Aria Health Emergency Department Expansion

Philadelphia, Pennsylvania

FINAL REPORT

Robert M. Stano

APRIL 9TH, 2014 | ADVISER: DR. CHIMAY ANUMBA

Aria Health

Emergency Department

Expansion

Philadelphia, PA

AE | Bob Stano
Construction

Building Information

Name: ED Expansion

Owner: Aria Health System - Torresdale Campus

Location: 10800 Knights Road, Philadelphia, PA

Size: 80,000SF

Stories: 1 Below, 2 Above

Project Team

Architect: Francis Cauffman Architects

CM: Turner Construction Company

Structural Engineer: O'Donnell & Naccarato

MEP Engineer: PWI Engineering

Civil Engineer: Barry Isett & Associates, Inc.

Construction Information

- Design—Bid—Build
- 80,000SF
- $35 Million Total Cost
- Extensive Site and Structure Demolition
- Site Utility Relocation

Structural

- Concrete Foundation
- Steel Superstructure w/ Composite Beam and Deck Assembly
- Lightweight Concrete used in certain locations

Architectural

- Composite Metal Paneling
- Face Brick and Painted Concrete Panels
- Aluminum Curtain Wall w/ Insulated Glass

Mechanical

- Chiller/Boiler w/ Cooling Tower and Heat Exchanger
- VAV System w/ Supplementary Fan Coil Units and Unit Heaters
- Roof Top AHUs w/ EFs and DOAS Unit in Mechanical Room

Electrical

- New Medium Voltage Switchgear
- Site Electric Replacement
- 1MW Generator for Critical Backup
- 480/277V Substation in Mechanical Room

ARIA HEALTH

Turner Construction Company

Executive Summary

Throughout the 2013-2014 school year, a comprehensive study of the Aria Health Emergency Department Expansion project located in Philadelphia, Pennsylvania was performed. Detailed reports of the building systems, project cost and schedule, site logistics, and project delivery method were compiled after months of examination during the fall semester. After which, a final proposal was written to portray the changes that could have been implemented on the project for improvement. During the spring semester, four separate depth analyses were performed, including the implementation of a rainwater collection system for gray water reuse, the addition of 180 photovoltaic modules for self-production of electricity, an energy analysis due to the addition of operable solar shading devices, as well as a research study on the modularization of 42 patient treatment rooms.

Analysis 1 – Rainwater Collection

After calculating the total amount of rainfall per year based on historical weather data for Philadelphia, the building rainwater conductor riser diagram was used to find the total possible rainwater collection. The total gray water usage for sewage conveyance was then calculated based the flow rates for each of the specified water closets and urinals and an assumed value for flushes per day. It was found that total of 82,162.5 gallons of water was used monthly for flushing, which was below the monthly rainfall value of 93,792.09 gallons. A rainwater harvesting system was then designed around a 20,000 gallon storage tank, where all the associated piping, booster pumps, filters, valves, and hydropneumatic tanks were designed. The piping was then laid out within the building framework, along with specified manufacturers for each of the system components. After layout, two different detailed cost estimates were performed, to show the difference in cost between a copper and steel arrangement versus a PVC arrangement. The direct costs for the PVC piping system, including each of the required system components, was found to be $146,680.40. After finding an initial cost for the system, a comprehensive economic analysis was performed to depict the amount of time the system would take to pay for itself, along with the cumulative income produced over time. The payback period for the system as designed was found to be 12.18 years, while the cumulative income over a 25 year period was found to be $281,105.50.

Analysis 2 – Photovoltaic Array

Before performing the analysis for the addition of a photovoltaic array, a solar study was first conducted to determine where each of the modules should be located on the roof of the building. This was done in order to show the shading due to the parapet wall, as well as the modules themselves. After the solar study was done, the system had to be designed. The Sharp ND-F4Q300 300 watt solar panel was chosen as the basis of design, around which the entire system was formulated. It was decided that 180 photovoltaic modules would be added for a total of 54,000 kilowatts DC, or 44.3 kilowatts AC, all wired into five different groupings. Each of the five groupings consisted of six modules in series strings, with six of those series strings wired in parallel. Each of the conductors were sized accordingly, after which a wiring layout was performed in order to perform quantity take-offs. The entire system was designed, including the panels themselves, inverters, circuit breakers, disconnects, conductors, and racking system with specified manufacturers. A cost estimate was performed, where a grand total price was found to be $211,958.98, or $4.78 per usable watt. After the initial cost was found, an in-depth economic analysis was performed after finding the system capacity for electricity production. It was found that the system could potentially save $6,949.60 in utility costs annually. Taking several different factors into account, a payback period of 19.52 years was determined, with a cumulative tax exempt income of $94,467.20 over a 25 year period.

Analysis 3 – Operable Solar Shading

With the vast majority of the building curtain wall system facing southeast, operable solar shading devices were decided as a viable option to combat solar gain during the peak load times of the year. Colt Shadoglass, a product specifically designed for the intent stated above, was analyzed as an addition to the existing building façade. The system employs glass blades that allow natural light into the building almost exclusively, while simultaneously rejecting solar radiation back into the atmosphere. A conceptual cost estimate was performed, where the initial cost of the system was found to be $442,533.33. A site logistics plan, schedule, and installation phasing plan were included to show how the system would be constructed. The addition of the Colt Shadoglass was found not to affect the existing critical path of the project. In order to quantify cooling cost saving due to the Colt Shadoglass, an energy model was produced using IES Virtual Environment. After performing the energy model, it was found that an annual reduction of 46,220.7 BTU/h, or 20% reduction from the baseline data was possible, which equates to a $935.97 savings in cooling costs yearly. In addition to energy savings, it was found that a total of 12,856 lbs of greenhouse gas emissions could be kept from entering the earth's atmosphere. This 20% reduction in cooling load was then used to resize a section of ductwork present in the space that was modeled in IES.

Analysis 4 – Modularization of Patient Treatment Rooms

For the purpose of schedule reduction, modular construction techniques were researched and implemented into the Aria Health ED Expansion project. 42 patient treatment rooms were broken out into individual modules to be prefabricated in an off-site facility located 1.1 miles from the actual project site. Several different media were utilized during research, including online articles, peer reviewed journals, and interviews held with industry professionals experienced in modular construction. Off-site locations and shipping procedures were investigated, after which a site logistics plan was produced to show truck traffic on-site and how the modules would be set into place. A schedule was produced in order to quantify a savings of 15 days from the project critical path.

In conclusion, it was decided that only two of the four aforementioned analyses are recommended for implementation into the existing project. With only a 12.18 year payback and a cumulative income of $281,105.50, the rainwater collection system would serve as a valuable resource conservation technique and is recommended due to its income generation. The integration of a photovoltaic array, however, is not recommended due to its high initial investment and 19.52 year payback. The cumulative income is also not worth the upfront cost. The addition of the Colt Shadoglass system onto the façade is also not recommended, as the savings in cooling costs are not substantial enough to rectify a $442,533.33 investment. Lastly, modularization of the 42 patient treatment rooms is recommended for its critical path duration savings of 15 days.

Acknowledgements

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Dr. Chimay Anumba, FREng., Ph.D., D.Sc., Dr.h.c., P.E.

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All of my friends and family

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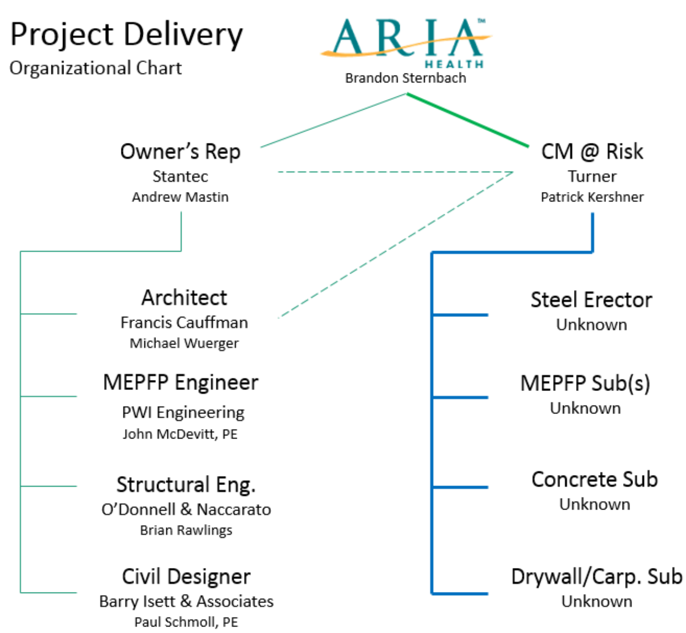
Building Information

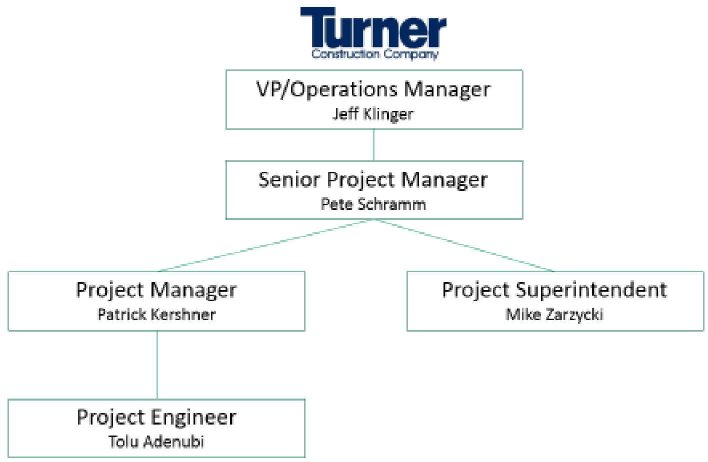
Aria Health systems is the largest healthcare provider within the Northeast Philadelphia and Lower Bucks County areas. In response to the need for higher emergency medical care capacity, Aria has decided to proceed with the $35 Million Emergency Department Expansion Project. With the many additional triage patient rooms, the increased floor area will provide less wait time for those needing immediate care. The new "Rapid Assessment" approach to emergency medicine will help doctors sort through less urgent patient cases, ultimately limiting the duration of overnight hospital stay. To get the project moving, budget was initially the owner's primary concern. As the project has progressed, managing that budget in conjunction with meeting an aggressive schedule has proved vital. The project coincides with an existing and fully operational hospital, in which patient and public disturbance must be kept to an absolute minimum. The operational logistics and rerouting of patient and staff has proven to be a difficult transition.

Project Team

Aria Health has hired Stantec as their representative throughout the design and construction process. Stantec fulfills the day-to-day role of the owner on-site. Turner Construction Company has been awarded the project based on qualifications and performed preconstruction services during the schematic and development phases of design, through the completion of construction documents. Turner has been contracted as a CM at Risk directly to Aria, in which the GMP was agreed upon with 100% of construction documents complete. Each of the subcontractors have been contractually bound to Turner through Lump Sum agreements in a traditional design-bid-build format. The Architect responsible for

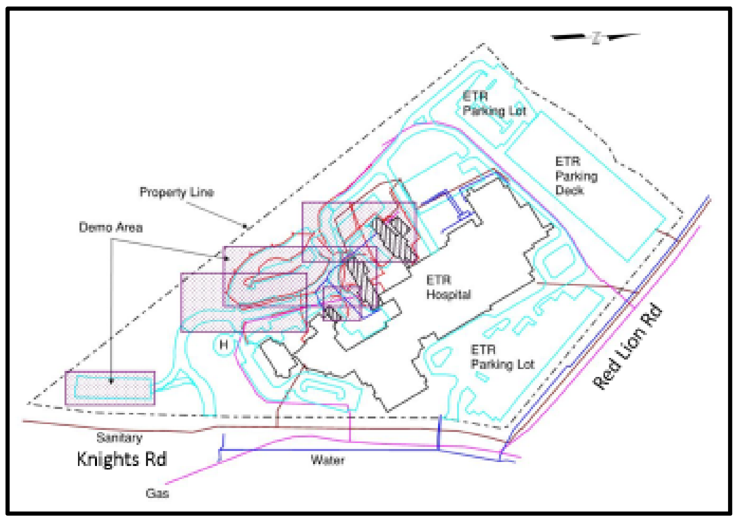


design is Francis Cauffman, with whom Turner has direct communication. The contractual agreements between Aria, Stantec, and the Design Team are unknown. The staffing arrangement for Aria ED Expansion Project Team consists of Patrick Kershner, Turner Project Manager, Tolu Adenubi, Project Engineer, and Mike Zarziycki, Superintendent, each of whom reside on site full-time. Pete Schramm, the Vice President and Operations Manager, as well as Jeff Klinger, Senior Project Manager, are located in the Philadelphia office for Turner Construction Company.



Existing Conditions

The existing site and utility conditions for the Aria site consist of gas, water, and sanitary mains to the East of the property line beneath Red Lion Road. Each of the mains then continue along Knights Road to the South. There are utility main taps off of Red Lion and Knights roads, each of which enter the existing hospital in different locations. The existing underground electric to the West of the existing building is a complicated labyrinth. There are several existing roadways, parking lots, and parking deck that are present and will remain through project completion. In preparation for the addition of the new emergency department, extensive demolition of existing structures, parking lots, underground utilities, and hospital interiors and systems was necessary. The underground electric has been removed to make room for a new medium voltage line to enter the building. The existing medium voltage switchgear will also be removed to be replaced with new. To the Southwest, an existing gravel pit will be removed to be replaced with a new infiltration basin. During the demolition of the existing structures, some asbestos and lead containing products had to be properly handled. Asbestos abatement efforts were required before the final tear down.



The new building will be tied into the existing hospital on the West side. During excavation for the new building foundation, some unexpected rock was encountered. Also during excavation, dewatering efforts were necessary due to inclement weather where 19 schedule days were lost. Soil conditions were considered suitable for load bearing capability, however along and underneath the existing building, lagging was necessary to prevent collapse and cave-in. A new parking lot and roadway will be constructed to the Southwest of the emergency department addition.

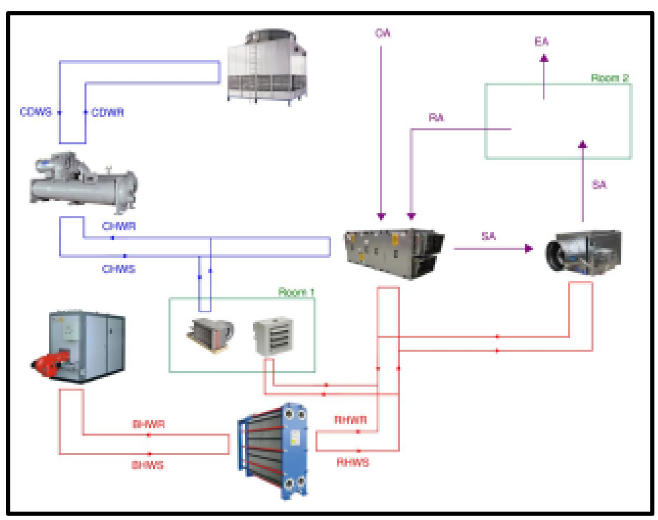
An existing helipad is present to the West, where emergency transport access will be maintained throughout the duration of the project. Construction traffic will enter on the South end of the project site, continue North and stop at one of two locations on either side of the addition. Traffic will then continue past the subcontractor trailers to the right and exit at the North end of the property. The construction site fence surrounds the new building restricting access to authorized personnel only. A separate fence also encompasses the Turner construction trailer, which is not connected to the construction site. Daily patient, staff, and public access and traffic patterns will be maintained to the East and North of the existing hospital.

Structural System and Façade

The building structure begins with a reinforced concrete foundation wall, supported by a continuous strip footing. Concrete spread footings then support the remaining structural steel superstructure which is composed of composite beam and metal deck assembly. Slab on grade and slab on metal deck consist of normal weight concrete at a minimum compressive strength of 3500PSI, with the exception of the second floor Northwest deck slab which contains lightweight concrete. All concrete was cast in place within panelized forms using a pump truck. The exterior walls vary by location. In the entrance area, the building utilizes an aluminum curtain wall assembly complete with insulated glass and composite metal paneling. The curtain wall is supported by curtain wall anchor points, which are attached to the steel superstructure. In other areas, wall assemblies are complete with sheathing, rigid insulation, and face brick, supported by 6” metal studs. Masonry anchors fasten the brick to the structural studs. Precast concrete panels with an exterior paint finish are also used extensively and are supported similarly to the face brick.

Mechanical System

The Aria Expansion mechanical system consists of a traditional chiller/boiler system, with auxiliary components such as fan coil units and water source unit heaters. The building also includes some perimeter radiant heating, which is generated from hot water. On the cooling side, the system begins with a water cooled chiller. Heat is absorbed by the refrigerant on the on the evaporator side, subsequently cooling the chilled water supply. On the condenser side, heat from the refrigerant is transferred to the condenser water supply, which is piped to the building cooling towers. The condenser water temperature then drops slightly, after the heat is rejected to atmosphere within the cooling tower.



Chilled water is pumped to air handling units, where the water is transported through a coiling coil. The air handlers then mix return air with outside air and blow the mixed air through a series of filters. The filtered air then passes through the cooling coil, where the air condenses. The condensate is then trapped in a pan and drained. The now conditioned air is then ducted to the hospital VAV boxes, where the volume of air entering the occupied spaces is modulated. The VAV boxes are also equipped with hot water reheat coils for total temperature control. It should be noted that all areas supplied with outdoor air must be exhausted the same amount, unless the room is pressurized. Chilled water is also supplied to multiple fan coil units, which circulate room air over a cooling coil. Outdoor air in these areas are supplied by a dedicated outdoor air unit inside the mechanical room.

On the heating side of the hospital mechanical system, boilers supply hot water to circulate through a plate and frame heat exchanger. This heat exchanger transfers heat to a closed loop of reheat water, also circulated through the heat exchanger, which is then pumped to the VAV box reheat coils, the AHU heating coil, unit heaters, and perimeter radiators. It should be noted that the air handling units are most likely cooling-only, due to the VAV system. The heating coils within the AHUs are probably for morning warm-up in the dead of winter, when the air temperature is very low.

Electrical System

Outside the new building, the medium voltage switchgear is being replaced with a 1200A, 13.2KV, 3PH, 500 MVA switchgear due to the increase load of the addition. Two electrical feeds are then run to the two separate 1000KVA, 13.2KV transformers. The electricity is then stepped down to 480/277V and fed to a substation located inside the new building mechanical room. Four electrical feeds run to the life safety/critical/equipment/elevator ATS panel, a 400A, 480/277V cooling tower breaker, the 600A, 480/277V boiler room switchgear, and a 400A, 480/277V distribution for branch circuits. The branch circuits employ multiple auxiliary transformers to step down from 480/277V to 120/208V. On the critical back up side, a new 1MW diesel generator feeds the existing main distribution panel, as well as the emergency distribution panel which powers the four automatic transfer switches for life safety, elevator, equipment, and critical power.

Plumbing and Process Piping System

The building is equipped with med gas, med air, and med vac, as well as a standard hot and cold domestic water system. A medical air compressor and a medical vacuum pump are located in the basement mechanical room of the new ED addition. The building fire suppression system includes wet and pre-action systems, depending on the occupancy rating for the rooms being served. In high danger areas, wet pipe, quick response upright sprinkler heads are capable of pumping out 0.2 GPM. In areas where accidental discharge is a concern, pre-action sprinkler heads require two triggers to be released. This could include heating the sprinkler filament, smoke detector activation, or a pull station activation.

Cost Overview

The total cost of construction for the project is approximately $35 Million, or $437/SF. This total includes all insurance, bonding, taxes, permits, site work, fees, and general conditions. The direct work total, excluding site work, demolition, taxes, fees, insurance, overhead, and profit, equates to approximately

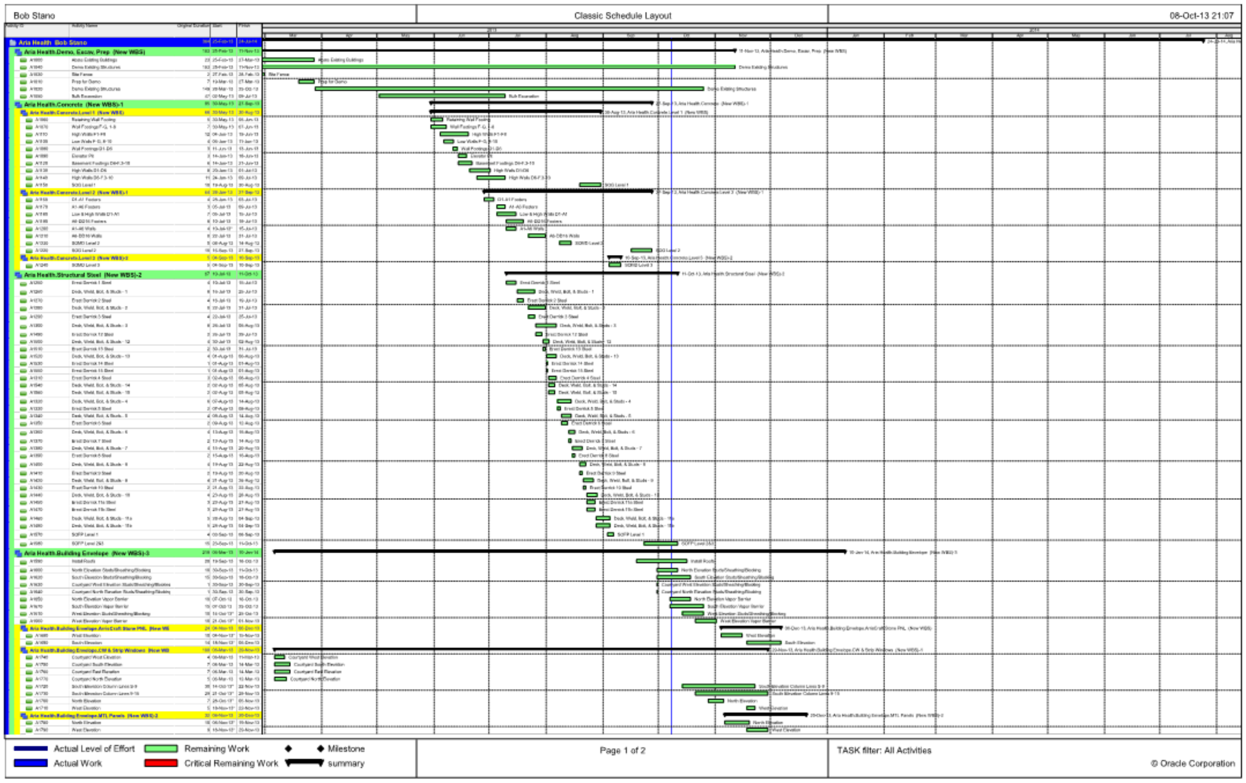
Actual Cost of Building			
Hospital Expansion		Sitework & Demolition	
Direct Work Total	$23,781,585	Building & Interior Demo	$283,600
General Requirements	$504,000	Sitework/Utilities/Excavation	$2,776,700
Subgurad	$279,000	Landscaping	$202,000
CCIP	$737,000	Site Electric	$589,400
Subtotal	**$25,301,585**	General Requirements	$11,500
		Subguard	$44,400
General Conditions	$1,180,000	CCIP	$117,200
Building Permit	$40,000	**Sutotal**	**$4,024,800**
Construction Contingency	$688,415		
Subtotal	**$27,210,000**	General Conditions	$150,000
		Subtotal	**$4,174,800**
Turner Surety Bond	$212,000		
Turner Insurance	$64,000	Turner Insurance	$5,000
Business Privilege Taxes	$137,000	Business Privilege Taxes	$21,000
Subtotal	**$27,623,000**	**Subtotal**	**$4,200,800**
Fee (FICTIONAL 10%)	$2,762,300	Fee (FICTIONAL 10%)	$420,080.0
Total	**$30,385,300**	**Total**	**$4,620,880**
Total Construction Cost	**$35,006,180**	**Cost/SF**	**$437.10**

$24 Million. The mechanical system cost value proved to be the most expensive of the building systems, equating to approximately 23% of the total project cost. This is to be expected considering the extensive mechanical equipment and material required for a hospital.

Primary Building Systems		
Trade	**Cost**	**% Direct Work**
Mechanical	$5,393,000	22.68%
Prepurchase-Mech	$1,491,298	6.27%
Electrical/Fire Alarm	$2,665,000	11.21%
Prepurchase-Elec	$1,742,600	7.33%
Electrical-Low Voltage	$955,000	4.02%
Structural Steel	$1,812,500	7.62%
Concrete	$1,467,000	6.17%
Masonry	$965,000	4.06%
Drywall/Carpentry	$2,051,400	8.63%

Schedule Overview

The overall project schedule includes design, preconstruction, procurement, construction, and project closeout. The total design phase, including schematic design, design development, and construction documents lasted approximately 317 days, while preconstruction and long lead procurement last 254 days and 155 days, respectively. The construction phase of the project, including abatement and demolition, will prove 384 days to completion. The extensive time left aside for TAB and Commissioning should be noted, as these tasks reveal any issues that must be resolved before occupancy. Although the project lost 40 work days due inclement weather and permitting issues, substantial completion is scheduled for 6/27/14, while the first patient day will occur on 7/24/14. A detailed schedule that has been produced can be seen on the following page.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Classic Schedule Layout
08-Oct-13 21:07
Actual Level of Effort
Actual Work
Remaining Work
Critical Remaining Work
Milestone
summary
Page 1 of 2
TASK filter: All Activities
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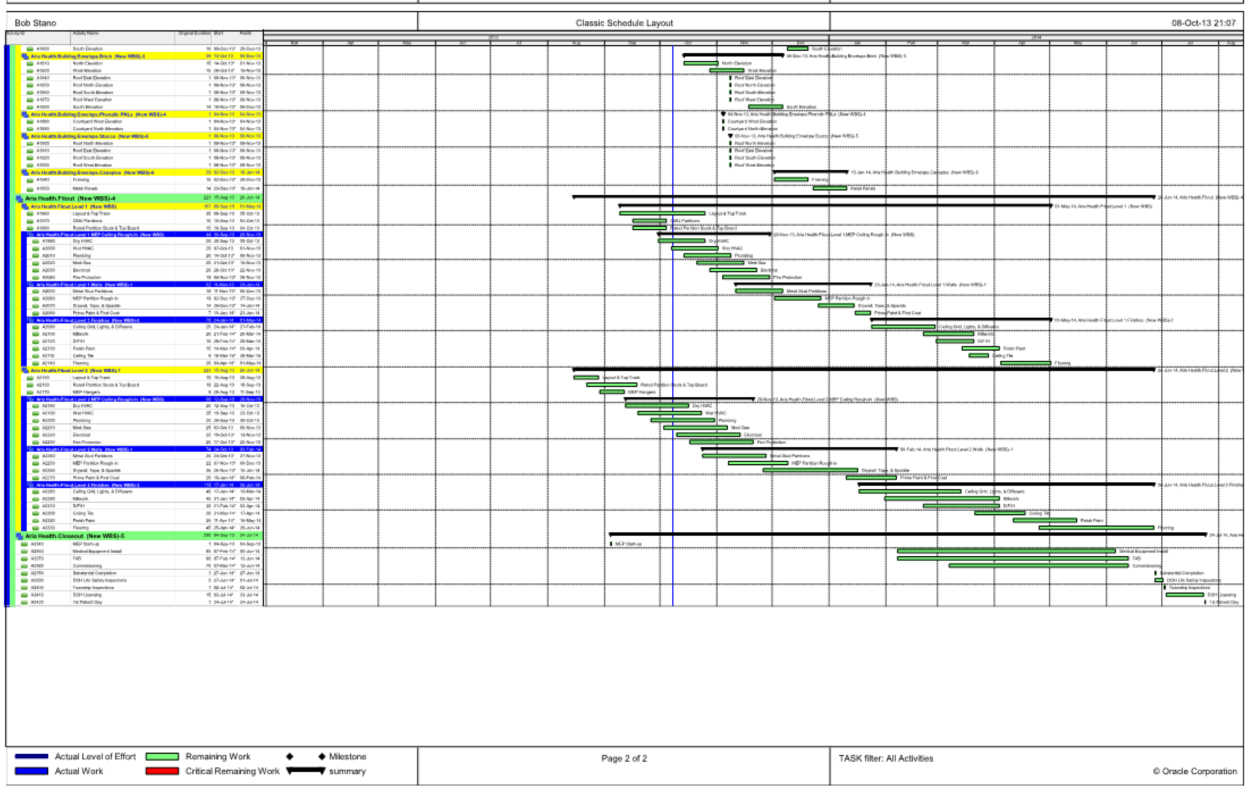
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Critical Remaining Work
Milestone
summary
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Current LEED Tracking

The Aria Health ED Expansion project is scheduled to achieve a LEED Certification with 45 probable points and 8 possible. The majority of these points are accomplished through Sustainable Sites, where the project team is tracking 22 probable points, with the addition of 1 possible point. The remaining points consist of 3 probable and 4 possible from Energy & Atmosphere, 5 probable and 1 possible from Materials & Resources, 7 probable and 2 possible from Indoor Environmental Quality, 6 probable from Innovation & Design Process, and lastly, 2 probable from Regional Bonus Credits. If all possible points are received, the project has the opportunity for LEED Silver. The LEED credit titles and associated point breakdown can be seen in Table 1.

Possible Improvements

There are many opportunities for improved green design and overall sustainability within the Aria Health ED Expansion. After careful examination of LEED 2009 for New Construction and Major Renovations, it was found that the most viable options for improvement consist of Water Efficiency, Energy & Atmosphere, and Indoor Environmental Quality, for a total of 23 additional points. If each of the new possible LEED credits were implemented, the sum of LEED points would equate to 76, or LEED Gold. Each of the LEED credit titles, requirements, and implementation descriptions can be seen in Table 2.

Analysis

Water Efficiency

Water Efficiency offers 10 additional points for the LEED credits chosen. The first credit to be analyzed was Water Efficient Landscaping. The requirements for this include the need to reduce or eliminate potable water consumption for irrigation use, which is quite possible through the use of storm water reclamation, recycled gray water, or utilizing plant species that do not require irrigation. Rainwater conductors throughout the building have the potential to transport water to collection basins, where it would be stored and then pumped for irrigation. Another possible addition to this system is to collect the irrigation water underneath the green space through a French drain-type collection pipe, to be pumped back to the original collection basin. Some losses would occur due to the utilization of water by the irrigated plants and grasses. This would pose many potential cost increases, however, with the additional piping, storage bins, and pumps required for operation.

The second Water Efficiency credit to be investigated is Innovative Wastewater Technologies, where the goal is to reduce 50% of the buildings potable water use for sewage conveyance or treat 50% of building wastewater to tertiary standards. This credit offers 2 points is easily attainable through the installation of low-flow water closets and faucets, as well as zero-flow urinals. There are also several packaged nutrient removal systems and high-efficiency filtration systems that could be used in conjunction with a reverse osmosis deionization system (RODI). This equipment can be quite costly, but could provide much water saving benefit.

Additionally, Water Use Reduction credits are also available, after a water savings of 30-40% against the building baseline is achieved. These credits could be possible after employing the above stated implementation strategies.

Energy & Atmosphere

Through the use of On-Site Renewable Energy, a minimum of 1 point and a maximum of 7 points are possible. Building energy usage must be calculated prior to optimizing energy performance through supplementary on-site sources. A possible energy reduction from 1-13% can be reached through many means including solar, wind, geothermal, hydro, biomass, or biogas strategies. All energy production on-site must be clean and non-polluting. The equipment and material necessary for these is extremely expensive, but special attention must be paid to the energy cost payback period. It must also be noted that these renewable electricity generators require specialized equipment such as AC converters because the electricity produced will be DC. However, geothermal heat transfer is a very efficient mechanism for heating and cooling, therefore could be a strongly viable option for supplementary air conditioning. The addition of a geothermal piping loop would prove very expensive considering the specialized labor and equipment involved with installation. This would also cause extensive re-design work by the engineer, which would also come with added cost.

The second Energy & Atmosphere credit to be considered is with the implementation of Enhanced Commissioning which provides to opportunity for 2 points. This credit would require early project involvement with a third-party commissioning agent hired by the owner. This agent would review and assess the building design before the construction document phase to scrutinize the design for commissioning purposes. Other activities to be performed by the agent include commissioning design review, submittal review, and a systems manual to be handed to the owner following commissioning completion.

The third option for an additional 2 points requires a contract by the owner to ensure at least 35% of the building's electricity is purchased from renewable resources. This could most easily be accomplished by using the Green-e Energy program. Green-e guidelines are most applicable for this credit, however renewable energy certificates (RECs), tradable renewable certificates (TRCs), green tags, or any other forms of sustainable power that comply with Green-e technical requirements are useable.

Indoor Environmental Quality

Indoor air quality is an important aspect of building mechanical design. Ventilation proves crucial inside a space where many people will be congregating, especially in areas where infection and disease control are of utmost concern. The Outdoor Air Delivery Monitoring credit could provide 1 point to LEED certification. CO_2 monitoring devices provide the best opportunity to measure the necessary outside air input within a space. These sensors would be required to sound an alarm to the BAS or the building operator after CO_2 levels deviate by 10% outside of the design values. This alarm would then signal a possible deficiency the building mechanical system prompting necessary action. The CO_2 sensors would add cost to the building controls system, but provide strong benefits.

The final LEED credit analyzed consists of Controllability of Lighting Systems, which offers 1 point. A 90% minimum of building occupants must be provided individual lighting controls for task needs. Any areas of shared spaced would require adjustments for group preferences. The addition of task lighting must also be managed as not to increase the overall building energy usage.

Current LEED Credits		
Credit Title	**Probable Points**	**Possible Points**
Sustainable Sites		
Site Selection	1	
Development Density & Community Connectivity	5	
Brownfield redevelopment	1	
Alternative Transportation, Public Transportation Access	6	
Alternative Transportation, Bicycle Storage & Changing Rooms	1	
Alternative Transportation, Low-Emitting & Fuel Efficient Vehicles	3	
Alternative Transportation, Parking Capacity	2	
Site Development, Maximize Open Space	1	
Stromwater Design, Quantity Control	1	
Stromwater Design, Quality Control	1	
Light Pollution Reduction		1
Sustainable Site Subtotal	**22**	**1**
Energy & Atmosphere		
Optimize Energy Performance		4
Enhanced Refrigeration Manageent	2	
Measurement & Verification	1	
Energy & Atmosphere Subtotal	**3**	**4**
Materials & Resources		
Construction Waste Management	2	
Recycled Content	2	
Regional Materials	1	1
Materials & Resources Subtotal	**5**	**1**
Indoor Environmental Quality		
Increased Ventilation		1
Construction IAQ Management Plan, During Construction	1	
Construction IAQ Management Plan, Before Occupancy		1
Low-Emitting Materials, Adhesives & Sealants	1	
Low-Emitting Materials, Paints & Coatings	1	
Low-Emitting Materials, Flooring Systems	1	
Controllability of Systems, Thermal Comfort	1	
Thermal Comfort, Design	1	
Thermal Comfort, Verification	1	
Indoor Environmental Quality Subtotal	**7**	**2**
Innovation & Design Process		
Exemplary Performance, Maximize Open Space	1	
Exemplary Performance, Construction Waste Management	1	
Innovation in Design, Low-Emitting Materials, Walls & Ceilings	1	
Innovation in Design, Resource Use, Design for Flexibility	1	
Innovation in Design, Education and Outreach Program	1	
LEED Accredited Professional	1	
Innovation & Design Process Subtotal	**6**	**0**
Regional Bonus Credits		
SSc3, Brownfield Redevelopment	1	
SSc5.2, Site Development, Maximize Open Space	1	
Regional Bonus Credits Subtotal	**2**	**0**
Total	**45**	**8**

Analysis 1 – Rainwater Collection

Problem Identification

The Aria Health ED Expansion project is currently tracked to be LEED Certified, however this may not follow through to completion. There are virtually no sustainable attributes on the project, which could be drastically improved. The objective of this analysis will be to study and integrate sustainable construction techniques to improve the energy efficiency of the Aria Health addition project in the areas of water reclamation for gray water usage. This implementation will provide sustainable aspects to the building and add value to the owner through resource conservation.

Background

The primary points associated with the current LEED tracking consist of the Sustainable Sites category, where 22 points have awarding potential. However, there are currently zero LEED points being tracked for Water Efficiency. Hospitals use a substantial amount of water, all of which is currently being supplied through the local water authority in Philadelphia. Because hospitals are under operation 24 hours per day, 365 days per year, water usage will be a great expense to the building owner. By recycling grey water from storm water runoff, operating costs could potentially be reduced.

Analysis Goals

The primary goal in performing an analysis pertaining to rainwater reclamation was to determine whether implementing a rainwater collection system for utilization as building gray water was economically feasible. Through the use of an initial cost estimate and an economic analysis over time, this information was to be used to determine the efficacy of the system as it was designed. Supplementary, a secondary goal associated with the rainwater collection system was to show the owner one specific way to provide efficient resource conservation, as water usage will only increase throughout future generations as costs and availability will decrease.

Process

<u>Rainwater Reclamation</u>

Rainfall Calculations

For the purpose of utilizing rainwater as gray water for the building sewage conveyance, first the total possible amount of rainfall reclaimed had to be determined. In doing this, the initial step was determine where each of the roof drains and rainwater conductors (RWCs) were located throughout the building. After the location was found, it was then necessary to analyze how much roof area each of those RWCs served. As can be seen in Figure 1 below, the building storm water riser diagram was used to find each RWC roof area.

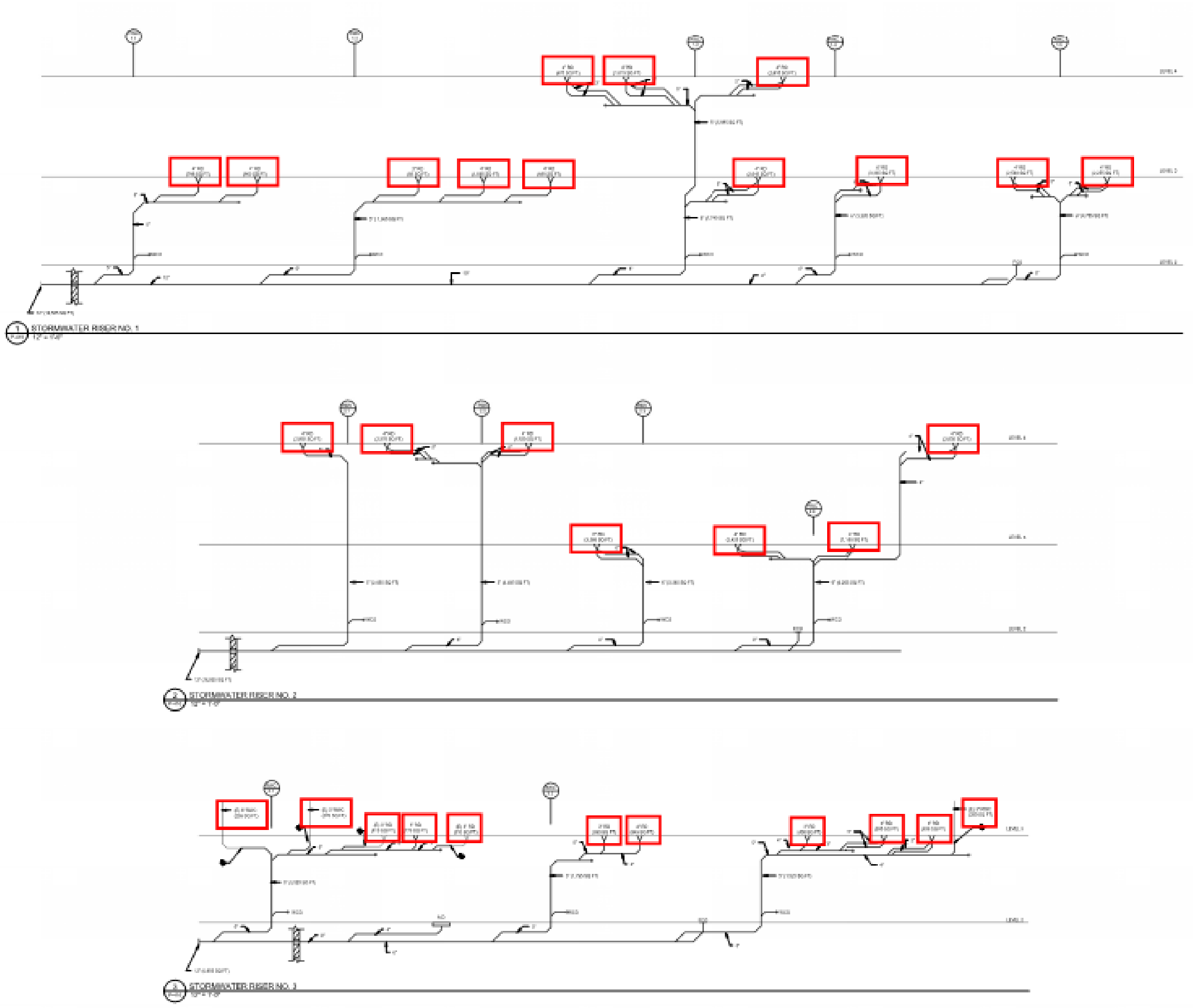


Figure 1.1 - Storm Water Riser Diagram

For more information, a larger, more readable version of Figure 1 can be seen in Appendix A.1.

After using the storm water riser diagram to find each RWCs roof service area, a simple calculation was done to find the total roof service area for the potential to capture and convey storm water runoff. A total of 43,475 SF of roof area was found to be capable of capturing rainwater. A table can be seen in Figure 1.2 where the summation of each RWC service area was performed.

Once the total roof area was found, it was then necessary to determine the total potential amount of rainfall that occurs in Philadelphia, PA annually. This data was found as a historical average value, based on the information found at Average-Rainfall.WeatherDB.com. It was found that 41.53 inches of rain falls every year. After determining the total amount of annual rainfall, a calculation was performed to convert this rain from inches per year to total gallons per year, as can be seen in Figure 1.4. This value then proved useful to account for sewage conveyance based on total hospital water closet flushes. A table of conversion factors can also be seen in Figure 1.3.

Rainwater Conductors

Tag	Size (in)	Service (SF of Roof Area)
RWC 1.1	5	1745
RWC 1.2	5	1960
RWC 1.3	6	7740
RWC 1.4	6	3385
RWC 1.5	6	4755
RWC 2.1	5	2855
RWC 2.2	5	4490
RWC 2.3	6	3385
RWC 2.4	6	6205
RWC 3.1	5	3020
RWC 3.2	5	1795
(E) RWC	5	1525
Misc. System No. 3		615
	Total SF	**43475**

Figure 1.2

Conversions

Average Annual Rainfall	**41.53**	**Inches**
1 Acre	**43560**	**SF**
1 Inch/1 Acre	**27154**	**Gal**

Figure 1.3

Rainfall Calculations

Roof Area (SF)	Roof Area (Acres)	Rainfall (Gal/Inch)	Annual Rainfall (Gal)	Monthly Rainfall (Gal)
43475	0.998	27101.01	1125505.09	93792.09

Figure 1.4

The calculated values presented in Figure 1.4 are based on the following formulas:

$$Roof\ Area\ (Acres) = \frac{Roof\ Area\ (SF)}{\#\ SF\ per\ Acre}$$

$$Rainfall\ \left(\frac{Gal}{Inch}\right) = (Inches\ per\ Acre)x(Roof\ Area\ (Acres))$$

$$Annual\ Rainfall\ (Gal) = (Average\ Annual\ Rainfall)\ x\ (Rainfall\ \left(\frac{Gal}{Inch}\right))$$

$$Monthly\ Rainfall\ (Gal) = \frac{Annual\ Rainfall\ (Gal)}{12\ Months}$$

After the above calculations were performed, it was found that a possible 93,792.09 gallons of rainwater could be reclaimed during each month throughout the year. This number is strictly an average value, as real-world rainfall data will vary from month to month, due to heavier amounts of rainfall occurring at different times of the year.

Once the total potential amount of rainfall (in gallons) was found for each month, the next step was to determine the actual gray water consumption for the hospital. This was done by first determining the total water consumption for each water closet and urinal present within the hospital. To do this, the fixtures to be analyzed were first found in the building specifications to find the fixture model numbers. These model numbers were then searched to find the gallons per flush (GPF). It was found that the water closets specified were American Standard AFWall FloWise Elongated Flushomaster Toilets (at 1.6 GPF) and the urinals were found to be American Standard Washbrook FloWise Universal Urinals (at 0.125 GPF). These fixtures can be seen below in Figure 1.5 and 1.6, respectively.

Figure 1.5

Figure 1.6

A more detailed look at these specific fixtures can be seen in Appendix A.2 and A.3 where the data sheets are provided.

In order to determine the total gray water use based on these particular fixtures, a quantity takeoff was done to find the total number of each fixture. These quantities were then multiplied by an assumed value of 50 flushes per day per fixture. This value was assumed based on 24 hours of operation, equating to approximately 2 flushes per hour per water closet. That product was then multiplied by each respective flush capacity to find the total gallons used in one day. The total gallons per day was then multiplied by an average of 30 days in one month to find the final total gallons used per month. The table found in Figure 1.7 shows these calculated values. It was found that all of the combined fixtures use a total of 82,162.5 gallons of water per month. These calculations were based on the following formulas:

Water Use Calculations

Fixture	Flushes/Day/Fixture	QTY	GPF	Gal/Day	Days/Mo	Gal/Mo
Water Closets	50	34	1.6	2720	30	81600
Urinals	50	3	0.125	18.75	30	562.5
					Total Water Usage	82162.5

Figure 1.7

$$\frac{Gal}{Moth} = (Flushes\ per\ day\ per\ fixture) x\ (QTY) x \left(\frac{Gal}{Day}\right) x\ (30\ days\ per\ mont)$$

As can be seen from the initial results between the potential rainwater reclamation and the actual water usage, it is evident that there is an adequate amount of water to service the building gray water for sewage conveyance. The total reclaimed rainwater was found to be 93,792.09 gallons per month, whereas the total water usage due to the water closets and urinals was found to be 82,162.5 gallons per month.

Design

After determining the total possible rainwater collection capacity, an actual reclamation system had to be designed in order to perform an accurate quantity takeoff, cost estimate, and economic analysis. The first step in the design process was to determine the size and material of the storage tank to be utilized. In doing this, several different tank manufacturers were researched, where two final candidates were analyzed, Highland Tank and Xerxes. These two were considered separately due to the material with which their tanks were constructed. Highland Tank offered a stainless steel tank, with the possibility for potable water consumption. Highland was also considered during design, due to their capability to provide a packaged rainwater collection system called HighDro-Pure Rainwater Harvesting System. The HighDro-Pure package can be seen in a detailed brochure shown in Appendix A.4. This system proved to be expensive however, so other options were explored. The second, less expensive option analyzed was Xerxes Fiberglass Water Tanks. This tank would be provide alone, however, aside from all the other necessary components for the system. The 20,000 Gallon option was found to be the best option for storm water collection, as this tank has the capacity to hold up to 2 weeks supply of gray water, while still proving less expensive than some of the higher capacity tanks. Fiberglass is also known to be a less expensive material, therefore this was the chosen option. This particular tank can be seen in Figure 1.8, as well as the data sheet shown in Figure 1.9. A complete brochure for Xerxes Fiberglass Water Tanks can be seen in Appendix A.5.

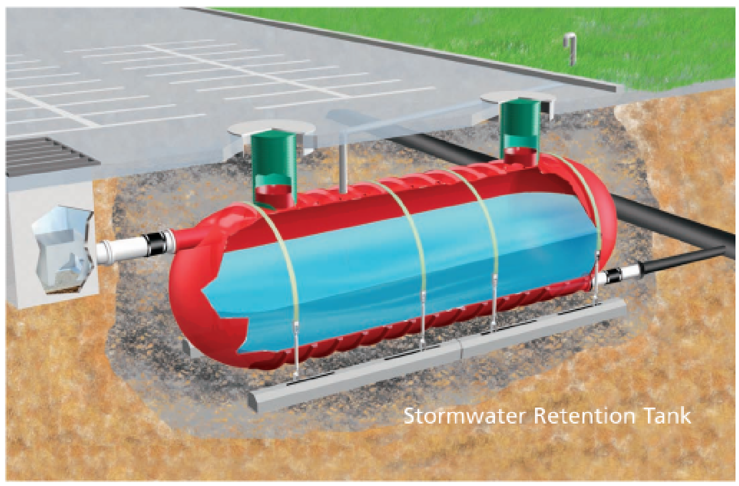


Figure 1.8

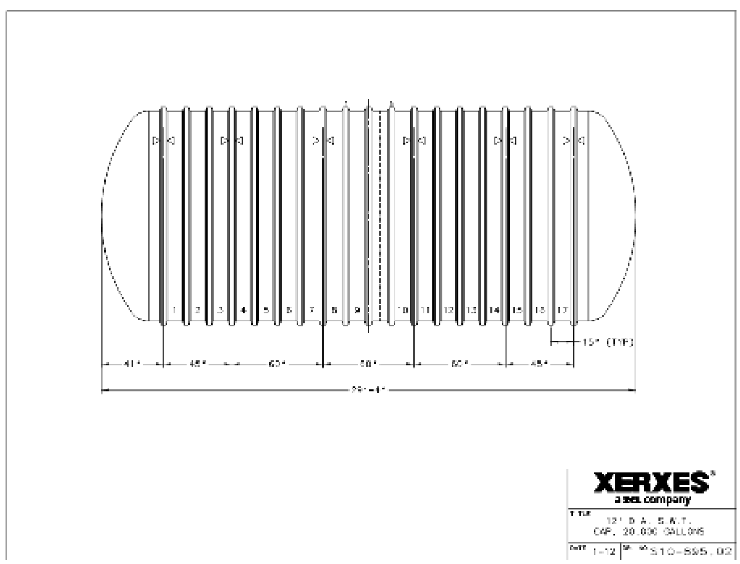


Figure 1.9

The next step in designing the rainwater collection system was to develop a schematic diagram showing each of the system components and where they would be located. After researching the necessary components and speaking with an industry professional, a single line schematic diagram was composed, as can be seen in Figure 1.10. The system includes a 20,000 Gal water retention cistern open to atmostpheric pressure, an 85 GPM submersable booster pump, four 317 Gal hydro-pneumatic tanks, a sediment filter, an unltra-violet water purifier, and several check valves, ball valves, and backflow preventers. Each of these components were deemed necessary for the efficacy of the system as a whole to function properly. A full sized version of this rainwater collection schematic can be seen in Appendix A.6.

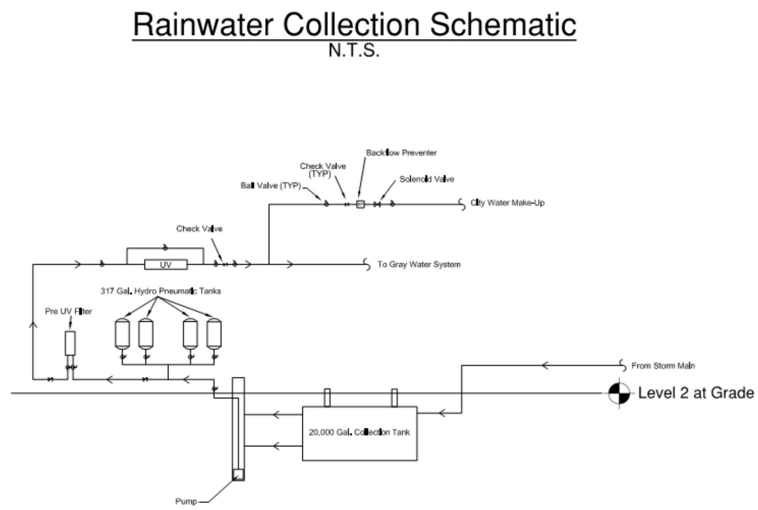


Figure 1.10

The new addititions to the existing rainwater conveyance structure begins at each of the three storm water mains exiting the building in the south wall. 12" storm mains tie into the existing lines and come together through a wye connection. This overall storm main then enters the 20,000 gallon storage tank where it deposits the rainwater for collection. In the event where capacity has been reached, an overflow pipe is present to tie into the city storm water main. This can be seen in the storm piping layout shown in Figure 1.11.

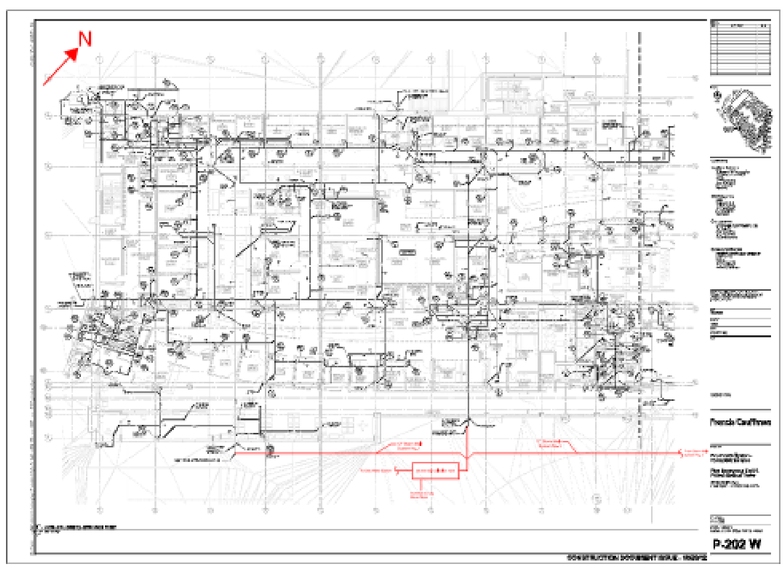


Figure 1.11

A larger version of this layout can be seen in more detail in Appendix A.7.

On the supply side, the system was designed to feed 34 water closets and 3 urinals present throughout the building, each complete with flush valves. Due to these flush valves, adequate water pressure was necessary. To size the submersable booster pump, an industry standard method was used by assuming 10 plumbing fixture units per water closet and 5 fixture units per urinal. A total of 355 fixture units were calculated as can be seen in the formula below.

$$(34\ Water\ Closets)(10\ Fixture\ Units) + (3\ Urinals)(5\ Fixture\ Units) = 355\ Fixture\ Units$$

This total fixture unit value was then cross referenced with the Hunter Curve to determine the flow rate of the submersable booster pump. The booster pump was found to need a capacity of 85 gallons per minute (GPM) to feed the 34 water closet and 3 urinals. After sizing the booster pump, a pipe wheel was used to calculate the pipe sizes feeding the bathrooms. It was assumed that the pipe pressure drop should be limited to 8’ of head per 100 linear feet of pipe and 8 ft/second to limit the amount of noise caused by the flow of water. It was found that the pipe main to the bathrooms should be 2.5” in diameter, the pipe inside the bathrooms should be 2” in diameter, and 1.5” in diamater for the pipe feeding each respective water closet or urinal. 1.5” is also the minimum size pipe diamter reccommended by flush valve manufacturers.

After determining the size of the pipes necessary to supply gray water to hospital water closets and urinals, the pipes were laid out systematically to match the existing rises and runs as to minimize additional rerouting of other existing systems. The piping system layout for Level 2 – West can be seen in Figure 1.12 in plan view. A larger version can be seen in Appendix A.8.

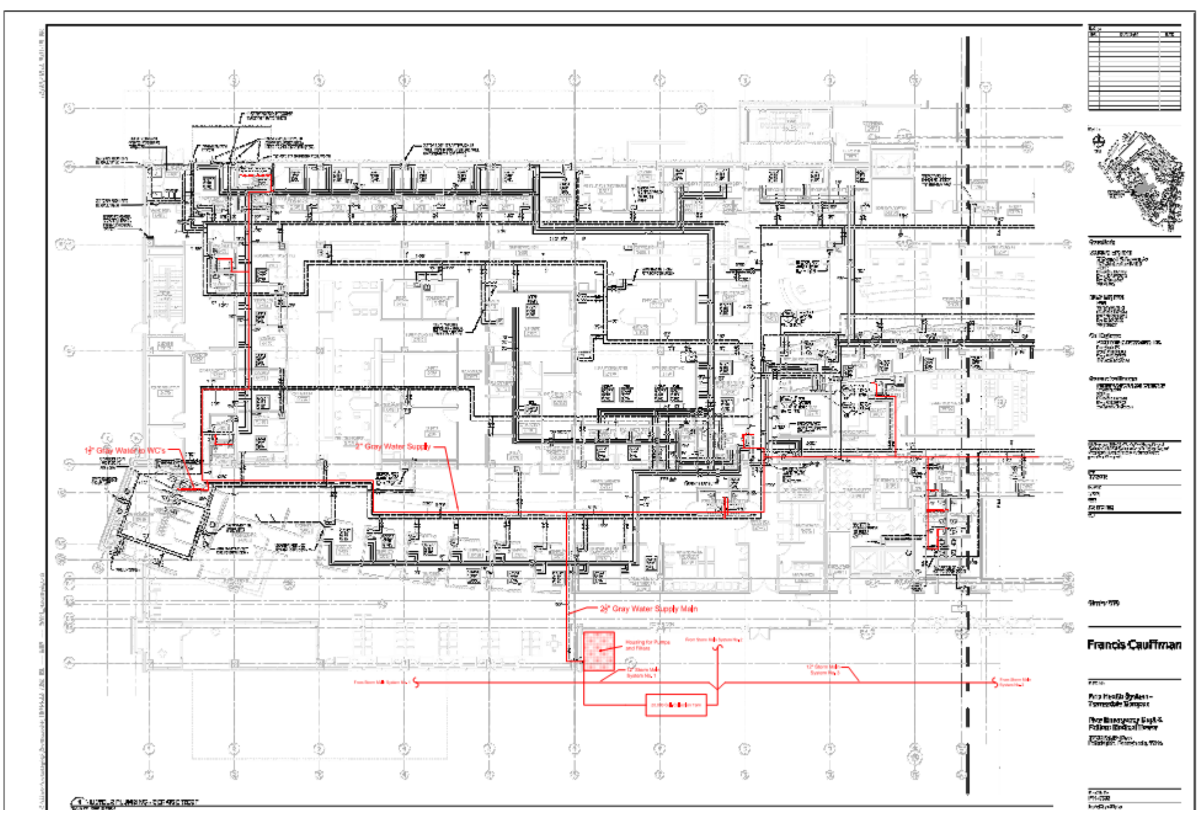


Figure 1.12

The piping layout for Level 2 – East and Level 1 can be seen in Figures 1.13 and 1.14, respectively. These documents are also available in Appendix A.8.

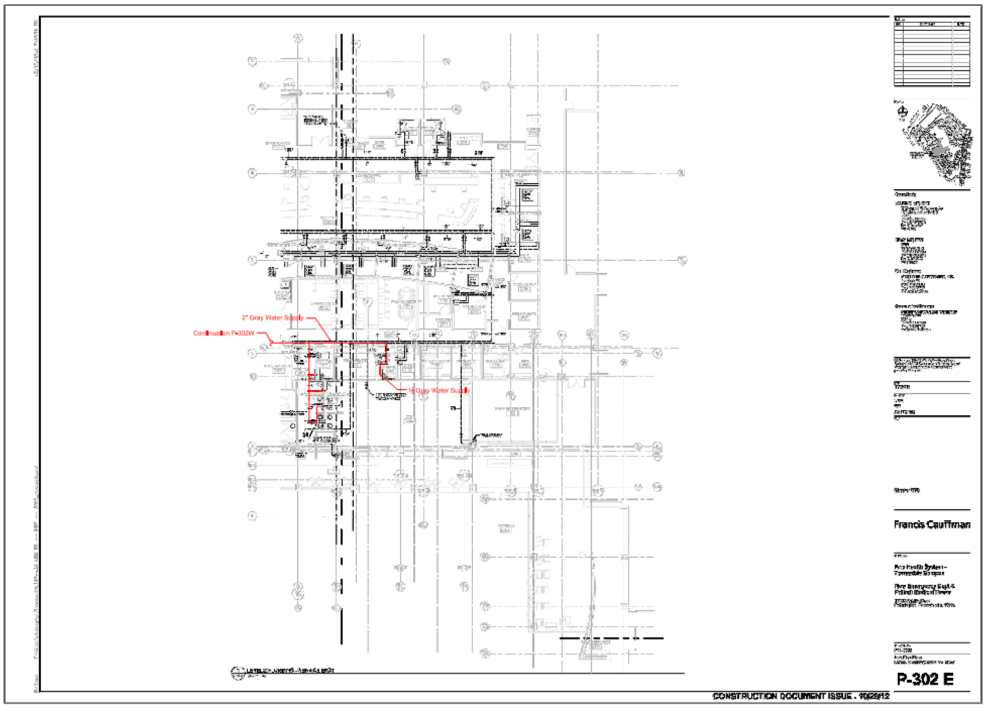


Figure 1.13

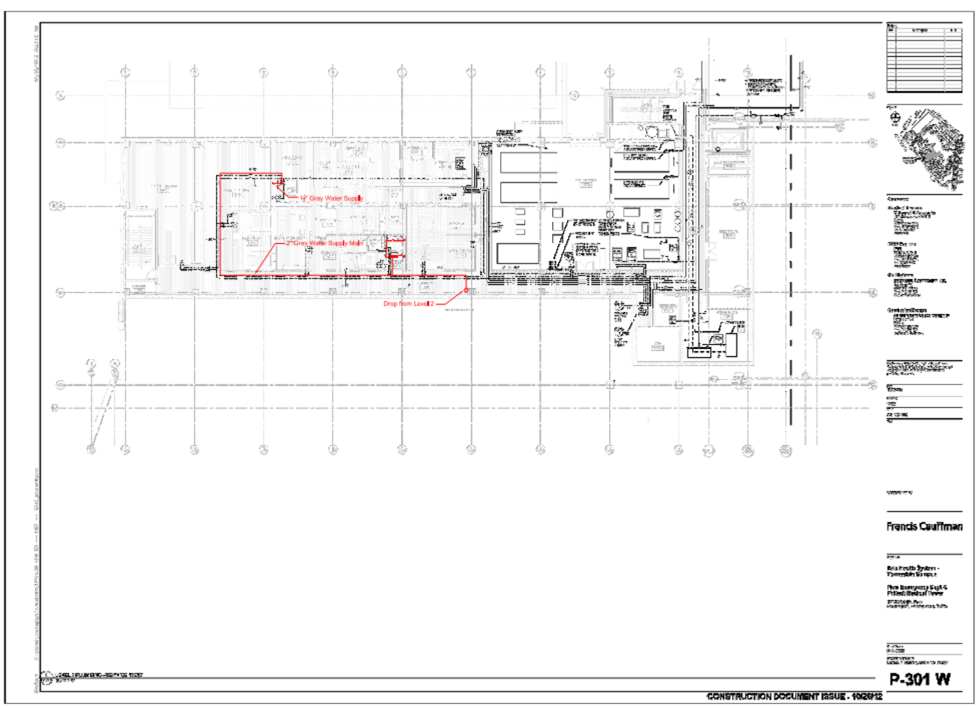


Figure 1.14

Figure 1.15 shows a sections view of how the gray water piping will enter the building, also available in Appendix A.8.

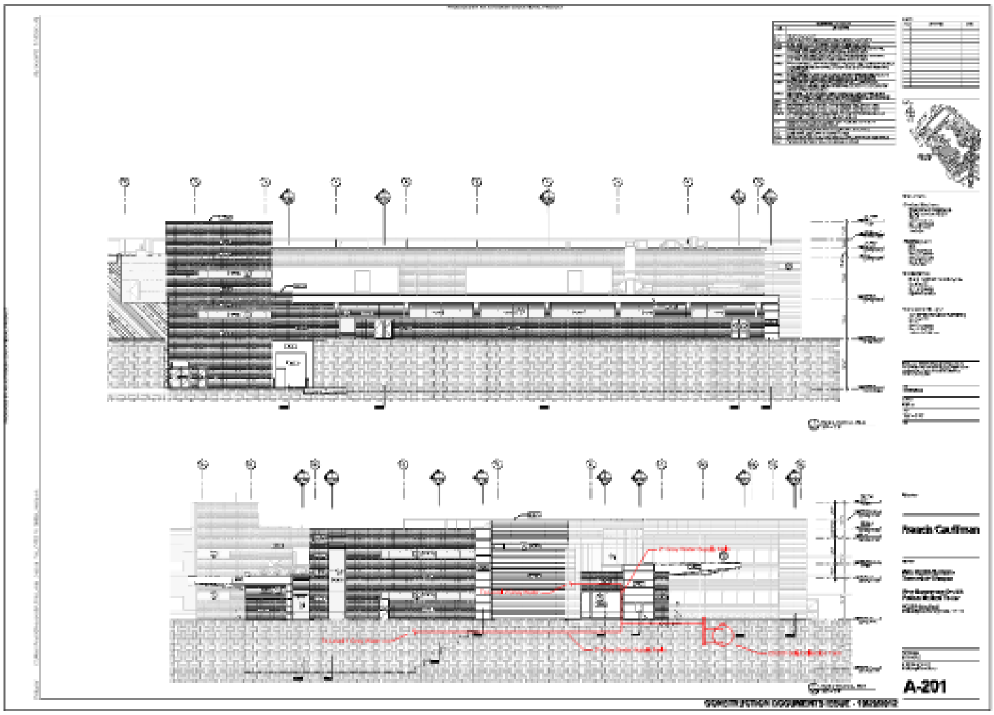
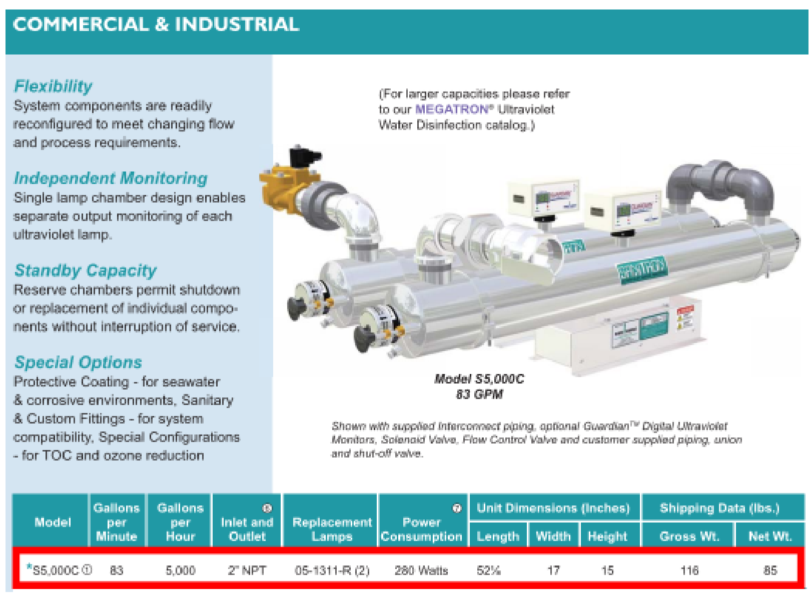


Figure 1.15

The ultraviolet system that has been chosen during design is the Sanitron Ultraviolet Water Purifer Model S5,000C. Several different manufacturers were analyzed, after which the Sanitron was chosen based on its specifications to fit the design criteria. This particular model offers a flow rate capacity of 83 GPM (2 GPM less than required, however this is within the boundary limits of design) and a 2" inlet and outlet diameter for piping attachment. This model can be seen in Figure 1.16, as well as Appendix A.9 where a full, detailed Sanitron brochure has been provided.



Model	Gallons per Minute	Gallons per Hour	Inlet and Outlet	Replacement Lamps	Power Consumption	Unit Dimensions (Inches) Length	Width	Height	Shipping Data (lbs.) Gross Wt.	Net Wt.
*S5,000C ①	83	5,000	2" NPT	05-1311-R (2)	280 Watts	52¼	17	15	116	85

Figure 1.16

The purpose of the hydro-pneumatic tanks is prevent excessive on-off cycling of the submersible booster pump. The controls will be set up as such that when the system pressure drops to 40 psig the pump will start. When the system pressure reaches 60 psig, the pump will kick off. The hydro-pneumatic tanks will separate air and water within tank with a rubber bladder.

It is assumed that 850 gallons of water will be available to the system before the pump kicks on, or 2/3 the tanks' capacity. With the tank configuration as designed, the pump will run approximately 4 times per day for 10 minutes. This is based on the following calculation:

$$\frac{\frac{93{,}792.09\,\frac{gal}{mo}}{30\ days}}{850\ gal} = 4\ times/day$$

$$\frac{850\ gal}{85\ GPM} = 10\ mins$$

Standard hydro-pneumatic tank sizes can be seen in Figure 1.17. The specific tank that has been used for design is shown in Figure 1.18.

Standard Tank Sizes

Part No.	Capacity Gallons	Size Dia x	O.A.L.	Water IN	Water Out	Recir	Relief	Temp Reg	Drain
2448	110	24	5'2"	1 1/2	1 1/2	1 1/4	3/4	1 1/4	1
2460	135	24	6'2"	1 1/2	1 1/2	1 1/4	3/4	1 1/4	1
2472	160	24	7'2"	1 1/2	1 1/2	1 1/4	3/4	1 1/4	1
2484	180	24	8'2"	1 1/2	1 1/2	1 1/4	3/4	1 1/4	1
3048	180	30	5'4"	2	2	1 1/2	1	1 1/4	1
3060	220	30	6'4"	2	2	1 1/2	1	1 1/4	1
3072	255	30	7'4"	2	2	1 1/2	1	1 1/4	1
3084	290	30	8'4"	2	2	1 1/2	1	1 1/4	1
3096	330	30	9'4"	2	2	1 1/2	1	1 1/4	1
30120	400	30	11'4"	2	2	1 1/2	1	1 1/4	1

Figure 1.17

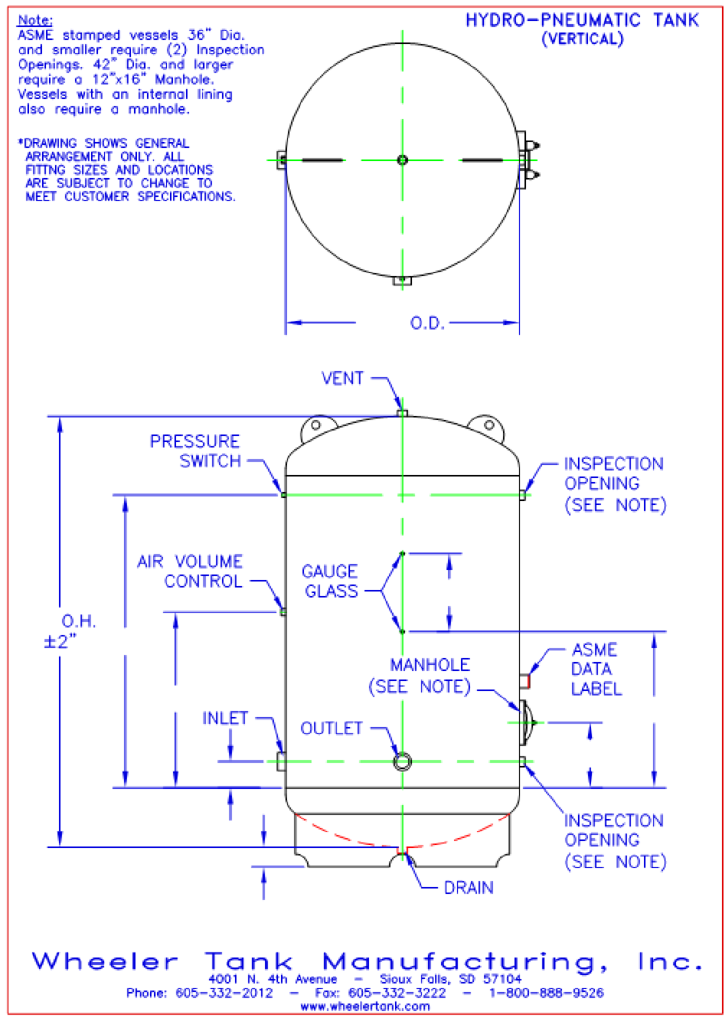


Figure 1.18

Cost Estimation

After completion of the rainwater reclamation system design and piping layout, an initial cost estimate could be performed. Quantity take offs were done for piping, fittings, tanks, and miscellaneous system components and were estimated using RS Means 2014 pricing for material and labor. Two separate material configurations were estimated in order to find the lowest cost for the system. The first configuration consisted of copper tubing and a stainless steel storage tank, whereas the second configuration consisted of PVC piping and a fiberglass storage tank. After completion of the upfront cost estimation associated with the rainwater harvesting system, it was found that the copper and steel arrangement cost $204,964.75, while the PVC and fiberglass arrangement cost $146,680.40, where each of those costs included a 10% add for overhead and profit, as well as a 6% add for tax. The cost breakdown of each line item can be seen below in Figure 1.19.

Total Rainwater Collection Estimate

Item	Copper/Steel	PVC/Fiberglass
Gray Water Piping	$74,849.30	$41,979.70
Fittings	$13,141.45	$4,255.92
Tanks	$56,300.00	$47,810.00
Harvesting Components	$32,403.00	$32,403.00
Sub Total	**$176,693.75**	**$126,448.62**
Overhead & Profit (10%)	$17,669.38	$12,644.86
Tax (6%)	$10,601.63	$7,586.92
Grand Total Cost	**$204,964.75**	**$146,680.40**

Figure 1.19

Quantity Takeoff Information

Piping Estimate

Horizontal Piping										
Item			Copper Tubing/Sch. 40 Steel, Flanged				PVC Pipe			
Level 2 West	QTY	UOM	Material	Labor	Total Unit Cost	Total Cost	Material	Labor	Total Unit Cost	Total Cost
12" Storm Main	181	LF	$163.00	$92.00	$255.00	$46,155.00	$103.00	$30.50	$133.50	$24,163.50
2 1/2" Gray Supply	70	LF	$35.00	$13.35	$48.35	$3,384.50	$9.15	$14.80	$23.95	$1,676.50
2" Gray Supply	366	LF	$22.00	$10.95	$32.95	$12,059.70	$5.95	$14.05	$20.00	$7,320.00
1 1/2" Gray Supply	70	LF	$14.35	$8.85	$23.20	$1,624.00	$4.76	$12.80	$17.56	$1,229.20
Level 2 East		LF								
2" Gray Supply	23	LF	$22.00	$10.95	$32.95	$757.85	$5.95	$14.05	$20.00	$460.00
1 1/2" Gray Supply	5	LF	$14.35	$8.85	$23.20	$116.00	$4.76	$12.80	$17.56	$87.80
Level 1		LF								
2 1/2" Gray Supply	5	LF	$35.00	$13.35	$48.35	$241.75	$9.15	$14.80	$23.95	$119.75
2" Gray Supply	145	LF	$22.00	$10.95	$32.95	$4,777.75	$5.95	$14.05	$20.00	$2,900.00
1 1/2" Gray Supply	15	LF	$14.35	$8.85	$23.20	$348.00	$4.76	$12.80	$17.56	$263.40

Total Horiz Copper	$69,464.55	Total Horiz PVC	$38,220.15

Vertical Piping										
			Copper Tubing/Sch. 40 Steel, Flanged				PVC Pipe			
Item	QTY	UOM	Material	Labor	Total Unit Cost	Total Cost	Material	Labor	Total Unit Cost	Total Cost
2 1/2" Gray Supply	25	LF	$35.00	$13.35	$48.35	$1,208.75	$9.15	$14.80	$23.95	$598.75
1 1/2" Gray Supply	180	LF	$14.35	$8.85	$23.20	$4,176.00	$4.76	$12.80	$17.56	$3,160.80

Total Vert Copper	$5,384.75	Total Vert PVC	$3,759.55
Total Copper	$74,849.30	Total PVC	$41,979.70

References and Assumptions:
All cost data based on RS Means 2014

Figure 1.20

As can be seen in Figure 1.20 above, the piping estimate has been broken up into horizontal and vertical piping, where the horizontal piping has been divided further into Level 2 West (Figure 1.12 layout), Level 2 East (Figure 1.13 layout), and Level 1 (Figure 1.14 layout). The vertical piping can be partially seen in the Figure 1.15 layout. Additionally, all of the piping has been split into two separate estimates, one for copper and one for PVC. The material and labor costs have been added together for a total unit cost for each line item. The formulas that have been used for the above calculations are as follows:

$$Total\ Cost = QTY\ x\ Total\ Unit\ Cost$$

$$Total\ Copper = Summation\ of\ \text{all "Total Cost" copper line items}$$

$$Total\ PVC = Summation\ of\ all\ \text{"Total Cost"}\ PVC\ line\ items$$

The total cost for copper and PVC piping was found to be $74,849.30 and $41,979.70, respectively.

Fittings Estimate										
Item			Copper Tubing				PVC Pipe			
Couplings	QTY	UOM	Material	Labor	Total Unit Cost	Total Cost	Material	Labor	Total Unit Cost	Total Cost
2 1/2"	10	EA	$22.00	$30.50	$52.50	$525.00	$3.81	$31.00	$34.81	$348.10
2"	53.4	EA	$36.50	$35.50	$72.00	$3,844.80	$1.72	$23.00	$24.72	$1,320.05
1 1/2"	27	EA	$78.00	$55.50	$133.50	$3,604.50	$1.13	$23.00	$24.13	$651.51
Tees										
2 1/2", 2"	1	EA	$0.00	$14.40	$14.40	$14.40	$11.75	$46.50	$58.25	$58.25
2", 1 1/2"	15	EA	$0.00	$13.15	$13.15	$197.25	$3.56	$34.50	$38.06	$570.90
90 Degree Elbows										
2 1/2"	3	EA	$146.00	$65.00	$211.00	$633.00	$8.80	$31.00	$39.80	$119.40
2"	19	EA	$73.00	$42.50	$115.50	$2,194.50	$2.89	$23.00	$25.89	$491.91
1 1/2"	28	EA	$40.00	$36.00	$76.00	$2,128.00	$1.85	$23.00	$24.85	$695.80
					Total Copper	$13,141.45			Total PVC	$4,255.92

References and Assumptions:
All cost data based on RS Means 2014

Figure 1.21

As can be seen in Figure 1.21, each of the fittings have been broken up into copper and PVC as well. The quantity take off for fittings was performed based on the piping layout composed during design development. The formulas that have been used for the above calculations are as follows:

$$Total\ Cost = QTY\ x\ Total\ Unit\ Cost$$

$$Total\ Copper = Summation\ of\ \text{all "Total Cost" copper line items}$$

$$Total\ PVC = Summation\ of\ all\ \text{"Total Cost"}\ PVC\ line\ items$$

The total cost for copper and PVC fittings was found to be $13,141.45 and $4,255.92, respectively.

Tanks Estimate

			Steel				Fiberglass			
Item	QTY	UOM	Material	Labor	Total Unit Cost	Total Cost	Material	Labor	Total Unit Cost	Total Cost
20,000 Gal. Storage Tank	1	EA	$36,300.00	$1,200.00	$37,500.00	$37,500.00	$26,000.00	$3,010.00	$29,010.00	$29,010.00
Hydro Pneumatic Tank	4	EA	$3,200.00	$1,500.00	$4,700.00	$18,800.00				
					Total Steel	$56,300.00			Total Fiberglass	$47,810.00

References and Assumptions:

Storage Tank - Underground, steel, sti-P3, set in place, 5/16" thick shell, hold-down bars, excavation, pad pumps and piping
Hydro Pneumatic Tank - Based on 320 Gallon Tank
All cost data based on RS Means 2014

Figure 1.22

Figure 1.22 shows the difference in cost between a 20,000 gallon steel water storage tank and a fiberglass tank, where steel was found to be $37,500 and fiberglass to be $29,010.00. Four steel hydro-pneumatic tanks were priced accordingly at $4,700 each for a total $18,800. The total cost for the steel arrangement was found to be $56,300, whereas the fiberglass arrangement was found to be $47,810.

Harvesting Components Estimate

Pumps

Item	QTY	UOM	Material	Labor	Total Unit Cost	Total Cost
Domestic Booster Pump	1	EA	$7,550.00	$860.00	$8,410.00	**$8,410.00**

Valves

Item	QTY	UOM	Material	Labor	Total Unit Cost	Total Cost
Check Valve	4	EA	$760.00	$55.50	$815.50	$3,262.00
Ball Valve	13	EA	$295.00	$51.00	$346.00	$4,498.00
Backflow Preventer	1	EA	$1,923.00	$60.00	$1,983.00	$1,983.00
Solenoid Valve	1	EA	$300.00	$50.00	$350.00	$350.00
					Total Valves	**$10,093.00**

Filters

Item	QTY	UOM	Material	Labor	Total Unit Cost	Total Cost
Pre-UV Filter	1	EA	$3,200.00	$800.00	$4,000.00	$4,000.00
UV Filter	1	EA	$8,700.00	$1,200.00	$9,900.00	$9,900.00
					Total Filters	**$13,900.00**

Total Components $32,403.00

References and Assumptions:

All cost data based on RS Means 2014

Figure 1.23

In addition to piping and fittings, several other components were necessary for the system to work properly. Figure 1.23 shows the takeoff and estimate data for the 85 GPM domestic booster pump, associated valves, and UV water purification system. These were not broken up by material however, because only one type of material cost information was provided in RS Means. The total cost of all components included in the system was found to be $32,403.00.

Economic Analysis

After completing a total estimate of the rainwater collection system, the PVC option was chosen due to the substantially cheaper initial cost. An economic analysis was then performed to show the relationship of cost savings over time and the payback period vs initial costs. Figure 1.25 shows an annual cash flow analysis over a 25 year period, where total costs are subtracted from total income. Total costs are defined as the initial cost of the rainwater collection system, as well as maintenance, and total income is defined as savings due to the self-production of water. To explain the table shown, the following statements must be understood:

- The initial cost of the rainwater collection system is a one-time cost, shown in year 1. For every year after that, a value of $0.00 is shown.
- For maintenance costs, values are based on 16 hours/year for a union plumber wage rate of $59.68/hour.
- The system is assumed to be maintenance-free for the first 5 years of operation, after which the above stated amounts will begin to accumulate.
- Total costs per year is shown in red.
- It is assumed that the general inflation rate of money will increase every year by 3% over a 25 year period.

Water Cost Calculations					
Amount of Reclaimed Water (Gal)	Amount of Reclaimed Water (kCF)	Utility Water (Cost/kCF)	Wastewater (Cost/kCF)	Total (Cost/1,000CF)	Total Annual Cost
1125505.09	150.07	$37.12	$26.19	$63.31	$9,500.76

References and Assumptions:
Philadelphia water cost data is from www.phila.gov/water
Information based on average annual rainfall in Philadelphia, PA
Conversion: 1 Gal = 7.5 CF
Conversion: 1kCF = 1,000 CF

Figure 1.24

- During the first year, the rainwater collection system will produce 1,125,505.09 gallons of water. The Philadelphia, PA water authority charges $37.12/1000 CF of water supply and $26.19/1000 CF of wastewater for treatment. After converting the initial amount of reclaimed water of 1,125,505.09 gallons to 150.07 thousand CF (kCF) and multiplying that 150.07 kCF by the total utility water cost of 63.31, it was found that in the first year of operation the system will save $9,500.76. These calculations can be seen in Figure 1.24. The water cost data can be found in Appnedix A.10.
- It is assumed that the inflation rate of water costs will increase every year by 5% over a 25 year period.
- Water production savings is to be considered income, where total income is shown in green.
- Annual cash flow is quantified by subtracting total costs (initial costs plus maintenance) from total income (water production savings)
- Cumulative cash flow per year is determined by adding that particular year's annual cash flow to the previous year's cumulative cash flow. For example:
    - In year 1: Cumulative cash flow = -$137,179.64
    - In year 2: Annual cash flow = $9,975.80

Economic Analysis for Rainwater Collection System

No. of Years

	After 25 Years	1	2	3	4	5	6	7	8	9	10	11	12
Total Upfront Costs:													
Cost of Rainwater Collection System	$146,680.40	$146,680.40	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Maintenance	$25,657.98	$0.00	$0.00	$0.00	$0.00	$0.00	$954.88	$983.53	$1,013.03	$1,043.42	$1,074.73	$1,106.97	$1,140.18
Total Costs	$172,338.38	$146,680.40	$0.00	$0.00	$0.00	$0.00	$954.88	$983.53	$1,013.03	$1,043.42	$1,074.73	$1,106.97	$1,140.18
Total Cost Savings:													
Water Production Savings	$453,443.89	$9,500.76	$9,975.80	$10,474.59	$10,998.32	$11,548.24	$12,125.65	$12,731.93	$13,368.53	$14,036.95	$14,738.80	$15,475.74	$16,249.53
Total Income	$453,443.89	$9,500.76	$9,975.80	$10,474.59	$10,998.32	$11,548.24	$12,125.65	$12,731.93	$13,368.53	$14,036.95	$14,738.80	$15,475.74	$16,249.53
Annual Cash Flow		-$137,179.64	$9,975.80	$10,474.59	$10,998.32	$11,548.24	$11,170.77	$11,748.41	$12,355.50	$12,993.53	$13,664.08	$14,368.78	$15,109.35
Cumulative Cash Flow	$281,105.50	-$137,179.64	-$127,203.83	-$116,729.24	-$105,730.92	-$94,182.68	-$83,011.91	-$71,263.51	-$58,908.01	-$45,914.48	-$32,250.40	-$17,881.63	-$2,772.27

	13	14	15	16	17	18	19	20	21	22	23	24	25
Total Upfront Costs:													
Cost of Rainwater Collection System	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Maintenance	$1,174.38	$1,209.61	$1,245.90	$1,283.28	$1,321.78	$1,361.43	$1,402.27	$1,444.34	$1,487.67	$1,532.30	$1,578.27	$1,625.62	$1,674.39
Total Costs	$1,174.38	$1,209.61	$1,245.90	$1,283.28	$1,321.78	$1,361.43	$1,402.27	$1,444.34	$1,487.67	$1,532.30	$1,578.27	$1,625.62	$1,674.39
Total Cost Savings:													
Water Production Savings	$17,062.01	$17,915.11	$18,810.86	$19,751.41	$20,738.98	$21,775.92	$22,864.72	$24,007.96	$25,208.35	$26,468.77	$27,792.21	$29,181.82	$30,640.91
Total Income	$17,062.01	$17,915.11	$18,810.86	$19,751.41	$20,738.98	$21,775.92	$22,864.72	$24,007.96	$25,208.35	$26,468.77	$27,792.21	$29,181.82	$30,640.91
Annual Cash Flow	$15,887.62	$16,705.49	$17,564.96	$18,468.13	$19,417.20	$20,414.49	$21,462.45	$22,563.61	$23,720.68	$24,936.47	$26,213.94	$27,556.20	$28,966.52
Cumulative Cash Flow	$13,115.35	$29,820.84	$47,385.80	$65,853.93	$85,271.13	$105,685.62	$127,148.07	$149,711.68	$173,432.37	$198,368.84	$224,582.78	$252,138.98	$281,105.50

Cost Payback After:	**12.18 Years**

Cumulative Income After 25 Years:	**$281,105.50**

References and Assumptions
Maintenance based on 16 Hours/Year after 5 maintenance-free years for a Union Plumber Rate of $59.68/Hour
http://www.plumbers690.org/library/document-library/20120719095713.Apprent%20Phila%2012-13%20wages.pdf
General Inflation Rate Assumed to be 3% for 25 Years
Water Inflation Rate Assumed to be of 5% per Year for 25 Years
Philadelphia Water Utility Cost/kCF is Assumed to be $37.12/kCF for Water and $26.19/kCF for Wastewater

Figure 1.25

- Therefore, in year 2, cumulative cash flow = -$127,203.83

In summation, based on the initial cost of the rainwater collection system, maintenance cost over 25 years, and total savings due to self-production of water over 25 years, it will take 12.18 years for the system to have paid for itself. Additionally, assuming the inflation rates and utility costs stated above will continue, the cumulative income over a 25 year period due to the rainwater collection system was found to be $281,105.50. In today's terms, based on an inflation rate of 3%, that amount of money would be valued at $131,269.16.

Recommendations

Due to the relatively short payback period of 12.18 years and the generous income generated from the rainwater collection system, it is recommended that the owner of the Aria Health ED Expansion project consider the system as it has been designed and estimated. It should be noted, however, that the upfront cost of $146,680.40 is a substantial investment and should not be taken lightly. It should also be noted that during the estimation process, any electrical and controls costs associated with the system were excluded.

Analysis 2 – Photovoltaic Array

Problem Identification

The Aria Health ED Expansion project is currently tracked to be LEED Certified, however this may not follow through to completion. There are virtually no sustainable attributes on the project, which could be drastically improved. The objective of this analysis will be to study and integrate sustainable construction techniques to improve the energy efficiency of the Aria Health addition project with the addition of a photovoltaic array. This implementation will provide sustainable aspects to the building and add value to the owner through self-production of electricity.

Background

The building currently utilizes purchased energy and electricity. With the addition of On-Site Renewable Energy, the hospital could supplement their energy usage with their own energy production. Because hospitals are under operation 24 hours per day, 365 days per year, it is extremely important to understand energy and resource usage. By producing their own electricity, operating costs could potentially be reduced.

Analysis Goals

As electricity costs increase over time and natural resources become continually depleted, renewable energy production will only increase in popularity and eventually be a necessary option for human habitation. The primary goal for the implementation of a photovoltaic array was to determine the economic feasibility of supplementary solar power during peak production times throughout the day and over the calendar year. After designing the system, an upfront cost estimate and economic analysis will be provided with accurate financial information to make a decision concerning the pros and cons of initial investment versus tax free solar energy income.

Process

<u>Photovoltaic Array</u>

Solar Angle Analysis

In order to begin the analysis regarding the addition of photovoltaic cells to the Aria Health ED Expansion addition, a solar angle study was conducted first. In order to perform this solar angle study, *Mechanical and Electrical Equipment for Buildings (MEEB)* was consulted to plan out the most appropriate strategy. The purpose of this solar study was to determine the spacing requirements for the photovoltaic array to ensure that no shadows fell onto the surface of the PV modules so that sun light collection would not be impeded. Initially, the shadow due to the 6-foot-high parapet wall on the south and west facing sides of the building were examined.

For the analysis, Philadelphia's location was considered to be 39.88° North Latitude, 75.25° West Longitude. For this location, a Vertical Projection Sun Path Chart was utilized to determine the altitude angle during the winter solstice, when the sun would be the lowest in the sky, subsequently casting the longest shadow. Also for the purpose of this analysis, the hours between 10:30AM and 1:30PM were considered to be the "peak sunshine" hours during the day, where insolation would be greatest. With that in mind, shadow distances were based on the case of winter solstice at 10:30AM. As can be seen in Figure 2.1, it was determined that the altitude angle for the above stated case was 22.5°. This altitude angle was then used to determine the distance the first PV module row was required to sit from the 6' parapet wall. This is shown in the diagram presented in Figure 2.2, where the formulas used for this calculation is as follows:

$$X = \frac{6}{\tan(22.5)} = 14.5'$$

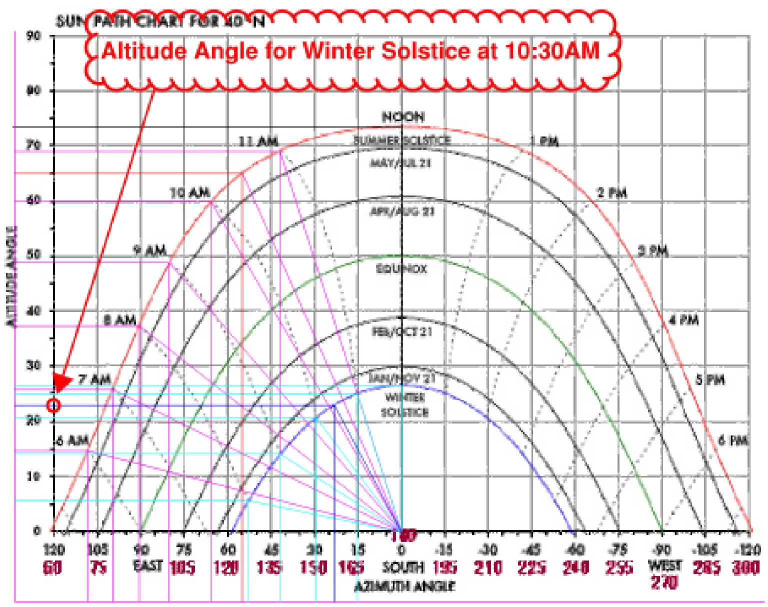


Figure 2.1

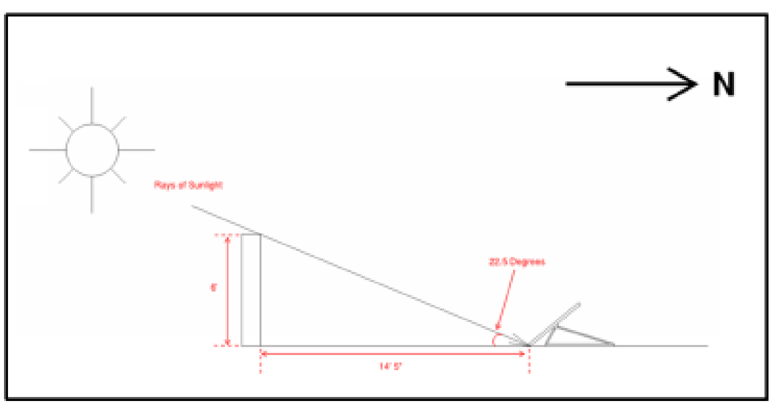


Figure 2.2

It was found that the first row of PV modules must be located at least 14.5' away from the parapet to keep from being shaded between the hours of 10:30AM and 1:30PM during the winter solstice. It should be noted that the PV panels are assumed to be facing due south, where no additional azimuth angles were included for simplification.

In addition to the shadow due to the parapet wall, the shadow cast by the PV modules themselves had to be calculated. According to page 1333 of *MEEB*, "for a stationary (non-tracking) array, total annual insolation is maximum for a tilt angle equal to the latitude of the site." With that said, it was determined that the PV modules placed on the roof would be tilted at 39.88^o from the horizontal. This tilt angle was then used to determine the shadow distance caused by a 3.5' wide module, as such that the sun was projected perpendicularly to the surface of the module face. A diagram depicting this can be seen in Figure 2.3, as well as in a larger version in Appendix B.1. The values shown were calculated using the following formulas:

$$y = 3.5\sin(39.88°) = 2.24'$$

$$x = \frac{2.24'}{\tan(50.12°)} = 1'10"$$

The distance required between each PV module was found to be 1' 10".

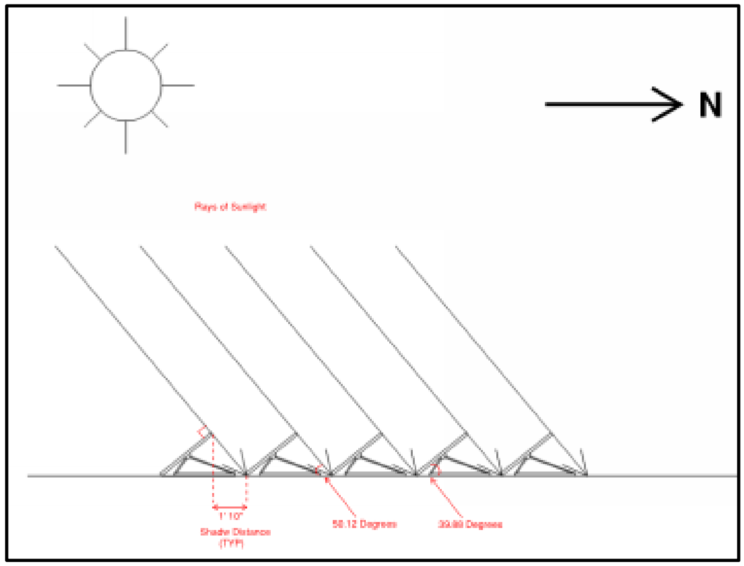


Figure 2.3

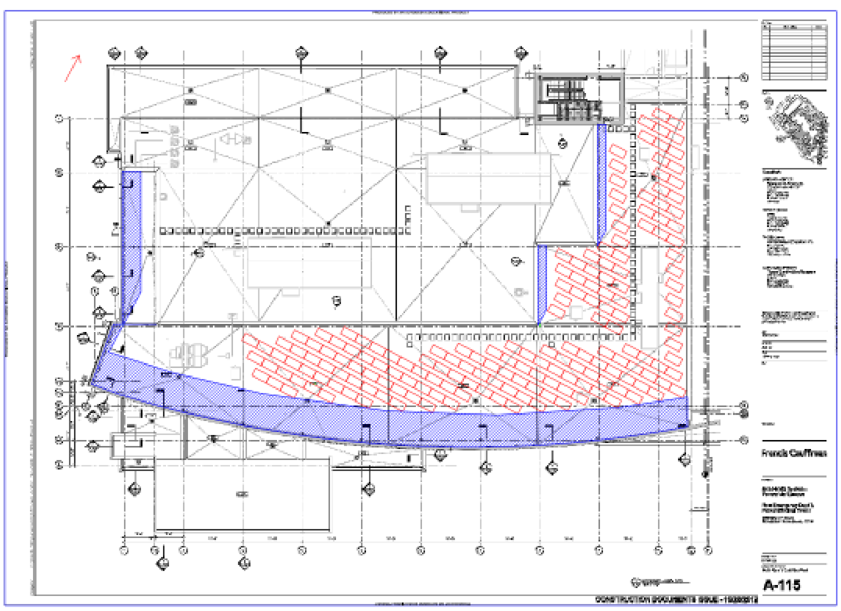


Figure 2.4

Based on the shadow projections calculated from the solar angles, height of the parapet wall, and width of the given solar module, a photovoltaic array was constructed, as can be seen in Figure 2.4. Shown in red are 180 PV modules, spaced according the shadow distances calculated. Shown in blue is the shadow projections due the 6' parapet wall. Any space where a PV module is not present has been occupied by another piece of equipment or roof drain. A full sized version of this layout can be seen in Appendix B.2.

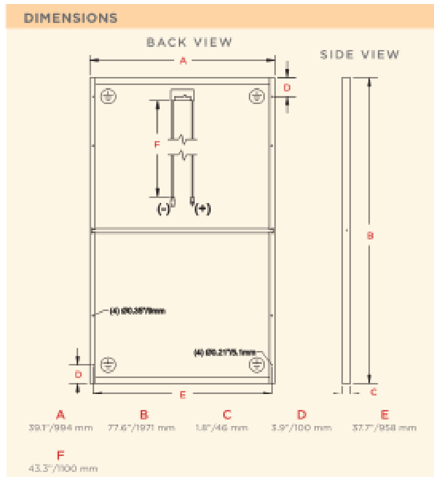
Design

After determining the required locations for the photovoltaic array, a real, detailed solar power production system had to be designed in order to perform an accurate quantity takeoff, cost estimate, and economic analysis. The first step in the design process was to choose a specific photovoltaic module to be used. Several different manufacturers were considered during schematic design, but ultimately the Sharp ND-F4Q300 was chosen.

ELECTRICAL CHARACTERISTICS	
Maximum Power (Pmax)*	300 W
Tolerance of Pmax	0%/5%
Type of Cell	Polycrystalline silicon
Cell Configuration	72 in series
Open Circuit Voltage (Voc)	45.1 V
Maximum Power Voltage (Vpm)	35.2 V
Short Circuit Current (Isc)	8.94 A
Maximum Power Current (Ipm)	8.52 A
Module Efficiency (%)	15.3%
Maximum System (DC) Voltage	1000 V
Series Fuse Rating	15 A
NOCT	46.2°C
Temperature Coefficient (Pmax)	-0.439%/°C
Temperature Coefficient (Voc)	-0.321%/°C
Temperature Coefficient (Isc)	0.050%/°C

*Illumination of 1 kW/m² (1 sun) at spectral distribution of AM 1.5 (ASTM E892 global spectral irradiance) at a cell temperature of 25°C.

MECHANICAL CHARACTERISTICS	
Dimensions (A x B x C below)	39.1" x 77.6" x 1.8"/994 x 1971 x 46 mm
Cable Length (G)	43.3"/1100 mm
Output Interconnect Cable	12 AWG with SMK Locking Connector
Weight	50 lbs / 22.7 kg
Max Load	30 psf (1440 Pascals)
Operating Temperature (cell)	-40 to 194°F / -40 to 90°C



Contact Sharp for tolerance specifications

ND-F4Q300

Figure 2.5

This particular PV module was chosen based on several factors, including its maximum power output of 300W, polycrystalline silicon structure, and high efficiency to size and weight ratio. The ND-F4Q300 is 3.5' wide and 6.5' long, where these dimensions were used in producing the array layout shown in Figure 2.4. This solar panel can be seen in Figure 2.5, as well as Appendix B.3 where the full specification data sheet can be seen.

After choosing a particular PV module, the next step was to design the configuration in which the panels would be physically wired. In doing so, total voltage and current traveling through each of the associated wires was kept in mind. A single line diagram was produced, as can be seen in Figure 2.6.

In order to maximize efficiency and limit the amount of voltage and current travelling through each conductor for reasons of safety and wire sizing, it was decided that 5 parallel feeders consisting of 6 series braches of 6 modules each was the best option. After speaking with an industry professional, it was understood that any DC circuit must be limited to 250V, as any higher becomes extremely dangerous. Also, while performing the single line diagram, *Solar Energy: Protecting and Isolating PV Systems* by ABB was referenced for design purposes. *Solar Energy* displayed two possible configurations for wiring a PV array, the first being Centralized Conversion and the second being Distributed Conversion. Ultimately, the Distributed Conversion option was chosen, which can be seen in Figure 2.7. The full version of *Solar Energy* can be seen in Appendix B.4 for further reference.

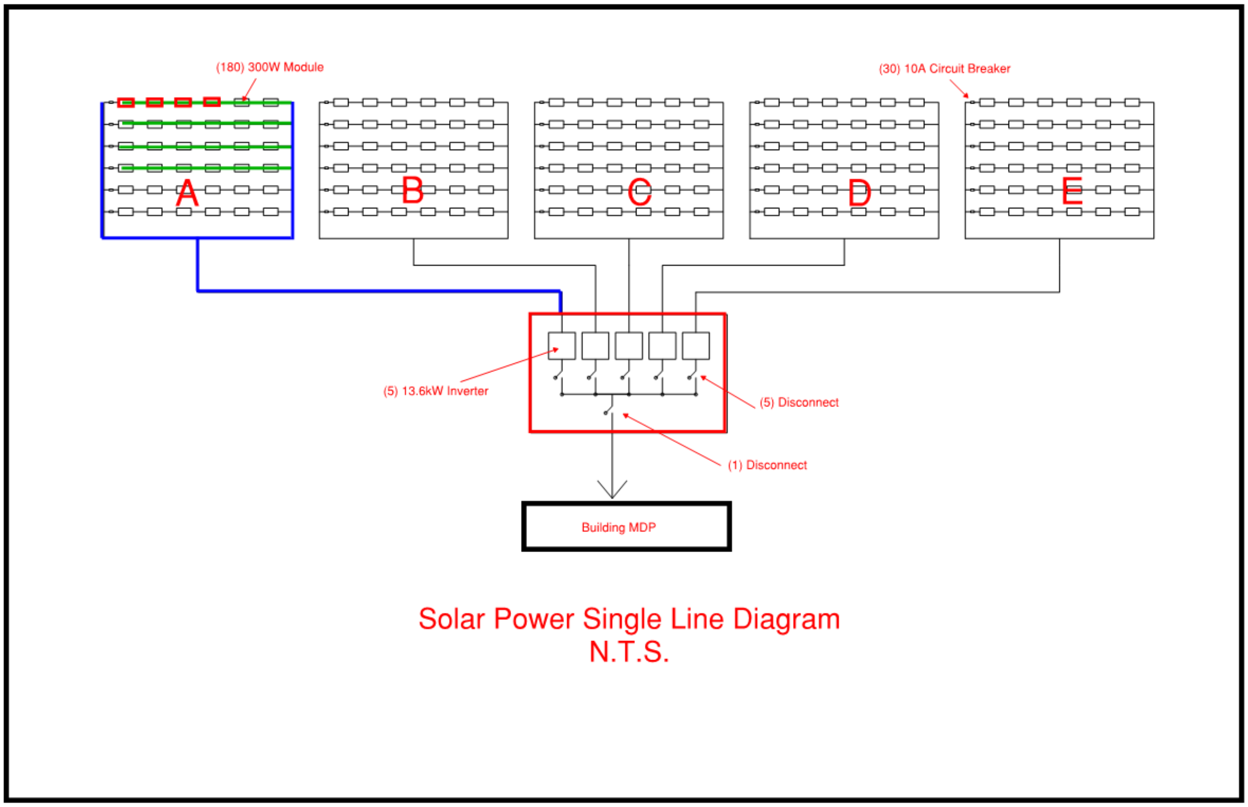


Figure 2.6

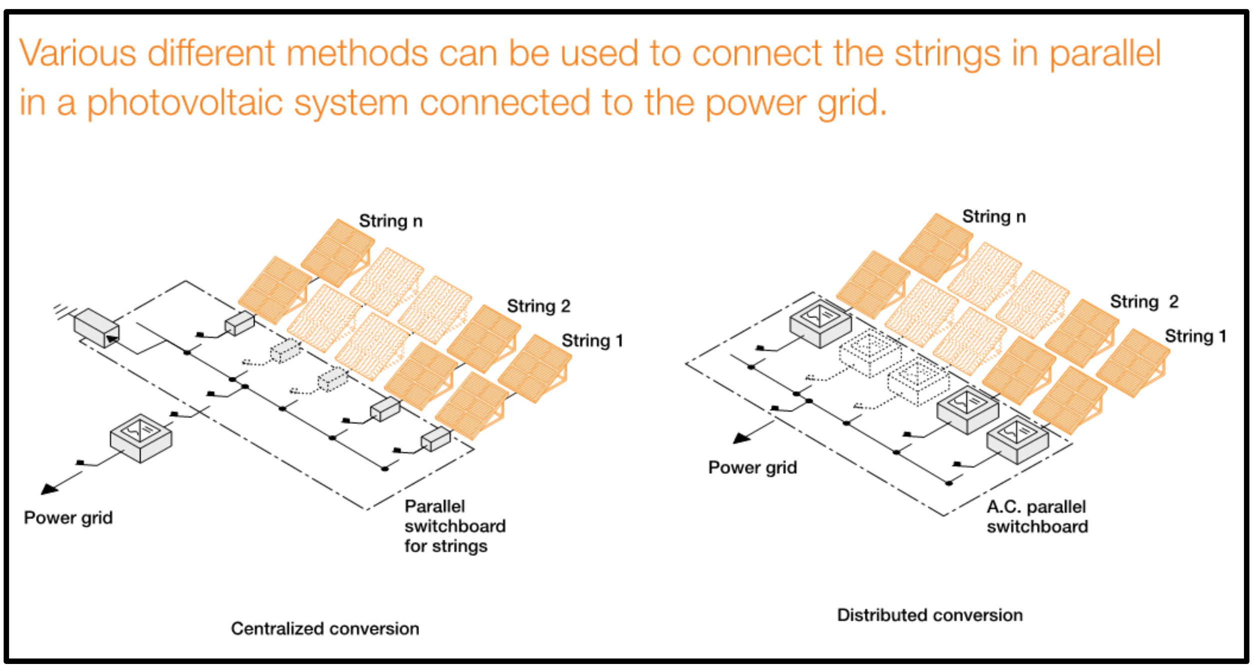


Figure 2.7

The single line diagram in Figure 2.7 shows 5 parallel strings, each string labeled A through E. To explain the design process, the difference between parallel and series circuits must first be understood. When dealing with parallel, voltage is held constant. Adversely, when dealing with series, current is held constant. Therefore, in conjunction with the earlier statement of keeping the maximum voltage per conductor under 250V, parallel circuitry was chosen. To explain the single line diagram in detail, reference the following calculations:

Electrical Breadth

For DC power systems, the formula used was

$$W = VA$$

As shown in the single line diagram, 6 modules at maximum voltage of 35.2V each (found in the Sharp ND-F4Q300 specifications) are wired in series.

$$V = (6\; modules)x(35.2V\; per\; module) = 211.2V, where\; 211.2V < 250V$$

To calculate the current through each series circuit

$$A = \frac{(6\; modules)x(300W\; per\; module)}{211.2\; V} = 8.52A$$

Holding voltage constant and summing the current throughout the parallel circuit consisting of 6 series braches, to calculate the current flowing through the parallel feeder

$$A = (8.52A)(6\; series\; branches) = 51.14A, where\; 211.2V\; is\; constant$$

To calculate the total power for one parallel feeder circuit

$$W = (36\; modules)(300W) = 10{,}800W$$

Consequently, for one parallel DC feeder, there will be a total of 10,800W, 51.14A, and 211.2V flowing through the conductor.

To further explain the single line diagram, five 13.6 kW inverters were used, housed inside a combining box. Additionally, using the online PV Watts AC Energy & Cost Savings tool (which will be discussed later in this document) assuming a DC to AC derate factor of 0.82, a total of 44.3 kW of AC power was produced. With that said, the AC feeder to the building main distribution switchgear shown on the single line diagram will be explained:

$$Total\; AC\; Power = 44{,}300\; W$$

Assuming an AC voltage of 480V, the following formula was used

$$A = \frac{W}{Vsqrt(3)}$$

$$A = \frac{44{,}300W}{(480V)sqrt(3)} = 53.28A$$

A summary of the above stated calculations can be seen in Figure 2.8, where wire sizes are also listed.

Conductor Schedule								
Item	**# Modules**	**Watts/Module**	**Tot W**	**VDC/Module**	**Tot VDC**	**Amps**	**Wire Size**	**Type**
Series Connection	6	300	1800	35.2	211.2	8.52	#12	AWG
Parallel Connection	36	300	10800	35.2	211.2	51.14	#4	AWG
To Building Grid (A/C)	180	300	44300	35.2	480	53.28	#4	AWG

Figure 2.8

The wire sizes shown were chosen based on the American Wire Gauge (AWG) Cable/Conductor Sizes and Properties shown in Figure 2.9, accounting for the maximum allowable current flowing through each wire.

Table 1: American Wire Gauge (AWG) Cable / Conductor Sizes and Properties

AWG	Diameter [inches]	Diameter [mm]	Area [mm^2]	Resistance [Ohms / 1000 ft]	Resistance [Ohms / km]	Max Current [Amperes]	Max Frequency for 100% skin depth
0000 (4/0)	0.46	11.684	107	0.049	0.16072	302	125 Hz
000 (3/0)	0.4096	10.40384	85	0.0618	0.202704	239	160 Hz
00 (2/0)	0.3648	9.26592	67.4	0.0779	0.255512	190	200 Hz
0 (1/0)	0.3249	8.25246	53.5	0.0983	0.322424	150	250 Hz
1	0.2893	7.34822	42.4	0.1239	0.406392	119	325 Hz
2	0.2576	6.54304	33.6	0.1563	0.512664	94	410 Hz
3	0.2294	5.82676	26.7	0.197	0.64616	75	500 Hz
4	0.2043	5.18922	21.2	0.2485	0.81508	60	650 Hz
5	0.1819	4.62026	16.8	0.3133	1.027624	47	810 Hz
6	0.162	4.1148	13.3	0.3951	1.295928	37	1100 Hz
7	0.1443	3.66522	10.5	0.4982	1.634096	30	1300 Hz
8	0.1285	3.2639	8.37	0.6282	2.060496	24	1650 Hz
9	0.1144	2.90576	6.63	0.7921	2.598088	19	2050 Hz
10	0.1019	2.58826	5.26	0.9989	3.276392	15	2600 Hz
11	0.0907	2.30378	4.17	1.26	4.1328	12	3200 Hz
12	0.0808	2.05232	3.31	1.588	5.20864	9.3	4150 Hz
13	0.072	1.8288	2.62	2.003	6.56984	7.4	5300 Hz
14	0.0641	1.62814	2.08	2.525	8.282	5.9	6700 Hz
15	0.0571	1.45034	1.65	3.184	10.44352	4.7	8250 Hz
16	0.0508	1.29032	1.31	4.016	13.17248	3.7	11 k Hz

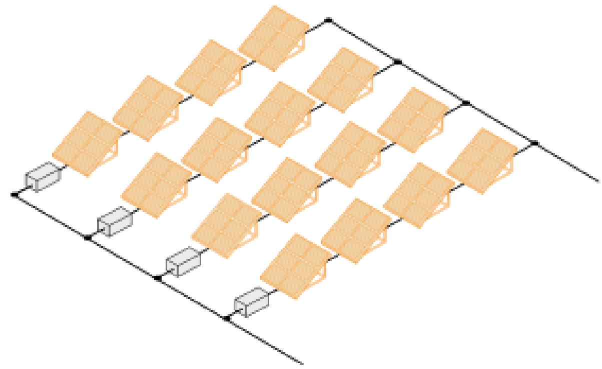
Figure 2.9

Additionally, the conduit was sized according to the Conduit Fill Chart shown in Figure 2.10. Based on the principles of DC power, each feeder and branch will require 3 wires; a positive, a negative, and a ground. For AC power, 5 wires are necessary. The series branch circuits will require a ½" EMT conduit, where the parallel feeder will require a 1" conduit.

Trade Size		Wire Size (THWN, THHN) Conductor Size AWG/kcmil															
		14	12	10	8	6	4	3	2	1	1/0	2/0	3/0	4/0	250	300	350
1/2	EMT	12	9	5	3	2	1	1	1	1	1						
	IMC	14	10	6	3	2	1	1	1	1	1	1					
	GRC	13	9	6	3	2	1	1	1	1	1						
3/4	EMT	22	16	10	6	4	2	1	1	1	1	1	1	1			
	IMC	24	17	11	6	4	3	2	1	1	1	1	1	1			
	GRC	22	16	10	6	4	2	1	1	1	1	1	1	1			
1	EMT	35	26	16	9	7	4	3	3	1	1	1	1	1	1	1	1
	IMC	39	29	18	10	7	4	4	3	2	1	1	1	1	1	1	1
	GRC	36	26	17	9	7	4	3	3	1	1	1	1	1	1	1	1

Figure 2.10

Continuing with the explanation of the single line diagram, shown are thirty 10A circuit breaks present on every series branch. This were deemed necessary after doing further research in ABB's *Solar Energy.* The configuration shown in the single line was based on the layout shown in Figure 2.11, which can be found in *Solar Energy*. The purpose of these circuit breakers is to isolate each series branch circuit. In the event of a reverse-surge in electricity, these 10A circuit breakers will protect each of the photovoltaic modules from damage. Additionally, when maintenance is required within one of the series braches, the circuit break can be switched off, providing a safe environment for work to be done.



Protection for the parallel connection of the strings of photovoltaic modules. Automatic circuit-breakers.

Advantages: a single device provides both the protection and isolating functions

Disadvantages: More expensive

Figure 2.11

The specific 10A circuit breaker in which the system is designed to include is the Schneider Electric 3P C60N. This can be seen in Figure 2.12, as well as in Appendix B.5 for a more detailed look at the entire product specifications.

3P C60N

Box Lug/Box Lug												
0.5	60100	125.00	60134	269.00	—	—	60117	125.00	60151	269.00	—	—
1	60101	125.00	60135	269.00	60168	387.00	60118	125.00	60152	269.00	60184	387.00
1.5	60102	125.00	60136	269.00	60169	387.00	60119	125.00	60153	269.00	60185	387.00
2	60103	125.00	60137	269.00	60170	387.00	60120	125.00	60154	269.00	60186	387.00
3	60104	125.00	60138	269.00	60171	387.00	60121	125.00	60155	269.00	60187	387.00
4	60105	125.00	60139	269.00	60172	387.00	60122	125.00	60156	269.00	60188	387.00
5	60106	125.00	60140	269.00	60173	387.00	60123	125.00	60157	269.00	60189	387.00
6	60107	114.00	60141	246.00	60174	356.00	60124	114.00	60158	246.00	60190	356.00
7	60108	114.00	60142	246.00	60175	356.00	60125	114.00	60159	246.00	60191	356.00
8	60109	114.00	60143	246.00	60176	356.00	60126	114.00	60160	246.00	60192	356.00
10	60110	114.00	60144	246.00	60177	356.00	60127	114.00	60161	246.00	60193	356.00
13	60111	114.00	60145	246.00	60178	356.00	60128	114.00	60162	246.00	60194	356.00
15	60112	114.00	60146	246.00	60179	356.00	60129	114.00	60163	246.00	60195	356.00
20	60113	114.00	60147	246.00	60180	356.00	60130	114.00	60164	246.00	60196	356.00
25	60114	114.00	60148	246.00	60181	356.00	60131	114.00	60165	246.00	60197	356.00
30	60115	120.00	60149	257.00	60182	372.00	60132	120.00	60166	257.00	60198	372.00
35	60116	120.00	60150	257.00	60183	372.00	60133	120.00	60167	257.00	60199	372.00

Figure 2.12

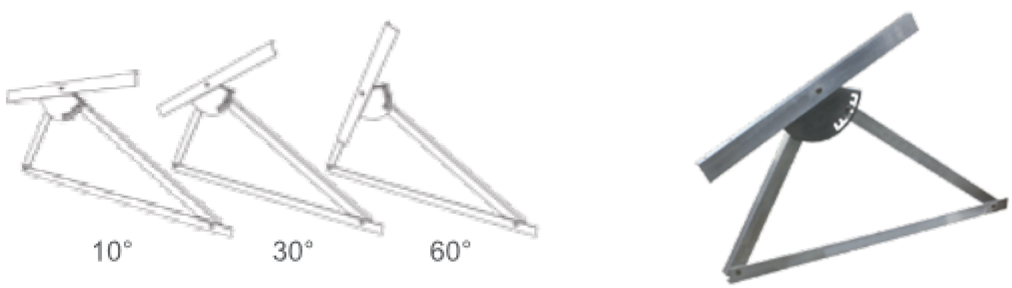
Lastly on the single line diagram, there are five 30A disconnect switches shown coming off of each 13.6 kW inverter, after which each conductor connects to the main AC feeder to the building MDP. In conjunction with this feeder, there is also one 100A disconnect switch. The disconnects provide safety measure for when power surges backward and will cut off the flow of electricity that could potentially damage all of the system component.

The inverter that has been chosen during design development is the Aurora PowerOne PVI-12.0-I 13.6 kW inverter. It is designed for commercial use and it considered to be up to 97.3% efficient. Several other manufactures were researched, however this one the only inverter that fit the design criteria. The Aurora PWI can be seen in Figure 2.13, as well as in Appendix B.6 for the full specifications.

The last component that has been chosen for construction is the photovoltaic racking system. The Schletter VarioTop adjustable flat roof support system has been used due to its strong versatility and strength to weight ratio. It is lighter than most racking systems, weighing only 15 pounds. This PV module support can be adjusted from 10 degrees to 60 degrees from the horizontal, which is more than enough to satisfy the 39.88 degree module tilt. This also provides the owner with the option of adjusting the tilt during different times of the year, which will consequently produce more direct sun light capture.

Figure 2.13

The VarioTop can be seen in Figure 2.14, as well as Appendix B.7 for the full specifications.



Material	Aluminium / high-grade steel 1.4301
Structural analysis and loading	System structural analysis acc. to DIN 1055, part 4 (03/2005), part 5 (06/2005), Eurocode 1 (available on the internet in the form of charts)
Base length	1545 mm
Setting range	10 to 60 degrees
Weight	7 kg
Fixed settings	Steps of 10 degrees (labelled)
Structural analysis	DIN 1055 new and Eurocode 1 Exact data on request
Substructures	• Concrete blocks, • Sheet metal roofs (on standing seam clamps, Kalzip clamps, etc.) • Bitumen roof • Pantile roof • Foundations (for open area elevations) • etc.

Figure 2.14

Cost Estimation

Before any quantity takeoffs or cost estimation could take place, the entire photovoltaic array had to be laid out and wired on paper, as if it were to be constructed in the field to find accurate linear footage for wire and conduit. Through the use of AutoCAD, each module was connected as shown in the single line diagram designed, connecting 6 modules in series branches and connecting 6 of those branches in parallel. Each parallel feeder is then connected back to a shed housing on the roof where the inverters are mounted. As can be seen in Figure 2.15, parallel groups A through E are shown, the same as in the single line diagram. A full-sized version of this document can be seen in Appendix B.8. As depicted in layout below, the red rectangles show the PV modules, green lines shows the series branches, and blue lines shows the parallel feeders.

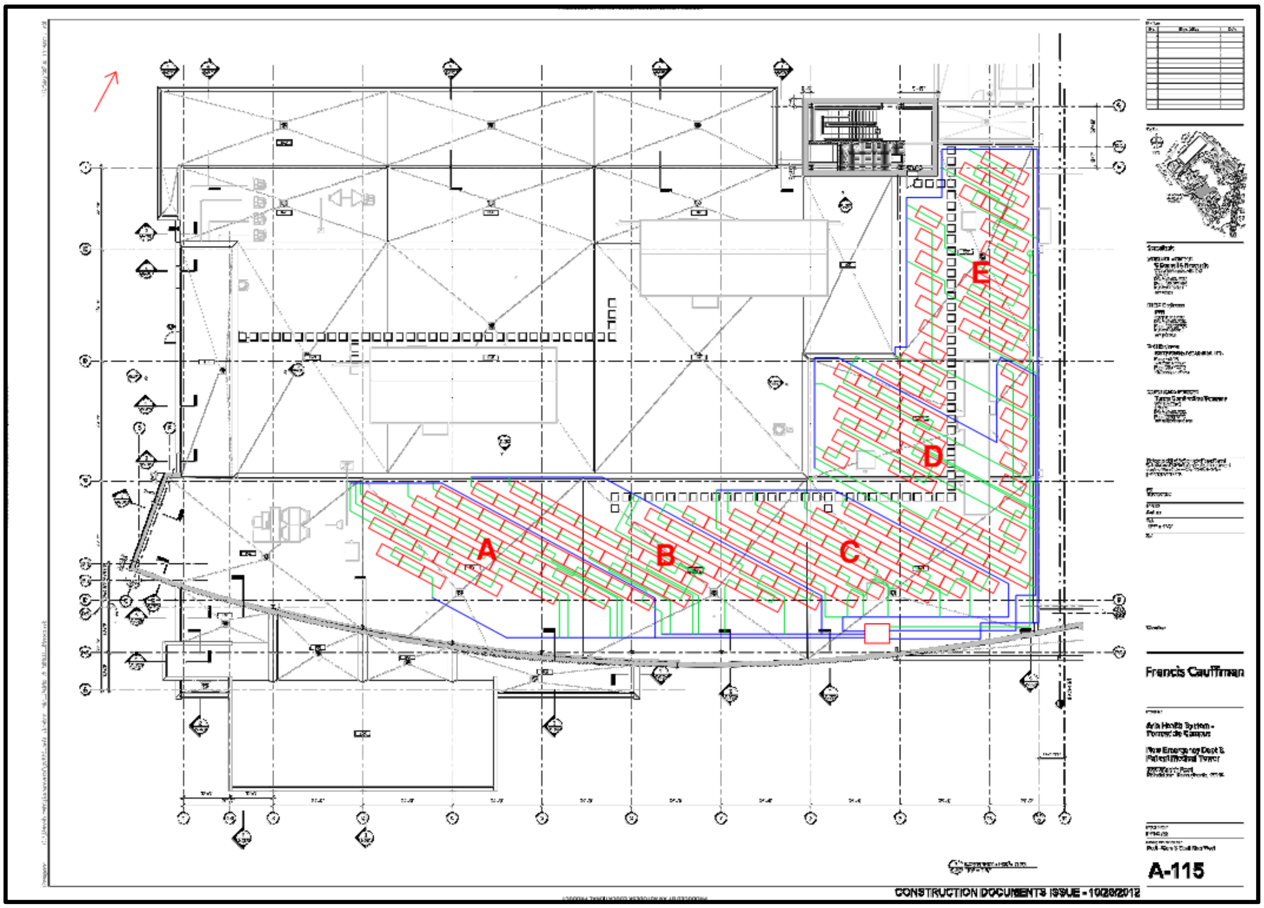


Figure 2.15

Quantity takeoffs were done for the PV modules, circuit breakers, inverters, disconnects, switchboards, racking system, conduit, and conductors and estimated using RS Means 2014. Unit costs were found for each of the electrical components and green building systems. A base build, hard cost estimate for the photovoltaic array was found to be $192,689.98. 10% was added to this cost to account for overhead and profit for a total cost estimate of $211,958.98. It was assumed that this type of construction would be considered tax-exempt due to green building initiatives, therefore no tax was included in this price. The final estimate is broken out by line item and can be seen in Figure 2.16.

Total Photovoltaic System Estimate	
Item	**Total Cost**
300W Module	$83,430.00
10A Circuit Breaker	$14,670.00
13.6 kW Inverter	$24,065.00
30A Disconnect	$1,095.00
100A Disconnect	$475.00
Paralleling Switchboard	$2,075.00
Racking System	$33,390.00
1/2" EMT Conduit	$13,054.00
1" EMT Conduit	$10,664.88
#12 Wire	$2,722.08
#4 Wire	$6,878.85
#8 Wire	$170.17
Sub Total	**$192,689.98**
Overhead & Profitt (10%)	$19,269.00
Tax (Exempt)	$0.00
Grand Total Cost	**$211,958.98**
Cost/Watt (AC)	**$4.78**

Figure 2.16

Copper Conductor Estimate											
Item	**Wire Size**	**No. Wires**	**LF**	**QTY**	**UOM**	**Material Cost**	**Labor Cost**	**Unit Cost**	**Total Cost**	**Daily Output**	**No. Days**
Series Branch	#12	3	2140	64.2	CLF	\$9.40	\$33.00	\$42.40	\$2,722.08	13.00	5
Parallel Feeder	#4	3	1014	30.42	CLF	\$101.00	\$80.50	\$181.50	\$5,521.23	10.60	3
A/C Feeder	#4	4	187	7.48	CLF	\$101.00	\$80.50	\$181.50	\$1,357.62	10.60	1
A/C Ground	#8	1	187	1.87	CLF	\$37.50	\$53.50	\$91.00	\$170.17	8.00	1

Total Wire	**\$9,771.10**	**Total Days**	**10**

References and Assumptions:
All cost and daily output data is from RS Means 2014

Figure 2.17

As can be seen in Figure 2.17, an estimate was performed for the copper wiring as shown in the wiring layout diagram. Each of the branch and feeder circuits were quantified using the design criteria for DC and AC circuits. A total linear footage was found first, then multiplied by the number of wires. That product was then divided by 100LF to put the unit of measure (UOM) into CLF for estimating purposes. Material cost and labor cost for each line item has been totaled to find the overall unit cost and multiplied by the quantity to find a total cost for each item. Formulas for the calculations above are as follows:

$$Total\ Cost = QTY\ x\ Total\ Unit\ Cost$$

$$Total\ Wire = Summation\ of\ all\ \text{"Total Cost"}\ line\ items$$

The total cost of wire was found to be \$9,771.10.

EMT Conduit Estimate										
Item	**Conduit Size**	**QTY**	**UOM**	**Material Cost**	**Labor Cost**	**Unit Cost**	**Total Cost**	**Daily Output**	**No. Days**	**Crew Size**
Series Branch	1/2"	2140	LF	\$1.83	\$4.27	\$6.10	\$13,054.00	100.00	5	4 Elec
Parallel Feeder	1"	1014	LF	\$3.53	\$5.35	\$8.88	\$9,004.32	80.00	3	4 Elec
A/C Feeder	1"	187	LF	\$3.53	\$5.35	\$8.88	\$1,660.56	80.00	1	2 Elec

Total Conduit	**\$23,718.88**	**Total Days**	**10**

Referencces and Assupmtions:
All cost and daily output data is from RS Means 2014

Figure 2.18

Figure 2.18 shows the estimate performed for EMT conduit, which was determined based on linear footage and the aforementioned design criteria.

$$Total\ Cost = QTY\ x\ Total\ Unit\ Cost$$

$$Total\ Conduit = Summation\ of\ all\ \text{"Total Cost"}\ line\ items$$

The total cost of conduit was found to be \$23,718.88.

PV Components Estimate										
Item	Qty	UOM	Material Cost	Labor Cost	Equipment Cost	Total Unit Cost	Total Cost	Daily Output	No. Days	Crew Size
300W Module	180	EA	$410.00	$53.50	$0.00	$463.50	$83,430.00	8.00	6	4 Elec
10A Circuit Breaker	30	EA	$356.00	$133.00	$0.00	$489.00	$14,670.00	3.20	3	3 Elec
13.6 kW Inverter	5	EA	$4,600.00	$213.00	$0.00	$4,813.00	$24,065.00	8.00	1	1 Elec
30A Disconnect	5	EA	$86.00	$133.00	$0.00	$219.00	$1,095.00	3.20	1	2 Elec
100A Disconnect	1	EA	$250.00	$225.00	$0.00	$475.00	$475.00	1.90	1	1 Elec
Paralleling Switchboard	1	EA	$1,300.00	$775.00	$0.00	$2,075.00	$2,075.00	1.10	1	1 Elec
Racking System	180	EA	$48.50	$137.00	$0.00	$185.50	$33,390.00	5.13	5	7 Elec

Total Components	$159,200.00	Total Days	17

References and Assumptions:
Price for (1) 300W Module - http://www.solartown.com/store/product/sharp-300w-solar-panel-nd-f4q300/#null;
Price for (1) 30A Circuit Breaker - http://www.standardelectricsupply.com/index.jsp?path=product&part=1926203&gclid=CPfSj-
Price for (1) 13.6 kW Inverter - http://www.eco-distributing.com/product.asp?itemid=946&gclid=CI2tlNWw6LwCFU_NOgod40YA8g
All other cost and daily output data is from RS Means 2014
"300W Module" pricing is based on Sharp 300W Panel ND-F4Q300
"10A Circuit Breaker" pricing is based on Schneider Electric Circuit Break, Lug, 3 Poles, 10A
"13.6 kW Inverter" pricing is based on Aurora Power-One PVI-12.0-I-OUTD-S2-US-480

Figure 2.19

For the photovoltaic components estimate as seen in Figure 2.19, real-life costs were found for the specific PV modules, circuit breakers, inverters, and disconnects chosen for the design of this system. Reference information for the cost data can be found by viewing the web pages listed under "References and Assumptions" above. RS Means cost information was used for labor.

$$Total\ Cost = QTY\ x\ Total\ Unit\ Cost$$

$$Total\ Components = Summation\ of\ all\ \text{"Total Cost"}\ line\ items$$

The total cost of PV components was found to be $159,200.00.

Economic Analysis

In order to perform an accurate economic analysis to show the payback period for the photovoltaic array as it has been design and constructed, calculations had to be performed in order to determine the actual amount of electricity produced every year. To do this, the PV Watts AC Energy & Cost Savings tool was utilized to determine the total annual kWh produced, as well as the associated cost savings of that self-production of power.

PV Watts AC Energy & Cost Savings

Station Identification	
City:	Philadelphia
State:	Pennsylvania
Latitude:	39.88 Degrees N
Longitude:	75.25 Degrees W
Elevation:	9m
PV System Specifications	
DC Rating:	54.0 kW
DC to AC Derate Factor:	0.82
AC Rating:	44.3 kW
Array Type:	Fixed Tilt
Array Tilt:	39.9 Degrees
Array Azimuth:	180 Degrees
Energy Specifications	
Cost of Electricity:	$0.10/kWh

Month	Solar Radiation (kWh/m^2/day)	AC Energy (kWh)	Energy Value ($)
1	3.30	4669.00	$466.90
2	4.16	5306.00	$530.60
3	4.74	6395.00	$639.50
4	5.06	6411.00	$641.10
5	5.20	6565.00	$656.50
6	5.43	6439.00	$643.90
7	5.51	6663.00	$666.30
8	5.67	6904.00	$690.40
9	5.07	6115.00	$611.50
10	4.59	5976.00	$597.60
11	3.37	4398.00	$439.80
12	2.67	3656.00	$365.60
Year	4.57	69496.00	$6,949.60

References and Assumptions:
http://rredc.nrel.gov/solar/calculators/pvwatts/version1/US/code/pvwattsv1.cgi
The DC to AC Derate Factor value of 0.82 was assumed

Figure 2.20

Figure 2.20 shows an annual energy production of 69,496 kWh and $6,949.60 in savings during the first year of operation. This chart shows the solar radiation capability for each month during the calendar year, as well as the associated energy production and cost savings. These numbers are based on the inputted values of location, DC power production due to the PV array, DC to AC derate factor, array tilt, and the cost of electricity for the given utility company. A "cost of electricity" value on $0.10 was entered based on the cost data shown in Figure 2.21 of 9.77 cents, which rounded up for this exercise.

Updated February 20, 2014

PECO Energy 1-800-494-4000 www.peco.com — Rate R — Regular Residential Service

	Prices in cents per kWh	Monthly Generation & Transmission Bill If You Use: 500 kWh	1000 kWh	2000 kWh	Early Cancellation Fee?
PECO Price to Compare through February 28, 2014	9.77 ¢	$48.85	$97.70	$195.40	

Figure 2.21

After completing the final estimate for the photovoltaic array, an economic analysis was performed to show the relationship of cost savings over a 25 year period and initial investment. Solar Renewable Energy Credits (SRECs) were also included in this analysis, as they can provide a valuable source of income for owners who choose solar power production for their buildings. SRECs are an incentive based program that "require electricity suppliers to secure a portion of their electricity from solar generators" (SRECTrade.com). These SRECs are bought and sold on an open market, where value is based on supply and demand, as well as the location in which they are being acquired. One SREC is obtained by producing 1Mwh of solar electricity. The value of these credits varies however, where the last known purchase was on January 15, 2014 for $40.01. The market trend can be seen below in Figure 2.22, which has been found at SRECTrade.com.

Figure 2.22

A calculation has been performed to show the amount of potential SRECs produced from the PV system that has been designed. These values have been summarized in Figure 2.23.

SREC Credit Value Calculations					
kWh Produced/Year	**Mwh Produced/Year**	**No. SREC**	**Income/SREC**	**Annual SREC Income**	**SREC Income/kWh**
69496	69.496	69	$40.01	$2,760.69	$0.04

References and Assumptions:
SREC trade price of $40.01 was used from the last trade on January 15, 2014 http://www.srectrade.com/srec_markets/pennsylvania

Figure 2.23

These values have been calculated based on the following formulas:

$$No.SRECs = \frac{kWh\ Produced\ per\ year}{1000} x \frac{1\ SREC}{1\ Mwh}$$

$$Annual\ SREC\ Income = No.SRECs\ x \frac{Income}{SREC}$$

Shown in Figure 2.24, is a detailed analysis of initial cost, maintenance costs, and income over 25 years, where an annual and cumulative cash flow is included. To explain this table, the following items must be understood:

- The cost of the photovoltaic system is a one-time, upfront cost shown in year 1, where a value of $0.00 dollars is shown for every following year.
- This system is assumed to be maintenance free for a five year period, where a maintenance cost is shown in year 6, as well as every subsequent year after that.
- Maintenance costs are based on 16 hours/year for a union electrician rate of $110.64/hour.
- Inflation is assumed to increase by 3% every year for the cost of maintenance.
- Total tax exempt cost is shown in red, where maintenance cost and initial costs are summed for each year.
- Solar power production is considered to be an income value, where the initial value of $6,949.60 is shown in year 1.
- The cost of electricity is assumed to increase by 5% every year, as averaged over the previous 25 years.
- An Initial SREC value is shown in year 1, where a deflation rate of 5% is expected every year for a ten year period, where after that ten year period, SRECs are assumed to become valueless.
- Total tax-exempt income is the summation of solar power production savings and SREC credit value, shown in green.
- Annual cash flow is found by subtracting total tax-exempt costs (shown in red) from total tax-exempt income (shown in green) every year.
- Cumulative cash flow for each year is found by adding that particular year's annual cash flow to the previous year's cumulative cash flow. For example:
  - In year 1: Cumulative cash flow = -$202,229.54
  - In year 2: Annual cash flow = $9,937.93
  - Therefore, in year 2, cumulative cash flow = -$202,229.54 + $9,937.93 = -$192,291.61

In summation, based on the initial investment, maintenance costs, and income values shown over a 25 year period, it is expected to take 19.52 years for the system to pay for itself. In addition, assuming the inflation and deflation rates stated above will stand over time, the system will generate $94,467.20 over 25 years. Today, based on a 3% inflation rate, that amount would be worth $44,113.79, or a return on investment (ROI) of 0.83% every year for 25 years.

Recommendations

Based on the payback period of 19.52 years and a very poor ROI of 0.83% per year, it is strongly recommended that the owner of the Aria Health ED Expansion project not consider adding a photovoltaic system. The initial investment is too high and the work necessary for completion is too much to be considered a viable option. Solar power production is a valuable source of energy, however, at this time history it just does not yet make sense financially.

Economic Analysis for Photovoltaic System

No. of Years

	After 25 Years	1	2	3	4	5	6	7	8
Total Upfront Costs:									
Cost of Photovoltaic System	$211,958.98	$211,958.98	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Maintenance	$47,567.01	$0.00	$0.00	$0.00	$0.00	$0.00	$1,770.24	$1,823.35	$1,878.05
Total Tax-Exempt Costs	$259,525.99	$211,958.98	$0.00	$0.00	$0.00	$0.00	$1,770.24	$1,823.35	$1,878.05
Total Cost Savings:									
Solar Power Production	$331,684.25	$6,949.60	$7,297.08	$7,661.93	$8,045.03	$8,447.28	$8,869.65	$9,313.13	$9,778.79
SREC Credit Value ($0.04/kWh)	$22,308.94	$2,779.84	$2,640.85	$2,508.81	$2,383.37	$2,264.20	$2,150.99	$2,043.44	$1,941.27
Total Tax-Exempt Income	$353,993.19	$9,729.44	$9,937.93	$10,170.74	$10,428.40	$10,711.48	$11,020.63	$11,356.57	$11,720.05
Annual Cash Flow		-$202,229.54	$9,937.93	$10,170.74	$10,428.40	$10,711.48	$9,250.39	$9,533.22	$9,842.00
Cumulative Cash Flow	$94,467.20	-$202,229.54	-$192,291.61	-$182,120.87	-$171,692.47	-$160,981.00	-$151,730.60	-$142,197.38	-$132,355.38

	9	10	11	12	13	14	15	16
Total Upfront Costs:								
Cost of Photovoltaic System	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Maintenance	$1,934.39	$1,992.42	$2,052.19	$2,113.76	$2,177.17	$2,242.49	$2,309.76	$2,379.05
Total Tax-Exempt Costs	$1,934.39	$1,992.42	$2,052.19	$2,113.76	$2,177.17	$2,242.49	$2,309.76	$2,379.05
Total Cost Savings:								
Solar Power Production	$10,267.72	$10,781.11	$11,320.17	$11,886.17	$12,480.48	$13,104.51	$13,759.73	$14,447.72
SREC Credit Value ($0.04/kWh)	$1,844.20	$1,751.99	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total Tax-Exempt Income	$12,111.93	$12,533.10	$11,320.17	$11,886.17	$12,480.48	$13,104.51	$13,759.73	$14,447.72
Annual Cash Flow	$10,177.54	$10,540.68	$9,267.97	$9,772.42	$10,303.31	$10,862.02	$11,449.97	$12,068.66
Cumulative Cash Flow	-$122,177.84	-$111,637.16	-$102,369.19	-$92,596.77	-$82,293.46	-$71,431.44	-$59,981.47	-$47,912.80

	17	18	19	20	21	22	23	24	25
Total Upfront Costs:									
Cost of Photovoltaic System	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Maintenance	$2,450.43	$2,523.94	$2,599.66	$2,677.65	$2,757.98	$2,840.72	$2,925.94	$3,013.72	$3,104.13
Total Tax-Exempt Costs	$2,450.43	$2,523.94	$2,599.66	$2,677.65	$2,757.98	$2,840.72	$2,925.94	$3,013.72	$3,104.13
Total Cost Savings:									
Solar Power Production	$15,170.11	$15,928.61	$16,725.04	$17,561.29	$18,439.36	$19,361.33	$20,329.39	$21,345.86	$22,413.15
SREC Credit Value ($0.04/kWh)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total Tax-Exempt Income	$15,170.11	$15,928.61	$16,725.04	$17,561.29	$18,439.36	$19,361.33	$20,329.39	$21,345.86	$22,413.15
Annual Cash Flow	$12,719.68	$13,404.67	$14,125.38	$14,883.65	$15,681.38	$16,520.61	$17,403.45	$18,332.15	$19,309.03
Cumulative Cash Flow	-$35,193.12	-$21,788.45	-$7,663.07	$7,220.58	$22,901.96	$39,422.57	$56,826.02	$75,158.17	$94,467.20

Cost Payback After:	**19.52 Years**

Cumulative Income After 25 Years:	**$94,467.20**

References and Assumptions
Maintenance based on 16 Hours/Year after 5 maintenance-free years for a Union Electrician Rate of $110.64/Hour
http://www.wdol.gov/wdol/scafiles/davisbacon/pa5.dvb
General Inflation Rate Assumed to be 3% for 25 Years
Electricity Inflation Rate Assumed to be of 5% per Year for 25 Years
SREC Credit Value Assumed to be $0.04/kWh - Based on 1 SREC Credit = 1MWh
SREC Credit Value Deflation Rate Assumed to be 5% per Year for 10 Years
After 10 Years, SREC Credit Values Assumed to Diminish Completely
Philadelphia Electric Company Cost/kWh is Assumed to be $0.10/kWh

Figure 2.24

Analysis 3 – Operable Solar Shading

Problem Identification

The building entrance, complete with curtain wall and a substantial amount of fenestration, faces the south western exposure where the majority of sun light and solar gain enters the building. This high amount of solar infiltration could potentially cause for a higher cooling load, resulting in higher cooling costs and a larger mechanical system. The principle objective for this analysis will be to undertake a value engineering study implementing operable solar shading devices that could provide a more energy efficient facade, reducing cooling costs throughout the year.

Background

As a value engineering issue, the possibility of changing the building façade to include programmable shading louvers provides several opportunities to add value to the Aria Health ED Expansion. This idea will not be implemented with the primary idea of cost cutting, rather improving the energy efficiency of the building enclosure. Building façades can leak and expel energy that could otherwise be used inside. With an improvement in solar radiation deflection while still allowing natural light to enter, the addition at Aria Health could perform more efficiently.

Analysis Goals

The primary goal of the addition an operable shading system is to reveal a decrease the cooling costs of the building operation throughout the year. Hospital cooling costs are very high, as cooling demand is present year round. The results of this analysis will be quantified through operating cost reduction calculations based on a reduction in solar gain and presented through the use of a building energy model. It is believed that although initial construction costs may increase, the value added to the project would be greatly improved. The goal will be primarily to show how the system could be implemented to reduce operating costs, provide a more energy efficient facade, and show how a portion of the building mechanical system could be downsized.

Process

System Description

Background

The emergency room department addition at the Torresdale Campus for Aria Health Systems is situated on site such that the primary building façade faces southeast, as can be seen in Figure 3.1. Southern exposures can provide benefits to a building façade, as natural light will illuminate the building's aesthetics throughout most of the daylight hours. This provides several design challenges however, in the form of sizing mechanical equipment for increased cooling load due to solar radiation, as well as unwanted glare from direct sunlight.

Throughout the year, the sun travels along different paths, lower altitudes in the sky during the winter months and higher during the summer months. These solar angles bottom out and peak at the winter and summer solstices, respectively. Similarly, azimuths (solar angle with respect to south) differ substantially throughout the day. This description can be seen in the diagrams presented in Figures 3.2 and Figure 3.3, which have been used with permission via *Colt Intelligent Envelopes*. A full version of *Colt Intelligent* can be seen in Appendix C.1.

To counteract the solar radiation that infiltrates the building façade, operable solar shading devices provide a substantial opportunity to relect this solar gain. With these operable blades, or louvers, the sun will be tracked throughout the day, to allow for the optimum amount of reflection. This is in contrast to fixed mounted shading devices, which do not have this capibility for movement. The system chosen for this analysis will be described below.

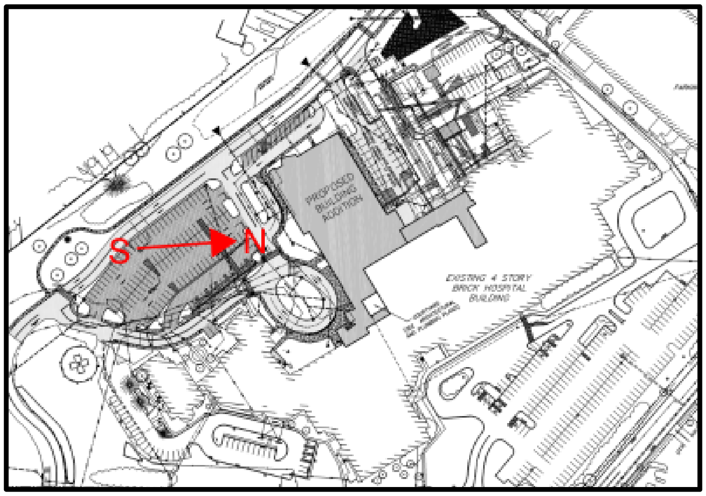


Figure 3.1

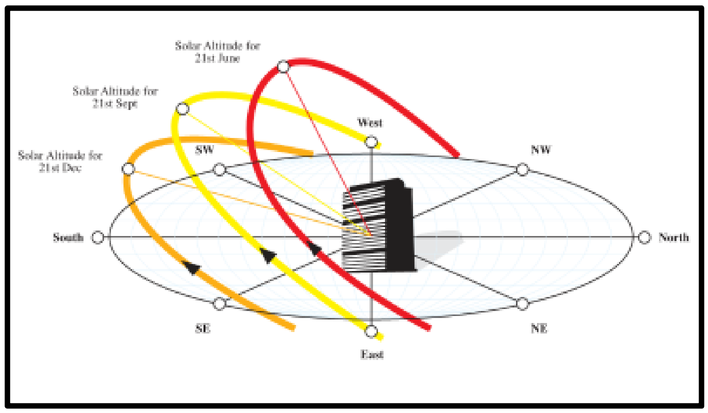


Figure 3.2

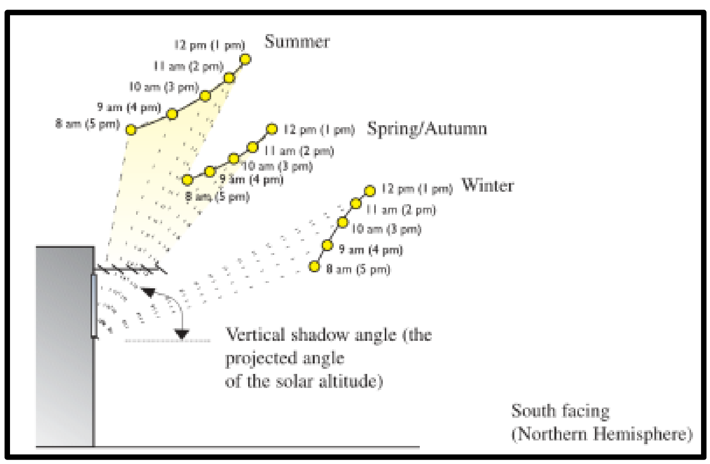


Figure 3.3

Colt Shadoglass

Figure 3.4

After consideration of several different solar shading manufacturers, Shadoglass by Colt Group was chosen for implementation onto the building façade. This particular louver system is available in widths up to 24" and lenghts up to 13', with a nominal ¼" gap between each louver. These blades can be manufactured with several different finishes and glazes, as directed by the design intent. Shadoglass can be installed as a fixed or operable system, where the operable version will be used for this analysis.

For the purpose of this analysis, Mestek Architectural Intelligent Envelopes were consulted, as Mestek holds a license agreement with Colt Group and are the sole manufacturer and distributer of the Shadoglass product in America. After an interview was held with Francis O'Neill, National Sales Manager with Mestek Architectural, valuable information was obtained.

During the traditional implementation of the Shadoglass system, the process begins with an architect who will ultimately specify Colt as the product to be installed. This is not the only way that the system can be used however, as the system is frequently installed during building retrofit projects. After Colt is introduced to the construction project, they will send their design parameters and structural loads to the structural engineer for the project. The engineer is then responsible for designing the superstructure to hold the shading devices in place. An exoskeleton-like exterior frame is also designed, to support the carrier system that is chosen to house the glass louvers themselves. This frame is typically carbon steel, to ensure maximum load bearing potential.

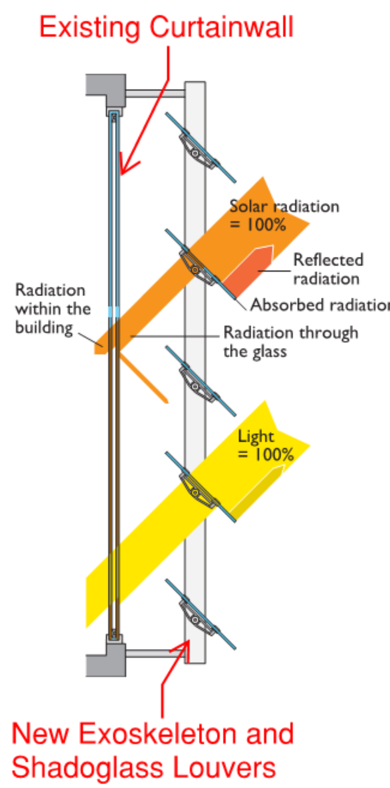


Figure 3.4

Design and Prefabrication

The solar shading system is designed by Mestek professionals, after analyzing the construction site location and other parameters necessary for consideration. Mestek Architectural is located in Moresville, Indiana, where the entire system is designed. The system shop drawings are then sent to Mestek's Linel Fabrication Facility, located in Indianapolis, Indiana, where the system mullions and framework are prefabricated. Prefabrication is employed as much as possible due to a safer, cleaner working environment free from inclament weather and site congestion, as well as quality control measures and cheaper labor costs. The glass louvers themselves are ordered to exact size, with the low-E coating installed on the interior of the glass. Each piece of glass is laminated through a heated and pressurized process, binded to a type of plastic. The low-E coating faces the exterior, laminated side. The glass blades are laminted for safety reasons, to reduce the problems associated with breakage. Lamination will keep the glass from shattering, almost akin to safety glass. The glass will reflect most solar radiation, while simoultaneously allowing natural light through and not obstructing views to the outdoors. Also during the prefabrication process, any and all drilling, cutting, and notching will take place, as to minimize on-site work.

System Automation

The Shadoglass system is equipped with a controlling device that is preprogrammed with settings specific to the buildings location and sun path projections, predecribed through historical weather data. The controller will send periodic electronic signals to the actuators connected to the blades, which will rotate according to the suns position in the sky. The system is also equipped with a weather station on the roof that gathers live weather information, which will send signals to the controller based on the current climatic conditions. For example, the station will recognize when it is snowing or sleeting outside, therefore reverting the blades to the safest position of fully closed, or completely vertical. While the blades are in this position, snow and ice is unable to accumulate, which aleviates the concern of debris falling from above. Additionally, the system has a lux sensor, which calculates the amount of sunlight shining. This means that during a cloudy day, the weather station will tell the actuators to open fully, or completely horizontal, as to allow the maximum amount of sunshine inside the building. Subsequently, during the the winter months, the controller will tell the blades to open to the horizontal position, as to allow maximum solar radiation into the building. This will allow for passive solar heating, further reducing utility costs required for heating.

Contractual Agreements

Mestek typically quotes their product on a lump sum basis in one of two fashions. The first includes a total cost for the design phase, material costs, prefabrication labor, and shipping. The second option is for a complete furnish and install contract, where Mestek would self-perform the installation of the solar shading devices. If option one is chosen, typically the on-site curatinwall contractor will install the shading system. Per discussion with Francis O'Neill, the skill set required for the job is that of an experience curtainwall contractor, where all of the components must be plum, true, and level. Installation is critical to the success of the system, as any miscalculations will result in faulty operation. Using the on-site curtainwall contractor has added benefits such as no addional mobilization, subsequently cutting down on general conditions costs. Commisioning of the system is also necessary and required by Mestek to ensure the system is functioning properly. This is done by a Mestek professional and is included in lump sum estimate for option one and two.

Procurement and Logistics

Lead time is solely dependent on project specifics, however there are standards that Mestek will typically uphold. The design and shop drawing approval process will take approximately 4-6 weeks, where prefabrication and shipping will last 16-20 weeks, depending on the jobsite location. Normal shipping procedures are utlized for transport, where the glass is house in crates. Flatbed trucks are used exclusively for transportaion, as this provides the easiest offloading capability. Cranes are necessary for hoisting, due to the average crate weight of 2,000 pounds. Special care must be taken, as the glass is very fragile and any breakage would be a costly addition to the project.

One of the biggest objections by building owners is ease of maintenance. The manufacturer is often asked how one is to clean the system when it becomes dirty. One option is to include a structural platform between the existing building curtainwall and the shading system exoskeleton. This provides a stable standing surface for workers to clean the glass blades and the curtainwall windows alike. Another concern regarding maintenance is the possibility of breakage. Building owners are skeptical of anything that moves or rotates, as this provides opportunity for challenges and replacement. In some areas, Mestek offers full-time, traveling employees that will replace any broken blades on-site at any time.

Cost Estimation

After speaking with Francis O'Neill, conceptual pricing for the Colt Shadoglass system was found to be approximately $100/SF for design, material costs, prefabrication labor, and shipping, where actual on-site installation costs were estimated to be about one-third more, or approximately $33.33/SF. These values are strictly conceptual however, as actual, concrete costs would only be tangible if Mestek Architectural were to provide lump sum quote. Actual costs depend on several, project-specific parameters that could only be quantified by the professionals themselves.

Based on the above stated total unit cost of $133.33 per square foot of elevation area, a total cost for the system was found to be $442,533.33, as can be seen in the table presented in Figure 3.5.

Solar Shading System - Conceptual Estimate

Elevation Area	UOM	Design, Material, Shop, Shipping	On-Site Installation	Unit Cost	Total Cost	Daily Output	Total Days
3319	SF	$100.00	$33.33	$133.33	$442,533.33	160	21

Assumptions:
Daily Output based on RS Means 2014 value for Maximum Glazed Curtain Walls
Cost Information based on interview held with Francis O'neill, National Sales Manager, Mestek Architectura

Figure 3.5

This total estimate includes overhead and profit, as prescribed by Mestek Architectural, which is unknown. The total cost is based on the following formulas:

$$Unit\ Cost = (Design, Material, Shop, Shipping) + (Onsite\ Installation)$$

$$Total\ Cost = (Elevation\ Area)\ x\ (Unit\ Cost)$$

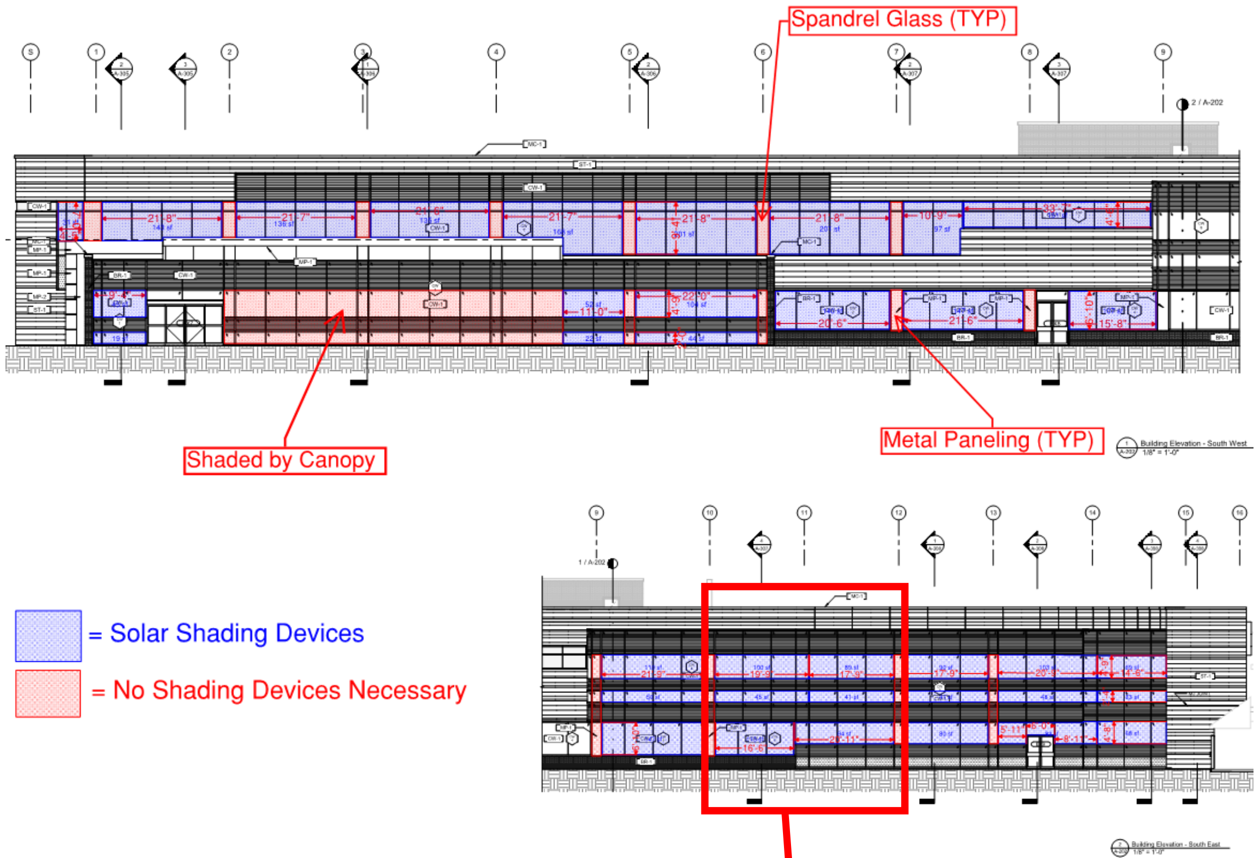


Figure 3.6

The total elevation area was quanitified by breaking the glazing up into sections, where an area was found for each section. As can be seen in Figure 3.6, each section the is to be shaded with the Shadoglass is shown in blue, where areas not to be shaded are shown in red. The areas not to be shaded are due to factors such as non-glazing materials, or existing shading due to the canopy over the vestibule entrance to the emergency department. A close up view of the area takeoffs can be seen in Figure 3.7, where a full sized version can be seen in Appendix C.2.

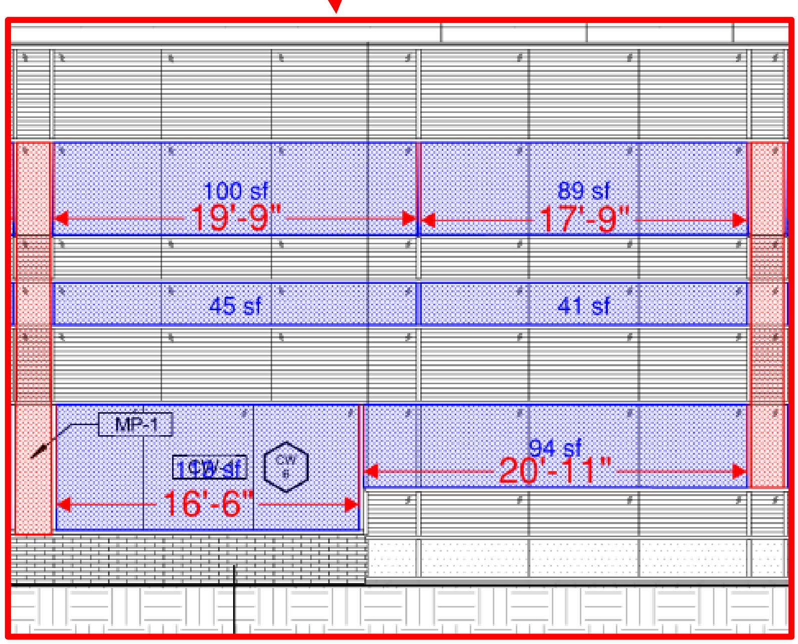


Figure 3.7

Site Logistics

In order to show how the Shadoglass system material and prefabricated sections would be brought to site, a site logistics plan was produced, as can be seen in Figure 3.8. Flatbed trucks carrying the crated glass louvers, prefabbed frames, and carbon steel exo-skeleton will enter the jobsite off of Knights Road to the east of the emergency department addition. The trucks will then head west along the site access road, as can be seen with red arrows. They will continue toward the building and follow the loop road located in fron of the building. Before turning around the loop, trucks will stop for the a mobile truck crane to pick materials and set them in the material staging area shown in green. The trucks will then turn around via the loop road and exit the way they came onto site. The mobile crane, shown in blue, will assist workers on the ground for the duration of the installation, hoisting material into place on the building façade where workers will fasten them into their final locations. As stated earlier, the largest load required for picking from the truck to the ground is approximately 2,000 pounds. This load is easily accomodated by a truck crane, with no need for the addition or erection of a larger, more permenantly stationed crane. A full sized version of this site logistics plan can be seen in Appendix C.3.

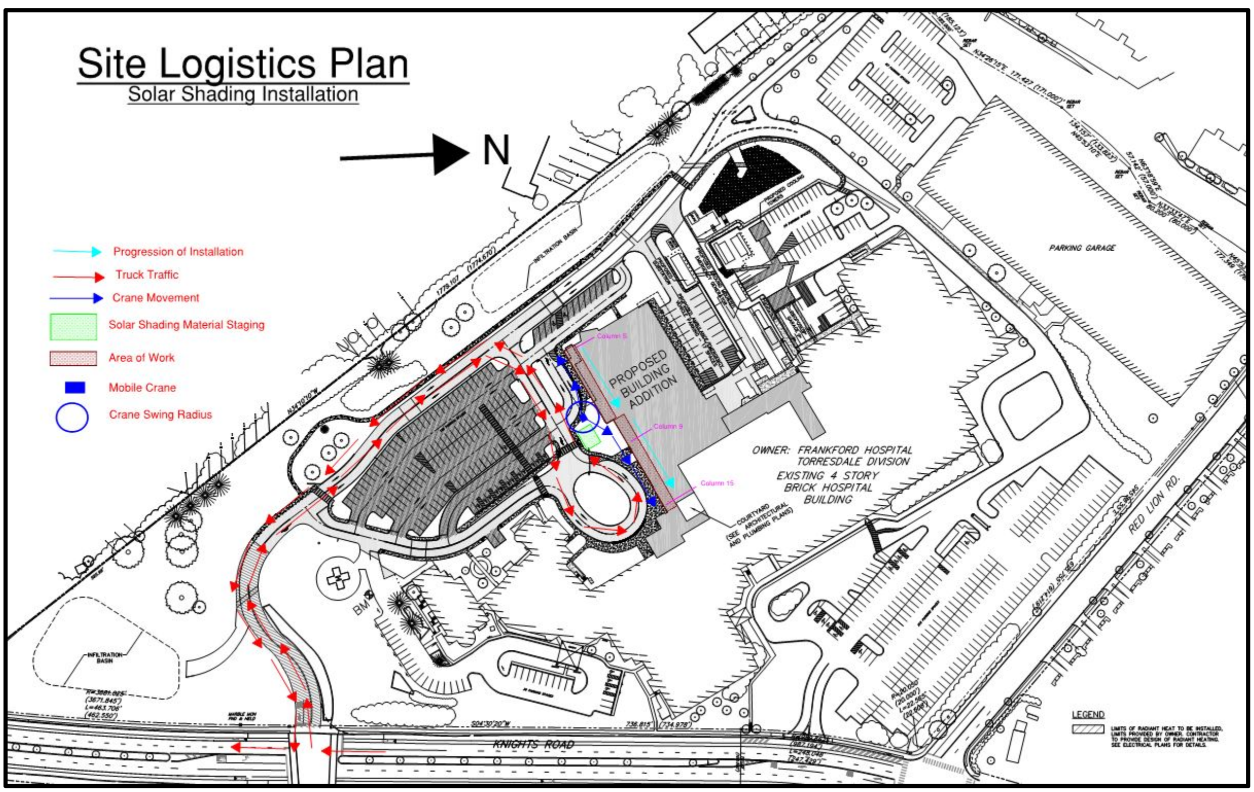
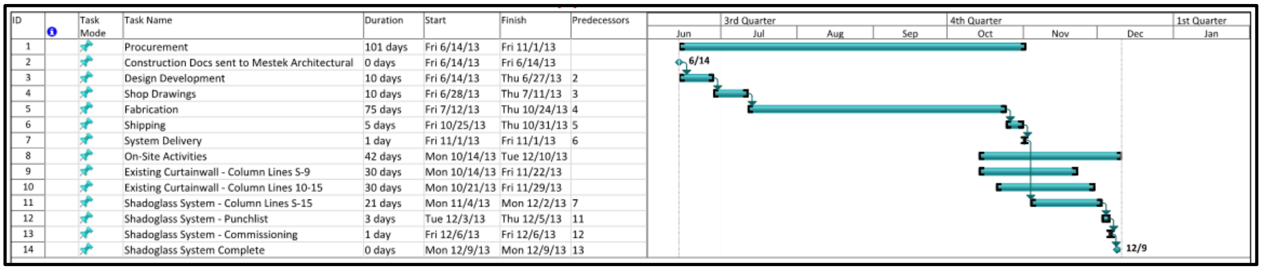


Figure 3.8

Schedule and Installation Sequence

After speaking with Francis O'Neill, it was found that common practice is to have the curtain wall contractor install the Shadoglass system on-site concurrently along with the curtain wall. With that in mind, a schedule was produced to depict the system impact on existing curtain wall installation. This schedule can be seen in Figure 3.9 below, where a full sized version can be seen in Appendix C.4.



ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors
1			Procurement	101 days	Fri 6/14/13	Fri 11/1/13	
2			Construction Docs sent to Mestek Architectural	0 days	Fri 6/14/13	Fri 6/14/13	
3			Design Development	10 days	Fri 6/14/13	Thu 6/27/13	2
4			Shop Drawings	10 days	Fri 6/28/13	Thu 7/11/13	3
5			Fabrication	75 days	Fri 7/12/13	Thu 10/24/13	4
6			Shipping	5 days	Fri 10/25/13	Thu 10/31/13	5
7			System Delivery	1 day	Fri 11/1/13	Fri 11/1/13	6
8			On-Site Activities	42 days	Mon 10/14/13	Tue 12/10/13	
9			Existing Curtainwall - Column Lines S-9	30 days	Mon 10/14/13	Fri 11/22/13	
10			Existing Curtainwall - Column Lines 10-15	30 days	Mon 10/21/13	Fri 11/29/13	
11			Shadoglass System - Column Lines S-15	21 days	Mon 11/4/13	Mon 12/2/13	7
12			Shadoglass System - Punchlist	3 days	Tue 12/3/13	Thu 12/5/13	11
13			Shadoglass System - Commissioning	1 day	Fri 12/6/13	Fri 12/6/13	12
14			Shadoglass System Complete	0 days	Mon 12/9/13	Mon 12/9/13	13

Figure 3.9

The total duration for the on-site installation of the system was found to be 21 days, as calculated in the table presented in Figure 3.5. This value was found by dividing the RS Means 2014 daily output value for curtain wall installation of 160 SF by the total elevation area for the system of 3,319 SF. The schedule shown begins with procurement, where design development would start on June 14th, 2013. The design process was assumed to take approximately 10 working days to complete. Shop drawing production comes next, beginning on June 28th, also with a 10 day duration. Prefabrication was expected to take the longest, where a duration of 75 days was used, starting on July 7th and ending on October 24th. After fabrication by Mestek, shipping to site was expected to last approximately 5 days, with an on-site delivery of November 1st, 2013. The total procurement period was scheduled to take approximately 101 days, a substantially long lead time.

On-site activities were expected to take a total of 42 days, starting with the existing curtain wall installation and ending with the completion of system commissioning. The curtain wall installation from column line S through 9 duration of 30 days was taken directly from the actual project schedule, starting on October 14th and ending on November 22nd. Column lines 10-15 duration was also taken from the project schedule with a start date of October 21st and finishing on November 29th. The Shadoglass system installation was added with a start date of November 4th and finishing on December 2nd, for a duration of 21 days, as calculated earlier. Following installation, punchlist and commissioning activities were also added, for a final Shadoglass completion date of December 9th, 2013.

The addition of the Shadoglass operable shading system was found not to affect the critical path for the project, as the total building envelope duration was found to be 292 days, with a water-tight date of December 20th, 2013, as can be seen in the screen shot of the actual project schedule in Figure 3.10 on the following page. This date of December 20th shows that the Shadoglass addition has 11 days of float before it affects the critical path.

322		**Building Envelope**	**292 days?**	**292 days?**	**Tue 8/13/13**	**Thu 11/8/12**	**Mon 12/9/13**	**Fri 12/20/13**
323		**Back-up wall w/ Vapor Barrier**	**25 days?**	**25 days?**	**Tue 8/13/13**	**Mon 9/30/13**	**Mon 9/16/13**	**Fri 11/1/13**
324		North Elevation Studs/Sheathing/Blocking	10 days	10 days	NA	Mon 9/30/13	NA	Fri 10/11/13
325		West Elevation Studs/Sheathing/Blocking	10 days	10 days	NA	Mon 10/14/13	NA	Fri 10/25/13
326		South Elevation Studs/Sheathing/Blocking	15 days	15 days	NA	Mon 9/30/13	NA	Fri 10/18/13
327		Courtyard West Elevation Studs/Sheathing/Blocking	1 day?	1 day?	NA	Mon 9/30/13	NA	Mon 9/30/13
328		Courtyard North Elevation Studs/Sheathing/Blocking	1 day?	1 day?	NA	Mon 9/30/13	NA	Mon 9/30/13
329		North Elevation Vapor Barrier	10 days	10 days	NA	Mon 10/7/13	NA	Fri 10/18/13
330		West Elevation Vapor Barrier	10 days	10 days	NA	Mon 10/21/13	NA	Fri 11/1/13
331		South Elevation Vapor Barrier	15 days	15 days	NA	Mon 10/7/13	NA	Fri 10/25/13
332		**ArrisCraft Stone Panel System**	**25 days**	**25 days**	**Tue 9/17/13**	**Mon 11/4/13**	**Mon 10/14/13**	**Fri 12/6/13**
333		West Elevation	10 days	10 days	NA	Mon 11/4/13	NA	Fri 11/15/13
334		South Elevation	15 days	15 days	NA	Mon 11/18/13	NA	Fri 12/6/13
335		**Glass CurtainWall & Strip Window System**	**193 days**	**193 days**	**Tue 10/15/13**	**Wed 3/6/13**	**Mon 12/9/13**	**Fri 11/29/13**
336		North Elevation	7 days	7 days	NA	Mon 10/28/13	NA	Tue 11/5/13
337		West Elevation	5 days	5 days	NA	Mon 11/18/13	NA	Fri 11/22/13
338		South Elevation Column Lines S-9	30 days	30 days	NA	Mon 10/14/13	NA	Fri 11/22/13
339		South Elevation Column Lines 9 -15	30 days	30 days	NA	Mon 10/21/13	NA	Fri 11/29/13
340		Courtyard West Elevation	4 days	4 days	NA	Wed 3/6/13	NA	Mon 3/11/13
341		Courtyard South Elevation	7 days	7 days	NA	Wed 3/6/13	NA	Thu 3/14/13
342		Courtyard East Elevation	7 days	7 days	NA	Wed 3/6/13	NA	Thu 3/14/13
343		Courtyard North Elevation	5 days	5 days	NA	Wed 3/6/13	NA	Tue 3/12/13
344		**Metal Panels**	**33 days**	**33 days**	**Tue 9/3/13**	**Wed 11/6/13**	**Mon 10/14/13**	**Fri 12/20/13**
345		North Elevation	10 days	10 days	NA	Wed 11/6/13	NA	Tue 11/19/13
346		West Elevation	10 days	10 days	NA	Mon 11/18/13	NA	Fri 11/29/13
347		South Elevation	10 days	10 days	NA	Mon 12/9/13	NA	Fri 12/20/13
348		**Brick**	**282 days?**	**282 days?**	**Tue 10/15/13**	**Thu 11/8/12**	**Mon 11/18/13**	**Fri 12/6/13**
349		North Elevation	15 days	15 days	NA	Mon 10/14/13	NA	Fri 11/1/13
350		West Elevation	15 days	15 days	NA	Mon 10/28/13	NA	Fri 11/15/13
351		South Elevation	15 days	15 days	NA	Mon 11/18/13	NA	Fri 12/6/13
352		Roof East Elevation	1 day?	1 day?	NA	Thu 11/8/12	NA	Thu 11/8/12
353		Roof North Elevation	1 day?	1 day?	NA	Thu 11/8/12	NA	Thu 11/8/12
354		Roof South Elevation	1 day?	1 day?	NA	Thu 11/8/12	NA	Thu 11/8/12
355		Roof West Elevation	1 day?	1 day?	NA	Thu 11/8/12	NA	Thu 11/8/12
356		**Phenolic Panels**	**1 day?**	**1 day?**	**Tue 9/17/13**	**Mon 11/4/13**	**Mon 10/7/13**	**Mon 11/4/13**
357		Courtyard West Elevation	1 day?	1 day?	NA	Mon 11/4/13	NA	Mon 11/4/13
358		Courtyard North Elevation	1 day?	1 day?	NA	Mon 11/4/13	NA	Mon 11/4/13
359		**Stucco**	**1 day?**	**1 day?**	**NA**	**Thu 11/8/12**	**NA**	**Thu 11/8/12**
360		Roof North Elevation	1 day?	1 day?	NA	Thu 11/8/12	NA	Thu 11/8/12
361		Roof East Elevation	1 day?	1 day?	NA	Thu 11/8/12	NA	Thu 11/8/12
362		Roof South Elevation	1 day?	1 day?	NA	Thu 11/8/12	NA	Thu 11/8/12
363		Roof West Elevation	1 day?	1 day?	NA	Thu 11/8/12	NA	Thu 11/8/12

Figure 3.10

In addition to the schedule shown in Figure 3.9, a sequencing diagram was produced to show the flow of work for the installation of the Shadoglass system, which can be seen in Figure 3.11. A full sized version of this flow diagram can be seen in Appendix C.5.

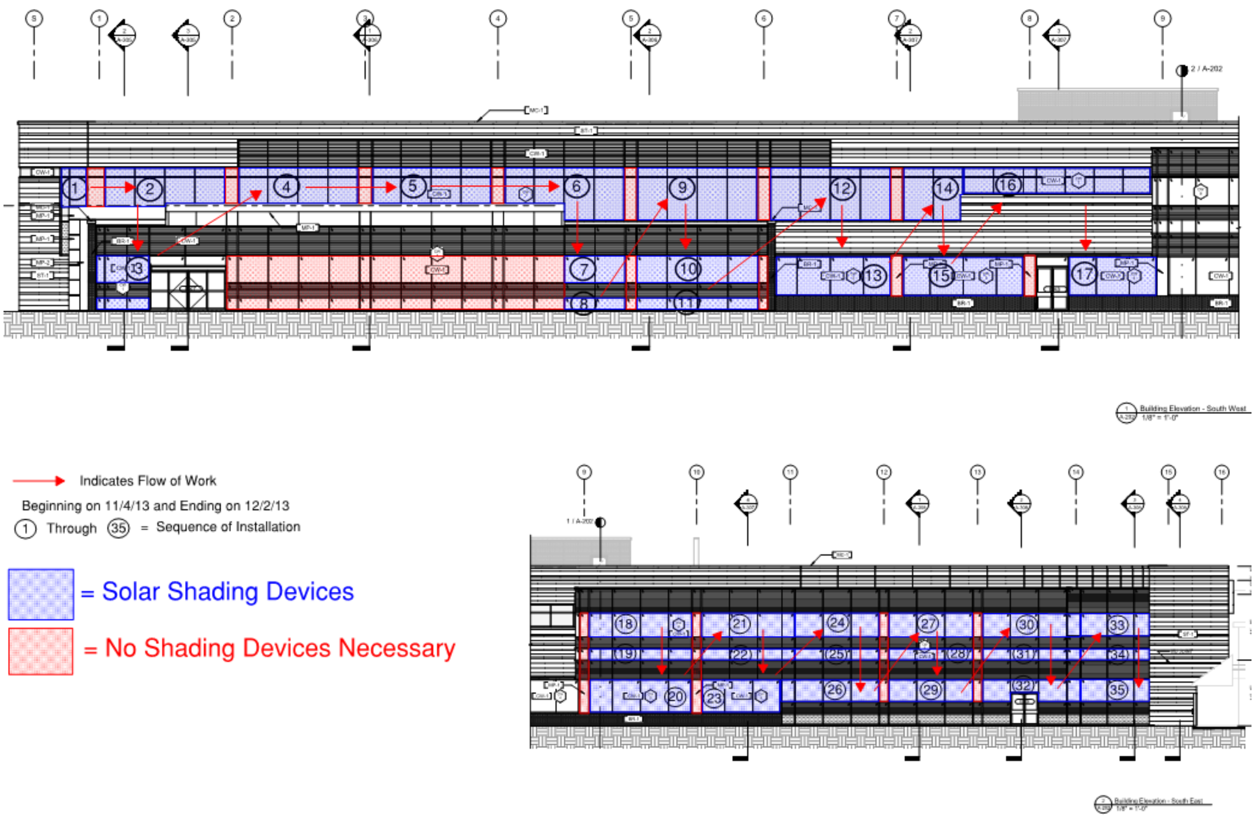


Figure 3.11

As can be seen in the flow diagram, the Shadoglass system has been broken up into 35 separate sections. Each of these sections would be installed sequentially, starting on November 4th and ending on December 2nd, 2013. The red arrows depict flow of work, where it was decided that sections on the second level above grade should be installed before the level below. This was done to alleviate safety concerns, as working concurrently on both levels provide an opportunity for debris to fall from above onto workers below.

Energy Model

For the purpose of quantifying energy savings due to the implementation of the Colt Shadoglass system, an energy model was produced using IES Virtual Environment software. The building floor plan was imported into the modeling software, where the actual project wall construction, glazing types, and materials were specified. A simulation was done twice, once to obtain baseline data without the solar shading and once again with the addition of the solar shades. For simplicity, only the space directly affected by solar gain was modeled which includes the entrance lobby, as well as a long corridor that spans the length of the building addition. The energy model can be seen in plan view in Figure 3.12, as well as in an isometric view in Figure 3.13 below. Also for simplicity, only Level 2 (or ground level) was modeled. In addition to simplification, the ground level was the only level that was modeled because Level 3 was to be constructed as a shell space only, with no heavy cooling load necessary. As can be seen in Figure 3.14, a cross section of how the shading louvers were modeled can be seen. The blades were modeled as three dimensional rectangular cylinders spanning the length of each window. This does not change how the sun would be reflected however, as it would not matter what the dimension of the object looks like.

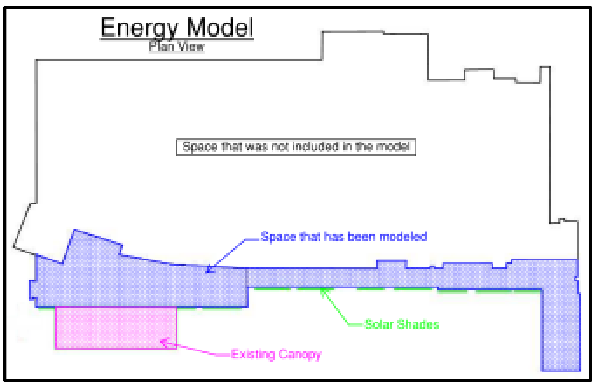


Figure 3.12

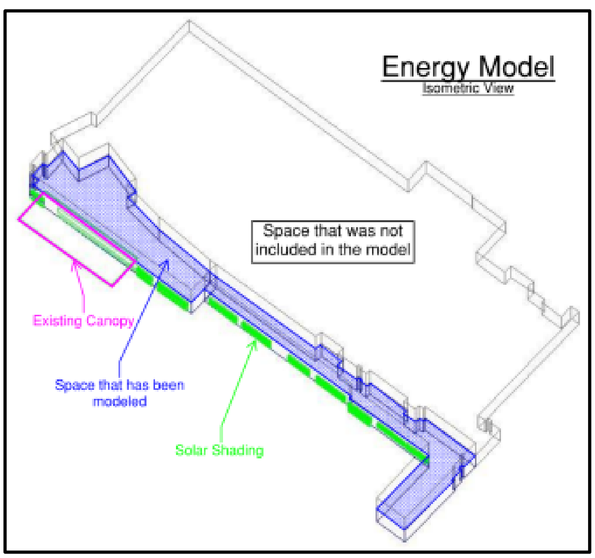


Figure 3.13

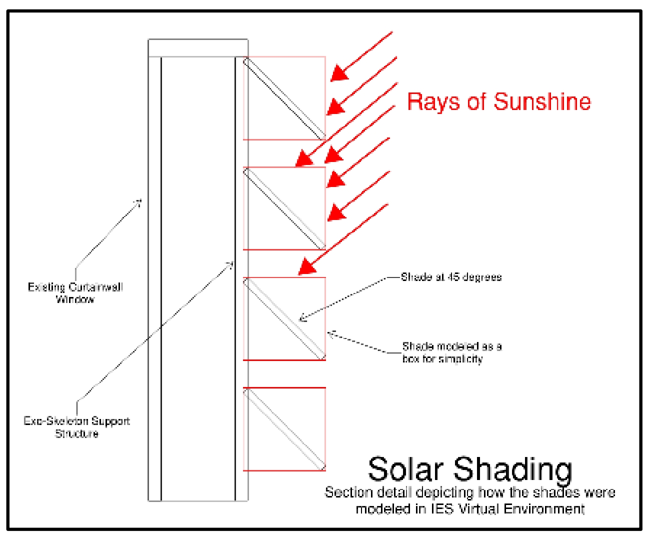
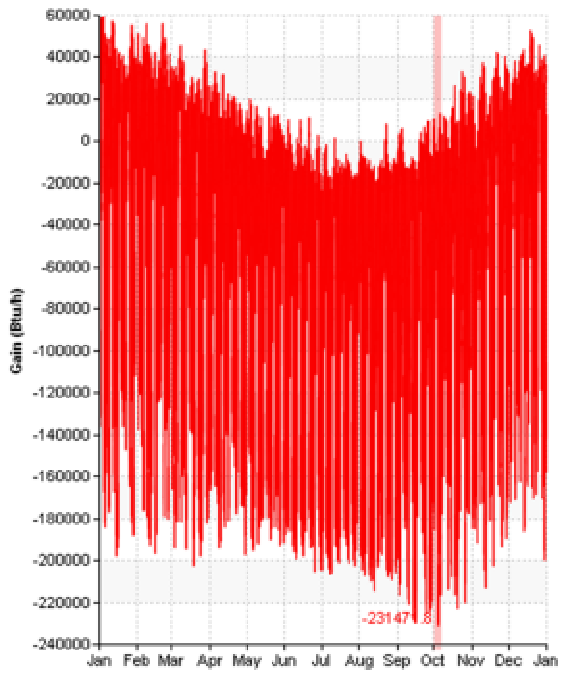
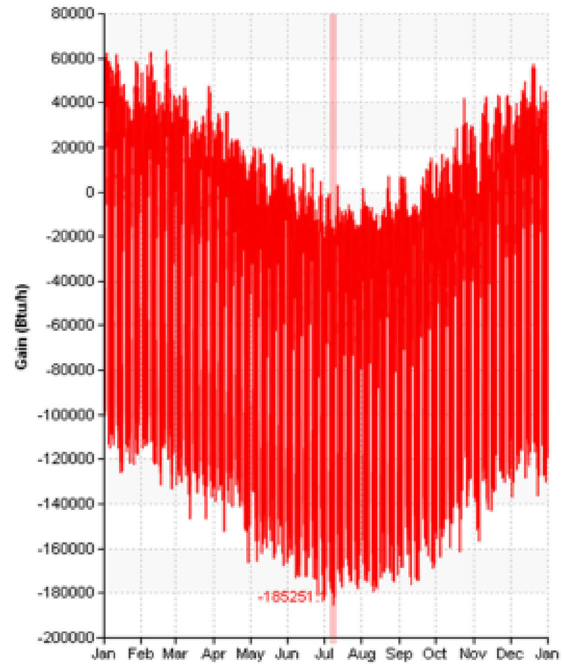


Figure 3.14

After each simulation was finished, it was found that the baseline data for peak energy usage without solar shading was 231,471.8 BTU/h, while the peak energy usage with solar shading implemented was found to be 185,251.1 BTU/h. This equates to a net energy savings of 46,220.7 BTU/h with the addition of the Colt Shadoglass system, or a 20% reduction. Two graphs depicting the annual energy usage for the space can be seen in Figure 3.15 on the following page, broken up for each month during the year.



Baseline Data



Proposed with Solar Shading

Figure 3.15

As can also be seen in Figure 3.15, the peak energy usage for the baseline data was during the month of October, where the peak energy usage for the proposed system was found to be during the month of July.

Cost Savings

Energy Savings due to Solar Shading						
Baseline (BTU/h)	**w/ Solar Shading (BTU/h)**	**Energy Savings (BTU/h)**	**Equivalent Load HRs/Yr**	**Energy Savings/Yr (BTU)**	**BTU/Ton**	**Energy Savings/Yr (Tons)**
231471.80	185251.10	46220.70	2700.00	124795890.00	12000.00	10399.66

References and Assumptions:
Energy data in BTU/h is from IES Virtual Environment enery model Equivalent Load HRs/Yr value based on industry rule of thumb

Figure 3.16

In order to convert the energy savings in BTU/h to BTU, an industry rule of thumb method was used. After speaking with an industry professional, it was found that the "equivalent load hours per year" for a hospital was 2,700 hours. This means that throughout one year, the cooling system would be active for 2,700 hours cumulatively. This value of BTUs was then converted to Tons of Cooling using 12,000 BTUs per ton. The total energy savings for one year was found to be 10,399.66 tons using the following formula.

$$\frac{Energy\ Savings}{year}(in\ tons) = \frac{\frac{Energy\ Savings}{year}\left(in\,\frac{BTU}{h}\right) x\ (Equivalent\ Load\ Hrs\ per\ year)}{12{,}000\ BTUs\ per\ Ton}$$

A summary of this data can be seen in Figure 3.16.

In order to quantify the above stated energy savings in currency, the total tons of cooling was converted into kWh/year, which was then converted into operating costs, which can be seen in Figure 3.17.

Cost Savings due to Solar Shading

Energy Savings/Yr (Tons)	kWh/Ton	Electricity Savings (kWh/Yr)	Cost of Electricity ($)	Cost Savings/Year
10399.66	0.90	9359.69	$0.10	$935.97

References and Assumptions:
kWh/Ton value is assumed to be the amount of electricity required to produce 1 ton of cooling
Cost of Electricity value based on PECO data from February 2013

Figure 3.17

After speaking with an industry professional, it was found that it takes approximately 0.9 kWh of electricity to produce 1 ton of cooling. With that in mind, the total tonnage of cooling was converted to total electricity savings per year using the following formula.

$$Electricity\ Savings\ \left(in\,\frac{kWh}{year}\right) = \frac{(Energy\ Savings)}{year}(in\ tons)\ x\ (\frac{kWh}{ton})$$

It was found that a total of 9,359.69 kWh/year could be saved with the implementation of the Colt Shadoglass system. This value was then found to save a total of $935.97 per year, based on a PECO utility cost of $0.10/kWh.

After finding the total cooling cost savings per year, a simple payback analysis was performed to show how long the yearly savings would take to pay for the initial cost of the system. Based on an initial cost value of $442,533.33 and a savings value of $935.97 per year, it was found that it would take a staggering 473 years for the system to pay for itself. This can be seen in Figure 3.18.

Payback Analysis

Initial Cost	Cost Savings/Year	Payback Period (Years)
$442,533.33	$935.97	473

Figure 3.18

With that said, cost may not always be the #1 reason for implementing a specific system of idea. In order to quantify the amount of emissions from to the building cooling system saved, an online calculation tool called Cleaner and Greener Program was used. After importing the savings in electricity (in kWh) into the program, it was found that a total of 12,856 lbs of greenhouse gases could be kept from entering the atmosphere. A summary of these greenhouse gas emissions savings can be seen in Figure 3.19 on the following page.

Emissions Calculator

You can offset the emissions caused by your energy use, no matter where you live...and in the USA it's even tax deductible!
Download a copy of the energy prices and emission factors used for this web calculator.
Note: If the calculator is not working properly, you may need to enable active scripts by clicking on the yellow bar at the top of the page and selecting "Allow Active Content." Do not use commas. Mercury factors are not available for DC, ID, RI, SD, VT.

Step 1 - **Your Estimated Annual Electricity Usage (kWh):** 9359.69

Step 2 - **Enter Your Estimated Annual Natural Gas Usage (therms):** 0

Step 3 - **Select your state:** U.S. Average

Results:

Your Electricity Usage Causes the Following Pollution:	
Greenhouse Gases	**Amount of Pollution Per Year**
Carbon Dioxide (CO_2)	12792 lbs
Methane (CH_4)	0.25 lbs
Nitrous Oxide (N_2O)	0.19 lbs
	12856 Total Greenhouse Gases (lbs CO_2e)
Pollution Affecting Health	**Amount of Pollution Per Year**
Sulfur Dioxide (SO_2)	46.73 lbs
Nitrogen Oxide (NO_x)	17.5 lbs
Mercury (Hg)	0.000269 lbs

Information about how we affect the environment from the Cleaner and Greener® Program,
a service of Leonardo Academy Inc., a nonprofit organization.

Figure 3.19

Mechanical Breadth

After a 20% reduction in cooling load was achieved due to the addition of the Colt Shadoglass system, calculations could be performed in order to estimate the reduction in air volume required to cool the revised space. As can be seen in Figure 3.20, the baseline air volume required for the space was found to be 10,716.29 CFM. With a floor area of approximately 7,200 SF, this equates to 1.49 CFM/SF, an allowable volume for an entrance lobby and corridor space. After the addition of the solar shading, the required air volume for space cooling was found to be 8,576.44 CFM, or 1.19 CFM/SF, as can be seen in Figure 3.21.

Supply Air Calculations - Baseline

BTU/h	Delta T		Constant Value	CFM	Area of Space (SF)	CFM/SF
231471.80	20.00	11573.59	1.08	10716.29	7200.00	1.49

References and Assumptions:
Room air temperature has been assumed to be 75 degrees Fahrenheit
Supply air temperature has been assumed to be 55 degrees Fahrenheit

Figure 3.20

Supply Air Calculations - Proposed

BTU/h	Delta T		Constant Value	CFM	Area of Space (SF)	CFM/SF
185251.10	20.00	9262.56	1.08	8576.44	7200.00	1.19

References and Assumptions:
Room air temperature has been assumed to be 75 degrees Fahrenheit
Supply air temperature has been assumed to be 55 degrees Fahrenheit

Figure 3.21

These values have been calculated based on the following formula.

$$\dot{q} = 1.08\ x\ CFM\ x\ (\Delta T)$$

With this reduction in air volume required for the space, the resizing of ductwork has been made possible. As can be seen in Figure 3.22, shown in blue is the area that has been affected by the reduction in cooling load. Shown in a red cloud is the area of ductwork that has been resized for the purpose of this mechanical breadth.

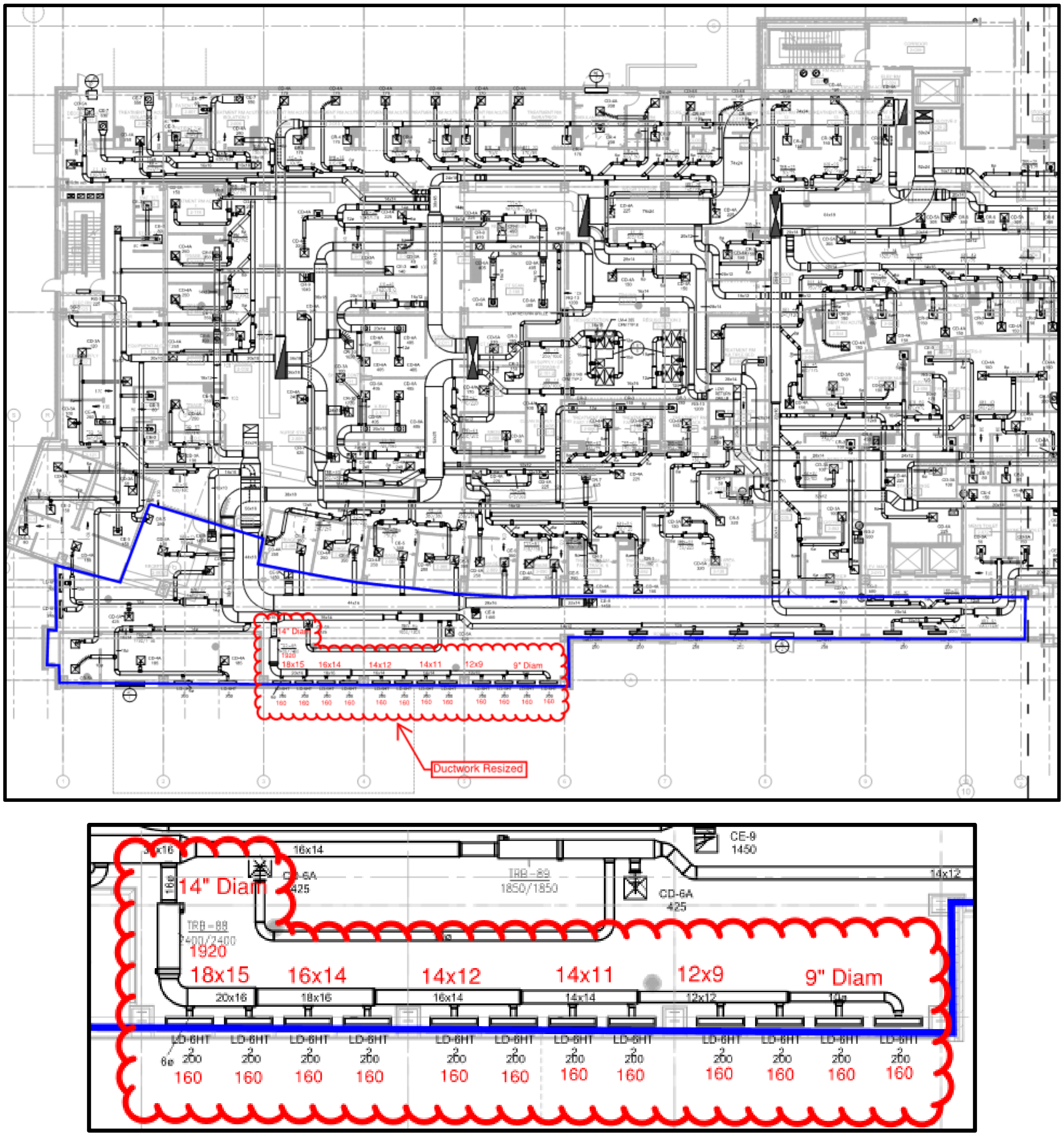


Figure 3.22

Baseline Ductwork		
Air Volume (CFM)	Velocity (FPM)	Duct Size (Inches)
400	750	10
800	925	12x12
1200	1000	14x14
1600	1200	16x14
2000	1100	18x16
2400	1175	20x16
2400	1750	16

Proposed Ductwork		
Air Volume (CFM)	Velocity (FPM)	Duct Size (Inches)
320	750	9
640	925	12x9
960	1000	14x11
1280	1200	14x12
1600	1100	16x14
1920	1175	18x15
1920	1750	14

References and Assumptions:
A 20% reduction in air volume was used based on the 20% in cooling load required for the space
Velocity for the baseline ductwork was held constant for the proposed ductwork
A ductulator was used to calculate the proposed ductwork size based on revised air volume and constant velocity

Figure 3.23

A summary table can be seen in Figure 3.23, where each of the ducts clouded in Figure 3.22 have been broken out by required CFM, velocity of air, and duct size. The baseline ductwork shows the system as is while the proposed ductwork shows the resized system. The velocity of air has been held constant, as this has been the design intent for noise and air pressure. A ductulator has been used to resize each of the ducts, where a picture can be seen in Figure 3.24.

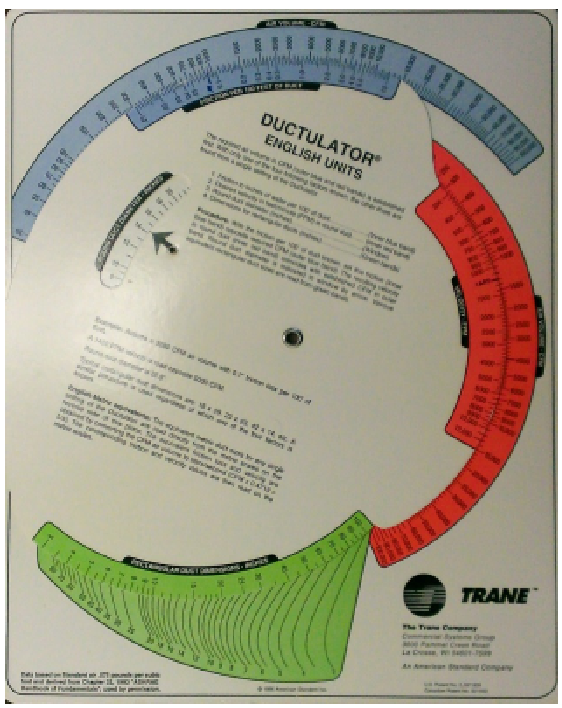


Figure 3.24

Recommendation

The addition of the Colt Shadoglass solar shading system has proved to reduce the cooling load required for the entrance lobby and corridor by 20%, simultaneously reducing the cooling costs for the building by $935.97 per year. The implementation of this system also has the capability to keep 12,856 lbs of greenhouse gases from entering our earth's atmosphere annually, which is a notable reduction. While each of these values may seem intriguing from the owner's perspective, the realization of a $442,533.33 initial investment and a 473 year payback cannot be ignored. It is for this reason that the implementation of the Colt Shadoglass product is not recommended for owner consideration. A much less expensive, fixed tilt solar shading system may be more applicable, where many of the expensive components of the Colt Shadoglass would be eliminated.

Analysis 4 – Modularization of Patient Treatment Rooms

Problem Identification

The Aria Health ED Expansion project was plagued with 40 total lost work days due to inclement weather and permitting issues in the early stages of the project. In addition to schedule delays, stick-built interiors can cause a congested jobsite, excess waste material, and could further disturb patients residing within the existing hospital.

Background

The second floor of the emergency department addition is where the clinical services reside, housing the staff areas and patient treatment spaces. There are 42 triage and acute patient treatment rooms, all of which are of similar size. Additionally, each of the rooms have almost identical space layout and features. The average room size is 12' wide and are approximately 14' long. They are all complete with a bed, overhead swiveling light, headwall, as well as a sink and casework. The layout and repeatability of these spaces provide the opportunity for off-site, multi-trade prefabrication to be modularized and installed on site as complete assemblies.

Analysis Goals

The primary objective of this analysis will be to research modular construction techniques for the purpose of accelerating the project schedule. This will provide an alternative to traditionally built building interior spaces. In addition to schedule acceleration, a site logistics plan will be developed, to depict how and where each building module will be brought into site and set in its respective final location. A sequencing plan will also be provided to show the flow of work for setting the modules themselves. Off-site warehouse locations will also be research, where one final location will be chosen. This site will be analyzed for cost implications and distance to the project site. Lastly, a summary of the research performed during this analysis will be presented, where attributes from the research will have been utilized in this report.

Miami Valley Hospital Southeast Addition Modular Construction, Skanska

Photo Reference: *http://blog.usa.skanska.com/prefab-vs-modular-construction-whats-the-difference/*

Process

Modules

For the purpose of accelerating the project schedule, modular construction practices were researched and implemented into the Aria Health ED Expansion project. Level 2 of the emergency department addition includes 42 patient treatment rooms, each of very similar size, shape, and configuration. Each room is rectangular and includes a vanity and sink. As can be seen in Figure 4.1, each of the modules are shown in blue, where the size of each module is approximately 12'x14'.

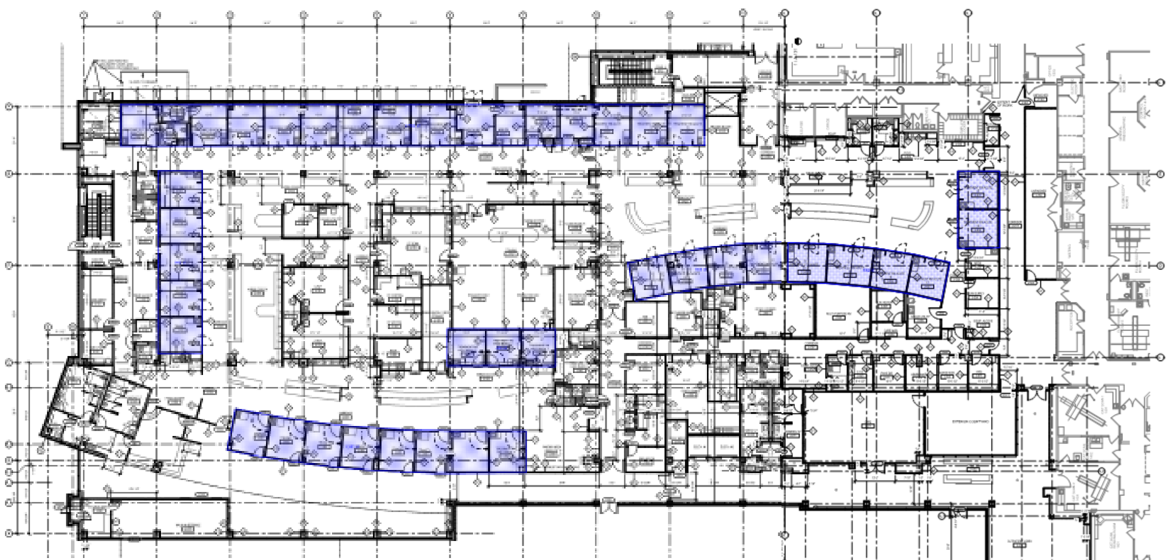


Figure 4.1

A full sized version of the module layout can be seen in Appendix D.1.

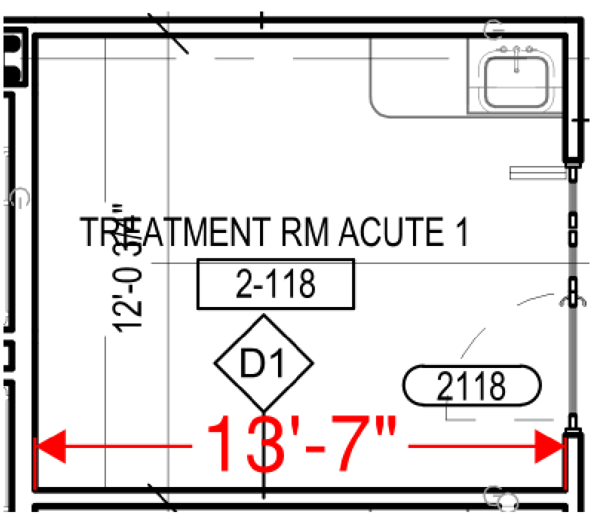


Figure 4.2

The floor area of modular construction to be performed was found to be 7,000 SF, or 16% of the total 45,000 SF floor area for all of Level 2. A typical module can be seen in Figure 4.2. Each module would include all necessary framing, drywall, conduit, wiring, plumbing, penetrations, and flooring required for the architectural intent. On-site MEP systems rough-in would connect directly to the prefabricated assembly after the module was set into place. Extreme attention to detail must be utilized, as any miscalculation in measurement would impede the connections of systems.

Schedule

A simplified schedule was produced depicting the actual project schedule as it stands currently. As can be seen in Figure 4.3, substantial completion is scheduled for June 27th, 2014 where Level 2 Fitout is runs directly up to the substantial completion deadline. This is due to interior finishes, as they are always the last on the list for a project team. A full sized schedule can be seen in Appendix D.2.

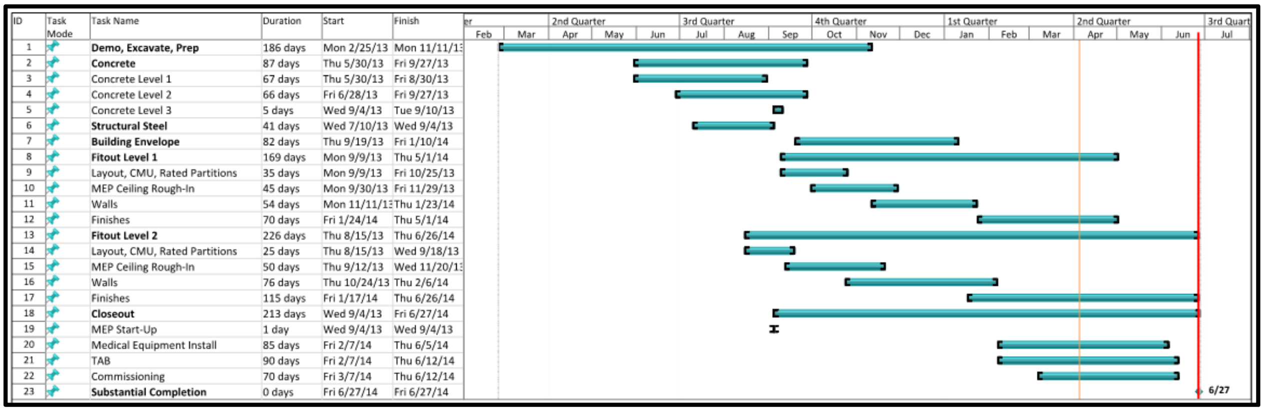


Figure 4.3

In order to calculate the schedule savings of implementing modular construction, the total duration for Level 2 fitout of 226 days was multiplied by a factor of 0.84, which produced a revised duration of 190 days. The 0.84 factor is attributed to the remaining work to be installed on-site after installation of the prefabricated modules, which encompassed 16% of the Level 2 fitout work to be completed. The individual activities were then reduced by the same factor. It was found that by implementing this off-site modular construction of the patient treatment rooms saved a total of 36 days. All of these days are not critical path days, however, as subsequent activities such as MEP start-up, medical equipment installation, testing and balancing, and commissioning finished after the revised Level 2 fitout end date of May 7th, 2013. Commissioning became the last necessary end date to the project schedule however, which then turned into the revised substantial completion date of June 12th, 2013. With that said, the total critical path savings due to the modularization of the patient treatment rooms was found to be 15 days. The revised project schedule can be seen in Figure 4.4, as well as Appendix D.3.

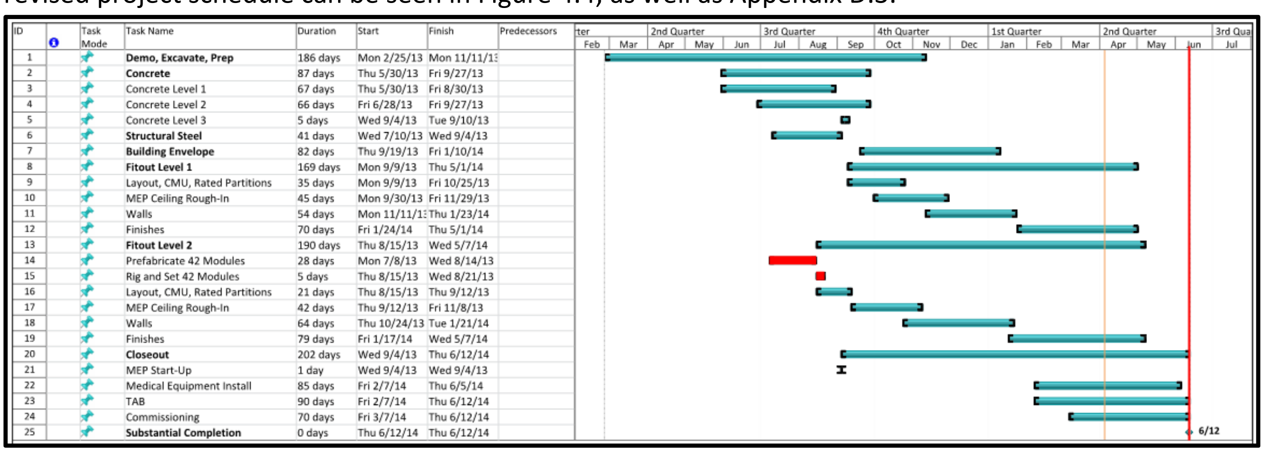


Figure 4.4

After studying “Lean Transformation in a Modular Building Company: A Case for Implementation” in the *Journal of Management in Engineering* by Haitao Yu and others, it was found that a typical building module produced on the assembly line during the case study at Kullman Building Corporate (KBC) was 12’x30’ in size (Haitao et. Al. 105). These modules were to be constructed as communication shelters, and be a completed assembly to be shipped to their respective sites. In addition, according to Haitao Yu and others, the duration to complete one module was found to be 1.73 days, including all trade work and finishes. The full journal article can be seen in Appendix D.4 for reference.

With that said, based on the article by Haitao Yu and others and for the purpose of this analysis, a productivity of 1.5 modules per day of off-site modular construction will be assumed. Even though the patient treatment rooms are 12’x14’, or half the size of the modules presented in the KBC case study, it is assumed that the complexity of the hospital room construction will be greater than that of a communication shelter. Additionally, each of the patient treatment rooms will be equipped with casework, a full functional sink, and associated plumbing, which will also increase the level of complexity for construction.

Based on a 1.5 module per day duration, it was calculated that the off-site multi-trade prefabrication would need to start on July 8th, 2013, with a total duration of 28 days. This value can be seen in activity 14 in Figure 4.4. Furthermore, as can be seen in activity 15, each of the Level 2 patient treatment rooms will be rigged and set into place between August 15th, 2013 and August 21st, 2015 for a duration of 5 days. This is based on the setting of 8 modules per day for days 1 through 3 and 9 modules per day for days 4 and 5.

Off-Site Warehouse and Shipping

After reviewing several different off-site warehouse locations, one industrial warehouse was found to be the most applicable. The building is located at 744 Walnut Ave, Bensalem, PA 19020, only 1.1 miles from the Aria Health ED Expansion project site. This location was chosen primarily due to its extremely close proximity to the jobsite, as well as its applicability and floor space available. The facility has 42,822 SF of open floor space, with a maximum clear height of 23 feet. The lot size is 3.31 acres with 12 drive-in, grade level overhead doors. This is plenty of space and access to remove the 12’ wide modules from the space. The leasing cost for this building is $4.50/SF/Year, where modular construction would only take place for one month, with one additional month for mobilization, set up, and site delivery. With that said, the total amount of floor space required for modular construction, could be as low as 15,000 SF, as the on-site floor area of the modules is only 7,000 SF. An additional 8,000 SF would be utilized for the actual assembly of each module, where the 7,000 SF would be used for module staging before delivery to side. Furthermore, the total rental cost for this space would be $11,250 for a total of two months. That number was found by using the following formula:

$$Total\ Cost = \left(\frac{\left(\frac{\$4.50}{\frac{SF}{Year}} \right) x(15{,}000\ SF)}{12}months \right) x(2\ months)$$

The warehouse can be seen in Figure 4.5, as well as the distance and direction to the project site in Figure 4.6.

Figure 4.5

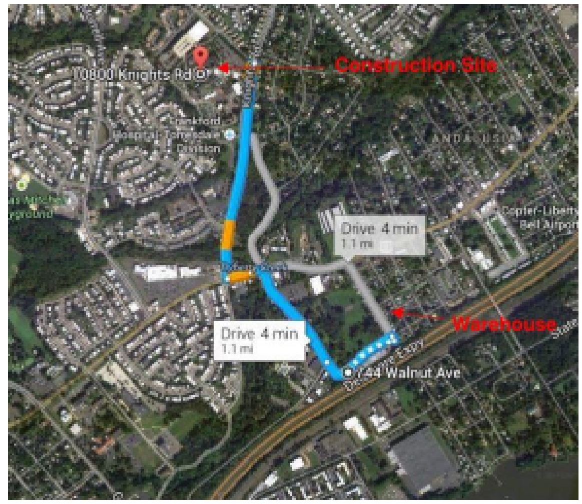


Figure 4.6

For delivery, a standard flatbed tractor trailer will be used to transport each of the modules to site. According to the U.S. Department of Transportation Federal Highway Administration, the maximum flatbed trailer length allowed for travel on the road in Pennsylvania is 53 feet. With that said, it will be possible for each trailer to carry 3 total modules on each truck, as the average length of each module is 14' feet. The total length of three modules will be 42 feet long, 11 feet below the maximum allowed. An example of modular building transportation can be seen in Figure 4.7.

Figure 4.7

Photo Reference: *http://modularhomeowners.com/the-definitive-guide-to-building-modular/modular-home-delivery/*

Site Logistics and Sequencing

A site logistics plan was produced to show the flow of work for the rigging and setting of each of the 42 patient treatment room modules. As can be seen in Figure 4.8, the flatbed trucks transporting the modules will enter the site from Knights Road at the east site entrance. The trucks will follow the access road and turn right toward the loop road in front of the building addition and stop. Crane 1 will then pick each of the modules for the first half of the modules, shown in light blue on the site logistics plan. Trucks carrying modules required for the second half of the assembly will follow the access road north and turn into the second access point for Crane 2. After offloading, the trucks will back up, and follow the access road farther north until the hit the large open parking lot, where they will be able to turn around and then follow the access road back out of the site to exit once again on Knights Road. The site logistics plan can also be viewed in Appendix D.5.

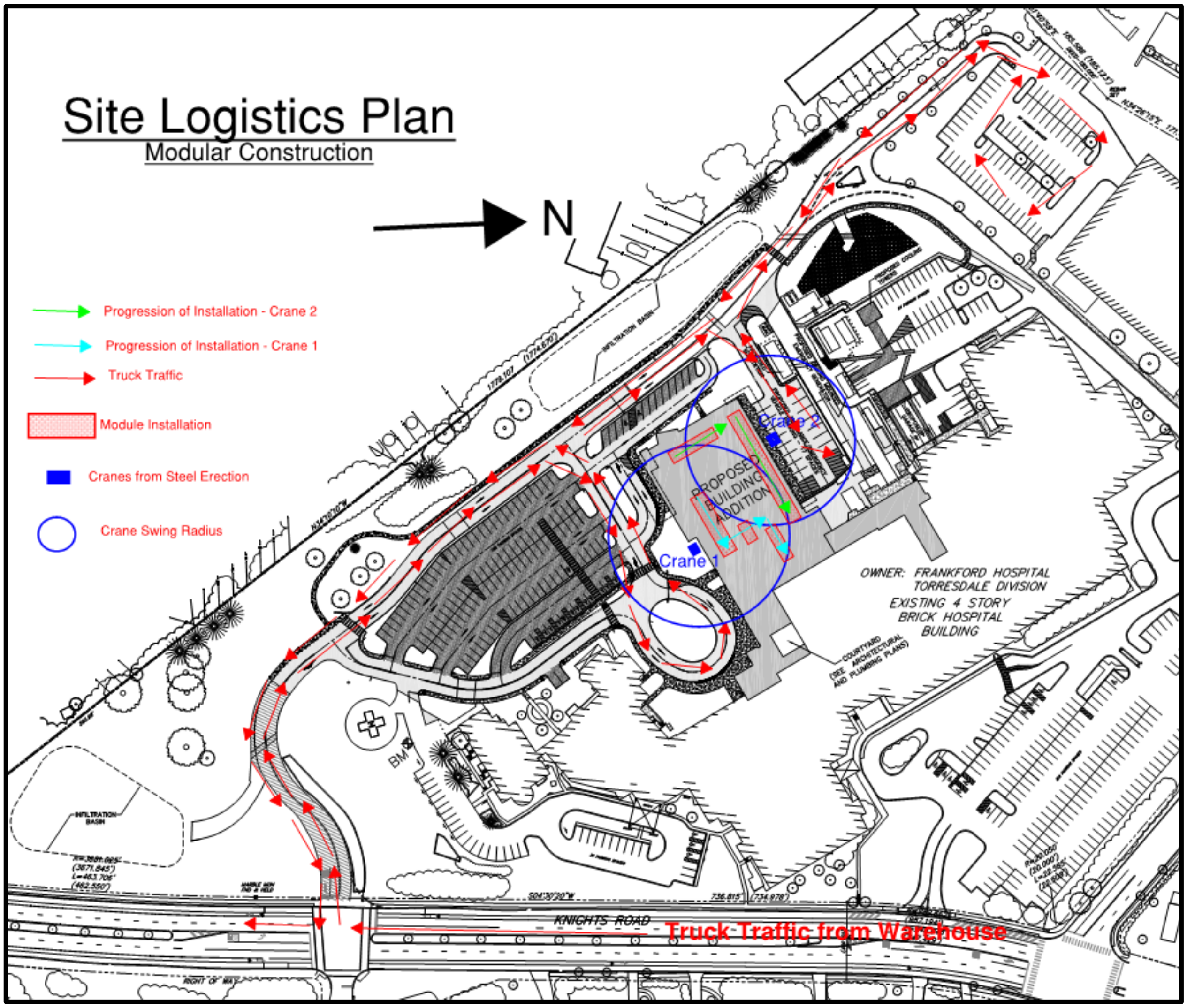


Figure 4.8

A blown up version of the installation sequence can be seen in Figure 4.9, where the architectural layout is also shown. A full sized version of this plan can also be seen in Appendix D.6.

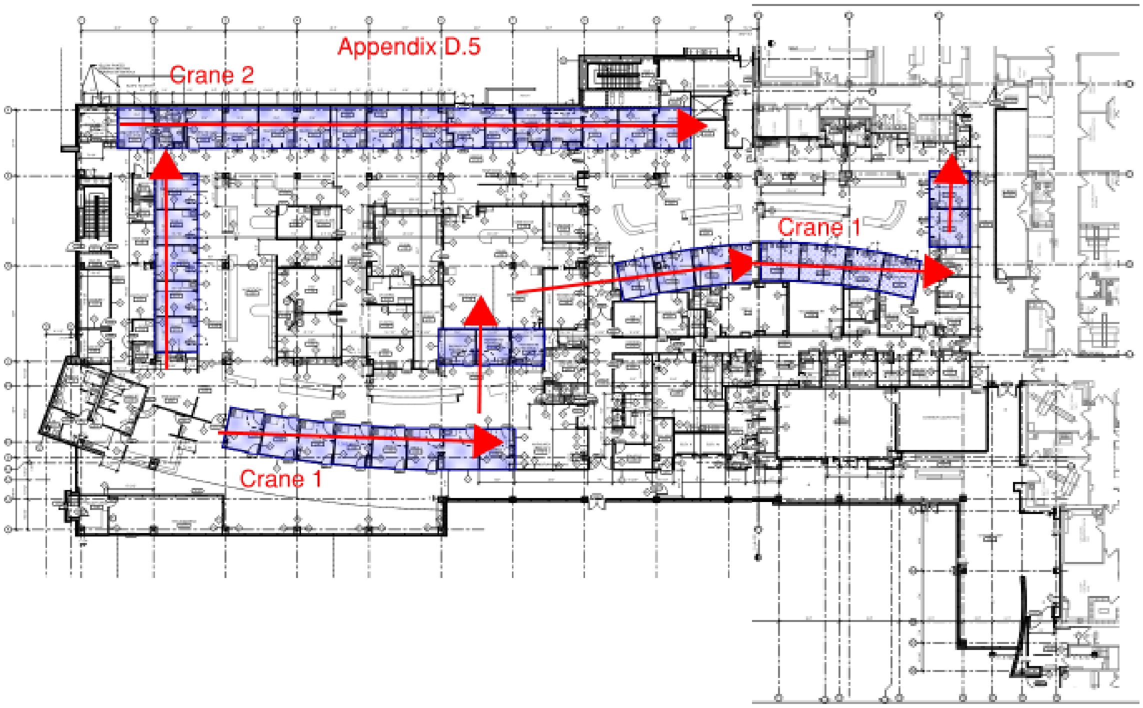


Figure 4.9

It should be noted that the crane picking sequence will be in conjunction with the Level 2 steel erection. If the steel erection had been completed prior to the setting of each of the modules, the modules would not have fit down into the superstructure, causing for serious constructability concerns. This sequence will still be difficult however, as special care must be taken when laying out the modules into place. Most of the modules sit in between the structural bays, which is why this could still be physically feasible.

Research

As this analysis serves as the "Research Topic" for this AE Senior Thesis project, several different research media were used while gathering information on this topic. These included an online news article resource documenting a successful modular healthcare project, a peer reviewed journal article pertaining to a modular construction case study, and an interview with an industry professional versed in modular construction practices.

<u>Miami Valley Hospital Addition, Dayton, Ohio</u>

In an effort that had initially been to reduce project schedule, Skanska Project Executive Marty Corrado and the other project team members of the Miami Valley Hospital project, have revolutionized multitrade prefabrication in healthcare facilities. The hospital consisted of 484,000 SF including 178 prefabricated patient treatment rooms and 120 overhead corridor utility racks, where 2 months were subtracted from the project schedule and a reduction in cost of 1-2% was obtained (Post 1). The 12-story addition was a joint venture with local contractor, Shook Construction and was said to "revamp the entire hospital delivery process as we know it" (Post 1). During prefabrication, all the MEP systems, as well as drywall, were included in prefabrication, where each of the headwalls were also included in the modules. The initial issue with the project was a 14 week delay, due to a foundation redesign and construction rework, where the prefabrication accelerated the project by 8 to 10 weeks (Post 1). Inside the warehouse where the modular construction took place, 18 workers prefabricated the 178 patient treatment rooms and 120 racks where productivity increased 300% for pipe fitting from onsite work (Post 1). Full collaboration of the project team had to be achieved, while much earlier design decisions had to be made where patient treatment room design had to be done four to six months earlier than the norm (Post 1). Additionally, all involved subcontractors had to be brought in during design development in order to ensure proper constructability. Inspiration for the multitrade prefabrication came from Corrado's Skanska counterpart in London, England where Skanska was doing similar prefabrication work. Building Information Modeling was used extensively during the design and construction of the patient treatment room modules to ensure proper placement within the building, including each of the systems connections (Post 1).

The foundation work for the project began in May 2008, after which the 14 week delay took place due to unsuitable soil conditions on site. Prefabrication began in February 2009, where a 35,000 SF warehouse was leased at $2.50/SF/Year in Dayton, OH only 3 miles from the project site. Due to the foundation delay, steel erection was also pushed back, which in turn delayed the setting of the prefabricated modules. For staging purposes, another 70,000 SF warehouse was also leased close to the project jobsite (Post 2). Saturday rigging and setting was necessary, as each of the modules were hoisted into place concurrently during steel erection with the existing tower crane already on site (Post 3). Rigging and setting of the units went so well, that the team then became months ahead of building envelope installation (Post 3).

Overall the modular construction of the patient treatment rooms was extremely successful, however several lessons were learned during the process. The most important of all, timing: "start planning the process from the onset of the project, not midway through design development" (Post 3).

Reference:

Post, Nadine. "Racking Up Big Points For Prefab." *Engineering News Record*. 08 09 2010: 1-3. Web. 6 Apr. 2014. <http://enr.construction.com/buildings/construction_methods/2010/0908-PrefabPotential-1.asp>.

Full article can be seen in Appendix D.7.

<u>*Lean Transformation in a Modular Building Company: A Case for Implementation* by Haitao Yu et. Al.</u>

Building construction has long been attempting to utilize the tried and true methods of lean manufacturing techniques in order to reduce waste and increase productivity. The construction industry is striving to industrialize the process, where the techniques and craftsmanship for building within a prefabrication facility is not much different from on-site, stick-built construction (Haitao et. Al. 1). This article describes the research performed by Haitao and others to "develop and implement a production system for the effective application of lean tools in building components prefabrication" (Haitao et. Al 1). A pilot project included one production line for the assembly of several communication shelters, ranging in size from 12'x30' to 12'x20' complete with different finishes and wall construction over six months, utilizing tools such as 5S (sort, straighten, shine, standardize, and sustain), standardized work, takt time planning, variation management, and value stream mapping (Haitao et. Al. 1). Kullman Building Corporate (KBC) is a modular building company who was chosen for the case study, while prior to the pilot project performed, KBC's products were consistently 10-20% more expensive than their competitors (Haitao et. Al. 2). The employees that took part in the study were unionized and were put through Lean 101 training delivered by outside resources (Haitao et. Al 2). Since the communication shelters within the pilot were all similar in size, the process for construction was simple to standardize where average labor hours were reduced by 20% per module during the study. Several questions were raised during the study, such as, "where is the best place to put this material (or equipment)?" while the answer was consistently "At the place where they are used" (Haitao et. Al 4). Simple questions and answers like this provided a more streamlined environment, where wasted time trying to find material was no longer an issue because "a given task should always be performed at a designated location so the required materials and equipment could be put next to that location" (Haitao et. Al 4). At the conclusion of the pilot production line, a 57% increase in productivity was achieved, from July where 1.1 modules per day were constructed, to January were 1.78 modules per day were constructed (Haitao et. Al 8). Furthermore, labor cost per modules was reduced by 18% (Haitao et. Al. 8). It was proven through this case study that lean manufacturing principles can be effectively applied to modular building construction (Haitao et. Al. 8).

Reference:

Haitao, Yu. "Lean Transformation in a Modular Building Company: A Case for Implementation." *Journal of Management in Engineering, ASCE*. (2013): 103. Print.

Full article can be seen in Appendix D.4.

Interview Summary with Ted Border, Vice President of The Whiting-Turner Contracting Company

After a phone interview was held with Ted Border, Vice President with The Whiting-Turner Contracting Company, several questions were answered regarding modular construction practices. Pertaining to the Muhlenberg College Dormitory project, it was found that modularization was planned out far in advance where prefabrication did not shorten the project schedule per se, but was rather built into the project schedule from the beginning in order to meet substantial completion in a three month time period. It was also found, that across the industry, some owners are now expecting prefabrication, as they see the benefits for a faster project delivery. Pertaining to labor costs during prefabrication, it was found that a company really has to do their research. With that said, labor rates for a specific jobsite may be different than the labor rates where prefabrication is taking place. If labor rates are cheaper in the location for prefabrication are lower than ones for the project site itself, a company could potentially save a lot of money. For example, the Muhlenberg College Dormitory employed modular construction in New Jersey, while the actual site location was in Pennsylvania. Aside from labor costs, mobilization and general conditions costs were also explained. Many project general conditions estimates account for weather proofing, tenting, plastic, and temporary propane heating. These costs would subsequently be reduced during prefabrication due to a controlled, warehouse environment. It was asked how renting costs may offset this savings, where it was found that the costs for leasing a facility were almost negligible. Additionally, project schedules most always include lost work days due weather, which are virtually eliminated in a facility. Construction sequencing was found to be the same as on-site construction, as all trade coordination and material staging would not change, aside from the physical location where activities are taking place. It was stated, however, that multiple modules could be prefabricated simultaneously, which is strictly a matter of man power. All material deliveries, movement paths, and other activities must be accounted for, similar to traditional stick-built construction. Issues may arise though, as was explained in the case of mixing bags of mortar where excessive dust could become a problem within an interior environment. Aside from dust, cramped construction areas and equipment fumes must be addressed.

For the Muhlenberg project, it was found that the prefabrication facility was located approximately 70 miles away, however, transportation was required to travel 120 miles. This was due to Penn Dot regulations, where extra wide loads necessitate flagging and spotters. Penn Dot also limits weight and height for large loads for the purpose of riding over and under bridges.

Several constructability concerns were addressed, as construction tolerances consistently cause issues when setting the modules themselves in their final locations on site. Strict quality control measures must be adhered to, as only the slightest differences in measure could provide opportunity for on-site installation issues. Shipping most definitely causes the most concern, as modules must be assembled to withstand road vibrations and jolts, breakage during transport and rigging, and must be packaged well enough to combat rain, sleet, and snow.

It was found that all prefabricated modules contain spreader beams for support during transportation, where each module's weight must be calculated to the highest degree of accuracy. A 10% factor of safety is also added. Once the module has been set on a truck, the actual weight could be accounted for with the built-in scale for weight verification.

Lastly, union labor must be accounted for while prefabricating facilities, where wage rates and labor agreements must be fully understood. If unions differ even slightly from the prefabrication facility to the jobsite, the unions may require the shipment of their own workers to the modular construction areas.

The actual documentation from the interview can be seen in Appendix D.8.

Recommendation

The benefits of building modular are continually becoming realized across the construction industry. The controlled environment, where tradesmen are able to work outside of the elements and inside facilities, is crucial to productivity and worker morale. The possibility of having an assembly line, where modules roll onto the following stations and workers do not have to move, saves time and money. Having tools, equipment, and materials right where they are needed reduces waste and eliminates turf wars that are always present on jobsites between trades.

Each of the aforementioned benefits could have been applied to the Aria Health ED Expansion project. It is because of these items, along with the savings in critical path duration of 15 days from the project schedule, that the modularization of the patient treatment rooms at Aria Health is recommended.

Conclusion

After an in-depth study of the implementation of a rainwater collection system for sewage conveyance, the addition of a photovoltaic array for self-production of electricity, the utilization of operable solar shading devices for the purpose of cooling cost savings, and the application of modular construction, several conclusions were found.

Analysis 1 – Rainwater Collection

The rainwater collection system that was designed was able to successfully provide the Aria Health ED Expansion building with enough gray water to supply each of the water closets and urinals for the purpose of flushing. After the analysis was performed, it was found that the system would pay for itself in 12.18 years and produce a cumulative income of $281,105.50 over a 25 year period. With an initial investment of $146,680.40, the benefits of the system outweigh the cons, for which is why the system has been recommended.

Analysis 2 – Photovoltaic Array

After designing a solar power production system from the addition of 180 photovoltaic modules, the assembly proved possible, however not without high initial costs. Based on an upfront price of $211,958.98, it was found that the system provided a 19.52 year payback and a poor return on investment of 0.83% per year, due to the 25 year income total of $94,467.20. It is for these reasons that system does not prove to be economically feasible and is therefore not recommended.

Analysis 3 – Operable Solar Shading

Colt Shadoglass, a product designed to allow maximum available natural light while simultaneously rejecting solar gain, was implemented into the building façade and analyzed for the purpose of reducing cooling costs within a space. Impressively, the system reduced the cooling load for the entrance lobby and adjacent corridor by 20%, a savings of 46,220.7 BTU/h. This value translated to a reduction in cooling costs of $935.97 per year. However, with an initial investment of $442,533.33, the addition of the system does not make sense financially and is therefore not recommended.

Analysis 4 – Modularization of Patient Treatment Rooms

After researching modular construction techniques through the use of online articles, peer reviewed journals, and interviews held with industry professionals, the benefits of multitrade prefabrication cannot be ignored. A controlled environment, along with a high level of planning and foresight, has the capability to increase productivity and reduce project schedule. It was found that by prefabricating 42 patient treatment rooms in an offsite facility, a total critical path duration of 15 days could have been saved. Because of this impressive schedule savings, the modularization of the patient treatment rooms at the Aria Health ED Expansion project is recommended.

Overall, while sustainable construction techniques and advancements in technology and way of thinking provide many opportunities within the construction industry, it has been learned that these opportunities do not always make rational sense. However, with the state of the world today and depleting natural resources, the aforementioned alternatives may provide the only possible options.

Appendix A

Rainwater Collection

Appendix A.1

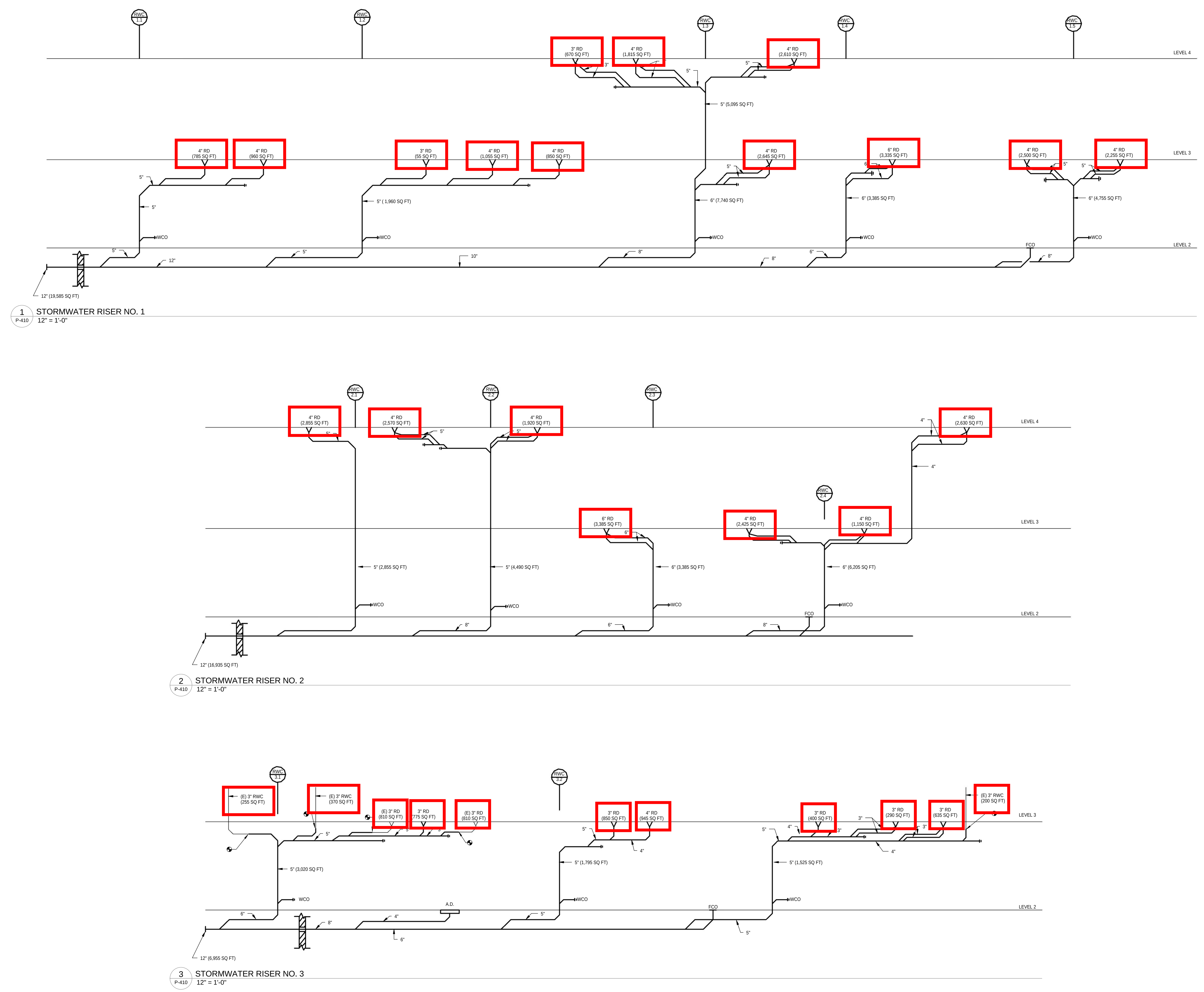


Figure 1.1

Revisions

No.	Description	Date

Key Plan

Consultants:

Structural Engineer:
O'Donnell & Naccarato
111 South Independence Mall East
Suite 950
Philadelphia, PA 19106
Phone: (215) 925-3788
Fax: (215) 627-1051
www.o-n.com

M/E/P Engineer:
PWI
327 North 17th Street
Philadelphia, PA 19103
Phone: (215) 241-9100
Fax: (215) 241-9112
www.pwius.com

Civil Engineer:
Barry Isett & Associates, Inc.
Pennsylvania 100
Trexlertown, PA 18087
Phone: (610) 398-0904
http://www.barryisett.com

Construction Manager:
Turner Construction Company
1835 Market Street
21st Floor
Philadelphia, PA 19103
Phone: (215) 496-8800
www.turnerconstruction.com

It is the responsibility of the Construction Manager/General Contractor and all Sub-Contractors to verify all dimensions and accept conditions of prior work by related trades before proceeding with any work.

Date
10/26/12

Drawn By
SAM

Scale
AS NOTED

Seal

Checker WTO

Francis Cauffman

Project Title

Aria Health System - Torresdale Campus

New Emergency Dept & Patient Medical Tower

10800 Knights Road
Philadelphia, Pennsylvania, 19114

Project Number
F11-5892

Drawing Title and Number
STORMWATER RISER DIAGRAM

P-410

CONSTRUCTION DOCUMENT ISSUE - 10/26/12

American Standard

BARRIER FREE

AFWALL® FloWise® ELONGATED FLUSHOMETER TOILET

VITREOUS CHINA LESS EVERCLEAN®

AFWALL® FloWise® ELONGATED TOILET LESS EVERCLEAN®

- Wall-mounted flushometer valve toilet
- Vitreous china
- Conventional glaze
- High Efficiency, Low Consumption. Operates in the range of 1.1 gpf to 1.6 gpf (4.2 Lpf to 6.0 Lpf)
- Meets definition of HET (High Efficiency Toilet) when used with a high efficiency flush valve (1.1 gpf / 1.28 gpf and 1.6 / 1.1 gpf dual flush)
- Condensation channel
- Elongated bowl
- Powerful direct-fed siphon jet action
- 1-1/2" inlet spud
- Fully-glazed 2-1/8" trapway
- 10" x 12" water surface area
- 100% factory flush tested

- ☐ **2257.001** Elongated bowl only, top spud
- ☐ **2633.001** Elongated bowl only, top spud with slotted rim for bedpan holding
- ☐ **2634.001** Elongated bowl only, back spud

SEE REVERSE FOR ROUGHING-IN DIMENSIONS

System MaP* Score:

- 1,000 grams of miso @ 1.6 gpf or 1.28 gpf when used with an American Standard flush valve

* Maximum Performance (MaP) testing performed by IAPMO R&T Lab. MaP Report conducted by Veritec Consulting, Inc. and Koeller and Company.

Component Parts:

☐ **047007-0070A** Inlet Spud (furnished with bowl)

Nominal Dimensions:

660 x 356 x 381mm
(26" x 14" x 15")

Recommended working pressure–between 25 psi at valve when flushing and 80 psi static

Fixture only, less seat, bolt caps, and flushometer valve

Compliance Certifications - Meets or Exceeds the Following Specifications:

- ASME A112.19.2-2008/CSA B45.1-08 for Vitreous China Fixtures

To Be Specified:

- ☐ Color: ☐ White
- ☐ Seat:
  - ☐ American Standard #5901.100 Heavy duty open front less cover
  - ☐ American Standard #5905.100 Extra heavy duty open front less cover
- ☐ Flushometer Valve:
  - ☐ 1.6 gpf:
    - ☐ Sensor-Operated: American Standard Selectronic® DC Power #6065.161.002 (Top Spud)
    - ☐ Sensor-Operated: American Standard Selectronic® AC Power #6067.262.002 (Back Spud)
    - ☐ Manual: American Standard #6047.161.002 (Top Spud)
  - ☐ 1.28 gpf:
    - ☐ Sensor-Operated: American Standard Selectronic® DC Power #6065.121.002 (Top Spud)
    - ☐ Sensor-Operated: American Standard Selectronic® AC Power #6067.222.002 (Back Spud)
    - ☐ Manual: American Standard #6047.121.002 (Top Spud)
  - ☐ 1.6 / 1/1 gpf Dual Flush:
    - ☐ Sensor-Operated: American Standard Selectronic® DC Power #6065.761.002 (Top Spud)

MEETS THE AMERICANS WITH DISABILITIES ACT GUIDELINES AND ANSI A117.1 REQUIREMENTS FOR ACCESSIBLE AND USABLE BUILDING FACILITIES - CHECK LOCAL CODES.

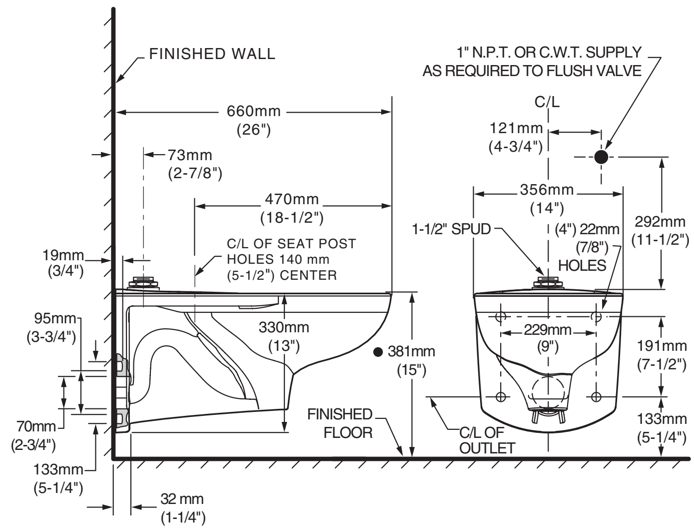
- When installed so top of seat is 432 to 483mm (17" to 19") from the finished floor.

WATER EFFICIENT PRODUCT

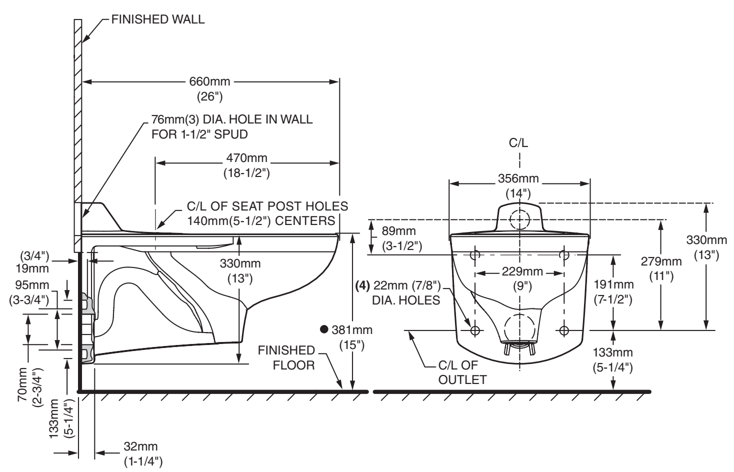
AFWALL® FloWise® ELONGATED FLUSHOMETER TOILET

VITREOUS CHINA LESS EVERCLEAN®

2257.001/2633.001



2634.001



NOTES:

● **Toilet designed to meet ADA accessibility standards when top of seat height set at 432 to 483mm (17" to 19") from finished floor.**

PRODUCT 2257 SHOWN, 2366 SAME EXCEPT WITH SLOTTED RIM FOR BED PAN HOLDING.
WASTE OUTLET SEAL RING MUST BE NEOPRENE OR GRAPHITE-FELT (WAX RING NOT RECOMMENDED).
SUGGESTED 2mm (1/16) CLEARANCE BETWEEN FACE OF WALL AND BACK OF BOWL.
TO COMPLY WITH AREA CODE GOVERNING THE HEIGHT OF VACUUM BREAKER ON THE FLUSHOMETER VALVE, THE PLUMBER MUST VERIFY DIMENSIONS SHOWN FOR SUPPLY ROUGHING.
FLUSHOMETER VALVE NOT INCLUDED WITH FIXTURE AND MUST BE ORDERED SEPARATELY.
CARRIER FITTING AS REQUIRED TO BE FURNISHED BY OTHERS.
PROVIDE SUITABLE REINFORCEMENT FOR ALL WALL SUPPORT.

IMPORTANT: Dimensions of fixtures are nominal and may vary within the range of tolerances established by ANSI Standard A112.19.2.
These measurements are subject to change or cancellation. No responsibility is assumed for use of superseded or voided pages

American Standard
Style That Works Better

BARRIER FREE

WASHBROOK™ FloWise® UNIVERSAL URINAL
VITREOUS CHINA

WASHBROOK™ FloWise® UNIVERSAL URINAL

- Vitreous china
- Ultra High Efficiency, Low Consumption. Operates in the range of 0.125gpf to 1.0gpf (0.5 Lpf to 3.8gpf)
- Flushing rim
- Elongated 14" rim from finished wall
- Washout flush action
- Extended sides for privacy
- 3/4" inlet spud
- Outlet connection threaded 2" inside (NPTF)
- 2 wall hangers
- Fixture only
- Strainer included
- Meets ASME flush requirements at 0.125 to 1.0 gpf

❑ **6590.001** Universal Top spud
❑ **6515.001** Universal Back spud

Nominal Dimensions:
360 x 480 x 664mm
(14-1/8" x 18-7/8" x 26-1/8")

Recommended working pressure – between 20 psi at valve when flushing and 80 psi static

Compliance Certifications -
Meets or Exceeds the Following Specifications:
- ASME A112.19.2-2008/CSA B45.1-08 for Vitreous China Fixtures

SEE REVERSE FOR ROUGHING-IN DIMENSIONS

To Be Specified:
❑ Color: ❑ White ❑ Bone ❑ Linen ❑ Black
❑ Flush Valve:

1.0 gpf Flush Valve: Sensor-Operated:
❑ American Standard Selectronic® #6063.101.002 DC Power (Top Spud)
❑ American Standard Selectronic® #6062.310.007 AC Power (Back Spud)

1.0 gpf Flush Valve: Manual-Operated:
❑ American Standard # 6045.101.002

0.5 gpf Flush Valve: Sensor-Operated:
❑ American Standard Selectronic® #6063.051.002 DC Power (Top Spud)
❑ American Standard Selectronic® #6062.305.007 AC Power (Back Spud)

0.5 gpf Flush Valve: Manual-Operated:
❑ American Standard #6045.051.002

0.125 gpf Flush Valve: Sensor-Operated:
❑ American Standard Selectronic® #6063.013.002 DC Power (Top Spud)
❑ American Standard Selectronic® #6062.301.007 AC Power (Back Spud)

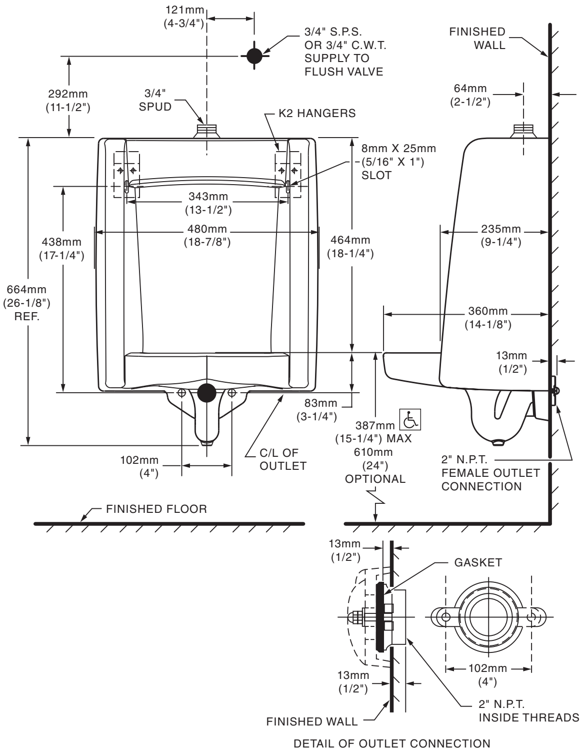
0.125 gpf Flush Valve: Manual-Operated:
❑ American Standard #6045.013.002

WATER EFFICIENT PRODUCT

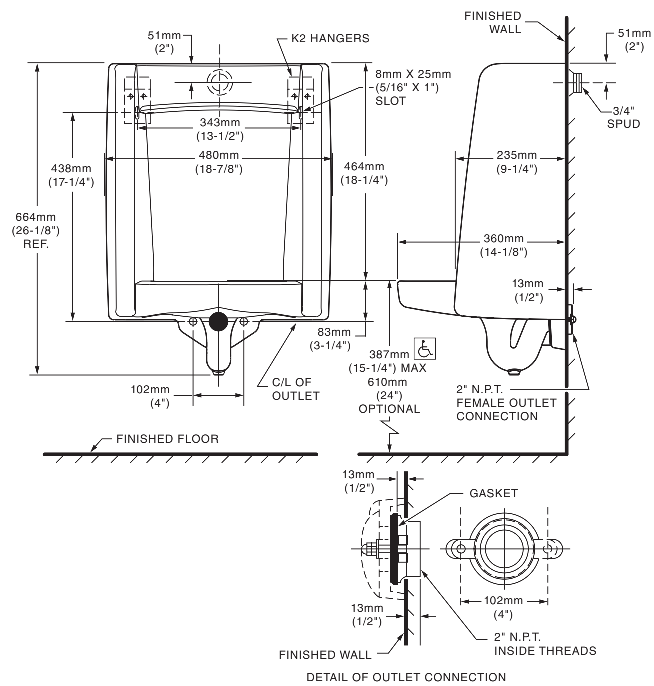
WASHBROOK™ FloWise® UNIVERSAL URINAL

VITREOUS CHINA

6590.001 TOP SPUD



6515.001 BACK SPUD



MEETS THE AMERICANS WITH DISABILITIES ACT GUIDELINES AND ANSI A117.1 ACCESSIBLE AND USABLE BUILDINGS AND FACILITIES - CHECK LOCAL CODES.

- When installed so top of rim is 387mm (15-1/4") from finished floor.

NOTES:
FLUSH VALVE NOT INCLUDED AND MUST BE ORDERED SEPARATELY.
PROVIDE SUITABLE REINFORCEMENT FOR ALL WALL SUPPORTS.

IMPORTANT: Dimensions of fixtures are nominal and may vary within the range of tolerances established by ANSI Standard A112.19.2. These measurements are subject to change or cancellation. No responsibility is assumed for use of superseded or voided pages.

HighDRO®-Pure Rainwater Harvesting System

Rainwater "Harvesting" and Reuse
Saves Money - Earns Valuable LEED Points!

Highland Tank®

Appendix A.4

HighDRO®-Pure Rainwater Harvesting Systems (HD-P-RHS) are designed to collect, store, and reuse rainwater.

The affordable HighDRO®-Pure system produces a sustainable and reliable alternative water source and helps reduce stormwater runoff.

The HD-P-RHS is a complete, packaged system consisting of:

- Flush Filter (HD-FF)
- Rainwater Collection Tank (HD-RCT)
- Duplex Submersible Feed Pumps with Floating Suction
- Advanced Water Filtration System (HD-AWFS)
- Control System (HD-CS)
- Day Tank (HD-DT)
- Booster Pumps (HD-BP) with Controls

The resulting non-potable water can be used for a wide range of purposes including:

- Toilet flushing
- Lawn and landscape irrigation
- Laundry washing
- Cooling towers
- Fire water supply
- Building power washing
- Industrial processing
- Pool/pond filling
- Vehicle washing

Highland's HighDRO®-Pure system can be incorporated into water efficiency designs that help qualify for valuable LEED credits. Additionally, our Rainwater Collection Tanks score high points for environmental sustainability. Our new steel products are made from recycled steel and can be recycled again at the end of their useful lives.

Features

- Unlimited storage capabilities
- Efficient, streamlined treatment process
- Low energy consumption per gallon treated.
- Measurement and verification
- Influent flow rates to 6,000 gpm
- Distribution flow rates from 5 to 300 gpm

Designers, engineers, and builders have long recognized and lauded Highland's protected steel water tanks for their strength, durability, and functionality. With the addition of our new HighDRO®-Pure systems, we are continuing our commitment to protect the environment and conserve our precious natural resources to benefit our world today and tomorrow.

Water Harvesting Solutions

The purpose of the HighDRO®-Pure Rainwater Harvesting System is to collect, store, and treat rain water from a storm event. It provides an alternative to the municipal water supply.

Applications

- Industrial
- Commercial
- Agricultural
- Fire Suppression
- Residential

Installing a HighDRO® system can help users reduce water supply costs. With rainwater harvesting systems, most of the cost is upfront cost, and systems ultimately pay for themselves within a few years, depending on the system and local water prices. Not only does the user save water consumption costs, but it also reduces stormwater runoff on the site.

Benefits

- Saves water consumption costs
- Reduces demands on municipal, surface, or ground water supplies
- Protects the integrity of local waterways by reducing nonpoint source pollution
- Beneficial for cleaning purposes as less detergent is needed
- Good for irrigation as water is free of salts and man-made pollutants
- Reduces flooding and erosion
- Helps you achieve valuable LEED Green Building points

In some areas, rainwater may represent the primary source of water. Collected rainwater can augment primary water sources and it is a good standby in times of emergency, such as during power outages, droughts, or when the well goes dry.

How It Works!

HighDRO®-Pure systems are suitable for many residential, commercial, and industrial buildings and can be retrofitted to existing buildings or integrated into new building designs. They are engineered for these site-specific applications and, as a result, consist of technologically advanced components.

They are highly efficient at collecting rooftop runoff. The collected water can be used for non-potable (non-drinking water) and potable (drinking water) demands. Additional water treatment components must be installed to treat potable water for drinking water use.

Rainwater that may have dirt, leaves, twigs, bird droppings, and other organic matter in it is collected by the gutters and routed to the downspouts.

To remove these contaminants, the rainwater is routed to the Flush Filter (HD-FF). The HD-FF, with its inlet strainer basket, internal "switchback" baffling, and gravel pack filter, is designed to remove any debris, settleable material, and suspended solids thereby improving the water quality.

An EZ Access manway allows for easy inspection, cleaning of the debris collection area, and flushing of the gravel pack filter. Any reject water is automatically discharged from the drain to the drain field and the clean water flows to the HighDRO® Rainwater Collection Tank (HD-RCT).

The HD-RCT protected steel storage tank is installed below ground to maintain a cool temperature and reduce the chances of bacterial growth. HD-RCTs range in size from 185 to 60,000 gallons depending on usage demand, collection area, and available on-site space.

The Inlet flow is directed against the Velocity Head Diffusion Baffle (VHDB) to reduce inflow speed and turbulence.

The VHDB prevents the disturbance and re-suspension of any fine sediment that accumulates on the bottom of the tank. It also distributes the fresh, filtered water while oxygenating it to further ensure pure stored water.

An emergency overflow outlet is installed near the top of the tank to provide for high water levels during heavy stormwater flows.

A manway with quick opening cover is provided for access to the tank for inspection and maintenance.

Water is drawn from the tank via Duplex Submersible Feed Pumps and floating suction as called for by pressure regulated conditions. The filter and suction intake floats just beneath the surface at the end of the pump's suction. The floating filter protects the pump against particles before the water is pumped for use.

The Feed Pumps and Controls are used to transfer the water to the Advanced Water Filtration System (HD-AWFS). The water is pumped through the tertiary filters for sediment removal and UV disinfection to control clarity, odor, and microbial contamination. Optional chlorine disinfection provides residual .5 ppm of chlorine. Water is deposited in the Day Tank (HD-DT) - the source of water for the Non-Potable Water Booster Pump(s) with controls.

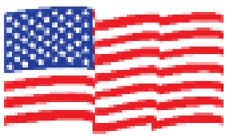
The Day Tank control stages are predetermined to enable and disable the non-potable water system equipment including pumps, filtration, disinfection system, and domestic water valve. A circulating pump is provided to prevent stagnation during off peak hours. The harvested rainwater is finally transferred either through the building system or outdoors under pressure for non-potable usage - toilet flushing, linen washing, facility cleaning, and/or irrigation.

HighDRO®-Pure Rainwater Harvesting Systems

Pre-packaged, turnkey systems designed for your needs.

1. **Flush Filter (HD-FF)**
2. **Rainwater Collection Tank (HD-RCT)**
3. **Floating Suction & Submersible Feed Pumps**
4. **Advanced Water Filtration System (HD-AWFS)**
5. **UV Filter**
6. **Chlorine/Dye**
7. **Control System (HD-CS)**
8. **Day Tank (HD-DT)**
9. **Booster Pump (HD-BP)**
10. **Flush Filter Overflow**
11. **Collection Tank Overflow**
12. **Water Supply to Building**
13. **Rainwater Source**

All Highland Tanks Are

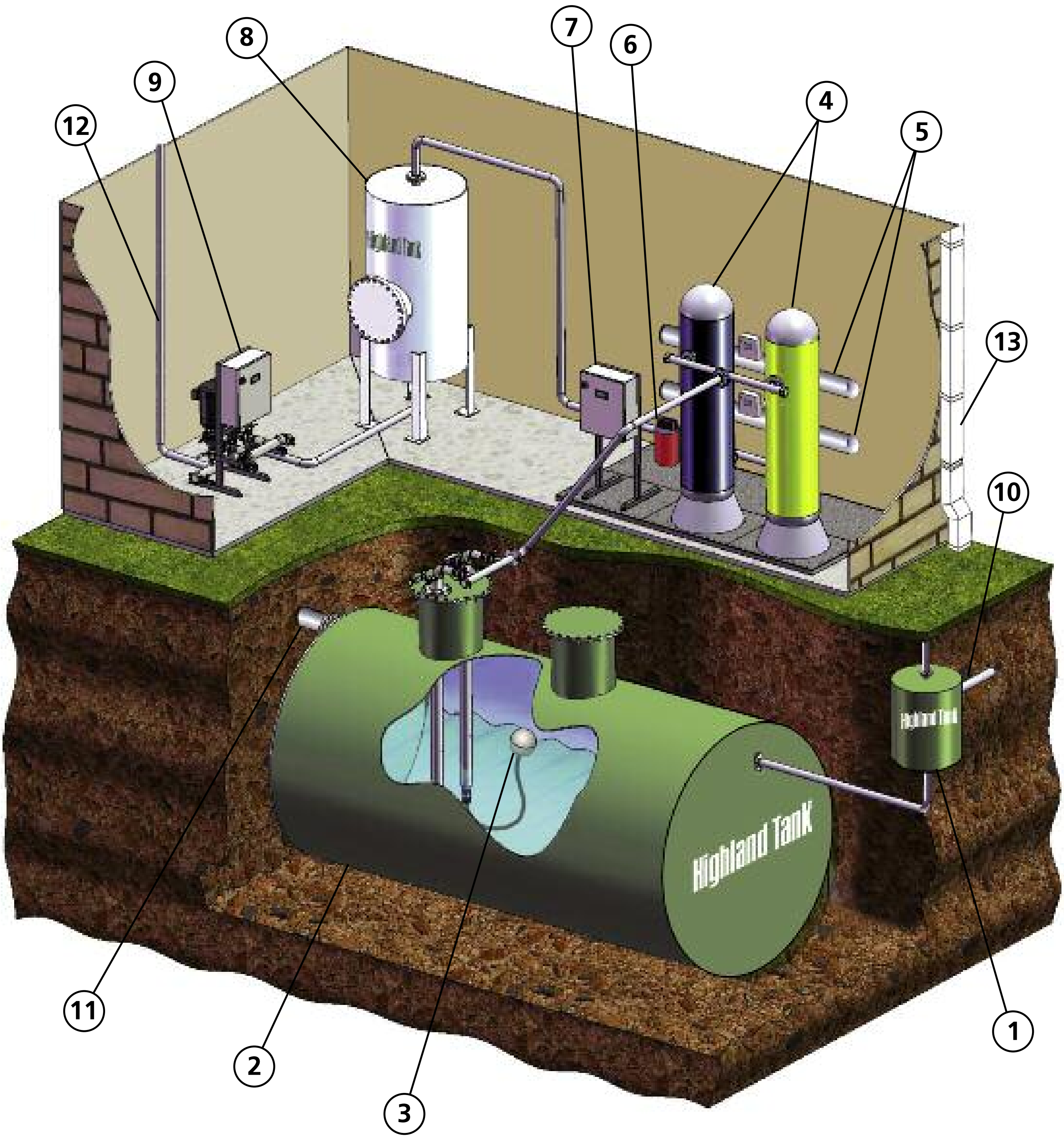


Proudly Made In America

Support American Workers by buying products Made in the USA!

HighDRO®-Pure Rainwater Harvesting System

The most complete rainwater recycling system available anywhere – custom designed and sized to collect, store, filter and provide non-potable water for a wide variety of uses, reducing stormwater runoff and dependence on domestic water.



HighDRO®-Pure Rainwater Harvesting System

There are six critical components to maintaining the water quality of the HighDRO®-Pure Rainwater Harvesting System


Flush Filter
(HD-FF)

Control System
(HD-CS)

Rainwater Collection Tank
(HD-RCT)

Day Tank
(HD-DT)

Advanced Water
Filtration System
(HD-AWFS)


Booster
Pump
(HD-BP)

Filter, Store, and Reuse!

HighDRO® Flush Filter (HD-FF)

HD-FFs are designed to filter out debris and control flow. The HD-FF removes dirt, leaves, dust, and organic matter from the captured rainwater. They divert this harmful material away from the collection tank and safely discharge it to the storm sewer. HD-FF are fabricated in either a vertical or horizontal configuration with a 3", 4", 6", 8", 10", or 12" diameter inlet/outlet to match typical roof conveyance components like downspouts, roof drains or piping.

HighDRO® Rainwater Collection Tanks (HD-RCT)

HD-RCTs provide storage for harvested water from multiple catchment areas. Whether it is rainwater from a rooftop or paved areas, the HD-RCT provides safe and reliable water storage for reuse. HD-RCTs are available for underground or aboveground (horizontal or vertical) installations. Capacities range from 185 to 60,000 gallons. These strong factory-welded stainless steel or factory-coated carbon steel water tanks (meets NSF and AWWA codes) come complete with internal diffusion baffles, manways, ladder, submersible feed pumps with floating suction, and all the necessary fittings for use with the system.

HighDRO® Day Tank (HD-DT)

HD-DTs provide safe storage for the daily usage of treated water. Available for aboveground or underground installations, HD-DTs are sized based on water requirements. Standard sizes are 300, 500, 750, 1,000, & 1,500 gallons with custom capacities available to fit your needs.

HighDRO® Advanced Water Filtration System (HD-AWFS)

The HD-AWFS is a modular filtration skid system that can be customized to meet specific health codes and standards for filtration and disinfection. The basic system is equipped with multi-media particulate filtration and ultraviolet primary disinfection, which are critical components for the reduction of contaminants and microbiological pathogens that may be present in the water supply. Optional treatment components include chlorine injection for secondary disinfection of stored water and dyeing for proper identification. Additional filtration and treatment options are also available depending on local regulations.

HighDRO® Control System (HD-CS)

The HD-CS is a plc based controller that monitors all aspects of the HighDRO®-Pure system. The HD-CS comes compete with touch screen display to scroll through and supervise water levels in day tank, multimedia back wash function, UV bulb intensity, meter pump on/off function and collection tank/booster pumps programs that is fully integrated to the design conditions of the project with a calendar and real time clock for automatic operations. The HD-CS controller is a "smart" device allowing Building Management System integration as well as the ability to adjust the system parameters as site conditions change. The HD-CS is available in either single phase or three phase voltage.

HighDRO® Booster Pumps (HD-BP)

Highland HD-BP utilizes the latest in pump technology. HD-BP pumps are all constant pressure, variable speed providing continuous water to fixtures under any condition. All pumps are bronze or stainless steel bodies; multistage with external or internal variable speed drives. Pumps are available in simplex duplex or triplex configurations from 1-1,000 gpm at any pressure or voltage. NEMA Enclosures and UL 508A listed.

Highland's HighDRO®-Pure Rainwater Harvesting System's unique design incorporates state-of-the-art components to provide clean sustainable water to promote environmental stewardship. Benefits such as innovative design, measurement and verification, and energy efficient components provide the LEED engineer and owner strategic points toward building qualification.

Highland Redefines Service

Rural, domestic, commercial, and industrial consumers throughout the country are choosing rainwater recycling systems for economic reasons as well as environmental concerns. When relying on rainwater to augment your water supply, the system to collect the rainwater and get it into your new HighDRO®-Pure RHS is a critical part of the overall system.

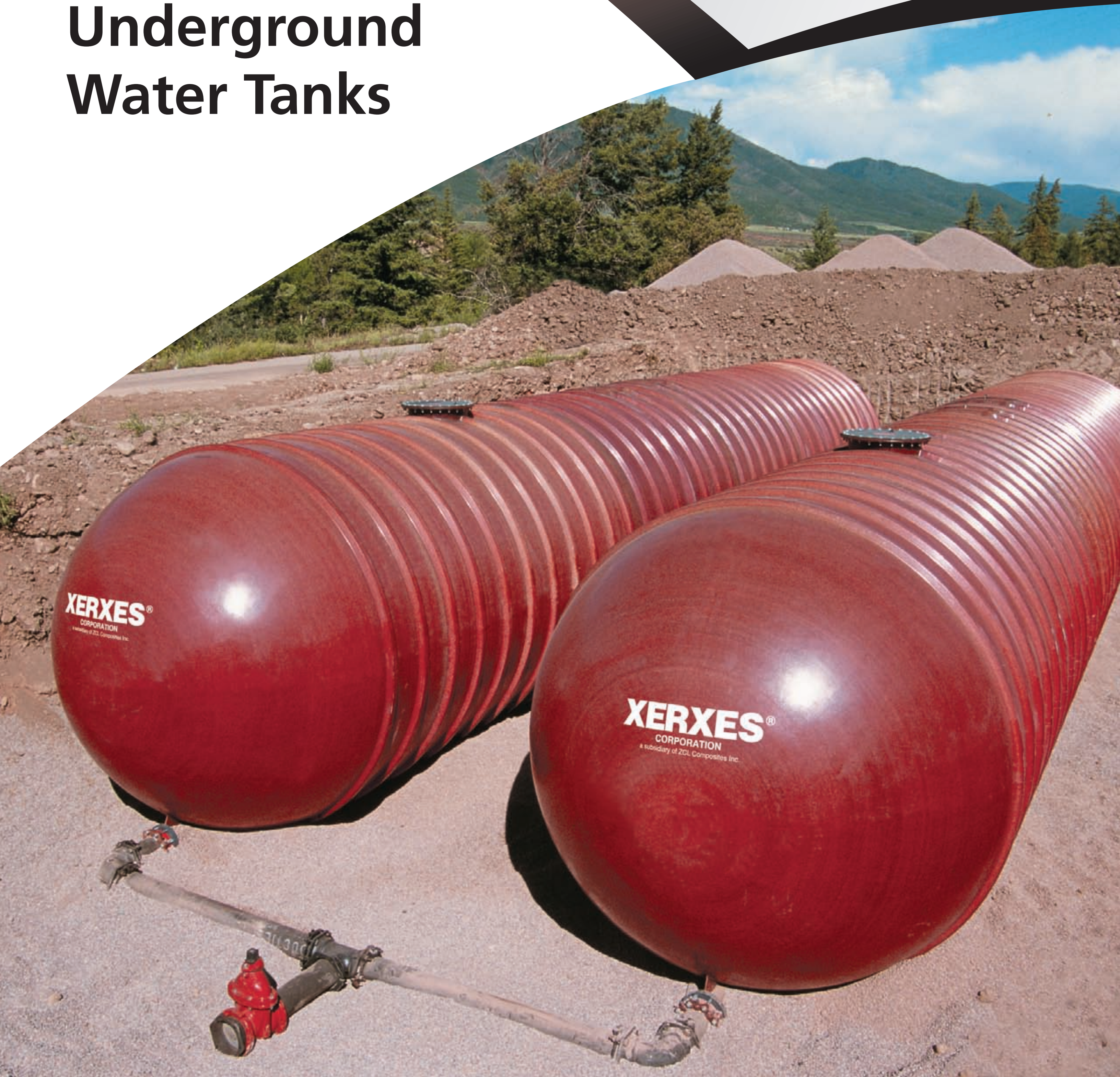
At Highland Tank you will find an experienced staff to assist with the design and sizing of your rainwater collection system. We can prepare drawings and specifications of the HighDRO®-Pure system tailored for your specific application.

One Highland Road Stoystown, PA 15563 814-893-5701 FAX 893-6126	4535 Elizabethtown Road Manheim, PA 17545 717-664-0600 FAX 664-0617	958 19th Street Watervliet, NYE 12189 518-273-0801 FAX 273-1365	2700 Patterson Street Greensboro, NCB 27407 336-218-0801 FAX 218-1292	2225 Chestnut Street Lebanon, PA 17042 717-664-0602 FAX 664-0631	1510 Stoystown Road Friedens, PA 15541 814-443-6800 FAX 444-8662

XERXES®
CORPORATION
a subsidiary of ZCL Composites Inc.

Appendix A.5

Fiberglass Underground Water Tanks



Xerxes® Fiberglass Water Tanks

Fiberglass Tanks for Long-Term Storage of Water

As communities, businesses and industries become increasingly accountable to meet environmental requirements for liquids that require safe, design-proven storage, Xerxes is in the forefront with innovative answers. When considering the options in customized systems to store water, facility designers and owners look for a long-term, structurally strong, watertight and cost-effective option. That is exactly what the Xerxes® fiberglass tank is.

For decades, Xerxes has been well-known as a major tank supplier to the petroleum industry, with more than 100,000 tanks installed. Many of the world's largest oil companies rely on Xerxes to supply environmentally safe underground tanks for storage of gasoline at their retail service stations. Throughout the neighborhoods and communities of America, Xerxes® underground tanks are in place, simultaneously storing products and protecting the environment.

Today Xerxes is taking its place in those same neighborhoods and communities as a major supplier of storage tanks for water — potable water, fire-protection water, irrigation water, gray water, rain water, stormwater and emergency-supply water — as well as other liquids, such as septage, leachate and chemicals. Each time a Xerxes fiberglass underground tank is delivered to a customer, the same performance standard has been met — a vessel for safe underground storage of liquid and careful protection of the environment.

Tanks Designed and Manufactured by a Long-Time Industry Leader

Xerxes is a leader in the design and manufacture of high-quality, cost-effective products that help protect the fragile relationship between humans and their environment. Each Xerxes water tank represents decades of innovation and proven experience developing and fabricating fiberglass storage tanks for underground storage of liquids.

At Xerxes, excellence in service is as highly valued as excellence in product design and manufacturing. Xerxes' strategically located manufacturing facilities in the United States provide customers with prompt, economical delivery and quality service. That gives Xerxes tanks one more advantage — they are readily available to customers wherever they are.

Features of Xerxes Water Tanks

- Constructed of rustproof, long-lasting fiberglass
- Manufactured to meet customers' functional requirements
- Designed for added strength with integral ribs
- Designed for H-20 and HS-20 load conditions
- Easy to ship and install
- Can be purchased with accessories that allow for both preinstallation and postinstallation pressure testing
- Manufactured to applicable requirements of Underwriters Laboratories (UL) 1316
- Manufactured with resin conforming to NSF Standard 61 requirements (potable water tanks)
- NSF listed tanks also available
- Available in sizes from 600 gallons to sizes in excess of 50,000 gallons

Watertight Tanks Featuring the Many Benefits of Fiberglass

A fiberglass water tank, both by virtue of its materials and its design, is inherently the superior choice for safe, long-term storage of water for a wide range of applications. The best storage system for water is structurally strong, corrosion-resistant, watertight, easily installed and cost-effective. All these elements come together in the design and manufacture of a Xerxes fiberglass water tank.

Xerxes uses only high-quality resin and glass in the manufacture of its fiberglass tanks. Integral ribs in the tanks add strength to the structure. Because the integral ribs and tanks are made of the same materials and are manufactured simultaneously, the result is an extremely robust tank.

Another common material used in tanks today is concrete, in either the form of precast concrete or cast-in-place concrete. Precast tanks are heavy, and therefore can be difficult to ship and to install. When larger capacity tanks (approximately 6,000 gallons and greater) are required, precast tanks are generally not available. Therefore, a cast-in-place tank is the only concrete option. Cast-in-place tanks cannot undergo the careful quality-control process that fiberglass tanks manufactured in a factory do. This quality control is key to producing a strong, watertight tank. The installation and proper curing of cast-in-place tanks can be very time-consuming, taking days or weeks, as opposed to the one-day installation typical for a Xerxes fiberglass tank.

Since a Xerxes fiberglass tank is significantly lighter in weight than comparably sized concrete tanks, a fiberglass tank is much easier to ship and install. This is especially important for water applications because many of these tanks are installed in hard-to-access or even remote locations, or are at sites with limited excavation space, and the heavy equipment required to install concrete or steel tanks presents a problem.

Lightweight fiberglass tanks are ideally suited to a variety of water tank projects, whether the site is in a rural community, a remote location or the middle of a city. A few examples of the many recent Xerxes® water tank installations are: potable water in a mountain housing development, emergency drinking supplies in a Florida community and firewater reserves in a U.S. National Forest Service ranger station.

Since water by nature can create a corrosive environment, it is likely that rust can be a major weakness in certain underground water storage systems. Unlike tanks made of other materials, Xerxes® fiberglass tanks are constructed of materials that are inherently rustproof. In contrast, to guard against corrosion or to provide compatibility with the water being stored, tanks constructed of concrete or steel may require internal and external coatings. Of the tank options available for water storage, a fiberglass tank offers the best long-term protection against leakage due to both internal and external corrosion.

Not only is a Xerxes tank rustproof, it is also watertight. Easily equipped for on-site pressure testing before and after installation, Xerxes water tanks give owners the confidence that the tank is watertight from the time it is installed.

Fiberglass Water Tanks for Potable Water Applications

Each Xerxes potable water tank is designed and manufactured to meet a customer's specific requirements. A major benefit of ordering a Xerxes® potable water tank is that it can be manufactured with materials that conform to the requirements of NSF / ANSI 61 — Drinking Water System Components — Health Effects. A Xerxes potable water tank is also available as an NSF-listed and labeled tank.

The National Sanitation Foundation (NSF) is a leading international organization that develops standards, and tests and certifies products in the areas of public health safety and environmental protection. Xerxes potable water tanks are manufactured with a resin that has been approved as conforming to NSF standards for drinking water system components, demonstrating once again that Xerxes is a pioneer in its industry.

The process by which Xerxes manufactures potable water tanks with NSF-listed materials offers a significant advantage over steel and concrete tanks. The Xerxes fiberglass potable water tank is an integral structure incorporating an NSF-listed-resin interior with a polyester-resin-glass exterior. This is the most effective combination for a potable water tank.

Steel and concrete storage systems typically use internal linings to meet industry standards for potable water. In order to be effective, these linings require a degree of adhesion that can be difficult to obtain in the manufacturing process and to maintain over the life of the system. When linings are constructed of materials different from the tank materials, the durability of the end product can be compromised. In short, a Xerxes fiberglass potable water tank offers many advantages over these systems.

Another significant advantage of a Xerxes potable water tank is that because it is lightweight a Xerxes tank can be easily installed in the remote locations that are common to potable water system installations, such as campgrounds, resorts, national parks and private homes.

Fiberglass Water Tanks for Fire-Protection Water Applications

Growing concerns about fire safety and increased use of sprinkler systems in building construction have resulted in a new demand for underground tanks for the storage of fire-protection water. Because of this, residential and commercial building designers need to find safe, reliable and cost-effective systems for the storage of fire-protection water in their projects. Often, new regulatory codes and insurance requirements are calling for stand-alone, standby water supplies. Common examples of fire-protection water applications are schools, housing developments, medical centers, resort properties and casinos.

Xerxes fiberglass water tanks are becoming an especially popular choice for all types of water applications in rural, suburban and urban facilities. Whether the need is as a sole source of water in rural areas or as a standby water reservoir to supplement a pressurized municipal water system, a Xerxes tank provides maintenance-free underground storage of water.

Recent changes in NFPA codes require system design alternatives, such as standby water reservoirs when the existing pressurized water supply is inadequate or when water-pressure levels are not dependable. The 2007 edition of NFPA 1142 Standard on Water Supplies for Suburban and Rural Fire Fighting depicts a fiberglass underground storage tank to illustrate a sole-source water cistern.

A Xerxes underground tank used as a water reservoir has many advantages over an aboveground tank used for the same purpose. For instance, it does not occupy valuable property that could be used for parking or other needs, and it makes the property aesthetically pleasing. Also, since the tank is buried, it does not require the expensive protection against water freezing that might be necessary with an aboveground tank.

A growing trend is to use a water tank as a dual-purpose tank, such as for potable water and fire-protection water. A Xerxes fiberglass tank using NSF-listed resin is ideally suited for such dual-purpose applications.

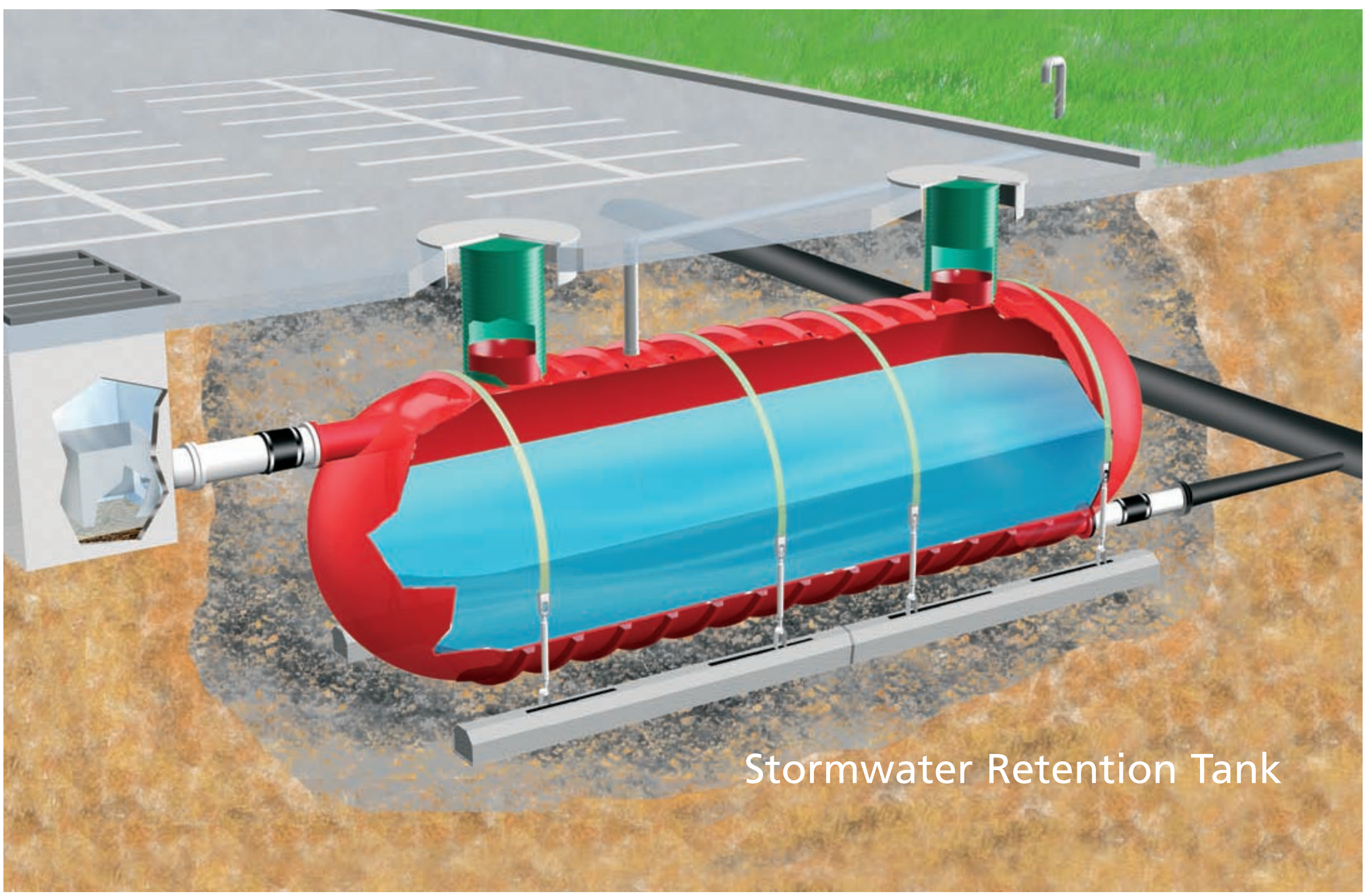
Fire-Protection Water Tank

Fiberglass Water Tanks for Stormwater Retention Applications

Changes in stormwater management are being driven from two directions — environmental concerns and land costs. To address the groundwater contamination or flooding that can occur when stormwater runs directly into sewer systems, new regulations in many communities require a specific retention time before allowing stormwater to run into the drainage system.

Traditionally, a retention pond has been used to meet this requirement. One of the major benefits of using an underground water tank for stormwater retention is that it allows developers and property owners to make better use of the property while simultaneously meeting retention-in-time requirements and protecting the environment. With property values high and parking space limited at many commercial sites, this is a significant advantage to property owners. In addition, a Xerxes tank is available nationwide and in a variety of sizes.

A Xerxes stormwater retention tank has all the usual advantages of an underground fiberglass tank. It is lightweight and, therefore, easy to install. It is watertight and can be purchased to be testable for watertightness. It is corrosion-resistant, thus easy to maintain. It is H-20 and HS-20 axle-load rated, which means it is ideally suited for use beneath parking lots. When a higher level of stormwater treatment is necessary, a Xerxes underground oil/water separator is a superior option. Xerxes has a variety of fiberglass products that meet the ever-changing needs of customers for stormwater retention.



Stormwater Retention Tank

Other Common Applications for a Xerxes Fiberglass Water Tank

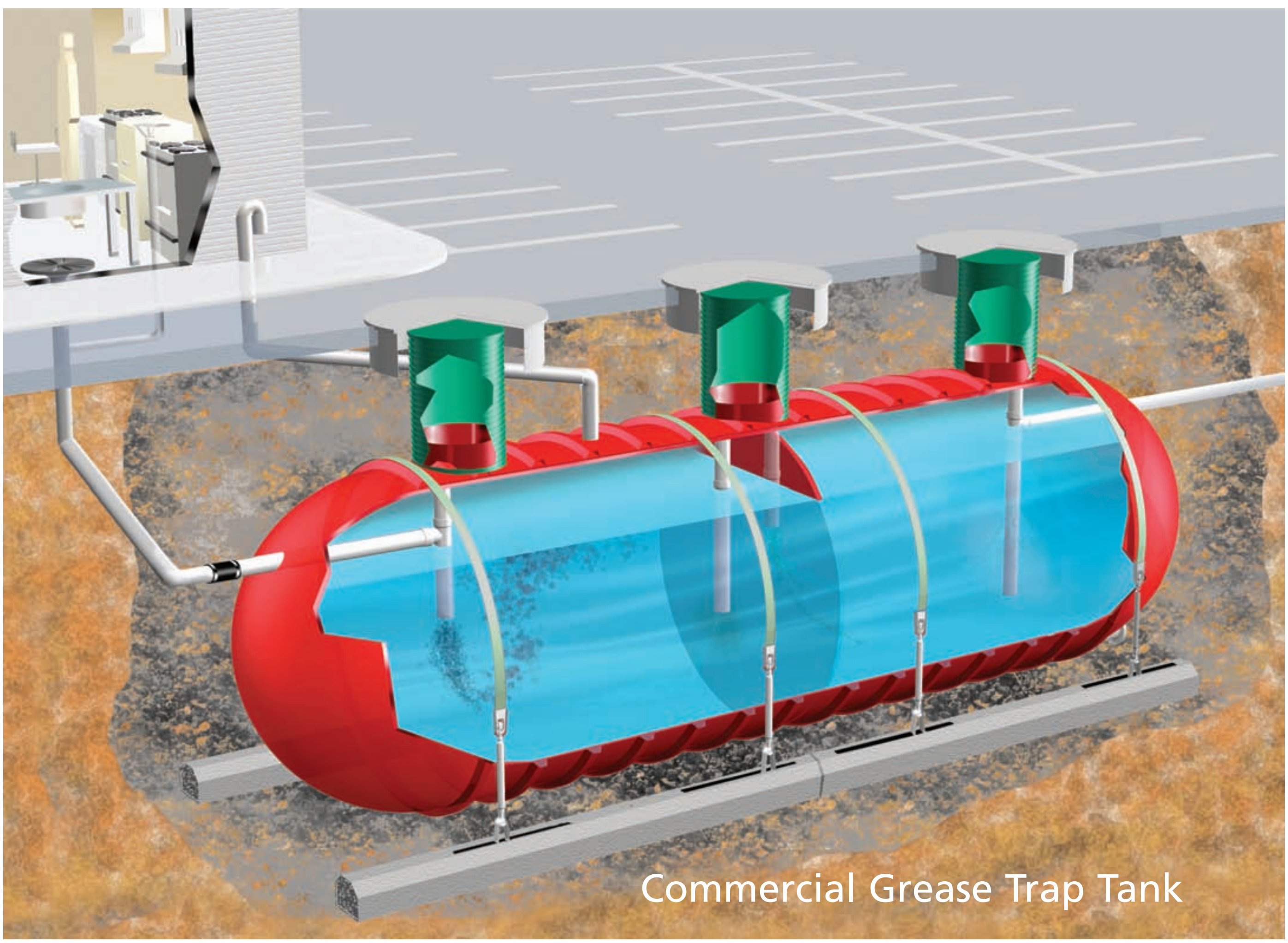
In addition to these uses of a Xerxes water tank — for potable water, fire-protection water and stormwater retention — a fiberglass water tank is a superior choice for numerous other water applications. Examples of the flexibility of Xerxes water tanks is that they can be designed and manufactured for such diverse applications as field-irrigation water, rainwater collection, livestock and wildlife water supplies, emergency water supplies and gray water (for example, residential dish-washing water, laundry water and bath water). Again, whatever a customer's water tank needs, a Xerxes water tank can be designed and manufactured to meet that particular application.

In addition to the specific types of water tanks outlined in this brochure, Xerxes also manufacturers tanks for other water and wastewater applications, oil/water separators with coalescers that can reduce the oil content of stormwater runoff to 10 ppm, grease traps commonly used in commercial kitchen applications and a wide variety of septic tanks that are increasingly popular in on-site wastewater systems. (Contact your Xerxes sales representative to obtain Xerxes sales literature on these specific products.)

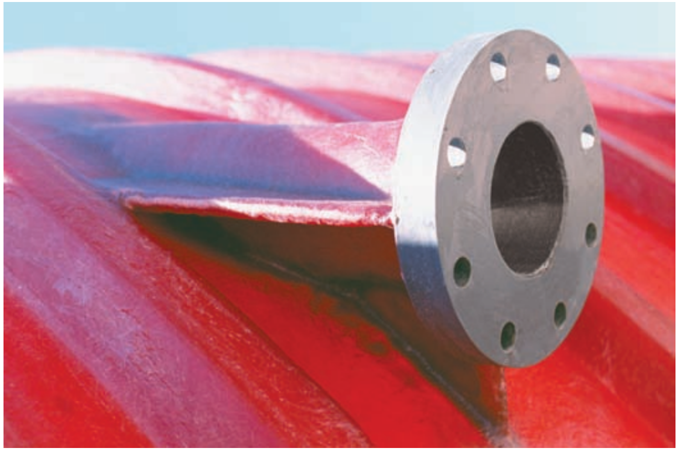
Xerxes has a proven record of innovative design and a quality-driven manufacturing process at its network of plants across the country. This results in a Xerxes tank that is high-quality and competitively priced. A Xerxes water tank has the added benefit that it can be removed, recertified and relocated. These features make a Xerxes tank a cost-effective option with expanded value for an initial investment.

Typical Water Applications

- National and state parks
- Housing developments
- Schools
- Resorts
- Campgrounds
- Emergency water supplies
- Rural properties
- Rest areas
- Truck stops
- Casinos
- Water recirculation systems
- Large private properties
- Livestock feeding operations
- Residential cisterns
- Car washes



Optional Tank Accessories to Fit a Variety of Water Applications



As the demand for Xerxes tanks expands into ever-growing types of water applications, the need for specific accessories to complement these tanks expands as well. A goal at Xerxes has always been to meet the challenge of a constantly changing market by meeting the functional requirements of system designers and owners. Xerxes meets that challenge by developing and manufacturing a wide — and growing — range of water tank accessories such as those listed on this page.

In some cases, Xerxes products that are commonly used in the petroleum industry, such as FRP hold-down straps and prefabricated concrete deadmen, have direct application in water tank system designs. In other cases, Xerxes has designed products specifically for use as water tank accessories, such as baffles/partition walls, access risers, pump platforms and anti-vortex plates (to name just a few). Together, these products provide solutions for the needs of the water storage industry.

One example of a cost-saving innovation introduced by Xerxes is the large-diameter tank bottom sump, which Xerxes designed to eliminate the need and expense of a separate lift station when full use of a tank's capacity is necessary. The Xerxes bottom sump provides that requirement while at the same time eliminating a potential source of leakage in the piping between a lift station and tank.

Whether a customer's particular water storage need is met by the full range of complementary accessories now available, or by a unique solution Xerxes develops for a specific customer requirement, Xerxes works diligently with customers and the industry to continue to offer solutions to a host of water storage needs.

Optional Water Tank Accessories

- FRP manways (22-inch, 30-inch and 36-inch in diameter)
- FRP manway extensions (variable length)
- FRP or PVC drop/fill tubes
- FRP ladders
- Internal pump platforms
- FRP anti-vortex plates
- Flanged FRP nozzles
- Threaded FRP or steel fittings
- Large-diameter bottom sumps
- Internal baffles/Partition walls
- Hinged and lockable lids
- FRP hold-down straps
- Concrete deadmen

Single-Wall Tank Chart

Nominal Capacity (gallons)	Actual Capacity (gallons)	Tank Length	Shipping Weight (pounds)	Number of Hold-Down Straps Required
4-Foot-Diameter Tanks				
600	602	6′-11 7/8″	500	2
1,000	1,009	11′-3 7/8″	700	2
1,500	1,449	16′-0″	1,000	2
6-Foot-Diameter Tanks				
1,500	1,779	10′-7 1/4″	800	2
2,000	2,376	13′-5 3/4″	1,000	2
3,000	2,973	16′-4 1/4″	1,200	2
4,000	4,131	21′-11 1/8″	1,600	2
5,000	5,064	26′-5″	1,900	4
6,000	5,960	30′-8 3/4″	2,200	4
8-Foot-Diameter Tanks				
2,000	2,189	9′-1/2″	900	2
3,000	3,271	12′-3″	1,200	2
4,000	4,218	15′-1/2″	1,400	2
5,000	5,165	17′-8 1/2″	1,700	2
6,000	6,084	20′-6 1/2″	2,000	2
7,000	6,946	23′-1″	2,200	4
8,000	7,950	26′-1/2″	2,500	4
9,000	8,869	28′-9″	2,700	4
10,000	9,816	31′-6 1/2″	3,000	4
11,000	10,763	34′-4″	3,200	4
12,000	11,682	37′-1/2″	3,500	4
13,000	13,081	41′-2″	4,000	6
14,000	14,028	43′-11 1/2″	4,200	6
15,000	14,975	46′-9″	4,500	6
10-Foot-Diameter Tanks				
10,000	10,563	21′-5 1/4″	3,200	4
11,000	11,364	22′-9 3/4″	3,400	4
12,000	12,068	24′-1/4″	3,600	4
13,000	12,966	25′-6 3/4″	3,800	4
14,000	13,767	26′-11 1/4″	4,000	4
15,000	15,248	29′-5 3/4″	4,500	4
20,000	20,055	37′-8 3/4″	5,700	6
22,000	22,580	42′-3/4″	6,600	8
25,000	25,783	47′-6 3/4″	7,900	8
30,000	30,590	55′-9 3/4″	9,400	10
35,000	35,397	64′-3/4″	10,500	12
40,000	41,004	73′-8 1/4″	12,100	14
12-Foot-Diameter Tanks				
20,000	20,781	29′-4″	9,200	6
25,000	25,541	35′-7″	10,600	8
30,000	31,253	43′-1″	12,500	10
35,000	36,013	49′-4″	13,900	12
40,000	39,821	54′-4″	15,000	12
48,000	48,389	65′-7″	17,700	18
50,000	50,293	68′-1″	18,300	18

Guide Specifications – Single and Double Wall Tanks for NSF Listed Potable Water Use

Short Form

The contractor shall provide a single-wall or double wall fiberglass reinforced plastic (FRP) NSF listed potable water tank as shown on the drawings. The tank size, fittings and accessories shall be as shown on the drawings. The fiberglass NSF listed potable water tank shall be manufactured by Xerxes® Corporation.

The NSF listed potable water tank shall be tested and installed according to the Xerxes Installation Manual and Operating Guidelines for Fiberglass Underground Storage Tanks in effect at time of installation.

Long Form

Part I: General

1.01 Quality Assurance

A. Acceptable Manufacturer: Xerxes Corporation

B. Governing Standards, as applicable:

1. Tank manufacturer shall be listed by NSF under NSF/ANSI Standard 61
Drinking Water System Components – Health Effects
2. Tank manufacturer shall be in the business of manufacturing tanks with materials conforming to the requirements of ANSI/AWWA D120-02 Thermosetting Fiberglass-Reinforced Plastic Tanks.
3. Tank manufacturer shall be in the business of manufacturing tanks to UL 1316 standards.
4. American Society for Testing and Materials (ASTM) Standards:
   a. ASTM D883: Standard Terminology Related to Plastics
5. Shop Drawings
   a. The manufacturer shall supply to engineer, contractor, and / or owner, a complete set of scale drawings detailing dimensions of heights, diameter, elevations to invert, pipe sizes and any other necessary details.
6. Calculations
   a. The manufacturer (upon request) shall supply the engineer, contractor, and / or owner buoyancy calculations assuming a fully flooded excavation with an installed empty tank.
   b. The sizing and construction of this tank shall be consistent with industry protocols and shall comply with the applicable regulations.

Part II: Products

2.01 Fiberglass Underground NSF listed potable water storage tanks

A. Loading Conditions – Potable water tank shall meet the following design criteria:

1. Internal Load – All potable tanks shall be testable and shall withstand a 5-psig air-pressure test with 5:1 safety factor. Maximum test pressure is 5 psig.
2. Surface Loads – Potable water tank shall withstand surface H-20 and HS-20 axle loads when properly installed according to manufacturers current Installation Manual and Operating Guidelines.
3. External Hydrostatic Pressure and Burial Depth – tank shall be capable of being buried in ground with 7' of overburden over the top of the tank, the hole fully flooded, and maintain a safety factor of 5:1 against gene ral buckling.
4. Tank shall support accessory equipment – such as manways, manway extensions, collar/ risers, FRP inlet/outlet piping, baffle wall, anti-vortex plates and pump platforms when installed according to tank manufacturers current Installation Manual and Operating Guidelines.
5. Buried tanks shall be manufactured with integral trapezoidal ribs for structural integrity.

B. Product Storage

1. Tank shall be capable of handling liquids with specific gravity up to 1.1.
2. Tank shall be vented to atmospheric pressure.
3. Tank shall be capable of handling Potable water for domestic use at ambient tempature.

C. Materials

1. Tank shall be manufactured with 100% premium resin (Terephthalic polyester or highly cross-linked Isophthalic polyester resins for the exterior and NSF Listed resin for the interior only), and chopped glass. No fillers or extenders will be used.
2. No General, Orthophthalic, or odd lot resin will be used.
3. All associated internal mounting hardware shall be rustproof.
4. Exposed internal FRP components to be constructed using NSF listed materials

D. Potable Water Tank Dimensions and Capability

1. Tank shall have nominal working capacity of _____ gallons.
2. Tank shall have nominal outside diameter of _____ feet.
3. Tank shall weight shall be approximately _____ pounds.

E. Interstitial Space (Double-Wall Applications)

1. Tank shall have a space between the primary and secondary walls to allow for the free flow and containment of leaked product from the primary tank. The space also allows the insertion of a monitoring device through a monitoring fitting.
2. Each interstitial space monitor fitting shall consist of a 4" NPT fitting.

2.02 Accessories

A. Manway Opening

1. All potable water tanks shall require at least one manway opening.
2. All manway openings shall be FRP, flanged, and a minimum of 22" (based on drawing), complete with gaskets, bolts, and covers.
3. Location(s) are shown on submittal drawing.
4. Optional manway extensions shall be FRP and provided by tank manufacturer

B. Internal Piping

1. All internal piping shall meet ANSI/NSF Standard 61
2. Location is shown on submittal drawings.

D. Fittings

1. All FRP nozzles shall be flat-faced, flanged (gusseted when needed), and conform to ANSI B16.5 150# bolting pattern and shall meet ANSI/NSF Standard 61
2. All threaded fittings shall be constructed of FRP, carbon steel or 304 Stainless Steel

E. Lifting Lugs

1. All Tanks shall have lifting lug(s) that are capable of withstanding weight of tank with a safety factor of at least 2:1.

F. Optional Suction/Fill tubes

1. Suction/Fill tubes shall be manufactured with materials listed under ANSI/NSF Standard 61
2. Suction/Fill tubes must be factory installed

3. Suction/Fill tubes shall terminate 4 inches above the bottom of tank

4. Location shall be as shown on submittal drawings.

G. Optional Anchoring

1. Straps shall be FRP anchor straps as supplied by tank manufacturer.

2. Number and location of straps shall be shown on submittal drawings.

3. Deadman shall be pre-manufactured and supplied by the tank manufacturer.

H. Optional Ladders

1. FRP ladders shall be NSF Listed under ANSI/NSF Standard 61 as supplied by tank manufacturer.

I. Optional Pump Platforms

1. FRP pump platforms shall be NSF Listed under ANSI/NSF Standard 61 as supplied by tank manufacturer.

Part III: Testing and Installation

3.01 Testing

A. Tank shall be tested according to the Xerxes Installation Manual and Operating Guidelines for Fiberglass Underground Storage Tanks in effect at time of installation.

3.02 Installation

A. Tank shall be installed according to the Xerxes Installation Manual and Operating Guidelines for Fiberglass Underground Storage Tanks in effect at time of installation.

B. Contractor shall be trained by the tank manufacturer, the state or other approved agency.

3.03 Operation and Maintenance

A. Tank should be set up on a regular clean out schedule and best management practices according to local jurisdictions.

Part IV: Warranty

4.01 Warranty

A. Warranty shall be manufacturer's Limited Warranty for Underground Potable Water Tanks in effect at time of purchase.

Limited Warranty

Underground Water and Potable Water Tanks

Xerxes® Corporation ("Xerxes") warrants to ("Owner") that our underground storage tanks for water other than potable water, if installed, used and maintained in the United States or Canada in accordance with Xerxes' published specifications, installation instructions and operating guidelines, and all applicable laws and regulations, and limited to the storage of water, other than potable water, at temperatures not to exceed 150° F (65° C), will be free from material defects in materials and workmanship for a period of one (1) year from date of original delivery by Xerxes.

Xerxes warrants to Owner that our underground storage tanks for potable water, if installed, used and maintained in the United States or Canada in accordance with Xerxes' published specifications, installation instructions and operating guidelines, and all applicable laws and regulations, and limited to the storage of potable water:

1) Will not fail for a period of thirty (30) years from date of original delivery by Xerxes due to natural external corrosion.
2) Will not fail for a period of thirty (30) years from date of original delivery by Xerxes due to internal corrosion, provided the tank is used solely for potable water, the customer provides Xerxes with written notice of its intended use before the tank is manufactured, and the water is stored at ambient temperatures.
3) Will not fail for a period of thirty (30) years from date of original delivery by Xerxes due to structural failure (defined as spontaneous breaking or collapse caused by material defects in materials or workmanship).
4) Will meet Xerxes' published specifications and will be free from material defects in materials and workmanship for a period of one (1) year following the date of original delivery by Xerxes.

Xerxes warrants to Owner that all Xerxes manufactured accessories for potable water tanks and water tanks other than for potable water, if installed, used and maintained in the United States or Canada in accordance with Xerxes' published specifications, installation instructions and operating guidelines, and all applicable laws and regulations, will be free from material defects in materials and workmanship for a period of one (1) year following the date of original delivery by Xerxes.

If any tank is to be removed from an installation, moved to Owner's new location and is intended for active service at the new location, the tank must be recertified by Xerxes in order to maintain the limited warranty as originally extended. The foregoing limited warranty does not extend to tanks or accessories (individually and collectively "Goods") damaged due to acts of God, war, terrorism, or failure of Goods caused, in whole or in part, by misuse, unlawful use, improper installation, storage, servicing or maintenance, or operation in excess of their rated capacity or contrary to their recommended use, whether intentional or otherwise, or any other cause or damage of any kind not the fault of Xerxes. Xerxes only warrants repairs or alterations performed by Xerxes or its authorized contractors. Xerxes does not warrant any product, components or parts manufactured by others.

Owner's sole and exclusive remedy for breach of warranty is limited at Xerxes' option to: (a) repair of the defective tank or accessory, (b) delivery of a replacement tank or accessory, to the point of original delivery, or (c) refund of the original purchase price. In the event of a breach of warranty claim, a claimant must give Xerxes the opportunity to observe and inspect the installation prior to the removal of any backfill below the tank top, and the removal of the tank and any accessory from the ground, or the claim will be forever barred. All claims must be made in writing within one (1) year after tank and/or accessory failure or be forever barred. THE FOREGOING LIMITED WARRANTY CONSTITUTES XERXES' EXCLUSIVE OBLIGATION AND XERXES MAKES NO OTHER WARRANTY OR REPRESENTATION, EXPRESS OR IMPLIED, WITH RESPECT TO THE GOODS, OR ANY SERVICE, ADVICE, OR CONSULTATION, IF ANY, FURNISHED TO OWNER BY XERXES OR ITS REPRESENTATIVES, WHETHER AS TO MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR OTHERWISE. THE SELLER (XERXES) UNDERTAKES NO RESPONSIBILITY FOR THE QUALITY OF THE GOODS, EXCEPT AS OTHERWISE PROVIDED IN THIS CONTRACT. THE SELLER (XERXES) ASSUMES NO RESPONSIBILITY THAT THE GOODS WILL BE FIT FOR ANY PARTICULAR PURPOSE FOR WHICH YOU (OWNER) MAY BE BUYING THESE GOODS, EXCEPT AS OTHERWISE PROVIDED IN THE CONTRACT. THE REMEDIES SET FORTH IN THE ABOVE WARRANTY ARE THE ONLY REMEDIES AVAILABLE TO ANY PERSON OR ENTITY FOR BREACH OF WARRANTY OR FOR BREACH OF ANY OTHER COVENANT, DUTY, OR OBLIGATION ON THE PART OF XERXES. XERXES SHALL HAVE NO LIABILITY OR OBLIGATION TO ANY PERSON OR ENTITY FOR BREACH OF ANY OTHER COVENANT, DUTY, OR OBLIGATION UNDER THIS LIMITED WARRANTY EXCEPT AS EXPRESSLY SET FORTH HEREIN. IT IS EXPRESSLY AGREED THAT THIS LIMITED WARRANTY DOES NOT FAIL OF ITS ESSENTIAL PURPOSE. XERXES SHALL HAVE NO LIABILITY FOR COSTS OF INSTALLATION OR REMOVAL OF GOODS, ENVIRONMENTAL CONTAMINATION, FIRES, EXPLOSIONS, OR ANY OTHER CONSEQUENCES ALLEGEDLY ATTRIBUTABLE TO A BREACH OF WARRANTY, OR STATUTORY ASSESSMENTS, FINES, PENALTIES, INCIDENTAL, CONSEQUENTIAL, PUNITIVE OR OTHER DAMAGES OF ANY DESCRIPTION, WHETHER ANY SUCH CLAIM OR DAMAGES BE BASED UPON WARRANTY, CONTRACT, NEGLIGENCE, STRICT LIABILITY OR OTHER TORT, OR OTHERWISE. IN NO EVENT SHALL XERXES' TOTAL LIABILITY HEREUNDER EXCEED THE ORIGINAL PURCHASE PRICE OF THE GOODS WHICH GAVE RISE TO SUCH LIABILITY.

Consumer Notice: This warranty gives you (Owner) specific legal rights. You (Owner) may also have other rights which vary from state to state.

Effective 6/15/10

Xerxes® Manufacturing Facilities

Anaheim, CA
Phone 714.630.0012
Fax 714.632.7133

Hagerstown, MD
Phone 301.223.6933
Fax 301.223.6836

Sequin, TX
Phone 830.372.0090
Fax 830.372.0321

Tipton, IA
Phone 563.886.6172
Fax 563.886.2042

ZCL™ Manufacturing Facilities

Edmonton, AB
Phone 800.661.8265
Fax 780.466.6126

Drummondville, QC
Phone 800.661.8265
Fax 780.466.6126

Waverley, NS
Phone 800.661.8265
Fax 780.466.6126

Hagerstown, MD

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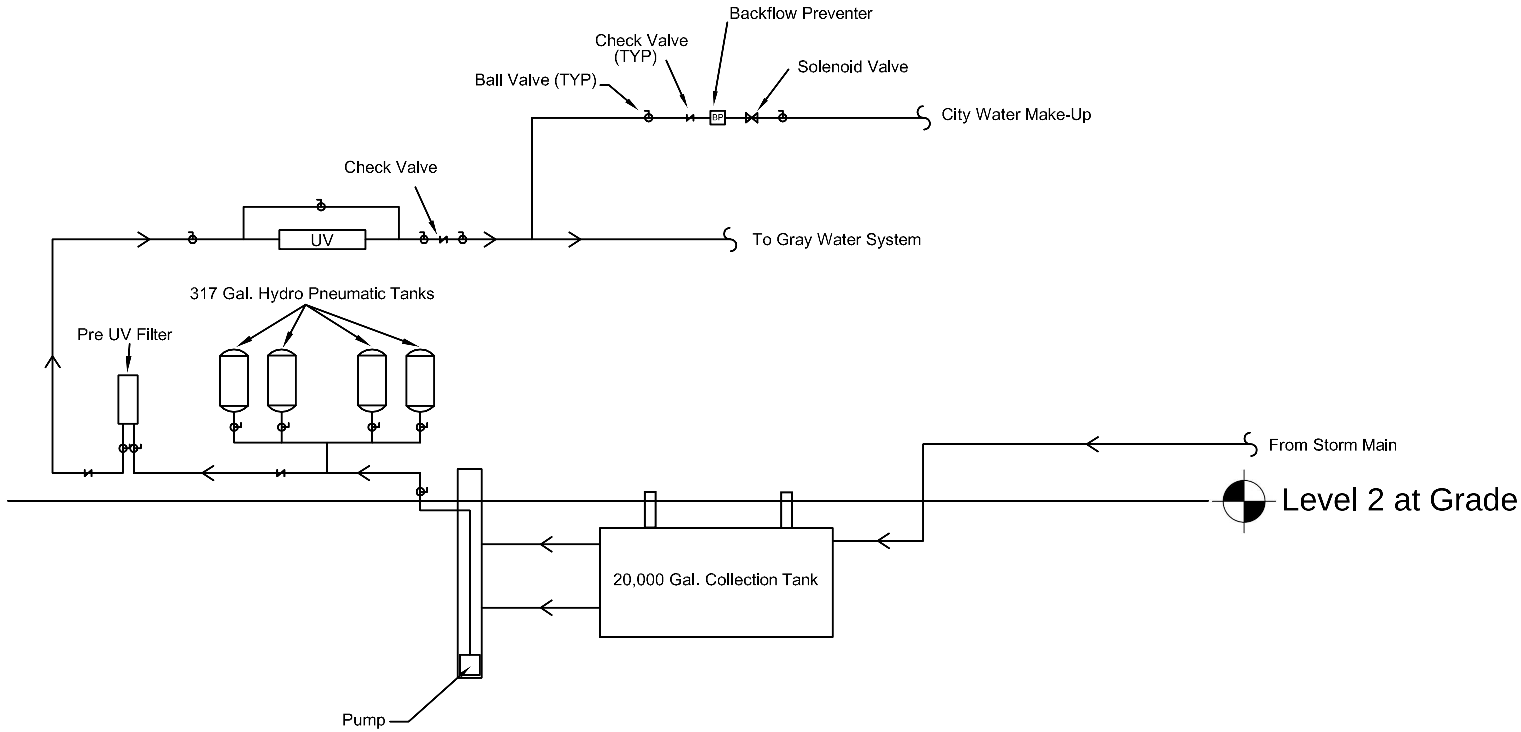
www.xerxes.com

XWT6/10pp

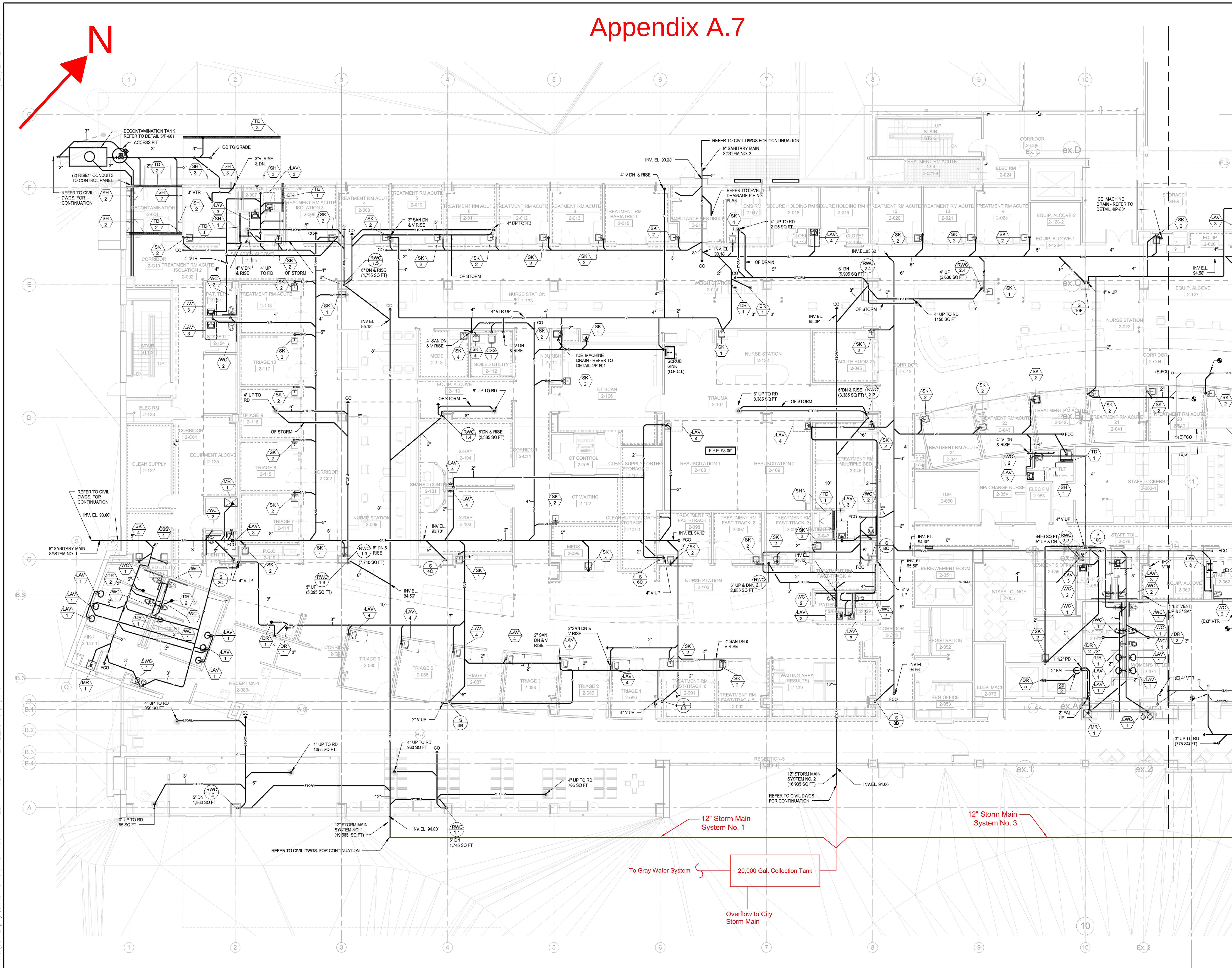
Appendix A.6

Rainwater Collection Schematic

N.T.S.



Appendix A.7



1 LEVEL 2 PLUMBING -DRAINAGE WEST
P-202 W 1/8" = 1'-0"

Revisions

No.	Description	Date

Key Plan

Consultants:

Structural Engineer:
O'Donnell & Naccarato
111 South Independence Mall East
Suite 950
Philadelphia, PA 19106
Phone: (215) 925-3788
Fax: (215) 627-1051
www.o-n.com

M/E/P Engineer:
PWI
327 North 17th Street
Philadelphia, PA 19103
Phone: (215) 241-9100
Fax: (215) 241-9112
www.pwius.com

Civil Engineer:
Barry Isett & Associates, Inc.
Pennsylvania 100
Trexlertown, PA 18087
Phone: (610) 398-0904
http://www.barryisett.com

Construction Manager:
Turner Construction Company
1835 Market Street
21st Floor
Philadelphia, PA 19103
Phone: (215) 496-8800
www.turnerconstruction.com

It is the responsibility of the Construction Manager/General Contractor and all Sub-Contractors to verify all dimensions and accept conditions of prior work by related trades before proceeding with any work.

Date
10/26/12

Drawn By
SAM

Scale
AS NOTED

Seal

Checker WTO

Francis Cauffman

Project Title
Aria Health System - Torresdale Campus

New Emergency Dept & Patient Medical Tower
10800 Knights Road
Philadelphia, Pennsylvania, 19114

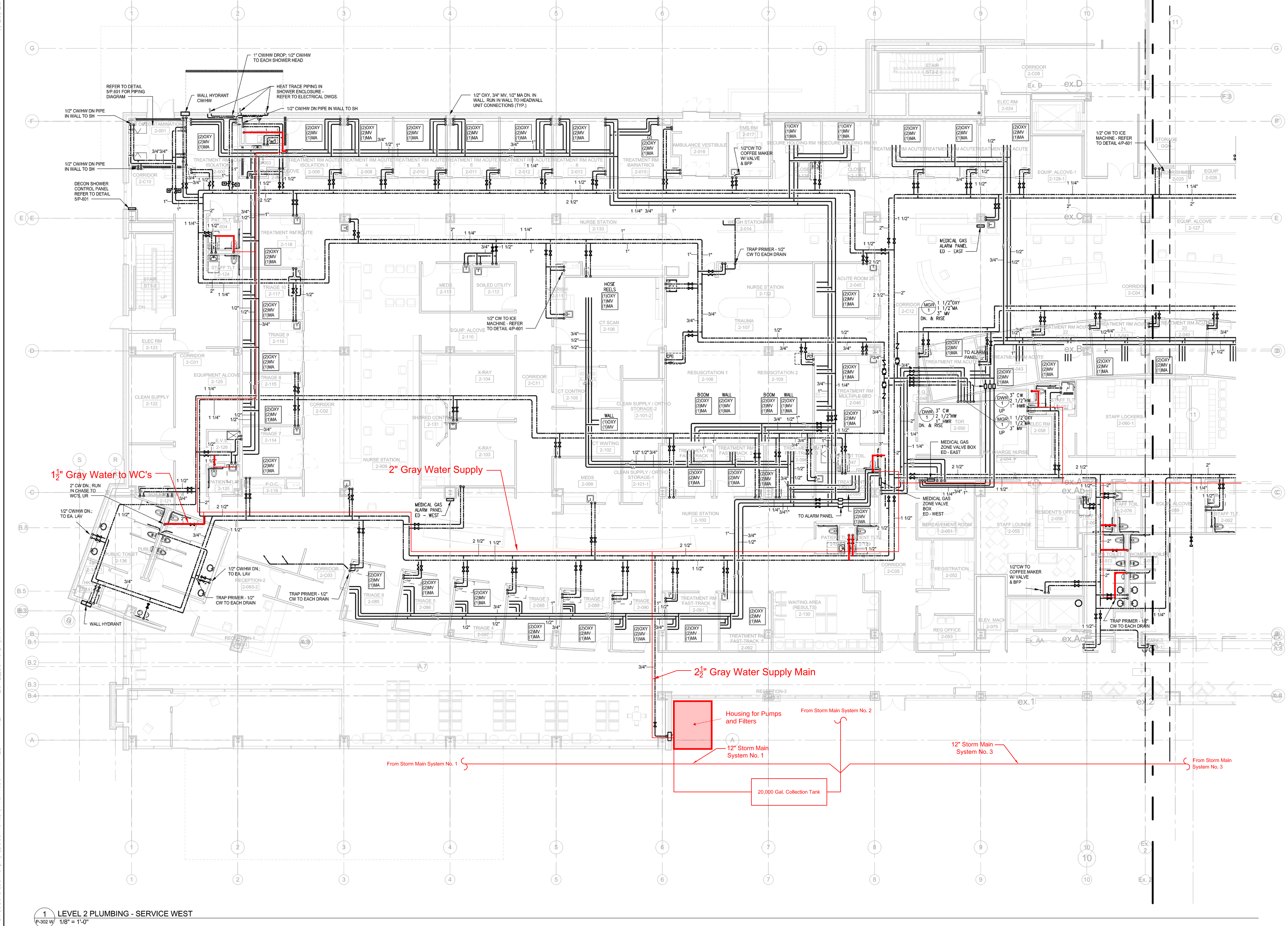
Project Number
F11-5892

Drawing Title and Number
LEVEL 2 DRAINAGE PIPING WEST

P-202 W

CONSTRUCTION DOCUMENT ISSUE - 10/26/12

Appendix A.8



Revisions

No.	Description	Date

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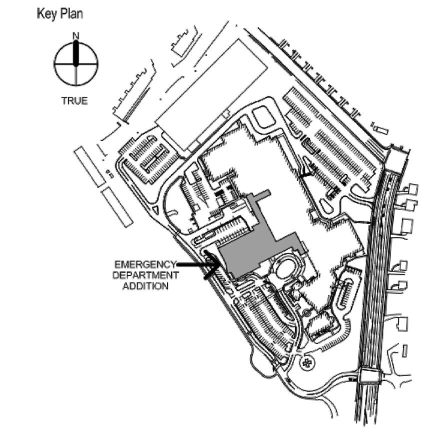

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Fax: (215) 241-9112
www.pwius.com

Civil Engineer:
Barry Isett & Associates, Inc.
Pennsylvania 100
Trexlertown, PA 18087
Phone: (610) 398-0904
http://www.barryisett.com

Construction Manager:
Turner Construction Company
1835 Market Street
21st Floor
Philadelphia, PA 19103
Phone: (215) 496-8800
www.turnerconstruction.com

It is the responsibility of the Construction Manager/General Contractor and all Sub-Contractors to verify all dimensions and accept conditions of prior work by related trades before proceeding with any work.

Date
10/26/12

Drawn By
SAM

Scale
AS NOTED

Seal

Checker WTO

Francis Cauffman

Project Title

Aria Health System - Torresdale Campus

New Emergency Dept & Patient Medical Tower

10800 Knights Road
Philadelphia, Pennsylvania, 19114

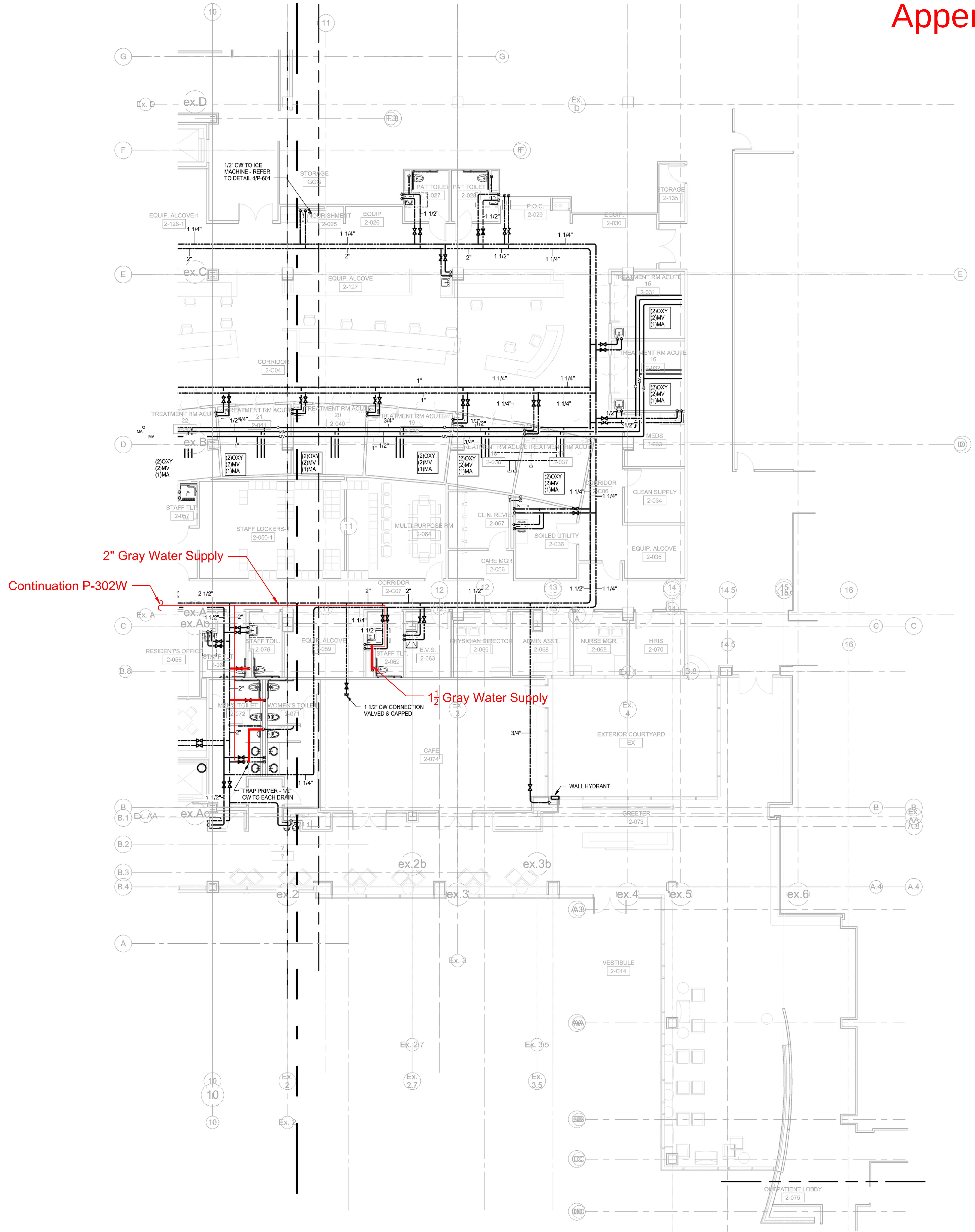
Project Number
F11-5892

Drawing Title and Number
LEVEL 2 SERVICE PIPING WEST

P-302 W

CONSTRUCTION DOCUMENT ISSUE - 10/26/12

Appendix A.8



1 LEVEL 2 PLUMBING - SERVICE EAST
P-302 E 1/8" = 1'-0"

Revisions		
No.	Description	Date

Key Plan

Consultants:

Structural Engineer:
O'Donnell & Naccarato
111 South Independence Mall East
Suite 950
Philadelphia, PA 19106
Phone: (215) 925-3788
Fax: (215) 627-1651
www.o-n.com

M/E/P Engineer:
PWI
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Philadelphia, PA 19103
Phone: (215) 241-9100
Fax: (215) 241-9112
www.pwius.com

Civil Engineer:
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Philadelphia, Pennsylvania, 19114

Project Number
F11-5892

Drawing Title and Number
LEVEL 2 SERVICE PIPING EAST

P-302 E

CONSTRUCTION DOCUMENT ISSUE - 10/26/12

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Designer

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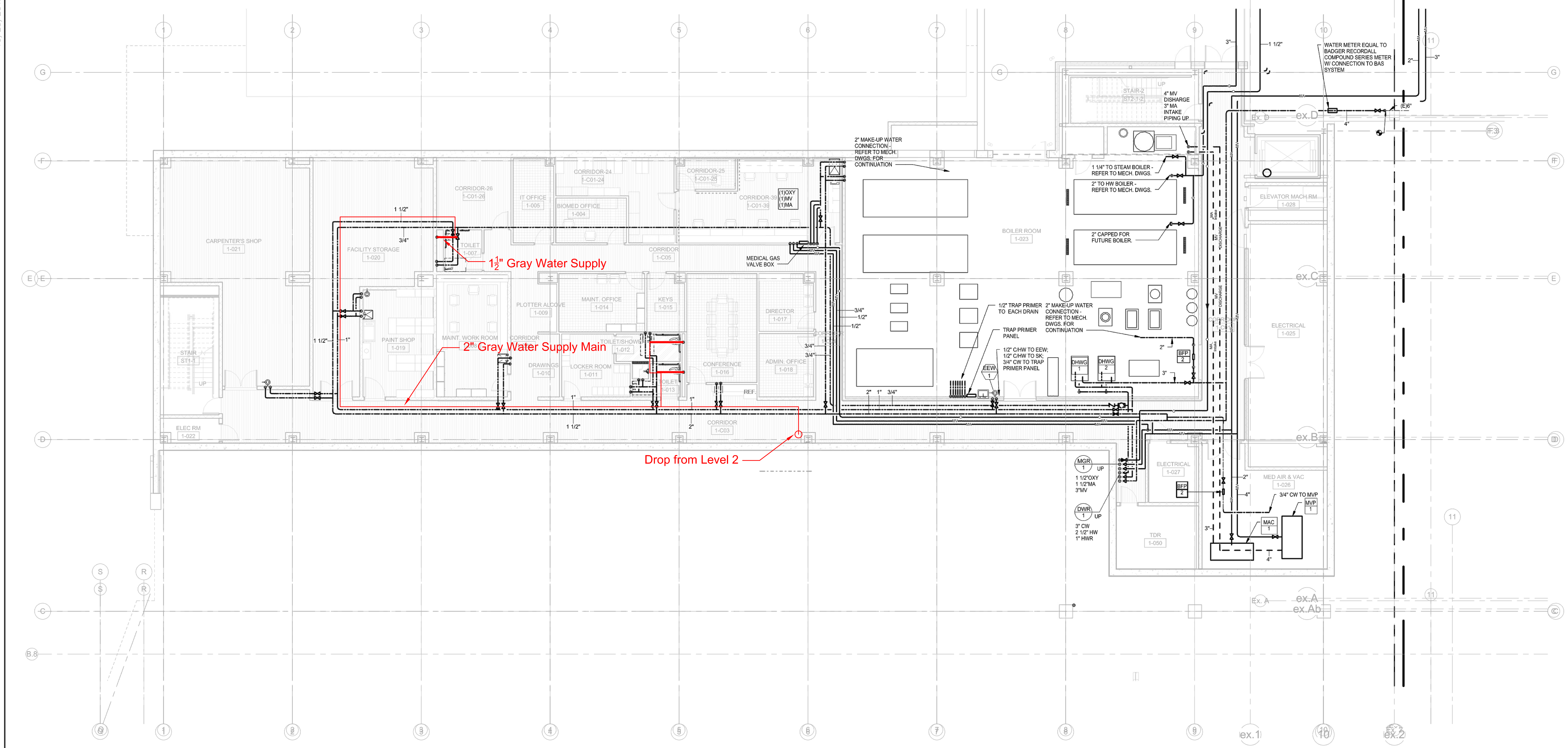
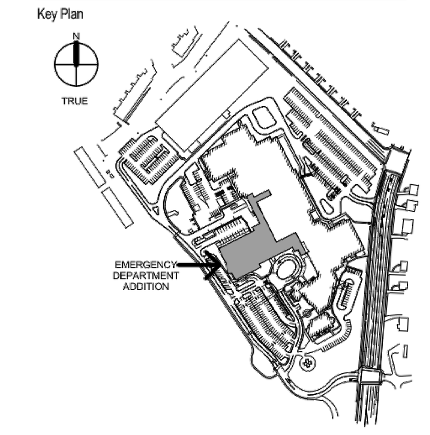
Appendix A.8



Revisions

No.	Description	Date

Key Plan



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Checker WTO

Francis Cauffman

Project Title

Aria Health System - Torresdale Campus

New Emergency Dept & Patient Medical Tower

10800 Knights Road
Philadelphia, Pennsylvania, 19114

Project Number
F11-5892

Drawing Title and Number
LEVEL 1 SERVICE PIPING WEST

P-301 W

1 P-301 W LEVEL 1 PLUMBING - SERVICE WEST
1/8" = 1'-0"

CONSTRUCTION DOCUMENT ISSUE - 10/26/12

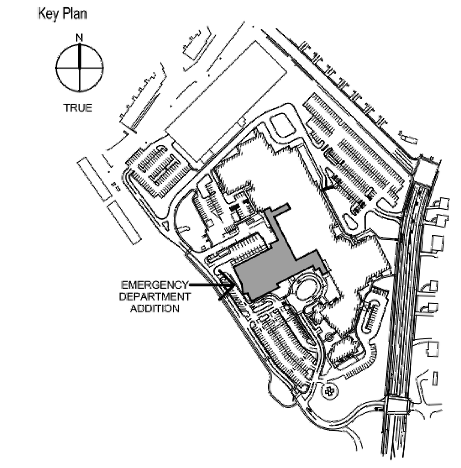
Appendix A.8

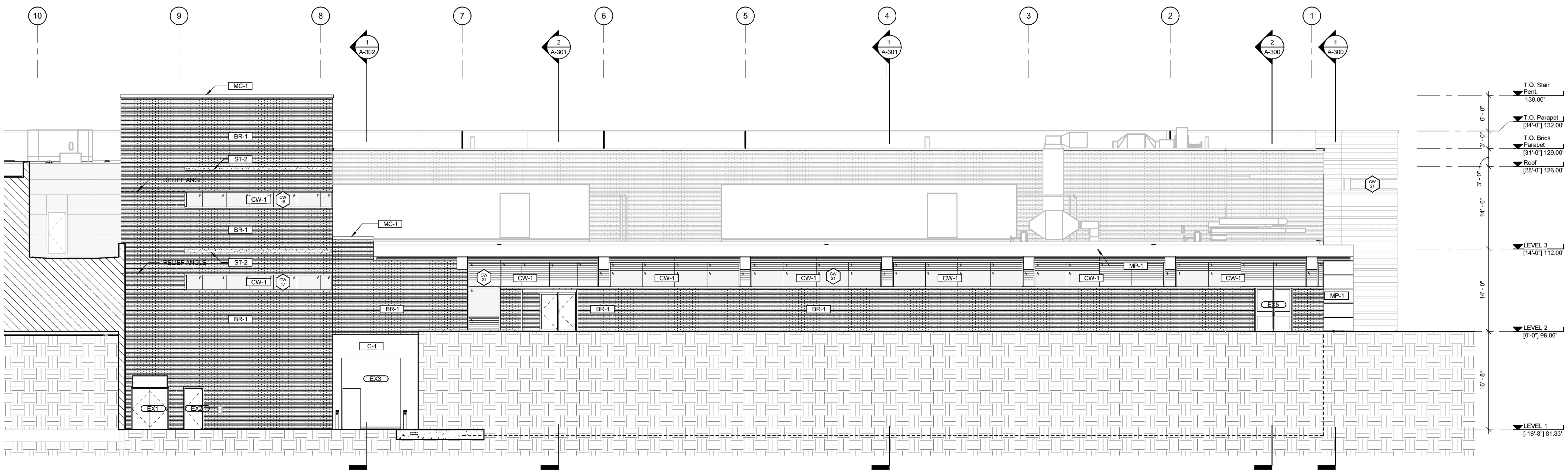
Exterior Material legend	
I.D.	Description
BR-1	BRICK, SEE SPEC'S
C-1	EXPOSED CONCRETE W/ EXT. PAINT FINISH, SEE SPEC'S
CW-1	7 1/2" DEEP ALUM. CURTAIN WALL SYSTEM, SEE SPEC'S
IGU-1	1" INSULATED CLEAR VISION GLASS IN ALUMINUM CURTAIN WALL SYSTEM, SEE SPEC'S FOR ADDITIONAL INFORMATION
IGU-2	1" INSULATED TINTED VISION GLASS IN ALUMINUM CURTAIN WALL SYSTEM, SEE SPEC'S FOR ADDITIONAL INFORMATION
IGU-3	1" INSULATED CLEAR VISION GLASS W/ FRIT & SHADOW BOX ASSEMBLY IN ALUMINUM CURTAIN WALL SYSTEM, SEE SPEC'S FOR ADDITIONAL INFORMATION
IGU-4	1" INSULATED CLEAR VISION GLASS W/ FRIT IN ALUMINUM CURTAIN WALL SYSTEM, SEE SPEC'S FOR ADDITIONAL INFORMATION
IGU-5	1" INSULATED TINTED VISION GLASS W/ FRIT & SHADOW BOX ASSEMBLY IN ALUMINUM CURTAIN WALL SYSTEM, SEE SPEC'S FOR ADDITIONAL INFORMATION
IGU-6	TEMPERED 1" INSULATED CLEAR SPANDREL GLASS IN ALUMINUM CURTAIN WALL SYSTEM, SEE SPEC'S FOR ADDITIONAL INFORMATION
MC-1	METAL COPING, SEE SPEC'S FOR COLOR & FINISH
MP-1	COMPOSITE METAL PANEL, SEE SPEC'S FOR COLOR & FINISH
MP-2	COMPOSITE METAL PANEL, SEE SPEC'S FOR COLOR & FINISH
PWP-1	EXTERIOR PHENOLIC WALL PANEL SYSTEM W/ CONCEALED ALUM SUPPORT SYSTEM. BASIS OF DESIGN: TRESPA
R-1	EPDM ROOFING ON TAPERED RIGID INSULATION (3" MIN) W/ PROTECTION BOARD, SEE SPEC'S
R-2	EPDM ROOFING ON 1/2" RIGID INSULATION, SEE SPEC'S
S-1	DIRECT APPLIED STUCCO FINISH SYSTEM
ST-1	ARRISCRAFT THIN CLAD STONE ON ALUM CLIP SYSTEM, SEE SPEC'S
ST-2	CAST STONE, SEE SPEC'S FOR COLOR & FINISH

Revisions

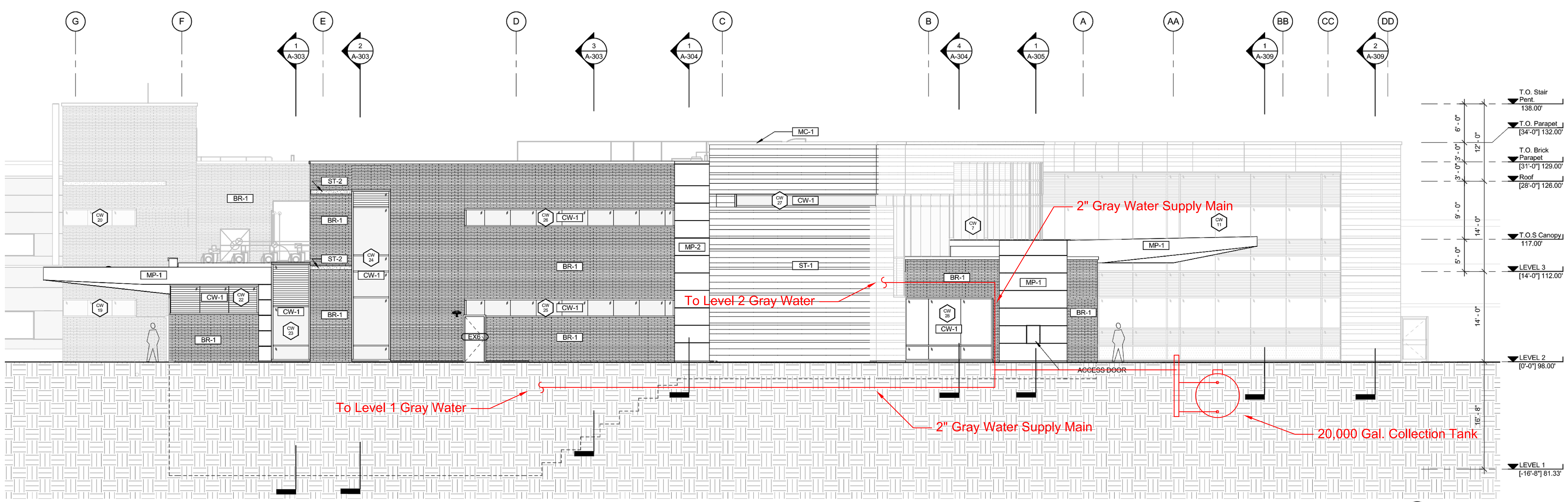
No.	Description	Date

Key Plan





1 A-201 Building Elevation - North
1/8" = 1'-0"



2 A-201 Building Elevation - West
1/8" = 1'-0"

Consultants:

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Suite 950
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Phone: (215) 925-3788
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Drawn By
Author

Scale
1/8" = 1'-0"

Seal

Checker

Francis Cauffman

Project Title
Aria Health System - Torresdale Campus

New Emergency Dept & Patient Medical Tower
10800 Knights Road
Philadelphia, Pennsylvania, 19114

Project Number
F11-5892

Drawing Title and Number
Building Elevations

A-201

CONSTRUCTION DOCUMENTS ISSUE - 10/26/2012

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Designer

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Appendix A.9

SANITRON®

ULTRAVIOLET WATER PURIFIERS

Model S2400C
40 GPM

ATLANTIC ULTRAVIOLET CORPORATION®

ABOUT US

Since 1963, Atlantic Ultraviolet Corporation has pioneered the discovery and development of beneficial uses of ultraviolet energy. Over the years these efforts have led to the development of valuable, cost effective and environmentally sound techniques and products now known and respected throughout the world. Atlantic Ultraviolet's application specialists assist customers in the selection of germicidal lamps and equipment. Their specialized knowledge is a valuable resource in formulating effective and cost-conscious ultraviolet solutions. Extensive inventories and a dedicated staff enable Atlantic Ultraviolet to fulfill its commitment to provide fast deliveries and responsive customer service.

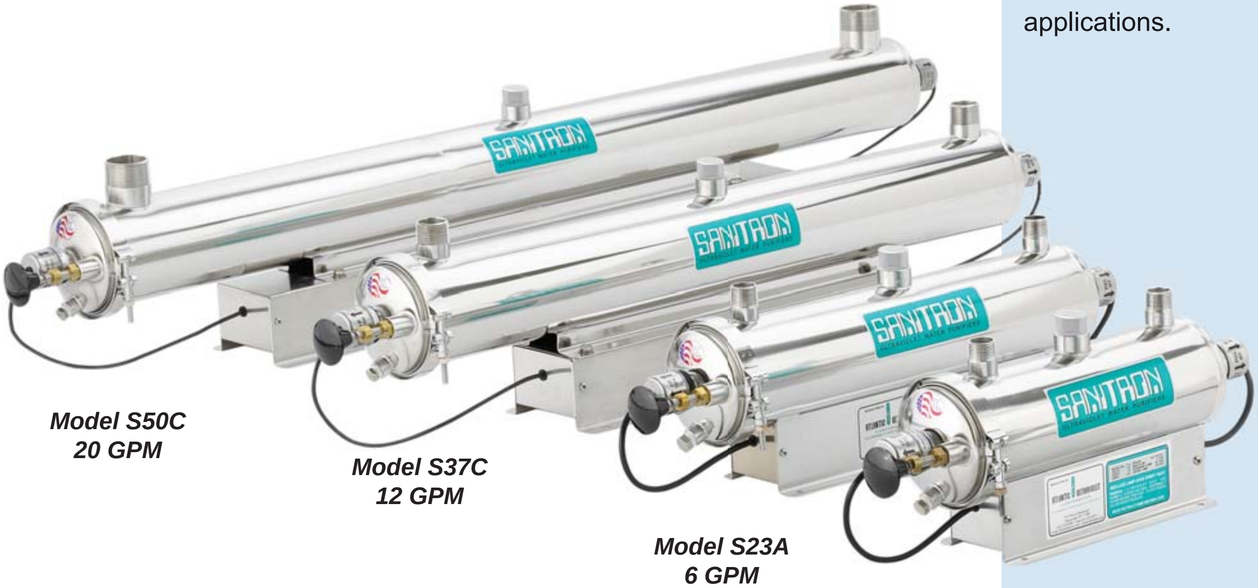
GERMICIDAL ULTRAVIOLET

Ultraviolet water purification is a unique and rapid method of water disinfection without the use of heat or chemicals.

SANITRON® Ultraviolet Purifiers utilize germicidal ultraviolet lamps that produce short wave radiation lethal to bacteria, viruses and other microorganisms present in water.

Through the years ultraviolet technology has become well established as a method of choice for effective and economical water disinfection.

SANITRON® Ultraviolet Water Purifiers are the ideal solution for an ever growing range of water treatment applications.



Model S50C
20 GPM

Model S37C
12 GPM

Model S23A
6 GPM

Model S17A
3 GPM

(For larger flow rates see page 9)

ATLANTIC ULTRAVIOLET CORPORATION®

ADVANTAGES

Effective
Virtually all microorganisms are susceptible to **SANITRON**® ultraviolet disinfection

Economical
Hundreds of gallons are purified for each penny of operating cost

Safe
No danger of overdosing, no addition of chemicals

Fast
Water is ready for use as soon as it leaves the purifier – no further contact time required

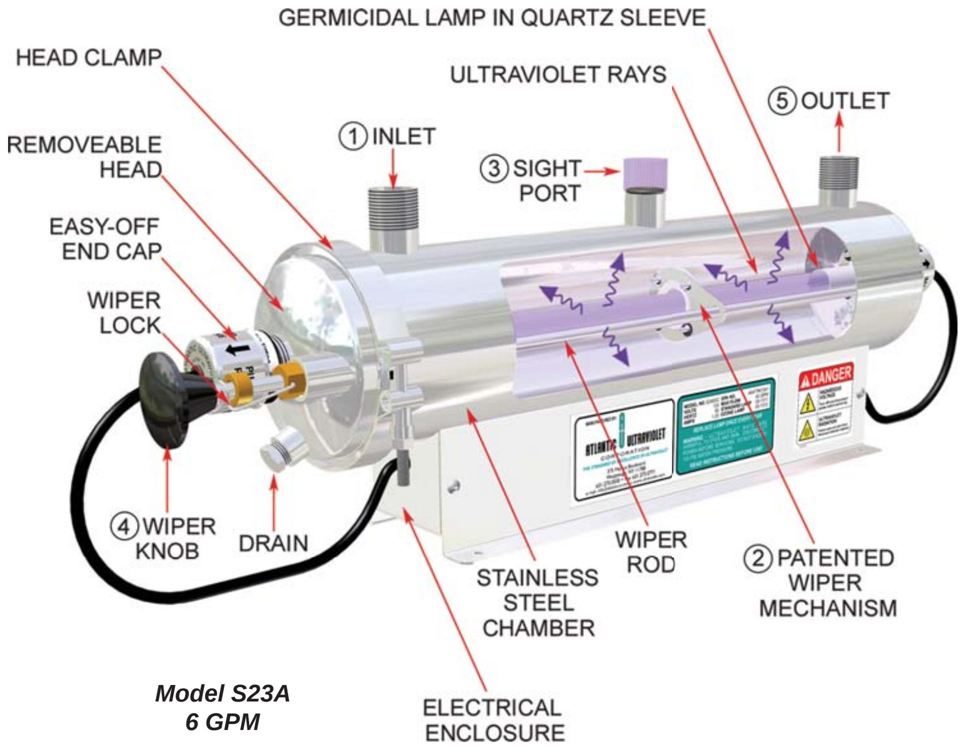
Easy
Simple installation and maintenance
Compact units require minimum space

Automatic
Provides continuous disinfection without special attention or measurement

Chemical Free
No chlorine taste or corrosion problems

Versatile
Capacities available from 3 to 416 gallons per minute (g.p.m.)

PRINCIPLE OF OPERATION



Model S23A
6 GPM

① The water enters the purifier and flows into the annular space between the quartz sleeve and the chamber wall.

② The wiper segments induce turbulence in the flowing liquid to assure uniform exposure of suspended microorganisms to the lethal ultraviolet rays.

③ Translucent sight port provides positive indication of germicidal lamp operation.

④ The wiper assembly facilitates periodic cleaning of the quartz sleeve without any disassembly or interruption of purifier operation.

⑤ Water leaving the purifier is instantly ready for use.

SPECIAL FEATURES

QUICK LAMP CHANGE
Exclusive Easy-Off ™ Retainer Cap enables effortless lamp replacement without shut down of water pressure or drainage of tank. No tools required.

FUSED QUARTZ SLEEVE
Insures optimum lamp output at normal potable water temperatures. (See interior detail page 3.)

REMOVABLE FLANGED HEAD
Units disassemble completely and easily in the event that repairs are necessary. No special tools or fixtures required.
(Models S2400C and larger feature dual removable heads.)

SIGHT PORT PLUG
Visible glow provides positive indication of germicidal lamp operation.

Model S2400C
40 GPM

DRAIN PLUG
Convenient, in-place drainage of purifier chamber.

WIPER LOCK
Locks wiper mechanism in retracted position.

PATENTED DUAL ACTION WIPER MECHANISM
Facilitates periodic cleaning of quartz sleeve without interruption of purifier operation. No disassembly required. Complies with U.S. Public Health Guidelines.

TYPE 316 STAINLESS STEEL CONSTRUCTION
Chamber, head and clamp are electropolished and passivated stainless steel for an attractive finish and dependable service.

INSTALLATION & MAINTENANCE

The purifier is installed horizontally as close as possible to the point of use. Connection of the inlet and outlet to water supply and insertion of power plug into 3-wire GFCI grounded outlet is all that is required.

Ordinary maintenance consists of cleaning the quartz sleeve with the manual wiper once monthly or more frequently where conditions dictate. Lamp replacement is recommended every 10,000 hours of operation (approximately 14 months of continuous service).

OPTIONAL ACCESSORIES

Audio Alarm
Activated by the Sentry™ or Guardian™- alerts user to any malfunction detected

Elapsed Time Indicator
Real-time, non-resettable display of accumulated operating hours

Solenoid Valves
Operates with the Guardian™ or Sentry™ and prevents flow during detected malfunctions. Available in nylon or brass

Time Delay Mechanism
Operates with Guardian™ or Sentry™ and solenoid valve to provide a 2-minute warm-up period for lamp to achieve full germicidal output

Flow Control Valves
Limits water flow to rated capacities. Available in PVC and stainless steel

Wall Mounting Kit
Stainless steel material provides professional finish. Pre-drilled and ready for quick and easy mounting of water purifier. Optimizes free air circulation to cool ballast housing

Quantum Thermal Optimizer
Used to help regulate the water temperature inside the purifier's chamber

MONITORING OPTIONS

Good

The STERALERT™ Lamp Status Alarm monitors visible light emitted through the sight port plug of the water purifier and activates an audible alarm when visible light falls below acceptable levels.

- Easy installation, no tools required
- Mounts on the sight port plug
- Operates on a 9v battery
- Monitors the visible light emitted by the ultraviolet lamp (does not monitor the ultraviolet intensity)
- Warns of lamp or power failure
- Produces a high frequency tone, pulsed at two to three cycles per second
- Available with Remote Sounder
- Available with Dry Contact for Connection to PLC
- Optional 120v 60Hz Power Adapter available
- Available for use with all **MIGHTYPURE**® and **SANITRON**® models

Better

The SENTRY™ Safety Sensor provides constant monitoring of the water purifier's ballast and germicidal lamp operation to give an indication of ballast and germicidal lamp status. The SENTRY™ Safety Sensor is capable of operating an optional audio alarm and/or solenoid valve.

- Easy installation
- Plug SENTRY™ into an electrical outlet, then plug water purifier into SENTRY™
- Operates optional Solenoid Valve and/or Audio Alarm
- Easily adaptable for use with other water purifier brands
- Warns of lamp failure
- Available for 120v 50/60Hz or 220v 50/60Hz water purifiers operating with electronic ballasts
- Available for use with most **Bio-Logic**®, **MINIPURE**®, **MIGHTYPURE**® and **SANITRON**® models

Best

The GUARDIAN™ Ultraviolet Monitor visually indicates the level of germicidal ultraviolet energy that penetrates the quartz sleeve and the water within the disinfection chamber. The GUARDIAN™ Ultraviolet Monitor is capable of operating an optional Audio Alarm and Solenoid Valve. In addition, the GUARDIAN™ Ultraviolet Monitor will detect loss of ultraviolet due to lamp outage, component or power failure. Use of the Ultraviolet Monitor is recommended by the US Public Health Service "Criteria for the Acceptability of an Ultraviolet Disinfection Unit".

The GUARDIAN™ Ultraviolet Monitor will detect reduction of ultraviolet levels due to:

1. Fouling or deposits on quartz sleeve.
2. Poor ultraviolet transmission through the water. (Color, turbidity, organic or other impurities in the water can reduce or interfere with the transmission of ultraviolet rays.)
3. Depreciation of lamp output due to usage or other cause. (Lamp output gradually depreciates with use. Lamp replacement is recommended once each year.)

The GUARDIAN™ Ultraviolet Monitor has three models; Analog, Digital and Digital Remote. Voltage Configurations include 120V 50/60Hz, 220-240V 50/60 Hz, or 12VDC. Contact factory for special requirements. NOTE: GUARDIAN™ Ultraviolet Monitor (analog, digital or digital remote) can be purchased and installed with the water purifier or at a later date for an existing installation.

The GUARDIAN™ Ultraviolet Analog and Digital Monitors are mounted directly onto the water purifier. The sensor probe (included) is threaded into the sight port fitting of the ultraviolet water purifier. The aluminum collar on the bottom of the GUARDIAN™ Ultraviolet Analog or Digital Monitor is secured over the sensor probe.

The GUARDIAN™ Ultraviolet Digital Remote Monitor is intended for use in a location away from the water purifier that is being monitored. In all other respects, the remote GUARDIAN™ behaves the same as the standard GUARDIAN™. Mounted on the back of the remote monitor is a socket into which the lead from an ultraviolet sensor is connected. Instead of being mounted inside the monitor housing, this sensor is contained within the remote probe. A standard length for the connecting cable supplied with the probe is 50 ft., but the lead length may be extended if desired. Please contact the factory for additional lengths.
- Available for use with all **MIGHTYPURE**® and **SANITRON**® models.

Options may be obtained when purchase of **SANITRON**® unit is made or added at a later date. For further details visit our website at **www.ultraviolet.com**.

ULTRAVIOLET DOSAGE

Germicidal lamps provide effective protection against microorganisms. A small cross-section is shown below.

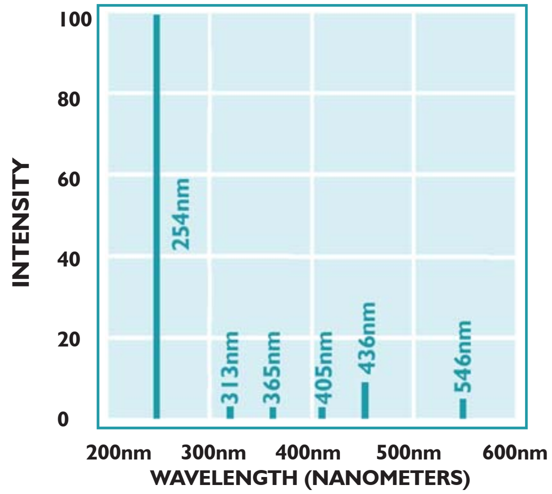
ORGANISM	ALTERNATE NAME	TYPE	DISEASE	DOSE*
Bacillus subtilis spores	*B. subtilis*	Bacteria	————	22,000
Bacteriophage	Phage	Virus	————	6,600
Coxsackie virus	————	Virus	Intestinal infection	6,300
Shigella spores	————	Bacteria	Bacterial Dysentery	4,200
Escherichia coli	*E. coli*	Bacteria	Food poisoning	6,600
Fecal coliform	————	Bacteria	Intestinal infection	6,600
Hepatitis A virus	Infectious Hepatitis virus	Virus	Hepatitis of the liver	8,000
Influenza virus	Flu virus	Virus	Influenza	6,600
Legionella pneumophila	————	Bacteria	Legionnaires' Disease	12,300
Salmonella typhi	————	Bacteria	Typhoid Fever	7,000
Staphylococcus aureus	Staph	Bacteria	Food poisoning, Toxic Shock Syndrome, etc.	6,600
Streptococcus spores	Strep	Bacteria	Strep throat	3,800

When used as directed to disinfect clear water, **SANITRON**® Water Purifiers provide an ultraviolet dosage in excess of 30,000 microwatt seconds per square centimeter (µWSec/cm2).

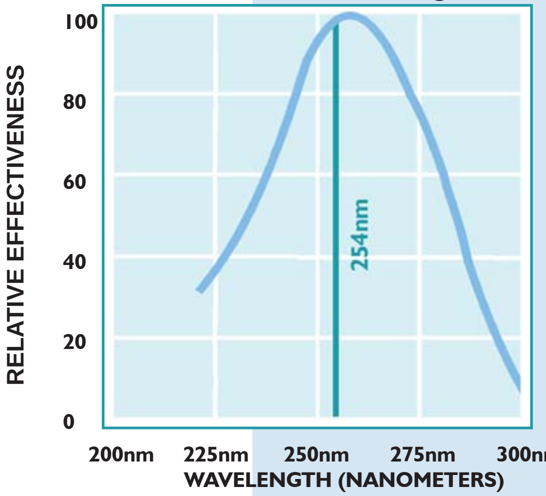
* Nominal Ultraviolet dosage (µWSec/cm2) necessary to inactivate better than 99% of specific microorganism. Consult factory for more complete listing.

OPERATING CHARACTERISTICS

Relative Spectral Energy Distribution (Typical)



Germicidal Effectiveness As Related to Wavelength



Approximately 95% of the ultraviolet energy emitted from **STER-L-RAY**™ germicidal lamps is at the mercury resonance line of 254 nanometers, the region of germicidal effectiveness most destructive to bacteria, mold and virus.

ATLANTIC ULTRAVIOLET CORPORATION®

GENUINE *STER-L-RAY®* GERMICIDAL LAMPS

STER-L-RAY® Germicidal Lamps are shortwave, low pressure mercury vapor discharge tubes that produce ultraviolet wavelengths lethal to microorganisms.

STER-L-RAY® Germicidal Lamps are well suited to applications requiring high ultraviolet intensity such as water sterilization.

STER-L-RAY® Slimline Germicidal Lamps are instant starting and utilize a coil filament on each end which operates hot. Lamp life is governed by the life of the electrodes and is affected by the frequency of starting.

STER-L-RAY® Preheat Germicidal Lamps are operated by a preheat-start circuit that employs a compact and economical ballast. The preheat circuit requires four electrical connections per lamp and a slight to moderate delay is needed to start the lamp.

STER-L-RAY® GX Germicidal Lamps yield 1/3 to 2/3 more ultraviolet output than standard lamps of the same length.

STER-L-RAY® and the ***STER-L-RAY®*** logo are trademarks of Atlantic Ultraviolet Corporation.

CAUTION: Exposure to direct or reflected germicidal ultraviolet rays will cause painful eye irritation and reddening of the skin. Personnel subject to such exposure must wear suitable faceshield, gloves and protective clothing.

Slimline Germicidal Lamps

Preheat Germicidal Lamps

GX Germicidal Lamps

GERMICIDAL LAMP DATA

Lamp Number	Purifier Model No.	Nominal Lamp Length	Power Consumption ①	Ultraviolet Output ②	Rated Effective Life
05-1098-R	S17A	11⅞" (302mm)	14 Watts	4.0 Watts	10,000 Hrs.
05-1097-R	S23A	17¾" (451mm)	21 Watts	7.3 Watts	10,000 Hrs.
05-1343-R	S37C	33⅞" (860mm)	41 Watts	15.0 Watts	10,000 Hrs.
05-1334-R	S50C	45⅞" (1165mm)	55 Watts	21.0 Watts	10,000 Hrs.
05-1311-R ③	S2400C & Larger	46¼" (1175mm)	110 Watts	48.0 Watts	10,000 Hrs.

① Wattage is lamp watts only and does not include ballast loss (approximate).
② Maximum rated output at 254 nanometers.
③ Patented by Atlantic Ultraviolet Corporation®.

The lamps listed above have been especially developed and are recommended for use with **SANITRON®** Water Purifiers.

All ***STER-L-RAY®*** lamps used in **SANITRON®** units are low pressure type which afford the maximum efficiency in producing the required germicidal rays. In addition, has advantage of high efficiency and low power requirements.

STANDARD MODELS

Model S37C
12 GPM

Model	Gallons per Minute	Gallons per Hour	① Inlet and Outlet	Replacement Lamps	② Power Consumption	Unit Dimensions (Inches)			Shipping Data (lbs.)	
						Length	Width	Height	Gross Wt.	Net Wt.
S17A	3	180	3/4" NPT	05-1098-R	18 Watts	19 ⅜	4 5/16	8 3/16	11	8
S23A	6	360	3/4" NPT	05-1097-R	25 Watts	25 ⅜	4 5/16	8 3/16	14	12
*S37C	12	720	1" NPT	05-1343-R	48 Watts	39 ⅜	5 11/16	9 ½	30	25
S50C	20	1,200	1-1/2" NPT	05-1334-R	65 Watts	52 ⅜	5 11/16	9 ½	36	29
*S2400C	40	2,400	2" NPT	05-1311-R	140 Watts	52 ⅜	6 ⅝	11 ½	49	36

① All inlets and outlets are male pipe threads.
② Total power consumption including ballast loss.

- Maximum recommended operating pressure for all purifiers is 100 PSI.
- Pressure drop at maximum recommended flow rate is 5 PSI or less.
- Flow rates are based on Maximum Concentration Levels.
- 120 Volt and 220 Volt units are standard.
- 12 and 24 Volt units are also available.
- SANITRON® is available for operation on public power supplied throughout the world.
- Consult factory with specific power requirements.

*** CE Compliant version available.**

WATER QUALITY RECOMMENDATIONS

Maximum Concentration Levels Before Ultraviolet

Turbidity	*5 NTU*
Suspended Solids	*10 mg/L*
Color	*None*
Iron	*0.3 mg/L*
Manganese	*0.05 mg/L*
pH	*6.5 - 9.5*
Hardness	*6 gpg*

Effectively treating water with higher concentration levels than listed above can be accomplished, but may require added measures to improve water quality to treatable levels.

ATLANTIC ULTRAVIOLET CORPORATION®

COMMERCIAL & INDUSTRIAL

Flexibility

System components are readily reconfigured to meet changing flow and process requirements.

Independent Monitoring

Single lamp chamber design enables separate output monitoring of each ultraviolet lamp.

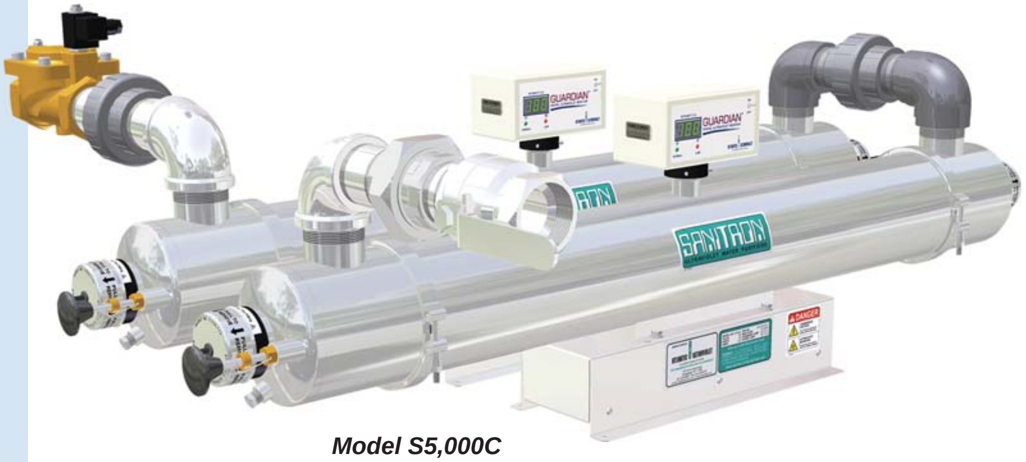
Standby Capacity

Reserve chambers permit shutdown or replacement of individual components without interruption of service.

Special Options

Protective Coating - for seawater & corrosive environments, Sanitary & Custom Fittings - for system compatibility, Special Configurations - for TOC and ozone reduction

(For larger capacities please refer to our **MEGATRON®** Ultraviolet Water Disinfection catalog.)



Model S5,000C
83 GPM

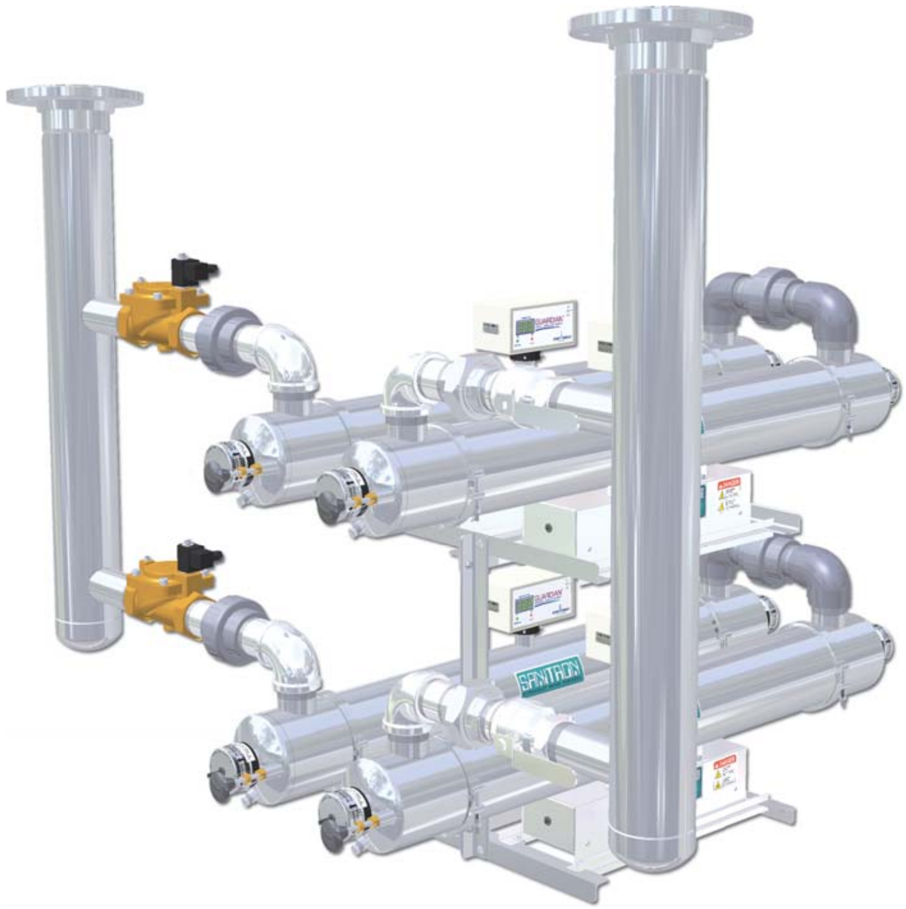
Shown with supplied Interconnect piping, optional Guardian™ Digital Ultraviolet Monitors, Solenoid Valve, Flow Control Valve and customer supplied piping, union and shut-off valve.

Model	Gallons per Minute	Gallons per Hour	⑥ Inlet and Outlet	Replacement Lamps	⑦ Power Consumption	Unit Dimensions (Inches)			Shipping Data (lbs.)	
						Length	Width	Height	Gross Wt.	Net Wt.
*S5,000C ①	83	5,000	2" NPT	05-1311-R (2)	280 Watts	52⅛	17	15	116	85
*S10,000C②	166	10,000	2" NPT	05-1311-R (4)	560 Watts	52⅛	21⅛	34¾	267	188
*S15,000C③	250	15,000	2" NPT	05-1311-R (6)	840 Watts	52⅛	21⅛	53¾	400	263
*S20,000C④	333	20,000	2" NPT	05-1311-R (8)	1120 Watts	52⅛	21⅛	71¾	534	396
*S25,000C⑤	416	25,000	2" NPT	05-1311-R (10)	1400 Watts	52⅛	21⅛	90¾	670	520

① Two S2400C's connected in series, 1 inlet and 1 outlet.
② Two S5,000C's connected in parallel, 2 inlets and 2 outlets.
③ Three S5,000C's connected in parallel, 3 inlets and 3 outlets.
④ Four S5,000C's connected in parallel, 4 inlets and 4 outlets.
⑤ Five S5,000C's connected in parallel, 5 inlets and 5 outlets.
⑥ All inlets and outlets are male pipe threads.
⑦ Total power consumption including ballast loss.

- Maximum recommended operating pressure for all purifiers is 100 PSI.
- Pressure drop at maximum recommended flow rate is less than 5 PSI.
- Flow rates are based on Maximum Concentration Levels, shown on page 8.
- 120 Volt and 220 Volt units are standard.
- **SANITRON®** is available for operation on public power supplied throughout the world.
- Consult factory with specific power requirements.

*** CE Compliant version available.**



Model S10,000C
166 GPM
Shown with supplied Interconnect Piping, optional Guardian™ Digital Ultraviolet Monitors, Solenoid Valves, Flow Control Valves and customer supplied manifolds, piping, unions and shut-off valves.

APPLICATIONS FOR ULTRAVIOLET WATER PURIFIERS

Institution systems...
- laboratories
- hospital
- clinics
- maternity areas
- labor & delivery areas
- pathology labs
- kidney dialysis labs
- nursing homes
- universities
- schools
- veterinary clinics

Transient systems...
- resorts, hotels, & motels
- ships, yachts, boats
- campgrounds
- restaurants
- water parks
- amusement parks
- golf course water holes
- lakes and ponds
- fountain water features
- ornamental ponds
- fish ponds
- swimming pool

Community systems...
- apartment complexes
- condominium complexes
- trailer parks
- rural water
- villages, towns, cities
- farms & ranches
- animal husbandry
- aquariums
- fish farms
- mollusk hatcheries
- water preserves
- well water

Industry systems...
- pharmaceutical mfg.
- electronic production
- cosmetic production
- cooling tower
- power generation
- food industry
- ice makers
- pulp & paper production
- water vending machines
- laundry water
- pure wash water
- bottled water
- beer, wine
- soft drinks
- fruit juices
- bottling facilities
- edible oils
- liquid sugar
- sweeteners
- water based lubricants
- dairy processing
- cistern applications

- TOC Reduction
- Ozone Reduction

ATLANTIC ULTRAVIOLET CORPORATION®

COMPARISON OF ATLANTIC ULTRAVIOLET WATER PURIFIERS

FEATURES [S] - Standard [O] - Optional [X] - Yes	Bio-Logic® Pure Water Pack™ 1.5 GPM	MINIPURE® 1 to 9 GPM	MightyPure® 3 to 20 GPM	SANITRON® 3 to 20 GPM	SANITRON® 40 to 416 GPM	MEGATRON® 90 to 450 GPM
Stainless Steel Construction	S	S	S	S	S	S
Germicidal Ultraviolet Lamp with10,000 Hours Rated Effective Life	S	S	S	S	S	S
Quick Lamp Change with the Easy Off™ Retainer Cap	S	S	S	S	S	S
Fused Quartz Sleeve	S	S	S	S	S	S
Lamp Out Indicator Light(s)	S	S	-	-	-	S
Sight Port to View Lamp Operation	-	-	S	S	S	S
Drain Fitting	-	-	S	S	S	S
Patented Dual Action Wiper Mechanism - Manual	-	-	-	S	S	S
Patented Dual Action Wiper Mechanism - Automatic	-	-	-	-	-	O
Head(s) that can be removed or rotated	S	-	-	S	S	S
Sediment and Carbon Filter	S	-	-	-	-	-
Mounting Kit / Bracket	S	O	O	O	O ①	-
Guardian™ Ultraviolet Monitor	-	-	O	O	O	S
Sentry™ Safety Sensor	O	O	O	O	O	-
Audio Alarm	O	O/S ③	O	O	O	O
Solenoid Valves	-	O	O	O	O	-
Flow Control Valves	-	O	O	O	O	-
Elapsed Time Indicator	O	O	O	O	O	S
Time Delay Mechanism	-	O	O	O	O	-
Residential Use	X	X	X	X	X	-
Commercial Use	-	-	X	X	X	X
CE Certified Models ②	-	-	X	X	X	-

NOTE: This list depicts options for 120v 50/60Hz operation. Consult factory for options with other power requirements

① Model S10,000C & larger come equipped with mounting rack

② MightyPure® MP36C and SANITRON® S37C, S2400C, S5000C, S10,000C, S15,000C and S20,000C are available as CE Certified

③ Standard feature in some MINIPURE® Units

THE STANDARD OF EXCELLENCE IN ULTRAVIOLET

Manufacturers / Engineers / Sales / Service

ATLANTIC ULTRAVIOLET CORPORATION®

375 Marcus Boulevard • Hauppauge, NY 11788 • 631.273.0500 • Fax: 631.273.0771 • E-mail: info@ultraviolet.com • ultraviolet.com

WWW.PHILA.GOV/WATER

Appendix A.10

What Does My Current Water Bill Pay For?

based on a current monthly average bill of $64.24 for 600 cubic feet of water

The average Philadelphia household uses about 600 cubic feet or almost 4500 gallons each month. The monthly bill includes costs for that amount of water usage, the wastewater treatment that keeps the water supply clean, the stormwater management that keeps the streets clear and the rivers healthy, and the billing and collecting done by the Water Revenue Bureau. The average bill comes to about $64.

Your 10 gallons of top quality tap water costs about 14 cents. In comparison, 10 gallons of bottled water (which is likely treated tap water) in that 99-cent, 20-ounce bottle from the local convenience store would cost about $63.

The payment of your monthly water bill allows the Philadelphia Water Department to continue to ensure safe, high quality drinking water while being a responsible steward of the region's waterways – the Delaware and Schuylkill Rivers along with the city's creeks – which are enjoyed by thousands of people every day.

Are assistance programs still available for customers who can't afford to pay their water, sewer and stormwater bills?

Low-income customers in danger of shut-off can still apply to the Water Revenue Bureau for the Water Revenue Assistance Program "WRAP." Eligible customers can receive grants up to $500 to pay water bills and get help in obtaining federal energy assistance.

* Stormwater Management charge includes $1.65 for billing and collecting

** The service charge includes the following: $7.85 for billing and collections of water and wastewater services; $2.75 for metering; $1.80 for sewage infiltration costs; and $0.40 for monitoring and preventing excessive pollution of our sewer system and waterways.

In addition to managing stormwater and treating wastewater, this pays for 150 gallons of high-quality drinking water per day, or:

- 3 showers
- 15 flushes
- 3 gallons drinking water
- 1 dishwasher load
- 10 faucet uses (to shave, wash face, brush teeth)

Information for Homes with Residential Fire Sprinkler Systems

Water service charges for customers with residential fire services are $1.95 higher for all meter sizes although the sewer service charges are the same as a residential customer with a 5/8 inch meter without a fire service. Please see the chart below if you have a residential fire service.

Monthly Service Charges for Customers with Residential Fire Service

Meter Size (Inches)	Meter Code	Monthly Water Charge	Monthly Sewer Charge*	Combined Monthly Charge*
3/4	Z	$ 9.42	$ 6.36	$ 15.78
1	Q	$ 11.92	$ 6.36	$ 18.28
1-1/2	P	$ 17.51	$ 6.36	$ 23.87
2	X	$ 25.01	$ 6.36	$ 31.37

* Does not include Stormwater Charges

Payment and Customer Service Locations

Payments by Mail
Water Revenue Bureau
P.O. Box 41496
Phila., PA 19101-1496

In-Person Authorized Payment Centers*

Center City Philadelphia
Municipal Services Building
1401 John F. Kennedy Blvd.
Concourse Level
Office Hours: Monday through Friday, 8:00 a.m. to 5:00 p.m.

*The Water Revenue Bureau is not responsible for payments made at any locations other than the authorized payment locations. Other authorized locations can be found at http://www.phila.gov/waterrev/Payment_Centers.html.

Important information

For more information about your water, sewer and stormwater bill and payment assistance programs, call the Water Revenue Bureau, Monday through Friday, 8:00 a.m. to 5:00 p.m.: 215-686-6880.

To order a copy of "Know Your Rights as a Residential Water and Sewer Customer," please call 215-686-6880. All residential properties must have an automatic meter reading device. If an automatic meter reading device has not been installed in your home, please call: 215-685-6300.

More information about the Department's rates process, as well as other Water Department projects, can be found on our websites at www.phillywatersheds.org or www.phila.gov/water.

Questions and Answers

about your new Water, Sewer and Stormwater Charges

Effective July 1, 2013

Para recibir una copia de este folleto en español llame al 215-685-6300.

Beginning July 1, 2013, your water, sewer and stormwater bill will reflect new rates for water and wastewater services for the period of July 1, 2013 to June 30, 2014.

These new rates are the second of a three-phase change to rates to be spread over a two-and-a-half-year period.

During the second phase, a typical residential customer's monthly bill will increase to $64.24, an increase of $3.50. A typical residential customer uses 600 cubic feet of water monthly and has a 5/8" meter.

For water and sewer emergencies, call 24 hours a day: 215-685-6300.

For billing questions and payment assistance programs, call Monday through Friday, 8:00 a.m. to 5 p.m.: 215-686-6880

What's in my bill?

Your bill consists of three parts: a **usage charge** for treatment and delivery of drinking water, the collection and treatment of sewage and related environmental services; a **service charge** for costs associated with metering, billing and collection operations; and a **stormwater charge** for the costs of collection and treatment of all rain water in the City that drains to our waterways or to our sewer collection system.

Most customers, including households and small businesses, have a 5/8-inch meter.

Wastewater Surcharges

Biochemical Oxygen Demand = $0.327 per pound of Biochemical Oxygen Demand in excess of 250 mg/l

Suspended Solids = $0.310 per pound of suspended solids in excess of 350 mg/l

1 Mcf = 1,000 cubic feet = 7,480 gallons

mg/l = milligrams per liter

Monthly Service Charges

Meter Size (Inches)	Meter Code	Monthly Water Charge	Monthly Sewer Charge*	Combined Monthly Charge*
5/8	R	$ 6.44	$ 6.36	$ 12.80
3/4	Z	$ 7.47	$ 7.81	$ 15.28
1	Q	$ 9.97	$ 11.05	$ 21.02
1-1/2	P	$ 15.56	$ 18.63	$ 34.19
2	X	$ 23.06	$ 28.35	$ 51.41
3	O	$ 39.69	$ 50.34	$ 90.03
4	W	$ 69.05	$ 86.21	$ 155.26
6	N	$133.73	$ 168.95	$ 302.68
8	V	$208.72	$ 266.14	$ 474.86
10	E	$302.78	$ 384.75	$ 687.53
12	T	$530.87	$ 691.38	$1,222.25

*Does not include Stormwater Charges.

HOSPITAL ?

Typical Residential Customer Monthly Billings

Period	Percentage Increase of Monthly Bill	Additional Monthly Water & Sewer Charge	Total Monthly Bill
First Phase: 1/1/13 to 6/30/13	5.8	$3.31	$60.74
Second Phase: 7/1/13 to 6/30/14	5.8	$3.50	$64.24
Third Phase: 7/1/14 to 6/30/15	5.0	$3.19	$67.43

Are discounts still available?

Yes. Qualifying seniors, 65 years of age or older, can receive a 25 percent discount. The income test to qualify for this discount is now $31,500 annually. The same discount applies to charities, churches, non-profit hospitals, schools and universities.

Sample of Current Typical Monthly Bill for Homeowners

Usage Charge + Service Charge + Stormwater Charge = Monthly Bill

If a customer uses 600 cubic feet (cf) or 4,488 gallons of water as measured by the meter, the usage charge would equal:

Water Usage:
600 cf x $37.12/1000 cf = $22.27 ?

? **Wastewater Usage:**
600 cf x $26.19/1000 cf = $15.72

Total Usage Charge: $37.99

The Service Charge for a 5/8-inch meter: $12.80 474.86

(See table to the left for allocation between water and sewer charges.)

Monthly Stormwater Charge: $13.45 ?

Total Monthly Bill:
$37.99 + $12.80 + $13.45 = $ 64.24

(Includes Usage, Service and Stormwater Charges)

Quantity Charges

Monthly Water Usage	Water Usage Charge per Mcf	Monthly Water Usage	Wastewater Usage Charge per Mcf
First 2 Mcf	$37.12	All billable water usage	$26.19
Next 98 Mcf	$30.20		
Next 1,900 Mcf	$27.56		
Next 2,000 Mcf	$20.93		

Why the change in rates?

New rates are required so that the Department can pay for all costs associated with operating a safe, reliable and economic water and wastewater system. Some of the key costs are associated with:

- Environmental regulatory requirements
- Increased costs of materials, services, supplies, chemicals and energy
- Increase in costs associated with employee pensions
- Higher costs associated with funding our capital program to repair/replace infrastructure
- Assistance Programs
- General Inflation and New Programs

Under the Philadelphia City Charter and various bond covenants with investors, the Water Department is not allowed to operate with a deficit. Our rates and revenues must be sufficient to enable us to meet all of our financial requirements. Without these new rates, we would be unable to meet our legal requirements.

Information about the stormwater fee for non-residential customers

As a result of the FY13-FY15 Rates Settlement, two programs under the Department's parcel based stormwater fee have been revised.

- Stormwater Fee Credit Program
- Stormwater Fee Customer Assistance Program

For more information on these two programs, please go to: http://www.phila.gov/water/Stormwater_Billing.html

Philadelphia PWD Water Department

34 3 w/c Eviends 25 40,000

What has the Department done to improve service and minimize costs?

The Department is currently undertaking a number of initiatives to reduce the costs to operate the utility while also improving efficiency and service. These projects include:

- Constructing an electric solar panel at the Southwest Water Pollution Control Plant and a biogas cogeneration facility at the Northwest Water Pollution Control Plant. The energy generated by these two projects alone will provide significant savings while reducing our impact on the environment.
- Bringing the City into compliance with the federal Clean Water Act through the *Green City, Clean Waters* plan. This green approach to managing stormwater will provide enormous long-term savings to our rate payers while also adding additional value to our neighborhoods.
- Improving operating efficiencies at each of PWD's seven major plants and facilities.
- Continuing to investigate and recover unpaid revenues, identifying additional billings of more than $25.4 million to date.
- Refinancing debt and upgrading the Water Department's bond credit ratings, saving over $100 million since 1993.
- Investing in a new cloud platform for the customer service call center to reduce delays and streamline requests.

Are discounts still available?

Yes. Qualifying seniors, 65 years of age or older, can receive a 25 percent discount. The income test to qualify for this discount is now $31,500.00 annually. The same discount applies to charities, churches, non-profit hospitals, schools and universities.

Are assistance programs still available for customers who can't afford to pay their water, sewer and stormwater bills?

Low-income customers in danger of shut-off can still apply to the Water Revenue Bureau for the Water Revenue Assistance Program "WRAP." Eligible customers can receive grants up to $500 to pay water bills and get help in obtaining federal energy assistance.

How are water and sewer rates set?

The process for setting rates involves a comprehensive hearing process during which all rate payers and other vested parties have the opportunity to participate and provide perspective and meaningful input into the final rate determination.

Community Legal Services – the public advocate appointed to represent residential customers – together with Citizens for Pennsylvania's Future, the Philadelphia Large Users Group, the Direct Dischargers Group, and Exelon, presented hundreds of hours of testimony and interrogations during the rate hearing process. A proposed settlement among these parties was then brought to an independent hearing officer. The hearing officer reviewed all of the information and provided a report to the Water Commissioner largely agreeing with the settlement among parties. The Water Commissioner then endorsed and confirmed the hearing officer's report on the rate agreement, settling the final rates on December 12, 2012.

Payment and Customer Service Locations

Payments by Mail
Water Revenue Bureau
P.O. Box 41496
Phila., PA 19101-1496

In-Person Authorized Payment Centers*

Center City Philadelphia
Municipal Services Building
1401 John F. Kennedy Blvd.
Concourse Level
Office Hours: Monday through Friday, 8:00 a.m. to 5:00 p.m.

For a current list of all In-Person Authorized Payment Centers, please call 215-686-6880.

*The Water Revenue Bureau is not responsible for payments made at any location other than the authorized payment locations listed above.

For more information

For more information about your water, sewer and stormwater bill and payment assistance programs, call the Water Revenue Bureau, Monday through Friday, 8:00 a.m. to 5:00 p.m.: 215-686-6880.

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Questions and Answers

about your new Water, Sewer and Stormwater Charges

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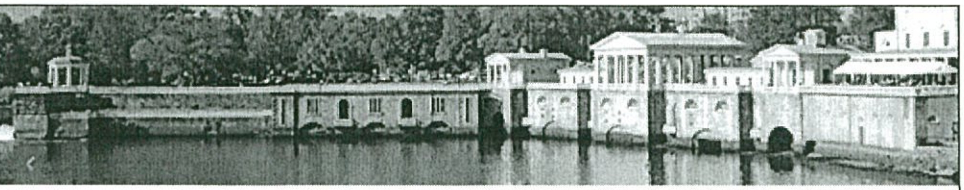
Beginning January 1, 2013, your water, sewer and stormwater bill will reflect new rates for water and wastewater services for the period of January 1, 2013 to June 30, 2013.

These new rates are the first of a three-phase change to rates to be spread over a two-and-a-half-year period.

During the first phase, a typical residential customer's monthly bill will increase to $60.74, an increase of $3.31. A typical residential customer uses 600 cubic feet of water monthly and has a 5/8-inch meter.

For water and sewer emergencies, call 24 hours a day: 215-685-6300.



HOME | RESIDENTS | BUSINESS | VISITORS | TERMS OF USE

Philadelphia Water Department

- Our Mission
- PWD Regulations
- Information, Phone Numbers and Contacts
- Investor Relations
- How To Do Business With Us
  - Service, Supplies & Equipment
  - Public Works
- PWD Newsroom
  - Drinking Water Quality
  - Literature and Brochures
  - Press Release Archives
- Water Bill Information
- Stormwater Billing Information
- Your Plumbing; Your Responsibilities
- Urban Water Cycle
- Our Commitment to Drinking Water Quality
- Facts About Your Water
  - Q&A on Pharmaceuticals in Drinking Water
- Our Commitment to Protecting Our Water Resources
- The Bureau of Laboratory Services
  - Cross Connection Control Program
- Industrial Waste Unit
- PWD Historical Collection Online Catalogue

Stormwater Billing

What is stormwater management? ▶ | Why am I being billed? ▶

How are charges calculated? ▶ | Where can I find more information? ▶

How are charges calculated?

PWD will now relate a property's burden on the sewer system directly to its stormwater charge by using the property's individual characteristics as the basis for this fee. We do this by using Geographic Information Systems technology, or high-tech mapping software, to measure a property's gross area and impervious area. Impervious area is classified as any surface that prevents water from soaking into the ground. Once we know a property's gross and impervious area, we use this formula to calculate the stormwater charge:

Stormwater Charge = (Gross Area Rate * Gross Area of Property) + (Impervious Area Rate * Impervious Area of Property)

To lessen the burden on customers who will see an increase in their bill, we are phasing in the new charge over a period of four years. The breakdown for each phase-in year is as follows:

Year	Existing Meter-based Charge	New Parcel-based Charge
7/1/10 to 6/30/11	75%	25%
7/1/11 to 6/30/12	50%	50%
7/1/12 to 6/30/13	25%	75%
7/1/13 to 6/30/14	0%	100%

Browse Properties

Need to speak to someone? ▶

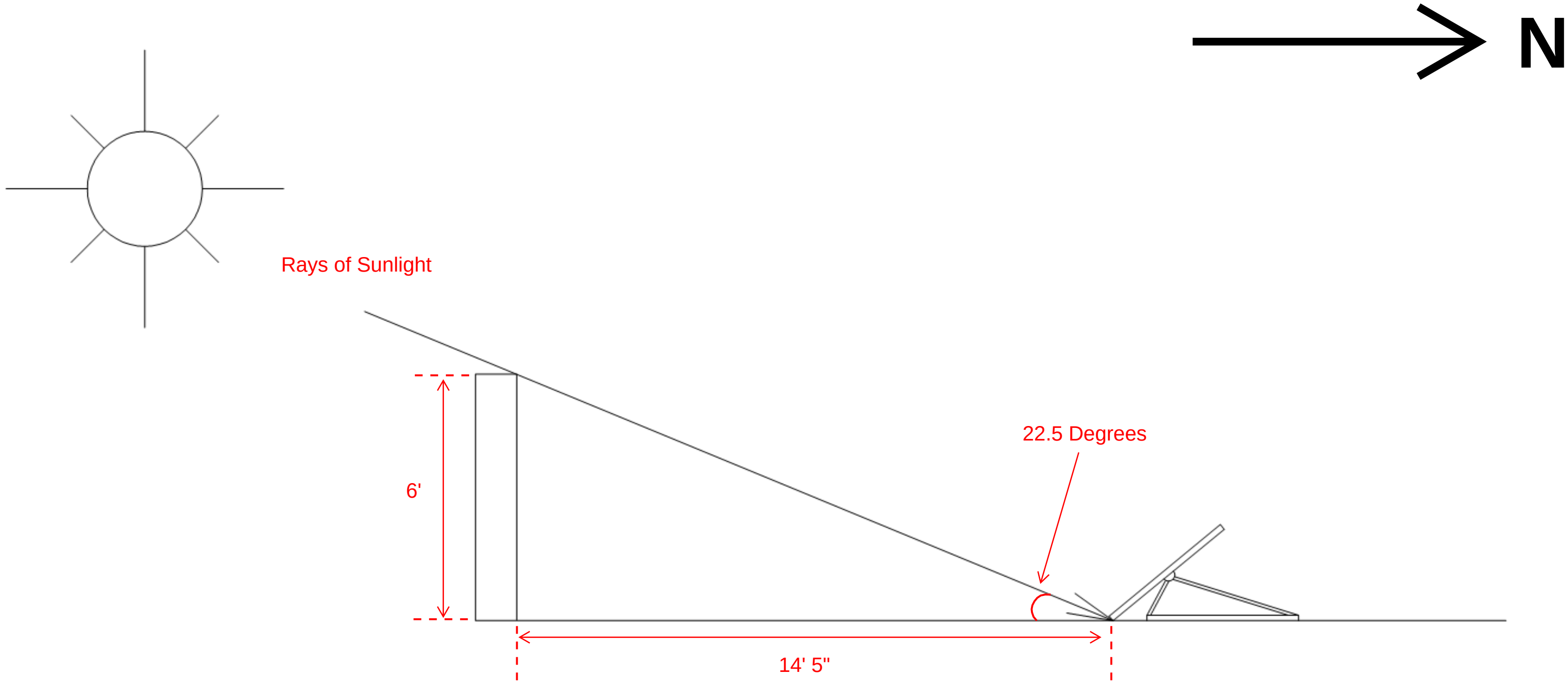
Appendix B

Photovoltaic Array

Appendix B.1

Shadow Calculations

Parapet - Section B - NTS

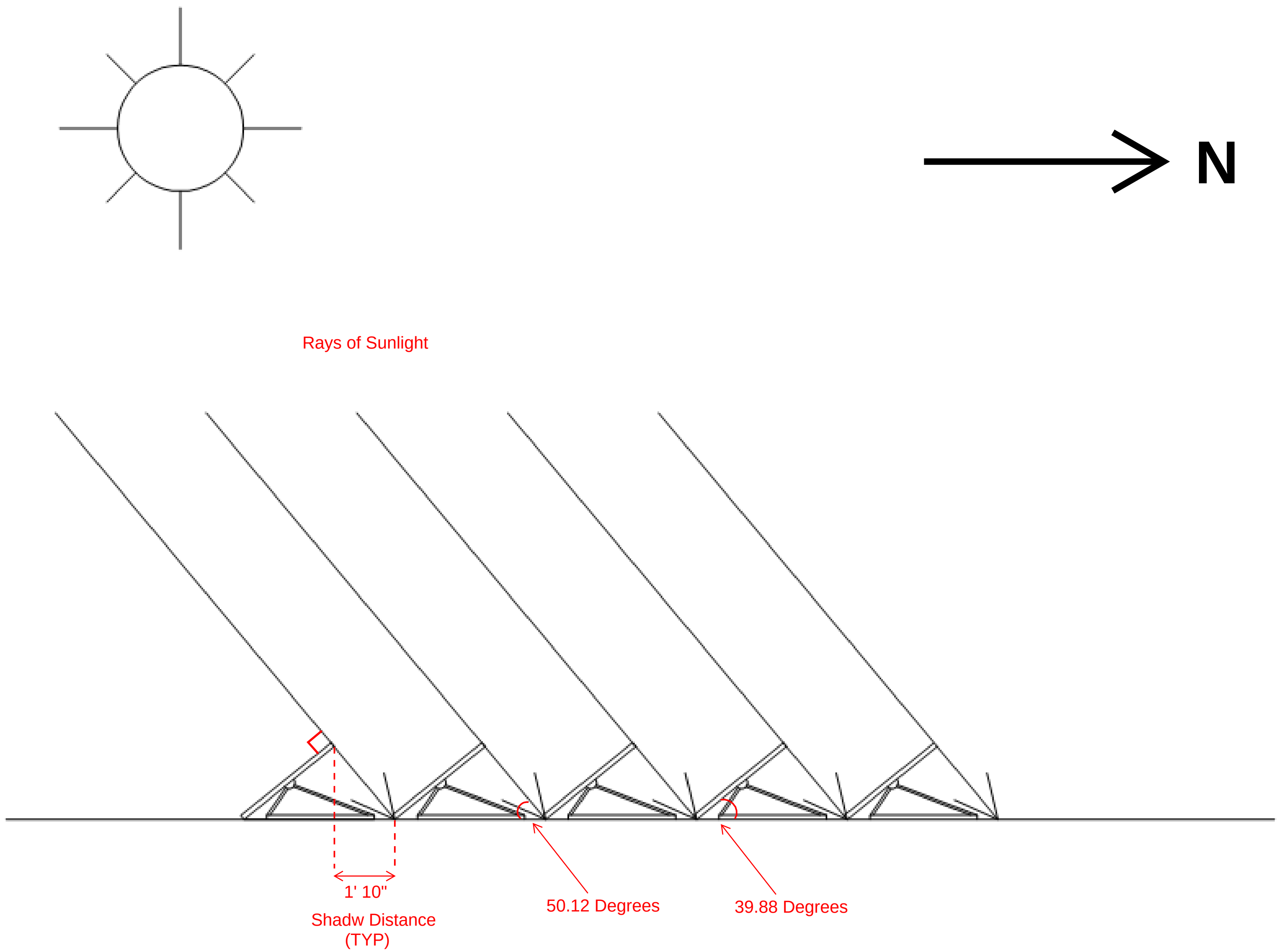


Location: 38.88 Degress NL
75.25 Degrees WL
Philadelphia, PA
Shadow Effect -10:30am/1:30pm During Winter Solstice

Appendix B.1

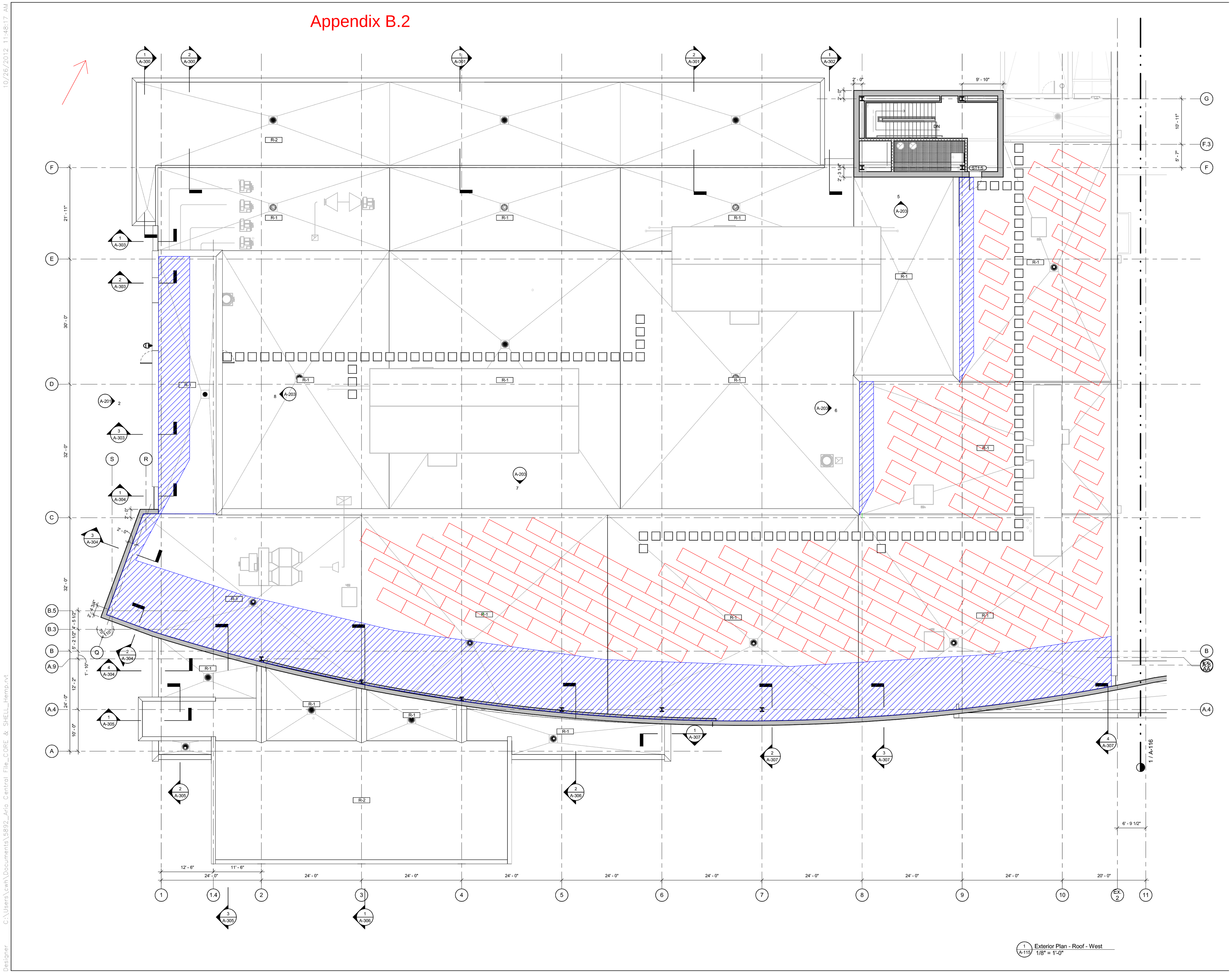
Shadow Calculations

Module Array - Section A - NTS



Location: 38.88 Degress NL
75.25 Degrees WL
Philadelphia, PA
Optimum *Annual* Insolation for Fixed Tilt Angle Module

Appendix B.2



Exterior Plan - Roof - West
1/8" = 1'-0"

Revisions

No.	Description	Date

Key Plan

Consultants:

Structural Engineer:
O'Donnell & Naccarato
111 South Independence Mall East
Suite 950
Philadelphia, PA 19106
Phone: (215) 925-3788
Fax: (215) 627-1051
www.o-n.com

M/E/P Engineer:
PWI
327 North 17th Street
Philadelphia, PA 19103
Phone: (215) 241-9100
Fax: (215) 241-9112
www.pwius.com

Civil Engineer:
Barry Isett & Associates, Inc.
Pennsylvania 100
Trexlertown, PA 18087
Phone: (610) 398-0904
http://www.barryisett.com

Construction Manager:
Turner Construction Company
1835 Market Street
21st Floor
Philadelphia, PA 19103
Phone: (215) 496-8800
www.turnerconstruction.com

It is the responsibility of the Construction Manager/General Contractor and all Sub-Contractors to verify all dimensions and accept conditions of prior work by related trades before proceeding with any work.

Date
10/26/2012

Drawn By
Author

Scale
1/8" = 1'-0"

Seal

Checker

Francis Cauffman

Project Title
Aria Health System - Torresdale Campus

New Emergency Dept & Patient Medical Tower

10800 Knights Road
Philadelphia, Pennsylvania, 19114

Project Number
F11-5892

Drawing Title and Number
Roof - Core & Shell Plan West

A-115

CONSTRUCTION DOCUMENTS ISSUE - 10/26/2012

PRODUCED BY AN AUTODESK EDUCATIONAL PRODUCT

SHARP®

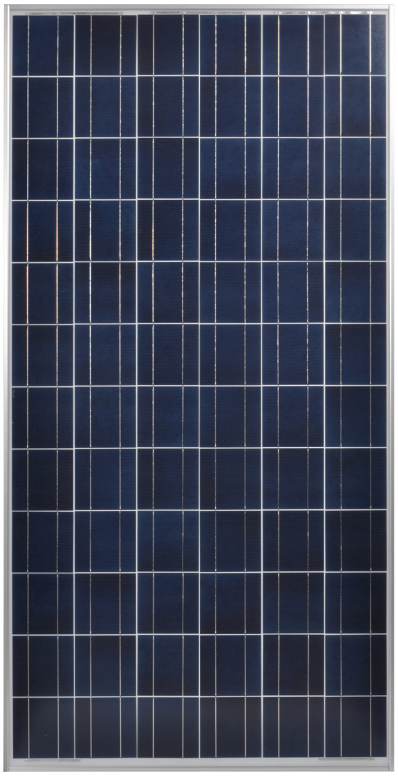
solar electricity

Appendix B.3

300 WATT

MULTI-PURPOSE MODULE

NEC 2008 Compliant



ND-F4Q300

MULTI-PURPOSE 300 WATT MODULE FROM THE WORLD'S TRUSTED SOURCE FOR SOLAR.

Using breakthrough technology, made possible by nearly 50 years of proprietary research and development, Sharp's ND-F4Q300 solar module incorporates an advanced surface texturing process to increase light absorption and improve efficiency. Common applications include commercial and residential grid-tied roof systems as well as ground mounted arrays. Designed to withstand rigorous operating conditions, this module offers high power output per square foot of solar array.

Business leaders install this module in large commercial applications, demonstrating financial astuteness and environmental stewardship.

ENGINEERING EXCELLENCE

High module efficiency for an outstanding balance of size and weight to power and performance.

DURABLE

Tempered glass, EVA lamination and weatherproof backskin provide long-life and enhanced cell performance.

RELIABLE

25-year limited warranty on power output.

HIGH PERFORMANCE

This module uses an advanced surface texturing process to increase light absorption and improve efficiency.

Sharp multi-purpose modules offer industry-leading performance for a variety of applications.

Improved Frame Technology

SHARP: THE NAME TO TRUST

The Sharp ND-F4Q300 module is covered by Sharp's 10 year materials or workmanship warranty. When you choose Sharp, you get more than well-engineered products. You also get Sharp's proven reliability, outstanding customer service and the assurance of our 25-year limited warranty on power output. A global leader in solar electricity, Sharp powers more homes and businesses than any other solar manufacturer worldwide.

BECOME POWERFUL

300 WATT

ND-F4Q300

NEC 2008 Compliant
Module output cables: 12 AWG PV Wire

ELECTRICAL CHARACTERISTICS	
Maximum Power (Pmax)*	300 W
Tolerance of Pmax	0%/5%
Type of Cell	Polycrystalline silicon
Cell Configuration	72 in series
Open Circuit Voltage (Voc)	45.1 V
Maximum Power Voltage (Vpm)	35.2 V
Short Circuit Current (Isc)	8.94 A
Maximum Power Current (Ipm)	8.52 A
Module Efficiency (%)	15.3%
Maximum System (DC) Voltage	1000 V
Series Fuse Rating	15 A
NOCT	46.2˚C
Temperature Coefficient (Pmax)	-0.439%/°C
Temperature Coefficient (Voc)	-0.321%/°C
Temperature Coefficient (Isc)	0.050%/°C

*Illumination of 1 kW/m² (1 sun) at spectral distribution of AM 1.5 (ASTM E892 global spectral irradiance) at a cell temperature of 25°C.

MECHANICAL CHARACTERISTICS	
Dimensions (A x B x C below)	39.1" x 77.6" x 1.8"/994 x 1971 x 46 mm
Cable Length (G)	43.3"/1100 mm
Output Interconnect Cable	12 AWG with SMK Locking Connector
Weight	50 lbs / 22.7 kg
Max Load	30 psf (1440 Pascals)
Operating Temperature (cell)	-40 to 194°F / -40 to 90°C

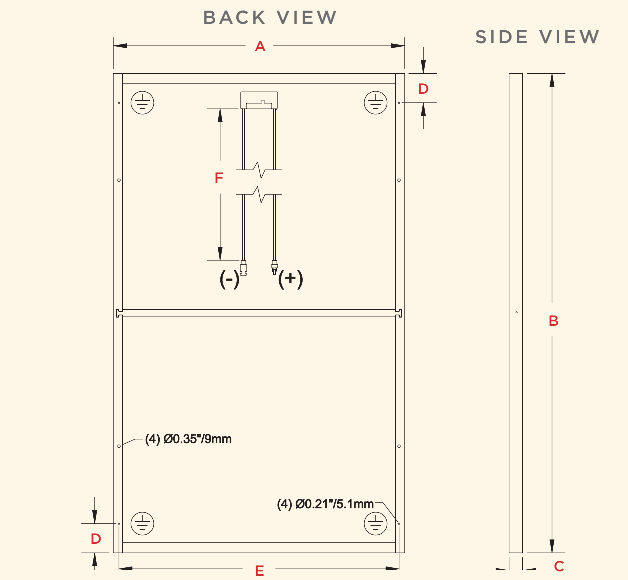
**PV Wire per UL Subject 4703

QUALIFICATIONS	
UL Listed	UL 1703
Fire Rating	Class C
IEC Listed	IEC 61215 / IEC 61730

WARRANTY

25-year limited warranty on power output
Contact Sharp for complete warranty information

DIMENSIONS



A	B	C	D	E
39.1"/994 mm	77.6"/1971 mm	1.8"/46 mm	3.9"/100 mm	37.7"/958 mm

F
43.3"/1100 mm

Contact Sharp for tolerance specifications

"BUY AMERICAN"

Sharp solar modules are manufactured in the United States and Japan, and qualify as "American" goods under the "Buy American" clause of the American Recovery and Reinvestment Act (ARRA).

Design and specifications are subject to change without notice.
Sharp is a registered trademark of Sharp Corporation. All other trademarks are property of their respective owners. Cover photo: Solar installation by Pacific Power Management, Auburn CA.

SHARP ELECTRONICS CORPORATION
5700 NW Pacific Rim Boulevard, Camas, WA 98607
1-800-SOLAR-06 • Email: sharpsolar@sharpusa.com
www.sharpusa.com/solar

1-25-13_JM

Appendix B.4

Low Voltage Products

Solar energy
Protecting and isolating PV systems

Power and productivity
for a better world™

Contents

Guide to the UK industry 2
The components of photovoltaic systems 3
Protection on the d.c. side 4
String protection 5-7
MCBs 8-9
Switch disconnectors 10-11
Fuse disconnectors 12
Surge arresters 13
Enclosed switch disconnectors 14
Surge arresters for AC 15
Isolators for AC 16
MCBs for AC 17
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Low voltage products for renewable energy
Guide to the UK industry

The UK Government have introduced a new initiative aimed at encouraging the nationwide adoption of renewable energy technologies.

Called the Feed-in Tariff, this initiative will see owners of renewable energy equipment being paid not only for the energy they use but also the amount of surplus energy they supply to the UK National Grid.

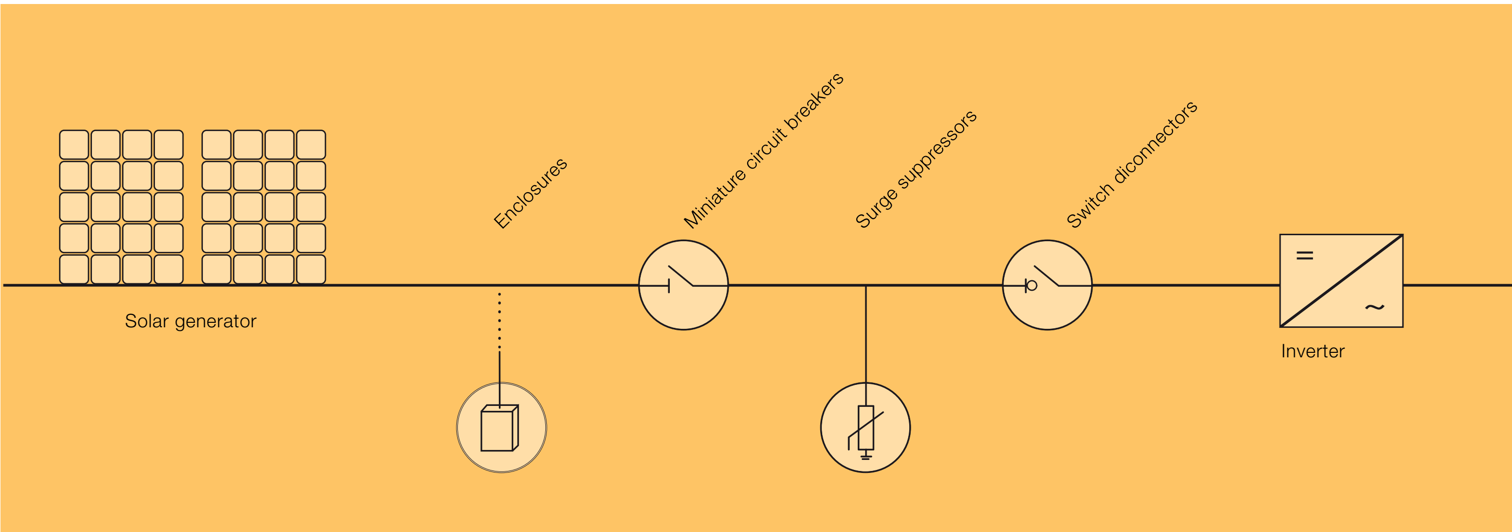
Inspired by similar schemes already operating in continental Europe, the UK Feed-in Tariff initiative is aimed at residential, commercial and industrial users of renewable energy sources. A table of the technologies covered are listed below.

How does the Feed-in Tariff Work?

The Feed-in Tariff is based on the amount of energy produced by a renewable energy source, plus where surplus energy is produced, a bonus to cover energy exported to the National Grid. By effectively paying producers more for the energy they don't use, the system is also aimed at encouraging energy efficiency.

To cover periods when the renewable energy source may be not producing sufficient electricity to cover demand, additional energy may be imported from the National Grid, with the user paying their electricity supplier for the amount consumed.

Technology	Tariff amount (pence per kWh) for installation fitted periods:		
	April 2010 - March 2011	April 2011 - March 2012	April 2012 - March 2013
Solar photovoltaic <4 kW (new)	36.1	36.1	36.1
Solar photovoltaic <4 kW (retrofit)	41.3	41.3	41.3
Solar photovoltaic >4 - 10kW	36.1	36.1	33.0
Solar photovoltaic >10 - 100 kW	31.4	31.4	28.7
Solar photovoltaic >100 - 5MW	29.3	29.3	26.8



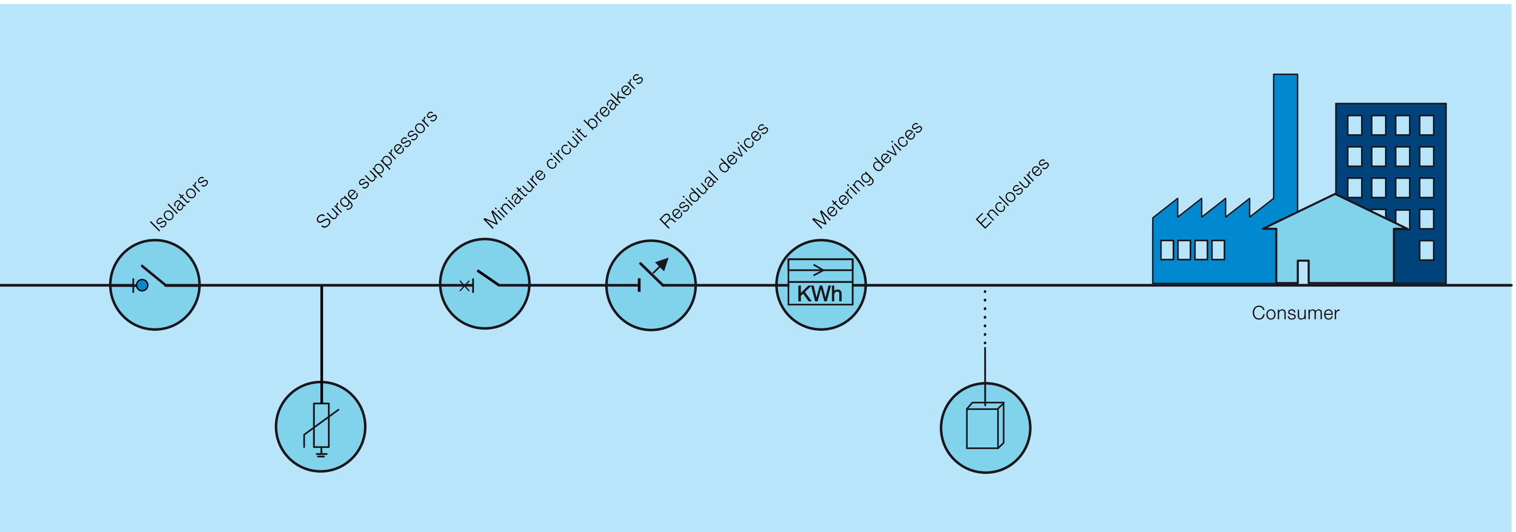
DC Side

The components of photovoltaic systems
The efficiency and quality of a system are measured by the efficiency and quality of each individual component

An accurate choice of components, especially the modules and inverters, is of fundamental importance if a photovoltaic system is to be a success. Before it can be considered a good investment, a photovoltaic system must be able to function efficiently for at least 20 years in all weathers and under the blazing sun.

What is commonly called the “BOS” (Balance of System), i.e. the “rest of the system” (electromechanical equipment for protection, control and isolation purposes, cables), undoubtedly plays an important role in ensuring that people and the buildings connected to the system are properly protected, and that there is an adequate production of energy over the years. From an economic viewpoint, it is even more important for each individual component of a photovoltaic system to be chosen on the basis of the warranties provided by the product and by its manufacturer than it is for a normal electric system. This is because the operating specifications of each device must remain unchanged throughout the entire life cycle of the system and the relative investment.

Always ready to meet any new demand from the market, ABB has developed a whole range of reliable products dedicated to photovoltaic applications and able to meet all installation requirements, from the string on the direct current side through to the alternate current grid connection point. ABB’s products include string boxes, miniature circuit breakers, switch-disconnectors, residual current-operated circuit breakers, interface relays, energy meters, fuse disconnecting switches and fuses, surge arresters, consumer units and enclosures suitable for outdoor installation, all specially designed for these applications. ABB can also provide a series of “plug & operate” solutions, i.e. finished, wired and certified switchgear able to suit the requirements of a vast range of installations: from the individual string for domestic use to the large solar park.



AC Side

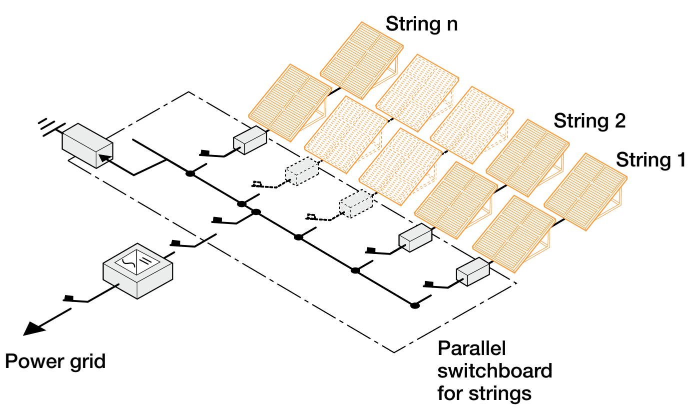
Protection on the d.c. side

The direct current section of a typical photovoltaic system consists of a generator formed by the parallel of the strings of solar panels connected in series.

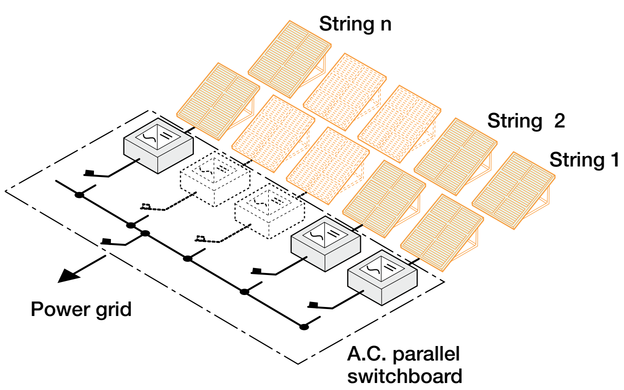
Along with the specific characteristic of the solar modules (inability to shut off the voltage other than by obscuring the solar panels and generation, by the strings, of short-circuit currents with values very near to those produced in normal conditions), the presence of voltage as high as 300-600 V d.c. and beyond requires a very careful assessment of the protection and isolating devices, which must be able to suppress direct fault currents under high voltages within a very short time.

In accordance with the provisions established by Standard IEC 64-8 (article 712), protection against overcurrents must be provided when the carrying capacity of the cable is less than 1.25 times the calculated fault current in any point.
This means that in the majority of small systems or when several inverters have been installed, it is sufficient to install a switch-disconnector which, as established by Guide 82-25, must be of the DC21 class at least.
Guide 82-25 also specifies that it is advisable to install an isolating device on each string to allow this latter to be inspected or serviced without having to shut down other parts of the system.
The exposed conductive parts of all the equipment must be earthed by means of the protection conductor to as to protect persons from indirect contacts. The PV generator can only be earthed if it is separated from the low voltage distribution network by a transformer.

Various different methods can be used to connect the strings in parallel in a photovoltaic system connected to the power grid.



Centralized conversion

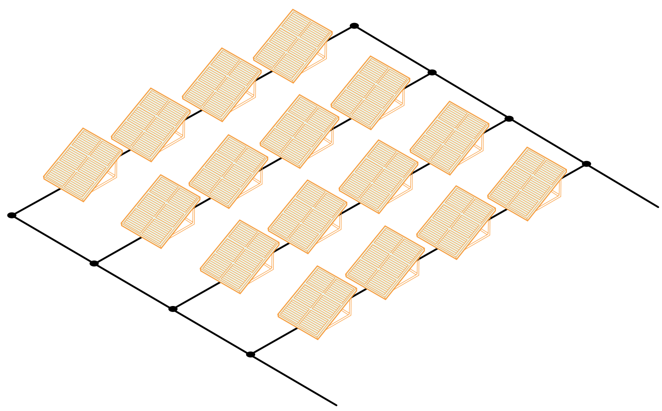


Distributed conversion

String protection against reverse currents

When the installation layout includes centralized conversion with the use of a single inverter, the strings must be protected against reverse current. This could circulate after faults or temporary unbalances in the system due, for example, to certain of the solar modules being partially in the shade or covered by snow, leaves, etc.

Recirculated current can reach extremely high values, especially when there are a large number of strings.
The modules are unable to withstand this sort of current and, in the absence of protection devices, they develop faults within a very short time.
There are different methods for connecting the strings of solar modules in parallel in safe conditions: if there are only a few strings (1 or 2), obviously formed by the same number of modules, the parallel connection can be made without danger, otherwise protection devices must be installed in series with each string.

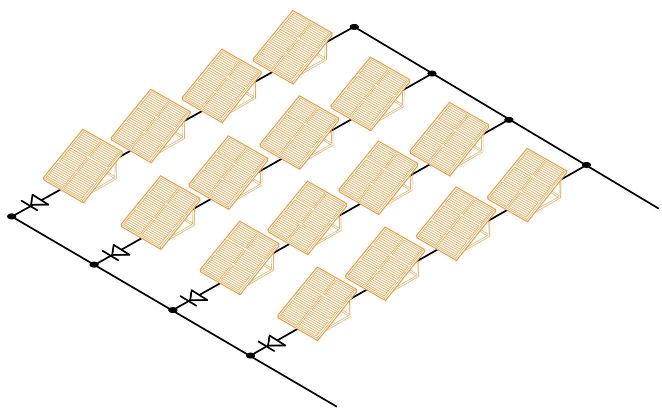


Protection for the parallel connection of the strings of photovoltaic modules. Simple parallel.

Advantages: simple to make
Disadvantages: the strings are liable to power reversals; can only be used for a very small number of strings

Reverse cut-off diode

This solution is inadvisable since not everyone considers it suitable for protecting the strings. It is not a substitute for over current protections (IEC TS 62257-7-1) as the blocking diode may not function correctly and could be short-circuited. Moreover, diodes lead to a power loss owing to the effect of the voltage drop on junction, a loss that can be reduced by using Schottky diodes with a 0.4 V drop instead of the 0.7 V drop created by conventional diodes.
If reverse cut-off diodes are chosen, their maximum reverse voltage (according to IEC 60364-7-712 standards) must be at least twice the open circuit UOC string voltage in STC conditions.
The direct over current must be higher than the short-circuit current ISC of the individual modules, with 1.25 ISC minimum value.



Protection for the parallel connection of the strings of photovoltaicmodules. Reverse cut-off diodes.

Advantages: Prevent power reversal
Disadvantages: They are not considered to be protection devices.
They lead to a power loss in the circuit.

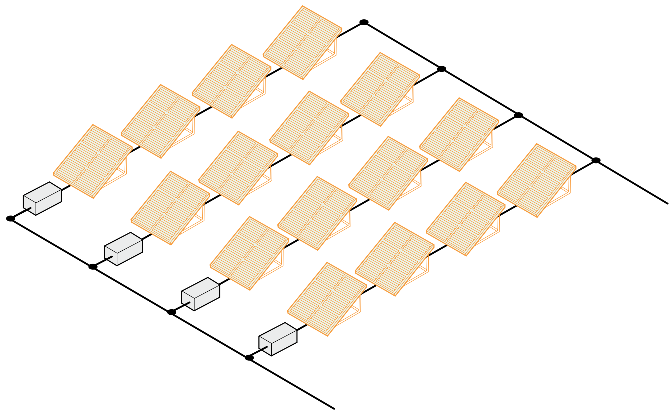
String protection against reverse currents

Fuses

Fuses are the string protection most widely used by designers since, unlike diodes, they disconnect the circuit if faults occur. However, although fuses are simple to use, the utmost care must be taken when they are sized and chosen as certain fundamantal requirements must be considered:

- they must possess trip characteristic gR, suitable for protecting circuits with semi-conductors;
- they must be sized for current values of no less than 1.25 IS and no more than the value indicated by the manufacturer for module protection. In the absence of specific indications, consider a value must be 2.0 IS or less;
- they must be installed in dedicated fuse-disconnectors able to dissipate the power that develops in the worst operating conditions.

With its small size and competitive cost, this solution does not completely prevent reverse current from circulating in the modules, which must consequently be able to withstand values of at least twice or three times the ISC (such values are normally supported by the majority of the modules available on the market).



Protection for the parallel connection of the strings of photovoltaic modules. Simple parallel.

Advantages: simple to make

Disadvantages: the strings are liable to power reversals; can only be used for a very small number of strings

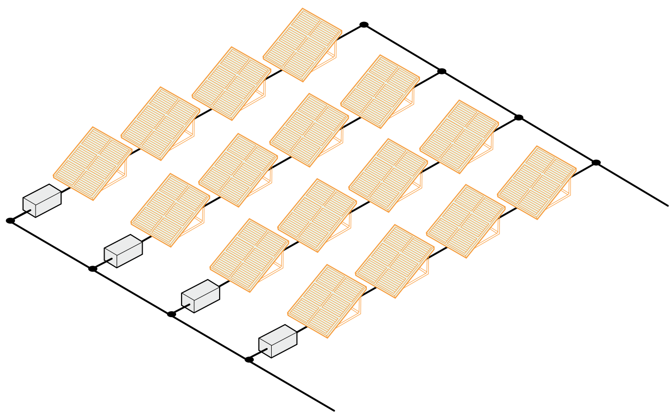
Miniature circuit-breakers

Use of thermo-magnetic circuit-breakers is a further method for protecting photovoltaic strings. Thus, manufacturers have created specific products comprising technological solutions able to function at high the direct current voltage values that are usual in these applications.

Technically speaking, this is the better solution even though it is not so economical.

In certain cases, it could also be liable to accidentally trip in the presence of transient overvoltage (e.g. of atmospheric origin). However, in such cases they can be reset without having to replace any components.

A further advantage is that the protection and isolating functions can be provided by a single device.



Protection for the parallel connection of the strings of photovoltaic modules. Automatic circuit-breakers.

Advantages: a single device provides both the protection and isolating functions

Disadvantages: More expensive

Isolating devices

A class DC21 switch-disconnector can also be installed in the parallel switchboards to allow the solar energy source to be disconnected if a fault occurs or, more frequently, when servicing is required.
If it is installed in the subsystem's parallel switchboards, lower current values can be used than those that would be obtained with a single isolation on the load side of the inverter, while it also allows the various different strings to be disconnected in a selective way.
To conduct maintenance work and inspections in the utmost safety, it is advisable to install isolating devices on each individual string.

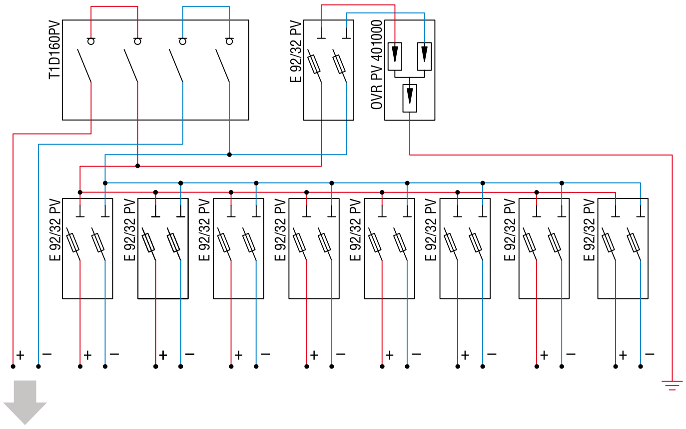


Diagram of a parallel switchboard for 8 strings inclusive of SPD and switch-disconnector

Surge arresters

Solar arrays, which are generally sited in exposed positions and, for the higher power versions, over wide areas, are subject to atmospheric activity and may be damaged by the over voltage generated by lightning.
To avoid problems, it is advisable to install Surge Protective Devices (SPD) on each polarity towards earth in the parallel switchboards once the risks have been correctly assessed in accordance with EN 62305-2 standards.
The impedance of these devices varies, depending on the voltage applied: when on hold, their impedance is extremely high and is reduced in the case of over voltage, by discharging the associated current towards earth.
It is advisable to choose the right sort of SPD with tripping thresholds that suit the operating voltage values of the circuit. The state of efficiency of the equipment must be constantly displayed locally and in the remote mode if necessary, by use of products equipped with remote signalling contacts.
SPD with varistors or combined SPD should be used in the protection for the direct current side. Inverters generally possess internal protection against over voltage, but the addition of SPD's at the terminals prevents surges from reaching the inverter which means the inverter maintains the production of energy and negates the need for the intervention of specialized personnel.

These SPD must therefore possess the following characteristics:
- type 2;
- maximum continuous operating voltage $U_c > 1.25\ U_{oc}$;
- protection level $U_p < U_{inv}$, where U_{inv} is the impulse withstand voltage of the inverter on the d.c. side;
- rated flashover current $I_n > 5$ kA;
- thermal protection with short-circuit extinction capacity at life end and coordination with a suitable backup protection.

Since the impulse withstand voltage of the string modules is generally higher than that of the inverter, the SPD installed to protect these generally allow the modules to be protected as well, so long as the distance between the modules and inverter is less than 10 meters. The SPD must be installed on the supply side (direction of the PV generator's energy) of the inverter's isolating device so that it also protects the modules when the isolating device is open.

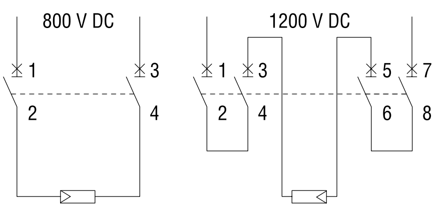
Miniature circuit-breakers
S800 PV-S

S800 PV-S miniature circuit-breakers can be used in networks up to 1200 V d.c. (four-pole version). These products and their vast range of accessories (auxiliary contacts, release coils) can be used to create countless system configurations. The main features of S800 PV-S circuit-breakers are:
- interchangeable terminals
- fault signalling lever in the central position
- contact status displayed for each individual pole
- no restrictions as to polarity or power direction in the wiring
- use of the rotary door operating handle

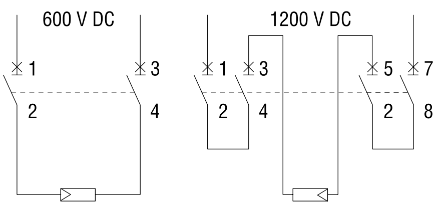
Main technical specifications		S800 PV-S	
Reference Standards		IEC EN 60947-2	
Rated current In	[A]	10…80	100, 125
Number of poles		2, 4	
Rated voltage Ue (d.c.) 2 poles* (d.c.) 4 poles*	 [V] [V]	 800 600	 1200 1200
Ultimate rated short-circuit breaking capacity Icu (d.c.) 600/800 V (2 poles) * (d.c.) 1200 V (4 poles) *	 [kA] [kA]	 5 5	 5 5
Thermomagnetic release characteristic		4 In ≤ Im ≤ 7 In	
Class of use		A	
Operating temperature	[°C]	-25…+60	
Mounting		on EN 60715 channel (35 mm) with a quick coupling device	

Please refer to wiring diagrams*

≥ 80A



≥ 100, 125A



Connection
Photovoltaic panel network
in earth-insulated systems

Poles	Rated current In [A]	Description Type	Order code
2	10	S802PV-S10	2CCP842001R1109
2	13	S802PV-S13	2CCP842001R1139
2	16	S802PV-S16	2CCP842001R1169
2	20	S802PV-S20	2CCP842001R1209
2	25	S802PV-S25	2CCP842001R1259
2	32	S802PV-S32	2CCP842001R1329
2	40	S802PV-S40	2CCP842001R1409
2	50	S802PV-S50	2CCP842001R1509
2	63	S802PV-S63	2CCP842001R1639
2	80	S802PV-S80	2CCP842001R1809
2	100	S802PV-S100	2CCP842001R1829
2	125	S802PV-S125	2CCP842001R1849
4	10	S804PV-S10	2CCP844001R1109
4	13	S804PV-S13	2CCP844001R1139
4	16	S804PV-S16	2CCP844001R1169
4	20	S804PV-S20	2CCP844001R1209
4	25	S804PV-S25	2CCP844001R1259
4	32	S804PV-S32	2CCP844001R1329
4	40	S804PV-S40	2CCP844001R1409
4	50	S804PV-S50	2CCP844001R1509
4	63	S804PV-S63	2CCP844001R1639
4	80	S804PV-S80	2CCP844001R1809
4	100	S804PV-S100	2CCP844001R1829
4	125	S804PV-S125	2CCP844001R1849

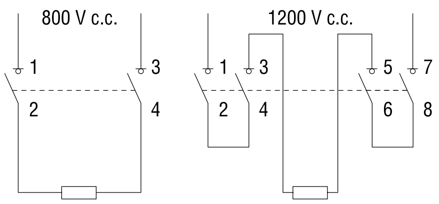
Miniature circuit-breakers
S800 PV-M

S800 PV-M switch-disconnectors can be used in networks up to 1200 V d.c. (four-pole version). These products and their vast range of accessories (auxiliary contacts, release coils) can be used to create countless system comfigurations. The main features of S800 PV-M switch-disconnectors are:

- interchangeable terminals
- contact status displayed for each individual pole
- no restrictions as to polarity or power direction in the wiring
- use of the rotary door operating handle

Main technical specifications		S800 PV-M
Reference Standards		IEC EN 60947-3
Rated current In	[A]	32, 63, 125
Number of poles		2, 4
Rated voltage Ue (d.c.) 2 poles* (d.c.) 4 poles*	 [V] [V]	 800 1200
Ultimate rated short-circuit breaking capacity Icu (d.c.) 600/800 V (2 poles) * (d.c.) 1200 V (4 poles) *	 [kA] [kA]	 1.5 1.5
Class of use		DC-21A
Operating temperature	[°C]	-25…+60
Mounting		on EN 60715 channel (35 mm) with a quick coupling device

Please refer to wiring diagrams*



Connection
Photovoltaic panel network
in earth-insulated systems

Poles	Rated current In [A]	Description Type	Order code
2	32	S802PV-M32	2CCP812001R1329
2	63	S802PV-M63	2CCD842001R1590
2	125	S802PV-M125	2CCP812001R1849
4	32	S804PV-M32	2CCP814001R1329
4	63	S804PV-M63	2CCD844001R1590
4	125	S804PV-M125	2CCP814001R1849

Isolators
OT

OT series disconnectors are available with 16 A to 125 A rated current values in 3, 4, 6 and 8 pole versions, depending on the direct current voltage used.

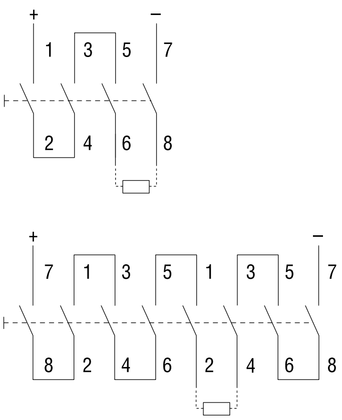
The main features of OT disconnectors are:

- quick make-break mechanism with independent tripping function (in the OT 45...125 versions).
- accessories that are snap-fitted on the circuit-breakers
- OT 45 ... 125 switch-disconnector mechanism for installation on DIN channel.
- can be locked with a locking adapter

Main technical specifications		OT		
Reference Standards		IEC EN 60947-3		
Rated current In	[A]	16, 25, 32		
Number of poles		4	6	8
Rated voltage Ue				
(d.c.) 4 poles*	[V]	500		
(d.c.) 6 poles*	[V]		550	
(d.c.) 8 poles*	[V]			800
Class of use		DC-21A		
Operating temperature	[°C]	-25…+60		
Mounting		on EN 60715 channel (35 mm) with a quick coupling device		

Please refer to wiring diagrams*

Poles	Rated current In [A]	Rated current/ DC21 [A/V d.c.] voltage	Description Type	Order code
4	16	16/440	OT16F4N2	1SCA104829R1001
6	16	16/550	OT16F6	1SCA104834R1001
6	25	25/550	OT25F6	1SCA104880R1001
6	32	32/550	OT40F6	1SCA104936R1001
8	16	16/800	OT16F8	1SCA104836R1001
8	25	25/800	OT25F8	1SCA104882R1001
8	32	32/800	OT40F8	1SCA104938R1001



Circuit Diagram

Switch-disconnectors
Tmax PV

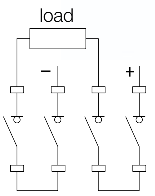
Tmax PV series disconnectors are available with up to 1600 A class DC-22B rated operating current values, for 1100 V d.c. maximum rated operating voltage. The switching devices of the Tmax PV series are the first box disconnectors for direct current high voltage available on the market. They are certainly of interest for use in any type of photovoltaic installation since they are ideal for all disconnecting requirements.

The main features of Tmax PV disconnectors are:

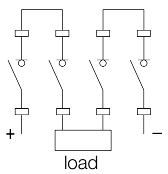
- Comprehensive range. There are 6 different sizes, from the compact T1 (which can be fixed to DIN channel) to T7, available in the two versions with operating lever and motor control
- Excellent performance-dimensions ratio
- Wide choice of accessories to suit every requirement

Main technical specifications		Tmax PV
Reference Standards		IEC EN 60947-3
Rated current In	[A]	160 - 1600
Number of poles		4
Rated voltage Ue	[Vd.c.]	1100
Rated insulation voltage Ui	[Vd.c.]	1150
Short time current Icw	[kA]	1.5 - 19.2
Class of use		DC-22B

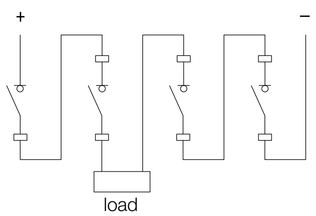
Poles	Ith	Operating current DC 22B [A/V d.c.]	Description Type	Order code
4	160	160/1100	T1D 160 PV	1SDA066881R1
4	250	200/1100	T3D 200 PV	1SDA066882R1
4	250	250/1100	T4D 250 PV	1SDA066883R1
4	630	500/1100	T5D 500 PV	1SDA066884R1
4	800	800/1100	T6D 800 PV	1SDA066885R1
4	1600	1600/1100	T7D 1600 PV	1SDA066886R1
4	1600	1600/1100	T7D 1600 PM	1SDA066887R1



Circuit Diagram
Valid for T1D PV, T3D PV, T6D PV, T7D PV,



Circuit Diagram
Valid for T4D PV, T5D PV



Circuit Diagram
Valid for all Tmax series

Fuse disconnectors
E 90 PV

The E 90 PV series fuse disconnectors has been designed for up to 1000 V direct current voltage with DC-20B class of use. The E 90 PV series is specifically used for protecting photovoltaic systems against overcurrents and provides a reliable, compact and inexpensive solution since it uses 10.3 x 38 mm cylindrical fuses. The main features of E 90 PV fuse disconnectors are:

- Handle opening through 90° that allows the horizontal fuse to be easily inserted even when wearing gloves or using the thumb
- Only an additional 17 mm larger in the open position than in the closed position
- 25 mm2 terminals with knurled terminal cage to allow the cable to be clamped in a better way
- Fully compatible with electric screwdrivers
- Pozidrive screws for flat-head and cross-point screwdrivers
- Lockable in the open position using the padlocks commonly available on the market, so as to ensure safe maintenance work
- Can be sealed in the closed position to prevent improper use
- Cooling chambers and ventilation slits to facilitate heat dispersion
- Versions with indicator light are available

Main technical specifications		E 90/32 PV
Reference Standards		IEC EN 60947-3
Rated service voltage	[Vd.c.]	1000
Class of use		DC-20B
Fuse	[mm]	10 x 38
Type of current		d.c.
Rated current	[A]	32
IP Rating		IP20
Lockable (when open)		Yes
Sealable (when closed)		Yes

Poles	Rated current In [A]	Modules	Description Type	Order code
1	32	1	E 91/32 PV	2CSM204713R1801
1	32	1	E 91/32 PVs*	2CSM204693R1801
2	32	2	E 92/32 PV	2CSM204703R1801
2	32	2	E 92/32 PVs*	2CSM256913R1801

*s: version with LED for blown fuse indication

Surge arresters for DC
OVR PV

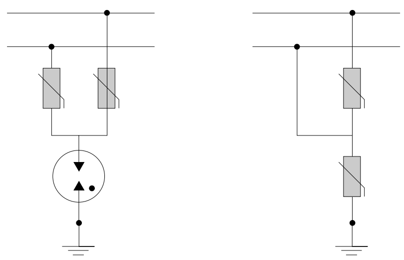


ABB provides a wide range of surge protection devices that have been specifically designed for photovoltaic systems.

The main features of the OVR PV surge arresters are:

- built-in thermal protection with 25 A d.c. breaking capacity*
- removable cartridges for easy maintenance with no need to isolate the line
- remote signalling contact for monitoring the operating status (TS versions)
- no subsequent short-circuit current
- no risk if the polarity is reversed

Main technical specifications		OVR PV
Electrical specifications		
Type of network		photovoltaic systems
Type		2
Response time	[ns]	25
Residual current	[mA]	< 1
Protection class		IP20
Built-in thermal protection		self-protected for up to 100 A d.c. short-circuit current
Back-up protection		
current Icc < 100A		not required
current Icc > 100A		10 A gR fuse
Mechanical specifications		
L/PE terminals		
rigid	[mm2]	2,5…25
flexible	[mm2]	2,5…16
Tightening torque L [	Nm]	2,80
Status indicator		yes
Remote signal contact		
Type		1 NA/NC
Minimum rating		12 V d.c. - 10 mA
Maximum rating		250 V a.c. - 1 A
Cable section	[mm2]	1,5
TS versions		
Operating temperature	[°C]	-40...+80
Storage temperature	[°C]	- 40...+80
Maximum altitude	[m]	2000
Housing material		PC RAL 7035
UL94 fire resistance		V0
Reference standards		IEC 61643-1 / EN 61643-11

***Note:**
For surge protection device installed at points of the network where short circuit current exceeds 25A DC suitable protection must be provided

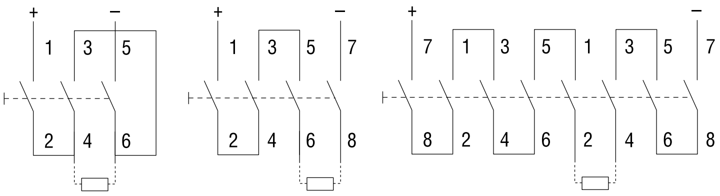
I Max	Protection Level (L-L/L-PE) kV	Description Type	Order code
40A	2.8/1.4	OVR PV 40 600 P	2CTB803953R5300
	2.8/1.4	OVR PV 40 600 P TS	2CTB803953R5400
	3.8	OVR PV 40 1000 P	2CTB803953R6400
	3.8	OVR PV 40 1000 P TS	2CTB803953R6500

Enclosed switch disconnectors DC OTP

Plastic enclosed switch-disconnectors 3 - 4 - 8 pole IP65

- IP65 rated
- Grey plastic enclosure
- Standard handle - Red/Yellow (padlockable in the off position)
- Cable entries top and bottom

1th [A]	No. Poles	Rated Operated Current/ voltage DC21-A[A]/[VDC]	Cable Outlets Side	Order Code
25	3	16/220	2xM20	OTP16BA3MS
	4	16/500	2xM25+M16	OTP16BA4MS
	8	16/800	2xM25+M16	OTP16BA8MS
32	3	32/220	2xM25+M16	OTP32BA3MS
	8	32/800	2xM25+M16	OTP32BA8MS



Circuit Diagram

Surge Arresters for AC
OVR T2

The OVR T2 protects inverters and installations from over voltages and impulse currents, such as switching and lighting surges. The device ensures the limitation of over voltage to an acceptable level for the equipment to be protected.

The device ha a remote signal control and removable cartridge for easy maintenance without needing to isolate the line.

These devices are available with a remote signal control and removable cartridge (...P TS) for easy maintenance without needing to isolate the line.

Main technical specifications	OVR T2
Rated operating voltage	230V and 400V AC
Poles	1, 2, 3, 4
Maximum discharge current	15, 40, 70kA
Residual current	< 1
Voltage protection level	1.2 .... 3.8kV
Standards	IEC 61643-1 IEC 61643-11

Network TT	I Max	Type	Order code
TT (3 + N)	25	OVR T1 3N 25 255 TS	2CTB815101R0700
TT (1 + N)	40	OVR T2 1N 40 275 SP TS	2CTB803952R0200
TT (3 + N)	70	OVR T2 3N 70 275 SP TS	2CTB803953R0100
TT (1 + N)	15	OVR T2 1N 15 275 P	2CTB803952R1200

Isolators for AC
E 200

The isolator is used as a master switch on the AC side. It offers reliable and safe switching under load.
Ease of maintenance is guaranteed by the special fastening for easy removal of the device from its present installation. The wide range of accessories facilitates use of all applications.

Main technical specifications	E 200
Reference Standards	IEC 947-3
Rated operating voltage	230V/400V AC
Rated current	16 ... 125A

Poles	Nominal Current	Description Type	Order code
2	100	E202/100R	2CDE282001R0100
3	100	E203/100R	2CDE283001R0100
4	100	E204/100R	2CDE284001R0100

Miniature circuit breaker for AC
S 200M

The S200 M protect installations against overload and short circuit, ensuring reliability and safety for operations. They are selectively switchable, even under load, in the event of a fault or for maintenance purposes. The standstill times are minimised thanks to the devices' reclosing capability. These devices offer users confidence thanks to their 100% factory testing. The devices, with their wide range of accessories, are suitable for international use.

The S200 M are known for their ease of maintenance – thanks to a special type of fastening for easy removal of the device from its present installation. Supply is possible from above or below, also for busbars. Without busbars, two terminal sections can be used. The tripping behaviour caters to customer requirements (B, C, D, K, Z characteristics)

Main technical specifications		S 200M
Reference Standards		IEC 60898, IEC 60947-2 UL 489, UL 1077
Rated operating current	[Vd.c.]	0,5 … 63 A
Ultimate short-circuit breaking capacity		6, 10, 25 kA
Rated operating voltage	1-pole 2-4 pole	12 … 230 VAC 12 … 400 VAC

Rated current In [A]	Rated breaking capacity [kA]	Poles	Description Type	Order code
10			S202MC10	2CDS272001R0104
16			S202MC16	2CDS272001R0164
20		2	S202MC20	2CDS272001R0204
25			S202MC25	2CDS272001R0254
32			S202MC32	2CDS272001R0324
10			S203MC10	2CDS273001R0104
16			S203MC16	2CDS273001R0164
20	10kA	3	S203MC20	2CDS273001R0204
25			S203MC25	2CDS273001R0254
32			S203MC32	2CDS273001R0324
10			S204MC10	2CDS274001R0104
16			S204MC16	2CDS274001R0164
20		4	S204MC20	2CDS274001R0204
25			S204MC25	2CDS274001R0254
32			S204MC32	2CDS274001R0324

RCDs for AC
F200 PV-B

Residual current devices ensure protection of people and installations against fault current to earth and fire risks. An RCD B type is required on the AC side in case of lack of electrical separation between the AC and the DC side.
The devices save money and improve global efficiency by using PV connectors without an internal insulation transformer. The devices, with their wide range of accessories are suitable for international use.
The RCCBs F202 PV B and F204 B are intended for installation of single and three phase PV converters. they protect against fire risks and leakage currents.

Main technical specifications	**F202 PV B, F204 B**
Rated operating current	25, 40, 63, 125A
Rated sensitivity current	30, 300, 500mA
Rated operating voltage	230 … 400 VAC
Poles	2 ... 4
Type	B, B S (selective version)
Reference Standards	IEC/EN61008 IEC52423

Poles	A / mA	Description Type	Order code
2	40 / 300	F202-A-40/300mA	2CSF202121R3400
2	63 / 300	F202-A-63/300mA	2CSF202121R3630
4	40 / 300	F204-A-40/300mA	2CSF204121R3400
4	63 / 300	F204-A-63/300mA	2CSF204121R3630
4	63 /300	F204-B-63/300mA	2CSF204501R3630

Enclosed switch disconnectors AC
OTP

Plastic enclosed switch-disconnectors 3 - 4 pole IP65

- IP65 rated
- Grey plastic enclosure
- Standard handle - Red/Yellow (padlockable in the off position)
- Cable entries top and bottom

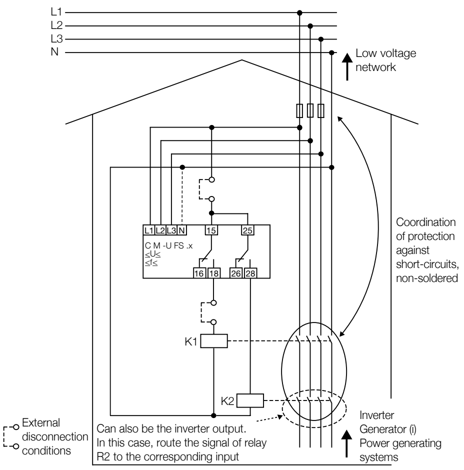
1th [A]	No. Poles	AC22	AC23	kW	Cable Outlets Side	Order Code
25	3	16	16	7.5	2xM20	OTP16BA3M
	4				2xM25+M16	OTP16BA4M
32	3	25	20	9	2xM25+M16	OTP25BA3M
	4				2xM25+M16	OTP25BA4M

Interface relay for connection to the power grid
CM-UFS

Even small distributed generating systems need to be connected to the power grid with guarantees as to completely safe operation, especially when the energy flow towards the network must be shut off for maintenance or if a fault occurs in the network itself. Rapid disconnection is essential if hazardous situations for the people who must work on the lines are to be avoided. This sort of protection can be achieved with an automatic monitoring device able to immediately detect faults in the network. The CM-UFS interface, which conforms to both the Italian ENEL Distribuzione Directive for connections to the electricity main and to German DIN V VDE 0126-1-1, answers to the need for safety for both the installations and the operators in the case of faults and malfunctions in the public power grid during parallel operation.

The main features of the CM-UFS interface relay are:

- Undervoltage protection
- Overvoltage protection
- Minimum frequency protection
- Maximum frequency protection
- Installation on DIN channel, dimension 22 mm
- Configurable connection for the neutral conductor
- 3 LED to indicate the operating status
- Power supply from the circuit under control
- Measurement of the true RMS value
- Can also be used for monitoring single-phase systems
- 2 switch contacts (SPDT)



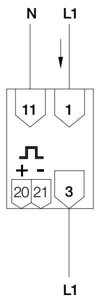
Main technical specifications		CM-UFS.1
Maximum voltage	[Vn]	> 115 %
Minimum voltage	[Vn]	< 80 %
Maximum frequency	[Hz]	> 50.2
Minimum frequency	[Hz]	< 47.5
Mean value	[Vn]	10 minutes 110 to 115 % adjustable

For markets where the German standard VDE is implemented

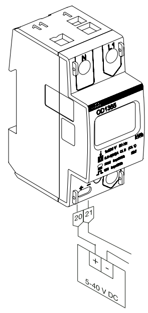
Main technical specifications		CM-UFS.2
Maximum voltage	[Vn]	> 120 %
Minimum voltage	[Vn]	< 80 %
Maximum frequency	[Hz]	> 50.3 or 51 upon the request of ENEL personnel
Minimum frequency	[Hz]	> 49.5 or 49 upon the request of ENEL personnel

Description Type	Order code
Interface device (VDE Type-approved) CM-UFS.1	1SVR630736R0300
Interface device (ENEL Type-approved) CM-UFS.2	1SVR630736R1300

Modular energy meters
ODINsingle and DELTAplus



Direct connection



Pulse output

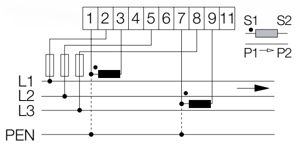
Modular energy meters are ideal for metering and monitoring the energy produced by a photovoltaic system. All the meters are tested and comply with the European MID directive, which allows the meters to be used whenever the energy readings must be used for payment quantification purposes. The terminal boards can be sealed so as to prevent the meter's programming functions from being accessed and to safeguard the inputs of the measuring signals.

ODINsingle:

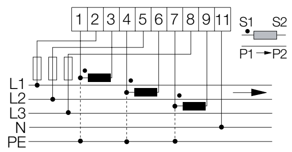
- Accuracy class B (1)
- MID certified for sub-billing purposes
- Direct connection in single-phase systems of up to 65 A
- OD1365 with pulse output
- OD1365 with re-setable register
- LCD display, excellent visibility in all lighting conditions
- Front LED for checking load

DELTAplus:

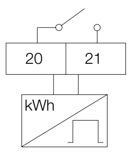
- Accuracy class B (1)
- MID certified for sub-billing purposes
- Connection by current and voltage transformers
- Active energy metering in three phase systems
- With programmable pulse output
- Electric parameters, voltage, current, power and frequency displayed
- Installation assessment: phase presence and sequence
- Front LED for checking load



Threephase system with neutral



Threephase system without neutral



Pulse output of active energy meters

Main technical specifications	ODINsingle	DELTAplus
Reference Standards	IEC EN 50470-1 IEC EN 50470-1	IEC EN 50470-3 IEC EN 50470-3
Voltage	230 V a.c.	3 x 57- 288 V (P+N) 3 x 100 - 500 V (P-P)
Max connection current	65 A	6 A
Start-up current	25 mA	2 mA
Frequency	50-60 Hz ± 5 %	50-60 Hz ± 5 %
Accuracy class	B (Class 1)	B (Class 1)

Poles	Description	Type	Order code
1 + N	65A Direct Class B	OD1065	2CMA131040R1000
1 + N	65A Direct with Reset	OD1365	2CMA131041R1000
3 + N	65A Direct Class A	OD4165	2CMA131024R1000
3 + N	80A Direct Class A	DBB23000	2CMA180800R1000
3 + N	80A Direct Class B	DBB13000	2CMA180801R1000
3 + N	80A Direct Class A	DBB22000	2CMA180802R1000

Enclosures
Europa Series

The Europa series wall-mounted consumer units feature IP65 protection which makes them ideal for installation outdoors. This means that they can be used for making string boxes on the load side of photovoltaic strings.

The main features of the Europa series wall-mounted consumer units:

- class II insulation
- manufactured in self-extinguishing thermoplastic material able to withstand abnormal heat and fire up to 650 °C (glow wire test) in compliance with IEC 60695-2-11 standards
- installation temperature: -25 °C to +60 °C
- rated insulation voltage: 1000 V a.c.; 1500 V d.c.
- shock resistance: 6 joules (IK 08 degrees)
- pull-out DIN channel holder frame for more convenient bench wiring. Can be disassembled (and re-assembled by means of a snap-fit mechanism) to make the individual wires easier to route
- 53, 68 and 75 mm depth switchgear can be installed
- models with 8 or more modules equipped with bi-metal and rigid flanges for easier insertion of pipes and cables
- consumer units in compliance with IEC 23-48, IEC 23-49 and IEC 60670 standards- IMQ Mark

Description	Dimensions	Order code
IP65 consumer unit P/smoke grey 4M	140 x 220 x 140	12744
IP65 consumer unit P/smoke grey 8M	205 x 220 x 140	12748
IP65 consumer unit P/smoke grey 12M	275 x 220 x 140	12752
IP65 consumer unit P/smoke grey 8M 1 row	380 x 220 x 140	12753
IP65 consumer unit P/smoke grey 24M 2 rows	275 x 370 x 140	12754
IP65 consumer unit P/smoke grey 36M 2 rows	380 x 370 x 140	12755

Cable gland		Nut		Dimensions mm		
Description	Order code	Description	Order code	Gauge	Min	Max
M12 cable gland with metric pitch	00 951	Nut for M12 cable gland	00 96	12 x 1.5	3.5	7
M16 cable gland with metric pitch	00 952	Nut for M16 cable gland	00 962	16 x 1.5	5.5	10

Junction boxes

ABB also provides IP65 polycarbonate junction boxes that are perfect for use in outdoor installations.

The main features of the junction boxes are:

- class II insulation
- manufactured in self-extinguishing thermoplastic material able to withstand abnormal heat and fire up to 960 °C (glow wire test) in compliance with IEC 60695-2-11 standards
- installation temperature: -25 °C to +60 °C
- rated insulation voltage: 1000 V a.c.; 1500 V d.c.
- shock resistance: 20 joules (IK 10 degrees)
- junction boxes in compliance with IEC 23-48 and IEC 60670 standards
- IMQ Mark

Description	Dimensions	Order code
Box IP65 PC	140 x 220 x 140	12804
	205 x 220 x 140	12808
	275 x 220 x 140	12812

Modular terminal blocks

ABB produces a complete range of modular terminal blocks, from the conventional screw-clamp and spring-clamp versions to the most technologically advanced self-stripping connection that provides a quick, safe and reliable connection (ADO) by means of a special tool. The screw-clamp or ADO (self-stripping technology) versions are more suitable for photovoltaic applications as they provide a more reliable long term connection.
Innovative and compact, ABB's new SNK series terminal blocks feature a modern design and can be supplied with countless accessories to suit the customers' requirements. They comply with all worldwide standards.

Main technical specifications

Connection	New SNK series screw type	self-stripping type (ADO System)*	spring type
Voltage max	1000 V max	1000 V max	800 V
Current	max 232 A	max 32 A	max 125 A
Section	max 95 mm²	max 4 mm²	max 35 mm²

Conform to IEC 60947-7-1, IEC 60947-7-2 standards
Parallel interconnections are available
V0 self-extinguishing material

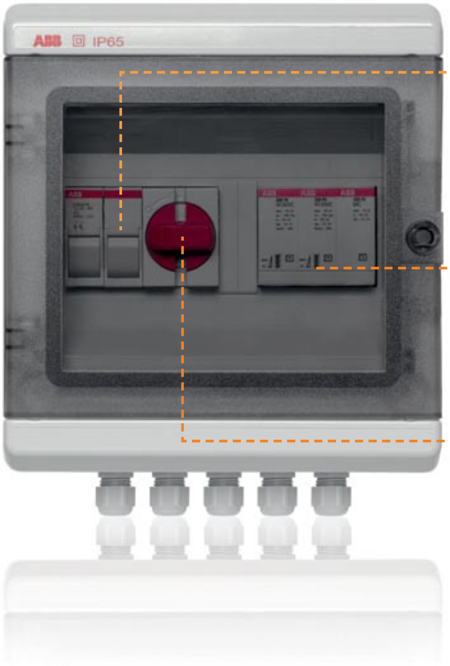
*Also available in the ADO-screw version

Description Type	Application	Section	I [A]	V [V]	Order code
Screw-screw terminal block					
ZS4	F	4 mm²	32	1000	1SNK505010R0000
ZS6	F	6 mm²	41	1000	1SNK506010R0000
ZS10	F	10 mm²	57	1000	1SNK508010R0000
ZS4-BL	N	4 mm²	32	1000	1SNK505020R0000
ZS6-BL	N	6 mm²	41	1000	1SNK506020R0000
ZS10-BL	N	10 mm²	57	1000	1SNK508020R0000
ZS4-PE	PE	4 mm²	480A/1s		1SNK505150R0000
ZS6-PE	PE	6 mm²	720A/1s		1SNK506150R0000
ZS10-PE	PE	10 mm²	1200A/1s		1SNK508150R0000

Accessories

End section	1SNK505910R0000
End stop	1SNK900001R0000
Circuit separator	1SNK900103R0000
Blank marker	1SNK149999R0000
Protective cover 5mm	1SNK900618R0000
Protective cover 6mm	1SNK900619R0000
Protective cover 8mm	1SNK900620R0000

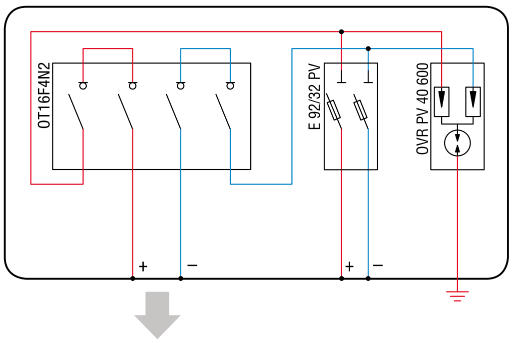
String boxes
1 string 16A 500V



Fuse Disconnectors E90 PV
E90 PV have been designed for up to 1000 V d.c. voltage values (class DC-20B) and are ideally used in photovoltaic systems to isolate the individual strings and protect them against short circuits.
All ABB string boxes are supplied with fuses as part of the standard equipment.

Surge Arresters OVR PV
All ABB string boxes are equipped with OVR PV series surge arresters specifically designed for photovoltaic applications. Only a specifically designed product can ensure that the cartridge functions properly until the end of its useful life, without the risk of short-circuits or dangerous polarity reversals.

Disconnectors OT
High-performance, readily available OT disconnectors stand out for their high voltage values and compliance with the most advanced international standards. They are an excellent choice for small systems both cost-wise and as to performance.



Note:
The following string boxes show options for 1, 2, 3 and 4 string.
Please consult us for other variations.

Direct current string boxes

One string 16 A 500 V

DC string box for string protection and isolation, consisting of:

– Europa series IP 65 wall-mounted 8-module consumer unit.
– disconnector OT 16 F4 N2
– surge arrester OVR PV 40 600 P
– fuse-disconnector E 92/32 PV 10.3 x 38 mm fuses – 1000 V d.c. 10 A
– 2.5 to 10 mm2 screw-clamp terminals (57 A) or above, for voltage up to 1000 V

Description	Dimensions (wxhxd mm)	Order code
DC string box 1str 16 A 500 V sd OT 16 F4 N2	205 x 220 x 140	1TVS151800S1991

One string 10 A 800 V

DC string box for string protection and isolation, consisting of:

– Europa series IP 65 wall-mounted 8-module consumer unit.
– miniature circuit-breaker S802 PV S10
– surge arrester OVR PV 40 1000 P
– 2.5 to 10 mm2 screw-clamp terminals (57 A) or above, for voltage up to 1000 V

Description	Dimensions (wxhxd mm)	Order code
DC string box 1str 10 A 800 V cd S802PV-S10	205 x 220 x 140	1TVS151800S1993

Direct current string boxes

Two strings 16 A 500 V

DC string box for string protection and isolation, consisting of:

– Europa series IP 65 wall-mounted 12-module consumer unit.
– disconnector OT 16 F4 N2
– surge arrester OVR PV 40 600 P
– fuse-disconnector E 92/32 PV 10.3 x 38 mm fuses – 1000 V d.c. 8 A
– 2.5 to 10 mm2 screw-clamp terminals (57 A) or above, for voltage up to 1000 V

Description	Dimensions (wxhxd mm)	Order code
DC string box 2str 16 A 500 V sd OT 16 F4 N2	275 x 220 x 140	1TVS151800S1995

Two strings 16 A 800 V

DC string box for string protection and isolation, consisting of:

– Europa series IP 65 wall-mounted 12-module consumer unit.
– miniature circuit-breaker S802 PV S16
– surge arrester OVR PV 40 1000 P
– 2.5 to 10 mm2 screw-clamp terminals (57 A) or above, for voltage up to 1000 V

Description	Dimensions (wxhxd mm)	Order code
DC string box 2str 16 A 800 V cb S802PV-S16	275 x 220 x 140	1TVS151800S1997

Direct current string boxes

Three strings 25 A 750 V

DC string box for string protection and isolation, consisting of:

– Europa series IP 65 wall-mounted 18-module consumer unit.
– disconnector OT 25 F8
– surge arrester OVR PV 40 1000 P
– fuse-disconnector E 92/32 PV 10.3 x 38 mm fuses – 1000 V d.c. 8 A
– 2.5 to 10 mm2 screw-clamp terminals (57 A) or above, for voltage up to 1000 V

Description	Dimensions (wxhxd mm)	Order code
DC string box 3str 25 A 750 V sd OT 25 F8	380 x 220 x 140	1TVS151800S1999

Three strings 32 A 800 V

DC string box for string protection and isolation, consisting of:

– Europa series IP 65 wall-mounted 18-module consumer unit.
– miniature circuit-breaker S802 PV-S32
– surge arrester OVR PV 40 1000 P
– fuse-disconnector E 92/32 PV 10.3 x 38 mm fuses – 1000 V d.c. 10 A
4A gR fuses for protecting OVR surge arrester
– 2.5 to 10 mm2 screw-clamp terminals (57 A) or above, for voltage up to 1000 V

Description	Dimensions (wxhxd mm)	Order code
DC string box 3str 32 A 800 V cb S802PV-S32	380 x 220 x 140	1TVS151800S2001

Four strings 32 A 750 V

DC string box for string protection and isolation, consisting of:

– Europa series IP 65 wall-mounted 36-module consumer unit.
– disconnector OT 40 F8
– surge arrester OVR PV 40 1000 P
– fuse-disconnector E 92/32 PV 10.3 x 38 mm fuses – 1000 V d.c. 10 A
4A gR fuses for protecting OVR surge arrester
– 2.5 to 10 mm2 screw-clamp terminals (57 A) or above, for voltage up to 1000 V

Description	Dimensions (wxhxd mm)	Order code
DC string box 4str 32 A 750 V sd OT 40 F8	380 x 370 x 140	1TVS151800S2003

Technical literature

Installation Equipment

2CSC400002D0208

MCCBs

1SDC210015D0204

Switch Disconnectors

1SCC301001C0201

SNK Series

1SNK161001C0201

5000 Series

1SNC160001C0207

Interface CM-UFS

1SDC112001L0901

Gemini Series

1SLC805001D0906

Contractor LV Essentials

http://view.digi-page.net/?id=1TXD00000P0209

Industrial LV Essentials

http://view.digi-page.net/?id=1TXD000001P0210

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Appendix B.5

1P C60N

2P C60N

3P C60N

Box Lug C60N

Ring Tongue C60N

Box/Ring C60N

Multi 9 C60N UL 489 Listed 240 V Miniature Circuit Breakers

- UL 489 Listed and CSA 22.2 No.5.1 for branch circuit protection
- Eliminates concerns and uncertainty of using a UL 1077 device where a UL 489 device is required
- Replaces fuses in low-ampere range; 17 ratings up to 35 A

Trip Curve	Use	Magnetic Release
C	For typical loads	7–10 x ampere rating (7–14 for DC)
D	For high inrush	10–14 x ampere rating

- 10 k AIR (1P @ 120 Vac; 2P and 3P @ 240 Vac)
- 60 Vdc for 1P and 125 Vdc for 2P (on C-curve circuit breakers only, see table below)
- Increased installation flexibility with standard box lugs or optional ring terminals
- Allows easy front-mounting and rear wiring when using ring terminals
- A wide range of electrical and mechanical accessories
- Suitable for reverse feeding
- Trip-free mechanism
- Positive indication of contact disconnect

Table 7.27: UL 489 Circuit Breakers (120/240 V)

Rating (A)	C Curve—7–10 Times Ampere Rating (7–14 DC)						D Curve—10–14 Times Ampere Rating					
	1P▲		2P■		3P		1P		2P		3P	
	Cat. No.	$ Price	Cat. No.	$ Price	Cat. No.	$ Price	Cat. No.	$ Price	Cat. No.	$ Price	Cat. No.	$ Price
Box Lug/Box Lug												
0.5	60100	125.00	60134	269.00	—	—	60117	125.00	60151	269.00	—	—
1	60101	125.00	60135	269.00	60168	387.00	60118	125.00	60152	269.00	60184	387.00
1.5	60102	125.00	60136	269.00	60169	387.00	60119	125.00	60153	269.00	60185	387.00
2	60103	125.00	60137	269.00	60170	387.00	60120	125.00	60154	269.00	60186	387.00
3	60104	125.00	60138	269.00	60171	387.00	60121	125.00	60155	269.00	60187	387.00
4	60105	125.00	60139	269.00	60172	387.00	60122	125.00	60156	269.00	60188	387.00
5	60106	125.00	60140	269.00	60173	387.00	60123	125.00	60157	269.00	60189	387.00
6	60107	114.00	60141	246.00	60174	356.00	60124	114.00	60158	246.00	60190	356.00
7	60108	114.00	60142	246.00	60175	356.00	60125	114.00	60159	246.00	60191	356.00
8	60109	114.00	60143	246.00	60176	356.00	60126	114.00	60160	246.00	60192	356.00
10	60110	114.00	60144	246.00	60177	356.00	60127	114.00	60161	246.00	60193	356.00
13	60111	114.00	60145	246.00	60178	356.00	60128	114.00	60162	246.00	60194	356.00
15	60112	114.00	60146	246.00	60179	356.00	60129	114.00	60163	246.00	60195	356.00
20	60113	114.00	60147	246.00	60180	356.00	60130	114.00	60164	246.00	60196	356.00
25	60114	114.00	60148	246.00	60181	356.00	60131	114.00	60165	246.00	60197	356.00
30	60115	120.00	60149	257.00	60182	372.00	60132	120.00	60166	257.00	60198	372.00
35	60116	120.00	60150	257.00	60183	372.00	60133	120.00	60167	257.00	60199	372.00
Ring Tongue/Ring Tongue												
0.5	60200	131.00	60234	282.00	—	—	60217	131.00	60251	282.00	—	—
1	60201	131.00	60235	282.00	60268	410.00	60218	131.00	60252	282.00	60284	410.00
1.5	60202	131.00	60236	282.00	60269	410.00	60219	131.00	60253	282.00	60285	410.00
2	60203	131.00	60237	282.00	60270	410.00	60220	131.00	60254	282.00	60286	410.00
3	60204	131.00	60238	282.00	60271	410.00	60221	131.00	60255	282.00	60287	410.00
4	60205	131.00	60239	282.00	60272	410.00	60222	131.00	60256	282.00	60288	410.00
5	60206	131.00	60240	282.00	60273	410.00	60223	131.00	60257	282.00	60289	410.00
6	60207	122.00	60241	261.00	60274	378.00	60224	122.00	60258	261.00	60290	378.00
7	60208	122.00	60242	261.00	60275	378.00	60225	122.00	60259	261.00	60291	378.00
8	60209	122.00	60243	261.00	60276	378.00	60226	122.00	60260	261.00	60292	378.00
10	60210	122.00	60244	261.00	60277	378.00	60227	122.00	60261	261.00	60293	378.00
13	60211	122.00	60245	261.00	60278	378.00	60228	122.00	60262	261.00	60294	378.00
15	60212	122.00	60246	261.00	60279	378.00	60229	122.00	60263	261.00	60295	378.00
20	60213	122.00	60247	261.00	60280	378.00	60230	122.00	60264	261.00	60296	378.00
25	60214	122.00	60248	261.00	60281	378.00	60231	122.00	60265	261.00	60297	378.00
30	60215	126.00	60249	273.00	60282	395.00	60232	126.00	60266	273.00	60298	395.00
35	60216	126.00	60250	273.00	60283	395.00	60233	126.00	60267	273.00	60299	395.00
Box Lug/Ring Tongue												
0.5	60300	129.00	60334	279.00	—	—	60317	129.00	60351	279.00	—	—
1	60301	129.00	60335	279.00	60368	404.00	60318	129.00	60352	279.00	60384	404.00
1.5	60302	129.00	60336	279.00	60369	404.00	60319	129.00	60353	279.00	60385	404.00
2	60303	129.00	60337	279.00	60370	404.00	60320	129.00	60354	279.00	60386	404.00
3	60304	129.00	60338	279.00	60371	404.00	60321	129.00	60355	279.00	60387	404.00
4	60305	129.00	60339	279.00	60372	404.00	60322	129.00	60356	279.00	60388	404.00
5	60306	129.00	60340	279.00	60373	404.00	60323	129.00	60357	279.00	60389	404.00
6	60307	120.00	60341	257.00	60374	372.00	60324	120.00	60358	257.00	60390	372.00
7	60308	120.00	60342	257.00	60375	372.00	60325	120.00	60359	257.00	60391	372.00
8	60309	120.00	60343	257.00	60376	372.00	60326	120.00	60360	257.00	60392	372.00
10	60310	120.00	60344	257.00	60377	372.00	60327	120.00	60361	257.00	60393	372.00
13	60311	120.00	60345	257.00	60378	372.00	60328	120.00	60362	257.00	60394	372.00
15	60312	120.00	60346	257.00	60379	372.00	60329	120.00	60363	257.00	60395	372.00
20	60313	120.00	60347	257.00	60380	372.00	60330	120.00	60364	257.00	60396	372.00
25	60314	120.00	60348	257.00	60381	372.00	60331	120.00	60365	257.00	60397	372.00
30	60315	125.00	60349	269.00	60382	387.00	60332	125.00	60366	269.00	60398	387.00
35	60316	125.00	60350	269.00	60383	387.00	60333	125.00	60367	269.00	60399	387.00

▲ 1P dual rated 120 Vac/60 Vdc.
■ 2P dual rated 240 Vac/125 Vdc.

Interrupting ratings . . . . Page 7-3
Accessories . . . . Page 7-20
Dimensions . . . . Page 7-54
Mounting Bases . . . . Page 7-13
DIN Mounting Rail . . . . Section 18

		QOU Circuit Breakers				QOM1 and QOM2 Main Circuit Breakers		Multi 9™ Circuit Breakers and Supplementary Protectors								EDB Circuit Breakers					
																					
Circuit Breaker Type	**Plug-on**	—			—	—	—	—			—					—		—		—	
	Bolt-on	—			—	QOM1-VH	QOM2-VH	—			—			New!		EDB		EGB		EJB	
	Unit Mount	QOU			QYU▲	—	—	UL 489 C60N			UL1077 C60N■			C60H-DC		—		—		—	
Number of Poles		1	2	3	1	2	2	1	2	3	1	2	3,4	1	2	1	2,3	1	2,3	1	2,3
Current Range		10–100	10–125	10–100	10–30	50–125	100–225	0.5–35	0.5–35	0.5–35	0.5–63	1–63	1–63	0.5–40	0.5–40	15–70	15–125	15–70	15–125	15–70	15–125
Interrupting Ratings																					
UL/CSA Rating (kA RMS) (50/60 Hz)	120 Vac	10	10	10	—	22	22	10	—	—	10	10	10	—	—	25	25	65	65	100	100
	120/240 Vac	10	10	10	—	22	22	5	10	10	10	10	10	—	—	18	25	35	65	65	100
	240 Vac♦	—	—	10	—	—	—	5	10	10	10	10	10	—	—	18	25	35	65	65	100
	277 Vac	—	—	—	5	—	—	—	—	—	5	5	5	—	—	18	18	35	35	65	65
	480Y/277 Vac	—	—	—	—	—	—	10	10	10	—	5	5	—	—	—	18	—	35	—	65
DC Ratings	48 Vdc	5★	5★	5★	—	—	—	—	—	—	10	10	—	5	5	—	—	—	—	—	—
	60 Vdc	5▼	5▼	5▼	—	—	—	10	10	—	—	—	—	5	5	—	—	—	—	—	—
	65 Vdc	—	—	—	—	—	—	—	—	—	10	10	—	5	5	—	—	—	—	—	—
	125 Vdc	—	—	—	—	—	—	—	10	—	—	10	—	5	5	—	—	—	—	—	—
	250 Vdc	—	—	—	—	—	—	—	—	—	—	—	—	5	5	—	—	—	—	—	—
	500 Vdc	—	—	—	—	—	—	—	—	—	—	—	—	—	5◒	—	—	—	—	—	—
IEC 60947-2 (50/60 Hz) Icu	240 Vac	—	—	—	—	—	—	20	20	20	10	10	10	20	10	20	—	—	—	—	—
	415 Vac	—	—	—	—	—	—	—	10	10	—	5	5	—	—	10	—	—	—	—	—
Special Ratings																					
Fed. Specs W-C-375B/GEN		X	X	X	X	X	X	X	X	X	—	—	—	—	—	X	X	X	X	X	X
Other Standard		HACR △			—	—	—	—	—	—	◻	—	—	—	—	HACR					
Accessories and Modifications																					
Shunt Trip		X◊	X◊	X◊	X◊	—	X ◊	X	X	X	X	X	X	X	X	X ◊	X ◊	X ◊	X ◊	X ◊	X ◊
Undervoltage Trip		—	—	—	—	—	—	X	X	X	X	X	X	X	X	—	—	—	—	—	—
Auxiliary Switches		X◊	X◊	X◊	X◊	—	—	X	X	X	X	X	X	X	X	X◊	X◊	X◊	X◊	X◊	X◊
Alarm Switch		X◊	X◊	X◊	X◊	—	—	X	X	X	X	X	X	X	X	X◊	X◊	X◊	X◊	X◊	X◊
Handle Operators		—	—	—	—	—	—	X	X	X	X	X	X	X	X	—	—	—	—	—	—
Handle Padlock Attachment		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Trip System Type																					
Thermal-magnetic		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Molded Case Switch		—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dimensions (1P Unit Mount)																					
Dimensions (1P Unit Mount) in. (mm)	Height	4.05 (103)				5.09 (129)☆	5.60 (142)☆	4.21 (107)▽			3.19 (81)			3.19 (81)		5.66 (144)					
	Width	0.75 (19)				5.00 (127)☆	5.07 (129)☆	0.71 (18)			0.71 (18)			0.71 (18)	1.42 (36)	0.98 (25)					
	Depth	2.92 (74)				3.47 (88)☆	3.60 (91)☆	2.76 (70)			2.76 (70)			2.56 (65)		4.05 (103)					
Pages		Pages 7-14				Pages 1-2		Pages 7-16 through 7-19								Page 9-17					

Note: All circuit breakers on this chart are UL Listed and CSA Certified unless otherwise noted.

- ▲ QYU is a UL 1077 supplementary protector.
- ■ C60N are recognized components per UL 1077.
- ♦ For information regarding 3Ø corner grounded systems see the Supplemental Digest.
- ★ 1P and 2P, 10–70 A and 3P 10–60 A only.
- ▼ QOU is UL Listed for 60 Vdc per pole 80–100 A, 1P; 80–125 A, 2P; and 70–100 A, 3P.
- △ HACR on QOU 1P and 3P 15–100 A, 2P 15–125 A;
- ◻ UL 489A for DC Telecom applications (1-pole only).
- ◊ Factory-installed option only
- ☆ QOM1 and QOM2 dimensions are for 2-pole unit.
- ▽ 480 V C60 height is 5.56 in. (141 mm).
- ◒ 2 poles must be wired in series for 500 Vdc.

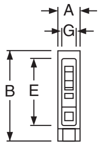


Figure 1

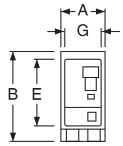


Figure 2

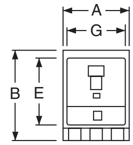
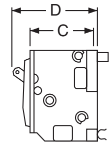


Figure 3



QO, QOB

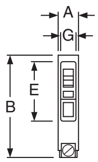


Figure 4

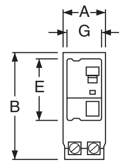
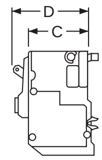


Figure 5



QO-GFI, QO-PL
QO-EPD

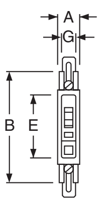


Figure 6

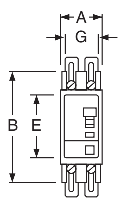


Figure 7

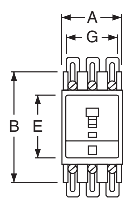
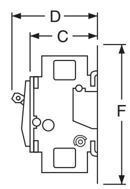


Figure 8



QOU, QYU
Low Ampere

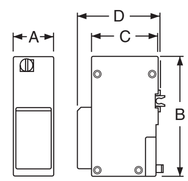


Figure 9
QO-PLPS

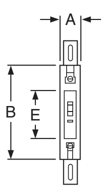


Figure 10

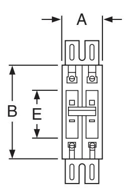


Figure 11

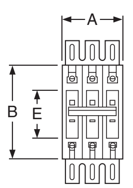
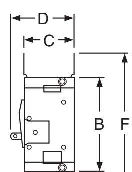


Figure 12



QOU
High Ampere

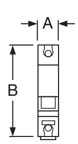


Figure 13

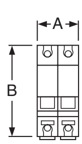


Figure 14

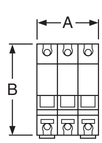


Figure 15

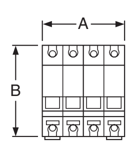
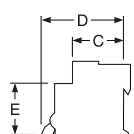


Figure 16



C60

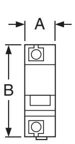


Figure 17

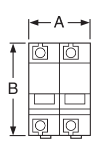


Figure 18

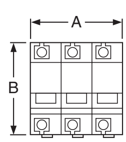


Figure 19

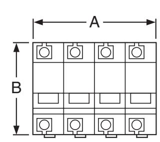
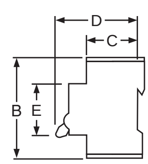


Figure 20



C120

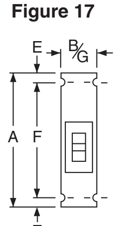


Figure 21

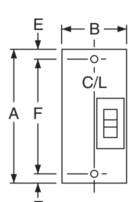


Figure 22

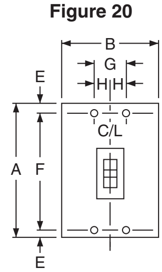
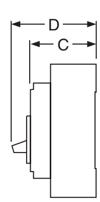


Figure 23



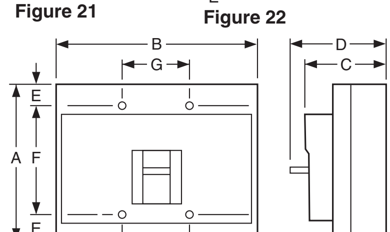


Figure 24

Table 7.140: QO®, QOU, Multi 9™ Circuit Breakers

Circuit Breaker Cat. No. Prefix	Poles	Fig. No.	Dimensions—Inches						
			A	B	C	D	E	F	G
QO, QOB	1	1	0.75	3.00▲	2.31	2.91	2.25	—	0.59
	2	2	1.50	3.00▲	2.31	2.91	2.25	—	1.34
	3	3	2.25	3.00▲	2.31	2.91	2.25	—	2.09
QOB-VH 150 A	2	2	3.0	5.72	2.53	4.90	3.78	—	2.85
QOB-VH 110–150 A	3	3	4.50	5.72	2.53	4.90	3.78	—	4.35
QO-PL, QO-GFI, QO-EPD	1	4	0.75	4.12■	2.31	2.91	2.25	—	0.59
	2	5	1.50	4.12■	2.31	2.91	2.25	—	1.34
	3	5	2.25	4.12■	2.31	2.91	2.25	—	2.09
QOU, QYU, Low Ampere	1	6	0.75	4.05♦	2.38	2.98	2.25	5.00★	0.62
	2	7	1.50	4.05♦	2.38	2.98	2.25	5.00★	1.37
	3	8	2.25	4.05★	2.38	2.98	2.25	5.00△	2.12
QOU High Ampere	1	10	0.75	4.45	2.37	2.96	2.25	6.78	—
	2	11	1.50	4.45	2.37	2.96	2.25	6.78	—
	3	12	2.25	4.45	2.37	2.96	2.25	6.78	—
Multi 9™ C60N	1	13	0.71	3.19	1.73	2.76	1.77	—	—
	2	14	1.42	3.19	1.73	2.76	1.77	—	—
	3	15	2.13	3.19	1.73	2.76	1.77	—	—
	4	16	2.84	3.19	1.73	2.76	1.77	—	—
QO-PLPS Power Supply	2	9	1.45	4.35	2.42	3.11	—	—	—

▲ 35–70 A is 3.12 in; 80–100 A 2P and 70–100 A 3P are 3.50 in.
■ QO-PL is 4.55 in.
♦ 80–100 A 1P and 80–125 A 2P are 4.45 in
★ 80–100 A 1P and 80–125 A 2P are 6.78 in.
▼ 70–100 A 4.45 in.
△ 70–100 A is 6.78 in.

Table 7.141: QB, QD, QG, QJ, Q4, FA, FI, KA, KC, KI, LA, LC, LI, LE, LX, LXI, MA Circuit Breakers

Circuit Breaker Cat. No. Prefix	Poles	Fig. No.	Dimensions—Inches							
			A	B	C	D	E	F	G	H
QB, QD, QG, QJ	2	22	6.47	3.00	3.02	3.93	◻	4.25	—	—
	3	23	6.47	4.50	3.02	3.93	◻	4.25	1.50	0.75
FAL, FHL	1	21	6.00	1.50	3.16	4.13	0.44	5.13	1.50	—
	2	22	6.00	3.00	3.16	4.13	0.44	5.13	—	—
	3	23	6.00	4.50	3.16	4.13	0.44	5.13	1.50	0.75
FIL, KAL, KCL, KHL, KIL	2 & 3	23	8.00	4.50	3.66	4.75	0.44	7.13	1.50	0.75
Q4L, LAL, LHL	2 & 3	23	11.00	6.00	4.06	5.84	0.88	9.25	2.00	1.00
LIL, LEL, LXL, LXIL, LCL	2 & 3	24	11.86	7.50	5.48	6.74	0.55	10.75	2.50	
MAL, MHL	2 & 3	23	14.00	9.00	4.53	6.50	1.66	10.69	3.00	1.50

◻ Dimensions E are 1.59 in at ON end and 0.63 in at OFF end.

Table 7.142: Shipping Weights◊

Frame Size	Approx. Shipping Weight (Lbs.)	Frame Size	Approx. Shipping Weight (Lbs.)
FAL, FHL 1P	2	KIL	9
FAL, FHL 2P	3	LAL, LHL	15
FAL, FHL 3P	5	LEL, LIL, LXL, LXIL, LCL	25
FIL	8	Q4L	15
QB, QD, QG, QJ	4	MAL, MHL	34
KAL, KHL	7		

◊ All weights are for 3P circuit breakers unless otherwise noted.

PVI-12.0-I

-S1 version

GENERAL SPECIFICATIONS
OUTDOOR MODELS

-S2 version

Designed for commercial usage, this three-phase inverter is highly unique in its ability to control the performance of the PV panels, especially during periods of variable weather conditions.
This device has two independent MPPTs and efficiency ratings of up to 97.3%.

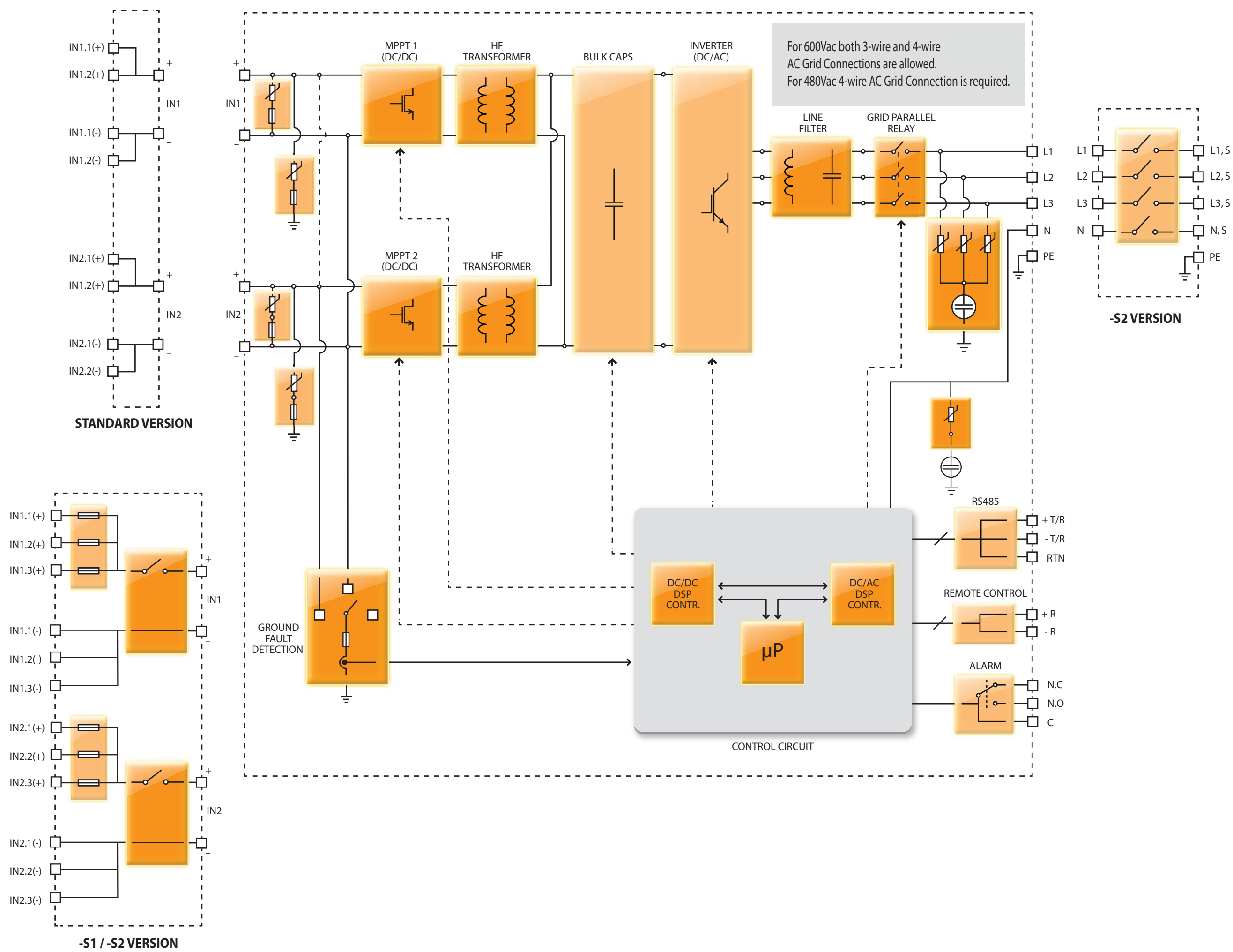
The input voltage range makes the inverter suitable to installations with reduced string size. The HF isolation allows positive or negative ground configuration.

It is available with an optional fully-integrated DC combiner box equipped with DC or AC and DC disconnect switches and DC fuses. The unit is free of electrolytic capacitors, leading to a longer product lifetime and reliability.

Features

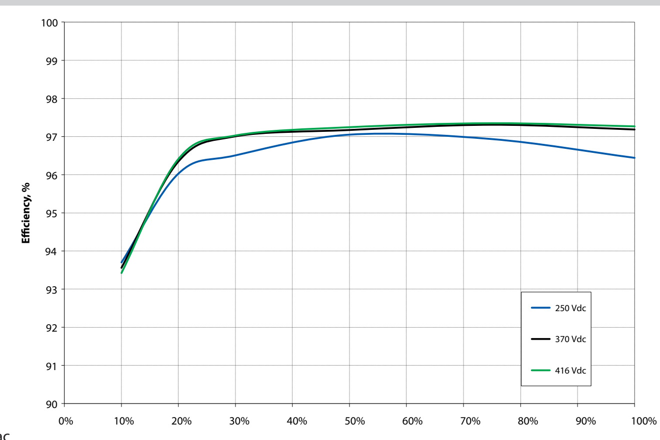
- High speed and precise MPPT algorithm for real time power tracking and improved energy harvesting
- Flat efficiency curves ensure high efficiency at all output levels ensuring consistent and stable performance across the entire input voltage and output power range
- ‘Electrolyte-free’ power converter to further increase the life expectancy and long term reliability
- True three-phase bridge topology for DC/AC output converter
- Night wake up button to access energy harvesting data and error log when inverter is sleeping
- Dual input sections with independent MPPT, allows optimal energy harvesting from two sub-arrays oriented in different directions
- NEMA 4X outdoor enclosure for unrestricted use under any environmental conditions
- Integrated combiner box equipped with a DC switch in compliance with international standards (-S1,-S2)
- RS-485 communication interface (for connection to laptop or datalogger)
- Compatible with PVI-RADIOMODULE for wireless communication with Aurora PVI-DESKTOP

BLOCK DIAGRAM OF PVI-12.0-I FOR NORTH AMERICA



Block Diagram and Efficiency Curves

PVI-12.0-I*



* Efficiency shown for inverters operating at 480Vac

TECHNICAL DATA	VALUES	PVI-12.0-I-OUTD-US	PVI-12.0-I-OUTD-CAN	
Nominal Output Power	W	12000	12000	12000
Maximum Output Power	W	13200**	12000***	12000***
Rated Grid AC Voltage	V	480	480	600
Input Side (DC)				
Number of Independent MPPT Channels		2; programmable as a single paralleled input	2; programmable as a single paralleled input	
Maximum Usable Power for Each Channel	W	6800	6800	
Absolute Maximum Voltage (Vmax)	V	520	520	
Start- Up Voltage (Vstart)	V	200 (Adj. 120-350)	200 (Adj. 120-350)	
Full Power MPPT Voltage Range	V	250-470	250-470	
Operating MPPT Voltage Range	V	0.7 x Vstart-520	0.7 x Vstart.-520	
Maximum Current (Idcmax) for both MPPT in Parallel	A	50	50	
Maximum Usable Current per Channel	A	25	25	
Maximum Short Circuit Current Limit per Channel	A	29	29	
Number of Wire Landing Terminals per Channel		Standard version: 2; -S1/-S2 version: 3	Standard version: 2; -S1/-S2 version: 3	
Array Wiring Termination Type		Terminal Block, Pressure Clamp, 20AWG-6AWG	Terminal Block, Pressure Clamp, 20AWG-6AWG	
Output Side (AC)				
Grid Connection Type		3Ø/4W+Ground	3Ø/4W+Ground	3Ø/3W or 4W+Ground
Adjustable Voltage Range (Vmin-Vmax)	V	422-528	422-528	528-660
Grid Frequency	Hz	60	60	
Adjustable Grid Frequency Range	Hz	57-63	57-63	
Maximum Current (Iac max)	A_{RMS}	16.0	16.0	12.8
Power Factor		>0.995 (+/-0.9)	>0.995 (+/-0.9)	
Total Harmonic Distortion At Rated Power	%	<2	<2	
Grid Wiring Termination Type		Terminal Block, Pressure Clamp, 12AWG-4AWG	Terminal Block, Pressure Clamp, 12AWG-4AWG	
Protection Devices				
Input				
Reverse Polarity Protection		Yes	Yes	
Over-Voltage Protection Type		Varistor, 2 for each channel	Varistor, 2 for each channel	
PV Array Ground Fault Detection		GFDI (GFD fuse) per UL1741/NEC690.5 (A)	GFDI (GFD fuse) per UL1741/NEC690.5 (A)	
Output				
Anti-Islanding Protection		Meets UL1741/IEEE1547 requirements	Meets UL1741/IEEE1547 requirements	
Over-Voltage Protection Type		3 + gas arrester Varistor, One per line + spark gap to Ground	3 + gas arrester Varistor, One per line + spark gap to Ground	
Efficiency				
Maximum Efficiency	%	97.3	97.3	
CEC Efficiency	%	97.0	97.0	
Operating Parameters				
Feed-In Power Threshold	W_{RMS}	30	30	
Stand-by Consumption	W_{RMS}	< 8	< 8	
Communication				
User-Interface (Display)		16 Characters X 2 lines LCD display	16 Characters X 2 lines LCD display	
Remote Monitoring (1xRS485 incl.)		AURORA-UNIVERSAL (opt.)	AURORA-UNIVERSAL (opt.)	
Wired Local Monitoring (1xRS485 incl.)		PVI-USB-RS485_232 (opt.), PVI-DESKTOP (opt.)	PVI-USB-RS485_232 (opt.), PVI-DESKTOP (opt.)	
Wireless Local Monitoring		PVI-DESKTOP (opt), with PVI-RADIO MODULE (opt)	PVI-DESKTOP (opt), with PVI-RADIO MODULE (opt)	
Environmental				
Ambient Air Operating Temperature Range	F(°C)	-13 to +140 (-25 to +60) Derating above +113 (+45)	-13 to +140 (-25 to +60) Derating above +113 (+45)	
Ambient Air Storage Temperature Range	F(°C)	-40 to +176 (-40 to +80)	-40 to +176 (-40 to +80)	
Relative Humidity	%RH	0-100 condensing	0-100 condensing	
Acoustic Noise Emission Level	db (A) @1m	<50	<50	
Maximum Operating Altitude without Derating	ft(m)	6560 (2000)	6560 (2000)	
Mechanical Specifications				
Enclosure rating		NEMA 4X	NEMA 4X	
Cooling		Natural Convection	Natural Convection	
Dimensions (H x W x D)	in//mm	28.2" x 25.4" x 8.7" / 716mm x 645mm x 222mm // 37.7" x 25.4" x 8.7" / 958mm x 645mm x 222mm (-S/-S1/-S2 version)	28.2" x 25.4" x 8.7" / 716mm x 645mm x 222mm // 37.7" x 25.4" x 8.7" / 958mm x 645mm x 222mm (-S/-S1/-S2 version)	
Unit Weight	lbs(kg)	101(45.8) (US version); 107(48.5) (S1 version); 114(51.7)(S2 version)	101(45.8) (US version); 107(48.5) (S1 version); 14(51.7)(S2 version)	
Shipping Weight	lbs(kg)	with pallet: 254(<115); without pallet: 143 (<65)	with pallet: 254(<115); without pallet: 143 (<65)	
Conduit Connections		Bottom: (1) 1/2" EKO,(2) 1" pluggable opening, (4) 1/2" pluggable openings / Left and Right Side: (1) Concentric EKOs 3/4", 1" Back: (2) Concentric EKOs 3/4", 1", (2) Concentric EKOs 3/4", 1"	Bottom: (1) 1/2" EKO,(2) 1" pluggable opening, (4) 1/2" pluggable openings / Left and Right Side: (1) Concen-tric EKOs 3/4", 1" Back: (2) Concentric EKOs 3/4", 1", (2) Concentric EKOs 3/4", 1"	
Mounting System		Wall Brackett	Wall Brackett	
Ground Fault Detector Fuse Size/ Type	A/V / mm	1/600/10x38	1/600/10x38	
Optional String Combiner Fuse Size/Type	A, A/V / mm	12, 15/600/10x38	12, 15/600/10x38	
DC Switch Current Rating (Per Contact)	A	32	32	
Safety				
Isolation Level		Isolated - High Frequency transformer	Isolated - High Frequency transformer	
Safety and EMC Standard		UL1741, CSA22.2 #107.1-01	UL1741, CSA22.2 #107.1-01	
Safety Approval		$_{c}$CSA$_{us}$	$_{c}$CSA$_{us}$	
Warranty				
Standard Warranty	Years	10	10	
Extended Warranty	Years	15 & 20	15 & 20	
Available Models				
Standard		PVI-12.0-I-OUTD-US-480-NG	PVI-12.0-I-OUTD-CAN-480-NG	PVI-12.0-I-OUTD-CAN-480-NG
With DC Switch and DC Fuses		PVI-12.0-I-OUTD-S1-US-480-NG	PVI-12.0-I-OUTD-S1-CAN-480-NG	PVI-12.0-I-OUTD-S1-CAN-600-NG
With AC and DC Switches and DC Fuses		PVI-12.0-I-OUTD-S2-US-480-NG	PVI-12.0-I-OUTD-S2-CAN-480-NG	PVI-12.0-I-OUTD-S2-CAN-600-NG

*All data is subject to change without notice

**Capability enabled at power-factor of +/-.995 and with sufficient DC power available.

***Inverter can be field configured to output up to 110% of rated power under certain conditions

Ver. 2012-03.1-NA - All products are subject to technical improvements without notice .

www.power-one.com

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Singapore	Asia Pacific	+65 6896 3363	sales.singapore@power-one.com
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Italy	Europe	00 800 00287672 Opt. n°5	sales.italy@power-one.com
Spain	Europe	+34 91 879 88 54	sales.spain@power-one.com
United Kingdom	Europe	+44 1903 823 323	sales.UK@power-one.com
Dubai	Middle East	+971 50 100 4142	sales.dubai@power-one.com
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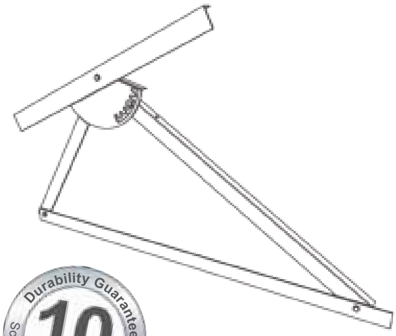
USA Central	North America	+1 877 261-1374	sales.usacentral@power-one.com
USA West	North America	+1 877 261-1374	sales.usawest@power-one.com

VarioTop

The adjustable flat roof support with summer and winter setting



- 10 % annual extra yield on average
- Complete string can be adjusted by one person within a few minutes
- The modules remain virtually snow free in the winter time
- Wide adjusting range (10 to 60 degrees)

Description

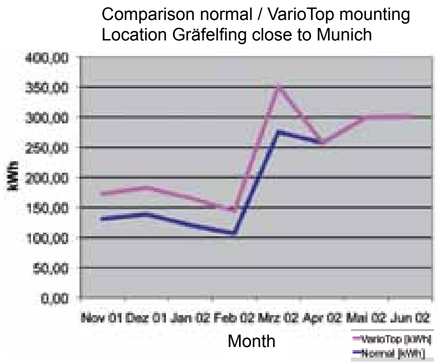
The **VarioTop** – support is made of aluminium L-angles and an aluminium turn-tilt plate. The turning mechanism is welded free of play in order to avoid wind noises. Fixed angle settings in steps of 10 degrees are marked on the turn-tilt plate.
A module row is usually mounted with two cross beams onto a row of supports. So it can be tilted as a whole. A plant with 1kW can be adjusted by one person within one or two minutes, for example.
The VarioTop support can be screwed directly onto the substructure or can also be combined with all kinds of fixation elements (gravel trays, Kalzip clamps, standing seam clamps, roof hooks, etc.).

Areas of application

The **VarioTop**- support is especially suitable for flat roof plants on schools, community projects, shareholding projects etc.. The economic efficiency calculation of a plant is considerably improved by the additional yield of 10%. Moreover, many customers want to be able to operate their plants themselves.
All in all, VarioTop gives you the opportunity to offer your customers a considerable advantage in comparison to your competitors! Just offer VarioTop as an alternative to fixed elevations!

Due to the tendency to keel over, we recommend an installation in combination with the KompaktVario system in case of multi-row elevations on flat roofs with burden-stabilized supports (stabilized with gravel or concrecte blocks, for example)

Economic efficiency

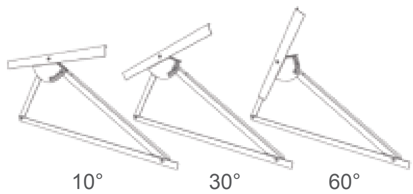


In comparison to plants with fixed elevation angles, plants with VarioTop are very efficient economically:

- By means of a steeper setting in the winter half year, a more favourable irradiation angle can be obtained.
- At a setting of 60 degrees in the winter half year, the modules remain virtually snow-free.
- The extra yield of 10% (measured in Greater Munich) improves the economic efficiency of the plant by 10%, the extra cost for VarioTop only have an effect on the costsd of the mounting system, and therefore only has little influence on the overall investment costs have relatively little effect.
- The adjustment only requires little effort (about one to two minutes ones or twice a year for a plant with 1kW). Normally, the adjustment can be combined with regular maintenance intervals.

The extra yields measured (see chart at the right) were measured with settings of 60 degrees in the winter half year and 30 degrees in the summer half year. More frequent adaptions in smaller steps are possible at any time. Information on solar altitude can be found on the internet (in Germany: www.stadtklima.de). The following chart gives a short overview for South Germany:

Jan	Feb	Mrz	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez
19	27	39	50	61	66	63	55	44	31	22	18



Technical data

Material	Aluminium / high-grade steel 1.4301
Structural analysis and loading	System structural analysis acc. to DIN 1055, part 4 (03/2005), part 5 (06/2005), Eurocode 1 (available on the internet in the form of charts)
Base length	1545 mm
Setting range	10 to 60 degrees
Weight	7 kg
Fixed settings	Steps of 10 degrees (labelled)
Structural analysis	DIN 1055 new and Eurocode 1 Exact data on request
Substructures	• Concrete blocks, • Sheet metal roofs (on standing seam clamps, Kalzip clamps, etc.) • Bitumen roof • Pantile roof • Foundations (for open area elevations) • etc.

Get all system prices fast and easy with our auto - calculator!

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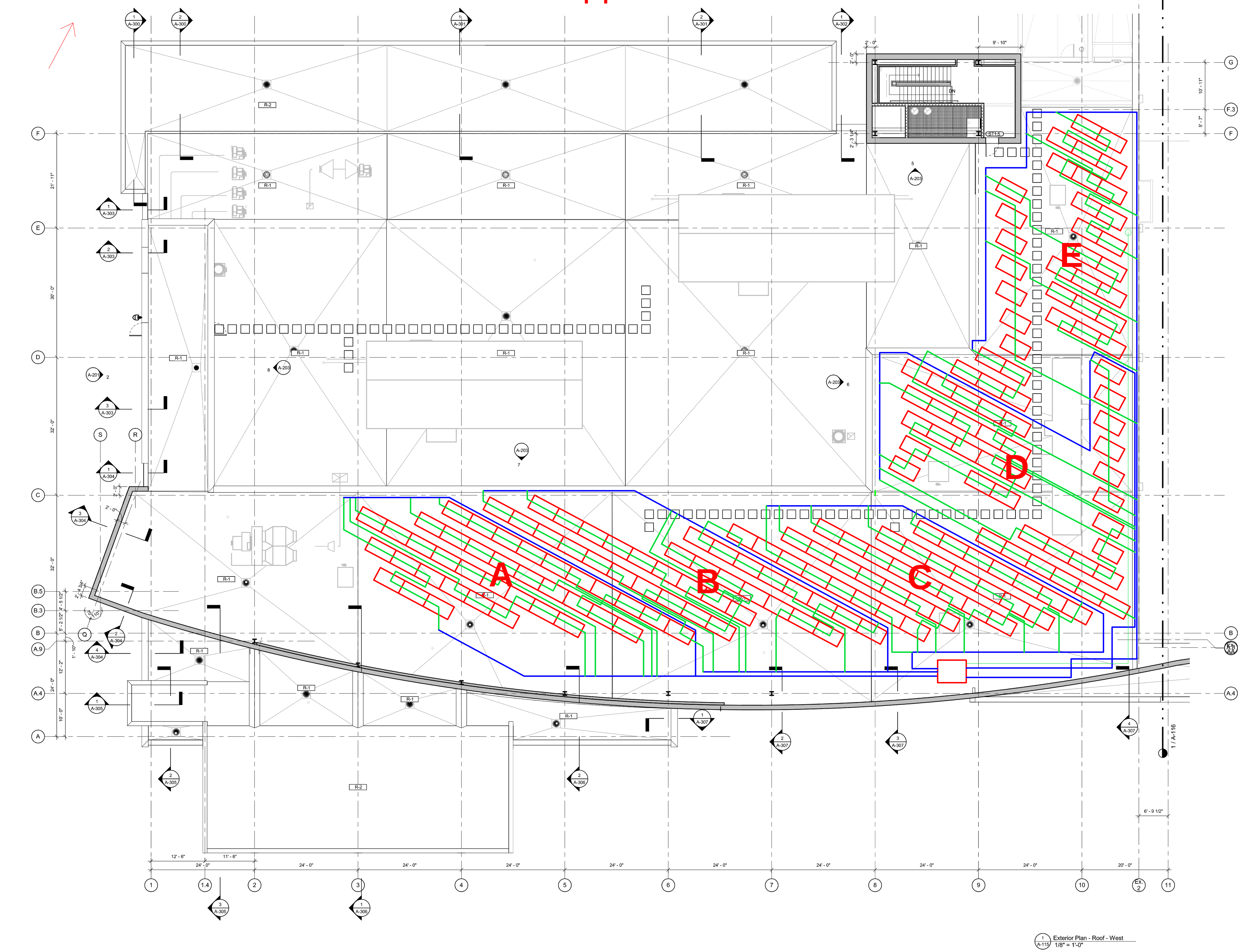
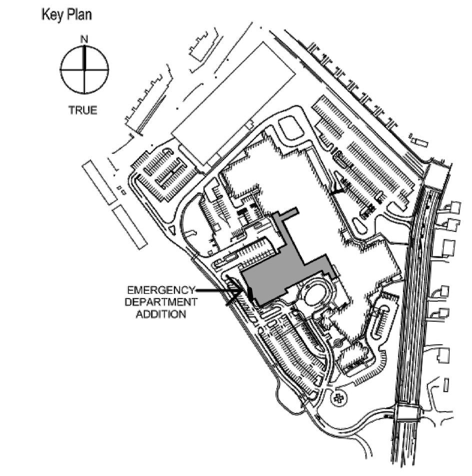
Appendix B.8



No.	Description	Date

Key Plan



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http://www.barryisett.com

Construction Manager:
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21st Floor
Philadelphia, PA 19103
Phone: (215) 496-8800
www.turnerconstruction.com

It is the responsibility of the Construction Manager/General Contractor and all Sub-Contractors to verify all dimensions and accept conditions of prior work by related trades before proceeding with any work.

Date
10/26/2012

Drawn By
Author

Scale
1/8" = 1'-0"

Seal

Checker

Francis Cauffman

Project Title
Aria Health System - Torresdale Campus

New Emergency Dept & Patient Medical Tower

10800 Knights Road
Philadelphia, Pennsylvania, 19114

Project Number
F11-5892

Drawing Title and Number
Roof - Core & Shell Plan West

A-115

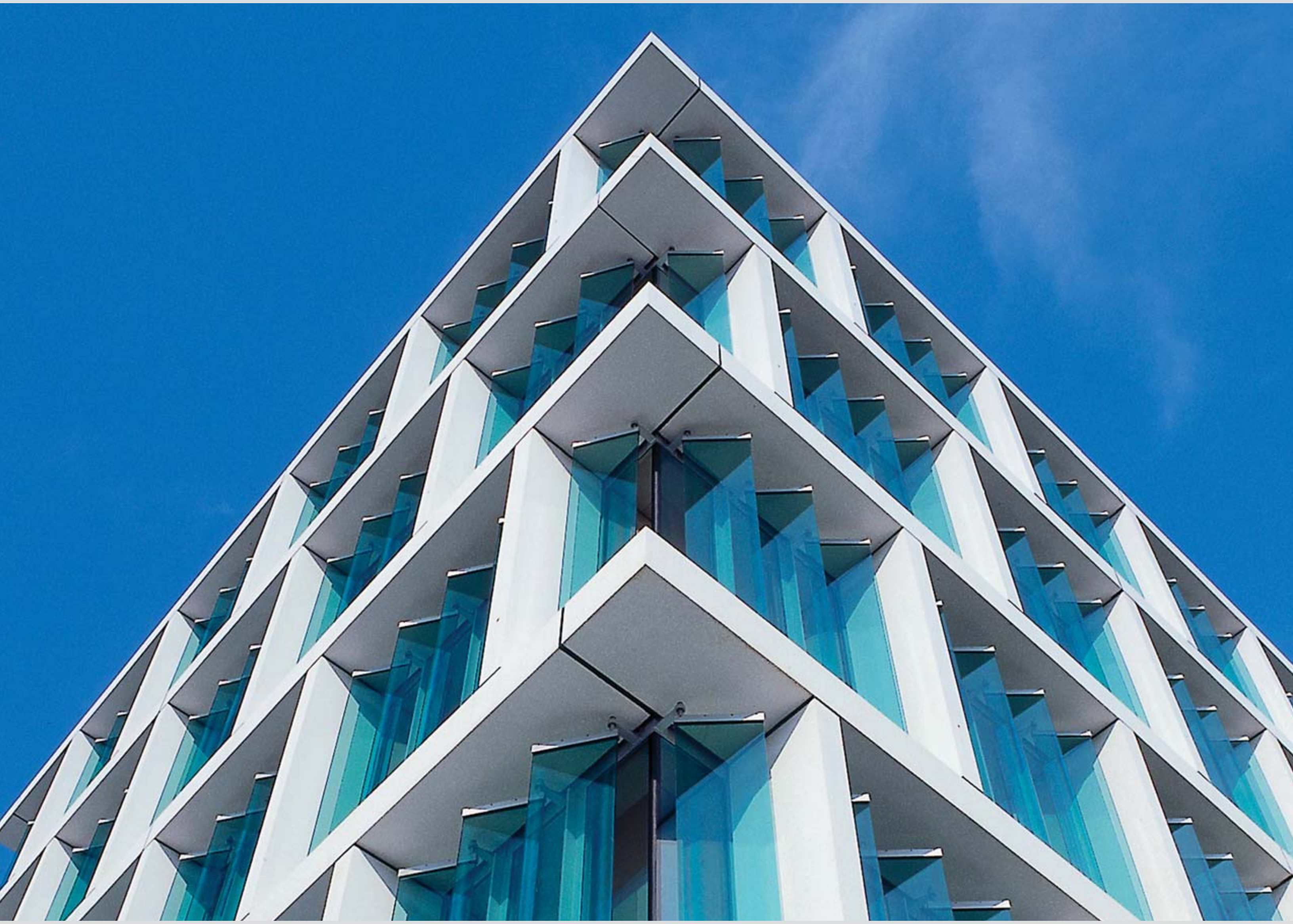
CONSTRUCTION DOCUMENTS ISSUE - 10/26/2012

Appendix C

Operable Solar Shading

Appendix C.1

Solar Shading Louver Systems



IntelligentEnvelopes™

Introduction

Mestek has a strategic alliance and exclusive licence agreement with Colt Group USA. Mestek is the exclusive licensee to produce and market the Colt designed products for the US market and all products are produced in the USA.

Additionally, Mestek's Architectural activities include Linel and AWV. The emphasis for these companies is in providing products and solutions that beautify and improve the performance of buildings through Intelligent Envelopes™.

MESTEK
ARCHITECTURAL
IntelligentEnvelopes™

The movement toward sustainable building designs is being driven largely by environmentally-sensitive building owners and/or their prospective tenants. As these owners and their consultants weigh their design objectives and alternatives, they often find that exterior solar shading systems are an ideal part of the "green" solution for their buildings.

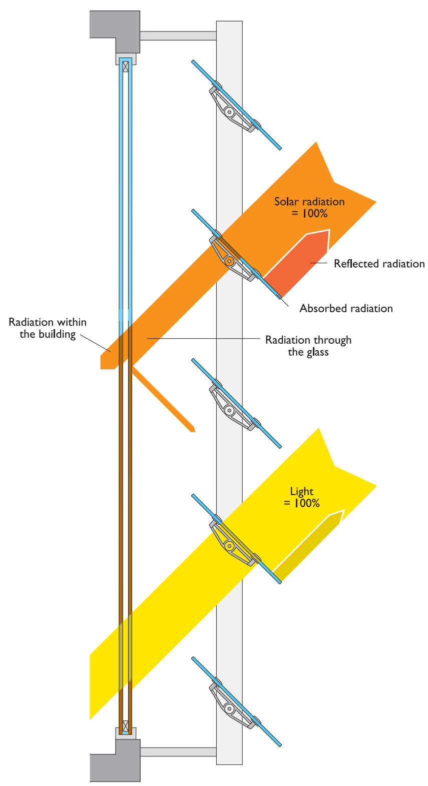
An exterior solar shading system blocks a significant amount of the solar radiation from entering the building's windows - which results in reduced HVAC installed costs due to equipment down-sizing and reduces operating costs due to reduced cooling loads.

Indeed, some form of exterior solar shading is now part of the prescriptive design requirements in the new Standard for the Design of High Performance, Green Buildings, except for Low-rise Residential Buildings (ANSI, ASHRAE's, USGBC, IES 189.1).

SHADING LOUVERS

Solar shading louver systems are one of the most effective ways to reduce air conditioning loads, while offering designers the opportunity for distinctive architectural impact.

Radiation from the sun is transmitted, absorbed and reflected by the louvers. As a result solar heat gain is prevented from passing into the building. If an operable system is chosen, the adjustable louvers will track the position of the sun increasing the systems shading effectiveness and further reducing glare. On overcast days, the operable louvers can be opened to maximize the natural daylight into the building.



COLT'S OFFERING

- Computer modeling of the solar shading louver system including calculation of sun angles and reduction in solar heat gains by exposure throughout the year.
- All Colt solar shading louver systems are custom designed for your application and can be provided in various configurations, materials, finishes and coatings to meet each project's requirements.
- Two control options are available for the operable systems – SolTronic III for most projects and the ICS 4-link for very large projects with additional functionality.
- All systems are durable with low maintenance needs.

COLT'S TRACK RECORD & CAPABILITIES

Colt has more than 40 years experience in the design and supply of solar shading louver systems. Colt was the first to incorporate electricity generating photovoltaic cells into solar shading systems. Colt continues to build on this experience and has been providing solar shading systems for the US market since 2006.

We offer an extraordinary range of solar shading systems from fixed to fully operable with a variety of carrier systems, materials and finishes.

Colt is dedicated to innovation and has comprehensive design capabilities. While this brochure provides a general overview of our capabilities, we welcome the opportunity to develop solutions to satisfy your unique requirements.

SOLAR GEOMETRY

The sun rises in the East and sets in the West. The sun travels in an arc, reaching its highest altitude in the summer and its lowest altitude in the winter.

NORTH FACING FAÇADES

For predominately north facing façades in all but the lowest latitudes the façade will not receive direct sunlight and solar shading is not required or beneficial from an energy perspective.

Shading louvers may be used for an asthetic look complimentary with the other south, east and west facing façades.

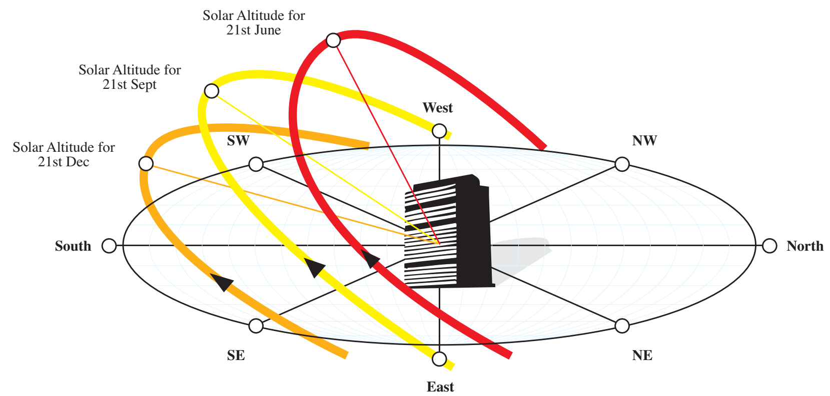
SOUTH, EAST AND WEST FACING FAÇADES

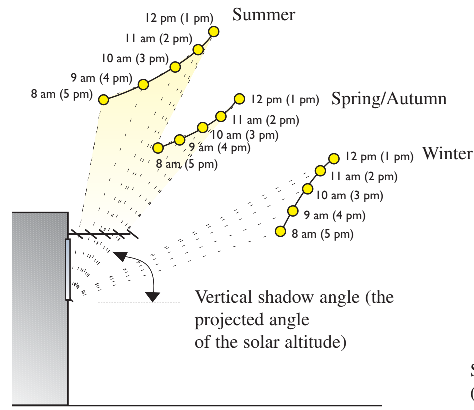
For a predominately South facing façade, a small amount of solar shading can be achieved using a fixed horizontal brise soleil sunshade. In winter such a device, however, cannot stop direct rays from the sun penetrating the building's windows since the sun is much lower.

While passive solar heating at times is beneficial, some might be surprised to learn that the cooling loads on many southern-facing zones peak in the late fall/early winter due to the solar radiation.

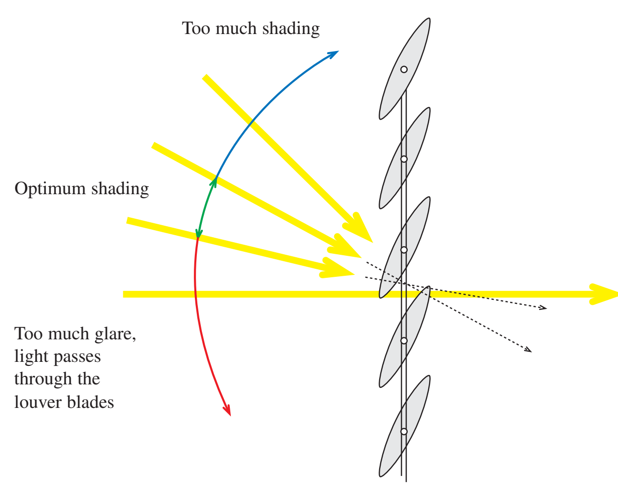
With a predominately East or West facing façade, a fixed system will not perform well throughout the day as the altitude of the sun varies throughout the day.

Effective solar shading on the South, East and West façades can be achieved only by using an operable shading louver system on the building's façade. The angle of the louvers is adjusted throughout the day to provide optimal shading.





South facing
(Northern Hemisphere)



Louver Materials & Finishes

Colt offers a variety of materials and finishes for the shading louvers –
- Shadoglass – Glass with various colors, surface finishes, patterns and coatings
- Shadovoltaic – Glass with photovoltaic cells
- Shadoprism – Non-specular prisms
- Shadotex – Textile fabrics
- Shadometal – Metal - solid or perforated
- Shadotimber – Timber wood

SHADOGLASS

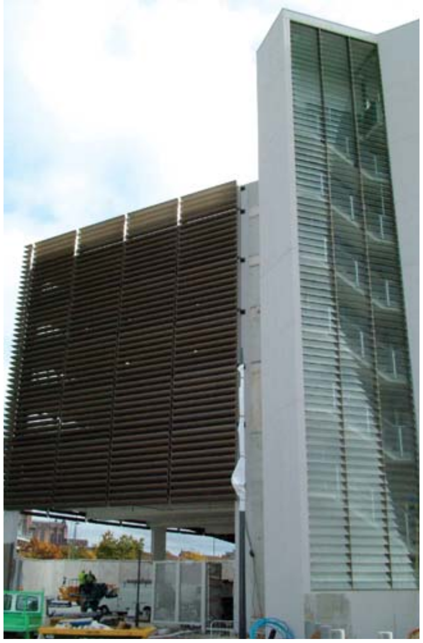
Shadoglass are fixed or operable exterior solar shading systems that incorporate glass louvers. The louvers can be installed either horizontally or vertically on the building's façade. A Shadoglass shading system can significantly reduce solar heat gain while providing unobstructed views and natural daylight. With today's glass technology, very effective shading performance can be achieved with glass louvers.

Glass louvers are available in various colors, surface finishes, patterns and coatings to meet specific design requirements. This enables the designer to control the quality of light entering the building.

Features and benefits

- Available in widths up to a nominal 24".
- Available in unsupported spans up to a nominal 6.5', supported spans up to a nominal 13' (depending on wind loads and other design criteria).
- Wide range of colors, surface finishes, patterns and coatings (i.e. fritted).
- All principal support components are manufactured from corrosion-resistant extruded aluminum alloy with stainless steel fixings.
- Fully operable or fixed.






Louver Materials & Finishes

SHADOVOLTAIC

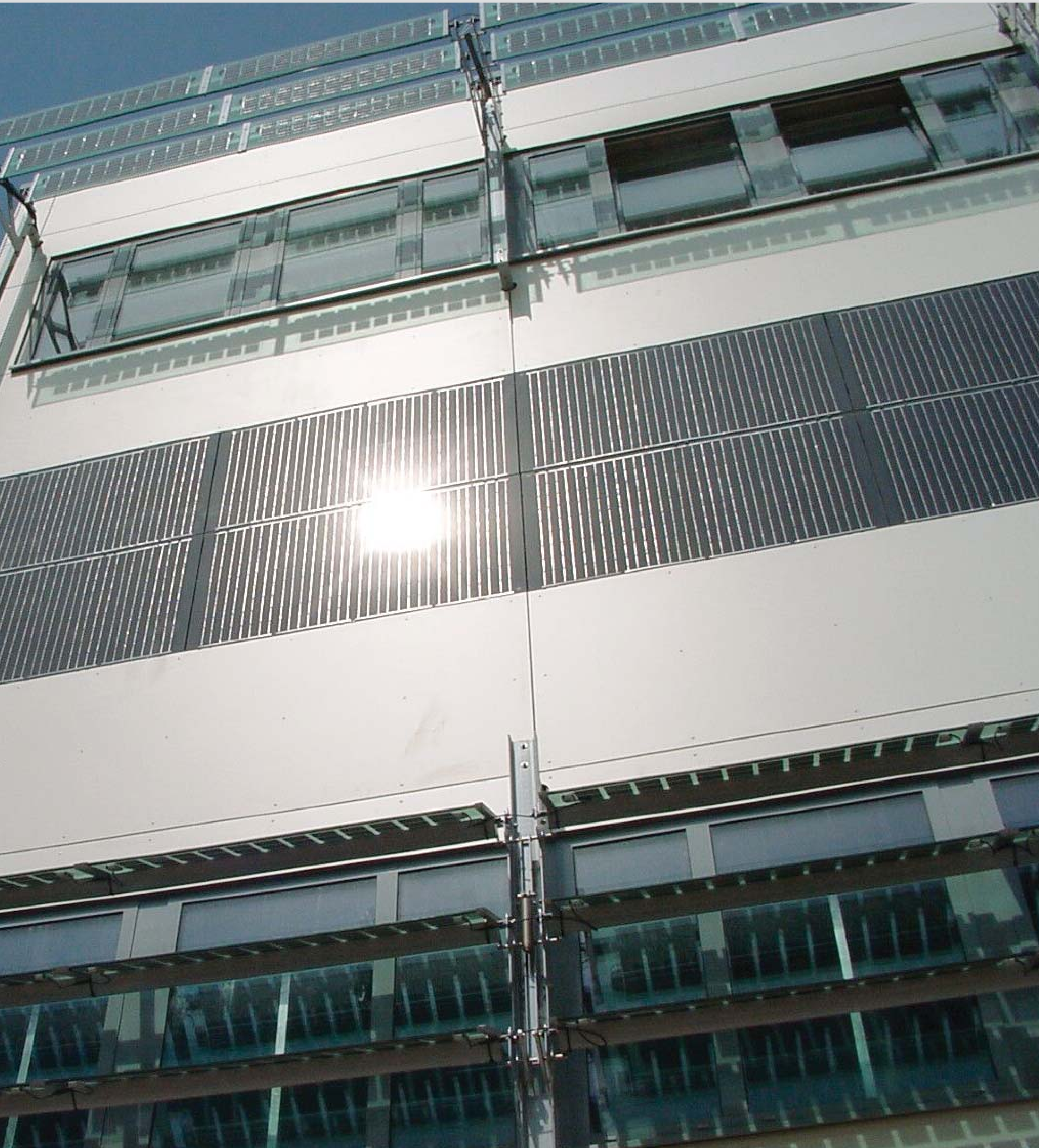
Shadovoltaic are fixed or operable exterior solar shading systems that incorporate glass louvers with photovoltaic cells integrated into the glass to generate electricity at the same time as providing shading. The louvers can be installed either horizontally or vertically on the building's façade.

Both monocrystalline and polycrystalline cells are available. The photovoltaic cells may be integrated into the glass, either by attaching them on the underside of the glass louver or by laminating them between two layers of glass. The glass panels are heat soak tested toughened glass with the edges treated to remove stress. Glass thicknesses of between a nominal 0.3" and 0.6" are available. The glass specification can be tailored to suit each application.

Photovoltaic glass louvers are available in various colors, surface finishes, patterns and coatings to meet specific design requirements.

Features and benefits

- Combines the functions of solar shading with the generation of electrical power.
- Available in widths up to a nominal 24".
- Available in supported spans up to a nominal 13' (depending on wind loads and other design criteria).
- All principal support components are manufactured from corrosion-resistant extruded aluminum alloy with stainless steel fixings.
- Fully operable or fixed. An operable BIPV system which tracks the sun's position typically generates about 20% more electricity than a fixed system.



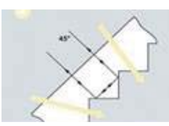
Louver Materials & Finishes

SHADOPRISM

Shadoprism are operable exterior solar shading systems that incorporate non-specular prismatic plates.

The system is a transparent sun protection system for façades and glass roofs that prevents the ingress of the direct sun's heat into the interior of the building and at the same time lets through a maximum of diffuse daylight.

Total reflection of the daylight occurs where the prism angle is 90° relative to the daylight. This total reflection functions only within a very narrow range of angle. As such, the operating prismatic louvers will track the sun's position – reflecting the maximum amount of direct sunlight while allowing in all the diffuse light.



On overcast days, the prism louvers can be opened to allow unhindered vision and maximum natural daylight through the glazing.

Features and benefits

- Highly effective shading performance with maximizing natural diffuse daylight into the building.
- Available in widths up to a nominal 24".
- Available in unsupported spans up to a nominal 6.5', supported spans up to a nominal 13' (depending on wind loads and other design criteria).
- All principal support components are manufactured from corrosion-resistant extruded aluminum alloy with stainless steel fixings.
- Normally operable.

Louver Materials & Finishes

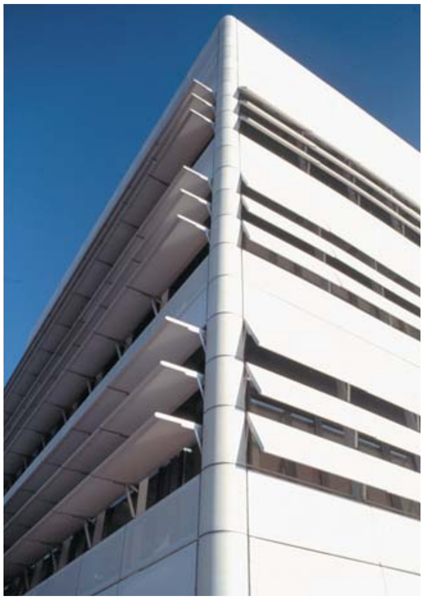
SHADOTEX

Shadotex are fixed or operable exterior solar shading louver systems that incorporate a unique, alternate solar shading solution. It consists of a special fabric stretched between two sides of a louver support frame. The fabric is manufactured with a weave to prevent solar glare and solar heat gain. The fabric can also create attractive diffused light and allow a degree of vision. The louvers can be installed either horizontally or vertically on the building's façade.

This type of system is extremely light weight which allows for very large spans without the need for additional supporting framework.

Features and benefits

- A wide variety of fabric and color choices including PVC-coated polyester, Teflon glass fiber, silicon glass fiber and ETFE (colored, translucent or screen printed).
- High solar absorption and high solar reflection.
- Light weight construction – ideal for large spans.
- Good external visibility.
- Easy to clean as the fabric is typically resin/Teflon coated.
- All principal support components are manufactured from corrosion-resistant extruded aluminum alloy with stainless steel fixings.
- Fully operable or fixed.



Louver Materials & Finishes

SHADOMETAL

Shadometal are fixed or operable exterior solar shading systems that may be installed vertically or horizontally onto the building's façade or roof, and incorporate metal louvers. Perforated, solid, curved louvers and other configurations are available. The perforated louvers can also create attractive diffused light and allow a degree of vision.

Features and benefits

- Available as standard in widths up to a nominal 16" in one piece construction and up to 41" in multiple (clipped together) construction.
- Available in unsupported spans up to a nominal 33' (depending on wind loads and other design criteria).
- Solid or perforated for improved visibility.
- Wide range of over 20 standard louver profiles.
- All principal support components are manufactured from corrosion-resistant extruded aluminum alloy with stainless steel fixings.
- Fully operable or fixed.

COLT

Louver Materials & Finishes

SHADOTIMBER

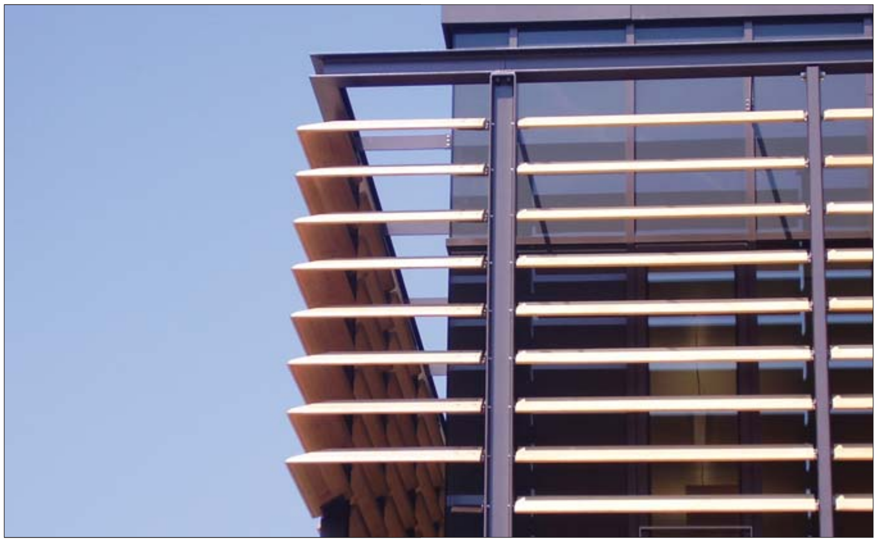
Shadotimber are fixed or operable exterior solar shading louver systems that incorporate a unique, alternate solar shading solution. It consists of timber wood louvers, usually western red cedar which, if left untreated, ages to a silvery-grey tone. The louvers can be installed either horizontally or vertically on the building's façade.

Alternatively, a simulated wood appearance can be provided on shadometal louvers through a dye-sublimation process which will remain colorfast at the original appearance.

This type of system is generally intended for shorter spans without the need for additional supporting framework.

Features and benefits

- Although normally western red cedar, other types of timber wood can be provided.
- Ideal for shorter spans and thinner louvers.
- All principal support components are manufactured from corrosion-resistant extruded aluminum alloy with stainless steel fixings.
- Fully operable or fixed.



Carrier Systems

Colt offers a variety of carrier systems for the solar shading systems –

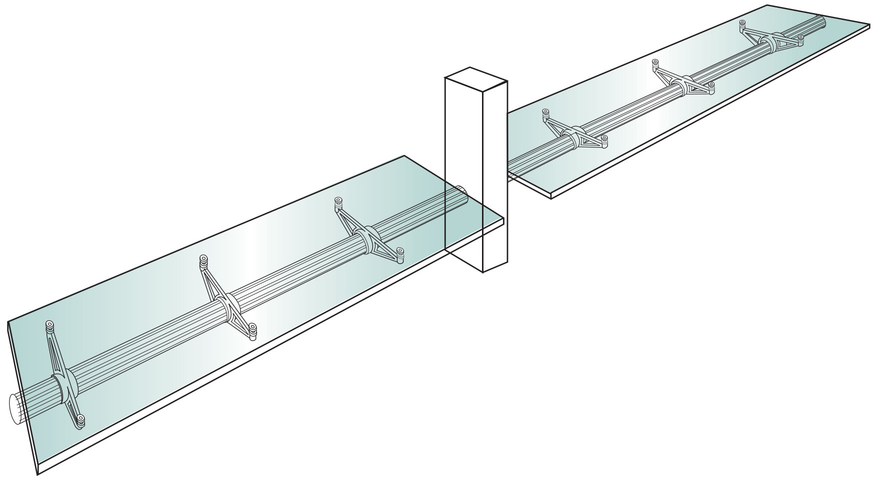
- System 1 – Center pivot supported at various points along the length by a torsion tube
- System 2 – Center pivot point-supported at the ends
- System 3 – Center pivot continuously supported over the entire length by a torsion tube
- System 4 – Back pivot point-supported at the ends
- System 5 – Center pivot continuously supported at the ends

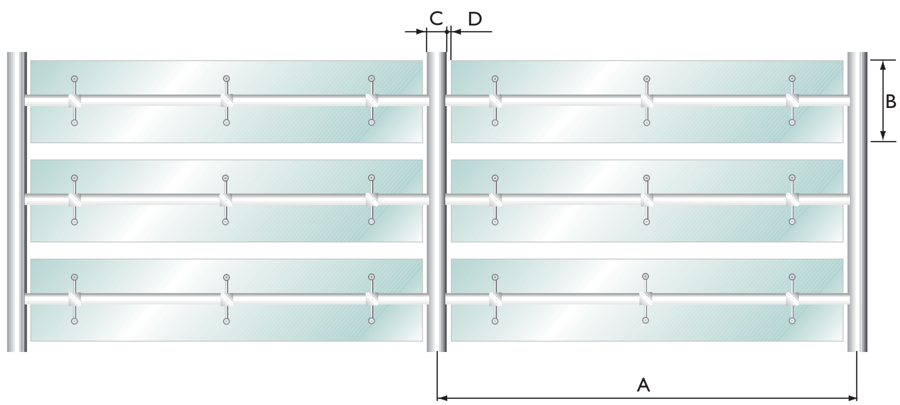
CARRIER SYSTEM 1

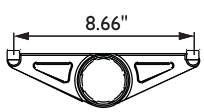
Intended for wider spans, carrier system 1 incorporates a central aluminum torsion tube along the entire length of the louver, and is ideal for continuous facades, as well as for roofs.

For glass louvers, cross sectional widths from a nominal 12" to 24" are available.

This carrier system is also suitable for use with a variety of louver materials including glass, metal, fabric, timber wood, terracotta clay and translucent acrylic.







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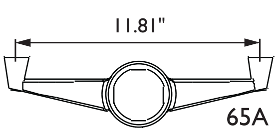
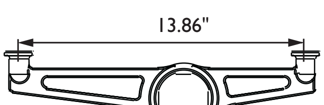


65A

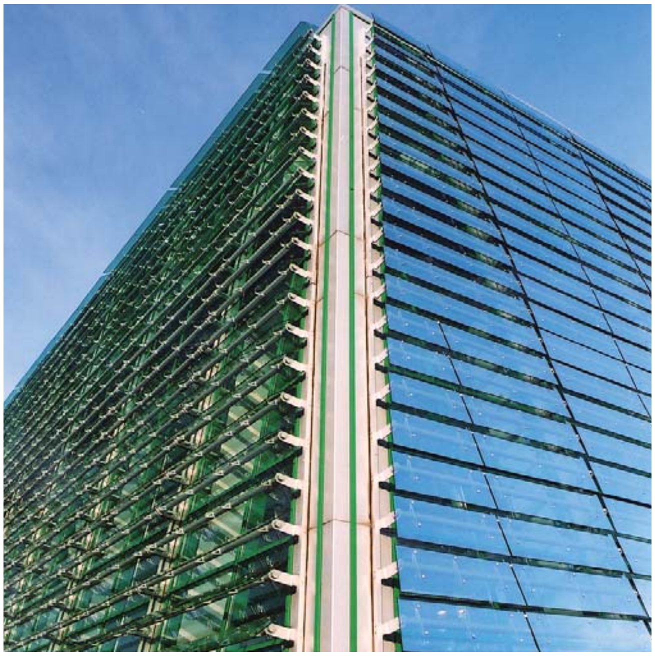


65B

Glass Parameters Table

Dimensions	LS1 - 55	LS1 - 65A	LS1 - 65B
A (max)	98.42"	129.92"	129.92"
B	11.81" - 19.68"	13.78" - 21.65"	16.54" - 23.62"
C	2.36"	2.36"	2.36"
D	0.39"	0.39"	0.39"
Angle of rotation	0 - 100°	0 - 100°	0 - 100°
Torsion tube dia.	2.17"	2.56"	2.56"

Note: Table to be used as a guide only. Allowable dimensions depend upon the specific requirements of the project.



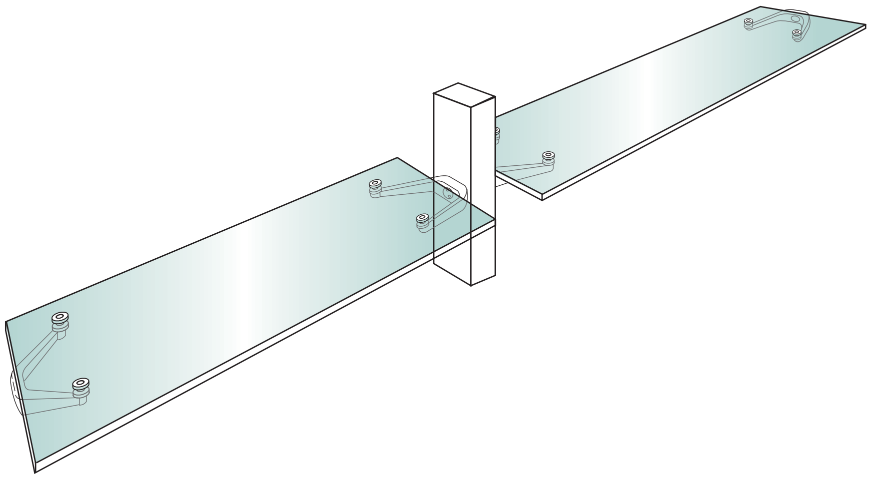
Carrier Systems

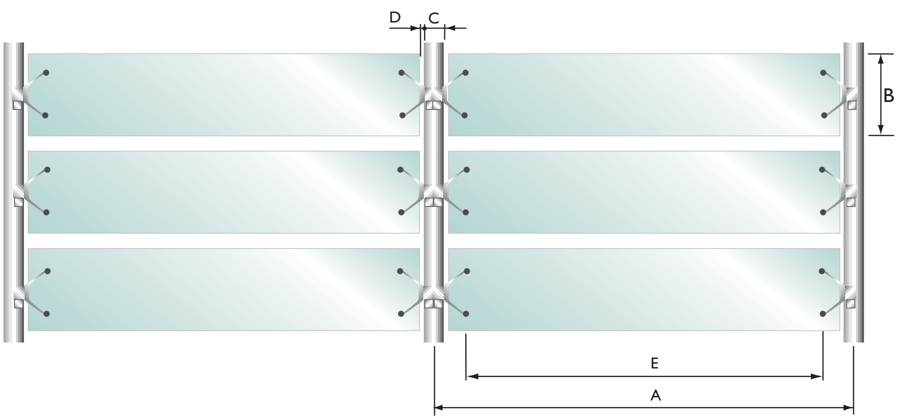
CARRIER SYSTEM 2

Primarily intended for shorter spans or where frequent anchor support points are available, carrier system 2 provides minimum obstruction from the louver so when used with glass louvers it maximizes the natural daylight and enhances the views to the outside.

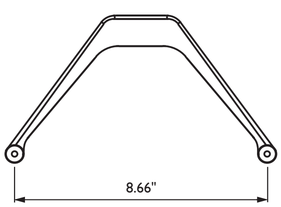
For glass louvers, carrier system 2 is available in cross sectional louver widths of up to a nominal 20".

This carrier system is also suitable for use with a variety of louver materials including glass, metal, fabric, timber wood, terracotta clay and translucent acrylic.

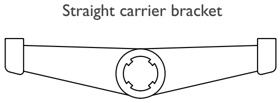




Plan view of LS2-30 bracket



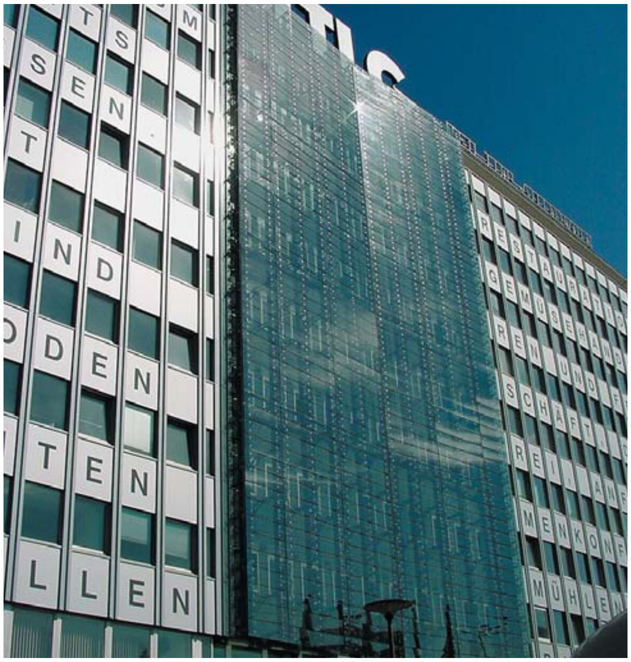
Straight carrier bracket



Glass Parameters Table

Dimensions	LS2-30
A (max)	78.74"
B	19.68"
C	2.36"
D	0.39"
E	66.93"
Angle of rotation	0 - 100°

Note: Table to be used as a guide only. Allowable dimensions depend upon the specific requirements of the project.


IND
ODEN
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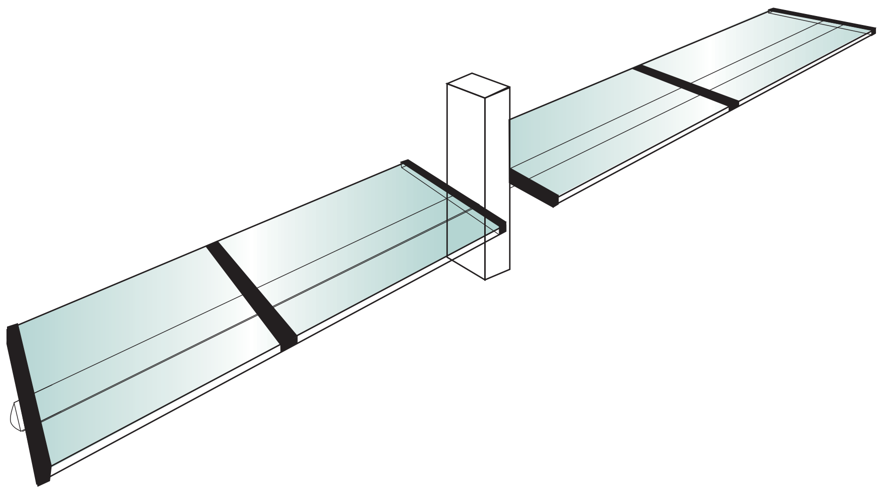
Carrier Systems

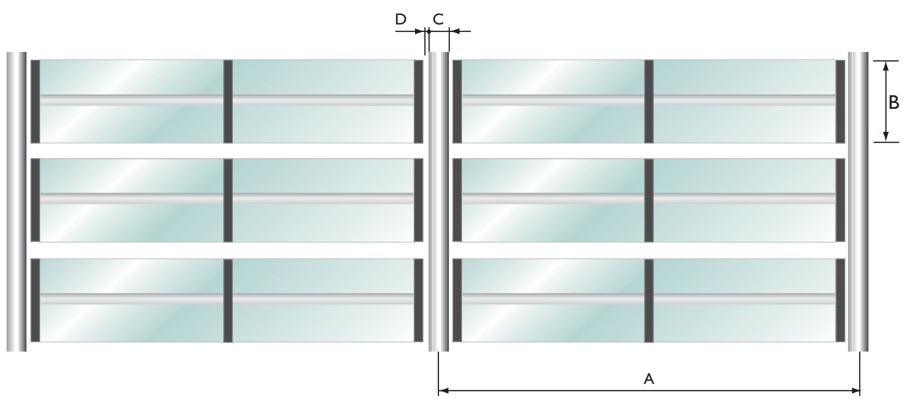
CARRIER SYSTEM 3

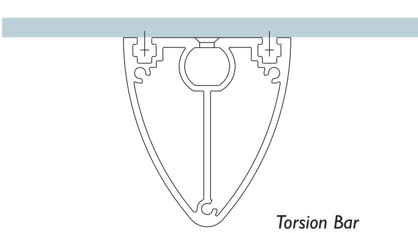
Like carrier system 1, carrier system 3 is intended for wider spans and incorporates a discreet central aluminum torsion tube along the entire length of the louver. It is ideal for continuous facades as well as for roofs.

For glass louvers, carrier system 3 offers spans up to a nominal 13 feet long without adding any additional supporting structure and cross sectional louver widths up to a nominal 24".

This carrier system is also suitable for use with a variety of louver materials including glass, metal, fabric, timber wood, terracotta clay and translucent acrylic.







Torsion Bar

Glass Parameters Table

Dimensions	LS3
A (max)	157.48"
B	23.62"
C	2.36"
D	0.20"
Angle of rotation	0 - 100°

Note: Table to be used as a guide only. Allowable dimensions depend upon the specific requirements of the project.

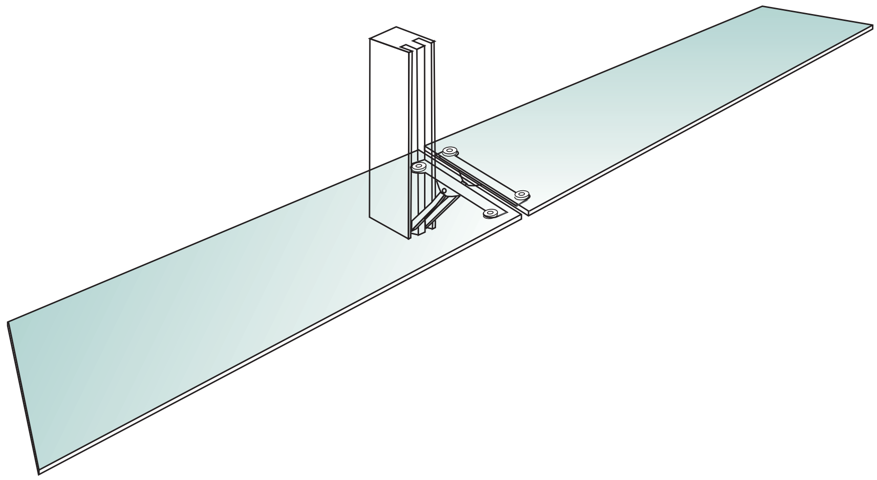
Carrier Systems

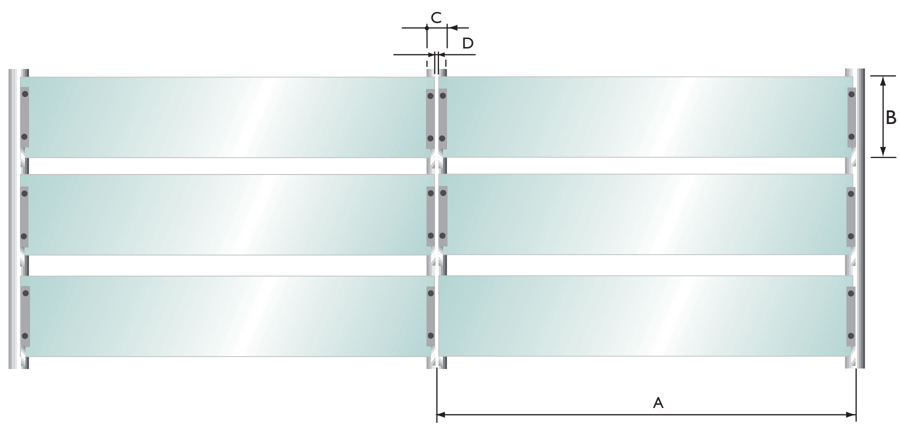
CARRIER SYSTEM 4

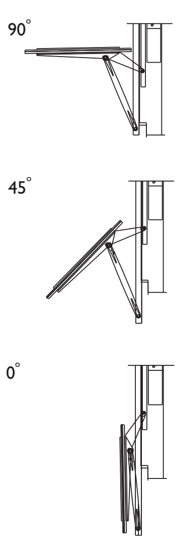
Carrier systems 1, 2, 3 and 5 are center pivoted systems. System 4 provides a back hung end pivoted solution with hidden control mechanisms integrated within the main vertical mullion supports. This allows for seamless continuous louvers with unobtrusive supports when viewed from the outside.

For glass louvers, carrier system 4 offers smaller spans up to a nominal 6 feet long and in cross sectional louver widths up to a nominal 24".

This carrier system is also suitable for use with a variety of louver materials including glass (with our without photovoltaic cells), metal, fabric, timber wood, terracotta clay and translucent acrylic.



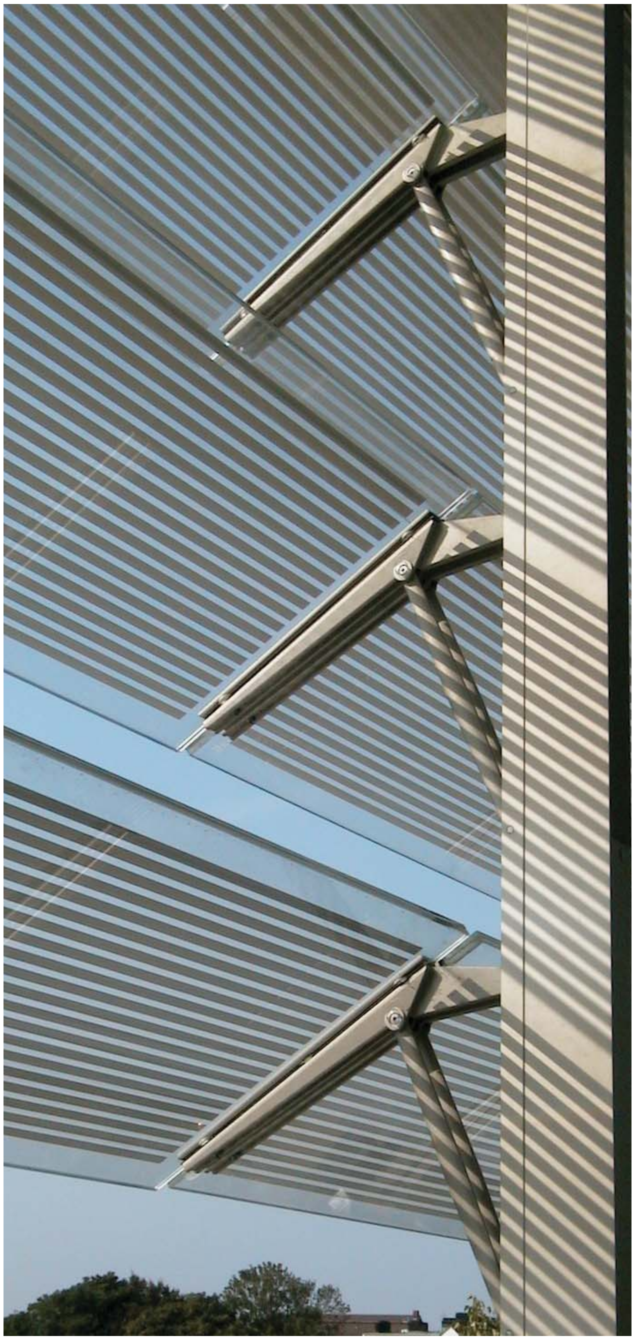




Glass Parameters Table

Dimensions	LS4
A (max)*	70.87"
B	13.78" min / 23.62" max
C	2.56"
D	0.39"
Angle of rotation	0 - 85°

Note: Table to be used as a guide only. Allowable dimensions depend upon the specific requirements of the project.
* If spanning across an intermediate mullion, max 141.73".



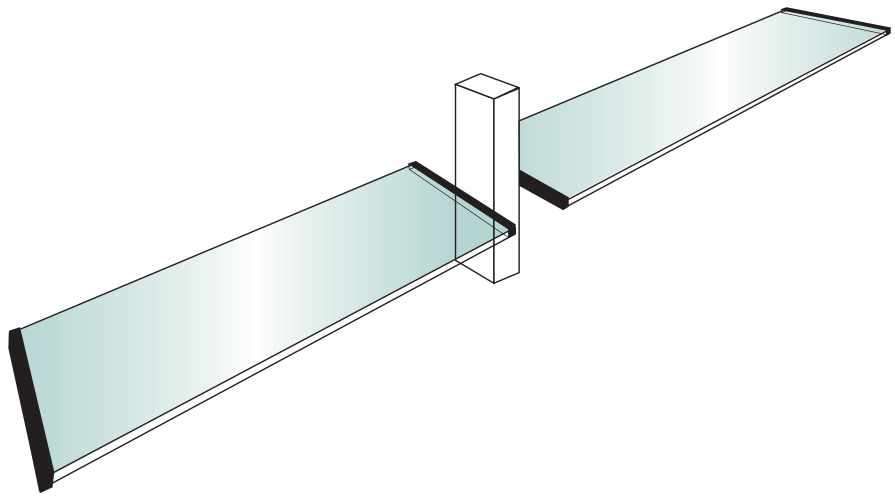
Carrier Systems

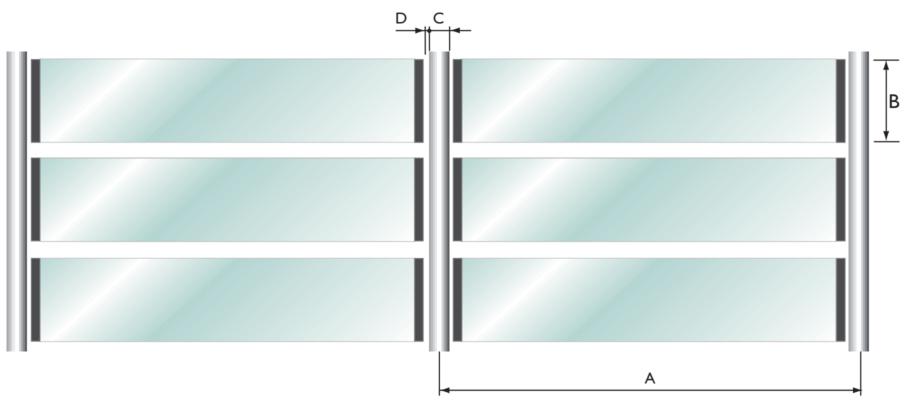
CARRIER SYSTEM 5

Carrier system 5 is a fully centered pivoted system which provides maximum visibility. Louvers are supported at each end by a bonded and extruded end cap.

For glass louvers, carrier system 5 offers smaller spans up to a nominal 6 feet long without any additional support work, in cross sectional louver widths up to a nominal 24".

This carrier system is also suitable for use with a variety of louver materials including glass, metal, fabric, timber wood, terracotta clay and translucent acrylic.





Glass Parameters Table

Dimensions	LS5
A (max)	70.87"
B	23.62"
C	1.97/2.36"
D	0.39"
Angle of rotation	0 - 100°

Note: Table to be used as a guide only. Allowable dimensions depend upon the specific requirements of the project.

Controls

OPERABLE VERSUS FIXED SYSTEMS

Operable solar shading louver systems adjust the shading louver's position to provide the most effective shading. The benefits of increased shading effectiveness and resultant energy savings far exceed the modest cost addition between a fixed and fully operable system.

With operable systems occupant comfort can also be enhanced as glare can be lessened during bright days, while maximizing the natural daylight entering the building when overcast. Typically, multiple banks of louvers are operated by linear actuators though a system of levers and push rods or by rotary actuators through a system of worm gears.

SOLTRONIC III

The Solaronic III system can control up to 15 groups of actuators (exposures) with 15 actuators per group which is enough for the vast majority of systems.

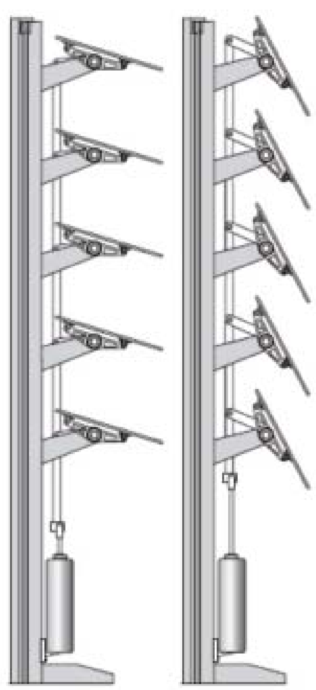
ICS 4 LINK

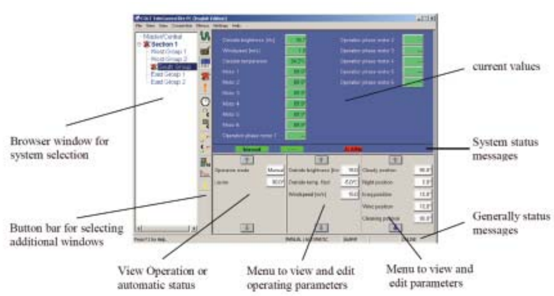
The ICS4 Link system can be programmed with customer specific programs. It can handle a very large number of exposures and actuators through the main control panel w/CPU (and sub-panels w/CPUs). The ICS4 Link system can be fully integrated with a BMS and offers remote access over the Internet, data logging and other data-driven operating flexibility/features.

With both control systems, the actuators typically have a cycle time from fully closed to fully open of about 90 seconds. To fully calibrate/synchronize the actuators/louvers as there are slight differences in each actuators cycle time, each actuator is provided with a MSG.

At the initial commissioning, all the actuators will be cycled and the MSG will adjust the control of each actuator to account for the slight differences in cycle time to assure proper alignment of the louver blades.

With an ICS 4 link system should a problem with an operable system arise, Colt can investigate the problem remotely communicating with the control system over the internet to trouble shoot most problems.

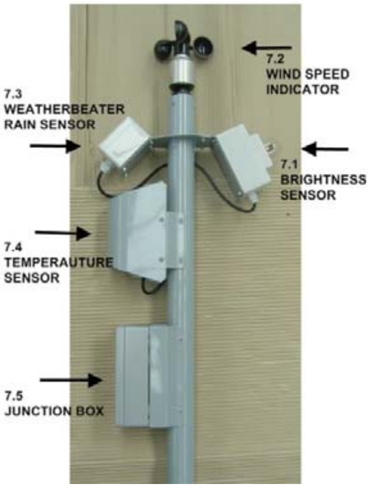




CONTROL FUNCTIONALITY

Colt operable shading louver systems employ a weather station to provide much more functionality. The weather station (usually one per building) is typically installed on the roof and includes:

- Lux sensor for brightness
- Wind speed sensor
- Water (rain/ice/snow) sensor
- Outside air temperature sensor



In addition to management of the shading louvers positions though its sun tracking program, Colt's control systems with weather station have many more features:

- The control systems have a relay to interlock with the fire alarm system. If there is a fire alarm, the louvers are driven to a fully open (horizontal) position.
- If the wind sensor indicates a wind speed in excess of about 25 MPH, the louvers will be driven to the wind safe position (the most effective wind safe position is 37 degrees down from horizontal).
- If the outside air temperature approaches 32º F per the outdoor air temperature sensor and water is detected by the water sensor, the louvers are driven to the freeze protection position (slightly less than fully closed).

  This is a major advantage of operable over fixed systems. Snow and ice can gather on a fixed blade (even at a 45 degree angle). This snow and ice can ultimately fall endangering the pedestrians below. With the operable system's freeze protection position, this concern is greatly reduced.

  Operable systems have another major advantage over fixed systems. The moving louver blades discourage birds from perching and nest building as opposed to a fixed system which does not.

- The control systems have a maintenance switch. If the maintenance switch is activated the louvers are driven to a fully open (horizontal) position for cleaning.
- The control systems have a 24-hour clock. If it is "after dark" the louvers are driven to their nighttime position (which could be anything from fully open to fully closed). From a nighttime "light pollution" perspective, the nighttime position would normally be fully closed.
- If it is an overcast day as sensed by the lux sensor (under 15k lux), the louvers will be driven to the fully open (horizontal) position. (As a comparison, a bright day might have a lux reading of 80k lux).
- If none of the above conditions are present, the control system will position the louvers automatically per the sun tracking software.

Installation and Maintenance

INSTALLATION

A wide variety of mounting options are possible including mounting the shading louvers directly to the curtain wall mullions or to the building structure. The method to be used for each project requires structural analysis and engineering to account for the dead weight, wind, snow and ice loads. Please consult with us on the most appropriate mounting method for your specific project.

Proper alignment of the mullions is key to a smooth installation.

In some cases the louvers can be factory pre-assembled or "unitized" to reduce installation time.

In either case, the operating mechanisms such as bearings, rods and levers are typically factory installed and aligned in the mullions. After commisioning, a capping piece will be installed on the mullions to protect these mechanisms from the elements.

COMMISSIONING

Proper commissioning by experts is essential. We recommend that our staff commission and certify the system.

MAINTENANCE

The actuators linkages and non-lubricated bearings are free from routine maintenance. An annual visual inspection of the shading louvers should be sufficient.

The actuators are tested to 10,000 cycles in each direction (20,000 total).

Should a louver or window behind the louver need replacement, Colt typically employs a spring-bolt mounting design which allows for the removal of each individual louver independently avoiding the need to remove all the preceeding louvers within the row.

WASHING

The washing method to be used of the surfaces of the exterior windows and shading louvers is normally anticipated in the solar shading louver system's design. A titanium dioxide coating can be provided on the glass louvers to reduce the maintenance effort associated with glass cleaning.

A variety of window washing approaches can be accommodated.

■ A bosun's chair can be lowered between the exterior windows and shading louvers.

■ The use of a working platform lowered between the exterior windows and shading louvers is a common approach. In some cases, rails or cradle runners are integrated into the mullions and supporting structure to guide the working platform. In other cases, outriggers can be provided to protect the windows and shading louvers from the working platform.

■ Catwalks can be incorporated into the structure supporting the shading louvers. This approach is less common due to the expense of the additional structural elements.

Custom Solutions

Colt is dedicated to innovation and has comprehensive design capabilities. While this brochure provides a general overview of our capabilities, we welcome the opportunity to develop solutions to satisfy your unique requirements. The following are a few other custom solutions we have provided on selected projects.

TEXTURED LOOK

Varying the ceramic frit in a random pattern on the Shadoglass louvers can give the building a distinctive aesthetically pleasing textured look.

FULLY OPERABLE AND RETRACTABLE VENETIAN BLINDS WITHIN A DOUBLE FAÇADE

Double façades are gaining in popularity due to their energy savings. To increase these saving further, Colt can provide large venetian blinds that lower and track the sun's position for maximum shading effectiveness. When the sky is overcast, the blinds can be fully retracted to maximize views to the outside and the natural daylight entering the building.

INSERTS

Shadometal louvers can be provided with the ability to accept an insert to compliment the other elements of the building's façade. In this case terra cotta inserts were used to make a striking architectural appearance.

PHOTOVOLTAIC LOUVERS WITH INTEGRATED DAY LIGHTING

The Shadovoltaic (blue tinted) louvers in the center of the shading louver system generate power for the building's use. Their position is constantly adjusted as the louvers track the sun's position to maximize the electricity generated. The Shadoprism louvers (white tinted) above and below the Shadovoltaic louvers reflect direct sunlinght, while allowing indirect light for natural daylight into the building.

Portfolio of Selected Projects

NEW YORK TIMES HEADQUARTERS
New York, NY
Renzo Piano-Fox/ Fowle Architects
Operable Shadometal

SCHOOL OF ARCHITECTURE, UNIVERSITY OF VIRGINIA
Charlottesville, VA
William Sherman and SMBW Architects
Operable and Fixed Shadoglass

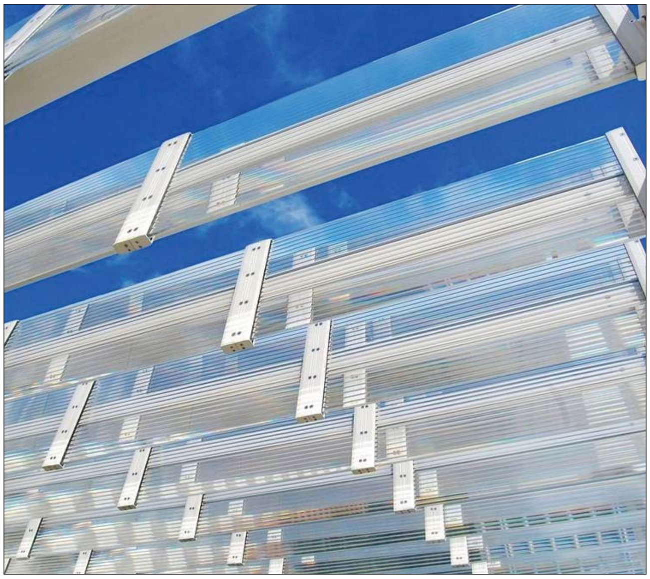
NORTHWEST VISTA (ACCD) COLLEGE LIBRARY
San Antonio, TX
Overland Partners Architects
Operable Shadometal

ONE RIVER TERRACE
Battery Park, NY
Polshek Partnership and Ismael Leyva Architects
Operable Shadovoltaics and Shadowmetal

PAPAGO GATEWAY CENTER
Tempe, AZ
Smith Group Architects
Operable Shadometal

HAMILTON COLLEGE
Clinton, NY
Butler Rogers Baskett Architects
Fixed Shadometal

ADVANCED ENERGY CENTER, SUNY STONYBROOK
Stonybrook, NY
Flad Architects
Operable Shadovoltaics



NATURE RESEARCH CENTER – NC DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
Raleigh, NC
O'Brien/Atkins Associates
Operable Shadoprism

MESTEK
ARCHITECTURAL
IntelligentEnvelopes™

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www.linel.co
www.awv.com
www.coltgroupusa.com

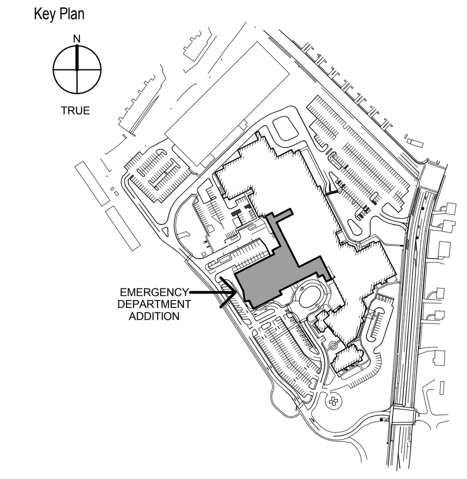
Appendix C.2

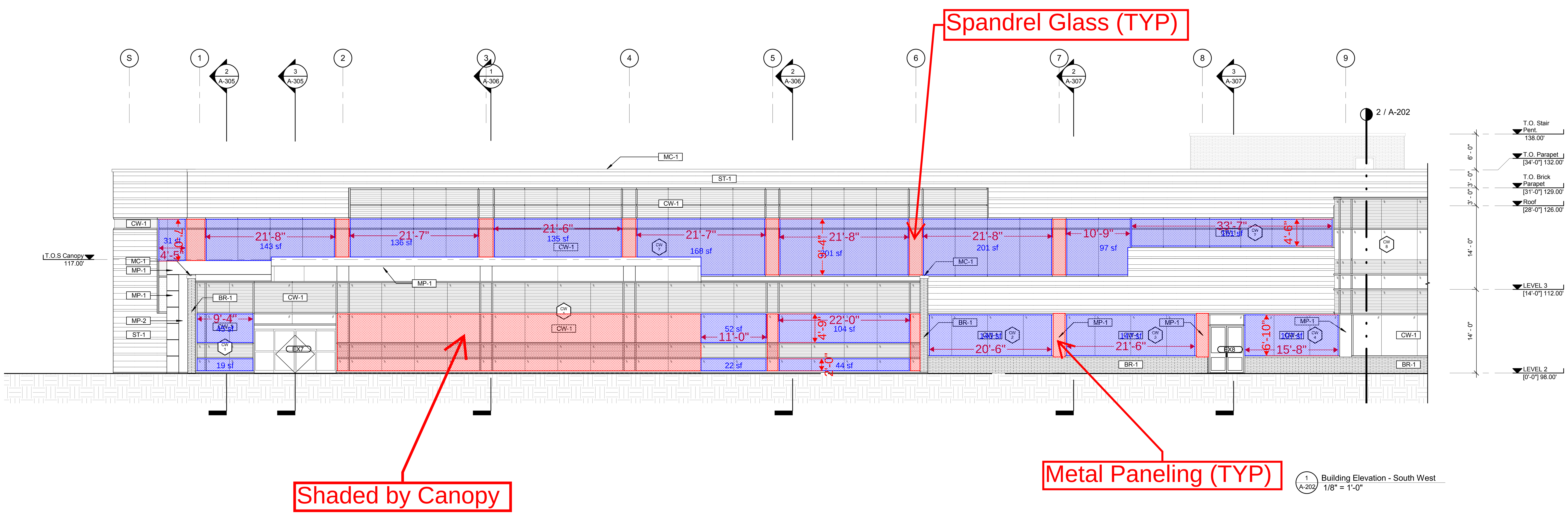
Solar Shading Layout

Exterior Material legend	
I.D.	**Description**
BR-1	BRICK, SEE SPEC'S
C-1	EXPOSED CONCRETE W/ EXT. PAINT FINISH, SEE SPEC'S
CW-1	7 1/2" DEEP ALUM. CURTAIN WALL SYSTEM, SEE SPEC'S
IGU-1	1" INSULATED CLEAR VISION GLASS IN ALUMINUM CURTAIN WALL SYSTEM, SEE SPEC'S FOR ADDITIONAL INFORMATION
IGU-2	1" INSULATED TINTED VISION GLASS IN ALUMINUM CURTAIN WALL SYSTEM, SEE SPEC'S FOR ADDITIONAL INFORMATION
IGU-3	1" INSULATED CLEAR VISION GLASS W/ FRIT & SHADOW BOX ASSEMBLY IN ALUMINUM CURTAIN WALL SYSTEM, SEE SPEC'S FOR ADDITIONAL INFORMATION
IGU-4	1" INSULATED CLEAR VISION GLASS W/ FRIT IN ALUMINUM CURTAIN WALL SYSTEM, SEE SPEC'S FOR ADDITIONAL INFORMATION
IGU-5	1" INSULATED TINTED VISION GLASS W/ FRIT & SHADOW BOX ASSEMBLY IN ALUMINUM CURTAIN WALL SYSTEM, SEE SPEC'S FOR ADDITIONAL INFORMATION
IGU-6	TEMPERED 1" INSULATED CLEAR SPANDREL GLASS IN ALUMINUM CURTAIN WALL SYSTEM, SEE SPEC'S FOR ADDITIONAL INFORMATION
MC-1	METAL COPING, SEE SPEC'S FOR COLOR & FINISH
MP-1	COMPOSITE METAL PANEL, SEE SPEC'S FOR COLOR & FINISH
MP-2	COMPOSITE METAL PANEL, SEE SPEC'S FOR COLOR & FINISH
PWP-1	EXTERIOR PHENOLIC WALL PANEL SYSTEM W/ CONCEALED ALUM SUPPORT SYSTEM. BASIS OF DESIGN: TRESPA
R-1	EPDM ROOFING ON TAPERED RIGID INSULATION (3" MIN) W/ PROTECTION BOARD, SEE SPEC'S
R-2	EPDM ROOFING ON 1/2" RIGID INSULATION, SEE SPEC'S
S-1	DIRECT APPLIED STUCCO FINISH SYSTEM
ST-1	ARRISCRAFT THIN CLAD STONE ON ALUM CLIP SYSTEM, SEE SPEC'S
ST-2	CAST STONE, SEE SPEC'S FOR COLOR & FINISH

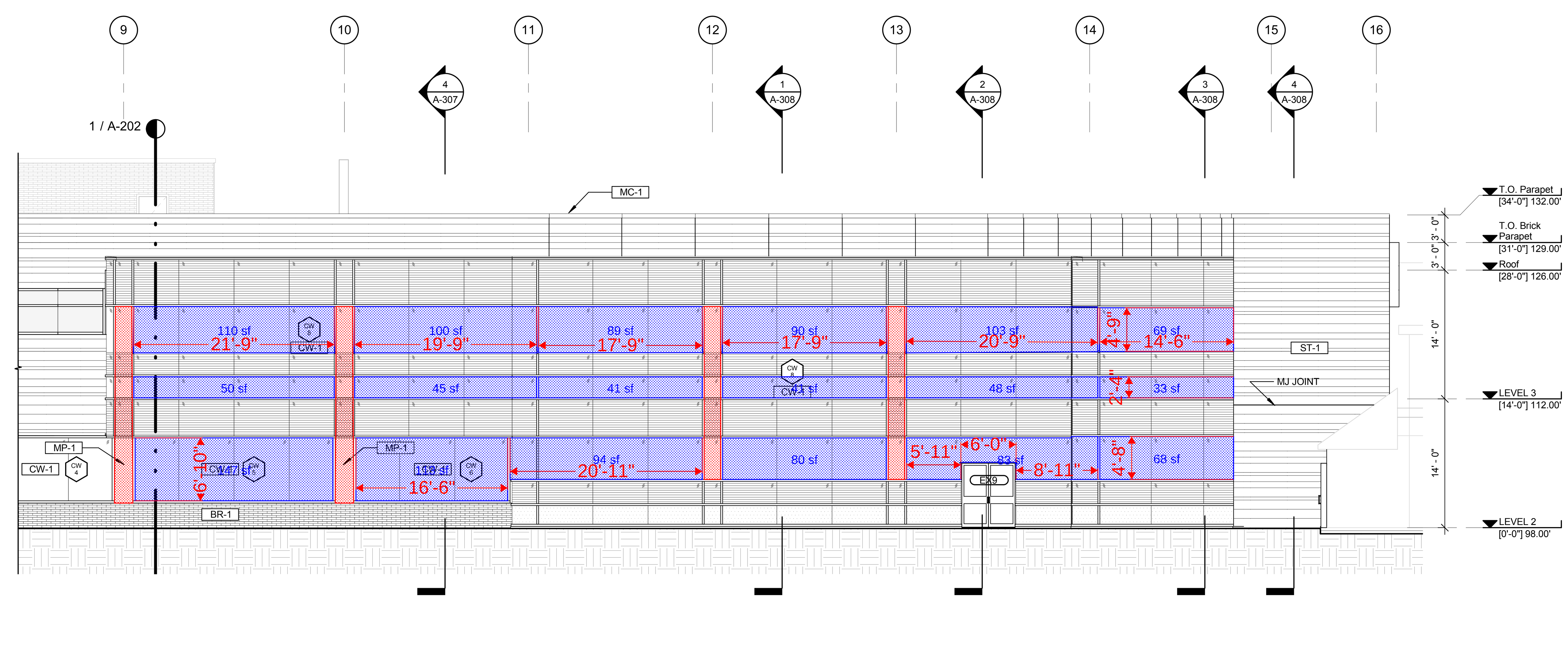
Revisions		
No.	Description	Date

Key Plan





1 / A-202 Building Elevation - South West
1/8" = 1'-0"



2 / A-202 Building Elevation - South East
1/8" = 1'-0"

= Solar Shading Devices

= No Shading Devices Necessary

Consultants:

Structural Engineer:
O'Donnell & Naccarato
111 South Independence Mall East
Suite 950
Philadelphia, PA 19106
Phone: (215) 925-3788
Fax: (215) 627-1051
www.o-n.com

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Date
10/26/2012

Drawn By
Author

Scale
1/8" = 1'-0"

Seal

Checker

Francis Cauffman

Project Title
Aria Health System - Torresdale Campus

New Emergency Dept & Patient Medical Tower

10800 Knights Road
Philadelphia, Pennsylvania, 19114

Project Number
F11-5892

Drawing Title and Number
Building Elevations

A-202

CONSTRUCTION DOCUMENTS ISSUE - 10/26/2012

C:\Users\cwh\Documents\5892_Aria Central File_CORE & SHELL_Hemp.rvt

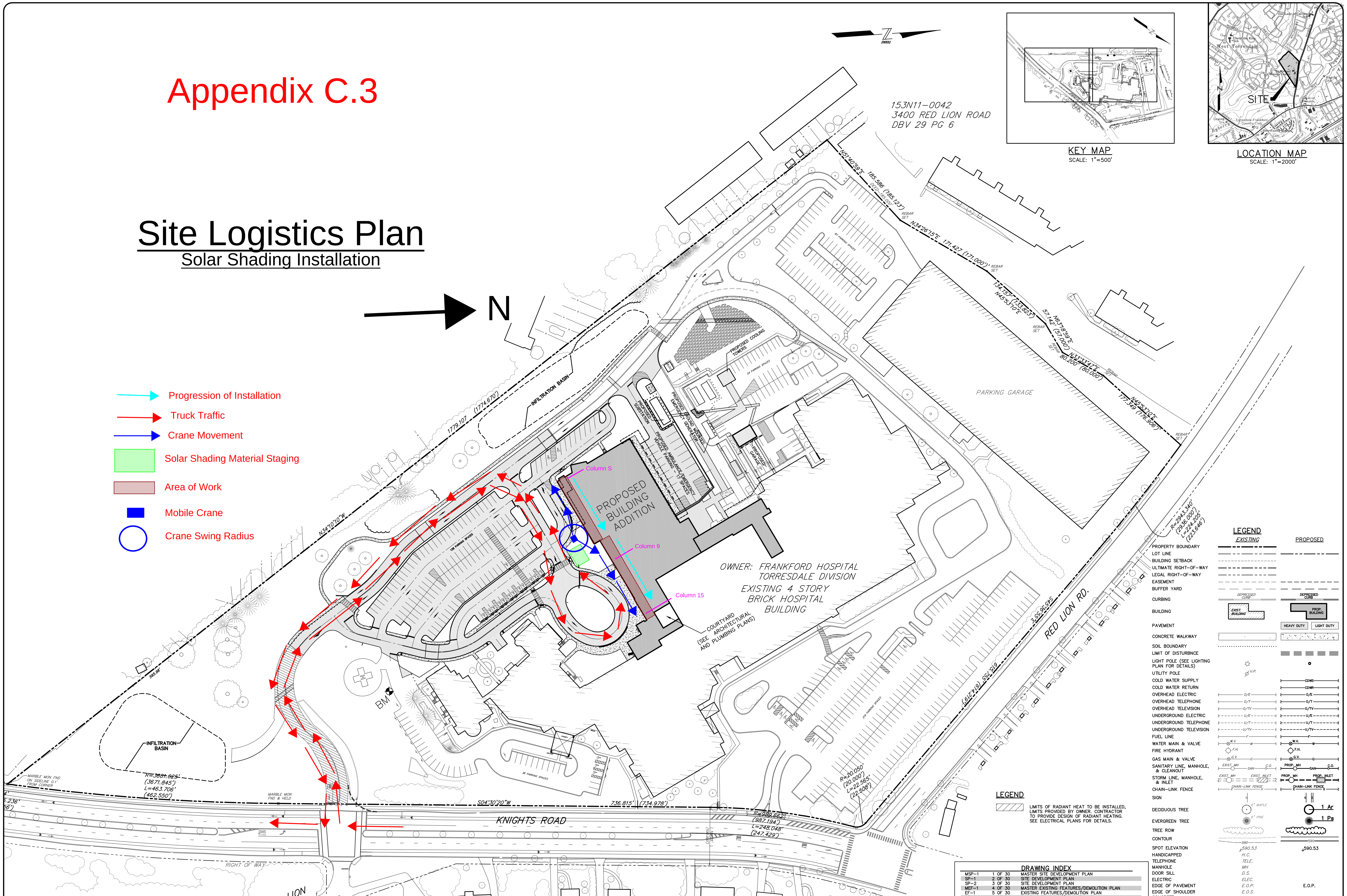
10/26/2012 11:48:33 AM

Designer

Appendix C.3

Site Logistics Plan

Solar Shading Installation



LEGEND

LIMITS OF RADIANT HEAT TO BE INSTALLED, LIMITS PROVIDED BY OWNER. CONTRACTOR TO PROVIDE DESIGN OF RADIANT HEATING. SEE ELECTRICAL PLANS FOR DETAILS.

NOTE:

"PURSUANT TO THE REQUIREMENTS OF PA ACT 287 OF 1974 AS AMENDED BY ACT 121 OF 2008 73P.S. § 176 et seq. THE LOCATIONS OF ALL EXISTING UTILITIES SHOWN ON THESE PLANS HAVE BEEN DEVELOPED FROM EXISTING UTILITY RECORDS AND/OR ABOVE-GROUND EXAMINATIONS OF THE SITE. COMPLETENESS, ACCURACY, LOCATION AND DEPTH OF UNDERGROUND UTILITIES OR STRUCTURES CANNOT BE GUARANTEED. THE CONTRACTORS, AT LEAST THREE (3) DAYS PRIOR TO PERFORMING ANY EXCAVATIONS, SHALL BE RESPONSIBLE FOR VERIFYING THE LOCATIONS AND DEPTHS OF ALL UNDERGROUND FACILITIES LOCATED WITHIN THE VICINITY OF THE WORK SITE IN ACCORDANCE WITH ACT 121. (PA ONE CALL SYSTEM, INC. 1-800-242-1776)."

CALL BEFORE YOU DIG!

PENNSYLVANIA LAW REQUIRES 3 WORKING DAYS NOTICE FOR CONSTRUCTION PHASE AND 10 WORKING DAYS IN DESIGN STAGE - STOP CALL

Pennsylvania One Call System, Inc.

1-800-242-1776

NOTES

1. PROPERTY SHOWN HEREON IS SUBJECT TO SETBACKS, EASEMENTS, AND RESTRICTIONS OF RECORD.
2. THIS DRAWING HAS BEEN PREPARED BASED ON THE BEST AVAILABLE INFORMATION. B.I.A., INC. HAS NOT VERIFIED THE ACCURACY OF THE UNDERGROUND UTILITIES AND SHALL NOT BE RESPONSIBLE FOR ANY ERRORS OR OMISSIONS WHICH MAY BE INCORPORATED HEREIN AS A RESULT. A SUBSURFACE UTILITY MAP WAS PROVIDED BY GEO-GRAF GEOPHYSICAL INVESTIGATIONS DATED JULY 15, 2011.
3. TOPOGRAPHIC FEATURES SHOWN ALONG THE SOUTHWESTERLY 400 FOOT +/- PORTION OF THIS PROPERTY FROM KNIGHTS ROAD TO THE NORTHERLY PROPERTY LINE ARE BASED UPON A GROUND SURVEY PERFORMED IN JUNE AND JULY OF 2011. A BOUNDARY SURVEY WAS PERFORMED DURING THE SAME TIME FRAME. TOPOGRAPHIC FEATURES SHOWN ALONG THE NORTHEASTERLY PORTION OF THE SITE (BETWEEN THE BUILDING AND RED LION ROAD) ARE BASED UPON A COMPILATION OF MAPS AND OTHER SOURCES OF INFORMATION AND SHOULD NOT BE RELYED UPON FOR DESIGN PURPOSES.
4. BUILDING AREA DATA HAS BEEN PROVIDED BY THE ARCHITECT AND OWNER.

DRAWING INDEX

MSP-1	1 OF 30	MASTER SITE DEVELOPMENT PLAN
SP-1	2 OF 30	SITE DEVELOPMENT PLAN
SP-2	3 OF 30	SITE DEVELOPMENT PLAN
MEF-1	4 OF 30	MASTER EXISTING FEATURES/DEMOLITION PLAN
EF-1	5 OF 30	EXISTING FEATURES/DEMOLITION PLAN
EF-2	6 OF 30	EXISTING FEATURES/DEMOLITION PLAN
MGP-1	7 OF 30	MASTER GRADING PLAN
GP-1	8 OF 30	GRADING PLAN
GP-2	9 OF 30	GRADING PLAN
MUP-1	10 OF 30	MASTER UTILITY PLAN
UP-1	11 OF 30	UTILITY PLAN
UP-2	12 OF 30	UTILITY PLAN
PP-1	13 OF 30	PLAN AND PROFILES
PP-2	14 OF 30	PLAN AND PROFILES
PP-3	15 OF 30	PLAN AND PROFILES
PP-4	16 OF 30	PLAN AND PROFILES
MLA-1	17 OF 30	MASTER LANDSCAPE PLAN
LA-1	18 OF 30	LANDSCAPE PLAN
LA-2	19 OF 30	LANDSCAPE PLAN
MLI-1	20 OF 30	MASTER LIGHTING PLAN
LI-1	21 OF 30	LIGHTING PLAN
LI-2	22 OF 30	LIGHTING PLAN
PC-1	23 OF 30	POST CONSTUCTION STORMWATER MANAGEMENT PLAN
PCD-1	24 OF 30	POST CONSTUCTION STORMWATER MANAGEMENT DETAILS
MES-1	25 OF 30	MASTER EROSION & SEDIMENTATION CONTROL PLAN
ES-1	26 OF 30	EROSION & SEDIMENTATION CONTROL PLAN
ES-2	27 OF 30	EROSION & SEDIMENTATION CONTROL PLAN
ESD-1	28 OF 30	EROSION & SEDIMENTATION CONTROL DETAILS
DE-1	29 OF 30	CONSTRUCTION DETAILS
DE-2	30 OF 30	CONSTRUCTION DETAILS

REVISIONS	DATE	BY
1. CONSTRUCTION DOCUMENTS	10/12/12	PTS

BARRY ISETT & ASSOCIATES, INC.
Multidiscipline Engineers & Consultants
Allentown, PA 610.398.0904
Valley Forge, PA 610.935.2175
Berlin, MD 410.629.0883
Hazleton, PA 570.455.2999
Phillipsburg, NJ 908.454.9500
www.barryisett.com

MASTER SITE DEVELOPMENT PLAN
EMERGENCY & OUTPATIENT SERVICE ADDITION
ARIA HEALTH -TORRESDALE CAMPUS
10800 KNIGHTS ROAD
PHILADELPHIA, PA

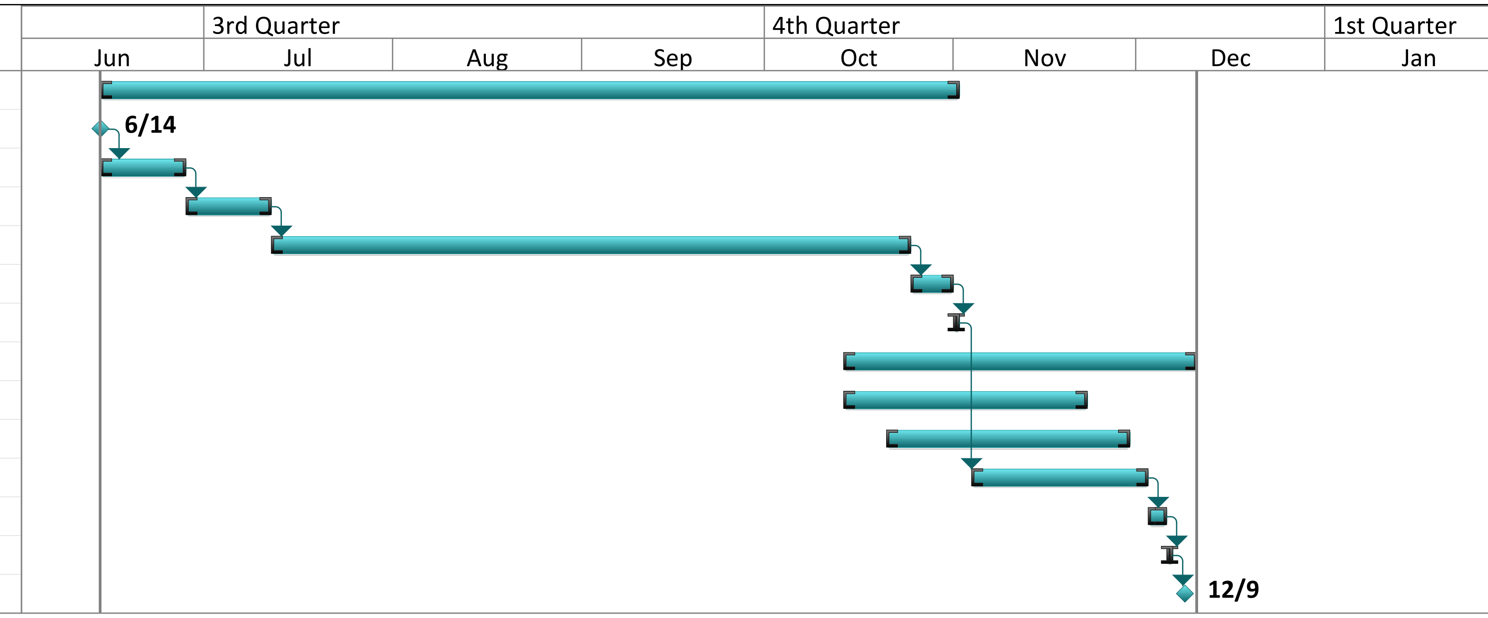
DATE: 10/12/12	DSGN: PTS
SCALE: 1"=60'	CHK: PTS
DRAWN: DFG	APPRD: JAM
JOB: 1010110.000	P MGR: PTS
COPYRIGHT 2011	
SHEET: 1 of 30	

MSP-1

FILENAME: \\Bisces.com\work\Land_Serv\TTOWN\Projects\2010\1010110\dwg\1010110UB.DWG

Appendix C. 4

ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors
1			Procurement	101 days	Fri 6/14/13	Fri 11/1/13	
2			Construction Docs sent to Mestek Architectural	0 days	Fri 6/14/13	Fri 6/14/13	
3			Design Development	10 days	Fri 6/14/13	Thu 6/27/13	2
4			Shop Drawings	10 days	Fri 6/28/13	Thu 7/11/13	3
5			Fabrication	75 days	Fri 7/12/13	Thu 10/24/13	4
6			Shipping	5 days	Fri 10/25/13	Thu 10/31/13	5
7			System Delivery	1 day	Fri 11/1/13	Fri 11/1/13	6
8			On-Site Activities	42 days	Mon 10/14/13	Tue 12/10/13	
9			Existing Curtainwall - Column Lines S-9	30 days	Mon 10/14/13	Fri 11/22/13	
10			Existing Curtainwall - Column Lines 10-15	30 days	Mon 10/21/13	Fri 11/29/13	
11			Shadoglass System - Column Lines S-15	21 days	Mon 11/4/13	Mon 12/2/13	7
12			Shadoglass System - Punchlist	3 days	Tue 12/3/13	Thu 12/5/13	11
13			Shadoglass System - Commissioning	1 day	Fri 12/6/13	Fri 12/6/13	12
14			Shadoglass System Complete	0 days	Mon 12/9/13	Mon 12/9/13	13



Project: Schedule - Solar Shading
Date: Mon 3/24/14

Task
Split
Milestone
Summary
Project Summary
External Tasks
External Milestone
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Deadline
Progress

Appendix C.5

Solar Shading Installation Sequence

Exterior Material legend	
I.D.	**Description**
BR-1	BRICK, SEE SPEC'S
C-1	EXPOSED CONCRETE W/ EXT. PAINT FINISH, SEE SPEC'S
CW-1	7 1/2" DEEP ALUM. CURTAIN WALL SYSTEM, SEE SPEC'S
IGU-1	1" INSULATED CLEAR VISION GLASS IN ALUMINUM CURTAIN WALL SYSTEM, SEE SPEC'S FOR ADDITIONAL INFORMATION
IGU-2	1" INSULATED TINTED VISION GLASS IN ALUMINUM CURTAIN WALL SYSTEM, SEE SPEC'S FOR ADDITIONAL INFORMATION
IGU-3	1" INSULATED CLEAR VISION GLASS W/ FRIT & SHADOW BOX ASSEMBLY IN ALUMINUM CURTAIN WALL SYSTEM, SEE SPEC'S FOR ADDITIONAL INFORMATION
IGU-4	1" INSULATED CLEAR VISION GLASS W/ FRIT IN ALUMINUM CURTAIN WALL SYSTEM, SEE SPEC'S FOR ADDITIONAL INFORMATION
IGU-5	1" INSULATED TINTED VISION GLASS W/ FRIT & SHADOW BOX ASSEMBLY IN ALUMINUM CURTAIN WALL SYSTEM, SEE SPEC'S FOR ADDITIONAL INFORMATION
IGU-6	TEMPERED 1" INSULATED CLEAR SPANDREL GLASS IN ALUMINUM CURTAIN WALL SYSTEM, SEE SPEC'S FOR ADDITIONAL INFORMATION
MC-1	METAL COPING, SEE SPEC'S FOR COLOR & FINISH
MP-1	COMPOSITE METAL PANEL, SEE SPEC'S FOR COLOR & FINISH
MP-2	COMPOSITE METAL PANEL, SEE SPEC'S FOR COLOR & FINISH
PWP-1	EXTERIOR PHENOLIC WALL PANEL SYSTEM W/ CONCEALED ALUM SUPPORT SYSTEM. BASIS OF DESIGN: TRESPA
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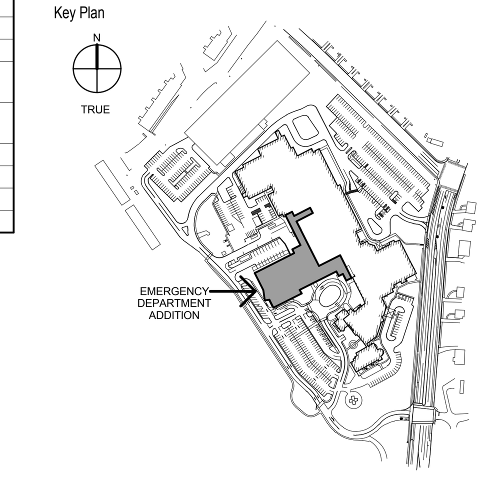
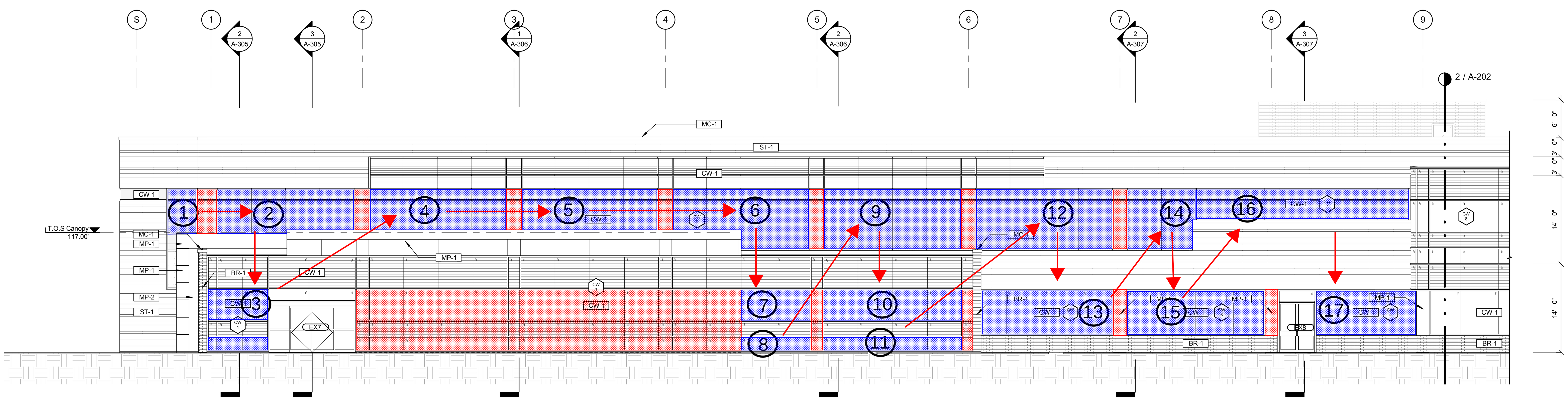
ST-1	ARRISCRAFT THIN CLAD STONE ON ALUM CLIP SYSTEM, SEE SPEC'S
ST-2	CAST STONE, SEE SPEC'S FOR COLOR & FINISH

Revisions

No.	Description	Date

Key Plan





1 / A-202 Building Elevation - South West
1/8" = 1'-0"

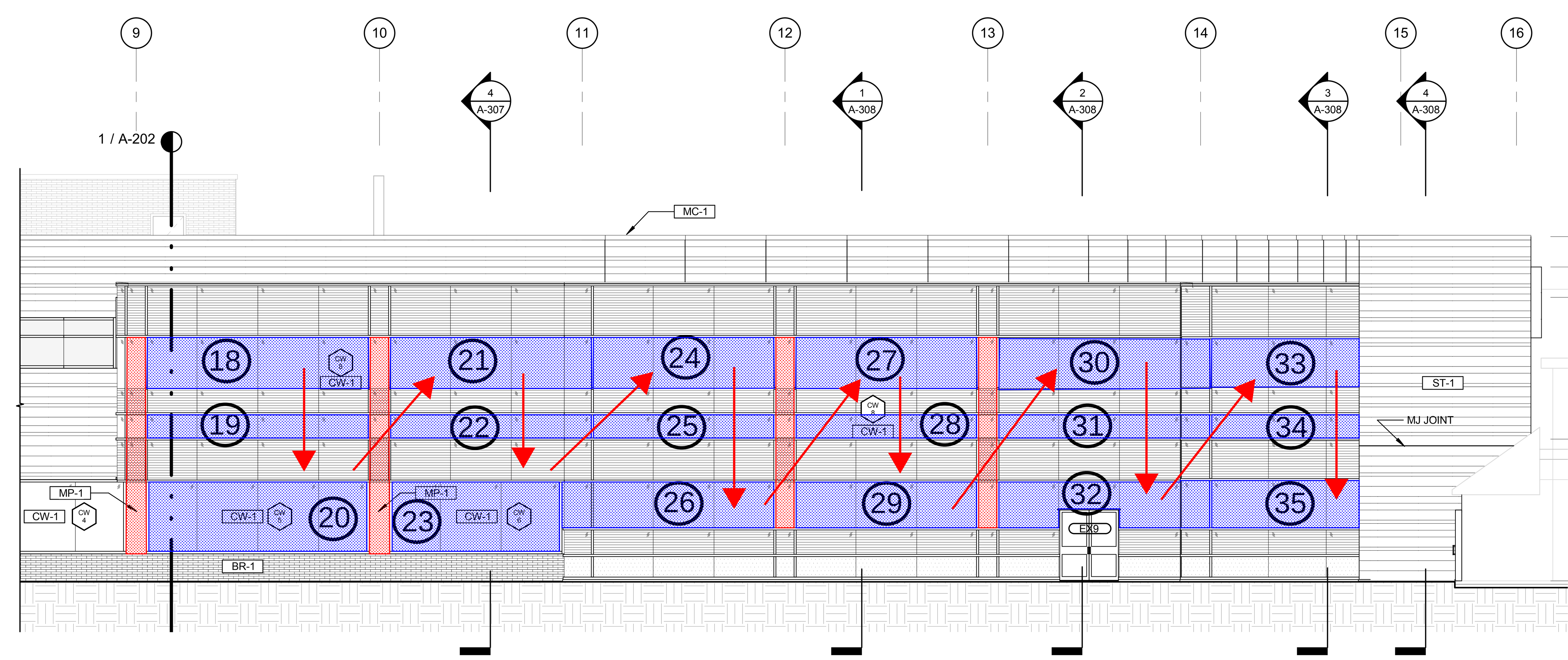
Indicates Flow of Work

Beginning on 11/4/13 and Ending on 12/2/13

1 Through 35 = Sequence of Installation

= Solar Shading Devices

= No Shading Devices Necessary



2 / A-202 Building Elevation - South East
1/8" = 1'-0"

Consultants:

Structural Engineer:
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111 South Independence Mall East
Suite 950
Philadelphia, PA 19106
Phone: (215) 925-3788
Fax: (215) 627-1051
www.o-n.com

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327 North 17th Street
Philadelphia, PA 19103
Phone: (215) 241-9100
Fax: (215) 241-9112
www.pwius.com

Civil Engineer:
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Phone: (610) 398-0904
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Construction Manager:
Turner Construction Company
1835 Market Street
21st Floor
Philadelphia, PA 19103
Phone: (215) 496-8800
www.turnerconstruction.com

It is the responsibility of the Construction Manager/General Contractor and all Sub-Contractors to verify all dimensions and accept conditions of prior work by related trades before proceeding with any work.

Date
10/26/2012

Drawn By
Author

Scale
1/8" = 1'-0"

Seal

Checker

Francis Cauffman

Project Title
Aria Health System - Torresdale Campus

New Emergency Dept & Patient Medical Tower

10800 Knights Road
Philadelphia, Pennsylvania, 19114

Project Number
F11-5892

Drawing Title and Number
Building Elevations

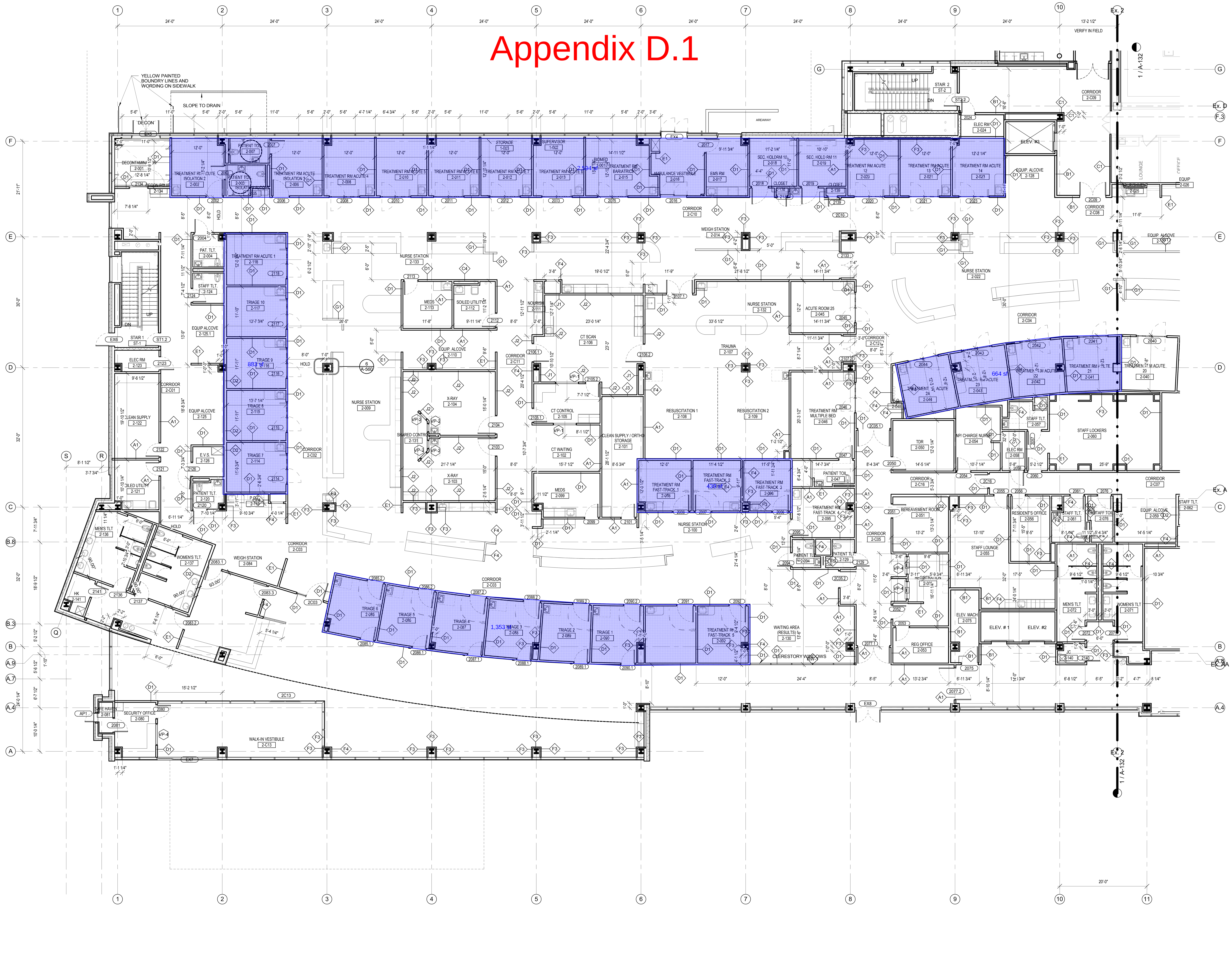
A-202

CONSTRUCTION DOCUMENTS ISSUE - 10/26/2012

Appendix D

Modularization of Patient Treatment Rooms

Appendix D.1



LEVEL 2 ARCHITECTURAL PLAN- WEST
1/8" = 1'-0"

No.	Description	Date

Revisions

Key Plan

Consultants:

Structural Engineer:
O'Donnell & Naccarato
111 South Independence Mall East
Suite 950
Philadelphia, PA 19106
Phone: (215) 925-3788
Fax: (215) 627-1051
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Date
10/26/2012

Drawn By
Author

Scale
1/8" = 1'-0"

Seal

Checker

Francis Cauffman

Project Title

ARIA HEALTH SYSTEM - TORRESDALE CAMPUS

EMERGENCY DEPARTMENT ADDITION

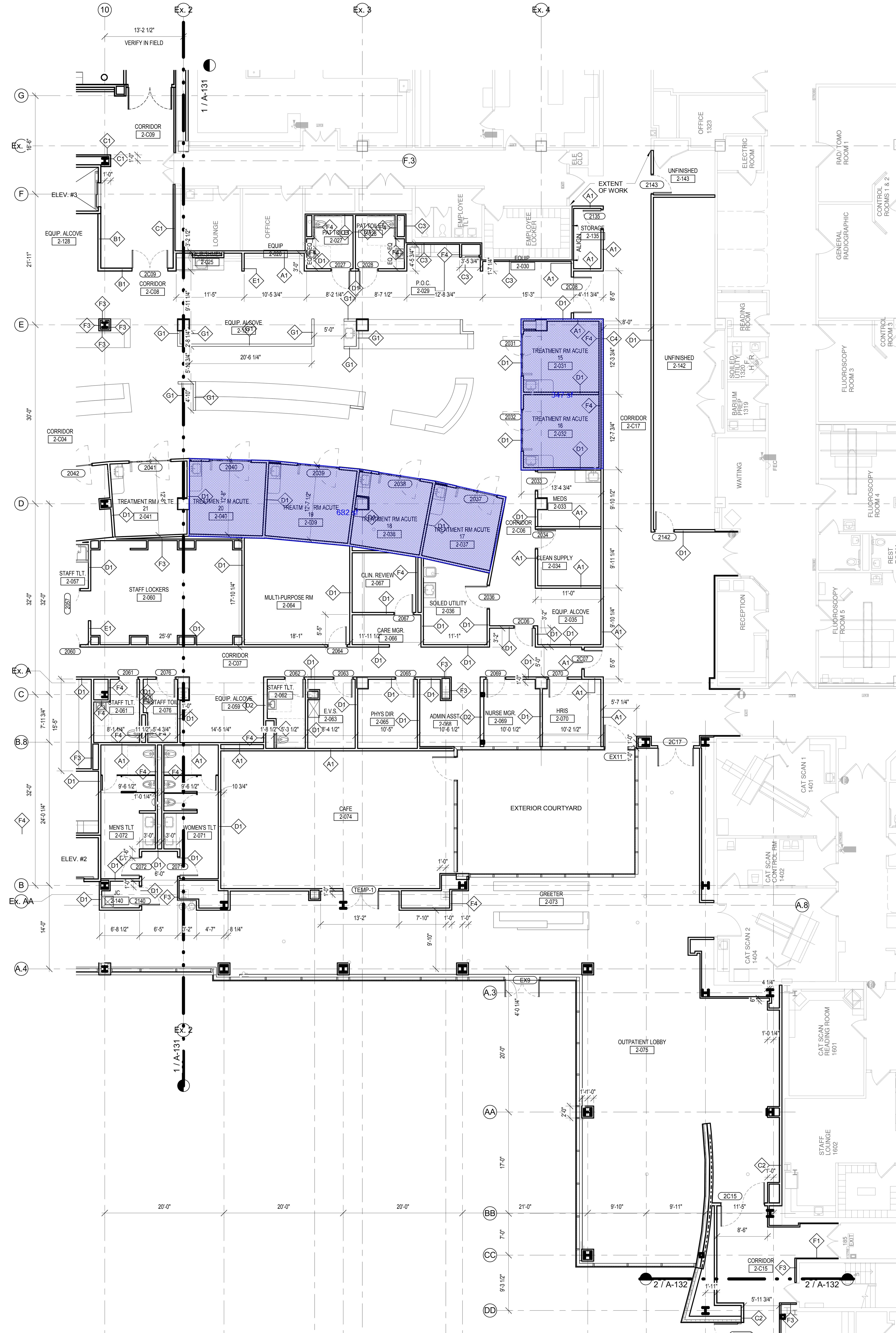
10800 KNIGHTS ROAD
PHILADELPHIA, PENNSYLVANIA
19114

Project Number
F11-5892

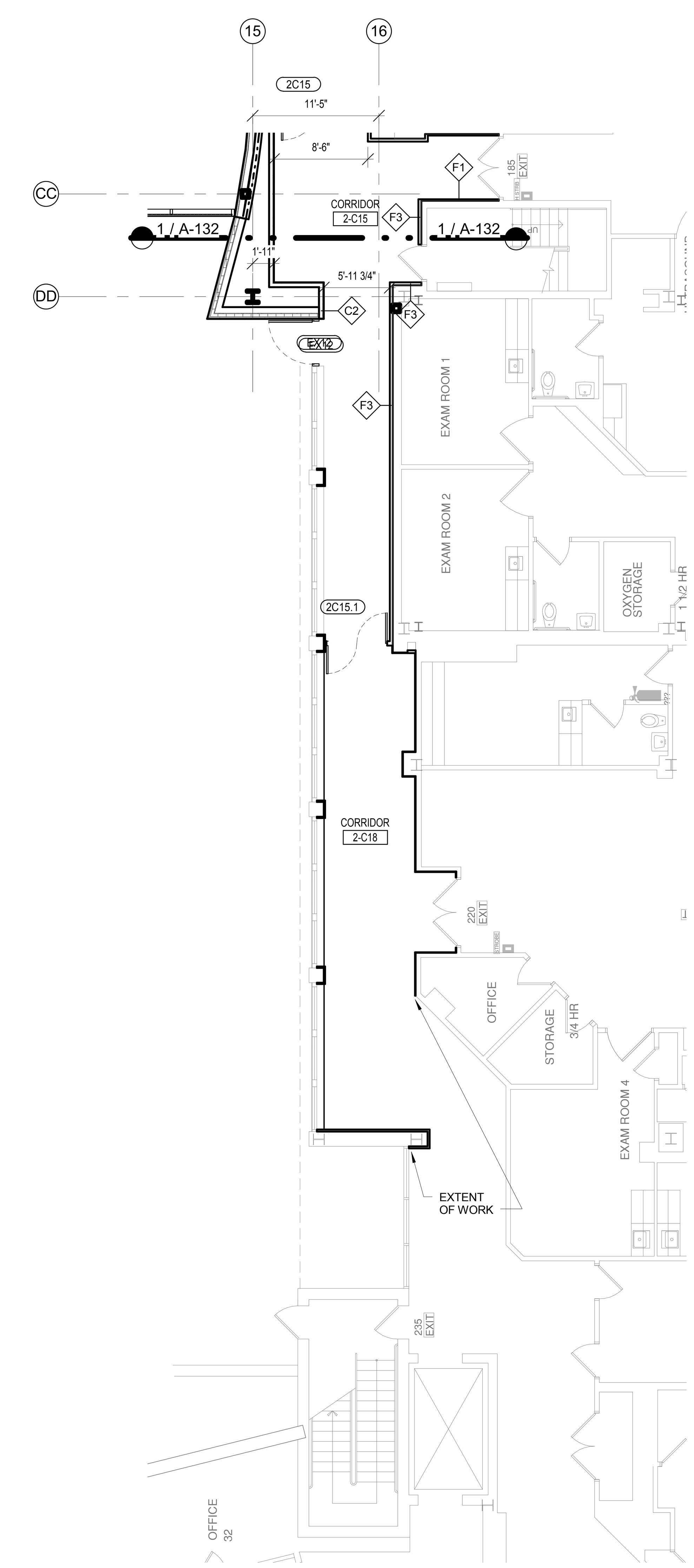
Drawing Title and Number
LEVEL 2 - ARCHITECTURAL PLAN WEST

A-131

CONSTRUCTION DOCUMENTS ISSUE - 10/26/2012



1 LEVEL 2 ARCHITECTURAL PLAN- EAST
A-132 1/8" = 1'-0"

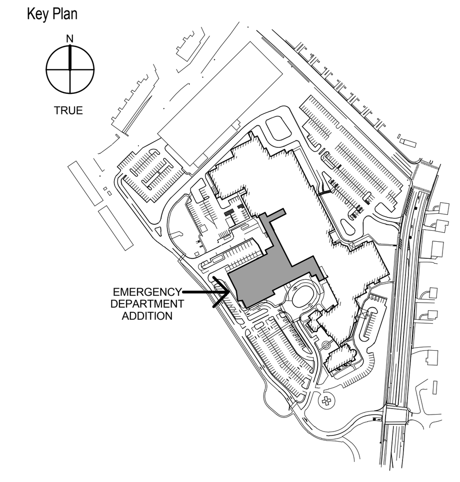


2 LEVEL 2 ARCHITECTURAL PLAN - EAST CORRIDOR
A-132 1/8" = 1'-0"

Revisions

No.	Description	Date

Key Plan



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Date
10/26/2012

Drawn By
Author

Scale
1/8" = 1'-0"

Seal

Checker

Francis Cauffman

Project Title

ARIA HEALTH SYSTEM - TORRESDALE CAMPUS

EMERGENCY DEPARTMENT ADDITION

10800 KNIGHTS ROAD
PHILADELPHIA, PENNSYLVANIA
19114

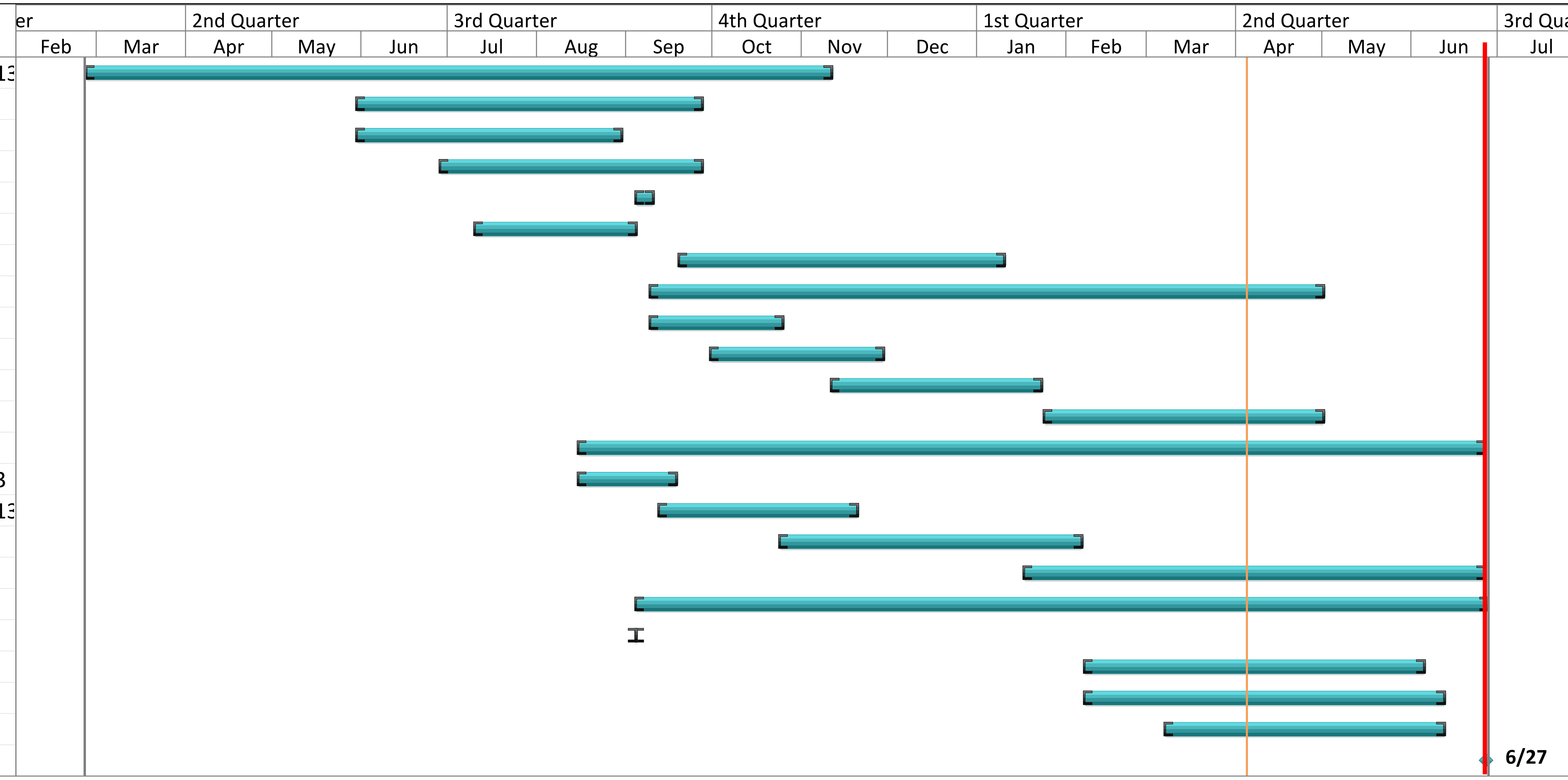
Project Number
F11-5892

Drawing Title and Number
LEVEL 2 - ARCHITECTURAL PLAN EAST

A-132

CONSTRUCTION DOCUMENTS ISSUE - 10/26/2012

ID	Task Mode	Task Name	Duration	Start	Finish
1		**Demo, Excavate, Prep**	186 days	Mon 2/25/13	Mon 11/11/13
2		**Concrete**	87 days	Thu 5/30/13	Fri 9/27/13
3		Concrete Level 1	67 days	Thu 5/30/13	Fri 8/30/13
4		Concrete Level 2	66 days	Fri 6/28/13	Fri 9/27/13
5		Concrete Level 3	5 days	Wed 9/4/13	Tue 9/10/13
6		**Structural Steel**	41 days	Wed 7/10/13	Wed 9/4/13
7		**Building Envelope**	82 days	Thu 9/19/13	Fri 1/10/14
8		**Fitout Level 1**	169 days	Mon 9/9/13	Thu 5/1/14
9		Layout, CMU, Rated Partitions	35 days	Mon 9/9/13	Fri 10/25/13
10		MEP Ceiling Rough-In	45 days	Mon 9/30/13	Fri 11/29/13
11		Walls	54 days	Mon 11/11/13	Thu 1/23/14
12		Finishes	70 days	Fri 1/24/14	Thu 5/1/14
13		**Fitout Level 2**	226 days	Thu 8/15/13	Thu 6/26/14
14		Layout, CMU, Rated Partitions	25 days	Thu 8/15/13	Wed 9/18/13
15		MEP Ceiling Rough-In	50 days	Thu 9/12/13	Wed 11/20/13
16		Walls	76 days	Thu 10/24/13	Thu 2/6/14
17		Finishes	115 days	Fri 1/17/14	Thu 6/26/14
18		**Closeout**	213 days	Wed 9/4/13	Fri 6/27/14
19		MEP Start-Up	1 day	Wed 9/4/13	Wed 9/4/13
20		Medical Equipment Install	85 days	Fri 2/7/14	Thu 6/5/14
21		TAB	90 days	Fri 2/7/14	Thu 6/12/14
22		Commissioning	70 days	Fri 3/7/14	Thu 6/12/14
23		**Substantial Completion**	0 days	Fri 6/27/14	Fri 6/27/14



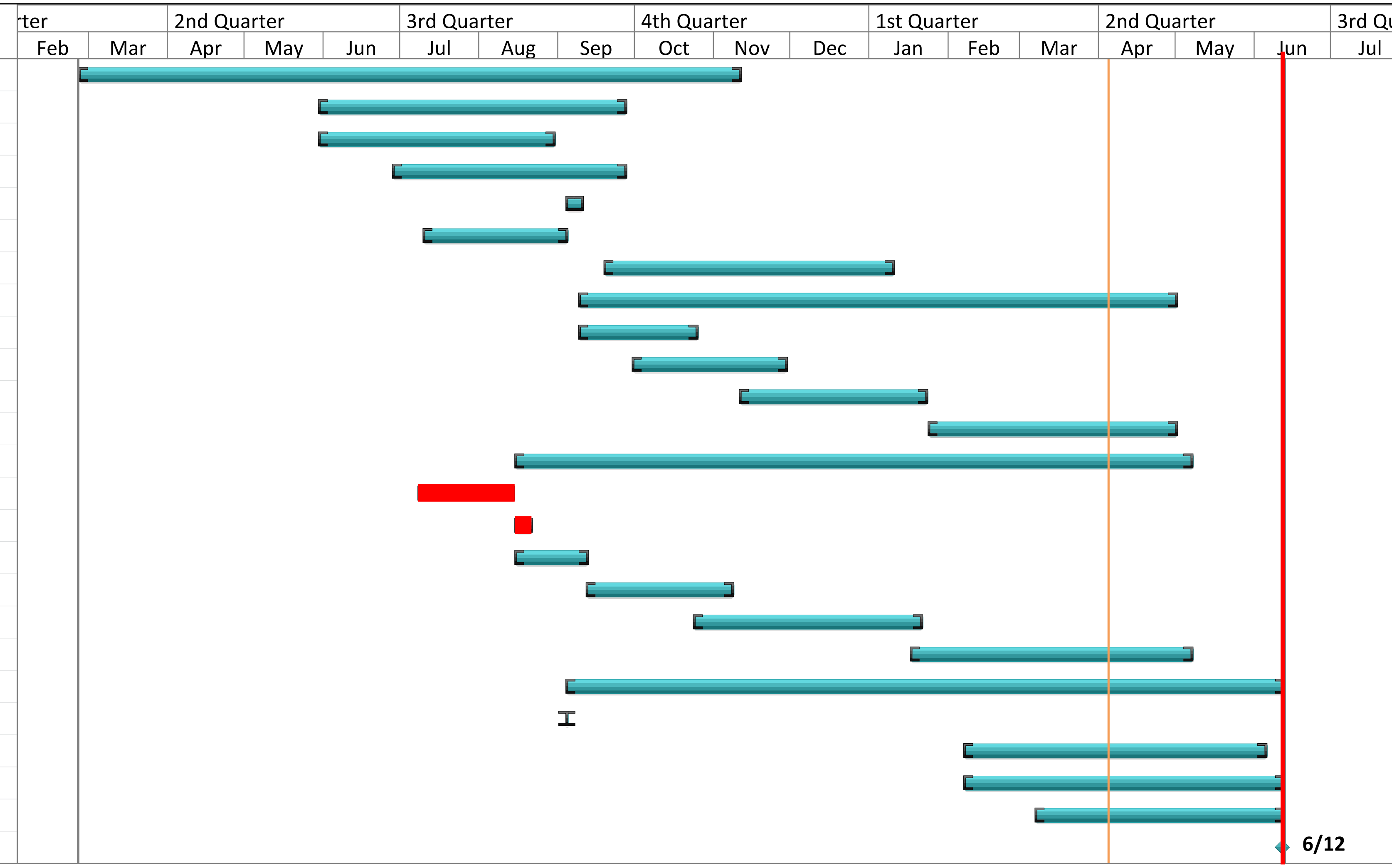
Appendix D.2

Schedule without Modular Construction

Project: Schedule - Without Modu
Date: Sat 4/5/14

Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Deadline	
Split		External Tasks		Inactive Summary		Manual Summary		Progress	
Milestone		External Milestone		Manual Task		Start-only			
Summary		Inactive Task		Duration-only		Finish-only			

ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors
1			**Demo, Excavate, Prep**	186 days	Mon 2/25/13	Mon 11/11/13	
2			**Concrete**	87 days	Thu 5/30/13	Fri 9/27/13	
3			Concrete Level 1	67 days	Thu 5/30/13	Fri 8/30/13	
4			Concrete Level 2	66 days	Fri 6/28/13	Fri 9/27/13	
5			Concrete Level 3	5 days	Wed 9/4/13	Tue 9/10/13	
6			**Structural Steel**	41 days	Wed 7/10/13	Wed 9/4/13	
7			**Building Envelope**	82 days	Thu 9/19/13	Fri 1/10/14	
8			**Fitout Level 1**	169 days	Mon 9/9/13	Thu 5/1/14	
9			Layout, CMU, Rated Partitions	35 days	Mon 9/9/13	Fri 10/25/13	
10			MEP Ceiling Rough-In	45 days	Mon 9/30/13	Fri 11/29/13	
11			Walls	54 days	Mon 11/11/13	Thu 1/23/14	
12			Finishes	70 days	Fri 1/24/14	Thu 5/1/14	
13			**Fitout Level 2**	190 days	Thu 8/15/13	Wed 5/7/14	
14			Prefabricate 42 Modules	28 days	Mon 7/8/13	Wed 8/14/13	
15			Rig and Set 42 Modules	5 days	Thu 8/15/13	Wed 8/21/13	
16			Layout, CMU, Rated Partitions	21 days	Thu 8/15/13	Thu 9/12/13	
17			MEP Ceiling Rough-In	42 days	Thu 9/12/13	Fri 11/8/13	
18			Walls	64 days	Thu 10/24/13	Tue 1/21/14	
19			Finishes	79 days	Fri 1/17/14	Wed 5/7/14	
20			**Closeout**	202 days	Wed 9/4/13	Thu 6/12/14	
21			MEP Start-Up	1 day	Wed 9/4/13	Wed 9/4/13	
22			Medical Equipment Install	85 days	Fri 2/7/14	Thu 6/5/14	
23			TAB	90 days	Fri 2/7/14	Thu 6/12/14	
24			Commissioning	70 days	Fri 3/7/14	Thu 6/12/14	
25			**Substantial Completion**	0 days	Thu 6/12/14	Thu 6/12/14	



Appendix D.3

Schedule WITH Modular Construction

Project: Schedule - WITH Modular
Date: Sat 4/5/14

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

Appendix D.4

Case Study

Lean Transformation in a Modular Building Company: A Case for Implementation

Haitao Yu[1]; Mohamed Al-Hussein, M.ASCE[2]; Saad Al-Jibouri[3]; and Avi Telyas[4]

Abstract: Encouraged by the remarkable productivity improvements in the manufacturing sector, the construction industry has a long history of trying to garner the benefits of manufacturing technologies. Whereas industrialized construction methods, such as modular and manufactured buildings, have evolved over decades, core techniques used in prefabrication plants vary only slightly from those employed in traditional site-built construction. The objective of this research was to develop and implement a production system for the effective application of lean tools in building components prefabrication. To overcome the prevalent skepticism among middle management, the lean journey started with a pilot project involving one production line. Over a six-month period, lean tools such as 5S (sort, straighten, shine, standardize, and sustain), standardized work, takt time planning, variation management, and value stream mapping were implemented to a communication shelter production line. The implementation successfully won the support of the middle managers and established the foundation for expanding lean practices to other parts of the factory and applying relevant lean tools and techniques. **DOI: 10.1061/(ASCE)ME.1943-5479.0000115.**

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Introduction

For decades, construction practitioners have been enticed by the idea of modeling construction after manufacturing, which experienced significant productivity improvement in the past century (Crowley 1998). In general, two strategies have been used for industrializing construction. The product approach aims at minimizing on-site construction activities by turning buildings into products that can be manufactured in a factory environment, whereas the process approach focuses on applying a manufacturing management model to the current construction process. The product approach had a strong impact on design and construction in the 1960s, with the evolution of a building system that was underpinned by three principles: standardization, prefabrication, and dimensional coordination. Prefabrication of building components on a large scale changed a substantial part of the construction from craft to manufacturing. As a result, productivity in the construction industry went up over a short span of years in some European countries that adopted the prefabrication method. However, when the buying power increased in the 1970s, the market asked for more individuality, and construction, to a great extent, went back into being a craft. There have been significant debates around modeling construction after manufacturing (Winch 2003). The particularities of the construction process, such as a one-of-a-kind product, on-site construction, temporary supply chain, and trade-based workforce (Bertelsen 2003), were regarded as evidence that the management principles and techniques used in manufacturing were not applicable in construction.

The manufacturing model regained the attention of the construction industry in the early 1990s, when the lean production system became a new manufacturing paradigm. An important step in that was the work described by Koskela (1992), who introduced a tripartite view of the construction process as transformation, flow, and value generation (also termed the TFV theory of production). The concept was further elaborated upon in his dissertation (Koskela 2000). Another important milestone in lean construction is the work carried out by Ballard and Howell on construction workflow variability (Ballard 1993; Ballard and Howell 1994b). Their work led to a lean-based construction workflow planning and management tool, the last planner system (LPS) (Ballard 2000). Other research efforts on the transfer of lean manufacturing techniques to construction included the use of 5S (sort, straighten, shine, standardize, and sustain) to increase site visualization (Dos Santos et al. 1998), establishing a fail-safe (Poka-yoke) system to ensure first-time quality compliance (Milberg and Tommelein 2003), using Kanban to control on-site material inventory (Arbulu et al. 2003), and applying the PDCA (plan, do, check, and act) cycle to redesign critical assignment (Ballard and Howell 1994a). Salem et al. (2006) summarized previous research efforts in the area of lean construction and assessed the impact of these techniques on project performance by a designed case study. Although the research literature suggested positive results from the application of lean theory to the construction process (process approach), the inherent differences between construction and manufacturing impeded achieving the full potential of the lean production system (Salem et al. 2006).

Recently, there has been a tendency for the two aforementioned approaches to converge in the format of modularization, in which modules are individually designed, produced, and assembled with

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the efficiency of industrialization (Bertelsen 2005). Modular construction has been used by the construction industry for years, but the potential benefits of modularization have not been realized because most modular producers have failed to take advantage of modern manufacturing technologies to improve their production process [Manufactured Housing Research Alliance (MHRA) 2005]. The manufactured housing industry seized the value of lean manufacturing on process improvement. Two major streams of research in this area were plant layouts optimization based on lean principles and lean implementation plan development using simulation (Senghore et al. 2004; Mehrotra et al. 2005; Jeong et al. 2006).

This paper describes a lean implementation initiative in a U.S.-based modular building company, Kullman Building Corporate (KBC). In collaboration with the University of Alberta, a modular production line that was relatively easy to control was selected as a lean pilot project, and a number of lean production techniques were tailored and implemented. The lean journey started with 5S and standardized work. This was followed by using the value stream mapping technique to analyze current practice, formulate a lean production model, and develop a kaizen plan. The implementation results were documented in detail to verify the effectiveness of the lean production model. Through the lean transformation of the production line, middle management was convinced that lean production was workable and could remarkably improve productivity and reduce waste. The success also led to the lean implementation in other parts of the factory and management's long-term commitment to a lean culture.

Lean Production and the Modular Building Industry

Although in the past 30 years lean production has been studied and introduced into numerous workplaces regardless of industrial field or scale, there have always been arguments by the construction practitioners that construction is distinct from auto manufacturing and that lean production is not applicable. A high level of customization in building design makes building modules mostly one-of-a-kind products. The need for variety has been regarded by many as a major reason that a lean production system is not feasible for modular production, but ironically, variety is in fact the soil in which the lean production system was cultivated and the very reason that lean production surpasses conventional mass production in effectiveness. A major factor that drove Toyota to conceive lean production was the reality that the Japanese automobile market in the postwar period required the production of small quantities of many varieties under conditions of low demand. There were more than 200,000 cars per month that came off the assembly lines in a virtually infinite number of varieties. The number of varieties reached to the thousands just by considering the combinations of car size and style, body type, engine size, and transmission method. If colors and combinations of various options were included, it was rare to see two completely identical cars (Ohno 1998).

Moreover, an automobile, like a building modular, is made of thousands of parts; the number of processes involved is immense. It is extremely difficult to apply just-in-time (JIT) to a production plan of every process in an orderly way. An upset in prediction, a mistake in the paperwork, defective products and rework, trouble with the equipment, absenteeism—the problems that could arise are countless. A problem early in the process always results in a defect product later. Stops and changes in the production process will happen regardless of planning.

Background of Case Study

The case study company, KBC, is one of the leading modular building manufacturers in the U.S. The company was founded in 1927 by a young salesperson to provide turn-key, portable diners that served a market seeking fast, low-cost, home-cooked meals. After 80 years of growth, KBC now has over 200 employees and has expanded its market to produce a variety of building types, including equipment shelters, schools, dormitories and multistory residential buildings, correctional facilities, healthcare facilities, and U.S. embassies. The company coined the term accelerated construction to describe a building process free from uncertainties of weather, site conditions, and contractor relations. While modularization provides KBC significant competitive advantages in terms of site construction time, quality control, and predictability, the company has not yet realized its full potential. Considering the cost of transportation and installation, KBC's products were typically 10–20% more expensive than their counterparts built on-site. As a result, its customers were limited primarily to wireless providers, education institutes, and government, which are less cost

Fig. 1. Module production of a 3-story dormitory project

constrained. A fundamental reason for the high cost was that KBC, like other modular manufacturers, still "stick build under the roof," and failed to take advantage of modern manufacturing technologies that could significantly improve their production process (Nasereddin et al. 2007). Fig. 1 shows the production of a dormitory project that consisted of five 3-story buildings, which were built in the factory in modules and shipped to the site. In this example, the modules were stocked inside the factory and various trades and materials went to the building in sequence, similar to the on-site construction.

Both the KBC chief executive officer (CEO) and the chief operating officer (COO) came from the semiconductor industry and had profound knowledge in lean manufacturing; both of them believed that modularization would be the future of construction and had a passion to transform KBC from a traditional construction company to a lean manufacturer. The company had two vice presidents (VP), including VP of personnel, accounting, and project management, and VP of sales.

The KBC organization had a conventional hierarchical structure, with a manager for each functional area. The head of production was a plant manager who reported to the CEO. The production planning and workforce on the floor were managed by a production control manager, assisted by five line managers. A logistics manager was responsible for the procurement and storage of all materials and tools. All middle managers in the production department were company veterans, having been with the company for more than ten years. Although most of them had taken Lean 101 training, they did not have any experience in manufacturing and showed little interest in lean implementation at the beginning of the project.

The frontline workforce of KBC consisted of 110 full-time employees and temporary workers from two agencies. These workers represented a wide variety of trade disciplines: carpentry, welding, electrical, painting, plumbing, rigging, and computer numerical control machine operation. The KBC employees were unionized, with an average of four years of tenure. Frontline workers had also taken Lean 101 training provided by an external consultant, but they were generally reluctant to change. Skepticism was prevalent because of concerns that eliminating waste might result in increased work intensity and workforce reduction.

Lean Pilot Project and 5S

Lean transformation requires complete commitment from top management, but the biggest challenge and key success factor is to let the middle management and frontline workers see the necessity of change and the effectiveness of lean production. In KBC, this was done by focusing the lean implementation on a pilot project and 5S campaign.

The communication shelter production line, a discrete assembly line with a continuous work flow, was selected as the demonstration area of lean transformation. Because 95% of the communication shelters were 3.7×9.1 m (12×30 ft) or 3.7×6.1 m (12×20 ft) standard modules with similar configurations, standardization of the production process was relatively easy. Meanwhile, as a major production line generating 40% of the overall revenue of the company, it was highly visible. Backed by the top management, a top-down approach was adopted, and the objectives of the project were defined as synchronizing the production line to takt time, reducing average labor hours per module by 20%, and controlling overtime under 10% of total labor hours. The duration of the pilot project was scheduled as six months, and the first step was planned to be the process documentation of the communication shelter line and a 5S campaign.

The 5S plan has been recommended by many lean experts as the starting point of lean transformation (Productivity Press 2006), because compared to other lean tools, 5S, which focuses on cleaning and organizing the workplace, is easier to get workers to buy-in and it produces immediate visible results. More importantly, effective cleaning and efforts to sustain a better organized workplace involve many key lean principles and methods, such as standardized work and visual management. The 5S plan can help people that have no lean production experience build teamwork, discipline, and a culture of continuous improvement, which are the cornerstones of lean implementation.

After shop floor observation, a series of workshops were held with frontline workers to review the findings. At each workshop, the basic concepts of 5S and seven types of wastes were explained, pictures like Fig. 2(a) were presented, and examples of workplace management at some world-class lean enterprises were introduced. Following these, a brainstorming session was conducted to identify three top areas of waste and to develop a team action plan with possible solutions, completion deadline, and persons responsible. The production manager and line managers also attended these workshops to show their commitment and support to the initiatives.

In two weeks, workers at the communication shelter line were organized into eight workgroups, each with its own 5S action plan and biweekly 5S meetings. The working condition of the shop floor was remarkably improved, as shown in Fig. 2(b). One advantage of starting a lean journey with 5S was that people could see the results

(a) (b)

Fig. 2. Work area of station 3: (a) before 5S; (b) after 5S

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in a relatively short period of time and become excited about the progress and improvement. Moreover, 5S efforts soon went beyond cleaning activities to other lean implementations. In 5S meetings, a repeatedly asked question was "Where is the best place to put this material (or equipment)?" The answer was always "At the place where they are used." This led to the establishment of on-station inventory and the development of Kanban, a scheduling system used in lean to achieve JIT. Meanwhile, standardized work became a natural choice, because a given task should always be performed at a designated location so that required materials and equipment could be put next to that location. Comparing the two states shown in Fig. 2, the second one was not only much cleaner, but held all the materials and equipment required by the operations at station 3.

Standardized Work and Variation Management

Standardized work is regarded as the backbone of lean processes and the basis for continuous improvement and quality. If a process is always shifting, then any effort for improvement just creates one more variation that is occasionally used and mostly ignored (Liker 2004). One common problem in construction is that most construction tasks are done by trades people based on their skill and experience. Although the production of communication shelters in KBC was on an assembly line, the production process was highly unpredictable. The line manager dynamically assigned workers to tasks on a daily or hourly basis, and the line was moved when most of the tasks had been done. As a result, the production process varied and people did not know which state was normal.

The first step of standardized work was to determine takt time, the maximum time allowed for a modular to stay in a station. According to its definition, takt time can be calculated using the following formula:

$$T = \frac{T_a}{T_d} \tag{1}$$

where T = takt time; T_a = net time available to work; and T_d = customer demand. Based on a time series analysis of the historical data of customer orders and demand forecast provided by customers, takt time was determined as seven hours in months two to four and six hours in months five to seven. Because the average production cycle time in the current month (month one) was eight hours, to synchronize the production line to the takt time target meant a 25% improvement in production capacity in three months.

Operation standardization was done through a standard worksheet that consisted of two elements. A work combination table (Fig. 3) determined the task sequence and workforce requirements at a given station and clarified the work scope for which a crew was responsible. For each task, a standard work procedure (Fig. 4) provided step-by-step instructions to ensure workers follow the best practice. Because all workers had been trained to perform the operation in a standardized way before they were released to the job, they did not have to refer to standard worksheets during their operation. However, the combination table and standard work procedures were posted at each station to provide a visual reference for management to check adherence to the standard. Any deviation from the standard meant an abnormal situation, usually caused by problems. The role of management was to recognize the deviation, uncover the root causes, ensure that they were corrected quickly, and reestablish the standardized work.

One unique characteristic of construction is the high level of customization; it is rare to see two identical buildings. The production of communication shelters faced the same challenge. Some of the modules were so different that workloads in one or two stations changed dramatically. For example, compared to a standard 3.7×9.1 m (12×30 ft) module with a single interior gypsum board and exterior stenni finish, a module with double-layer interior and exterior boarding, waterproofing, and hand-laid brick almost doubled the carpenters' workloads at station 2 and station 3. The extra workload for one task might have a remarkable impact on the overall work sequence. When there was only one layer of interior gypsum board, the interior finishing crew started its work one hour after the start of the installation of interior boarding so they could both complete their job within takt time. However, if there were two layers of interior boarding, the interior finishing crew could not start until the entire first layer and 20% of the second layer of interior boards had been completed. To maintain the synchronization of the production process, measures had to be taken to accommodate workload fluctuation.

The two most commonly used methods for this purpose are overtime and workforce pool, but they need to be used in a systematic way to minimize waste. In KBC, different standard work sequences for each station were developed to deal with the different module types and takt time requirements. For instance, the work combination table shown in Fig. 3 was an 8-h takt time work sequence for a 3.7×9.1 m (12×30 ft) module with double interior and exterior gypsum board, which accounts for 35% of modules passing through the station. There were separate work

Scenario 1: Double Interior and Exterior Gypsum Board on 12x30 MOD (35%)

Task	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	Work location	Note
FRP and plywood	Crew 1 (2C) / 270 min								Equip. Rm	Go Station 5 to trim/ finish carp after finishing task
Ceiling, lights & uni-strut (equip. room)	Crew 2 (2C) / 260 min								Equip. Rm	
Ceiling, lights & uni-strut (Gen. room)					Crew 2 (2C) / 110 min				Gen. Rm	
Wireway	Crew 3 (1C) / 300 min								Equip. Rm	
Containment Pan							Crew2 (2C) / 100 min		Gen. Rm	

Fig. 3. Work combination table of station 3 (takt time = 8 h)

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Standard Working Procedure (VZW-C30-21)

Task: Vinyl GWB Ceiling

Workforce: 2 carpenters

Standard cycle time:

Equipment room or 12x20 building	Generator room	Vinyl GWB ceiling: 25 min /board Uni-strut: 6 min/unit per worker Light fixture: 10 min/unit
260 min	110 min	

Standard work procedure:

1. Install nailer plate in positions where a uni-struts or a light fixture cannot be attached to a roof joist rib (c1) (figure 1).
   Tips: Read the blueprint to see position of nailer plate. Where connecting cable trays are 4-ft or longer, nailer plate will be needed to receive unistrut.
2. Move the ceiling lift in the room (c2).
3. Measure the actual width of the room and the position of roof joist rib to decide the size of the first Vinyl GWB (2c).
   Tips: Be sure that the last piece is larger than one bay width.
4. Install ceiling vinyl GWBs
   1) Measure and cut the GWB to right size (c2).
      Tips: a) Cut the board from the side with vinyl finish; b) The edge of cut should be trimmed.
   2) Mark the lines of roof joist ribs, and the points of screws (c2).
      Tips: Screws are 8-in c/c on the long edges and 16-in c/c on front and rear wall sides.
   3) Put the GWB on the ceiling lift (2c).

(2c & 1 helper).

GWB (2c).

Fig. 4. Example of standard work procedure

combination tables for the 3.7 × 9.1 m (12 × 30 ft) modules with single or no boarding and the 3.7 × 6.1 m (12 × 20 ft) modules. Float workforce, which did not belong to any work station, was used to deal with the extra workload for different module types, schedule delays, workers' vacations, and absenteeism. In normal situations, the float workforce worked on an off-line module, which was usually a special module with significant workload variation that could not be accommodated at the production line.

Value Stream Mapping

Standardized work is a great tool to stabilize the process and help people identify problems that lead to abnormal situations. However, a standardized procedure is not necessarily the best practice, and the current process often needs to be adjusted to meet the changed requirements. In the case of KBC, a new production model was needed to reduce the takt time of the communication shield line from eight hours to six hours. To achieve this goal, value stream mapping (VSM), a widely used lean planning tool, was selected because of its process view and the ability to link lean initiatives into a whole. Based on standardized work, a four-step method was adopted to develop the future lean production model: (1) current-state mapping; (2) existing practice analysis; (3) formulation of a future production model; and (4) laboratory testing of the model using simulation.

Prior to the commencement of VSM, two management decisions must be made: (1) select a value stream; and (2) decide the level of mapping. In this research, those two decisions were interrelated. When the door-to-door production flow was looked at as a value stream, the mapping could only be done at the station level, because a single map encompassing all tasks conducted within each station would be too large and cumbersome for a VSM team to handle. A high-level value stream map like the one shown in Fig. 5 provided a big picture of the process, but showed little detail of the operations; it could not be used for root cause analysis and future map formulation. In contrast, a station could be seen as a value stream with the preceding station as the supplier and the following station as the customer, as shown in Fig. 6. The problem with mapping the process at this level was that the value stream was not stable, because it might be necessary to move a task from one station to another to optimize the production line or to achieve a different takt time. In this research, maps at two levels were used simultaneously for waste identification and solution development.

Upon drawing up the current-state map, several wastes could be identified immediately. For a linear assembly line, a basic lean principle is to balance the workload and synchronize the station cycle time to takt time. This may be common sense, but in practice it is not an easy job for production management. From the data in Fig. 5, it is easy to see that the production cycle times (C/T) of some stations were much lower than the takt time, which was 480 min in the current-state map. That meant the production capacities of those stations were higher than the demand. Conversely, the percentage of completion (Completion), which was defined as the percentage of modules with all tasks completed at the time of being moved to the next station, were quite low, even at the stations with a much lower cycle time. For instance, the average station cycle time of station 3 was 400 min, approximately 17% lower than the takt time, but the percentage of completion at station 3 was only 80%; one of every five modules moved to the next station had unfinished tasks. For stations with a cycle time close to the takt time, the incompletion rates were much higher. In the case of station 5, almost half of the modules were moved out of the station unfinished. The ripple effect of unfinished tasks disturbed the production pace and led to significant wastes. For instance, if the electricians at station 4 did not finish the rough conduit

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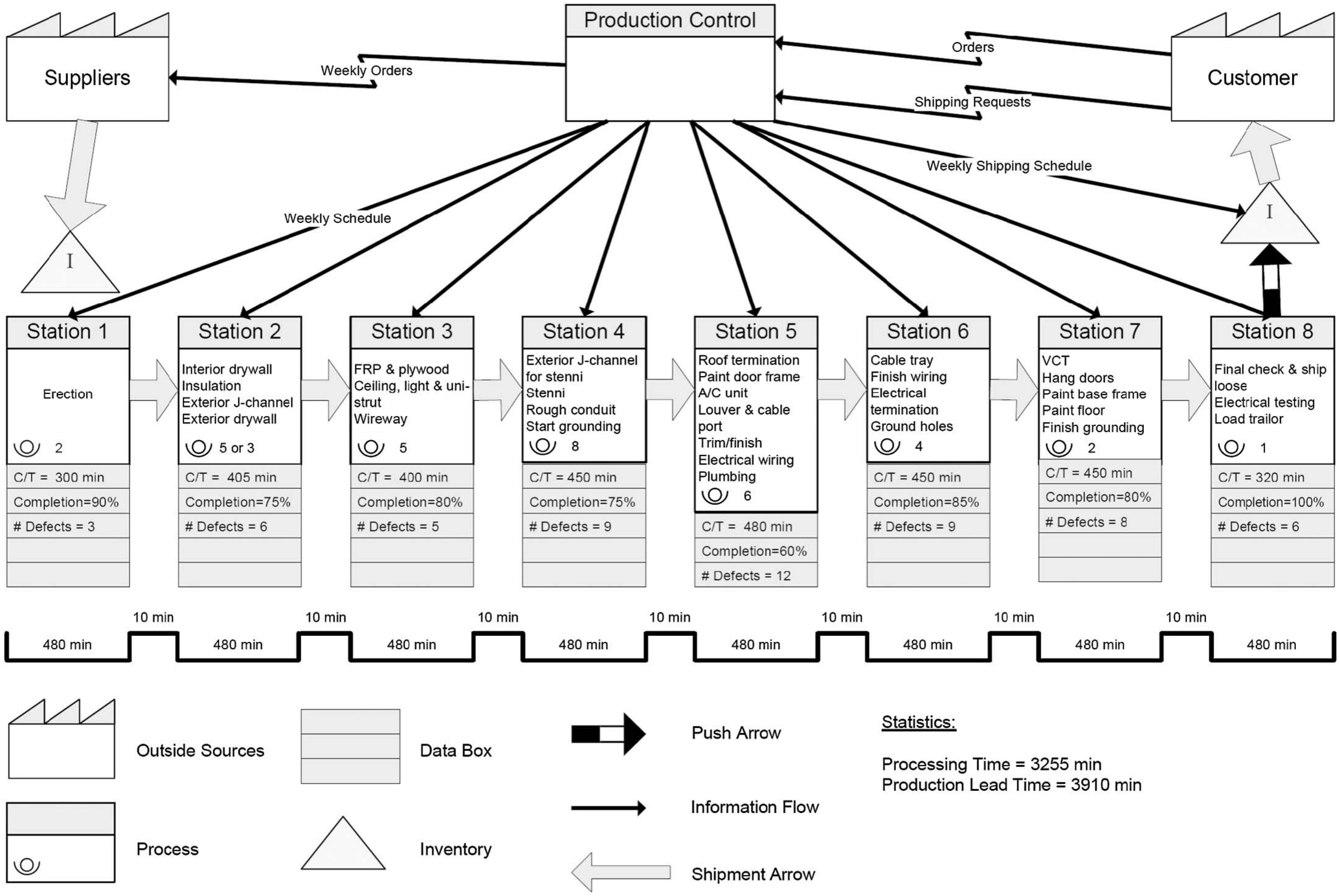

Fig. 5. Current-state map (high level)

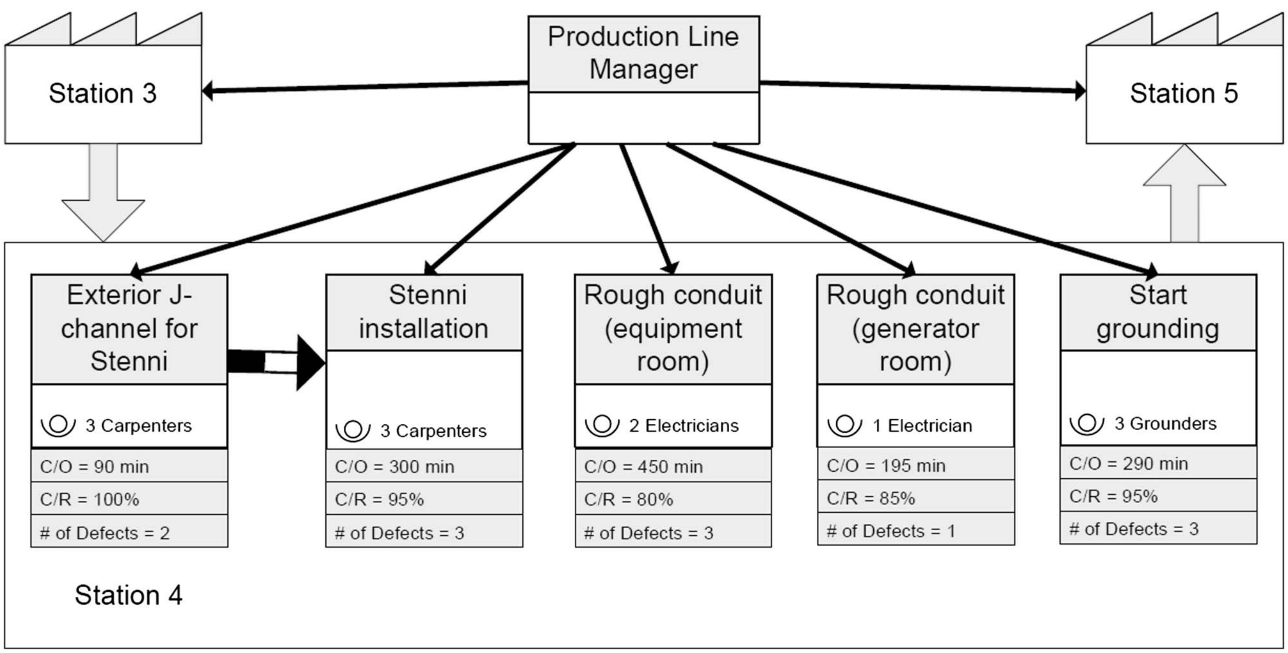

Fig. 6. Current-state map (station 4)

in the equipment room, they needed to continue their job at station 5. Then the workers who should pull electrical wires could not start their job on time, so they were idle at the beginning and had to hurry at the end to finish their job before the module moved to the next station. Moreover, installing rough conduits at station 5 meant that workers had to move back and forth between station 4 and station 5 to get tools and materials, and the more time they spent at station 5, the less time they had for the next module in station 4.

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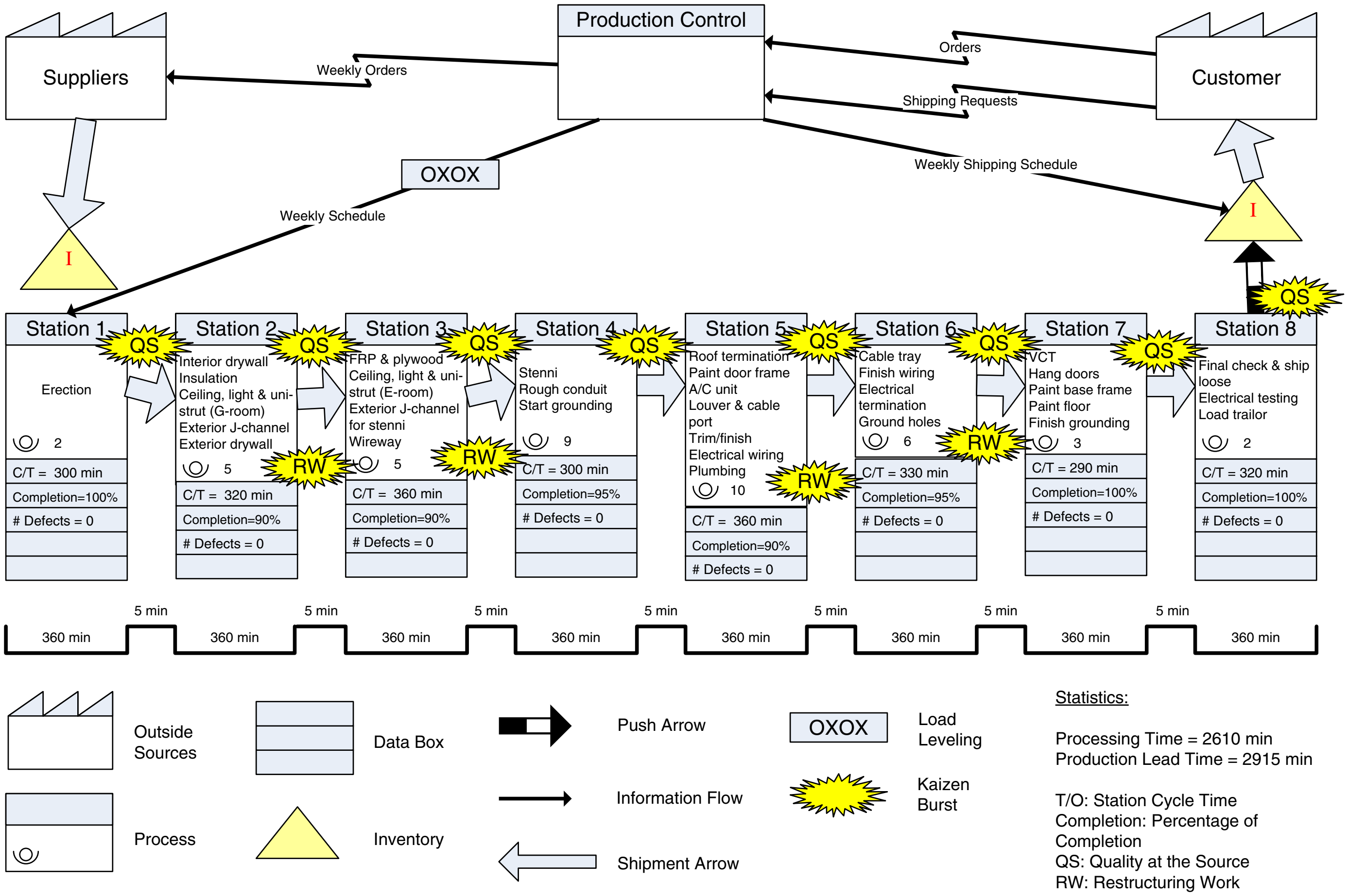

Fig. 7. Future-state map (high level)

A major reason for the low percentage of completion was the variation of workload caused by different module configurations. The average cycle time of station 2 was 405 min, but 35% of the modules were 3.7 × 9.1 m (13 × 30 ft) with double interior and exterior gypsum boards that needed 480 min to install. There was no time buffer in this case, and any delay would result in unfinished tasks. Although flexible workforce and overtime were effective tools to handle the workload variation, as explained in the previous section, a further measure was necessary to reduce the variation at the source. Quality problems were another cause of high variation in cycle time. It was quite common that a worker had to stop his or her work and go to a downstream station to fix defects.

The focus of future-state mapping was to eliminate the root causes of wastes and to link the value stream in a smooth flow. As shown in Fig. 7, three measures, including workload-leveling, restructuring work, and in-station quality, were used to increase process reliability and achieve a 6-h takt time. The basic idea of workload leveling is to meet varying customer demand (a mix of modules with variations) without workload fluctuation in the manufacturing process. In typical manufacturing, load leveling is done through a heijunka box showing the quantity of a mix of products being produced over a specific time period. In modular production, the major method of load leveling is to establish an optimized production sequence to ensure that the delay in the completion of one module does not lead to the delay of the next module, and that crews shared by multiple tasks at different stations have enough time to perform all assigned tasks. As a part of lean production planning, the responsibility of deciding production sequence was moved from sales to production line managers. Every Wednesday, the sales department sent a tentative 2-week schedule to production based on the sequence of orders and customers' demanding dates, and the line manager adjusted the module sequence in the schedule based on a set of predefined rules. For instance, if there was a 3.7 × 9.1 m (12 × 30 ft) module with hand-laid bricks (Nailite) as exterior finishing in the schedule, two extra workers would be needed at station 4, because the labor hour of brick installation was almost 60% more than that of stenni installation. According to the production design, these two workers were crew 1 of station 2. The optimal production sequence was as shown in Fig. 8.

The purpose of restructuring work is to balance the production line so that the overall cycle time of each station can be as close to

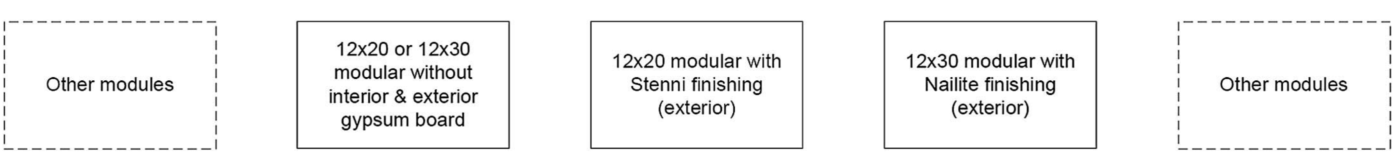

Fig. 8. Optimal production sequence after Nailite finishing module

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the takt time as possible. However, the more the production line is synchronized to the takt time, the higher the risk that some tasks will not be completed within the takt time period. The process shown in the future-state map (Fig. 7) required high reliability of workers' operations and effective variation management measures. Standardized work and quality at the source were the keys to reduce operation variability.

Future-State Map Implementation

The changes brought by 5S and standardized work based on the current practice established a solid foundation for the lean pilot project. In fact, after one month of 5S initiatives, production management was eager for the next step of lean implantation. A task group that included the production manager, line managers, and station leaders was established to lead the implementation of the future-state map. The team met weekly to develop kaizen (improvement) plans, coordinate training, and review progress. After six months of implementation, the throughput of the production line improved from 1.1 modules per workday in July (8-h takt time) to 1.73 modules per workday (5-h takt time) in January, as shown in Fig. 9. There was a learning curve for KBC's production management to realize the importance of having a process view and following the kaizen plan, because any ad hoc adjustment based on improvement in one or two individual tasks did not improve the overall performance of the production line, but instead disturbed the flow. During this project, simulation played an important role to help researchers and production management guide the lean implementation process and develop interim lean models. The future-state map presented the ideal state at which the production line was expected to be in six months, but it would not be possible to implement the entire lean system at once, and in reality, the workers had disparate attitudes toward changes, which led to varying improvement progress. The management had to consistently adjust the lean implementation plan and develop interim lean models based on the real situation to keep the production line balanced and turn improvement on an individual task into the improvement of the entire process. Considering the complexity brought by a high variety of modules and its impact on workload and task cycle time, it was tedious and difficult to manually adjust the production line. Computer-based simulation provided a powerful tool for identifying the optimal model through scenario analysis and helping management to better understand the effect of changes. A detailed discussion of the simulation method and results is beyond the scope of this paper and will be reported in a subsequent paper.

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Workdays	23	21	21	23	20	23	20	17	22
Throughput	21	23	22	25	22	31	28	24	38
Productivity	0.91	1.10	1.05	1.09	1.10	1.35	1.40	1.41	1.73

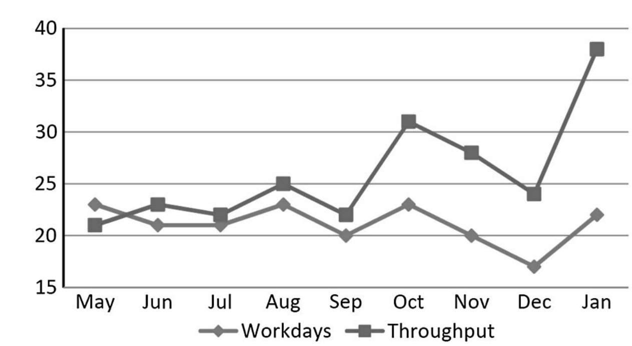

Fig. 9. Throughput of communication shelter production line

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Average Workers Actually on Line	43	43	44	45	48	49	47	53
Average Absent %	15	17	14	10	5	2	6	4
Labor-hour/MOD	383	367	352	346	312	320	271	254
Overtime %	21	13	9	5	11	14	1	4

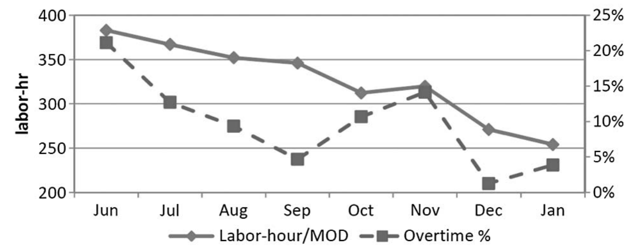

Fig. 10. Improvements on productivity and overtime

As pointed out by Ohno (1998), the goal of any lean improvement is cost reduction, and this can be done by either increasing the production quantity or by reducing the number of workers. However, the quantity is determined by sales, a number that cannot be increased arbitrarily. From May to September, the customer demands were quite stable around 22 modules per month. KBC's lean efforts focused on standardizing the production process and working procedure. In four months, the direct labor efficiency, measured by labor hours per module, was improved by 10%, and labor cost reduced by 18%. KBC did not lay off any workers, but reduced overtime from 20% of the total labor hours to 5%, as shown in Fig. 10. In October, the number of orders increased by almost 50%. Instead of hiring more people, KBC initiated a training campaign to reduce absenteeism and promote radical kaizen. The future-state map was used as a guideline to optimize the production process and to reduce takt time from eight hours in September to seven hours in October and to six hours in December. In January, five workers were added to the workforce on the communication shelter line to deal with the backlog from December and to reduce overtime. The average labor hours spent on one module was reduced to 254 hours, which meant a 34% decrease from the June level.

Conclusions

The lean implementation results show that lean production principles and techniques can be effectively applied in modular building production. Most modular building producers like KBC have a long tradition of operating as construction companies, and the management does not have the necessary training and knowledge of lean production. Although modules are built in the factory environment, the building methods and management tools used in modular production are the same as those used in conventional on-site construction. A detailed examination of the current practice, the way the production line was planned and managed, revealed that a jumbled process and unbalanced production line led to significant wastes, and that the production system could be improved through stabilizing the process and restructuring work.

The biggest challenge in applying a lean production system in construction is to get buy-in from middle management and frontline workers. In this research, 5S proved to be an effective way to get people involved in lean initiatives and enthused about lean by realizing immediate results. Moreover, the efforts to organize the workplace and sustain results involved the implementation of many other lean principles and techniques, such as standardized work and visual management, and established a solid foundation for lean production model implementation. The lean approach developed in this research was the result of viewing the entire production line as a whole, focusing on balancing the production line with process stability rather than solely on improving the productivity of each operation. Detailed production data were collected and used to describe the current practice and evaluate the lean implementation results. After six months of lean implementation, a dramatic improvement in terms of production throughput, productivity, and labor cost was observed.

The success of the pilot project won the support of middle management, and research on lean implementation at three other production lines in KBC is ongoing. The communication shelter line is unique in modular building production. The lean production model developed in the pilot project cannot be used for other production lines, but the lean implementation approach and key strategies presented in this paper could be generalized for the modular building industry and tailored for any particular modular production line. The fundamental implementation of this research is that the current practice of modular building production has large potential for improvement through the application of lean production principles and techniques.

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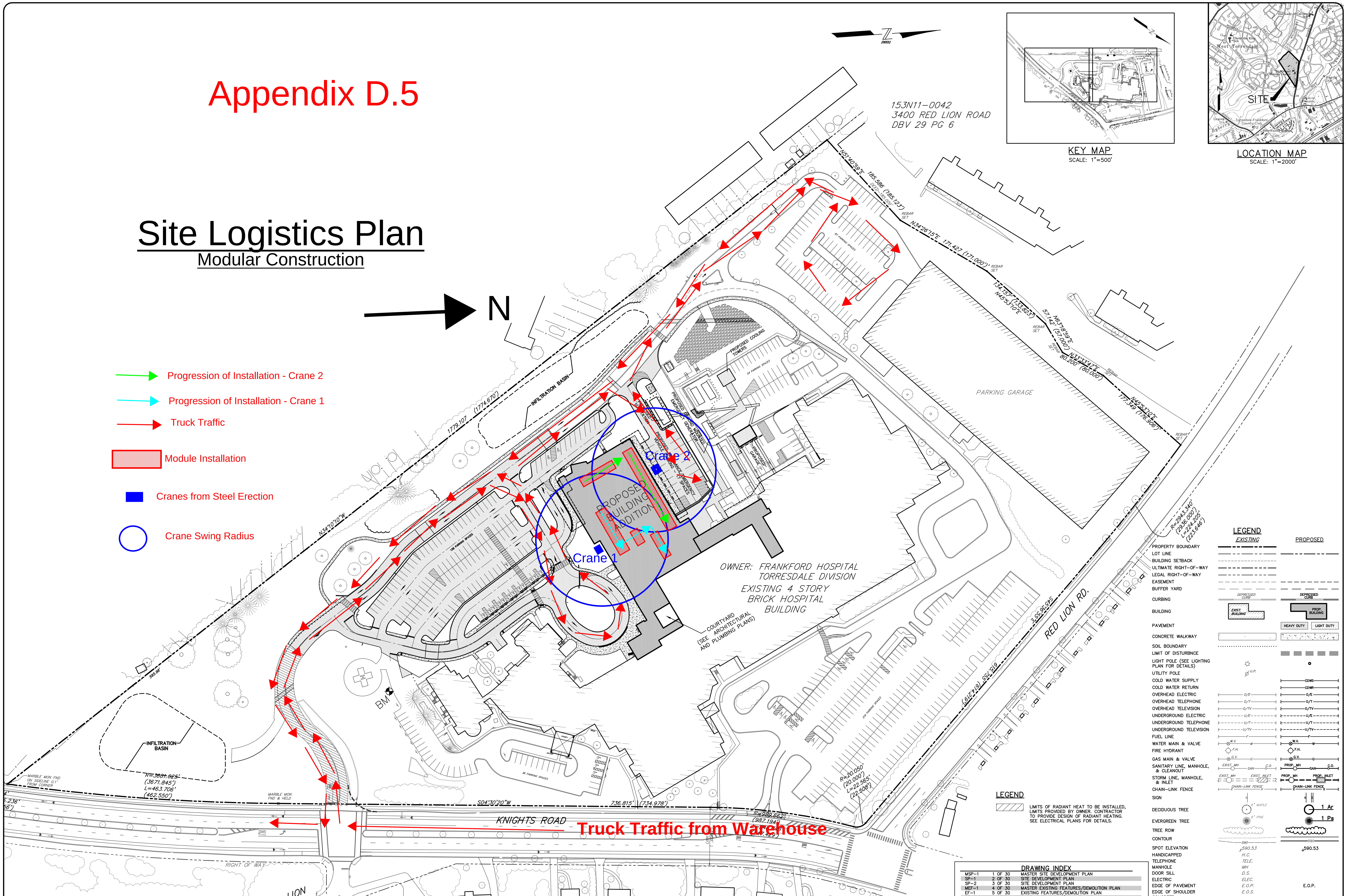
Appendix D.5

Site Logistics Plan

Modular Construction



LEGEND

LIMITS OF RADIANT HEAT TO BE INSTALLED, LIMITS PROVIDED BY OWNER. CONTRACTOR TO PROVIDE DESIGN OF RADIANT HEATING. SEE ELECTRICAL PLANS FOR DETAILS.

DRAWING INDEX

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SP-1	2 OF 30	SITE DEVELOPMENT PLAN
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ESD-1	28 OF 30	EROSION & SEDIMENTATION CONTROL DETAILS
DE-1	29 OF 30	CONSTRUCTION DETAILS
DE-2	30 OF 30	CONSTRUCTION DETAILS

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MSP-1

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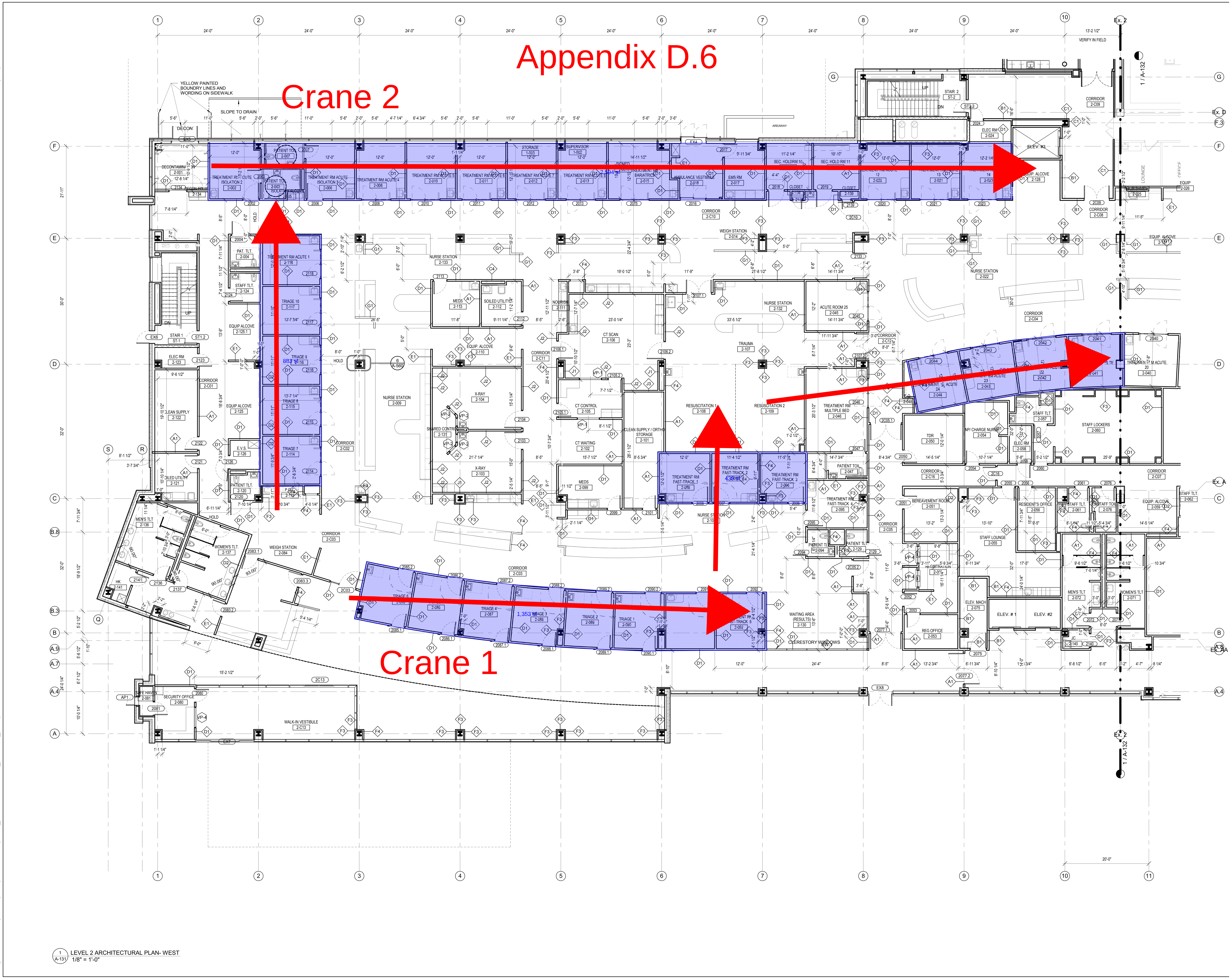

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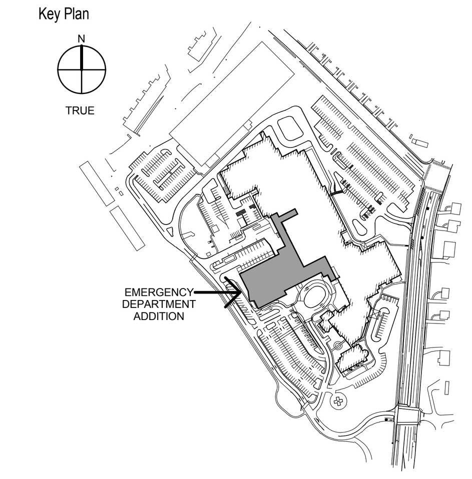

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10/26/2012

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Author

Scale
1/8" = 1'-0"

Seal

Checker

Francis Cauffman

Project Title

ARIA HEALTH SYSTEM - TORRESDALE CAMPUS

EMERGENCY DEPARTMENT ADDITION

10800 KNIGHTS ROAD
PHILADELPHIA, PENNSYLVANIA
19114

Project Number
F11-5892

Drawing Title and Number
LEVEL 2 - ARCHITECTURAL PLAN WEST

A-131

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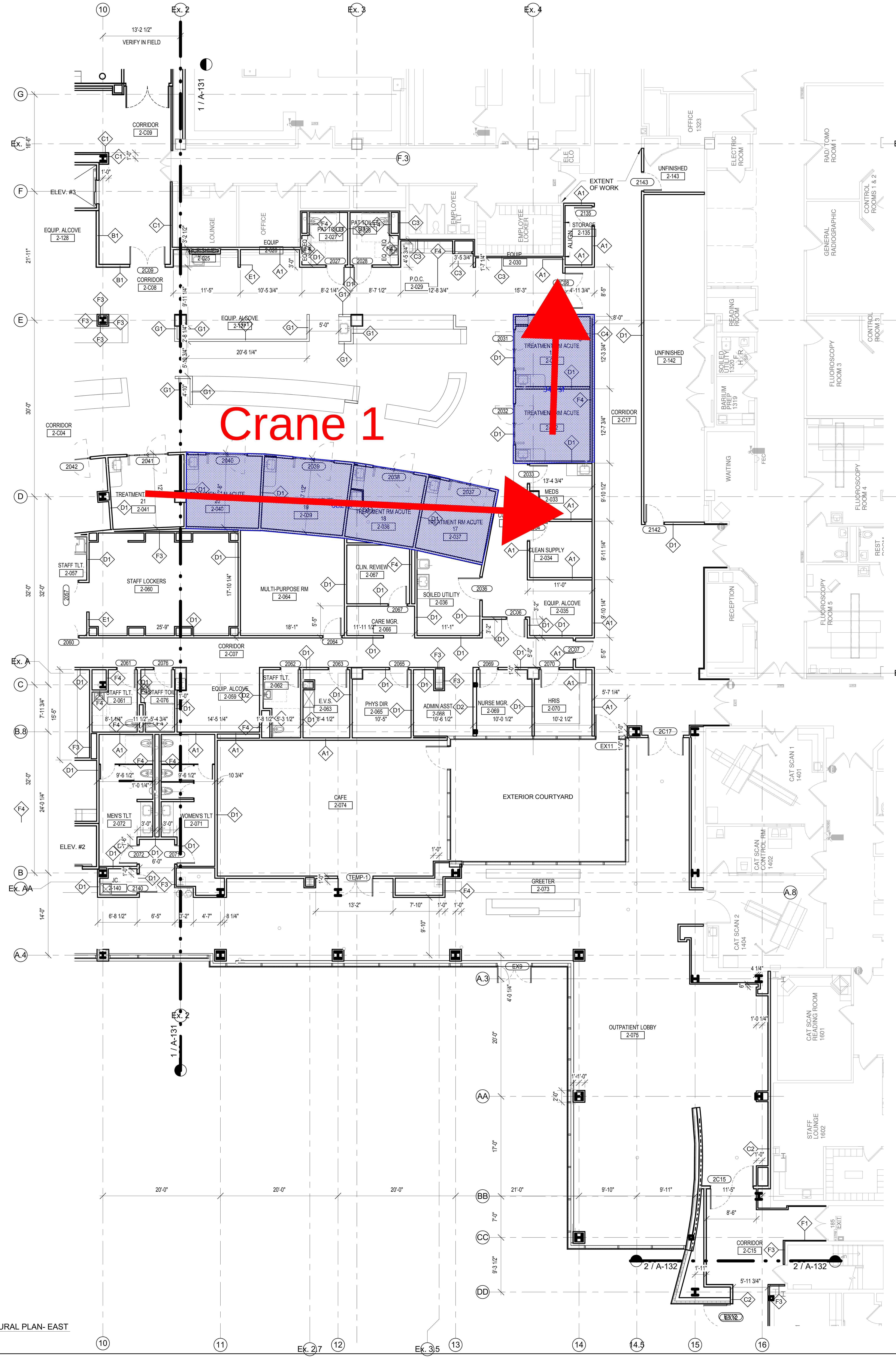
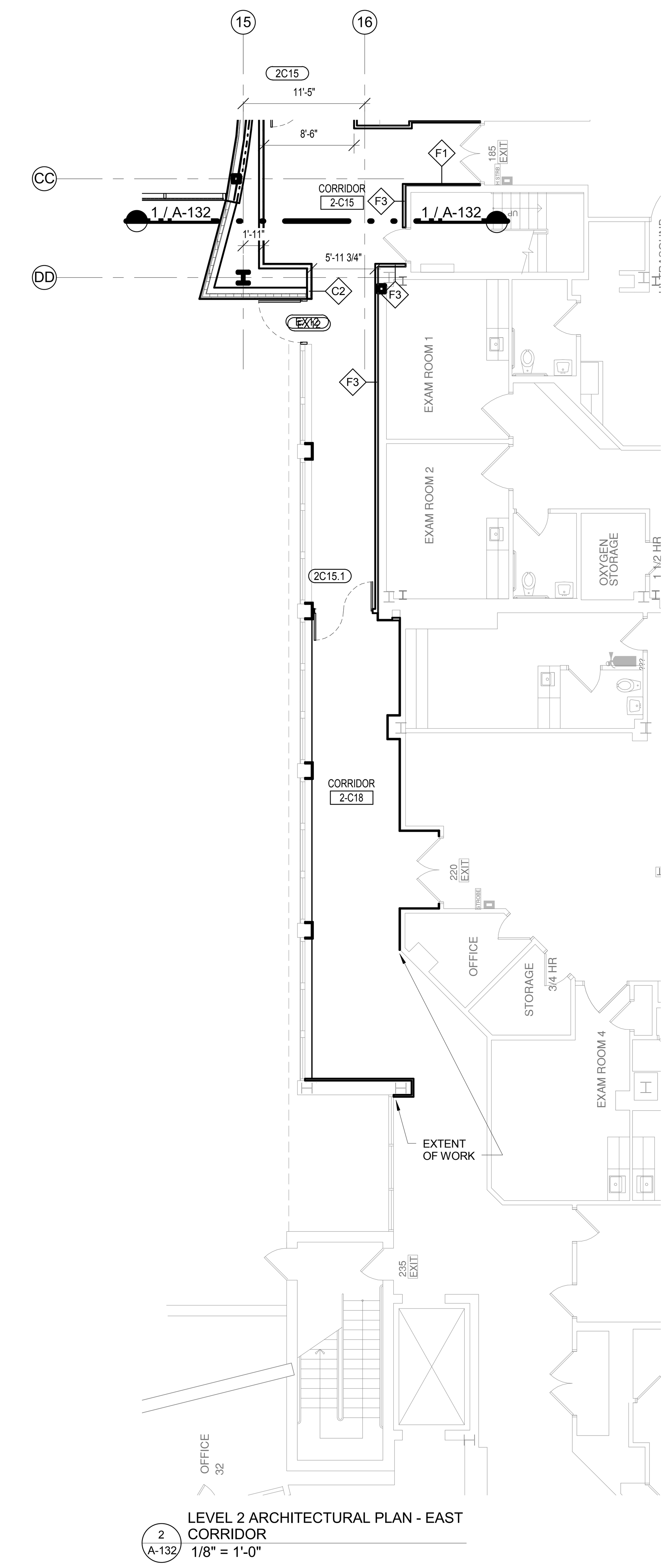


1 LEVEL 2 ARCHITECTURAL PLAN- EAST
A-132 1/8" = 1'-0"



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Francis Cauffman

Project Title
ARIA HEALTH SYSTEM - TORRESDALE CAMPUS
EMERGENCY DEPARTMENT ADDITION
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PHILADELPHIA, PENNSYLVANIA
19114

Project Number: F11-5892

Drawing Title and Number
LEVEL 2 - ARCHITECTURAL PLAN EAST

A-132

CONSTRUCTION DOCUMENTS ISSUE - 10/26/2012

Appendix D.7

Racking Up Big Points For Prefab

Hospital team is gung ho about the potential of multitrade prefab to produce better buildings faster, more safely and for less money

09/08/2010

By Nadine M. Post

[Page 1 of 3] Text size: A A

An inadvertent meeting of the minds during planning for a 484,000-sq-ft hospital in Dayton, Ohio, turned into an effort that has propelled multitrade prefabrication of hospital components to a new level. In the most ambitious U.S. implementation of the strategy, the construction manager estimates that prefabbing the 178 identical patient rooms and 120 overhead corridor utility racks sliced more than two months from construction and 1% to 2% off the cost of the $152-million building, which is 90% complete.

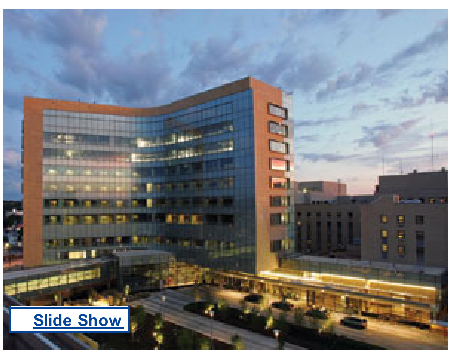

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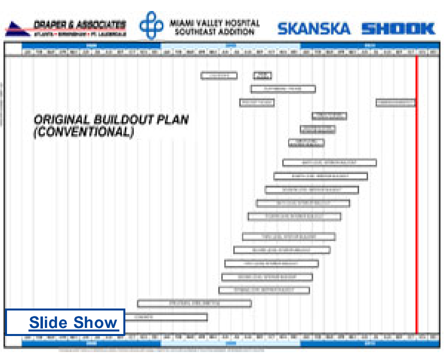
Photo: Skip Peterson



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Graph Image: Skanska-Shook

Skanska-Shook's original schedule for the Miami Valley Hospital did not include the multitrade prefabrication of the 120 overhead corridor racks and the 178 hospital patient rooms on five levels of the 12-story building.

Related Links:
Perfecting Multitrade Prefab: Miami Valley Hospital

The first effort is seen as just a beginning. “I want to change the design of hospitals with this process,” says Marty Corrado, project executive for field operations in Skanska USA Building Inc.’s Nashville office. Skanska leads a joint venture with the local Shook Construction to build the 12-story Miami Valley Hospital Southeast Addition. “This is going to revamp the entire [hospital-delivery] process as we know it,” says Corrado.

For the job, building team leaders decided, during design development, to join mechanical, electrical, plumbing (MEP) and drywall trades in a warehouse to assemble five levels of racks, bathroom pods and bed “head” walls. “The unique part of this project was combining the MEP in our prefab unit,” Bobby Coyle, executive vice president of drywall contractor Dayton Walls & Ceilings Inc., Dayton.

If the decision to prefab had been made on day one, the team could have cut four to six months from the schedule and still produced a higher-quality building more safely, says Corrado.

As it was, the prefab strategy helped recoup a large part of a 14-week delay, caused by the need to pull out 10 footings and redesign foundations after the discovery of a sandy seam of soil missed during test bores. “They picked up eight to 10 weeks because of the prefab,” says Bob Eling, director of strategic construction for Miami Valley Hospital (MVH), which is owned by Premier Health System.

Multitrade prefab has all the pluses of single-trade prefab: a controlled environment; increased safety by doing typical overhead work, including welding, at bench height rather on ladders; increased productivity, eliminated turf wars and minimized waste. In the warehouse, there were only 18 workers assembling 178 patients’ rooms and 120 racks. There were no shop injuries.

Worker productivity for laying pipe, for example, went up 300% over site-work productivity, while labor costs were down about 20%, says Corrado.

“I want to change the design of

hospitals with this process."

– MARTY CORRADO, PROJECT EXECUTIVE,
SKANSKA USA BUILDING INC.

A schedule boost is concurrent prefab and building structure work, without crews tripping over each other. "We built 35% to 40% of the project without even stepping onto the site," says Bill Riddle, vice president of construction for TP Mechanical Contractors, Cincinnati.

With multitrade prefab, jobsite safety is easier to manage because fewer workers are required, site deliveries and storage needs are reduced, and turf battles are eliminated. In the field, it took an eight-hour work day to install 33 bathroom pods and only 1.5 weeks to rough-in a 30,000-sq-ft patient floor.

To achieve the advantages, the approach requires full-team collaboration, early design decisions and shifts in process and schedule. "The earlier the process starts, the more successful the prefab will be," says Mark Smith, project manager for the local Chapel Electric Co. LLC.

"Decisions about how the utilities attach to the building frame and decisions about patient-room design had to be accelerated four to six months," adds Tim Fishking, a principal in the Columbus office of project architect NBBJ.

For multitrade prefab, affected subcontractors need to be brought in about halfway through design development, to offer their two cents on production efficiency and constructibility. Prefab works best under a design-build scenario, but design-assist also works, says Corrado.

On MVH, the meeting of the minds occurred when the topic of prefab came up during a planning session of NBBJ, Skanska-Shook and MVH, on Oct. 18, 2007. Independently,...

[Page 1 of 3] NEXT ➤

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Anonymous wrote:

Brilliant - Pref Fab Units sitting around for months in a building which is not closed in. Been there, done that...Mold Mitigation, Aspergillium, Legionella etc.....No problem here with sick building syndrome - in a Hospital no less......yee ha SKANSKA. The Pror Planning Prevents Poor Performance, the 5-P's didn't go so well here eh?

In the end, due to non-adherence to the 5-P's the experiment is with patient health & the potential for many lawsuits....insulation, drywall, duct liner getting wet......failure to mitigate, startup the HVAC & blow all the spores around and about - Kudo's to the briilant on site project staff.

And, to top it all off, you blew the schedule and burned the Owner on the substantial compeltion date and now come back with whiny excuses as to why. If we could only get away with paying minimum wage to all the Union Workers without benefits, the world would be a better place right? Afterall, this entire concept centers on eliminating Union Labor & Benefits, in cahoots with the Employer Associations, all of whom are do-nothing highly compensated executives. As long as they get theirs, to heck with all the rest.

While your experimenting with this, you need to call in a micr-biologist and conduct secret tests, best done on third shift when no one is paying attention, just to cover your tail, legally speaking of course. Sleep well patients, sleep well...just try not to breath.

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Anonymous wrote:

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Racking Up Big Points For Prefab

Hospital team is gung ho about the potential of multitrade prefab to produce better buildings faster, more safely and for less money

09/08/2010

By Nadine M. Post

[Page 2 of 3]

Text size: A A

...Corrado and Fishking had been exploring prefab racks. “We all remember the meeting because we had this simultaneous ‘a-ha’ moment,” says Fishking. Corrado adds, “It pretty much snowballed from there.”

At the time, Corrado had been checking into even more ambitious prefab work by his Skanska counterparts in Europe. Fishking initially had been intrigued by a photo he had seen of a prefabbed overhead rack, minus the drywall, for the St. Clare Health Center near St. Louis, completed in 2009 by Alberici Constructors.

The MVH prefab trip was not without bumps; there were naysayers, even within Skanska. “The pioneer is the guy with all the arrows in his back,” Corrado says. “No one wants to follow him, but they shoot at him,” he adds.

To get up to speed, Corrado made two trips to London to observe a Skanska prefab operation under way there. The first trip was with Scott Hansma, Skanska’s MEP superintendent. The second trip was with representatives of TP and Chapel and MVH’s Eling. That “sealed the deal” with the owner, says Corrado.

Eling, who became a fan of prefab, adds, “We said, ‘If the budget and schedule are not going to change, go ahead.’ ”

Prefab in London, where craftworkers are under one employer’s roof, is one thing. Prefab in the U.S. meant dealing with union and open-shop contractors working side by side, says Corrado.

Tasks all got sorted out. “The [union] electricians were OK working with an open-shop contractor,” he says.

“We learned how to work better with MEP contractors,” adds Dayton’s Coyle.

Key to the success of the strategy was the use of building information modeling. For the work, there were separate design and construction BIMs. “Using 3D layout during design” aided the modeling of the whole assembly, says Brian Braaksma, president of Korda Engineering, the Columbus-based MEP consultant.

Full-scale physical mock-ups of patient rooms and racks, for bidding purposes, were also critical to success. Built on the hospital campus, mock-ups also allowed end-users to give input and regulatory agencies to grasp the approach.

“We don’t usually mock up corridor utilities,” says NBBJ’s Fishking.

Mock-ups were detailed down to electrical outlet locations because, once the model was set, all 178 rooms would be done the same way. To establish the final design, users even did simulations of patient and caregiver conditions.

The addition has five patient-room floors. Each floor has three wings. Each wing contains a single-loaded, 16-ft-wide corridor with 11 “same-handed” rooms, rather than pairs of mirror-image rooms. The same-handed rooms were designed to accommodate the need for repetition on the “assembly line.” Two, 8-ft-wide corridor racks, each 20 ft long, are positioned side by side, running the corridor’s length.

Braaksma says the racks serve double duty: Mechanical and electrical supports serve as the building structure’s seismic restraint, required by code, and the rack’s frame serves as seismic restraint for ductwork, piping, conduit and cable trays.

The design significantly reduces clutter above the ceiling, which will aid hospital maintenance staff, says Braaksma, as will the consistent and repetitive location of subcomponents, such as valves, terminal boxes and cable trays, from area to area and floor to floor.

Foundation work started in May 2008. On June 1, worked stopped for 14 weeks because of the soil snag. The prefab operation got under way on Feb. 2, 2009, in 35,000 sq ft of space in a nearby warehouse. Leasing warehouse space in Dayton costs $2.00 to $2.50 per sq ft per year.

The original plan was for just-in-time delivery of prefab units to the site, three miles away. But instead of producing two to five racks per week, workers produced eight to 10. “We filled up the warehouse in six weeks with prefab for two hospital floors,” says Corrado.

Because of the foundation delay, the steel structure was not ready to receive units until mid-July 2009. To keep prefab production going, Skanska leased 70,000 sq ft in another warehouse three miles in the other direction from the jobsite.

In hindsight, to keep production from piling up, prefab work could have started in early March 2009. Without the schedule delay, installation could have started that June 1 and been completed by mid-August. Substantial completion of patient floors would have been at the end of last March instead of mid-July. Substantial completion of the rest of the hospital would have been by mid-June 2010, rather than mid-October. (Substantial completion actually has been pushed to December because of the foundation delay.)

At the jobsite, once concrete deck was cast and the drywall contractor had laid out and shot down the top track of all corridor walls, TP laid out and installed the clips that suspend the racks. Fireproofing followed.

Racks then were hauled from the warehouse on Saturdays the tower crane was available. It would typically take one day to haul and place on the floor a full level’s worth of racks. It would take about a week to a week and a half to hoist racks into final position and secure them.

Bathroom pods and head-wall units for that level followed on the next available Saturday, usually about two weeks later. Crews would spend the next work week distributing, leveling and attaching the pods and head-wall units to the floors. Once all the components were installed, crews began remaining rough-in work.

Saturday hoisting was mandatory because all prefab components had to be swung into the building via tower crane,...

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Anonymous wrote:

Brilliant - Pref Fab Units sitting around for months in a building which is not closed in. Been there, done that...Mold Mitigation, Aspergillium, Legionella etc.....No problem here with sick building syndrome - in a Hospital no less......yee ha SKANSKA. The Pror Planning Prevents Poor Performance, the 5-P's didn't go so well here eh?

In the end, due to non-adherence to the 5-P's the experiment is with patient health & the potential for many lawsuits....insulation, drywall, duct liner getting wet......failure to mitigate, startup the HVAC & blow all the spores around and about - Kudo's to the briilant on site project staff.

And, to top it all off, you blew the schedule and burned the Owner on the substantial compeltion date and now come back with whiny excuses as to why. If we could only get away with paying minimum wage to all the Union Workers without benefits, the world would be a better place right? Afterall, this entire concept centers on eliminating Union Labor & Benefits, in cahoots with the Employer Associations, all of whom are do-nothing highly compensated executives. As long as they get theirs, to heck with all the rest.

While your experimenting with this, you need to call in a micr-biologist and conduct secret tests, best done on third shift when no one is paying attention, just to cover your tail, legally speaking of course. Sleep well patients, sleep well...just try not to breath.

1/30/2012 4:39 PM CST

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Anonymous wrote:

Re: Prefab role in infectious disease is inaccurate. Insufficient heating of the hot-water system was cause:

http://www.daytondailynews.com/news/dayton-news/legionnaires-outbreak-linked-to-water-1212598.html

8/19/2011 8:15 AM CDT

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Anonymous wrote:

The critical path is a good tool for evaluating a schedule, but could not possible factor in the reduced

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Racking Up Big Points For Prefab

Hospital team is gung ho about the potential of multitrade prefab to produce better buildings faster, more safely and for less money

09/08/2010

By Nadine M. Post

...which was used for ongoing steel erection during the week. "Tower cranes were our only option for hoisting due to the extremely limited lay-down area around the site and the 'landlocked' orientation of our building," says Corrado.

Unit installation went so smoothly that it got ahead of the curtain-wall installation. "There was an ironic disadvantage," says Dayton's Coyle. "We set bathroom pods so quickly, followed by wall framing, that we were months ahead of the closing up of the exterior shell," he adds.

"We had to wait an extended period of time to hang interior drywall," he says.

Members of the team gleaned several lessons from this first-time prefabrication effort, which they all hope to apply to future jobs. The first lesson is timing: Start planning the process from the onset of the project, not midway through design development, they chorus. Also, time the prefab production so product can be shipped to the site just in time, to avoid the cost of more leased warehouse space.

Corrado would like the design team to finalize the unitized curtain wall earlier in the process, so that, even though prefab units were designed to be able to get wet, the prefab installation does not leapfrog over the curtain-wall installation and delay finish work. "We need earlier decisions on glass and on finishes and on who can produce and install units properly," he says.

On future jobs, both Skanska and NBBJ hope to expand the prefab operation to more types of components. The opportunities for improvement include parts of examination rooms and post-op and pre-op bays as well as the many single-patient toilet rooms embedded in diagnostic and treatment areas.

Skanska has not yet used multitrade prefab on any other jobs, but it intends to use prefabrication techniques on institutional projects when it is practical. "We are starting to make schedule commitments based on the MVH experience," says Corrado, who also thinks prefab can give Skanksa a competitive edge on bids.

The final lesson: For multitrade prefab, no firm stands alone. "We all had to buy into this process to make it work," says Fishking.

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Appendix D.8

Modular Construction Interview with Ted Border (paraphrased):

Me: How does modular construction translate to schedule reduction and cost savings?

Ted Border: It depends. Some projects having modular construction already built into the schedule. It doesn't shorten the duration if it was planned, just gives the ability to meet the schedule. Owners expect it to keep schedule down. It has been in the industry for a little while and common place for wall panels to be built and shipped.

Me: Is labor during prefabrication cheaper that on-site construction?

Ted Border: A company really has to do their research. If you're doing a project in New Jersey or New York, and labor rates are really high in the city and you prefab in another state, you can save money. If you're project is in a cheaper state, and prefab in a more expensive labor state, you lose money. The Muhlenberg project was located in PA and prefabbed in New Jersey.

Me: Does modular construction reduce mobilization and general conditions costs? If so, how? Is this off-set by cost of renting facilities? (i.e. utilities, rent and/or own, etc.)

Ted Border:

1. Mobilization and GCs – if you're trying to get something done in three months, prefab is being used to get to that deadline. It depends on the owner and schedule being met.
2. If you're building in a controlled environment, you can reduce weather proofing such as tenting, plastic, propane heating. Savings during cold weather.
3. Renting costs versus cold weather protection – but you don't lost any bad weather delays and have guaranteed no lost work days. Average bad weather days per year anywhere from 2.5 -6 days just for bad weather.

Me: Is the flow of work similar to on-site construction? For example: studs, MEP rough-in, drywall, paint?

Ted Border: Doesn't matter whether you're inside or outside, sequencing doesn't change.

Me: If so, is the schedule savings due to several rooms being prefabricated at the same time?

Ted Border: You can prefab as much as you want at the same time, it's all about man power and quality control. The problem is, if you're stacking units, you have to make sure you're working tolerances into the construction and design.

Me: Do the different trades get in the way of each other?

Ted Border: The cleanup is easier, the workers are typically a little easier to control. But coordination is still the same as on site.

Me: How does material storage work in the prefab rental facility?

Ted Border: The laydown areas and material staging areas are the same as onsite. Deliveries are the same, path of movement has to be the same for safety measures. Mortar mixing, for example, could be an issue with dust in the interior environment. Cramped construction inside the facility is also an issue. Equipment running inside must be electric or propane, as no fumes are allowed inside a facility.

Me: Was a specific warehouse or facility rented or leased for prefabrication during the Muhlenberg College Dormitory project?

Ted Border: The rental facility was in New Jersey, over 120 miles away. Any shipment outside of a lane for a tractor trailer need permits. You need to plan through Penn Dot for high loads on roads or bridges. You may only be 70 miles for one route, but you might need to travel 120 miles to be able to transport the loads. You can get extra wide loads, but need flags and spotters. Everything is based on weights and physical sizes allowable by the transportation authority. Height is a big limiting factor under and over bridges.

Me: Are there any problems or issues that are specific to modular construction that does not occur in stick built construction?

Ted Border: Tolerances are the most important. Modules eventually have to get to the site and fit together. Strict QC program must be adhered to. At Disney, while units were being stacked, they started gaining 1/8 of an inch per floor. Once to the fifth floor, modules could not fit into building. Tolerances can create a big problem.

Me: How are the modules rigged into place? Do the modules have to be on some sort of steel frame or assembly for a crane to be able to pick it?

Ted Border: All modules have specialized spreader beams and a lifting apparatus that can handle the weights. Weights will have to be calculated and the crane will have to be sized for the heaviest weight at the longest distance. Figuring out the weights is very detailed, where it has to be exact, plus a 10% factor. But you can weigh the modules on the trucks themselves for verification.

Me: Are there ever any union labor disputes during prefabrication?

Ted Border: It depends where you are doing the work and where you are doing the prefab. If you're project is in a strong union environment, you may have to ship workers to the warehouse. You must be very familiar with wage rates and labor agreements for where you are working on site and where you are prefabricating.

Me: How does modular construction reduce waste?

Ted Border: Waste is still generated at the warehouse, it's the same waste, it's just easier to clean up.

Me: What are some constructability issues that must be addressed when utilizing modular construction?

Ted Border: Shipping the modules. Vibrations, jolts while loading, driving to destination, and unloading are all problems. The easy part is putting them into place. The biggest issue is breakage during transport and handling. You have to package them so they are able to withstand bumps, rain, sleet, snow, etc.