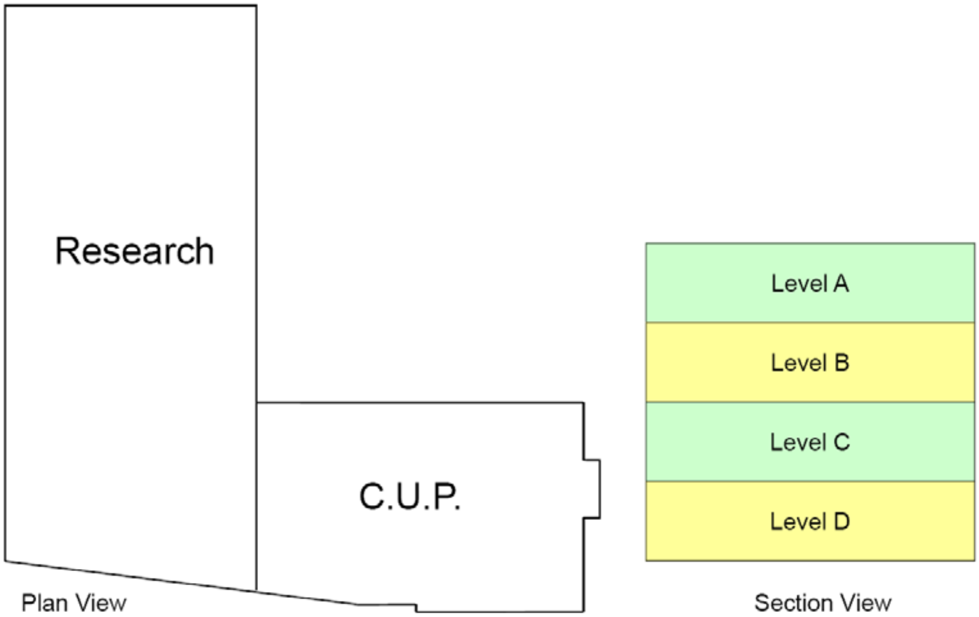


Figure 5.2 Building Plan

Electrical/Lighting:

The building has two normal power services at 13.2 KV which are located at the south entrance and (2) two megawatt emergency generator at 480V for backup power. Power is fed from the utility company into a medium voltage secondary selective system using three 5000 KVA double ended substations with tie-in. The substations service the electric chiller (2,000 ton), central utility plant, and research facility. Automatic transfer switches are used to divide power into branches of critical, life safety, and equipment in accordance with section 517.30 of the NEC code (2002). Wye-Delta transformers are used to step down the medium voltage supplied to the building to utilization voltages of 120V, 208V, 277V, and 480V as needed.

There are a variety of lighting fixtures used through out the city hospital project, ranging from strip lighting, direct/indirect fixtures, etc. These fixtures use a range of incandescent lamps, compact fluorescents, tubular fluorescents (T-5 and T-8), and HID lamps. Generally, lighting fixtures are mounted in a variety of ways, such as pendants, recessed, or suspended. A couple of specialized lightings, such as operating lights and procedure lights are used to focus a very high intensity of light when carrying out intricate procedures. The offices, research labs and conference rooms use continuous dimming tubular fluorescent ballasts. These types of dimming controls are implemented for the sustainability effect and bid to comply with LEED credit requirement of the project.

Mechanical:

The central utility plant (Levels A through D) houses most of the mechanical equipment. The central cooling towers are located above the A level loading dock. The primary components of the mechanical system include (1) 2,000 ton steam turbine chiller, (1) 2,000 ton electrical chiller, (4) 1,000 ton cooling towers, (4) 800 hp dual fuel boilers, 18 air handling units ranging from 2,500 to 100,000 CFM, and (2) 120,000 cfm exhaust air handling units with heat recovery. The supply air is distributed through industrial air handling units and variable air volume boxes that give occupants the ability to control specific temperature zones from a re-settable set point or by various ventilation motors. This controls help to enhance occupant comfort, thereby leading to greater productivity. Steam for this facility will be provided from the new CUP. 125 psig; steam shall be reduced in pressure as required and distributed to building heating, research and clinical equipment. The air conditioned source for the new building shall be from a new chilled water plant. The hydronic system will provide building reheat, primary chilled water, secondary chilled water, condenser water, process chilled water, heat recovery / OA glycol water, and future radiation heating.

The building is equipped with a building automation system called direct digital controls (DDC) which enables the facility managers and authorized personnel the ability to monitor and control various function of the mechanical equipment. The system also records the performance of the equipment and compares it to the expected performance. If there is a major difference (depending on how it is configured) a visible or audible alarm is used to signal the conditions.

Structural:

Masonry

The exterior of the research facility consist primarily of a concrete masonry unit (CMU) cavity wall system (4" CMU veneer, 2" air space, 2" rigid insulation, a fluid applied vapor permeable air barrier system, and 8" CMU). The interior partitions are also mainly constructed with 8" CMU; mortar and grout will be used for bonding. The units have an average compressive strength of 1900 psi. The CMU was erected using regular framing scaffold.

Steel Frame

The structural system for the City Hospital uses structural steel columns, wall bracing bays and beams ranging from W12x45 to W24x55. The slab construction consists of 3" deep composite steel deck with 6x6- W4.0x4.0 WWF throughout plus additional reinforcement as required. The steel decking is attached by means of welded shear connectors to the steel beams. A tower crane will be utilized for all steel erection.

Concrete

The foundation consists of cast-in-place concrete spread footings (4,000 psi) with a thick cast-in-place slab on grade. The steel deck carries a 4 ½" normal weight concrete fill. The roof of C.U.P. is constructed by a 4" pour in place concrete over a 5 ½" concrete slab with a waterproofed membrane roof system to accommodate traffic on the loading dock. The 4,000 psi concrete shear walls were formed and poured 72 ft high in one pour. To eliminate the need for internal vibration of the concrete, a ready-mix supplier was used to develop self-consolidating concrete. The steel stairs will require concrete fill-in. The below grade exterior of all precast concrete will be coated with an epoxy coating which is moisture insensitive. Coal tar epoxy will be applied to the exterior precast walls.

Support of Excavation:

The type of support used for excavation for the research facility is a temporary sheeting and shoring technique with rock bolting. Since the spread footing and rock is within the water table, temporary and permanent dewatering was provided. Water pumping is required for deep excavation. A storm water pollution prevention system is being enforced.

Plumbing:

The design for the research facility consists of several components which include sanitary drainage, storm water/roof drainage, foundation drainage, domestic hot water, cold water, and natural gas piping. A 10” domestic water service main enters the building through Level B and drops to a water meter and goes through a reduced pressure backflow preventer. The temperature for the hot water piping which is heated by steam is set at 140°F and runs to plumbing fixtures through out the building. This includes the sinks, water closets, showers, urinals, etc. The re-circulating pumps are used to keep the water in motion so it does not freeze in the pipes. The storm water system roof drains are located above B level research and A level C.U.P loading dock. The main sanitary waste lines leaves through the south end of the building and runs down to an interceptor drain.

Fire Protection:

The building is protected with a wet pipe system, which is complaint with the Americans with Disabilities Act, with recessed flush type sprinkler heads and fire hose standpipe connections. Unheated spaces and the loading docks are protected with a dry pipe sprinkler system. The electrically actuated pre-action sprinkler system protects zoned areas. Each zoned floor is furnished with flow switches, tamper switch, supervised shut off valves, test connections and associated drains in accordance with NFPA 13 and 14.

The preaction system is used in buildings that are susceptible to water damage. There is sensitive equipment like computers and research equipment that has to be protected from unnecessary water in the case of a false alarm. The double interlock preaction system is a system that allows the pipes to be filled with compressed air. When the smoke detector is triggered, the system sounds the alarm and releases the preaction valves; air pressure releases the water out into the previously dry pipes and stays there until a sprinkler head opens. Fire extinguishers will be located throughout the building to help put fire out manually.

The fire protection system consist of a an electrically driven horizontal foot mounted, open drip proof, 250HP, 3575 RPM solid state soft start squirrel cage induction motor wound for 480V ac, three phase, 60Hz, fire pump system and a 3HP, 3500RPM three phase 60Hz 480V jockey pump system, and controllers.

Security:

The main security office is located near the south loading dock on “A” level. Some equipment that serves to enhance the security of the entire building are emergency generator annuciators, remote emergency generator start, fire department key box, security panel, and elevator control

panel. Door security hardware throughout the building consists of airlock and inter-lock doors, card reader access, etc. They are interfaced with security and the fire alarm system. Security cameras are installed at various locations in the building. Elevators and research rooms are also equipped with card readers for access. Security devices and wiring is provided by Carr & Duff and Truefit.

Transportation:

There is provision for eleven standard hydraulic elevators in the hospital. Ten of the elevators are located in the research portion of the building. There are seven elevators being installed as part of Phase 1 of the construction project that will service levels A to level D. Only one service elevator will service all the floors in the building (phase 1 and phase 2). There are six stairwells located throughout the building. These stairwells will play a crucial role in evacuation of occupants in the case of an emergency. The major means of egress on each level in research is through two parallel corridors running from north to south. In the C.U.P the major means of egress is a long corridor running from east to west.

Telecommunication:

The telecommunication system includes a raceway support system for all essential low voltage communication wiring provided in the building. The raceway support system shall include rough-in, outlet boxes, conduit, junction boxes, etc. to accommodate various parts of the system. Cabling will be installed for the telephone system, security system (door access, card reader system), data system (CAT 5E/6 copper cabling), and television system. Phones and data jacks are provided in each room. This wiring system installed will ensure the research space runs as a state of the art research facility and provides sufficient communication abilities.

F. Project Schedule

The detailed project schedule for City Hospital is a 34 month schedule for a 266,000 square foot research facility. This is a very tight schedule for a project of this size and magnitude due to the fact that future phases will be constructed as Phase I is closing out in an overlapping technique. So if any phase fails to meet its schedule, it will have a ‘domino’ effect that will affect all the other phases of the project and ultimately lead to inconveniencing other aspects of the project, if the project is going to meet its scheduled completion date. The schedule includes the design, procurement and the construction phases of the project.

Turner Construction divided the activities in the schedule between the central utility plant and the research space. This allows for trades to move as quickly as possible through the building while staying out of each other’s way in the process. The site work included in Phase I includes

grading and the paving of the South Road and installation of new water service, storm and sanitary sewers, and electrical services. The critical activities and key milestones are outlined in the schedule, Appendix B. For example, steel construction began on July 27, 2006. This date is a crucial date for the schedule due to the timing and delivery of the mill order. The building is scheduled to be weather tight on June 6, 2007 after 11 months of construction. Completing this milestone is important to avoid excess moisture that may cause serious damage or health risk. To save time in the schedule, the concrete shear walls were poured in single lifts ranging from forty to seventy-five feet. The shear walls were the highest ever poured in the region using the EFCO plate girder system as shown in Figure 2.5. The fit-out of the research space includes masonry partitions, drywall ceilings, resinous floors and epoxy paint. Whereas C.U.P fit-out consist of chillers, boilers, and air handler and is designed for future expansion.

The project schedule, Appendix B, is organized by the following trades or phases:

- Site work
- Concrete
- Steels & Metals
- Thermal/Moisture Protection
- Masonry
- Plumbing
- H.V.A.C.
- Electrical
- Fire Protection
- Equipment
- Finishes
- ATC
- Elevators
- Commissioning

Figure 5.3: Pouring of concrete shear wall

G. Project Cost

The following data is a cost evaluation for City Hospital in Southeast Pennsylvania. Included in this evaluation is building costs, total project costs, and various systems costs such as electrical, HVAC, plumbing, and equipment.

Construction Cost: $149 M
Total Project Cost: $156 M
Building Square Foot: 266,000

Building Systems		
Div.	**System**	**Cost**
GR	General Requirements	$3,000,000.00
03000	Concrete	$15,234,046.00
04810	Masonry	$5,707,757.00
05000	Steel & Metals	$12,663,863.00
14420	Conveying System	$1,757,799.00
08000	Doors & Windows	$392,243.00
07000	Thermal & Moisture	$4,357,769.00
15400	Plumbing	$5,670,468.00
15300	Fire Protection	$1,952,558.00
15700	HVAC	$20,747,890.00
16000	Electrical	$19,730,101.00
	Total	**$91,214,494.00**

Figure 5.4: Project Cost Data

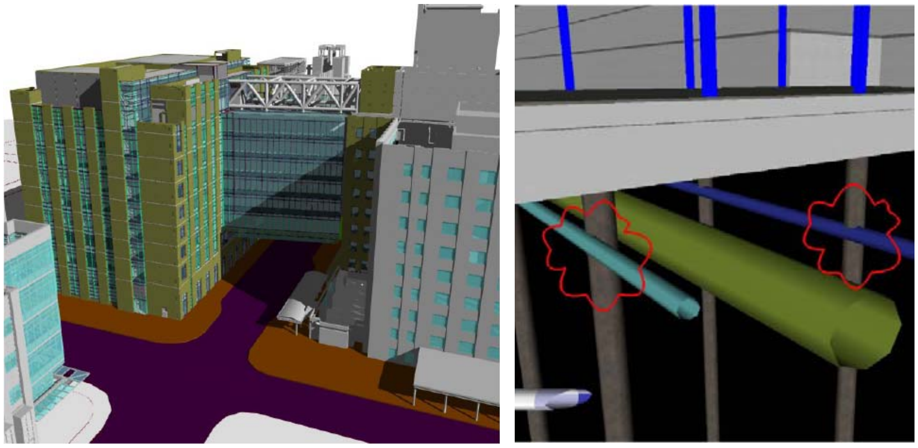
II. Depth: BIM- 3D Modeling

Background Information

BIM is a documentation process that consists of information about a building project in design and construction with the use of technology and collaboration. BIM is beneficial for design, construction, operational visualization, data modeling efficiency and effectiveness. Construction applications such as estimating, scheduling, and design coordination can be implemented with BIM. In order to get the most benefit out of BIM on a project, it has to be implemented at the early stages of the project by the designers, which include the project team, owners, construction manager, and contractors. One of the many advantages of BIM-3D aspect is the visual coordination of the various systems of a building such as the MEP systems. The model in Figure 5.5 shows the possible conflicts and problems between construction and management of trades. With the detection of these conflicts at an early stage in the design, the design team is able to resolve the problem before more time and money is invested, thereby saving the owner money in change orders during construction. BIM's capability is making a positive impact on the construction industry today. A hurdle that is slowing the progress of BIM in the industry today is the fact that owners do not require the design team to use BIM. In a paper, published in 2004 by The National Institute of Standards and Technology (NIST), "The cost of inadequate interoperability in the U.S. capital facilities industry to be $15.8 billion per year. The intended audiences are owners and operators of capital facilities, design, construction, operation & maintenance, and other providers of professional services in the capital facilities industry". The assumption made with BIM is that it is not currently a knowledgeable subject and more explanation is needed on how it is used. Like every new technology older employees often have some difficulty while trying to understand how the new technology is used and determining the benefits of its use. Some may believe that it is too risky to invest in it and may never realize how it will benefit the construction process. Just as AutoCAD is the current design tool today, BIM will be a standard practice and will become the new requirement for design and construction in the future. Clients such as the General Services Administration and the Department of Defense are already defining their requirements for BIM.

After research and further discussion at the PACE Roundtable, I decided that the topic I was most interested in and felt would be most applicable, for my thesis project is the use of Building Information Modeling (BIM)-3D modeling on the City Hospital project. Although this technology was not implemented on Phase I, there are some advantages that would have been gained in designing the hospital with the use of 3D modeling. Building Information Modeling is very exciting because it potentially solves a lot of conflicting issues by helping the design team to determine possible conflicts in the design phase of a project before construction begins. This potential is the reason why I decided to investigate how the use of BIM-3D modeling during the

design phase would have potentially eliminated most of the conflicts between trades during the construction phase of Phase I on the City Hospital project, especially because, upon first look, it seems this project requires a great amount of communication and coordination and therefore stood to gain a lot by utilizing BIM. Weighing and comparing the advantages and disadvantages between using BIM and not using BIM will form the foundation of this research.



http://www.virtualbuilders.org/VBR_Presentations/ViConTurner.pdf

Figure 5.5: MEP Clash detection

Methodology

1. Review literature on BIM-3D modeling.
2. Conduct phone interview with Jan Reinhardt, the Program Manager of ViCon - Virtual Design and Construction, at Turner Construction to ask questions listed in Figure 5.6.
3. Attend a 3D modeling coordination meeting with Paul White, MEP coordinator on Phase 2 of the City Hospital project and subcontractors to get an understanding of some of the issues faced and how these issues could have potentially been eliminated during Phase 1 between trades during the construction phase if BIM was used.

Questions:
Questions for Paul White:
1. Why was BIM (3D) not used in Phase I?
2. How and who would be trained for the use of 3D modeling if it were to be used on Phase I? What skills are required?
3. What would have been the benefits to using this technology on Phase I? Explain.
4. Were there any conflicts that could have been avoided if this technology was used on Phase I?
5. What are the necessary steps required in implementing 3Dmodeling?
6. What are some of the challenges being faced in Phase II with the use of this new technology?
7. How much time would have been considered necessary to start up the 3D/4D modeling process? How long did it take in Phase II?
Questions for Jan Reinhardt:
1. How much time would be considered necessary to start up the 3D modeling process on a project?
2. What are the necessary steps required in implementing 3D/4D modeling on a project?
3. What are some of the advantages in using BIM-3D/4D modeling on a project?
4. What parties would be involved in the BIM process?
5. Are owners becoming more responsive to the idea of BIM?
6. How does Turner initiate BIM to their clients?

Figure 5.6: Research Questions

Research

Current practice utilized on the project:

The conventional way of documenting the design and construction process of a project, used by City Hospital Phase 1, is through the use of 2D drawings. Lines were used to represent the building and drafted into plans, sections, and elevations to show how the building is to be constructed. A booklet of the drawings is communicated with large enough scales so that one can visualize the project. One of the disadvantages of 2D modeling is if a change is to be made in 2D drawings, the change must be modified in all the drawings; elevation, plan, and section. Today, structures can be designed using electronic software such as AutoCAD in 2D and transported as an electronic format. This allows for more detailed and more affluent information.

Proposed Implementation of BIM in Phase 1

In recent years, there has been a growing movement to adopt 3D modeling in developing construction projects. Phase 2 of the City Hospital Project is currently using 3D modeling to coordinate the design and construction process. Unlike Phase 1 of the project, they were able to include the 3D modeling package into the subcontractors' contract. The use of 3D modeling manages any changes made for you, which is very unlike 2D modeling. Once an object is modified in any view, the change is reflected in all views. This reduces the inefficiency caused by poorly coordinated 2D drawings. Buildings are becoming more complicated, especially with the push for more environmentally friendly buildings. The requirements for extensive documentation to achieve LEED points increase the benefits of implementing BIM on a project. For example, the idea of building for sustainability requires the regulation and recording of day-lighting, energy analysis, quantity takeoffs, and to quantify other green effects on a project. The 4D feature is time, the project schedule and the budget can be linked to the integrated model.

During a phone interview on January 26, 2008 with Jan Reinhardt, I was able to get the answers to the questions about 3D modeling as shown in Figure 5.7 below. The answers are based on past or existing projects that use BIM-3D modeling.

Answered Research Questions:

Questionnaire for Jan Reinhardt:

Q1. How much time would be considered necessary to start up the 3D modeling process on a project?

A1.The time required to start up the BIM 4D modeling process on project would take about two to three weeks among the group. It would take about two weeks to develop the 3D modeling and one day to link the schedule to the model (4D aspect).

Q2. What are the necessary steps required in implementing 3D/4D modeling on a project?

A2. The steps are:
Develop a plan
Decide how to break up the building in terms of level of detail /elements
Develop a 3D model (contract out each package, ex: electrical, plumbing, etc.)
Develop a schedule
Link a schedule to plan

Coordination meeting are held weekly and sometimes daily thereafter.

Q3. What are some of the advantages in using BIM-3D/4D modeling on a project?

Q3. It makes you think harder about the schedule and allows for questions to be asked upfront. This process allows parties that are affected by the schedule to ask questions and communicate among themselves. The process minimizes the risk of schedule overlap or delays by months.

Q4. What parties would be involved in the BIM process?

Q4. Anyone that is developing the drawings (design drawings) for example the architect, structural engineer, etc.

Q5. Are owners becoming more responsive to the idea of BIM?

A5.Absolutely, they are asking for it and request it on their projects.

Q6. How does Turner initiate BIM to their clients?

A6.It is brought up during the preconstruction phases. But this tool is so useful; Turner implements the process even if the owner does not request it.

Additional Questions and Answers:

Why was BIM (3D and 4D modeling) not used in Phase I?

It was not included in the contracts of Phase 1 due to time constraints. The request must be included in each contractor's contract and states they are to provide a 3D model of their shop drawings.

Which and how would personnel be trained to use BIM-3D ?

The project engineers (MEP) of the general contractors must have basic AutoCAD knowledge to be able to use BIM. The contractors must also have basic AutoCAD knowledge to be able to convert 2D shop drawings into 3D. It takes about a week to learn 3D and another week to convert drawings into 3D.

How is BIM introduced to owners and the construction industry?

Through conferences, newspapers, advertising, workshops, invitations to projects, and word of mouth. About 15% of architects were using BIM software in 2006 and 30% in 2007 according to AIA. Today 50% of architects are using it and by 2009 about 75%. The big general contractors are already using BIM and the smaller ones are getting there but over all everyone is using it. Turner has currently used BIM on 40 of their projects.

Figure 5.7 Answered Research Questions

To get a better understanding of some of the issues faced on Phase 1 and how these issues could have potentially been eliminated during the construction phase, if 3D Modeling was used, I decided to attend a Modeling coordination meeting at City Hospital for Phase 2 on March 13, 2008.

Most of the trades from Phase 1 were also on Phase 2 and this allowed me to gather information on what issues were faced from both phases for my research topic.

The 3D modeling aspect of BIM is a complex process that requires extensive coordination. Before 3D modeling was implemented on Phase 2, Jan Reinhardt, the Program Manager of ViCon - Virtual Design and Construction at Turner Construction kicked off a 3D modeling meeting with all the trades that were to be involved in the summer of 2007. During this meeting the following steps were decided:

1. Developing a plan

   Turner manages the sequencing of the coordination.

2. Decide how to divide building in terms of level and elements (ex: levels and zones)
3. Develop a discipline specific 3D model (ex: electrical, plumbing, etc.)

   The 3D feature of BIM requires the MEP and other trades to each construct a three dimensional digital model of the systems using 3D software such as AutoCAD Revit to be imported into one format that is compatible with other engineering software. The modeling responsibilities of each trade on Phase 2 are shown in Figure 5.8. City Hospital Phase 2 consists of 9 levels and 5 to 6 zones per level. It took about two to three weeks among the group to start up the 3D modeling process on City Hospital.

4. Integrate discipline specific 3D model into NavisWorks

   It took about two to three weeks for each subcontractor to develop the 3D modeling and for Turner to integrate the drawings into NavisWorks as one drawing.

5. Identify conflicts between systems/connections

   Coordination meeting with the presence of the disciplines is held biweekly. During the meetings NavisWorks is used to perform clash detection.

6. Decide how to resolve conflicts

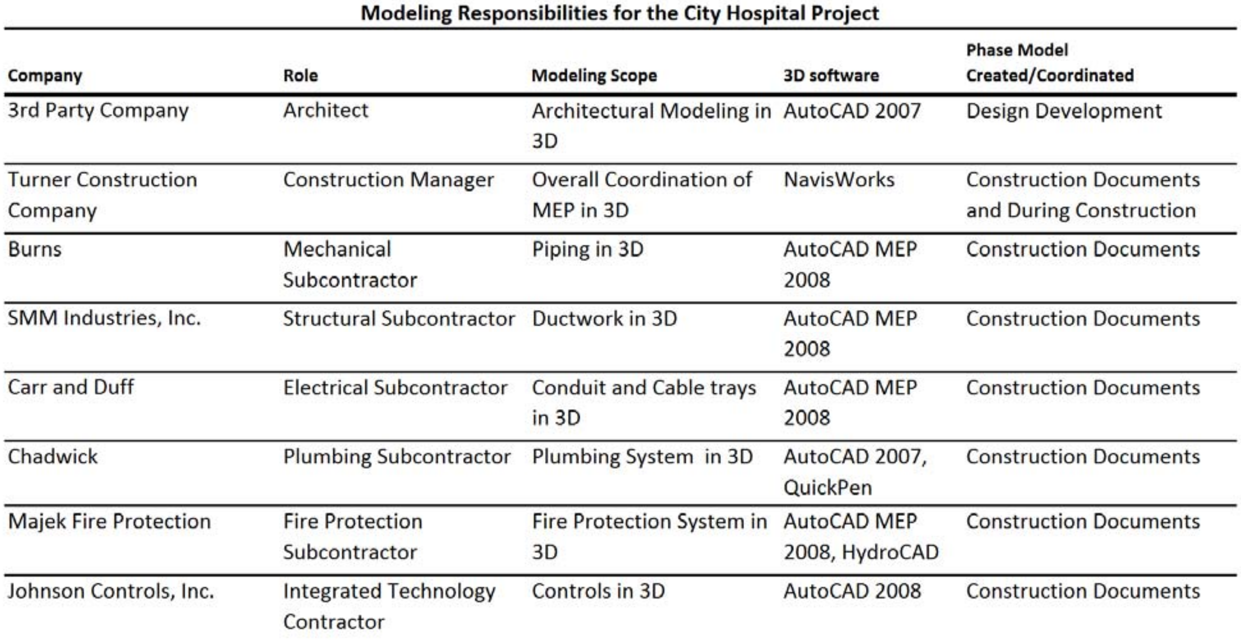
Conflicts are addressed and discussed during the coordination meetings and resolved during or after the meeting.

The subcontractors are at a point where they are comfortable with the modeling software that they are able to perform their own clash detection using NavisWorks before the coordination meetings. This allows for subcontractors to resolve issues among themselves before attending the coordination meeting where major issues are discussed.

7. Documentation of conflicts and solutions

   The drawings and clash reports are maintained by Turner Construction on Turner ViCon server and are updated weekly. All conflicts and clashes are resolved independently by each discipline and that the design corrections are to be uploaded to the server within the deadline given. Most of the clashes on Phase 2 were due to the pitch of the plumbing pipes and conflicts with the HVAC sheet metal.

Steps 4-6 as shown in Figure 5.9 will be repeated until there are no clashes detected during the clash detection or all parties are comfortable with constructability of the final coordinated design.



Modeling Responsibilities for the City Hospital Project

Company	Role	Modeling Scope	3D software	Phase Model Created/Coordinated
3rd Party Company	Architect	Architectural Modeling in 3D	AutoCAD 2007	Design Development
Turner Construction Company	Construction Manager	Overall Coordination of MEP in 3D	NavisWorks	Construction Documents and During Construction
Burns	Mechanical Subcontractor	Piping in 3D	AutoCAD MEP 2008	Construction Documents
SMM Industries, Inc.	Structural Subcontractor	Ductwork in 3D	AutoCAD MEP 2008	Construction Documents
Carr and Duff	Electrical Subcontractor	Conduit and Cable trays in 3D	AutoCAD MEP 2008	Construction Documents
Chadwick	Plumbing Subcontractor	Plumbing System in 3D	AutoCAD 2007, QuickPen	Construction Documents
Majek Fire Protection	Fire Protection Subcontractor	Fire Protection System in 3D	AutoCAD MEP 2008, HydroCAD	Construction Documents
Johnson Controls, Inc.	Integrated Technology Contractor	Controls in 3D	AutoCAD 2008	Construction Documents

Figure 5.8: Modeling Responsibilities on Phase 2 of City Hospital

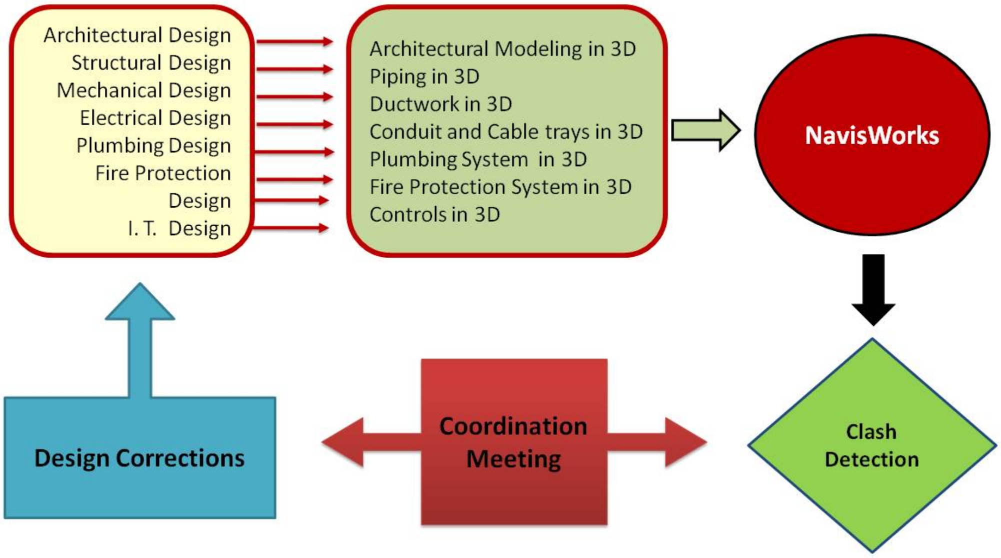


Figure 5.9: Conflict Resolution Process on Phase 2 of City Hospital

There are a few challenges faced with using this new technology on Phase 2. For example, some of the subcontractors who were new to the 3D learning programs had to overcome the learning curve to use the program. Once applications became repetitive or they began to get a feel for the process it began to run smoothly and meeting times were lessened. The project manager for Chadwick (Plumbing) commented, “It was frustrating at first but once you get a hang of it, you quickly see the benefits”. For all the contractors, City Hospital was the first project where all the subcontractors were using 3D modeling for coordination. For SSM Industries (HVAC), City Hospital was their first project using 3D modeling. Another challenge was the price for software packages needed for 3D modeling and the constant upgrades or new software being introduced to the subcontractors on a semiannual or annual basis. Chadwick stated that the upgrades would not have any significant difference to prior versions of the software and continues to use the AutoCAD 2006 even though AutoCAD 2008 is the most recent version being used. Also, 3D modeling software outpaces the hardware on computer systems. For example, a 3D model for the first level of Phase 2 would take about 800 MB of space. So subcontractors have the added cost of upgrading computer hardware apart from upgrading the modeling software.

According to the subcontractors that were working on Phase 1 and currently working on Phase 2, using 3D modeling would have been a huge advantage if it were to be used on Phase 1. Since Phase 1 houses the Central Utility Plant which consists of immense MEP equipment and connections, 3D modeling would have been ideal in seeing the spatial relationships and allowing the project team to integrate their designs electronically to identify conflicts in three dimensions. Using 2D drawings is time consuming and inefficient when compared to 3D. There

were several conflicts experienced during Phase 1 that is believed could have been avoided with the use of 3D modeling. For example, 80- 4” electrical conduits were to span from Level A (Phase 1) to Level 7 (Phase 2). There were many issues with this system running into other systems as it was to rise through each level to level 7. The use of 3D modeling may have potentially made it easier to detect the systems that would have clashed with 80 conduits and helped to redesign a more feasible system before construction. In another example, there was a clash between Burns Mechanical and Chadwick’s piping. A 24” pipe was interfaced with other piping and it resulted in changes to the pipe on three separate occasions. On Phase 2, the use of 3D modeling allows Chadwick to prefabricate their piping which reduces installation time on the project site.

Although it is too early to determine the overall benefits of using 3D or 4D modeling on Phase 2 since it’s still under construction, there are examples from other healthcare facilities that were successful with the use of BIM. The Comer Center for Children and Specialty Care at the University of Chicago Hospitals were able to “shorten the design schedule … reduce interferences between M/E and structural systems… [and only] six RFI’s compared to hundreds using traditional 2D drawings” with the use of the technology (Barista, 28). The 250,000 s. f. Camino Medical Group medical office building in California experienced zero RFI’s and change orders having to do with mechanical and electrical coordination and they were able to prefabricate building systems which reduced their MEP and fire protection labor cost by 20%.

With City Hospital intending to be LEED silver certified, the use of BIM on City Hospital has the ability to support key aspects of the sustainable design and implementation. Environmental concerns have been a huge topic in the media due to the issue of greenhouse gas emissions and the rising cost of energy. With the building industry contributing “30% of greenhouse gas emissions and generate[ing] 136 million tons of construction and demolition waste (approx. 2.8 lbs/person/day)”, a new approach of practicing the design, construction, and operation was needed (Autodesk, 1). BIM helps manage information and documentation for LEED certification very easily and under one database, a centralized design management tool. For example, the management of material quantities, material usage, lighting design, specifications, design alternatives, submittals, energy performance, the scheduling of building equipment, etc. The fourth dimension of BIM helps determine areas, volumes, and cost of materials that are needed to be submitted for LEED credits such as renewable, reused, and recycled materials. Specifically on hospitals, BIM aids in the design and construction of the complex and repetitive nature of the buildings. The real time visualization aspect of BIM allows for designers to present alternative set-ups to their clients. Not only can MEP activities and interrelations be monitored but patient and staff flow can be documented. The fourth dimension can help plan for temporary egress, construction sequencing, and material and equipment staging.

III. Analysis 1: Implementing Gold LEED® Certification

Green buildings and sustainable methods of construction are emerging topics and will only continue to grow. City Hospital is seeking LEED® Silver Certification for New Construction which requires the project to earn between 33- 38 points. Some of the credits the hospital are applying for are construction activity pollution control, complying to minimum energy performance standard as set forth by ASHRAE90.1-2004, storage and collection of recyclables on site, and complying with minimum indoor air quality act.

Problem Statement

The basis of my research is to identify four LEED® points that are not currently being explored. I would explore different design and construction methods to encourage a Gold LEED® rating (39-51 points). For example, the goal of controlling stormwater run-off lessens contamination of receiving waters by implement a stormwater management plan can be aligned with *SS Credit 6.2: Stormwater Design: Quality Control*. The second analysis on this topic would be a more detailed research on the LEED® credit *SS Credit 6.2: Stormwater Design: Quality Control* from the credits established initially for LEED® Gold rating. This analysis will require a large amount of research that will impact the schedule and the cost. The credits I will pursue will implement value engineering and schedule reduction.

Methodology

1. Literature review to become familiar with the different LEED® points
2. Review the LEED® points that are intended to be achieved on the project
3. Review potential LEED® points with LEED® consultant, Gabriella Edwards on the City Hospital project
4. Identify four LEED® additional points for Gold Certification (includes *SS Credit 6.2*)
5. Investigate the implementation of *SS Credit 6.2: Stormwater Design: Quality Control* which includes research options such as limiting the disturbance of natural water hydrology by managing stormwater runoff.

Solution

Leadership in Energy and Environmental Design (LEED®) is becoming the standard in sustainable design. There are six major categories under the LEED® rating system; they are sustainable sites, water efficiency, energy & atmosphere, materials & resources, indoor environment quality, and innovation & design process. Under these categories there are prerequisites and credits outlined in the scoring system. Executing the credits under these

categories in terms of cost may range in savings to incredibly costly during construction and operation. Although there is a high cost to constructing a sustainable building, the advantages are very rewarding. For hospitals and healthcare facilities, the benefits to people are equally impressive. Studies show that green buildings dramatically increase health and productivity. “Anecdotal studies demonstrate that people in green buildings have 40-60 percent fewer incidents of colds, flu, and asthma; patients in green hospitals are discharged as much as two and a half days earlier...” (Holowka, 1) The first LEED® hospital, Boulder Community Foothills Hospital was awarded LEED® v2.0 Silver Certification. “Since the LEED® program started in 2000, only four health care facilities have achieved certification, although there are 71 healthcare projects that have been registered and are expecting LEED® certification once complete.” (Weller, 1) There are very few LEED® hospitals because of the high cost involved. As a result, the Green Guide for Health Care was developed and is modeled after the LEED® rating system to the needs of hospitals. Now the US Green Building Council developed the LEED® for Healthcare Rating System and has adopted Green Guide for Health Care which addresses the challenges of health care buildings, considering health issues as a factor in each credit, and integrates the healing process into the design of the facility.

A few examples of some of the credits that can be gained, according to the guide, are using innovative technologies that address health care’s significant energy and water consumption, eliminating and containing toxic chemicals, provide occupants with connections between indoor and outdoor spaces, implementing green housekeeping and incorporating staff break rooms with views. LEED® hospitals recognize that there is a link between the value of the environment and the value of health.

The four LEED® points that I have identified that would explore different design and construction methods on the City Hospital project are:

EA Credit 5: Measurement & Verification (1 Point)

The intent of this credit is ensuring that water and energy cost savings are maintained overtime after building occupancy. This allows for ongoing documentation and improvement of building energy and water consumption over the life of the facility.

LEED® requires a Measurement and Verification Plan with reference to the “*International Performance Measurement & Verification Protocol (IPMVP)*” which provides the support and management for the measurement and verification of building energy performance. Metering equipment is to be installed to measure energy use which will be compared to predicted performance. Systems can be monitored by Sophisticated Electrical Management Systems, Building Automation Systems or Direct Digital Control systems. The Measurement &

Verification and information collected from post-occupancy is essentially providing feedback from the building such as the buildings energy efficiency.

City Hospital is currently using a building automation system called direct digital control (DDC) to monitor and control various function of the mechanical equipment. To earn the measurement and verification credit, City Hospital can expand this system and incorporate the use of data loggers (Figure 5.10) on the project site. Onset Computer Corporation offers the technology "HOBO data loggers" to independently measure and monitor the buildings temperature, humidity, light intensity, CO_2 levels, air pressure and quality, and voltage which can assist with building commissioning, the monitoring of occupant comfort settings, and energy use and efficiency. For example, energy use from lighting and equipment can be monitored to determine whether they are cutting electricity costs. Outdoor and indoor units are available that can measure up to 24 hrs a day, 7 days a week. They can be battery powered or hardwired through USB connections to be connected to an existing network or to the internet for easy data access.

www.**onset**comp.com

Figure 5.10: Data Loggers

The factors that should be considered with this system are function, initial cost, operating cost, and schedule. The system is expandable allowing up to hundred data loggers to use multiple monitoring stations and that can be easily relocated. Not only is data collected and stored, it is also backed up across the network allowing data to be continuously recorded in an event of a power failure.

The following table in Figure 5.11 recognizes the requirements City Hospital would need to meet this credit.

Requirements
1. Develop a Measurement & Verification Plan
2. Include a schedule of the instrumentation and controls for the following monitoring categories.
• Lighting controls and systems
• Energy efficiency systems and equipment
• Boiler efficiency
• Chiller efficiency
• Cooling load
• Air and water economizer and heat recovery cycles
• Air distribution pressures and ventilation air volumes
• Variable frequency drive operation
• Constant and variable motor loads
• Water risers
3. Include cut sheets of sensors and the data collection system used to provide metering.

Figure 5.11: Requirements for Measurement &Verification

This LEED® point requires early planning into the design and construction effort so that mechanical and electrical engineer are able to design systems that can be monitored easily for comparisons. For example, electrical equipment can be connected onto one panel board for ease of monitoring. One of the benefits of this system is most of these design requirements are zero or negligible cost items if included as part of the original design.

The Measurement and Verification scope of work will interface with other LEED® credits to be obtained or proposed for by the City Hospital such as *WE Credit 2*: Innovative Wastewater Technologies, *EA Credit 3*: Additional Commissioning, *IEQ Prerequisite 1*: Minimum IAQ Performance, *IEQ Credit 1*: Carbon Dioxide (CO_2) Monitoring, and *IEQ Credit 6:* Controllability of Systems. For example, the measurement and verification credit will coordinate with the CO_2 monitoring system to make certain it functions properly over time and innovative wastewater technologies to include water treatment and reuse in the plan.

EQ Credit 1: Outdoor Air Delivery Monitoring (1 Point)

The focus of this credit is to monitor outdoor air ventilation rates to ensure that they supply the required amount of fresh air to the building that will maintain the minimum indoor air quality requirements. This credit interfaces with *EA Credit 5*: Measurement & Verification as proposed

which uses data loggers to measure air flow and CO_2 levels. The data loggers would feed the information to the Direct Digital Control which would trigger an alarm if conditions fluctuate by 10% from the normal.

LEED® requires:

> **For mechanically ventilated spaces:**
>
> Install carbon dioxide monitors between 3 feet and 6 feet above the floor within all spaces occupied by 25 or more people per 1000 sq. ft.
>
> Install outdoor airflow measurement devices (+/- 15% accuracy of design minimum outdoor air rate) for each HVAC system serving non-densely occupied spaces.
>
> **For naturally ventilated spaces:**
>
> Install carbon dioxide monitors between 3 feet and 6 feet above the floor. One carbon dioxide sensor may be used to represent multiple spaces if the design meets requirements.

For City Hospital the data loggers would essentially be operating as a carbon dioxide monitor to maintain low levels of CO_2. The advantages of using this system are to improve indoor air quality which in turn would improve the occupants' health, comfort and productivity. Also especially in a hospital setting this would eliminates the risk of allergies, asthma and other health effects. The system provides significant energy cost savings by limiting the amount of unnecessary outside air for ventilation purposes.

***WE Credit 2*: Innovative Wastewater Technologies (1 Point)**

The intent of this credit is to decrease the use of waste water and potable water usage on site by 50%. The most common way to achieve this LEED® point is to specify high efficiency fixtures. Usually, efficient fixtures alone are not enough to get to the 50% standard.

In the case of the City Hospital, *SS Credit 6.2*: Stormwater Design: Quality Control implements a rainwater capturing system to further reduce potable water consumption. The steps below are the requirements proposed for the City Hospital Project.

1. Use high efficiency fixtures, such as toilets and waterless urinals.

Kohler provides a variety of efficient fixtures. High efficiency toilets use 1.2 gallons of water or less per flush, averaging about $300 per unit, compared to 1.6 gpf typically used today. Waterless urinals conserve thousands of gallons of water per fixture per year. The Wellworth® Pressure Lite™ 1.1 gpf toilet and the Steward™ S waterless urinal provides value to the customer by reducing water, sewage and maintenance costs. Each unit cost $451.20 and $489.25, respectively

www.us.kohler.com

Figure 5.12: Kohler water fixtures

2. Reuse of stormwater and non-potable applications such as mechanical systems and irrigation.

   Proposed in credit ***SS Credit 6.2*****: Stormwater Design: Quality Control**

SS Credit 6.2**: Stormwater Design: Quality Control (1 Point)**

This credit is used to reduce water pollution by capturing and treating stormwater runoff.

A plan must be put in place to:

1. treat and capture 90% storm water runoff
2. remove 80% TSS (total suspended solids)
3. use acceptable Best Management Practices such as sustainable design strategies and alternative surfaces

According to EPA, “A unique rooftop rainwater recovery system captures and filters rainwater for use in wastewater fixtures; it cuts treated domestic water use by approximately 50 percent and reduces site runoff by 40 percent…LEED® documentation estimates an annual water savings of 735,000 gallons from this unique system.” This system can be used to earn this credit on City Hospital; a Stormwater Catchment System. Captured rainwater runoff must be treated then stored in tanks or pipes for reuse. On a crammed site like City Hospital, the water would be reused for irrigation and cooling towers. The components of this system include the rainwater catchment area (roof), transportation system (gutter and piping), filtration system,

storage system (cistern), and a pump to distribute the captured rainfall to the landscape or building as shown in Figure 5.13. A leaf screen can be used along the gutter or downspout to collect debris and other objects to preventing clogging.

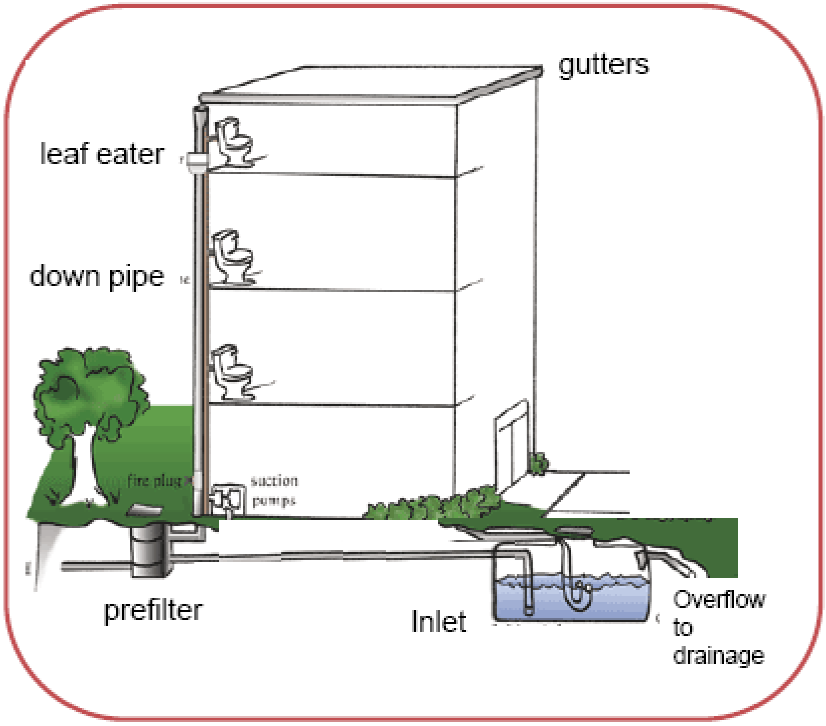


Figure 5.13: Stormwater Catchment System

A few factors that must be considered upon using this method for stormwater catchment are the budget, aesthetic features, planning, site layout and conditions, and local weather patterns. This cistern is costly but “the payback period for cistern systems is less than 10 years” (Hunt, 6). “The entire system cost for installation ranges from $0.75 per gallon for larger cisterns to nearly $2 per gallon for smaller cisterns.” (Hunt, 6) Before installing the cistern, local utilities company must be contacted to locate buried pipes and cables. Also a support system for the cistern is needed and shown not be located immediately next to the building in order to avoid damage to the building’s foundation. Rainfall in the Philadelphia area should be calculated to size the cistern. This system will include a pump (submersible pump or jet pump) to pump the treated water to be reused for the cooling towers and irrigation. The Lane Counter Flow Technology Water Quality Unit (Lane CFT) can be used to intercept the stormwater flow, remove pollutants, and discharge treated flow in a manner suitable for today’s stormwater

regulator. It helps with pollutants removal in the first flush. The first flush occurs at the beginning of each rain event as sediments deposited from the previous event, as well as floatable debris is collected and carried away with the initial rainwater flow. When evaluating and comparing to determine the critical concerns when implementing this system, there will be advantages and disadvantages.

Some of the advantages that will be gained in using this system are;

- Below ground cisterns are not visible to the viewer
- Reduces water bills and system pays for itself over time
- Reduces erosion and pollution caused by runoff
- Tax credits and rebate program available
- Reduces the harm done to the environment

Some of the disadvantages in implementing this system are;

- Due to the large size and weight of cisterns, delivery charges are often substantial
- Underground cisterns limit access after installation for repairs

Calculations for sizing cistern:

The size of the cistern depends on the rainfall supply and demand. According to LEED®, the stormwater system must be designed to handle 90% of the average annual rainfall. In Philadelphia, 1 inch of rainfall is 90% of the average annual rainfall. Figure 5.14 provides the cistern capacity; the calculations below are used to size the cistern for the project.

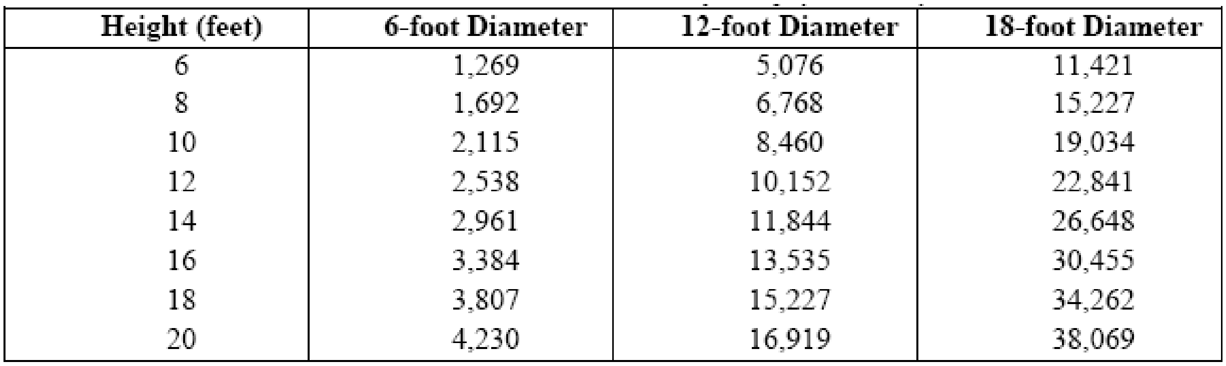
1” of rain over the area × Catchment Area (Roof) = water (gal.) stored in cistern

$$\left[1'' \times \frac{1'}{12''}\right] \times 87{,}432\,sq.\ ft. = 7{,}286\,cu.\,ft. = 54{,}503\,gal.$$

Philadelphia average annual rainfall = 42.05”

Annual rain fall × Catchment area (Roof) = water (gal.) collected per year

$$\left[42.05'' \times \frac{1'}{12''}\right] \times 87{,}432\,sq.\ ft. = 306{,}376\,cu.\,ft. = 2{,}291{,}852\,gal.$$



Height (feet)	6-foot Diameter	12-foot Diameter	18-foot Diameter
6	1,269	5,076	11,421
8	1,692	6,768	15,227
10	2,115	8,460	19,034
12	2,538	10,152	22,841
14	2,961	11,844	26,648
16	3,384	13,535	30,455
18	3,807	15,227	34,262
20	4,230	16,919	38,069

http://www.twdb.state.tx.us/publications/reports/RainwaterHarvestingManual_3rdedition.pdf

Figure 5.14: Cistern Capacity (Galloons)

Cistern Structural Support:

The soil that the cistern will be supported by must be known to determine whether the soil can support the structure. Structural support will be needed if the load “is greater than 2,000 lb/ ft^2 load bearing capacity of the soil.” (Jones, 6) The calculation below can be used to determine the need for support. Concrete or a layer of gravel can be used as a support system.

$$\text{Cistern Load} = \frac{\text{Capacity} \times 8.35\ \text{lbs/gal} + \text{Cistern Weight}}{\text{Footprint Area}}$$

The proposed Stormwater Catchment System in section and plan view for City Hospital can be found in Appendix C.

MEP Coordination:

The coordination of mechanical, electrical, and plumbing (MEP) systems with the stormwater system will be required. Plumbing designers and contractors will need to configure piping from roof to the cooling towers and irrigation system. Electrical connections will be needed to power the pump, cisterns and controls. Overall this system will affect the schedule; therefore coordination before construction will need to take place.

IV. Analysis 2: Supplying Power to Emergency System using Medium Voltage Generator

The City Hospital’s emergency distribution system is currently designed to utilize two 2 MW generators supplying power at 480V to power Phase 1, in the event of an interruption of normal power. A medium voltage system such as 4160V has some advantages and disadvantages that has been considered and dispelled during the course of this research. The pros and cons has been weighed, the conclusion I derived is that the final choice between choosing to supply emergency power at 480V or 4160V depends on various quantifiable and some unquantifiable factors like the preference of the owner, the impact on the budget, the local authority having jurisdiction, the availability of the system, impact to the distribution system, etc. There has to be some tradeoff between available design alternatives.

Some of the advantages that will be gained in supplying emergency power at medium voltage are;

- The cost saving due to different sized wires: The savings that can be gained by the change in wire size is reflected in the unit of power which is:

  Kilowatts (KW) = Power Factor (PF) * Volt Amperes (VA)
  Volt Amperes (VA) = Volt (V) * Amperes (A)

  The amount of power that the hospital need is unchanged so we will assume in this scenario that it is a constant. We can choose to increase the voltage, thereby reducing the amount of amperes that is transmitted in the feeders from the generator to the emergency switchgear. This reduction in amperes enables us to be able to use feeders of lower ampacity to transmit the power to the emergency switchgear. The price of the feeders generally increase with the ampacity of the wire, so using smaller feeders (feeders with less ampacity) will give us some cost savings. The longer the distance between the generator and the emergency switch gear, the more the savings gained in using a medium voltage emergency power supply. This is the same reason why the normal power serving the hospital is medium voltage.

Some of the disadvantages of supplying emergency power at medium voltage are;

- Facilities maintenance staff would prefer not to maintain medium voltage system due to the amount of caution and knowledge required to maintain them. They have to be specially trained and authorized to handle this voltage. I believe due to the fact that the normal distribution system already utilizes medium voltage, the facility staff would already be trained to work with medium voltage systems.

- Emergency systems upstream of the automatic transfer switches are typically inactive until normal power fails and the generators are started. Medium voltage cable has a tendency to fail when it's energized after sitting in a de-energized state. This problem is worse at higher voltages, but still exists to a lesser degree at 5kV class systems. This problem can be avoided, by regularly scheduled maintenance which has the added benefits of prolonging the life of the generator and adhering to manufacturers safe practice guidelines.

Problem Statement

This technical analysis will consist of quantitative and qualitative investigation of the advantages of using a medium voltage generator (4160V) instead of the low voltage generator (480V) currently used, and the effects this substitution will have on the emergency distribution system. The hospital is currently using (2) 2MW diesel powered generator at 480V as emergency power. My research is to determine which voltage would be more advantageous in terms of cost, installation, support, etc.

Methodology

1. Review literature on using medium voltages on construction projects
2. Review case studies of Hospitals that uses Medium voltage
3. Review City Hospital electrical drawings and specifications for information about the (2) 2MW diesel generators
4. Conduct an analysis using 4160V generator
5. Compare costs, installation, materials used between existing system and 4160V analysis

Solution

Currently Designed system:

The current design as shown is appendix D, shows two 2MW generator. Each connected via 32#600 & 8#400 - (8) 4”C to a 3000A emergency switchboard. The two switchboards are then tied together using a bus duct, then synchronized using a Kurt key interlock.

Proposed Alternative Design:

The proposed redesign replaces the two 2MW generators supplying power at 480V with two 2MW generator supplying power at 4160V. A transformer will be placed downstream of the generators to step the voltage back down to the utilization level of 480/277V. This change in

supply voltage will cause a change in the quantity and size of the feeders serving the emergency switchboard.

$$2\,MW = 2{,}000{,}000W$$
$$KiloWatts\,(KW) = Power\,Factor\,(PF)\times Volt\,Amperes\,(VA)$$
$$*\,Assume\,a\;\;Power\,Factor\,(PF)\,of\;0.8$$
$$Volt\,Amperes\,(VA) = Volt\,(V)\times Amperes\,(A)$$
$$2{,}000{,}000W \div 0.8 = 2{,}500{,}000\;VA = 2.5\,MVA$$

To size the feeder connecting the generator to the transformer:

$$\frac{2.5MVA}{\sqrt{3}\times 4160V} = 347A$$

We will need a feeder with an ampacity greater that 347A.

Sizing Feeder:

Using the feeder schedule in NEC Table 310-16 (See Appendix D for an extraction of actual table from NEC), a copper feeder of temperature rating of 75 degree Celsius will be used. From the table it was determined that the next highest feeder with an ampacity greater than 347A is the 500 MCM feeder which has an ampacity of 380A.

Sizing of Conduit:

Using the NEC [Chapter 9, Tables 1 to 7], the known feeder size and the number of feeders needed to be run in the conduit, a 3-1/2" conduit will be used. Therefore power is going to be transmitted from the generator to the transformer that steps down the voltage via 4#500MCM - 3-1/2"conduit.

Sizing of Transformer:

A transformer is needed for the 4160V system to step down the voltage supplied to the switch board to 480V. To maximize the savings gained from using medium voltage the transformer is located in the C.U.P., in the Emergency Switchgear room. The transformer that is being specified is the VPE transformer. Transformer capacity is rated in Kilovolt-amperes (KVA) and it remains constant. The constant KVA allows us to form a relationship for finding the

amperage on the secondary side of the transformer. The transformer that would be utilized is a 2500KVA transformer. We are using a 2500KVA transformer because of the generator size is 2000KW and a power factor of 0.8. We multiply them and get 2500KVA.

To get the size of the amperage on the secondary side:

Primary Current X Primary Voltage = Secondary current X Secondary Voltage

$$V_P \times I_P = V_S \times I_S$$

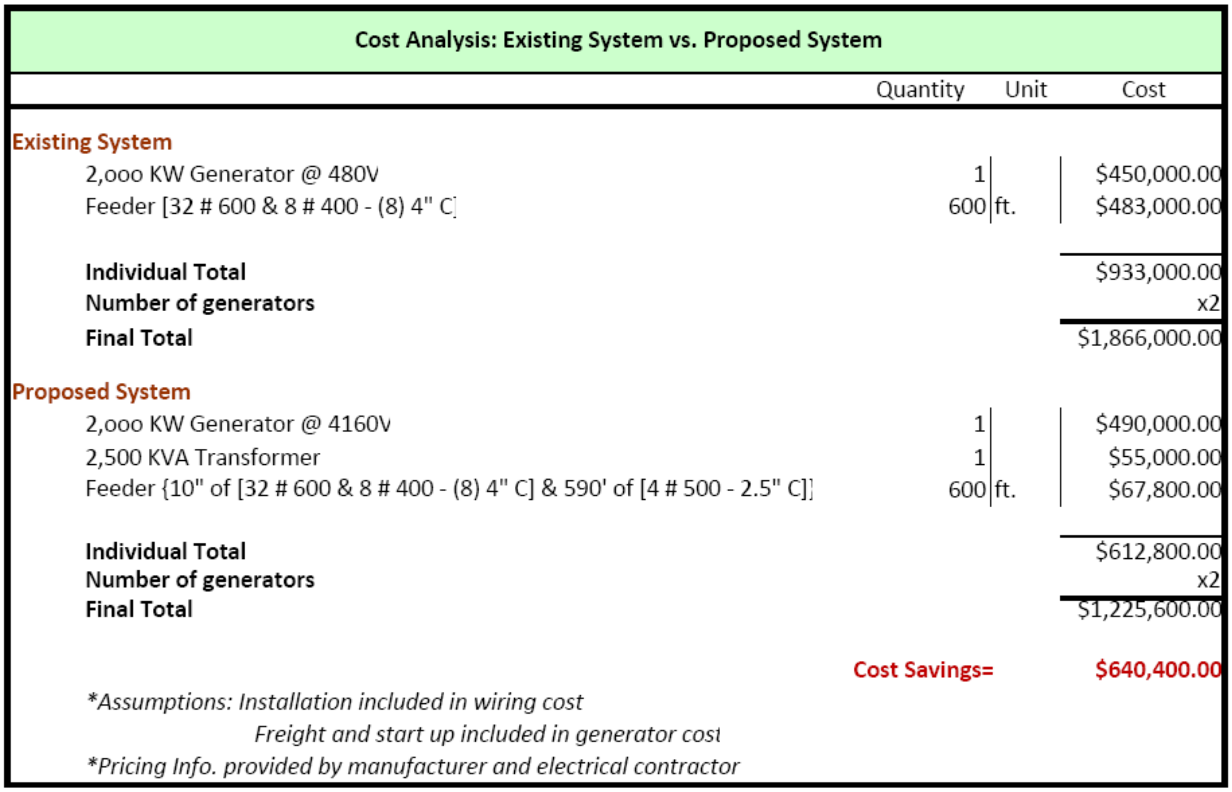
$$4160V \times 347A = 480 \times ?A$$

$$?A = 3007.33A$$

Now we can connect the transformers secondary to the existing emergency switchgear. The approximate vertical length of run is 150’. The approximate horizontal run is 500’.

Cost Analysis:

The difference in cost, installation, equipment, and materials used between the existing system and proposed system can be found in Figure 5.15.



Cost Analysis: Existing System vs. Proposed System

	Quantity	Unit	Cost
Existing System			
2,ooo KW Generator @ 480V	1		$450,000.00
Feeder [32 # 600 & 8 # 400 - (8) 4" C]	600	ft.	$483,000.00
Individual Total			$933,000.00
Number of generators			x2
Final Total			$1,866,000.00
Proposed System			
2,ooo KW Generator @ 4160V	1		$490,000.00
2,500 KVA Transformer	1		$55,000.00
Feeder {10" of [32 # 600 & 8 # 400 - (8) 4" C] & 590' of [4 # 500 - 2.5" C]}	600	ft.	$67,800.00
Individual Total			$612,800.00
Number of generators			x2
Final Total			$1,225,600.00
	Cost Savings=		$640,400.00

**Assumptions: Installation included in wiring cost*
Freight and start up included in generator cost
**Pricing Info. provided by manufacturer and electrical contractor*

Figure 5.15: Cost Analysis-Existing System vs. Proposed System

V. Conclusions

The critical industry issue affecting the City Hospital Phase 1 project is the use of Building Information Modeling – 3D Modeling. BIM is already well known and is becoming highly demand in the construction industry. Some pioneer schools have already implemented BIM courses into their curriculum, for example, University of Minnesota. BIM has great potential for the next generation of architects, engineers, and construction managers. On the Phase 2 of this City Hospital project, BIM has already proven to be an effective tool in evaluating the construction process on a LEED® rated hospital and will impact the project by reducing the cost and schedule.

The first technical analysis examines some LEED® point options that can be additionally obtained by City Hospital to achieve a GOLD rating instead of the SILVER rating that is currently being aimed for. The additional credits include EA Credit 5: Measurement & Verification, EQ Credit 1: Outdoor Air Delivery Monitoring, WE Credit 2: Innovative Wastewater Technologies and SS Credit 6.2: Stormwater Design: Quality Control. There is an initial costs associated with incorporating such systems into the building but energy savings would outweigh the costs over time. The stormwater system is a feasible option for City Hospital and would be recommended. The first cost of a rainwater system typically would range from $25,000 to $40,000 depending on the components incorporated with an annual savings of about $5,000.

The second technical analysis compares a medium voltage generator (4160V) to the low voltage generator (480V) currently used on the project. The factor that will need to be considered is mechanical ventilation due to radiated heat from the transformer. Also, the proposed location of the transformer (Level B) is currently in a place where electrical water cooler is located, the plumbing the contractor will have to coordinate relocation of the cooler. In terms of electrical work, it was realized that the proposed system would reap savings of $640,400. The result of my study suggests that with fewer wires being installed it would be easier for the contractors to coordinate conduit run which would decrease time on the schedule.

In conclusion, the design, coordination, and construction process has and will always require careful planning; sustainable design, and efficient application.

VI. Works Cited

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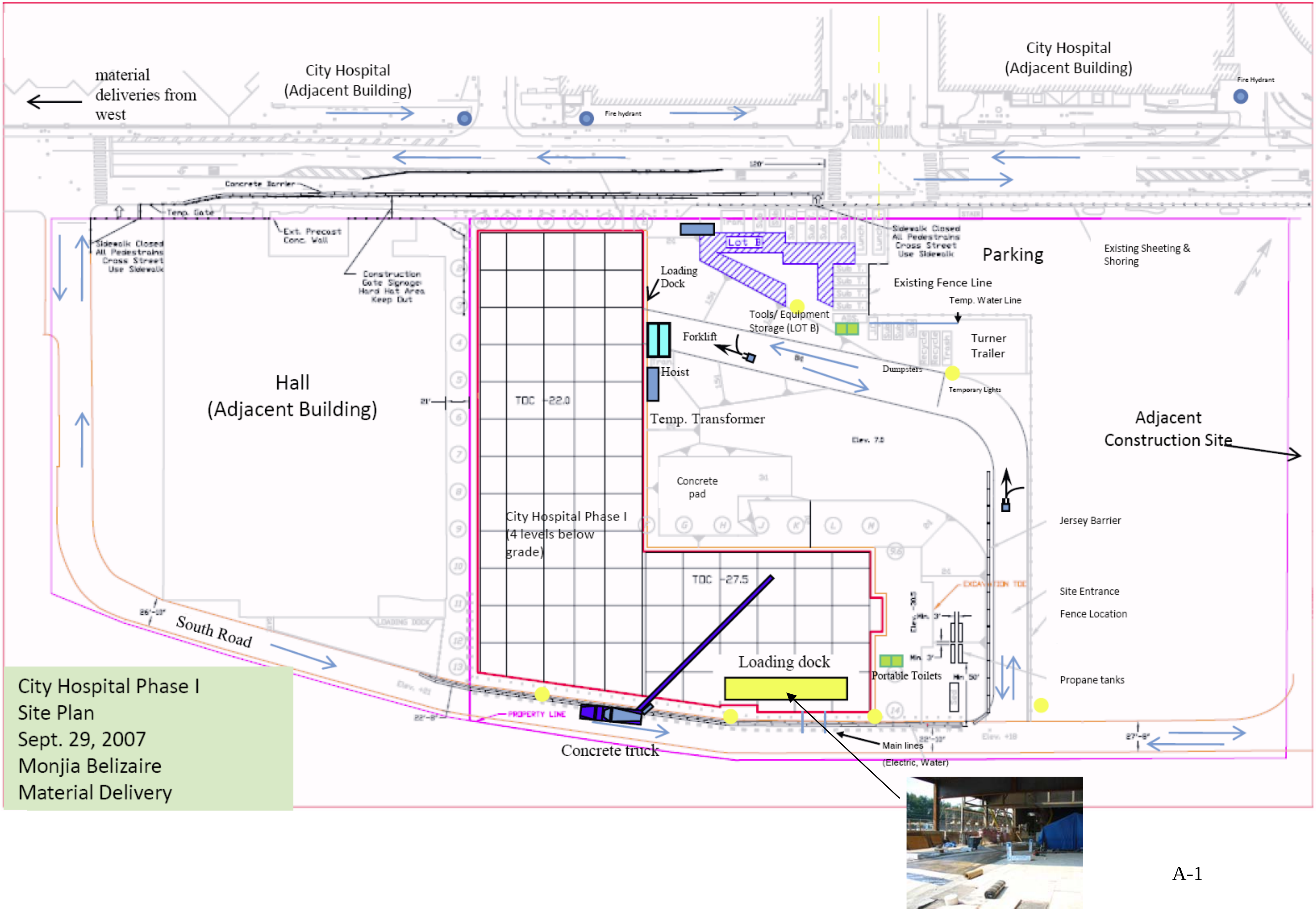
APPENDIX A : SITE PLAN

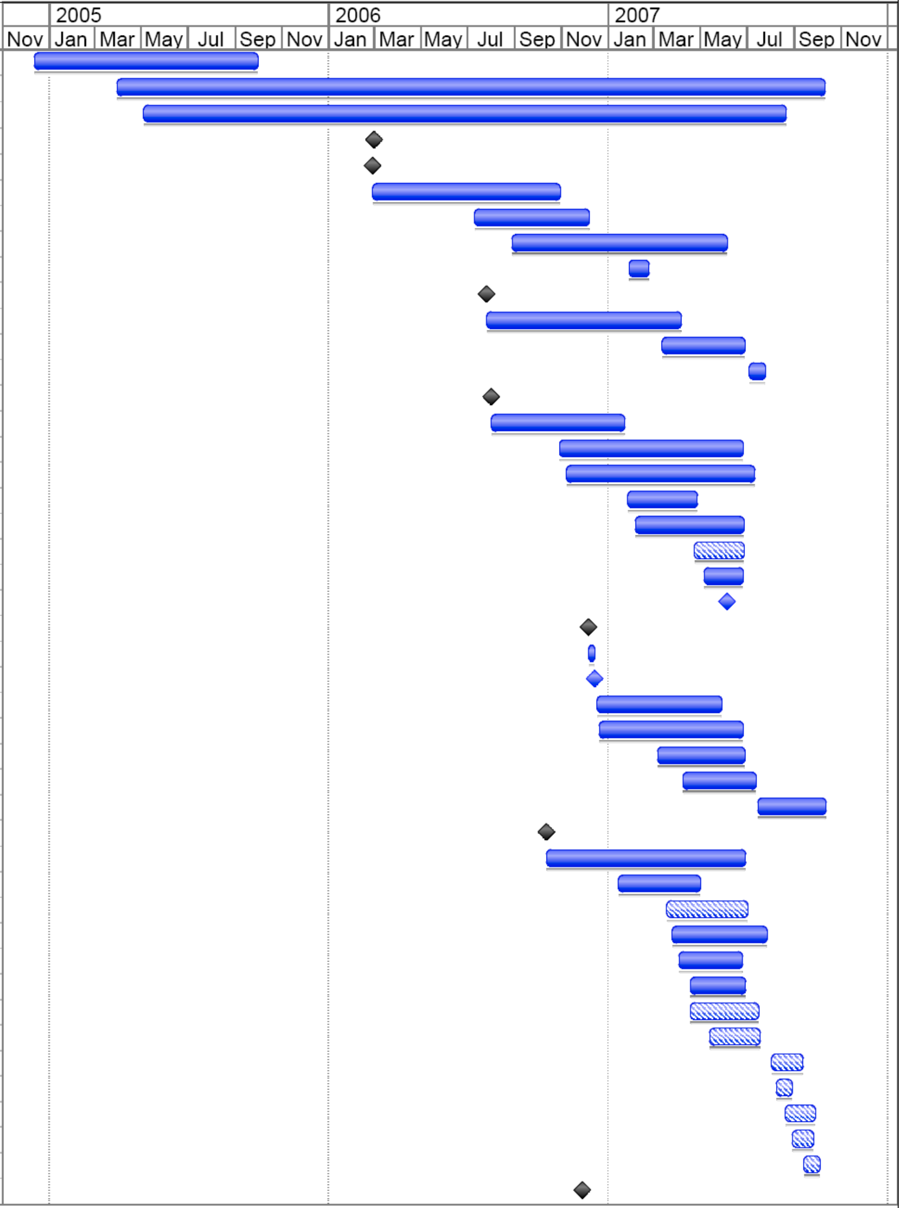


City Hospital Phase I
Site Plan
Sept. 29, 2007
Monjia Belizaire
Material Delivery

APPENDIX B : PROJECT SCHEDULE

City Hospital
Project Schedule

ID	Task Name	Duration	Start	Finish
1	**Design Develpoment**	**210 days**	**Mon 12/13/04**	**Fri 9/30/05**
2	**Procurement of Services**	**664 days**	**Thu 3/31/05**	**Thu 10/11/07**
3	**Site work**	**602 days**	**Thu 5/5/05**	**Tue 8/21/07**
4	**Contract Awarded (Phase1)**	**1 day**	**Thu 3/2/06**	**Thu 3/2/06**
5	**Concrete**	**1 day**	**Tue 2/28/06**	**Tue 2/28/06**
6	Foundations	176 days	Tue 2/28/06	Mon 10/30/06
7	Slab on Grade	110 days	Tue 7/11/06	Thu 12/7/06
8	Prep & Pour Concrete on Deck	204 days	Tue 8/29/06	Tue 6/5/07
9	Prep & Pour Walls	20 days	Mon 1/29/07	Fri 2/23/07
10	**Steel & Metals**	**1 day**	**Thu 7/27/06**	**Thu 7/27/06**
11	Erect Steel & Metal Deck	185 days	Thu 7/27/06	Fri 4/6/07
12	Steel Stairs	78 days	Tue 3/13/07	Thu 6/28/07
13	AHU Grating Platform- (CUP)	15 days	Thu 7/5/07	Wed 7/25/07
14	**Thermal/Moisture Protection**	**1 day**	**Wed 8/2/06**	**Wed 8/2/06**
15	Spray on Fire Proofing (CUP)	126 days	Wed 8/2/06	Mon 1/22/07
16	Waterproofing Foundation Walls (CUP)	174 days	Mon 10/30/06	Tue 6/26/07
17	Waterproofing Foundation Walls (Research)	178 days	Wed 11/8/06	Wed 7/11/07
18	Spray on Fire Proofing (Research)	66 days	Sat 1/27/07	Fri 4/27/07
19	Roofing (CUP)	102 days	Tue 2/6/07	Wed 6/27/07
20	Temporary Roofing (research)	47 days	Tue 4/24/07	Wed 6/27/07
21	Waterproofing (Loading Dock)- CUP	37 days	Mon 5/7/07	Tue 6/26/07
22	Building Weathertight	1 day	Wed 6/6/07	Wed 6/6/07
23	**Masonry**	**1 day**	**Thu 12/7/06**	**Thu 12/7/06**
24	Mobilize Masonry & Set up Scaffold	6 days	Thu 12/7/06	Thu 12/14/06
25	Exterior Skin Start	1 day	Fri 12/15/06	Fri 12/15/06
26	Masonry (Exterior)- (C.U.P.)	118 days	Mon 12/18/06	Tue 5/29/07
27	Masonry (Interior)- (CUP)	135 days	Thu 12/21/06	Tue 6/26/07
28	Masonry (Interior)-(Research)	82 days	Wed 3/7/07	Thu 6/28/07
29	Masonry (Exterior)- (Research)	70 days	Mon 4/9/07	Fri 7/13/07
30	Exterior walls	65 days	Mon 7/16/07	Fri 10/12/07
31	**Plumbing**	**1 day**	**Fri 10/13/06**	**Fri 10/13/06**
32	Domestic Water Hangers/Rough-ins (CUP)	188 days	Fri 10/13/06	Fri 6/29/07
33	Natural Gas Piping/Equip./Connections (CUP)	78 days	Mon 1/15/07	Tue 5/1/07
34	Sanit./ Storm & Acid Waste Hangers/Rough-in (Research)	76 days	Mon 3/19/07	Mon 7/2/07
35	In Wall Plumbing Rough-in (Research)	90 days	Mon 3/26/07	Fri 7/27/07
36	Process Chilled Water Hangers/ Rough-in (Research)	59 days	Wed 4/4/07	Mon 6/25/07
37	Domestic Water Hangers/ Rough-in (Research)	52 days	Thu 4/19/07	Fri 6/29/07
38	Medical Gas Hangers/ Rough-in (Research)	63 days	Thu 4/19/07	Mon 7/16/07
39	In-Wall Plumbing Rough-in (Research)	48 days	Mon 5/14/07	Wed 7/18/07
40	Domestic Water Fixtures/ Finishes (Research)	29 days	Fri 8/3/07	Wed 9/12/07
41	Install & Pipe Dom. Hot Water Generator (CUP)	15 days	Thu 8/9/07	Wed 8/29/07
42	Medical Gas Oulets/ Finishes (Research)	29 days	Tue 8/21/07	Fri 9/28/07
43	Install & Pipe Service Air & Vacuum Equip. (CUP)	20 days	Thu 8/30/07	Wed 9/26/07
44	Piping Insulation (CUP)	15 days	Fri 9/14/07	Thu 10/4/07
45	**H.V.A.C.**	**1 day**	**Wed 11/29/06**	**Wed 11/29/06**

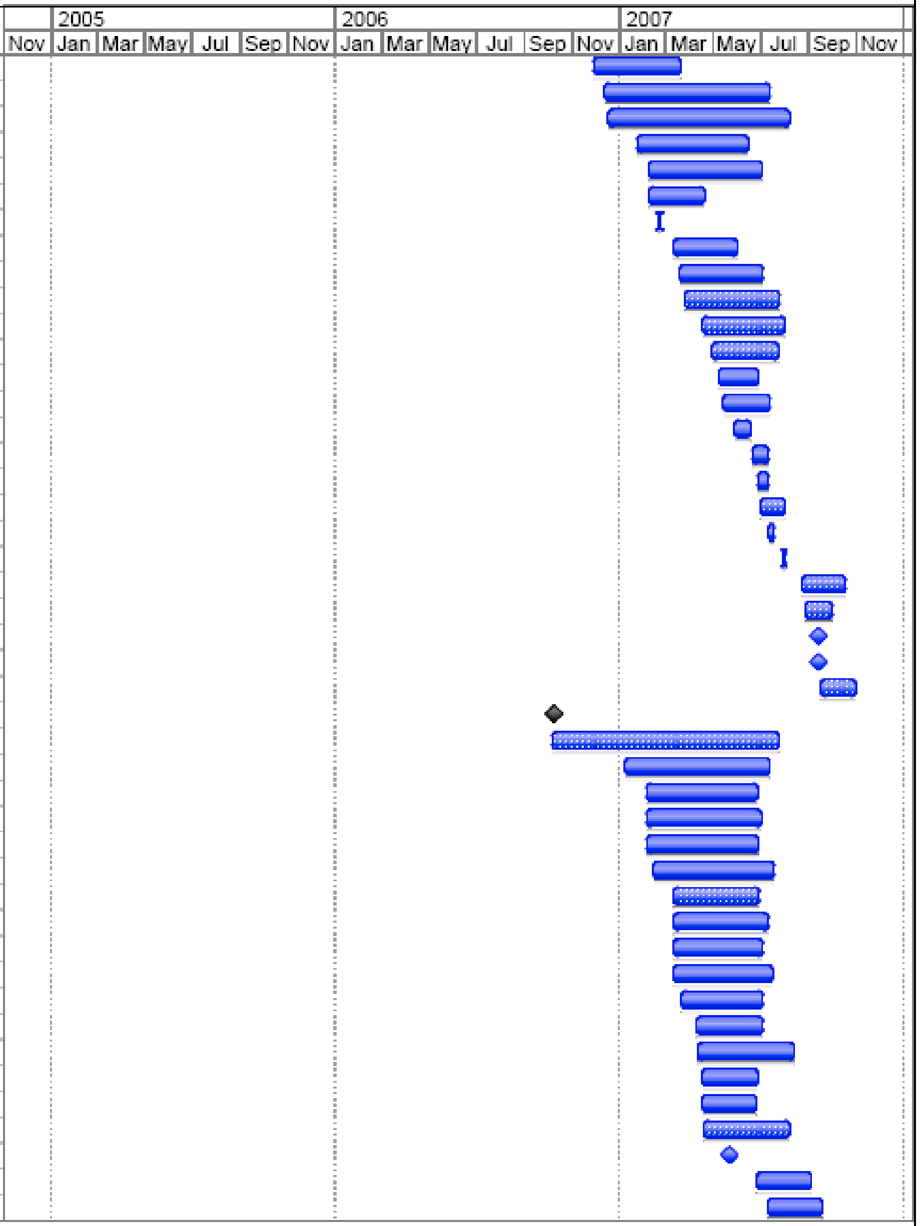


Date: Sat 4/5/08

Task	▬	Summary	▬	Rolled Up Progress	▬	Project Summary	▬
Critical Activity	▨	Rolled Up Task	▬	Split	┈	Group By Summary	▬
Milestone	◆	Milestone	◆	External Tasks	▬	Deadline	⇩

City Hospital
Project Schedule

ID	Task Name	Duration	Start	Finish
46	Bolier System- Install Boiler Breeching (CUP)	81 days	Wed 11/29/06	Tue 3/20/07
47	ACU System Rough-in	154 days?	Wed 12/13/06	Fri 7/13/07
48	AHU- Rough-In Ductwork (CUP)	168 days	Mon 12/18/06	Tue 8/7/07
49	Duct Riser Rough-in (Research)	104 days	Wed 1/24/07	Fri 6/15/07
50	Duct Main Rough-in (Research)	104 days	Thu 2/8/07	Tue 7/3/07
51	Duct Main Rough-in (Research)	52 days	Thu 2/8/07	Fri 4/20/07
52	Set Chiller #1 and #2 (CUP)	2 days	Wed 2/21/07	Thu 2/22/07
53	Install Branch Duct and Air Valves (Research)	60 days	Mon 3/12/07	Fri 6/1/07
54	Duct Branches Hangers/ Rough-in (Research)	77 days	Tue 3/20/07	Wed 7/4/07
55	Install Mech. Piping (Research)	88 days	Mon 3/26/07	Wed 7/25/07
56	Duct & Piping Insulation (Research)	76 days	Wed 4/18/07	Wed 8/1/07
57	Steam Piping Hangers/ Rough-in (Research)	62 days	Mon 4/30/07	Tue 7/24/07
58	Trim-out (CUP)	37 days	Wed 5/9/07	Thu 6/28/07
59	Install VCV Boxes-Level A- (Research)	44 days	Tue 5/15/07	Fri 7/13/07
60	Steam Piping Hangers/Rough-in (Research)	15 days	Tue 5/29/07	Mon 6/18/07
61	Hot Water Piping Hangers & Rough-in (Research)	15 days	Thu 6/21/07	Wed 7/11/07
62	Hang CHU's & Final Connections	10 days	Thu 6/28/07	Wed 7/11/07
63	Steam Piping Final Connections (Research)	23 days	Mon 7/2/07	Wed 8/1/07
64	Hang Unit Heaters & Connections (Research)	5 days	Thu 7/12/07	Wed 7/18/07
65	Set Cooling Towers	4 days	Mon 7/30/07	Thu 8/2/07
66	CUP Mechanical Equipment Start-up	40 days	Fri 8/24/07	Thu 10/18/07
67	Duct Accessories (Research)	25 days	Tue 8/28/07	Mon 10/1/07
68	Cooling Towers Start Up	1 day	Fri 9/14/07	Fri 9/14/07
69	Coolling Towers Start-Up	1 day	Fri 9/14/07	Fri 9/14/07
70	CUP Mechanical Equip. Commissioning	33 days	Mon 9/17/07	Wed 10/31/07
71	**Electrical**	**1 day**	**Tue 10/10/06**	**Tue 10/10/06**
72	Elect. Power/Light./Fire Alarm Rough-In (CUP)	210 days	Sat 10/7/06	Tue 7/24/07
73	Security Rough-in (CUP)	134 days	Tue 1/9/07	Thu 7/12/07
74	Install Electrical Equip. (CUP)	103 days	Mon 2/5/07	Wed 6/27/07
75	Install Electrical Power Panels (CUP)	106 days	Mon 2/5/07	Mon 7/2/07
76	Install Electrical Lighting Panels (CUP)	104 days	Mon 2/5/07	Thu 6/28/07
77	Telecommunications/ Data Rough-in (CUP)	111 days	Wed 2/14/07	Wed 7/18/07
78	Electrical Power Rough-in (Research)	80 days	Mon 3/12/07	Fri 6/29/07
79	Electrical Lighting Rough-in (Research)	88 days	Mon 3/12/07	Wed 7/11/07
80	Electrical Security Rough-in (Research)	83 days	Mon 3/12/07	Wed 7/4/07
81	In-Wall Electrical Rough-in (Research)	91 days	Mon 3/12/07	Mon 7/16/07
82	Run Commun. Ductbank for Tele./Data (Research)	75 days	Thu 3/22/07	Wed 7/4/07
83	Corridor Electrical Rough-in (Research)	62 days	Tue 4/10/07	Wed 7/4/07
84	Electrical Fire Alarm Rough-in (Research)	88 days	Thu 4/12/07	Mon 8/13/07
85	Heating Hot Water Hangers/ Rough-in (Research)	51 days	Wed 4/18/07	Wed 6/27/07
86	Chilled Water Mains Hanger/ Rough-in (Research)	49 days	Wed 4/18/07	Mon 6/25/07
87	Telecommunications/ Data Rough-in (Research)	78 days	Fri 4/20/07	Tue 8/7/07
88	Permanent Power	1 day	Wed 5/23/07	Wed 5/23/07
89	Electrical Power Panel/ Outlet Finishes (CUP)	50 days	Wed 6/27/07	Tue 9/4/07
90	Electrical Lighting Panel/ Fixture Finishes (CUP)	50 days	Wed 7/11/07	Tue 9/18/07



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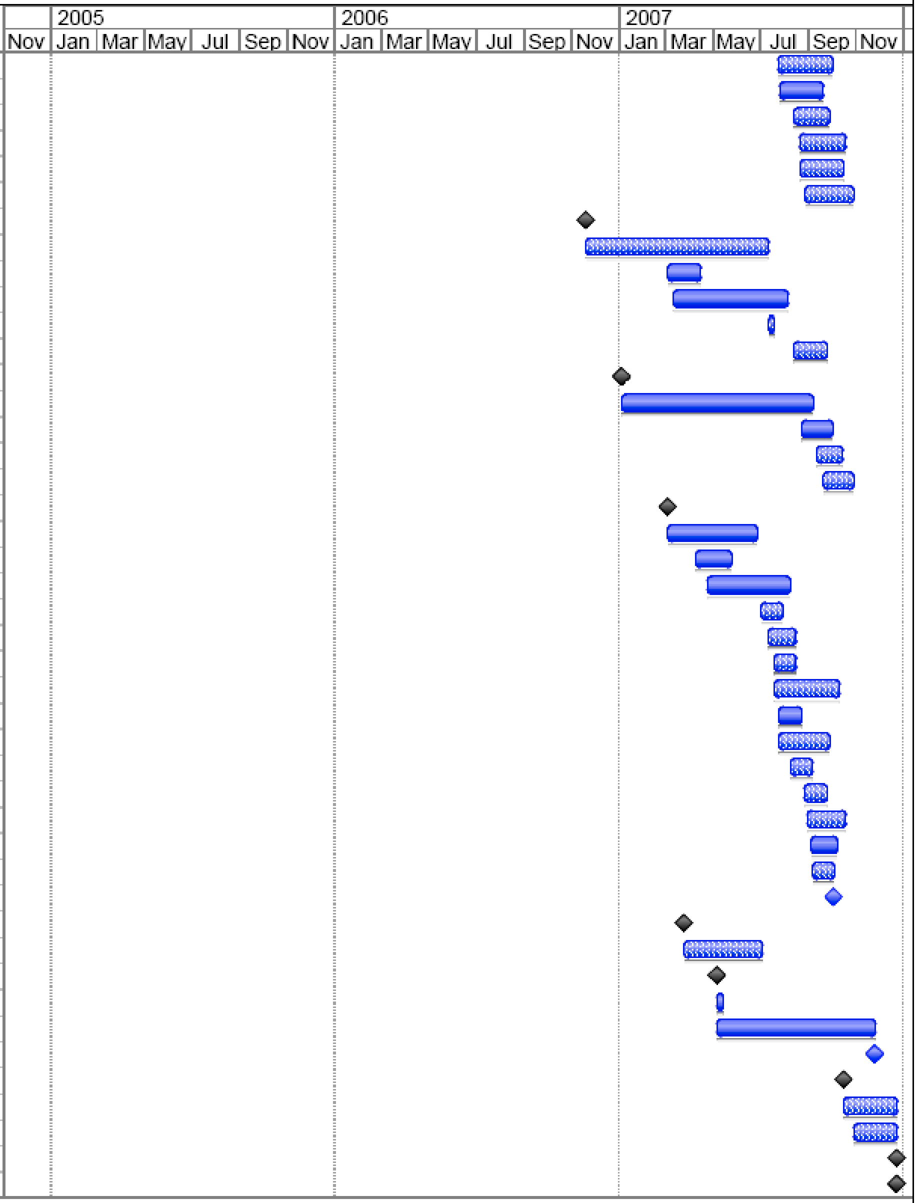
Task	▬	Summary	▬	Rolled Up Progress	▬	Project Summary	▬
Critical Activity	▨	Rolled Up Task	▬	Split	┈	Group By Summary	▬
Milestone	◆	Milestone	◆	External Tasks	▬	Deadline	⇩

City Hospital
Project Schedule

ID	Task Name	Duration	Start	Finish
91	Electrical Fire Alarm Devices/ Finishes (CUP)	50 days	Wed 7/25/07	Tue 10/2/07
92	Telecommunications/ Data Outlets/ Finishes(CUP)	40 days	Fri 7/27/07	Thu 9/20/07
93	Electrical Lighting Fixtures/ Finishes (Research)	34 days	Tue 8/14/07	Fri 9/28/07
94	Security, F/A, Data System Trimout (Research)	44 days	Tue 8/21/07	Fri 10/19/07
95	Electrical Security Devices/ Finishes (CUP)	40 days	Wed 8/22/07	Tue 10/16/07
96	Electrical Power Trimout (Research)	45 days	Tue 8/28/07	Mon 10/29/07
97	**Fire Protection**	**1 day**	**Mon 11/20/06**	**Mon 11/20/06**
98	Sprinklers Rough-in and Equip. Install. (CUP)	170 days	Mon 11/20/06	Thu 7/12/07
99	Corridor Fire Protection Rough-in (Research)	31 days	Mon 3/5/07	Mon 4/16/07
100	Install Fire Suppression System (Research)	106 days	Mon 3/12/07	Mon 8/6/07
101	Sprinklers Testing (CUP)	5 days	Fri 7/13/07	Thu 7/19/07
102	Install sprinkler Hood & Heads (Research)	31 days	Tue 8/14/07	Tue 9/25/07
103	**Equipment**	**1 day**	**Fri 1/5/07**	**Fri 1/5/07**
104	Metal Doors & Hardware- (Research)	177 days	Fri 1/5/07	Fri 9/7/07
105	Toilet & Locker Room Finishes (Research)	28 days	Fri 8/24/07	Tue 10/2/07
106	Metal Door & Hardware- (CUP)	24 days	Wed 9/12/07	Mon 10/15/07
107	Install Equip., Casework, & Furniture (Research)	27 days	Fri 9/21/07	Mon 10/29/07
108	**Finishes**	**1 day**	**Mon 3/5/07**	**Mon 3/5/07**
109	Layout Partitions (Research)	83 days	Mon 3/5/07	Wed 6/27/07
110	Stud Framing & Drywall (Research)	34 days	Tue 4/10/07	Fri 5/25/07
111	Hang Gypsum Board Walls (Research)	77 days	Wed 4/25/07	Thu 8/9/07
112	Frame Gypsum Board Ceilings (Research)	20 days	Tue 7/3/07	Mon 7/30/07
113	Hang Ceiling Gypsum Board (Research)	26 days	Thu 7/12/07	Thu 8/16/07
114	Ceiling and Flooring Painting- (CUP)	20 days	Fri 7/20/07	Thu 8/16/07
115	Interior Finishes- (CUP)	60 days	Fri 7/20/07	Thu 10/11/07
116	Ceramic Tile (Research)	21 days	Thu 7/26/07	Thu 8/23/07
117	Painting (Research)	47 days	Thu 7/26/07	Fri 9/28/07
118	Install Acoustical Ceiling- (CUP)	20 days	Fri 8/10/07	Thu 9/6/07
119	Lay-in Ceiling Tile	22 days	Mon 8/27/07	Tue 9/25/07
120	Resinous Floor Finish (Research)	36 days	Fri 8/31/07	Fri 10/19/07
121	Install Flooring (Research)	24 days	Wed 9/5/07	Mon 10/8/07
122	Install Flooring- (CUP)	20 days	Fri 9/7/07	Thu 10/4/07
123	Interior Finishes Complete	1 day	Thu 10/4/07	Thu 10/4/07
124	**ATC**	**1 day**	**Mon 3/26/07**	**Mon 3/26/07**
125	Install ATC Systems (Research)	73 days	Mon 3/26/07	Wed 7/4/07
126	**Elevators**	**1 day**	**Mon 5/7/07**	**Mon 5/7/07**
127	Elevator Installation (C.U.P.)	6 days	Mon 5/7/07	Mon 5/14/07
128	Elevator Installation (Research)	146 days	Mon 5/7/07	Mon 11/26/07
129	Elevators Finish	1 day	Mon 11/26/07	Mon 11/26/07
130	**Commissioning**	**1 day**	**Wed 10/17/07**	**Wed 10/17/07**
131	Punchlist	49 days	Wed 10/17/07	Mon 12/24/07
132	MEP Commissioning/ Test and Balance	40 days	Tue 10/30/07	Mon 12/24/07
133	Temp. Cert. of Occupany	1 day	Mon 12/24/07	Mon 12/24/07
134	Substanstial Completion	1 day	Mon 12/24/07	Mon 12/24/07



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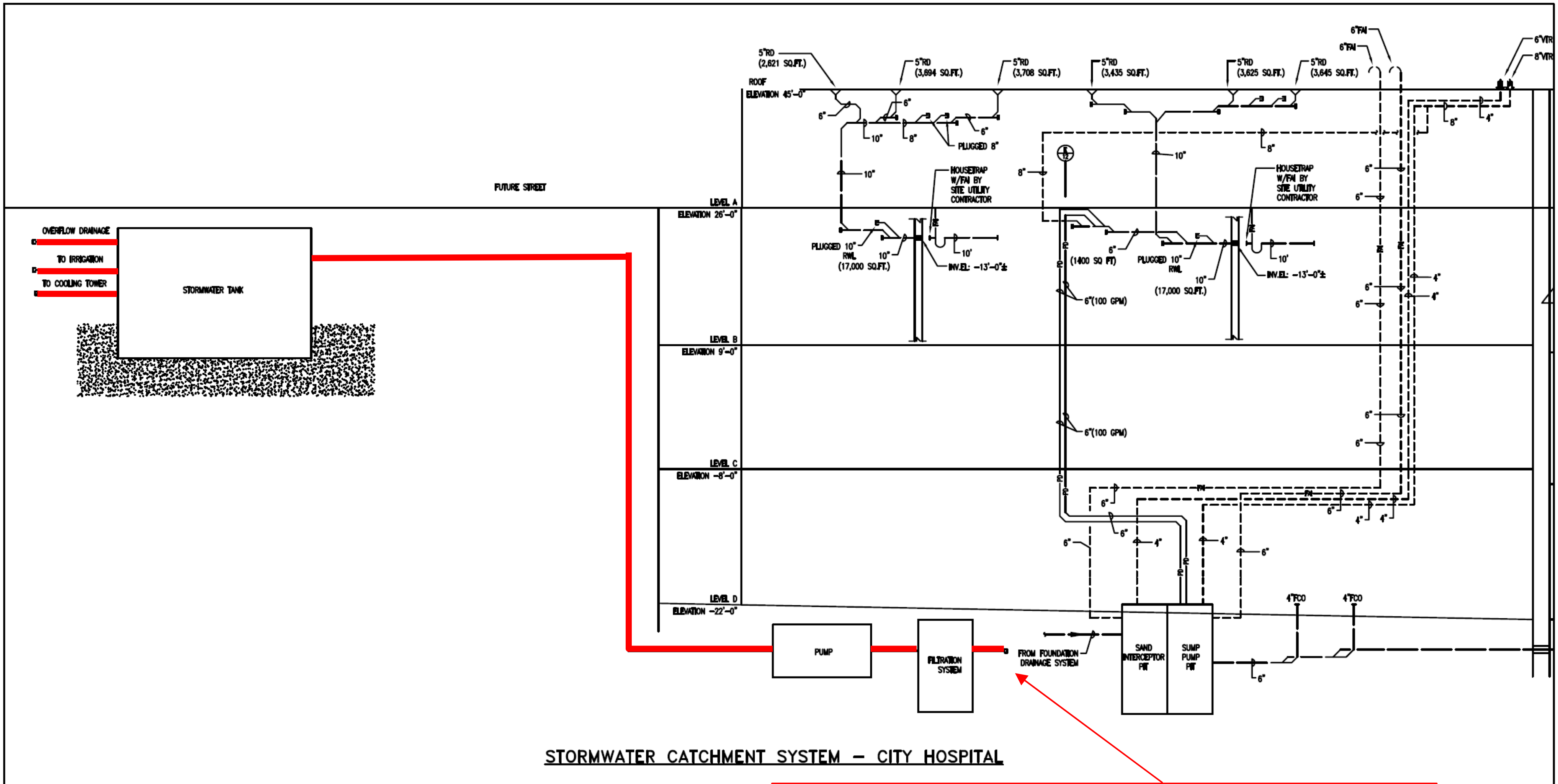
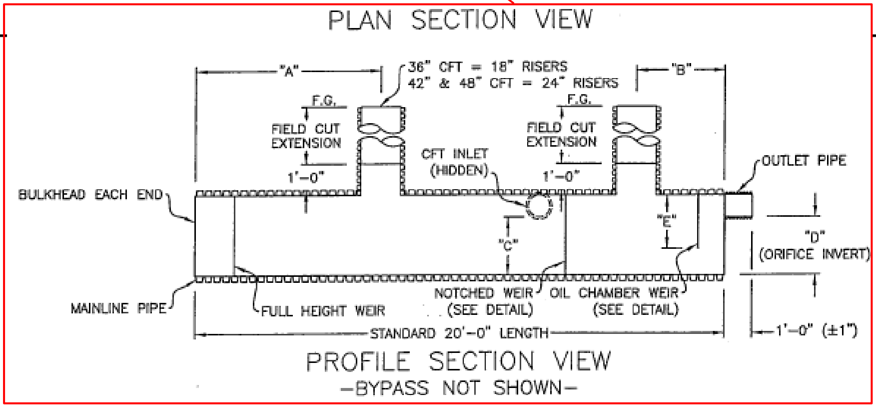
Task	▬	Summary	▬	Rolled Up Progress	▬	Project Summary	▬
Critical Activity	▨	Rolled Up Task	▬	Split	┅	Group By Summary	▬
Milestone	◆	Milestone	◆	External Tasks	▬	Deadline	⇩

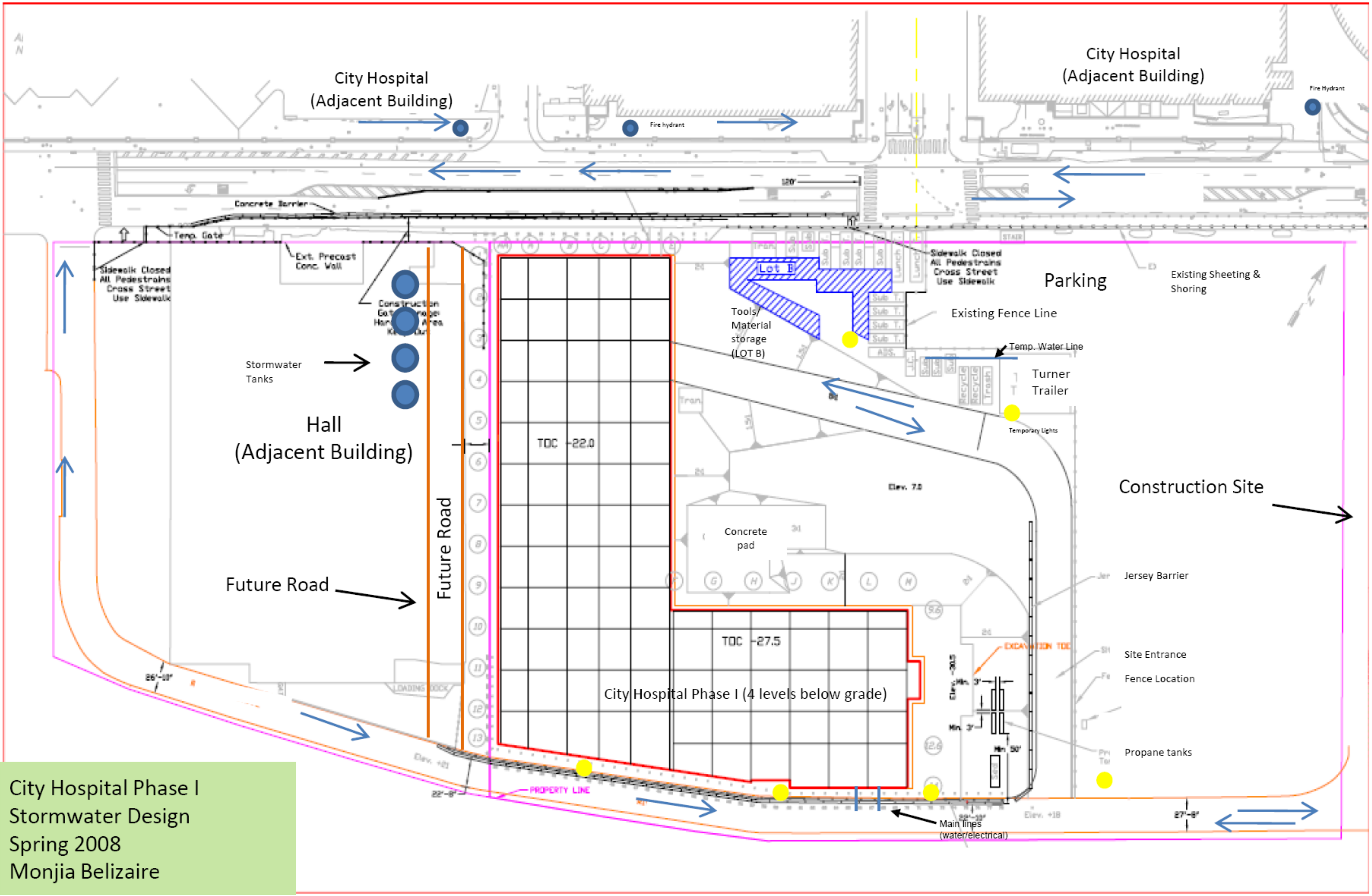
APPENDIX C : LEED® POINT EXECUTION



STORMWATER CATCHMENT SYSTEM – CITY HOSPITAL



http://www.lane-enterprises.com/



City Hospital Phase I
Stormwater Design
Spring 2008
Monjia Belizaire

APPENDIX D : ELECTRICAL PROPOSAL

NEC Table 310-16

Ampacities of Insulated Conductors Rated 0-2000 Volts, 60º to 90ºC

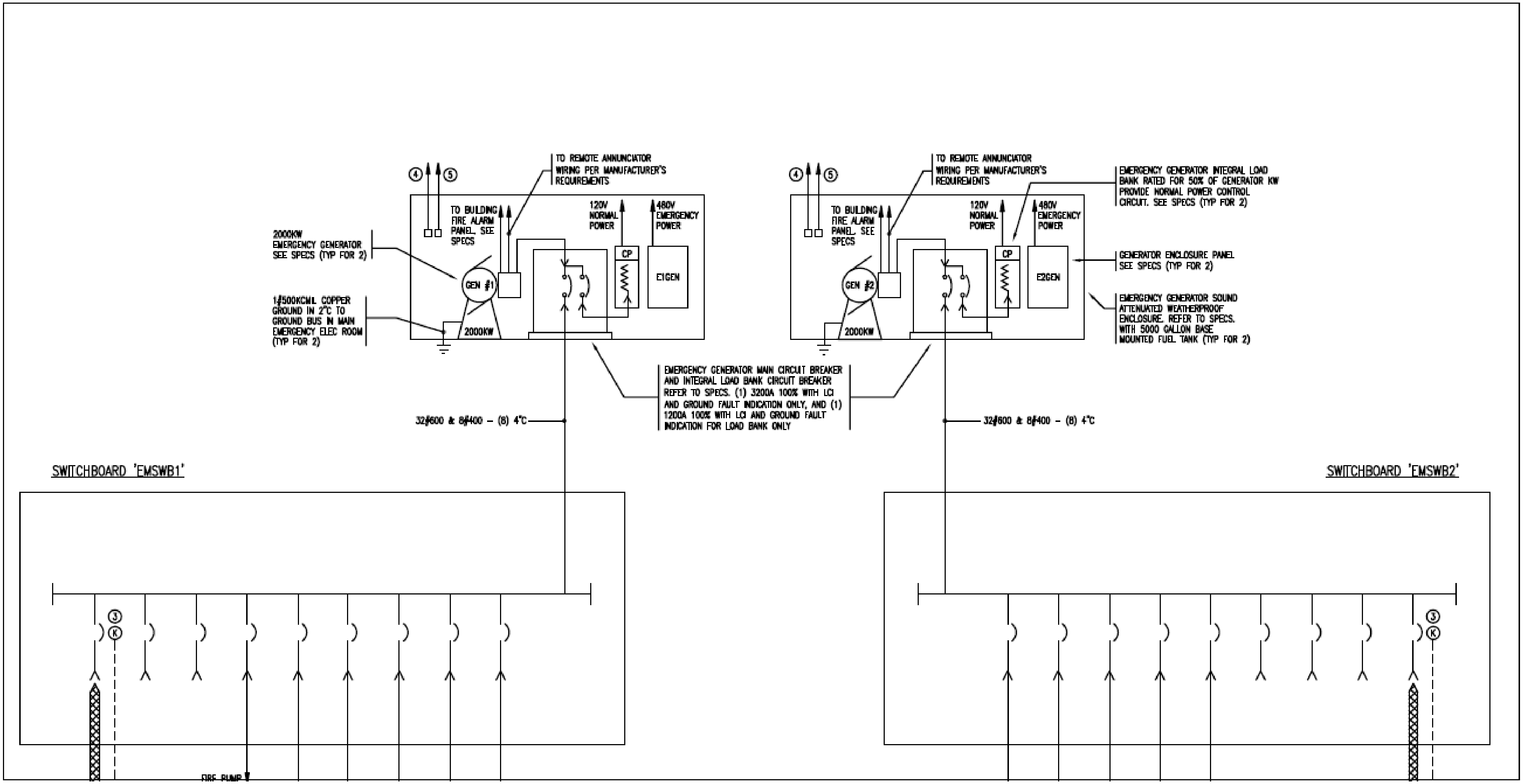
Not more than three conductors in raceway or cable or earth (directly buried).

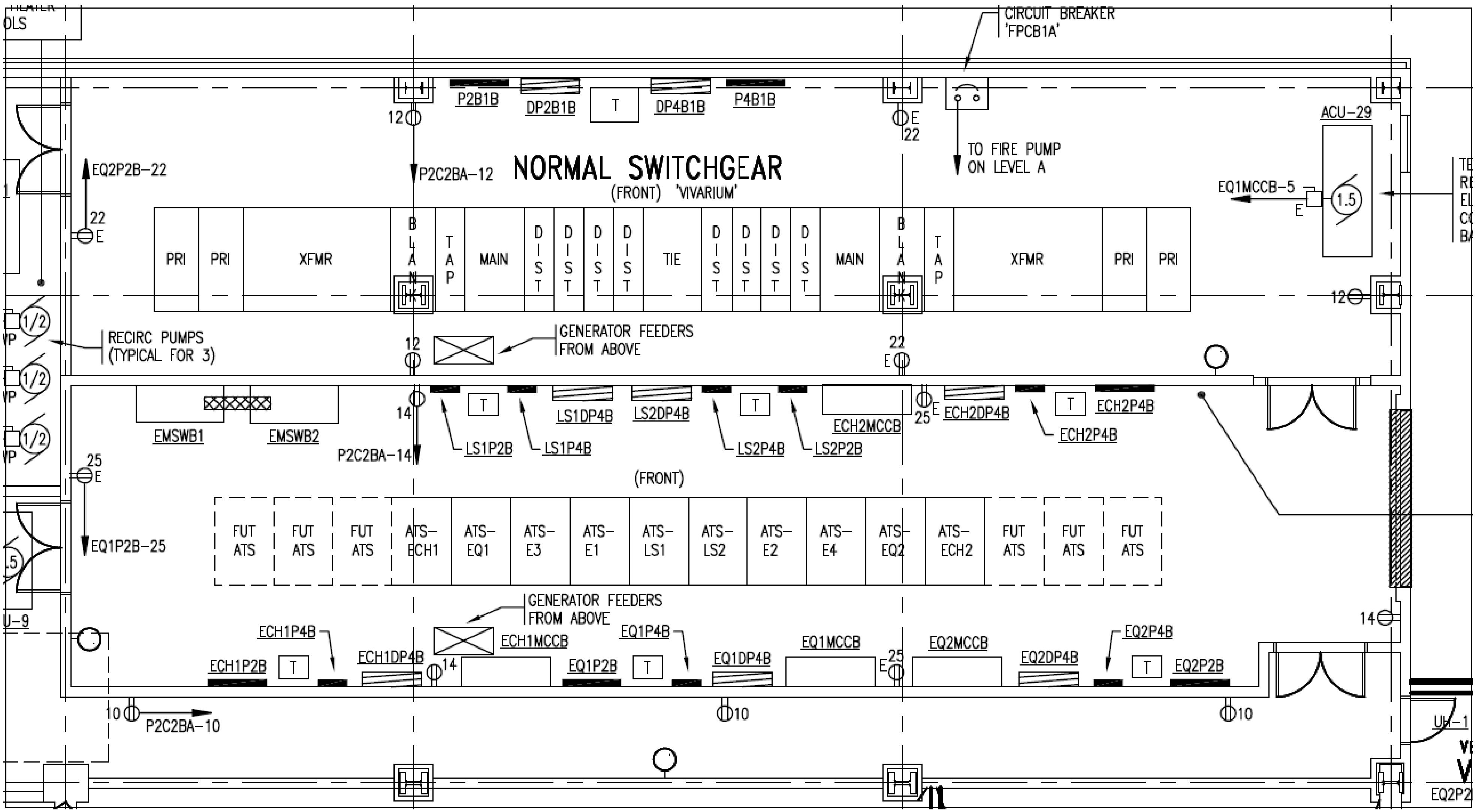
Based on ambient temperature of 30ºC (86ºF)

Size	Temperature Rating of Conductor						Size
AWG	60ºC (140ºF)	75ºC (167ºF)	90ºC (194ºF)	60ºC (140ºF)	75ºC (167ºF)	90ºC (194ºF)	AWG
	Types	Types	Types	Types	Types	Types	
	T TW UF	THW THWN XHHW USE	RHH THHN XHHW	T TW UF	THW THWN XHHW USE	RHH THHN XHHW	
	Copper			Aluminum			
14	20	20	25	----	----	----	----
12	25	25	30	20	20	25	12
10	30	35	40	25	30	35	10
8	40	50	55	30	40	45	8
6	55	65	75	40	50	60	6
4	70	85	95	55	65	75	4
3	85	100	110	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	150	85	100	115	1
0	125	150	170	100	120	135	0
00	145	175	195	115	135	150	00
000	165	200	225	130	155	175	000
0000	195	230	260	150	180	205	0000
250	215	255	290	170	205	230	250
300	240	285	320	190	230	255	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	355	420	475	285	340	385	600
700	385	460	520	310	375	420	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	450	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000

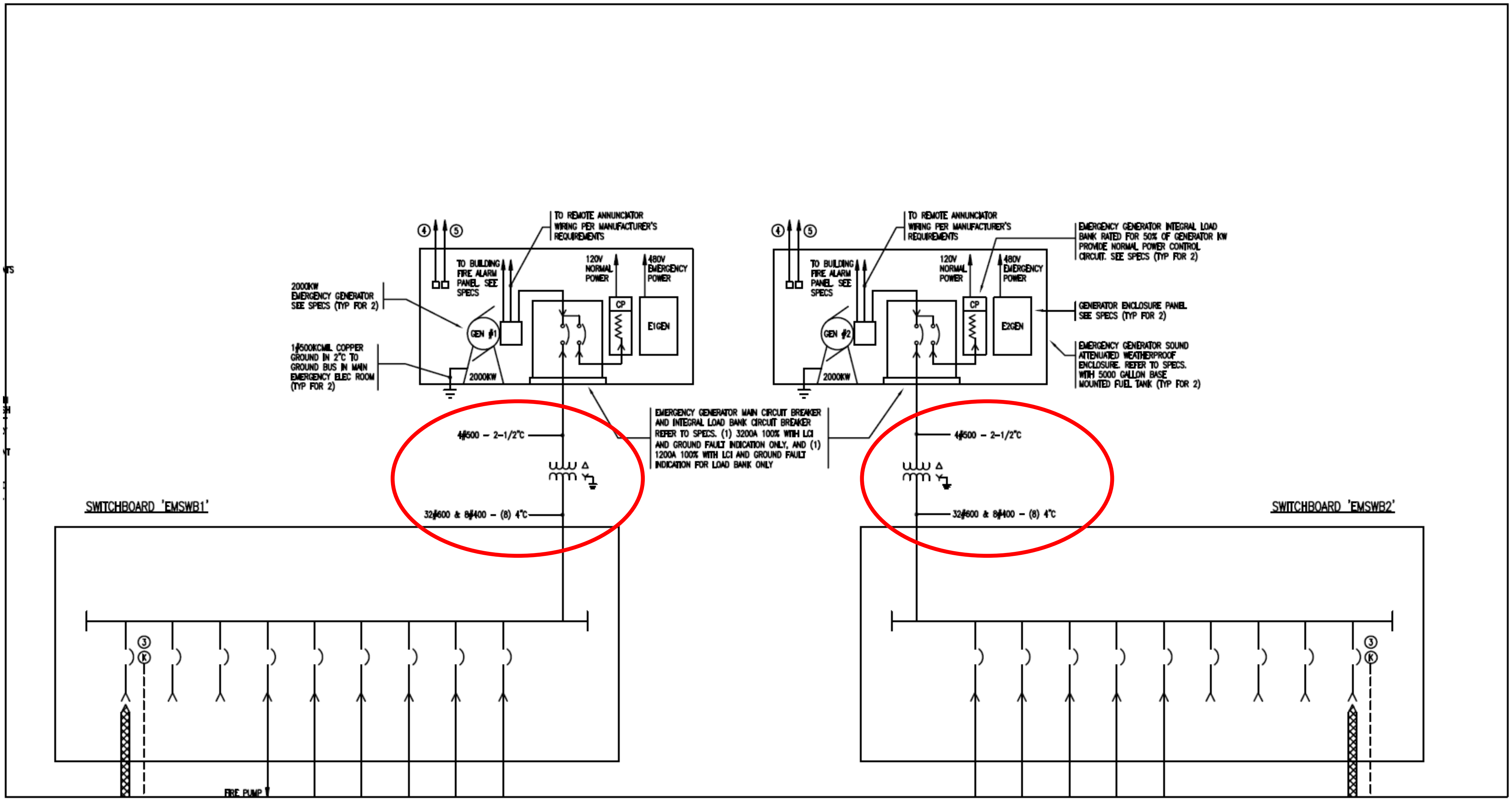
http://www.mc2-ice.com/support/estref/popular_conversion_files/electrical/insulated_conductors.html

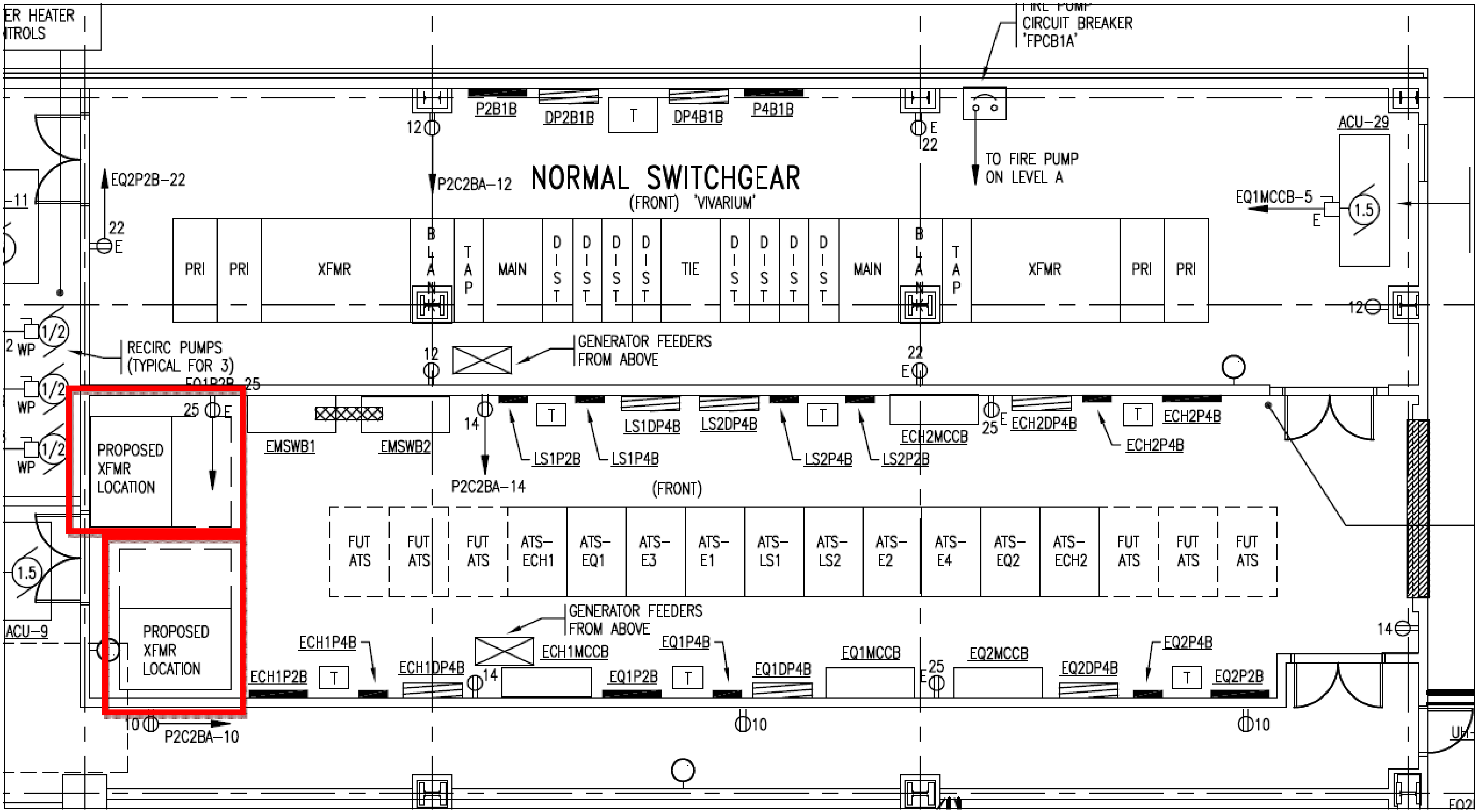
Existing System




CIRCUIT BREAKER 'FPCB1A'
P2B1B
DP2B1B
T
DP4B1B
P4B1B
12
E 22
TO FIRE PUMP ON LEVEL A
ACU-29
EQ2P2B-22
P2C2BA-12
NORMAL SWITCHGEAR
(FRONT) 'VIVARIUM'
EQ1MCCB-5
E
1.5
22 E
PRI
PRI
XFMR
BLANK
TAP
MAIN
DIST
DIST
DIST
DIST
TIE
DIST
DIST
DIST
DIST
MAIN
BLANK
TAP
XFMR
PRI
PRI
12
1/2
RECIRC PUMPS (TYPICAL FOR 3)
12
GENERATOR FEEDERS FROM ABOVE
22 E
1/2
1/2
14
T
T
LS1DP4B
LS2DP4B
ECH2MCCB
25 E
ECH2DP4B
T
ECH2P4B
EMSWB1
EMSWB2
LS1P2B
LS1P4B
LS2P4B
LS2P2B
ECH2P4B
P2C2BA-14
25 E
(FRONT)
FUT ATS
FUT ATS
FUT ATS
ATS-ECH1
ATS-EQ1
ATS-E3
ATS-E1
ATS-LS1
ATS-LS2
ATS-E2
ATS-E4
ATS-EQ2
ATS-ECH2
FUT ATS
FUT ATS
FUT ATS
EQ1P2B-25
U-9
GENERATOR FEEDERS FROM ABOVE
14
ECH1P4B
ECH1MCCB
EQ1P4B
EQ1MCCB
EQ2MCCB
EQ2P4B
ECH1DP4B
14
EQ1DP4B
25 E
EQ2DP4B
ECH1P2B
T
EQ1P2B
T
T
EQ2P2B
10
P2C2BA-10
10
10
UH-1
EQ2P2

Proposed System




ER HEATER
ITROLS
FIRE PUMP
CIRCUIT BREAKER
'FPCB1A'
P2B1B
DP2B1B
T
DP4B1B
P4B1B
12
E
22
TO FIRE PUMP
ON LEVEL A
ACU-29
EQ2P2B-22
P2C2BA-12
NORMAL SWITCHGEAR
(FRONT) 'VIVARIUM'
EQ1MCCB-5
1.5
E
-11
22
E
PRI
PRI
XFMR
BLANK
TAP
MAIN
DIST
DIST
DIST
DIST
TIE
DIST
DIST
DIST
DIST
MAIN
BLANK
TAP
XFMR
PRI
PRI
12
1/2
WP
RECIRC PUMPS
(TYPICAL FOR 3)
GENERATOR FEEDERS
FROM ABOVE
12
22
E
EQ1P2B-25
25
E
PROPOSED
XFMR
LOCATION
EMSWB1
EMSWB2
14
P2C2BA-14
T
LS1P2B
LS1P4B
LS1DP4B
LS2DP4B
T
LS2P4B
LS2P2B
ECH2MCCB
25
E
ECH2DP4B
ECH2P4B
T
ECH2P4B
(FRONT)
FUT ATS
FUT ATS
FUT ATS
ATS-ECH1
ATS-EQ1
ATS-E3
ATS-E1
ATS-LS1
ATS-LS2
ATS-E2
ATS-E4
ATS-EQ2
ATS-ECH2
FUT ATS
FUT ATS
FUT ATS
1.5
ACU-9
PROPOSED
XFMR
LOCATION
GENERATOR FEEDERS
FROM ABOVE
ECH1P4B
ECH1MCCB
EQ1P4B
EQ1MCCB
EQ2MCCB
EQ2P4B
14
ECH1P2B
T
ECH1DP4B
14
EQ1P2B
T
EQ1DP4B
E
25
EQ2DP4B
T
EQ2P2B
10
P2C2BA-10
10
10
UH-
EQ2

Dry-Type Transformers

Product Offering

- VPI, VPE, RESIBLOC®, Cast
- 113 kVA – 25 MVA
- Up to 46 kV, 150 kV BIL primary
- Up to 15 kV secondary

Standards

- ANSI C57.12.01/C57.12.91
- UL® available
- Seismic Zone 4 certification

Industry Applications

- Commercial and institutional
- Industrial users (petrochemical, oil & gas, pulp & paper/forest)
- Utilities

VPI/VPE Dry-Type Transformers

Application

The Eaton's Cutler-Hammer VPI and VPE transformers are custom designed dry-type power transformers which give environmental protection, for both indoor and outdoor applications. The transformers are explosion resistant, fire resistant, non-polluting to the environment, and ideally suitable for use in coordinated unit substations. Typical applications of VPI/VPE transformers are:

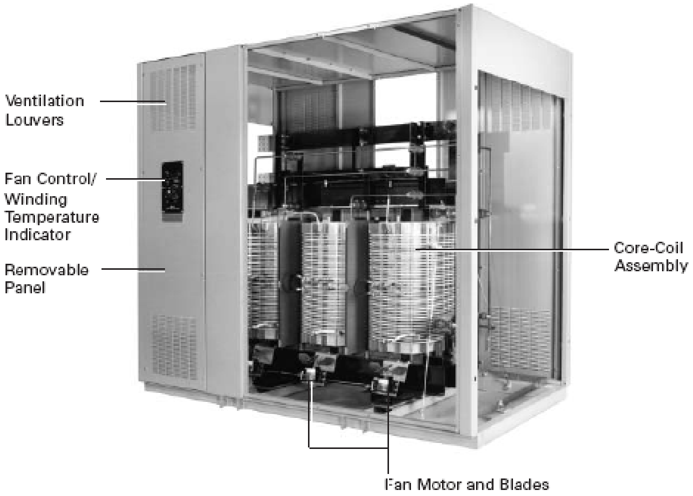
- Schools, hospitals, shopping centers.
- High-rise buildings.
- Industrial environments.

Benefits

- Custom design flexibility to meet special customer needs and applications.
- Computerized loss-evaluated designs for specific customer load and evaluation criteria.
- Environmental protection.
- Low maintenance.
- High short circuit strength.
- ANSI short time overload capability.
- Aluminum or copper windings.
- Available in NEMA 1, 2 and 3R enclosures.
- Economical.

Ratings

- 112.5 kVA – 3,750 kVA.
- Primary voltages: 600 V – 35 kV.
- Primary BIL: up to 150 kV.
- Secondary voltages: 120 V – 15 kV.
- Secondary BIL: up to 75 kV.
- Temperature rise: 80/115/150°C.



Dry-Type Substation Transformer

Design and Technology

The dry-type transformers are custom designed and manufactured with coils insulated with 220°C Class H Nomex®, insulation system. Environmental protection is provided by vacuum pressure impregnation with polyester resin (VPI). Enhanced environmental protection is available through the use of silicone resin encapsulation (VPE). The VPE process provides 4-cycle enhanced environmental protection. The entire core and coil assembly is vacuum pressure encapsulated with a silicone resin per MIL-1-24092. Both systems are superior to the conventional dry-type technology known as "Dip and Bake." Both resin types, and Nomex, insulation system are 220°C Class H rated. Transformers with Class H insulation are suitable for use up to 150°C average rise over a maximum ambient temperature of 40°C, not to exceed 30°C average for any 24-hour period. Other temperature rise options are 80°C and 115°C, which allow the transformer to be overloaded up to 150°C rise.

Taps are provided on the central section of the HV coil face. Taps are accessed by removing enclosure panels, and taps are changed by moving the flexible bolted links from one connecting point to the other. To simplify these changes, the connection points are clearly identified.

Material used for cores is non-aging, cold rolled, high permeability, grain-oriented silicone steel. Cores are constructed with step lap mitered joints and are rigidly braced to reduce sound levels and losses in the finished product.

To reduce the transfer of noise to the case, the core is mounted on neoprene rubber vibration dampeners. The core is electrically grounded by means of a flexible ground braid.

The enclosure has removable panels for access to taps and for core and coil inspection. The complete case can be removed and knocked down to reduce size and weight for rigging into tight locations.

VPI and VPE Ventilated Dry-Type

Table 14.0-22. Aluminum Windings, Standard Design, Delta-Wye, 60 Hz, Indoor, 600 Volt LV Class at 10 kV BIL, Indoor ①

150°C Rise

kVA	HV, kV	HV BIL, kV ②	Dimensions in Inches (mm) H_{TX}	W_{TX}	D_{TX}	Weight Lbs. (kg)
300	5	60	90 (2286.0)	78 (1981.2)	60 (1524.0)	3200 (1453)
	15	95	90 (2286.0)	84 (2133.6)	60 (1524.0)	3600 (1634)
	27	125	102 (2590.8)	90 (2286.0)	66 (1676.4)	4000 (1816)
	38	150	102 (2590.8)	102 (2590.8)	68 (1727.2)	4500 (2043)
500	5	60	90 (2286.0)	78 (1981.2)	60 (1524.0)	4400 (1998)
	15	95	90 (2286.0)	90 (2286.0)	60 (1524.0)	4600 (2088)
	27	125	102 (2590.8)	102 (2590.8)	66 (1676.4)	5000 (2270)
	38	150	102 (2590.8)	114 (2895.6)	68 (1727.2)	5500 (2497)
750	5	60	90 (2286.0)	84 (2133.6)	60 (1524.0)	5500 (2497)
	15	95	90 (2286.0)	96 (2438.4)	66 (1676.4)	6200 (2815)
	27	125	102 (2590.8)	114 (2895.6)	68 (1727.2)	6500 (2951)
	38	150	102 (2590.8)	114 (2895.6)	72 (1828.8)	7000 (3178)
1000	5	60	90 (2286.0)	84 (2133.6)	66 (1676.4)	6300 (2860)
	15	95	90 (2286.0)	96 (2438.4)	66 (1676.4)	7400 (3360)
	27	125	112 (2844.8)	120 (3048.0)	68 (1727.2)	7500 (3405)
	38	150	112 (2844.8)	120 (3048.0)	78 (1981.2)	8000 (3632)
1500	5	60	90 (2286.0)	84 (2133.6)	66 (1676.4)	8200 (3723)
	15	95	90 (2286.0)	96 (2438.4)	66 (1676.4)	9300 (4222)
	27	125	112 (2844.8)	126 (3200.4)	68 (1727.2)	10,000 (4540)
	38	150	120 (3048.0)	132 (3352.8)	78 (1981.2)	10,500 (4767)
2000	5	60	90 (2286.0)	96 (2438.4)	66 (1676.4)	9400 (4268)
	15	95	90 (2286.0)	108 (2743.2)	66 (1676.4)	10,500 (4767)
	27	125	120 (3048.0)	132 (3352.8)	72 (1828.8)	12,000 (5448)
	38	150	124 (3149.6)	132 (3352.8)	78 (1981.2)	12,500 (5675)
2500	5	60	90 (2286.0)	102 (2590.8)	66 (1676.4)	11,700 (5312)
	15	95	102 (2590.8)	108 (2743.2)	66 (1676.4)	13,000 (5002)
	27	125	130 (3302.0)	138 (3505.2)	78 (1981.2)	14,500 (6583)
	38	150	130 (3302.0)	144 (3657.6)	78 (1981.2)	15,000 (6810)
3000	5	60	102 (2590.8)	108 (2743.2)	66 (1676.4)	15,000 (6810)
	15	95	112 (2844.8)	120 (3048.0)	66 (1676.4)	16,000 (7264)
	27	125	120 (3048.0)	144 (3657.6)	78 (1981.2)	18,000 (8172)
	38	150	140 (3556.0)	150 (3810.0)	78 (1981.2)	19,000 (8626)
3750	5	60	102 (2590.8)	114 (2895.6)	66 (1676.4)	16,000 (7264)
	15	95	112 (2844.8)	120 (3048.0)	66 (1676.4)	17,000 (7718)
	27	125	125 (3175.0)	144 (3657.6)	78 (1981.2)	19,000 (8626)
	38	150	120 (3048.0)	150 (3810.0)	78 (1981.2)	21,000 (9534)

80° or 115°C Rise

kVA	HV, kV	HV BIL, kV ②	Dimensions in Inches (mm) ① H_{TX}	W_{TX}	D_{TX}	Weight Lbs. (kg)
300	5	60	90 (2286.0)	78 (1981.2)	60 (1524.0)	4000 (1816)
	15	95	90 (2286.0)	90 (2286.0)	60 (1524.0)	5000 (2270)
	27	125	102 (2590.8)	96 (2438.4)	66 (1676.4)	6000 (2724)
	38	150	102 (2590.8)	108 (2743.2)	66 (1676.4)	6500 (2951)
500	5	60	90 (2286.0)	84 (2133.6)	60 (1524.0)	5200 (2361)
	15	95	90 (2286.0)	96 (2438.4)	60 (1524.0)	5900 (2633)
	27	125	102 (2590.8)	102 (2590.8)	66 (1676.4)	7000 (3178)
	38	150	102 (2590.8)	108 (2743.2)	68 (1727.2)	7500 (3405)
750	5	60	90 (2286.0)	90 (2286.0)	66 (1676.4)	6200 (2815)
	15	95	90 (2286.0)	102 (2590.8)	66 (1676.4)	7000 (3178)
	27	125	102 (2590.8)	114 (2895.6)	72 (1828.8)	8000 (3632)
	38	150	102 (2590.8)	114 (2895.6)	78 (1981.2)	8500 (3859)
1000	5	60	90 (2286.0)	90 (2286.0)	66 (1676.4)	7900 (3541)
	15	95	90 (2286.0)	102 (2590.8)	66 (1676.4)	8750 (3972)
	27	125	112 (2844.8)	120 (3048.0)	72 (1828.8)	9500 (4313)
	38	150	112 (2844.8)	126 (3200.4)	78 (1981.2)	10,000 (4540)
1500	5	60	90 (2286.0)	96 (2438.4)	66 (1676.4)	9500 (4313)
	15	95	102 (2590.8)	108 (2743.2)	66 (1676.4)	10,500 (4767)
	27	125	112 (2844.8)	132 (3352.8)	78 (1981.2)	11,000 (4994)
	38	150	112 (2844.8)	132 (3352.8)	78 (1981.2)	11,500 (5221)
2000	5	60	90 (2286.0)	102 (2590.8)	66 (1676.4)	12,000 (5448)
	15	95	102 (2590.8)	108 (2743.2)	66 (1676.4)	13,000 (5002)
	27	125	120 (3048.0)	138 (3505.2)	78 (1981.2)	13,200 (5993)
	38	150	120 (3048.0)	138 (3505.2)	78 (1981.2)	13,500 (6129)
2500	5	60	90 (2286.0)	120 (3048.0)	66 (1676.4)	15,000 (6810)
	15	95	112 (2844.8)	126 (3200.4)	66 (1676.4)	15,900 (7173)
	27	125	130 (3302.0)	144 (3657.6)	78 (1981.2)	16,000 (7264)
	38	150	130 (3302.0)	150 (3810.0)	78 (1981.2)	16,500 (7491)
3000	5	60	102 (2590.8)	126 (3200.4)	66 (1676.4)	17,000 (7718)
	15	95	112 (2844.8)	144 (3657.6)	66 (1676.4)	18,000 (8172)
	27	125	130 (3302.0)	144 (3657.6)	78 (1981.2)	20,000 (9080)
	38	150	140 (3556.0)	150 (3810.0)	78 (1981.2)	22,000 (9988)
3750	5	60	102 (2590.8)	126 (3200.4)	66 (1676.4)	18,000 (8172)
	15	95	112 (2844.8)	144 (3657.6)	66 (1676.4)	19,000 (8626)
	27	125	130 (3302.0)	150 (3810.0)	78 (1981.2)	22,000 (9988)
	38	150	140 (3556.0)	150 (3810.0)	78 (1981.2)	24,000 (10,896)

① For outdoor base construction, add 12 inches (304.8 mm) to height and 6 inches (152.4 mm) to width and depth. Roof overhangs 8.5 inches (215.9 mm) front and rear.

② 30 kV BIL is standard for 5 kV class; 60 kV BIL is available as an option. 60 kV BIL is standard for 15 kV class; 95 kV BIL is available as an option.

Note: Smaller dimensions/weights may be available, refer to Eaton.

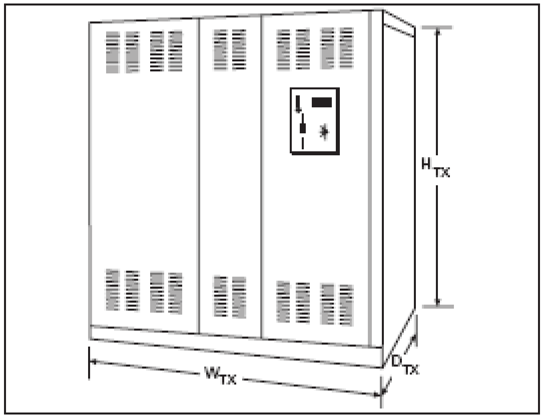


Figure 14.0-14. Indoor Ventilated Enclosure (NEMA 1 Construction)

Dimensions for estimating purposes only.