Andy Penev
Final Report
4/3/2013
Advisor: Dr. Messner

CityCenterDC | Parcel 1

Washington, D.C.

CityCenterDC | Parcel 1

Washington, D.C.

Size: 257,500 sq. ft.

Stories: 11

Function: Office & Retail

Delivery Method:

Design-Bid-Build

Construction Dates: 4/11 - 1/14

Owner: Hines-Archstone

GC: Clark-Smoot

Architect: Foster + Partners

Civil Engineer: Delon Hampton & Assoc.

Structural Engineer: SK&A

MEP Engineers: Tolk, Inc.

Electrical Contractor: Truland

Mechanical Contractor: Madison

Architecture

- Part of six building development in center of Washington, D.C.
- One of two identical office buildings
- Curtain wall enclosure
- First two floors used for retail space

Mechanical System

- Utilizes a chilled water cooling system
- 3 cooling towers
- Chilled water AHUs every floor
- Fan powered terminal units and VAV boxes
- Electric heat

Electrical System

- 480/277V
- (1) 4000A & (1) 3000A switchboard
- 750kW emergency generator
- Electrical room every floor

Special Thanks To:

Hines

CLARK CONSTRUCTION

TRULAND BEYOND CURRENT

Construction

- On-site concrete batch plant
- Built simultaneously with remaining five buildings
- 7 total tower cranes for project
- Shared foundation/garage

Structural

- Cast-in-place concrete
- 8” post-tensioned slabs with 6” drop panels at columns
- Interior core shear walls

Andy Penev | CM Option

http://www.engr.psu.edu/ae/thesis/portfolios/2013/ahp5034/index.html

Executive Summary

Over the course of the 2012/2013 academic year, Office Building 1 of the CityCenterDC development was analyzed to identify areas in which alternative solutions in either construction or design would enhance the project. Through feedback from the project team, independent research, and multiple site visits, three major areas were chosen for additional analysis. The following report presents the three analyses performed as part of the final senior thesis project. It is important to note that the purpose of this thesis and analysis is strictly educational and is not intended to critique the project team in any way.

Analysis #1: SIPS

The first analysis looked to create a new phasing and scheduling plan for the typical floor construction, and implement the results through a Short Interval Production Schedule. The repetitive nature of the activities on each floor allowed for specific crews to be assigned to specific tasks that would repeat on each floor. A reorganization of the activities and new floor logistic planning optimized the efficiency and use of each area. As a result, the schedule was shortened by 13 days and savings from general conditions were estimated at $20,524.40. More importantly, the schedule acceleration would allow the owner to lease the property quicker, resulting in earlier payments from the tenant.

Analysis #2: Construction Analysis of Electrical Redesign

Investigation into the existing electrical distribution system revealed that the power density was nearly twice as high as generally designed for. As a result, a thorough redesign of the electrical distribution system for Office Building 1 was performed (Breadth 1). A construction analysis of the results revealed that the new design would produce savings of $120,940. The electrical riser work schedule can be cut in half or the work force reduced. A constructability analysis of the new system revealed that a total of 182 labor hours will be saved and that the proposed equipment will be easier to install.

Analysis #3: Alternative Footbridge Construction Method

Five steel footbridges span between Office Building 1 and Office Building 2. Each bridge serves as an enclosed walkway from one structure to the other. The chosen method of construction consisted of prefabricating the bridges onsite and lifting them into position using a 500 ton mobile crane. Although the method proved successful, many challenges were encountered which led to additional resource use. This analysis proposes the use of VSL Heavy Lifting technology to install the footbridges. This system uses four hydraulic jacks located at the top of the building to lift each footbridge into place. Bridges will still be prefabricated onsite, but no crane will be required. After ensuring the structural integrity of the building was not compromised (Breadth 2), it was found that the proposed system would produce savings of $350,000. The original start and finish dates will not be affected, as this system will neither save nor delay the schedule.

Acknowledgments

Academic:

Dr. John Messner

Dr. Robert Leicht

Dr. Richard Mistrick

Bob Holland

Ronald Dodson

Kevin Parfitt

Industry:

CLARK CONSTRUCTION

TRULAND BEYOND CURRENT

Hines

TSI Architectural Metals, Inc.

VSL

Special thanks to:

Al Hedin

Jared Oldroyd

Matt Orosz

Mike Current

CityCenterDC Project Team

PACE Industry Members

My Family and Friends

Table of Contents

Project Information

Background

The idea for CityCenterDC started over a decade ago when Mayor Anthony Williams decided to launch an initiative to redevelop the site of the old convention center in Washington, D.C. In 2002, after two years of research and studies, he announced the space would be best served as a development consisting of apartments/condominiums, along with parking and office space. An RFP was issued, and by 2004 Hines-Archstone was selected as the developer for the project. Soon thereafter, Shalom Baranes Associates and Foster + Partners began developing a design.

For the next couple of years, the District and developers struggled to come to terms on the details of the project. Approvals and financing from both sides dragged this process along until finally in 2008, with a finalized master plan, Hines-Archstone issued an RFP for a general contractor. Clark/Smoot were awarded a joint venture contract. Due in part to the financial crisis, the project was put on hold until the latter part of the decade. It wasn't until March 2011 that CityCenterDC finally broke ground.

The focus of this report is Office Building 1 of the CityCenterDC development. Office Building 1 is an 11-story, 257,500 sq. ft. core and shell, curtain wall enclosed structure, see Figure 1.

Figure 1: Rendering of Office Building 1 | Image courtesy of Neoscape

Existing Conditions

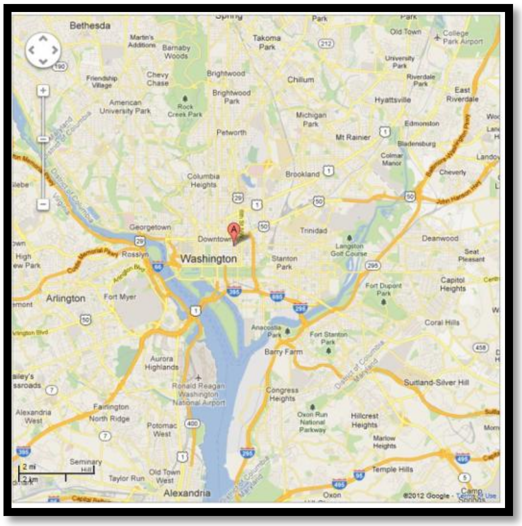


Figure 2: Map | Google Maps

CityCenterDC is a two block development located in the heart of Washington, D.C. (see Figure 2). The site of the project was once the Washington Convention Center. Since it's demolition in 2004, the lot has been used as a parking lot for the surrounding businesses. Office Building 1 is located on 11th St. and New York Avenue, as seen outlined in Figure 3.

While space is not a constraining factor on site, the surroundings raise some safety and logistical issues. The construction site is located in the middle of a multitude of operating businesses and busy streets. This means that construction is in progress in the midst of heavy pedestrian and vehicular traffic. To ensure the safety of those around the site, all sidewalks bordering the site are closed. Sidewalks on the opposite side of those streets are wide enough to accommodate the pedestrian traffic. An 8' fence surrounds the entire site, and access to the site is carefully monitored. The layout of the trailers and concrete batch plant are consistent throughout the entirety of the project. Multiple streets and access points prevent major traffic jams on any of the streets.

Figure 3: Aerial | Hines-Archstone

A unique aspect of this project is the introduction of two new streets. As highlighted in Figure 3, new sections of 10th Street and I Street will be introduced. The current lot does not include any part of these new streets, and as a result, the city utility grid needs to be extended. This requires additional work under the surface of the road. For 10th Street, this will be done simultaneously with the project. Since the trailers and material lay down areas are situated on top of future I Street extension during construction, the grid and street will be constructed at a later date.

The underground utilities that run through this part of the city are very extensive. Underneath all of the streets surrounding the site are existing water lines, electric lines, gas lines, telecom lines, fiber lines, etc. Ten 36” pipes in a sewer manifold run on the southern edge of the site. This abundance of utilities is due to the prime location of the project. Due to the existing, former, and future buildings in the area, utilities under the streets have been previously installed with expansion in mind. All of the tunnels are easily accessible and will only require tie-ins for the new buildings.

Delivery Method

The project team implemented a design-bid-build delivery method for the CityCenterDC development. Shalom Baranes Associates, the started developing the initial designs toward the middle of the decade. A joint venture contract was awarded to Clark/Smoot in 2008. The project was broken down into 4 packages, each of which required a separate GMP contract.

Schedule

As mentioned before, CityCenterDC was broken down into four separate packages: parking garage, office, rentals, and condominiums. As soon as the massive excavation was complete, crane foundations were set and the seven cranes were erected, as they would be embedded in buildings throughout construction. The parking garage would be erected first, as it spans the entire footprint of the site, and acts as the foundation for the buildings above.

Only upon the successful and substantial completion of the parking garage could the remaining buildings begin construction. As a result, the garage’s timely completion ultimately determined the end date for the entire project.

Once the garage was completed, a seamless transition into the construction of the offices, rentals, and condos began. The north office and condo were the first two buildings to begin construction. Their southern counterparts followed behind by one floor. A month later, the rental units in middle of the site rose above grade, approximately four floors behind the office. Office Building 1 in the meantime rose by about one floor per week.

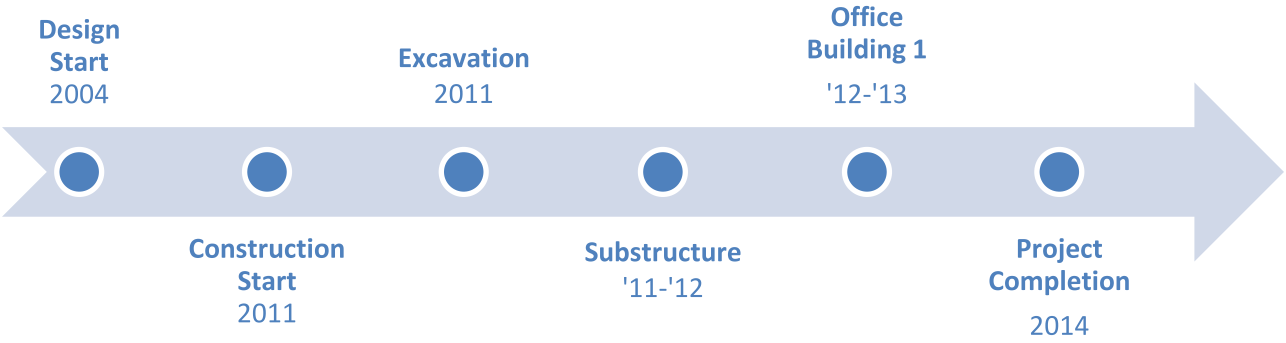


Figure 4: Timeline

Excavation & Subgrade Structure

All six buildings in the CityCenterDC development share the same excavation and foundation. The entire site was excavated at once, footings for cranes were poured, and the cranes were set in place. With the cranes and an engineered ramp in place, the cast-in-place concrete foundations were poured. Once the entire subgrade structure was complete, each building's above grade structure was ready to begin.

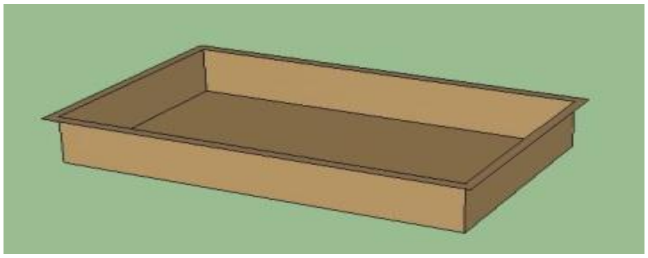


Figure 5.1: Excavation

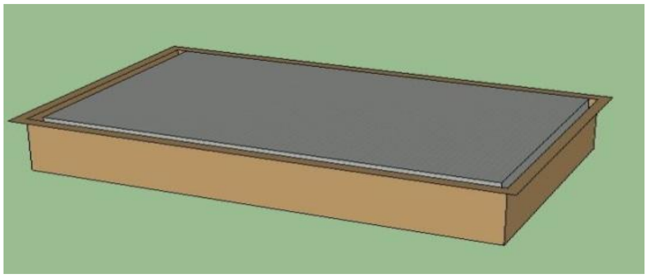


Figure 5.2: Subgrade Structure

Above Grade Structure

Due to the similarity of the floor-to-floor structure of the office building, the above grade structure erection process was very efficient. In fact, the average duration for construction of one floor slab was one week.

First, the formwork and temporary shoring was erected. Post-tensioned cables along with rebar were arranged on stools to create a grid. Next, the slab was poured, starting from the west side of the building towards the east. This process was repeated for all of the floors of the office building.

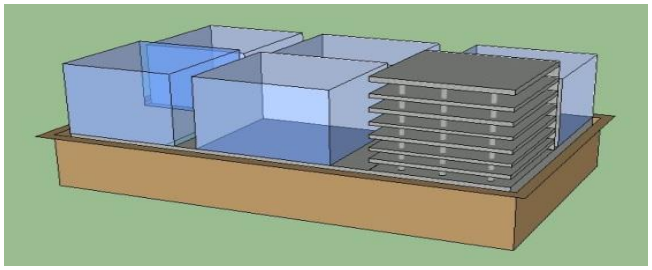


Figure 5.3: Above Grade Structure

Building Enclosure

Just around the time the last floor was being poured, the construction of the curtain wall began on the second floor. The curtain wall system used special embeds in the slabs to attach to the structure. Every floor was enclosed in approximately 12 working days. With the climate in mind, the curtain wall enclosure was started at the beginning of May with the intent to finish before the harsh winter months.

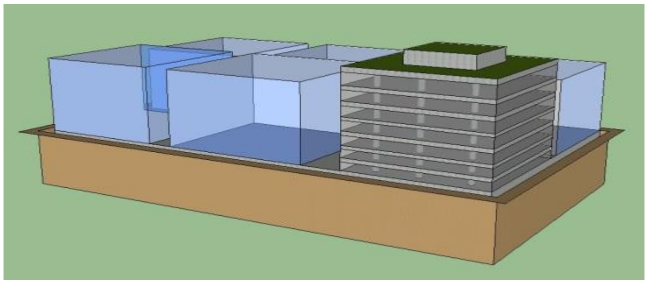


Figure 5.4: Enclosure

Building Systems Overview

Structural Steel Frame

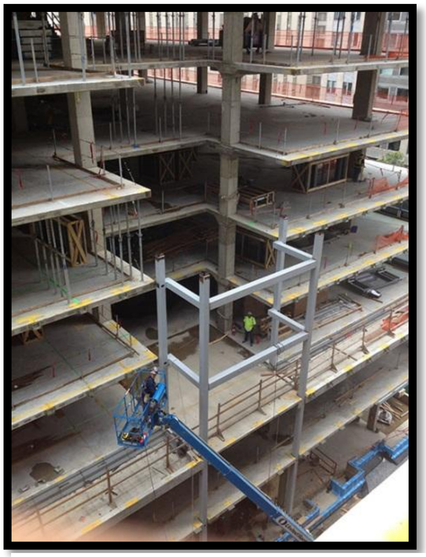


Figure 6: Atrium | Andy Penev

The only sections of the building that utilize steel construction are the atrium and mechanical penthouse. The atrium, which extends the entire height of the building, is composed of W and HSS beams, as seen in Figure 6. An enclosed curtain-wall footbridge connects the atriums of each building. The penthouse mezzanine and roof framing are also composed of W beams, ranging from W10 to W18. This is due to the heavy loads associated with the mechanical equipment. Also, by using steel beams, more space is allotted for openings, chases, and cores in between the beams, whereas the typical post-tensioned slab would have reinforcement that would interfere. If concrete beams were to replace the steel beams, they would have a much larger depth because of the loads, and as a result, take away from the ceiling height on the lower level. Structural steel framing is used on each floor at the core of the building, to enclose the bathrooms, mechanical, electrical, and storage spaces.

The inability to place cranes around the buildings called for an embedded arrangement within the structures. Seven tower cranes (see Figure 7), with reaches from 124' to 213', were placed at strategic locations throughout the development to ensure that all points of the site could be reached by at least one crane. After erection of the superstructure, the cranes were disassembled and the holes filled in with the appropriate material.

Figure 7: Cranes | OxBlue

Cast-in-Place Concrete

The majority of the structure, including the floor slabs, drop panels, columns, and shear walls are cast-in-place concrete. Typical on every floor are 8" thick post-tensioned slabs with 6" drop panels at the columns. Formwork for the slabs consists of No. 2 lumber and plywood, supported by traditional shoring. Temporary steel beams support the plywood and lumber, where the rebar and post-tensioning cable are arranged on stools. The crane hoists buckets to the desired location and the slab is poured and formed. A concrete batch plant was set up due to the extremely large demand for concrete for the entire project. The addition of this plant eliminated the travel time for trucks, and fresh concrete was more readily available.

Underneath the office building is a four-story garage. As a result, the first floor slab includes rigid insulation between the garage roof slab and the office building first floor slab. This was done in order to reduce the noise from the garage below and minimize the heat loss through the floor. The foundations of the office building tie into the parking garage structure, which was designed to carry the loads of all 6 buildings.

Mechanical System

The office building utilizes a chilled water system to provide cooling to the spaces. A chilled water air handling unit is located in the mechanical room on every floor of the structure. Outside air, along with return air, is cooled via chilled water coils and circulated to the fan powered terminal units. Each floor is separated into zones to provide optimal control for the user. Multiple FPTUs have been designed to allow tenants to control and condition zones of the floor differently. Electric heaters in the AHU and FPTUs provide heat to the space during the winter months. The AHU on each floor is located in the core, with the pipes and ductwork webbing out to the remaining space. Three cooling towers, outside air handlers, and several other rainwater filtration systems are housed in the mechanical penthouse on the roof of the building.

Fire suppression for this office building is quite extensive, due in part to the high-rise classification. Smokeproof/pressurized stairways, sprinklers, and fire dampers are utilized throughout the building. Two hour ratings are mandatory for most assemblies, including shafts, elevator hoistways, exit passageways, the structural frame, and the floor.

Electrical System

City Center Parcel 1 uses a 480/277V electrical distribution system. Service is provided by PEPCO at 480/277V, run through a utility meter, and into the switchboards. The two office buildings share an electrical room on level B1, the uppermost level of the garage. There are four switchboards, 2-3000A and 2-4000A. Each 4000A switchboard feeds the electrical closets on every floor of its respective building via a 4000A busway. 480/277V to 208/120V step-down transformers are located in each electrical closet and at every location that requires lower voltage. This allows runs to floors to have smaller wire sizes due to the higher voltage feeders. In the case of interrupted or lost service, there is a 750kW standby generator designated for backup power to the fire pump, life safety systems, smoke removal systems, equipment, and elevators. Automatic transfer switches are used to detect outages and relay to the generator.

Curtain Wall

A curtain wall system is used for the entirety of the building façade. It is identical on every floor and wraps around the entire building. The curtain wall is supported via embed plates in the slabs, as seen in Figure 8. The curtain wall runs from slab to slab, and clings on at these connection locations. Insulation is included in the curtain wall assembly. At the top and bottom of each floor, special attachments to the assembly fasten to the ceiling and floor to create a uniform and flush appearance.

Figure 8: Curtain Wall Embed Connection | Andy Penev

Excavation

Typical to the region, this project consisted of a massive excavation, about 4 stories, supported by soldier piles and lagging (see Figure 9). The quality of these supports was crucial, as three sides of the site were bordered by existing, operating, busy streets. CityCenterDC is located in the middle of downtown D.C., and as a result, calls for stringent mud control. Each truck entering or leaving the site had to go through a cleaning station prior to its exit off the site. The extra space on site, created by the excess parking lot, allowed for extra room for this cleaning station and control of all trucks.

Figure 9: Excavation | OxBlue

LEED Rating & Green Features

The CityCenterDC development is pursuing a LEED Gold certification under the LEED 2009 for Neighborhood Development (ND) rating system. Due to the size and combination of residential, non-residential, and public spaces, this project was deemed appropriate for the Neighborhood Development Pilot Program. Since these types of development projects have significantly longer construction durations, CityCenterDC was assigned a Stage 2 conditional approval, meaning it was pre-certified as LEED Gold.

Instead of utilizing the standard LEED for New Construction certification system, the project team chose to pursue certification from the most recently released LEED for Neighborhood Development. The USGBC, in conjunction with the Congress for the New Urbanism and the Natural Resources Defense Council, created this system in order to establish a standard for rewarding neighborhood establishment projects. While other LEED rating systems focus on green building practices, the ND system places emphasis on site selection, design, and construction elements. The goal is to bring buildings and infrastructure together, and integrate them with the neighborhood, landscape, and regional context. All the elements of the development should be beneficial to the community and individuals, as well as the surrounding environment.

Cost

The construction cost for Office Building 1 is approximately $42 million, or $163.44/SF. With the addition of general conditions, fees, bonds, etc., the project price arrives at about $48 million, or $186.19/SF. Since the two office buildings are almost identical, the cost for the bundle, as packaged in the contract, is ~$96 million. The cost of the sitework and garage/foundation for the office buildings is approximately $36 million. Broken down to just Office Building 1, this amounts to approximately $18 million. Per request of the owner, more detailed cost information cannot be provided at the moment.

Depth 1: SIPS

Problem Identification

The commercial floors, 3-11, of Office Building 1 were designed without the knowledge of who the future tenant would be. As a result, each floor's essential components (risers, rough-ins, MEP systems, elevators, etc.) would be installed first. When these components were installed, and the developer had found their tenant, the remaining work (finishes, wall partitions, furniture, etc.) would be completed.

The repetitive nature of each floor creates a great opportunity for exploration into phasing and scheduling of the essential components of each floor. The majority of the work revolves around the core of each floor, where the main MEP closets and risers are located. The remaining space on each floor is left open, with only the MEP systems installed in the ceiling.

Furthermore, upon investigation into the outcome of the actual schedule it was found that many activities on each floor went over their originally specified durations. From the owner's perspective, the sooner the core of each floor is completed, the sooner they can enter into a contract with the tenant. Once in a contract, the tenant will either approve the current furnished design, or request a new one. Regardless, the owner will start receiving monthly payments from the tenant for the lease.

Analysis Goals

The aforementioned situation implies that any acceleration of the schedule would be beneficial to the owner. In order for the contractor to benefit from schedule acceleration, incentives would be necessary. Due to the contract and overall project schedule, savings from accelerating the core would not guarantee the contractor additional savings. However, if schedule savings can be produced without the addition of new resources for the contractor, they could save on general conditions costs. Consequently, the goal of this depth is to develop an alternative phasing and scheduling plan for the essential components of each floor, which will be implemented through a Short Interval Production Schedule. Financial, constructability, and scheduling impacts will be analyzed. It is believed that through a new phasing and scheduling plan, two weeks can be saved from the typical floor build-up. General conditions savings will be estimated from the schedule savings.

Process

Analysis of original schedule

Before any new phasing or scheduling propositions could be made, the actual schedule had to be analyzed.

First, the activities associated with the construction of the essential components of each floor were identified. Their respective original durations were then noted. Next, via the actual schedule, the start and end dates of those activities were found for each floor. The net amount of workdays in between those dates was then calculated. Any deviation from the originally specified duration was noted. Table 1 illustrates some examples from the findings.

For complete schedule refer to Appendix A.1.

Table 1: Activities and their respective start and end dates, along with the actual duration.

Floor	Item	Original Duration	Start Date	End Date	Actual Duration
2	Mechanical Riser Rough In	5	4/25/2012	5/1/2012	5
2	Install AHU	2	5/3/2012	5/7/2012	**3**
2	Install VAV boxes	5	5/10/2012	5/17/2012	**6**
3	Frame & Hang Shaft Walls	5	5/9/2012	5/15/2012	5
3	Close In Shafts	3	5/16/2012	5/18/2012	3
3	Frame Walls	5	5/24/2012	6/1/2012	**7**
5	Duct Rough In	5	6/15/2012	6/22/2012	**6**
6	Electrical Riser Rough In	5	5/23/2012	5/29/2012	5
6	Install AHU	2	5/29/2012	5/30/2012	2
7	Rough In Duct Mains	5	6/15/2012	6/22/2012	**6**
8	Install Sprinkler Standpipes	5	7/7/2012	7/13/2012	5
8	Duct Riser Rough In	5	7/7/2012	7/13/2012	5
8	Plumbing Riser Rough In	5	7/7/2012	7/13/2012	5

After the schedule of each floor was analyzed, it was found that, on average, 12 out of the 21 activities on each floor exceeded their originally specified durations. This amounts to an 11.9 day delay in the overall schedule of the essential floor components.

The tasks which most commonly went over their original duration were noted. These tasks, shown in Table 2, were found to be located at the second half of the typical floor schedule.

Table 2: Tasks which most commonly went over original duration

Activities		
Layout & Top Track	Frame Walls	Sprinkler Rough In
Install Lavatory Support Steel	Mechanical Pipe Rough In	Frame Ceilings
Rough In Duct Mains	Plumbing Rough In	Fire Alarm Rough In
Install VAV boxes	Duct Rough In	Electrical Rough In

This analysis indicated that the second half of each typical floor schedule consistently created problems. Therefore, the next step was to examine the activities in more detail. Figure 10 illustrates a typical floor schedule.

Figure 10: Original Schedule | Clark

The activities following "Install VAV Boxes" follow a rather linear pattern. More so, while one activity is being performed, for example framing of walls, no other work is being performed on that floor. This happens multiple times in this schedule layout.

Figure 11 further illustrates the sequence of activities of the original schedule. The linear flow only allows one trade/set of activities to be performed on the floor at once. Even if that particular activity will install a product along the entire floor, it can only work sections at a time. For example, duct rough in work will follow the path of the duct. The duct cannot all be installed at the same time, everywhere on the floor. This type of sequence causes for large portions of the floor to be vacant while some work is being done in a particular section, creating inefficiency. Also, if one activity falls behind, the remaining work suffers a schedule delay because of the dependency. This amounts to loss of productivity, schedule, and cost.

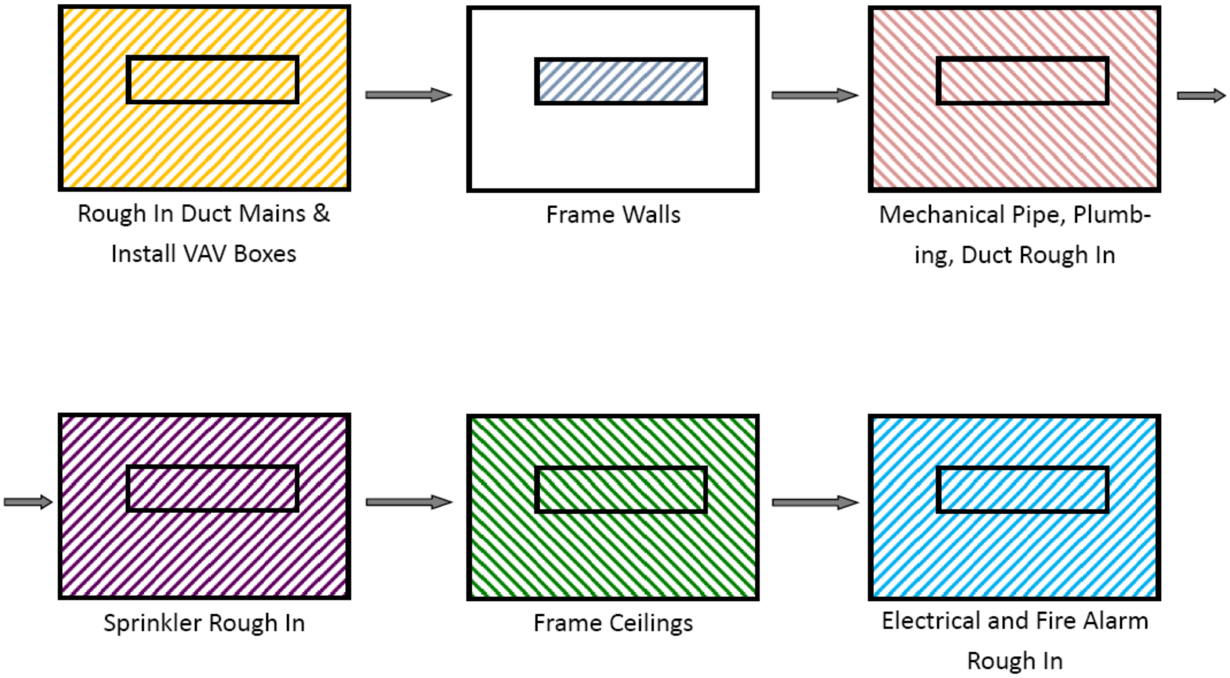


Figure 11: Original workflow illustration

New Schedule & Phasing

As a result of the aforementioned findings, it was deemed that the original sequence and phasing could be altered to accelerate the schedule. The primary principal behind the new phasing plan would revolve around overlapping activities on a single floor. That is, instead of a linear schedule, as previously described, areas of a floor would be sectioned off and designated to a particular activity. As those activities completed work in that area, they would move to the next area. Thus, the wasted space otherwise created by having one trade/activity on each floor would be utilized by another trade/activity.

The following sections outline the new phasing details.

Rough In Duct Mains & Install VAV Boxes **AND** Frame Walls

The first new phasing sequence involves roughing in duct mains and installing VAV boxes (DM-VAV) in one area of the floor, while beginning to frame walls on the other. As seen in the schedule cutout in Figure 13, lavatory support steel is erected while roughing in duct mains and installing VAV boxes. Once the lavatory steel is complete, instead of only working on duct mains and VAV boxes, framing of the walls can begin.

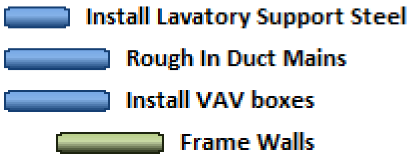


Figure 12: Green bar indicates schedule change from original

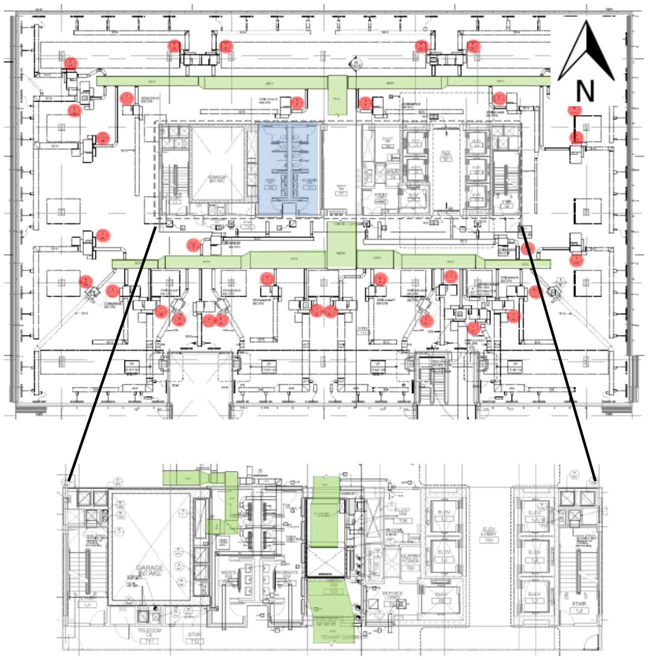


Figure 13: Component identification

In order to properly section off areas of the floor, duct mains, VAV boxes, walls, and the lavatory needed to be identified. Figure 12 shows the duct mains highlighted in green and the VAV boxes highlighted in red. The walls are located only in the core of the building. The lavatory is highlighted in blue.

Based on the location of these components, a phasing plan was developed to show the working areas for the respective activity. DM-VAV will start at the core and east side of the building while the lavatory steel is being erected. Once lavatory steel is complete, DM-VAV will move to the west open floor area of the building, while framing of the walls will begin on the east core.

Please refer to Figures 1 & 2 in Appendix A.2 for a detailed illustration of the new phasing plan.

Frame Walls **AND** Mechanical Pipe, Plumbing, & Duct Rough In

Next, once DM-VAV is complete, the mechanical pipe, plumbing, and duct rough in (MPDRI) will begin. Framing of the walls will now move to the west side of the building, and MPDRI will begin on the east side. Figure 14 shows the newly scheduled activities.

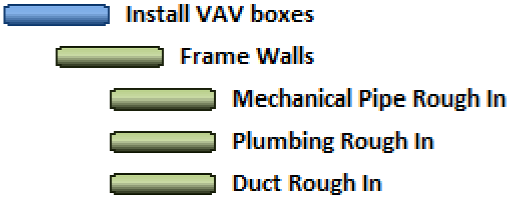


Figure 14: Schedule cutout

Please refer to Figure 3 in Appendix A.2 for a detailed illustration of the new phasing plan.

Mechanical Pipe, Plumbing, & Duct Rough In **AND** Electrical and Fire Alarm Rough In

Once framing of the walls is comlpete, MPDRI will move to the west side of the building. Electrical and fire alarm rough in will begin on the east side of the building. Figure 15 shows the newly scheduled activities.

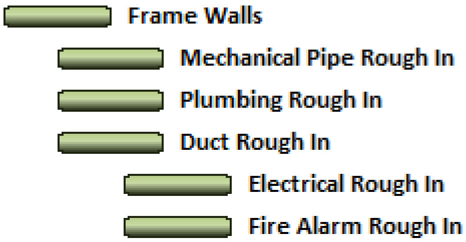


Figure 15: Schedule cutout

Please refer to Figure 4 in Appendix A.2 for a detailed illustration of the new phasing plan.

Electrical and Fire Alarm Rough In **AND** Sprinkler Rough In

When the electrical and fire alarm rough in is done on the east side of the building, it will move to the west. Sprinkler rough in will then start on the east. Figure 16 shows the newly scheduled activities.

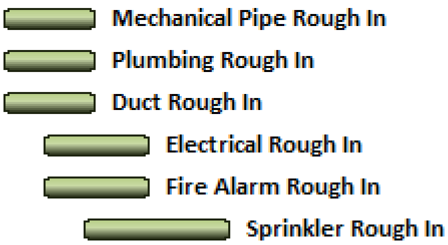


Figure 16: Schedule cutout

Please refer to Figure 5 in Appendix A.2 for a detailed illustration of the new phasing plan.

Sprinkler Rough In **AND** Frame Ceilings

Finally, sprinkler rough in will move to the west side and framing of ceilings will start on the east. The sprinkler rough in will finish halfway through the framing of the ceilings. The west side of the ceilings will be finished and the floor will be complete. Figure 17 shows the newly scheduled activities.

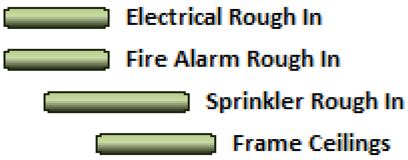


Figure 17: Schedule cutout

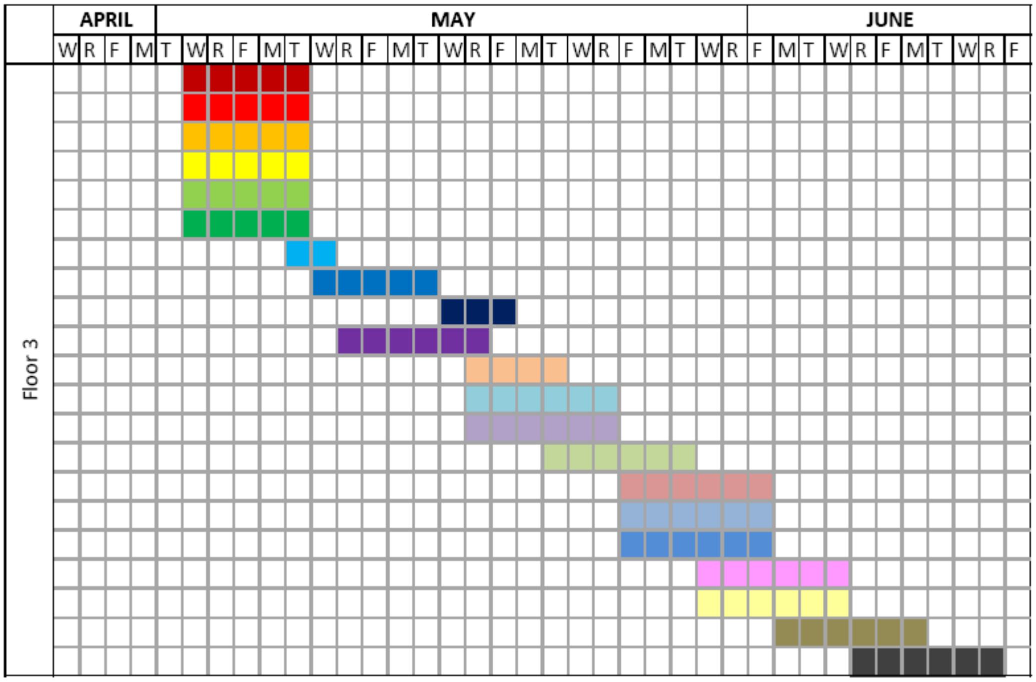
Please refer to Figures 6 & 7 in Appendix A.2 for a detailed illustration of the new phasing plan.

SIPS

The new re-organization and phasing of the activities was then implemented into a Short Interval Production Schedule (SIPS), seen in Figure 18. Each color-coded bar represents an activity. Every activity has a set duration and crew. Once the crew is complete with their work on a floor, they move to next floor. This process is repeated until they reach the final floor.

As evidenced through the original schedule analysis, the majority of activities from the second half of the schedule went over their originally specified duration. This version of the SIPS was made with those extended durations of the activities. Another version, with the original durations can be seen in Appendix A.3. Using the extended durations produced a 3 day float in the overall schedule and a single day float for each of the effected activities.

Please refer to Appendix A.4 for full SIPS.



Activity	Color	Activity	Color
Install Sprinkler Standpipes	🟥	Rough In Duct Mains	🟦
Duct Riser Rough In	🟥	Install VAV boxes	🟪
Plumbing Riser Rough In	🟧	Frame Walls	🟩
Mechanical Riser Rough In	🟨	Mechanical Pipe Rough In	🟥
Telecom/Security Riser Rough In	🟩	Plumbing Rough In	🟦
Electrical Riser Rough In	🟩	Duct Rough In	🟦
Install AHU	🟦	Sprinkler Rough In	🟫
Frame & Hang Shaft Walls	🟦	Frame Ceilings	⬛
Close In Shafts	🟦	Fire Alarm Rough In	🟪
Layout & Top Track	🟪	Electrical Rough In	🟨
Install Lavatory Support Steel	🟧		

Figure 18: SIPS

Results

The implementation of the new SIPS was estimated to accelerate each floor schedule, and consequently the whole essential components schedule, by 13 days. As stated earlier, this acceleration allows work for the finishes to begin earlier, saving both the contractor and owner money. Appendix A.5 illustrates the difference between the original typical floor schedule, and the new typical floor schedule.

The schedule savings also come to no additional resource cost to the contractors. The exact same crews and durations are used as in the original schedule. Cost savings can be incurred by the contractor through general conditions from the 13 saved days. See Table 3 for estimated general conditions cost savings.

Table 3: General Conditions

General Conditions Savings				
Item	Unit	Units Saved	Cost/Unit	Total Cost
Project Manager	Week	2	$2,425	$4,850
Field Engineer	Week	2	$1,100	$2,200
Project Engineer	Week	2	$1,300	$2,600
Superintendent	Week	2	$2,250	$4,500
Safety Manager	Week	2	$1,500	$3,000
Waste Removal	Week	2	$375	$750
Temporary Power	Month	.5	$4,200	$2,100
Office Trailer	Month	.5	$648.71	$324.4
Office Equipment	Month	.5	$250	$125
Office Supplies	Month	.5	$150	$75
Total Savings				**$20,524.40**

Constructability

The successful implementation of the aforementioned re-phasing and Short Interval Production Schedule depends greatly on the organization of the project team. While none of the activities have changed in respect to difficulty, a higher level of collaboration is required. Each crew is now assigned a specific floor area in which they must complete their work in a given amount of time. Any delay from a particular crew could cause the remaining activities to be delayed, due to their dependency. In response to this concern, the second half of the activities were given an extra day float, as many proved to require it even with the original schedule.

The re-organization of the activities was also done with the intent to improve the constructability and decrease the chance of complications along the way. For example, the original schedule called for the sprinkler rough in to precede both the fire alarm and electrical rough in. In most cases, it is much easier to install electrical rough in before sprinkler, due to the size and quantity of the components. Installing the sprinkler pipes and having an electrical contractor work around them can lead to undesirable clashes, and possibly even re-work. In addition, the original schedule called for the ceiling to be framed before the electrical rough in and fire alarm. This increases the degree of difficulty for those contractors even more. Having to work around a framed ceiling, installing conduit, boxes, etc. would be a very difficult and time consuming task. Essentially, this additional degree of difficulty is adding time onto the estimated duration of the electrical and fire alarm rough in. It is very possible that these contractors could run over their estimated durations and delay the progress of the remaining building. Thus, the new schedule places the electrical and fire alarm rough in before the sprinkler rough in and ceiling framing to avoid any of the previously mentioned problems.

Another constructability consideration which influenced the way the phasing was decided upon was the fact that the activities in the schedule do not individually require the entire floor space. Some activities are specific to the core while others are specific to the remaining space. For example, wall framing involves only framing at the core of the building, as the remaining office space does not even have walls. In the original schedule, it is the sole activity being performed on a floor. Roughing in duct mains and installing VAV boxes is also an activity which does not need the entire floor space at once. Crews can easily begin at one end of the building, while another crew works on the opposite end. Once they are done with their respective sides, they can switch. As long as the contractors clean up after themselves and are on time, there should not be any great difficulty achieving this. Once again, Appendix A.2 shows the phasing plans and designated regions for each activity.

Timely deliveries and on site storage also need to be carefully planned and executed to ensure optimal success of this scheduling plan. Because each trade is now working in slightly tighter quarters, they need manage their materials more efficiently. This is particularly applicable to the mechanical contractor, as ducts can take up considerable space. As a result, the mechanical contractor needs to carefully plan their delivery and storage of material to avoid impeding another trade’s work.

In regard to the feasibility of implementing a Short Interval Production Schedule, Clark/Smoot is very knowledgeable and experienced. Most buildings on the CityCenterDC project utilize SIPS, from structural work to finishes. The crews are all trained and have had experience with SIPS. Thus, it is a very practical and comfortable solution to both the laborers and management.

Recommendations

Per the results of this analysis, it is recommended that the proposed phasing plan and SIPS schedule be implemented on this project. The proposed schedule does not incur any additional expenses to any parties on the project. Contractor savings from general conditions are estimated at $20,524.40. The owner will benefit from beginning the tenant fit-out process sooner, ultimately delivering the building to the client quicker and receiving lease payments earlier.

MAE Requirements

AE 570: Production Management in Construction

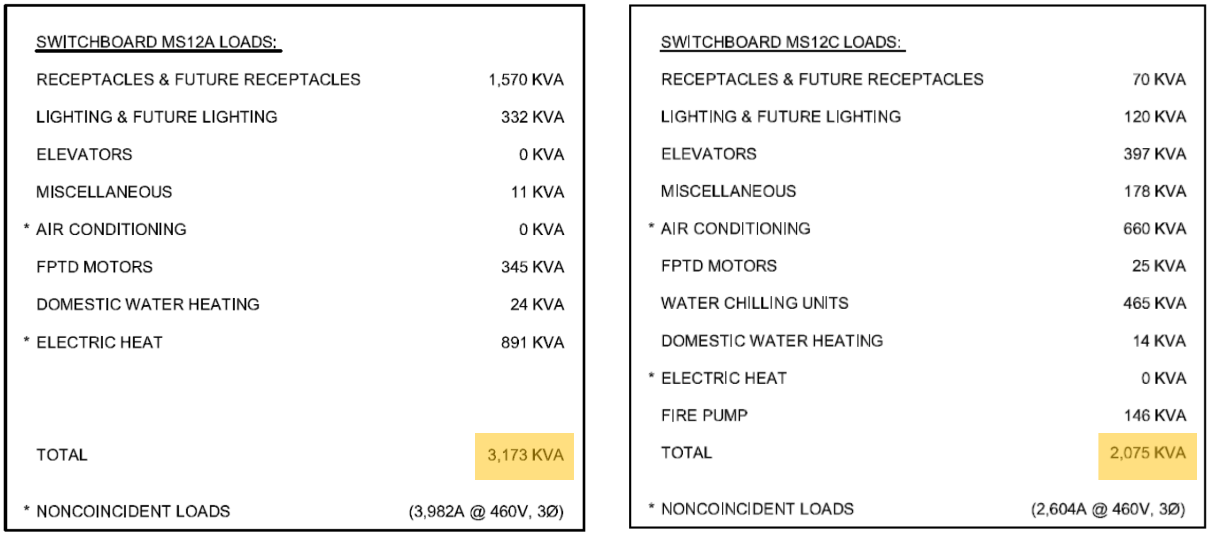
This course focuses on the exploration of production management to efficiently manage the delivery of construction projects. One of the planning tools learned in the course was Short Interval Production Scheduling. The course helped explain this tool through definitions, examples, case studies, and presentations by industry members. Students were then responsible for applying the knowledge through research projects. In addition, logistics planning and efficiency maximization techniques were taught in the course. Analysis 1 revolves around the creation and implementation of a Short Interval Production Schedule to the CityCenterDC project. Knowledge from the course was applied to recognize the potential applicability of implementing SIPS. Then, logistics diagrams were created to organize and maximize efficiency of the work. After some schedule reorganization, a SIPS was created for a typical floor plan. It was then applied to all floors and a master SIPS was created. Thus, the knowledge obtained from AE570 about SIPS, logistics planning, and efficiency maximization was applied to this analysis.

Depth 2: Construction Analysis of Electrical Redesign

Breadth 1: Electrical Distribution System Redesign

Problem Identification

An electrical system overview, performed during Technical Report 1, revealed that Office Building 1 relied on two switchboards to power the facility. A 4000A switchboard was designated for the electrical closets on each floor, and a 3000A switchboard for the remaining equipment and emergency power. The total kVA load from these switchboards, as seen in Figure 19, is 5,248 kVA, or 20.4 W/SF. A typical office building, consumes about 10-12 W/SF, or half of what Office Building 1 does. Office Building 1 does not contain a data center or any similar space that could add significant amounts of load; it is strictly office space. The retail space, on the bottom two floors, will be fed from a separate power supply, not connected to the office power.



SWITCHBOARD MS12A LOADS:

RECEPTACLES & FUTURE RECEPTACLES	1,570 KVA
LIGHTING & FUTURE LIGHTING	332 KVA
ELEVATORS	0 KVA
MISCELLANEOUS	11 KVA
* AIR CONDITIONING	0 KVA
FPTD MOTORS	345 KVA
DOMESTIC WATER HEATING	24 KVA
* ELECTRIC HEAT	891 KVA
TOTAL	3,173 KVA
* NONCOINCIDENT LOADS	(3,982A @ 460V, 3Ø)

SWITCHBOARD MS12C LOADS:

RECEPTACLES & FUTURE RECEPTACLES	70 KVA
LIGHTING & FUTURE LIGHTING	120 KVA
ELEVATORS	397 KVA
MISCELLANEOUS	178 KVA
* AIR CONDITIONING	660 KVA
FPTD MOTORS	25 KVA
WATER CHILLING UNITS	465 KVA
DOMESTIC WATER HEATING	14 KVA
* ELECTRIC HEAT	0 KVA
FIRE PUMP	146 KVA
TOTAL	2,075 KVA
* NONCOINCIDENT LOADS	(2,604A @ 460V, 3Ø)

Figure 19: Switchboard Loads for Office Building 1

Background Information

In order to understand why this discrepancy was occurring, an analysis of the existing electrical design was performed. As mentioned in previous reports, Office Building 1 uses a 480/277V electrical distribution system. Step down transformers are used throughout the building for lower voltage requirements. Electrical closets are fed via the 4000A busway designated to each 4000A switchboard.

During the analysis of the electrical system, the loads for the 4000A switchboard were examined. It was found that the lighting and receptacle loads were abnormally high. According to ASHRAE, office lighting power density should be 0.9 W/SF (see Appendix B.1). Also, according to Table 28.1 in MEEB, reference Appendix B.2, receptacle power density should be 2.4 W/SF. In Office Building 1, the combined lighting and receptacle load is 2092 kVA, or 7.7 W/SF, 2.3 times more than normally designed for. More interestingly, 1902kVA of that load is designated on the 4000A switchboard.

As a result of the unusually high lighting and receptacle load on the 4000A switchboard (MS12A), further investigation was performed. The first noteworthy component is that the busway only feeds the electrical closets on floors 2-11. Each electrical closet contains five panelboards, a control panel, and a step down transformer, as seen in Figure 20.

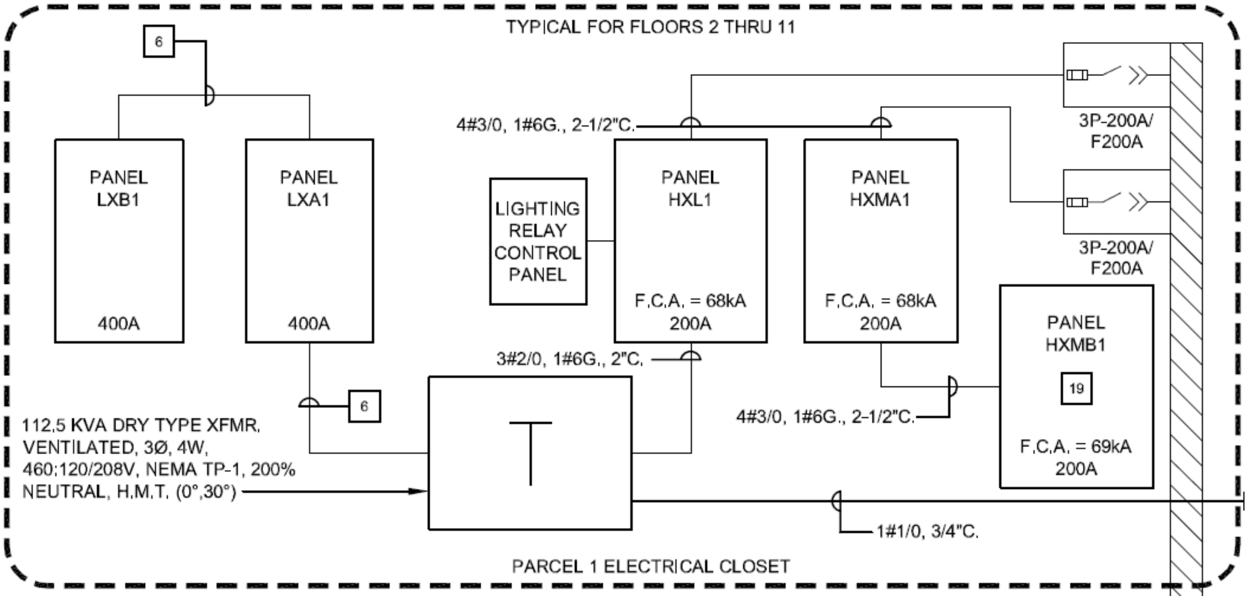


Figure 20: Typical Floor Electrical Room Components

Each one of these electrical closets is responsible for the loads on that particular floor. While examining the schedules for these panels, it was found that all of the HVAC loads, and some lighting, receptacle, sensor, and miscellaneous loads were already designated within the panels. However, these loads all amounted to only 177kVA. The only loads remaining to be circuited were lighting and receptacle.

Schedules for original panels can be found in Appendix B.3.

Redesign and Analysis Goals

Based on the findings from the investigation into the electrical system, it is believed that a redesign of the distribution system will benefit the project in several aspects. The goal of the redesign is to lower the watts per square foot consumption to a level more appropriate and generally accepted by the industry, while still providing sufficient redundancy. Through this redesign, it is believed that cost and schedule savings can be achieved. Constructability of the redesigned system will be evaluated to ensure feasibility and practicality. Both material and labor savings are anticipated.

Electrical Redesign

There were four major redesigns of the electrical distribution system. Design followed code from the NFPA 70 – NEC 2011. The following subsections outline each of the four major redesigns of the system and their respective labor and cost savings.

Main Distribution

Process

The lighting and receptacle loads for MS12A (the 4000A switchboard) were more than twice as high as design recommendations. As briefly mentioned earlier, there is no need for this much capacity for a standard office building. Consequently, 800kVA of load from the combined lighting and receptacle capacity (1902kVA) was removed. This brought the power density of lighting and receptacle loads down to 4.1 W/SF. The recommended power density for these combined loads is 3.3 W/SF (ASHRAE & MEEB). An additional 0.8 W/ SF was left to ensure that there was sufficient room for expansion. Refer to Appendix B.4 for calculations.

Results

Through the reduction of capacity on the system, the full load amps required dropped to below 3000A. This meant that the switchboard size, and consequently the busway size, could be reduced from 4000A to 3000A. Table 4 illustrates the material and labor cost differences.

Table 4: Main Distribution Cost Savings

Description	Mat. $	Equip. $	Lbr Hr.	Lbr. Rate $	Total Lbr. $	Total $
Original Package						
4000A MS12A DISTRIBUTION SWITCHBOARD		$67,200	80.5	$45	$3,622.50	$70,822.50
4000A CU LZ DUCT	$245,700		719.9	$45	$32,395.50	$278,095.50
Total			800.4			$348,918.00
Redesign Package						
3000A MS12A DISTRIBUTION SWITCHBOARD		$40,700	80.5	$45	$3,622.50	$44,322.50
3000A CU LZ DUCT	$163,800		626	$45	$28,170.00	$191,970.00
Total			706.5			$236,292.50
Savings			93.9			**$112,625.50**

As can be seen from the table above, the change from a 4000A distribution switchboard and busway to a 3000A distribution switchboard and busway produced savings of $112,625.50. In addition, the new system saved 93.5 labor hours. Material, equipment, and labor prices for the entire redesign were quoted from an electrical contractor (undisclosed name) and Crawford Electric.

HVAC Panels

Process

Two of the five panelboards on each floor are designated for HVAC loads, highlighted in red in Figure 21. After examining the two panels, it was found that there was enough space to allocate the loads to a single panelboard. In order to do this, a new panelboard was created, and all of the loads inserted. The phases were then balanced, and the breaker properly sized. This change occurred on floors 3-11 of Office Building 1.

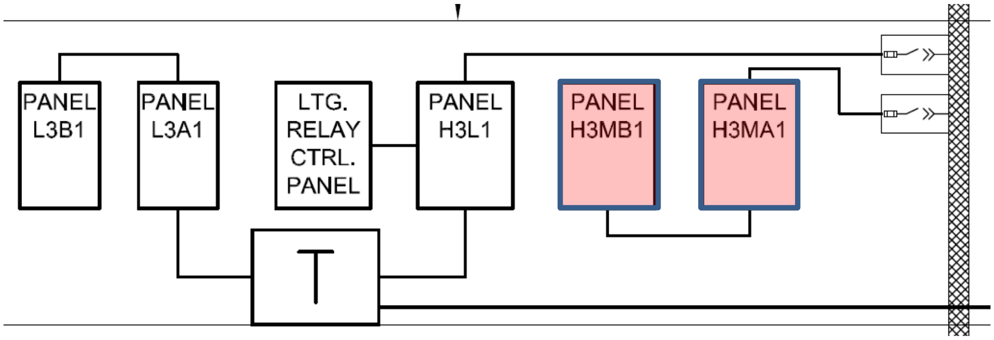


Figure 21: Two HVAC Panels (highlighted in red)

Results

Through the consolidation of these two panels, one entire panelboard was removed, see Figure 22. Although almost all of the circuits are now active, the adjacent 480/277V panel provides additional space if necessary. Because the HVAC system is fully designed, and extensively so, there will be no need for expansion in the near future. Figure 23 on page 24 shows the new typical HVAC panelboard schedule.

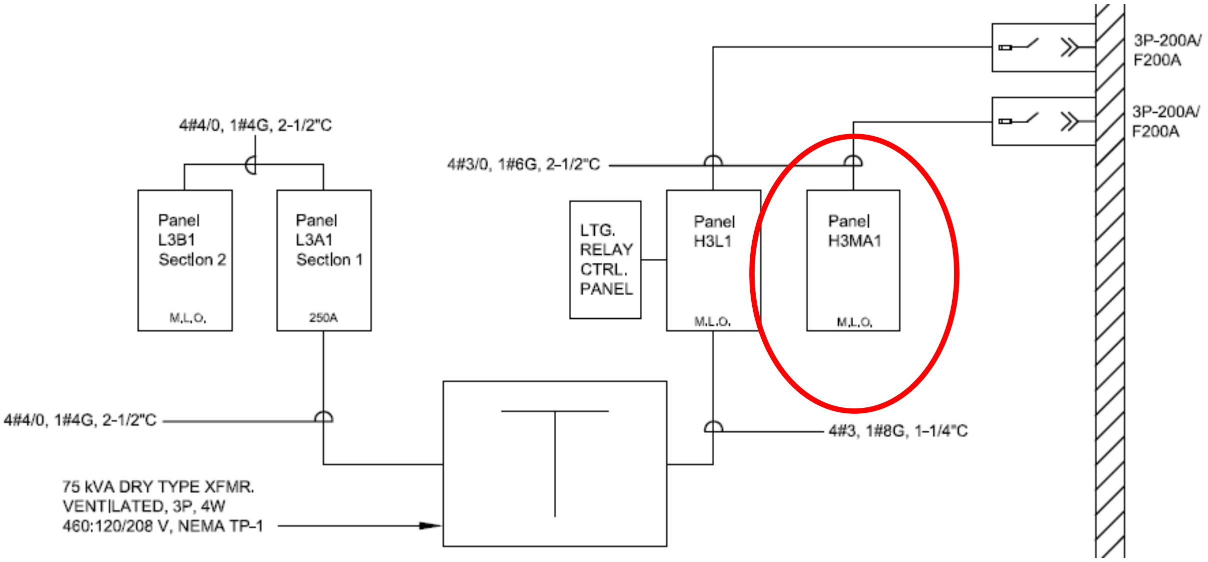


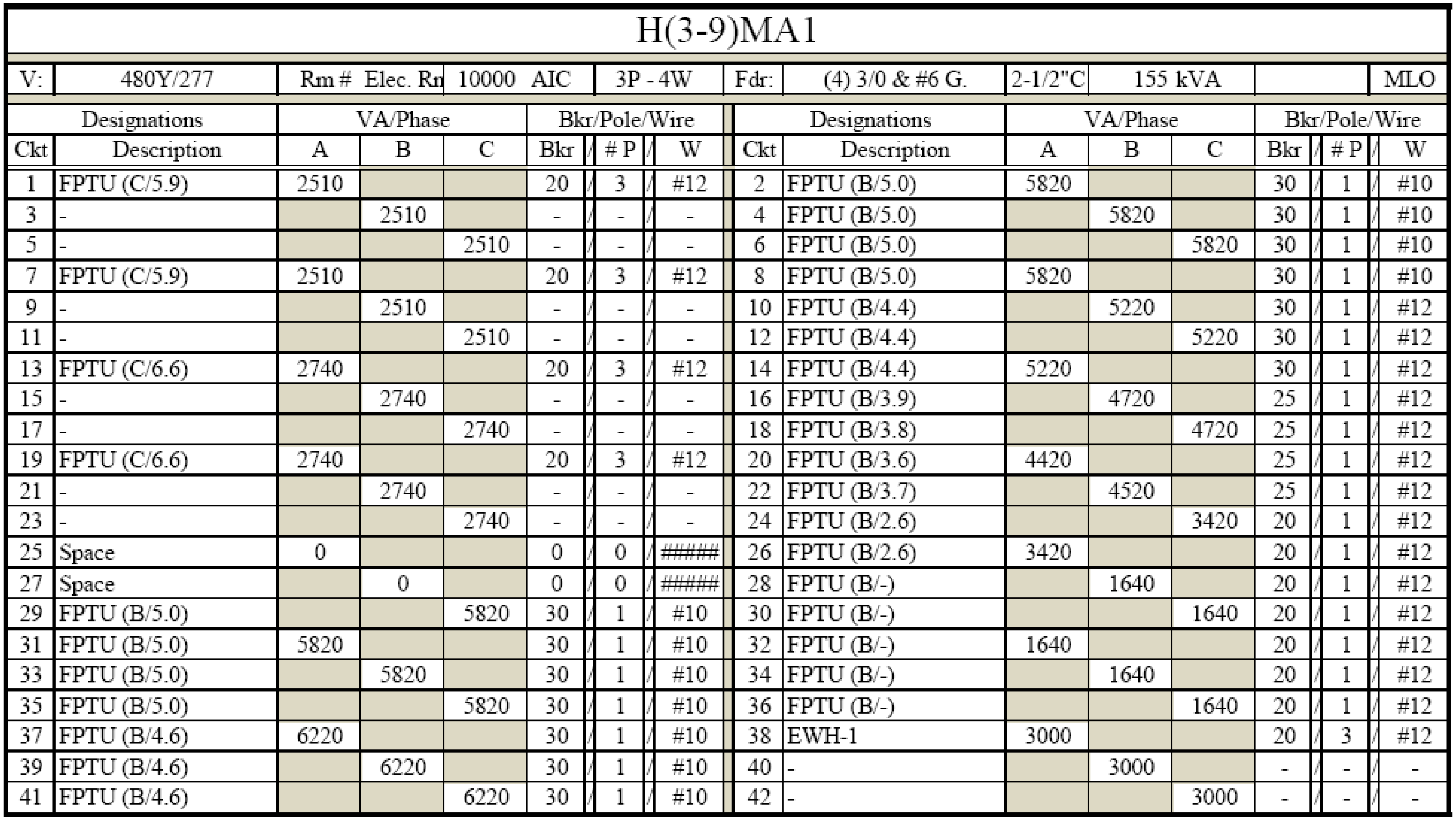
Figure 22: Typical Floor Consolidated Panel

Please refer to Appendix B.5 for the two original panelboard schedules and calculations. Note that panel H3MA1 had 14 empty circuits and panel H3MB1 had 30 empty circuits. This was deemed too much empty space for a system that could not be, and was not planned on being expanded. In addition, as mentioned before, panel HXL1 provides supplementary 480/277V circuits if needed. As can be seen in Table 5, the consolidation of the HVAC panels produced cost savings of $2,630.

Note: Feeder pricing not included in table below as it did not change. Pricing information on feeder can be found in Appendix B.11.

Table 5: HVAC Panel Consolidation Cost Savings

Description	Count	Equip. $	Lbr Hr.	Lbr. $	Total Lbr. $	Total $
Original Package						
225A HXMA1 PANELBOARD	7	$7,600.00	119	$45.00	$5,355.00	$12,955.00
225A HXMB1 PANELBOARD	7	$4,900.00	70	$45.00	$3,150.00	$8,050.00
Total			189		$8,505.00	$21,005.00
Redesign Package						
225A HXMA1 PANELBOARD	7	$10,500.00	175	$45.00	$7,875.00	$18,375.00
Total			175		$7,875.00	$18,375.00
Savings			14			**$ 2,630.00**



H(3-9)MA1

V: 480Y/277 | Rm # Elec. Rn | 10000 AIC | 3P - 4W | Fdr: (4) 3/0 & #6 G. | 2-1/2"C | 155 kVA | MLO

Designations		VA/Phase			Bkr/Pole/Wire			Designations		VA/Phase			Bkr/Pole/Wire		
Ckt	Description	A	B	C	Bkr	# P	W	Ckt	Description	A	B	C	Bkr	# P	W
1	FPTU (C/5.9)	2510			20	3	#12	2	FPTU (B/5.0)	5820			30	1	#10
3	-		2510		-	-	-	4	FPTU (B/5.0)		5820		30	1	#10
5	-			2510	-	-	-	6	FPTU (B/5.0)			5820	30	1	#10
7	FPTU (C/5.9)	2510			20	3	#12	8	FPTU (B/5.0)	5820			30	1	#10
9	-		2510		-	-	-	10	FPTU (B/4.4)		5220		30	1	#12
11	-			2510	-	-	-	12	FPTU (B/4.4)			5220	30	1	#12
13	FPTU (C/6.6)	2740			20	3	#12	14	FPTU (B/4.4)	5220			30	1	#12
15	-		2740		-	-	-	16	FPTU (B/3.9)		4720		25	1	#12
17	-			2740	-	-	-	18	FPTU (B/3.8)			4720	25	1	#12
19	FPTU (C/6.6)	2740			20	3	#12	20	FPTU (B/3.6)	4420			25	1	#12
21	-		2740		-	-	-	22	FPTU (B/3.7)		4520		25	1	#12
23	-			2740	-	-	-	24	FPTU (B/2.6)			3420	20	1	#12
25	Space	0			0	0	#####	26	FPTU (B/2.6)	3420			20	1	#12
27	Space		0		0	0	#####	28	FPTU (B/-)		1640		20	1	#12
29	FPTU (B/5.0)			5820	30	1	#10	30	FPTU (B/-)			1640	20	1	#12
31	FPTU (B/5.0)	5820			30	1	#10	32	FPTU (B/-)	1640			20	1	#12
33	FPTU (B/5.0)		5820		30	1	#10	34	FPTU (B/-)		1640		20	1	#12
35	FPTU (B/5.0)			5820	30	1	#10	36	FPTU (B/-)			1640	20	1	#12
37	FPTU (B/4.6)	6220			30	1	#10	38	EWH-1	3000			20	3	#12
39	FPTU (B/4.6)		6220		30	1	#10	40	-		3000		-	-	-
41	FPTU (B/4.6)			6220	30	1	#10	42	-			3000	-	-	-

Figure 23: Typical Floor HVAC Panel

XFMR Consolidation

Process

Every electrical closet of Office Building 1 contained a step down transformer. This transformer fed two low voltage panels, designated primarily for receptacle loads. In the new proposed design, one transformer feeds the low voltage panels for two floors. This is made possible by the fact that all electrical closets align on top of each other at the core of the building. One of the low voltage panels from the floor with the transformer will feed the two low voltage panels on the floor below. This will eliminate the transformer on the floor below, producing significant material and labor savings. Six total floors will be affected by this design change, three with transformers and three without. Refer to Figure 24 for an illustration of the redesign. For original typical floor refer to Figure 20.

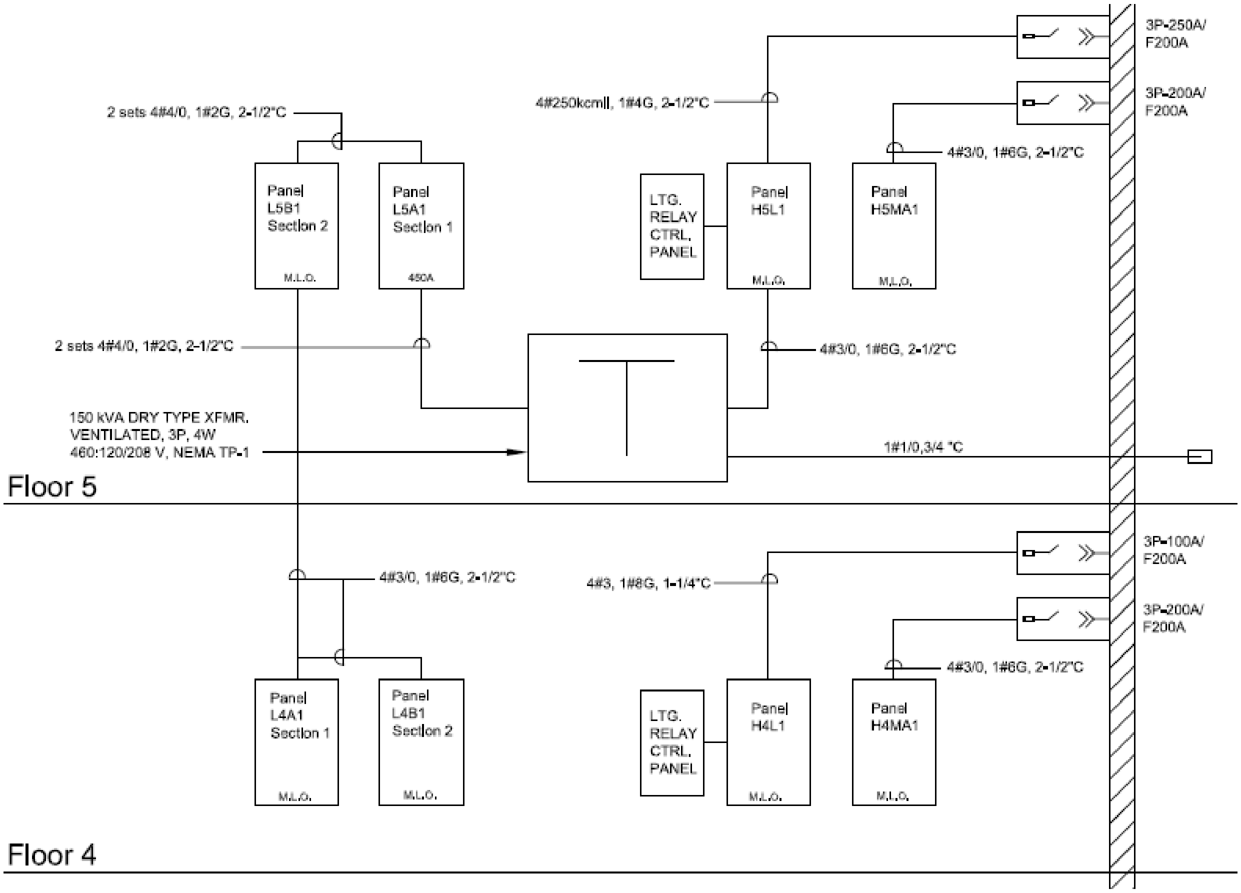


Figure 24: New Floor Layout

Results

The decreased power density discussed earlier applies directly to the low voltage panels, as they deal primarily with receptacle loads. Calculations were performed based on the new power density and it was determined that the transformer ought to be stepped up to 150 kVA from 112.5 kVA. Feeders were resized accordingly and the bus plug (breaker) was also stepped up to 250A due to the increased load. The new layout also helped in creating more space inside the electrical room for both working purposes and future renovations.

The replacement of the 400A panels with 600A panels, along with the new feeders and their respective coring, added cost to the system. These costs were then offset by the material savings from the transformers. The original design called for (7) 112.5 kVA transformers, valued at $53,994. The redesign called for (1) 75 kVA and (3) 150 kVA transformers, valued at $36,001. The final cost savings from this redesign were estimated at approximately $5,000. Full pricing information for all components can be found on the Bill of Materials in Appendix B.11 and in the takeoffs in Appendix B.7.

For calculations refer to Appendix B.6.

3rd Floor Redesign

The 3rd floor low voltage panels could not be streamlined with another floor. With the decreased power density though, the transformer could be reduced in size. Calculations determined that instead of a 112.5 kVA transformer, a 75 kVA transformer would suffice. Figure 25 illustrates the new 3rd floor layout.

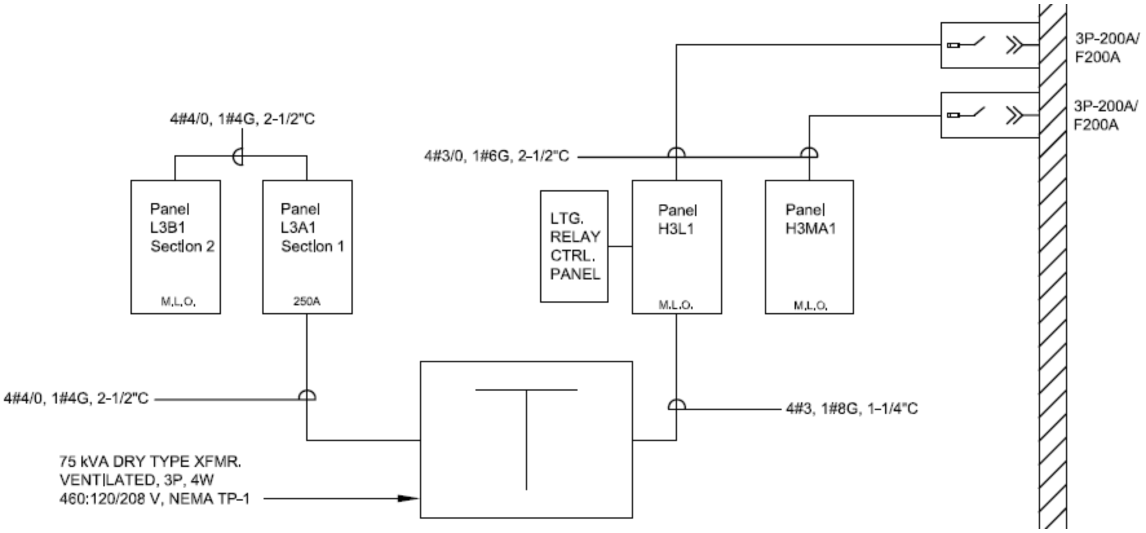


Figure 25: New 3rd Floor Redesign

Please refer to Appendix B.8 for calculations and new panel schedules.

Table 6: Transformer Downsize Cost Savings

Description	Mat. $	Equip. $	Total Mat. $	Lbr Hr.	Lbr. $	Total Lbr. $	Total $
Original Package							
112.5 KVA 3PH 480V STEEL FLEX WITH GROUND	$766	$5,064	$5,831	42	$45	$1,883	$7,713
Total	$766	$5,064	$5,831	42		$1,883	$7,713
Redesign Package							
75 KVA 3PH 480V STEEL FLEX WITH GROUND	$558	$4,200	$4,758	29	$45	$1,296	$6,055
Total	$558	$4,200	$4,758	29		$1,296	$6,055
Savings				13			**$1,659**

Redesign Conclusions

All of the previously mentioned redesigns involved extensive resizing of components downstream and upstream. That is, when one panelboard or transformer was changed, the feeders associated with it would also need to be resized. All resizing was done following the NFPA 70 National Electric Code. In addition, panel schedules were required for every panel as resizing and consolidation occurred at every point in the system. All new schedules can be found in Appendix B.9.

Full riser diagrams of the original and new redesigns can be found in Appendix B.10.

Cost

After the original and redesign systems were completely priced, it was found that the redesign was $120,940 cheaper than the original design. Much of the savings came from the material costs associated with each system. The aforementioned analyses generally reduced equipment in both size and quantity. The largest savings came from the reduction of the system capacity. By downsizing the switchboard and busway by 1000A, over $100,000 was saved. The redesign also reduced the total labor hours from 2012 to 1830. At a labor rate of $45/hour, this amounts to over $8,000 in labor savings. The cost savings from the redesign amount to approximately 4.5% of the original electrical system cost. It is believed that this is a significant value and the redesign should therefore be strongly considered.

For complete Bill of Materials see Appendix B.11.

Schedule

The original electrical work schedule is broken down into two activities, “Electrical Riser Rough In” and “Electrical Rough In.” The “Electrical Riser” activity involves mounting the busway, the plug ins, and the transformers in each room. The “Electrical Rough In” activity includes installation of all other panels and feeders. Each one of these activities has an original duration of 5 days. The riser rough in required a crew of 2 laborers to complete the work in the given duration. The other electrical activity required a crew of 4 laborers.

The electrical redesign saved 182 labor hours compared to the original. In order to pinpoint where the savings applied, the original and redesign labor hours per floor were calculated. For the “Electrical Riser Rough In,” the total original labor hours amounted to 76. The redesign “Electrical Riser Rough In” was broken down into two categories: floor w/ a transformer & w/o a transformer. The floor with the transformer totaled 80 labor hours, slightly above the original, but still keeping the crew size at 2. However, the floor without the transformer totaled to 32 labor hours. Given the more than 50% labor savings, the contractor can elect to either bring the crew size down to 1 laborer, or finish their task twice as fast. If the contractor elects to finish their task faster, they will not shorten the entire project schedule. Nevertheless, this would create the opportunity to relocate their resources elsewhere on the project where they may be required. This is due to the fact that there are 5 other riser activities occurring simultaneously. They require the entire 5 days, and until the risers are completely done in all trades, no other work can be done on the floor. Refer to Figure 26 for clarification.

Figure 26: All riser activities occur simultaneously, so even if electrical riser finishes, the following activities cannot start until the remaining riser work is complete.

Table 7: Labor Hour Comparison

ELECTRICAL RISER ROUGH IN	Hours per Floor	Crew Size
Original Design	76	2
Redesign Floor w/ XFMR	79.75	2
Redesign Floor w/o XFMR	31.42	1*

**Crew size can be either be 1 laborer (as indicated) or the duration of the task can be cut in half.*

On the other hand, the original labor hours per floor for the "Electrical Rough In" were 149. Once again, this task was broken into two categories: floor w/ a transformer and with/ a transformer. The redesign labor hours for the floor with a transformer amounted to 148.33 and the labor hours for the floor without the transformer amounted to 142.33. While the two new labor hour times are lower than the original, they would not produce any schedule savings or reduction in crew size.

ELECTRICAL ROUGH IN	Hours per Floor	Crew Size
Original Design	149	4
Redesign Floor w/ XFMR	142.33	4
Redesign Floor w/o XFMR	148.33	4

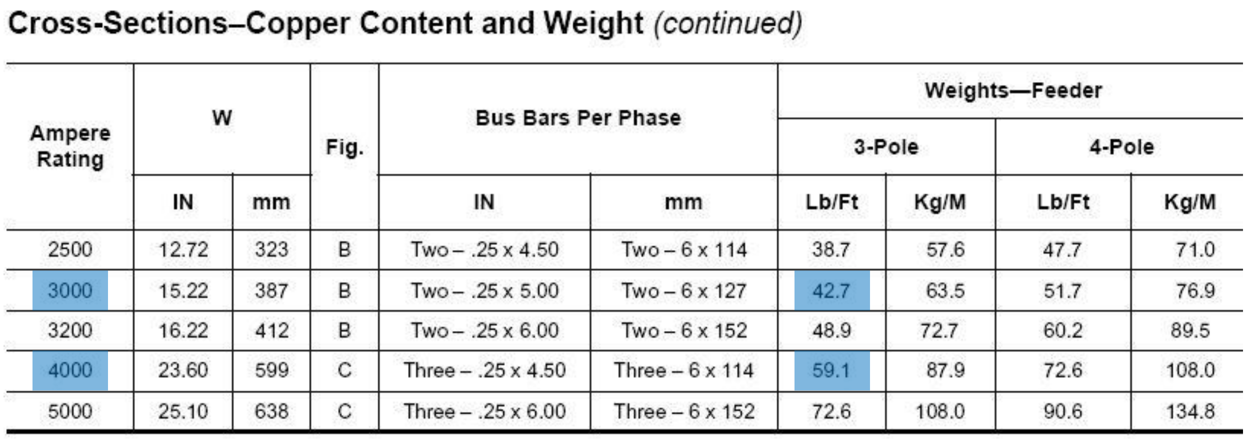
In conclusion, the schedule can be reduced by 2-3 days only from the "Electrical Riser Rough In." Once again, this would not shorten the project schedule, as it is dependent upon other variables, but can help the electrical contractor with resource allocation. It is important to note that the CityCenterDC project has a total of six buildings. This means that work could be required at any time at any of one of these buildings. Having the capability to free up one laborer to use where some tasks are behind in schedule could help the electrical contractor tremendously on the entire project scale.

Constructability

One of the major constructability considerations, and advantages, to reducing the busway to 3000A is the installation aspect. A 4000A busway compared to a 3000A busway weighs 16.4 lbs/1 foot-run more, see Figure 27. According to an electrical foreman from an undisclosed electrical contractor with experience in busway installation, a 4000A busway would require approximately 10-15% more labor hours than a 3000A busway. The most challenging aspect of installing busway is the horizontal components leading from the switchboard to the riser. This is due to the difficulty with which heavier objects and components are set. The heavier they are, the more manpower, equipment, and time required to install them. Once at the riser, special mechanical equipment can be used to hoist the bus duct through the shaft. There was no difference in labor required for the installation of the actual switchboards.

Table 8: Labor Savings from Busway

Item	Labor Hours
4000A Busway	719.9
3000A Busway	626
Labor Savings	**93.9**



Cross-Sections–Copper Content and Weight *(continued)*

Ampere Rating	W		Fig.	Bus Bars Per Phase		Weights—Feeder			
						3-Pole		4-Pole	
	IN	mm		IN	mm	Lb/Ft	Kg/M	Lb/Ft	Kg/M
2500	12.72	323	B	Two – .25 x 4.50	Two – 6 x 114	38.7	57.6	47.7	71.0
3000	15.22	387	B	Two – .25 x 5.00	Two – 6 x 127	42.7	63.5	51.7	76.9
3200	16.22	412	B	Two – .25 x 6.00	Two – 6 x 152	48.9	72.7	60.2	89.5
4000	23.60	599	C	Three – .25 x 4.50	Three – 6 x 114	59.1	87.9	72.6	108.0
5000	25.10	638	C	Three – .25 x 6.00	Three – 6 x 152	72.6	108.0	90.6	134.8

Figure 27: Compares the weights of the two busway sizes

The elimination of the second HVAC panel slightly reduced the labor. Instead of installing two semi-active panelboards, only one fully active panelboard was installed. The type of work and difficulty were the same as the previous design. With the new design though, more wall space was cleared up, allowing for easier workability around the area and less clutter in the electrical closet.

The transformer consolidation aspect of the redesign added a slight level of complexity to the constructability of the system. While less equipment, i.e. a transformer, was installed, the downstream components became more complex. Feeding the two lower level voltage panels from the upper level required coring of the slab. Office Building 1, as mentioned in the Project Information section, utilizes post-tensioned slabs. This means that all of the coring needs to be put in place before the slab is poured and stressed. If the coring had to be done after the slab was poured, drilling into the slab could compromise the structural integrity of the post-tensioned cables. As a result, this design would have needed to exist prior to construction of the slab. A change order in the middle of the project would not be recommended to perform this design change. Careful coordination of the location of the cores would also have to be performed to ensure the proper placement and alignment of the panels. Additional labor would be added for the new feeders and fire-proofing as well. Because the feeders from the upper panels to the lower panels go through the floor slab, they need to be fire-proofed. This could be done via fire-proofed sleeves or application of special caulking after the feeder is placed. However, the total amount of labor for this redesign does not increase. The elimination of the lower level transformer means elimination of labor associated with installing the equipment, wiring, grounding, etc. Thus, while labor is added to one aspect of the system, it is subtracted from another.

Recommendation

Based on the findings of this analysis, it is recommended that this electrical redesign is implemented (prior to the pouring of the slabs). The original system was deemed over-designed and unnecessarily redundant for Office Building 1. Lighting and receptacle power densities were far above the recommended and generally accepted quantities. The $120,940 cost savings amount to a 4.5% savings from the entire electrical system for Office Building 1. Even with the redesign, there is sufficient space for expansion of the system.

Depth 3: Alternative Footbridge Construction Method

Breadth 2: Structural Support

Problem Identification

Five steel footbridges span between Office Building 1 and 2. Each bridge serves as an enclosed walkway from one building to the other. The bridges are supported on either end via steel connections. The structure of the bridges however is separate from the building. That is, while the office buildings are post-tensioned slabs, the bridges are made entirely of steel. They would have to be built separately, either in place or prefabricated, and eventually tied into the existing structure. The project team knew from the onset of the project that the bridges would be one of the most challenging constructability issues. Among the most important considerations were safety of the laborers, effects on the surrounding work, crane placement, and installation. The chosen method of construction proved to be successful, as all bridges were safely and securely installed. However, significant challenges arose during the planning and installation of the bridges. More resources and efforts than originally planned were required to complete the task. The complexity and uniqueness of the task creates a great opportunity for exploration into an alternative construction method.

Background Information

TSI Exterior Wall Systems Inc., the architectural metals contractor responsible for the bridges, devised the installation plan. The first major decision was to prefabricate each of the bridges. Installing the bridges in place would have meant taking extreme safety measures and impacting work around the affected area, resulting in an increased use of resources, accumulating both cost and time. Prefabrication eliminated the safety risks associated with constructing a bridge suspended between two buildings. It also allowed work around the bridge locations to continue without delay. In addition, the level of difficulty associated with constructing the bridge on ground rather than the air was much lower. Crews could work more efficiently and any mistakes on the unique bridge could be resolved without major repercussions. A mistake made while suspended in between two buildings would not only be dangerous, but have significant cost and schedule impacts. However, the new major issue that arose from this decision was how to pick and place the bridges to their final location.

TSI chose a 500 ton Liebherr mobile crane, with a lifting capacity of 51,717 lbs and 138’ jib length. The crane would be mobilized at the intersection of parcels, 1, 2, 3, and 4, as seen in Figure 28 on the next page. The bridges would be assembled, one by one, alongside Parcel 2, within reach of the crane. The crane would then lift each bridge, set it in place, and crews fasten the steel connections.

One of the most challenging aspects of this lift would be to transport the bridge without any structural damage. Calculations showed that if only the steel frame of the bridge was set in place, and then the curtain wall attached on one side, the entire structure would twist and damage the connections, potentially collapsing the unit. As a result, the curtain wall was installed on the ground. To combat both the glass from shattering and the structure from twisting mid-lift, a set of temporary diagonal steel braces were applied to the structure. Once the bridge was installed, they would be removed.

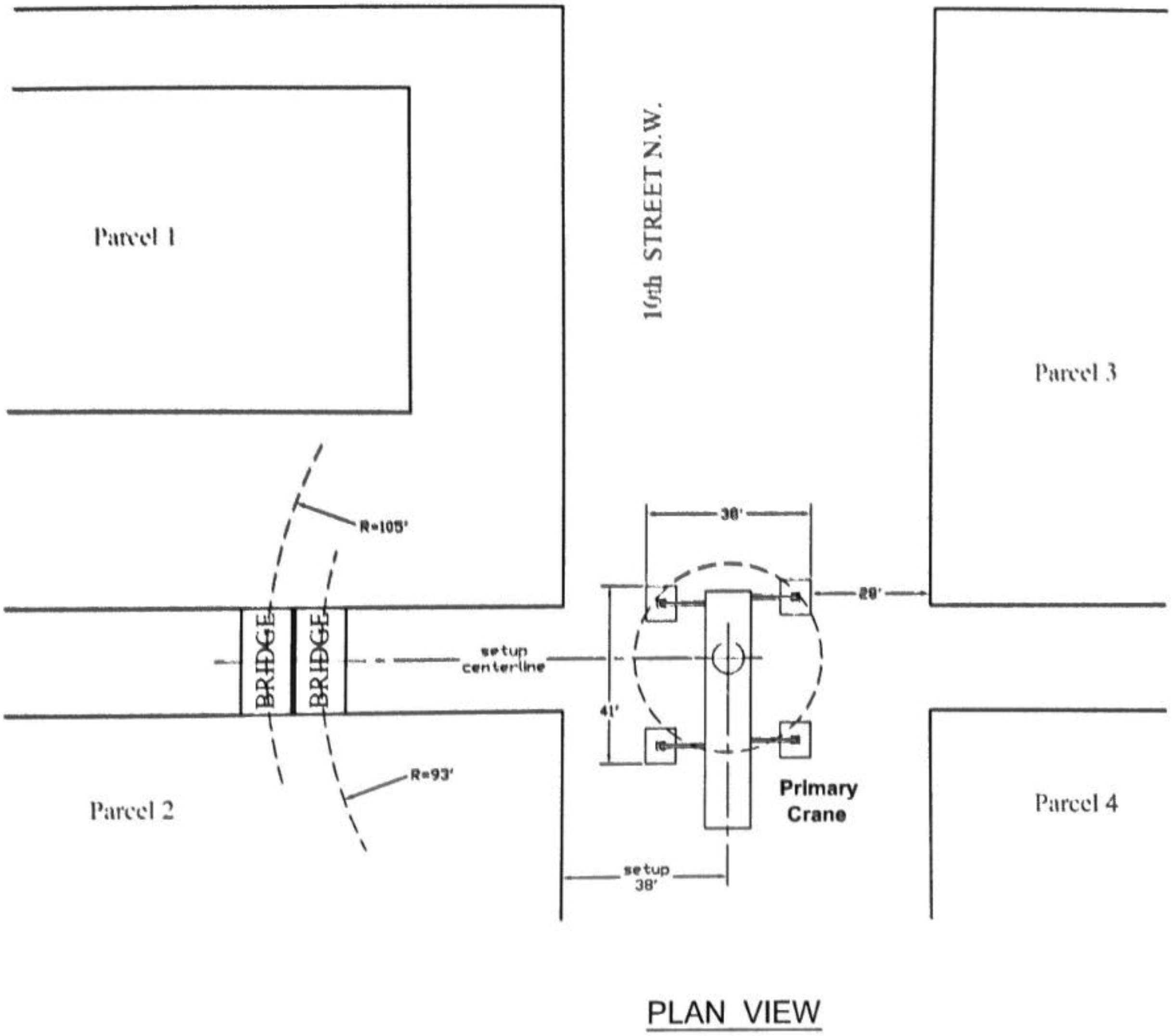


Figure 28: Crane Positioning Diagram

Table 9: Loads

Crane Capacity (lbs)	Load Weight (lbs)	Counterweight (lbs)
51,717	37,681	220,500

As seen in Table 9, the load weight was approximately 73% of the crane capacity. The max working radius was 105', or 23' less than the jib length.

The next, and perhaps most difficult challenge, was ensuring the ground could support the crane. Underneath the location of the crane is a four story concrete parking garage. After calculations of the loads, it was determined that the structure could not support the high loads of the crane and counterweight (220,500 lbs). Unfortunately, there was no other place a crane could be placed onsite, as the garage spanned the entire development. Busy Washington D.C. streets ran around the perimeter of the development, which meant a crane could not be placed there either. In order to combat this problem, TSI designed a shoring system for the four floors beneath the crane. The solution proved successful, and the bridges were successfully installed.

The aforementioned challenges, along with some others, were not fully anticipated by the project team. TSI did an outstanding job at providing effective solutions. However, there were great risks taken to achieve these results and a significant amount of additional resources used.

Research

Facing the difficulties behind the unique footbridges and site conditions, an alternative construction technique was sought after. Following exploration into projects with similar circumstances and structures, a firm specializing in specialty construction was found. VSL Heavy Lifting, a Swiss owned company, provides services “for projects where notable weight, dimensions or space limitations exclude the use of cranes or other conventional handling” (VSL). Their use of specialized hydraulic lifting equipment has proved successful on some of the biggest construction projects around the world. The unique methods have shown to be cost effective as well, as they are able to decrease the supports and false work, limit the size and quantity of cranes, and save time.

What is the VSL System?

The main components of the VSL Strand System, designed for lifting suspended loads, are the motive unit, the pump, and its controls. The motive unit is a tensile member with the anchorage for the load. It consists of a hydraulic center hole jack and upper and lower anchorages, where the upper anchorage is attached to the jack piston. For lifting operations, the jack is extended causing the individual strands of the tensile member to be gripped by the upper anchorage, moving them upwards. When the piston starts to move downward, the strands are gripped by the lower anchorage, while the upper anchorage opens, resulting in the load movement in a step-by-step process. Refer to Figure 29 for illustration.

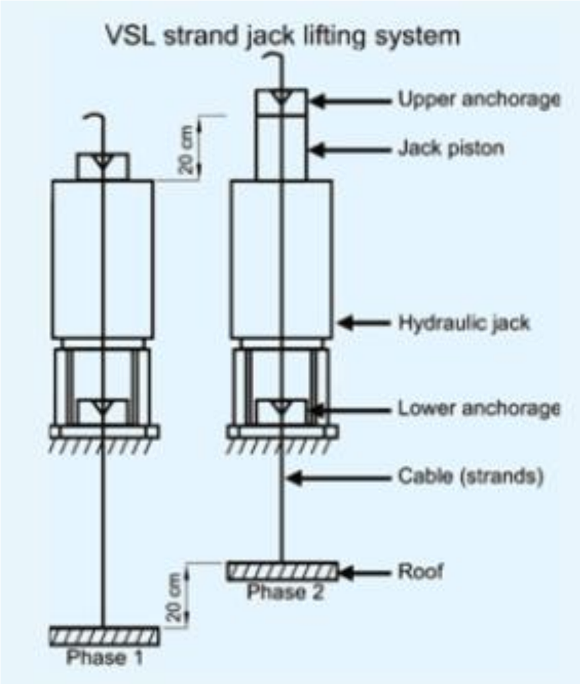


Figure 29: VSL Lifting System | Image courtesy of VSL

Steel strands, 16mm to 254mm in diameter, are used as the tensile members, see Figure 30. They are anchored to the load by a specially designed end anchorage. Electro-hydraulic pumps then provide the motive units with oil flow. Built-in gauges and other control features allow these pumps to create synchronized jack movements, as multiple jacks are usually required for a lift. The speed at which these units can move the load can reach be in excess of 20 m/hour. The units can be controlled either manually or by remote control, achieving precision within millimeters. The range of loads the equipment can lift can reach up to 10,000 tons.

Figure 30: Steel Strands (Tensile Member)

Case Studies

Petronas Twin Towers, Malaysia

The Petronas Twin Towers in Malaysia were the tallest buildings in the world until 2004. Their unique design embodies many aspects of the culture in Malaysia. One of the distinct features of the project was the Skybridge, located in between the 41st and 42nd floor, see Figure 31. The skybridge was prefabricated in South Korea, as building it in-place would have been a nearly impossible task. It was broken up into 5 sections: the main center section (1), the legs (2), and the end blocks (3); refer to Figure 31. Due to the height and weight of these components, a crane could simply not lift them into place. As a result, VSL Heavy Lifting utilized the hydraulic jack system to lift the components into place.

The first step was to lift the legs, one a time, up to their permanent bearings. Next, the two end blocks were lifted, individually, to their final position on level 41. They were slightly offset to provide sufficient clearance for the center section during lifting. The center section, weighing 325 tons, was then ready to be lifted.

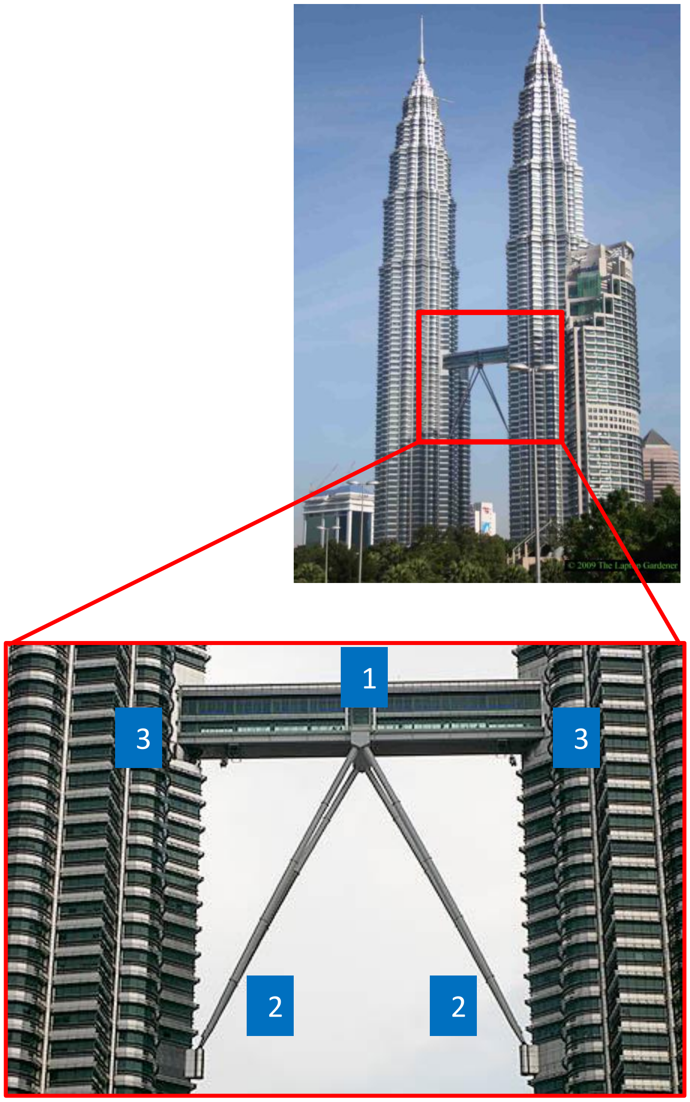


Figure 31: Petronas Towers Skybridge | Google Images

A total of eight lifting jacks were installed to lift the center section. Four were located at level 50, and connected to the bridge center (in blue in Figure 32), and the other four were located on level 48, and connected to the bridge ends (in red). After an extensive series of checks and verifications, the center piece was lifted into place, at a speed of about 12 m/hour. The entire lifting process took approximately 30 hours. In the middle of the lift, weather conditions suddenly changed and strong winds developed. Due to the thorough planning, there were no damages or mishaps from the situation. All of the sections were then connected and fastened to each other.

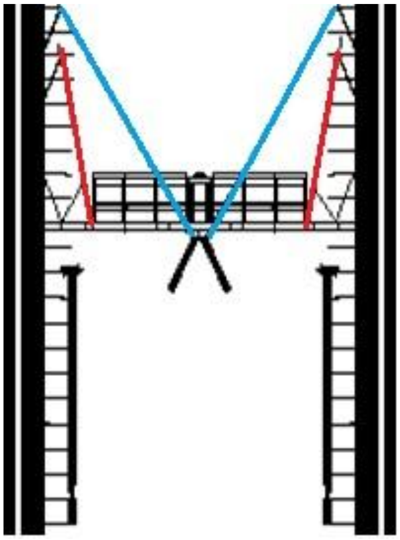


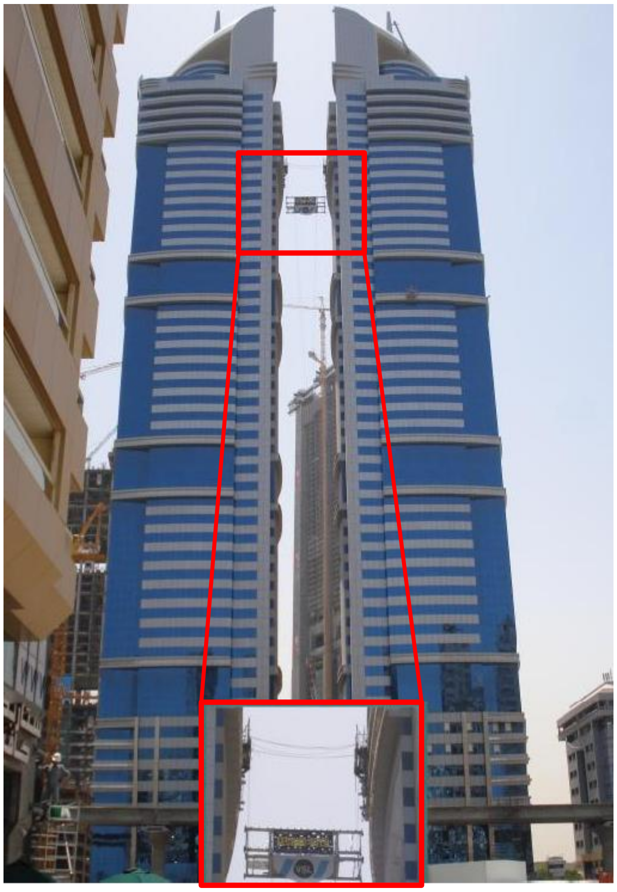
Figure 32: Lifting of center section

VSL's execution of the Petronas Tower's Skybridge lift was a great success and demonstrated the safety and reliability of the unique lifting technique. Their special construction solutions have been applied to many other areas of construction including bridges and roofs. The following is another short examples of the system as applied to footbridges.

Damas Tower Footbridge, UAE

The Damas Towers in Dubai are connected via two footbridges, positioned at 22m and 165m. The bridges were lifted into place using four hydraulic lifting units. Due to strong winds, four more guiding cables were attached to the structure to prevent it from swinging. They were progressively released and controlled from the ground during the entire lift, which took approximately 13 hours.

This project once again demonstrated the effectiveness, both cost and execution-wise, of the VSL Heavy Lifting technology. It is also important to note that the Damas Tower Footbridge is also very similar in shape, size, and material to the bridges at CityCenterDC.



Analysis Goals

Findings from the previously mentioned research suggest that the VSL Heavy Lifting technology would be a suitable alternative to the crane lifting operations of the CityCenterDC footbridges. The following analysis will look into the constructability and feasibility of using VSL's Heavy Lifting system for the CityCenterDC project. It is believed that using this system will improve the constructability, and in turn reduce the extensive costs associated with the mobile crane operation. A schedule analysis will be performed to determine whether this system could save the project valuable time. In addition, a structural breadth will be performed to ensure that the structural integrity of the existing buildings is not compromised, as the jacks and supports needed for this system must be tied into the structure.

Application Results

Before developing a specific work plan, the affected work area must be examined. As seen in Figure 33, the atriums of each building rise 18.5' above the 11th floor level. There are a total of five footbridges, located on levels 3,5,7,9, and 11, highlighted in red. Their positions alternate from the left side to the right side of the atrium. The gap in between the atriums, where the footbridges will be placed, is approximately 20'. The atriums are constructed from steel, primarily HSS and W shaped beams and columns.

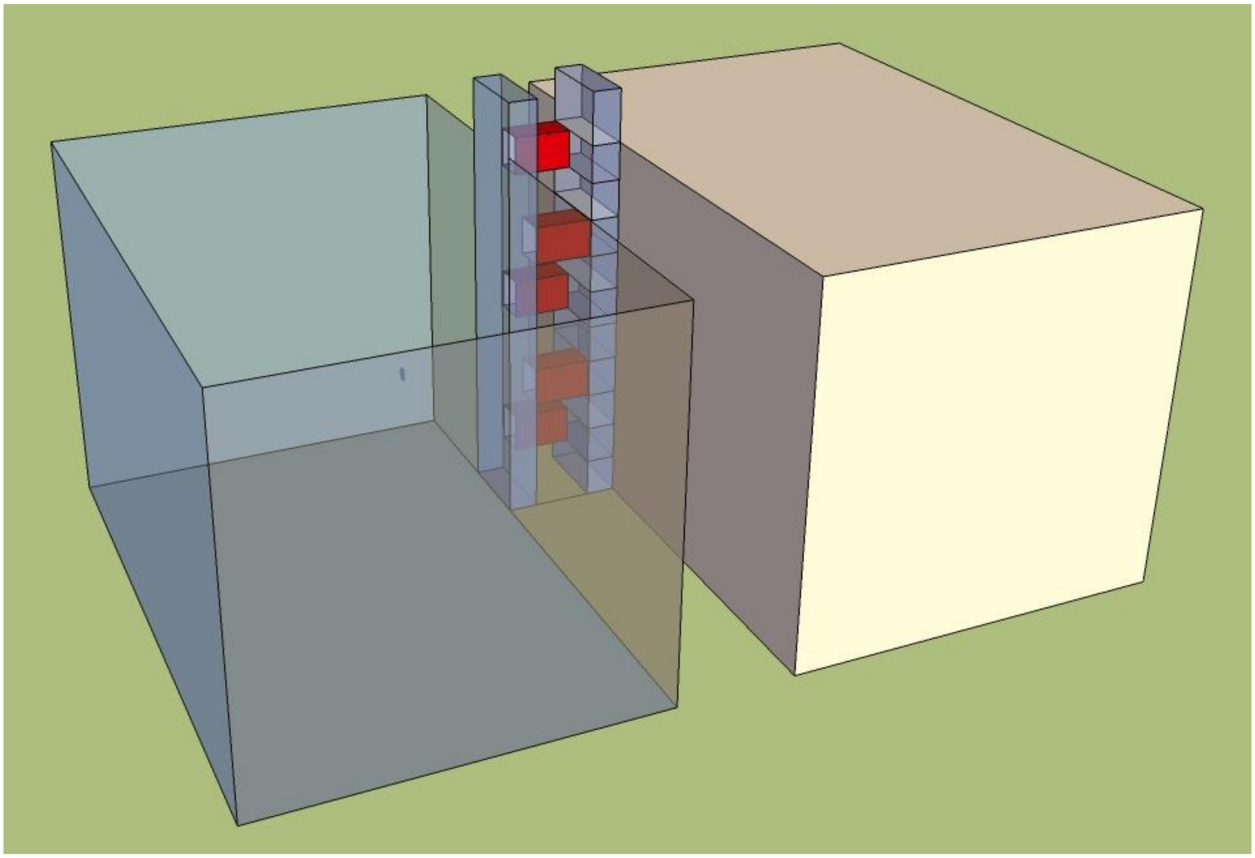


Figure 33: Footbridges shown in red

The first step in establishing this system is to determine the quantity of jacks required, and their respective locations. For the purpose of lifting these footbridges, it was decided that four jacks will be utilized. Each jack will be anchored at a specific location. Determining the best location to anchor the jack will depend greatly on angles. That is, positioning the cable to have a more vertical direction toward the load will decrease the force required to lift it because it decreases the horizontal force component.

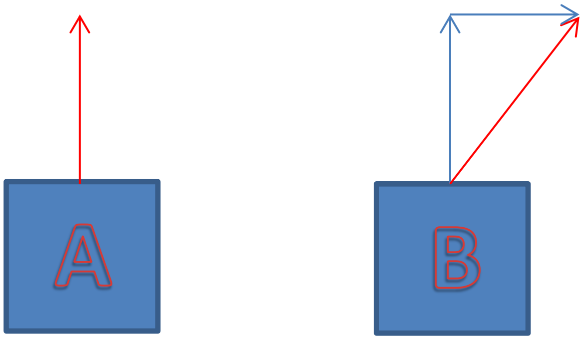


Figure 34: Red indicates the way from which the object is being lifted. The force required to lift Box B will be greater due to the additional horizontal component.

In addition, the T.O.S. of the uppermost footbridge is flush with the roof of the building. This means that if the jack were placed on the roof of the building, the jack would experience an almost completely horizontal force when lifting the final bridge in place. As a result, it was found that the most ideal place to set the jacks was on top of the atrium. Two temporary beams will be spanned across from one atrium to the other. A jack will be placed on either side of the beam, offset 2’ from the edge of the atrium, see Figure 35. By placing the jacks on the beams, directly above the footbridge, a large part of the horizontal force mentioned above is eliminated.

Figure 35: Temporary beam and jacks

The tensile members (strands) from each jack will go to one of the four corners of the footbridge. This will allow for a very regulated and even lift of the structure. Note from Figure 25 below that two of the jacks will have a much larger horizontal component, and thus experience a greater force. This is due to the fact that the bridges alternate from left to right on the atrium. As a result, depending on the bridge, two of the four jacks will experience slightly greater loads. The temporary beams and hydraulic jacks will be removed once all of the footbridges are set in place.

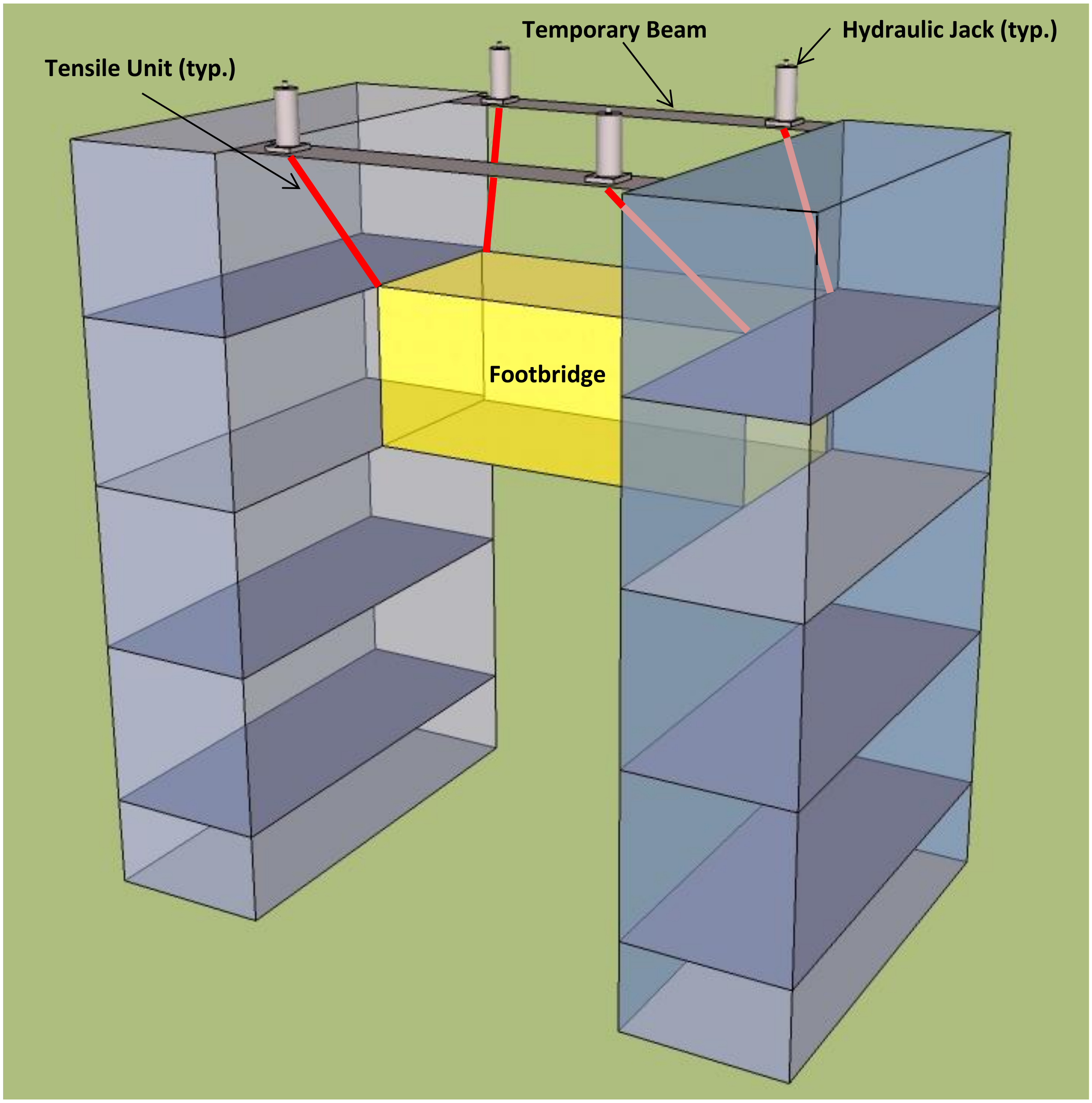


Figure 36: Illustration of lifting of a footbridge

Structural Considerations

The integration of the VSL Heavy Lifting system introduces new loads and forces on the existing structures. By placing the temporary beams in between the two atriums, and attaching the hydraulic jacks on top, axial load is added to the steel columns of the atrium. The beam will experience a moment from the two point loads of the jacks and the tensile units must be able to withstand the forces of holding up the footbridge, which as mentioned before, can have both vertical and horizontal components.

Tensile Units & Selection of Equipment

Each of the four jacks uses steel strands, anchored to each corner of the footbridge, to lift it. In an ideal situation, the jacks would be located directly above each corner of the bridge, and would carry a quarter of the footbridge weight. Unfortunately, this is not possible in this situation due to the positioning of the bridges and jacks which create angles. In order to choose the equipment (jack) with adequate capacity, the greatest force a cable could experience had to be found. As explained earlier, the larger the horizontal component, the larger the total force. Consequently, all positions of the lifts of all the bridges were analyzed and the optimal position was found. It was determined that this position was the uppermost bridge, at the point when it was being maneuvered into its final position. Figure 37 below is an illustration of this position. The red cable, labeled X, will experience the largest force. Calculations of the forces can be found in Appendix C.1.

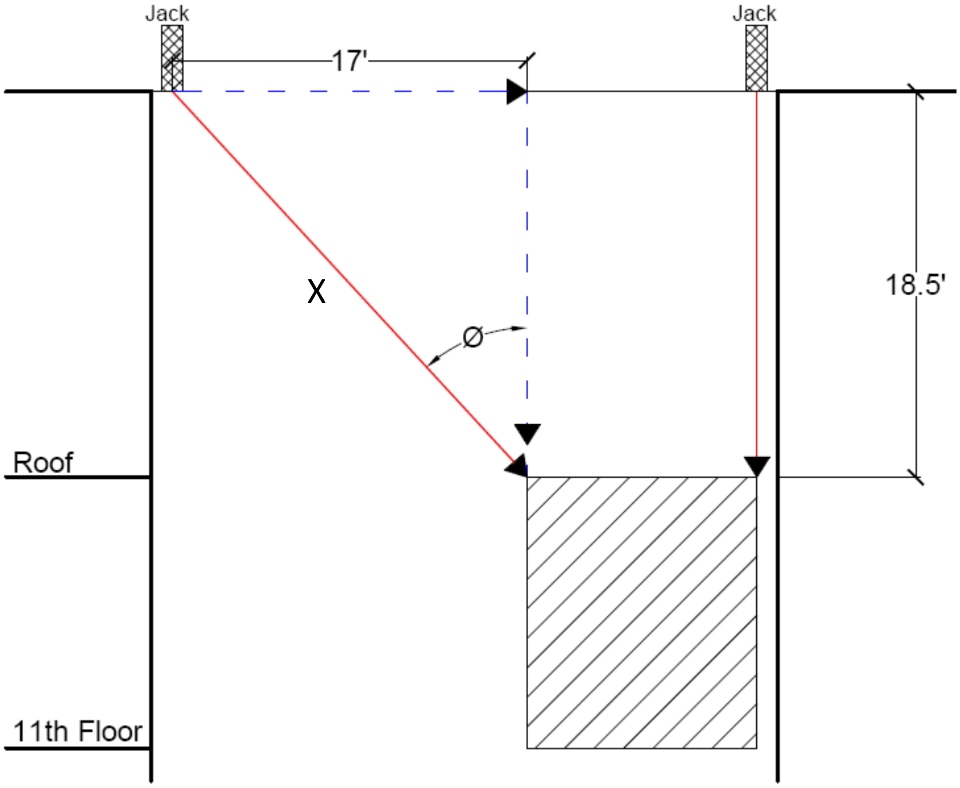
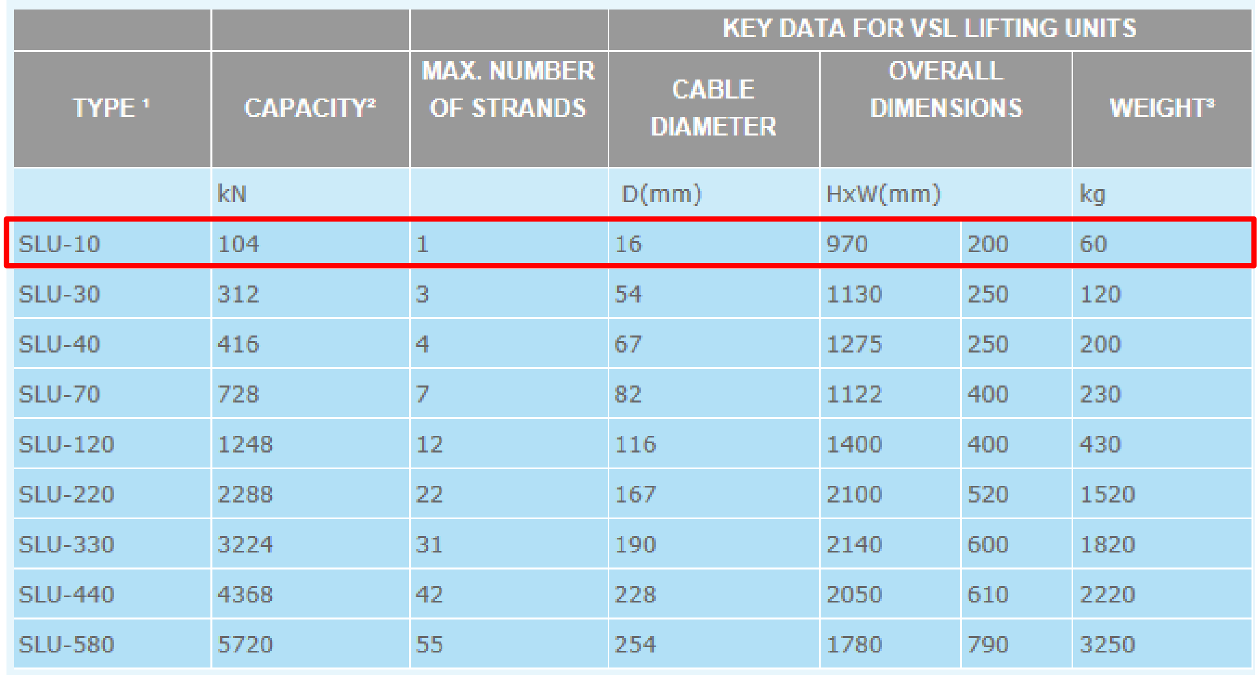


Figure 37: Position where cable X will experience the most force

The next step was to select the appropriate equipment. Table 10, provided by VSL, lists the various sizes, specifications, and capacities of the different available jacks. From the previous step, the maximum force that will be exerted on a strand was equivalent to 12.6 kips. Comparing this, as well as the stress, to the units in the table below, it was found that SLU-10 provided sufficient capacity. In fact, it provided almost twice the necessary capacity. It is also important to consider that the capacities given also have a factor of safety built into them. Thus, Type SLU-10 will be more than sufficient for the job.

Table 10: Equipment Specs



			KEY DATA FOR VSL LIFTING UNITS			
TYPE [1]	CAPACITY[2]	MAX. NUMBER OF STRANDS	CABLE DIAMETER	OVERALL DIMENSIONS		WEIGHT[3]
	kN		D(mm)	HxW(mm)		kg
SLU-10	104	1	16	970	200	60
SLU-30	312	3	54	1130	250	120
SLU-40	416	4	67	1275	250	200
SLU-70	728	7	82	1122	400	230
SLU-120	1248	12	116	1400	400	430
SLU-220	2288	22	167	2100	520	1520
SLU-330	3224	31	190	2140	600	1820
SLU-440	4368	42	228	2050	610	2220
SLU-580	5720	55	254	1780	790	3250

Please refer to Appendix C.1 for calculations.

Column Buckling

Positioning the jacks on the temporary beams spanning in between the atriums would add axial load to the steel columns. As a result, it was necessary to determine if the existing columns would withstand buckling. In order to perform this calculation, all of the roof, floor, exterior, and live loads were found. After finding the floor and exterior wall tributary areas, the total load was calculated for each floor. Please refer to Appendix C.1 for detailed calculations. Next, the capacity of all the steel columns was found from the AISC Steel Manual. It was found that the HSS 10x10x1/2 columns had a capacity of 615 kips. The largest floor load was 171.2 kips. An additional 12.6 kips from the jack and beam would increase the load to 183.8 kips at this location, which was still well below the capacity of the column. Thus, the load added from the temporary beam and jacks would not affect the structural integrity of the steel column on which they rest. The reason the columns seem so over-sized is because they, along with the beams of the atrium structure, must support the footbridges and all the moments and forces associated with them.

Temporary Beam

It was also important to ensure that the temporary beam was properly designed to resist the moment the hydraulic jacks would put on it. Figure 38 illustrates the two point loads the beam would sustain. For sizing purposes, the 12.6 kip maximum load calculated from the previous section was used. As mentioned before, it is the largest load that any strand will experience at any time. The resulting moment from these loads is 25.2 ft-kips. Using the AISC Steel Manual, it was found that the minimum wide flange beam size is W12x14. Web stiffeners should also be used to stiffen the beams from out of plane deformations. Larger beams may be used if larger flange width is required to support jack anchorage.

Wide flange beams were selected for loading and feasibility purposes. The actual beam size, shape, and composition selected by VSL may be different. However, no matter what type of support they choose, it must resist the 25.2 ft-kip moment created by the hydraulic jacks.

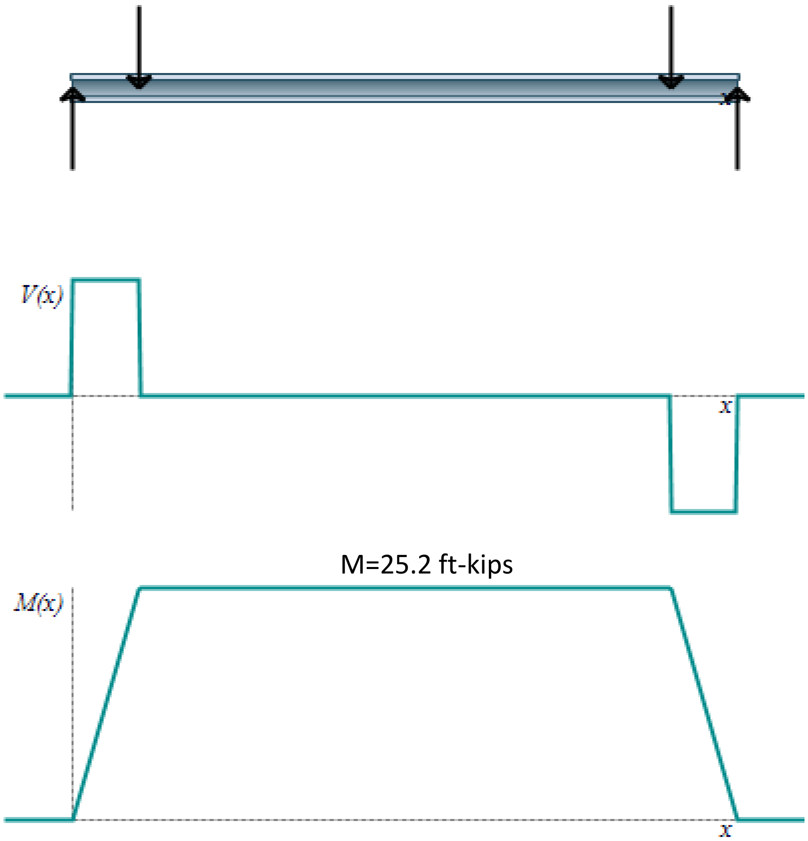


Figure 38: Shear and moment diagram for temporary beam loading

Additional Constructability Considerations

One of the other important constructability challenges is creating an efficient logistical erection plan. First, the prefabrication of the bridges on-site will remain the same as the original plan. Off-site prefabrication was not possible due to the size of the footbridges and the height limitations associated with transporting it on a truck through the streets of Washington D.C. Thus, the footbridges will be constructed on-site, next to Parcel 2, and then transported underneath the hydraulic jacks for lifting. In order to avoid the implications of a mobile crane, as mentioned in the background information section, the bridges will be built on a transportable platform. That is, this platform will sit on wheels, similar to a truck bed, so that it can be rolled to the lifting location. See Figure 39 below for transportation logistics.

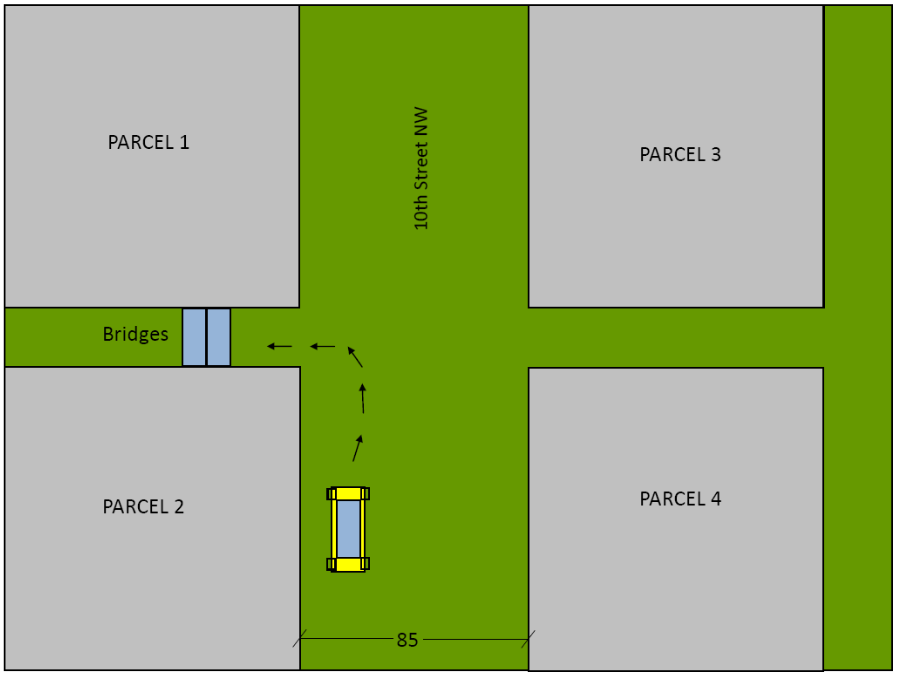


Figure 39: Bridge Transportation

Next, the logistics behind the order in which the bridges would be picked had to be established. If the top bridge was lifted first, the cables would not be able to reach down to the remaining bridges. Consequently, it was decided that the bottom bridge would be first in line, followed by the second, third, fourth, and finally the uppermost. However, once the first two bridges were lifted, the laydown area for the third bridge would have to shift to the side. That is, it could no longer be underneath the hydraulic jacks, because the other two bridges blocked the route. As a result, it was offset enough to where the cables could pick the bridge at an angle and lift it into position without hitting the other bridges. Guiding cables, such as those used in the Damas Tower Footbridges, would be used to stabilize the bridge from swinging. All angles were checked to make sure that they did not exceed the maximum angle used in the cable force calculations above. The maximum offset distances were also calculated to ensure there was sufficient space around the work area to accommodate the pick. Please refer to Appendix C.2 for an illustration of the logistics.

Cost

The total actual cost of the footbridges, from design to installation equated to $1,575,000. Table 11 below provides a breakdown of the costs for the bridges, with material and labor included in each category. It can be seen that the price for the equipment totals $500,000, or 32% of the total cost. In the initial estimate, this figure was smaller and the material prices were higher. Due to the previously mentioned challenges, including shoring, the material prices were reduced, and the equipment prices increased. In the end, the highly skilled team of the contractor did not lose money from the operation.

Table 11: Bridge Cost Breakdown

Item	Cost
Shop Drawings/Engineering	$200,000
Materials	$750,000
Shop Fabrication	$125,000
Equipment	$500,000
Total	**$1,575,000**

VSL's cost effective solutions have been very appealing for large-scale projects around the world. Heavy loads require large cranes, which are scarcer and more expensive as size increases. According to a VSL executive, any work requiring a crane of 200 tons or more will see cost savings if the VSL system is used instead. Consequently, VSL pursues projects of substantial size. In the case of CityCenterDC, as mentioned before, a 500 ton crane was used. Such large cranes are quite scarce to geographical areas, and as a result, very expensive. The equipment used for this job cost $500,000 month alone. The VSL executive, after looking through the details of the project provided a cost estimate for lifting the five footbridges using VSL Heavy Lifting systems. Mobilization costs were estimated at $50,000 and each bridge lift at $20,000, totaling $150,000 for the entire operation. The shop drawings, materials, and shop fabrication would remain the same, as stated earlier. Thus, the total cost of the bridge installation using the VSL hydraulic lifting systems totals $1,225,000, or $350,000 less than the traditional method.

Table 12: Total Cost Using VSL

Item	Cost
Shop Drawings/Engineering	$200,000
Materials	$750,000
Shop Fabrication	$125,000
Equipment	$150,000
Total	**$1,225,000**

Schedule

As mentioned in the Background Information section, the weight of the crane called for shoring in the four underground levels. The shoring took a little over 20 days to install, after which the crane was brought in and mobilized in 4 days. Thus, the mobilization time for the original lifting system was approximately 24 days.

Mobilization of the VSL Heavy Lifting system, from arrival on site to lift, was estimated at 2 months. This included erection of the temporary beams, bracing of the hydraulic jacks, and setting up and testing of the control equipment. Engineers perform extensive simulations and calculations before the lifts to ensure all equipment is working properly. These preparations are crucial to a successful and safe lift.

In order for the VSL system to be applied without delaying the entire schedule, it was necessary for mobilization to occur two months prior to the scheduled lift dates. Mobilization of the VSL system required the steel atriums to be erected, as the temporary beams and jacks spanned across them. After analyzing the steel erection schedule, it was found that the T.O.S. of the atriums was scheduled to be completed 2 months and 10 days before the scheduled lifts. Thus, there was sufficient time for mobilization of the system. Table 13 below outlines the important dates.

Table 13: Important Dates. Note that VSL Mobilization will finish before scheduled lift of Bridge #1.

Activity	Start Date	End Date
Set 9-12 Steel	9/7/12	9/8/12
VSL Mobilization	9/8/12	11/8/12
Shoring	10/18/12	11/2/12
Crane Mobilization	11/2/12	11/7/12
Set Bridge #1	11/20/12	11/20/12

Setting each bridge will take, at most, 3 hours. The original allotment for setting a bridge was 1 day, which is more than twice the time needed. In conclusion, using the VSL hydraulic lifting system will not affect the project schedule. Neither cost savings nor delays will occur due to its implementation.

See Appendix C.3 for complete schedule of atrium steel and bridges.

Recommendations

Based on the results of this analysis it is recommended that the VSL hydraulic lifting system is used in place of the 500 ton mobile crane. The key benefits of this system are fewer constructability concerns and issues and cost savings totaling $350,000. Although this is towards the lower end of the project size VSL would typically pursue, the executive stated that the company would definitely be interested in such a job.

Final Recommendations

Over the course of the 2012/2013 academic year, Office Building 1 of the CityCenterDC development was analyzed to identify areas in which alternative solutions in either construction or design would enhance the project. Through feedback from the project team, independent research, and multiple site visits, three major areas were chosen for additional analysis. A new schedule and phasing plan was implemented through a Short Interval Production Schedule, an electrical redesign was performed, along with a full construction analysis, and an alternative bridge installation method was proposed. It is important to note that the purpose of this thesis and analysis is strictly educational and is not intended to critique the project team in any way.

Analysis #1: SIPS

The first analysis looked to create a new phasing and scheduling plan for the typical floor construction, and implement the results through a Short Interval Production Schedule. The repetitive nature of the activities on each floor allowed for specific crews to be assigned to specific tasks that would repeat on each floor. Per the results of this analysis, it is recommended that the proposed phasing plan and SIPS be implemented on this project. The proposed schedule does not incur any additional expenses to any parties on the project. Contractor savings from general conditions are estimated at $20,524.40. The owner will benefit from beginning the tenant fit-out process sooner, ultimately delivering the building to the client quicker and receiving lease payments earlier.

Analysis #2: Construction Analysis of Electrical Redesign

Investigation into the existing electrical distribution system revealed that the power density was nearly twice as high as generally designed for. As a result, a thorough redesign of the electrical distribution system for Office Building 1 was performed (Breadth 1). Based on the findings of this analysis, it is recommended that this electrical redesign is implemented (prior to the pouring of the slabs). The original system was deemed over-designed and unnecessarily redundant for Office Building 1. Lighting and receptacle power densities were far above the recommended and generally accepted quantities. The $120,940 cost savings amount to a 4.5% savings from the entire electrical system cost for Office Building 1. Even with the redesign, there is sufficient space for expansion of the system. The electrical riser work schedule can be cut in half or the work force reduced. A constructability analysis of the new system revealed that a total of 182 labor hours will be saved and that the proposed equipment will be easier to install.

Analysis #3: Alternative Footbridge Construction Method

Five steel footbridges span between Office Building 1 and Office Building 2. Each bridge serves as an enclosed walkway from one structure to the other. The chosen method of construction consisted of prefabricating the bridges onsite and lifting them into position using a 500 ton mobile crane. Although the method proved successful, many challenges were encountered which led to additional resource use. This analysis proposed the use of VSL Heavy Lifting technology to install the footbridges. Based on the results of this analysis it is recommended that the VSL hydraulic lifting system is used in place of the 500 ton mobile crane. The key benefits of this system are fewer constructability concerns and issues and cost savings totaling $350,000. The original start and finish dates will not be affected, as this system will neither save nor delay the schedule. Structural integrity of the structure will not be compromised through the use of this system.

Conclusion

In conclusion, it is recommended that all three proposed alternatives are applied to the CityCenterDC project. Cost savings from all three analyses would result in project savings of $491,464.40, or 1% of the total project cost. Although the project schedule would not see savings, due to the dependency of the finish work per request of future tenants, the owner will start receiving lease payments earlier. Also, all three analyses provide alternatives which will help reduce constructability issues. As a result, the three analyses are recommended as they are believed to benefit the CityCenterDC project.

Appendix A.1

Original Schedule Durations

Floor	Item	Original Duration	Start Date	End Date	Actual Duration
2	Install Sprinkler Standpipes	5	4/25/2012	5/1/2012	5
2	Duct Riser Rough In	5	4/25/2012	5/1/2012	5
2	Plumbing Riser Rough In	5	4/25/2012	5/1/2012	5
2	Mechanical Riser Rough In	5	4/25/2012	5/1/2012	5
2	Telecom/Security Riser Rough In	5	4/25/2012	5/1/2012	5
2	Electrical Riser Rough In	5	4/25/2012	5/1/2012	5
2	Install AHU	2	5/3/2012	5/7/2012	3
2	Frame & Hang Shaft Walls	5	5/2/2012	5/8/2012	5
2	Close In Shafts	3	5/9/2012	5/11/2012	3
2	Layout & Top Track	5	5/3/2012	5/10/2012	6
2	Install Lavatory Support Steel	3	5/10/2012	5/15/2012	4
2	Rough In Duct Mains	5	5/10/2012	5/17/2012	6
2	Install VAV boxes	5	5/10/2012	5/17/2012	6
2	Frame Walls	5	5/17/2012	5/24/2012	6
2	Mechanical Pipe Rough In	5	5/24/2012	6/1/2012	6
2	Plumbing Rough In	5	5/24/2012	6/1/2012	6
2	Duct Rough In	5	5/24/2012	6/1/2012	6
2	Sprinkler Rough In	5	6/1/2012	6/8/2012	6
2	Frame Ceilings	5	6/8/2012	6/15/2012	6
2	Fire Alarm Rough In	5	6/15/2012	6/22/2012	6
2	Electrical Rough In	5	6/15/2012	6/22/2012	6
3	Install Sprinkler Standpipes	5	5/2/2012	5/8/2012	5
3	Duct Riser Rough In	5	5/2/2012	5/8/2012	5
3	Plumbing Riser Rough In	5	5/2/2012	5/8/2012	5
3	Mechanical Riser Rough In	5	5/2/2012	5/8/2012	5
3	Telecom/Security Riser Rough In	5	5/2/2012	5/8/2012	5
3	Electrical Riser Rough In	5	5/2/2012	5/8/2012	5
3	Install AHU	2	5/8/2012	5/9/2012	2
3	Frame & Hang Shaft Walls	5	5/9/2012	5/15/2012	5
3	Close In Shafts	3	5/16/2012	5/18/2012	3
3	Layout & Top Track	5	5/10/2012	5/17/2012	6
3	Install Lavatory Support Steel	3	5/17/2012	5/22/2012	4
3	Rough In Duct Mains	5	5/17/2012	5/24/2012	6
3	Install VAV boxes	5	5/17/2012	5/24/2012	6
3	Frame Walls	5	5/24/2012	6/1/2012	6
3	Mechanical Pipe Rough In	5	6/1/2012	6/8/2012	6
3	Plumbing Rough In	5	6/1/2012	6/8/2012	6
3	Duct Rough In	5	6/1/2012	6/8/2012	6
3	Sprinkler Rough In	5	6/8/2012	6/15/2012	6
3	Frame Ceilings	5	6/15/2012	6/22/2012	6
3	Fire Alarm Rough In	5	6/22/2012	6/29/2012	6
3	Electrical Rough In	5	6/22/2012	6/29/2012	6
4	Install Sprinkler Standpipes	5	5/9/2012	5/15/2012	5

4	Duct Riser Rough In	5	5/9/2012	5/15/2012	5
4	Plumbing Riser Rough In	5	5/9/2012	5/15/2012	5
4	Mechanical Riser Rough In	5	5/9/2012	5/15/2012	5
4	Telecom/Security Riser Rough In	5	5/9/2012	5/15/2012	5
4	Electrical Riser Rough In	5	5/9/2012	5/15/2012	5
4	Install AHU	2	5/15/2012	5/16/2012	2
4	Frame & Hang Shaft Walls	5	5/16/2012	5/22/2012	5
4	Close In Shafts	5	5/23/2012	5/30/2012	5
4	Layout & Top Track	5	5/17/2012	5/24/2012	6
4	Install Lavatory Support Steel	3	5/24/2012	5/30/2012	4
4	Rough In Duct Mains	5	5/24/2012	6/1/2012	6
4	Install VAV boxes	5	5/24/2012	6/1/2012	6
4	Frame Walls	5	6/1/2012	6/8/2012	6
4	Mechanical Pipe Rough In	5	6/8/2012	6/15/2012	6
4	Plumbing Rough In	5	6/8/2012	6/15/2012	6
4	Duct Rough In	5	6/8/2012	6/15/2012	6
4	Sprinkler Rough In	5	6/15/2012	6/22/2012	6
4	Frame Ceilings	5	6/22/2012	6/29/2012	6
4	Fire Alarm Rough In	5	6/29/2012	7/9/2012	6
4	Electrical Rough In	5	6/29/2012	7/9/2012	6
5	Install Sprinkler Standpipes	5	5/16/2012	5/22/2012	5
5	Duct Riser Rough In	5	5/16/2012	5/22/2012	5
5	Plumbing Riser Rough In	5	5/16/2012	5/22/2012	5
5	Mechanical Riser Rough In	5	5/16/2012	5/22/2012	5
5	Telecom/Security Riser Rough In	5	5/16/2012	5/22/2012	5
5	Electrical Riser Rough In	5	5/16/2012	5/22/2012	5
5	Install AHU	2	5/22/2012	5/23/2012	2
5	Frame & Hang Shaft Walls	5	5/23/2012	5/30/2012	5
5	Close In Shafts	3	5/31/2012	6/4/2012	3
5	Layout & Top Track	5	5/24/2012	6/1/2012	6
5	Install Lavatory Support Steel	3	6/1/2012	6/6/2012	4
5	Rough In Duct Mains	5	6/1/2012	6/8/2012	6
5	Install VAV boxes	5	6/1/2012	6/8/2012	6
5	Frame Walls	5	6/8/2012	6/15/2012	6
5	Mechanical Pipe Rough In	5	6/15/2012	6/22/2012	6
5	Plumbing Rough In	5	6/15/2012	6/22/2012	6
5	Duct Rough In	5	6/15/2012	6/22/2012	6
5	Sprinkler Rough In	5	6/22/2012	6/29/2012	6
5	Frame Ceilings	5	6/29/2012	7/9/2012	6
5	Fire Alarm Rough In	5	7/9/2012	7/16/2012	6
5	Electrical Rough In	5	7/9/2012	7/16/2012	6
6	Install Sprinkler Standpipes	5	5/23/2012	5/30/2012	5
6	Duct Riser Rough In	5	5/23/2012	5/30/2012	5
6	Plumbing Riser Rough In	5	5/23/2012	5/30/2012	5
6	Mechanical Riser Rough In	5	5/23/2012	5/30/2012	5
6	Telecom/Security Riser Rough In	5	5/23/2012	5/30/2012	5
6	Electrical Riser Rough In	5	5/23/2012	5/29/2012	4

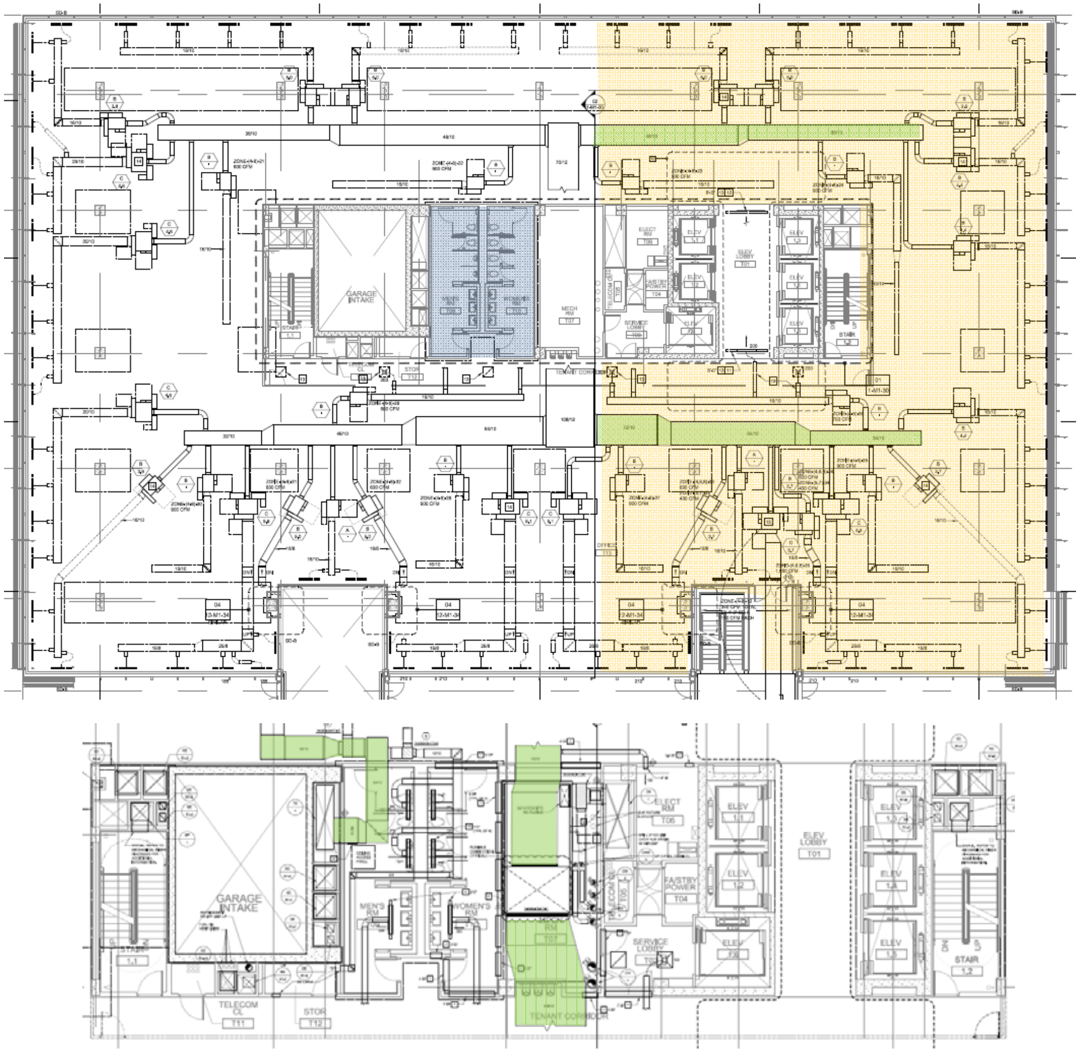
6	Install AHU	2	5/29/2012	5/30/2012	2
6	Frame & Hang Shaft Walls	5	5/31/2012	6/6/2012	5
6	Close In Shafts	3	6/7/2012	6/11/2012	3
6	Layout & Top Track	5	6/1/2012	6/8/2012	6
6	Install Lavatory Support Steel	3	6/8/2012	6/13/2012	4
6	Rough In Duct Mains	5	6/8/2012	6/15/2012	6
6	Install VAV boxes	5	6/8/2012	6/15/2012	6
6	Frame Walls	5	6/15/2012	6/22/2012	6
6	Mechanical Pipe Rough In	5	6/22/2012	6/29/2012	6
6	Plumbing Rough In	5	6/22/2012	6/29/2012	6
6	Duct Rough In	5	6/22/2012	6/29/2012	6
6	Sprinkler Rough In	5	6/29/2012	7/6/2012	5
6	Frame Ceilings	5	7/6/2012	7/13/2012	6
6	Fire Alarm Rough In	5	7/13/2012	7/20/2012	6
6	Electrical Rough In	5	7/13/2012	7/20/2012	6
7	Install Sprinkler Standpipes	5	5/31/2012	6/6/2012	5
7	Duct Riser Rough In	5	5/31/2012	6/6/2012	5
7	Plumbing Riser Rough In	5	5/31/2012	6/6/2012	5
7	Mechanical Riser Rough In	5	5/31/2012	6/6/2012	5
7	Telecom/Security Riser Rough In	5	5/31/2012	6/6/2012	5
7	Electrical Riser Rough In	5	5/30/2012	6/5/2012	5
7	Install AHU	2	6/1/2012	6/5/2012	3
7	Frame & Hang Shaft Walls	5	6/7/2012	6/13/2012	5
7	Close In Shafts	3	6/14/2012	6/18/2012	3
7	Layout & Top Track	5	6/8/2012	6/15/2012	6
7	Install Lavatory Support Steel	3	6/15/2012	6/20/2012	4
7	Rough In Duct Mains	5	6/15/2012	6/22/2012	6
7	Install VAV boxes	5	6/15/2012	6/22/2012	6
7	Frame Walls	5	6/22/2012	6/29/2012	6
7	Mechanical Pipe Rough In	5	6/29/2012	7/6/2012	5
7	Plumbing Rough In	5	6/29/2012	7/9/2012	6
7	Duct Rough In	5	6/29/2012	7/9/2012	6
7	Sprinkler Rough In	5	7/9/2012	7/16/2012	6
7	Frame Ceilings	5	7/16/2012	7/23/2012	6
7	Fire Alarm Rough In	5	7/23/2012	7/30/2012	6
7	Electrical Rough In	5	7/23/2012	7/30/2012	6
8	Install Sprinkler Standpipes	5	7/7/2012	7/13/2012	5
8	Duct Riser Rough In	5	7/7/2012	7/13/2012	5
8	Plumbing Riser Rough In	5	7/7/2012	7/13/2012	5
8	Mechanical Riser Rough In	5	7/7/2012	7/13/2012	5
8	Telecom/Security Riser Rough In	5	7/7/2012	7/13/2012	5
8	Electrical Riser Rough In	5	6/6/2012	6/12/2012	5
8	Install AHU	2	6/14/2012	6/15/2012	2
8	Frame & Hang Shaft Walls	5	6/14/2012	6/20/2012	5
8	Close In Shafts	3	6/21/2012	6/25/2012	3
8	Layout & Top Track	5	6/15/2012	6/22/2012	6
8	Install Lavatory Support Steel	3	6/22/2012	6/27/2012	4

8	Rough In Duct Mains	5	6/22/2012	6/29/2012	6
8	Install VAV boxes	5	6/22/2012	6/29/2012	6
8	Frame Walls	5	6/29/2012	7/9/2012	6
8	Mechanical Pipe Rough In	5	7/9/2012	7/16/2012	6
8	Plumbing Rough In	5	7/9/2012	7/16/2012	6
8	Duct Rough In	5	7/9/2012	7/16/2012	6
8	Sprinkler Rough In	5	7/16/2012	7/23/2012	6
8	Frame Ceilings	5	7/23/2012	7/30/2012	6
8	Fire Alarm Rough In	5	7/30/2012	8/6/2012	6
8	Electrical Rough In	5	7/30/2012	8/6/2012	6
9	Install Sprinkler Standpipes	5	6/14/2012	6/20/2012	5
9	Duct Riser Rough In	5	6/14/2012	6/20/2012	5
9	Plumbing Riser Rough In	5	6/14/2012	6/20/2012	5
9	Mechanical Riser Rough In	5	6/14/2012	6/20/2012	5
9	Telecom/Security Riser Rough In	5	6/14/2012	6/20/2012	5
9	Electrical Riser Rough In	5	6/13/2012	6/19/2012	5
9	Install AHU	2	6/19/2012	6/20/2012	2
9	Frame & Hang Shaft Walls	5	6/21/2012	6/27/2012	5
9	Close In Shafts	3	6/28/2012	7/2/2012	3
9	Layout & Top Track	5	6/22/2012	6/29/2012	6
9	Install Lavatory Support Steel	3	6/29/2012	7/5/2012	4
9	Rough In Duct Mains	5	6/29/2012	7/9/2012	6
9	Install VAV boxes	5	6/29/2012	7/9/2012	6
9	Frame Walls	5	7/9/2012	7/16/2012	6
9	Mechanical Pipe Rough In	5	7/16/2012	7/23/2012	6
9	Plumbing Rough In	5	7/16/2012	7/23/2012	6
9	Duct Rough In	5	7/16/2012	7/23/2012	6
9	Sprinkler Rough In	5	7/23/2012	7/30/2012	6
9	Frame Ceilings	5	7/30/2012	8/6/2012	6
9	Fire Alarm Rough In	5	8/6/2012	8/13/2012	6
9	Electrical Rough In	5	8/6/2012	8/13/2012	6
10	Install Sprinkler Standpipes	5	6/21/2012	6/27/2012	5
10	Duct Riser Rough In	5	6/21/2012	6/27/2012	5
10	Plumbing Riser Rough In	5	6/21/2012	6/27/2012	5
10	Mechanical Riser Rough In	5	6/21/2012	6/27/2012	5
10	Telecom/Security Riser Rough In	5	6/21/2012	6/27/2012	5
10	Electrical Riser Rough In	5	6/20/2012	6/26/2012	5
10	Install AHU	2	6/22/2012	6/25/2012	2
10	Frame & Hang Shaft Walls	5	6/28/2012	7/5/2012	5
10	Close In Shafts	3	7/6/2012	7/10/2012	3
10	Layout & Top Track	5	6/29/2012	7/9/2012	6
10	Install Lavatory Support Steel	3	7/9/2012	7/12/2012	4
10	Rough In Duct Mains	5	7/9/2012	7/16/2012	6
10	Install VAV boxes	5	7/9/2012	7/16/2012	6
10	Frame Walls	5	7/16/2012	7/23/2012	6
10	Mechanical Pipe Rough In	5	7/23/2012	7/30/2012	6
10	Plumbing Rough In	5	7/23/2012	7/30/2012	6

10	Duct Rough In	5	7/23/2012	7/30/2012	6
10	Sprinkler Rough In	5	7/30/2012	8/6/2012	6
10	Frame Ceilings	5	8/6/2012	8/13/2012	6
10	Fire Alarm Rough In	5	8/13/2012	8/20/2012	6
10	Electrical Rough In	5	8/13/2012	8/20/2012	6
11	Install Sprinkler Standpipes	5	6/28/2012	7/5/2012	5
11	Duct Riser Rough In	5	6/28/2012	7/5/2012	5
11	Plumbing Riser Rough In	5	6/28/2012	7/5/2012	5
11	Mechanical Riser Rough In	5	6/28/2012	7/5/2012	5
11	Telecom/Security Riser Rough In	5	6/28/2012	7/5/2012	5
11	Electrical Riser Rough In	5	6/27/2012	7/3/2012	5
11	Install AHU	2	6/27/2012	6/28/2012	2
11	Frame & Hang Shaft Walls	5	7/6/2012	7/12/2012	5
11	Close In Shafts	3	7/13/2012	7/17/2012	3
11	Layout & Top Track	5	7/9/2012	7/16/2012	6
11	Install Lavatory Support Steel	3	7/16/2012	7/19/2012	4
11	Rough In Duct Mains	5	7/16/2012	7/23/2012	6
11	Install VAV boxes	5	7/16/2012	7/23/2012	6
11	Frame Walls	5	7/23/2012	7/30/2012	6
11	Mechanical Pipe Rough In	5	7/30/2012	8/6/2012	6
11	Plumbing Rough In	5	7/30/2012	8/6/2012	6
11	Duct Rough In	5	7/30/2012	8/6/2012	6
11	Sprinkler Rough In	5	8/6/2012	8/13/2012	6
11	Frame Ceilings	5	8/13/2012	8/20/2012	6
11	Fire Alarm Rough In	5	8/20/2012	8/27/2012	6
11	Electrical Rough In	5	8/20/2012	8/27/2012	6
				Total Days Over	**119**

Appendix A.2

SIPS Logistics Diagrams

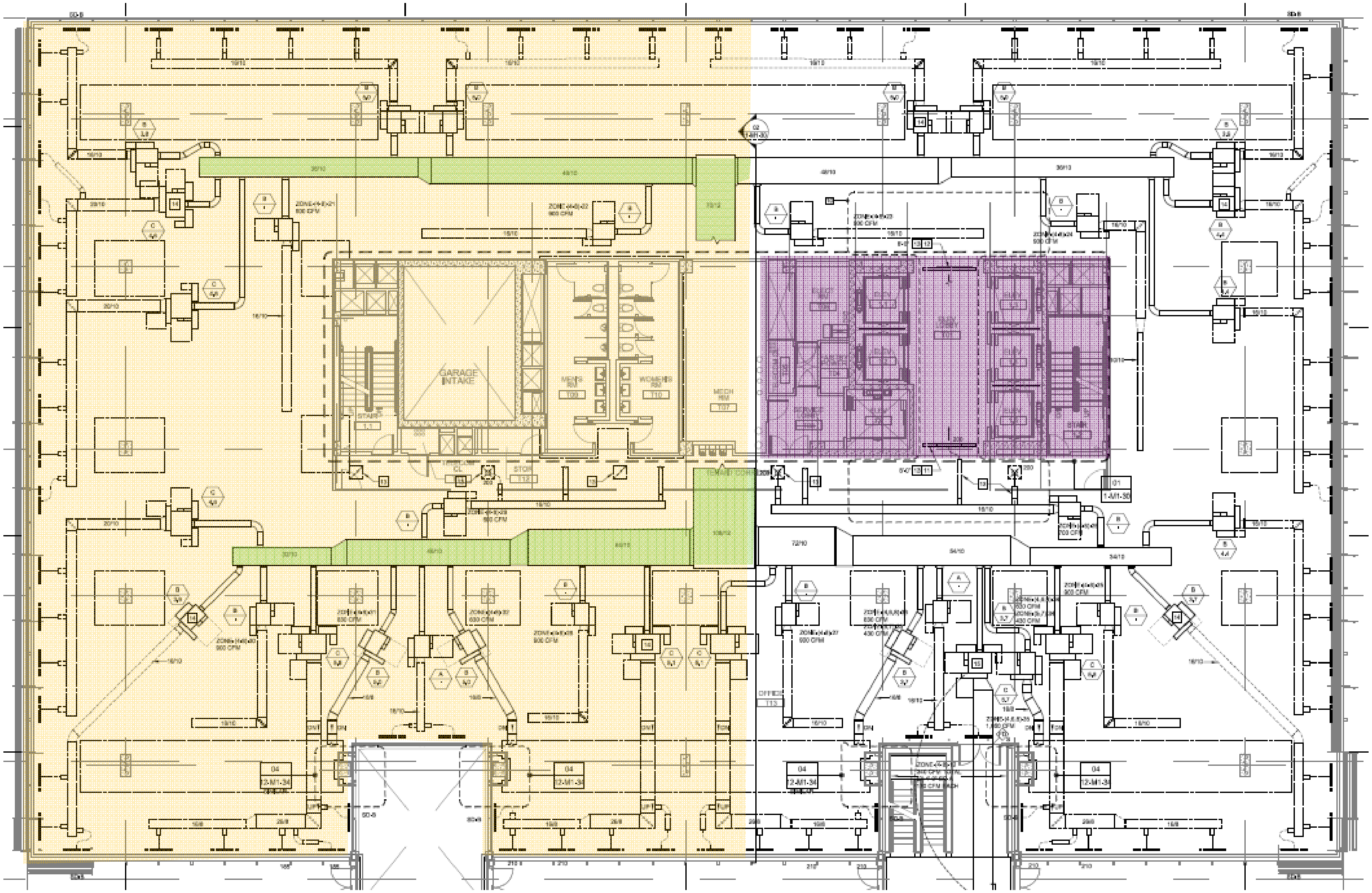


Rough In Duct Mains & Install VAV Boxes **AND** Lavatory Steel

🟨 Install VAV Boxes

🟦 Lavatory Steel

🟩 Rough In Duct Mains

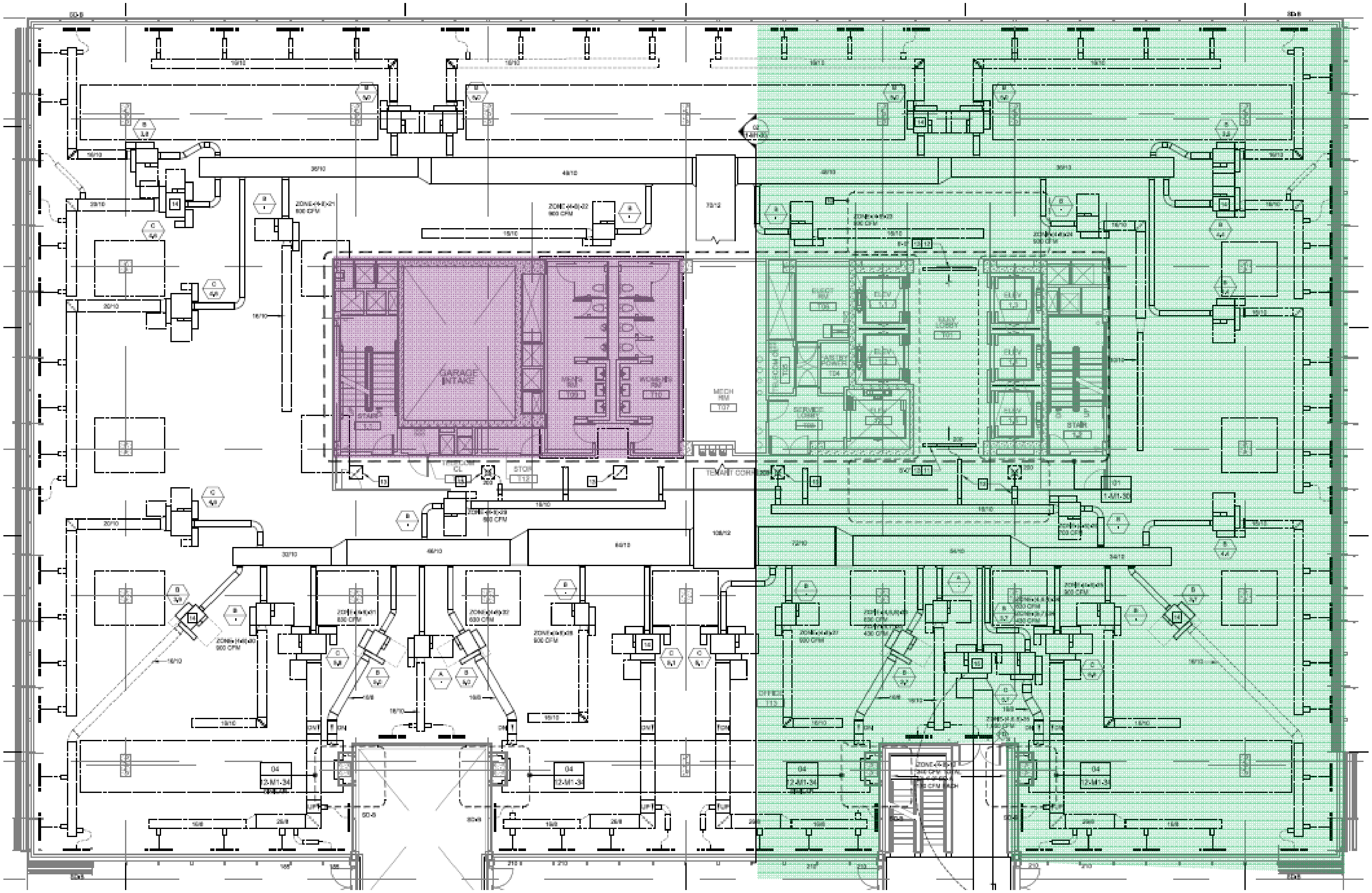


Rough In Duct Mains & Install VAV Boxes **AND** Frame Walls

🟨 Install VAV Boxes

🟪 Frame Walls

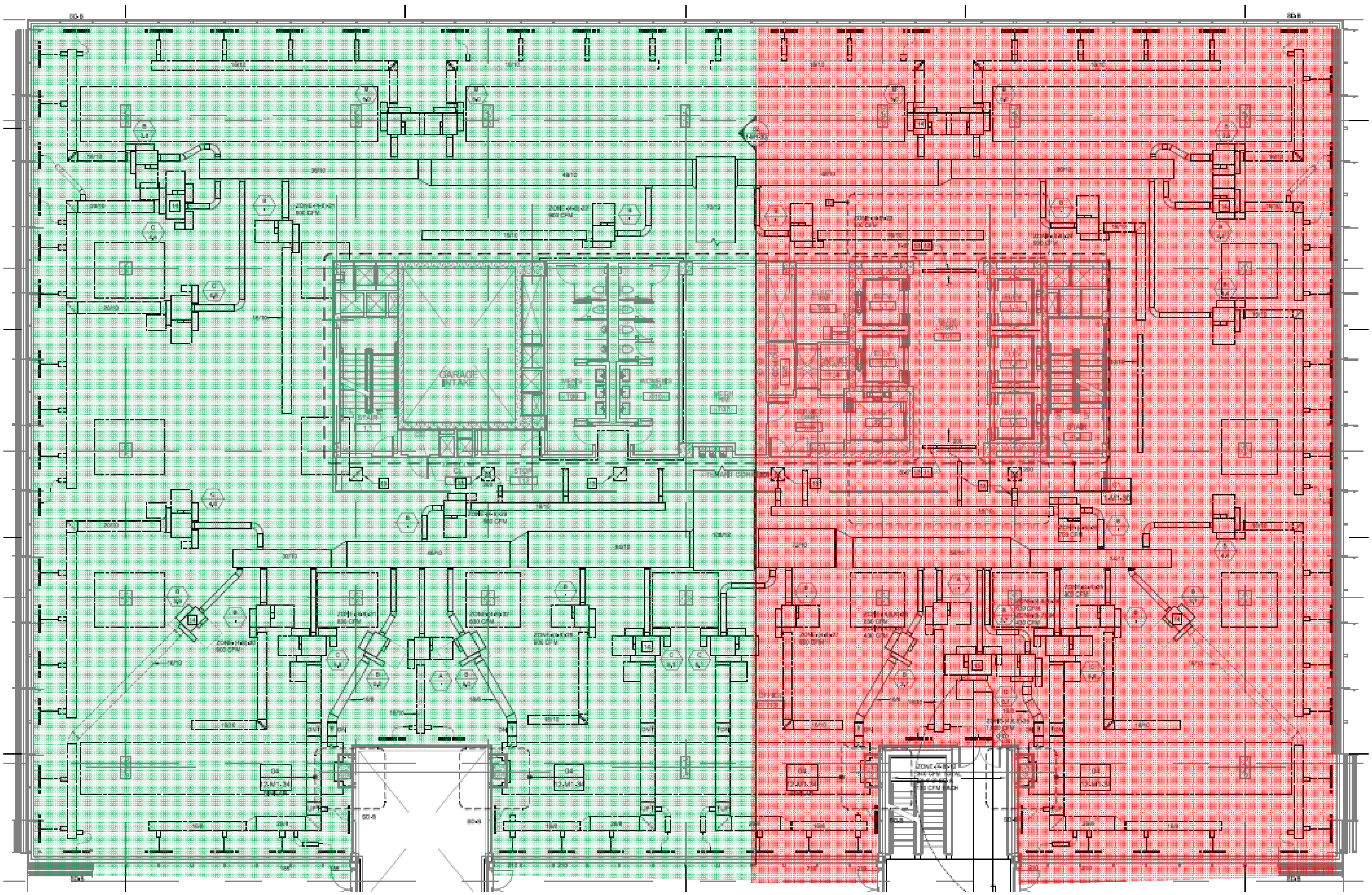
🟩 Rough In Duct Mains



Frame Walls **AND** Mechanical Pipe, Plumbing, Duct Rough In

🟩 Mechanical Pipe, Plumbing, Duct Rough In

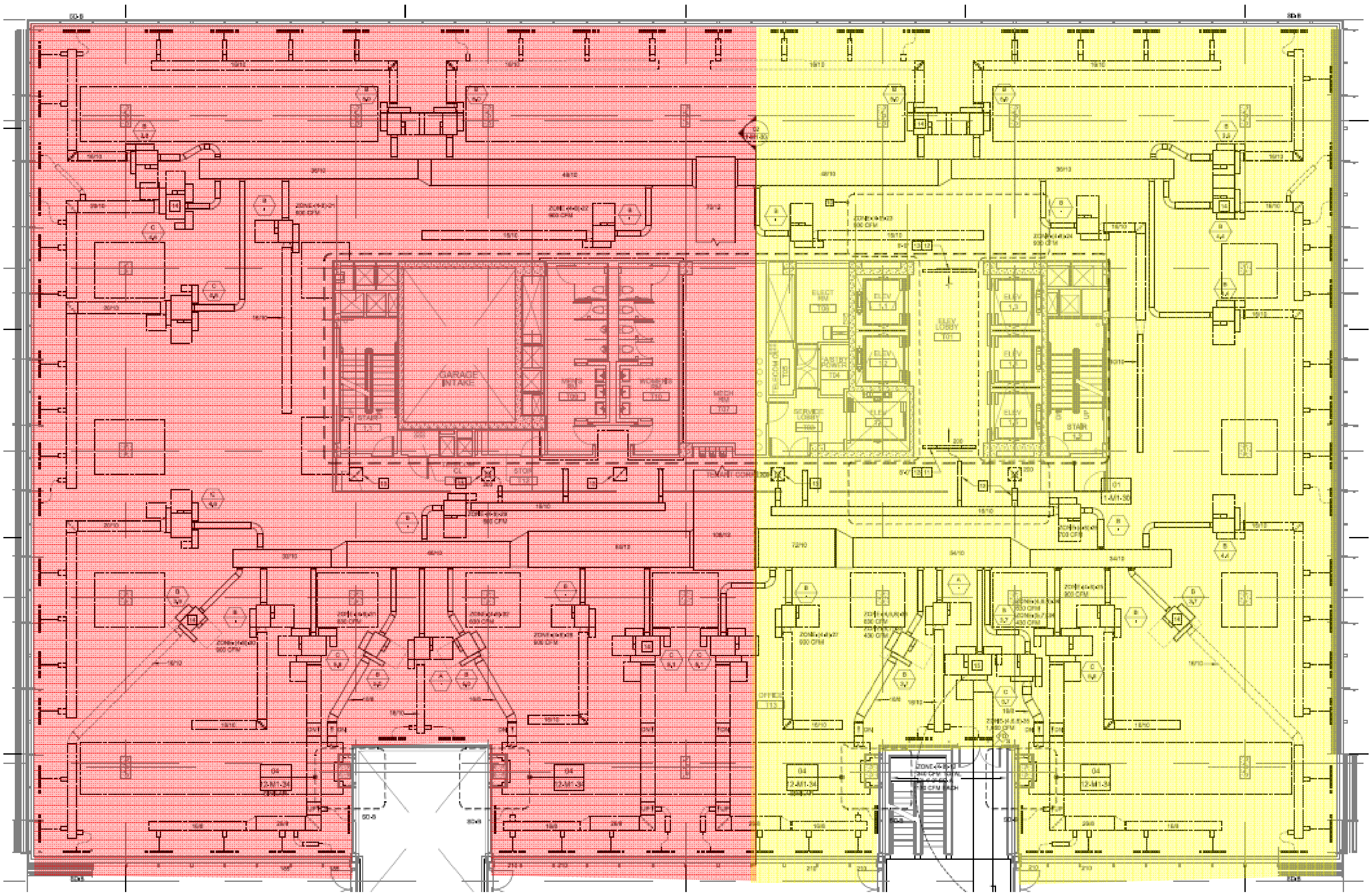
🟪 Frame Walls



Mechanical Pipe, Plumbing, Duct Rough In **AND** Electrical and Fire Alarm Rough In

🟩 Mechanical Pipe, Plumbing, Duct Rough In

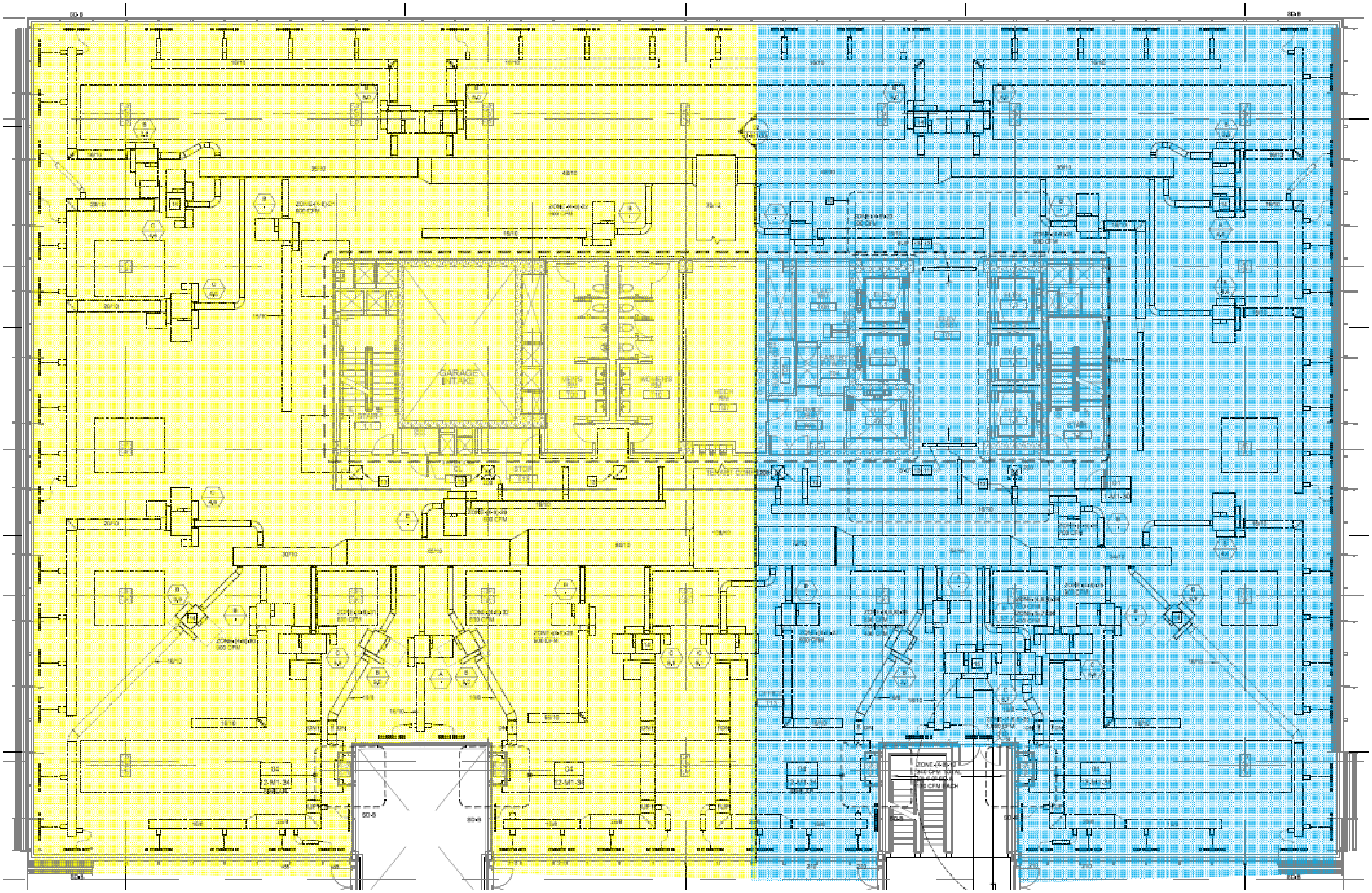
🟥 Electrical and Fire Alarm Rough In



Electrical and Fire Alarm Rough In **AND** Sprinkler Rough In

🟨 Sprinkler Rough In

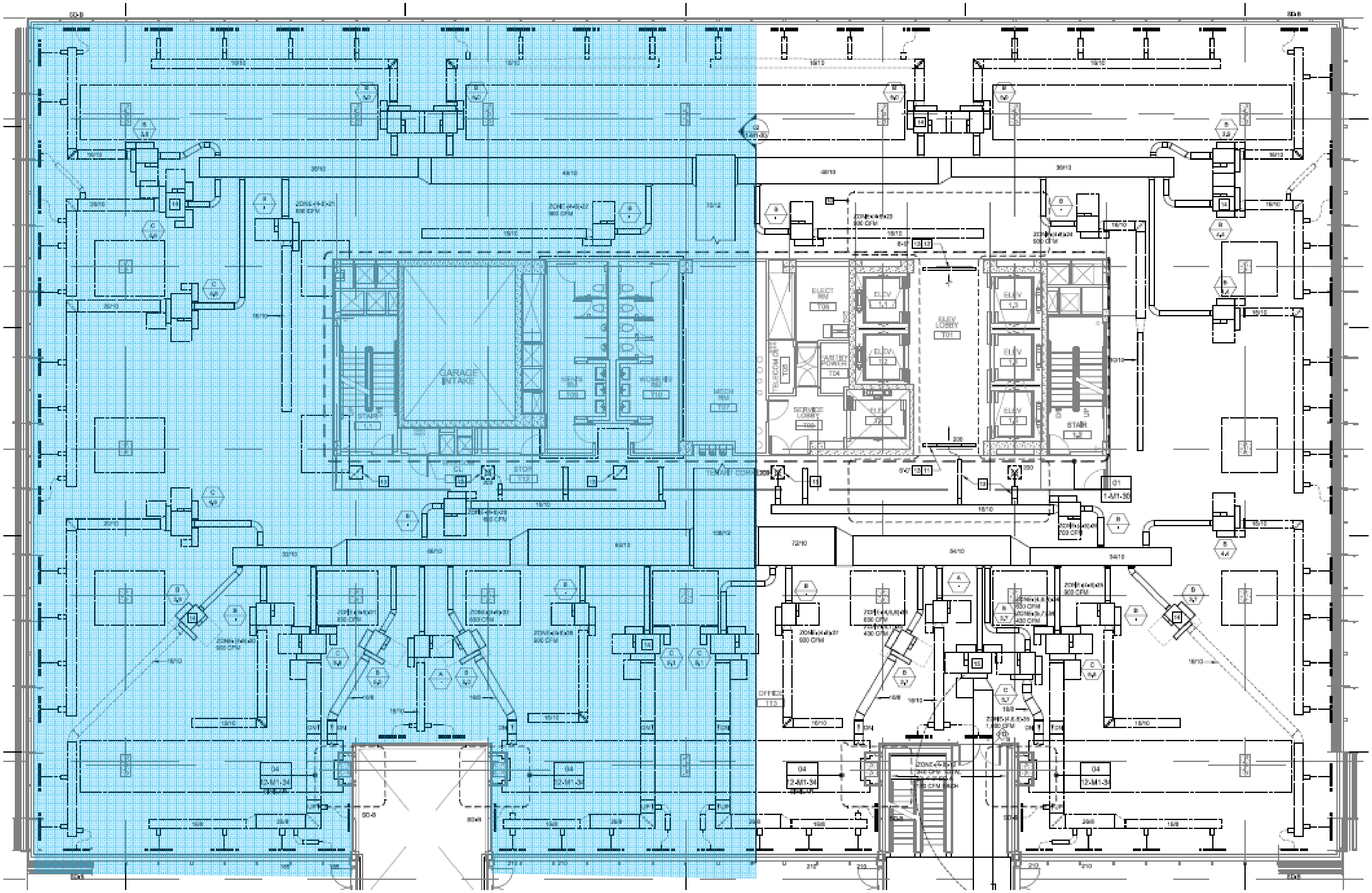
🟥 Electrical and Fire Alarm Rough In



Sprinkler Rough In **AND** Frame Ceilings

🟨 Sprinkler Rough In

🟦 Frame Ceilings



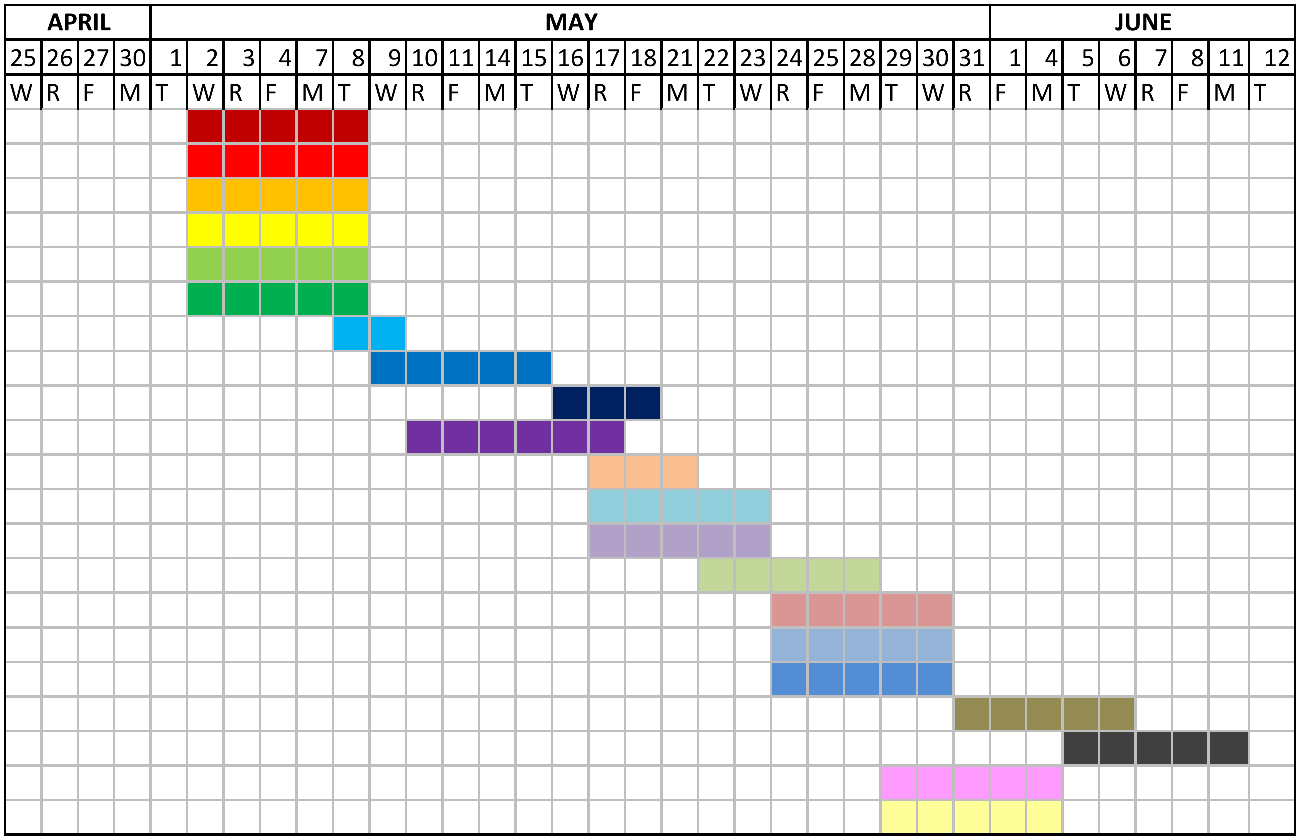
Finish Framing Ceilings

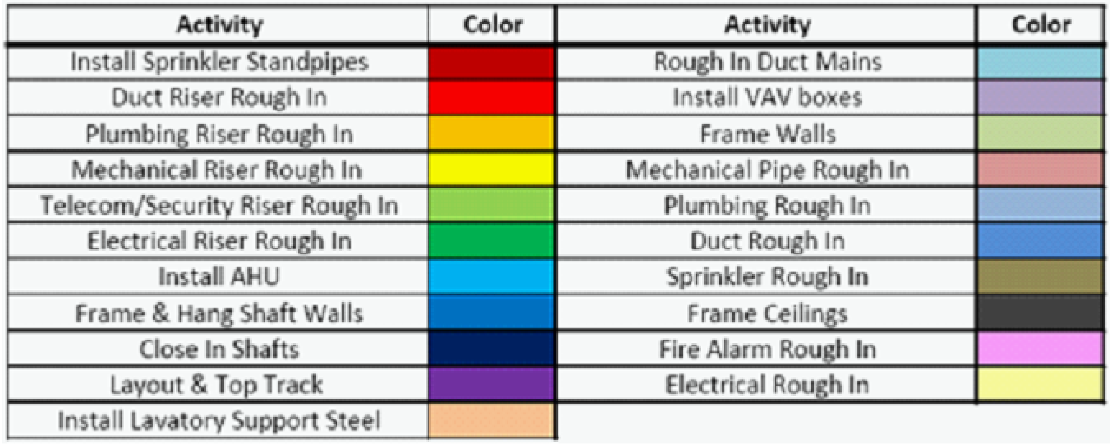
🟦 Frame Ceilings

Appendix A.3

Original Duration SIPS

Original Durations Sips





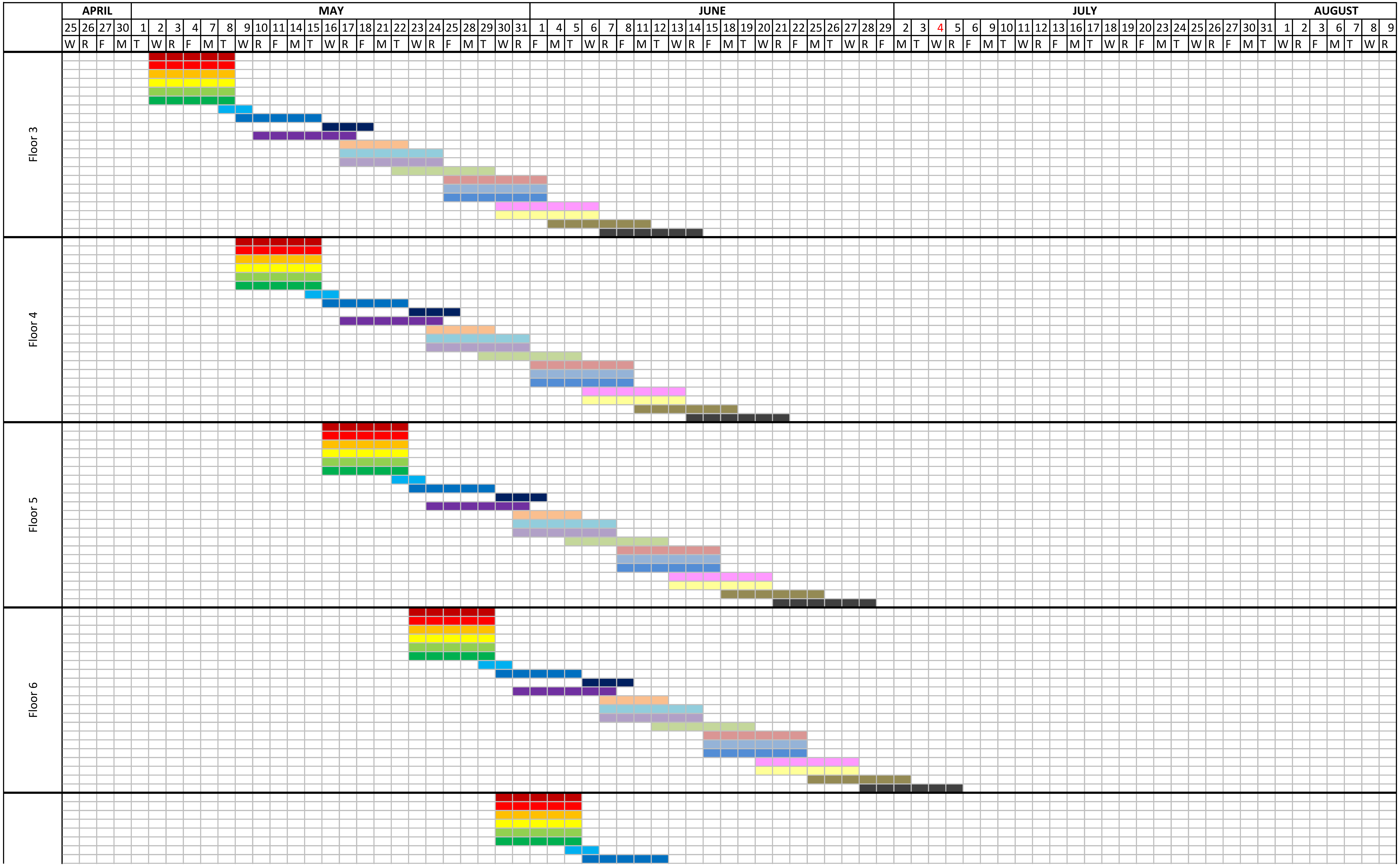
Activity	Color	Activity	Color
Install Sprinkler Standpipes	🟥	Rough In Duct Mains	🟦
Duct Riser Rough In	🟥	Install VAV boxes	🟪
Plumbing Riser Rough In	🟧	Frame Walls	🟩
Mechanical Riser Rough In	🟨	Mechanical Pipe Rough In	🟥
Telecom/Security Riser Rough In	🟩	Plumbing Rough In	🟦
Electrical Riser Rough In	🟩	Duct Rough In	🟦
Install AHU	🟦	Sprinkler Rough In	🟫
Frame & Hang Shaft Walls	🟦	Frame Ceilings	⬛
Close In Shafts	🟦	Fire Alarm Rough In	🟪
Layout & Top Track	🟪	Electrical Rough In	🟨
Install Lavatory Support Steel	🟧		

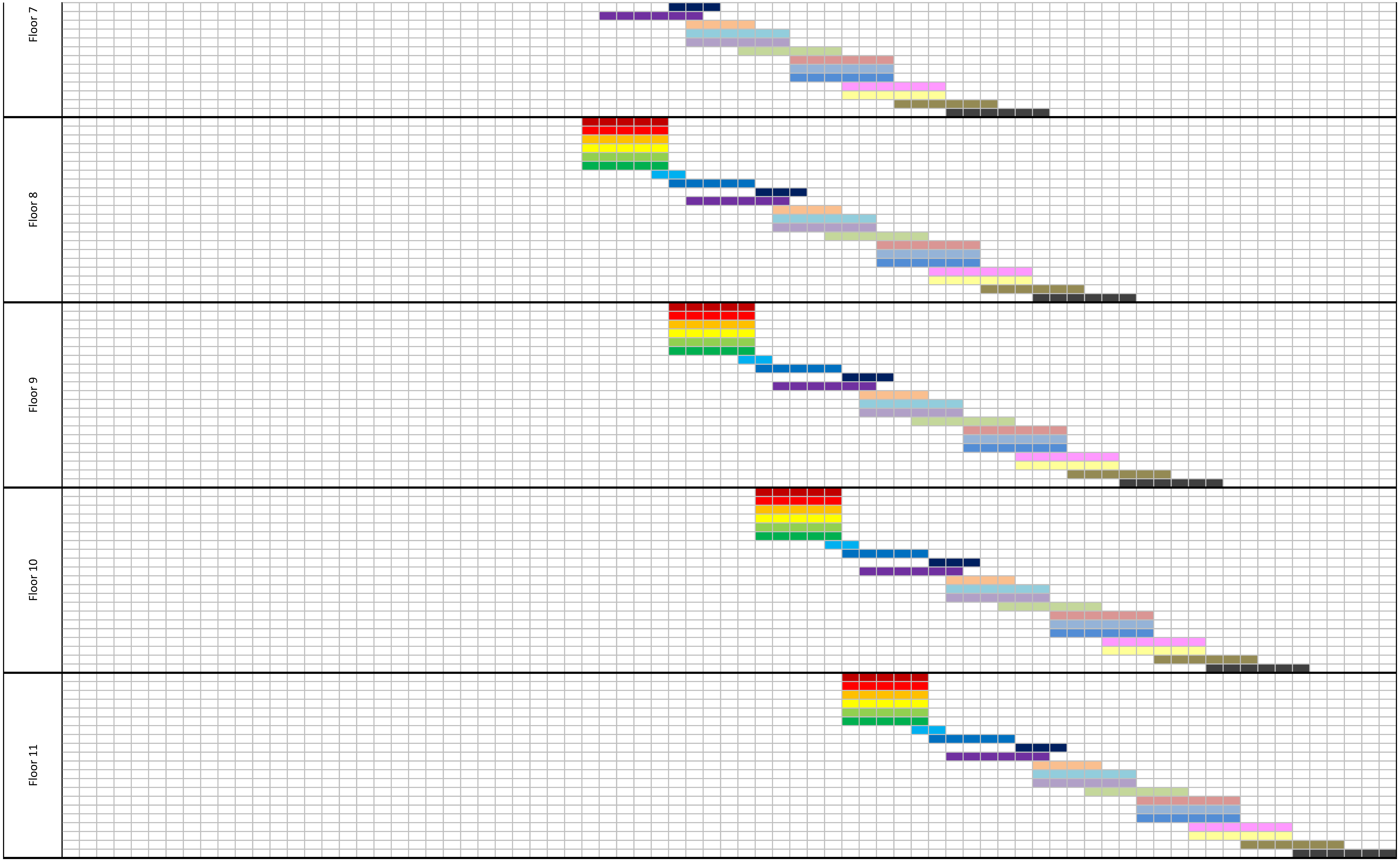
Appendix A.4

SIPS Schedule

SIPS Key

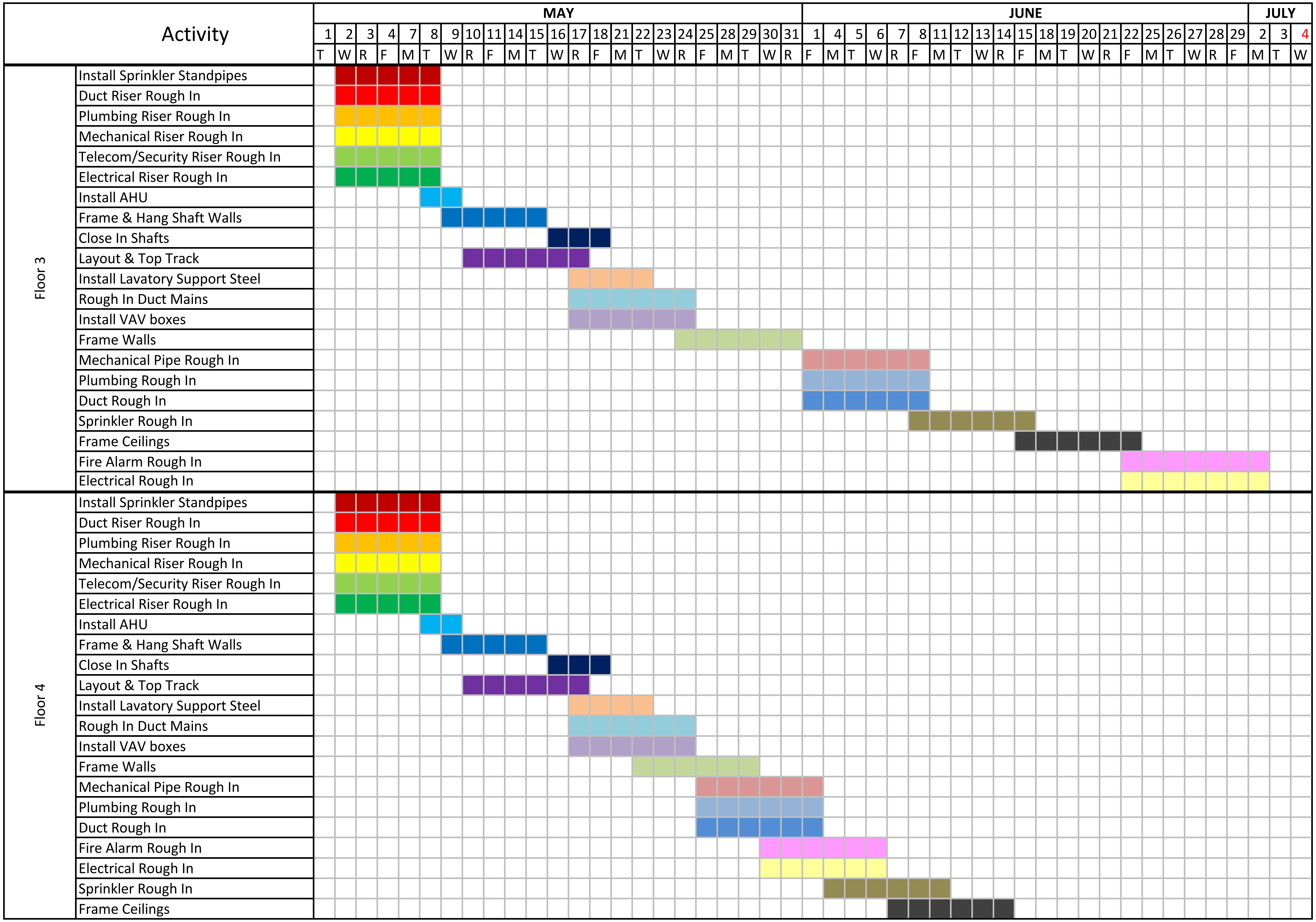
Activity	Color
Install Sprinkler Standpipes	🟥
Duct Riser Rough In	🟥
Plumbing Riser Rough In	🟧
Mechanical Riser Rough In	🟨
Telecom/Security Riser Rough In	🟩
Electrical Riser Rough In	🟩
Install AHU	🟦
Frame & Hang Shaft Walls	🟦
Close In Shafts	🟦
Layout & Top Track	🟪
Install Lavatory Support Steel	🟧
Rough In Duct Mains	🟦
Install VAV boxes	🟪
Frame Walls	🟩
Mechanical Pipe Rough In	🟥
Plumbing Rough In	🟦
Duct Rough In	🟦
Sprinkler Rough In	🟫
Frame Ceilings	⬛
Fire Alarm Rough In	🟪
Electrical Rough In	🟨


APRIL
MAY
JUNE
JULY
AUGUST
25 26 27 30 1 2 3 4 7 8 9 10 11 14 15 16 17 18 21 22 23 24 25 28 29 30 31 1 4 5 6 7 8 11 12 13 14 15 18 19 20 21 22 25 26 27 28 29 2 3 4 5 6 9 10 11 12 13 16 17 18 19 20 23 24 25 26 27 30 31 1 2 3 6 7 8 9
W R F M T W R F M T W R F M T W R F M T W R F M T W R F M T W R F M T W R F M T W R F M T W R F M T W R F M T W R F M T W R F M T W R F M T W R F M T W R
Floor 3
Floor 4
Floor 5
Floor 6


Floor 7
Floor 8
Floor 9
Floor 10
Floor 11

Appendix A.5

Schedule Comparison



	Activity	MAY																							JUNE																					JULY		
		1	2	3	4	7	8	9	10	11	14	15	16	17	18	21	22	23	24	25	28	29	30	31	1	4	5	6	7	8	11	12	13	14	15	18	19	20	21	22	25	26	27	28	29	2	3	4
		T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W
Floor 3	Install Sprinkler Standpipes		■	■	■	■	■																																									
	Duct Riser Rough In		■	■	■	■	■																																									
	Plumbing Riser Rough In		■	■	■	■	■																																									
	Mechanical Riser Rough In		■	■	■	■	■																																									
	Telecom/Security Riser Rough In		■	■	■	■	■																																									
	Electrical Riser Rough In		■	■	■	■	■																																									
	Install AHU						■	■																																								
	Frame & Hang Shaft Walls							■	■	■	■	■																																				
	Close In Shafts												■	■	■																																	
	Layout & Top Track								■	■	■	■	■	■																																		
	Install Lavatory Support Steel													■	■	■	■																															
	Rough In Duct Mains													■	■	■	■	■	■																													
	Install VAV boxes													■	■	■	■	■	■																													
	Frame Walls																		■	■	■	■	■	■																								
	Mechanical Pipe Rough In																								■	■	■	■	■	■																		
	Plumbing Rough In																								■	■	■	■	■	■																		
	Duct Rough In																								■	■	■	■	■	■																		
	Sprinkler Rough In																													■	■	■	■	■	■													
	Frame Ceilings																																		■	■	■	■	■	■								
	Fire Alarm Rough In																																							■	■	■	■	■	■	■		
	Electrical Rough In																																							■	■	■	■	■	■	■		
Floor 4	Install Sprinkler Standpipes		■	■	■	■	■																																									
	Duct Riser Rough In		■	■	■	■	■																																									
	Plumbing Riser Rough In		■	■	■	■	■																																									
	Mechanical Riser Rough In		■	■	■	■	■																																									
	Telecom/Security Riser Rough In		■	■	■	■	■																																									
	Electrical Riser Rough In		■	■	■	■	■																																									
	Install AHU						■	■																																								
	Frame & Hang Shaft Walls							■	■	■	■	■																																				
	Close In Shafts												■	■	■																																	
	Layout & Top Track								■	■	■	■	■	■																																		
	Install Lavatory Support Steel													■	■	■	■																															
	Rough In Duct Mains													■	■	■	■	■	■																													
	Install VAV boxes													■	■	■	■	■	■																													
	Frame Walls																■	■	■	■	■	■																										
	Mechanical Pipe Rough In																			■	■	■	■	■	■																							
	Plumbing Rough In																			■	■	■	■	■	■																							
	Duct Rough In																			■	■	■	■	■	■																							
	Fire Alarm Rough In																						■	■	■	■	■	■																				
	Electrical Rough In																						■	■	■	■	■	■																				
	Sprinkler Rough In																									■	■	■	■	■	■																	
	Frame Ceilings																												■	■	■	■	■	■														

Appendix B.1

ASHRAE Lighting Power Allowances

Table 1. ASHRAE/IES 90.1 lighting power allowances using the Building Area Method.

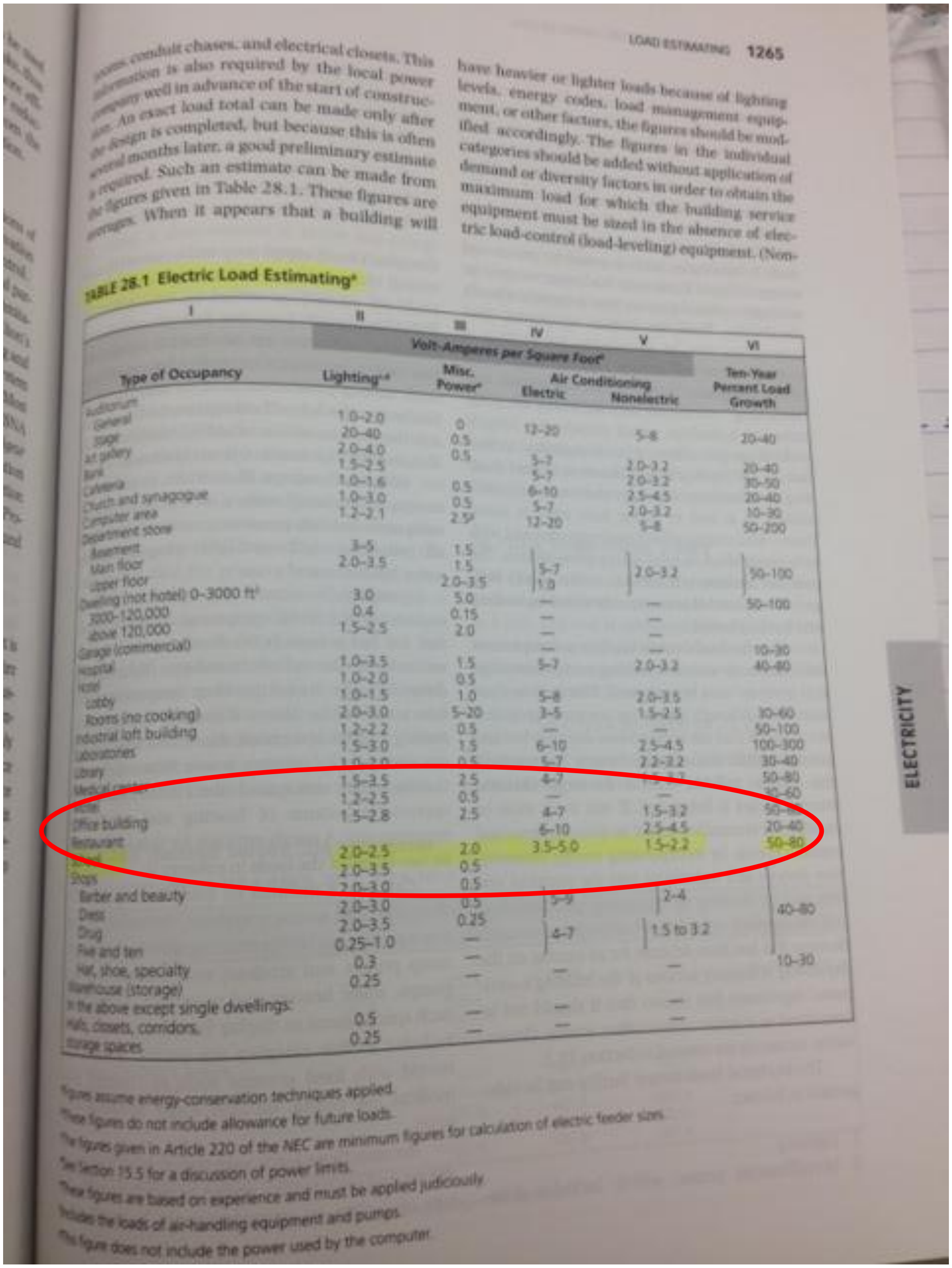
Building Type	Maximum Lighting Power Density (W/sq.ft.) Allowed Per Version of the ASHRAE/IES 90.1 Standard			
	1989	1999/2001	2004/2007	2010
Automotive Facility	0.96	1.5	0.9	0.982
Convention Center	2.07	1.4	1.2	1.08
Court House	1.44	1.4	1.2	1.05
Dining: Bar Lounge/Leisure	1.37	1.5	1.3	0.99
Dining: Cafeteria/Fast Food	1.37	1.8	1.4	0.90
Dining: Family	1.37	1.9	1.6	0.89
Dormitory	1.15	1.5	1.0	0.61
Exercise Center	2.07	1.4	1.0	0.88
Gymnasium	2.07	1.7	1.1	1.00
Healthcare Clinic	1.44	1.6	1.0	0.87
Hospital	1.44	1.6	1.2	1.21
Hotel	1.15	1.7	1.0	1.00
Library	1.29	1.5	1.3	1.18
Manufacturing Facility	0.96	2.2	1.3	1.11
Motel	1.15	2.0	1.0	0.88
Motion Picture Theater	2.07	1.6	1.2	0.83
Multi-Family	1.15	1.0	0.7	0.60
Museum	2.07	1.6	1.1	1.06
Office	1.26	1.3	1.0	0.90
Parking Garage	1.03	0.3	0.3	0.25
Penitentiary	1.44	1.2	1.0	0.97
Performing Arts Theatre	2.07	1.5	1.6	1.39
Police/Fire Station	1.44	1.3	1.0	0.96
Post Office	1.44	1.6	1.1	0.87
Religious Building	2.07	2.2	1.3	1.05
Retail	2.25	1.9	1.5	1.40
School/University	1.29	1.5	1.2	0.99
Sports Arena	2.07	1.5	1.1	0.78
Town Hall	1.44	1.4	1.1	0.92
Transportation	2.07	1.2	1.0	0.77
Warehouse	1.03	1.2	0.8	0.66
Workshop	0.96	1.7	1.4	1.20

Appendix B.2

MEEB Other Power Density

Mechanical and Electrical Equipment for Buildings (10th edition)

Stein, Reynolds, Grondzik, Kwok



access, conduit chases, and electrical closets. This information is also required by the local power company well in advance of the start of construction. An exact load total can be made only after the design is completed, but because this is often several months later, a good preliminary estimate is required. Such an estimate can be made from the figures given in Table 28.1. These figures are averages. When it appears that a building will have heavier or lighter loads because of lighting levels, energy codes, load management equipment, or other factors, the figures should be modified accordingly. The figures in the individual categories should be added without application of demand or diversity factors in order to obtain the maximum load for which the building service equipment must be sized in the absence of electric load-control (load-leveling) equipment. (Non-

TABLE 28.1 Electric Load Estimating[a]

I	II	III	IV	V	VI
	Volt-Amperes per Square Foot[b]				
Type of Occupancy	Lighting[c,d]	Misc. Power[e]	Air Conditioning		Ten-Year Percent Load Growth
			Electric	Nonelectric	
Auditorium					
General	1.0-2.0	0	12-20	5-8	20-40
Stage	20-40	0.5			
Art gallery	2.0-4.0	0.5	5-7	2.0-3.2	20-40
Bank	1.5-2.5		5-7	2.0-3.2	30-50
Cafeteria	1.0-1.6	0.5	6-10	2.5-4.5	20-40
Church and synagogue	1.0-3.0	0.5	5-7	2.0-3.2	10-30
Computer area	1.2-2.1	2.5[g]	12-20	5-8	50-200
Department store					
Basement	3-5	1.5			
Main floor	2.0-3.5	1.5	5-7	2.0-3.2	50-100
Upper floor		2.0-3.5	1.0		
Dwelling (not hotel) 0-3000 ft^2	3.0	5.0	—	—	50-100
3000-120,000	0.4	0.15	—	—	
above 120,000	1.5-2.5	2.0	—	—	
Garage (commercial)			—	—	10-30
Hospital	1.0-3.5	1.5	5-7	2.0-3.2	40-80
Hotel	1.0-2.0	0.5			
Lobby	1.0-1.5	1.0	5-8	2.0-3.5	
Rooms (no cooking)	2.0-3.0	5-20	3-5	1.5-2.5	30-60
Industrial loft building	1.2-2.2	0.5	—	—	50-100
Laboratories	1.5-3.0	1.5	6-10	2.5-4.5	100-300
Library	1.0-2.0	0.5	5-7	2.2-3.2	30-40
Medical center	1.5-3.5	2.5	4-7	1.5-3.2	50-80
Motel	1.2-2.5	0.5	—	—	30-60
Office building	1.5-2.8	2.5	4-7	1.5-3.2	50-80
Restaurant			6-10	2.5-4.5	20-40
School	2.0-2.5	2.0	3.5-5.0	1.5-2.2	50-80
Shops	2.0-3.5	0.5			
Barber and beauty	2.0-3.0	0.5			
Dress	2.0-3.0	0.5	5-9	2-4	
Drug	2.0-3.5	0.25			40-80
Five and ten	0.25-1.0	—	4-7	1.5 to 3.2	
Hat, shoe, specialty	0.3	—			
Warehouse (storage)	0.25	—	—	—	10-30
In the above except single dwellings:					
Halls, closets, corridors	0.5	—	—	—	
Storage spaces	0.25	—	—	—	

[a] Figures assume energy-conservation techniques applied.

[b] These figures do not include allowance for future loads.

[c] The figures given in Article 220 of the NEC are minimum figures for calculation of electric feeder sizes.

[d] See Section 15.5 for a discussion of power limits.

[e] These figures are based on experience and must be applied judiciously.

[f] Includes the loads of air-handling equipment and pumps.

[g] This figure does not include the power used by the computer.

ELECTRICITY

Appendix B.3

Original Panel Schedules

PANEL H(3-11)L1

BREAKER INTERUPTING RATING: SERIES RATED | M.L.O. | 3 Ø - 4 WIRE

CONDUIT SIZE	WIRE SIZE	SERVING	KVA A Ø	KVA B Ø	KVA C Ø	CKT BKR	CKT NO	CKT NO	CKT BKR	KVA A Ø	KVA B Ø	KVA C Ø	SERVING
1/2"	2#12	TOILET RM. LTS.	1.34			1P-20	1	2	1P-20	1.00			LTG. RELAY PANEL
1/2"	2#12	CORRIDOR LTS.		0.38		|	3	4	|				SPARE
		SPARE				|	5	6	|				|
		|				|	7	8	|				|
		|				|	9	10	|				|
		|				|	11	12	|				|
		|				|	13	14	|				|
		|				|	15	16	|				|
		V				V	17	18	V				V
		SPACE					19	20					SPACE
		|					21	22					|
		|					23	24					|
		|					25	26					|
		|					27	28					|
		|					29	30					|
		|					31	32					|
		|					33	34					|
		|					35	36					V
		|					37	38	3P-175	1.62			112.5 KVA XFMR
		|					39	40			0.54		(PANEL LXA1)
		V					41	42				0.50	
			1.3	0.4	0.0					2.6	0.5	0.5	

A Ø = 4 KVA

B Ø = 1 KVA

C Ø = 1 KVA

TOTAL = 5 KVA

PANEL H3MA1

BREAKER INTERUPTING RATING: SERIES RATED | M.L.O. | 3 Ø - 4 WIRE

CONDUIT SIZE	WIRE SIZE	SERVING	KVA A Ø	KVA B Ø	KVA C Ø	CKT BKR	CKT NO	CKT NO	CKT BKR	KVA A Ø	KVA B Ø	KVA C Ø	SERVING
		SPACE					1	2	1P-30	5.82			FPTU (B/5.0)
		|					3	4	|		5.82		FPTU (B/5.0)
		|					5	6	|			5.82	FPTU (B/5.0)
		|					7	8	|	5.82			FPTU (B/5.0)
		|					9	10	|		5.22		FPTU (B/4.4)
		|					11	12	|			5.22	FPTU (B/4.4)
		|					13	14	V	5.22			FPTU (B/4.4)
		|					15	16	1P-25		4.72		FPTU (B/3.9)
		|					17	18	|			4.72	FPTU (B/3.8)
		|					19	20	|	4.42			FPTU (B/3.6)
		|					21	22	V		4.52		FPTU (B/3.7)
		|					23	24	1P-20			3.42	FPTU (B/2.6)
		|					25	26	|	3.42			FPTU (B/2.6)
		V					27	28	|		1.64		FPTU (B/-)
3/4"	2#10	FPTU (B/5.0)			5.82	1P-30	29	30	|			1.64	FPTU (B/-)
|	|	FPTU (B/5.0)	5.82			|	31	32	|	1.64			FPTU (B/-)
|	|	FPTU (B/5.0)		5.82		|	33	34	|		1.64		FPTU (B/-)
|	|	FPTU (B/5.0)			5.82	|	35	36	V			1.64	FPTU (B/-)
|	|	FPTU (C/4.6)	6.22			|	37	38	3P-15	3.00			EWH-1
|	|	FPTU (C/4.6)		6.22		|	39	40			3.00		(9.0 KW)
V	V	FPTU (C/4.6)			6.22	V	41	42				3.00	
			12.0	12.0	17.9		FEED THRU LUGS			29.3	26.6	25.5	

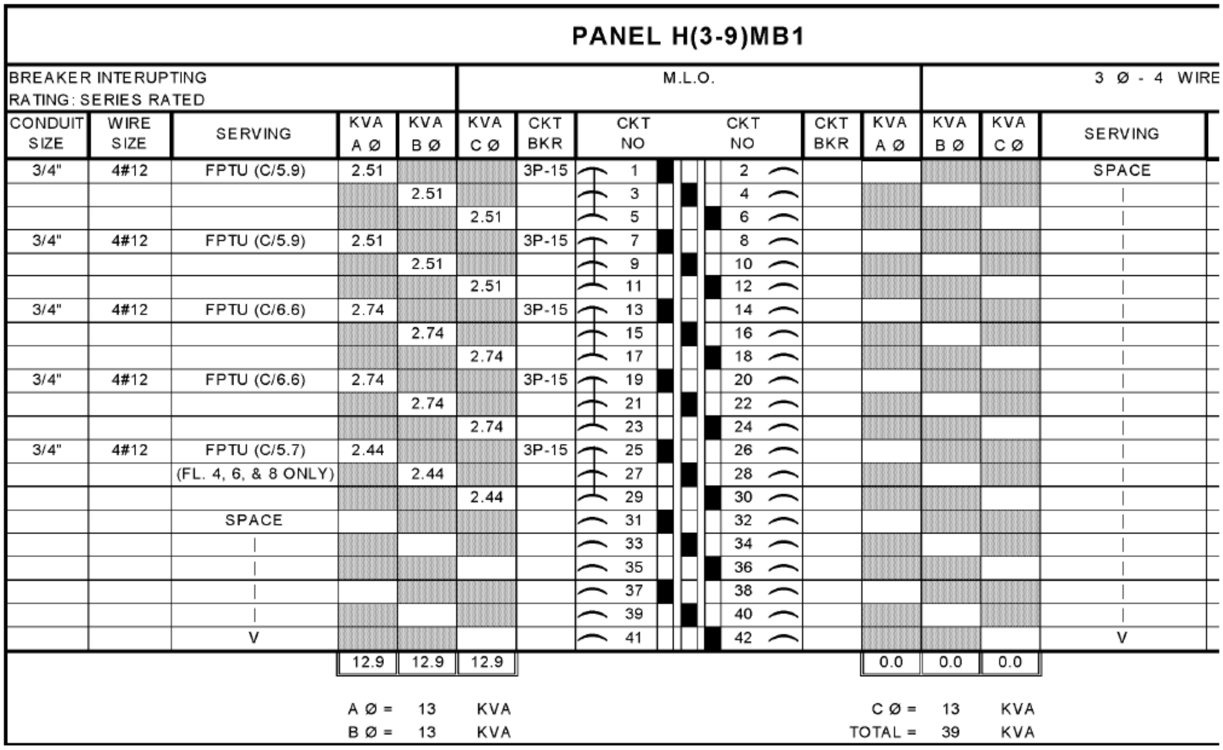
A Ø = 41 KVA

B Ø = 39 KVA

C Ø = 43 KVA

TOTAL = 123 KVA

NOTE: CONTRACTOR SHALL LABEL ALL FPTU CIRCUITS WITH MECHANICAL ZONE DESIGNATIONS (E.G., "FPTU 2-1"). REFER TO MECHANICAL DRAWINGS FOR ZONE DESIGNATIONS.



PANEL H(3-9)MB1

BREAKER INTERUPTING
RATING: SERIES RATED

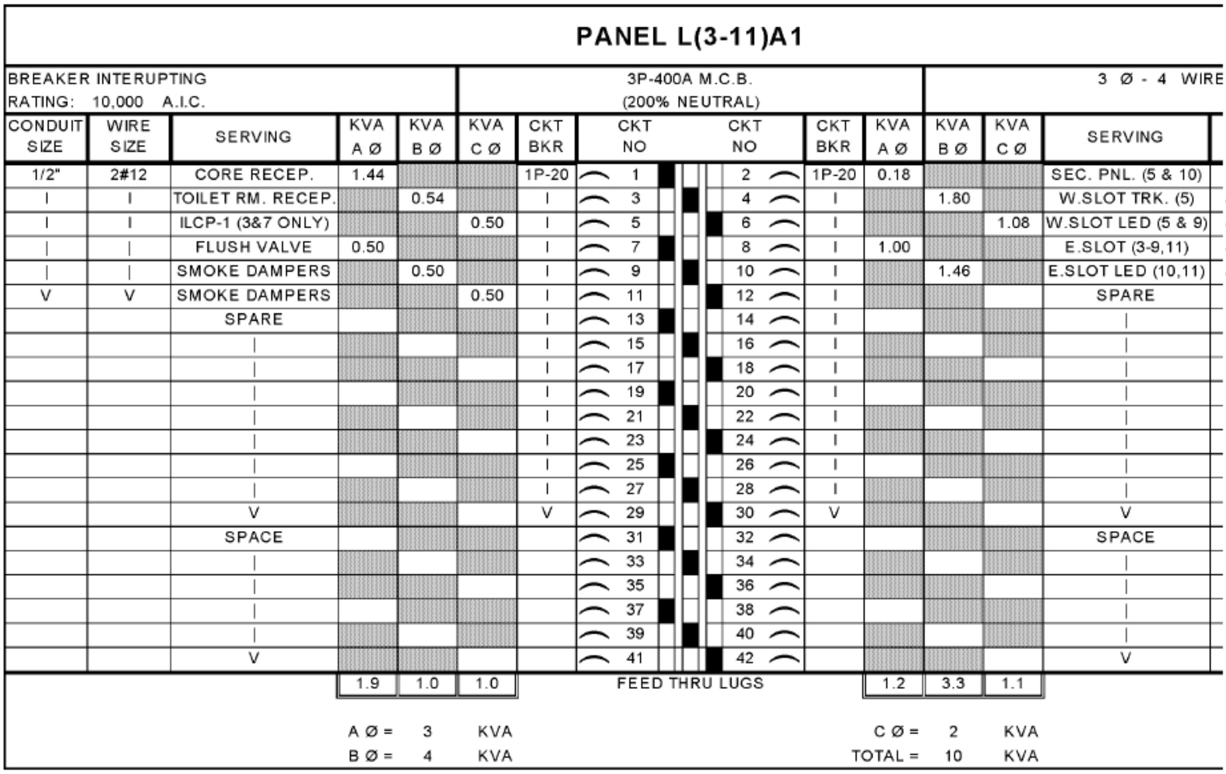
M.L.O.

3 Ø - 4 WIRE

CONDUIT SIZE	WIRE SIZE	SERVING	KVA A Ø	KVA B Ø	KVA C Ø	CKT BKR	CKT NO	CKT NO	CKT BKR	KVA A Ø	KVA B Ø	KVA C Ø	SERVING
3/4"	4#12	FPTU (C/5.9)	2.51			3P-15	1	2					SPACE
				2.51			3	4					|
					2.51		5	6					|
3/4"	4#12	FPTU (C/5.9)	2.51			3P-15	7	8					|
				2.51			9	10					|
					2.51		11	12					|
3/4"	4#12	FPTU (C/6.6)	2.74			3P-15	13	14					|
				2.74			15	16					|
					2.74		17	18					|
3/4"	4#12	FPTU (C/6.6)	2.74			3P-15	19	20					|
				2.74			21	22					|
					2.74		23	24					|
3/4"	4#12	FPTU (C/5.7)	2.44			3P-15	25	26					|
		(FL. 4, 6, & 8 ONLY)		2.44			27	28					|
					2.44		29	30					|
		SPACE					31	32					|
		|					33	34					|
		|					35	36					|
		|					37	38					|
		|					39	40					|
		V					41	42					V
			12.9	12.9	12.9					0.0	0.0	0.0	

A Ø = 13 KVA
B Ø = 13 KVA
C Ø = 13 KVA
TOTAL = 39 KVA

NOTE: CONTRACTOR SHALL LABEL ALL FPTU CIRCUITS WITH MECHANICAL ZONE DESIGNATIONS (E.G., "FPTU 2-1"). REFER TO MECHANICAL DRAWINGS FOR ZONE DESIGNATIONS.



PANEL L(3-11)A1

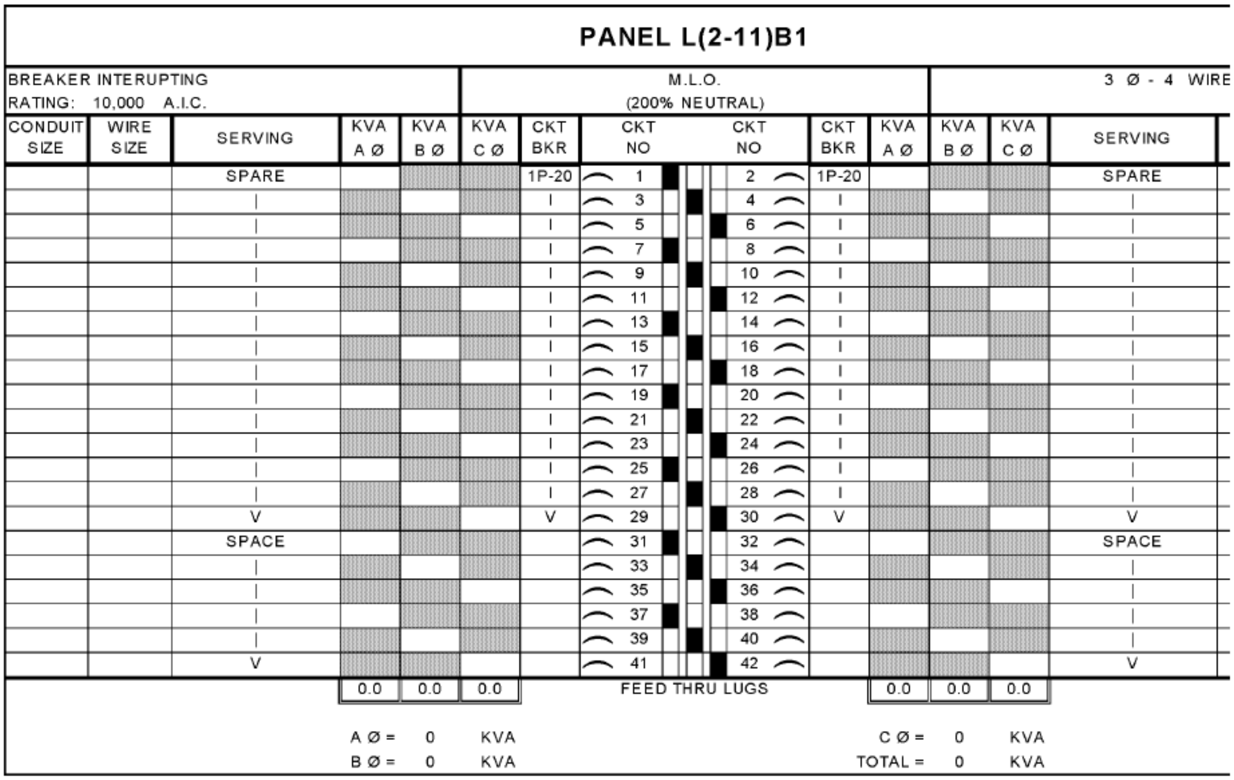
BREAKER INTERUPTING
RATING: 10,000 A.I.C.

3P-400A M.C.B.
(200% NEUTRAL)

3 Ø - 4 WIRE

CONDUIT SIZE	WIRE SIZE	SERVING	KVA A Ø	KVA B Ø	KVA C Ø	CKT BKR	CKT NO	CKT NO	CKT BKR	KVA A Ø	KVA B Ø	KVA C Ø	SERVING	
1/2"	2#12	CORE RECEP.	1.44			1P-20	1	2	1P-20	0.18			SEC. PNL. (5 & 10)	
|	|	TOILET RM. RECEP.		0.54		|	3	4	|		1.80		W.SLOT TRK. (5)	○
|	|	ILCP-1 (3&7 ONLY)			0.50	|	5	6	|			1.08	W.SLOT LED (5 & 9)	○
|	|	FLUSH VALVE	0.50			|	7	8	|	1.00			E.SLOT (3-9,11)	○
|	|	SMOKE DAMPERS		0.50		|	9	10	|		1.46		E.SLOT LED (10,11)	○
V	V	SMOKE DAMPERS			0.50	|	11	12	|				SPARE	
		SPARE				|	13	14	|				|	
		|				|	15	16	|				|	
		|				|	17	18	|				|	
		|				|	19	20	|				|	
		|				|	21	22	|				|	
		|				|	23	24	|				|	
		|				|	25	26	|				|	
		|				|	27	28	|				|	
		V				V	29	30	V				V	
		SPACE					31	32					SPACE	
		|					33	34					|	
		|					35	36					|	
		|					37	38					|	
		|					39	40					|	
		V					41	42					V	
			1.9	1.0	1.0		FEED THRU LUGS			1.2	3.3	1.1		

A Ø = 3 KVA
B Ø = 4 KVA
C Ø = 2 KVA
TOTAL = 10 KVA



PANEL L(2-11)B1

BREAKER INTERUPTING RATING: 10,000 A.I.C.

M.L.O. (200% NEUTRAL)

3 Ø - 4 WIRE

CONDUIT SIZE	WIRE SIZE	SERVING	KVA A Ø	KVA B Ø	KVA C Ø	CKT BKR	CKT NO	CKT NO	CKT BKR	KVA A Ø	KVA B Ø	KVA C Ø	SERVING
		SPARE		▨	▨	1P-20	1	2	1P-20		▨	▨	SPARE
		|	▨		▨	I	3	4	I	▨		▨	|
		|	▨	▨		I	5	6	I	▨	▨		|
		|		▨	▨	I	7	8	I		▨	▨	|
		|	▨		▨	I	9	10	I	▨		▨	|
		|	▨	▨		I	11	12	I	▨	▨		|
		|		▨	▨	I	13	14	I		▨	▨	|
		|	▨		▨	I	15	16	I	▨		▨	|
		|	▨	▨		I	17	18	I	▨	▨		|
		|		▨	▨	I	19	20	I		▨	▨	|
		|	▨		▨	I	21	22	I	▨		▨	|
		|	▨	▨		I	23	24	I	▨	▨		|
		|		▨	▨	I	25	26	I		▨	▨	|
		|	▨		▨	I	27	28	I	▨		▨	|
		V	▨	▨		V	29	30	V	▨	▨		V
		SPACE		▨	▨		31	32			▨	▨	SPACE
		|	▨		▨		33	34		▨		▨	|
		|	▨	▨			35	36		▨	▨		|
		|		▨	▨		37	38			▨	▨	|
		|	▨		▨		39	40		▨		▨	|
		V	▨	▨			41	42		▨	▨		V
			0.0	0.0	0.0		FEED THRU LUGS			0.0	0.0	0.0	

A Ø = 0 KVA

B Ø = 0 KVA

C Ø = 0 KVA

TOTAL = 0 KVA

Appendix B.4

Switchboard Calculations

Electrical Redesign Calculations

Switchboard MS12A resize

Capacity:

Lighting & Receptacle Capacity: 1902 kVA

$$1902kVA = \frac{kW}{1000 \cdot 0.95} = 1807000W$$

$$\Rightarrow \frac{1807000W}{257500SF} = 7.02W/SF \text{ \textit{Capacity}}$$

Recommendations:

ASHRAE, Sec. 9, provides maximum lighting power density recommendation for office building (W/SF)

- ASHRAE 2007 = 1.0 W/SF
- ASHRAE 2010 = 0.9 W/SF

**http://lightingcontrolsassociation.org/ashrae-releases-90-1-2010-part-1-design-scope-administrative-requirements/*

Per MEEB, pg. 1265, receptacle (misc. power) power density recommendation is: 2.375 W/SF

Therefore,

$$0.9W/SF + 2.375W/SF = 3.275W/SF \text{ \textit{for lighting \& receptacle loads}}$$

Switchboard MS12A provides an excess of 3.645 W/SF for these loads

Proposal:

Remove 800kVA from lighting & receptacle loads

From 1902kVA to 1102KVA

$$1102kVA \cdot 1000 \cdot 0.95 = 1046900W$$

$$\Rightarrow \frac{1046900W}{257500SF} = 4.1W/SF \text{ \underline{\textit{NEW}} \textit{lighting \& receptacle capacity}}$$

This is still 0.8 W/SF more than design recommendations

Note: A PF of 0.95 was used in all calculations

Effect:

Initial Switchboard total kVA load: 3173 kVA (3982A @ 460V, 3ϕ)

Revised Switchboard total kVA load: 2373 kVA (2978A @ 460V, 3ϕ)

<u>Therefore</u>,

You can go from 4000A switchboard to 3000A switchboard!!

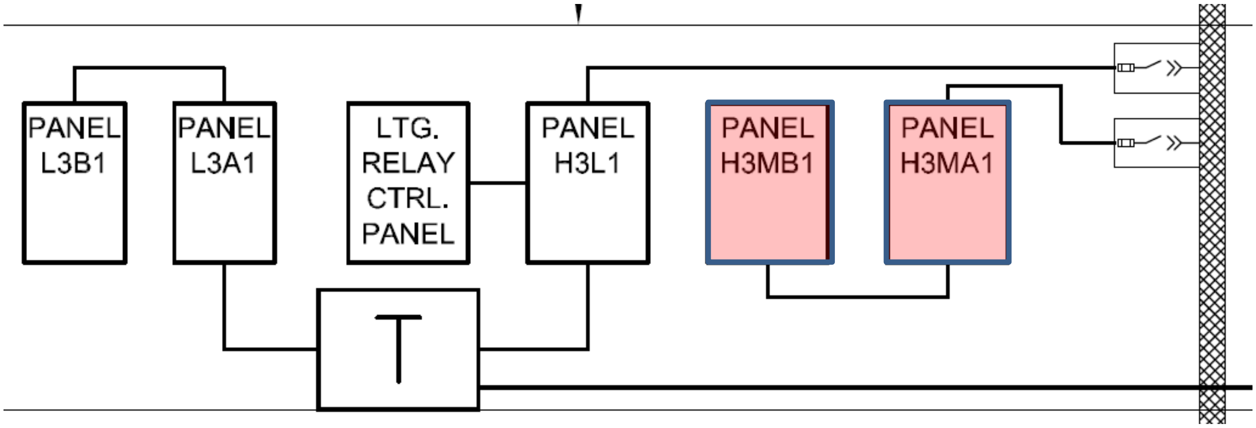
Appendix B.5

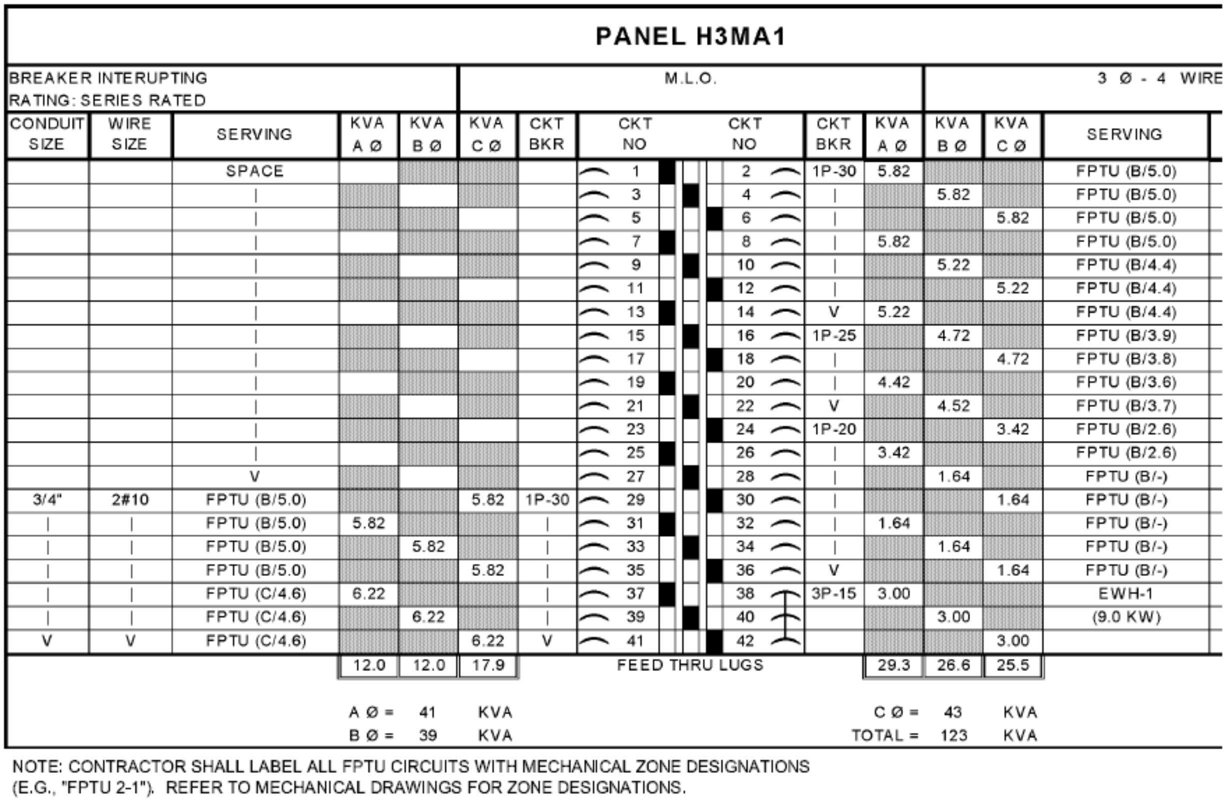
Panel Consolidation Calculations

Floors 3-9 480V panel consolidation

Proposal:

Consolidate Panel H3MB1 with Panel H3MA1 (floors 3-9)





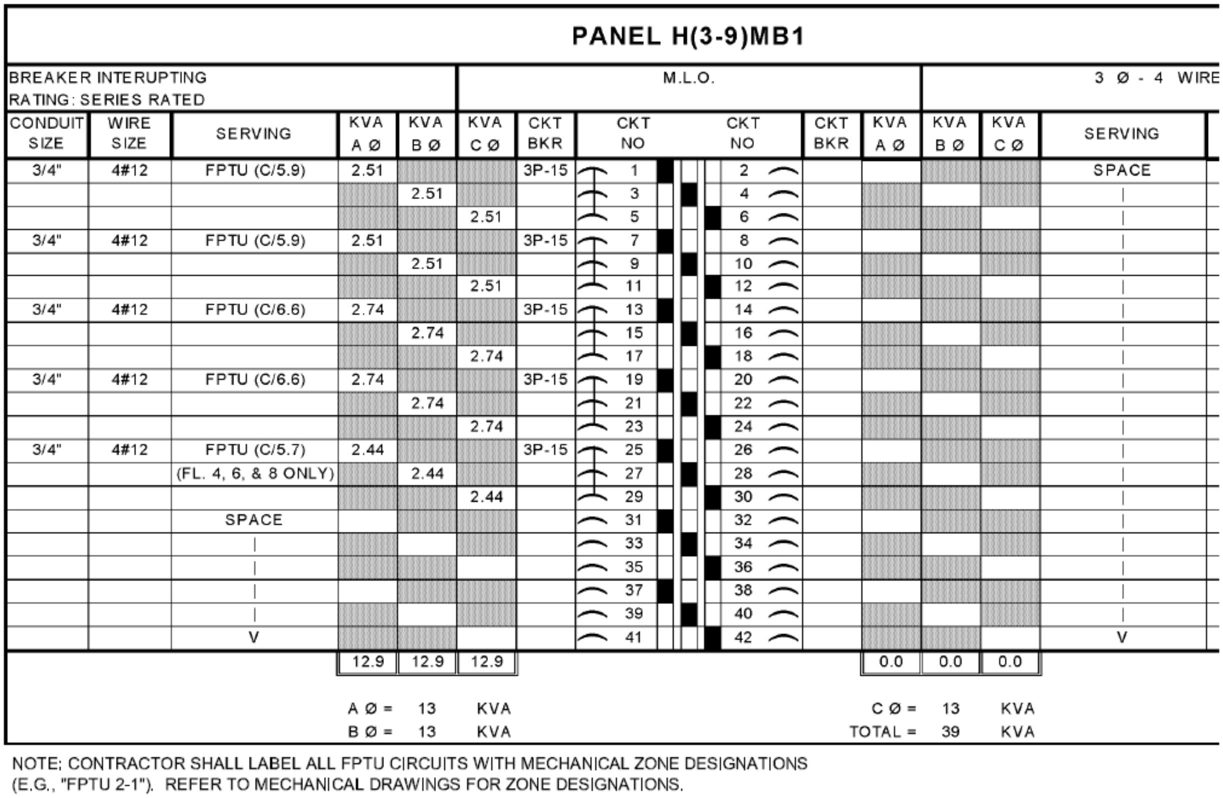
PANEL H3MA1

BREAKER INTERUPTING RATING: SERIES RATED | M.L.O. | 3 Ø - 4 WIRE

CONDUIT SIZE	WIRE SIZE	SERVING	KVA A Ø	KVA B Ø	KVA C Ø	CKT BKR	CKT NO	CKT NO	CKT BKR	KVA A Ø	KVA B Ø	KVA C Ø	SERVING
		SPACE					1	2	1P-30	5.82			FPTU (B/5.0)
		|					3	4	|		5.82		FPTU (B/5.0)
		|					5	6	|			5.82	FPTU (B/5.0)
		|					7	8	|	5.82			FPTU (B/5.0)
		|					9	10	|		5.22		FPTU (B/4.4)
		|					11	12	|			5.22	FPTU (B/4.4)
		|					13	14	V	5.22			FPTU (B/4.4)
		|					15	16	1P-25		4.72		FPTU (B/3.9)
		|					17	18	|			4.72	FPTU (B/3.8)
		|					19	20	|	4.42			FPTU (B/3.6)
		|					21	22	V		4.52		FPTU (B/3.7)
		|					23	24	1P-20			3.42	FPTU (B/2.6)
		|					25	26	|	3.42			FPTU (B/2.6)
		V					27	28	|		1.64		FPTU (B/-)
3/4"	2#10	FPTU (B/5.0)			5.82	1P-30	29	30	|			1.64	FPTU (B/-)
|	|	FPTU (B/5.0)	5.82			|	31	32	|	1.64			FPTU (B/-)
|	|	FPTU (B/5.0)		5.82		|	33	34	|		1.64		FPTU (B/-)
|	|	FPTU (B/5.0)			5.82	|	35	36	V			1.64	FPTU (B/-)
|	|	FPTU (C/4.6)	6.22			|	37	38	3P-15	3.00			EWH-1
|	|	FPTU (C/4.6)		6.22		|	39	40			3.00		(9.0 KW)
V	V	FPTU (C/4.6)			6.22	V	41	42				3.00	
			12.0	12.0	17.9		FEED THRU LUGS			29.3	26.6	25.5	

A Ø = 41 KVA
B Ø = 39 KVA
C Ø = 43 KVA
TOTAL = 123 KVA

NOTE: CONTRACTOR SHALL LABEL ALL FPTU CIRCUITS WITH MECHANICAL ZONE DESIGNATIONS (E.G., "FPTU 2-1"). REFER TO MECHANICAL DRAWINGS FOR ZONE DESIGNATIONS.



PANEL H(3-9)MB1

BREAKER INTERUPTING RATING: SERIES RATED

M.L.O.

3 Ø - 4 WIRE

CONDUIT SIZE	WIRE SIZE	SERVING	KVA A Ø	KVA B Ø	KVA C Ø	CKT BKR	CKT NO	CKT NO	CKT BKR	KVA A Ø	KVA B Ø	KVA C Ø	SERVING
3/4"	4#12	FPTU (C/5.9)	2.51			3P-15	1	2					SPACE
				2.51			3	4					|
					2.51		5	6					|
3/4"	4#12	FPTU (C/5.9)	2.51			3P-15	7	8					|
				2.51			9	10					|
					2.51		11	12					|
3/4"	4#12	FPTU (C/6.6)	2.74			3P-15	13	14					|
				2.74			15	16					|
					2.74		17	18					|
3/4"	4#12	FPTU (C/6.6)	2.74			3P-15	19	20					|
				2.74			21	22					|
					2.74		23	24					|
3/4"	4#12	FPTU (C/5.7)	2.44			3P-15	25	26					|
		(FL. 4, 6, & 8 ONLY)		2.44			27	28					|
					2.44		29	30					|
		SPACE					31	32					|
		|					33	34					|
		|					35	36					|
		|					37	38					|
		|					39	40					|
		V					41	42					V
			12.9	12.9	12.9					0.0	0.0	0.0	

A Ø = 13 KVA

B Ø = 13 KVA

C Ø = 13 KVA

TOTAL = 39 KVA

NOTE; CONTRACTOR SHALL LABEL ALL FPTU CIRCUITS WITH MECHANICAL ZONE DESIGNATIONS (E.G., "FPTU 2-1"). REFER TO MECHANICAL DRAWINGS FOR ZONE DESIGNATIONS.

Panel H3MA1 has 123 kVA (148 load amps), on a 200A panel.

Panel H3MB1 has 39 kVA (47 load amps), on a 200A panel.

Consolidated: 155 kVA (187 load amps) on a 225A panel

**See next page for new panel layout*

# of receptacle circuits necessary

$$22436SF \cdot 2.5W/SF = 56090W$$

$$56090W/180\frac{VA}{rec} = 312rec$$

$$\frac{312rec}{6\frac{rec}{ckt}} = 52ckts$$

For the 3^{RD} Floor, panels L3A1 & L3B1 have XX spare 70 ckts …. OK

For remaining floors, top panels have 67 spare ckts, and bottom panels have 70 spare ckts…. OK

Appendix B.6

Typical Floor Redesign Calculations

Remaining Typical Floor Layout

Original XFMR anticipated max load of 112.5 kVA from low voltage panels, or 4.8 W/SF.

By reducing receptacle power density to 2.5 W/SF, I propose…

Eliminate XFMRs on floors 4, 6, & 8

The low voltage panels on those floors will be fed by the XFMR on the above floor

So,

Current max kVA for low voltage panels is 112.5kVA, or 4.8 W/SF

Receptacle power density changed to 2.5W/SF

Factor in existing 10kVA load, or .4 W/SF…

$$\frac{112.5kVA}{4.8W/SF} = \frac{X}{2.9W/SF}$$

$$X = 68kVA$$

Therefore, a set of panels require 68 kVA

Meaning both sets together will be a total of 136 kVA

Consequently, you will need a 150 kVA XFMR

*Refer to riser diagram for additional wire and breaker sizing

Appendix B.7

Detailed Takeoff and Pricing

Description	Qty	Trade Price	Disc.	Net Cost	Unit	Total Material	Labor	Unit	Total Hours
4000A MS12A DISTRIBUTION SWITCHBOARD	1	0	100	0	E	0	30	E	30
225A HXMA1 PANELBOARD	7	0	100	0	E	0	17	E	119
225A HXMB1 PANELBOARD	7	0	100	0	E	0	10	E	70
225A HXL1 PANELBOARD	7	0	100	0	E	0	25	E	175
400A LXA1 PANELBOARD	7	0	100	0	E	0	25	E	175
400A LXB1 PANELBOARD	7	0	100	0	E	0	25	E	175
2 1/2" EMT CONDUIT FEEDERS	63	688.47	64.35	245.44	C	154.63	12	C	7.56
2 1/2" EMT STL SS CONN	4	1,676.43	76.62	391.95	C	15.68	0	C	0
2 1/2" EMT STL SS CPLG	15	1,374.75	77.73	306.16	C	45.92	0	C	0
2 1/2" EMT 90 DEG ELBOW	10	2,582.00	53.04	1,212.51	C	121.25	70	C	7
2" PLASTIC BUSHING	42	392.23	95.97	15.81	C	6.64	0	C	0
2 1/2" PLASTIC BUSHING	4	883.09	96.69	29.23	C	1.17	0	C	0
2" STRAIGHT FLEX CONN	21	2,143.50	50	1,071.75	C	225.07	70	C	14.7
2" STEEL FLEX	84	668.54	47	354.33	C	297.64	15	C	12.6
2" STL 90 DEG FLEX CONN	21	6,622.00	63.49	2,417.55	C	507.69	70	C	14.7
#6 THHN BLACK	88	1,325.73	57.11	568.61	M	50.04	12	M	1.06
#4 THHN BLACK	70	2,104.22	57.11	902.5	M	63.17	13	M	0.91
#3 THHN BLACK	350	2,635.93	57.11	1,130.55	M	395.69	14	M	4.9
#3/0 THHN BLACK	912	8,176.50	57.11	3,506.90	M	3,198.29	23	M	20.98
#4/0 THHN BLACK	210	10,267.70	56.71	4,444.89	M	933.43	25	M	5.25
1-H CRIMP LUG #4 GRAY	14	500.64	60	200.26	C	28.04	15	C	2.1
1-H CRIMP LUG #2 BROWN	42	977.55	60	391.02	C	164.23	17	C	7.14
1-H CRIMP LUG #3/0 ORANGE	70	1,469.44	60	587.78	C	411.45	28	C	19.6
1-H CRIMP LUG #4/0 PURPLE	21	1,638.87	60	655.55	C	137.67	30	C	6.3
600 VOLT WIRE TERMINATION #1 THRU 3/0	16	1.24	0	1.24	E	19.84	0.6	E	9.6
225A CU BUS DUCT	1	0	0	0	E	0	20	C	0.2
1/4-20x 1 3/4 WEDGE ANCHOR - 1 1/8" MIN DEPTH	7	0	44	0	C	0	8	C	0.56
1/4" THREADED ROD - PLTD	19	75.66	95.77	3.2	C	0.61	2.5	C	0.47
1/4-20 HEX NUT - PLTD STL	13	2.36	25	1.77	C	0.23	2	C	0.26
ERICO CD6B 2 1/2" EMT/GRC CLAMP	7	159.32	0	159.32	C	11.15	20	C	1.4
SWBD M C BRKR 4000A 3P	1	0	100	0	E	0	40	E	40
SWBD MTR/INST SECTION 4000A	1	0	100	0	E	0	8	E	8
175A 3P MOLDED CASE BRKR OPEN	7	0	100	0	E	0	4.5	E	31.5
400A 3P MOLDED CASE BRKR OPEN	7	0	100	0	E	0	7.5	E	52.5
200A 250V FUSIBLE DSN SW NEMA 1	14	1,003.80	100	0	E	0	6	E	84
112.5KVA 3PH 480V DRY XMER	7	0	100	0	E	0	26	E	182
TVSS	1	0	100	0	E	0	2.5	E	2.5
1" GRD CLAMP FOR BARE WIRE	14	41.02	60	16.41	E	229.74	0.7	E	9.8
Totals	**2192**					**7019.25**			**1291.59**

Description	Qty	Trade Price	Disc.	Net Cost	Unit	Total Material	Labor	Unit	Total Hours
3000A MS12A DISTRIBUTION SWITCHBOARD	1	0	100	0	E	0	30	E	30
225A HXMA1 PANELBOARD	7	0	100	0	E	0	25	E	175
225A H3L1 PANELBOARD	1	0	100	0	E	0	25	E	25
225A H4L1 PANELBOARD	3	0	100	0	E	0	25	E	75
225A H5L1 PANELBOARD	3	0	100	0	E	0	25	E	75
400A L3A1 PANELBOARD	1	0	100	0	E	0	25	E	25
400A L3B1 PANELBOARD	7	0	100	0	E	0	25	E	175
600A LXA1 PANELBOARD	3	0	100	0	E	0	25	E	75
600A LXB1 PANELBOARD	3	0	100	0	E	0	25	E	75
1 1/4" EMT CONDUIT FEEDERS	28	314.85	66.75	104.69	C	29.31	6	C	1.68
2 1/2" EMT CONDUIT FEEDERS	171	688.47	64.35	245.44	C	419.7	12	C	20.52
1 1/4" EMT STL SS CONN	2	249.63	73.88	65.2	C	1.3	0	C	0
2 1/2" EMT STL SS CONN	12	1,676.43	76.62	391.95	C	47.03	0	C	0
1 1/4" EMT STL SS CPLG	7	289.66	77.52	65.12	C	4.56	0	C	0
2 1/2" EMT STL SS CPLG	43	1,374.75	77.73	306.16	C	131.65	0	C	0
1 1/4" EMT 90 DEG ELBOW	4	656	47.92	341.64	C	13.67	40	C	1.6
2 1/2" EMT 90 DEG ELBOW	26	2,582.00	53.04	1,212.51	C	315.25	70	C	18.2
1 1/4" PLASTIC BUSHING	2	157	95.02	7.82	C	0.16	0	C	0
1 1/2" PLASTIC BUSHING	2	211.94	93.93	12.86	C	0.26	0	C	0
2 1/2" PLASTIC BUSHING	32	883.09	96.69	29.23	C	9.35	0	C	0
1 1/2" STEEL FLEX	4	546.9	47	289.86	C	11.59	11.25	C	0.45
2 1/2" STEEL FLEX	40	812.77	47	430.77	C	172.31	18.75	C	7.5
1 1/2" STL FLEX CONN	1	2,069.20	63.5	755.35	C	7.55	50	C	0.5
2 1/2" STL FLEX CONN	10	5,294.13	63.48	1,933.31	C	193.33	80	C	8
1 1/2" STL 90 DEG FLEX CONN	1	5,282.93	63.56	1,924.89	C	19.25	50	C	0.5
2 1/2" STL 90 DEG FLEX CONN	10	18,692.00	65.68	6,414.77	C	641.48	80	C	8
#8 THHN BLACK	38	775.5	52.34	369.6	M	14.04	10	M	0.38
#6 THHN BLACK	203	1,325.73	57.11	568.61	M	115.43	12	M	2.44
#4 THHN BLACK	108	2,104.22	57.11	902.5	M	97.47	13	M	1.4
#3 THHN BLACK	152	2,635.93	57.11	1,130.55	M	171.84	14	M	2.13
#2 THHN BLACK	150	3,299.36	57.11	1,415.10	M	212.26	14	M	2.1
#1/0 THHN BLACK	30	5,199.40	57.11	2,230.02	M	66.9	19	M	0.57
#3/0 THHN BLACK	772	8,176.50	57.11	3,506.90	M	2,707.33	23	M	17.76
#250MCM THHN BLACK	432	12,379.60	56.71	5,359.13	M	2,315.14	28	M	12.1
#350MCM THHN BLACK	90	17,481.40	56.71	7,567.70	M	681.09	32	M	2.88
1-H CRIMP LUG #6 BLUE	2	383.82	60	153.53	C	3.07	13	C	0.26

1-H CRIMP LUG #4 GRAY	10	500.64	60	200.26	C	20.03	15	C	1.5
1-H CRIMP LUG #2 BROWN	18	977.55	60	391.02	C	70.38	17	C	3.06
1-H CRIMP LUG #1/0 PINK	3	1,071.60	60	428.64	C	12.86	24	C	0.72
1-H CRIMP LUG #250 YELLOW	35	1,925.60	60	770.24	C	269.58	34	C	11.9
1-H CRIMP LUG #350 RED	9	2,284.24	60	913.7	C	82.23	40	C	3.6
600 VOLT WIRE TERMINATION #6 THRU #2	8	0.63	0	0.63	E	5.04	0.5	E	4
600 VOLT WIRE TERMINATION #1 THRU 3/0	40	1.24	0	1.24	E	49.6	0.6	E	24
600 VOLT WIRE TERMINATION 4/0 THRU 400 MCM	8	2.29	0	2.29	E	18.32	0.9	E	7.2
225A CU BUS DUCT	3	0	0	0	E	0	20	C	0.6
3000A LOW IMPED CU DUCT	390	0	0	0	E	0	160	C	624
1/4-20x 1 3/4 WEDGE ANCHOR - 1 1/8" MIN DEPTH	23	0	44	0	C	0	8	C	1.84
1/4" THREADED ROD - PLTD	63	75.66	95.77	3.2	C	2.02	2.5	C	1.58
1/4-20 HEX NUT - PLTD STL	42	2.36	25	1.77	C	0.74	2	C	0.84
ERICO CD3B 1 1/2" EMT/1 1/4" GRC CLAMP	4	65.72	0	65.72	C	2.63	10	C	0.4
ERICO CD6B 2 1/2" EMT/GRC CLAMP	19	159.32	0	159.32	C	30.27	20	C	3.8
SWBD M C BRKR 3000A 3P	1	0	100	0	E	0	40	E	40
SWBD MTR/INST SECTION 3000A	1	0	100	0	E	0	8	E	8
100A 3P MOLDED CASE BRKR OPEN	1	0	100	0	E	0	3	E	3
200A 3P MOLDED CASE BRKR OPEN	6	0	100	0	E	0	4.5	E	27
500A 3P MOLDED CASE BRKR OPEN	3	0	100	0	E	0	9	E	27
100A 250V FUSIBLE DSN SW NEMA 1	3	646.8	100	0	E	0	4	E	12
200A 250V FUSIBLE DSN SW NEMA 1	11	1,003.80	100	0	E	0	6	E	66
75KVA 3PH 480V DRY XMER	1	0	100	0	E	0	18	E	18
150KVA 3PH 480V DRY XMER	3	0	100	0	E	0	30	E	90
TVSS	1	0	100	0	E	0	2.5	E	2.5
1" GRD CLAMP FOR BARE WIRE	8	41.02	60	16.41	E	131.28	0.7	E	5.6
1/4"x4"x10' COPPER BAR	1	600	0	600	E	600	2	E	2
BLOCKOUT/SLEEVE/SEAL 300	1	30	0	30	E	30	0.6	E	0.6
Totals	**3117**					**9727.33**			**1829.69**

Description	Length	Count	Mat. $	Equip. $	Total Mat. $	Lbr Hr.	Lbr. $	Total Lbr. $	Total $
4000A MS12A DISTRIBUTION SWITCHBOARD		1		$67,200.00	$ 67,200.00	80.5	$ 45.00	$ 3,622.50	$ 70,822.50
225A HXMA1 PANELBOARD		7		$ 7,600.00	$ 7,600.00	119	$ 45.00	$ 5,355.00	$ 12,955.00
225A HXMB1 PANELBOARD		7		$ 4,900.00	$ 4,900.00	70	$ 45.00	$ 3,150.00	$ 8,050.00
225A HXL1 PANELBOARD		7		$ 5,400.00	$ 5,400.00	206.5	$ 45.00	$ 9,292.50	$ 14,692.50
400A LXA1 PANELBOARD		7		$10,250.00	$ 10,250.00	227.5	$ 45.00	$ 10,237.50	$ 20,487.50
400A LXB1 PANELBOARD		7		$ 5,400.00	$ 5,400.00	175	$ 45.00	$ 7,875.00	$ 13,275.00
112.5 KVA 3PH 480V STEEL FLEX WITH GROUND		7	$ 5,364.33	$35,450.00	$ 40,814.33	292.88	$ 45.00	$ 13,179.60	$ 53,993.93
225A CU BUS DUCT	1	14		$18,450.00	$ 18,450.00	84.2	$ 45.00	$ 3,789.00	$ 22,239.00
BUS PLUG -> PNL HXMA1 - 2 1/2" EMT [4] 3/0, [1] 6GRD CONC T-R	35*7	1	$ 6,566.98		$ 6,566.98	19.94	$ 45.00	$ 897.30	$ 7,464.28
BUS PLUG -> PNL HXL1 - 2 1/2" EMT [40 3/0, [1] 6GRD CONC T-RO	28*7	1	$ 5,017.60		$ 5,017.60	16.08	$ 45.00	$ 723.60	$ 5,741.20
4000A CU LZ DUCT	390	1	##########		$ 245,700.00	719.9	$ 45.00	$ 32,395.50	$ 278,095.50
Total									**$507,816.41**

Description	Length	Count	Mat. $	Equip. $	Total Mat. $	Lbr Hr.	Lbr. $	Total Lbr. $	Total $
3000A MS12A DISTRIBUTION SWITCHBOARD		1		$ 40,700.00	$ 40,700.00	80.5	$ 45.00	$ 3,622.50	$ 44,322.50
225A HXMA1 PANELBOARD		7		$ 10,500.00	$ 10,500.00	175	$ 45.00	$ 7,875.00	$ 18,375.00
225A H3L1 PANELBOARD		1		$ 450.00	$ 450.00	28	$ 45.00	$ 1,260.00	$ 1,710.00
225A H4L1 PANELBOARD		3		$ 4,510.00	$ 4,510.00	75	$ 45.00	$ 3,375.00	$ 7,885.00
225A H5L1 PANELBOARD		3		$ 5,800.00	$ 5,800.00	88.5	$ 45.00	$ 3,982.50	$ 9,782.50
400A L3A1 PANELBOARD		1		$ 1,170.00	$ 1,170.00	25	$ 45.00	$ 1,125.00	$ 2,295.00
400A L3B1 PANELBOARD		7		$ 4,900.00	$ 4,900.00	175	$ 45.00	$ 7,875.00	$ 12,775.00
600A LXA1 PANELBOARD		3		$ 6,500.00	$ 6,500.00	102	$ 45.00	$ 4,590.00	$ 11,090.00
600A LXB1 PANELBOARD		3		$ 3,190.00	$ 3,190.00	88.5	$ 45.00	$ 3,982.50	$ 7,172.50
75 KVA 3PH 480V STEEL FLEX WITH GROUND		1	$ 558.27	$ 4,200.00	$ 4,758.27	28.81	$ 45.00	$ 1,296.45	$ 6,054.72
150 KVA 3PH 480V STEEL FLEX WITH GROUND		3	$ 3,612.46	$ 19,800.00	$ 23,412.46	145.2	$ 45.00	$ 6,534.00	$ 29,946.46
250A CU BUS DUCT	1	3		$ 7,180.00	$ 7,180.00	18.2	$ 45.00	$ 819.00	$ 7,999.00
200A CU BUS DUCT	1	8		$ 16,000.00	$ 16,000.00	48.2	$ 45.00	$ 2,169.00	$ 18,169.00
100A CU BUS DUCT	1	3		$ 4,800.00	$ 4,800.00	12.2	$ 45.00	$ 549.00	$ 5,349.00
BUS PLUG -> PNL H3MA1 - 2 1/2" EMT [4] 3/0, [1] 6GRD CONC T-ROD	35	1	$ 865.17		$ 865.17	19.42	$ 45.00	$ 873.90	$ 1,739.07
BUS PLUG -> PNL H3L1 - 2 1/2" EMT [4] 3/0, [1] 6GRD CONC T-ROD	28	1	$ 716.80		$ 716.80	16.08	$ 45.00	$ 723.60	$ 1,440.40
BUS PLUG -> PNL H4MA1 - 2 1/2" EMT [4] 3/0, [1] 6GRD CONC T-ROD	35	1	$ 840.92		$ 840.92	18.02	$ 45.00	$ 810.90	$ 1,651.82
BUS PLUG -> PNL H4L1 - 1 1/4" EMT [4] 3, [1] 8GRD CONC T-ROD	28	1	$ 243.02		$ 243.02	10.93	$ 45.00	$ 491.85	$ 734.87
BUS PLUG -> PNL H5MA1 - 2 1/2" EMT [4] 3/0, [1] 6GRD CONC T-ROD	35	1	$ 840.92		$ 840.92	18.02	$ 45.00	$ 810.90	$ 1,651.82
BUS PLUG -> PNL H5L1 - 2 1/2" EMT [4] 250, [1] 4 CONC T-ROD	28	1	$ 1,019.43		$ 1,019.43	19.27	$ 45.00	$ 867.15	$ 1,886.58
PNL LXB1 -> PNL LXA1 - 2 1/2" EMT [4] 3/0, [1] 6GRD CONC T-ROD	10*3	1	$ 1,291.08		$ 1,291.08	11.88	$ 45.00	$ 534.60	$ 1,825.68
3000A CU LZ DUCT	390	1	$ 600.00	$ 163,800.00	$ 164,400.00	626	$ 45.00	$ 28,170.00	$ 192,570.00
Total									**$ 386,425.92**

Package 1 - Andy

Line Item #	Description	Length	Count	Additional Components/Items
1	MS12A (4000A Distribution Switchboard): 4000A MCB	n/a	1	Internal: 4000A Bus, TVSS, Elec. Digital Meter
2	HXMA1 (480Y/277V, 225A Panelboard: MLO, No Main Breaker)	n/a	7	28 Active Ckts
3	HXMB1 (480Y/277V, 225A Panelboard: MLO, No Main Breaker)	n/a	7	15 Active Ckts
4	HXL1 (480Y/277V, 225A Panelboard: MLO, No Main Breaker)	n/a	7	Minimum Active Ckts; (1)-175 3P Internal Breaker
`	LXA1 (208Y/120V, 400A Panelboard: 400A MCB)	n/a	7	Minimum Active Ckts
6	LXB1 (208Y/120V, 400A Panelboard: MLO, No Main Breaker)	n/a	7	Minimum Active Ckts
7	112.5 kVA Step Down XFMR: (Dry Type Indoors)	n/a	7	Include Typ. Feeders & Grounding
8	200A, 3P Bus Plug	n/a	14	Fused, 200A Breaker
9	Feeder: from Bus Plug to HXMA1	35'	1	(4)#3/0, (1)#6, 2-1/2" C; (6) 90 Degree Elbows, 15' Wire Makeup
10	Feeder: from Bus Plug to HXL1	28'	1	(4)#3/0, (1)#6, 2-1/2" C; (4) 90 Degree Elbows, 10' Wire Makeup
11	4000A Busway 3P, 4W 277/480V, Full Neutral	390'	1	Copper Busbar

Assumptions:

1. Concrete Building
2. EMT Conduit, Set Screw Connections

Package 2 - Andy

Line Item #	Description	Length	Count	Additional Components/Items
1	MS12A (300A Distribution Switchboard): 3000A MCB	n/a	1	Internal: 3000A Bus, TVSS, Elec. Digital Meter
2	HXMA1 (480Y/277V, 225A Panelboard: MLO, No Main Breaker)	n/a	7	All circuits active
3	H3L1 (480Y/277V, 225A Panelboard: MLO, No Main Breaker)	n/a	1	Minimum Active Ckts; (1)-100 3P Internal Breaker
4	H4L1 (480Y/277V, 225A Panelboard: MLO, No Main Breaker)	n/a	3	Minimum Active Ckts
5	H5L1 (480Y/277V, 225A Panelboard: MLO, No Main Breaker)	n/a	3	Minimum Active Ckts; (1)-200 3P Internal Breaker
6	L3A1 (208Y/120V, 400A Panelboard: 250A MCB)	n/a	1	Minimum Active Circuits
7	L3B1 (208Y/120V, 400A Panelboard: MLO, No Main Breaker)	n/a	7	Minimum Active Circuits
8	LXA1 (208Y/120V, 600A Panelboard: 450A MCB)	n/a	3	Minimum Active Circuits
9	LXB1 (208Y/120V, 600A Panelboard: MLO, No Main Breaker)	n/a	3	Minimum Active Ckts; (1)-200A 3P Internal Breaker
10	75 kVA Step Down XFMR: (Dry Type Indoors)	n/a	1	Include Typ. Feeders & Grounding
11	150 kVA Step Down XFMR: (Dry Type Indoors)	n/a	3	Include Typ. Feeders & Grounding
12	250A, 3P Bus Plug	n/a	3	Fused, 250A Breaker
13	200A, 3P Bus Plug	n/a	8	Fused, 200A Breaker
14	100A, 3P Bus Plug	n/a	3	Fused, 100A Breaker
15	Feeder: from Bus Plug to H3MA1	35	1	(4)#3/0, (1)#6, 2-1/2" C; (6) 90 Degree Elbows, 10' Wire Makeup
16	Feeder: from Bus Plug to H3L1	28	1	(4)#3/0, (1)#6, 2-1/2" C; (4) 90 Degree Elbows, 10' Wire Makeup

Package 2 (cont'd) - Andy

Line Item #	Description	Length	Count	Additional Components/Items
17	Feeder: from Bus Plug to H4MA1	35	1	(4)#3/0, (1)#6, 2-1/2" C; (4) 90 Degree Elbows, 10' Wire Makeup
18	Feeder: from Bus Plug to H4L1	28	1	(4)#3, (1)#8, 1-1/4"C; (4) 90 Degree Elbows, 10' Wire Makeup
19	Feeder: from Bus Plug to H5MA1	35	1	(4)#3/0, (1)#6, 2-1/2" C; (4) 90 Degree Elbows, 10' Wire Makeup
20	Feeder: from Bus Plug to H5L1	28	1	(4)#250kcmil, (1)#4, 2-1/2"C; (4) 90 Degree Elbows, 10' Wire Makeup
21	Feeder: from LXB1 to LXA1 (through floor)	10	1	(4)#3/0, (1)#6, 2-1/2" C; (4) 90 Degree Elbows, 5' Wire Makeup; fire insulation through slab
22	3000A Busway 3P, 4W 277/480V, Full Neutral	390'	1	Copper busbar

Assumptions:

1. Concrete Building
2. EMT Conduit, Set Screw Connections

Thesis Quoted Items

#	Description	Count	Additional Components/Items	Price $	
14	(4000A Distribution Switchboard): 4000A MCB	1	Internal: 4000A Bus, TVSS, Elec. Digital Meter	**$67,200.00**	EA
15	(480Y/277V, 225A Panelboard: MLO, No Main Breake	7	28 Active Ckts	**$7,600.00**	TOTAL
16	(480Y/277V, 225A Panelboard: MLO, No Main Breake	7	15 Active Ckts	**$4,900.00**	TOTAL
17	(480Y/277V, 225A Panelboard: MLO, No Main Breake	7	Minimum Active Ckts; (1)-175 3P Internal Breaker	**$5,400.00**	TOTAL
18	(208Y/120V, 400A Panelboard: 400A MCB)	7	Minimum Active Ckts	**$10,250.00**	TOTAL
19	(208Y/120V, 400A Panelboard: MLO, No Main Breake	7	Minimum Active Ckts	**$5,400.00**	TOTAL
20	112.5 kVA Step Down XFMR: (Dry Type Indoors)	7	NEMA TP-1, 200% Neutral	**$35,450.00**	TOTAL
21	200A, 3P Bus Plug	14	Fused, 200A Breaker	**$18,450.00**	TOTAL
22	4000A Busway 3P, 4W 277/480V, Full Neutral	1	Copper Busbar	**$6,300.00**	PER 10 FT
23	(300A Distribution Switchboard): 3000A MCB	1	Internal: 3000A Bus, TVSS, Elec. Digital Meter	**$40,700.00**	EA
24	(480Y/277V, 225A Panelboard: MLO, No Main Breake	7	All circuits active	**$10,500.00**	TOTAL
25	(480Y/277V, 225A Panelboard: MLO, No Main Breake	1	Minimum Active Ckts; (1)-100 3P Internal Breaker	**$450.00**	EA
26	(480Y/277V, 225A Panelboard: MLO, No Main Breake	3	Minimum Active Ckts	**$4,510.00**	TOTAL
27	(480Y/277V, 225A Panelboard: MLO, No Main Breake	3	Minimum Active Ckts; (1)-200 3P Internal Breaker	**$5,800.00**	TOTAL
28	(208Y/120V, 400A Panelboard: 250A MCB)	1	Minimum Active Circuits	**$1,170.00**	EA
29	(208Y/120V, 400A Panelboard: MLO, No Main Breake	7	Minimum Active Circuits	**$4,900.00**	TOTAL
30	(208Y/120V, 600A Panelboard: 450A MCB)	3	Minimum Active Circuits	**$6,500.00**	TOTAL
31	(208Y/120V, 600A Panelboard: MLO, No Main Breake	3	Minimum Active Ckts; (1)-200A 3P Internal Breaker	**$3,190.00**	TOTAL
32	75 kVA Step Down XFMR: (Dry Type Indoors)	1	NEMA TP-1, 200% Neutral	**$4,200.00**	EA
33	150 kVA Step Down XFMR: (Dry Type Indoors)	3	NEMA TP-1, 200% Neutral	**$19,800.00**	TOTAL
34	250A, 3P Bus Plug	3	Fused, 250A Breaker	**$7,180.00**	TOTAL
35	200A, 3P Bus Plug	8	Fused, 200A Breaker	**$16,000.00**	TOTAL
36	100A, 3P Bus Plug	3	Fused, 100A Breaker	**$4,800.00**	TOTAL
37	3000A Busway 3P, 4W 277/480V, Full Neutral	1	Copper busbar	**$4,200.00**	PER 10 FT

Appendix B.8

3^{rd} Floor Redesign Calculations & Schedules

3RD Floor Redesign

XFMR

Square footage of office space (minus core) = 22,436 SF

Panels L3A1 & L3B1 (120/208V) are designated for receptacles + already designated loads

So,

$$2.5W/SF \cdot 22436SF = 56090W$$

$$\frac{56090W}{0.95PF} = 59042kVA \approx 59kVA$$

Add in existing circuit loads $59kVA + 10kVA + 0kVA = 69kVA$

(10kVA from panel L3A1 and 0kVA from panel L3B1)

Therefore, transformer can be reduced from 112.5 kVA to **75** kVA

Which means your primary breaker can be 100A and your secondary breaker can be or 250A

See PAGES XXX FOR PANEL SCHEDULES

H3MA1

Consolidation of panels H3MA1 & H3MB1

See Floors 3-9 480V panel consolidation section

Wiring

Refer to riser diagram

All calculations based off NFPA 70 – NEC 2011

H(3-9)MA1

V:	480Y/277	Rm # Elec. Rn	10000 AIC	3P - 4W	Fdr:	(4) 3/0 & #6 G.	2-1/2"C	155 kVA		MLO

Designations		VA/Phase			Bkr/Pole/Wire					Designations		VA/Phase			Bkr/Pole/Wire				
Ckt	Description	A	B	C	Bkr	/	# P	/	W	Ckt	Description	A	B	C	Bkr	/	# P	/	W
1	FPTU (C/5.9)	2510			20	/	3	/	#12	2	FPTU (B/5.0)	5820			30	/	1	/	#10
3	-		2510		-	/	-	/	-	4	FPTU (B/5.0)		5820		30	/	1	/	#10
5	-			2510	-	/	-	/	-	6	FPTU (B/5.0)			5820	30	/	1	/	#10
7	FPTU (C/5.9)	2510			20	/	3	/	#12	8	FPTU (B/5.0)	5820			30	/	1	/	#10
9	-		2510		-	/	-	/	-	10	FPTU (B/4.4)		5220		30	/	1	/	#12
11	-			2510	-	/	-	/	-	12	FPTU (B/4.4)			5220	30	/	1	/	#12
13	FPTU (C/6.6)	2740			20	/	3	/	#12	14	FPTU (B/4.4)	5220			30	/	1	/	#12
15	-		2740		-	/	-	/	-	16	FPTU (B/3.9)		4720		25	/	1	/	#12
17	-			2740	-	/	-	/	-	18	FPTU (B/3.8)			4720	25	/	1	/	#12
19	FPTU (C/6.6)	2740			20	/	3	/	#12	20	FPTU (B/3.6)	4420			25	/	1	/	#12
21	-		2740		-	/	-	/	-	22	FPTU (B/3.7)		4520		25	/	1	/	#12
23	-			2740	-	/	-	/	-	24	FPTU (B/2.6)			3420	20	/	1	/	#12
25	Space	0			0	/	0	/	#####	26	FPTU (B/2.6)	3420			20	/	1	/	#12
27	Space		0		0	/	0	/	#####	28	FPTU (B/-)		1640		20	/	1	/	#12
29	FPTU (B/5.0)			5820	30	/	1	/	#10	30	FPTU (B/-)			1640	20	/	1	/	#12
31	FPTU (B/5.0)	5820			30	/	1	/	#10	32	FPTU (B/-)	1640			20	/	1	/	#12
33	FPTU (B/5.0)		5820		30	/	1	/	#10	34	FPTU (B/-)		1640		20	/	1	/	#12
35	FPTU (B/5.0)			5820	30	/	1	/	#10	36	FPTU (B/-)			1640	20	/	1	/	#12
37	FPTU (B/4.6)	6220			30	/	1	/	#10	38	EWH-1	3000			20	/	3	/	#12
39	FPTU (B/4.6)		6220		30	/	1	/	#10	40	-		3000		-	/	-	/	-
41	FPTU (B/4.6)			6220	30	/	1	/	#10	42	-			3000	-	/	-	/	-

H3L1

V:	480Y/277	Rm # Elec. Rn	10000 AIC	3P - 4W	Fdr:	(4) #3/0, #6 G	2-1/2"C	6 kVA		MLO

Designations		VA/Phase			Bkr/Pole/Wire					Designations		VA/Phase			Bkr/Pole/Wire				
Ckt	Description	A	B	C	Bkr	/	# P	/	W	Ckt	Description	A	B	C	Bkr	/	# P	/	W
1	Toilet Rm. Lts.	1340			20	/	1	/	#12	2	Ltg. Relay Panel	1000			20	/	1	/	#12
3	Corridor Lts.		380		20	/	1	/	#12	4	Space		0		0	/	0	/	#####
5	Space			0	0	/	0	/	#####	6	Space			0	0	/	0	/	#####
7	Space	0			0	/	0	/	#####	8	Space	0			0	/	0	/	#####
9	Space		0		0	/	0	/	#####	10	Space		0		0	/	0	/	#####
11	Space			0	0	/	0	/	#####	12	Space			0	0	/	0	/	#####
13	Space	0			0	/	0	/	#####	14	Space	0			0	/	0	/	#####
15	Space		0		0	/	0	/	#####	16	Space		0		0	/	0	/	#####
17	Space			0	0	/	0	/	#####	18	Space			0	0	/	0	/	#####
19	Space	0			0	/	0	/	#####	20	Space	0			0	/	0	/	#####
21	Space		0		0	/	0	/	#####	22	Space		0		0	/	0	/	#####
23	Space			0	0	/	0	/	#####	24	Space			0	0	/	0	/	#####
25	Space	0			0	/	0	/	#####	26	Space	0			0	/	0	/	#####
27	Space		0		0	/	0	/	#####	28	Space		0		0	/	0	/	#####
29	Space			0	0	/	0	/	#####	30	Space			0	0	/	0	/	#####
31	Space	0			0	/	0	/	#####	32	Space	0			0	/	0	/	#####
33	Space		0		0	/	0	/	#####	34	Space		0		0	/	0	/	#####
35	Space			0	0	/	0	/	#####	36	Space			0	0	/	0	/	#####
37	Space	0			0	/	0	/	#####	38	75 kVA XFMR	887			100	/	3	/	#12
39	Space		0		0	/	0	/	#####	40	-		887		-	/	-	/	-
41	Space			0	0	/	0	/	#####	42	-			887	-	/	-	/	-

L3A1 (Section 1)

V:	208Y/120	Rm # Elec. Rn	10000 AIC	3P - 4W	Fdr:	(4) #4/0, #4 G	2-1/2"C	10 kVA	250 A	MCB

Designations		VA/Phase			Bkr/Pole/Wire					Designations		VA/Phase			Bkr/Pole/Wire				
Ckt	Description	A	B	C	Bkr	/	# P	/	W	Ckt	Description	A	B	C	Bkr	/	# P	/	W
1	Core Rec.	1440			20	/	1	/	#12	2	Sec. Pnl (5 &10)	180			20	/	1	/	#12
3	Toilet Rm. Recep.		540		20	/	1	/	#12	4	W. Slot Trk. (5)		1800		20	/	1	/	#12
5	ILCP-1 (3&7 only)			500	20	/	1	/	#12	6	W. Slot LED (5&9)			1080	20	/	1	/	#12
7	Flush Valve	500			20	/	1	/	#12	8	E. Slot Trk. (3-9,11)	1000			20	/	1	/	#12
9	Smoke Dampers		500		20	/	1	/	#12	10	W. Slot LED (10,11)		1460		20	/	1	/	#12
11	Smoke Dampers			500	20	/	1	/	#12	12	Space			0	0	/	0	/	#####
13	Space	0			0	/	0	/	#####	14	Space	0			0	/	0	/	#####
15	Space		0		0	/	0	/	#####	16	Space		0		0	/	0	/	#####
17	Space			0	0	/	0	/	#####	18	Space			0	0	/	0	/	#####
19	Space	0			0	/	0	/	#####	20	Space	0			0	/	0	/	#####
21	Space		0		0	/	0	/	#####	22	Space		0		0	/	0	/	#####
23	Space			0	0	/	0	/	#####	24	Space			0	0	/	0	/	#####
25	Space	0			0	/	0	/	#####	26	Space	0			0	/	0	/	#####
27	Space		0		0	/	0	/	#####	28	Space		0		0	/	0	/	#####
29	Space			0	0	/	0	/	#####	30	Space			0	0	/	0	/	#####
31	Space	0			0	/	0	/	#####	32	Space	0			0	/	0	/	#####
33	Space		0		0	/	0	/	#####	34	Space		0		0	/	0	/	#####
35	Space			0	0	/	0	/	#####	36	Space			0	0	/	0	/	#####
37	Space	0			0	/	0	/	#####	38	Space	0			0	/	0	/	#####
39	Space		0		0	/	0	/	#####	40	Space		0		0	/	0	/	#####
41	Space			0	0	/	0	/	#####	42	Space			0	0	/	0	/	#####

L3B1 (Section 2)

V:	208Y/120	Rm # Elec. Rn	10000 AIC	3P - 4W	Fdr:	Section 2		kVA		MLO

Designations		VA/Phase			Bkr/Pole/Wire					Designations		VA/Phase			Bkr/Pole/Wire				
Ckt	Description	A	B	C	Bkr	/	# P	/	W	Ckt	Description	A	B	C	Bkr	/	# P	/	W
1	Space	0			0	/	0	/	#####	2	Space	0			0	/	0	/	#####
3	Space		0		0	/	0	/	#####	4	Space		0		0	/	0	/	#####
5	Space			0	0	/	0	/	#####	6	Space			0	0	/	0	/	#####
7	Space	0			0	/	0	/	#####	8	Space	0			0	/	0	/	#####
9	Space		0		0	/	0	/	#####	10	Space		0		0	/	0	/	#####
11	Space			0	0	/	0	/	#####	12	Space			0	0	/	0	/	#####
13	Space	0			0	/	0	/	#####	14	Space	0			0	/	0	/	#####
15	Space		0		0	/	0	/	#####	16	Space		0		0	/	0	/	#####
17	Space			0	0	/	0	/	#####	18	Space			0	0	/	0	/	#####
19	Space	0			0	/	0	/	#####	20	Space	0			0	/	0	/	#####
21	Space		0		0	/	0	/	#####	22	Space		0		0	/	0	/	#####
23	Space			0	0	/	0	/	#####	24	Space			0	0	/	0	/	#####
25	Space	0			0	/	0	/	#####	26	Space	0			0	/	0	/	#####
27	Space		0		0	/	0	/	#####	28	Space		0		0	/	0	/	#####
29	Space			0	0	/	0	/	#####	30	Space			0	0	/	0	/	#####
31	Space	0			0	/	0	/	#####	32	Space	0			0	/	0	/	#####
33	Space		0		0	/	0	/	#####	34	Space		0		0	/	0	/	#####
35	Space			0	0	/	0	/	#####	36	Space			0	0	/	0	/	#####
37	Space	0			0	/	0	/	#####	38	Space	0			0	/	0	/	#####
39	Space		0		0	/	0	/	#####	40	Space		0		0	/	0	/	#####
41	Space			0	0	/	0	/	#####	42	Space			0	0	/	0	/	#####

Appendix B.9

Panel Schedules

H(3-9)MA1

V:	480Y/277	Rm # Elec. Rn	10000 AIC	3P - 4W	Fdr:	(4) 3/0 & #6 G.	2-1/2"C	155 kVA		MLO

Designations		VA/Phase			Bkr/Pole/Wire					Designations		VA/Phase			Bkr/Pole/Wire				
Ckt	Description	A	B	C	Bkr	/	# P	/	W	Ckt	Description	A	B	C	Bkr	/	# P	/	W
1	FPTU (C/5.9)	2510			20	/	3	/	#12	2	FPTU (B/5.0)	5820			30	/	1	/	#10
3	-		2510		-	/	-	/	-	4	FPTU (B/5.0)		5820		30	/	1	/	#10
5	-			2510	-	/	-	/	-	6	FPTU (B/5.0)			5820	30	/	1	/	#10
7	FPTU (C/5.9)	2510			20	/	3	/	#12	8	FPTU (B/5.0)	5820			30	/	1	/	#10
9	-		2510		-	/	-	/	-	10	FPTU (B/4.4)		5220		30	/	1	/	#12
11	-			2510	-	/	-	/	-	12	FPTU (B/4.4)			5220	30	/	1	/	#12
13	FPTU (C/6.6)	2740			20	/	3	/	#12	14	FPTU (B/4.4)	5220			30	/	1	/	#12
15	-		2740		-	/	-	/	-	16	FPTU (B/3.9)		4720		25	/	1	/	#12
17	-			2740	-	/	-	/	-	18	FPTU (B/3.8)			4720	25	/	1	/	#12
19	FPTU (C/6.6)	2740			20	/	3	/	#12	20	FPTU (B/3.6)	4420			25	/	1	/	#12
21	-		2740		-	/	-	/	-	22	FPTU (B/3.7)		4520		25	/	1	/	#12
23	-			2740	-	/	-	/	-	24	FPTU (B/2.6)			3420	20	/	1	/	#12
25	Space	0			0	/	0	/	#####	26	FPTU (B/2.6)	3420			20	/	1	/	#12
27	Space		0		0	/	0	/	#####	28	FPTU (B/-)		1640		20	/	1	/	#12
29	FPTU (B/5.0)			5820	30	/	1	/	#10	30	FPTU (B/-)			1640	20	/	1	/	#12
31	FPTU (B/5.0)	5820			30	/	1	/	#10	32	FPTU (B/-)	1640			20	/	1	/	#12
33	FPTU (B/5.0)		5820		30	/	1	/	#10	34	FPTU (B/-)		1640		20	/	1	/	#12
35	FPTU (B/5.0)			5820	30	/	1	/	#10	36	FPTU (B/-)			1640	20	/	1	/	#12
37	FPTU (B/4.6)	6220			30	/	1	/	#10	38	EWH-1	3000			20	/	3	/	#12
39	FPTU (B/4.6)		6220		30	/	1	/	#10	40	-		3000		-	/	-	/	-
41	FPTU (B/4.6)			6220	30	/	1	/	#10	42	-			3000	-	/	-	/	-

H(4,6,8)L1

V:	480Y/277	Rm # Elec. Rn	10000 AIC	3P - 4W	Fdr:	(4) #3 & #8G	1-1/4"C	3 kVA		MLO

Designations		VA/Phase			Bkr/Pole/Wire					Designations		VA/Phase			Bkr/Pole/Wire				
Ckt	Description	A	B	C	Bkr	/	# P	/	W	Ckt	Description	A	B	C	Bkr	/	# P	/	W
1	Toilet Rm. Lts.	1340			20	/	1	/	#12	2	Ltg. Relay Panel	1000			0	/	1	/	#12
3	Corridor Lts.		380		0	/	1	/	#12	4	Space		0		0	/	0	/	#####
5	Space			0	0	/	0	/	#####	6	Space			0	0	/	0	/	#####
7	Space	0			0	/	0	/	#####	8	Space	0			0	/	0	/	#####
9	Space		0		0	/	0	/	#####	10	Space		0		0	/	0	/	#####
11	Space			0	0	/	0	/	#####	12	Space			0	0	/	0	/	#####
13	Space	0			0	/	0	/	#####	14	Space	0			0	/	0	/	#####
15	Space		0		0	/	0	/	#####	16	Space		0		0	/	0	/	#####
17	Space			0	0	/	0	/	#####	18	Space			0	0	/	0	/	#####
19	Space	0			0	/	0	/	#####	20	Space	0			0	/	0	/	#####
21	Space		0		0	/	0	/	#####	22	Space		0		0	/	0	/	#####
23	Space			0	0	/	0	/	#####	24	Space			0	0	/	0	/	#####
25	Space	0			0	/	0	/	#####	26	Space	0			0	/	0	/	#####
27	Space		0		0	/	0	/	#####	28	Space		0		0	/	0	/	#####
29	Space			0	0	/	0	/	#####	30	Space			0	0	/	0	/	#####
31	Space	0			0	/	0	/	#####	32	Space	0			0	/	0	/	#####
33	Space		0		0	/	0	/	#####	34	Space		0		0	/	0	/	#####
35	Space			0	0	/	0	/	#####	36	Space			0	0	/	0	/	#####
37	Space	0			0	/	0	/	#####	38	Space	0			0	/	0	/	#####
39	Space		0		0	/	0	/	#####	40	Space		0		0	/	0	/	#####
41	Space			0	0	/	0	/	#####	42	Space			0	0	/	0	/	#####

H(5,7,9)L1

V:	480Y/277	Rm # Elec. Rn	10000 AIC	3P - 4W	Fdr:	(4)#250kcmil & #4 G	2-1/2"C	4 kVA		MLO

Designations		VA/Phase			Bkr/Pole/Wire					Designations		VA/Phase			Bkr/Pole/Wire				
Ckt	Description	A	B	C	Bkr	/	# P	/	W	Ckt	Description	A	B	C	Bkr	/	# P	/	W
1	Toilet Rm. Lts.	1340			20	/	1	/	#12	2	Ltg. Relay Panel	1000			0	/	1	/	#12
3	Corridor Lts.		380		0	/	1	/	#12	4	Space		0		0	/	0	/	#####
5	Space			0	0	/	0	/	#####	6	Space			0	0	/	0	/	#####
7	Space	0			0	/	0	/	#####	8	Space	0			0	/	0	/	#####
9	Space		0		0	/	0	/	#####	10	Space		0		0	/	0	/	#####
11	Space			0	0	/	0	/	#####	12	Space			0	0	/	0	/	#####
13	Space	0			0	/	0	/	#####	14	Space	0			0	/	0	/	#####
15	Space		0		0	/	0	/	#####	16	Space		0		0	/	0	/	#####
17	Space			0	0	/	0	/	#####	18	Space			0	0	/	0	/	#####
19	Space	0			0	/	0	/	#####	20	Space	0			0	/	0	/	#####
21	Space		0		0	/	0	/	#####	22	Space		0		0	/	0	/	#####
23	Space			0	0	/	0	/	#####	24	Space			0	0	/	0	/	#####
25	Space	0			0	/	0	/	#####	26	Space	0			0	/	0	/	#####
27	Space		0		0	/	0	/	#####	28	Space		0		0	/	0	/	#####
29	Space			0	0	/	0	/	#####	30	Space			0	0	/	0	/	#####
31	Space	0			0	/	0	/	#####	32	Space	0			0	/	0	/	#####
33	Space		0		0	/	0	/	#####	34	Space		0		0	/	0	/	#####
35	Space			0	0	/	0	/	#####	36	Space			0	0	/	0	/	#####
37	Space	0			0	/	0	/	#####	38	150 kVA XFMR	297			200	/	3	/	#12
39	Space		0		0	/	0	/	#####	40	-		297		-	/	-	/	-
41	Space			0	0	/	0	/	#####	42	-			297	-	/	-	/	-

L(4,6,8)A1 (Section 1)

V:	208Y/120	Rm # Elec. Rn	10000 AIC	3P - 4W	Fdr:	(4) #3/0, #6 G	2-1/2"C	10 kVA		MLO

Designations		VA/Phase			Bkr/Pole/Wire					Designations		VA/Phase			Bkr/Pole/Wire				
Ckt	Description	A	B	C	Bkr	/	# P	/	W	Ckt	Description	A	B	C	Bkr	/	# P	/	W
1	Core Recep.	1440			20	/	1	/	#12	2	Sec. Pnl. (5 & 10)	180			20	/	1	/	#12
3	Toilet Rm. Recep.		540		20	/	1	/	#12	4	W. Slot Trk. (5)		1800		20	/	1	/	#12
5	ILCP-1 (3&7 only)			500	20	/	1	/	#12	6	W. Slot LED (5 & 9)			1080	20	/	1	/	#12
7	Flush Valve	500			20	/	1	/	#12	8	E. Slot Trk. (3-9,11)	1000			20	/	1	/	#12
9	Smoke Dampers		500		20	/	1	/	#12	10	E. Slot LED (10,11)		1460		20	/	1	/	#12
11	Smoke Dampers			500	20	/	1	/	#12	12	Space			0	0	/	0	/	#####
13	Space	0			0	/	0	/	#####	14	Space	0			0	/	0	/	#####
15	Space		0		0	/	0	/	#####	16	Space		0		0	/	0	/	#####
17	Space			0	0	/	0	/	#####	18	Space			0	0	/	0	/	#####
19	Space	0			0	/	0	/	#####	20	Space	0			0	/	0	/	#####
21	Space		0		0	/	0	/	#####	22	Space		0		0	/	0	/	#####
23	Space			0	0	/	0	/	#####	24	Space			0	0	/	0	/	#####
25	Space	0			0	/	0	/	#####	26	Space	0			0	/	0	/	#####
27	Space		0		0	/	0	/	#####	28	Space		0		0	/	0	/	#####
29	Space			0	0	/	0	/	#####	30	Space			0	0	/	0	/	#####
31	Space	0			0	/	0	/	#####	32	Space	0			0	/	0	/	#####
33	Space		0		0	/	0	/	#####	34	Space		0		0	/	0	/	#####
35	Space			0	0	/	0	/	#####	36	Space			0	0	/	0	/	#####
37	Space	0			0	/	0	/	#####	38	Space	0			0	/	0	/	#####
39	Space		0		0	/	0	/	#####	40	Space		0		0	/	0	/	#####
41	Space			0	0	/	0	/	#####	42	Space			0	0	/	0	/	#####

L(4,6,8)B1 (Section 2)

V:	208Y/120	Rm # Elec. Rn	10000 AIC	3P - 4W	Fdr:	Section 2		kVA		MLO

Designations		VA/Phase			Bkr/Pole/Wire					Designations		VA/Phase			Bkr/Pole/Wire				
Ckt	Description	A	B	C	Bkr	/	# P	/	W	Ckt	Description	A	B	C	Bkr	/	# P	/	W
1	Space	0			0	/	0	/	#####	2	Space	0			0	/	0	/	#####
3	Space		0		0	/	0	/	#####	4	Space		0		0	/	0	/	#####
5	Space			0	0	/	0	/	#####	6	Space			0	0	/	0	/	#####
7	Space	0			0	/	0	/	#####	8	Space	0			0	/	0	/	#####
9	Space		0		0	/	0	/	#####	10	Space		0		0	/	0	/	#####
11	Space			0	0	/	0	/	#####	12	Space			0	0	/	0	/	#####
13	Space	0			0	/	0	/	#####	14	Space	0			0	/	0	/	#####
15	Space		0		0	/	0	/	#####	16	Space		0		0	/	0	/	#####
17	Space			0	0	/	0	/	#####	18	Space			0	0	/	0	/	#####
19	Space	0			0	/	0	/	#####	20	Space	0			0	/	0	/	#####
21	Space		0		0	/	0	/	#####	22	Space		0		0	/	0	/	#####
23	Space			0	0	/	0	/	#####	24	Space			0	0	/	0	/	#####
25	Space	0			0	/	0	/	#####	26	Space	0			0	/	0	/	#####
27	Space		0		0	/	0	/	#####	28	Space		0		0	/	0	/	#####
29	Space			0	0	/	0	/	#####	30	Space			0	0	/	0	/	#####
31	Space	0			0	/	0	/	#####	32	Space	0			0	/	0	/	#####
33	Space		0		0	/	0	/	#####	34	Space		0		0	/	0	/	#####
35	Space			0	0	/	0	/	#####	36	Space			0	0	/	0	/	#####
37	Space	0			0	/	0	/	#####	38	Space	0			0	/	0	/	#####
39	Space		0		0	/	0	/	#####	40	Space		0		0	/	0	/	#####
41	Space			0	0	/	0	/	#####	42	Space			0	0	/	0	/	#####

L(5,7,9)A1 (Section 1)

V:	208Y/120	Rm # Elec. Rn	10000 AIC	3P - 4W	Fdr:	2 sets (4)#4/0 & #2G	2-1/2"C	10 kVA	450 A	MCB

Designations		VA/Phase			Bkr/Pole/Wire					Designations		VA/Phase			Bkr/Pole/Wire				
Ckt	Description	A	B	C	Bkr	/	# P	/	W	Ckt	Description	A	B	C	Bkr	/	# P	/	W
1	Core Rec.	1440			20	/	1	/	#12	2	Sec. Pnl (5 &10)	180			20	/	1	/	#12
3	Toilet Rm. Recep.		540		20	/	1	/	#12	4	W. Slot Trk. (5)		1800		20	/	1	/	#12
5	ILCP-1 (3&7 only)			500	20	/	1	/	#12	6	W. Slot LED (5&9)			1080	20	/	1	/	#12
7	Flush Valve	500			20	/	1	/	#12	8	E. Slot Trk. (3-9,11)	1000			20	/	1	/	#12
9	Smoke Dampers		500		20	/	1	/	#12	10	E. Slot LED (10,11)		1460		20	/	1	/	#12
11	Smoke Dampers			500	20	/	1	/	#12	12	Space			0	0	/	0	/	#####
13	Space	0			0	/	0	/	#####	14	Space	0			0	/	0	/	#####
15	Space		0		0	/	0	/	#####	16	Space		0		0	/	0	/	#####
17	Space			0	0	/	0	/	#####	18	Space			0	0	/	0	/	#####
19	Space	0			0	/	0	/	#####	20	Space	0			0	/	0	/	#####
21	Space		0		0	/	0	/	#####	22	Space		0		0	/	0	/	#####
23	Space			0	0	/	0	/	#####	24	Space			0	0	/	0	/	#####
25	Space	0			0	/	0	/	#####	26	Space	0			0	/	0	/	#####
27	Space		0		0	/	0	/	#####	28	Space		0		0	/	0	/	#####
29	Space			0	0	/	0	/	#####	30	Space			0	0	/	0	/	#####
31	Space	0			0	/	0	/	#####	32	Space	0			0	/	0	/	#####
33	Space		0		0	/	0	/	#####	34	Space		0		0	/	0	/	#####
35	Space			0	0	/	0	/	#####	36	Space			0	0	/	0	/	#####
37	Space	0			0	/	0	/	#####	38	Space	0			0	/	0	/	#####
39	Space		0		0	/	0	/	#####	40	Space		0		0	/	0	/	#####
41	Space			0	0	/	0	/	#####	42	Space			0	0	/	0	/	#####

L(5,7,9)B1 (Section 2)

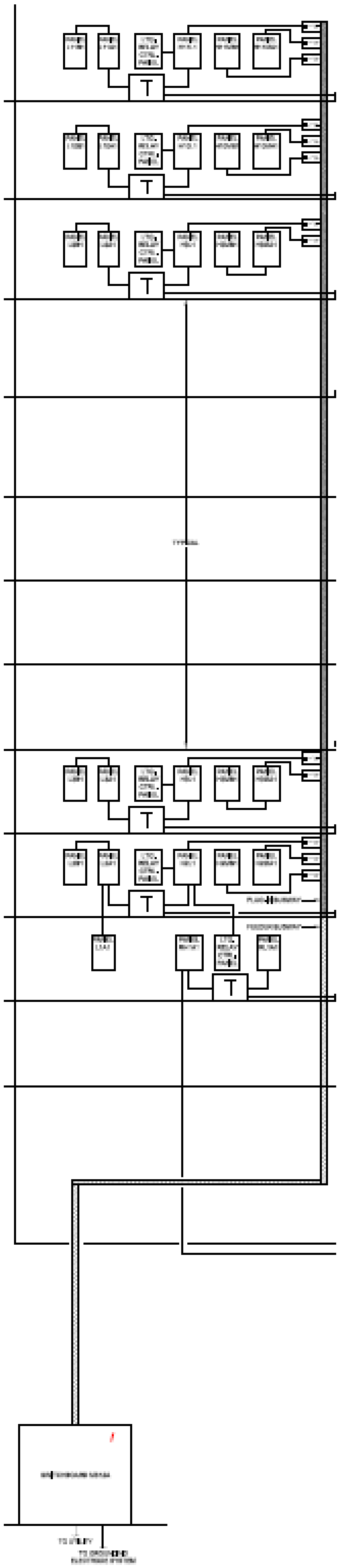
V:	208Y/120	Rm # Elec. Rn	10000 AIC	3P - 4W	Fdr:	Section 2		10 kVA		MLO

Designations		VA/Phase			Bkr/Pole/Wire					Designations		VA/Phase			Bkr/Pole/Wire				
Ckt	Description	A	B	C	Bkr	/	# P	/	W	Ckt	Description	A	B	C	Bkr	/	# P	/	W
1	Space	0			0	/	0	/	#####	2	Space	0			0	/	0	/	#####
3	Space		0		0	/	0	/	#####	4	Space		0		0	/	0	/	#####
5	Space			0	0	/	0	/	#####	6	Space			0	0	/	0	/	#####
7	Space	0			0	/	0	/	#####	8	Space	0			0	/	0	/	#####
9	Space		0		0	/	0	/	#####	10	Space		0		0	/	0	/	#####
11	Space			0	0	/	0	/	#####	12	Space			0	0	/	0	/	#####
13	Space	0			0	/	0	/	#####	14	Space	0			0	/	0	/	#####
15	Space		0		0	/	0	/	#####	16	Space		0		0	/	0	/	#####
17	Space			0	0	/	0	/	#####	18	Space			0	0	/	0	/	#####
19	Space	0			0	/	0	/	#####	20	Space	0			0	/	0	/	#####
21	Space		0		0	/	0	/	#####	22	Space		0		0	/	0	/	#####
23	Space			0	0	/	0	/	#####	24	Space			0	0	/	0	/	#####
25	Space	0			0	/	0	/	#####	26	Space	0			0	/	0	/	#####
27	Space		0		0	/	0	/	#####	28	Space		0		0	/	0	/	#####
29	Space			0	0	/	0	/	#####	30	Space			0	0	/	0	/	#####
31	Space	0			0	/	0	/	#####	32	Space	0			0	/	0	/	#####
33	Space		0		0	/	0	/	#####	34	Space		0		0	/	0	/	#####
35	Space			0	0	/	0	/	#####	36	Space			0	0	/	0	/	#####
37	Space	0			0	/	0	/	#####	38	Panel L4A1	3333			200	/	3	/	#10
39	Space		0		0	/	0	/	#####	40	-		3333		-	/	-	/	-
41	Space			0	0	/	0	/	#####	42	-			3333	-	/	-	/	-

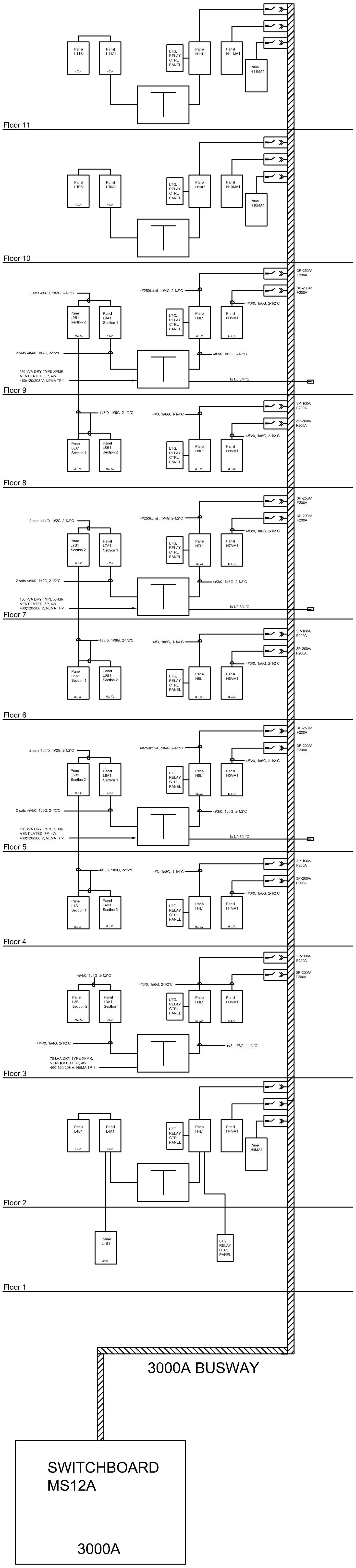
Appendix B.10

Riser Diagrams

Original Riser



Redesign Riser Diagram



Appendix B.11

Bill of Materials/Cost Summary Comparison

Package 1 - Original

Description	Length	Count	Mat. $	Equip. $	Total Mat. $	Lbr Hr.	Lbr. $	Total Lbr. $	Total $
4000A MS12A DISTRIBUTION SWITCHBOARD		1		$ 67,200.00	$ 67,200.00	80.5	$ 45.00	$ 3,622.50	$ 70,822.50
225A HXMA1 PANELBOARD		7		$ 7,600.00	$ 7,600.00	119	$ 45.00	$ 5,355.00	$ 12,955.00
225A HXMB1 PANELBOARD		7		$ 4,900.00	$ 4,900.00	70	$ 45.00	$ 3,150.00	$ 8,050.00
225A HXL1 PANELBOARD		7		$ 5,400.00	$ 5,400.00	206.5	$ 45.00	$ 9,292.50	$ 14,692.50
400A LXA1 PANELBOARD		7		$ 10,250.00	$ 10,250.00	227.5	$ 45.00	$ 10,237.50	$ 20,487.50
400A LXB1 PANELBOARD		7		$ 5,400.00	$ 5,400.00	175	$ 45.00	$ 7,875.00	$ 13,275.00
112.5 KVA 3PH 480V STEEL FLEX WITH GROUND		7	$ 5,364.33	$ 35,450.00	$ 40,814.33	292.88	$ 45.00	$ 13,179.60	$ 53,993.93
225A CU BUS DUCT	1	14		$ 18,450.00	$ 18,450.00	84.2	$ 45.00	$ 3,789.00	$ 22,239.00
BUS PLUG -> PNL HXMA1 - 2 1/2" EMT [4] 3/0, [1] 6GRD CONC T-ROD	35*7	1	$ 6,566.98		$ 6,566.98	19.94	$ 45.00	$ 897.30	$ 7,464.28
BUS PLUG -> PNL HXL1 - 2 1/2" EMT [40 3/0, [1] 6GRD CONC T-ROD	28*7	1	$ 5,017.60		$ 5,017.60	16.08	$ 45.00	$ 723.60	$ 5,741.20
4000A CU LZ DUCT	390	1	$ 245,700.00		$ 245,700.00	719.9	$ 45.00	$ 32,395.50	$ 278,095.50
Total					$ 417,298.91	2,011.50		$ 90,517.50	**$ 507,816.41**

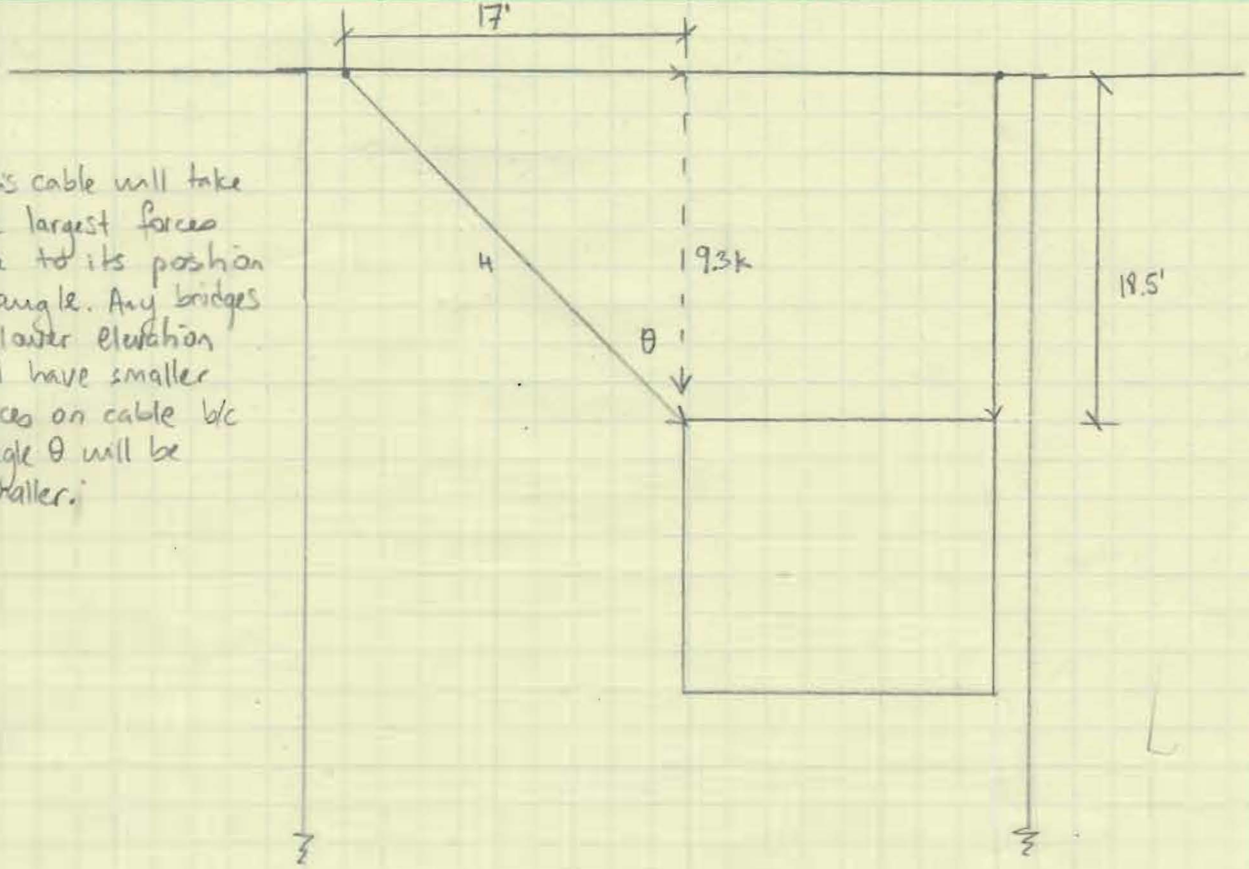
Package 2 - New

Description	Length	Count	Mat. $	Equip. $	Total Mat. $	Lbr Hr.	Lbr. $	Total Lbr. $	Total $
3000A MS12A DISTRIBUTION SWITCHBOARD		1		$ 40,700.00	$ 40,700.00	80.5	$ 45.00	$ 3,622.50	$ 44,322.50
225A HXMA1 PANELBOARD		7		$ 10,500.00	$ 10,500.00	175	$ 45.00	$ 7,875.00	$ 18,375.00
225A H3L1 PANELBOARD		1		$ 1,500.00	$ 1,500.00	28	$ 45.00	$ 1,260.00	$ 2,760.00
225A H4L1 PANELBOARD		3		$ 4,510.00	$ 4,510.00	75	$ 45.00	$ 3,375.00	$ 7,885.00
225A H5L1 PANELBOARD		3		$ 5,800.00	$ 5,800.00	88.5	$ 45.00	$ 3,982.50	$ 9,782.50
400A L3A1 PANELBOARD		1		$ 1,170.00	$ 1,170.00	25	$ 45.00	$ 1,125.00	$ 2,295.00
400A L3B1 PANELBOARD		7		$ 4,900.00	$ 4,900.00	175	$ 45.00	$ 7,875.00	$ 12,775.00
600A LXA1 PANELBOARD		3		$ 6,500.00	$ 6,500.00	102	$ 45.00	$ 4,590.00	$ 11,090.00
600A LXB1 PANELBOARD		3		$ 3,190.00	$ 3,190.00	88.5	$ 45.00	$ 3,982.50	$ 7,172.50
75 KVA 3PH 480V STEEL FLEX WITH GROUND		1	$ 558.27	$ 4,200.00	$ 4,758.27	28.81	$ 45.00	$ 1,296.45	$ 6,054.72
150 KVA 3PH 480V STEEL FLEX WITH GROUND		3	$ 3,612.46	$ 19,800.00	$ 23,412.46	145.2	$ 45.00	$ 6,534.00	$ 29,946.46
250A CU BUS DUCT	1	3		$ 7,180.00	$ 7,180.00	18.2	$ 45.00	$ 819.00	$ 7,999.00
200A CU BUS DUCT	1	8		$ 16,000.00	$ 16,000.00	48.2	$ 45.00	$ 2,169.00	$ 18,169.00
100A CU BUS DUCT	1	3		$ 4,800.00	$ 4,800.00	12.2	$ 45.00	$ 549.00	$ 5,349.00
BUS PLUG -> PNL H3MA1 - 2 1/2" EMT [4] 3/0, [1] 6GRD CONC T-ROD	35	1	$ 865.17		$ 865.17	19.42	$ 45.00	$ 873.90	$ 1,739.07
BUS PLUG -> PNL H3L1 - 2 1/2" EMT [4] 3/0, [1] 6GRD CONC T-ROD	28	1	$ 716.80		$ 716.80	16.08	$ 45.00	$ 723.60	$ 1,440.40
BUS PLUG -> PNL H4MA1 - 2 1/2" EMT [4] 3/0, [1] 6GRD CONC T-ROD	35	1	$ 840.92		$ 840.92	18.02	$ 45.00	$ 810.90	$ 1,651.82
BUS PLUG -> PNL H4L1 - 1 1/4" EMT [4] 3, [1] 8GRD CONC T-ROD	28	1	$ 243.02		$ 243.02	10.93	$ 45.00	$ 491.85	$ 734.87
BUS PLUG -> PNL H5MA1 - 2 1/2" EMT [4] 3/0, [1] 6GRD CONC T-ROD	35	1	$ 840.92		$ 840.92	18.02	$ 45.00	$ 810.90	$ 1,651.82
BUS PLUG -> PNL H5L1 - 2 1/2" EMT [4] 250, [1] 4 CONC T-ROD	28	1	$ 1,019.43		$ 1,019.43	19.27	$ 45.00	$ 867.15	$ 1,886.58
PNL LXB1 -> PNL LXA1 - 2 1/2" EMT [4] 3/0, [1] 6GRD CONC T-ROD	10*3	1	$ 1,291.08		$ 1,291.08	11.88	$ 45.00	$ 534.60	$ 1,825.68
3000A CU LZ DUCT	390	1	$ 163,800.00		$ 163,800.00	626	$ 45.00	$ 28,170.00	$ 191,970.00
Total					$ 304,538.07	1,829.73		$ 82,337.85	**$ 386,875.92**

Savings **$ 120,940.49**

Appendix C.1

Structural Calculations



* This cable will take the largest forces due to its position & angle. Any bridges @ lower elevation will have smaller forces on cable b/c angle θ will be smaller.

$\tan\theta = \frac{17'}{18.5'}$

$\theta = 42.6°$

$\cos 42.6° = \frac{9.3\text{K}}{H}$

$H = 12.6\text{ k}$

$\sigma = \frac{F}{A}$

$\sigma = \frac{12600}{10.4} = 1212\ \text{lb}/\text{in}^2$

for SLU-30 (3 strands)

$A = \pi r^2$

$D_{\text{one strand}} = 54\text{mm} = 2.1''$

$R_{\text{one strand}} = 1.05''$

$A_{\text{one strand}} = 3.14 \cdot (1.05)^2 = 3.46\text{in}^2 \times 3 \text{ strands} = 10.4\text{ in}^2$

$\sigma = \frac{\overset{\text{capacity}}{70140}}{10.4} = 6744\ \text{lb}/\text{in}^2$ ✓

for SLU-10 (1 strand) choose SLU-10

$D_{\text{one}} = 16\text{mm} = 0.63''$

$R = .32''$

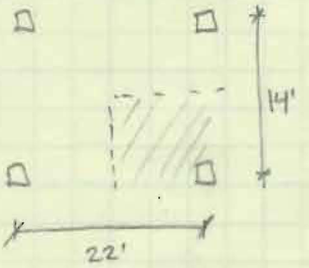
$A = 3.14 \cdot (0.32)^2 = 0.32\text{ in}^2$

$\sigma = \frac{12600}{0.32} = 39375\ \text{lb}/\text{in}^2$ $\sigma = \frac{\overset{\text{capacity}}{23380}}{0.32} = 73062\ \text{lbs}/\text{in}^2$ ✓

Making sure columns don't buckle from added jack load

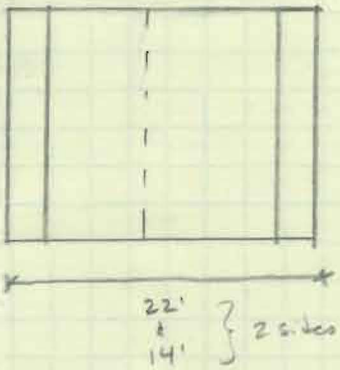
Tributary Area

Floor + Roof



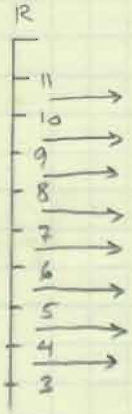
$A_T = \left(\frac{22}{2}\right)\left(\frac{14}{2}\right) = 77$ Φ

Exterior Wall



$A_T = \underset{\text{lengths - HSS on each side}}{(11\times10) + (11\times6)} = 176$ Φ/floor

LL Red



Flr		
11	$0.25 + \frac{15}{\sqrt{616}} =$	.85
10	↓	.67
9		.6
8		.55
7		.52
6		.50
5		.48
4		.46
3		.45

Roof Loads

$DL = \underset{\text{roofing}}{10} + \underset{\text{joists}}{5} + \underset{\text{SDL}}{8} + \underset{\text{insul/deck}}{4} = 27$ psf

$S = 30$ psf

Floor Loads

$DL = \underset{\text{deck}}{60} + \underset{\text{SDL}}{10} + \underset{\text{beams}}{5} = 75$ psf

$LL = 80$ psf

Load from curtain wall = 15 psf

HSS 10x10x ___ use conservative KL = 15'

— R

½ $1.2(27)(77) + 1.6(30)(77) = 6.2^k$

— 11

½ ⑤↓

$$\overbrace{1.2(27)(77) + 0.5(30)(77)}^{3.6^k} + \overbrace{1.2(75)(77) + 1.2(15)(176)}^{10.1^k}$$

$$\underbrace{+ 1.6(0.85)(80)(77)/1000}_{8.4} = 22.1^k$$

— 10

½ $3.6 + 2(10.1) + 1.6(0.67)(80)(77)(2)/1000 = 37^k + 9.2^k = 46.2k$

— 9

½ ④↓ $3.6 + 3(10.1) + 1.6(0.6)(80)(77)(3)/1000 = 51.6^k + 9.2^k = 60.8k$

— 8

½ $3.6 + 4(10.1) + 1.6(.55)(80)(77)(4)/1000 = 65.7^k + 2(9.2) = 84.1k$

— 7

½ ③↓ $3.6 + 5(10.1) + 1.6(.52)(80)(77)(5)/1000 = 79.7^k + 2(9.2) = 98.1k$

— 6

½ $3.6 + 6(10.1) + 1.6(.5)(80)(77)(6)/1000 = 93.8^k + 3(9.2) = 121.4$

— 5

½ ②↓ $3.6 + 7(10.1) + 1.6(.48)(80)(77)(7)/1000 = 107.4^k + 3(9.2) = 135k$

— 4

½ $3.6 + 8(10.1) + 1.6(.46)(80)(77)(8)/1000 = 120.7^k + 4(9.2) = 157.5k$

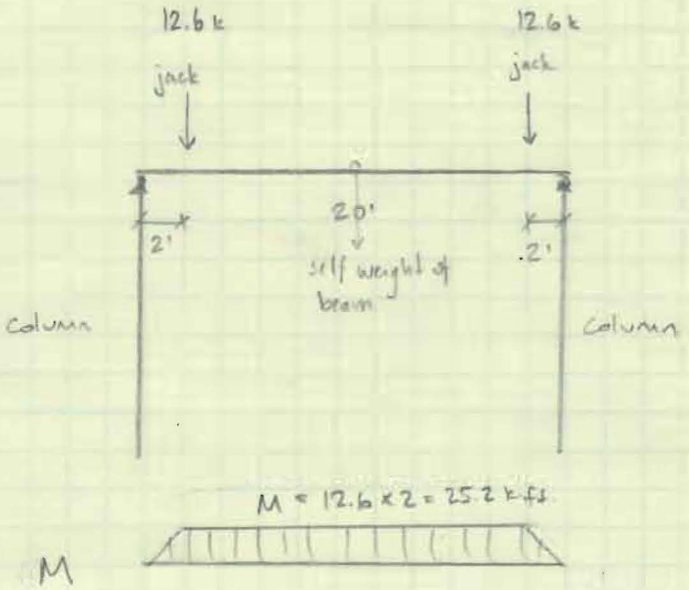
— 3

½ ①↓ $3.6 + 9(10.1) + 1.6(.45)(80)(77)(9)/1000 = 134.4^k + 4(9.2) = 171.2k$

* End of steel columns

HSS 10x10x1/2 Capacity = $\underline{\underline{615^k}}$

① through ⑤ indicate load from footbridges. One column takes 1/4 of the footbridge weight, or 9.2k.



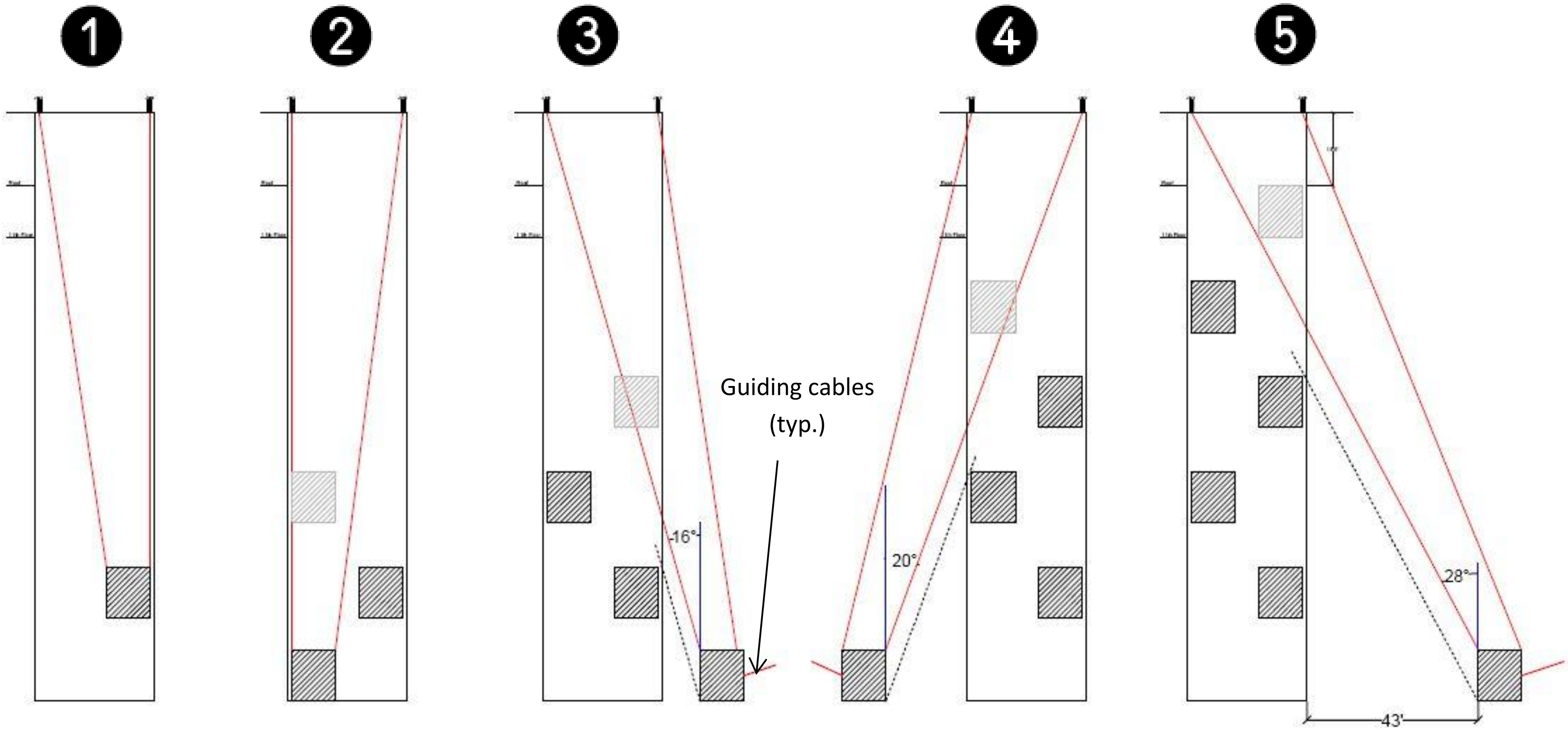
- * place beam to span the two atriums.
- * Hydraulic jacks will then be placed on top of beams
- * use wide flange beam w/ web stiffeners to support jacks

* Use minimum W12 × 14. Size up if necessary to fit hydraulic jack on.

* Used AISC Steel Construction Manual, 14th edition

Appendix C.2

Lifting Logistics



Red lines represent tensile units. Light gray represents final location of footbridge.

Appendix C.3

Original Lifting Schedule

ID	ⓘ	Task Mode	Task Name	Duration	Start	Finish
1		📌?	**11/8/2012 - Schedule Meeting**			
2		📌?	**NO WORK SCHEDULED FOR 12/24 - 12/26, 11/21-11/23, 12/31-1/1. Mininal Saturday/Sunday work figured for bridge building and bridge installation. TSI will use Saturdays as makeup days.**			
3		📌?	**Pending Information**			
4		📌?	TSI to resubmit COR60 steel drawings			
5		📌?	IOTT Handrail Drawings - to submit week of 11/12			
6		📌?	3rd Party Shoring Review			
7		📌?	Dance Floor Meeting Above Roof - 10/9 Tuesday. Safeway to get involved and follow up meeting. Clark to handle purchasing from Safeway.			
8		📌?	12th floor embed - in review with TTE			
9		📌?	West Slot Paint - to UBS the week of 11/26. Paint chips approved by Chiara at 11/5 Canopy Meeting.			
10		📌?	East Intumescent Paint - Matt to find out 11/9.			
11		📌?	Troweled sample - texture accepted verbally by Chiara. All intumescent to be troweled.			
12		📌?	East Cafco Board to be used in place of cementitious - waiting on Davenport for product data and location.			
13		⇨				
14		📌?	**Parcel 1 - West Slot**			
15		📌	Set 9 - 12 Steel	2 days	Fri 9/7/12	Sat 9/8/12
16		📌	Set Penthouse Steel - Pending Tower Crane Availability - complete	2 days	Thu 10/4/12	Fri 10/5/12
17		📌	Weld Out Slot Steel - complete	8 days	Mon 10/8/12	Wed 10/17/12
18		📌	Weld Inspections - Inspected up through 9th floor - complete	1 day	Thu 10/18/12	Thu 10/18/12
19		📌	Finish Paint - paint to start the week of 11/26.	10 days	Mon 11/26/12	Fri 12/7/12
20		📌	Curtainwall Anchors and Units - after finish paint	19 days	Mon 12/10/12	Thu 1/3/13
21		📌	Skylight Units and Glass - after finish paint. This date will be pushed out due to glass not getting to Baker in time.	17 days	Mon 12/10/12	Tue 1/1/13
22		📌?				

Project: City Center Alley Schedul
Date: Fri 11/9/12

Task	▬	Inactive Summary	▭
Split	┈┈┈	Manual Task	▬
Milestone	◆	Duration-only	▬
Summary	▬	Manual Summary Rollup	▬
Project Summary	▬	Manual Summary	▬
External Tasks	▬	Start-only	[
External Milestone	◆	Finish-only	]
Inactive Task	▭	Deadline	⇩
Inactive Milestone	◇	Progress	▬

ID	ⓘ	Task Mod	Task Name	Duration	Start	Finish
23		📌?	**Parcel 2 - West Slot**			
24		📌	Set 9 - 12 Steel - complete	3 days	Wed 9/5/12	Fri 9/7/12
25		📌	Set Skylight and Penthouse Steel - dependent on roof cleanup and AIW finishing work - complete	2 days	Thu 10/4/12	Fri 10/5/12
26		📌	Weld Out Slot Steel (no skylight) - thru 12th floor - complete	11 days	Mon 9/10/12	Sat 9/22/12
27		📌	Weld Out Skylight Steel - assuming skylight steel set 9/25 and 9/26 - complete	8 days	Mon 10/8/12	Wed 10/17/12
28		📌	Final Weld Inspections - up through roof - complete	1 day	Thu 10/18/12	Thu 10/18/12
29		📌	Final Weld Inspections - skylight - complete	1 day	Fri 10/19/12	Fri 10/19/12
30		📌	Finish Paint - paint to start the week of 11/26.	10 days	Mon 11/26/12	Fri 12/7/12
31		📌	Curtainwall Anchors and Units - after finish paint	16 days	Mon 12/10/12	Mon 12/31/12
32		📌	Skylight Units and Glass - after finish paint.	15 days	Mon 12/10/12	Fri 12/28/12
33		📌?				
34		📌?	**Parcel 1 - East Slot**			
35		📌	Set 10 Steel - complete	1 day	Wed 9/12/12	Wed 9/12/12
36		📌	Set 11 Table - complete	1 day	Fri 9/28/12	Fri 9/28/12
37		📌	Set 12 Table - complete	1 day	Thu 10/4/12	Thu 10/4/12
38		📌	Set Penthouse Steel - Pending Tower Crane Availability - complete	2 days	Mon 10/8/12	Tue 10/9/12
39		📌	Weld Out Slot Steel - complete	6 days	Wed 10/10/12	Wed 10/17/12
40		📌	Welding Inspections - complete	1 day	Thu 10/18/12	Thu 10/18/12
41		📌?	See Bridge Installation Dates Below (11/2 - 1/18). Bridge #1 set 11/15. Contingent on 10th street and shoring plan.			
42		📌	Skylight Units and Glass - after bridge and infill units set	19 days	Sat 1/21/12	Wed 2/15/12
43		📌	Intumescent Paint - after skylight glass installed	15 days	Thu 2/16/12	Wed 3/7/12
44		📌	Paint Inspections - changed from 3 days to 1 day per Current	1 day	Thu 3/8/12	Thu 3/8/12
45		📌?				
46		📌?	**Parcel 2 - East Slot**			
47		📌	Set 9 - complete	1 day	Wed 9/12/12	Wed 9/12/12
48		📌	Set 10 Table - complete	1 day	Wed 9/12/12	Wed 9/12/12
49		📌	Set 11 Table - complete	2 days	Mon 9/17/12	Tue 9/18/12

Project: City Center Alley Schedul
Date: Fri 11/9/12

Task	▬	Inactive Summary	▭
Split	┈┈┈	Manual Task	▬
Milestone	◆	Duration-only	▬
Summary	▬	Manual Summary Rollup	▬
Project Summary	▬	Manual Summary	▬
External Tasks	▬	Start-only	[
External Milestone	◆	Finish-only	]
Inactive Task	▭	Deadline	⬇
Inactive Milestone	◇	Progress	▬

ID	ⓘ	Task Mode	Task Name	Duration	Start	Finish
50		📌	Set 12 Table - complete	2 days	Fri 9/28/12	Mon 10/1/12
51		📌	Set Penthouse Steel - complete	2 days	Tue 10/2/12	Wed 10/3/12
52		📌	Weld Out Slot Steel - complete	10 days	Thu 10/4/12	Wed 10/17/1
53		📌	Welding Inspections - complete	1 day	Thu 10/18/12	Thu 10/18/12
54		📌?	See Bridge Installation Dates Below (11/2 - 1/18). Bridge #1 set 11/15. Contingent on 10th street and shoring plan.			
55		📌	Skylight Units and Glass - after bridge and infill units set	19 days	Sat 1/21/12	Wed 2/15/12
56		📌	Intumescent Paint - after skylight glass installed	15 days	Thu 2/16/12	Wed 3/7/12
57		📌	Paint Inspections - changed from 3 days to 1 day per Current	1 day	Thu 3/8/12	Thu 3/8/12
58		📌?				
59		📌?	**Stair Fabrication**			
60		📌	Parcel # 2 Stair - primer only	51 days	Mon 10/22/1	Mon 12/31/1
61		📌	Parcel # 1 Stair - primer only	59 days	Tue 9/11/12	Fri 11/30/12
62		📌?				
63		📌?	**Bridge Installation - contingent on shoring plan. As of 11/8 the first bridge will be set 11/15. Specific bridge and stair installation dates depend on logistics onsite.**			
64		📌	Mobilize Crawler Crane - 2012.9.10 - changed from 3 days to 4 days per Current	4 days	Fri 11/2/12	Wed 11/7/12
65		📌	Set Parcel # 1 Stairs	5 days	Wed 11/7/12	Tue 11/13/12
66		📌	Parcel #1 Protection Installation	4 days	Wed 11/14/1	Mon 11/19/1
67		📌	Welding Parcel #1 Stairs	18 days	Tue 11/20/12	Thu 12/13/12
68		📌	Build Bridge #1	17 days	Thu 10/11/12	Fri 11/2/12
69		📌	Set Bridge # 1 - while stair welding is going on	1 day	Tue 11/20/12	Tue 11/20/12
70		📌	Infill Curtainwall - Flrs 3-4	5 days	Mon 11/26/1	Fri 11/30/12
71		📌	Build Bridge #2	17 days	Thu 10/11/12	Fri 11/2/12
72		📌	Set Bridge # 2	1 day	Mon 12/3/12	Mon 12/3/12
73		📌	Infill Curtainwall - Flrs 5-6	5 days	Tue 12/4/12	Mon 12/10/1
74		📌	Build Bridge #3	17 days	Fri 10/19/12	Mon 11/12/1
75		📌	Set Bridge # 3	1 day	Tue 12/11/12	Tue 12/11/12
76		📌	Infill Curtainwall - Flrs 7-8	5 days	Tue 12/11/12	Mon 12/17/1

Task	▬	Inactive Summary	▽▬▽
Split	┈	Manual Task	▬
Milestone	◆	Duration-only	▬
Summary	▼▬▼	Manual Summary Rollup	▬
Project Summary	▽▬▽	Manual Summary	▼▬▼
External Tasks	▬	Start-only	[
External Milestone	◆	Finish-only	]
Inactive Task	▭	Deadline	⬇
Inactive Milestone	◇	Progress	▬

ID		Task Mode	Task Name	Duration	Start	Finish
77			Build Bridge #4	17 days	Fri 10/19/12	Mon 11/12/1
78			Set Bridge # 4	1 day	Tue 12/18/12	Tue 12/18/12
79			Infill Curtainwall - Flrs 9-10	8 days	Tue 12/18/12	Thu 12/27/12
80			Build Bridge #5	20 days	Fri 11/30/12	Thu 12/27/12
81			Set Bridge # 5	1 day	Fri 12/28/12	Fri 12/28/12
82			Infill Curtainwall - Flrs 11-roof	6 days	Wed 1/2/13	Wed 1/9/13
83			Set Parcel # 2 Stairs	5 days	Wed 1/9/13	Tue 1/15/13
84			Parcel #2 Protection Installation	6 days	Mon 1/16/12	Sat 1/21/12
85			Weld Parcel #2 Stairs	15 days	Tue 1/22/13	Mon 2/11/13
86			Tear Down Crawler Crane - 9/10/2012 - changed from 8 days to 3 days per Current	3 days	Wed 1/16/13	Fri 1/18/13
87						
88			**Tower Curtainwall Installation**			
89			Parcel 2 Not at Alley - West, South, East - complete	25 days	Mon 9/10/12	Fri 10/12/12
90			Parcel 2 North - Fill in from West Slot to 4 units before the East Slot. Start when West Slot CW begins.	25 days	Mon 10/29/12	Fri 11/30/12
91			Parcel 1 Not at Alley - West, North, East - complete	25 days	Mon 9/10/12	Fri 10/12/12
92			Parcel 1 South - Fill in from the West Slot to 4 units before the East Slot. Start when West Slot CW begins.	25 days	Mon 10/29/12	Fri 11/30/12
93						
94			**Sunshades - Sequence West (P1,P2), South (P2), East (P1,P2). Dates are dependent on Baker getting material complete.**			
95			P1 West, P2 West	23 days	Mon 11/26/1	Wed 12/26/1
96			P2 South	27 days	Mon 12/17/1	Tue 1/22/13
97			P1 East, P2 East	22 days	Sat 1/7/12	Mon 2/6/12
98						
99			**Interior Curtainwall**			
100			P1 West		Thu 11/8/12	
101			P2 West		Thu 11/8/12	
102			P1 East - after stair welding complete		Fri 12/14/12	
103			P2 East - after stair welding complete		Sun 2/12/12	
104						

Project: City Center Alley Schedul
Date: Fri 11/9/12

Task	▬	Inactive Summary	▭
Split	┈┈┈	Manual Task	▬
Milestone	◆	Duration-only	▬
Summary	▬	Manual Summary Rollup	▬
Project Summary	▬	Manual Summary	▬
External Tasks	▬	Start-only	[
External Milestone	◆	Finish-only	]
Inactive Task	▭	Deadline	⬇
Inactive Milestone	◇	Progress	▬

ID	ⓘ	Task Mod	Task Name	Duratior	Start	Finish
105		⇨				
106		📌?	Bridge Fabrication - contingent on 10th street and shoring plan			
107		📌	**Bridge # 1 (17 days)**	17 days	Thu 10/11/12	Fri 11/2/12
108		📌	Mobilize Steel Trusses to Site	2 days	Thu 10/11/12	Fri 10/12/12
109		📌	Spray Fireproofing	1 day	Mon 10/15/12	Mon 10/15/12
110		📌	Intumescent Paint	1 day	Tue 10/16/12	Tue 10/16/12
111		📌	HVAC Installation	1 day	Wed 10/17/12	Wed 10/17/12
112		📌	Electrical Installation	1 day	Thu 10/18/12	Thu 10/18/12
113		📌	Sprinkler Installation	1 day	Fri 10/19/12	Fri 10/19/12
114		📌	Decking	1 day	Mon 10/22/12	Mon 10/22/12
115		📌	Curtainwall Installation	3 days	Tue 10/23/12	Thu 10/25/12
116		📌	Cladding (Belly and Roof)	4 days	Fri 10/26/12	Wed 10/31/12
117		📌	Caulking	2 days	Thu 11/1/12	Fri 11/2/12
118		📌?				
119		📌	**Bridge # 2 (17 days)**	17 days	Thu 10/11/12	Fri 11/2/12
120		📌	Mobilize Steel Trusses to Site	2 days	Thu 10/11/12	Fri 10/12/12
121		📌	Spray Fireproofing	1 day	Mon 10/15/12	Mon 10/15/12
122		📌	Intumescent Paint	1 day	Tue 10/16/12	Tue 10/16/12
123		📌	HVAC Installation	1 day	Wed 10/17/12	Wed 10/17/12
124		📌	Electrical Installation	1 day	Thu 10/18/12	Thu 10/18/12
125		📌	Sprinkler Installation	1 day	Fri 10/19/12	Fri 10/19/12
126		📌	Decking	1 day	Mon 10/22/12	Mon 10/22/12
127		📌	Curtainwall Installation	3 days	Tue 10/23/12	Thu 10/25/12
128		📌	Cladding (Belly and Roof)	4 days	Fri 10/26/12	Wed 10/31/12
129		📌	Caulking	2 days	Thu 11/1/12	Fri 11/2/12
130		📌?				
131		📌	**Bridge # 3 (17 days)**	17 days	Fri 10/19/12	Mon 11/12/12
132		📌	Mobilize Steel Trusses to Site	2 days	Fri 10/19/12	Mon 10/22/12
133		📌	Spray Fireproofing	1 day	Tue 10/23/12	Tue 10/23/12
134		📌	Intumescent Paint	1 day	Wed 10/24/12	Wed 10/24/12
135		📌	HVAC Installation	1 day	Thu 10/25/12	Thu 10/25/12
136		📌	Electrical Installation	1 day	Fri 10/26/12	Fri 10/26/12
137		📌	Sprinkler Installation	1 day	Mon 10/29/12	Mon 10/29/12
138		📌	Decking	1 day	Tue 10/30/12	Tue 10/30/12

Project: City Center Alley Schedul
Date: Fri 11/9/12

Task	▬	Inactive Summary	▭
Split	……	Manual Task	▬
Milestone	◆	Duration-only	▬
Summary	▬	Manual Summary Rollup	▬
Project Summary	▬	Manual Summary	▬
External Tasks	▬	Start-only	[
External Milestone	◆	Finish-only	]
Inactive Task	▭	Deadline	⇩
Inactive Milestone	◇	Progress	▬

ID	ⓘ	Task Mod	Task Name	Duration	Start	Finish
139		📌	Curtainwall Installation	3 days	Wed 10/31/12	Fri 11/2/12
140		📌	Cladding (Belly and Roof)	4 days	Mon 11/5/12	Thu 11/8/12
141		📌	Caulking	2 days	Fri 11/9/12	Mon 11/12/12
142		📌?				
143		📌	**Bridge # 4 (17 days)**	17 days	Fri 10/19/12	Mon 11/12/12
144		📌	Mobilize Steel Trusses to Site	2 days	Fri 10/19/12	Mon 10/22/12
145		📌	Spray Fireproofing	1 day	Tue 10/23/12	Tue 10/23/12
146		📌	Intumescent Paint	1 day	Wed 10/24/12	Wed 10/24/12
147		📌	HVAC Installation	1 day	Thu 10/25/12	Thu 10/25/12
148		📌	Electrical Installation	1 day	Fri 10/26/12	Fri 10/26/12
149		📌	Sprinkler Installation	1 day	Mon 10/29/12	Mon 10/29/12
150		📌	Decking	1 day	Tue 10/30/12	Tue 10/30/12
151		📌	Curtainwall Installation	3 days	Wed 10/31/12	Fri 11/2/12
152		📌	Cladding (Belly and Roof)	4 days	Mon 11/5/12	Thu 11/8/12
153		📌	Caulking	2 days	Fri 11/9/12	Mon 11/12/12
154		📌?				
155		📌	**Bridge # 5 (17 days)**	20 days	Fri 11/30/12	Thu 12/27/12
156		📌	Mobilize Steel Trusses to Site	2 days	Fri 11/30/12	Mon 12/3/12
157		📌	Spray Fireproofing	1 day	Tue 12/4/12	Tue 12/4/12
158		📌	Intumescent Paint	1 day	Wed 12/5/12	Wed 12/5/12
159		📌	HVAC Installation	1 day	Thu 12/6/12	Thu 12/6/12
160		📌	Electrical Installation	1 day	Fri 12/7/12	Fri 12/7/12
161		📌	Sprinkler Installation	1 day	Mon 12/10/12	Mon 12/10/12
162		📌	Decking	1 day	Tue 12/11/12	Tue 12/11/12
163		📌	Curtainwall Installation - 9/10/2012 - Glass will need to be released by the first week of October	3 days	Wed 12/12/12	Fri 12/14/12
164		📌	Cladding (Belly and Roof)	4 days	Mon 12/17/12	Thu 12/20/12
165		📌	Caulking	5 days	Fri 12/21/12	Thu 12/27/12

Project: City Center Alley Schedul
Date: Fri 11/9/12

Task	▬	Inactive Summary	▭
Split	········	Manual Task	▬
Milestone	◆	Duration-only	▬
Summary	▬	**Manual Summary Rollup**	▬
Project Summary	▬	**Manual Summary**	▬
External Tasks	▬	**Start-only**	[
External Milestone	◆	**Finish-only**	]
Inactive Task	▭	**Deadline**	⇩
Inactive Milestone	◇	**Progress**	▬