Final Thesis Report
Spring Thesis Project

50 Connell Drive Office Building
Berkeley Heights, NJ

Submitted 4/7/09
Submitted by: Jason Salyer
Option: Construction Management
Thesis Advisor: Dr. Messner

50 Connell Drive
Berkeley Heights, NJ

About the Building:

Owner: The Connell Company
CM: Turner Construction
Architect: HLW International

General Data:
- 4 Story High End Office Building with Cafeteria
- 185,000 Total Square Feet
- Pursuing LEED Gold Certification

Mechanical Systems:
- Concealed Mechanical Penthouse
- 2 pipe direct return air/water system
- (4) McQuay Destiny Air Handling Units
- Floor by Floor VAV Heating and Cooling Units
- (2) Closed Circuit Induced Draft 432 Ton Cooling Towers

Architectural:
- Granite Panel Facade with Curtain Wall Sections
- Reflective Roof with Fully Adhered Membrane

Electrical/Lighting:
- 13.2 KV Main Power Feed
- (2) 15 KV Switchgears
- TP-1 Transformers Step Power from 480V to 277V
- Natural Gas Powered Emergency Generator
- Fluorescent lighting with multiple fixture types

Construction:
- Schedule July 2007 – Jan. 2009
- Clearing of a Wooded 16 Acre Site
- Erected in Bays with 150 Ton Crawler Crane

Structural:
- Concrete Footings and Grade Beams
- Structural Steel Frame
- Composite Metal Deck Floor Slabs
- Vertical Steel Cross Bracing

Jason Salyer, LEED AP
Construction Management
http://www.engr.psu.edu/ae/thesis/portfolios/2009/jcs5018/

Table of Contents

Executive Summary:

The study regarding the alignment problems on the façade found that using an integrated contractor to install both the exterior stone and glass is not a practical solution. This is because there is no contractor in the area who specializes in this type of work and there is a concern that if both packages were awarded to a single contractor they would subcontract a portion of the work. This would remove the CM one step further out of control over that work. A system re-design was not necessary because the work was due to poor field performance. Coordination and understanding the small tolerances is key to a successful installation of the windows.

The analysis of high performance glazing revealed that significant savings can be achieved by upgrading the vision glass to SolarBan70XL. A computer simulation estimates that annual energy consumption can be reduced by 9% and upfront equipment costs can be reduced by 16%. Not only does this glass provide energy savings but its material cost is $1.20 per square foot cheaper than the glass used on the project. This would provide an upfront savings of nearly $25,000 for the material cost alone.

The analysis which aimed to find elements of the project that could benefit from prefabrication had mixed findings. A study of a modular central plant estimated that it would save about a month of schedule time to finish work in the mechanical penthouse. However the building's structure is not strong enough to support the system and the cost to strengthen the structure would likely not be worth the effort. Typically these plants are located on grade. From a design point of view the modular plant offers less control than the 8 ACCU units that were actually used throughout the building. Since the building is rented spaces it is possible to have unoccupied floors. The actual design allows for energy savings by turning off the ACCU's on these floors. However that is not possible with a single modular plant. Maintenance is also easier on the ACCU's. The analysis also found that using prefabricated plumbing pipe sections in the bathrooms is not practical because the size and number of units does not justify the cost.

Common methods to reduced operating costs that would work well for this building include a combination of:

- Energy efficient design
- Energy modeling prior to construction
- Use of efficient equipment & water efficient fixtures
- Energy monitory
- Optimizing operating set points
- Taking advantage of state and federal incentives of installing efficient equipment
- Continuous commissioning

General Building Data:

Building Name: 50 Connell Drive Office Building

Location: Berkeley Heights, NJ 07922

Occupant Name: L'Oreal USA Inc.

Occupancy: A-2 Assembly, Group B Business

Gross Square Footage: 184,564 total square feet and 170,000 square feet of office space

Total stories: 4 floors above grade

Architect: HLW International LLP

Civil/Structural Engineer: CMX Engineering (formerly known as Schoor Depalma Engineers)

MEP Engineers: RDK Engineers

Vertical Transportation Engineers: Van Deusen Associates

LEED Consultant: Viridian Energy and Environmental

Owner: Connell Real Estate and Development Company

Construction Manager: Turner Construction is providing services for the core and shell.

Dates of Construction (start-finish): Construction began on 7/2/07 and turnover for the tenant fit out is expected on 1/27/09. The owner is planning on having occupancy in July of 2009.

Overall Construction Cost: Turner's contract for the core and shell, including general conditions and fee is $38.9 Million. This number does not include the site work that the owner had done prior to Turner's arrival. After the tenant completes the fit out of the building it is expected that the overall construction cost will be $46,200,000.

Project Delivery Method: Cost Plus

Architecture

Design and functional components: The building is a simple design dedicated to optimizing office space. The building footprint is rectangular. The interior layout of the building places the restrooms, elevators, stairwells and storage areas of the building in the central core. The outer perimeter of the building is dedicated to office space. The skin of the building is composed of granite panels and glass curtain wall. The glass curtain wall is nearly the full floor height. This allows for natural daylight to penetrate into the office space which will reduce energy loads. In addition to taking advantage of reduced energy consumption the large windows allow the occupants to have views towards the outdoors. This results in a more enjoyable more productive working environment. The first floor has a cafeteria for the workers. This is a functional component of architecture which makes a convenient alternative to leaving the building for lunch. A loading dock services the building adjacent to the cafeteria.

Zoning: The land is zoned as Commercial.

Building Envelope: The building envelope is composed of glass, concrete and stone. The exterior wall is a panel system of granite, limestone and shop fabricated architectural pre-cast concrete attached to a metal truss/panel system. Aluminum ribbon windows make up glass curtain wall sections. The roof is composed of 6” concrete topping on a 1 ½” steel deck supported by 3’ 4” open web K series steel joists. There is a fully adhered membrane roofing system with mechanically fastened roof insulation and cover boards. The membrane has a minimum solar reflective index of 78 to meet the strict LEED building requirements of the project.

Primary Engineering Systems

Construction

The Connell Company, through its division Connell Real Estate and Development Company hired Turner Construction as the construction manager on their new office building. The company develops and manages Class A commercial office buildings. Construction began in July of 2007 and is scheduled for completion in January of 2009. The building, 50 Connell Drive, will be comprised of four floors and a mechanical penthouse on the roof. The finished product will be approximately 185,000 total square feet. The building will be the newest addition to the 170 acre Connell Corporate Park and will later be known as Connell Corporate Center VI.

The building was constructed in bays. A 150 ton crawler crane was used to place all the structural steel. Construction of the bays began on the northeast side of the building. From here they moved west. Once construction of the northwest side of the building was complete the crawler crane was positioned on the southwest corner of the building and worked it way east. A concrete pump was used to place all concrete. The project team decided to use an atypical arrangement to finish the floors. Instead of using the traditional top-down or bottom-up approach they decided to finish the floors in the following order: $2^{nd} \rightarrow 3^{rd} \rightarrow 1^{st} \rightarrow 4^{th}$. The team decided that this would be the most efficient order to follow. The team did not want to do a traditional top-down sequence because the roof above the 4^{th} floor is composed entirely of bar joists. This means that in order for the 4^{th} floor to be ready for interior work they would need to wait for the spray on fire proofing to be completely installed on both the bar joists and underside of the roof. The team did not want to follow a bottom-up sequence because the 1^{st} floor has a lot of mechanical equipment, a kitchen and cafeteria. By jumping floors they were able to sequence efficiently and actually managed to get ahead of schedule.

Electrical

Primary electrical service is 13.2KV. Power enters the building through 15KV cables within an underground duct bank. The building has two main switchgears. Each of the 15KV Medium Voltage switchgears has a #600 cable that carries power to an 800 amp bus duct riser and a #400 cable that carries power to a 1000A duct riser. Once power is carried up the building through the riser it enters the branch circuits. Heavy equipment within the building uses 480 volt 3 phase power. There is a 15 KV dry type transformer on each floor that steps the power down from 480V to 208Y/120V for normal office applications. The transformers in this building are highly efficient and comply with NEMA TP-1 standards. There are 24 panelboards throughout the building. Spectra Power panelboards are provided for all applications over 400 amps and to accommodate multiple branch breakers greater than 125 amps. In the event of a service failure the building also has an emergency generator capable of producing electricity with a natural gas driven engine. The generator has a 2900 MBH capacity. The building also has battery powered emergency lighting.

Lighting:

There is a variety of lighting fixtures in and around the building. Included are HID, florescent, Tungsten-halogen and incandescent lamps. A 277 volt system provides power to the fixtures. All fluorescent fixtures have electronic ballasts with high power factor. Ballasts are instant start. General office lighting is provided by a combination of recessed 26 watt compact fluorescent 6" downlights, F32T8 lamps are used in both chain hung 1x4 fluorescent uplights and Lithonia pendant mounted 2x4 fluorescent fixtures. Passageways are lit by recessed 32 watt compact fluorescent wall washers. The entry lobby utilizes a combination of recessed compact fluorescent downlights and metal halide fixtures. Cafeteria lighting is provided by a combination of recessed fluorescents, F32T8 pendant fixtures and Q35MR16 recessed halogens.

Mechanical:

The building utilizes a combination air/water system with a two pipe direct return. The majority of the mechanical equipment that services the building is located inside a penthouse on the roof. There are a total of four McQuay Destiny air handling units that supply air to the building. AHU-1 and AHU-2 do the bulk of the work. AHU-1 & 2 in the penthouse are 100% outside air units that feed ACCU units (2 per floor). However AHU-1 & 2 only preheat the outdoor air, they do not cool it. They are capable of supplying 15,500 CFM and 18,400 CFM with a capacity of 710 MBU and 841 MBU respectively. The building also makes use of a smaller 2000 CFM, 180 MBU unit located in the penthouse. This provides heating and ventilation solely for the two penthouse rooms. It is not part of the central system. The last air handling unit is located at the loading dock. It heats and cools the air for that area only.

Each floor has self contained heating/cooling units (ACCU's) that are used to control the indoor environment. Fan powered VAV terminal unit boxes, electric unit heaters and self contained AC units are used to control the air temperature in each room. A 1739 MBU capacity boiler located within the penthouse is used to heat the building's water supply. Also located on the penthouse are two Baltimore Air Coil closed circuit cooling towers, each with a 432 ton capacity. They are of an induced draft design with vertical air discharge. The towers use an aqueous glycol solution as the heat transfer fluid.

Structural:

The substructure of 50 Connell Drive consists of square concrete spread footings which support the interior steel columns. Continuous strip footings support a foundation wall along the north side of the building. The spread footings range in size from 3'x3' and 1' deep to 13'x13' and 2'9" deep. The footings sit on engineered fill/undisturbed stratum with minimum bearing capacity of 4000 psi. The SOG varies in thickness from 4" to 12" however the majority of the ground floor slab is 6". The mechanical room is built on a 12" SOG to support the heavy equipment. Drainage under slabs is compacted gravel. All footings, piers, grade beams, walls and non composite slabs consist of 4000 psi normal weight concrete. Composite slabs use 3000 psi normal weight concrete.

The superstructure for the building is a steel skeleton composed of wide flange sections. The columns are spaced on 30' grids throughout the building. The structural steel framing is composed mainly of Grade 50 W21x50 girders and W16x26 beams. Lateral forces are resisted through the use of moment resisting connections and vertical structural bracing. Structural steel columns range in size from W14x48 to W14x132. The elevated slabs are 2 ¼" composite steel decks with 4" of normal weight concrete.

Building Location: Berkeley Heights, NJ

Aerial Photo 1 - Location

Aerial Photo 2 – Building Site

50 Connell Drive
Aerial Photo 3 – Site Photo

Construction Photos:

October 2007

December 2007

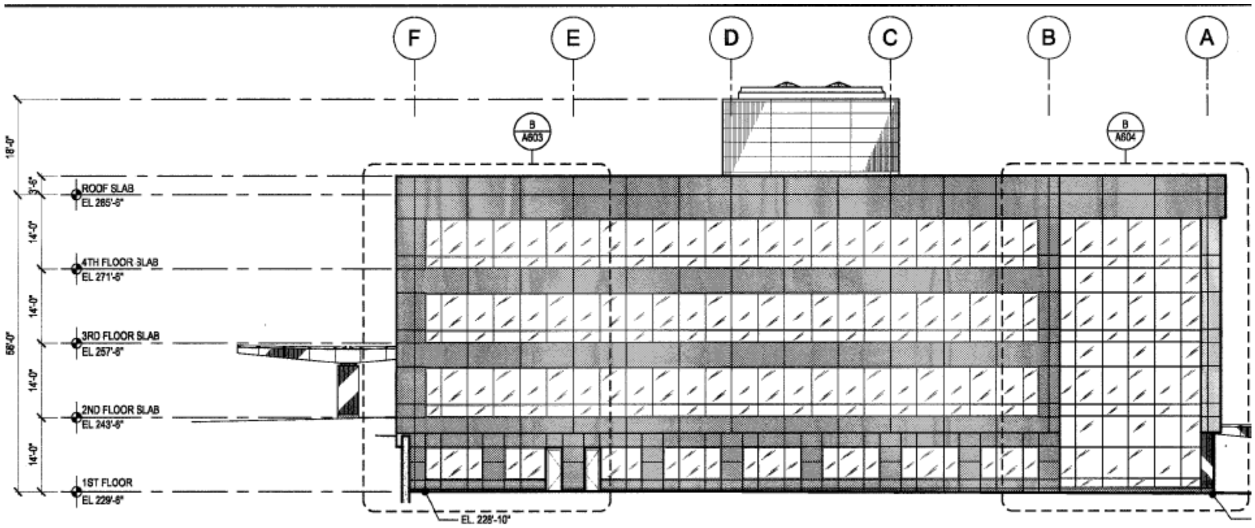
January 2008

February 2008

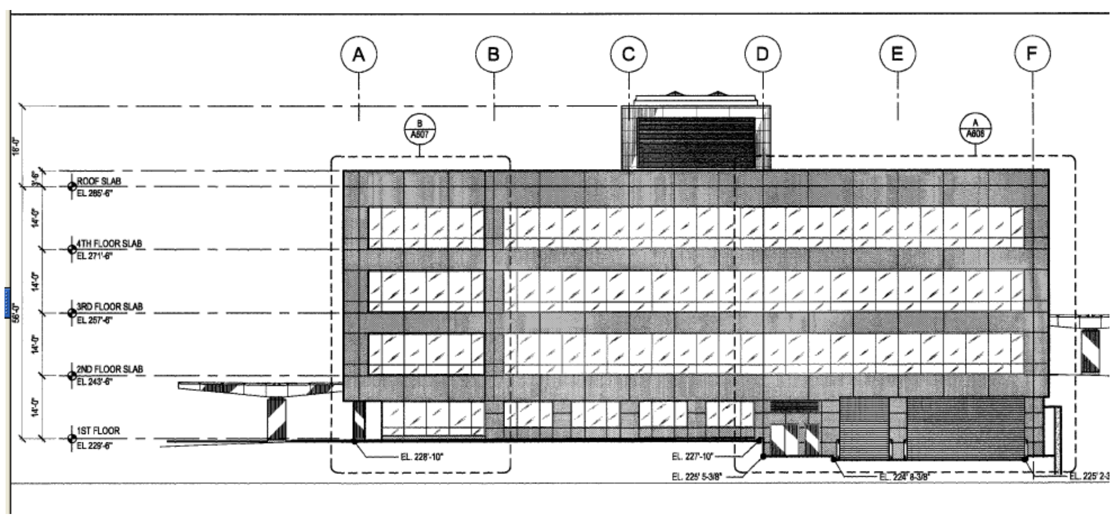
April 2008

June 2008

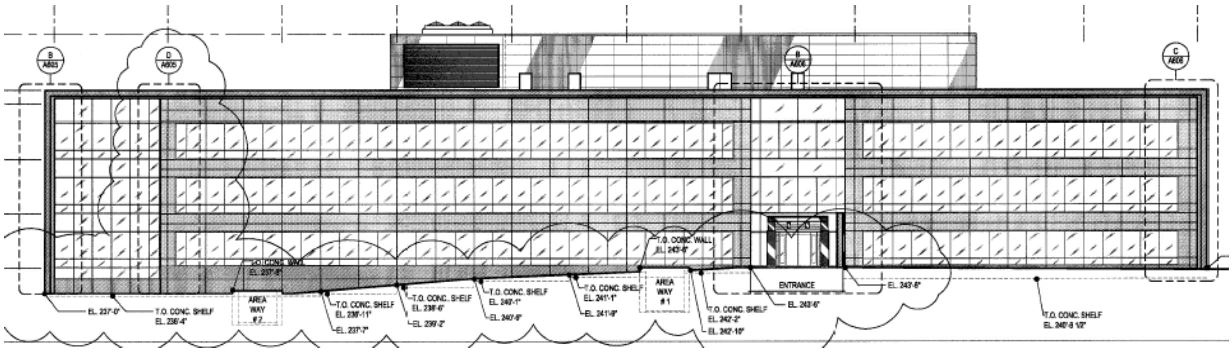
Building Plans, Elevations & Sections:



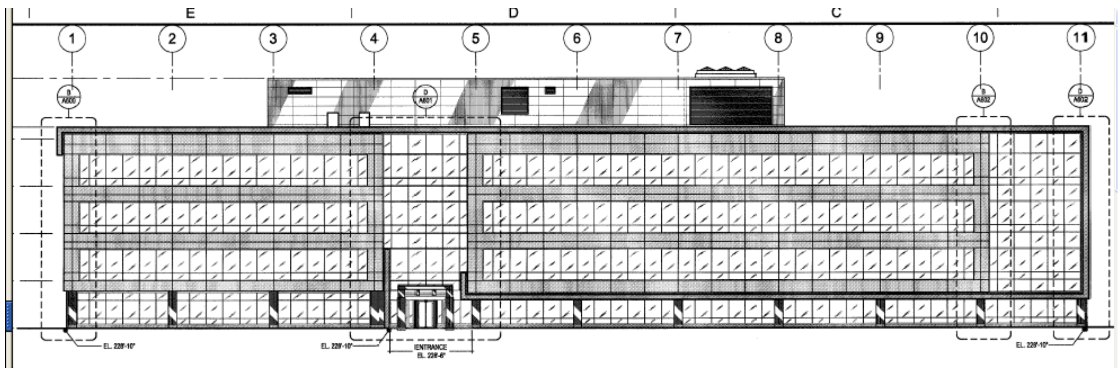
West Elevation



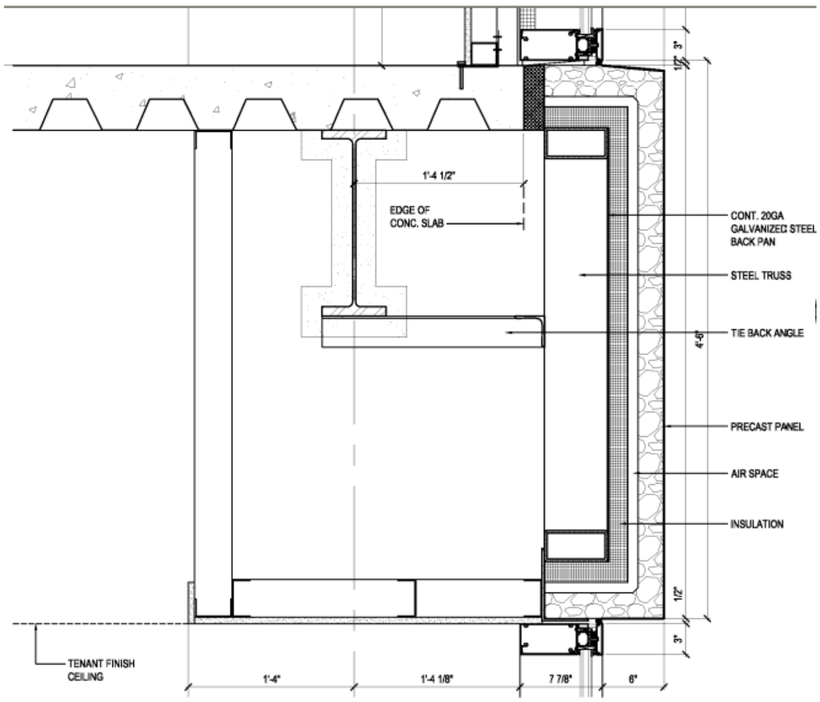
East Elevation



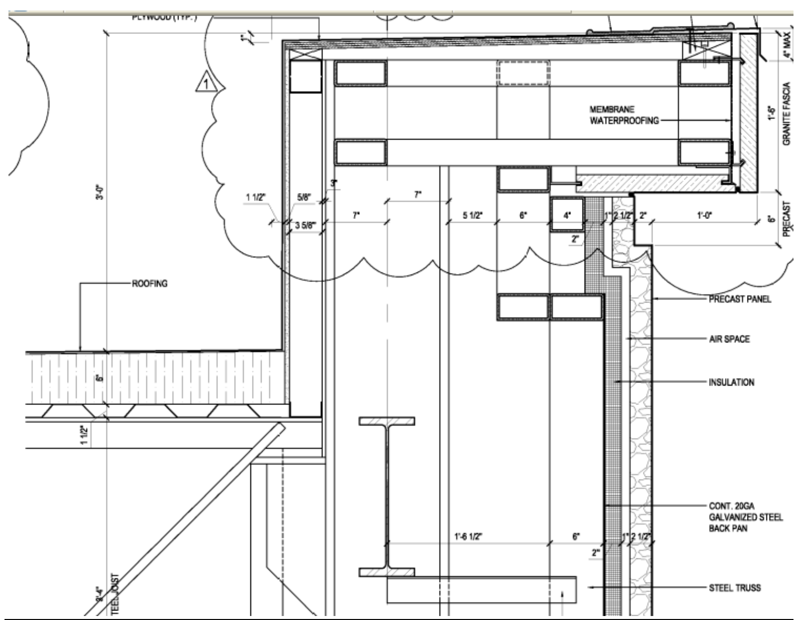
North Elevation



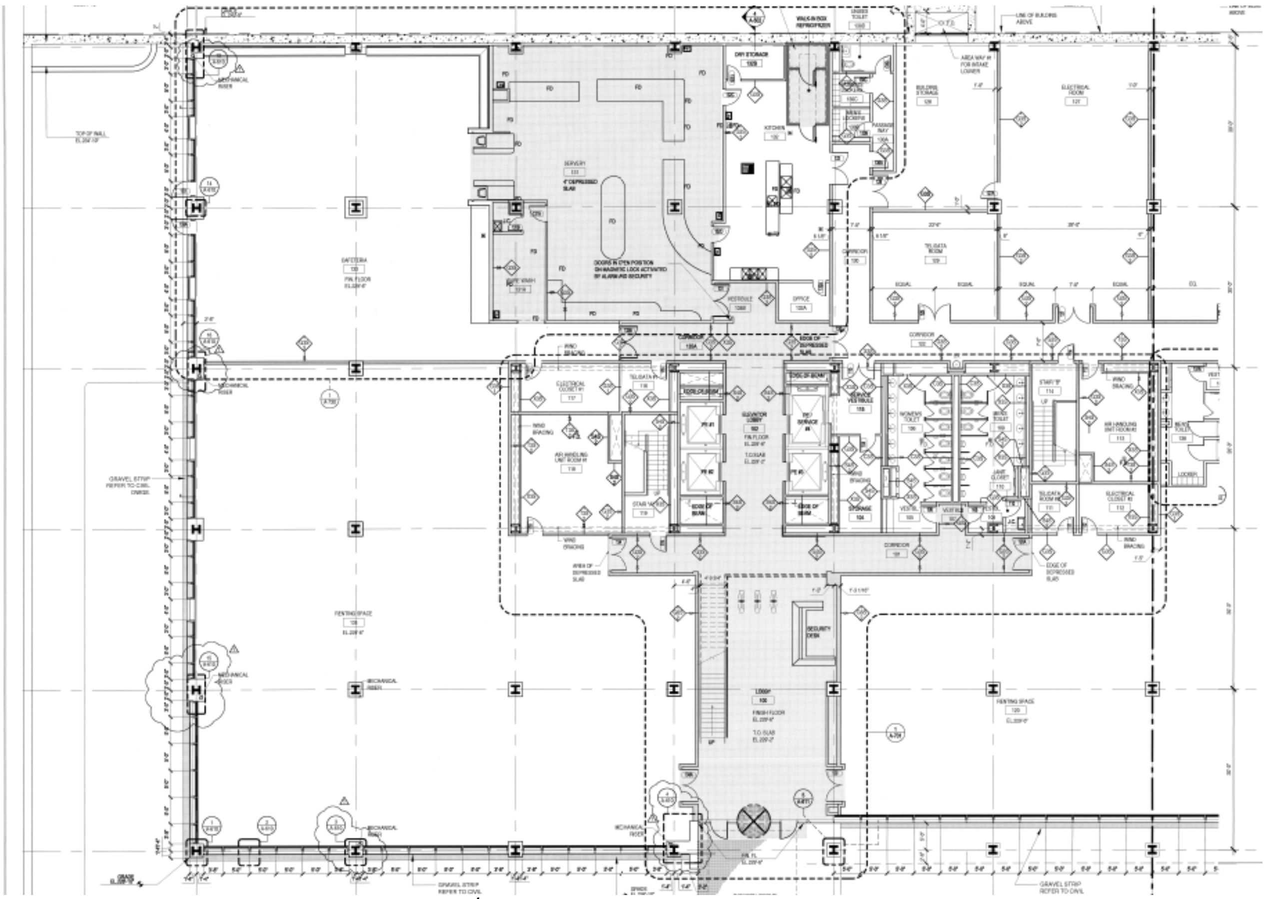
South Elevation



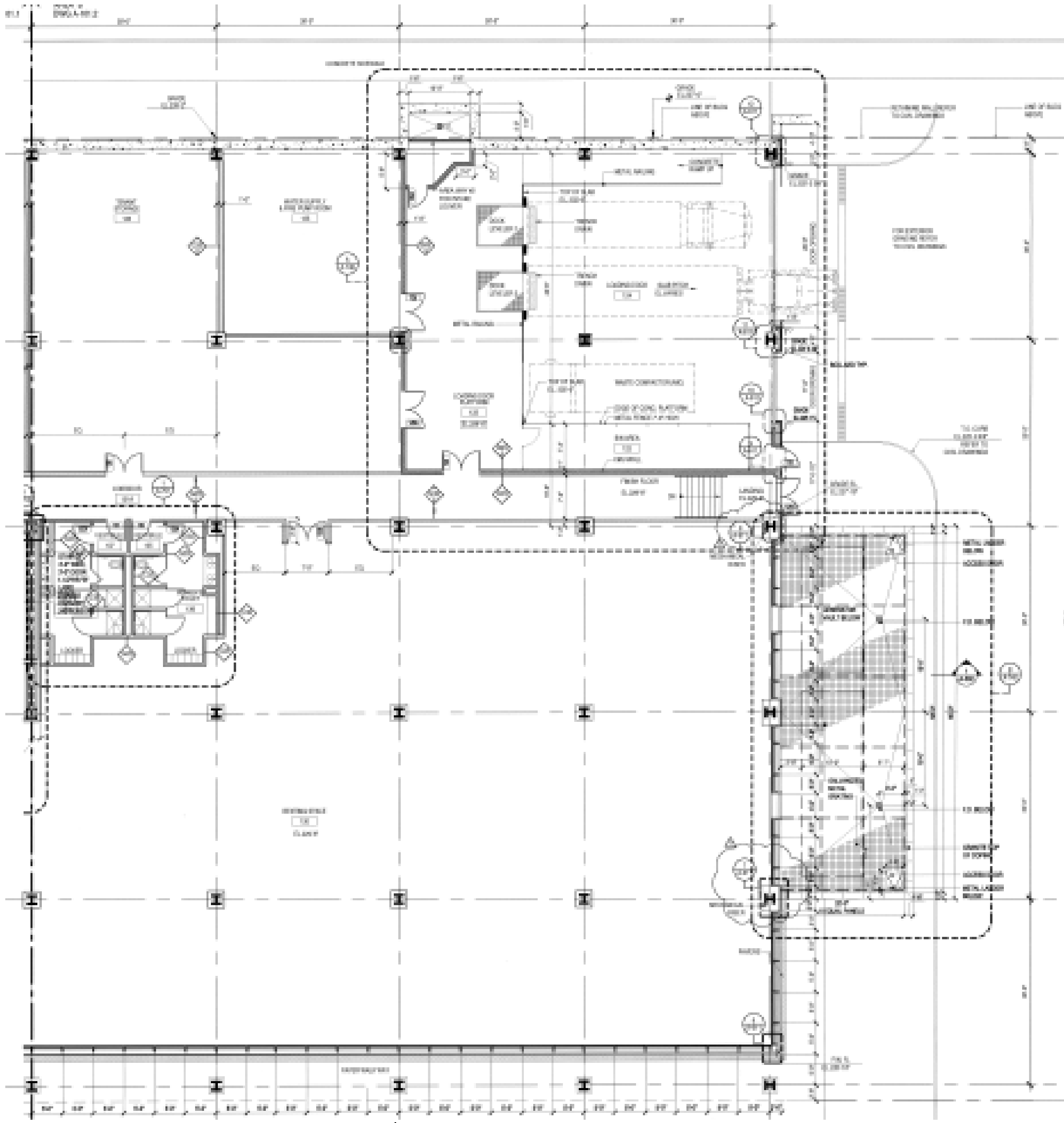
Exterior Wall Section at Stone Panel



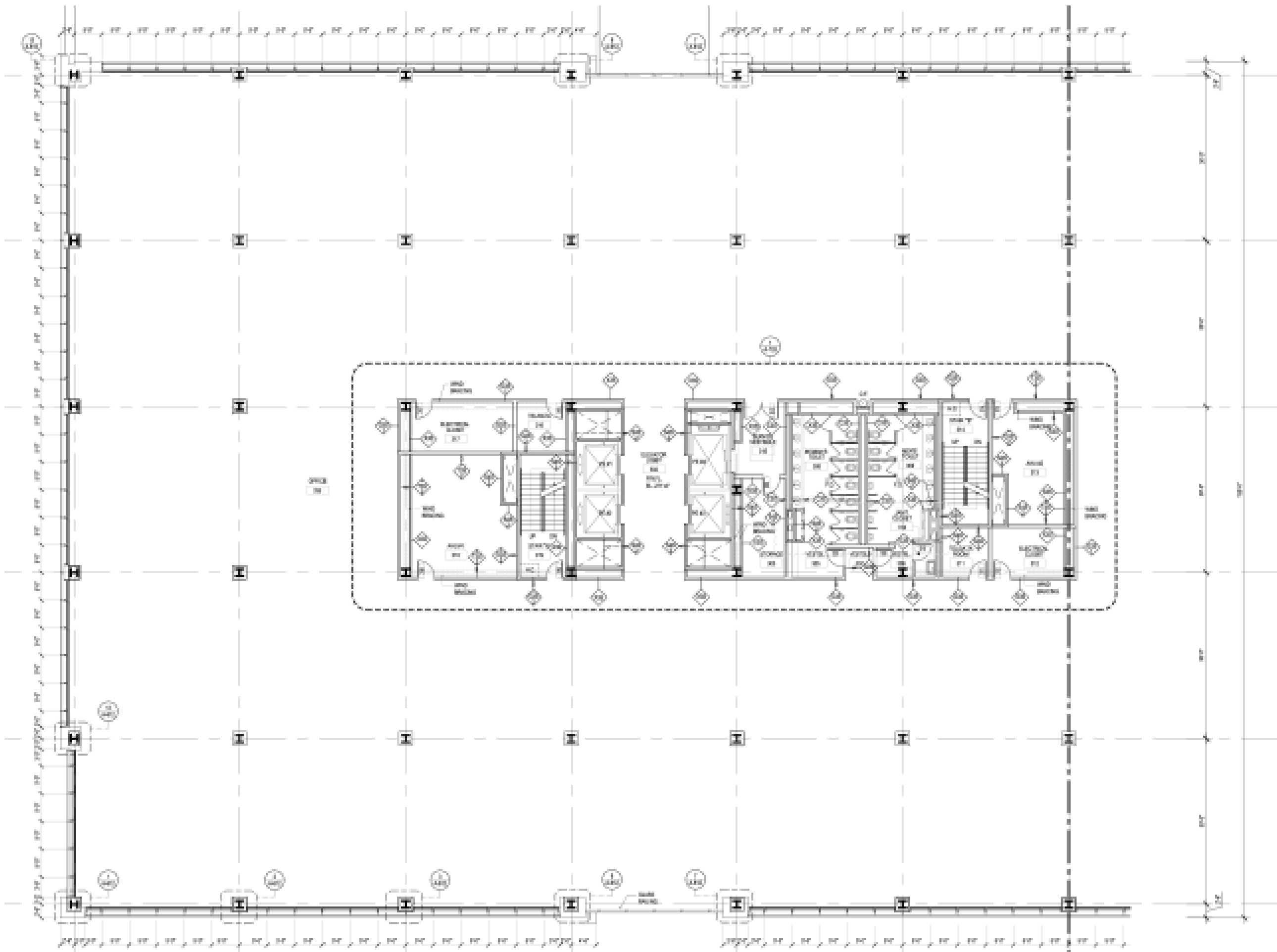
Exterior Wall Section at Parapet



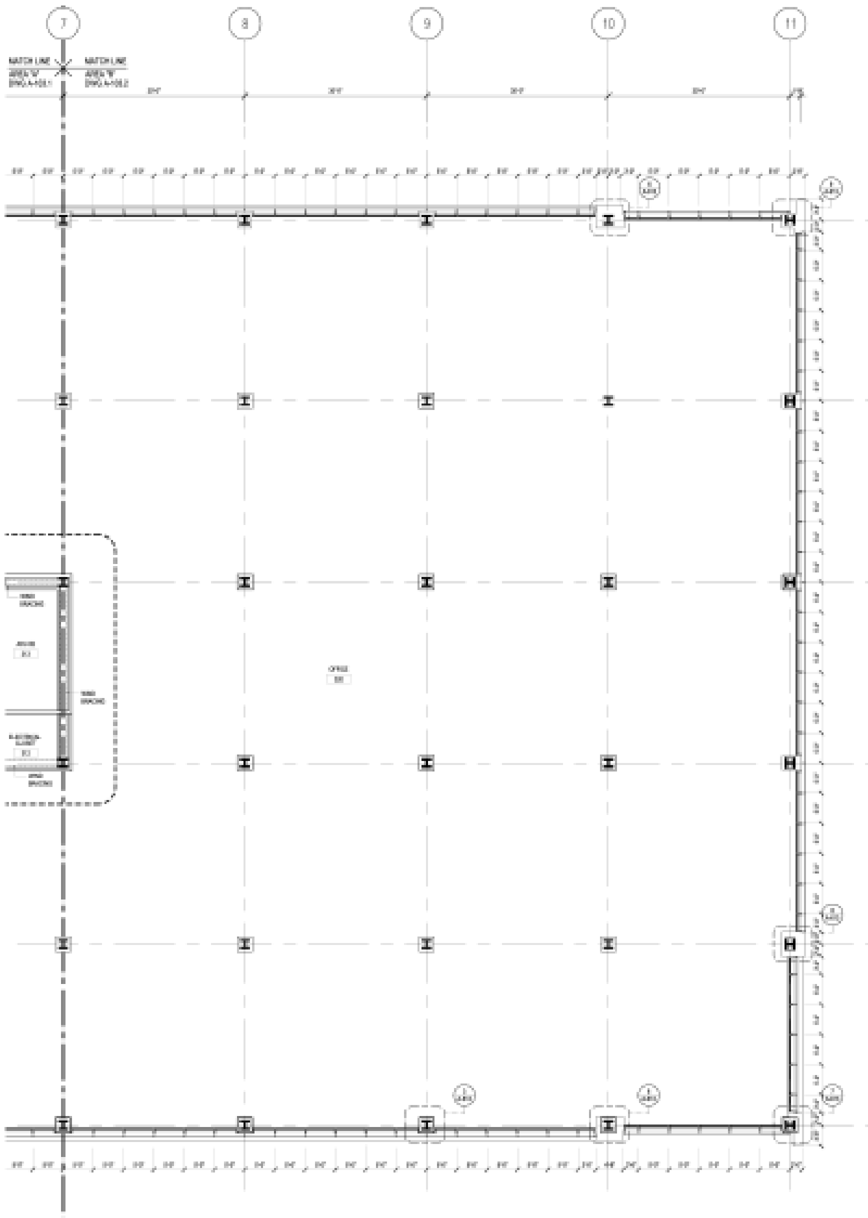
1st Floor 'Area A'



1st Floor 'Area B'



Typical Floor 'Area A'



Typical Floor 'Area B'

Analysis 1: Panelized Facade System

Introduction:

The project team encountered difficulties installing the façade. The goal of this analysis was to investigate what caused these problems and determine if anything could be learned from this situation and applied to future projects. At the time this analysis was proposed it was unclear whether these problems were due to poor design, poor shop drawing coordination or careless work in the field.

Background Info:

Prefabricated Stone Panels

The exterior wall is composed of three main elements: stone, glass and a few precast concrete sections. To speed up construction time the exterior stone panels that the façade is built from were pre-engineered and delivered to the site on pre-cast trusses. The contractor, Atlantic Exterior Wall Systems, performed much of the work in their shop. This resulted in a reduction of field labor. The Trainor Glass Company provided the glazing for the curtain wall. Together the stone panels and glazing form the building's envelope.

The project superintendent described this system as a genius idea. However this system did not work as well as expected. Aside from inconsistencies in the stone and poor drawings that lacked dimensions the panels also proved to be very difficult to align properly with respect to the glazing.

Figure 1.1 – Prefab Stone Panels

Unitized Curtain Wall

A unitized curtain wall was used on the project. The components of a unitized wall system came together at the manufacturer's facility. This facility became specialized to configure a specific custom curtain wall. Shop components of the unitized curtainwall included:

- Glass
- Insulation
- Back pans
- Stainless steel & aluminum panels
- Extrusions

A unitized façade offers many advantages over the system that was used on the project. It is a pre-engineered, pre-fabricated and pre-assembled curtain wall. The glazing and framing is assembled at the factory and delivered to the site in sections. This helps to minimize the amount of field work that is required and accelerates the assembly of the wall. It also reduces the dependence on field weatherseals. Many manufacturers also claim that the system has enhanced water resistance and air performance.

The unitized wall speeds up construction time. Since less field labor is required for installation, as opposed to the alternative stick built system, installation is a much quicker process. This resulted in a faster enclosure. The sooner the building becomes watertight the sooner crews can begin work on the interior finishes.

Figure 1.2
Placing a Prefab Curtainwall Section on a Similar Building

Many of these advantages are the same as those that were desired by the project team when they decided to use pre-fabricated stone sections. A unitized curtain wall system is actually very similar to the pre engineered stone trusses that were used. Much of the work was done in the shop and the panels are delivered to the site. Then they were lifted into place and fastened to the structure.

Figure 1.3 - Finished West Facade

<u>How the System Worked:</u>

Figure 1.4- Prefab Section on Truck

First the stone panels were installed and then the glass crews followed. The quarry, New England Stone, cut and drilled sinkages and holes into the stone for anchors, fasteners, supports, and lifting devices as needed to set the stone securely in place. Then the quarry delivered the cut sections of stone to the metal truss/panel fabricator. The fabricator shaped the beds to fit the supports. Once the truss fabricator obtained the stone they incorporated it into steel trusses/panels. The panels are designed for small movement when subjected to seasonal and cyclic day/night temperature ranges and when wind loads are imposed.

The panels were delivered to the site on flat bed trucks and then hoisted by crane into place. The panels were attached to the building by bolting them to a steel angle that had been welded to the steel frame. The angles had a slotted hole that allowed for adjustment in placement.

Once the stone panels had been installed separate crews would install the glass curtain wall. Each piece of glass was lifted into place with a modified JLG boom lift that was specially designed to lift the pieces with glass cups. There were 2 men in the building that reached out with glass cups to accept each piece as it was lifted to them from the lift. The men then installed each piece.

Installation Problems:

The stone panels were fabricated as 5' wide sections. Each piece of glass between the panels measured 5'x7'. There is a joint between each of these sections that should measure ¼" wide. In some areas it was difficult to fit the sections precisely and impossible to get ¼" joints. Some of the pieces were installed with ½" joints. This difference may sound insignificant but these discrepancies add up quickly to create a problem. The 300 foot long north and south façade required 60 separate panels to span that horizontal distance. If only a handful of those panels have the incorrect joint thickness it throws the alignment off. The tolerances are so small that there is no room for error.

The stone and the glass were both designed as 5' wide sections so that the vertical joint between each piece of glass meets the vertical joints between each piece of stone. The architect wanted it to appear as if there was one continuous joint that ran from the top of the façade to the bottom. Refer to **Figure 1.5**. Turner eventually noticed that as work proceeded the vertical joints were not lining up with one another as illustrated in **Figure 1.6**. As work proceeded with the window installation it was apparent that not all of the windows would be able to fit between the stone panels.

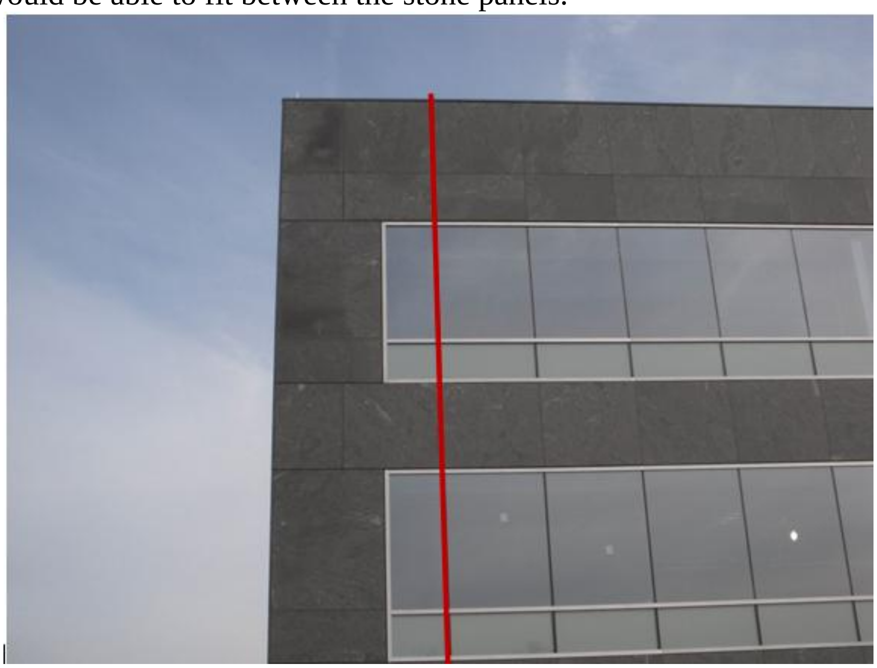


Figure 1.5 – Desired Finish Showing Continuous Vertical Joints

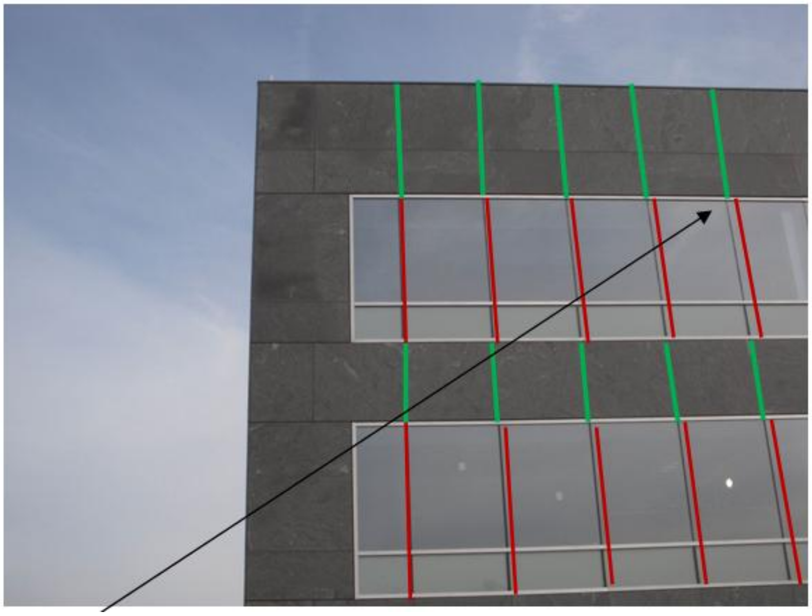


Figure 1.6 – Illustration of Alignment Problems

Notice how the vertical joints between the stone and glass become more and more skewed as you move down the building.

Why there were Complications:

One critical flaw with this system is that the envelope was designed as two separate systems and delivered by two separate contractors. A high degree of precision and coordination was required by the contractors. The joints between each piece of glass and the stone/glass interface only measured ¼”. The glass contractor had difficulties meeting this tolerance. Some of the pieces did not have the correct joint thickness. Many were installed with ½” joints between each piece of glass.

The small tolerances made it difficult to install the windows. Once the granite panels were installed the window contractor had to fit the glazing between the panels. If the placement of just one window was slightly off then the windows would not fit correctly. If there was more than ¼” gap between the glass/stone interface or between any two pieces of glass the contractor would not have enough space to fit his last piece of glass.

The fact that there were two contractors involved with the installation made the process even more difficult. A high level of coordination and precision was required by both contractors to perform the job effectively. Typically contractors want to install their work as quickly as possible and move on to the next project. Subcontractors may not realize how much of an impact their work has on another subcontractor or the project as a whole.

As a result the quality of their work can suffer. In a situation like this one, with two separate systems that depend on each other, if something goes wrong both contractors deny any wrong doing and try to place the blame on the other contractor.

<u>Impact of the Complications:</u>

The glass panels were not fitted together properly. The vertical joints between the glass did not align with the vertical joints between the stone as the architect desired. Every panel that was installed improperly compounded the problem. The vertical joints on the first few windows that were installed appeared correct but as work progressed down the building it had become more and more noticeable that there was a problem. Later it became clear that as a result of this misplacement the last piece of glass that sits against the granite would not be able to fit.

The glass contractor blamed the stone contractor for the problem. He claimed the stone panels were set improperly which resulted in the misalignment of the joints and also made it impossible to fit all of the glass within the space. The stone contractor blamed the glass contractor and claimed that the glass was not placed correctly. This arguing went back and forth and work on the façade was temporarily halted until the cause of the problem was determined. Fortunately litigation was avoided.

It was later determined that the reason the panels were not fitting correctly was because the window contractor did not place the glass properly. Human error was to blame for the glass being placed improperly. To solve the problem 20% of the windows had to be removed, moved over and re-aligned. This caused delays in others areas as well. Landscape crews were forced to delay work around the perimeter of the building until the façade was complete.

<u>Potential Solutions</u>

1. Integrated Envelope Contractor:

An analysis was performed to investigate the feasibility of awarding the entire façade to a single contractor. It was determined that this option comes with its own set of advantages and disadvantages.

If a single contractor was responsible for the design and installation of the building's envelope that would provide a strong incentive for that contractor to perform quality work. It would also eliminate the short comings of relying on two separate systems to fit together properly. Having one subcontractor eliminates the need for coordination between the glazing and stone contractors and also eliminates the chance of "finger pointing" between these two parties if a problem does occur.

The first concern with this option is finding contractors who are willing and able to bid on this package. Fortunately this project is located in a region where there is a lot of construction and a lot of contractors, suppliers and manufacturers to meet those construction needs.

Atlantic Exterior Wall Systems was the contractor who fabricated and installed the pre-fabricated stone trusses for this project. A phone interview was conducted with the company's president, Joseph Farina. This interview revealed that even though the company specialized in prefabricated panelized stone and brick truss systems they would have bid on both the glass and stone package if they were asked to. He claims that the company is fully capable of delivering such a system. He also believes that they would be able to do the work more cost effectively than the method that was used on the project.

The CM has several concerns with using an envelope contractor. The concern that they have is that the envelope contractor would subcontract one of the work packages to another party. There are a few reasons why this is not good from a construction manager's perspective. This gives them less management control. For example, if the envelope contractor specializes in stonework they may decide to subcontract the work for the glazing. Since Turner would not hold the contract with the glazing contractor they have little authority over them. The other concern is that this would shift the risk away from the envelope contractor and put it on someone else. This defeats the point for using a single contractor for the façade. If they subcontract the work then they are have reduced their risk. This does not provide a strong incentive for the envelope contractor to perform the work to the best of their abilities. The CM is also concerned that the envelope contractor may hire an inexperienced subcontractor who is not qualified to perform the work.

2. Dedicated Quality Control Management

Some people who were involved with the project believe that the problem is not due to poor design but simply careless work in the field. A dedicated quality control manager on the site could have caught the problem before it became a major issue.

This may have prevented the problem but it would come at a high cost. Adding a quality control manager would have cost the CM approximately $8,000 per month.

3. Shop Drawing Coordination

Some experts that were consulted for advice on this issue believe that this problem was a result of poor shop drawing coordination. It is to carefully review the shop drawings prior to beginning work. Each contractor, Trainor Glass and Atlantic Exterior Wall Systems, provided their own shop drawings for their portion of the work.

Prior to writing this report shop drawings were obtained from the contractor's and compared with one another. There were no obvious mistakes or coordination problems. If the components were installed as the drawings show they would have fit into place. It should be noted that the contractor's did not want these drawings included in the report or posted to the CPEP website for privacy reasons.

Conclusions:

After performing research on the topic it is fair to say that the problems encountered on the exterior wall was due to poor execution in the field. It appears that a lack of shop drawing coordination was not to blame and a system re-design is not necessary.

Using a single contractor to install the façade is not a good idea. After analyzing the advantages and disadvantages of using an integrated contractor it has been determined that the disadvantages outweigh the advantages. The CM is uncomfortable with the idea and so are other construction management professionals that have been consulted. This may have been a good solution if there was no chance of the contractor subcontracting the work to another party. Since there is no contractor in the area that specializes in both prefab stone panels and unitized curtainwall there is a very high likely hood that an integrated contractor would subcontract some of the work.

Adding extra staff to the project with the sole purpose of quality control management may have caught this problem sooner. However the cost of this option does not seem appropriate for a project this size. The problem could have been caught just as easily with the staff that was used on the project. This experience is a lesson learned for the CM and now they will have a trained eye to look for similar problems on future projects.

Analysis 2: High Performance Building Envelope

Problem Statement:

The goal of this analysis was to determine how changes can be made to improve the energy performance of the façade. The analysis focused specifically on glazing upgrades. The upfront costs of these upgrades were calculated along with a life cycle cost analysis of how long the system will take to pay for itself. Manufacturer's data sheets were used to obtain information on the thermal performance of different materials. This information was simulated in a computer model to obtain information on the building's performance.

The goal of my research is to determine how changes can be made to improve the current design, what will the upfront cost be to implement the improved system and how long it will take for the system to pay for itself.

Research Methods:

Research was conducted on various high performance glazings that are on the market today. Manufacturer's data sheets were used to obtain information regarding the thermal properties of the glass. A schematic estimate of the building's energy consumption was performed by using the U.S. Department of Energy's (DOE) 2.2 Building Energy Analysis Simulation Tool.

Background Information: Mechanical System

The building utilizes a combination air/water system with a two pipe direct return. The majority of the mechanical equipment that services the building is located inside a penthouse on the roof. There are a total of four McQuay Destiny air handling units that supply air to the building. AHU-1 and AHU-2 do the bulk of the work. AHU-1 & 2 in the penthouse are 100% outside air units that feed ACCU units (2 per floor). However AHU-1 & 2 only preheat the OA, they do not cool it. They are capable of supplying 15,500 CFM and 18,400 CFM with a capacity of 710 MBU and 841 MBU respectively. The building also makes use of a smaller 2000 CFM, 180 MBU unit located in the penthouse. This provides heating and ventilation solely for the two penthouse rooms. It is not part of the central system. The last air handling unit is located at the loading dock. It heats and cools the air for that area only.

Each floor has self contained heating/cooling units (ACCU's) that are used to control the indoor environment. Fan powered VAV terminal unit boxes, electric unit heaters and self contained AC units are used to control the air temperature in each room. A 1739 MBU capacity boiler located within the penthouse is used to heat the building's water supply. Also located on the penthouse are two Baltimore Air Coil closed circuit cooling towers, each with a 432 ton capacity. They are of an induced draft design with vertical air discharge. The towers use an aqueous glycol solution as the heat transfer fluid.

General Information

The quality of the building's envelope has a tremendous effect on the efficiency of the building's systems. To optimize the envelope it is important to understand New Jersey's climate. New Jersey experiences very cold dry winters and very hot humid summers. As a result of this climate type, a high value of thermal resistance is required in roofs, walls and windows.

Much of the building's winter heat loss comes as a result of conduction through the curtain wall glass. Likewise, during the summer months, conduction through the glass results in unwanted solar heat gain. In either case this puts an unwanted load on the HVAC equipment. A low U-Value is very desirable when choosing the glazing material that will be installed on a project.

Glazing Used on Project

The curtain wall glass on this project was manufactured by YKK AP. The product that was used was their YCW 750 Spline Tech glazing. This glass is a 1" insulated unit. It also provides a low-e. The U-Value measures 0.45 BTU/HR/SF/F. According to the authors of "Green BIM" this product offers a level of thermal performance that is typical of "market buildings" and below their recommended standard for "green buildings". See **Table 2.1** below. This is an issue of concern because the project is required to become LEED Gold Certified building. They recommend using a glazing with a U-Value of at least 0.29 for LEED Gold projects.

Design Criteria		**Market**			**LEED Gold**			**LEED Platinum**		
Glazing %	North	60			40			40		
	South	60			40			40		
	East	60			25			20		
	West	60			25			20		
Glazing Characteristics		U	SC	VLT	U	SC	VLT	U	SC	VLT
	North	0.42	0.6	0.71	0.29	0.43	0.7	0.16	0.35	0.6
	South	0.42	0.6	0.71	0.29	0.43	0.7	0.16	0.35	0.6
	East	0.42	0.6	0.71	0.31	0.4	0.47	0.16	0.31	0.6
	West	0.42	0.6	0.71	0.31	0.4	0.47	0.16	0.31	0.6
	Insulation & Operability	Double glazed, fixed			Double glazed, operable			Triple glazed, operable with controls		
	Light shelves	No			Yes			Yes		
Thermal Properties	Wall R-value	R8			R25			R33		
Temperature Range (F)	Cooling/RH	72			76			78		
	Heating/RH	72			68			68		

Table 2.1

Glazing & thermal property recommendations

Proposed Glazing

SolarBan 70XL is a high performance glazing that offers superior thermal performance compared to the YCW 750 Spline Tech glazing. It is manufactured by PPG. This glazing has a U-Value of 0.26. This offers a considerable improvement over the glazing that was used on the project and meets the recommendations for a LEED Gold building. This glass also allows architects to incorporate vast areas of vision glass into a building's design while minimizing the load on HVAC heating and cooling systems. Another advantage of this glass is it combines the clear appearance of transparent, color-neutral glass with a combination of solar control and visible light transmittance that was previously only attainable with a tinted glass.

Figure 2.1 Solarban70XL on a CSU Building

The owner would truly value the energy-related cost savings that SolarBan provides. According to the manufacturer a recent study by an independent energy and environmental research firm found that Solarban70XL glass has the potential to reduce annual energy costs by 5 percent or more in comparison with leading Solar Control Low-E coated glasses.

Energy Modeling:

An energy consumption simulation was conducted with the U.S. Department of Energy (DOE) 2.2 Building Energy Analysis Simulation Tool developed at the Lawrence Berkeley National Laboratory and Los Alamos National Laboratory. See **Appendix A** for the energy report. It is recognized as the most accurate and well-documented energy modeling tool available in the U.S.

The simulation was performed online from PPG's website. Users are able to enter limited information about their project. The data generated by this energy modeling program was for comparative purposes only. It is general in nature and will vary slightly from the actual building's performance. An effort was made to make the simulation as reasonable as possible.

Solarban70XL was modeled against various other types of glazing. It was not possible to compare Solarban70XL to the actual glass that was used on the project, YCW 750 Spline Tech. However the thermal properties of the various glazings are close to that of the Spline Tech glass. Again, this analysis was for comparison purposes only and will vary slightly from actual building performance.

Energy Modeling Assumptions:

Geometry and U Values	
Floor area (sf)	270,000 (sf)
Number of stories	8 story office
Wall window to wall ratio	90%
Wall U-value	0.124
Roof U-value	0.065
Wall area	56,640 sf
Glass area	50,979
Climate	
Location	Philadelphia
Operating Schedules	
Cooling setpoint	75 F
Heating setpoint	70 F
Standard day schedule	7 am - 6 pm weekdays
	8 am - 12 pm weekends
	All year
HVAC Equipment	
Air Handling System	VAV
Cooling plant type	Centrifugal chiller
Economizer	Yes
Heating plant type	Hot water boiler
Service hot water	Hot water boiler
Peak Internal Loads	
Occupants (sf/person)	448
Lighting (W/sf)	1.3
Equipment (W/sf)	0.75

Table2.2
Assumption for energy simulation

Utility Rates	
Electric Rates:	PECO Energy Company
Monthly charge	$25.00
Energy Charge:	
First 100 kWh	0.2246 $/kWh
Next 50,000 kWh	0.1145 $/kWh
Next 100,000 kWh	0.0785 $/kWh
Over 150,000 kWh	0.044 $/kWh
Gas Rates:	PECO Energy Company
Monthly charge	$14.40
First 2,000 Therms	1.41095 $/Therm
Over 2,000 Therms	1.32434 $/Therm

Table 2.3
Utility Rates for simulation

Simulation Results:

A detailed report of the energy model simulation can be found in **Appendix A** The table below summarize the results.

Glazing Type	Estimated Operating Expenses*	Estimated Total Capital Cooling HVAC Costs*
Standard Double Pane	$1.60/sf	$7.81/sf
Solexia Sungate 500	$1.52/sf	$7.46/sf
SolarBan70XL	$1.41/sf	$6.34/sf

*Based on energy model with 270,000 sf building

Table 2.4
Simulation Results

Table 2.4 above shows the estimated operating expenses and equipment cost for three types of glass. The glass used on this project, Spline Tech 750, has thermal properties in between the Standard Double Pane and Solexia Sungate 500. It was estimated that since it has thermal properties in between the two types of glass the cost would also be in between the two types of glass. **Table 2.5** below estimates the cost of 750 Spline Tech by taking the average of the costs from Standard Double Pane and Solexia Sungate 500.

Glazing Type	Estimated Operating Expenses	Annual Operating Savings	Estimated Total Capital Cooling HVAC Costs	Initial Capital Cost Savings	1st Year Savings
Spline Tech	$1.56/sf	N/A	$7.63/sf	N/A	N/A
SolarBan70XL	$1.41/sf	$25,500*	$6.34/sf	$1.29/sf	$244,800*

*Based on 170,000 sf of office space

Table2.5
Estimated Energy Related Savings

The simulation revealed that using Solarban70XL glass for the façade will result in lower operating costs and a lower total capital HVAC equipment cost. The estimated costs which were based on the simulation predict that $239,700 a year will be used to operate the building with Solarban70XLand $265,200 if Spline Tech 750 is used. This is equivalent to a savings of $25,500 per year.

Estimated total capital cooling HVAC costs were $1.3 million with Spline Tech 750 glass and only $1.1 million using SolarBan70XL.

Since the simulation was based on a similar building and not the actual project being analyzed these numbers are for comparison purposes only.

Glass Material Cost

Glazing Type	Square Foot Cost	Size of Panels (sf)	Cost per Unit	Number of Glass Units	Total Material Cost
Spline Tech	$10.45	35	$365.75	589	$215,427
SolarBan70XL	$9.25	35	$323.75	589	$190,689

Table 2.6
Glass Material Cost

Calculations

SolarBan70XL = $9.25/sf
This price was the highest number provided by two vendors that I contacted. The other glass company estimated the cost to be $8.50.

YCW 750 Spline Tech was purchased at = $10.45/sf

Each vision glass panel = 5' x 7' = 35sf

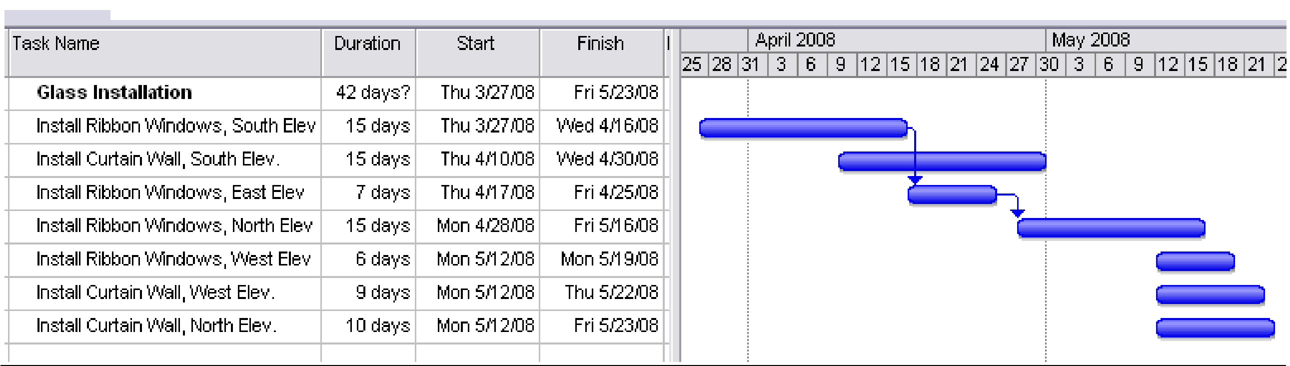
Material cost for each SolarBan panel = $9.25/sf * 35sf = $323.75 per panel
Material cost for each Spline Tech panel = $10.45/sf * 35sf = $365.75 per panel

South façade = 228 units
West façade = 109 units
North façade = 153 units
East façade = 99 units
Total = 589 vision glass units

SolarBan70XL total material cost = 589 units* $323.75 /unit = $190,689
Spline Tech 750 = 589 units* $365.75/unit = $215,426

<u>Schedule:</u>

Figure 2.2, displayed below, shows the schedule for the glass installation.



Task Name	Duration	Start	Finish
Glass Installation	42 days?	Thu 3/27/08	Fri 5/23/08
Install Ribbon Windows, South Elev	15 days	Thu 3/27/08	Wed 4/16/08
Install Curtain Wall, South Elev.	15 days	Thu 4/10/08	Wed 4/30/08
Install Ribbon Windows, East Elev	7 days	Thu 4/17/08	Fri 4/25/08
Install Ribbon Windows, North Elev	15 days	Mon 4/28/08	Fri 5/16/08
Install Ribbon Windows, West Elev	6 days	Mon 5/12/08	Mon 5/19/08
Install Curtain Wall, West Elev.	9 days	Mon 5/12/08	Thu 5/22/08
Install Curtain Wall, North Elev.	10 days	Mon 5/12/08	Fri 5/23/08

Figure 2.2 - Schedule

<u>Conclusions:</u>

Side - By - Side Glass Comparison							
Glazing Type	**U-Value**	**Square Foot Cost**	**Cost per Unit**	**Total Glass Material Cost**	**Glass Material Cost Savings**	**Estimated Energy Reduction**	**Estimated Equipment Cost Reduction**
Spline Tech	0.45	$10.45	$365.75	$215,427	N/A	N/A	N/A
SolarBan70XL	0.26	$9.25	$323.75	$190,689	$24,738	9%	16%

Table 2.7
Glass Comparison

The findings of this analysis are summarized above in **Table 2.7**. Significant energy savings can be obtained by upgrading to a high performance glazing on the façade. With the aid of a computer simulation an estimated annual energy savings of nearly 9% can be achieved. This is consistent with the manufacturer's (PPG) claim that the glass will reduce operating costs by at least 5% in comparison to standard solar control low-e glass. It also predicted a 16% reduction in first equipment costs due to the lower load on the building. Again, these numbers are for comparison purposes only and actual building performance would vary.

Surprisingly, the material cost for the high performance glazing, SolarBan70XL, was lower than the cost of the glass that was actually used on the project. Using SolarBan would save nearly $25,000 in upfront material costs for glass alone. It seems unusual that a product of lower cost can offer such high returns. It should be noted that the cost information that was obtained from vendors was their estimated material cost and it is possible that the real cost may be higher if they were to bid this project.

The numbers in this analysis clearly show that the owner would save money by upgrading to the high performance glass. This was a good analysis because the findings show real savings.

Analysis 3: Prefabrication

Problem Statement:

Prefabrication is becoming more commonplace in the industry. The only part of this building that utilized prefabrication was the panel wall system. This analysis will determine whether there are any other building components that can benefit from prefabrication. Benefits of standardization of parts would be measured by the schedule and cost savings impact that it has on the project.

Systems Analyzed:

- Prefab plumbing pipe
- Modular central plant

Research Methods:

Research was conducted through several means. Consulting with construction experts, contacting suppliers/contractors and online literary reviews were all used to obtain information about these systems. I also consulted with the Turner team who ran the project to see if they could help identify areas that would benefit from standardization.

Expected Outcome:

I expect that there can be some measurable schedule and cost savings from utilizing standardization of parts on this project. Research has shown that highly repetitive tasks that normally require a lot of field labor have the most potential for benefit. There is concern that that there are not enough bathrooms in this building for prefabricated plumbing assemblies to be economical. A modular central plant should greatly reduce installation time since it is delivered pre-engineered and pre-assembled, complete with chillers, pumps, cooling towers and interconnected piping.

Background Info:

Mechanical System

The building utilizes a combination air/water system with a two pipe direct return. The majority of the mechanical equipment that services the building is located inside a penthouse on the roof. There are several air handling units within the building. Their total connected load is 757 tons. There are a total of four McQuay Destiny air handling units that supply air to the building. AHU-1 and AHU-2 do the bulk of the work. They are capable of supplying 15,500 CFM and 18,400 CFM with a capacity of 710 MBU and 841 MBU respectively. AHU-1 & 2 are in the penthouse and are 100% outside air units that preheat the air, they do not cool it, and feed it to air cooled condensing units (ACCU). There are two ACCU's per floor. The building also makes use of a smaller 2000 CFM, 180 MBU unit located in the penthouse. This provides heating and ventilation solely for the two penthouse rooms. It is not part of the central system. The last air handling unit is located at the loading dock. It heats and cools the air for that area only.

Each floor has two self contained heating/cooling units (ACCU's) that are used to control the indoor environment. Fan powered VAV terminal unit boxes, electric unit heaters and self contained AC units are used to control the air temperature in each room. A 1739 MBU capacity boiler located within the penthouse is used to heat the building's water supply. Also located on the penthouse are two Baltimore Air Coil closed circuit cooling towers, each with a 432 ton capacity. They are of an induced draft design with vertical air discharge. The towers use an aqueous glycol solution as the heat transfer fluid.

Proposed System Description:

Modular Central Plant

A McQuay Modular Central Plant will be the piece of equipment examined for this analysis. A modular central plant come pre assembled from one supplier with the chiller, cooling tower, pumps, and interconnecting condenser water piping in one module. Their unique modular configuration reduces site installation time. They are a low cost, highly efficient alternative to site built plants. The McQuay Modular Central Plant is internally controlled, and is run from a single control panel. Units are shipped to the job site for final assembly, bypassing the need for traditional site built cooling plants. The major advantage to this system is it reduces trade coordination costs and site assembly time. This type of system was recently installed on the Herakles Data Center project. The entire installation period took just one week from the time it was dropped into place, bolted, wired and piping hooked up.

Figure3.1

Modular configuration allows easy delivery to site

Figure 3.2

Hoisting a Modular Central Plant into place

Figure 3.3

Crew placing a Modular Central Plant

Figure 3.4

Modular Central Plant with a plate in frame heat exchanger with secondary pumping

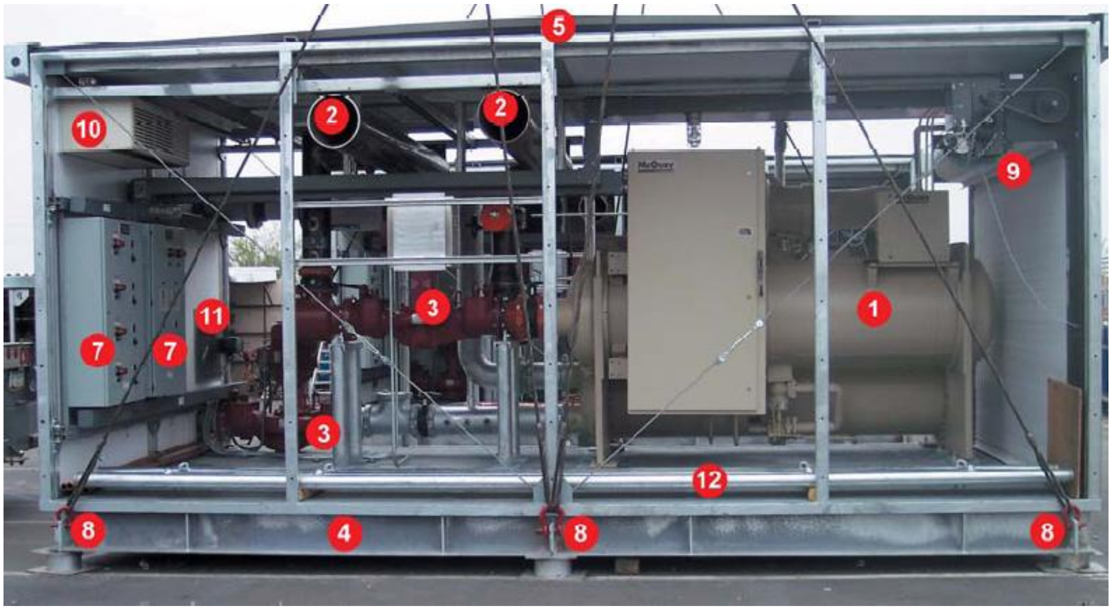


Figure 3.5
Components of a modular central plant

1. Chiller—scroll, screw, or centrifugal
2. Interconnecting chilled water supply and return pipe headers
3. Split-coupled, in-line pump
4. Fully engineered, galvanized, welded, and point-loading steel structure, with seismic bracing where required
5. Removable roof with integral gutters and flashing
6. Removable wall panel with lifting handles
7. UL listed motor starter and VFD panels
8. Lifting and multiple-module connecting lugs
9. Motorized roll-up access door
10. Packaged terminal air-conditioner unit
11. Enclosure ventilation fan
12. Complete interconnecting hardware provided and shipped with modules

Figure 3.6
Housing of a modular central plant

Complete with cooling tower, interconnecting condenser water piping...

Figure 3.7
Complete package on flatbed truck

13 Cooling tower—cross flow type with stainless steel hot and cold water basins optional

14 Fully engineered, galvanized, welded, and point-loading steel structure, with seismic bracing where required

15 Interconnecting galvanized condenser water supply and return piping and pipe supports

16 Main distribution panel with single point electrical 480 volt/3-phase connection (one per module)

<u>Advantages of Modular Plant:</u>

Installing a modular central plant has many advantages from a construction perspective. They are summarized in **Table 3.1**. Since all of the components are coming from a single supplier there is less risk that coordination problems will arise. A single source supplier means there are also fewer chances for suppliers to fall behind schedule and not deliver the product on time. The biggest advantage with this option is the system’s modular design allows it to be delivered to the site on a flatbed truck in one pre-assembled unit. This equates to dramatically reduced site assembly time. The only work that needs to be done once it has been dropped into place and bolted is hook up the wiring and piping.

Less field labor is needed compared to the site built systems that were used on the project. The owner will also appreciate the fact that the capacity of a modular unit is easily expandable if future energy needs surpass its current capacity.

Disadvantages of Modular Plant:

Construction Concerns

One can also make an argument against using a modular central plant. There are several disadvantages from a construction viewpoint. These are also summarized in **Table 3.1**. A contractor will be concerned about lead time. This piece of equipment is a long lead item. An order must be placed months in advance. It is not something that can be picked up readily from the supplier because it needs to be custom designed for the project.

The plant is also a very heavy piece of equipment. It weighs 132,000 pounds or 66 tons. There are two main concerns regarding its weight. It will require a crane to hoist it into place. Riggers and rigging equipment will be needed to safely hoist the unit. See **Figures 3.9** and **3.10.** Multiple shackles, adjustable spreader bars and cables all must be included for the lift.

The other major concern is that the building's structural system cannot support a modular plant. A STAAD analysis revealed that the beams which support the floor of the mechanical penthouse are not strong enough to support the added weight. There would be a considerable amount of structural costs involved with supporting the larger equipment.

Figure 3.8
Placing equipment on grade

An alternative to placing the equipment in the penthouse would be to locate it on grade. See **Figures 3.11** and **3.12** for a typical equipment setup. This is typical for modular central plants. This would eliminate the need for a mechanical penthouse. However it will likely take away from available parking space on the ground. The mechanical equipment was placed in a penthouse because the architect did not want the equipment within view of the public. A modular central plant located on grade would require a barrier to block it from public view.

Modular Central Plant	
Advantages	**Disadvantages**
Reduced owner & contractor risk	Long lead time
Single source supplier	Heavy loads
Fast site assembly time	Structural coordination
Reduced trade coordination	Rigging & crane requirements
Less field labor required	Vibration isolation
Easily expandable	May need to locate on grade

Table 3.1
Construction Issues

Design Concerns

There are also design concerns that arise when considering the use of a modular plant. A reason for not using one central unit is if the unit goes down, the entire building is without service until the unit is fixed. A building can limp along when one of the eight ACCU's is not working, or is down for maintenance. This is not the case with the proposed modular central plant. The current design allows for one unit on a floor to be off for service while the other unit handles the entire floor. Both units running at full speed would only be required only during peak cooling design load, so this makes scheduled maintenance easier.

Another reason against using the modular plant is that this building is rentable space. It is possible to have only one floor occupied, or part of one floor and another part of a different floor. If using one central unit, it must run for occupied mode during normal business hours. This could be a large waste of energy if the building is under-occupied. It could also be difficult to get all the VAV boxes and fan powered boxes to work properly if the main supply fan is slowed for the low load.

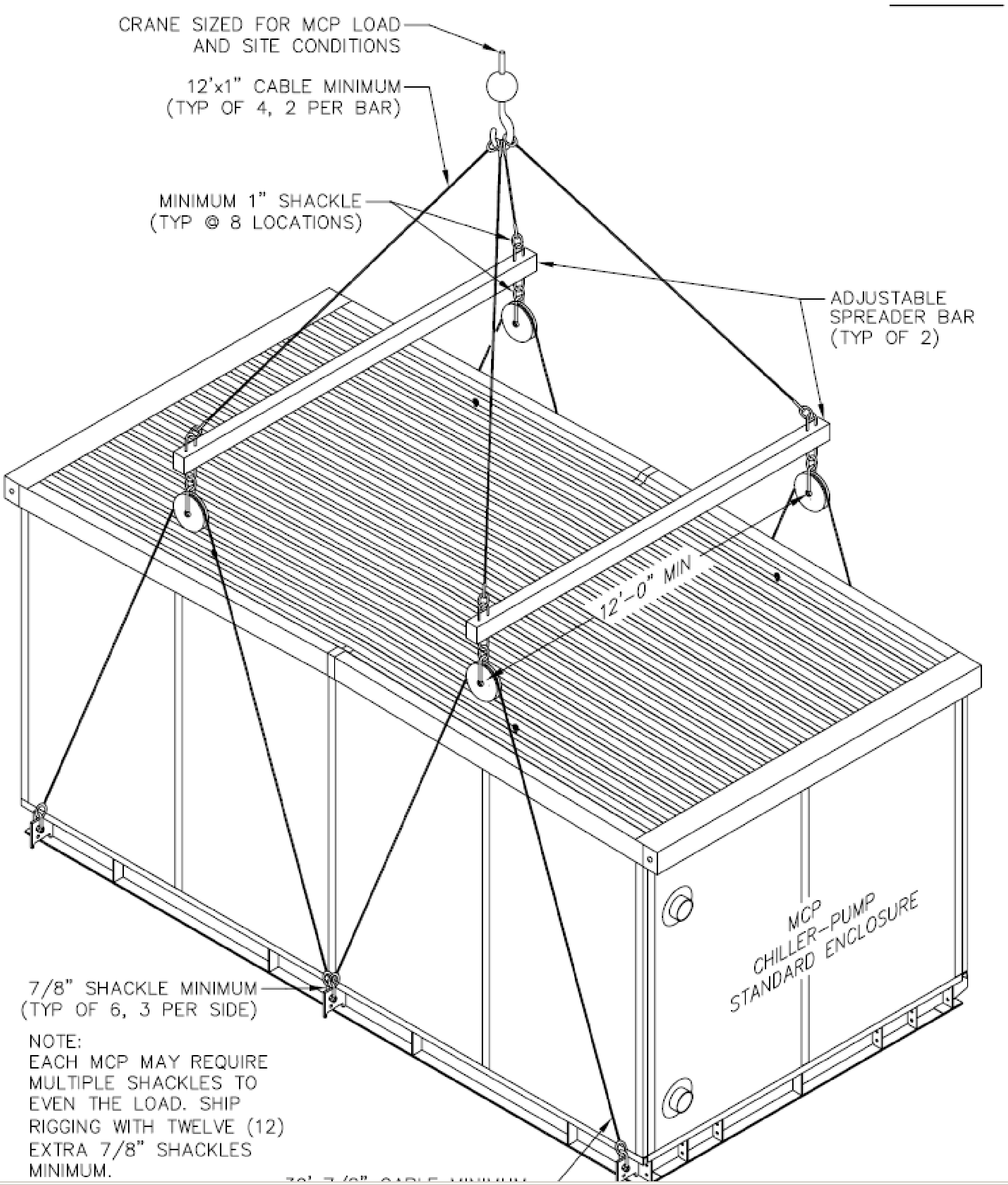


Figure 3.9 – Chiller/Pump Rigging Requirements

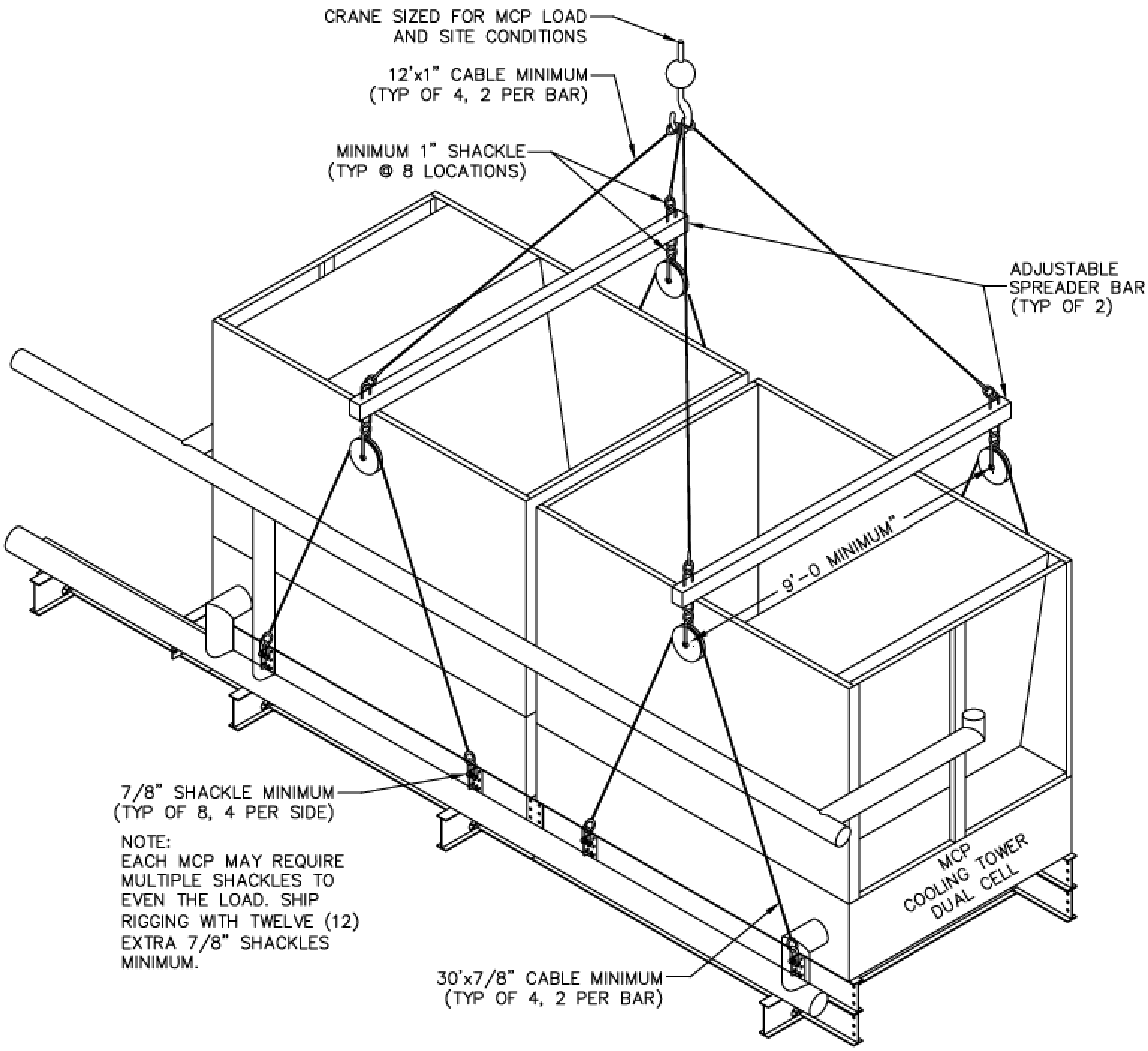


Figure 3.10
Dual Cell Cooling Tower Rigging Requirements

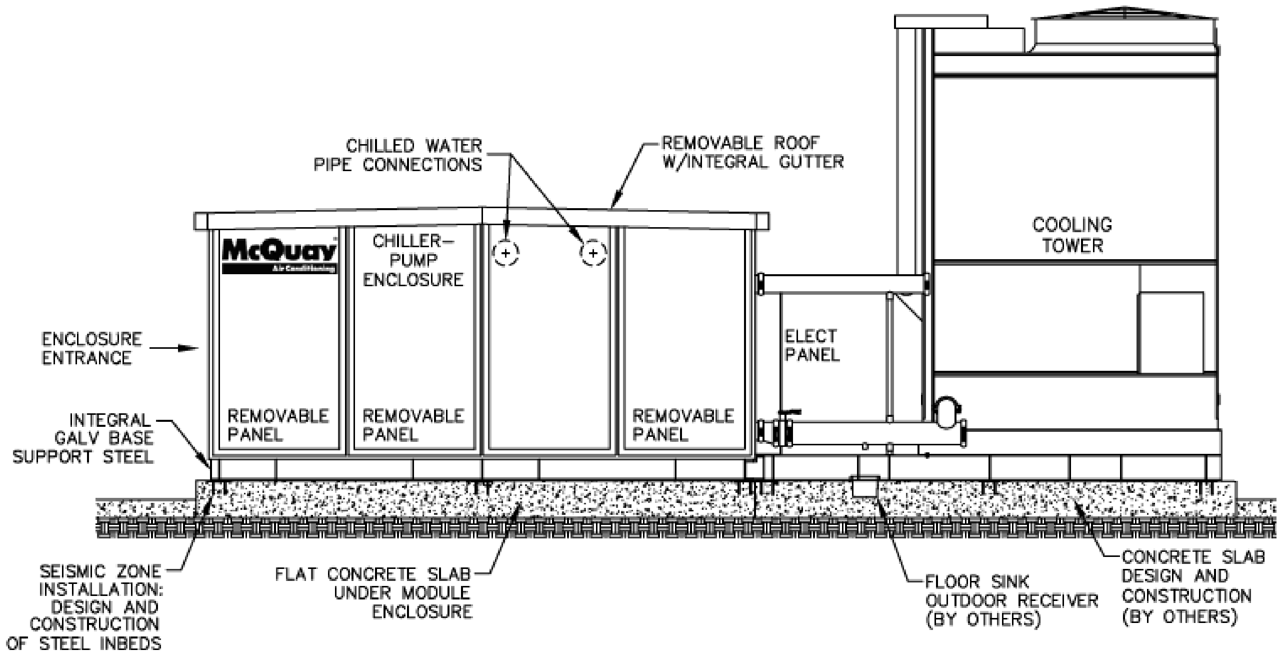


Figure 3.11
Elevation View of Concrete Slab Mounting

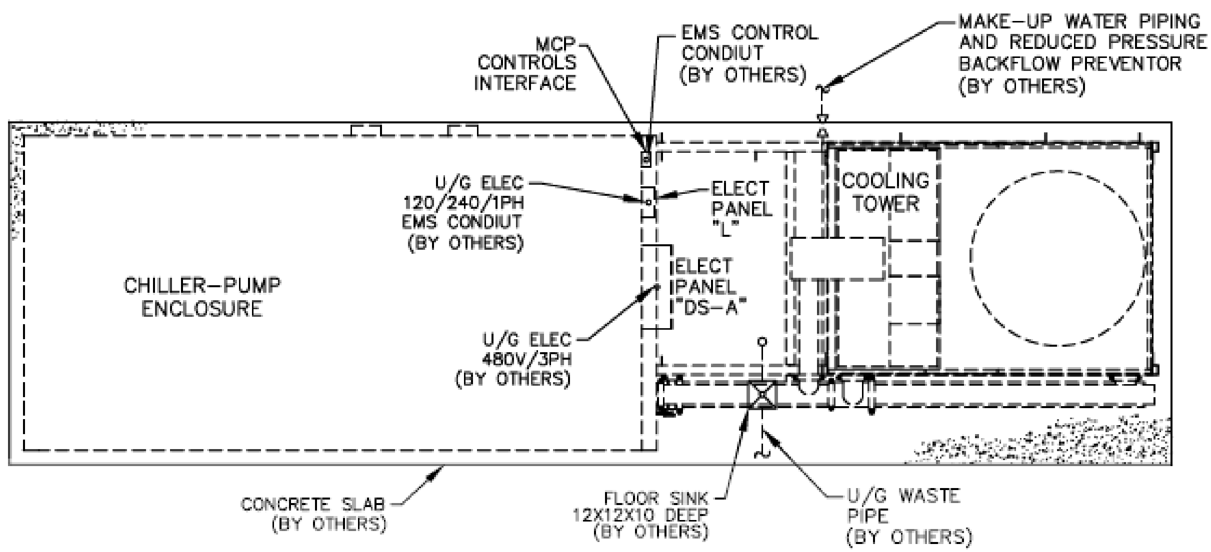


Figure 3.12
Plan View of Concrete Slab Mounting

Schedule Comparison:

It is estimated that the amount of time spent working on mechanical equipment in the penthouse could have been reduced from 126 days to 89 days if a modular plant were used. This time savings of 37 days is possible because the components of the modular plant are pre-installed and ready to be hooked up to the system.

There are some sequencing differences between this option and traditional equipment. Traditional equipment is put into place and then crews work to install the supporting piping and wiring. Typically when a modular plant is used the work is done in reverse. The piping and wiring is installed and then the modular plant is dropped into place and hooked up. See **Figure 3.13** on the next page for more details on the schedule comparison.

Task Name	Duration	Start	Finish
Install Traditional HVAC Equipment	**126 days**	Tue 3/25/08	Tue 9/16/08
Install AHU's	10 days	Tue 3/25/08	Mon 4/7/08
Install Boilers	10 days	Wed 4/2/08	Tue 4/15/08
Install Exhaust Fans	10 days	Wed 4/2/08	Tue 4/15/08
Install Heating Pumps	10 days	Wed 4/16/08	Tue 4/29/08
Install Cooling Towers	20 days	Wed 4/16/08	Tue 5/13/08
Install Mechanical Piping in Penthouse	67 days	Wed 5/7/08	Thu 8/7/08
Install Cooling Pumps	11 days	Wed 5/14/08	Wed 5/28/08
Install Equipment Conduit & Wire	83 days	Fri 5/23/08	Tue 9/16/08
	1 day	Wed 9/17/08	Wed 9/17/08
Install Modular Central Plant	**89 days**	Tue 3/25/08	Fri 7/25/08
Install Mechanical Piping in Penthouse	67 days	Tue 3/25/08	Wed 6/25/08
Install Equipment Conduit and Wire	70 days	Tue 4/8/08	Mon 7/14/08
Lift Modular plant into Place	1 day	Tue 7/15/08	Tue 7/15/08
Bolt-Up Modular Plant	1 day	Tue 7/15/08	Tue 7/15/08
Wiring & Piping Hook-Ups	7 days	Wed 7/16/08	Thu 7/24/08
Begin Start up and Testing	1 day	Fri 7/25/08	Fri 7/25/08

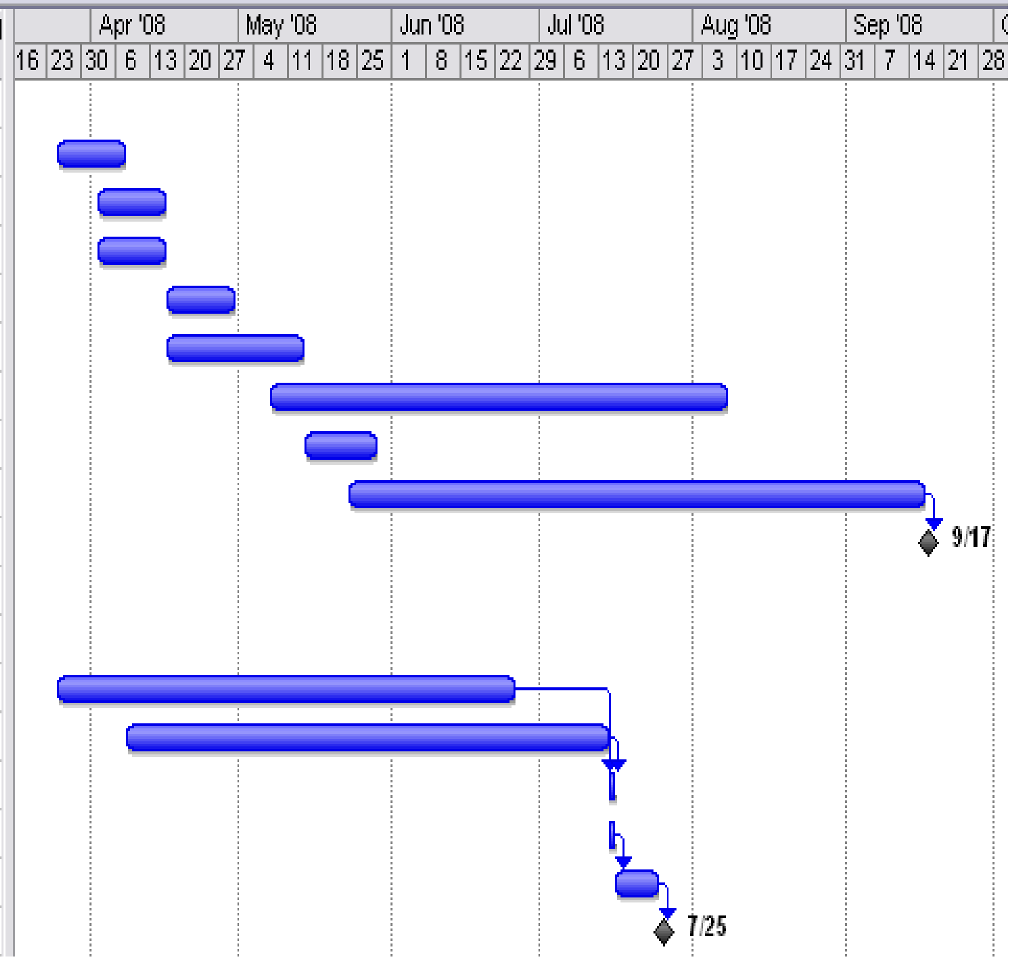


Figure 3.13 – Schedule Comparison

Structural Breadth Study:

The building's structural system was analyzed to determine whether they would be able to support the proposed modular central plant. The analysis was performed by modeling the structure in STAAD. See **Appendix E** for details. Instead of modeling the entire building's structural system a simplified analysis was performed. The beams that support the slab of the mechanical penthouse were modeled with a uniform distributive load that was equivalent to the weight of the equipment and the weight of the slab. Since W18x35's are used throughout the entire penthouse a single W18x35 beam with a 30 foot span was analyzed with the distributive load to determine if it can support the load. See **Figure 3.14** for the framing plan and equipment location.

Results:

The STAAD analysis revealed that the weight of the modular plant would cause the supporting W18x35 beams to deflect 2 inches. This deflection is greater than L/240 and equal to L/180. The calculation assumed the equipment weight is uniform over its entire area. However this is not actually the case. The chillers are heavier than most of the equipment and that weight would be concentrated in a small area. The actual load on the beam would be higher than the 1.6 Kips/ft that was used in the analysis to obtain the 2" deflection. Sound engineering judgment can be used to reason that the beams in the penthouse are not strong enough to support the load of the modular plant.

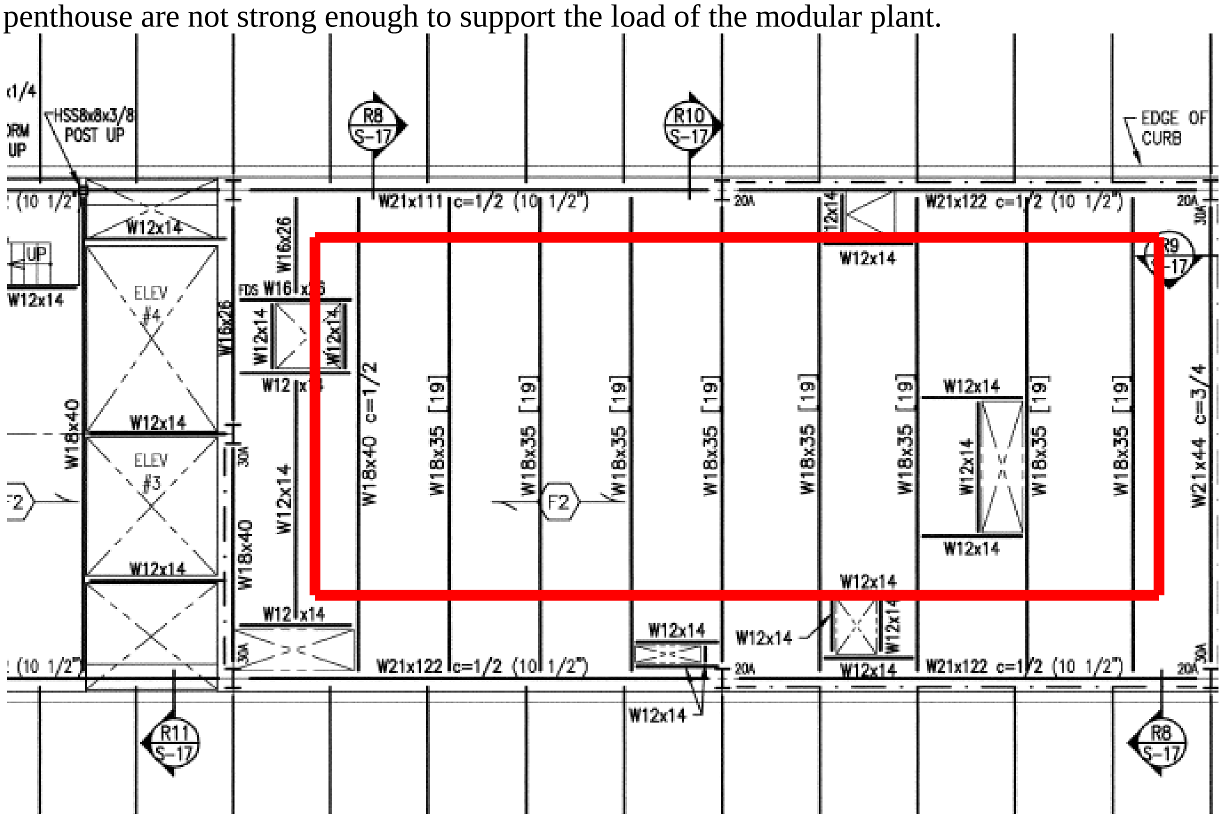


Figure 3.14- Location of Modular Central Plant

Calculations:
6” concrete slab
Concrete = 150pcf
150 pcf * .5 ft = 75 psf
75 psf * 6 ft beam spacing = 450 plf
Base Modular central plant with no add on options = 132,000 lbs = 66 tons
Modular plant dimensions (L x W) = 52’ x 23’
Central Plant = 110psf * 6 ft beam spacing = 660 plf
Live load reduction = 1.2D + 1.6L = 1.2*450plf + 1.6*660plf = 1,596plf = 1.6klf
Allowable Deflection:
L/240 = (30*12)/240 = 1.5”
L/180 = (30*12)/180 = 2”

<u>Proposed System Description:</u>

Plumbing Tree

A plumbing tree is a prefabricated set of drain waste, vent, and supply lines for use in bathrooms. They are assembled in a factory and delivered to the site in sections. Each section is placed in the building and connected to the adjacent sections and/or the plumbing fixture. In this building it would be used to fabricate the run of pipes behind the toilets, sinks and urinals. See **Figure 3.14** below for an illustration.

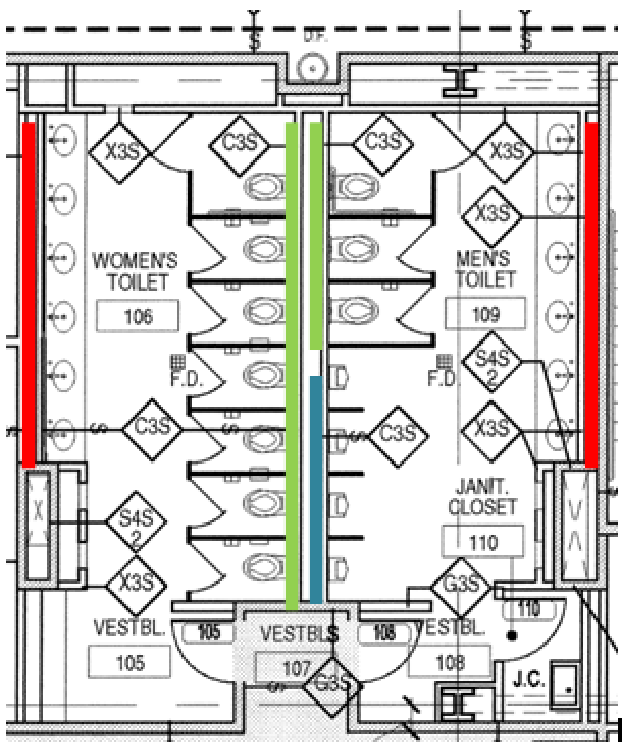


Figure 3.15 – Prefab plumbing sections

Advantages of Plumbing Tree

The main advantage of using this method is less field labor is required. As a result it has a faster assembly time. This allows finishing crews to enter the bathrooms earlier than they would have been able to if the piping had been assembled on site piece by piece.

Disadvantages of Plumbing Tree

A plumbing tree is not economically feasible on all projects. The transportation costs for a plumbing tree are higher than that of piping that is installed entirely on site. That is because plumbing trees take up a lot of space and must be packed accordingly while regular piping can be packed tightly onto a truck. They are most often used on projects that have a lot of plumbing and are best used for repetitive work. Another constructability concern that must be taken into consideration is the length of the sections. The size of the material hoist is the limiting factor. For example a convenient plumbing tree length for this building would be 25 feet since that is the length of the row of toilets in the bathroom. However a 25 foot section will not fit in a 15 foot long material hoist. There is also a lead time associated with the prefabricated sections.

Conclusions:

Modular Central Plant

The disadvantages outweigh the advantages of using a modular central plant for this project. The central plant would require about a month less time to install but there are major shortfalls that come with this system. The operating requirements and extra weight are major problems. The mechanical engineers that designed the current system did a good job and choose the correct system. Nonetheless it was worth taking a look at the modular central plant option.

Plumbing Tree

After consulting with members of the Penn State AE faculty, an OPP manager, industry members and my own personal literary research I have determined that the benefits of using prefabricated plumbing on this project do not outweigh the costs. The reason this is the case is because of the type of project this is. A four story commercial office building has limited opportunity to use this system because there are only two bathrooms per floor. The time saved installing the prefab sections would not justify the cost of the material. If this building were a high rise or an apartment building with a lot of repetitive units using prefabricated piping would be a good idea because there would be enough work to make it economically feasible.

Reducing Operating Costs

Critical Industry Issue

Introduction:

This analysis will focus on different techniques that owners are using to reduce their annual operating costs. Energy and water consumption will be the two main issues examined. The analysis will focus on both general design practices that can be applied broadly to the building industry and on specific practices that can applied to effectively reduce the operating costs of 50 Connell Drive.

In recent years the operating costs of buildings has increased. This is due mainly to an increase in energy consumption. The rise of energy consumption is due to an increasing demand. Today's buildings have more equipment that requires electricity than buildings of past generations. Designers must consider the impact of computers, monitors, appliances, copiers, printers and others. For example a modern office building may have thousands of computers. Not only do these computers use energy to operate but they also put out a lot of heat. This heat load raises the temperature of the indoor environment. As a result a greater cooling load is required by the HVAC system.

Energy Efficient Design:

It is important to understand where the costs come from. The combined cooling and heating loads of office buildings can be expected to be between 35% and 40% of the total energy load. Conduction, the transfer of heat through matter such as the materials that make up the envelope of the building, is responsible for much of this load. One study found that 50-60% of the heating load is from conduction and about 30-40% of the cooling load is a result of conduction [Green BIM, Eddy Krygiel and Bradley Nies, 2008].

A study by Eddy Krygiel and Bradley Nies, the authors of "Green BIM" has found that some of the most common energy efficient measures include:

- Building orientation
- Optimized envelope
- Optimized glazing
- Optimized shading
- Daylight dimming
- Optimized lighting
- Efficient equipment and fixtures
- Passive solar
- Natural ventilation
- Optimized mechanical systems

Many of these items have a synergistic affect on a building's performance. Applying just one or two of these techniques will likely result in a relatively small increase in performance while applying all of these strategies together will greatly reduce energy consumption and result in a truly high performing building. Many of these design practices take advantage of the earth's most powerful natural resource, the sun. The sun provides light and heat, two important resources that designers should take advantage of. Building orientation, massing and optimized envelope, glazing, shading and lighting combined with daylight dimming can be combined for a synergistic effect resulting in a collectively better performance.

A quality building envelope is one of the most basic strategies for saving energy in an office building. New Jersey experiences very cold dry winters and very hot humid summers as shown in **Figure 4.1**. As a result of this climate type, a high value of thermal resistance is required in roofs, walls and windows if owner wish to operate their building at a set temperature and humidity

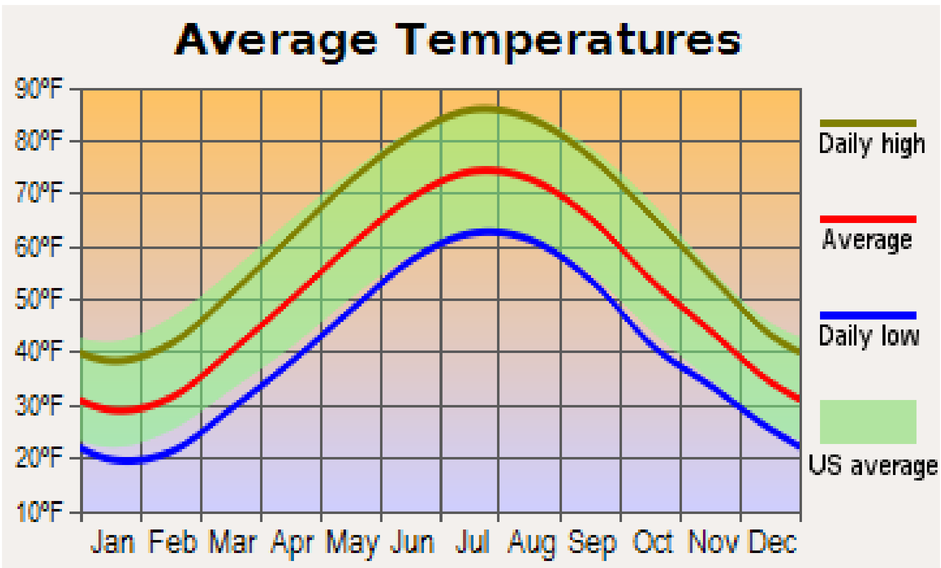


Figure 4.1 – Temperature Fluctuations of NJ

The southern exposure of a building offers a great source of solar heat gain from the sun. To take advantage of the sun's energy the building should be oriented to face solar south and the building's mass should be elongated in the east-west direction. Selecting the proper amount of glazing, location and type of glass for the south façade the usable daylight can be harvested. This can decrease the amount of overhead artificial light required to light the space. By combining daylight dimmers on the south perimeter the amount of artificial light that is used in the space can be optimized. A clear advantage of this is less energy is required to light the space since the sun provides most of the lighting needs. A second advantage that may be less obvious is the cooling load on the building is actually reduced. This is because artificial lights emit heat into the indoor environment and now the amount of heat emitted by these lights has been reduced. The amount of solar light that penetrates into the space can be further controlled by introducing external shading devices and internal light shelves. This can be particularly helpful on the southern façade. These shades can reduce unwanted solar heat gain during the summer months.

Each façade of the building should be treated differently with respect to glazing. Designers must consider which direction the sunlight is coming from. The sun is very low in the sky during the early morning and late evening hours. This makes it difficult to control within the office space. For this reason it is good practice to place a relatively small percentage of glazing on the east and west facades of the building. It is also important to consider the percentage of glass used to provide daylight and the thermal conductive resistance of the exterior wall for comfort within the space. The three important factors to consider when choosing the type of glass is the U-value, visible light transmittance (VLT) and solar heat gain coefficient (SHGC). These all affect the design's ability to permit daylight penetration which in turn affects the heating and cooling loads within the space.

<u>The Operator's Role:</u>

Operating costs can also be controlled by the building's operators. Energy consumption can be reduced simply by setting the thermostat slightly higher in the summer months and slightly lower in the winter months. Typically 71 degrees is the set point for heating. A fairly large amount of energy can be saved by setting the system to 70 degrees. Likewise the typical set point for cooling is 73 degrees. Operators can reduce energy consumption by operating at 76 degrees. One study found that these changes can lower a building's energy consumption by 8%. If more energy savings is desired consider varying the set point temperatures even more. The same study found that energy consumption can be reduced by 23% by heating at 66 degrees and cooling at 78 degrees. See **Table 4.1** for more detailed information on the energy savings associated with changing heating and cooling set points.

	Heating/Cooling Setpoint					
	Baseline	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Item	**71/73**	**70/74**	**70/76**	**70/78**	**68/76**	**66/78**
Hot Water	68.5	68.5	68.5	68.5	68.5	68.5
Lights	600.6	600.6	600.6	600.6	600.6	600.6
Misc. Equipment	549.2	549.2	549.2	549.2	549.2	549.2
Heating	1483.2	1403.9	1309.5	1262.1	1106.6	921
Cooling	331.8	312.8	266.3	223.9	257.3	221.1
Pumping	213.6	204.6	194.7	189.8	164.9	138.8
Ventilation Fans	363.8	349.4	330.8	318.2	309.9	282.6
Total MBTU/Year	3610.7	3489	3319.6	3212.3	3057	2781.8
% Energy Reduction vs Baseline	**0%**	**3%**	**8%**	**11%**	**15%**	**23%**

* Data represents 5 story, 50,000 sf office building
located in Boston

Table 4.1 – Energy Savings with Different Temperature Setpoints

Water Consumption:

Paying for energy is not the only operating cost that must be considered by building owners. Water consumption is often overlooked. Drinking water is often used for irrigating turf grass lawns and flushing toilets. These areas offer the most potential to reduce the overall consumption of water. Existing buildings that are older than 15 years typically use 3.5 gallons per flush (GPF). Owners of these buildings should strongly consider upgrading to the current standard of 1.6 GPF or less. The plumbing industry has introduced toilet fixtures that have an average flush volume lower than the mandated 1.6 gallons per flush. New projects can take advantage of dual flush (1.6/.8 GPF), low flow (1.2 GPF), ultra low flow (.8 GPF) or even waterless toilets. Urinals are now offered with similar options. Currently urinals are mandated to be 1 GPF or less

Bathroom sinks can also take advantage of low flow fixtures. Infrared sensor and metered (self closing) sink faucets save a substantial amount of water. These savings can amount to 75% less water as compared to a standard faucet. Owners who are serious about reducing their operating costs may favor the metered faucets over the infrared sensors. This is because the infrared system requires hard wired power or battery power in order to operate. The flow rate of the water through the faucet is another factor that must be taken into consideration. Many states mandate a maximum of 2.2 GPM.

Rainwater harvesting offers an innovative solution to reduce consumption of the domestic water supply. Rainwater can be collected from parking lots and roofs and stored in cisterns until it is ready for use. The harvested water can be used for a variety of applications. These applications include flushing toilets, irrigation, industrial processes and chiller water. Not only is harvesting rainwater free but it puts less demand on the municipal water supply and conserves resources. It is recommended that non potable needs be given priority as there are filtration and cleaning costs involved. It is unlikely that a rainwater harvesting system can create potable water more cost efficiently than the municipal potable water supply.

Irrigation for landscaping can consume massive amounts of water. Owners should consider planting indigenous landscaping species which do not require irrigation. If owners really wish to use plants and turf that require irrigation, or they simply do not feel comfortable not having control over irrigation, they should give strong consideration to highly efficient irrigation systems or rainwater harvesting. Drip irrigation systems use approximately 50% less water than traditional irrigation systems.

Mechanical Systems

When selecting a standard packaged air cooled mechanical unit the engineer should look carefully at the Energy Efficiency Ratio (EER). This is a measurement of a peak rating performance at 80 degrees indoors and 95 degrees outdoors. The engineer should also check Integrated Part Load Value (IPLV). This measurement provides overall unit efficiency under partial loading conditions. It is important to note that EER and IPLV ratings are for air cooled equipment only.

Water cooled equipment is usually considered to be more efficient than its air cooled counterparts. To take advantage of this technology the owner must be willing to invest money in the cooling tower and pumps.

There are also factors to consider when selecting a boiler or furnace. Since these units use heat to transfer energy it is important to consider their thermal efficiency. In most parts of the United States natural gas is cheaper than electricity per thermal unit. In these areas gas powered units can be used to take advantage of the energy savings.

Since heat transfer is used for boilers and furnaces there is an inherent amount of lost energy in the form of heat. Creative engineers can capture the lost heat and use it for other systems within the building. The heat energy that is wasted from these systems can be exhausted to a heat exchanger for preheating the return air or water. This is a low cost solution which results in higher total system efficiency.

On demand water heating units are becoming more commonplace in the building industry. These units heat water as it moves through the pipes to the sinks, showers and other fixtures. Heating the water as it is requested is much more efficient than the traditional system which uses a storage tank that is maintained at a constant temperature. Another advantage to the on demand heating system is that it is of small size and can be placed near the fixture.

Since nearly all office buildings cannot rely solely on daylighting for task lighting it is important to choose efficient electric lighting for the building. Typically commercial office buildings use fluorescent lighting in the office space. Two important factors should be considered when selecting the light fixture. The Ballast Efficiency Factor is a measure of the ballast's efficiency. A higher number means a more efficient ballast. Second, the efficiency of the lamp itself, measured by efficacy, must be taken into consideration.

Recommendations for 50 Connell Drive

Many of the techniques previously mentioned have potential to reduce operating costs for 50 Connell Drive. This section will examine what areas the project can improve its performance and highlight what was done well.

Energy Modeling:

RDK Engineers did not perform an energy model on this building. It is recommended that computer simulations are used to evaluate a building's energy needs. Too often engineers rely on what was used for on a previous building of similar use and size by these engineers. This often leads to an oversized system. Sizing the mechanical system may be the single most important measure in reducing both upfront costs and operating costs. Excessive on-off cycling, a common reason for oversizing the system, leads to a rise in energy use, higher purchase cost and even shorter product life for the heating and cooling systems. It is also extremely important to select the most efficient equipment and provide the proper control system.

Water Reduction:

Water consumption can be reduced by replacing the standard toilets and urinals with ultra low flush versions. All of the toilets in the building use have a standard 1.6 GPF and urinals use the standard 1.0 GPF. Upgrading to an ultra low 0.8 GPF toilets and 0.125 GPF urinals will not only result in a substantial reduction in water consumption but will reduce the total amount of water and sewer bills that the owner is charged by the water company. It should be noted that water and sewer bills could be further reduced by using waterless toilets and urinals but the owner is not interested in this technology because they are concerned about maintenance and cleaning requirements.

It is estimated that the building will have a total of approximately 1000 occupants. If 50% of the occupants are female and each of those occupants use the toilet twice a day that is a savings of 800 gallons of water per day. If it is assumed that males use each the toilet and urinal once a day that is equivalent to a savings of 838 gallons per day over the standard fixtures. The savings totals to 8190 gallons of water saved over one week and 425,880 saved annually. The New Jersey American Water Company charges a water rate of $5.3825 per 1000 gallons and a sewage rate $3.4102 per 1000 gallons. If these rates are applied to the reduction in water usage the building's owner will save $3,745 per year by upgrading to more efficient fixtures.

Using metered faucets with a low flow rate in the bathrooms would also be beneficial to this project. A faucet with a 0.5 GMP flow rate would offer reduced water consumption compared to the maximum allowable rate of 2.2 GPM. It somewhat difficult to predict how much water will be saved since each user controls how much water they want but some estimates put the water consumption savings at 75%. The commercial brand faucets on the market today come with an adjustable cap that controls how long the water will flow. This offers flexibility. In addition these faucets are now offered in a variety of finishes and styles that can suit most any owner's desire. As mentioned earlier, infrared sensors are also effective for reducing water consumption but a metered faucet has less operating costs associated with maintenance since it does not require batteries or electric energy.

Highly efficient irrigation equipment is used on the grounds of 50 Connell Drive. This is very good and will make a big impact in reducing water consumption and the costs that that are charged from the water company. If the owner would like to further reduce their water needs it is recommended that they replace any turf grass and non indigenous plant species with plants that grow naturally in the region. Plants that grow well in that particular climate will require less or possibly even no irrigation or fertilizers.

Air Handling Unit Upgrade:

Air handling units1 and 2 could incorporate energy recovery units with desiccant wheels. This would make the air handlers more expensive and physically larger, but save energy. Energy recovery will reduce the tonnage and heating load. However the air flows cannot be reduced too much because the building will feel stuffy to the occupants.

New Jersey Energy Efficiency Program:

New Jersey SmartStart BUILDINGS®

There is a statewide energy efficiency program available through New Jersey's electric and gas utility companies. This is known as the New Jersey Smart Start Buildings Program. The Connell Company has the opportunity to benefit from this program. The Smart Start program offers incentives for using energy efficient equipment. The program is used mainly for improvements to existing buildings but this project is also eligible during its construction because the area has been designated for growth in the NJ State Development and Redevelopment Plan. These incentives offset some of the added cost to purchase qualifying equipment which provides significant long-term energy savings. Eligible equipment is listed below:

Electric Chillers

- Water-cooled chillers ($12 - $170 per ton)
- Air-cooled chillers ($8 - $52 per ton)

Gas Cooling

- Gas absorption chillers ($185-$450 per ton)
- Gas Engine-Driven Chillers (Calculated through Custom Measure Path)

Electric Unitary HVAC

- Unitary AC and split systems ($73 - $92 per ton)
- Air-to-air heat pumps ($73 - $92 per ton)
- Water-source heat pumps ($81 per ton)
- Packaged terminal AC & HP ($65 per ton)
- Central DX AC Systems ($40 - $72 per ton)
- Dual Enthalpy Economizer Controls ($250)

Ground Source Heat Pumps

- Closed Loop & Open Loop ($370 per ton)

Gas Heating

- Gas-fired boilers < 300 MBH ($300 per unit)
- Gas-fired boilers ≥ 300 MBH - 1500 MBH ($1.75 per MBH)
- Gas-fired boilers ≥ 1500 MBH - ≤ 4000 MBH ($1.00 per MBH)
- Gas-fired boilers > 4000 MBH (Calculated through Custom Measure Path)
- Gas furnaces ($300-$400 per unit)

Variable Frequency Drives

- Variable air volume ($65 - $155 per hp)
- Chilled-water pumps ($60 per hp)
- Compressors ($5,250 to $12,500 per drive)

Natural Gas Water Heating

- Gas water heaters ≤ 50 gallons ($50 per unit)
- Gas-fired water heaters > 50 gallons ($1.00 - $2.00 per MBH)
- Gas-fired booster water heaters ($17 - $35 per MBH)

Premium Motors

- Three-phase motors ($45 - $700 per motor)

Prescriptive Lighting

- T-5 and T-8 lamps with electronic ballast in existing facilities ($10 - $30 per fixture, depending on quantity of lamps)
- Hard-wired compact fluorescent ($25 - $30 per fixture)
- Metal halide w/pulse start ($25 per fixture)
- LED Exit signs ($10/$20 per fixture)
- T-5 and T-8 High Bay Fixtures ($16 - $284 per fixture)

Lighting Controls

- Occupancy Sensors
  - Wall mounted ($20 per control)
  - Remote mounted ($35 per control)
  - Daylight dimmers ($25 per fixture controlled)
  - Occupancy controlled hi-low fluorescent controls ($25 per fixture controlled)
- HID or Fluorescent Hi-Bay Controls
  - Occupancy hi-low ($75 per fixture controlled)
  - Daylight dimming ($75 per fixture controlled)

Other Equipment Incentives*

- Performance Lighting ($1.00 per watt per square foot below program incentive threshold, currently 5% more energy efficient than ASHRAE 90.1-2004 for New Construction and Complete Renovation.)

NJ Smart Start Buildings Program:

The NJ Clean Energy Program supports solar electricity, small wind, and sustainable biomass equipment. These alternatives are attractive to building owners because under this program they receive:

- A 10% Federal tax credit on solar electric systems
- Full exemption from NJ state sales tax on the investment in solar electric and wind systems
- Lower energy costs by offsetting supply charges

Enterprise Energy Management System:

Enterprise Energy Management System (EEMS) enables real time energy use monitoring at one or more building locations. This is an investment that the Connell Company may find this technology useful since they have 5 buildings on their property. See **Figure 4.2** below. The system allows tracking and analyzing variations in electrical use over a day, a week or a season. This information allows engineers to identify anomalies in energy consumption.

Figure 4.2 – Connell's Property Consists of 6 Buildings

This technology has been used successfully by many companies and institutions. Penn State University and IBM were both studied to learn how they implemented this technology and the cost savings they were able to achieve.

IBM hooked up meters at 20 facilities into a central data collection and display system. Energy usage was monitored at regular 15 minute intervals. Their engineering team was accustomed to reviewing and implementing known hardware and operating level energy efficiency opportunities such as high-efficiency fluorescent lighting systems, time of day building controls, variable speed fans, high-efficiency pumps, etc. However, they had no methodology for performing ongoing optimization of building and system operations that would utilize real electrical use. Collection of electrical use over the day provided a view into two important factors. It revealed anomalies in energy use such as short-term transients of high electrical use and increases in electrical use over time against a baseline electrical use profile.

Lessons learned

This data collection system demonstrated that real-time collection and display of energy use revealed energy-use patterns that are not seen through a review of the monthly utility bills.

Two Examples
At one IBM facility a large power increase was seen between 4:00 and 8:00 and was unexplained. An investigation revealed that for some unknown reason, an electrical boiler was programmed to turn on at 4:00 and off again at 8:00. The boiler was serving no useful function. Plant managers decided the boiler was not needed. The boiler was turned off, and later removed and sold. This resulted in annual energy savings of 1,250 MWh and $125,000 in energy expenses.

At another facility, an evaluation of the time of day data for a specific building indicated that the electrical load was too constant over the day. An evaluation of the building's energy use resulted in the re-tuning of two air handling units and shutting off 544 light fixtures. These actions resulted in a savings of over 500 MWh of electricity and $34,000 per year.

Short Term Dedicated Meters	$5,000	$5,000	$10,000
LongTermwithExistingMeters	$4,000	$3,500	$7,500
Long Term with Dedicated Meters	$17,000	$3,500	$20,500

Table4.2
Typical Costs for Metering a Building

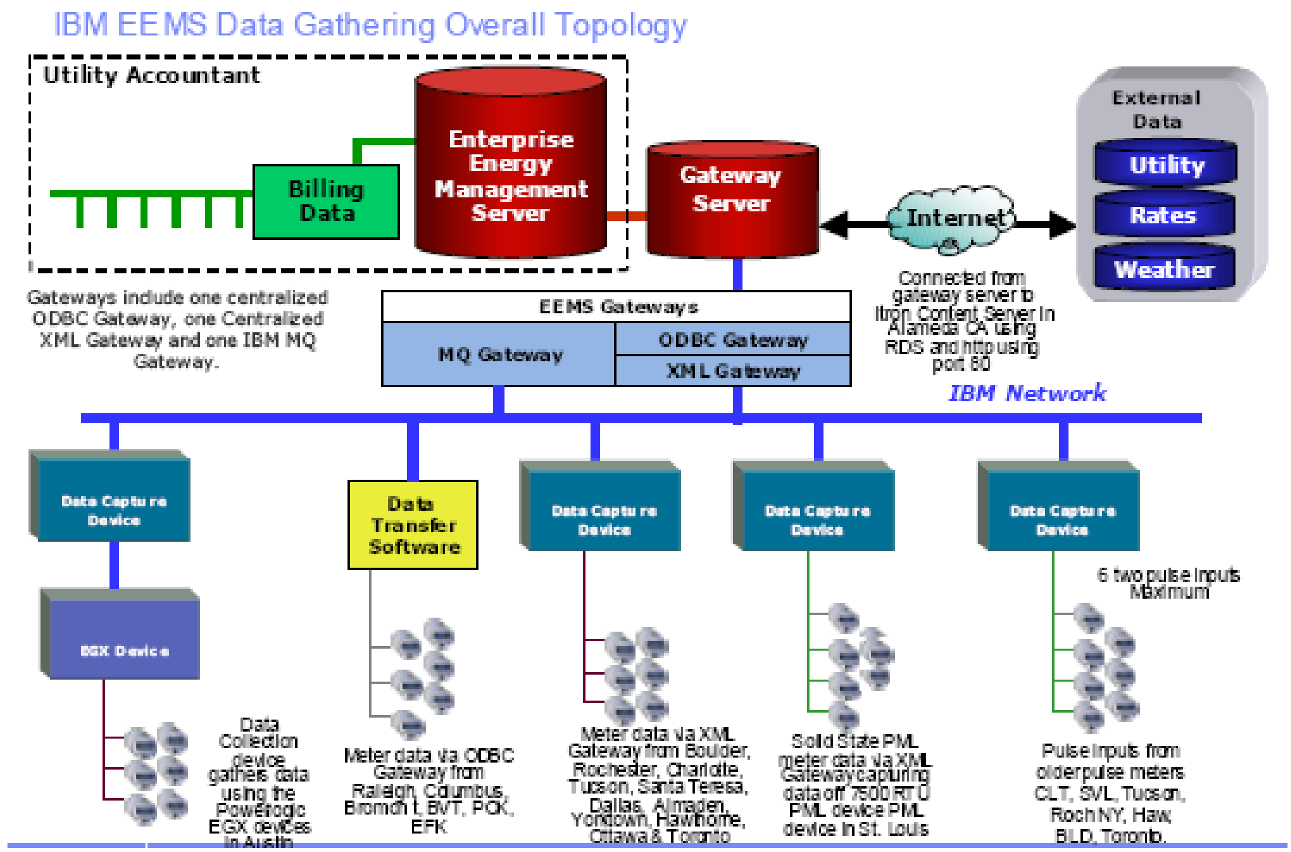


Figure 4.3
Components of a metering system

LEED Trends:

LEED buildings have become very popular with owners who are aiming to reduce their operating costs. Penn State has mandated that all of its future buildings be LEED certified. John Bechtel of OPP was able to provide details of the university's LEED requirements. Penn State's LEED requirements are a good insight as to what owners view as important. The components of PSU's plan that impacts operating costs are briefly outlined below.

Mandatory LEED Credits
- 20% Water Use Reduction
- Optimize Energy Performance
- Enhanced Commissioning
- Outdoor Air Delivery Monitoring
- Controllability of Systems: Lighting

Significant Effort LEED Credits
- 30% Water Use Reduction
- On Site Renewable Energy

Continuous Commissioning:

Continuous commissioning is an ongoing process to resolve operating problems, improve comfort, optimize energy use and identify retrofits for existing buildings. The process is lead by an engineer. This concept has become increasingly popular among owners due to increased energy costs. Continuous commissioning focuses on optimizing HVAC system operation and control for existing building conditions. Unlike traditional commissioning, continuous commissioning focuses on meeting the building's current existing needs rather than ensuring the system functions as originally designed.

Continuous commissioning results from 130 buildings revealed that the average utility savings were about 20%. Payback periods were often less than two years. These results were based on the experience of the Texas Engineering Experiment Station's Energy System Laboratory at Texas A & M University during the last 10 years.

The continuous commissioning process maintains long term savings by ongoing monitoring. It improves the system reliability and building comfort by optimizing system operation and control schedules based on actual building conditions. An engineer leads the process and works closely with O & M staff. This translates to a higher skill level for O & M staff. The process also reduces operating and maintenance costs.

Building that should strongly be considered for continuous commissioning have one or more of the following criteria:

- The building provides poor thermal comfort
- The building consumes excessive energy
- The design features of the facility's HVAC system are not fully used

Building Type	Number of Buildings	Savings ($/1000 ft^2/yr)	Labor Cost ($/ 1000 ft^2/yr)	Simple Payback (Years)
Hospitals	6	$430	$474	1.1
Laboratory/Offices	7	$1260	$368	0.3
Classroom/Offices	5	$430	$226	0.5
Offices	8	$220	$329	1.5
Schools	2	$170	$336	2.0
Averages/Total	28	$540	$359	0.7

Table 4.3- Savings and Payback period by building type of 28 buildings

Conclusion:

There are many techniques that owners can use to fight rising operating costs. The effort to reduce operating costs begins in the design phase and continues throughout the lifetime of the building. These measures include but are not limited to:

- Energy efficient design
- Energy modeling
- Efficient equipment
- Energy monitory
- Optimize operating set points
- Taking advantage of state and federal incentives of installing efficient equipment
- LEED trends
- Continuous commissioning

Credits/Acknowledgments

This report would have been impossible to compile without the help of others. Much of the information within this report was obtained through other people. These people helped guide me through the thinking process and provided valuable information which shaped the report into its final form. I would like to give special thanks to all of the individuals listed below:

John Messner – AE Faculty
Robert Holland – AE Faculty
Kevin Parfitt – AE Faculty
David Riley – AE Faculty
Jim Faust – AE Alum
John Bechtel – Penn State OPP
Frank Simeone – Connell's Representative
Steve Kern – Turner
Paul Angelini – Turner
Mike Squilla – Turner
Kathleen McCartney - Turner
Janet Shipton – RDK Engineers
Scott Wolf – Tri State HVAC
Joe Farina – Atlantic Exterior Wall Systems
Amy Prebil – Architectural Aluminum & Glass

Glass • Coatings • Paint

Report on Energy Modeling of Select Architectural Glazings

The data generated by this energy modeling program is for comparative purposes only. It is general in nature and will vary for specific buildings according to numerous variables, including building design and type, site location, occupation and utilization levels, local utility costs and more.

Energy consumption simulations are based on modeling conducted with the U.S. Department of Energy (DOE) 2.2 Building Energy Analysis Simulation Tool developed at the Lawrence Berkeley National Laboratory and Los Alamos National Laboratory. It is the most accurate and well-documented energy modeling tool available in the U.S.

DOE-2 calculates hour-by-hour energy consumption by the prototype facility over an entire year (8,760 hours) using hourly climate data for the location under consideration. Input into the DOE-2 Model consists of detailed descriptions of the buildings being analyzed, including the hourly scheduling of occupants, lighting, equipment and thermostat settings.

The DOE-2 Model provides accurate simulation of building features such as shading, fenestration, interior building mass, envelope building mass, and the dynamic response of differing heating and air conditioning system types and controls.

All energy simulation scenarios are calculated with the following data:

- Total Electric Consumption (kWh)
- Total Natural Gas Consumption (therms)
- Total Electric Cost ($)
- Total Natural Gas Cost ($)
- Total Building Energy Consumption Cost ($)
- Total Cooling HVAC Capital Cost ($)
- Annual Energy Savings Using Low E Coatings ($)
- Initial Capital Savings Using Low E Coatings ($)
- Annual CO2 Reduction Using Low E Coatings (tons)
- 40 Year CO2 Reduction Using Low E Coatings (tons)

Results

Glazing	Electricity	Gas	Total Operating Electric Cost	Total Operating Gas Cost	Total Operating Cost	Total Capital Cooling HVAC Cost	Annual Operating Cost Savings of Low E Coatings vs DT	Initial Capital Cost Savings of Low E Coatings vs DT	Annual CO2 Savings of Low E vs DT	40 Year Building Life CO2 Savings of Low E Coatings vs DT
Double Pane Tinted	4,668,441	106,206	$289,615	$142,896	$432,511	$2,107,615	$	$		
Solarban 60 (2)	4,357,313	87,585	$275,926	$118,215	$394,141	$1,903,811	$38,370	$203,804	266	10,642
Solarban 70XL (2)	**4,232,593**	**81,963**	**$270,438**	**$110,722**	**$381,160**	**$1,713,032**	**$51,351**	**$394,583**	**363**	**14,502**
Solarban 80 (2)	4,188,706	81,528	$268,506	$110,131	$378,637	$1,667,658	$53,874	$439,957	388	15,521
Solexia Sungate 500 (3)	4,480,418	95,400	$281,344	$128,579	$409,923	$2,013,789	$22,588	$93,826	158	6,333
VE 2-2M (2)	4,313,646	84,398	$274,003	$113,967	$387,970	$1,786,403	$44,541	$321,212	307	12,261

Criteria: Solarban 70XL (2), 8-Story Office with Window Wall in Philadelphia

Details on Selection Criteria

1. *Glazing Type* – This energy modeling program contains comparative data for eight (8) commonly specified glazing types. The table below lists the specific glazing types along with their manufacturer-published performance characteristics (when they are used as part of a standard one-inch insulating glass unit).

To ensure valid comparisons, this program automatically reports data on glazings that are similar in appearance to the one selected by the user. For example, when Solarban 60 glass (PPG) is chosen by the user, comparative data for Solarban 70XL glass (PPG) and VE2-2M (Viracon) are included in the report. That's because these glazings feature a clear, color-neutral aesthetic. Tinted glazings such as Solexia glass (PPG), Solarban z50 glass (PPG) and VE1-52 (Viracon) are grouped similarly.

Glazing	Tvis	Rfvis	Tsol	Rfsol	U-Value	Shading Coefficient (SC)	Solar Heat Gain Coefficient (SHGC)
Double Pane Tinted	0.620	0.100	0.540	0.090	0.570	0.720	0.620
Solarban 60 (2)	0.704	0.112	0.328	0.293	0.291	0.438	0.380
Solarban 70XL (2)	0.617	0.108	0.227	0.347	0.286	0.311	0.270
Solarban 80 (2)	0.470	0.330	0.200	0.380	0.290	0.280	0.240
Solarban z50 (2)	0.510	0.080	0.250	0.230	0.290	0.360	0.310
Solexia Sungate 500 (3)	0.640	0.140	0.330	0.090	0.350	0.510	0.450
VE 1-52 (2)	0.500	0.160	0.320	0.200	0.320	0.460	0.400
VE 2-2M (2)	0.600	0.090	0.240	0.100	0.290	0.360	0.310

Figures may vary due to manufacturing tolerances. All tabulated data is based on NFRC methodology using the LBL 5.2 software. Variations from previously published data are due to minor changes in the LBL Window 5.2 software versus Version 4.1.

2. *City* - Energy simulations with DOE 2.2 software are based on the utility rates and weather data of the city selected.

Philadelphia

Electric Rates:	PECO Energy Company	
Monthly Charge:	$25.00	
Energy Charge:		
First 100 kWh	0.2246	$/kWh
Next 50,000 kWh	0.1145	$/kWh
Next 100,000 kWh	0.0785	$/kWh
Over 150,100 kWh	0.044	$/kWh
Demand Charge:	No Demand Charge	
Gas Rates:	PECO Energy Company	
Monthly Charge:	$14.40	
Energy Charge:		
First 2,000 Therms	1.41095	$/Therm
Over 2,000 Therms	1.32434	$/Therm

	Philadelphia
Average Drybulb Temperature (F)	53.6
Average Wetbulb Temperature (F)	47.9
Average Daily Max Temperature (F)	62.0
Average Daily Min Temperature (F)	45.4
Heating Degree Days (Base 65)	5,181
Cooling Degree Days (Base 65)	1,053
Maximum Temp (F)	95
Minimum Temp (F)	11
No of Days Max Temp 90 and Above	12
No of Days Max Temp 32 and Below	19
No of Days Min Temp 32 and Below	99
No of Days Max Temp 0 and Below	0
Average Wind Speed (MPH)	9.6
Average Day Temp (F)	59.1
Average Night Temp (F)	48.1
Average RH at 4 AM	78.0
Average RH at 10 AM	63.1
Average RH at 4 PM	53.9
Average RH at 10 PM	71.2

3. *Glazing Design* – This DOE-2 simulation is based on a Window Wall scenario.

The following chart shows the estimated total glass area for the façade of the glazing design/building selection.

Glazing Design / Building	Total Wall Area (sqft)	Window to Wall Ratio	Total Glass Area (sqft)
Window Wall / 8 - Story Office	56,640	90%	50,976

4. *Building Prototype Description and Characteristics* – The characteristics for the selected building type is displayed below. These characteristics were developed in a study conducted by the Lawrence Berkley Laboratory's Applied Science Division, based on regional and national criteria. Each building type was adjusted to be compliant with ASHRAE 90.1-1999.

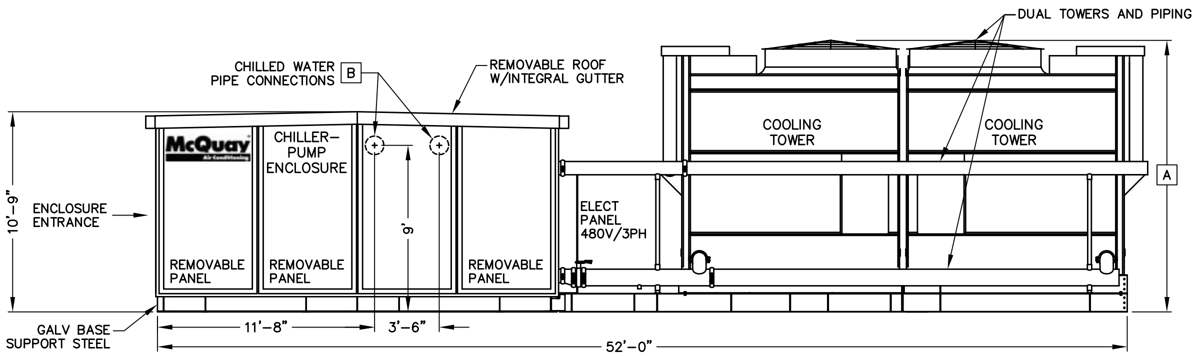
	Office
Geometry and U-values	
Floor Area (sq ft)	270,000
Number of Stories	8
Punch Window to Wall Ratio[1]	59%
Wall Window to Wall Ratio[2]	90%
Wall U-Value (Btu/ ft2-hr-F)[3]	0.124
Roof U-Value (Btu/ ft2-hr-F)[4]	0.065
Glazing Type	Dual Pane Tint
	Solarban-60
	Solarban-70
	Solarban-80
	VE 2-2M
	Solexia x S500
	Solarban z50
	VE 1-52
Operating Conditions	
Cooling Temp Setpoint (F)	75
Heating Temp Setpoint (F)	70
Standard Day Schedule	7 AM - 6 PM Wkdays
	8 AM - 12 PM Wkends
	All Year
HVAC Equipment	
Air Handling System	VAV
Cooling Plant Type	Centrifugal Chiller
Economizer	Yes
Heating Plant Type	Hot Water Boilers
Service Hot Water	Hot Water Boilers
Internal Loads (Peak)	
Occupants (ft2/ person)	448
Lighting (W/ ft2)	1.3
Equipment (W/ ft2)	0.75

1 Punch Window to Wall Ratio is based on most of the walls being window

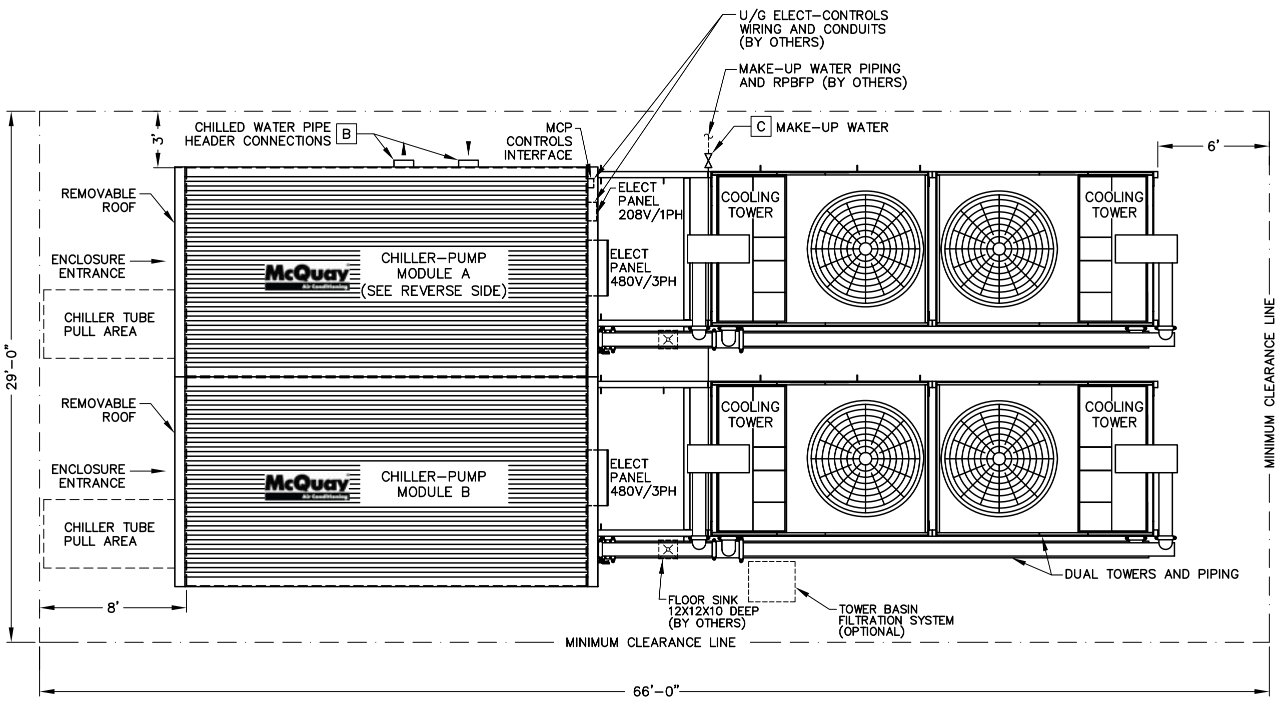
2 Wall Window to Wall Ratio is based on the national building prototype

3 Wall U-Values are based on ASHRAE 90.1-1999 for each selected city

4 Roof U-Values are based on ASHRAE 90.1-1999 for each selected city



MCP MODULE – ELEVATION VIEW



MCP MODULE – PLAN VIEW

NOT FOR CONSTRUCTION – DO NOT SCALE

ALL INFORMATION IS APPROXIMATE AND SHOULD BE CONFIRMED WITH FACTORY CERTIFIED PROJECT SUBMITTAL DRAWINGS AT TIME OF PURCHASE

PROJECT INFO:

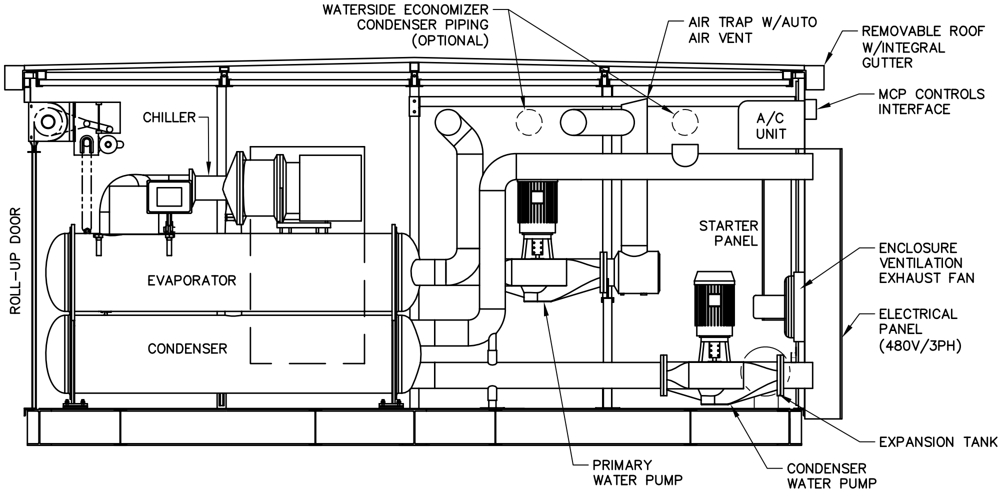
WSC
650-850 TONS

McQuay® Air Conditioning

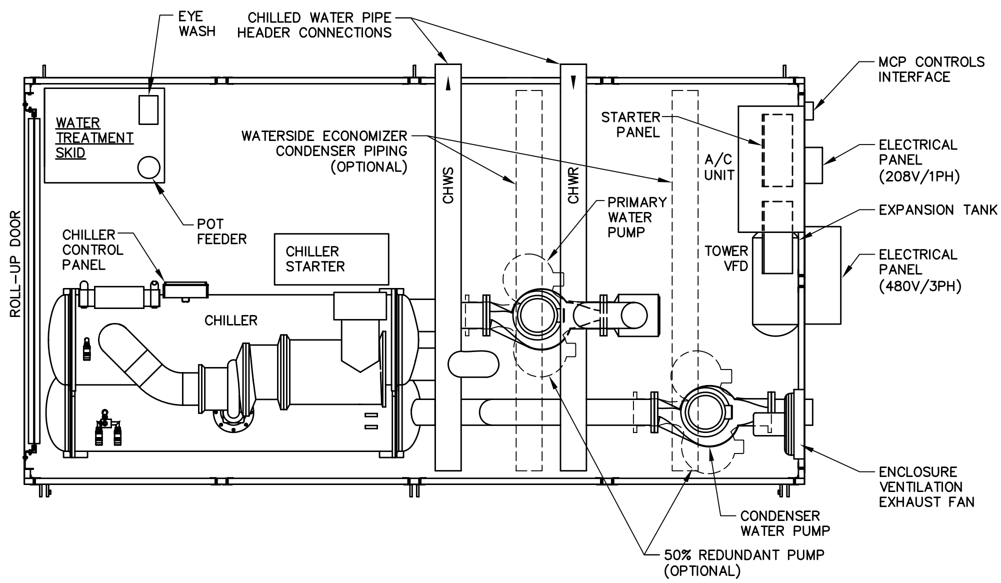
MODULAR CENTRAL PLANT (MCP)
SINGLE CHILLER STANDARD (SCS)

WSC-SCS-(325-425)-2

Rev1.1



CHILLER/PUMP ENCLOSURE – ELEVATION VIEW



CHILLER/PUMP ENCLOSURE – PLAN VIEW

MCP-WSC-SCS-XXX-2

TOTAL OUTPUT CAPACITY (TONS)	650	700	750	800	850
MODEL NUMBER (XXX)	325	350	375	400	425
TOTAL OPERATING WEIGHT (LBS)	124,800	128,800	129,000	131,600	135,600
MAXIMUM EQUIPMENT HEIGHT A	17'–3"	17'–3"	17'–3"	17'–3"	18'–8"
CHW PIPE HEADER CONNECTIONS B	8"	8"	8"	10"	10"
MAKE–UP WATER CONNECTION C	2"	2"	2"	2"	2"
CHILLED WATER FLOW (2.0 GPM/TON)	1,300	1,400	1,500	1,600	1,700
ELECTRICAL LOAD 480V/3PH (MCA)	903	1,002	1,039	1,071	1,261
ELECTRICAL LOAD 208V/1PH (MCA)	67	67	67	67	67
OVERALL UNIT PERFORMANCE (KW/TON)	0.731	0.758	0.737	0.716	0.768

NOT FOR CONSTRUCTION – DO NOT SCALE

ALL INFORMATION IS APPROXIMATE AND SHOULD BE CONFIRMED WITH FACTORY CERTIFIED PROJECT SUBMITTAL DRAWINGS AT TIME OF PURCHASE

McQuay® Air Conditioning

MODULAR CENTRAL PLANT (MCP)
SINGLE CHILLER STANDARD (SCS)

WSC–SCS–(325–425)–2

WSC 650–850 TONS

NOTES:
1. MAX WEIGHT IS FOR A STANDARD UNIT, NO OPTIONAL EQUIPMENT WEIGHT IS INCLUDED.
2. "HAND" ORIENTAION IS FACING ENCLOSURE ENTRANCE.
3. MINIMUM CLEAR DIMENSIONS ARE MINIMUM SERVICE AND ACCESS REQUIREMENTS. PROVIDE ADDITIONAL SPACE AS NECESSARY PER LOCAL CODES.

Rev1.1

GENERAL DATA MCP-WSC-SCS-XXX-2

NOMINAL CAPACITY PER MODULE		325	350	375	400	425
MCP SUMMARY (Note 2)						
Number of Modules	(Qty)	2	2	2	2	2
Output Capacity	(Tons)	650	700	750	800	850
Floor Plan Dimensions - L x W (Note 3)	(ft x ft)	52 x 23	52 x 23	52 x 23	52 x 23	52 x 23
Maximum Equipment Height	(ft)	17.25	17.25	17.25	17.25	18.75
Minimum Clearance Dimensions - L x W (Note 4)	(ft x ft)	66 x 29	66 x 29	66 x 29	66 x 29	66 x 29
Total Operating Weight	(lbs)	124,800	128,800	129,000	131,600	135,600
Chilled Water Flow	(GPM)	1,300	1,400	1,500	1,600	1,700
Entering/Leaving Water Temperature - EWT/LWT	(°F)	56/44	56/44	56/44	56/44	56/44
Chiller Water Pipe Connection	(in)	8	8	8	10	10
Electrical Load - 480V/60Hz/3PH (Note 5)	(MCA)	903	1,002	1,039	1,071	1,261
Electrical Load - 208V/60Hz/1PH (Note 6)	(MCA)	67	67	67	67	67
MCP Performance	**(kW/Ton)**	**0.731**	**0.758**	**0.737**	**0.716**	**0.768**

MCP COMPONENTS PER MODULE

		325	350	375	400	425
CHILLER						
Designation		WSC	WSC	WSC	WSC	WSC
Compressor Type		Centrifugal	Centrifugal	Centrifugal	Centrifugal	Centrifugal
Actual Capacity	(Tons)	323.1	350	375	400	425
Number of Compressors	(Qty)	1	1	1	1	1
Electrical	(V/Hz/P)	460/60/3	460/60/3	460/60/3	460/60/3	460/60/3
Input Power	(kW)	191.5	213	224.4	234.2	255.8
Compressor Full Load Power	(RLA each)	267	298	312	325	354
Evaporator Pressure Drop	(Ft Hd)	10.7	12.2	13.9	9.4	10.4
Condenser Pressure Drop	(Ft Hd)	7.5	8.5	11.9	10.8	12
Full Load Performance	(kW/Ton)	0.593	0.609	0.598	0.585	0.602
Part Load Performance (IPLV)	(kW/Ton)	0.562	0.577	0.57	0.553	0.586
COOLING TOWER (Note 7)						
Manufacturer - Marley	(Model No)	AV6301	AV6301	AV6301	AV6301	AV6403
Type		Open Crossflow	Open Crossflow	Open Crossflow	Open Crossflow	Open Crossflow
Quantity	(Qty)	2	2	2	2	2
Electrical	(V/Hz/P)	460/60/3	460/60/3	460/60/3	460/60/3	460/60/3
Motor Horsepower	(Hp each)	10	10	10	10	20
Starter Type		VFD	VFD	VFD	VFD	VFD
STANDARD CHILLED WATER PUMP (Note 8)						
Manufacturer - Armstrong	(Model No)	4300	4300	4300	4300	4300
Quantity	(Qty)	1	1	1	1	1
Chilled Water Flow	(GPM each)	650	700	750	800	850
Pressure External to MCP	(Ft Hd)	75	75	75	75	75
Motor Horsepower	(Hp each)	25	30	30	30	30
CONDENSER WATER PUMP (Note 8)						
Manufacturer - Armstrong	(Model No)	4300	4300	4300	4300	4300
Quantity	(Qty)	1	1	1	1	1
Condenser Water Flow	(GPM each)	975	1,050	1,125	1,200	1,275
Motor Horsepower	(Hp each)	15	20	20	20	25
PACKAGED TERMINAL A/C UNIT						
Cooling Capacity	(btuh)	14,400	14,400	14,400	14,400	14,400
Heating Capacity	(Watts)	9,900	9,900	9,900	9,900	9,900
Electrical	(V/Hz/P)	208/60/1	208/60/1	208/60/1	208/60/1	208/60/1
EXPANSION TANK						
Manufacturer - Wessels Company	(Model No.)	NLAP-150	NLAP-150	NLAP-150	NLAP-150	NLAP-150
Type		Bladder	Bladder	Bladder	Bladder	Bladder
Aceptance Volume	(Gal)	36	36	36	36	36

OPTIONAL EQUIPMENT (Note 12)

~Seismic Construction ~Hurricane (Dade County) Construction ~LonWORKS Controls Interface ~Extended Parts and Labor Warranty ~Waterside Economizer ~Stainless Steel Tower Water Basins ~Complete Tower Stainless Steel Construction ~Tower HW Basin Work Handrails, Ladders and Safety Cage ~Tower Basin Filtration ~Redundant Pumps ~Secondary Chilled Water Pumps ~Heat Trace ~Air Separator ~Air and Dirt Separator ~Factory Installed Chilled Water Pipe Insulation ~Factory Installed Condenser Water Pipe Insulation

NOTES

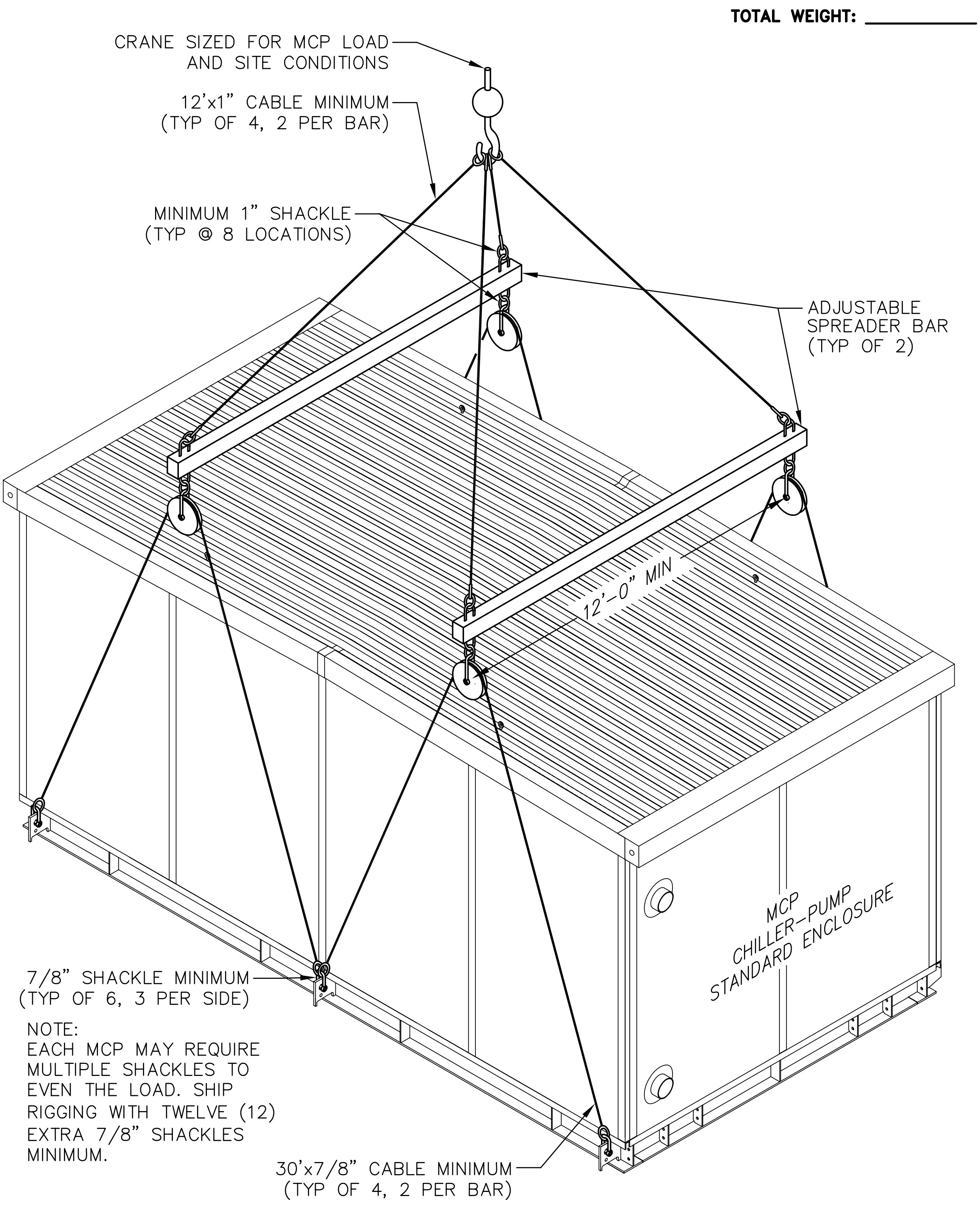
1 McQuay reserves the right to change data at any time. Consult your local McQuay representative for the most current information.
2 MCP Summary includes all modules and is based on standard equipment. No optional equipment is included.
3 Floor Plan Dimensions is the overall MCP base support steel foot print.
4 Minimum Clearance Dimensions are minimum service and access requirements. Provide additional space as necessary per local code requirements.
5 One (1) 460 volt connection per module. MCA (Minimum Circuit Ampacity) is the total 460 volt electrical load for the complete MCP, inclusive of all modules. Electrical load is based on Standard Chilled Water Pumps. Refer to Optional Pump Data for 460 volt electrcial loads associated with optional pump configurations.
6 One (1) 208 volt electrical connection for all MCP modules. MCA (Minimum Circuit Ampacity) is the total 208 volt electrical load for all MCP modules.
7 Cooling Tower performance is based on 78°F WB project design condition. Consult factory for projects with higher design conditions.
8 Pumps are split-coupled, 460V-60Hz-3P, vertical in-line type. Refer to Optional Pump Data for optional pump configurations.
9 Wall and roof panels are 2" thick, expanded polystyrene panel core with stucco embosed aluminum panel facing and an overrall R-value of 9, standard.
10 Structural steel base, wall and roof frame are constructed of hot or cold rolled galvanized steel, standard.
11 All condenser water piping, fittings and couplings are galvanized steel, standard.
12 Consult the factory for availablity of Optional Equipment specific to each MCP.

MCP-WSC-SCS-XXX-2 OPTIONAL PUMP DATA

NOMINAL CAPACITY PER MODULE		325	350	375	400	425
50 FEET HEAD						
Manufacturer - Armstrong	(Model No)	4300	4300	4300	4300	4300
Quantity	(Qty)	1	1	1	1	1
Chilled Water Flow	(GPM each)	650	700	750	800	850
Motor Horsepower	(Hp each)	20	20	25	20	20
MCP Electrical Load - 480V/60Hz/3PH	(MCA)	889	976	1,027	1,045	1,235
100 FEET HEAD						
Manufacturer - Armstrong	(Model No)	4300	4300	4300	4300	4300
Quantity	(Qty)	1	1	1	1	1
Chilled Water Flow	(GPM each)	700	700	750	800	850
Motor Horsepower	(Hp each)	40	40	40	40	40
MCP Electrical Load - 480V/60Hz/3PH	(MCA)	939	1,026	1,063	1,095	1,285
REDUNDANT PUMPS (Note 3)						
CHILLED WATER PUMPS - 50 FEET HEAD						
Manufacturer - Armstrong	(Model No)	4302	4302	4302	4302	4302
Quantity	(Qty)	2	2	2	2	2
Redundancy	(%)	50	50	50	50	50
Chilled Water Flow	(GPM each)	325	350	375	400	425
Motor Horsepower	(Hp each)	15	15	15	15	15
MCP Electrical Load - 480V/60Hz/3PH	(MCA)	961	1,036	1,073	1,105	1,281
CHILLED WATER PUMPS - 75 FEET HEAD						
Manufacturer - Armstrong	(Model No)	4302	4302	4302	4302	4302
Quantity	(Qty)	2	2	2	2	2
Redundancy	(%)	50	50	50	50	50
Chilled Water Flow	(GPM each)	325	350	375	400	425
Motor Horsepower	(Hp each)	20	20	25	25	25
MCP Electrical Load - 480V/60Hz/3PH	(MCA)	985	1,060	1,125	1,157	1,333
CHILLED WATER PUMPS - 100 FEET HEAD						
Manufacturer - Armstrong	(Model No)	4302	4302	4302	4302	4302
Quantity	(Qty)	2	2	2	2	2
Redundancy	(%)	100	100	100	100	100
Chilled Water Flow	(GPM each)	650	700	750	800	850
Motor Horsepower	(Hp each)	40	40	40	50	50
MCP Electrical Load - 480V/60Hz/3PH	(MCA)	981	1,056	1,093	1,151	1,327
CONDENSER WATER PUMPS						
Manufacturer - Armstrong	(Model No)	4302	4302	4302	4302	4302
Quantity	(Qty)	2	2	2	2	2
Redundancy	(%)	50	50	50	50	50
Condenser Water Flow	(GPM each)	488	525	563	600	638
Motor Horsepower	(Hp each)	15	15	15	15	15
PRIMARY-SECONDARY CHILLED WATER PUMPING (Note 4)						
PRIMARY PUMPS						
Manufacturer - Armstrong	(Model No)	4300	4300	4300	4300	4300
Quantity	(Qty)	1	1	1	1	1
Chilled Water Flow	(GPM each)	650	700	750	800	850
Motor Horsepower	(Hp each)	7.5	7.5	7.5	7.5	10
Electrical Load Per Module - 480V/60Hz/3PH	(MCA)	407	445	463	479	571
SECONDARY PUMPS						
Manufacturer - Armstrong	(Model No)	4300	4300	4300	4300	4300
Quantity	(Qty)	2	2	2	2	2
Redundancy	(%)	50	50	50	50	50
Chilled Water Flow	(GPM each)	650	700	750	800	850
Motor Horsepower - 50 Ft Hd	(Hp each)	15	15	15	15	15
Pump Module Electrical Load - 480V/60Hz/3PH	(MCA)	53	53	53	53	53
Motor Horsepower - 75 Ft Hd	(Hp each)	25	30	30	30	30
Pump Module Electrical Load - 480V/60Hz/3PH	(MCA)	85	100	100	100	100
Motor Horsepower - 100 Ft Hd	(Hp each)	30	30	30	30	40
Pump Module Electrical Load - 480V/60Hz/3PH	(MCA)	100	100	100	100	130

NOTES

1 McQuay reserves the right to change data at any time. Consult your local McQuay representative for the most current information.
2 All pumps are split-coupled, vertical in-line type, 460V/60Hz/3P. Indicated pump head values (Ft Hd) are external to the MCP unless noted otherwise.
3 Redundant Pumps sized for less than 100% of total design flow rate (GPM), operate simultaneously.
4 Secondary pumps are located in the Pump Module. Refer to Pump Module tab.



NOT FOR CONSTRUCTION – DO NOT SCALE

ALL INFORMATION IS APPROXIMATE AND SHOULD BE CONFIRMED WITH FACTORY CERTIFIED PROJECT SUBMITTAL DRAWINGS AT TIME OF PURCHASE

PROJECT INFO

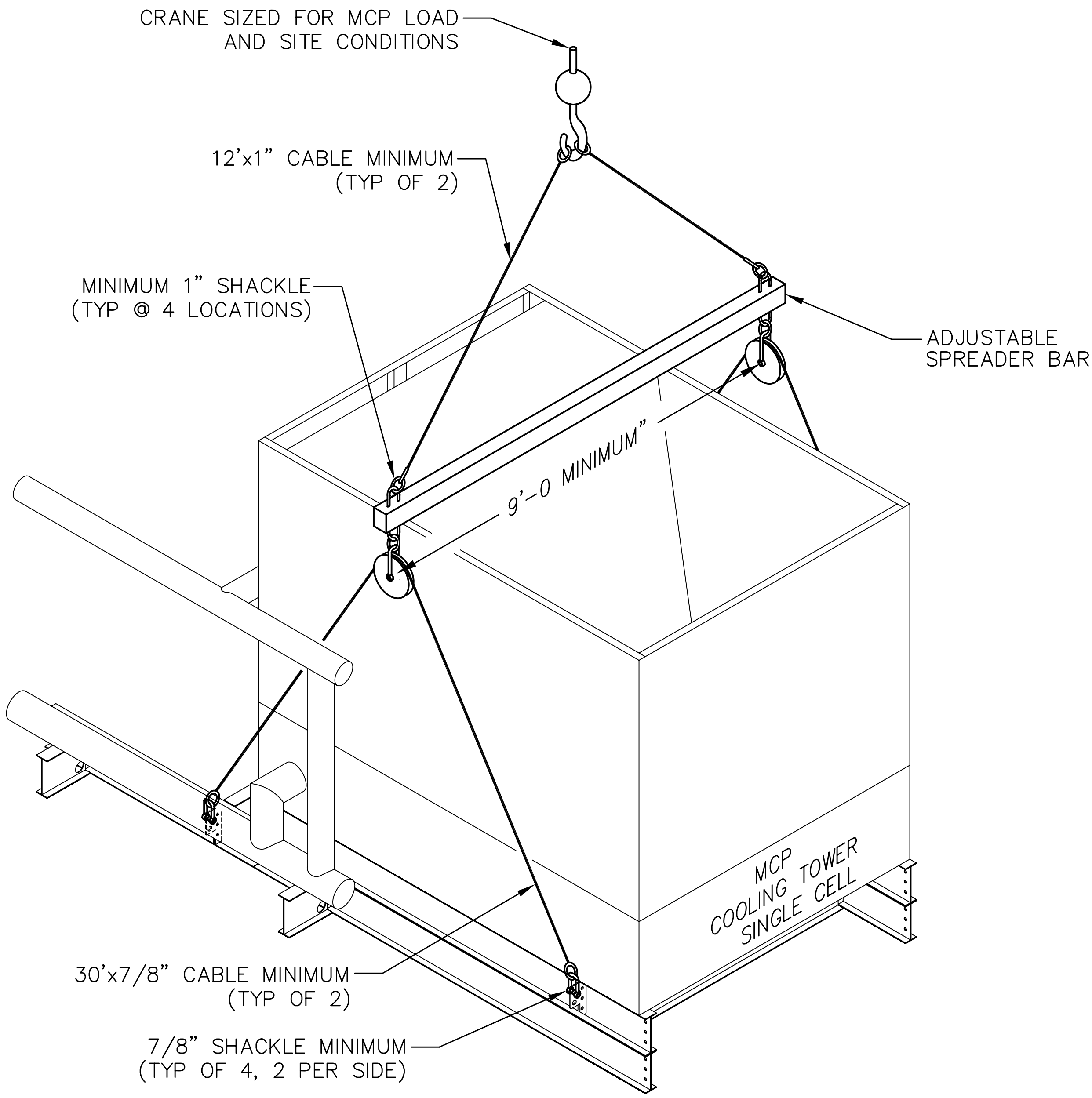
McQuay Air Conditioning

MODULAR CENTRAL PLANT (MCP)
SINGLE CHILLER STANDARD (SCS)

**MCP RIGGING
STANDARD ENCLOSURE**

Rev1.1

TOTAL WEIGHT: ___________



NOTE:
EACH MCP MAY REQUIRE MULTIPLE SHACKLES TO EVEN THE LOAD. SHIP RIGGING WITH TWELVE (12) EXTRA 7/8" SHACKLES MINIMUM.

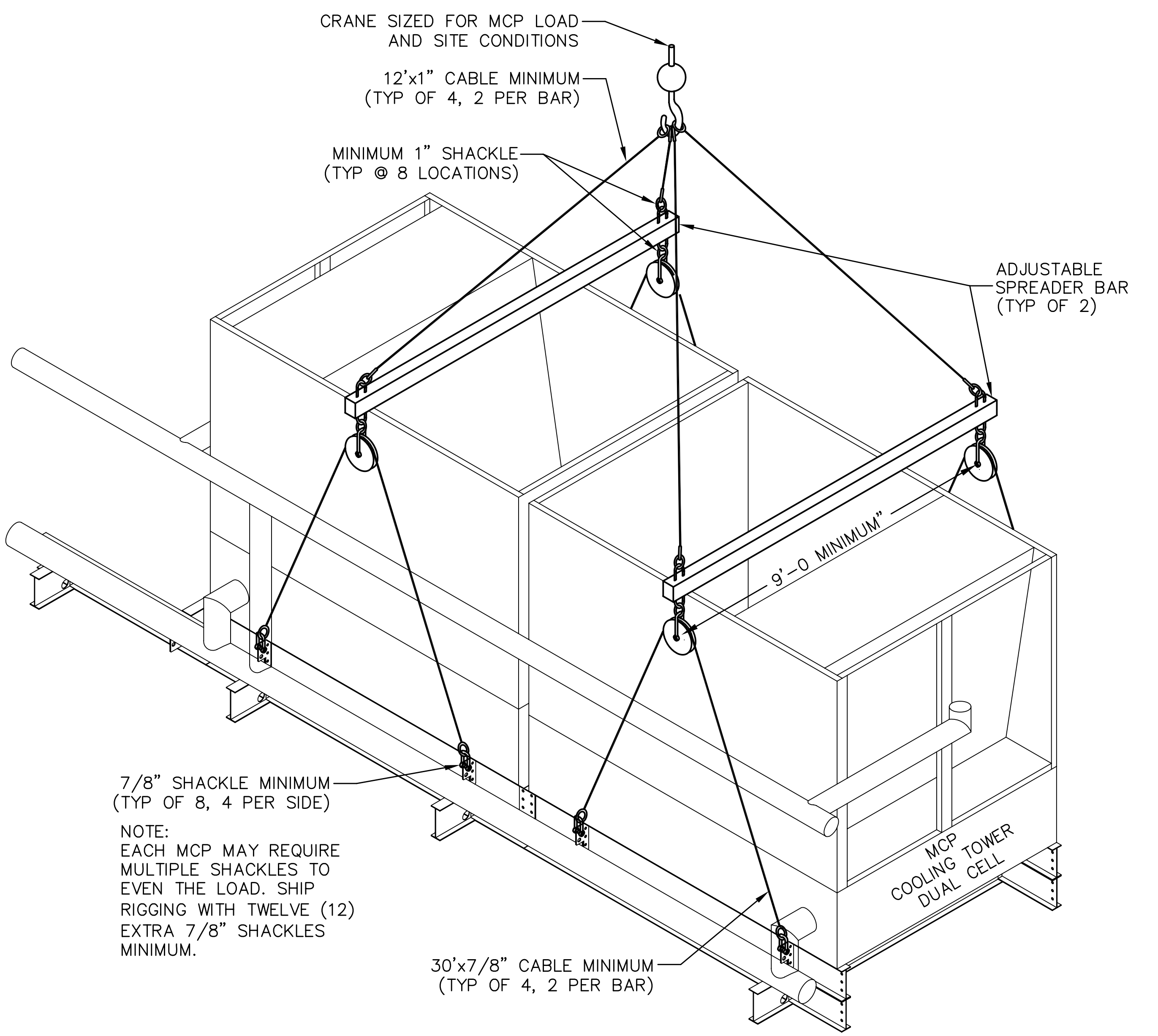
NOT FOR CONSTRUCTION – DO NOT SCALE

ALL INFORMATION IS APPROXIMATE AND SHOULD BE CONFIRMED WITH FACTORY CERTIFIED PROJECT SUBMITTAL DRAWINGS AT TIME OF PURCHASE

PROJECT INFO	McQuay® Air Conditioning MODULAR CENTRAL PLANT (MCP) SINGLE CHILLER STANDARD (SCS) **MCP RIGGING SINGLE COOLING TOWER**

Rev1.1

TOTAL WEIGHT: ______________

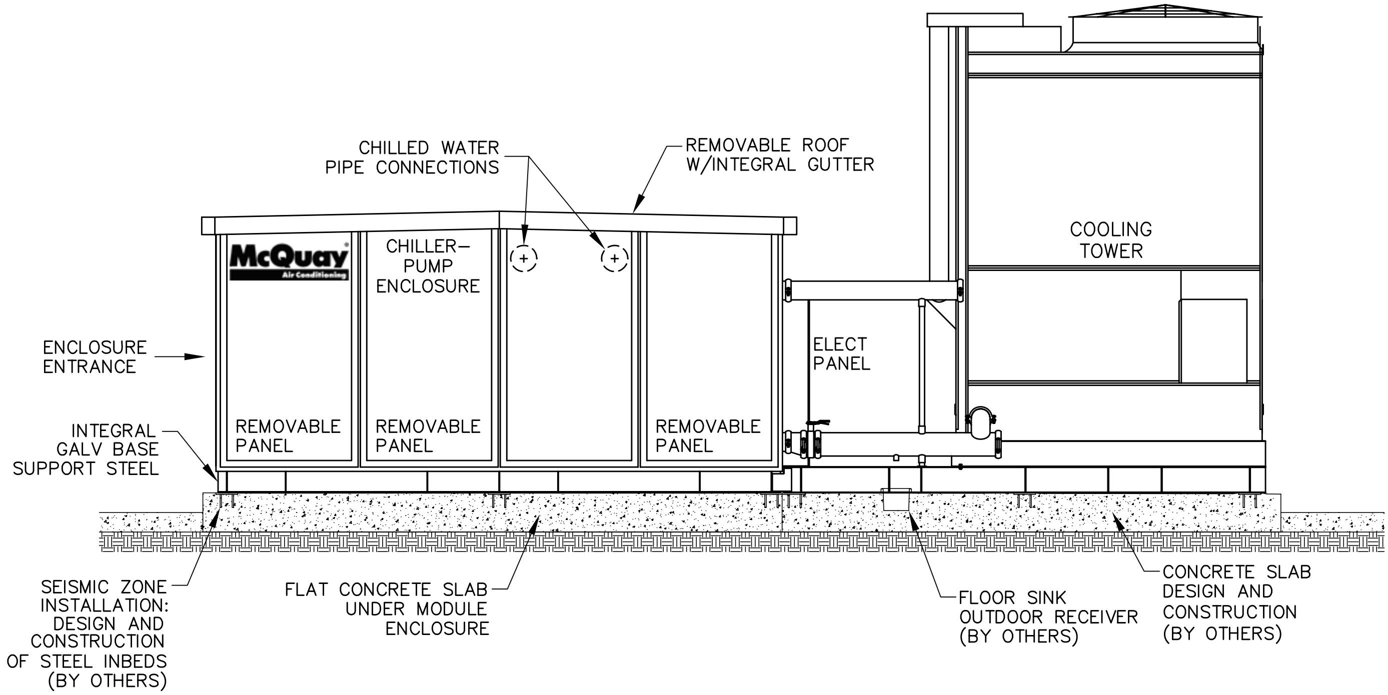


NOT FOR CONSTRUCTION – DO NOT SCALE

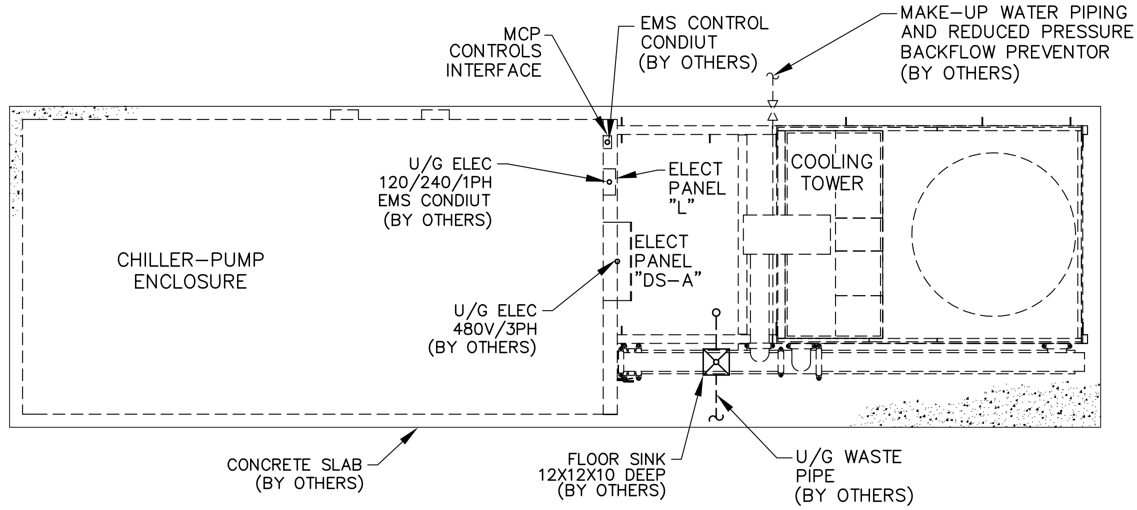
ALL INFORMATION IS APPROXIMATE AND SHOULD BE CONFIRMED WITH FACTORY CERTIFIED PROJECT SUBMITTAL DRAWINGS AT TIME OF PURCHASE

PROJECT INFO	McQuay® Air Conditioning MODULAR CENTRAL PLANT (MCP) SINGLE CHILLER STANDARD (SCS) **MCP RIGGING DUAL COOLING TOWER**

Rev1.1



CONCRETE SLAB MOUNTING ELEVATION VIEW



CONCRETE SLAB MOUNTING PLAN VIEW

GENERAL NOTES:

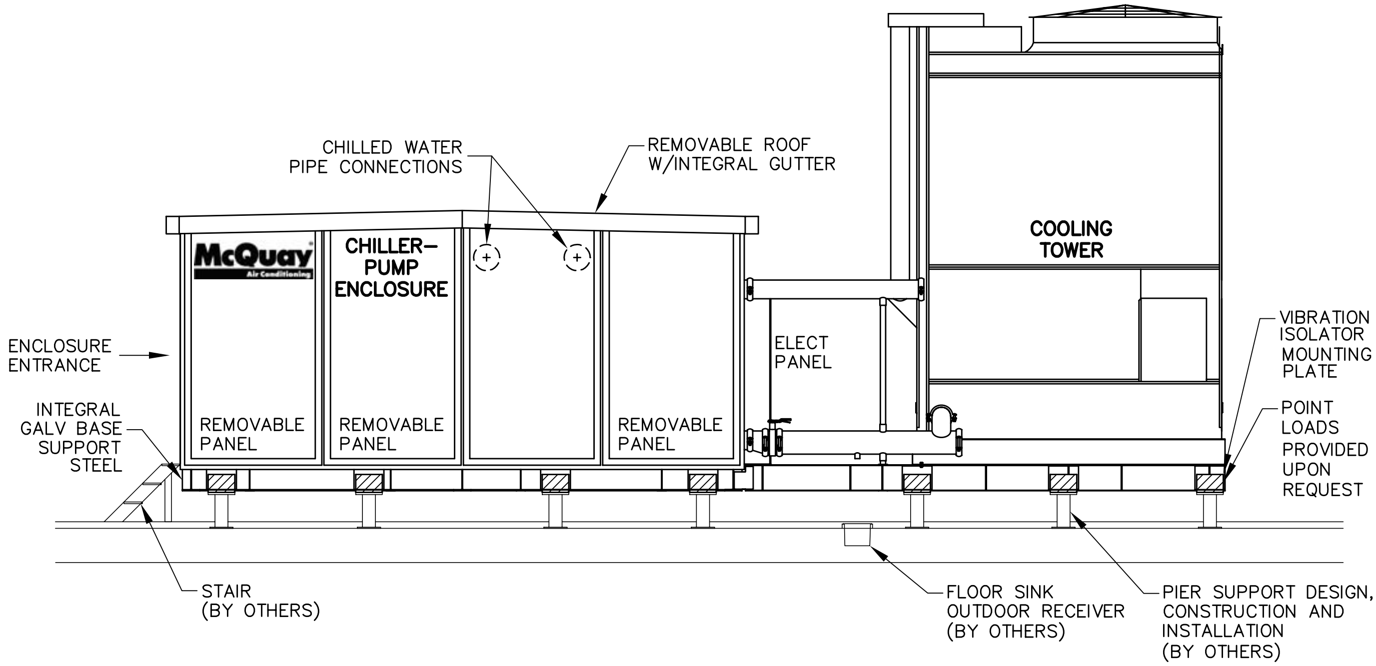
1. CONCRETE SLAB DESIGN SHALL BE BY A REGISTERED STRUCTURAL ENGINEER.
2. MAKE–UP WATER ROUGH–IN AND RPBP SHALL BE PROVIDED AND INSTALLED BY THE PROJECT PLUMBING CONTRACTOR.
3. PLUMBING WASTE ROUGH–IN AND FLAT VENT SHALL BE PROVIDED AND INSTALLED BY THE PROJECT PLUMBING CONTRACTOR.
4. FLAT VENT SHALL NOT TERMINATE, FLAG POLE OR BE ATTACHED IN ANY MANNER TO THE CENTRAL PLANT OR IT'S COMPONENTS.
5. ELECTRICAL UNDERGROUND WIRING SHALL BE PROVIDED AND INSTALLED BY THE ELECTRICAL CONTRACTOR.

NOT FOR CONSTRUCTION – DO NOT SCALE

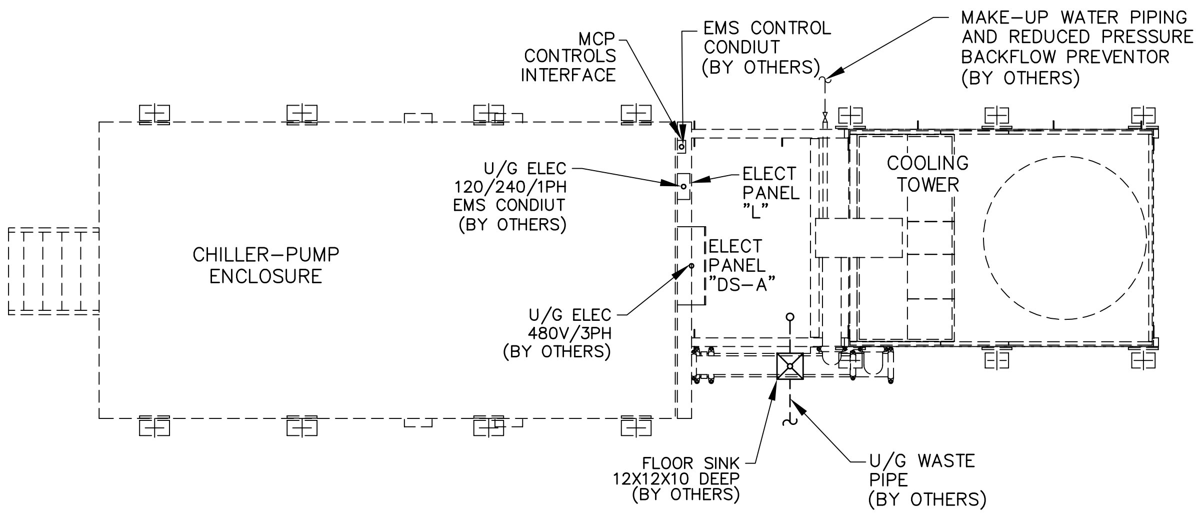
ALL INFORMATION IS APPROXIMATE AND SHOULD BE CONFIRMED WITH FACTORY CERTIFIED PROJECT SUBMITTAL DRAWINGS AT TIME OF PURCHASE

PROJECT INFO	McQuay® Air Conditioning MODULAR CENTRAL PLANT (MCP) SINGLE CHILLER STANDARD (SCS) **MCP UTILITY COORD GROUND INSTALL**

Rev1.1



PIER SUPPORT MOUNTING ELEVATION VIEW



PIER SUPPORT MOUNTING PLAN VIEW

GENERAL NOTES:

1. PIER SUPPORT DESIGN SHALL BE BY A REGISTERED STRUCTURAL ENGINEER.
2. MAKE–UP WATER ROUGH–IN AND RPBP SHALL BE PROVIDED AND INSTALLED BY THE PROJECT PLUMBING CONTRACTOR.
3. PLUMBING WASTE ROUGH–IN AND FLAT VENT SHALL BE PROVIDED AND INSTALLED BY THE PROJECT PLUMBING CONTRACTOR.
4. FLAT VENT SHALL NOT TERMINATE, FLAG POLE OR BE ATTACHED IN ANY MANNER TO THE CENTRAL PLANT OR IT'S COMPONENTS.
5. ELECTRICAL UNDERGROUND WIRING SHALL BE PROVIDED AND INSTALLED BY THE ELECTRICAL CONTRACTOR.

NOT FOR CONSTRUCTION – DO NOT SCALE

ALL INFORMATION IS APPROXIMATE AND SHOULD BE CONFIRMED WITH FACTORY CERTIFIED PROJECT SUBMITTAL DRAWINGS AT TIME OF PURCHASE

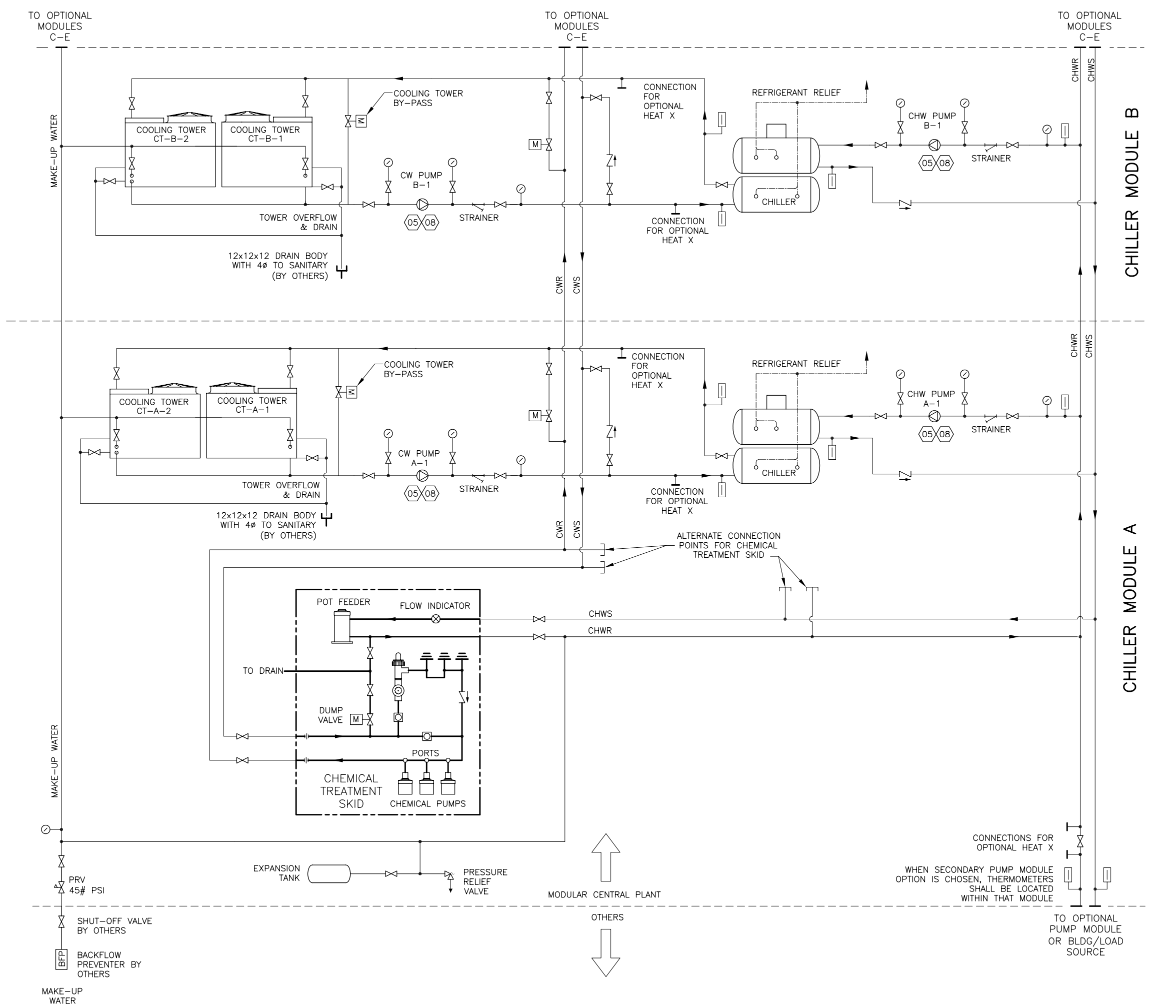
PROJECT INFO

McQuay® Air Conditioning

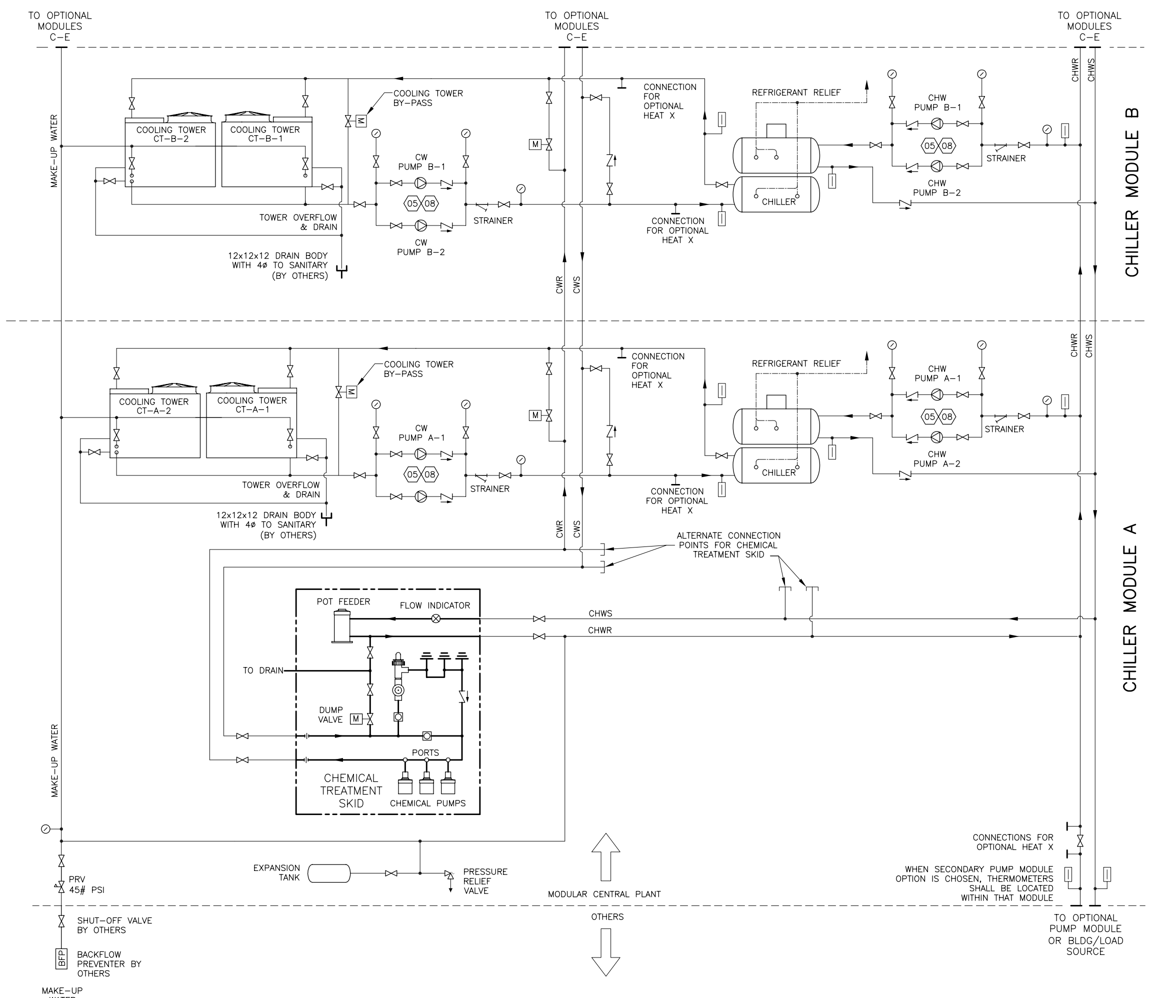
MODULAR CENTRAL PLANT (MCP)
SINGLE CHILLER STANDARD (SCS)

MCP UTILITY COORD ROOF INSTALL

Rev1.1

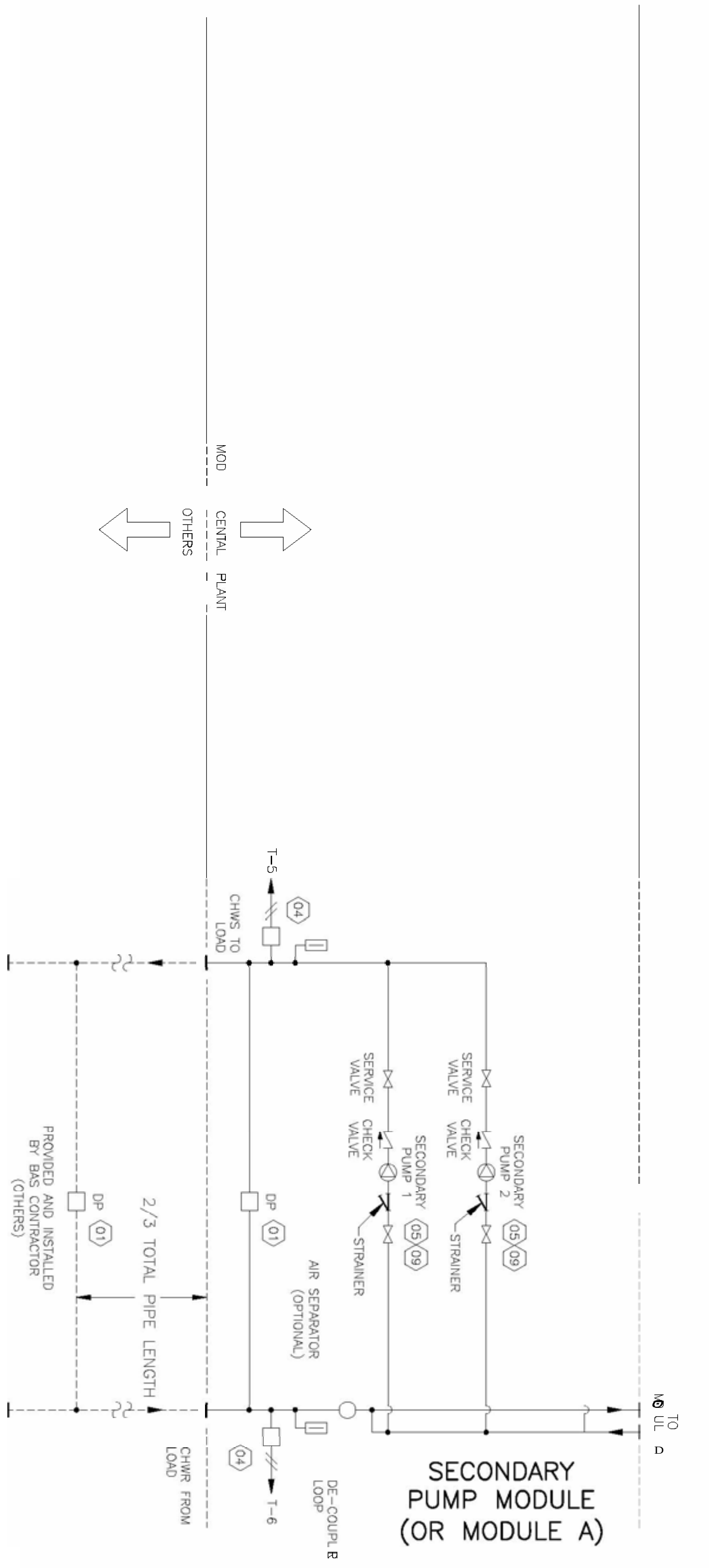


McQuay Air Conditioning	TITLE: FLOW AND CONTROL DIAGRAM MCP–XXX–SCS–(325–600)–2	DRAWING SCALE: NONE UNLESS OTHERWISE SPECIFIED; DO NOT SCALE DRAWING; JOB NUMBER: — DATE: 02–28–08; DWG NO: FC–1.1

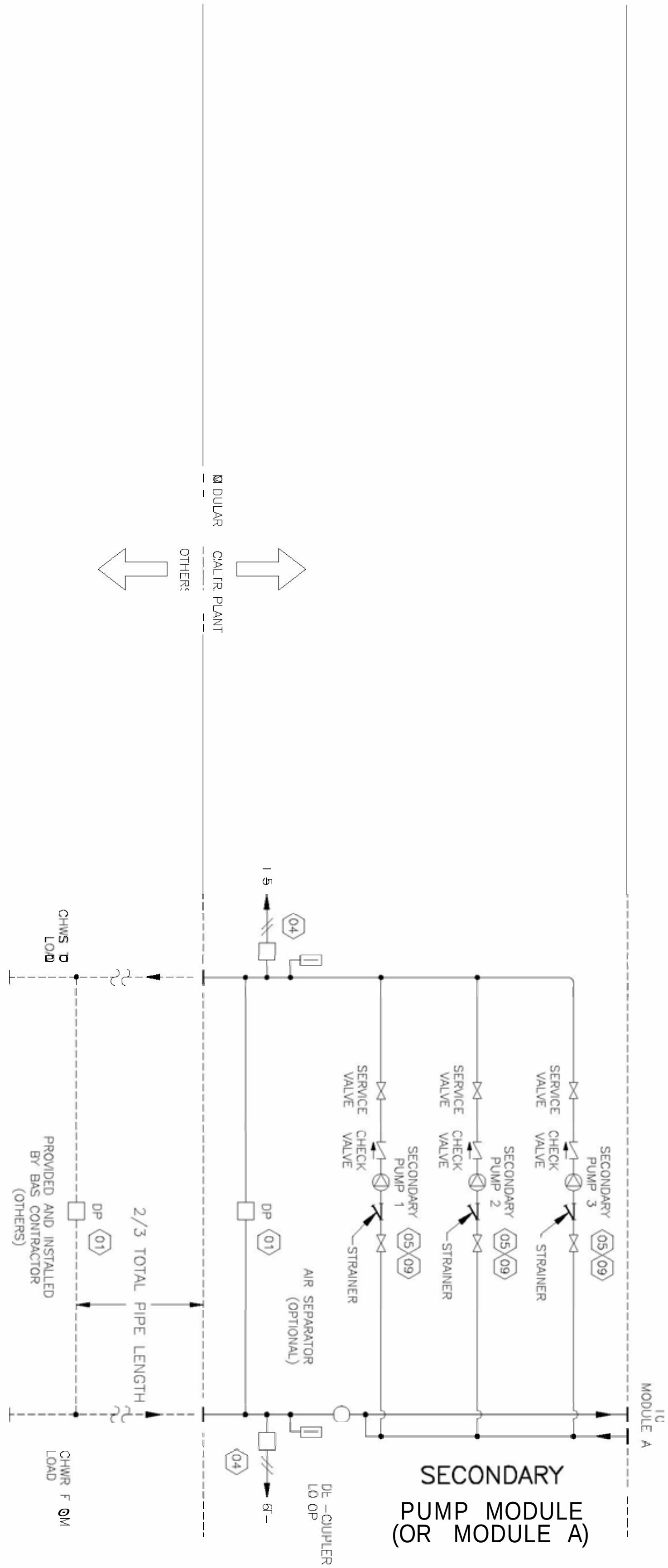


WITH REDUNDANT PUMP

McQuay Air Conditioning	TITLE: FLOW AND CONTROL DIAGRAM MCP–XXX–SCS–(325–600)–2	DRAWING SCALE: NONE UNLESS OTHERWISE SPECIFIED	DATE: 02–28–08
		DO NOT SCALE DRAWING	DWG NO: FC–1.1R
		JOB NUMBER:	



McQuay Air Conditioning	TITLE FLOW AND CONTROL DIAGRAM FOR OPTIONAL SECONDARY PUMP MODULE	DRAWING SCALE NONE UNLESS OTHERWISE SPECIFIED DO NOT SCALE DRAWING JOB NUMBER	DATE 02-28-08 DWG NO FC-1.2



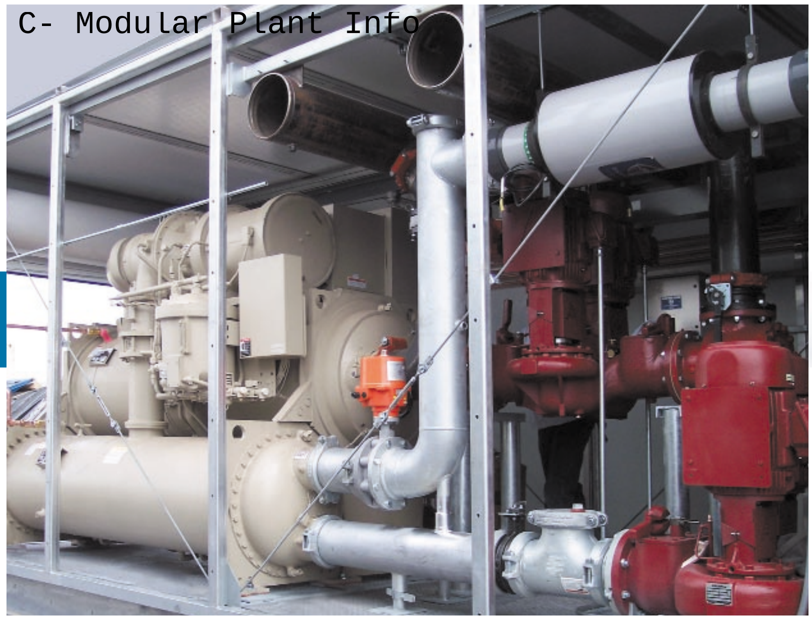
FLOW AND CONTROL DIAGRAM FOR OPTIONAL SECONDARY PUMP MODULE	DRAWING SCALE NONE UNLESS OTHERWISE SPECIFIED DO NOT SCALE DRAWING JOB NUMBER	DATE 02-28-08 DWG NO FC-1.2

Innovative Central Plant Solutions

Modular Central Plants

McQuay®
Air Conditioning

Engineered for flexibility and performance™



McQuay Modular Central Plant

Thinking inside and outside the box.

Options Available

- Redundant primary and condenser water pumps
- Redundant cooling towers
- Tower basin filtration
- Tower basin heater
- Stainless steel hot and cold water basins
- Complete stainless steel tower construction
- Air separator
- Air and dirt separator
- Chiller 65,000 AIC breakers
- MCP extended parts and labor warranty
- Waterside economizer
- Chilled and condenser water insulation

The spacious interior of the Modular Central Plant provides easy access to the control panel and other interior components. The box is built with workable space in mind to comply with code requirements.

The High Efficiency, Low Cost Alternative to Site-Built Central Plants

Available Benefits

Reduced Owner and Contractor Risk
Reduced risk with single source OEM supplier and complete system performance standards. Reduces trade coordination costs and site assembly time.

Lower Installed Cost
Lower costs per ton compared to traditional "site-built" plants.

High Quality
Pre-engineered, factory fabrication and assembly provide quality that exceeds outside field practices.

Improved Efficiency
Efficient design costs less than a comparable built-up system, while providing energy efficiency expected in more expensive systems. Comes standard with cooling tower VFDs for optimized performance.

Expandable
Easily expandable design with no messy remodels or expensive down time. Standard connections for a rental chiller allow emergency backup capability.

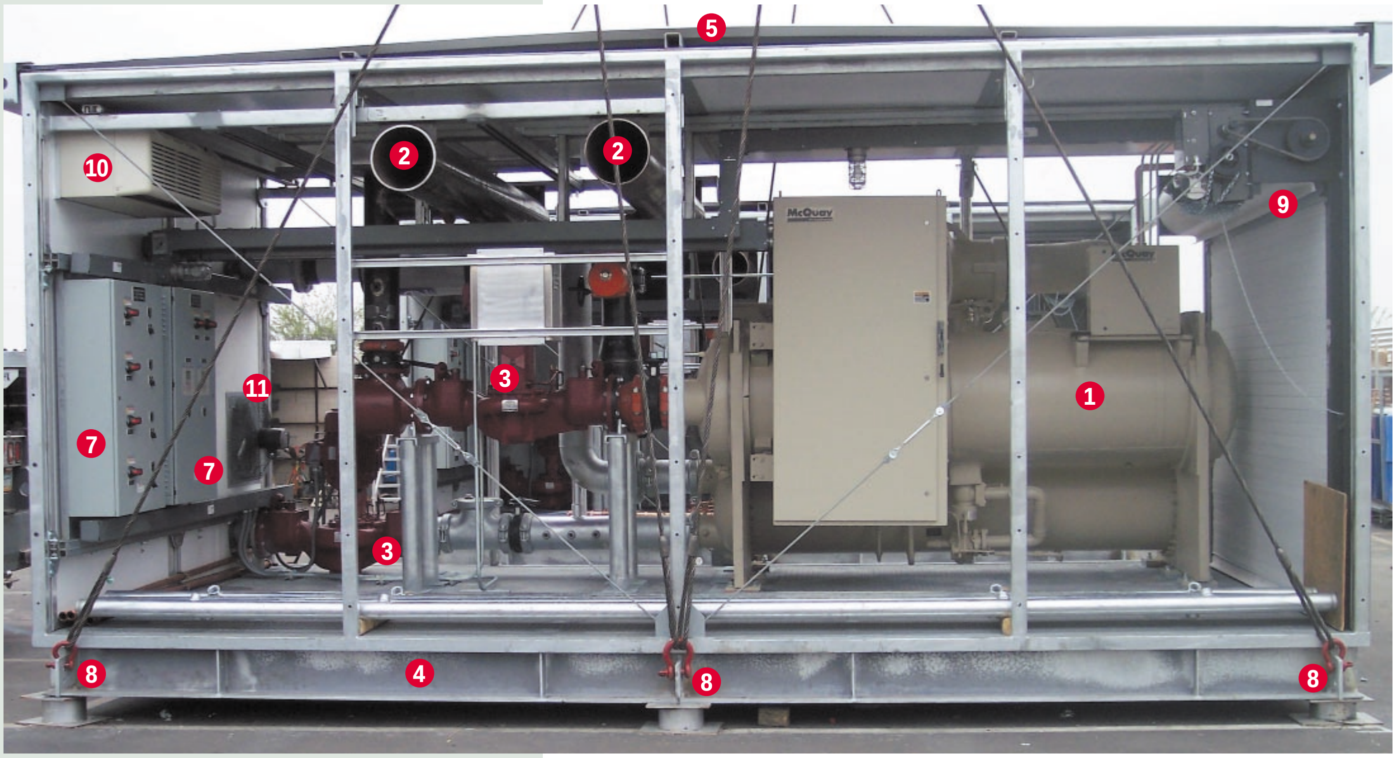
High Quality
Galvanized finish on all structural steel and condenser water piping is standard, not a maintenance-heavy painted finish.

Simplified Installation
Pre-engineered and pre-assembled in a wide selection of sizes from 100–600 tons in a single compact package with unique modular design that allows central plants up to 2400 tons.

Green Refrigerant
Selected chillers use HFC-134a refrigerant with no ozone depletion potential and no phase-out schedule.

The Modular Central Plant (MCP) Advantage

Innovation inside…



...and outside the box

1. Chiller—Scroll, Screw or Centrifugal.
2. Interconnecting chilled water supply and return pipe headers.
3. Split-coupled, in-line pump.
4. Fully engineered, galvanized, welded, and point-loading steel structure, with seismic bracing where required.
5. Removable roof with integral gutters and flashing.
6. Removable wall panel with lifting handles.
7. UL listed motor starter and VFD panels.
8. Lifting and multiple-module connecting lugs.
9. Motorized roll-up access door.
10. Packaged terminal air-conditioner unit.
11. Enclosure ventilation fan.
12. Complete interconnecting hardware provided and shipped with modules.

Complete with cooling tower, interconnecting condenser water piping…

...and chemical water treatment equipment

13 Cooling tower—cross flow type with stainless steel hot and cold water basins optional.

14 Fully engineered, galvanized, welded, and point-loading steel structure, with seismic bracing where required.

15 Interconnecting galvanized condenser water supply and return piping and pipe supports.

16 Main distribution panel with single point electrical 480volt/3phase connection (one per module).

17 Chemical treatment tanks, metering pumps,controller, coupon rack, pot feeder and containment pan skid mounted for either internal or external insulation.

Innovative Central Plant Solutions

Pre-engineered and pre-assembled McQuay Modular Central Plants ship for final assembly anywhere in North America.

Single / Multiple / Dual Module, Water-Cooled Chiller Options

Scroll Chiller

MCP-WGZ-SCS
Module capacity—
Single: 75 to 100 tons
Multiple: 150 to 500 tons

Screw Chiller

MCP-WGS-SCS
Module capacity—
Single: 125 to 175 tons
Multiple: 250 to 975 tons

MCP-WGS-DCS
Dual: 250 to 350 tons

Magnetic Bearing Centrifugal Chiller

MCP-WMC-SCS
Module capacity—
Single: 100 to 300 tons
Multiple: 200 to 1500 tons

MCP-WMC-DCS
Dual: 200 to 500 tons

Standard Centrifugal Chiller

MCP-WSC-SCS
Module capacity—
Single: 200 to 600 tons
Multiple: 400 to 2400 tons

A global leader in system solutions for air conditioning, heating, ventilating and refrigeration.

McQuay® International

(800) 432-1342
www.mcquay.com

For more information, contact McQuay International.
e-mail: chillerapplications@mcquay.com
phone: 540-248-9207

Centrifugal Chillers
Data Center

CASE STUDY

Herakles Data Gains Increased Capacity and Energy Savings with "Mission Critical" Installation of McQuay Modular Central Plants

Positioning itself as the ultimate data center, Herakles Data of Sacramento, California, offers uninterruptible power, improved cooling and redundant internet bandwidth to its co-location customers seeking to outsource their primary or disaster recovery IT infrastructure. At a co-location data center, corporations rent specific spaces to operate their data servers, along with the servers of other companies, in a common physical location.

With all the critical servers housed in the facility generating heat, cooling is critical for the data center. "Cooling is essential to our business, in fact it's the number two essential factor after uninterrupted power for our customers," said Laurence Stancil, director of facilities at Herakles Data.

Herakles Data President and CEO Lou Kirchner stresses how essential cooling is to their success. "We've had customers come to us after leaving a previous data center because cooling was inadequate or unreliable," Kirchner said. "And with the newer servers being more powerful and more compact than ever, they produce even more heat. With our facility near 100% capacity, it's critical that our cooling capacity be able to handle the heat of the newest generation of servers."

Herakles Data's 52,500-sq ft co-location data center in Sacramento, California.

McQuay Modular Central Plant

Mission-Critical Challenge

Earlier this year Herakles Data realized that its rapid business growth meant that it had outgrown the capacity of its existing four air-cooled McQuay chillers. It now needed additional capacity that could meet the demands of its mission-critical interior space and ambient temperatures that typically reach 95 degrees during the summer. "Under California's Title 24 standards, we couldn't add a fifth chiller to meet our growing capacity needs, so we had to consider alternatives outside the box," said Stancil. "Our number one requirement in selecting a new system was speed. The new cooling system had to be installed and operating as fast as possible, with minimal interruption to our cooling requirements."

A Pre-Engineered, Pre-Assembled Solution

Working with representatives from Norman Wright Mechanical Equipment Corporation, the McQuay representative in Sacramento, the facility team from Herakles Data evaluated alternative solutions and selected McQuay Modular Central Plants. Modular central plants are pre-engineered and pre-assembled from

McQuay® Air Conditioning

Engineered for flexibility and performance.™

Inside the Herakles Data Center, the newest generation of servers housed there are more powerful and more compact than ever, producing more heat and more cooling capacity demand.

one supplier with the chiller, pumps, cooling tower and interconnected piping, and then shipped to the jobsite for final assembly. Their unique modular configuration reduces site assembly time compared to traditional "site built" cooling plants with the chiller, cooling tower, pumps and piping all coming from separate sources.

"We were comfortable going with McQuay again because we've had five years of excellent, reliable support from McQuay Factory Service," Kirchner said.

Although he was also comfortable with McQuay, Stancil was initially skeptical of the modular central plant concept but the installation process made him a believer. "Our first four Modular Central Plants were dropped, bolted and wired – fully assembled – in a week. I'd compare it to changing a propeller in flight," Stancil said. "You have to get it right the first time. And we did. Final site assembly was a very clean process – fast, easy and efficient."

It was so fast and easy that Stancil now prefers the modular central plant concept to the traditional site-built central cooling plant. "I would never do it the old way again," he said.

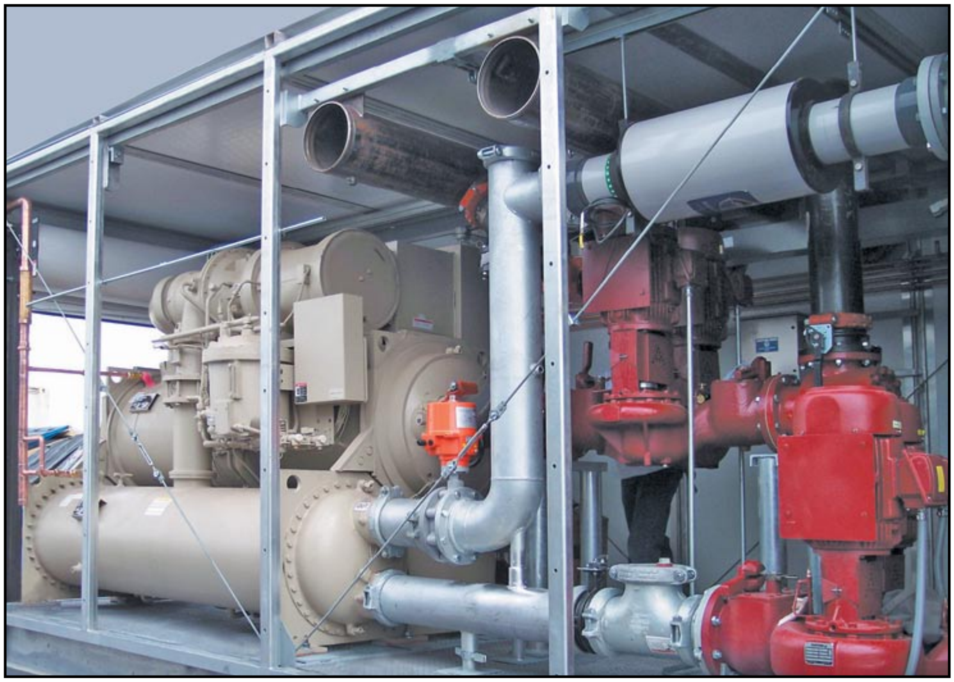
Kirchner was especially pleased that the one-week installation process resulted in zero downtime for the data center saying, "It was seamless for our customers."

Capacity Goals Surpassed

Since June 2007, a total of six McQuay Modular Central Plants have provided chilled water to 59 computer room air conditioning units in the 52,500 square foot data center. Each of the modules consists of a 500-ton McQuay centrifugal compressor water chiller pre-engineered and pre-assembled with pumps, piping, cooling tower, control panel and associated water treatment system.

Kirchner's original goal of increased cooling capacity to meet Herakles Data's projected growth was not only achieved, but also surpassed. "We provide N+1 business solutions for our customers, meaning we meet their needs plus provide redundancy," he said. "Today, however, we have surpassed that goal because we typically run only two of the four original modular central plants. That results in 2N cooling capacity today available to our data center customers."

Four of the six McQuay Modular Central Plants that provide mission critical cooling for the Herakles Data Center.



Each of the McQuay Modular Central Plants consists of a 500-ton McQuay centrifugal chiller pre-engineered with pumps, piping, cooling tower, control panel and associated water treatment system.

Energy Savings a Bonus

In addition to fast-track construction and commissioning, the new McQuay central plants resulted in impressive energy savings compared to the old system. "Our old system used 3,600 Kwh/ton a day; the new system uses 2,800 Kwh/ton a day for a 22% reduction in energy," Stancil added.

That reduced energy usage earned a $50,000 rebate from the Sacramento Municipal Utility District to Herakles Data for the new system.

With the energy savings, the benefits of the McQuay Modular Central Plant extend beyond the initial benefits of the fast, easy installation. "Those energy savings were a very good bonus," Stancil said. "With our new modular central plants, we not only got the increased capacity that we needed, we also got significant energy savings over the life of the equipment."

"The Only Way to Go"

Kirchner sums up the entire experience as phenomenal. "Modular central plants are a simple yet brilliant solution to today's business requirement for consistent, quality design and zero downtime. It's the only way to go."

2F-4017 (09/07)

Software licensed to PSUAE	Job No	Sheet No **1**	Rev
	Part		
Job Title	Ref		
	By	Date 19-Mar-09	Chd
Client	File staad.std	Date/Time 19-Mar-2009 14:00	

Job Information

	Engineer	Checked	Approved
Name:			
Date:	19-Mar-09		

Structure Type	FLOOR

Number of Nodes	2	Highest Node	2
Number of Elements	1	Highest Beam	1

Number of Basic Load Cases	1
Number of Combination Load Cases	0

Included in this printout are data for:

All	The Whole Structure

Included in this printout are results for load cases:

Type	L/C	Name
Primary	1	LOAD CASE 1

Node Displacement Summary

	Node	L/C	X (in)	Y (in)	Z (in)	Resultant (in)	rX (rad)	rY (rad)	rZ (rad)
Max X	1	1:LOAD CASE	**0.000**	0.000	0.000	0.000	0.000	0.000	-0.018
Min X	1	1:LOAD CASE	**0.000**	0.000	0.000	0.000	0.000	0.000	-0.018
Max Y	1	1:LOAD CASE	0.000	**0.000**	0.000	0.000	0.000	0.000	-0.018
Min Y	1	1:LOAD CASE	0.000	**0.000**	0.000	0.000	0.000	0.000	-0.018
Max Z	1	1:LOAD CASE	0.000	0.000	**0.000**	0.000	0.000	0.000	-0.018
Min Z	1	1:LOAD CASE	0.000	0.000	**0.000**	0.000	0.000	0.000	-0.018
Max rX	1	1:LOAD CASE	0.000	0.000	0.000	0.000	**0.000**	0.000	-0.018
Min rX	1	1:LOAD CASE	0.000	0.000	0.000	0.000	**0.000**	0.000	-0.018
Max rY	1	1:LOAD CASE	0.000	0.000	0.000	0.000	0.000	**0.000**	-0.018
Min rY	1	1:LOAD CASE	0.000	0.000	0.000	0.000	0.000	**0.000**	-0.018
Max rZ	2	1:LOAD CASE	0.000	0.000	0.000	0.000	0.000	0.000	**0.018**
Min rZ	1	1:LOAD CASE	0.000	0.000	0.000	0.000	0.000	0.000	**-0.018**
Max Rst	1	1:LOAD CASE	0.000	0.000	0.000	**0.000**	0.000	0.000	-0.018

Software licensed to PSUAE	Job No	Sheet No 2	Rev
	Part		
Job Title	Ref		
	By	Date 19-Mar-09	Chd
Client	File staad.std	Date/Time 19-Mar-2009 14:00	

Beam Displacement Detail Summary

Displacements shown in italic indicate the presence of an offset

	Beam	L/C	d (ft)	X (in)	Y (in)	Z (in)	Resultant (in)
Max X	1	1:LOAD CASE	0.000	**0.000**	0.000	0.000	0.000
Min X	1	1:LOAD CASE	27.000	**-0.000**	-0.611	0.000	0.611
Max Y	1	1:LOAD CASE	0.000	0.000	**0.000**	0.000	0.000
Min Y	1	1:LOAD CASE	15.000	-0.000	**-1.961**	0.000	1.961
Max Z	1	1:LOAD CASE	0.000	0.000	0.000	**0.000**	0.000
Min Z	1	1:LOAD CASE	0.000	0.000	0.000	**0.000**	0.000
Max Rst	1	1:LOAD CASE	15.000	-0.000	-1.961	0.000	**1.961**

Beam End Displacement Summary

Displacements shown in italic indicate the presence of an offset

	Beam	Node	L/C	X (in)	Y (in)	Z (in)	Resultant (in)
Max X	1	1	1:LOAD CASE	**0.000**	0.000	0.000	0.000
Min X	1	1	1:LOAD CASE	**0.000**	0.000	0.000	0.000
Max Y	1	1	1:LOAD CASE	0.000	**0.000**	0.000	0.000
Min Y	1	1	1:LOAD CASE	0.000	**0.000**	0.000	0.000
Max Z	1	1	1:LOAD CASE	0.000	0.000	**0.000**	0.000
Min Z	1	1	1:LOAD CASE	0.000	0.000	**0.000**	0.000
Max Rst	1	1	1:LOAD CASE	0.000	0.000	0.000	**0.000**

Beam End Force Summary

The signs of the forces at end B of each beam have been reversed. For example: this means that the Min Fx entry gives the largest tension value for an beam.

				Axial	Shear		Torsion	Bending	
	Beam	Node	L/C	Fx (kip)	Fy (kip)	Fz (kip)	Mx (kip·in)	My (kip·in)	Mz (kip·in)
Max Fx	1	1	1:LOAD CASE	**0.000**	24.000	0.000	0.000	0.000	-0.000
Min Fx	1	1	1:LOAD CASE	**0.000**	24.000	0.000	0.000	0.000	-0.000
Max Fy	1	1	1:LOAD CASE	0.000	**24.000**	0.000	0.000	0.000	-0.000
Min Fy	1	2	1:LOAD CASE	0.000	**-24.000**	0.000	0.000	0.000	-0.000
Max Fz	1	1	1:LOAD CASE	0.000	24.000	**0.000**	0.000	0.000	-0.000
Min Fz	1	1	1:LOAD CASE	0.000	24.000	**0.000**	0.000	0.000	-0.000
Max Mx	1	1	1:LOAD CASE	0.000	24.000	0.000	**0.000**	0.000	-0.000
Min Mx	1	1	1:LOAD CASE	0.000	24.000	0.000	**0.000**	0.000	-0.000
Max My	1	1	1:LOAD CASE	0.000	24.000	0.000	0.000	**0.000**	-0.000
Min My	1	1	1:LOAD CASE	0.000	24.000	0.000	0.000	**0.000**	-0.000
Max Mz	1	1	1:LOAD CASE	0.000	24.000	0.000	0.000	0.000	**-0.000**
Min Mz	1	1	1:LOAD CASE	0.000	24.000	0.000	0.000	0.000	**-0.000**

Software licensed to PSUAE	Job No	Sheet No 3	Rev
	Part		
Job Title	Ref		
	By	Date 19-Mar-09	Chd
Client	File staad.std	Date/Time 19-Mar-2009 14:00	

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given from beam end A.

				Axial	Shear		Torsion	Bending	
	Beam	**L/C**	**d** (ft)	**Fx** (kip)	**Fy** (kip)	**Fz** (kip)	**Mx** (kip-in)	**My** (kip-in)	**Mz** (kip-in)
Max Fx	1	1:LOAD CASE	0.000	**0.000**	24.000	0.000	0.000	0.000	-0.000
Min Fx	1	1:LOAD CASE	0.000	**0.000**	24.000	0.000	0.000	0.000	-0.000
Max Fy	1	1:LOAD CASE	0.000	0.000	**24.000**	0.000	0.000	0.000	-0.000
Min Fy	1	1:LOAD CASE	30.000	0.000	**-24.000**	0.000	0.000	0.000	-0.000
Max Fz	1	1:LOAD CASE	0.000	0.000	24.000	**0.000**	0.000	0.000	-0.000
Min Fz	1	1:LOAD CASE	0.000	0.000	24.000	**0.000**	0.000	0.000	-0.000
Max Mx	1	1:LOAD CASE	0.000	0.000	24.000	0.000	**0.000**	0.000	-0.000
Min Mx	1	1:LOAD CASE	0.000	0.000	24.000	0.000	**0.000**	0.000	-0.000
Max My	1	1:LOAD CASE	0.000	0.000	24.000	0.000	0.000	**0.000**	-0.000
Min My	1	1:LOAD CASE	0.000	0.000	24.000	0.000	0.000	**0.000**	-0.000
Max Mz	1	1:LOAD CASE	0.000	0.000	24.000	0.000	0.000	0.000	**-0.000**
Min Mz	1	1:LOAD CASE	15.000	0.000	0.000	0.000	0.000	0.000	**-2.16E 3**

Reaction Summary

			Horizontal	Vertical	Horizontal	Moment		
	Node	**L/C**	**FX** (kip)	**FY** (kip)	**FZ** (kip)	**MX** (kip-in)	**MY** (kip-in)	**MZ** (kip-in)
Max FX	1	1:LOAD CASE	**0.000**	24.000	0.000	0.000	0.000	0.000
Min FX	1	1:LOAD CASE	**0.000**	24.000	0.000	0.000	0.000	0.000
Max FY	1	1:LOAD CASE	0.000	**24.000**	0.000	0.000	0.000	0.000
Min FY	1	1:LOAD CASE	0.000	**24.000**	0.000	0.000	0.000	0.000
Max FZ	1	1:LOAD CASE	0.000	24.000	**0.000**	0.000	0.000	0.000
Min FZ	1	1:LOAD CASE	0.000	24.000	**0.000**	0.000	0.000	0.000
Max MX	1	1:LOAD CASE	0.000	24.000	0.000	**0.000**	0.000	0.000
Min MX	1	1:LOAD CASE	0.000	24.000	0.000	**0.000**	0.000	0.000
Max MY	1	1:LOAD CASE	0.000	24.000	0.000	0.000	**0.000**	0.000
Min MY	1	1:LOAD CASE	0.000	24.000	0.000	0.000	**0.000**	0.000
Max MZ	1	1:LOAD CASE	0.000	24.000	0.000	0.000	0.000	**0.000**
Min MZ	1	1:LOAD CASE	0.000	24.000	0.000	0.000	0.000	**0.000**