Final Report

Millennium Science Complex

University Park, PA

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Executive Summary

The Millenium Science Complex is a four story, 275,600 square foot, LEED Gold Certified laboratory and office facility for the Life and Material Sciences on The Pennsylvania State University, University Park campus. Located on the eastern end of campus, the Millennium Science Complex is the focus of the Integrated Project Delivery / Building Information Modeling Thesis (IPD / BIM Thesis). The building will house research facilities for the Material Science and Life Science departments. This report includes the final design alternatives completed by Building Stimulus design team during the Spring 2011 Semester. Each alternative presented was done to utilize an integrated project delivery method and building information modeling approach as applicable.

Building Stimulus focused the design alternatives to achieve an overall team goal of improving the efficiency and performance of the building while still maintaining the architectural integrity that the architect, Raphael Vinoly intended for its contribution to the University Park Campus. In order to accomplish this overall goal, three areas of concentration were identified.

The main focus for the design team in order to improve the efficiency of the building's performance involved redesigning the façade of the Millennium Science Complex. This allowed an extensive implementation of integrated project development as this component affected each discipline. A double skin façade was designed to allow for enhanced thermal performance and daylighting control for the perimeter spaces of Millennium Science. After several iterative processes, this design was implemented on two of the building's faces. Not only were the glazing and solar louver systems reconceived, but also the panel design associated with façade. The current precast panels were redesigned to decrease the structural load on the building and to accommodate the twenty-four inch air gap provided for the double skin.

Through the use of BIM processes and Revit MEP, enhanced accuracy in terms of modeling the building's energy performance was also achieved. By modeling the mechanical and electrical components, the original energy model developed in the fall semester was revised to account for accurate plug loads designated in the laboratory spaces to obtain a more realistic energy profile. In order to facilitate the energy performance, lighting designs were created to efficiently meet IESNA design criteria and ASHRAE 90.1 lighting power densities. Lighting designs were also incorporated with the mechanical system through the implementation of chilled beams in the office spaces to reduce energy consumption.

The final area of concentration for Building Stimulus lied with the most iconic portion of the building, the large cantilever. At the cantilever is where the two wings of the building, Life Science and Material Science, join to merge the two research facilities. The truss system of the cantilever was modified by introducing an additional column to each truss, decreasing the unsupported length of the cantilever by 22 feet. The web and chord members were also redesigned to be optimized for strength and deflection, resulting in a savings of 76 tons of steel. Underneath the cantilever, a new lighting design for the existing plaza was created to enhance the iconic stature of the cantilever.

Building Overview

Building Statistics

Architecture

The Millennium Science Complex is a 4-story LEED-Certified laboratory facility housing Life Sciences and Materials Sciences on The Pennsylvania State University, University Park campus. Located on the eastern end of campus at the corner of E. Pollack and Bigler Rd, the Millennium Science Complex is an L-shaped building with stepping cantilevers and expansive green roofs. Stepping green roofs allow for minimal intrusion on pedestrian areas while concentrating the heart of the building away from the street, maximizing green space. Designed by Rafael Viñoly Architects the building was designed with continuous horizontal glazing along each floor creating a plethora of natural light.

The building is composed of two wings joined with a 150-ft cantilever that stretches out over an open air public plaza. The cantilever allows for the addition of necessary isolated research laboratories to be located beneath the plaza without transferring vibrations through structural members. Over the plaza the wings of the building join at the 3rd and 4th floor to create the L-shaped research facility. The 3rd floor is composed of open meeting areas and lounge space, whereas the 4th floor is dedicated entirely as mechanical space. Rafael Viñoly Architects have created a unique state of the art facility that compliments Penn State's faculty while providing the tools for research in the field of life and materials sciences.

Construction Background

The Millennium Science Complex is a multi-use research facility found on the Northeastern region of Penn State University's University Park campus. Located on the corner of Bigler Road and Pollock Road, the facility sits in one of the most densely populated regions of campus. The structure is also located on the direct route between East Hall dormitories and Pollock dormitories in one of the most highly trafficked pedestrian walkways on campus. Buildings directly adjacent to the Millennium Science Complex include the Penn State Medical Center, Eisenhower Parking Deck, Life Sciences Building, and Thomas Building.

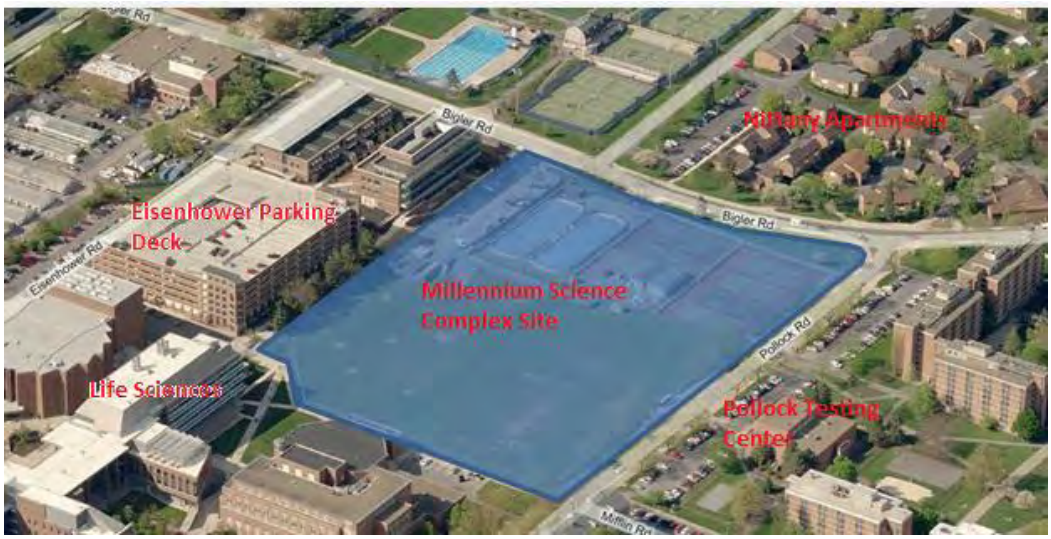


Figure 1: Site of Millennium Science Complex

As seen in Figure 1, the original site of the Millennium Science Complex was occupied by multiple tennis courts, roller hockey rinks, as well as a small parking region. The open grass region was frequently used for intramural sports and leisure activities.

Construction in such a location introduces a plethora of logistic and safety issues. Bigler Road and Pollack Road are subject to high vehicular traffic during early afternoon and evening hours, including a CATABUS Stop servicing community routes, as well as the Blue and White Campus Loops. High volume traffic caused delivery complications of large items such as structural steel, precast panels, and various pieces of equipment utilized on the project. Delivery of oversized items, such as those previously mentioned, was delivered during early morning hours via University Drive. Turning onto Hastings drive from University Drive will lead into Bigler Road and the Bigler Road site access gate.

Additional pedestrian safety concerns primarily focus on the construction of the Life Sciences wing cantilever which reaches over pedestrian walkways, as well as a portion of Pollock Road. Temporary fencing was applied to the perimeter of the site, as well as shutting down of portions of Pollock Road during crane picks and architectural precast panel installation

Whiting-Turner developed a two phase site logistics plan for the construction of the Millennium Science Complex. Phase one, seen in Figure 2, planned the use of the site from site preparation through the completion of the foundation. Phase two, seen in Figure 3, was used from steel erection through the completion of interior finishes.

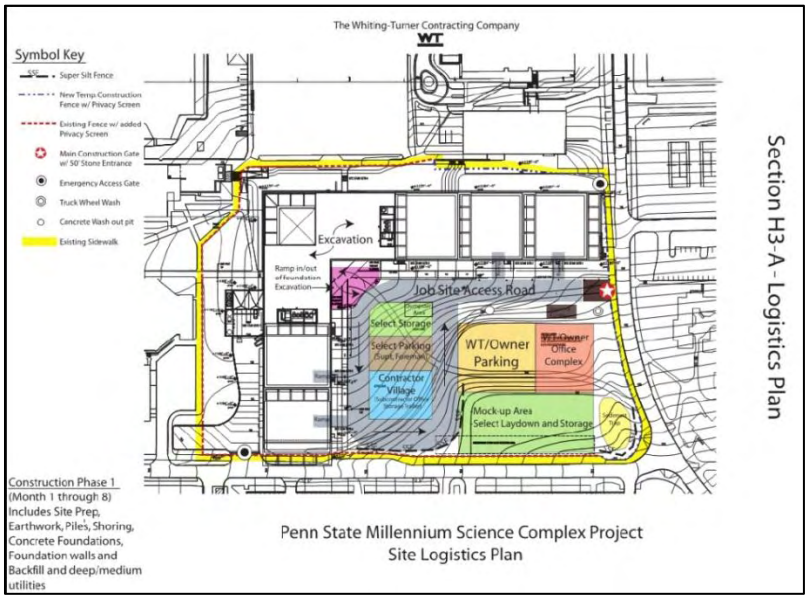


Figure 2: Phase One Site Logistics Plan.

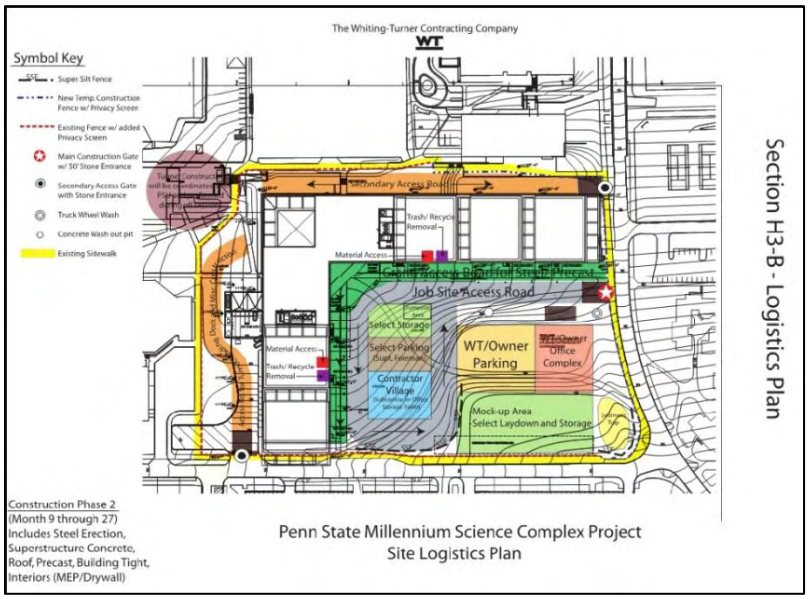


Figure 3: Phase Two Site Logistics Plan.

Project Schedule

The schedule provided represents a summary of significant phases of construction for the Millennium Science Complex. The full detailed schedule of existing activities is provided in Appendix D: Construction Management. Below are the key durations and milestones to be utilized during general conditions estimates of schedule impacts from various analyses.

Table 1: Schedule Durations and Milestones.

Phase	Start	Finish	Duration (Days)	Work Weeks
Foundation/Substructure	2/16/2009	2/26/2010	270	54
Super Structure	7/7/2009	7/23/2010	274	54.8
Concrete	8/18/2009	5/28/2010	204	40.8
Enclosure	11/9/2009	1/5/2011	303	60.6
Mechanical	3/29/2010	11/12/2010	165	33
Electrical	2/12/2010	11/30/2010	208	41.6
Interior Finishes	9/9/2010	3/22/2011	139	27.8
Construction	8/12/2008	7/7/2011	758	151.6

Project Delivery Type

As with most of Penn State University's projects, the Millennium Science Complex is primarily a Design-Bid-Build delivery type. The project also utilizes a form of Construction Management Agency and Fee with Whiting-Turner Contracting Company. Much of the funding for the Millennium Science Complex is backed by the Department of General Services (DGS). DGS funding is public funding which, by law, requires that Penn State University directly hold contracts with the construction service provider. DGS funding is typically allocated to early activities in case state budgets determine that funding be reduced or removed. Therefore, Penn State University holds the contracts to much of the early upfront activities in which Whiting-Turner Construction oversees, manages, and coordinates as a Construction management Agent to Penn State University. For the remaining work, Whiting-Turner performs work for a fee. While they do not self-perform their own work, Whiting-Turner monitors and manages the work of their subcontractors. See Appendix D: Construction Management

Project Cost Evaluation

Actual cost estimations of the Millennium Science Complex are difficult to produce considering the complexities of the facility, namely the research technology and ever-changing finishes within the building. Below are the best estimations of Millennium Science Complex's overall cost and cost per square foot.

Table 2: Total Building Cost.

Total Cost	Total Cost Per Square Foot
$215,000,000	$788/SF

Table 3: Total Construction Cost.

Construction Cost*	Construction Cost Per Square Foot
$139,176,843	$510/SF

***Construction Cost does not include contingency, general conditions, insurance and fees.**

Table 4: Building System Cost.

Building System	Percentage of Project Cost	Cost	Cost Per Square Foot
Structure	17.6%	$24,559,974	$90.06/SF
Plumbing	4.8%	$6,731,107	$24.68/SF
Enclosure	11.8%	$16,459,873	$60.36/SF
Interior Finishes	6.8%	$9,540,237	$34.98/SF
Excavation and Foundation	11.9%	$16,644,502	$61.04/SF
Special Requirements	8.9%	$12,404,386	$45.49/SF
HVAC	18.1%	$25,159,105	$92.26/SF
Electrical	8.9%	$12,313,658	$45.15/SF

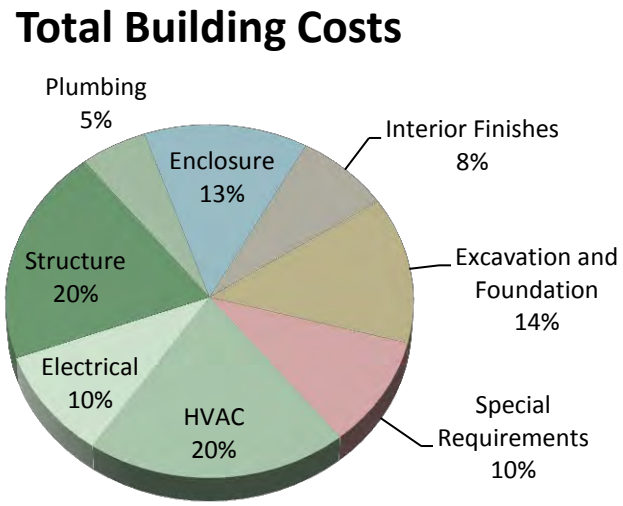


Figure 4: Total Building Costs by Type.

Millennium Science Complex is a state-of-the-art facility, incorporating many of the Material and Life Sciences most advanced and complex research equipment. Accompanied with the facility's complex structure and cantilever, the Millennium Science Complex is considered incomparable to any seemingly relevant building type. Due to the limitations of D4Cost Estimations as well as RS Means Square Foot Estimates, no direct estimates can be made. However, using RS Means Square Foot estimates, comparisons can be made to visualize the complexity of the Millennium Science Complex. Below are square foot estimates of similar size facilities of building types that are present in the Millennium Science Complex. Listed as well are recently constructed buildings on the University Park Campus, as well as the recently constructed New York Times building in New York City due its large scale and significant complexity.

Table 5: Building Cost Comparisons.

Building Type	Cost	Cost Per Square Foot
Office Building	$47,772,500	$183.74/SF
Hospital	$77,436,500	$224.46/SF
College Laboratory	$15,325,000	$144.85/SF
The New York Times Building	$1 billion	$667.00/SF
The New Dickinson School of Law *	$60,000,000	$530.97/SF
Life Sciences Building*	$37,790,085	$245.39/SF
Student Health Center*	$26,000,000	$406.25/SF
(*) denotes PSU Infrastructure		

Building Envelope

A complex pre-cast panel system comprises the majority of the Complex's building enclosure. Each of the 338 precast pieces were fabricated in York, PA and trucked to the site. The exterior is clad in "Penn State" brick with bands of recessed dark-fired brick adhered to 6" of concrete. This panel is backed by 4" of rigid insulation and a vapor barrier. Each 22' panel is mechanically attached to the exterior column structure by a threaded rod and gusset plate system. Between each precast section, two lites of glass are broken by an exterior shading device, meant to help control solar heat gain and glare, while adding a valuable aesthetic feature. The lower vision lite wraps around the entire building providing views to the exterior, while the upper lite is fritted and meant to improve day lighting. A system of metal panels and storefront glazing encloses the building around the landscaped exterior atrium.

The roofing system, once designed to be the largest green roof in the United States, will span 60,000 sq. ft. This extensive sedum green roof will require a shallow depth of soil and drainage, and will be waterproofed from the concrete structure below. The mechanical penthouse will not have a green roof, rather it will be built of rigid insulation covered by a black EPM waterproofing membrane.

The vibration isolated laboratories located under the exterior atrium will be enclosed in a system unique to the building. As these labs are located underground, they will be surrounded by 24" of concrete to mitigate sound and vibration transmittance, while providing moisture protection and thermal resistance.

Structural System

Foundations

The foundation of the Millennium Science Complex utilizes a system of micropiles, pile caps, and grade beams. Each column is supported by a pile cap composed of 6000 psi concrete on grid lines spaced 22 feet apart in a square pattern. Drilled micropiles are attached to the pile caps and descend through the soil to bear on bedrock. The variation in depth of the local bedrock leads to a large difference in pile depths throughout the building. For example, there was a peak difference of 128 feet in depth, in a single pile cap. Each of these pile caps are connected by grade beams which help to reduce differential settlement, a crucial design consideration for a laboratory building.

Forming the floor of the basement are four different slabs on grade in the occupied area of the basement, shown in Figure 5. Slabs on grade, foundation walls, footings and piers use 4000 psi concrete. The basement covers only a portion of the entire footprint of the building, the area colored in white indicates the presence of compacted fill occupying the space between the basement level and first floor level. Columns and piers extend from the pile caps at the basement level up through the compacted fill, in this area of each wing, to the first floor. This was presumably designed in the event that the University would want to expand the basement level under each wing. Further evidence of this assumption can be found in the foundation walls called out in red around the perimeter of the west wing, which enclose the compacted fill, and are in line with the exterior walls of the building. The accessible areas of the basement lie directly under the cantilever and extend to the edge of the compacted fill outlined in blue. Three isolation labs were placed at this level (highlighted in green), designed to be completely disparate of the structural elements that make up the rest of the building.

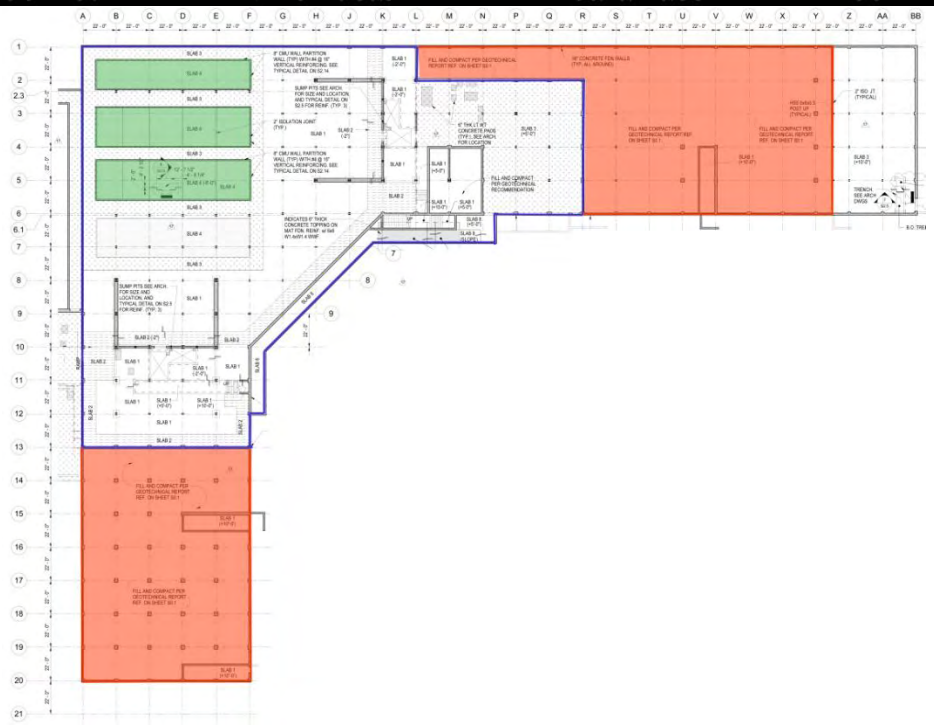


Figure 5: Foundation Plan.

Gravity System

The gravity system of the Millennium Science Building is composed of steel framing and concrete topping on composite metal decking. The steel framing is organized in a typical 22 foot square layout with intermediate beams spaced at 11 feet and the metal decking spanning across the short direction. The typical floor layout is organized with a centralized corridor in each wing with lab and office spaces along the perimeter of the corridor. The most common floor decking configuration seen in the building is 3 inch 18 gage metal deck with 3 ¼ in light weight concrete topping. The typical steel framing configuration is made up of W21 beams and W24 girders which frame into W14 columns. Beyond the typical dead and live loads, there are specialty loads from the green roof, mechanical equipment, and the pedestrian traffic at the entrance which call for increased slab strengths. A 3 inch metal deck is used with a 7 inch normal weight concrete topping immediately below the cantilever where pedestrian traffic is heaviest as people enter and exit the building, and a 4½ inch normal weight topping is used to support each green roof.

Lateral System

Two moment frames, several bays of braced frames, and two shear walls located at the stairwells make up the lateral system for the building. The moment frames are located at grid lines Q and 19, which are midway and at the end of their respective wings. The location of these moment frames correspond with shear walls placed in either wing several structural bays away, as shown in Figure 6:. The objective of these staggered frames and walls is to distribute the lateral forces over the entire floor diaphragm, preventing excessive torsion due to lateral loads along wing. The shear walls supporting the cantilever offer a large amount of lateral stiffness to the lateral system of the building however, lateral support must be provided along the wings to prevent torsional effects that otherwise may be experienced at the ends of the wings. State College itself does not suffer from large wind or seismic loads given building height restrictions and geographical location. Along with the large span trusses and C-shaped shear walls that support the cantilever, the lateral system more than suffices in resisting the maximum lateral loads State College has to offer.

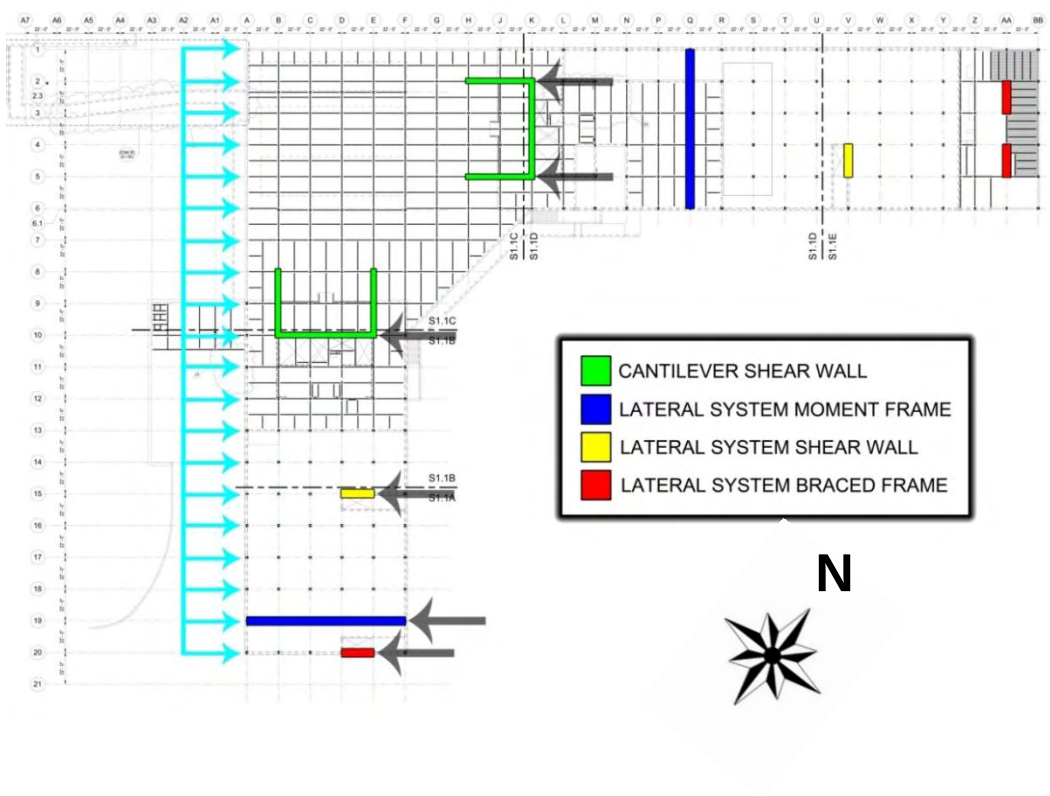


Figure 6: Lateral Elements Diagram.

As the wind is applied to the structure, loads are transferred from the exterior façade to the floors, acting as a diaphragm, which distribute the load to the lateral system.

Specialty Systems

To cope with the massive stresses induced by the 150 foot cantilever a truss design was used to handle the gravity forces. Two different trusses from each wing extend to meet at the tip of the cantilever composing the structural support for this iconic building. Gravity loads are transferred into the diagonal compression members and continue along the load path as shown in the figure below. The loads are then distributed into a 30-inch thick shear wall integral with the truss frame and into the foundation. One of the two identical frames is shown in Figure 7:, indicating that the micropiles shown in blue act in compression and those in red act in tension resisting the overturning moment induced by loads applied to the cantilever structure. As revealed by a Thornton Tomasetti representative, the cantilever was originally designed to be supported solely by the steel truss system and the addition of the concrete shear wall was a necessity to dampen vibrations originating from the mechanical equipment located on the mechanical penthouse supported by the cantilever.

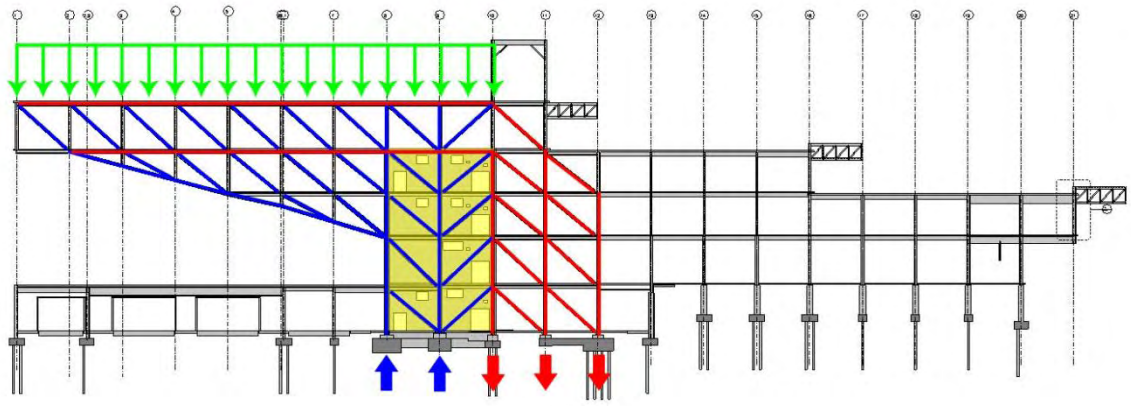


Figure 7: Truss Stress Diagram.

Shown above is one of the four truss frames dedicated to supporting the cantilever. The members highlighted in blue are under compression; the red members are under tension. The shear wall is highlighted in yellow and provides added stiffness to the frame where foundational reactions change from positive to negative directions. The green distributed load represents gravity loads on the frame. This frame is located at grid line B.

Mechanical Systems

The Millennium Science Complex combines both Materials Science and Life Sciences functions and spaces into one building. Each of these spaces contains offices, laboratories, and unique rooms such as a vivarium and a clean room. Different HVAC strategies are required to handle the varying requirements of this unique building.

The Millennium Science Complex connects into the existing campus steam lines and chilled water lines. Steam enters the building at high pressure, 140 psi, but requires two pressure reducing stations to reduce the steam pressure to medium and low pressures of 60 psi and 15 psi respectively. Medium pressure steam is utilized for sterilization, heat exchangers, and other equipment loads. Low pressure steam is used for the steam coils within the AHUs and in heat exchangers that produce hot water for a finned tubed perimeter heating systems as well as reheat-coils at terminals devices. All steam condensate is pumped to heat exchangers to preheat incoming domestic water.

Chilled water is pumped throughout the building using three (3) variable speed split case pumps, with one reserved as a standby. An auxiliary low flow pump is utilized for part load conditions. The AHUs that serve the animal care facility and main lab are connected to standby power to allow for cooling of these spaces during the loss of power.
The laboratory areas of the building are served by five (5) 50,000 CFM VAV AHUs. Each of these AHUs contains a supply fan, cooling coils, heating coils, humidification equipment, and MERV-14 filters. All laboratory AHUs deliver 100% outside air. In an effort to save operating cost and energy in the 100% outdoor air systems, general laboratory exhaust air enters an enthalpy wheel with the incoming supply air. The laboratory fume hood exhaust is not included in the enthalpy wheel due to the potential contaminants within the exhausted fume hood air.
The office, lobbies, and common areas are served by three (3) 40,000 CFM VAV AHUs. These AHUs do not provide 100% outdoor air and instead contain a mixing box with CO2 sensors in the outdoor air, return air, and all conference rooms to ensure that the CO2 concentrations in these areas are maintained at appropriate levels by supplying enough outdoor air.

More specifically, the animal care facility is served by two (2) 25,000 CFM 100% outdoor air units. Each unit is sized to handle the full load of the space. The redundancy is needed to allow for continual service to the animal holding rooms and the rest of the animal facility should one unit fail. The clean room also has its own AHU that is designed to maintain the room's humidity levels at 45% RH. The animal care facility AHUs, quiet lab AHU, and clean room AHU all utilize run around heat recovery coils in an effort to reduce energy usage.

In addition to the main AHUs, cabinet unit heaters, electric heaters, fan coil units, supplemental air conditioning units, and other local equipment are used to address areas of the building where the main HVAC equipment cannot feasibly serve the area. It is necessary to have all of the previously mentioned components in order to effectively keep the building operating under optimum conditions for the various building occupants.

Electrical Systems

Power Distribution

The electrical system for the Millennium Science Complex is a 12.47kV service feeding a set of dual 4000A, 480Y/277V switchgears (main-tie-main) through two pad mounted transformers. Distribution begins with 480Y/277V for lighting and other systems, and then stepped down at further locations to 208Y/120V for receptacle and equipment power. Emergency power is fed from two separate switchgears which feed multiple ATS's with both normal and emergency power. To limit the EMF from interfering with sensitive equipment, electrical closets are encased with aluminum shielding and in certain areas rigid conduit is used in place of standard conduit.

Lighting:

All lighting is on 277V service. All building perimeter offices and laboratories are controlled by both occupancy and daylighting sensors with appropriate dimming ballasts. Typical internal laboratory and office rooms are controlled by the occupancy sensor. Three general types of ballasts are used. Class B quiet dimming ballasts are used in the quiet labs. Lutron's Hilume dimming ballasts are installed for rooms requiring less than 10% dimming from full power. Advance Mark7 dimming ballast is used in rooms with regular dimming conditions. A system of addressable ballasts is used in accordance with Lutron's GRAKIF Eye system.

Lightning Protection:

The Millennium Science Complex is protected by Cooper Air Terminals in coordination with NFPA 780. Air terminals located in spaces within the bounds of roof walls are mounted on bases provided by Cooper. Cooper provides the grounding conductor, which is fastened by clips to the top of the perimeter walls. Down conductors penetrate the roof and route behind the concrete panels of the façade in PVC conduit where they ultimately terminate at a ten foot ground rod.

Telecommunications:

The telecom system consists of only a few major components – combination voice and data outlets, telephone outlets, and paging speakers. The majority of spaces contain combination voice and data outlets prewired into furniture components. Several voice/data outlets are located along all corridors and several locations have above-ceiling mounted telecom outlets for wireless access points. All offices contain at least one quad outlet and one duplex telecom outlet, while conference rooms contain one wall-mounted duplex outlet and a floor-mounted quad outlet. Computation/study areas and conference rooms also contain floor poke-through routing capability. Basket-type, twelve inch by four inch, cable trays route telecom wiring throughout corridors. Each floor is fed by several IDFs – two for the basement, four each for the first and second floors, and two for the third floor. The telecom backbone consists of one 24-strand multimode, one 24-strand single mode fiber optic cable, one 50-pair CAT-3 UTP cable, and one RG-11 coaxial cable between the MDF and each IDF. The telecom system is grounded through the telecommunications main grounding bus bar back to the building electrical ground.

Fire Alarm

The Millennium Science Complex fire alarm system was designed in accordance with NFPA 72. The fire alarm system consists of audio, visual, and combination audio/visual notification devices. Activation devices consist of smoke detectors, heat detectors, and fire alarm pull stations. The system also contains tamper and water flow switches in the stair wells. The systems Fire Alarm Control Panel is located in Receiving N-041.

Security System

The security system was designed in accordance with NFPA 70, NFPA101, and NEC. The system consists of magnetic swipe card access with electronic strike, door contacts, and request to exit. Exterior doors, and egress stairwells have local audible alarms. Access control panels, along with class "E" fire alarm relays are located in the security/telecom closets. Millennium Science Complex also has a CCTV system consisting of fixed type cameras. All data recorded are stored on a Digital Video Recorder in LS/MS Server Room N-020.

Fire Protection System

The Millennium Complex will be protected on all floors by an automatic fire alarm notification system. Manual pull stations will not be required where the alarm notification appliances activate upon sprinkler water flow in this fully sprinklered building. The First Floor Outdoor Plaza must also be fully sprinklered as there is potential for combustible materials to be handled under the canopy. The laboratories will be designed to meet Ordinary Hazard Group 1 or 2, while storage rooms with dispensing capabilities must be designed to Extra Hazard Group 2.

An automatic standpipe system will be required throughout the building, and hose connections will be required on each floor at an intermediate landing level in stairways. A minimal residual pressure of 100 psi is required at the outlet of the hydraulically most remote 2 ½ inch hose connection.

Sustainability

The Millennium Science Complex is designed to achieve LEED© Gold Certification by employing several sustainable features. One of the most unique features is the extensive green roof located on both wings of the building. It serves not only as a storm water control strategy, but also to reduce the building energy loads by acting as an insulator, extend the life of the roof, and filter pollutants and greenhouse gases from the air. Storm water collected will be diverted to underground cistern and used for the site's landscaping. The Millennium Science Complex will be the third building on Penn State's University Park campus to utilize a green roof system. The remainder of the roof consists of white elastomeric sheet roofing which has a high reflectance and high emissivity to help reduce the thermal gradient.

During construction of the complex, almost 90% of the construction waste was diverted from disposal and at least 10% of the materials used were from recycled content, including the steel-frame, concrete, and precast concrete. In addition to the recycled content, sustainably harvested wood was used for carpentry and 10% of the materials were regionally sourced.
Throughout the interior, stringent criteria for low-emitting materials for adhesives, sealants, paints, coatings, and carpet systems were strictly enforced to promote indoor air quality. Independent exhaust is provided for each laboratory, vivarium, and other rooms where hazardous gases and chemicals may be present to help ensure indoor air quality as well. Carbon dioxide monitors are provided in all densely occupied spaces.

Natural daylight is provided extensively throughout the building, including the offices and laboratories. The interior architecture also allows the daylight to reach the hallways from the offices and laboratories. Semitransparent glass, solar shades, and louvers are found throughout the entire façade to encourage daylight without heat gain or glare. Individual lighting controls is provided for 90% of the building occupants as well as lighting controllability for shared spaces. Advanced control systems are also designed for the management of the HVAC systems to emphasize energy efficiency.

Building Orientation

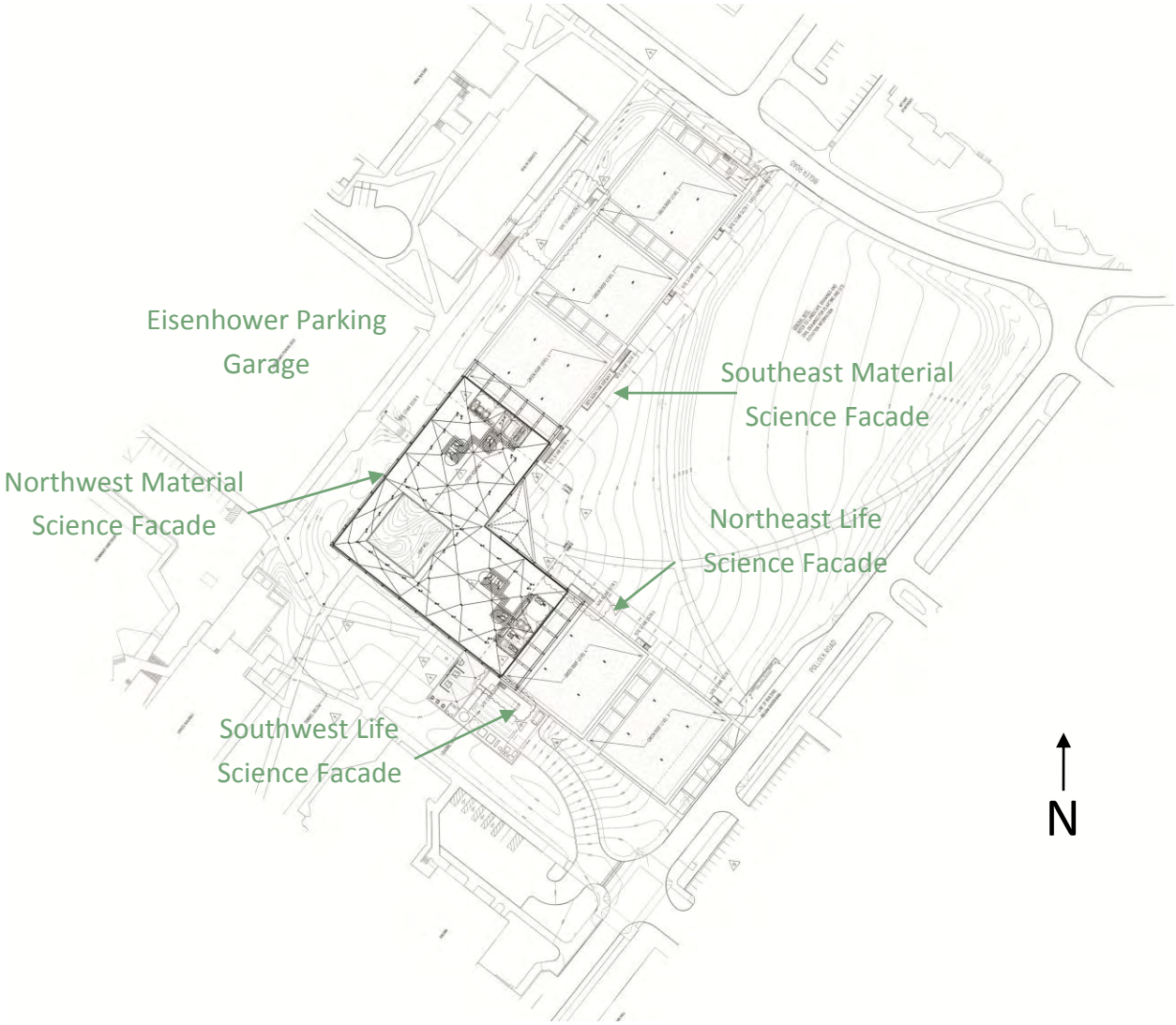


Figure 8: MSC Site Plan View - Solar North Orientation.

Facade

Summary & Goals

Background

According to the architect Rafael Viñoly, the intended design inspiration for the Millennium Science Complex was to give the appearance of a floating building. To accomplish this, the façade's original design intent was to enhance the linearity of the building by placing continuous horizontal glazing on all floors and stacked "Penn State" brick with bands of recessed dark-fired brick adhered to eight inch thick pre-cast concrete panels along each face of the building. As a team, this element of the building was determined to be a great opportunity for redesign due to its impact on each discipline.

The existing façade system is an eight inch thick pre-cast concrete panel, each spanning 22 feet (1 bay) horizontally. The glazing configuration consists of a 1 inch thick insulated glass unit supported by an aluminum mullion system bearing on the pre-cast panel below. Solar shading is incorporated into this façade system through three techniques: an 18 inch louver placed at the midpoint of each exterior glazing, a 2'3" setback of the glazing off the face of the precast brick façade, and a fritted glass on the upper half of the glazing. Refer to Appendix E: Daylighting Results & Information for detailed drawings and assemblies.

Redesign Goals and Methods

As stated previously the façade was chosen as an area of interest for redesign because it provided a unique opportunity for the group to utilize BIM/IPD principles. It was also theorized early in the decision making process that the façade could have the potential for increased thermal efficiency and daylighting integration. A double-skin façade system with integrated horizontal louvers was chosen to achieve this potential. The design of the façade relied heavily on coordination among team members to ensure the result was an efficient design. The goals for this redesign were as follows:

1. Increase the thermal efficiency of the façade panel and overall system
2. Decrease the weight of the precast panel to reduce the façade loads on the structural system
3. Increase the daylighting efficiency and improve user comfort
4. Determine the most efficient method of construction

Façade Design

Preliminary Designs

Before the specific dimensions of the precast panels were redesigned, Building Stimulus underwent a preliminary investigation of alternative panel materials. The primary focus of the investigation was lightweight material that still provided the structural stability, as well as the aesthetic quality of the existing architectural precast panels. Materials researched included the following:

- Architectural Metal Panels
- Precast Concrete with Carbon Fiber Reinforcing
- Glass Curtain Wall

Architectural metal panels, as well as a glass curtain wall, provide significant benefits including ease of installation, reduction in cost, and reduction in weight; however, the use of this type of building envelope proved to severely alter the architectural intent of the building and was thus discarded.

Precast Concrete Panels with Carbon Fiber Reinforcing uses carbon fiber sheets to increase the structural integrity of the panel while allowing a reduction in total concrete, creating a significantly lighter panel. After consulting manufacturers, however, it was concluded that carbon fiber reinforced panels could not be designed to the required dimensions for the Millennium Science Complex without creating serious moisture permeability, as well as structural stability issues, both of which were unacceptable on a double-skin façade. Therefore, the remaining alternative materials were deemed impractical for use.

Single Skin Facade

The existing envelope consists of a single skin façade, described previously in report. During the redesign process of the façade, it was Building Stimulus' initial intention to implement a double skin façade along the entire perimeter of the building. However, upon further review, it was concluded that specific facades were unable to produce the same benefits and energy savings needed to justify the costs of the double skin façade. Therefore, the existing single skin façade system remains on the facades indicated below, with the new precast panel design.

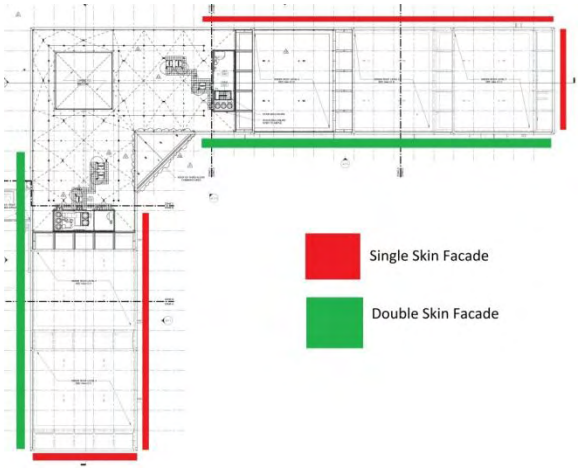


Figure 9: Facade Placement

Double Skin Façade

A double skin façade is a unique enclosure design in which two building skins envelope the building. The composition of the two skins complicates the building envelope immensely on numerous fronts, including but not limited to the constructability, accurate thermal modeling, and overall enclosure design. Enclosure design is the process by which the building envelope is designed to be functional and efficient. Complete and functional building envelope design was out of the scope of this thesis report. However, initial design processes and potential issues were researched and considered during the design phase of the façade.

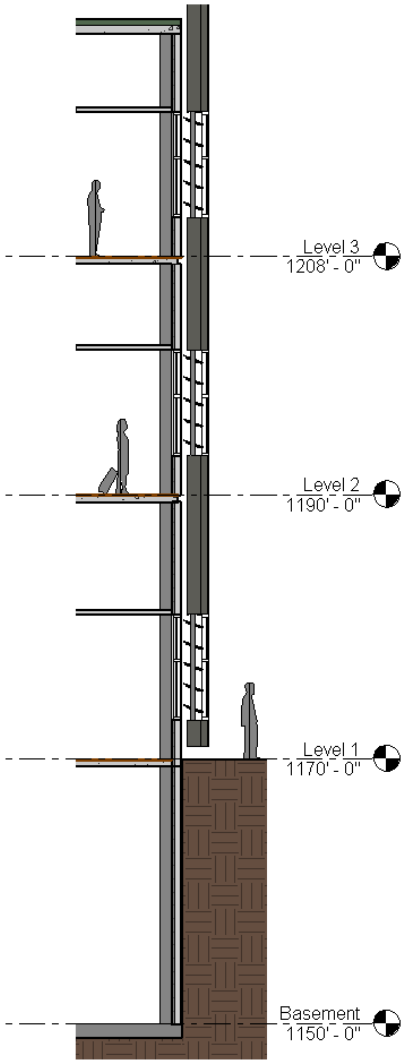


Figure 10: Double Skin Facade Section.

The double-skin façade proposed by Building Stimulus for this system is comprised of two glazing configurations which consist of an interior glazing system and an outer single pane glazing. The redesigned glazing and mullion design consists of a 10 mm annealed PVB laminated outer glazing connected via T5 5mm thick 100 mm x 150 mm mullions and transoms. A sample calculation of this design can be found in Appendix B: Enclosure Analysis. Laminated glass was chosen for the exterior enclosure due to the building's operation as a sensitive laboratory environment and due to the potential for the building to experience high wind loading. The glazing and mullion system was designed for the local components and cladding wind pressure of 32psf using ASTM standard 1300 – 04 and ASCE7-05.

The two glazing configurations for the double skin are separated by a 24 inch air gap. The two foot interstitial space acts as a thermal buffer between the outdoor environmental conditions and the interior perimeter spaces of the building. For the interior glazing, the high performance glass used in Millennium Science's current design was selected, Viracon VE-12M. This selection was maintained due to the current glazing's excellent U-value rating of 0.29 and visible transmittance of 70% for daylighting purposes. The low-emittance coatings on the interior glass provided reduced solar heat gains to the interior and serves as the insulating layer.

Several iterations were performed to select the exterior glazing for the second skin of the façade. Initially other high performance glazing types were selected, such as Viracon VE6-2M and VNE1-63, (see results in Appendix C: Energy Analysis). However, after consultation with John Jackson, an associate from HOK engineering and design firm, the design was reconfigured to consist of a hardened single glazing for the exterior skin. By specifying a glass with lower performance capabilities, it allowed the air gap to perform similar to a greenhouse, allowing the solar heat to collect in the space to create a lower temperature difference between the perimeter spaces and the outside air during the heating period for the winter. The resulting U-value for the new configuration of the double skin façade was determined to be 0.126 BTU/hr ft^2 ^oF.

Table 6: Glazing Properties.

		Transmittance			Reflectance			U-Value		SHGC	LSG
Location	Product	Visible	Solar	U-V	Vis-out	Vis-in	Solar	Winter	Summer		
Exterior Glazing	Clear	79%	61%	46%	14%	14%	11%	0.47	0.49	0.7	1.12
Interior Glazing	VE1-2M	70%	32%	10%	11%	12%	31%	0.29	0.26	0.38	1.84

Within the air gap, adjustable frosted glass louvers were placed to provide a shading system for the interior perimeter spaces. This allows for more dynamic control of the daylighting and solar heat gain within the perimeter spaces of the Millennium Science Complex. The design of the double-skin façade is a continuous system that allows air to flow from the ground floor to the roof to serve as preheat for the air handling units during the winter. The relative heat gain for this configuration, on a center of glass basis was determined to be 50.8 BTU/hr ft^2 for the winter and 81.2 BTU/hr ft^2 for the summer conditions. In the summer time the air flow in the interstitial space is naturally exhausted at each floor by opening dampers located at each floor to prevent excess heat gain for the perimeter spaces since the solar heat gain is much greater.

One significant issue arouse with the double skin façade in terms of determining the cleaning and maintenance for its lifespan. The inner clearance between the two envelopes, as previously mentioned, is 24 inches, which can possibly provide enough space for a maintenance worker. However, the presence of the stationary louver system occupies much of this space and therefore access to the space is not an option. The compromise Building Stimulus arrived at was to have all maintenance and cleaning be performed via a hinged outer glazing system that is accessible by means of a scissor lift. It is estimated that all double skin façades will have to be cleaned once per year. In addition, for this method of operation the glazing panel must be sealed to outer enclosure via a dry gasket and latching system. This gasket provides a potential for failure over long term exposure to the elements. Therefore, in addition to yearly cleaning, it is recommended that this dry gasket on each glazing system (1 bay, 22ft x 8ft section) must be replaced every five to ten years based on yearly inspection. The design of this building envelope system proved to be an educational experience, however, due to the extreme costs and complexity of the system it would be advised to not continue with this design.

Precast Panels

The focus of the façade, structurally, was concentrated mainly on the design of the precast panel. A number of iterations were produced before the final solution was reached, including a thicker slab without returns, a one-way joist system, carbon fiber reinforced slab, etc. Figure 11 below shows a number of different panel configurations that were analyzed for strength and deflection under dead and wind loading, in and out-of-plane. Once the group determined that the mechanical efficiency would benefit from having a continuous air gap rather than a non-continuous air gap, the challenge was to design a panel without returns running laterally across the panel which would inhibit the flow of air vertically up the double skin façade. Once this was realized, the design of the pre-cast panel proved to be mostly dictated by providing adequate clearance between the inner faces of the interior and exterior enclosures. This clearance was determined early in the design process to be 24 inches. This would ensure that a continuous air gap was achieved for thermal efficiency and the louvers used to optimize daylighting efficiency would have enough space to operate.

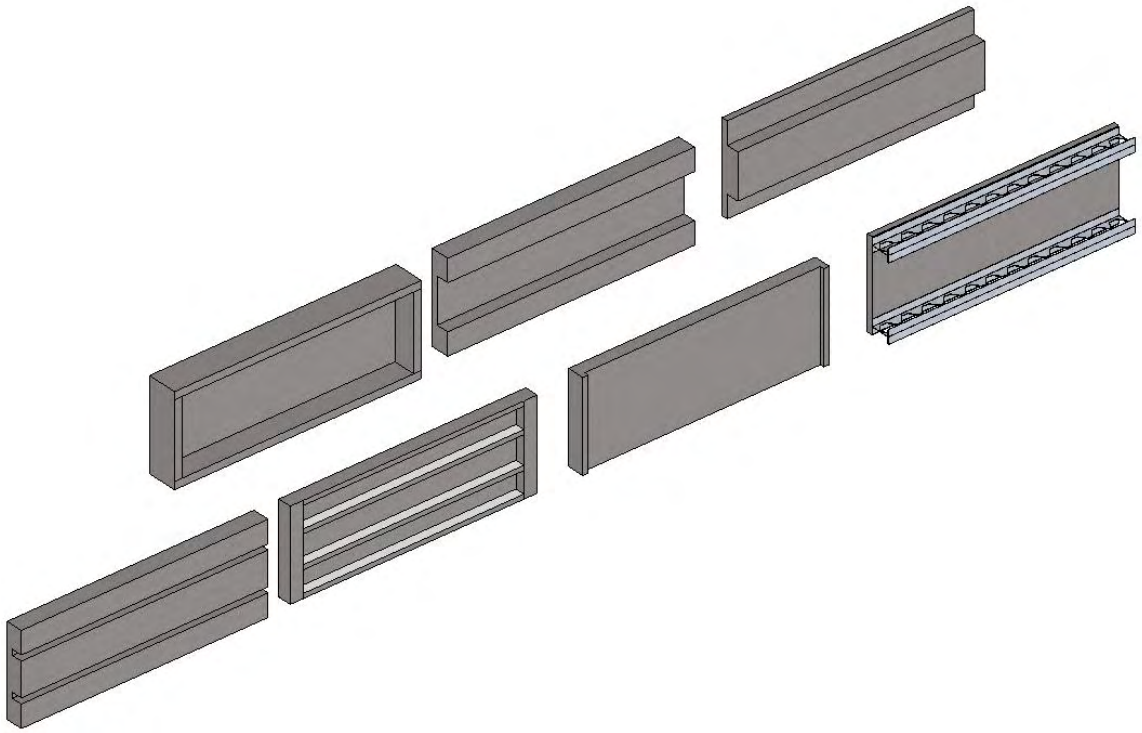


Figure 11: Precast Panel Iterations

The redesigned system (Figure 12) features a flat slab of 6 inches thick and 3 beams 8 in x 12 in placed at the ends and middle of the panel, running vertically up the panel. The beams were necessary to prevent the panel from cracking under its own self-weight during storage and construction and to provide extra lateral support under wind loading (calculations can be found in Appendix B: Enclosure Analysis). The existing panel-to-structure connections were used in the redesigned system with the addition of one lateral resisting connection on the middle beam of the panel which is connected to the structure at the midpoint of the steel beam of the gravity system. In addition to adding flexural strength to resist the lateral loads the panel would experience after installation, the center beam also prevents the panel from cracking under its own self weight during storage, transportation, and erection. It should be noted that the panel must be stored and transported with the beams facing down to ensure cracking and chipping does not occur on the face brick.

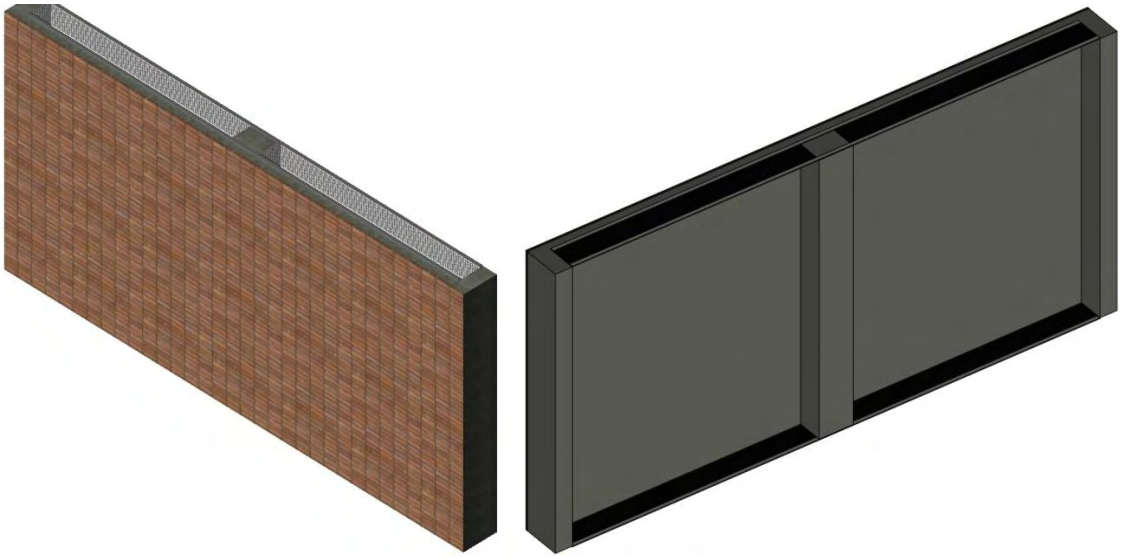


Figure 12: Redesigned Precast Panel (black indicates location of non-structural horizontal grating)

Sequence of Panel Installation

The construction of the double-skin façade requires significant adjustment to the original schedule. The original sequence of precast panel installation can be seen in the diagram below:

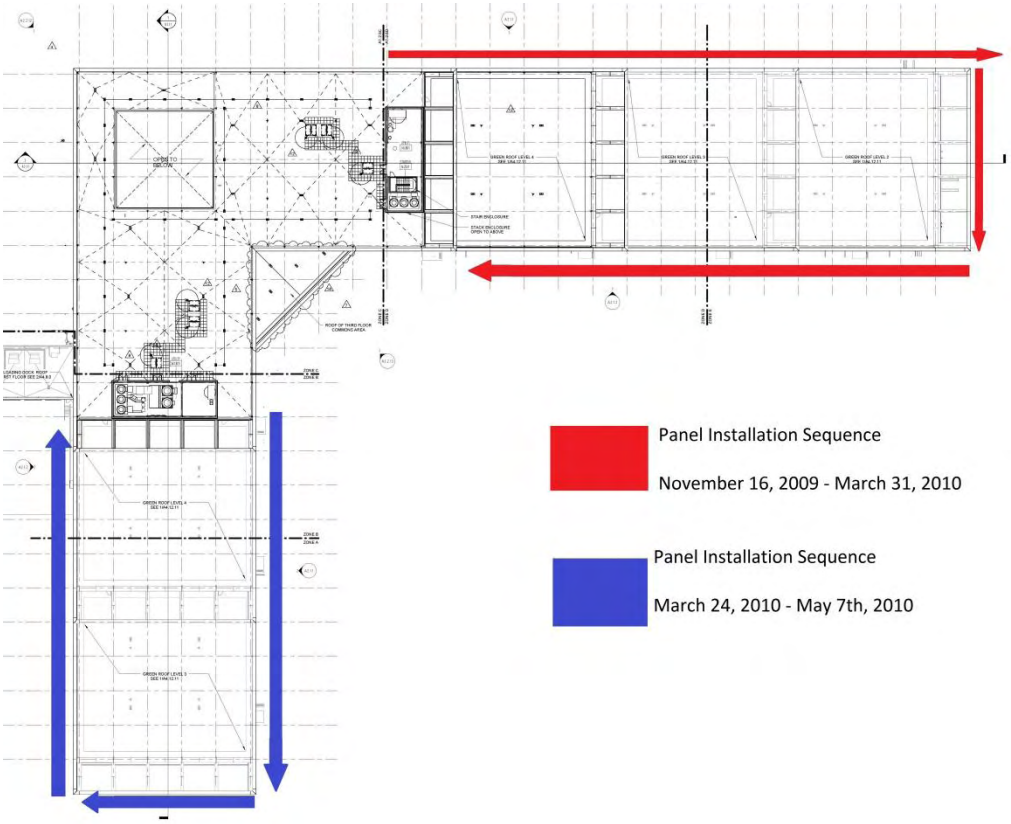


Figure 13: Panel Erection Sequence.

Panel erection began on the North elevation of the Material Sciences wing on November 16th, 2009 and continued clockwise until the Material Sciences wing was completed on March 31st, 2010. The East elevation of the Life Sciences wing began on March 24th, 2010, continued clockwise around the Life Sciences wing until the west elevation was completed on May 7th, 2010. The full schedule of activities can be found in Appendix D: Construction Management.

To implement a double-skin façade, the sequence of precast panel erection must be rescheduled to create an efficient process. The construction of a double-skin façade demands that specific activities be completed by the time precast panel installation occurs, namely the completion of perimeter studs along the facades utilizing the double-skin. Refer to the Double-Skin Façade Construction section for more discussion on sequence of double-skin construction. Originally, the first area to have perimeter wall studs installed was Material Sciences wing, Level 2, on March 29th, 2010. However, interior walls are laid out much earlier, with the first instance being December 14th, 2009 in the lab space on Level 1. Therefore, with the installation of perimeter wall studs dictating the time that

double-skin façade panels can be erected, it is logical to move perimeter wall studs to an earlier date, and move interior stud construction to a later date to ensure that there is no crowding amongst trades. An updated double-skin erection schedule can be found in Appendix D: Construction Management. While the double-skin façade requires perimeter stud construction to be completed, the single-skin façade does not. Therefore, the sequence of panel erection has been revised, completing all single-skin façades first, before beginning double-skin facades. Doing so allows perimeter studs of Life Science West elevation and Material Science South elevation, the double-skin façades, to be constructed, while single-skin precast panels are being erected concurrently. The revised direction of panel erection can be seen below:

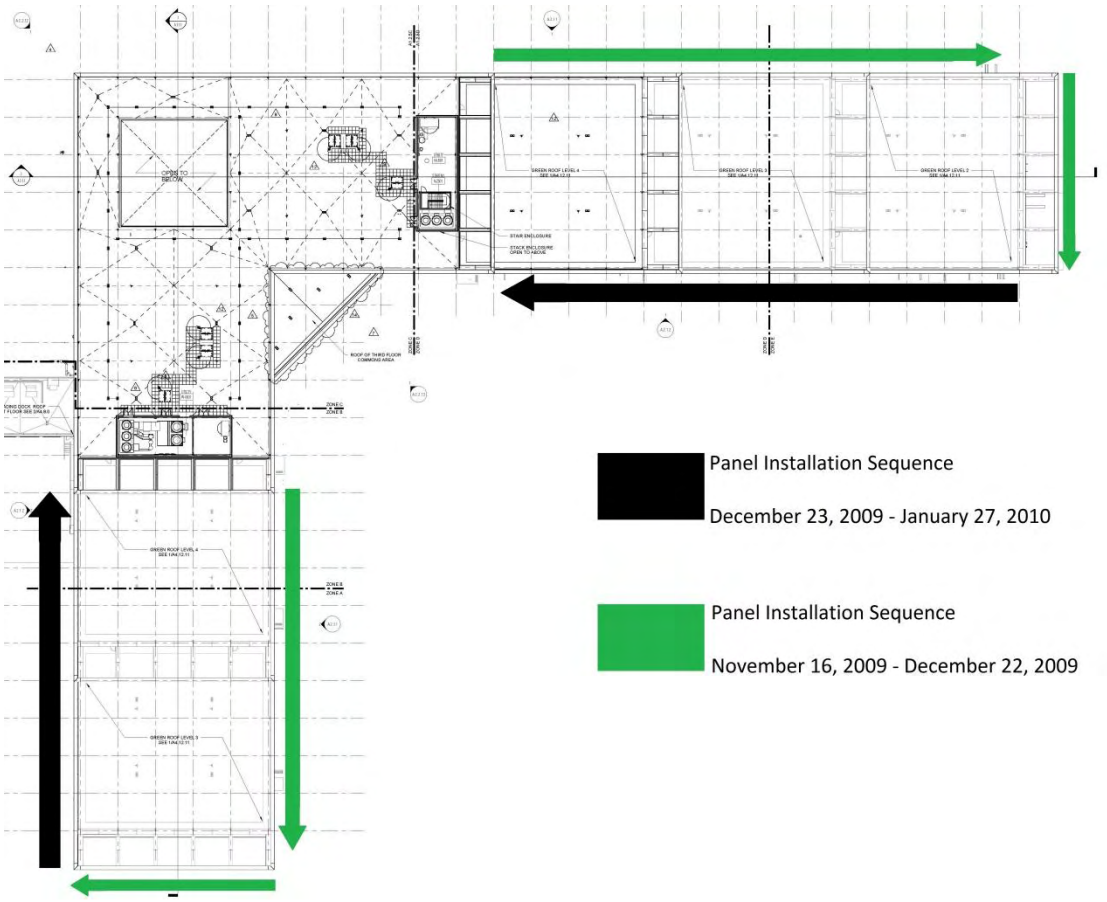


Figure 14: Panel Erection Sequence.

According to Whiting-Turner, architectural precast panels can be erected at a conservative estimate of 7 panels per day, making the North elevation the longest duration at 90 panels erected over 13 days, and the shortest duration being east elevation of Life Sciences at 9 days. Whiting-Turner took 83 days to complete the south elevation of Material Sciences wing, and 40 days to complete the west elevation of Life Sciences wing. These lengthy durations were intentional as these elevations were left incomplete to allow the distribution of large materials into the facility easily. This concept will continue, however, the south elevation of the Material Sciences wing cannot be used due to interior studs completed early for double-skin construction. Therefore, the north elevation of Material Sciences wing will remain incomplete to allow the distribution of materials instead of the south elevation.

Double-Skin Façade Construction

The double-skin façade is a specialized system that requires a unique approach to construction, and is only complicated by its use with precast panels. Double-skin facades are predominantly fully glazed systems with two layers of glass. Using brick panels with a double-skin façade requires careful considerations for construction, including:

- Ensuring interior wall is protected from moisture
- Applying thermal and/or vapor barriers on interior wall
- Installing interior glazing without damaging materials
- Ensuring interior wall is complete prior to installation of precast panels

The double-skin façade is designed to allow outside air to flow through the cavity. In the winter months this air will be very cold. In the summer months, this air may have high moisture content. Therefore, appropriate thermal and moisture barriers must be present. Building Stimulus has redesigned the insulation on double-skin facades to be placed on the exterior-most side of the interior walls as compared to directly behind the precast panels on the original façade. A polyethylene vapor barrier will be applied on the interior wall as well to prevent moist summer air or inclement weather from entering the interior wall.

Applying the thermal insulation and vapor barrier properly requires that the precast panel not be installed yet. The existing schedule of activities has been altered to have the perimeter wall studs of the double-skin façade to be completed before panels are installed. The panels are then welded into place and lateral connections are fastened.

This method of construction presents several issues. As the thermal barrier is applied, an opening must be created for the bearing support of the panel. This creates an opportunity for the building envelope to fail. These openings are vulnerable to moisture penetration and extra care must be taken when the vapor barrier is installed. Additionally, protective material must be applied to nearby vapor barriers and insulation, as welding poses a threat to the integrity of the aforementioned materials.

Daylight Integration

Integrating shading devices into the façade designs of the Millennium Science Complex provides various advantages for building occupants, owners, and designers. The opportunity exists to lower solar heat gain, lower electrical lighting power consumption, and increase overall user comfort in perimeter spaces.

There are generally three types of spaces that can be classified as perimeter rooms that which daylight integration directly affects. These spaces are offices, student study areas and open lab work areas labeled as “Neurophys-Invitro.” These perimeter spaces are intensive work areas, where occupants will be using computers and doing lab research.

Daylighting summaries can be found on page 308 in Appendix E: Daylighting Results & Information. Extensive hourly illumination contours of all façade orientations on design dates can be found at:

http://www.engr.psu.edu/ae/thesis/BIMTeam22010/Final/Daylighting%20Contours.pdf

Shading Devices

While the Millennium Science Complex Currently uses a continuous static shading lover along the buildings' façade, the redesign incorporated façade orientation based dynamic shading systems. American Warming and Ventilating (AWV) provide a slim, self-adjusting system that can be integrated within the proposed double skin façade.

The system is comprised of five 20' long by 19" frosted glass louvers. AWV provides their systems with "Shadoglass," which are glass blades with a vast array of material and color choices. The advantage of choosing frosted glass versus alternatives, such as perforated metal shades, is the ambient glow produced by the shades while simultaneously reducing glare into the space. View to the exterior is important to maintain when shading devices are utilized. With proper use, the system can maximize user comfort while retaining a view to the exterior.

Solar shading device cutsheets and information can be found in Appendix E: Daylighting Results & Information.

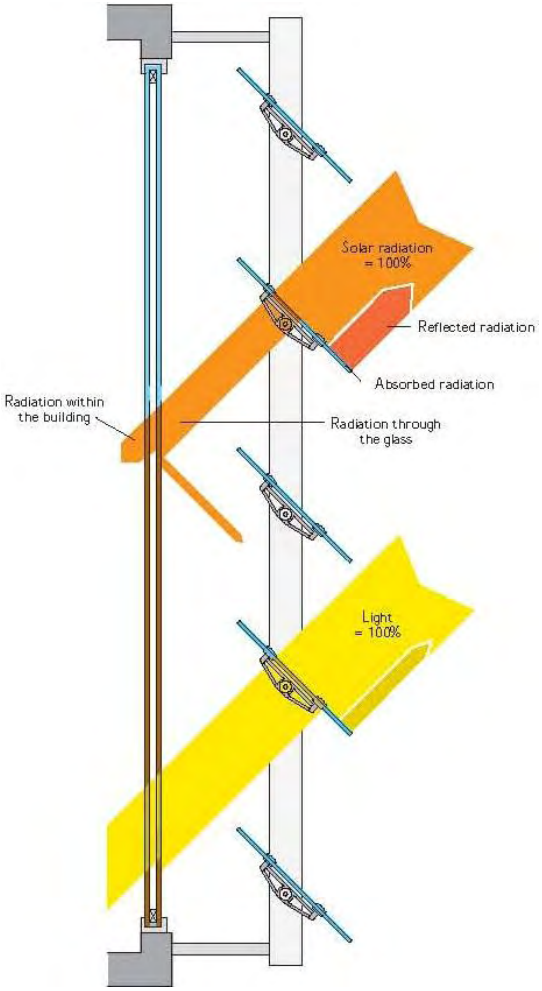


Figure 15: AWV Solar Shading Device Section.

Daylighting Controls

Shading Device Controls

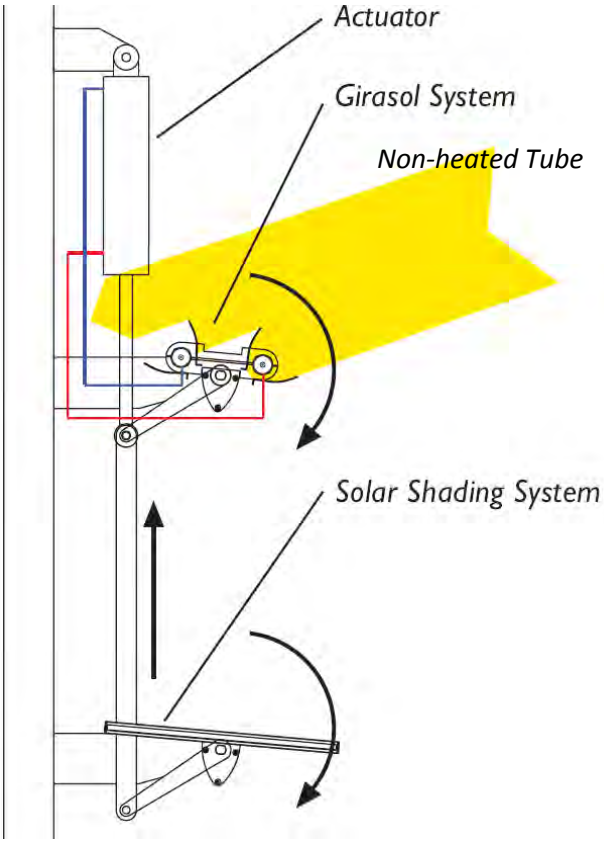


Figure 16: Girasol Shading Control.

AWV provides three different control systems for their shading systems. There are two electronic options and a single non-electronic control system.

SolTronic is a small electronic control system that can control ten actuators and responds to external weather conditions.

ICS-4-LINK is a large electronic system that can integrate HVAC controls, smoke control, as well as the control for the shading systems.

The non-electrical control system (shown to the right) is AWV's "Girasol." This control system is unique in the fact that it does not use electrical solar tracking or control devices. The system instead uses two absorber tubes filled with a hydraulic fluid. One tube is allowed to absorb solar radiation, while the other is not. When the exterior tube is heated by direct solar radiation, the pressure balance between the two tubes creates an imbalance. This imbalance of pressure causes the glass blades to open or close as desired.

The Girasol system was chosen for the Millennium Science Complex's facade shading control. This system will not burden the electrical system, and will require no programming. The Girasol system will allow the shading devices to operate differently from one facade orientation to another. Control systems such as this will allow for maximizing the functionality of the system, benefiting user comfort, electrical light energy, and lowering mechanical loads.

Electric Light Controls

Use of occupancy sensors has been incorporated into student study areas and perimeter public spaces to maximize energy savings from the use of dynamic shading devices within the double skin façade. The student study area has also been equipped with occupancy sensors due to the absence of nearby manual lighting controls, as this is a public space. Typical private offices that line the perimeter of the building will incorporate an integrated chilled beam luminaire that has two manual switching options that will be further discussed in the Luminaire Integration section on page 56.

Daylighting Overview by Façade Orientation

Southeast Facing Material Science Façade (Plan South)

The facades on plan west face a more southeasterly direction than that of what the plans show. This facade orientation faces more east than south as it is 52 degrees counterclockwise from facing solar south.

This particular facade orientation benefits greatly from the addition of dynamic shading devices. The perimeter spaces on this orientation will receive direct daylight penetration from early morning and into the early afternoon. Solar shading devices have been incorporated into the interstitial space of the double skin facade used on this orientation.

Southwest Facing Life Science Façade (Plan West)

The facades on plan west face a more southwesterly direction than that of what the plans show. This facade orientation faces more south than west as it is 52 degrees counterclockwise from facing solar west. The Southwest facing Life Science façade has used the double skin façade with the automatically adjusting louvers.

Northeast Facing Life Science Façade (Plan North)

The facades on plan east face a more northeasterly direction than that of what the plans show. This facade orientation faces more north than east as it is 52 degrees counterclockwise from facing solar east.

The northeast facing Life Science facade has not incorporated dynamic louvered solar shading devices. The facade will only receive early morning daylight penetration without shading, and does not seem productive to add shading louver devices for functionality and cost reasons. The northeast facing Life Science façade is not utilizing the double skin facade system and has retained the use of the existing fabric roller shades. Analysis of daylight contribution in perimeter spaces without the use of either double skin facades or fabric shades has shown that direct sunlight penetration will create significant visual issues with source/task luminance ratios.

Northwest Facing Material Science Façade (Plan West)

The facades on plan north face a more northwesterly direction than that of what the plans show. This facade orientation faces more west than north as it is 52 degrees counterclockwise from facing solar north.

The northwest facing Material Science facade shall not incorporate dynamic louvered solar shading devices. The Eisenhower Parking Garage to the northeast of this facade casts a substantial shadow on the Millennium Science Complex. There will be some minor inconvenient times when direct sunlight penetrates the space, though limited.

The northwest facing Material Science façade is not utilizing the double skin facade system and has retained the use of the existing fabric roller shades. Analysis of daylight contribution in perimeter spaces without the use of either double skin facades or fabric shades has shown that direct sunlight penetration will create significant visual issues with source/task luminance ratios.

Building Enclosure Analysis

A brief thermal/condensation analysis was performed for the redesigned precast façade system. The thermal analysis software H.A.M. Toolbox was used to determine the R-value and the potential for condensation in the interstitial cavity of the double skin façade. Both analysis procedures were performed a series of three times: 1) 4 in cavity, 2) 24 in cavity using 6 – 4 in cavity spaces, and 3) a 4 in cavity with adjusted permeance to act as 1 – 24 in cavity. The first analysis was used to provide comparison between a standard 4 in cavity and a 24 in cavity, and the third analysis was used to prove that 6 – 4 in cavities would perform the same as 1 – 24 in cavity.

As noted in the H.A.M. output found in Appendix B: Enclosure Analysis, no condensation should occur in the double skin façade cavity. This however, is higly idealized and assumes static air flow in the cavity. Any air gap or venting of the air space would influence these results greatly and possibly cause moisture to develop and condense within the cavity.

Mechanical Design

Using the program Win 6, created by Lawrence Berkeley National Laboratory, as recommended by several literatures and articles for analyzing double-skin facades, the energy performance of the double-skin façade was analyzed. This program allows the development of different glazing systems to be analyzed for energy and optical performance, and it also includes the option to model louvers within the glazing system, just as needed for the double skin façade. These calculations were based on ISO 15099 thermal performance for windows and shading device which is a simplified radiation and conduction model and the Waterloo Model, which is a convective model for integral shading devices.

It is well known that modeling the energy performance of double-skin facades is a very arduous task which does not always render completely accurate results since the façade is so dynamic based on external temperatures, solar radiation, and wind speed. Convection within the intermediate cavity occurs through thermal buoyancy and is also wind driven. The basis for this particular analysis made several assumptions to yield approximate results for the façade's performance. The thermal performance modeled in this analysis does not take into consideration completely the convective effects the airflow within the air gap has on the heat transfer ability of the façade. The performance was based solely on radiative and conductive performance of the glazing system by using an average u-value as calculated in the Win 6 program. The U-value for the system was reduced from 0.29 BTU/hr ft^2 F to 0.126 BTU/hr ft^2 F. Since it did not take into consideration the convective effects of the air gap, it should be noted that performance values determined slightly overestimates the actual performance of the double skin façade. This information was then input into the TRACE model previously developed during the fall semester for the third floor of the building to replace the existing façade.

Initially, the double-skin was evaluated for its performance on all faces of the building. From an energy perspective with respect to solar loads on the perimeter spaces, this yielded considerable savings for both the cooling and heating seasons. However, due to the cost and difficulty of construction versus daylighting and energy performance, the double skin was limited to just the southern and western facades of Millennium Science. According the daylighting analysis performed, these two facades experience the greatest solar exposure due to their orientation to the sun and also surrounding buildings. For instance, the north façade did not experience as great of energy improvement since it is almost constantly shaded by the student health services building, which is directly adjacent to Millennium Science and runs parallel to the north façade. (Throughout the remainder of the report the double skin façade used on only two facades will be referred to as "partial double skin.")

Figure 17 below illustrates a significant reduction for the solar heat gain for the façade during the summer for both double skin configurations. The partial double skin façade was able to save approximately 150,000 BTU/hr.

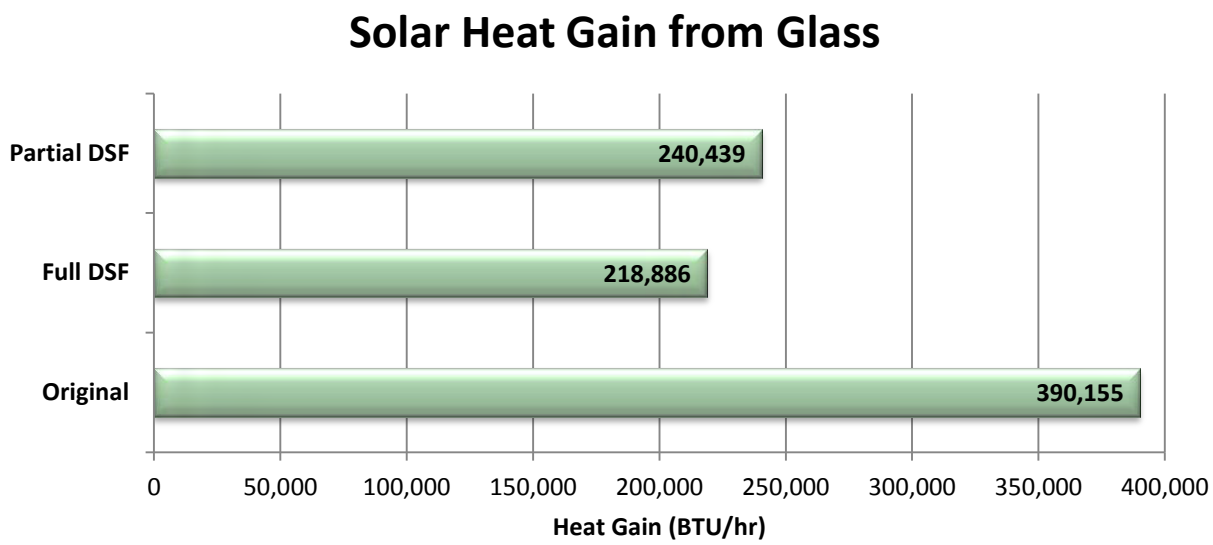


Figure 17: Glazing Solar Heat Gain on Third Floor for Summer Months.

The design criterion for the energy calculations was selected from OPP's interior design conditions and ASHRAE's 0.4% and 99.6% external conditions as seen in the tables below.

Table 7: ASHRAE Weather Data for University Park, PA.

ASHRAE Altoona, PA	Summer Design Condition: Cooling 0.4%	Winter Design Condition: Heating 99.6%
Outside Air Dry Bulb (°F)	4.7	88.5
Outside Air Wet Bulb (°F)	-	72.0

Table 8: Office of Physical Plant Interior Design Conditions.

Area	Season	Indoor	Outdoor
Comfort Areas	Summer	75°F DB, 50% RH	90°F DB, 74°F WB
	Winter	75°F DB, 50% RH	0°F DB
Labs	Summer	Lab specific	92°F DB, 74°F WB
	Winter		0°F DB
Animal Holding	Summer	64-79°F DB[1]	95°F DB, 75°F WB
	Winter	30-70% RH[1]	-10°F DB

Based on these design criteria, the total energy consumption for the third floor of the Millennium Science Complex was calculated using Trane TRACE software. The building energy model created from the fall semester's analysis was used as the building base for comparison. Figure 18 below illustrates the partial double skin façade configuration's ability to reduce the building's energy consumption by 676 MBtu per year for the 45,000 square feet (third floor's area). When extrapolated for 276,000 square feet for the entire building, this results in a savings of approximately 4,150 MBtu per year. All of the extrapolations made throughout the redesign analyses for the entire building can be used as an approximation for how the whole building would perform under the new designs. However, it should be noted that do to the increased amount of perimeter spaces on the lower floors and a slightly increased proportion of lab to office spaces would change the energy consumption of the building.

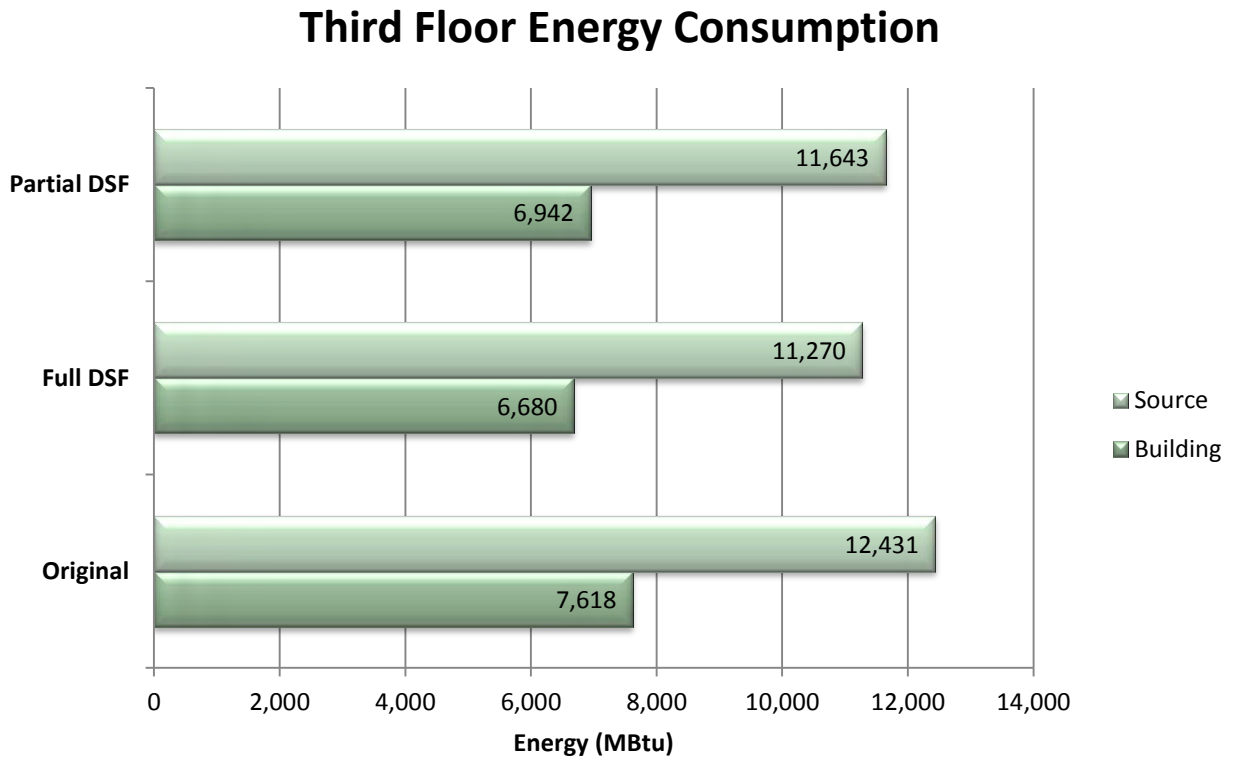


Figure 18: Third Floor Energy Consumption.

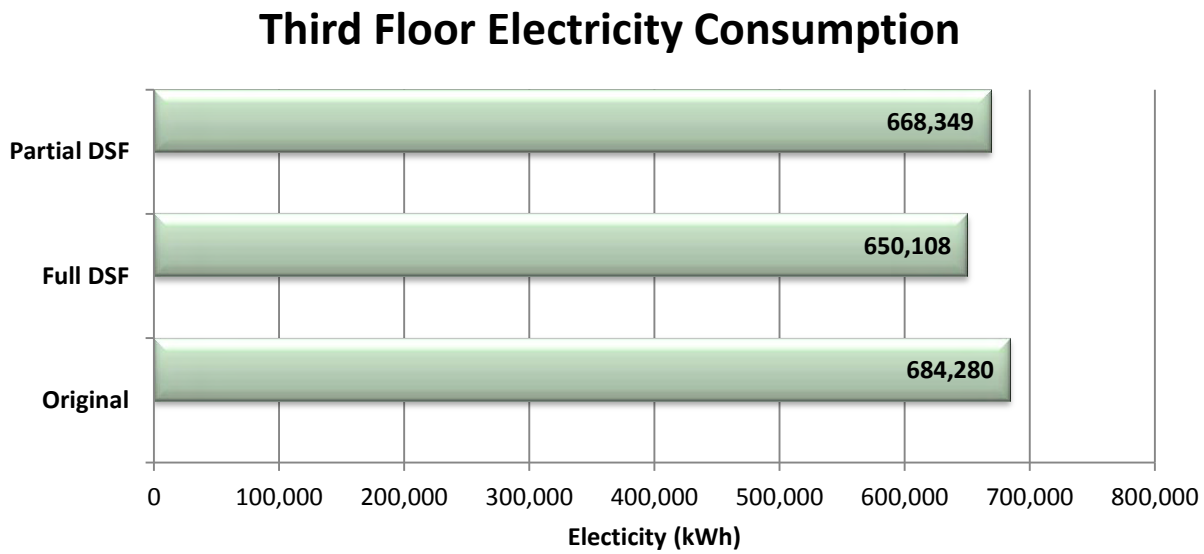


Figure 19: Third floor electricity consumption.

As shown in Figure 19 above, the new façade allows for the third floor to save 15,931 kWh in electricity consumption, which translates into a yearly building savings of 97,710 kWh.

Energy Cost Analysis

In order to determine the yearly operating costs for the building, the total energy consumption for each design alternative was applied to the Penn State Utility Fact Sheet. Table 9 details the utility cost information and it was assumed that all utilities will be purchased from Penn State at the prescribed rates.

Table 9: Penn State Utility Information.

Name of Utility	Cost ($)/Unit
Purchased Steam	0.82/therm
Purchased Chilled Water	0.22/ton-hr (1.83/therm)
Electric Consumption	0.07517/kWh

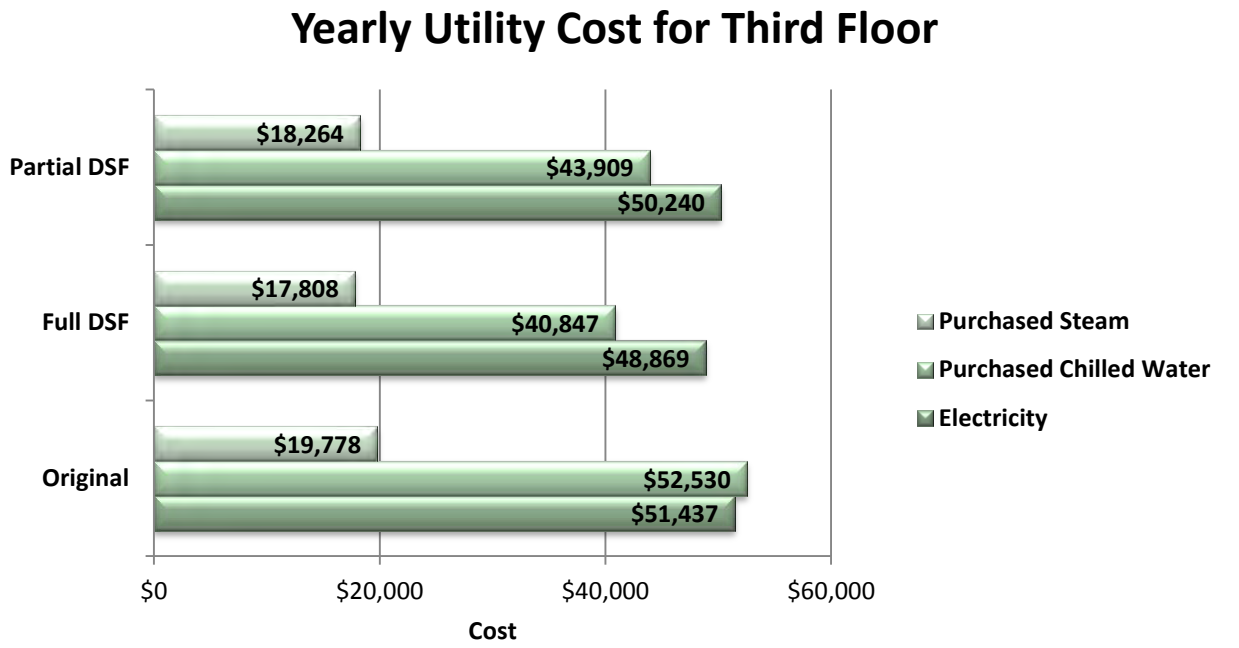


Figure 20: Third Floor Yearly Utility Cost.

The total utility cost for the third floor redesign using the double skin façade on only two faces of the building resulted in a savings of $11,332, which is a yearly savings of $69,503 for the entire building.

Source Energy Associated Emissions Analysis

The building emissions footprint of MSC was analyzed using the total source energy consumption data calculated from Trane Trace. In continual accordance with Building Stimulus' design goal of improved efficiency, reduction of source energy associated emissions was also pursued in the redesign. The emissions analysis was based on equivalent pounds of carbon dioxide, nitrous oxide, and sulfurous oxide pollutants. As previously mentioned, the model simulated was based on the third floor of the Millennium Science Complex. Figure 21 and Figure 22 show a decrease of 8.86% of equivalent carbon dioxide and nitrous sulfurous oxide for the third floor alone with the partial double skin façade. This is equivalent to a savings of 240,649 pounds of CO_{2e} for the third floor and extrapolated for the entire building, the savings is increased to 1,475,981 pounds of CO_{2e}.

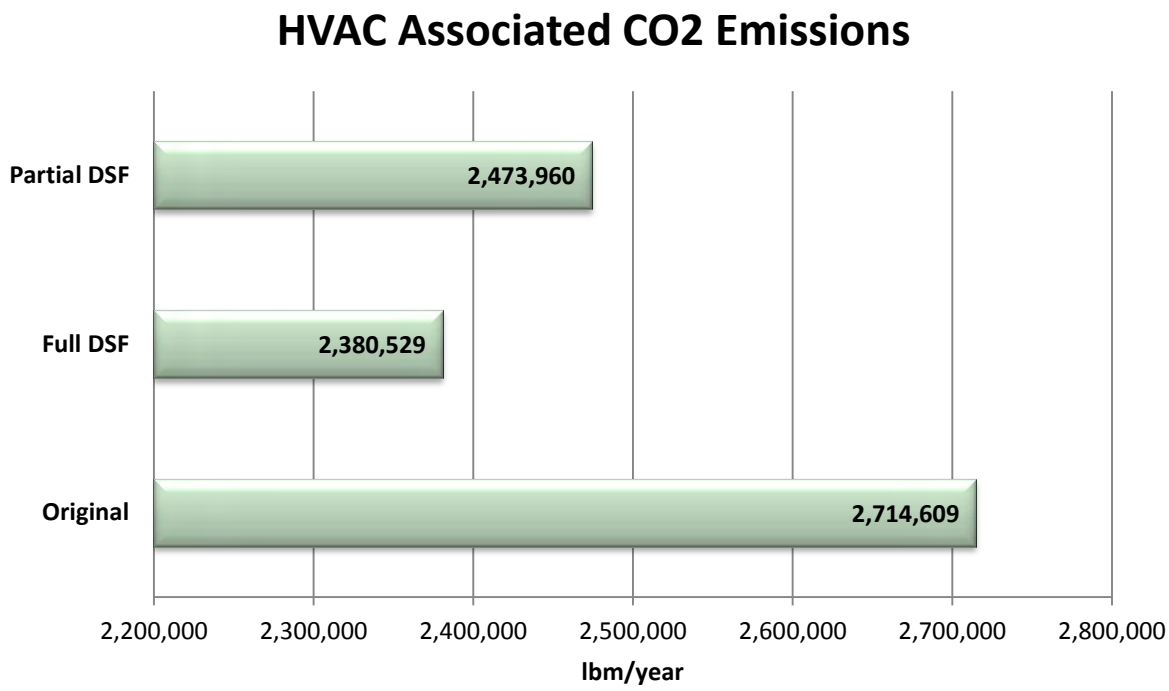


Figure 21: HVAC Associated CO_2 Emissions for the 3rd Floor.

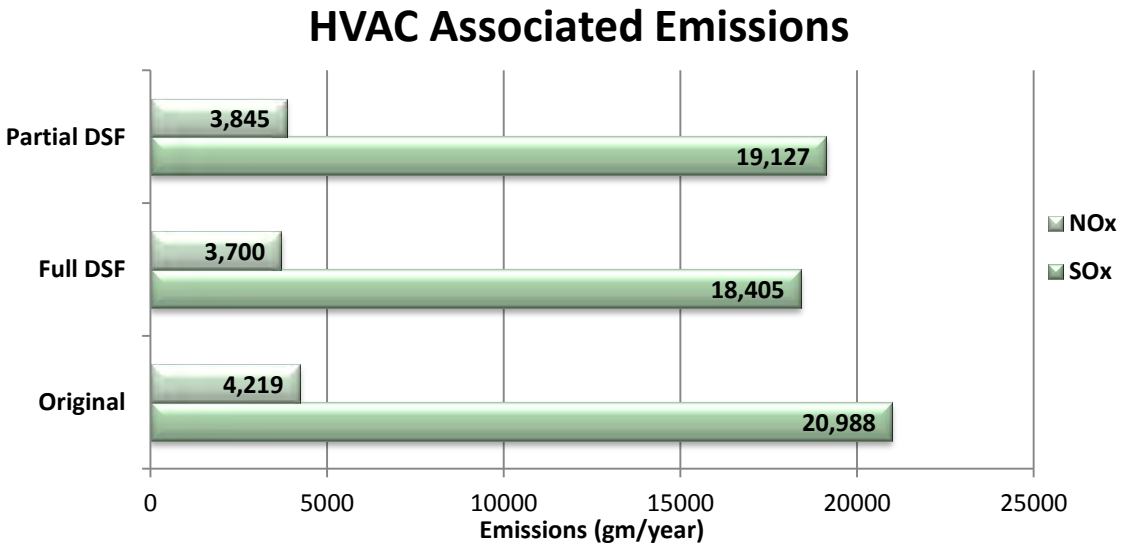


Figure 22: HVAC Associated Emissions for the 3rd Floor.

Student Study Area Lighting Design

Spatial Summary

The Student Study Areas throughout the Millennium Science Complex are located periodically along the perimeter of the building. Daylight integration with electrical lighting in these spaces is a focus of the design, and has been coordinated with other disciplines to ensure the most efficient overall design of the system on all fronts. Electric light in this space has been designed to complement the daylight integration and work in tandem to create a visually uniform and appealing workspace.

Since the Student Study Areas are open to the corridor, this lighting design has included a redesign of the corridor as well. The student study area and corridor designs have be transposed over the entire building.

Drawings & Layout

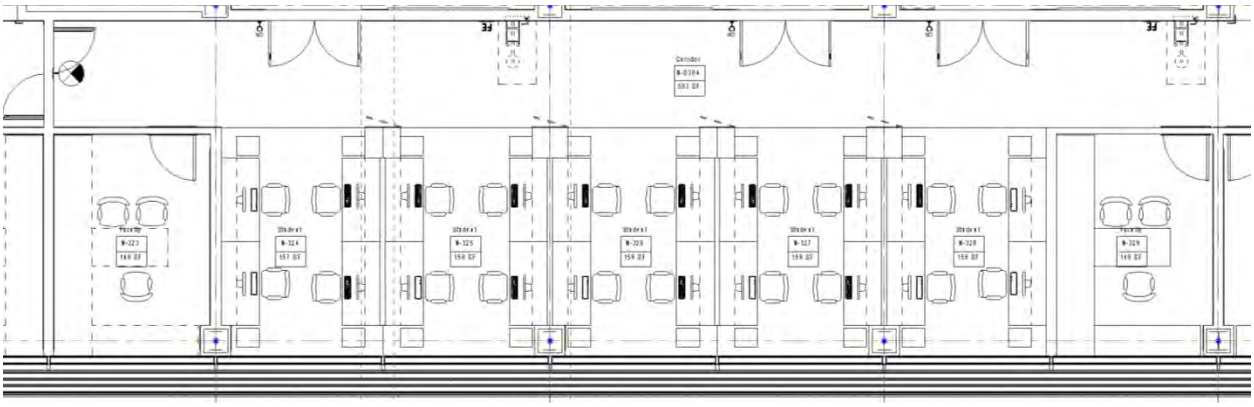


Figure 23: Student Study Area Plan.

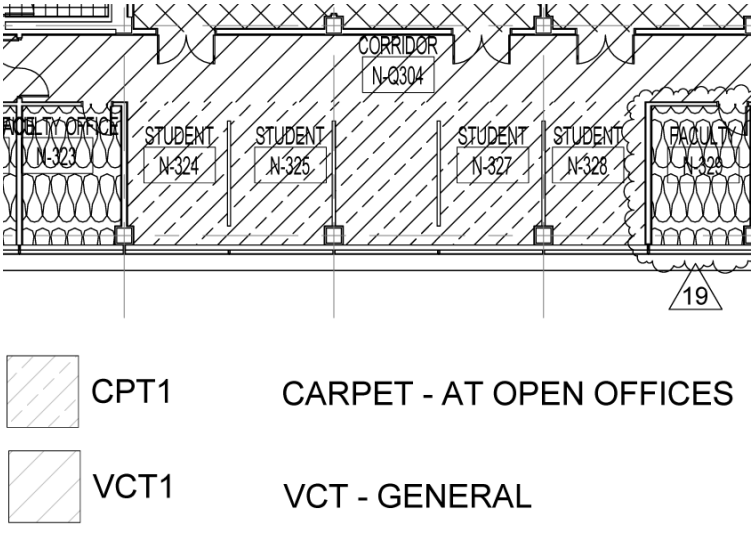


Figure 24: Corridor/Study Area Finish Floor Plan.

Tasks & Activities

This area of the Millennium Science Complex was a challenging space to design due to the Student Study Area's layout being open to the corridor. Therefore, tasks in this area are dual natured. At any given time, an occupant may be working at a computer station transferring notes from his or her laboratory report to a word processing engine while researchers are walking by in the corridor. The corridor is used primarily for transportation throughout the building.

Materials

Table 10: Conference Room Materials List.

Surface	Reflectance	Transmittance
Gypsum Ceiling	*0.80*	
Mullions	*0.60*	
Interior Glazing		0.60
Exterior Glazing		*0.85*
Gypsum Walls	*0.60*	
Corridor Floor	*0.62*	
*Study Area Floor***	*0.12*	
Desk Surface	*0.25*	

**Values from AGi32 swatches for similar materials

Design Considerations

- Study Area:
  - Considerations (IESNA Handbook)
    - Appearance of Space & Luminaires
    - Daylighting Integration & Control
    - Luminance's of Room Surfaces
    - Reflected Glare
    - Shadows
    - Source/Task Eye Geometry
    - System Control and Flexibility
    - Modeling of Faces
  - Design Criteria
    - Horizontal 30-50fc (IESNA Handbook)
    - Vertical 3fc (IESNA Handbook)
    - Power Density 1.2 W/SF (ASHRAE 90.1, Table 9.6.1)
- Corridor:
  - Considerations (IESNA Handbook)
    - Even Light Distribution
    - Direct Glare Avoidance
    - Modeling of Faces
  - Design Criteria
    - Horizontal 10fc (IESNA Handbook)
    - Power Density 0.5W/SF (ASHRAE 90.1, Table 9.6.1)

Luminaire Schedule

Table 11: Student Study Area & Corridor Luminaire Schedule.

Mark	Manuf.	Catalog Number	Description	Lamp	Ballast	Input Watts	Voltage
COR-D	Lightolier	CFS1GHP132277SO	High Performance Recessed Fluorescent Direct/Indirect 1' x 4' with Perforated Basket.	Philips: F32T8 ADV835 Alto II	Philips - Centium: ICN-2P32-SC	34.00	277V
STD-D	Lightolier	VPS1G12PR132277SO	1'x4' Recessed Fluorescent, 3" Deep, 12 Cell Parabolic Louvered Lens designed for intensive VDT use.	Philips: F32T8 ADV835 Alto II	Advance Mark 7: IZT-332-SC	34-6.7W 34.16VA	277V

Note: Comprehensive Luminaire Schedule can be found in Appendix F: Comprehensive Luminaire Schedule.

Table 12: Conference Room Light Loss Factors.

Fixture Type	LDD	LLD	RSDD	BF	Total LLF
COR-D	0.940	0.968	0.970	1.00	0.882
STD-D	0.940	0.968	0.970	1.05	0.927

*LDD calculated from new IESNA guidelines for Clean Environment based on 12 month cleaning interval.

Lighting Layout

The Student Study Ares of the Millennium Science Complex have been furnished with 20 computer stations that are setup perpendicular to the facade. The computer stations have been divided into 5 stalls, as shown in the plan detail in Figure 23. The lighting layout of the Student Study Areas use (3)-4' parabolic luminaires per computer stall. The luminaires that have been selected are designed specifically for computer spaces.

The corridor lighting design has been laid out with luminaires spaced 11' center to center while running parallel to the length of the corridor. Every third corridor luminaire has been connected to the emergency lighting system to comply with minimum pathway lighting levels exit pathways in the event of an outage. The corridor luminaires are laid out perpendicular to the Student Study Areas which provides a visual distinction between the two spaces.

Renderings & Color Images

Figure 25: Student Study Area - Perspective View.

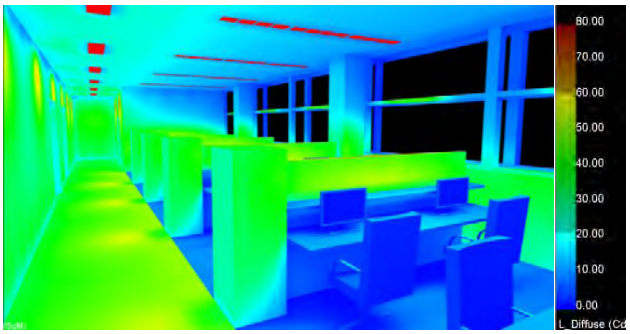


Figure 26: Student Study Area –Illuminance Pseudo Color.

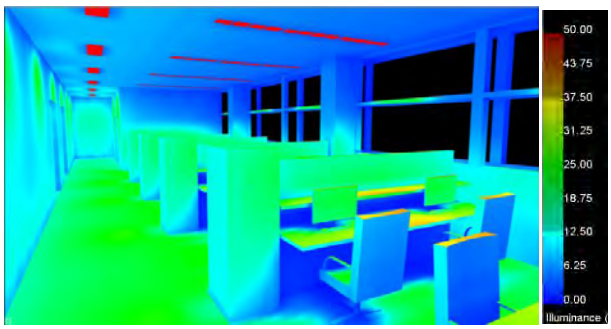
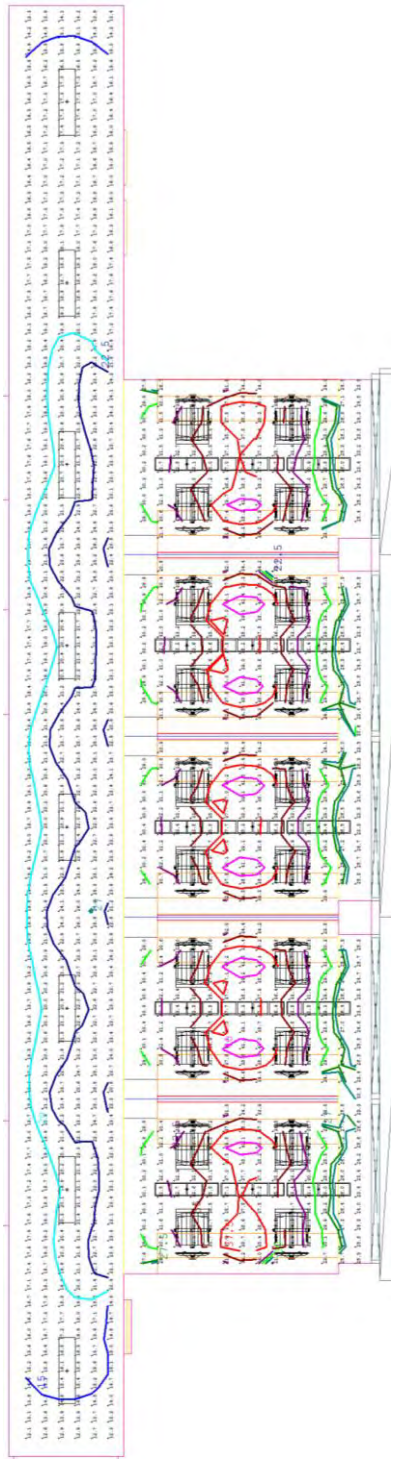


Figure 27: Student Study Area –Luminance Pseudo Color.

Performance Summary



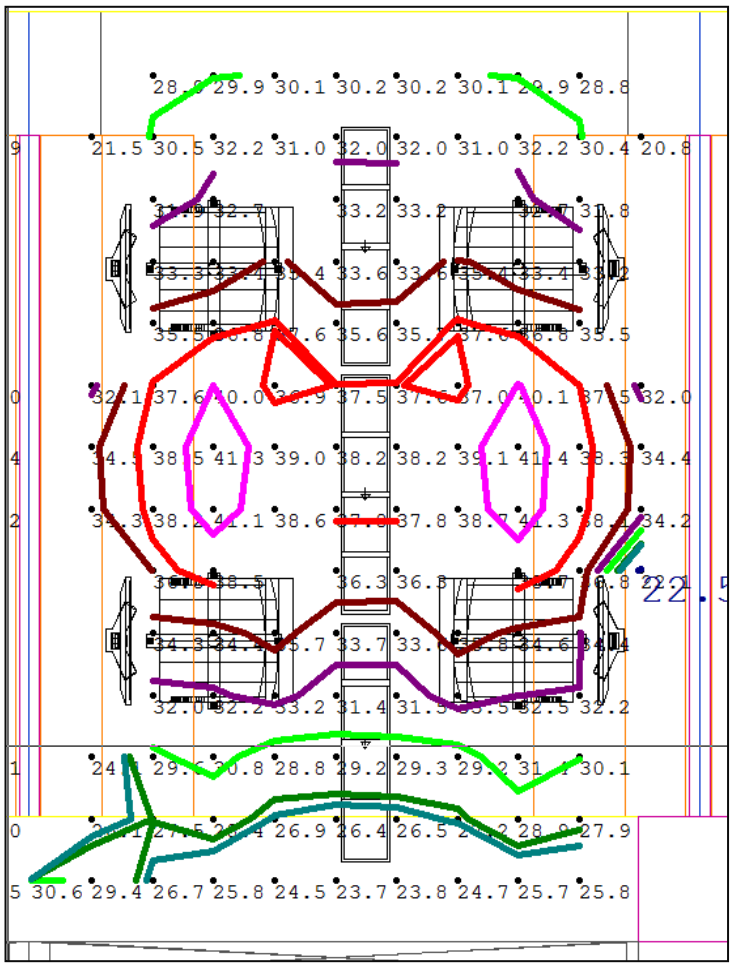


Figure 28: Student Study Area Illumination Contours - Cubical Detail,

15fc-20fc-22.5fc -25fc - 27.5fc - 30fc -32.5fc -37.5fc - 40fc

Figure 29: Student Study Area and Corridor Illumination Contours.

Table 13: Corridor & Student Study Area Lighting Performance.

Student Study Area & Corridor Performance Data	Corridor (Stand Alone)	Corridor (By Student Area)	Study Area
Avg. Illuminance (FC)	18.10	19.89	32.27
Max. Illuminance (FC)	20.30	27.20	40.90
Minimum Illuminance (FC)	14.00	12.10	22.20
Avg/Min	1.29	1.64	1.45
Max/Min	1.45	2.25	1.84
Max/Avg	1.12	1.37	1.27
Coefficient of Variation	0.07	0.16	0.14
Uniform Gradient	1.12	1.38	1.57
Power Density (W/SF)	0.45	0.45	0.68

Electrical Lighting Controls

The corridor is a life safety transportation path, and luminaires will remain on at all times. The doors of the lab spaces actually open up into the corridor due to the nature of the lab work being completed in the lab spaces. This feature of the lab space shows the need of a speedy exit in the event of a mishap in the midst of experiments. With this in mind, it has been determined that the best option would be to have the corridor luminaires remain on at all times for safety reasons.

The student study area is unique to this project, as it is the only design space that will incorporate photosensors for dimming with regards to daylight contributions. The LRF2-DCRB-WH photosensor will dim all Student Study Area luminaires.

Occupancy sensor locations, orientation and coverage have been shown below in Figure 30. Both LOS-CUS-500 and LOS-CUS-1000 will be used. The 1000SF coverage occupancy sensor lies on both ends of the Student Study Area, covering the first and last two stalls. The 500SF occupancy sensor is positioned in the center of the Student Study Area, covering the middle stall. This layout and orientation provides maximum coverage of motion in the Student Study Area while minimizing unwanted switching of luminaires when an occupant passes by in the nearby hallway. Switching and wiring diagrams showing both photosensors and occupancy sensors are available in Appendix I: Lighting Control Cutsheets.

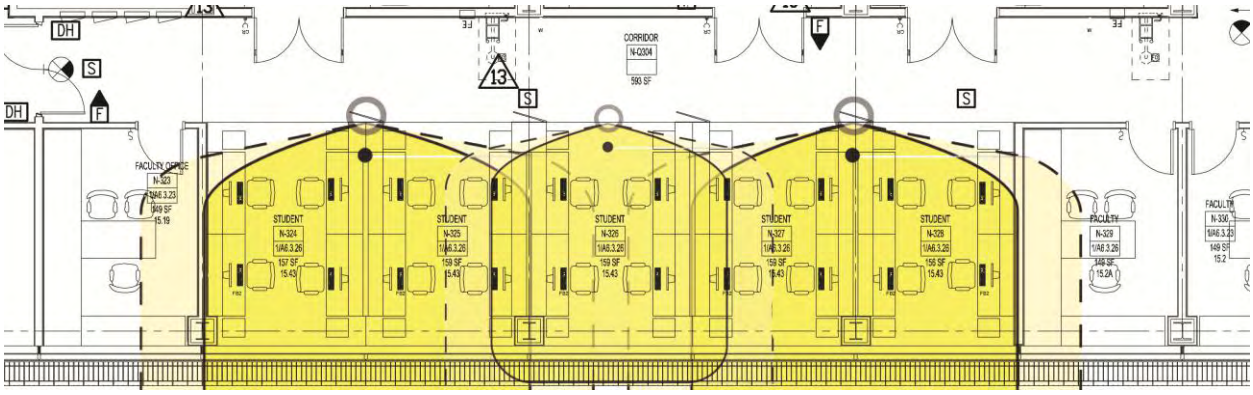


Figure 30: Student Study Area Occupancy Layout & Coverage Area.

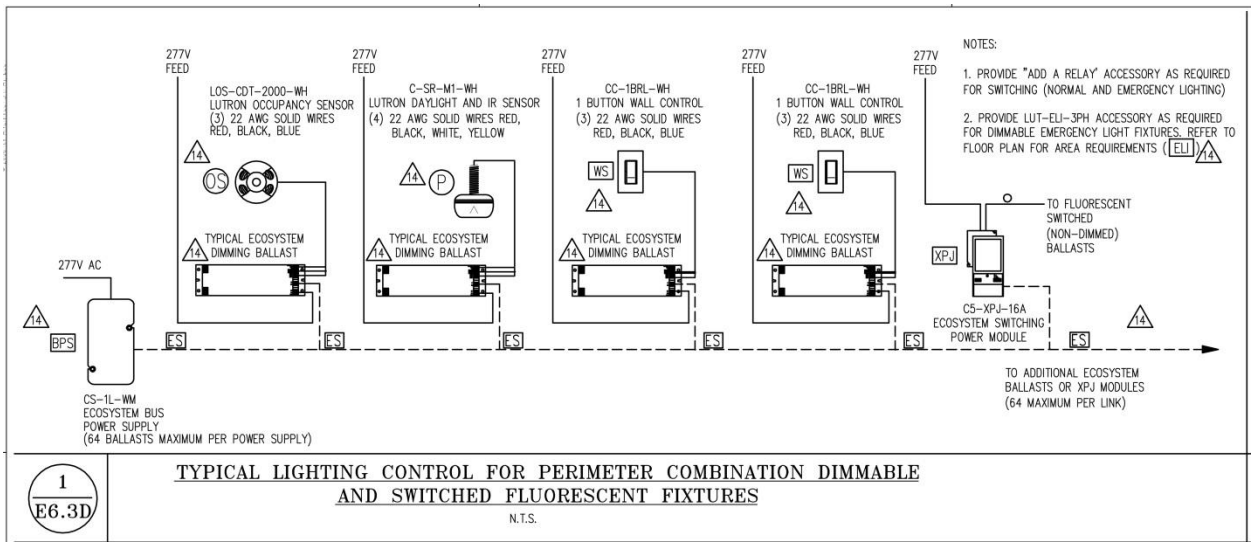


Figure 31: Existing Dimming Wiring Diagram.

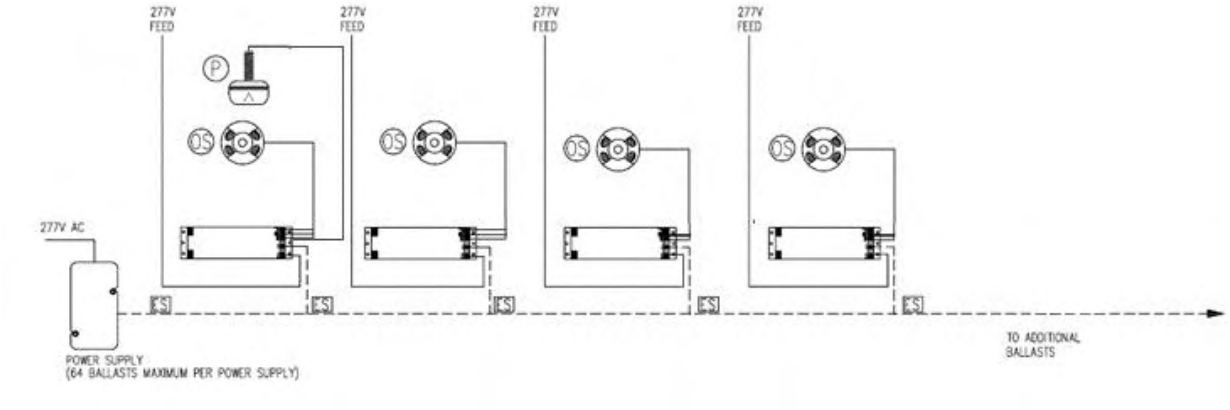


Figure 32: Redesign of Dimming System.

Cost Analysis

In the process of designing the double-skin façade to be used for the Millennium Science complex, simplicity was the primary focus with hopes to minimize costs. After a full detailed estimate, the Building Stimulus estimates that the use of a double-skin façade will increase construction costs by only $71,686. The full estimate of existing facades and the full estimate of the façade redesign can be found in Appendix D: Construction Management. A summary of façade costs are shown below, Table 14: Summary of Facade Costs.

Table 14: Summary of Facade Costs.

	Precast Panels	Insulation	Caulking	Metal Panels	Metal Framing	Louvers	Windows	Total
Existing Façade	$ 6,007,802	$ 741,949	$ 168,917	$ 4,276,244	$ 1,076,772	$ 366,600	$ 2,719,570	$ 15,357,853
Double-Skin Façade	$ 5,629,241	$ 842,792	$ 204,082	$ 4,276,244	$ 1,076,772	$ 123,200	$ 3,277,210	$ 15,429,539
							Cost	$ (71,686.34)

The Building Stimulus precast panel resulted in an estimate cost savings of $5.00 SF by reducing the quantity of concrete by approximately 30%, or 2 C.Y. for every 22' x 11' panel. By definition, the double-skin façade will require two 'skins' of glazing. The majority of costs incurred due to the double-skin façade resulted from installing a second glazing system. However, Building Stimulus was able to save a significant amount of costs by removing the existing static louver system across the entire Millennium Science Complex.

Conclusion

IPD

Throughout the design process to create an efficient façade system between four different design disciplines, issues were inevitable due to the differing goals of each member of Building Stimulus. Primary focuses generally revolved around cost savings and system efficiency. At first Building Stimulus had set individual goals for their respective aspects of the building enclosure. Once the individual goals were established, as a team Building Stimulus met and discussed a method that allowed for the best design approach to satisfy the majority of criteria set by designers. The implementation of a double skin façade was agreed upon by all team members as the most complete building enclosure for meeting design criteria of the Building Stimulus team.

Several originally unforeseen issues arose throughout the course of the design process. One of the more pressing issues was accurately modeling the airflow within the double-skin façade, as it is a dynamic system that is constantly dependent upon temperature, wind speed, and solar heat gain. To further complicate modeling of the airflow for the dynamic system between the interior and exterior glazing, the frosted glass louvers incorporated also significantly affect the airflow. In a non-vertical position, as shown in the figure below for the images with blue and yellow arrows, the louvers greatly constrict the area between the louver edge and glazing for air to flow through, thus increasing the velocity at these instances. At the same time, this reduction in area allows an accumulation of air to build up just before the openings since the louvers create compress and release areas throughout the façade for the air flow. The airflow is not altered as much in the angled position. Therefore, the greatest concern with airflow restriction arises when the shades are in a horizontal position, as they cover 19 in of the 24 in air gap between glazings.

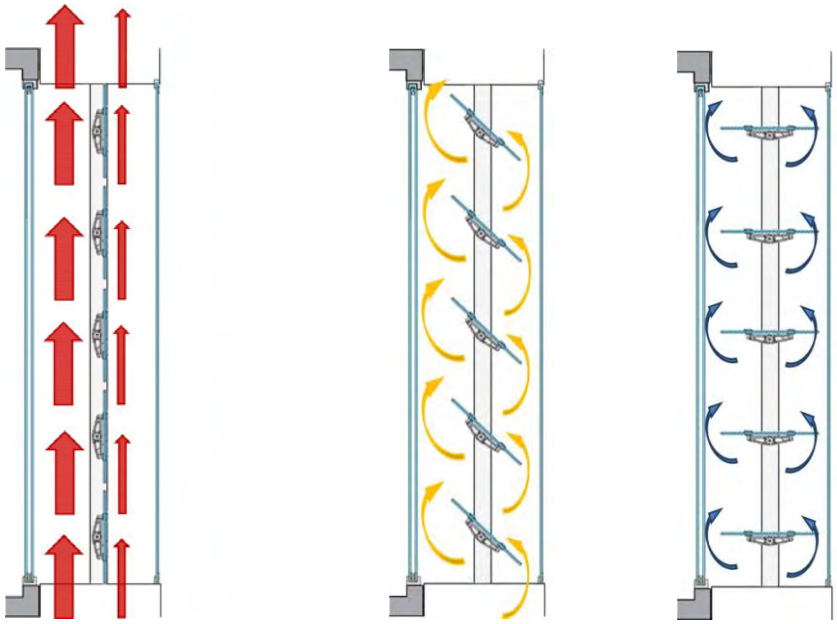


Figure 33: Windflow Around Solar Shades.

The Girasol automatic adjustment system for the louvers uses pressurized gases to rotate shades. The system uses two gas containers to push and/or pull actuators. One container is exposed to direct sunlight, while the other is shielded from the suns direct rays. The louvers will move to a more vertical position when exposed to direct solar radiation to help minimize both heat gain, and high illuminance levels in perimeter spaces. In this situation, the air in the double skin façade will be at its warmest and fastest velocity. The position of the louvers will allow for the hot air to rise in a virtually unobstructed path.

In contrast, when there is little to no direct solar gain, the louvers will move to a more horizontal position to allow more daylight illuminance into the space to maximize benefits from dimming electrical lighting. With little solar gain on the façade in this situation, the temperatures are not as high as when in direct sunlight. A lower temperature differential between the air gap and the exterior environment, allows air to move slower, and in turn creates less of a hindrance than what was originally thought.

The design of the precast panel proved to be highly dictated by providing adequate clearance between the inner faces of the interior and exterior enclosures to ensure that a continuous air gap would be achieved for thermal efficiency and the louvers used to optimize daylighting efficiency would have enough space to operate.

In terms of constructability, the double skin façade design presents several issues that must be acknowledged. The estimated cost to build the double skin façade does not place a significant financial burden on the owner, yet the constructability issues of the system demands significant monitoring of the construction process to avoid serious safety and scheduling issues. On double skin façade elevations, it is imperative to properly install a vapor barrier within the double skin plenum. As welding occurs to secure the panel to the structure, precautions must be taken to ensure vapor or thermal barriers are not damaged. Extra safety precautions must be taken as well during the installation of precast panels. With steel workers potentially working in the spaces between large precast panels and steel members, the panels must be safely secured before anyone enters those spaces.

Daylighting Analysis

Daylighting analysis program, DAYSIM (Penn State Release), has been utilized to determine the effectiveness of using both shading devices and photosensors to dim luminaires in terms of annual energy savings.

Table 15: Cost Savings from Dimming Luminaires.

	SEMS	NWMS	SWLS	NELS	Total
Annual Savings (kWh)	788.86	776.12	703.38	861.05	3718.4
Annual Savings ($)	$63.11	$62.09	$56.27	$68.88	$297.50
Modeled Facade Length	55’	55’	55’	55’	N/A
Dimmable Rooms Facade Length (3rd Floor)	66’	66’	99’	99’	330’
Dimmable Rooms Facade Length (2nd Floor)	121’	121’	209’	209’	660’
Dimmable Rooms Facade Length (1st Floor)	0’	0’	0’	176’	176’
Annual Savings	$277.68	$273.19	$371.38	$675.06	N/A
Grand Total Building Annual Savings	$1597.36/yr				

Though the overall cost savings from dimming electrical lighting can be considered low in comparison to the cost of the system, there are other benefits to integrating daylighting.

Occupant comfort is virtually unquantifiable in terms of money. Occupants of the perimeter spaces will see an increase in productivity and overall satisfaction of their workspaces with daylight integration. Daylight provides excellent color rendering, and provides an impression of brightness to the space. These two factors are essential for increase the appearance of a space, the overall visual environment.

Shading blades made of frosted glass allowed daylight to enter the space by diffusing it and spreading it out throughout the space. Frosted glass blades helped limit direct sunlight penetration while maintaining a view to the exterior. This exterior view is very important to achieve user comfort and overall satisfaction.

The solar shading devices used in this design lower the solar heat gain for the perimeter spaces on the Southeast Materials Science and Southwest Life Science facades.

Energy Modeling

The Millennium Science Complex is an intensive research lab with extensive electrical plug loads and research equipment throughout. Therefore, the use of ASHRAE suggested electrical design load watts/SF according to the type of room in question would be an underestimation for mechanical equipment sizing. The use of Revit MEP when designing an electrical system can allow the designer to provide each room with an actual connected load and power density for the mechanical design.

The use of an in depth program such as Revit MEP allows for quick integration between disciplines. Specifically, Mechanical and Electrical designers can exchange accurate design loads almost instantaneously. The process of setting up a Revit MEP Model can be intensive up front, yet allow for easy changes to systems and designs closer to the end of the design timeline. This was achieved during Building Stimulus' design process.

Building Stimulus took the opportunity to explore the use of Revit MEP as both an electrical design tool and a BIM/IPD design tool. Throughout the design process, electrical design loads were constantly modeled and updated in Revit MEP. Simultaneously, the redesign of the mechanical system was analyzed, using the existing building energy model created from the fall semester as a base. Once the electrical loads were completed, they were used to update the mechanical system's redesign to provide a more accurate energy profile of the building. This portion of the report illustrates the iterative process Revit MEP provides in the design process to further facilitate integration among the design team.

Mechanical Design

The current air distribution system used in the Millennium Science Complex is handled by variable air volume boxes for all the spaces. Air is supplied to the spaces through ceiling mounted low velocity radial diffusers to maintain the room temperature set-points using a traditional overhead ducted system. The current design of the air handling system is very efficient in that it utilizes several energy recovery techniques. All of the lab and vivarium spaces are supplied by 100% outdoor air AHUs which include an enthalpy heat recovery wheel and integral exhaust fan to operate concurrently with the supply for each unit. The fume hood and vivarium exhaust fans are also equipped with run around energy recovery coils that circulate glycol with two pumps to the preheat coils in the air handling units. For the remaining non-lab spaces within Millennium Science, the AHUs utilize outdoor air economizers to save energy for the three 33,000 cfm AHUs.

After analyzing the spaces throughout the third floor of Millennium Science, the corridors and offices presented themselves as optimal candidates for placement of active chilled beams. These spaces are considered to be load heavy, so the air supply is not driven by the ventilation requirements as in the lab spaces. Active chilled beams are commonly recommended for spaces that have high solar heat gain loads compared to the total thermal load, which is the case for the perimeter office spaces since they are directly exposed to the solar heat gain from the façade. As proposed, the chilled beams were used to take care of the cooling load instead of traditional excess air change via the current VAV boxes in these spaces. Utilizing this technology helped save air handling unit sizes and ventilation loads due to the reduction in airflow required to handle the space loads. This in turn allowed optimization of the HVAC system to maintain energy efficiency and indoor air quality. To achieve this optimization, an active chilled beam system coupled with a dedicated outdoor air system was modeled to replace the current variable air volume system for the perimeter office spaces and corridors. This system was designed to work in concurrence with the lighting design to utilize the application of luminaire integrated chilled beams.

Chilled Beam Analysis

Chilled Beam

In order to maximize integration among the design team, multiservice active chilled beams were selected for utilization in the redesign. Multiservice chilled beams incorporate not only the airflow and temperature control to provide proper thermal comfort and indoor air quality, as per ASHRAE 62.1, but also lighting and fire protection with integrated sprinklers. Several manufacturers were reviewed by Building Stimulus to select a system that best fit Millennium Science Complex's needs. Although chilled beams are not prevalently used throughout the United States, as they are more common in Europe, several companies do manufacture these relatively new systems in the US. Selecting a manufacturer that was located within the US was an important consideration for Building Stimulus due to its impact for cost and transportation requirements. One of the first manufacturers researched by Building Stimulus was Dadanco, since it is an American based company and has a manufacturing facility in Pennsylvania. It was considered as a possible candidate due to its very close manufacturing location to the building site and also for its BIM coordination, since Revit models are provided from the manufacturer's website. However, Dadanco does not offer the multiservice beams that provide the integration Building Stimulus was looking for to greater develop coordination among the team's disciplines.

Ultimately, the manufacturers that offered the best opportunities for the design team and Millennium Science in terms of integration were Carrier, Krueger by Halton, and Semco. Not only did these manufacturers provide multiservice active chilled beams, but also Revit models of their products to help facilitate the BIM process through design. Each product enables the coordination between the thermal comfort requirements, lighting, and fire protection services. Both Carrier and Semco are American based companies, with distribution centers located throughout the US, with centers as close as Virginia to the building site. Krueger is the American division of Halton (a company based out of Finland) that is headquartered out of Texas with the closest distribution center to MSC's site located in North Carolina. See Appendix C: Energy Analysis for cut sheets and full specifications of the multiservice chilled beams, including the component diagrams, construction sequence and serviceability.

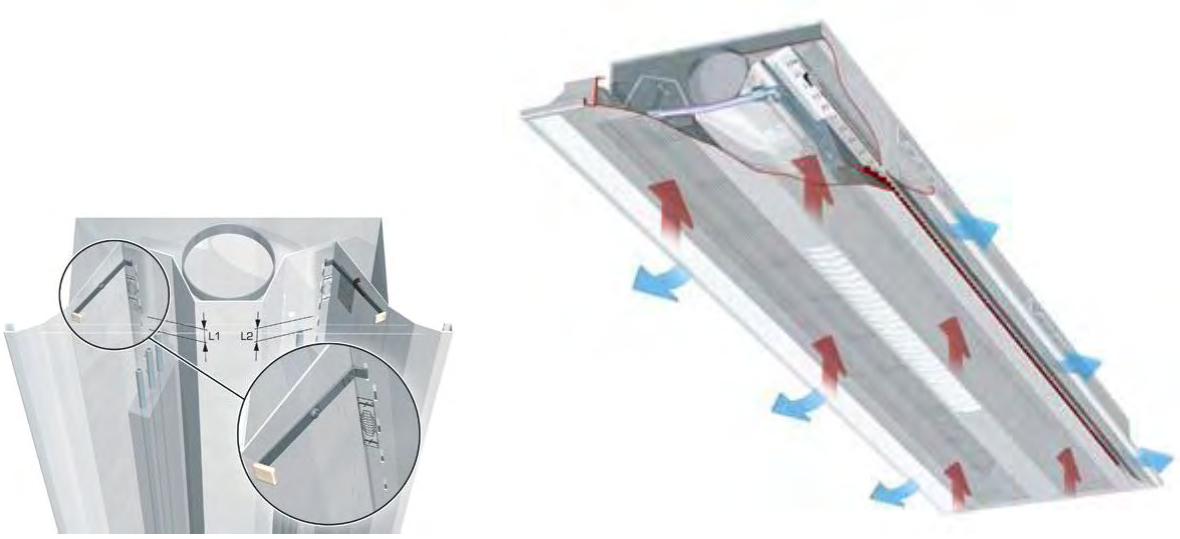


Figure 34: Semco Chilled Beam with Flow Control.

Semco's active chilled beams provide several advantages. The design of the chilled beam allows it to be equipped with Semco's patented Flow Pattern Control, to allow the beam air flow to be adjusted, just like a ceiling diffuser, which allows it to have a low water pressure drop and better compensate for heat gain through windows. This flow pattern adjustment makes equipment scheduling and installation easier because individual chilled beams do not have to be specified for each space. They can be adjusted upon installation. Semco's chilled beams also have an optional feature, "Comfort Control," that allows the amount of induction air and cooling capacity to be adjusted.

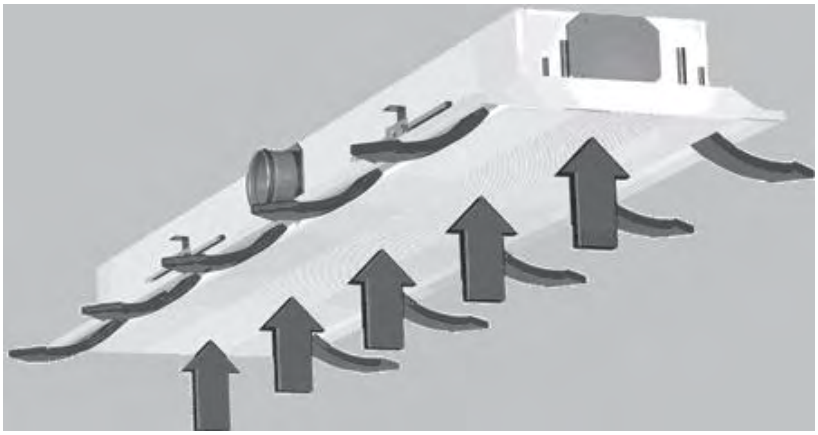


Figure 35: Krueger Chilled Beam.

Figure 36: Krueger Chilled Beam Office Application.

Chilled beams provided by Krueger also have an advantage to control air flow with their optional Halton Air Quality (HAQ) control attachment; however, it does not come standard in the beam design. For the design analysis, the Semco chilled beams, model IQID, were used as the basis for Millennium Science due to the company's availability for communication and information sharing as well as the Krueger chilled beams due to their direct lighting output profile.

Primary Energy Use

As a way to improve the overall efficiency performance of the Millennium Science Complex with respect to energy, a four-pipe, active chilled beam system was utilized in the perimeter spaces and corridors of the building to handle the heating and cooling loads. This system required several elements to be considered during the selection process to adequately enhance the efficiency performance. Energy use, total emissions, and overall lifecycle costs associated with the system were analyzed to adequately determine the viability of this alternative. The initial energy model developed was based on the fall semester's Trane TRACE model to complete the energy and emissions analysis.

The energy model allowed a comparison to be made between the previously noted existing variable air volume system and the active chilled beam system for the perimeter spaces and corridors, for the third floor of Millennium Science. According to the results of the analysis, the active chilled beam system is expected to achieve greater performance for energy consumption, total emissions, and operating costs. Accounting for dehumidification became an issue during the design of the system since chilled beams are only able to remove the sensible load. Therefore, the central air handling system was designed to still take care of the latent load, which was done by coupling the chilled beam system designed for the perimeter office spaces and corridors with a DOAS system. The DOAS system was modeled with a total enthalpy wheel, with a prescribed effectiveness of 0.64. By decoupling the ventilation and space conditioning requirements, the DOAS AHU was able to accommodate 100% of the space latent loads and outdoor air latent loads. Figure 37 is a schematic of the energy recovery techniques used to develop the system. It was modeled with both a total energy wheel and sensible only wheel to provide optimal performance.

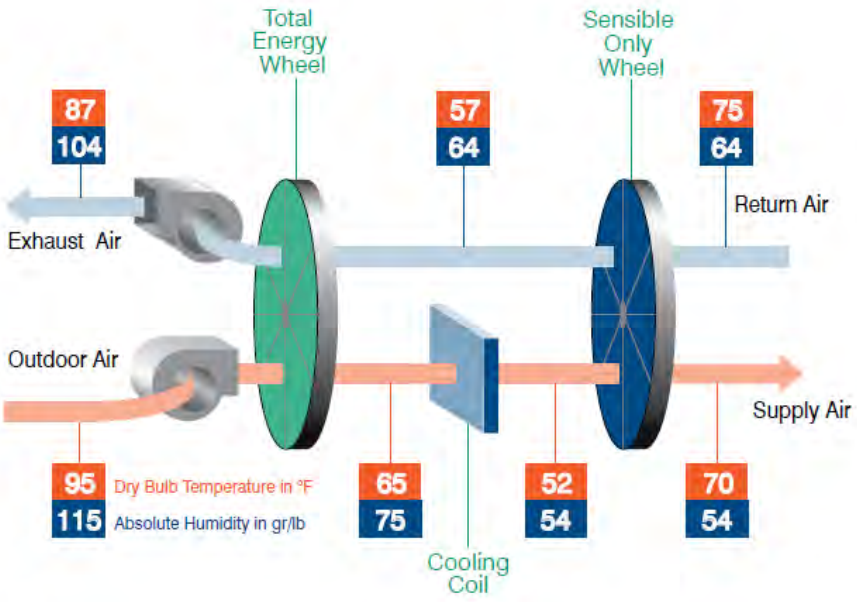


Figure 37: Dual Total Energy Wheel with Free Reheat, courtesy of Semco.

The active chilled beam system configuration, as shown in Figure 38, does provide some energy savings for the site and source energy consumption as compared to the existing VAV system by reducing the site energy use from 7,618 MBtu/yr to 7,441 MBtu/yr. This is viewed as a 2.3% savings in energy for the third floor alone.

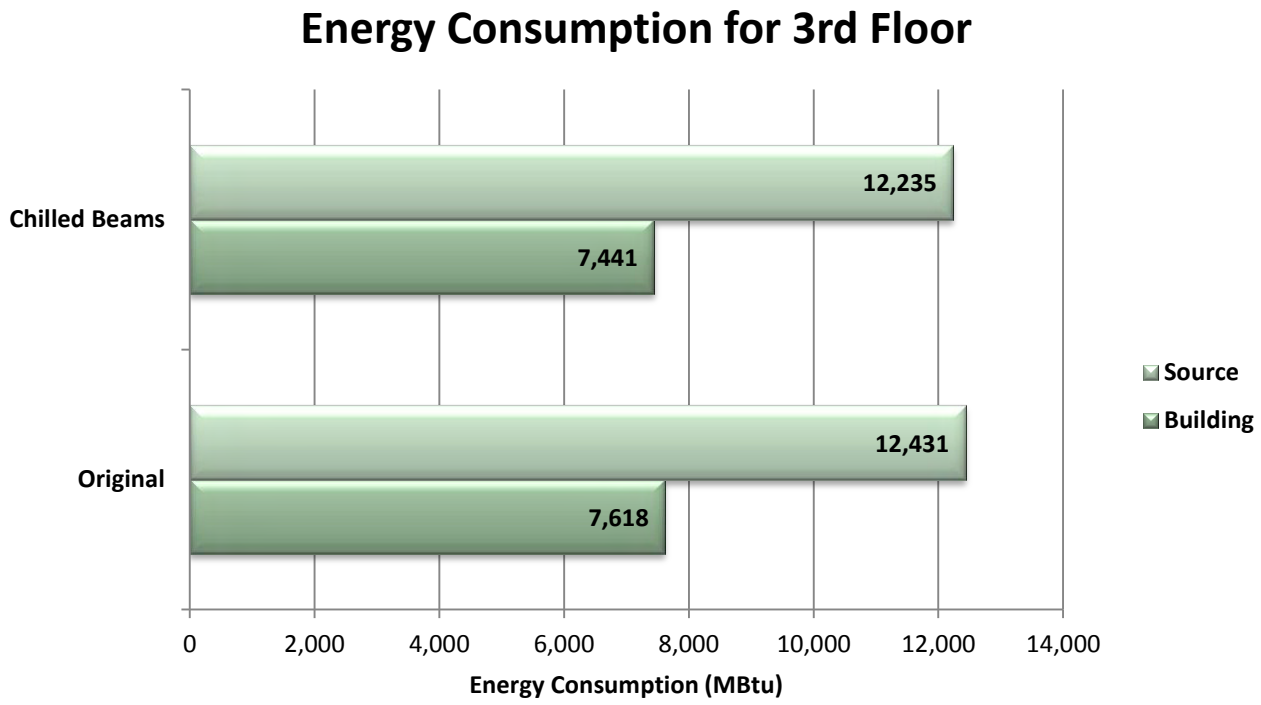


Figure 38: Third Floor Energy Consumption.

These energy savings can be accounted for due to the reduced airflow needed for the spaces. Utilizing the active chilled beam system allowed the airflow to be reduced from 29,390 cfm to 6,506 cfm for the third floor, allowing the air handling unit to be reduced for the less airflow.

Source Energy Associated Emissions Analysis

In continual accordance with Building Stimulus' design goal of improved efficiency, reduction of source energy associated emissions was also pursued in the redesign. The emissions analysis was based on equivalent pounds of carbon dioxide, nitrous oxide, and sulfurous oxide pollutants. As previously mentioned, the model simulated was based on the third floor of the Millennium Science Complex using the base model. Figure 39 and Figure 40 show a decrease of 63,022 lb_m of equivalent carbon dioxide emissions and a 487 gm/year decrease in nitrous oxide for the third floor alone.

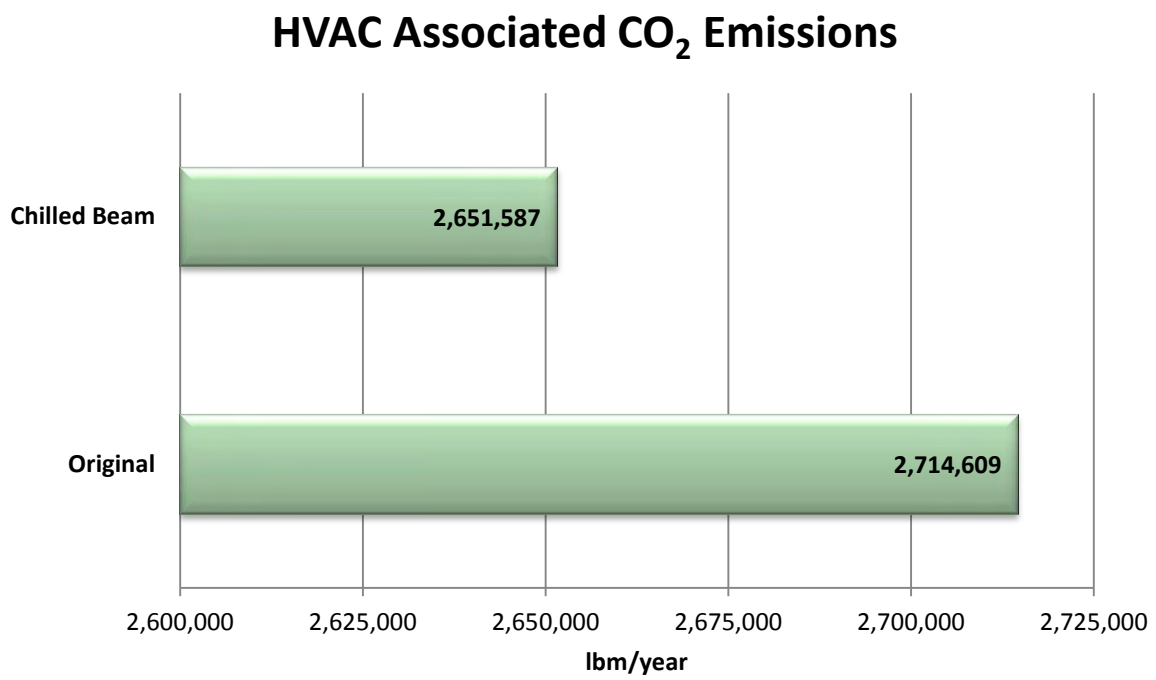


Figure 39: HVAC Associated CO_2 Emissions for the Third Floor.

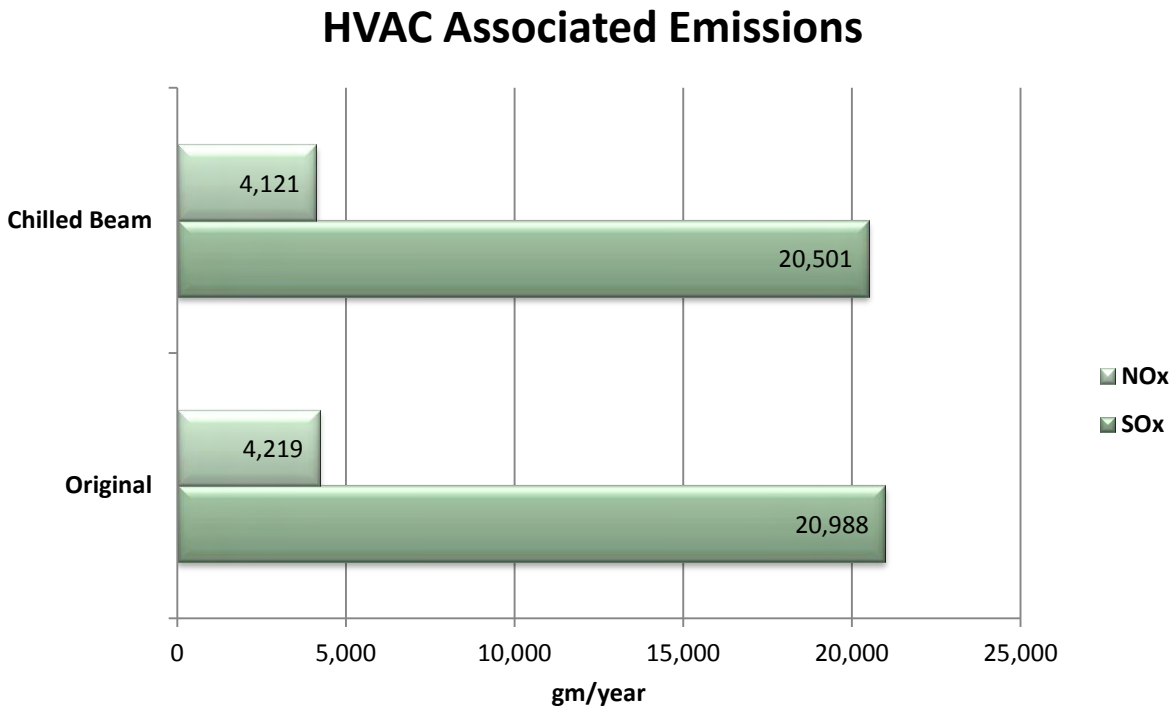


Figure 40: HVAC Associated NOx and SOx Emissions for the Third Floor.

Indoor Air Quality Analysis

Using knowledge attained from the Master's course, AE 552: Indoor Air Quality, the air conditions of the spaces replaced with active chilled beams were analyzed on a qualitative basis. The nozzles in the active chilled beam use high pressure to provide very high velocities at the inlets to create turbulence. This turbulence flow allows the air that is re-circulated around the cooling coil to become better mixed throughout the space, which results in less stratification of the air to provide better thermal comfort for the occupants. It greatly reduces the risk of drafts and large cold air deposits due to the induction of the air flow as well, allowing it to adhere to ASHRAE Std. 55.

Due to the use of a DOAS system to handle the latent loads for the spaces, the only air now supplied to the perimeter rooms is outdoor air. This eliminated the possibility of decreasing the quantity of outdoor air supplied, as per ASHRAE Standard 62.1 minimum outdoor air requirements, to the space when the load increases, as there is a possibility for this to happen with the original VAV system. For the original VAV system, dampers are required to adjust according to space load fluctuations to properly condition the space. However, if the dampers are not correctly set, inadequate ventilation air supply may be provided to the spaces, which lowers the indoor air quality of the space and enhances the possibility to re-circulate possible contaminants, such as CO_2 from the occupants.

Chilled Beam Lifecycle Cost Analysis

Figure 41 illustrates the decreased electricity consumption expected for the use of chilled beams to service the perimeter spaces. The third floor is able to consume 17,598 kWh less per year and this equates to a total building savings of 107,934 kWh per year.

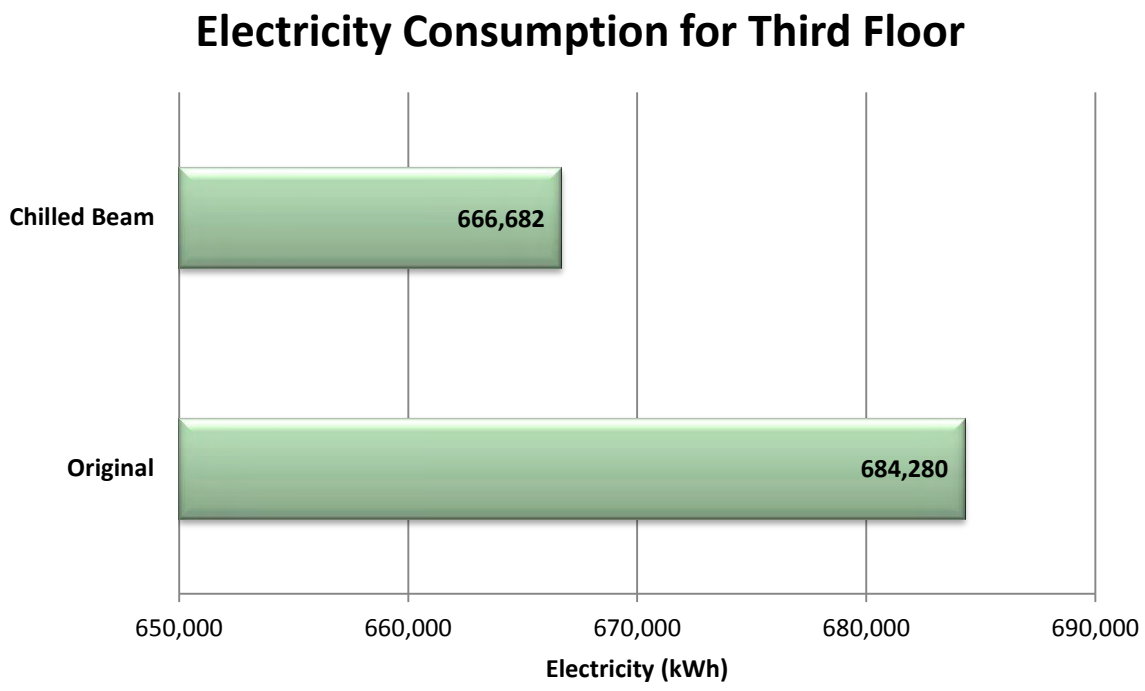


Figure 41: Third Floor Electricity Consumption.

From this savings in electricity consumption, in conjunction with the other utilities, as shown in Figure 42, a total utility cost savings of $15,720 for the third floor. This allows the entire building to decrease utility costs by $96,416 per year.

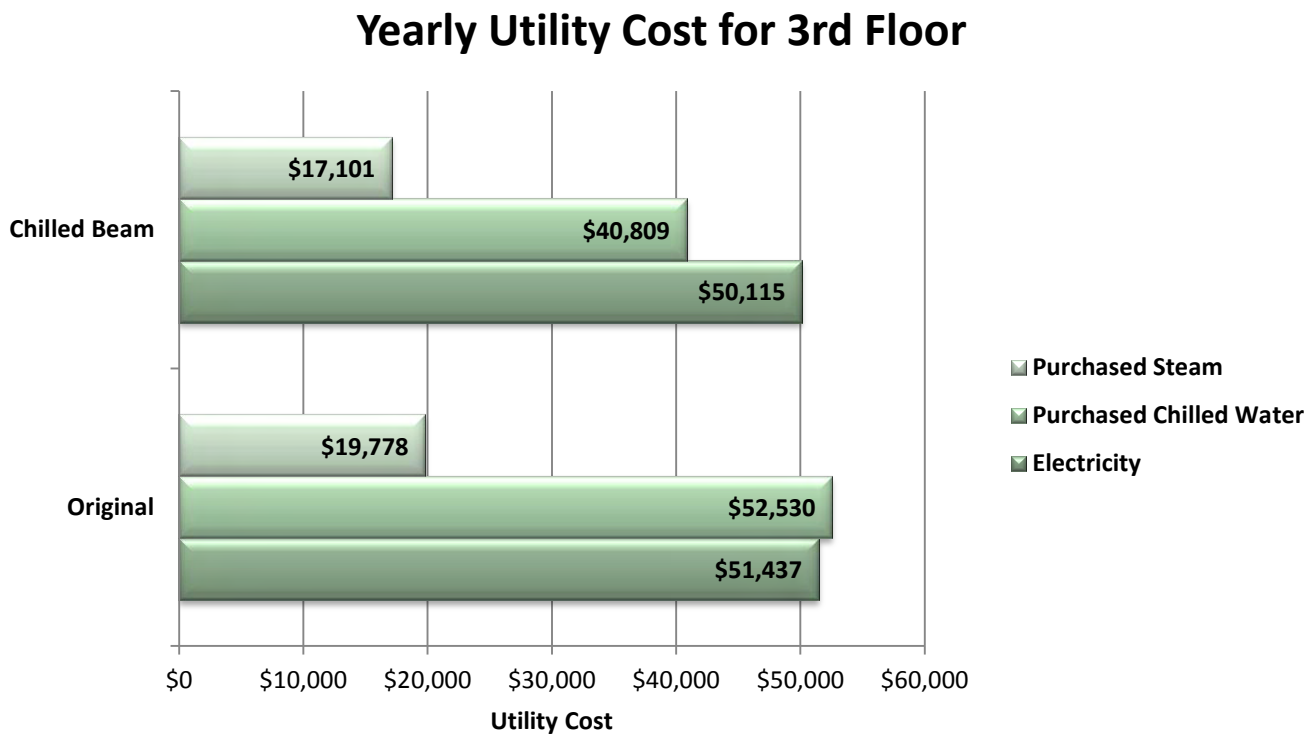


Figure 42: Utility Cost for HVAC Redesign.

Luminaire Integration

The lighting layout in the typical office has been integrated will mechanical chilled beams. There is a single twelve foot integrated chilled beams/luminaire down the center of the room. This luminaire layout in the ceiling has been chosen to match that of the adjacent Student Study Areas. Matching layouts of perimeter spaces allowed the visual uniformity to be maximized as viewed from the exterior.

The chilled beams selected for mechanical design has a setup for either one or two lamp configurations per four foot in length. The Krueger ADC chilled beam offers only lamping for 21W, 28W and 35W T5 Luminaires. Configurations using one using the single-lamp per four foot option were not able to meet the IESNA design criteria of 30fc average on the work-plane of the office. The use of two-lamp per four foot length of chilled beam configurations with 21W T5 lamps creates an average value of 29.28fc on the work-plane. This includes a minimum of around 17fc in the corners of the room, while producing around 40fc in the center of the F-shaped desk.

Detailed electrical lighting design is discussed in detail in the following section.

Office Lighting Design

Spatial Summary

Staff and Faculty Offices line the exterior of the Millennium Science Complex. These spaces are on each floor of the building. There is an F- shaped desk in each office that allows for plenty of desk space. Each office is 10'4" x 14'7", for a total of 150.5SF each.

Drawings & Layout

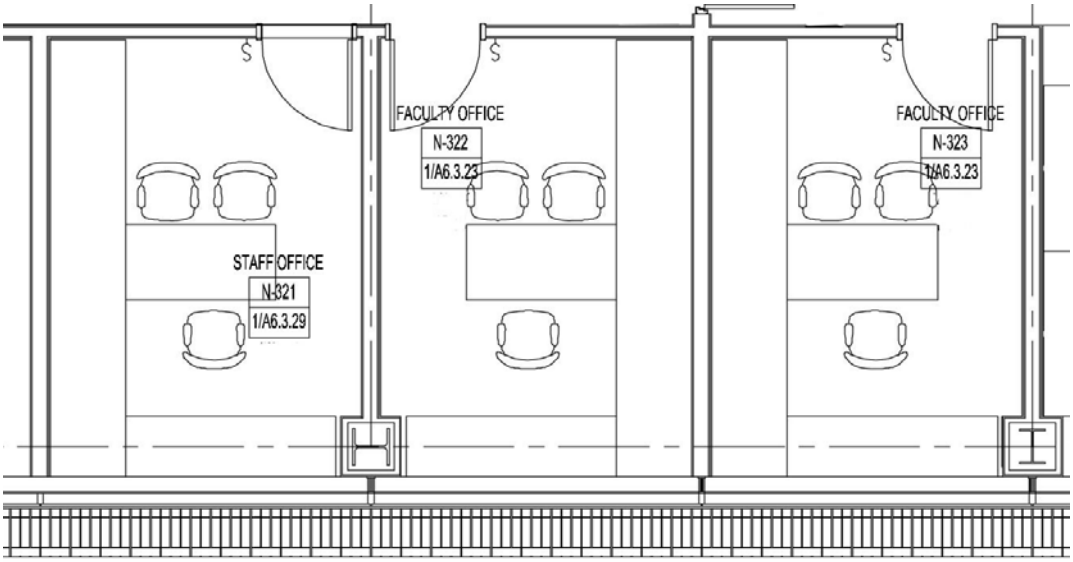


Figure 43: Typical Staff & Faculty Office - Plan View.

Tasks & Activities

General office tasks will take place in these spaces. Tasks such as typing and computing will take place with use of a flat-screen monitor and computer. Furniture layout also indicates that this space will be able to be used for small meeting tasks involving two to three people.

Materials

Table 16: Conference Room Materials

Surface	Reflectance	Transmittance
ACT Ceiling	0.78	
Interior Glazing		*.62*
Exterior Glazing		*.85*
Door**	0.50	
Door Trim**	0.50	
Floor**	0.13	
Wall	0.76	

**Values from AGi32 swatches for similar materials

Design Considerations

- Private Office:
  - Considerations (IESNA Handbook)
    - Appearance of Space & Luminaires
    - Direct Glare Avoidance
    - Modeling of Faces
    - Color Rendering
    - Uniformity
    - Source/Task/Eye Geometry
    - Daylighting Integration
  - Design Criteria
    - Horizontal 30-50fc (IESNA Handbook)
    - Vertical 5fc (IESNA Handbook)
    - Power Density 1.1 W/SF (ASHRAE 90.1, Table 9.6.1)

Luminaire Schedule

Table 17: Typical Office Luminaire Schedule.

Mark	Manuf.	Catalog Number	Description	Lamp	Ballast	Input Watts	Voltage
OFF-D12	Kruegar	Custom	4'x12' integrated chilled beam luminaire.	(6) Philips: F21T5 835 Alto 40 PK	Philips: ICN-2S28-N	147.0	277V
OFF-D8	Kruegar	Custom	4'x8' integrated chilled beam luminaire.	(4) Philips: F21T5 835 Alto 40 PK	Philips: ICN-2S28-N	98.0	277V
OFF-D4	Kruegar	Custom	4'x4' integrated chilled beam luminaire.	(2) Philips: F21T5 835 Alto 40 PK	Philips: ICN-2S28-N	49.0	277V

Table 18: Typical Office Light Loss Factors.

Fixture Type	LDD	LLD	RSDD	BF	Total LLF
OFF-D12	0.900	0.968	0.970	1.02	0.862
OFF-D12	0.900	0.968	0.970	1.02	0.862
OFF-D12	0.900	0.968	0.970	1.02	0.862

*LDD calculated from new IESNA guidelines for Clean Environment based on 12 month cleaning interval.

Renderings &Color Images

Figure 44: Typical Office - Perspective Side View (All Luminaires On).

Figure 45: Typical Office - Perspective Side View (Half Luminaires On).

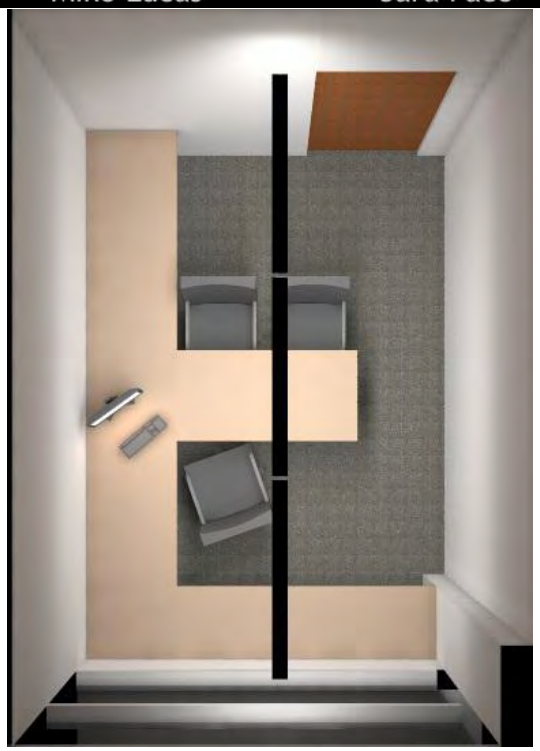


Figure 46: Typical Office - Perspective Top View (All Luminaires On).

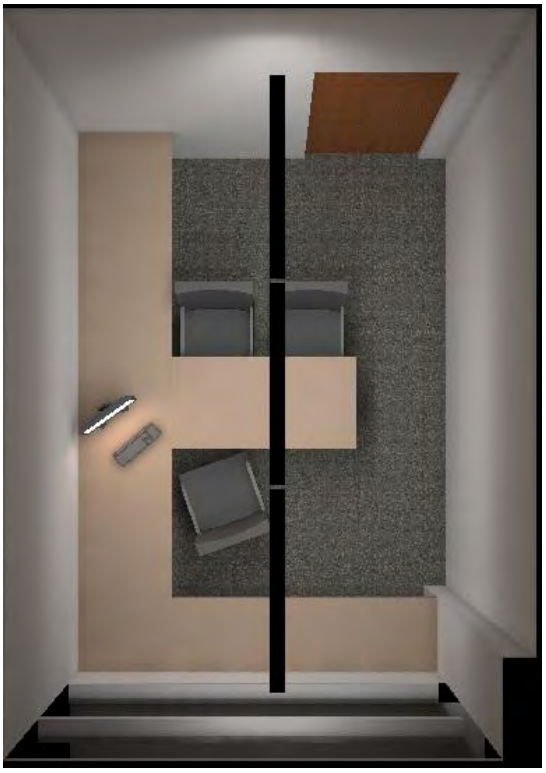


Figure 47: Typical Office - Perspective Top View (Half Luminaires On).

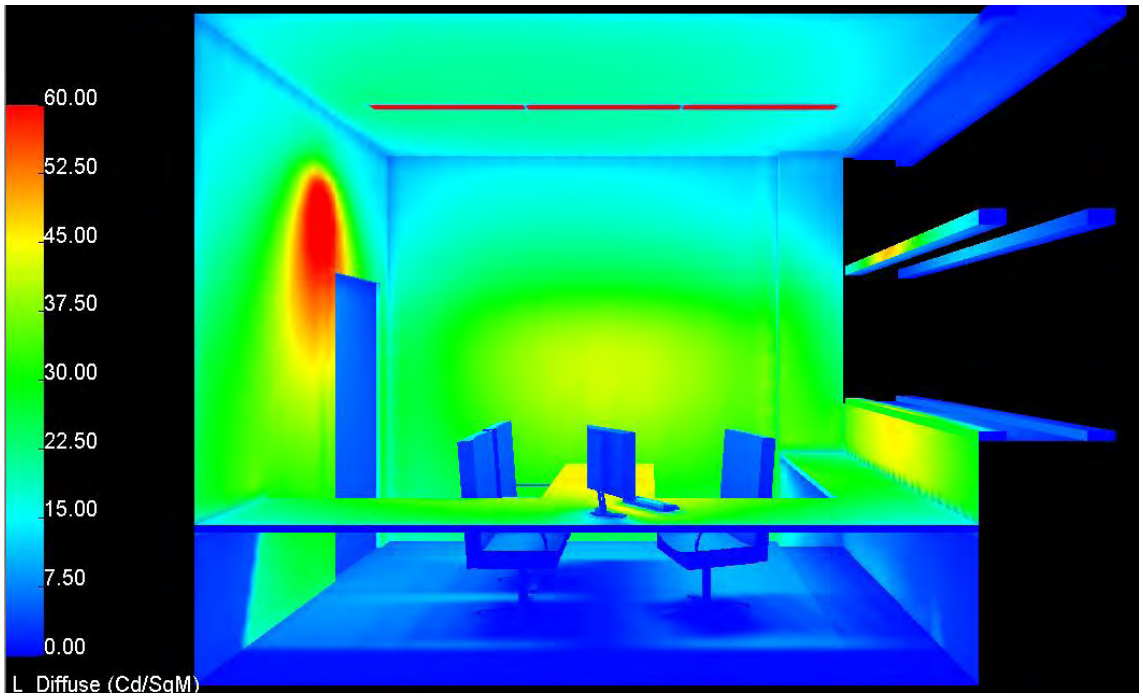


Figure 48: Typical Office - Luminance Color (All Luminaires On).

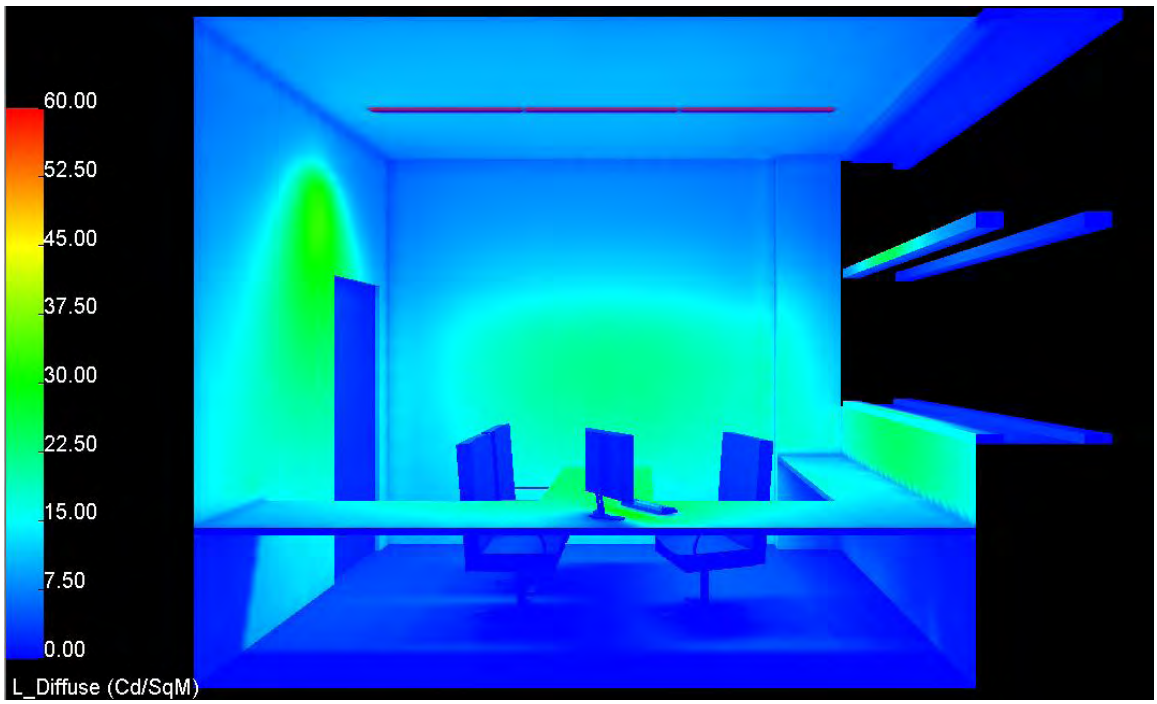


Figure 49: Typical Office - Luminance Color (Half Luminaires On).

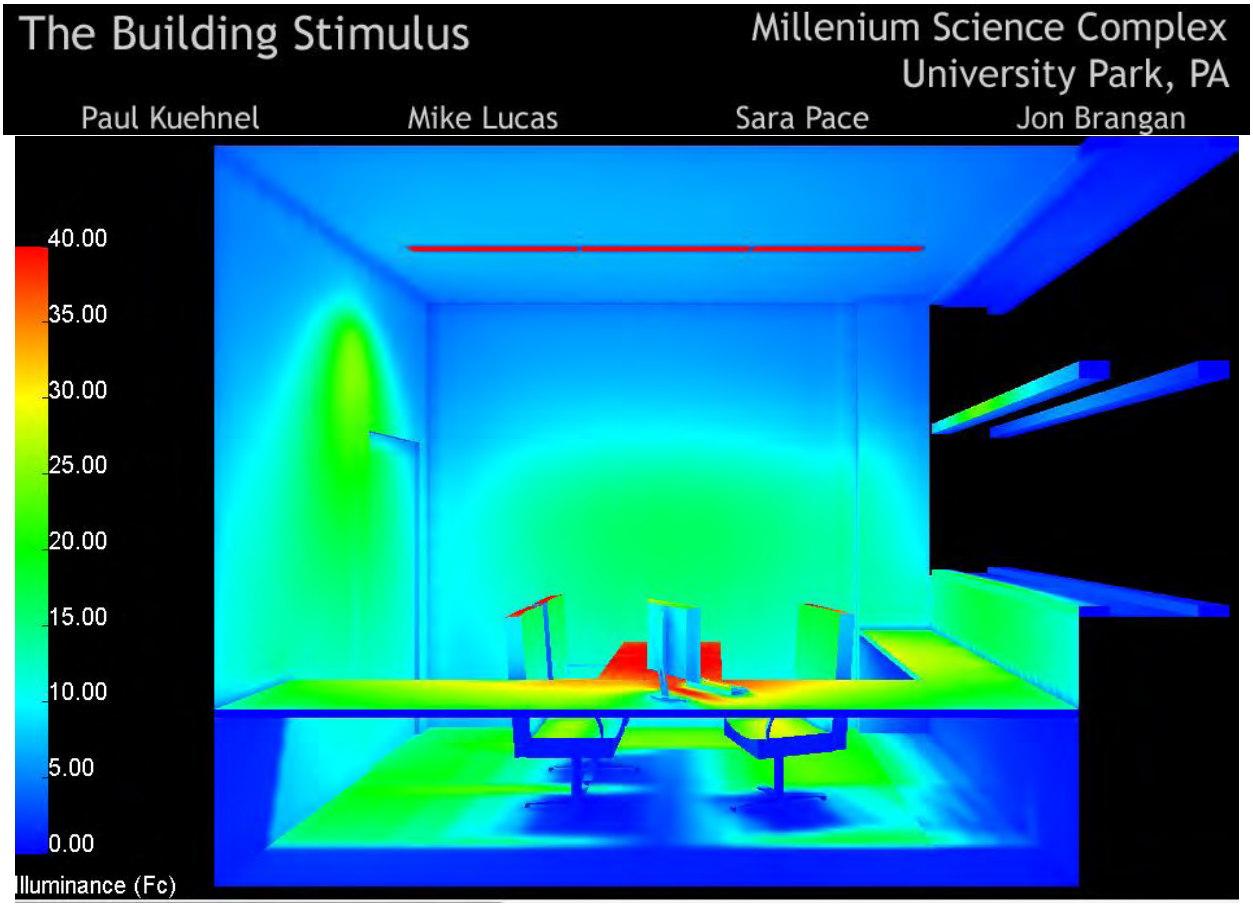


Figure 50: Typical Office - Illuminance Color (All Luminaires On).

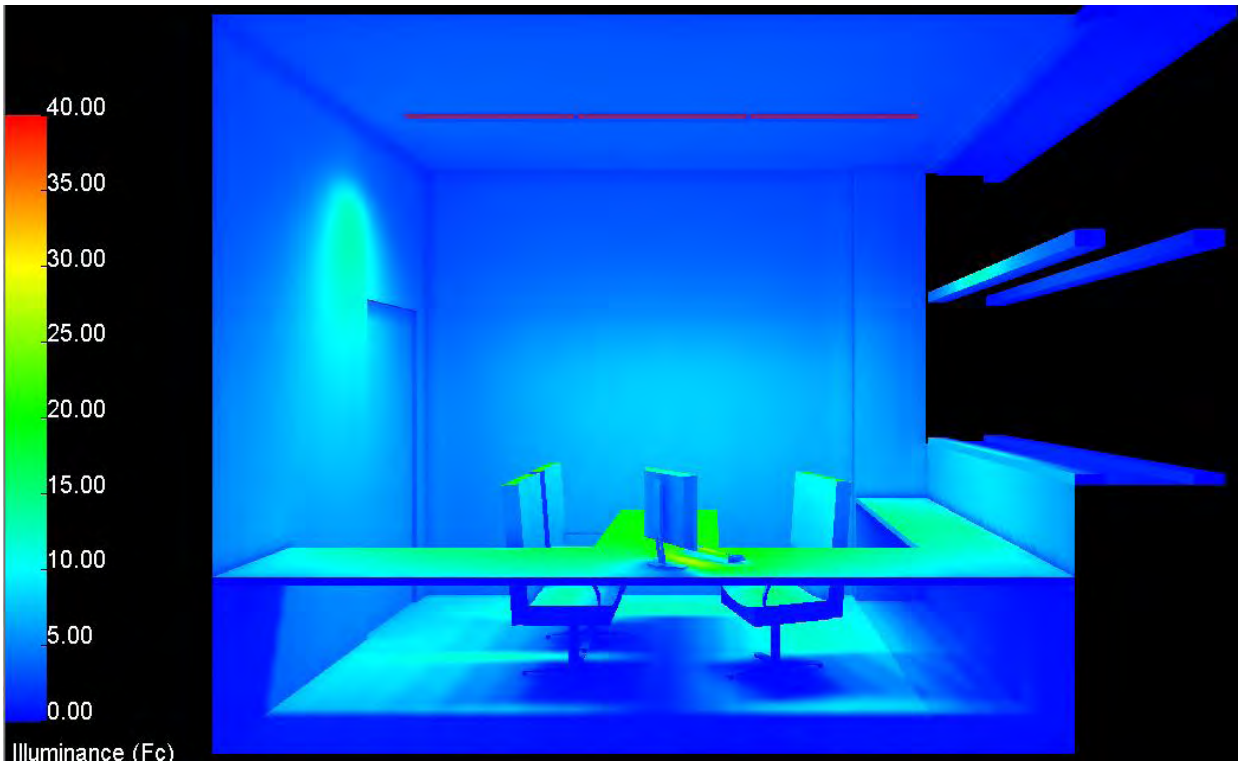


Figure 51: Typical Office - Illuminance Color (Half Luminaires On).

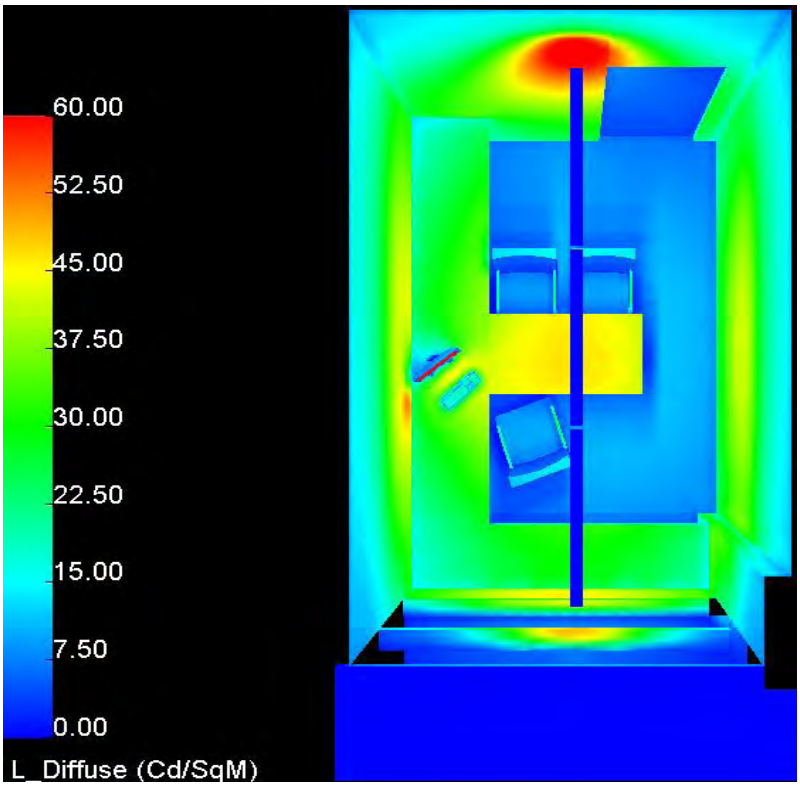


Figure 52: Typical Office - Luminance Color (All Luminaires On).

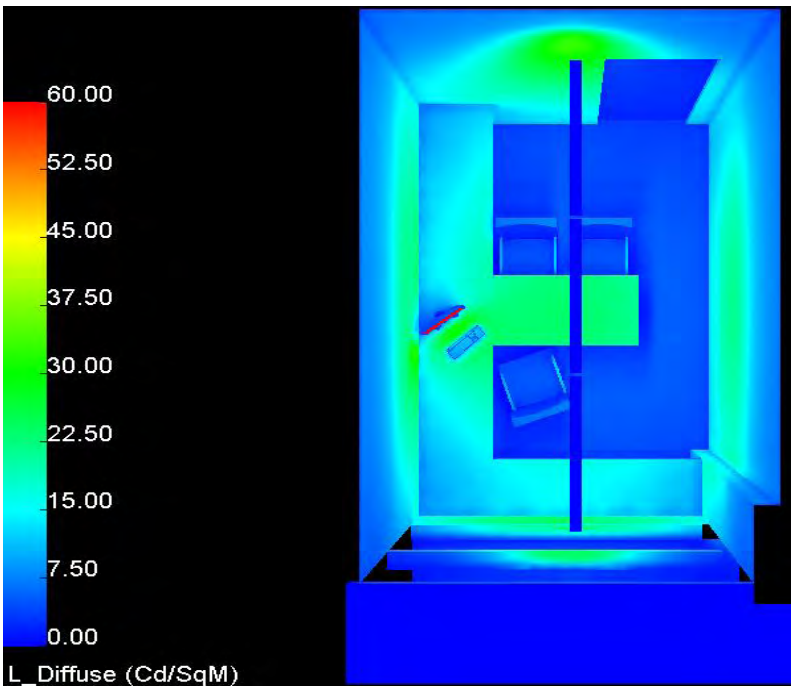


Figure 53: Typical Office - Luminance Color (Half Luminaires On).

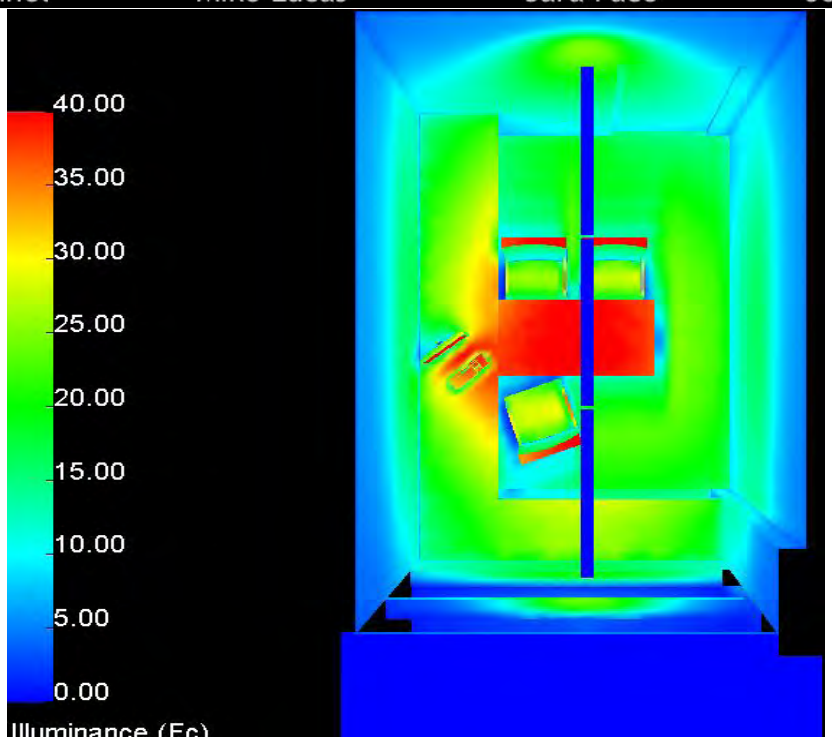


Figure 54: Typical Office - Illuminance Color (All Luminaires On).

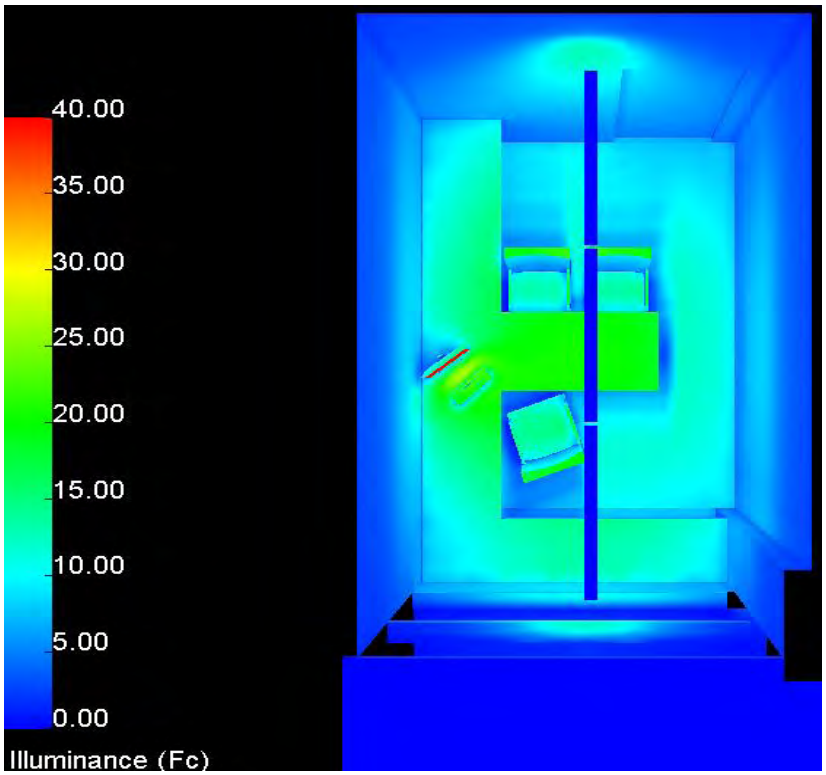


Figure 55: Typical Office - Illuminance Color (Half Luminaires On).

Controls

The Typical Private Office lighting control layout is a simple wall switch next to the door. The switching zones will allow the occupant of the space to switch either all or half the luminaires. This method allows the occupant to manually control the visual appearance of the space as needed. This option of controls has been chosen due to the private nature of the office, and the varying preference of users from one office to the next. Daylighting controls for electric light have not been incorporated into this perimeter space due to the private nature of the office. For full wiring diagrams of a typical private office, refer to Appendix G: Lighting Wire Diagrams.

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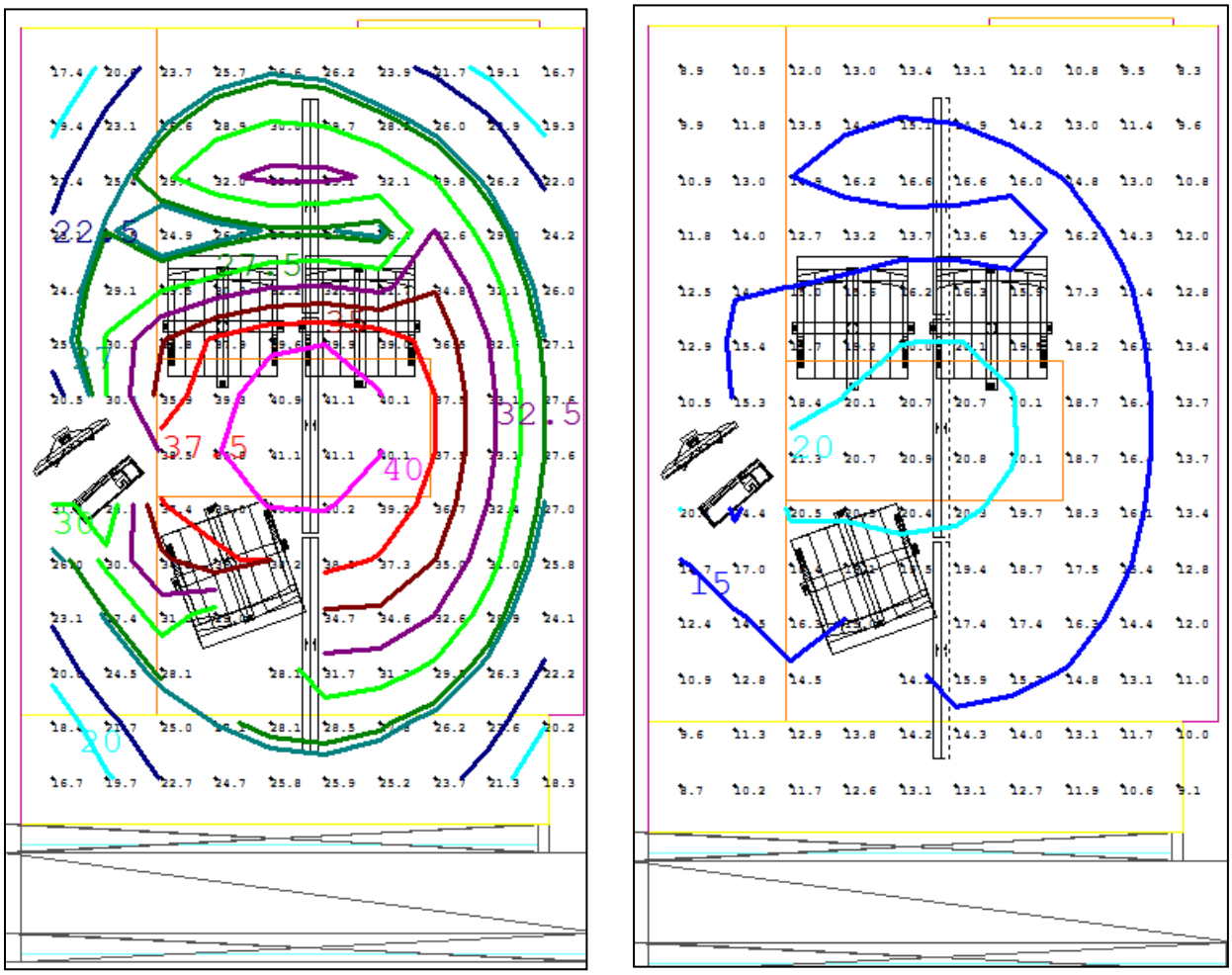
Performance Summary



15fc-20fc-22.5fc -25fc - 27.5fc - 30fc -32.5fc -37.5fc - 40fc

Figure 56: Typical Office Illumination Contours (Left - All Lights On) (Right – Half Lights on).

Table 19: Typical Office Performance Summary.

Typical Office Performance Data	All Luminaires On	Half Luminaires On
Avg. Illuminance (FC)	29.28	14.87
Max. Illuminance (FC)	41.10	21.30
Minimum Illuminance (FC)	16.70	8.30
Avg./Min	1.75	1.79
Max/Min	2.46	2.57
Max/Avg.	1.40	1.43
Coefficient of Variation	0.21	0.22
Uniform Gradient	1.46	1.46
Power Density (W/SF)	1.00	

Integrating Connected Equipment & Plug Loads

Further integration was pursued between the mechanical and electrical designs through Revit MEP. A functional Revit "MEP" model of the third floor was created and included the circuiting of existing electrical loads to their upstream counterparts. The purpose of this depth was to further understand the program as well as help quickly integrate changes in both electrical and mechanical designs in the future.

The original goal was to provide electrical plug loads, equipment loads, and lighting loads to the mechanical designer for the heating and cooling load calculations. Lighting loads have been omitted due to issues with getting electrical loads from light fixtures to "attach" themselves to a space. The issue stemmed from the fact that some of lighting fixtures originally modeled in Revit Architecture had not been done in a way to permit them to work correctly in an electrical model. All existing luminaire families were missing proper electrical input data such as electrical connectors, IES files, voltage systems and identity data. When it was attempted to add this data to the existing luminaires, it was discovered that most of them needed to be upside down in order for their electrical data to be included in a spaces W/SF summation. For the purposes of coordination and time constraints, the existing luminaires were left as is, and spaces have used ASHRAE Standard 90.1 lighting power densities for mechanical load calculation purposes.

Equipment & Receptacle Circuiting

The third floor of the Millennium Science Complex was the area of focus for the circuiting of existing equipment and receptacle loads. Existing panel schedules were used to verify loads of branch circuits in terms of volt-amperes. Details of the process used in order circuit these items have been written in detail in the Electrical Technical Report #1 (pages 4-9).

The depth topic was executed to better understand the inner functions of doing electrical design in a program such as Revit MEP. The final conclusion of this study is ¼" scale floor power plans as well as panel schedule sheets. Drawings produced from this study can be found on the Building Stimulus website at the following link:

http://www.engr.psu.edu/ae/thesis/BIMTeam22010/Final/Revit%20Sheets.pdf

An Electrical connector is a component in the Revit MEP program that allows the user to connect a piece of equipment to a desired circuit. In order to connect a family to a circuit, an electrical connector must be present. The properties of an electrical connector are the basis of calculations used to create panel schedules. Within the electrical parameter, the option of Load Classification is the parameter that makes the discretion of what the load will be calculated as. Power and Lighting are out of the box options with the availability to add user defined classifications such as motor loads, kitchen loads, or P.C. loads.

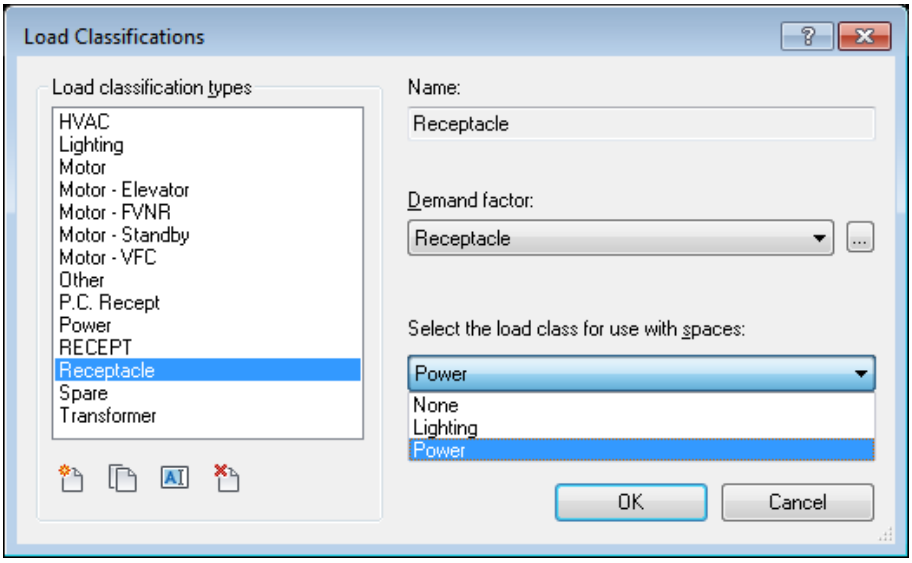


Figure 57: Revit MEP Load Classifications.

Figure 57 above shows the screen where the user can create the user defined load classifications. Classifying a load as either power or lighting for use with spaces will determine which category a space will assign the load to. This is important for collaborating with the mechanical designer what electrical heating loads each space will encounter.

The next step of setting up a load classification is to calculate a demand load for the type of load that has been circuited. For example, 2008 Edition National Electrical Code (NEC 2008) allows a demand factor reduction receptacles if more than 10kVA of receptacles are connected. The table from the NEC that states this is shown in Figure 58 below.

Table 220.44 Demand Factors for Non-Dwelling Receptacle Loads

Portion of Receptacle Load to Which Demand Factor Applies (Volt-Amperes)	Demand Factor (%)
First 10 kVA or less at	100
Remainder over 10 kVA at	50

Figure 58: NEC 2008 – Table 220.44 Demand Factors for Non-Dwelling Receptacle Loads.

Figure 59 below shows the screen at which demand factor is entered into Revit MEP's load classifications. The example shown is of receptacle demand factors as permitted by NEC, Table 220.44.

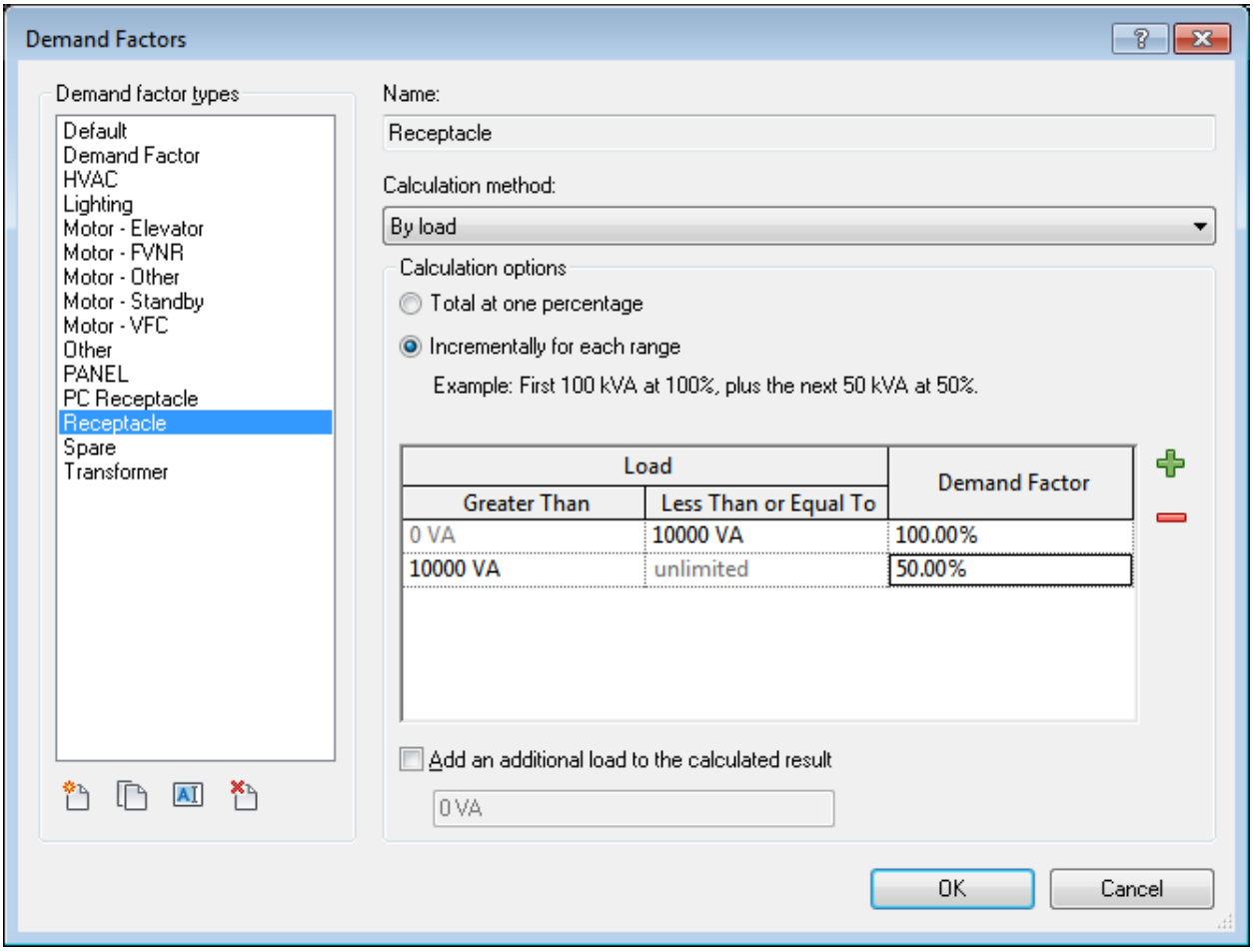


Figure 59: Revit MEP – Assigning Demand Factors.

The demand factor definition also allows the options of assigning a demand factor by quantity of items connected as well as the option of a constant demand factor. Table 20 summarizes the actual power densities modeled in Revit MEP.

Electrical Equipment Plug Loads

Table 20: Detailed Space by Space Electrical Loads.

Room Data			Plug Loads	
Room Number	Room Name	Area (SF)	Actual Power Load	Actual Power Load per Area
N-237A	Organic Elec. & Pho Chemical Lab	574	17500 W	30.50 W/ft²
N-301	Dry Lab Typical	471	2340 W	4.97 W/ft²
N-302	Staff Admin	516	3240 W	6.28 W/ft²
N-302A	Copy	67	540 W	8.12 W/ft²
N-302B	Reception	135	180 W	1.33 W/ft²
N-303	Dry Lab Typical	471	2340 W	4.97 W/ft²
N-305	IT Staff Office	252	1980 W	7.85 W/ft²
N-306A	Conference	193	720 W	3.73 W/ft²
N-306B	Conference	193	1440 W	7.45 W/ft²
N-307	Storage	271	1260 W	4.65 W/ft²
N-308A	Seminar Room	417	2700 W	6.48 W/ft²
N-308B	Seminar Room	417	2520 W	6.05 W/ft²
N-309	IT Staff Office	258	1980 W	7.67 W/ft²
N-310	Cafe/Commons	1960	5040 W	2.57 W/ft²
N-310B	Kitchen	232	1405 W	4.65 W/ft²
N-310C	Copy	139	1080 W	7.77 W/ft²
N-310D	Mail	201	720 W	3.59 W/ft²
N-310E	Copy	139	1080 W	7.77 W/ft²
N-314	Storage	83	360 W	4.36 W/ft²
N-315	Distinguished Office	293	1620 W	5.53 W/ft²
N-316	MSC Computational	214	1440 W	6.74 W/ft²
N-317	Staff Assistant	187	1080 W	5.78 W/ft²
N-319	Distinguished Office	229	1260 W	5.49 W/ft²
N-320	Staff Assistant	149	900 W	6.03 W/ft²
N-321	Staff Assistant	149	1080 W	7.23 W/ft²
N-322	Faculty	149	1080 W	7.23 W/ft²
N-323	Faculty	149	1080 W	7.25 W/ft²
N-324	Student	157	1800 W	11.50 W/ft²
N-324A	Organic Elec. & Pho Chemical Lab	558	22600 W	40.48 W/ft²
N-325	Student	159	2160 W	13.56 W/ft²
N-326	Student	159	2160 W	13.56 W/ft²
N-327	Student	159	2160 W	13.56 W/ft²
N-328	Student	156	2520 W	16.17 W/ft²
N-328A	Organic Elec & Pho Instrument Lab	589	15790 W	26.80 W/ft²

Room Number	Room Name	Area (SF)	Actual Power Load		Actual Power Load per Area	
N-329	Faculty	149	1080	W	7.25	W/ft²
N-330	Faculty	149	1080	W	7.25	W/ft²
N-331	Lounge	276	720	W	2.61	W/ft²
N-332	Faculty	157	1080	W	6.88	W/ft²
N-333	Faculty	149	1080	W	7.25	W/ft²
N-334	Student	157	2520	W	16.10	W/ft²
N-335	Student	157	1800	W	11.50	W/ft²
N-336	Faculty	149	1080	W	7.25	W/ft²
N-337	Faculty	157	1080	W	6.88	W/ft²
N-338	Lounge	277	720	W	2.60	W/ft²
N-339	Faculty	149	1080	W	7.25	W/ft²
N-340	Faculty	149	1080	W	7.25	W/ft²
N-341	Student	156	2520	W	16.17	W/ft²
N-341A	Electroact Polys Instrument Lab	589	13110	W	22.26	W/ft²
N-342	Student	159	2160	W	13.56	W/ft²
N-342A	Electroact Polys Fabrication Lab	574	29350	W	51.09	W/ft²
N-343	Student	159	2160	W	13.56	W/ft²
N-344	Student	159	2160	W	13.56	W/ft²
N-345	Student	157	1800	W	11.50	W/ft²
N-345A	Electroact Polys Chemical Lab	558	21170	W	37.93	W/ft²
N-346	PH.D Office	149	1080	W	7.23	W/ft²
N-347	PH.D Office	149	1080	W	7.23	W/ft²
N-348	Staff Office	149	1080	W	7.23	W/ft²
N-349	Staff Office	149	1080	W	7.23	W/ft²
N-350	Staff Office	149	1080	W	7.23	W/ft²
N-351	Staff Office	149	1080	W	7.23	W/ft²
N-352	Staff Office	149	1080	W	7.23	W/ft²
N-353	Staff Office	149	1080	W	7.23	W/ft²
N-354	Dry Lab Typical	214	1440	W	6.74	W/ft²
N-355	Staff Office	149	1080	W	7.23	W/ft²
N-356	Staff Office	163	1080	W	6.62	W/ft²
N-361	Equipment Corridor	679	6220	W	9.16	W/ft²
N-J346	Janitor Closet	38	0	W	0.00	W/ft²
N-P346	Electrical	36	4000	W	111.11	W/ft²
N-P347	Electrical	99	10000	W	100.00	W/ft²
N-Q301	Corridor	367	180	W	0.49	W/ft²
N-Q302	Corridor	728	360	W	0.49	W/ft²

Room Number	Room Name	Area (SF)	Actual Power Load		Actual Power Load per Area	
N-Q303	Corridor	668	180	W	0.27	W/ft²
N-Q304	Corridor	593	720	W	1.21	W/ft²
N-Q305	Corridor	500	180	W	0.36	W/ft²
N-Q306	Corridor	592	540	W	0.91	W/ft²
N-Q307	Corridor	742	180	W	0.24	W/ft²
N-Q308	Corridor	562	180	W	0.32	W/ft²
N-Q310	Corridor	837	1800	W	2.15	W/ft²
N-R323	Women	209	540	W	2.58	W/ft²
N-R324	Unisex Restroom	75	180	W	2.39	W/ft²
N-R346	Men	209	540	W	2.58	W/ft²
N-T347	Telecom	99	2100	W	21.22	W/ft²
Q-335A	EQPM Corridor G	304	21460	W	70.50	W/ft²
W-301	BCI Teaching	470	8600	W	18.32	W/ft²
W-302	Staff Admin	283	1800	W	6.36	W/ft²
W-302A	Staf Office	107	1120	W	10.48	W/ft²
W-302B	Staff Office	107	1120	W	10.48	W/ft²
W-302C	Reception	138	180	W	1.30	W/ft²
W-302D	Copy	64	1560	W	24.38	W/ft²
W-303	Elec EQPM Meas/Test	471	6580	W	13.96	W/ft²
W-305	Grad Student	259	2140	W	8.25	W/ft²
W-306A	Conference/Library	416	3950	W	9.49	W/ft²
W-306B	Conference/Library	416	4670	W	11.22	W/ft²
W-307	Kitchen/Break	273	3340	W	12.25	W/ft²
W-308A	Conference	193	1520	W	7.87	W/ft²
W-308B	Conference	193	760	W	3.93	W/ft²
W-309	Post Doc Office	258	1980	W	7.67	W/ft²
W-311	Faculty Office	163	1080	W	6.61	W/ft²
W-312	Faculty Office	149	1080	W	7.23	W/ft²
W-313	Faculty Office	149	1080	W	7.23	W/ft²
W-314	Light Machine Shop	214	9740	W	45.58	W/ft²
W-315	Faculty Office	149	1080	W	7.23	W/ft²
W-316	Faculty Office	149	1080	W	7.23	W/ft²
W-317	Faculty Office	149	1080	W	7.23	W/ft²
W-318	Hershey MD	149	1080	W	7.23	W/ft²
W-319	Hershey MD	149	1080	W	7.23	W/ft²
W-320	Senior Post Doc	149	1080	W	7.23	W/ft²
W-321	Neurophys-Invitro	472	6220	W	13.17	W/ft²
W-321A	Perfusion	107	5340	W	50.14	W/ft²

Room Number	Room Name	Area (SF)	Actual Power Load		Actual Power Load per Area	
W-321B	Tiss Prep	174	11180	W	64.21	W/ft²
W-321C	Manifold Gas	74	180	W	2.43	W/ft²
W-322	Neurophys-Invitro	480	5760	W	12.00	W/ft²
W-322A	EQPM Corridor G	304	18480	W	60.70	W/ft²
W-322A	EQPM Corridor G	304	18480	W	60.70	W/ft²
W-323A	Fume Hood	113	9080	W	80.52	W/ft²
W-323B	Procedure D Surgery	184	6680	W	36.21	W/ft²
W-324A	Hot Room	113	6320	W	56.08	W/ft²
W-324B	Proc A	105	9400	W	89.14	W/ft²
W-324C	Mirco C Comp	72	6160	W	85.53	W/ft²
W-325	Neurophys-Invitro	480	5940	W	12.38	W/ft²
W-325A	EQPM Corridor A4	304	23360	W	76.84	W/ft²
W-326	Neurophys-Invitro	742	8820	W	11.89	W/ft²
W-326A	Proc C Maze	113	7060	W	62.62	W/ft²
W-326B	Procedure B	184	3380	W	18.33	W/ft²
W-327A	Optical Imaging	666	10540	W	15.83	W/ft²
W-329	NuerophysInvitro	734	8640	W	11.77	W/ft²
W-329A	Procedure E In Vivo	335	10900	W	32.54	W/ft²
W-331A	Proc C Maze	107	1260	W	11.83	W/ft²
W-331B	Enviro A	89	6780	W	75.79	W/ft²
W-331C	Micro A	79	5180	W	65.57	W/ft²
W-332	Neurophys-Invitro	480	5940	W	12.38	W/ft²
W-332A	EQPM Corridor B1	305	14680	W	48.08	W/ft²
W-333A	Fume Hood	113	11660	W	103.47	W/ft²
W-333B	Confocal A	105	3780	W	35.84	W/ft²
W-333C	Mirco C Comp	72	6380	W	88.58	W/ft²
W-334A	Fume Hood	113	9920	W	87.79	W/ft²
W-334B	Tissue Culture B	184	8340	W	45.21	W/ft²
W-335	Neurophys-Invitro	480	5760	W	12.00	W/ft²
W-336A	Proc A	108	9820	W	91.31	W/ft²
W-336B	Service	74	720	W	9.75	W/ft²
W-336C	Autoclave	100	6340	W	63.71	W/ft²
W-337	Neurophys-Invitro	472	6300	W	13.34	W/ft²
W-338	Senior Post Doc	149	1120	W	7.53	W/ft²
W-339	Hershey MD	149	1160	W	7.78	W/ft²
W-340	Faculty Office	149	1120	W	7.51	W/ft²
W-341	Faculty Office	149	1120	W	7.51	W/ft²

Room Number	Room Name	Area (SF)	Actual Power Load		Actual Power Load per Area	
W-342	Faculty Office	149	1160	W	7.78	W/ft²
W-343	Staff Assistant	109	180	W	1.65	W/ft²
W-344	Distinguished Office	294	1660	W	5.65	W/ft²
W-345	Grad Student	214	2240	W	10.45	W/ft²
W-346	Storage	82	360	W	4.37	W/ft²
W-J337	Janitor Closet	74	180	W	2.43	W/ft²
W-J338	Janitor Closet	15	180	W	1.82	W/ft²
W-P338	Electrical	99	10000	W	100	W/ft²
W-Q301	Corridor	365	0	W	0.00	W/ft²
W-Q302	Corridor	740	0	W	0.00	W/ft²
W-Q303	Corridor	642	180	W	0.28	W/ft²
W-Q304	Corridor	604	720	W	1.19	W/ft²
W-Q305	Corridor	729	1400	W	1.92	W/ft²
W-Q306	Corridor	560	1400	W	2.50	W/ft²
W-R321	Women	209	720	W	3.44	W/ft²
W-R337	Men	208	540	W	2.60	W/ft²
W-T338	Telecom	99	2100	W	21.21	W/ft²

Once the plug loads were finalized in the Revit MEP model, they were imported into the existing TRACE model completed for the mechanical design. Table 21 details the power densities originally assumed for the base model.

Table 21: ASHRAE Std. 90.1 Lighting and Equipment Power Densities.

Common Space Types	LPD , W/ft^2	EPD , W/ft^2
Office –Enclosed	1.1	1.5
Office – Open Plan	1.1	1.5
Conference/Meeting/Multipurpose	1.3	1.0
Classroom/Lecture/Training	1.4	1.0
Lounge/Recreation	1.2	0.5
Dining Area	0.9	0.5
Food Preparation	1.2	1.5
Laboratory	1.4	1.5
Restrooms	0.9	0.3
Corridor/Transition	0.5	0.3
Stairs - Active	0.6	0.3
Active Storage	0.8	0.3
Inactive Storage	0.3	0.3
Electrical/Mechanical	1.5	0.3
Post Office – Sorting Area	1.2	1.0

Energy Analysis

The incorporation of the actual plug loads caused a significant increase in the receptacle energy consumption. As shown in Figure 60, the receptacle energy consumption increased by twelve times the amount of the original base model. This translated into an increased source energy consumption of more than 150% for the third floor, as well as a significant increase in the HVAC associated emissions, as illustrated in Figure 62 and Figure 63.

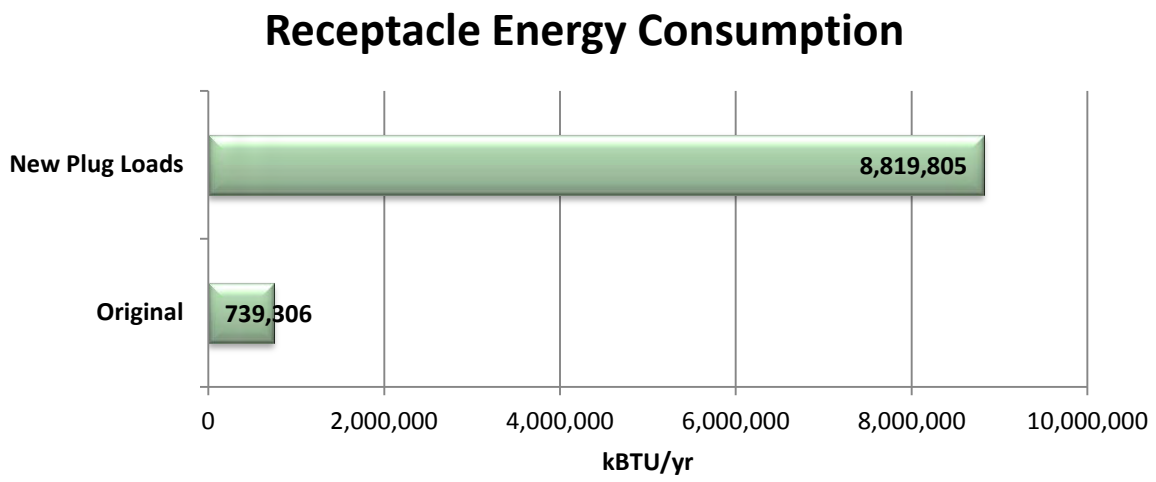


Figure 60: Receptacle Energy Consumption for Third Floor.

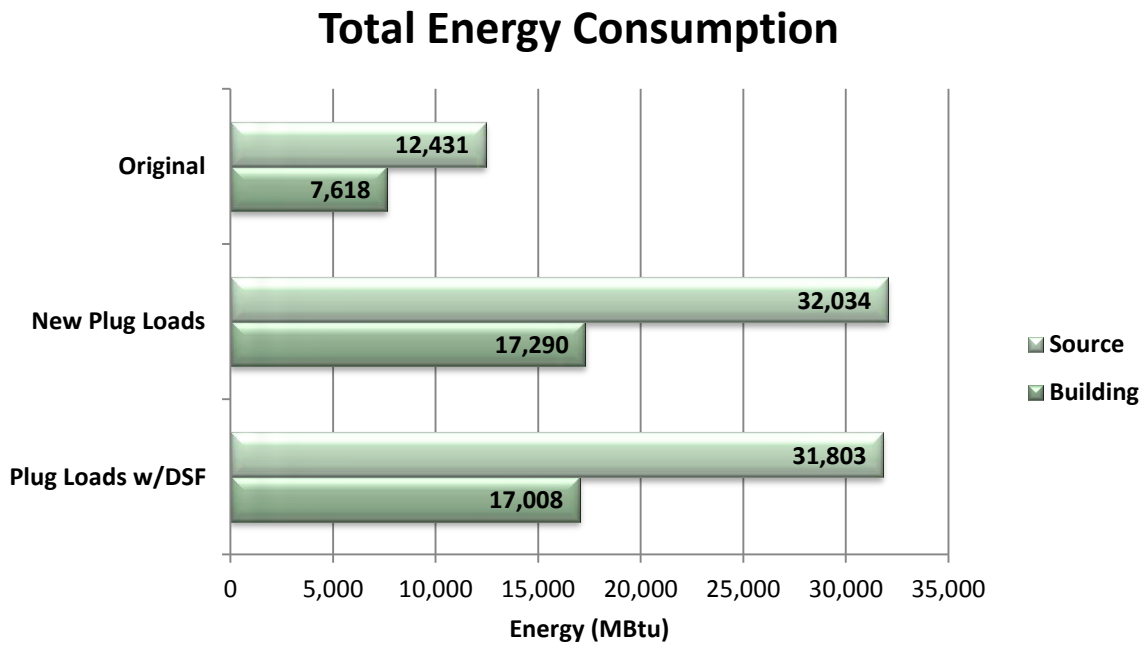


Figure 61: Energy Consumption for Third Floor.

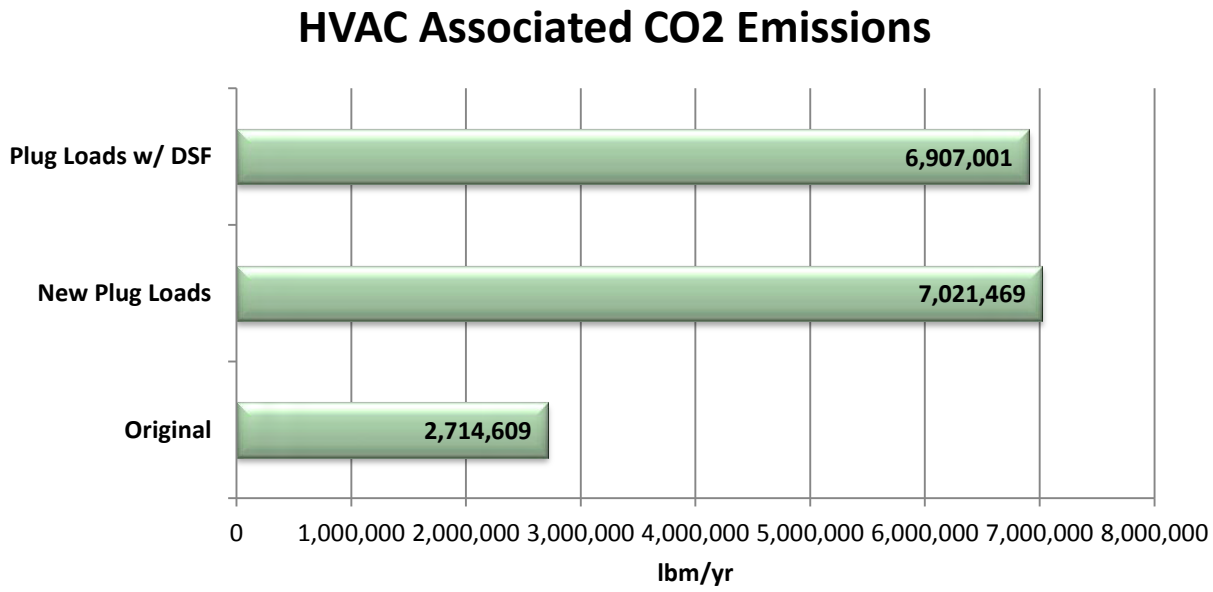


Figure 62: Third Floor Carbon Dioxide Emissions.

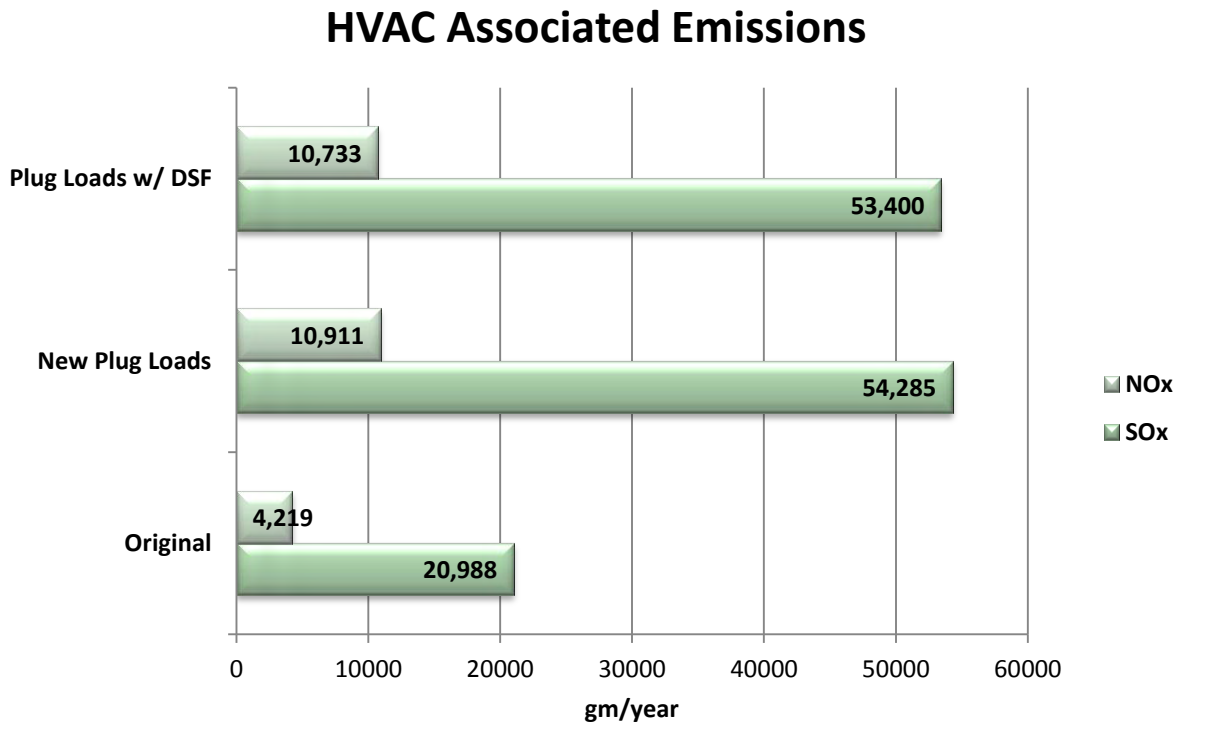


Figure 63: Third Floor Associated Emissions for SOx and NOx.

Combined Design Parameters

The final energy performance for the building's design alternatives were completed based on the updated power densities for the building. Summarized design outcomes for the original base energy model are presented in Appendix C:. For the combined double skin façade addition and chilled beams used for the perimeter zones, as extrapolated from the third floor analysis, the total building was able to save 716,110 lb_m/year in CO_2 emissions as well as 2,214 MBtu in source energy consumption.

Table 22: Building Energy Consumption for Final Design Parameters.

	Building (MBtu)	Source (MBtu)
New Plug Loads	106,045	196,475
Plug Loads w/DSF	104,316	195,058
CB with Plug	104,580	194,813
CB with DSF, Plug	104,285	194,261
Total Savings for Combined System	**1,760**	**2,214**

Table 23: HVAC Associated Emissions for Final Design Parameters.

	CO_2 (lbm/yr)	SOx (gm/yr)	NOx (gm/yr)
New Plug Loads	43,065,010	332,948	66,921
Plug Loads w/ DSF	42,362,939	327,520	65,829
Plug Load w/ Chilled Beam	42,470,009	328,348	65,995
Plug: CB and DSF	42,348,900	327,410	65,805
Total Savings for Combined System	**716,110**	**5,538**	**1,116**

As shown in Figure 64, the combination of the double skin façade on Millennium Science Complex's western and southern facades and chilled beams in the office spaces provided 57,567 kWh per year for the building.

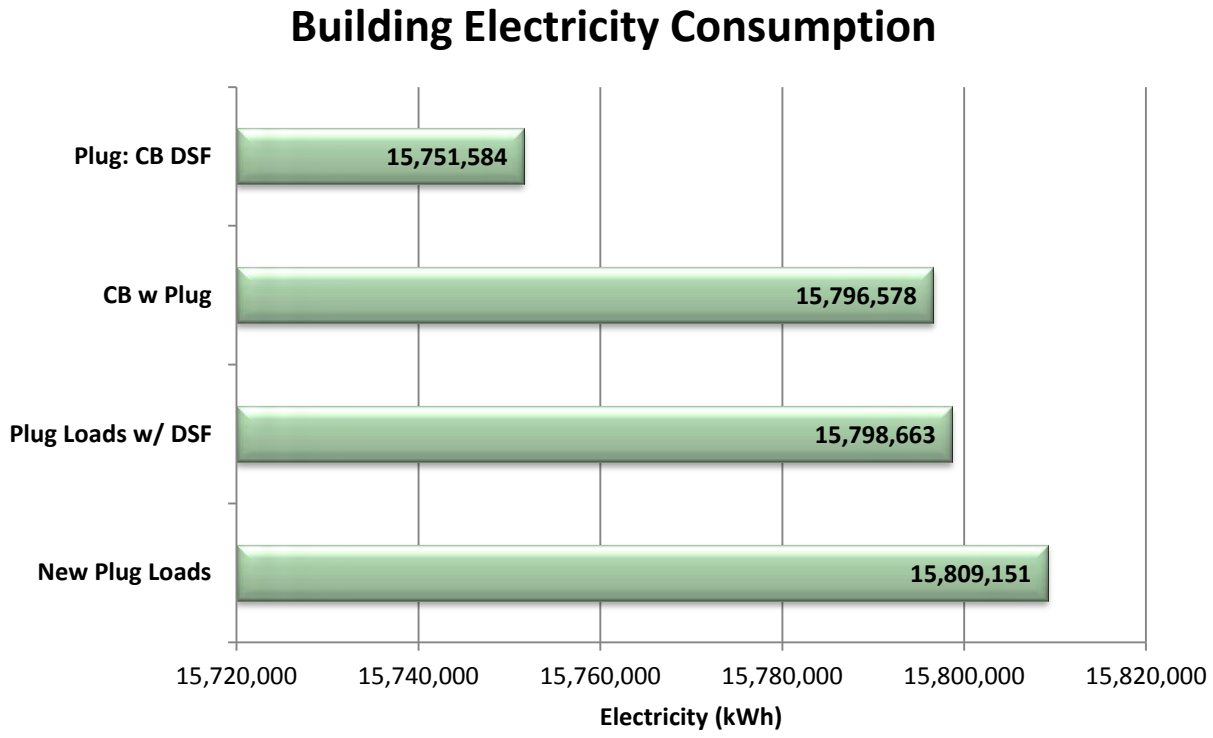


Figure 64: Building Electricity Consumption for Final Design Parameters.

The summarized utility costs for the final design is shown in Table 24. Based on the redesign, Millennium Science Complex is able to save $112,250 per year in utility costs.

Table 24: Yearly Utility Costs for Final Design Parameters.

	Electricity kWh	Cost of Electricity	Purchased Chilled Water (therms)	Cost of Chilled Water	Purchased Steam (therms)	Cost of Steam	Total Cost
New Plug Loads	15,809,151	$1,188,374	507,386	$928,517	154,873	$126,996	**$2,243,886**
Plug Loads w/ DSF	15,798,663	$1,187,586	495,567	$906,832	1749,463	$122,560	**$2,216,977**
Plug Load w/CB	15,796,577	$1,187,429	458,105	$838,332	138,233	$113,351	**$2,139,112**
Plug: CB and DSF	15,751,584	$1,184,047	456,228	$834,897	137,430	$112,692	**$2,131,636**
Total Savings for Combined System	**57,567**	**$4,327**	**51,158**	**$93,619**	**17,443**	**$14,303**	**$112,250**

Integrated Chilled Beam Cost Analysis

The use of chilled beams as a substitute to variable air volume systems was highly dependent on the location within the facility. Building Stimulus' mechanical designer and construction manager worked cooperatively to determine specific spaces to study on the 3rd floor of Millennium Science Complex. Upon doing so, results could be assumed consistent throughout the facility. A full take-off of VAV boxes to be replaced can be seen in Appendix D: Construction Management. RS Means costs were assigned to the take-offs and compared to estimated costs of the proposed chilled beam systems, which can be seen in Appendix D: Construction Management.

The IQID chilled beam system is integrated with lighting fixtures. To compare costs accurately, the 3rd floor were chosen to directly compare the overall savings and costs incurred due to the use of integrated chilled beams as a replacement for variable-air-volume boxes. It is important to be aware of the original light fixtures being removed from the typical office spaces as well. Overall take-offs of the 3rd floor can be found in Appendix D: Construction Management. Table 26 below shows the overall findings of upfront costs versus the original design.

Table 25: 3rd Floor ICB Cost.

	Size of Model	Quantity of Units	Cost Per Unit	Labor Cost	Labor Hours	Shipping Cost	Total Unit Cost	Supplier Discount	Total Cost
3rd Floor	4' Model	311	$871.00	$240.00	1.472	$35.00	$1,146.00	0.6	$213,843.60

Table 26: 3rd Floor ICB Cost Summary.

3rd Floor Systems	Chilled Beam System	Proposed Lighting Design	Original Lighting Design	Original VAV System	Difference
Cost	$213,843.60	$22,504.00	$49,934.00	$95,585.50	$90,828.10

Table 27 displays the payback period to meet the costs of the original mechanical and lighting design, as well as the payback period to reach net-zero.

Table 27: Cost and Payback Period.

Integrated Chilled Beam	Lighting Redesign	Difference to Original Design	Annual Savings	Payback to Original	Payback to Net Zero
$213,843.60	$22,504.00	$90,828.10	$104,774.00	0.87	$2.26

Integrated Chilled Beam Schedule Implications

The Integrated Chilled Beam system presents many cost benefits due to its annual savings. With a short payback period of 3.54 years to reach the cost of the original system, and a payback period of 9.39 years to reach net-zero, the financial benefits are undeniable. However, the chilled beam system does have negative impacts on the construction schedule. Upon analyzing the 3rd floor, the installation of the integrated chilled beam system requires

over twice as much time to complete versus the original design. The table below shows the direct comparison between the original systems versus the installation of 4' long integrated chilled beams.

Table 28: Chilled Beam Labor Durations

	Total Labor Hours	Total Days
Original System	206.89	25.86
Chilled Beam System	457.792	57.224

The installation of the original VAV system can be seen in the project schedule provided in Appendix D: Construction Management. RS Means estimated that the 3rd floor installation would require roughly 26 days. In actuality, the Material Sciences labs and core required 13 days, and the Life Sciences labs and core required 13 days for a total of 26 days.

The required labor hours of the integrated chilled beam system can be seen in Appendix D: Construction Management. Ways to significantly reduce the amount of required man hours of installation is to utilize different lengths of chilled beams. The labor hours above were based upon the use of the 4' chilled beam. Models can be designed to lengths of 4', 6', 8', 10', 12' as well as intermediate lengths upon special order, each length requiring minimal additional time. While the values in the table above were done conservatively, it can be assumed that in office spaces where (3) 4' light fixtures were replaced, (1) 12' integrated chilled beam was used. Doing so reduces the required man hours by nearly two thirds per space.

Cantilever Redesign

Structural Design

The structure of the cantilever was chosen as an area of interest for redesign because it is the main feature of the Millennium Science Building and provided a unique opportunity to attempt to optimize the efficiency of the truss structure. Through contact with Thornton Tomasetti (TT), it was discovered that the original design of the cantilever structure was initially designed for strength but did not satisfy deflection requirements. It was then redesigned primarily for stiffness to limit deflection at the tip of the cantilever. The deflection limit designed for by TT was 6 inches, specifically it was limited to a deflection of 4 inches under self-weight and an additional 2 inches under live load (chosen by "engineering judgment," source: TT rep). The existing system shown in Figure 65 utilizes compression bracing to transfer gravity loads to the foundation. By inspection and through modeling in SAP 2000 this has proven to be a very efficient design because of the direct load path to the foundation.

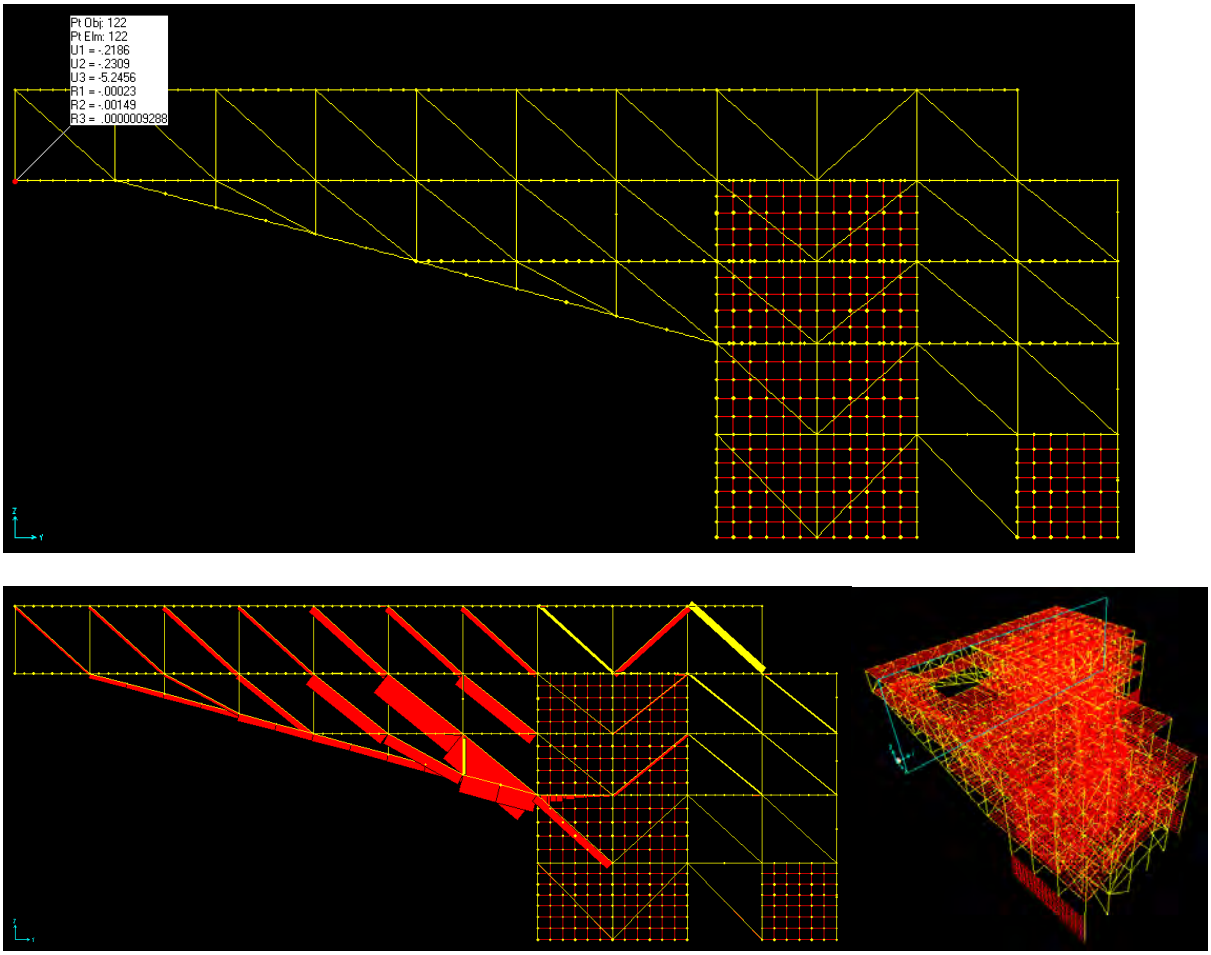


Figure 65: Existing Cantilever Truss Col Line 2.

The existing cantilever structural system was modeled in SAP and all applicable gravity loads applied to the structure, including: self-weight, super-imposed dead load, live load, and façade self-weight. The loading schedule can be found in Appendix A: Structural Analysis. The structure was then checked for strength and deflection. The deflection of the cantilever under total loading was 5.25 in and therefore satisfies the requirements assessed by TT. The strength of the web and chord members of the truss was determined by evaluating each member for the combined loading interaction equation found in Part 6 of AISC. An example calculation of this process can be seen in Appendix A: Structural Analysis. The braces and chords of the truss were relabeled in SAP and used to filter the data output to obtain the member forces of these specific members. The maximum axial load was then calculated and used to determine whether to use equation H1-1a or H1-1b. Following this, the combined loading factors were taken from AISC and entered for each specific member and length.

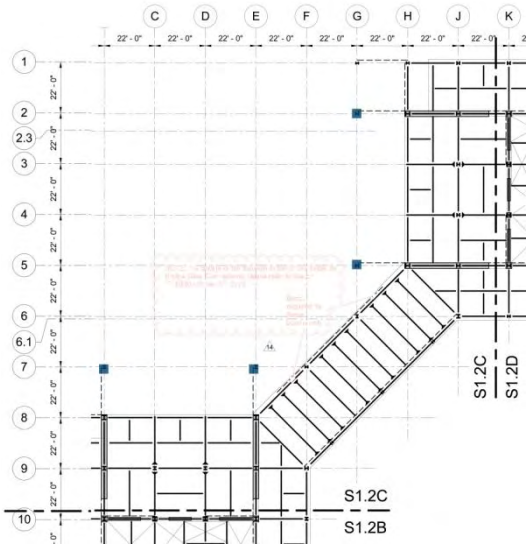


Figure 66: Column Locations (highlighted in blue).

Figure 67: Cantilever Existing Truss, Col Line 2.

The process of redesigning the cantilever structure involved many iterations, a few of which are shown in the figures to follow. To increase the efficiency of the truss structure the first thought was to decrease the unsupported length of the cantilever itself. To do this, additional columns were introduced at the locations shown in Figure 66, thereby reducing the unsupported length of the cantilever by 22 feet. This decreased the deflection at the tip of the cantilever and reorganized the location of the critical web members. In turn, a number of members were required to be sized-up or down in the locations shown in Figure 68 and Figure 69.

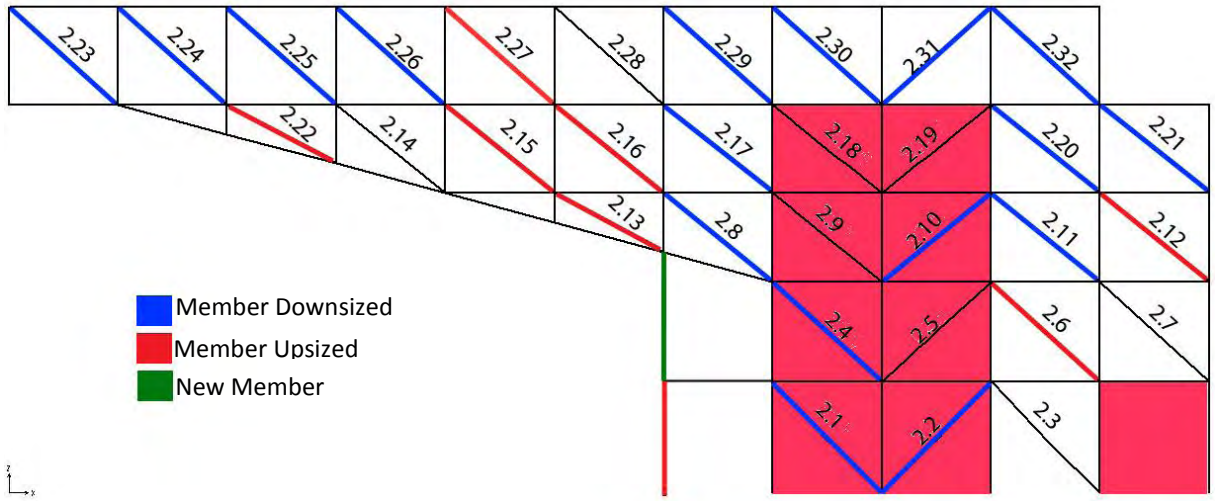


Figure 68: Cantilever Truss Redesign, Col Line 2.

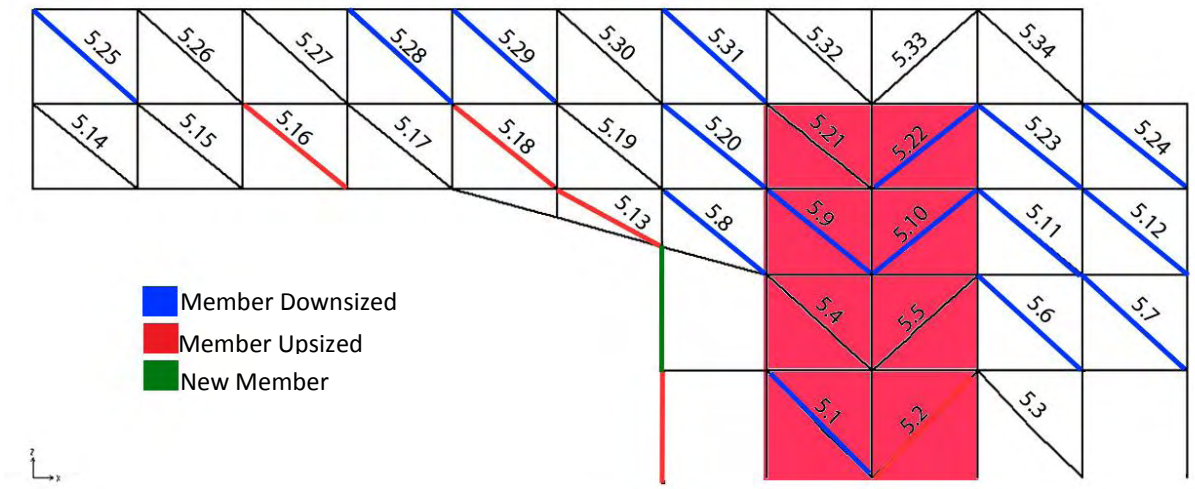


Figure 69: Cantilever Truss Redesign, Col Line 5.

Table 29: Cantilever Redesigned Member Sizes.

Existing				Redesign			
ID	Section	ID	Section	ID	Section	ID	Section
Frame 2.1	W14X99	Frame 5.1	W14X109	Frame 2.1	W14X90	Frame 5.1	W14X90
Frame 2.2	W12X120	Frame 5.2	W12X120	Frame 2.2	W14X90	Frame 5.2	W14X90
Frame 2.3	W14X90	Frame 5.3	W14X90	Frame 2.3	W14X90	Frame 5.3	W14X90
Frame 2.4	W14X455	Frame 5.4	W14X283	Frame 2.4	W14X311	Frame 5.4	W14X283
Frame 2.5	W14X145	Frame 5.5	W14X90	Frame 2.5	W14X145	Frame 5.5	W14X90
Frame 2.6	W14X90	Frame 5.6	W14X193	Frame 2.6	W14X90	Frame 5.6	W14X90
Frame 2.7	W14X193	Frame 5.7	W14X193	Frame 2.7	W14X193	Frame 5.7	W14X90
Frame 2.8	W14X455	Frame 5.8	W14X283	Frame 2.8	W14X257	Frame 5.8	W14X109
Frame 2.9	W14X193	Frame 5.9	W14X159	Frame 2.9	W14X193	Frame 5.9	W14X145
Frame 2.10	W14X398	Frame 5.10	W14X176	Frame 2.10	W14X233	Frame 5.10	W14X120
Frame 2.11	W14X193	Frame 5.11	W14X193	Frame 2.11	W14X120	Frame 5.11	W14X90
Frame 2.12	W14X193	Frame 5.12	W14X193	Frame 2.12	W14X120	Frame 5.12	W14X120
Frame 2.13	W14X193	Frame 5.13	W14X90	Frame 2.13	W14X342	Frame 5.13	W14X145
Frame 2.14	W14X193	Frame 5.14	W14X90	Frame 2.14	W14X193	Frame 5.14	W14X90
Frame 2.15	W14X193	Frame 5.15	W14X90	Frame 2.15	W14X211	Frame 5.15	W14X90
Frame 2.16	W14X311	Frame 5.16	W14X90	Frame 2.16	W14X370	Frame 5.16	W14X120
Frame 2.17	W14X193	Frame 5.17	W14X90	Frame 2.17	W14X120	Frame 5.17	W14X90
Frame 2.18	W14X193	Frame 5.18	W14X90	Frame 2.18	W14X193	Frame 5.18	W14X145
Frame 2.19	W14X233	Frame 5.19	W14X145	Frame 2.19	W14X233	Frame 5.19	W14X176
Frame 2.20	W14X193	Frame 5.20	W14X193	Frame 2.20	W14X120	Frame 5.20	W14X145
Frame 2.21	W14X193	Frame 5.21	W14X159	Frame 2.21	W14X120	Frame 5.21	W14X159
Frame 2.22	W14X61	Frame 5.22	W14X176	Frame 2.22	W14X90	Frame 5.22	W14X120
Frame 2.23	W14X145	Frame 5.23	W14X193	Frame 2.23	W14X90	Frame 5.23	W14X120
Frame 2.24	W14X145	Frame 5.24	W14X193	Frame 2.24	W14X90	Frame 5.24	W14X120
Frame 2.25	W14X145	Frame 5.25	W14X90	Frame 2.25	W14X109	Frame 5.25	W14X120
Frame 2.26	W14X145	Frame 5.26	W14X90	Frame 2.26	W14X109	Frame 5.26	W14X90
Frame 2.27	W14X145	Frame 5.27	W14X90	Frame 2.27	W14X159	Frame 5.27	W14X90
Frame 2.28	W14X145	Frame 5.28	W14X90	Frame 2.28	W14X145	Frame 5.28	W14X120
Frame 2.29	W14X145	Frame 5.29	W14X90	Frame 2.29	W14X90	Frame 5.29	W14X120
Frame 2.30	W14X145	Frame 5.30	W14X109	Frame 2.30	W14X90	Frame 5.30	W14X109
Frame 2.31	W14X145	Frame 5.31	W14X109	Frame 2.31	W14X120	Frame 5.31	W14X90
Frame 2.32	W14X193	Frame 5.32	W14X159	Frame 2.32	W14X159	Frame 5.32	W14X257
		Frame 5.33	W14X176	Frame 2.33	W14X550	Frame 5.33	W14X176
		Frame 5.34	W14X193	Frame 2.34	W14X550	Frame 5.34	W14X211
						Frame 5.35	W14X550
						Frame 5.36	W14X550

The next thought was that by switching the direction of the braces and therefore switching the loading of the bracing members from compression to tension loading the cross sectional area of the braces could be reduced and in turn the cost of the structure could be reduced. By switching the direction of the braces to the pattern in Figure 70, with the same members used in the existing design, the deflection at the tip of the cantilever increased to 6.45 in as to be expected. It was initially theorized that by using this type of loading the braces could possibly be changed to HSS members but by inspection the decrease in strength of an HSS member (Fy = 42 ksi) would lead to a further increase in cross sectional area to satisfy strength requirements and prevent excessive deformation. Aside from increasing the strength of the members itself (through an increase in cross-sectional area) the next thought would be increase the depth of truss at the location of greatest stress, ie. directly to the left of the new column. It was chosen as a group to not drastically alter the architecture of the existing cantilever therefore to increase the depth of the cantilever structure at this location either above or below was dismissed as a possible route in increasing the stiffness of the cantilever.

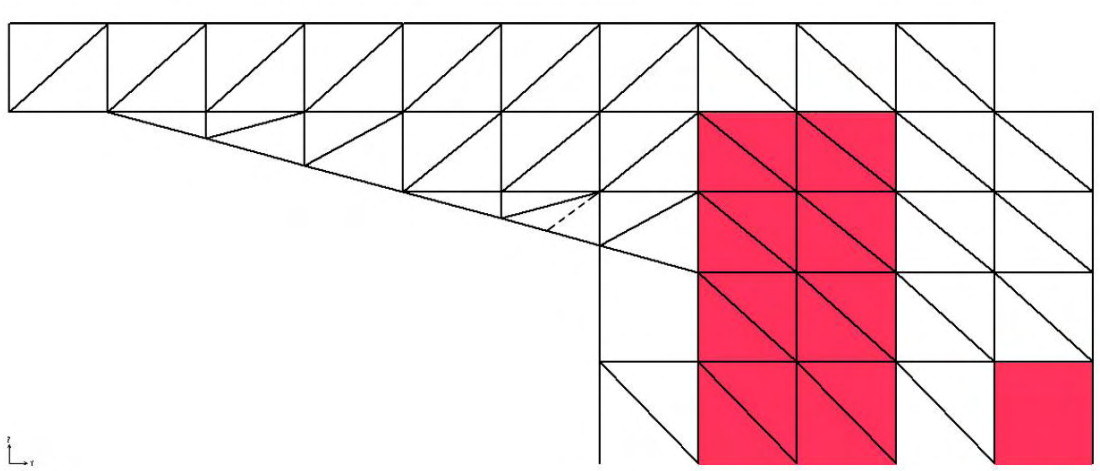


Figure 70: Cantilever Truss Iteration, Tension Col Line 2.

The final redesign of the cantilever structure can be seen in the figure below. As described above the final design involved the introduction an additional column 1 bay from the shear wall at each of 4 trusses supporting the cantilever. This allowed for a redesign of particular web and chord members of the truss and resulted in a net savings of 76 tons of steel between the existing and redesigned cantilever structure.

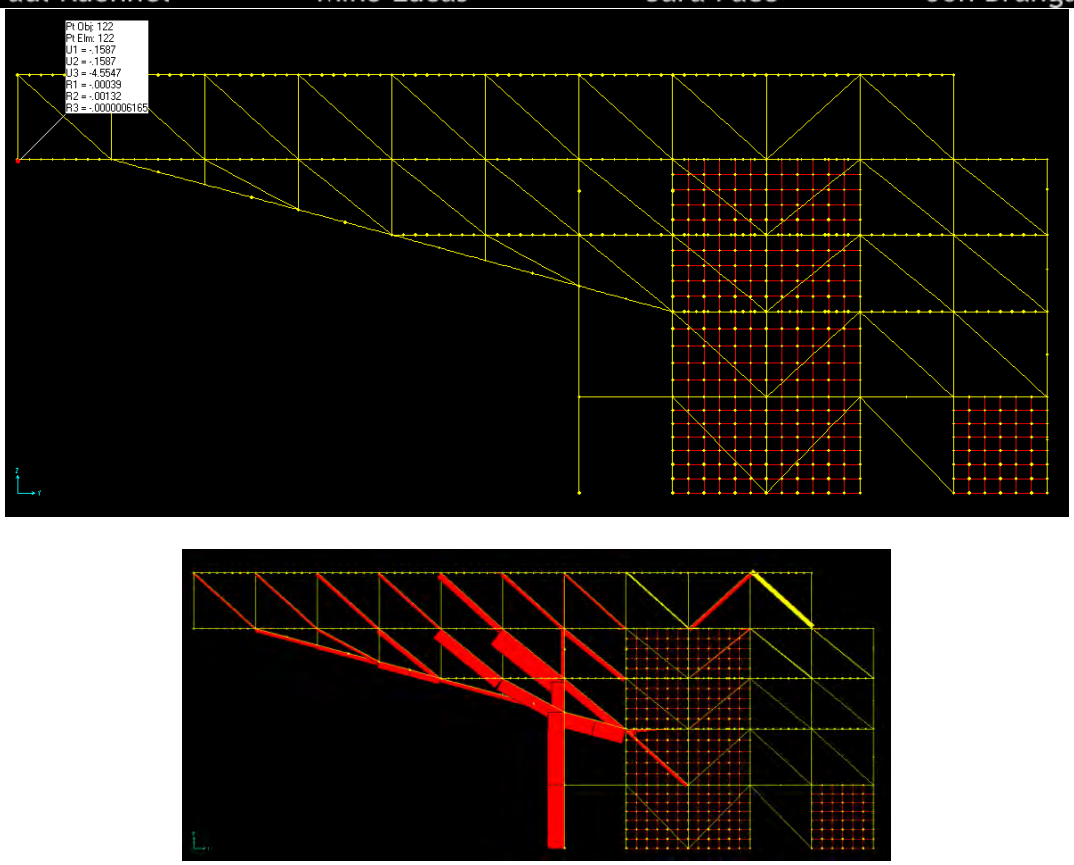
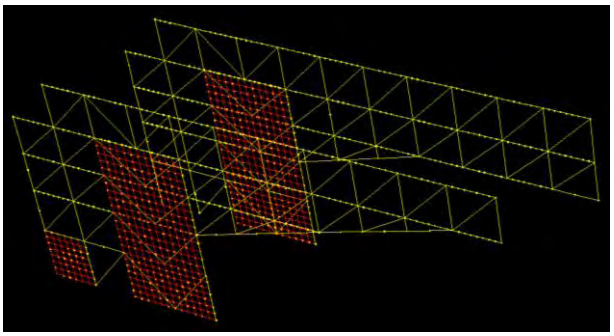


Figure 71: Redesign Cantilever Truss Col Line 2.

To optimize the load sharing between the two trusses, each truss was designed to have similar stiffness. The intent of this was to ensure that each truss was equally supporting the load of the cantilever. This is of particular importance because this would allow the cantilever to deflect uniformly especially at the intersection of the 4 trusses, each set of two spanning from the respective wings of the building. To check this, a 1000 kip unit load was placed at the tip of each individual truss and the resulting deflection was used to calculate the stiffness. This was performed for both the existing and redesigned trusses. Additionally, the percent difference between each truss in the respective designs was calculated and the stiffness of the redesigned trusses was less than that of the existing truss. This would result in a more efficient truss design for the cantilever structure.



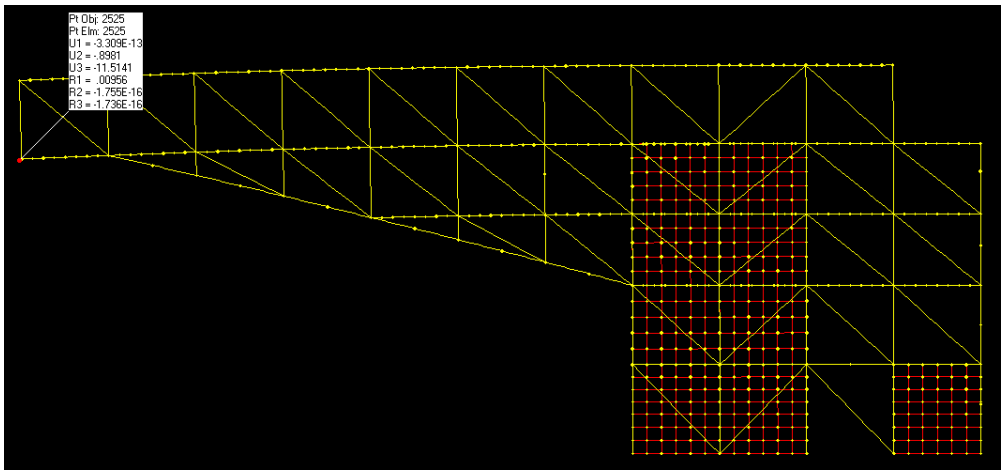


Figure 72: Stiffness Check Existing Col Line 2.

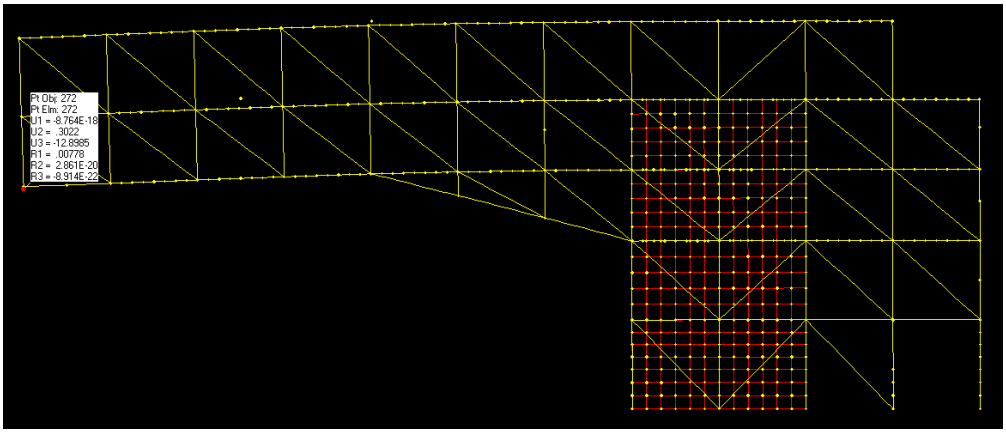


Figure 73: Stiffness Check Existing Col Line 5.

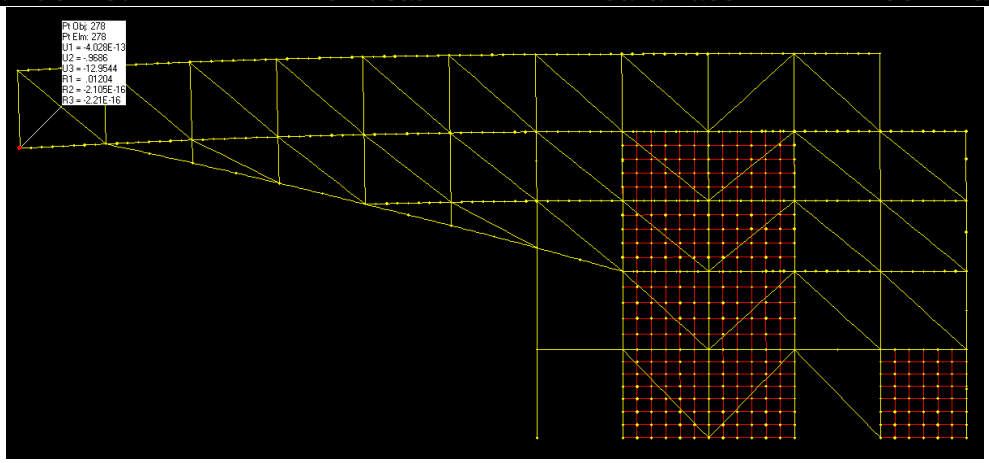


Figure 74: Stiffness Check Redesign Col Line 2.

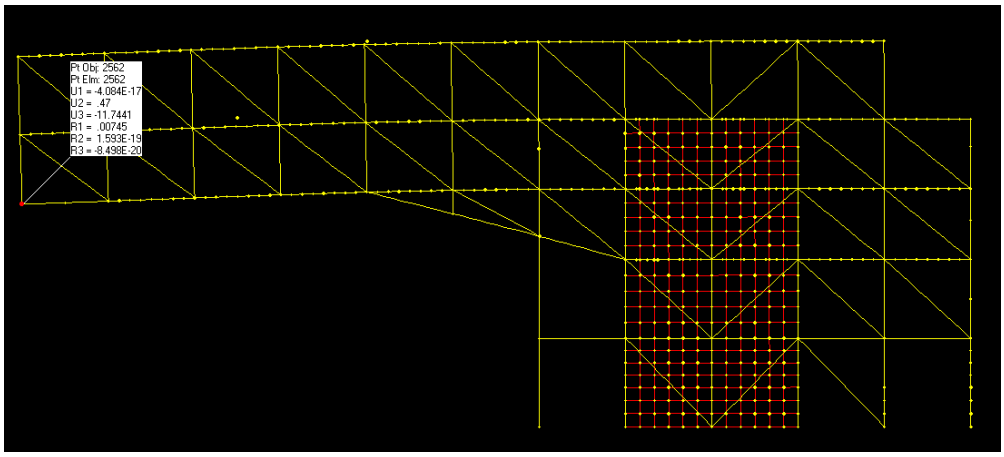


Figure 75: Stiffness Check Redesign Col Line 5.

Table 30: Stiffness Check.

	Existing		Redesign	
Frame	2	5	2	5
P	1000	1000	1000	1000
U	11.5141	12.8985	12.9544	11.7441
K	0.011514	0.012899	0.012954	0.011744
% diff		11.34		9.80

It should be noted that because of the nature of this thesis project, we were given the opportunity to act as the project architect. This allowed the group to make decisions that the original structural designer on the project would have been limited in making, ie. introducing a series of columns that may spoil the visions of the original architect. It is the opinion of Building Stimulus that the additional columns add significance to the entrance of the wings while not diminishing the "visual statement" of the massive cantilever.

Process and Material Take-Off

The primary focus of the structural redesign was the 4 major trusses, two running parallel to the Material Sciences wing, and two running parallel to the Life Sciences wing. The construction manager and structural designer, in a cooperative effort, redesigned the truss design including the addition of members as well as the resizing of existing members, and created a detailed estimate of the redesign compared to that of the original design. The full set of take-offs and estimates can be found in Appendix D: Construction Management.

Structural Costs

After completing take-offs of the original truss system, as well as the redesigned truss system, a detailed estimate was performed using RS Means. Upon accessing RS Means, it was found that data did not exist for the W30x90 structural member, which exists in the original design, as well as the redesign. To obtain an accurate cost for this member data was plotted and, using a linear trend line, a cost was estimated using extrapolation of known cost date.

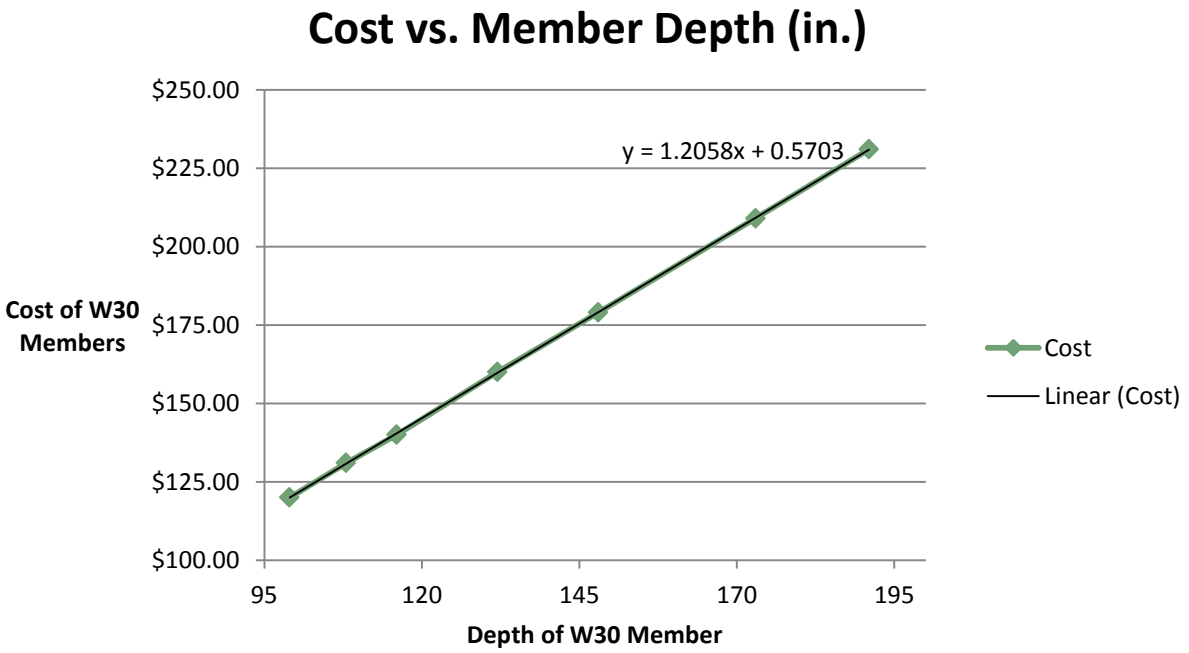


Figure 76: Cost vs. Member Depth Plot.

After developing a trend line equation, it was determined the W30 x 90 members cost $109.09 per linear foot. The full data plotted can be found in Appendix D: Construction Management. After cost was determined, remaining cost variables were estimated conservatively based on existing data. Bare labor cost, bare equipment cost, and labor hours were all chosen from existing RS Means values of similar sized members.

After performing a detailed estimate, it was conclusive that the redesigned truss system reduced costs by $140,569. The resizing of members also reduced overall weight of the truss system. Below is a summary of the findings. Full results are found in Appendix D: Construction Management.

Table 31: Truss System Comparison Summary.

	Original Truss System	Redesigned Truss System	Difference
Cost	$ 4,112,631.06	$ 3,967,985.69	$ (144,645.37)
Tons	1220.85	1143.66	-77.19
Labor Hours	637.73	655.225	17.495

Schedule Consideration

As can be seen in the Table 31 in the previous section, the redesigned structure reduces cost, as well as building weight, and requires negligible increase in man-hours of labor. The truss system, both original and redesigned, begins at column line M and ends at column line A in the Material Sciences wing. The Life Sciences truss system begins at column line 12 and ends at column line 1. In **Error! Reference source not found.** below, the trusses are represented by the orange regions, while the trusses column lines of origin are represented by the green regions.

Figure 77: Truss System Location and Origin.

According to Whiting-Turner, the original construction of these column lines lasted a total of 131 days for the Material Sciences wing, and 107 days for the life sciences wing. Below are the construction dates of the original system.

Table 32: Original Truss Construction Schedule.

Task Name	Duration	OD	Start	Finish
Structural Construction				
Material Sciences Wing	**131 days**	**114 days**	**Fri 10/16/09**	**Fri 4/16/10**
Column line M - H	74 days	59 days	Fri 10/16/09	Wed 1/27/10
Column Line H - E	47 days	20 days	Tue 1/12/10	Wed 3/17/10
Column Line E - A	27 days	35 days	Thu 3/11/10	Fri 4/16/10
Life Sciences Wing	**107 days**	**117 days**	**Thu 11/19/09**	**Fri 4/16/10**
Column Line 12 - 8	52 days	62 days	Thu 11/19/09	Fri 1/29/10
Column Line 8 - 5	37 days	20 days	Tue 1/26/10	Wed 3/17/10
Column Line 5 - 1	27 days	35 days	Thu 3/11/10	Fri 4/16/10

The time of the year for the scheduled construction must be noted with regards to the climate of State College, PA. These scheduled dates occur during the coldest months of the year for northeastern United States. Column OD in Table 32, which represents the activity's 'Original Duration', shows significant discrepancies between the Material Sciences wing's planned construction, and its actual construction. Column lines M-H, as well as H-E, were both planned to occur during the heart of the winter months, while the later activities occurring during the milder months made up for some lost time. It can be concluded that the structural redesign is of truss system in the Millennium Science complex provides financial benefits to the project. It is very difficult, however, to compare the estimated duration of the redesigned truss system versus the estimated and actual duration of the original design. While the estimated durations are essentially identical in duration, it is clear that unpredictable and uncontrollable delays dictate the true on-site duration.

Exterior Plaza Lighting Design

Spatial Summary

The main entrance of the Millennium Science Complex is located where each of the two wings joins each other. The cantilevered connection creates a plaza area that houses an entrance to each Material Science and Life Science wings. Under the square opening in the structure above, a pathway exist that sends walkers through a swirling pattern that leads from one entrance to the other. The design of the pathway has been intended to be directionless to discourage use. The structure below is a quiet lab area has been deemed extremely vibration sensitive and heavy use will disrupt the research and experiments below.

Drawings & Layout

Figure 78: Exterior Plaza - Plan View.

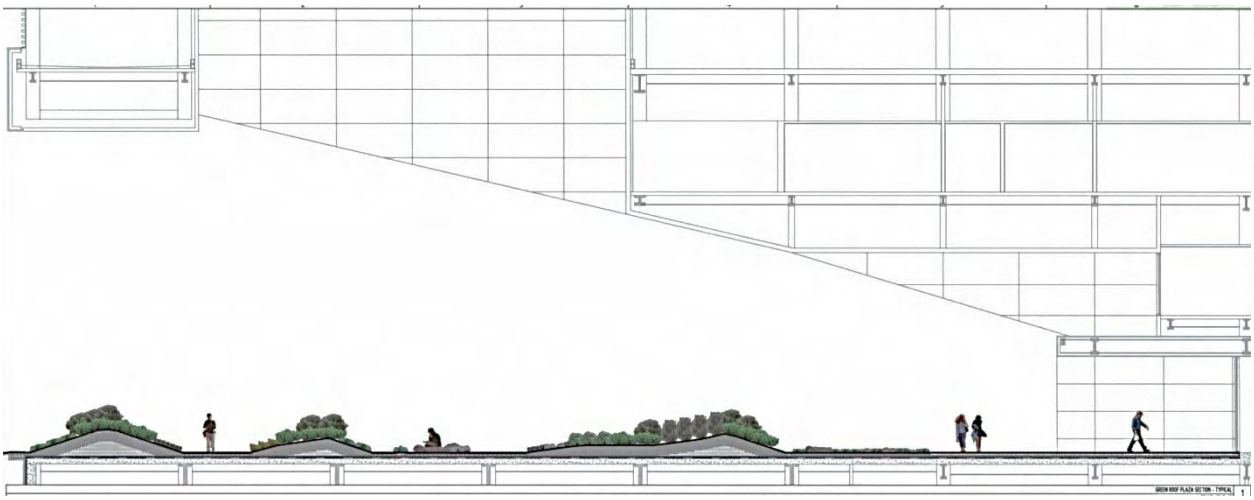


Figure 79: Exterior Plaza - North Section.

Tasks & Activities

The exterior plaza serves as the main entrance to both wings of the building. The space contains the primary architectural feature of the building, the 154 foot double cantilever that covers the exterior plaza. The meandering pathway under the cantilevered structures oculus exists to create a relaxing environment for users. The indirect routes and topography have been noted as deterrents of heavy traffic in this area due to the Nanotechnology lab below as vibrations are a primary structural design concern in this lab space. Primary tasks of this area will be simple foot travel into and out of the building with somewhat limited use of the gardens meandering pathway.

Materials

Table 33: Exterior Plaza Materials List.

Surface	Reflectance
*Grass***	*0.26*
*Fern Area***	*0.24*
*Ornamental Grass***	*0.26*
*Ground Cover***	*0.15*
*Mulch***	*0.20*
*Pathway***	*0.22*
*Sidewalk***	*0.28*
*Brick***	*0.26*
*Silver Paneling***	*0.34*
*Copper Paneling***	*0.34*

**Values from AGi32 swatches for similar materials

Design Considerations

- Gardens:
  - Considerations (IESNA Handbook)
    - Appearance of Space and Luminaires
    - Color Appearance
    - Direct Glare Avoidance
    - Light Distribution on Surfaces
    - Light Pollution/Trespass
    - Modeling of Faces
    - Peripheral Detection
    - Reflected Glare
    - Shadows
  - Design Suggestions
    - Horizontal 1.0fc (IESNA Handbook – Gardens: Paths)
    - Vertical 0.3fc (IESNA Handbook – Gardens: Paths)
    - Power Densities (ASHRAE 90.1, Table 9.4.5)
      - Building Grounds (walkways less than 10'wide)
        - 1.0W/Linear Foot (Tradable)
      - Walkways greater than 10' wide & Plaza Areas
        - 0.2W/SF (Tradable)
      - Canopies & Overhangs
        - 1.25W/SF (Tradable)
      - Building Facades
        - 1.25W/SF (Non-Tradable)

The exterior plaza will fall under ASHRAE 90.1, Table 9.4.5 LPD classification of Canopies and Overhangs, thus allowing the area of focus to be categorized at 1.25W/SF. The area under the cantilever is 28,423SF, allowing the use of 35,528 total connected watts of lighting fixtures in this area.

Luminaire Schedule

Table 34: Exterior Plaza Luminaire Schedule.

Type	Manuf.	Catalog No.	Description	Location	Ballast	Lamp	VA	Input Watts	BF	Volt
CAN-Ua	Elliptipar	M152-210C-V-06-2-V00	Adjustable wall mounted cooper color finish metal halide uplight.	Cantilever Underside Wash	Philips: AS205WQUA DEE	(1) Philips: CDM210/T9/930/ U/E	257.78	232.00	1.00	277V
CAN-Ub	Elliptipar	M151-070G-X-06-2-V00	Adjustable wall mounted cooper color finish metal halide uplight.	Cantilever Underside Wash	Philips: 71A5237P	(1) Philips: CDM70/T6/842	94.44	85.00	1.00	277V
CAN-R	Cooper: Iris	P406TAT-MH4CMH 39T6E-E4CMHCB-MB	Recessed medium beamlens downlight with 4"x4" square aperture.	Exterior Plaza Entryways and Sidewalks	Philips: 71A5037BP	(1) Philips: CDM35/T6/842	53.33	48.00	1.00	277V
CAN-W	Cooper: Iris	P406TAT-MH4CMH 39T6E- E4LWW-8H-SF-MTP4MB	Recessed Lens Wall Wash Luminaire with 4"x4" aperture.	Exterior Plaza Lobby Entryways	Philips: 71A5037BP	(1) Philips: CDM35/T6/842	53.33	48.00	1.00	277V
CAN-L	Elliptipar	F164-T128-H-07-2-000	2' cantilevered-pole-mounted fluorescent wall washing luminaire. Finish is to match metal paneling.	Cantilever Oculus	Philips - Centium: ICN-4S54-90-C2LS	(1) Philips: 54W/840 Min Bipin T5 HO ALTO	59.56	58.50	0.99	277V
XPO-1	Louis Poulsen	Kipp Model 416 with post 4.5-12 Black	PSU Campus standard pole mounted luminaire. 12' post height/	Exterior Pathways	Philips: 71A5337BP	(1) Philips: CDM 100W/840 Med ED17P CL ALTP+FB	131.11	118.00	1.00	277V

Note: Comprehensive Luminaire Schedule can be found in Appendix F: Comprehensive Luminaire Schedule.

Table 35: Exterior Plaza Light Loss Factors.

Fixture Type	LDD	LLD	RSDD	BF	Total LLF
CAN-Ua	0.90	0.913	0.75	1.00	0.616
CAN-Ub	0.90	0.852	0.75	1.00	0.575
CAN-R	0.90	0.867	0.95	1.00	0.741
CAN-W	0.90	0.867	0.95	1.00	0.741
CAN-L	0.90	0.890	0.79	0.99	0.626
XPO-1	0.85	0.860	0.90	1.00	0.658

*LDD calculated from new IESNA guidelines for Clean Environment based on 12 month cleaning interval.

Renderings & Color Images

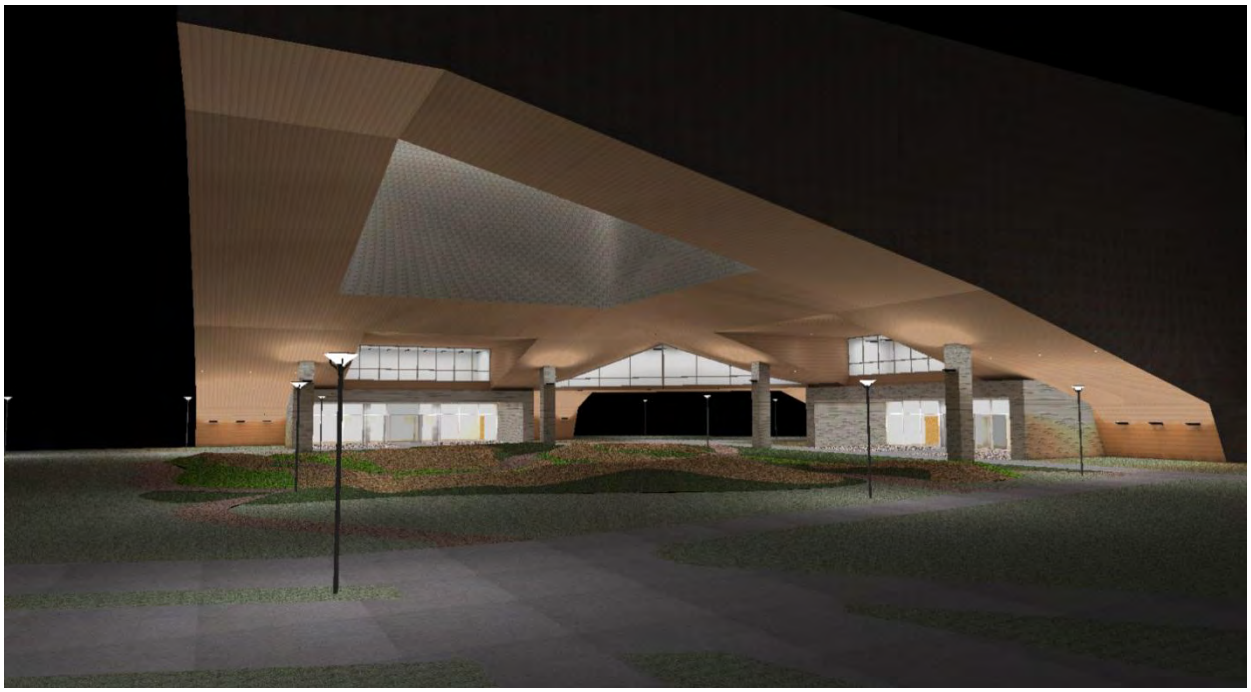


Figure 80: Exterior Plaza Lighting Design - Perspective View.

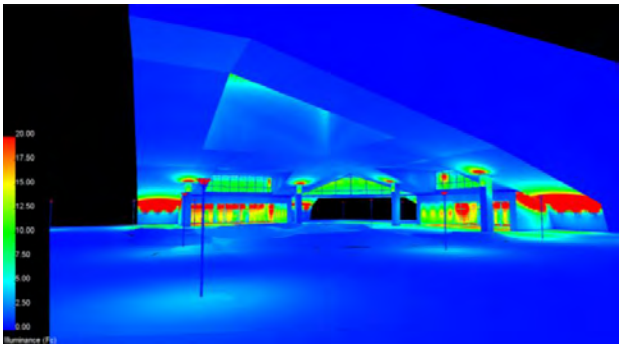


Figure 81: Exterior Plaza Lighting Design - Perspective View (Color: Illuminance).

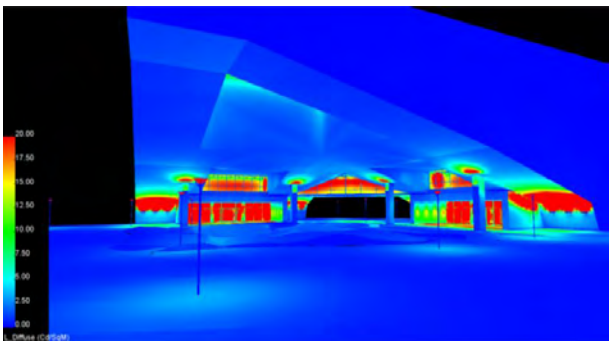


Figure 82: Exterior Plaza Lighting Design - Perspective View (Color: Luminance).

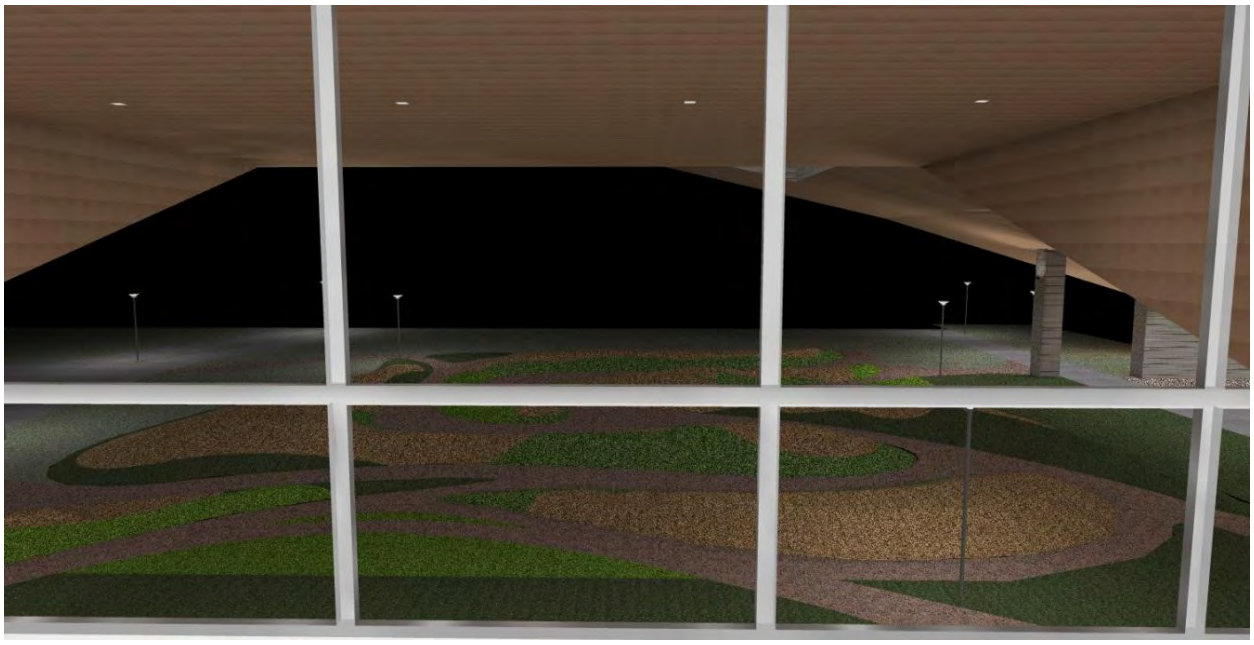


Figure 83: Exterior Plaza Lighting Design - Perspective View from 2nd Floor.

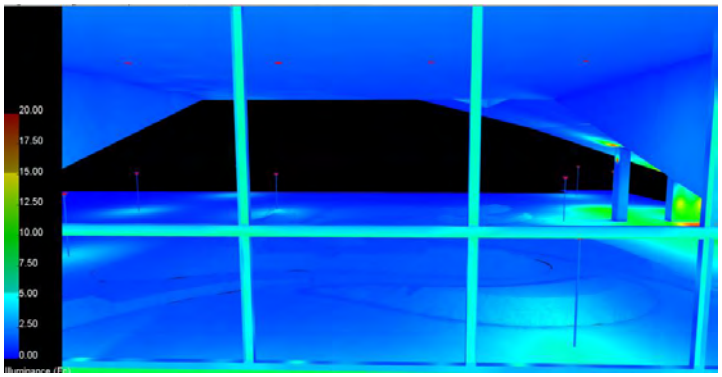


Figure 84: Exterior Plaza Lighting Design - Perspective View from 2nd Floor (Color: Illuminance).

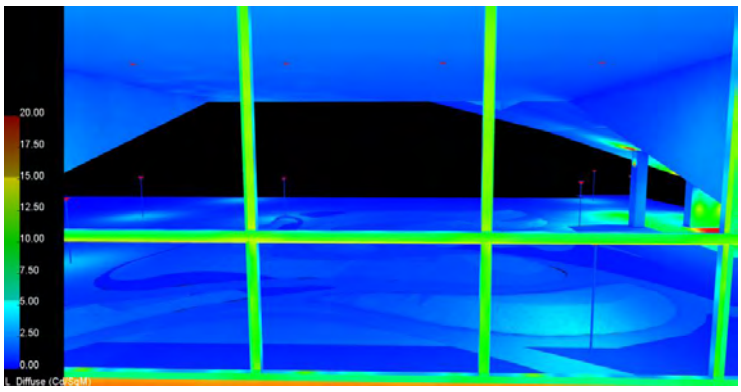


Figure 85: Exterior Plaza Lighting Design - Perspective View from 2nd Floor (Color: Luminance).

Figure 86: Exterior Plaza Lighting Design - Perspective View of Entrance & Lobby.

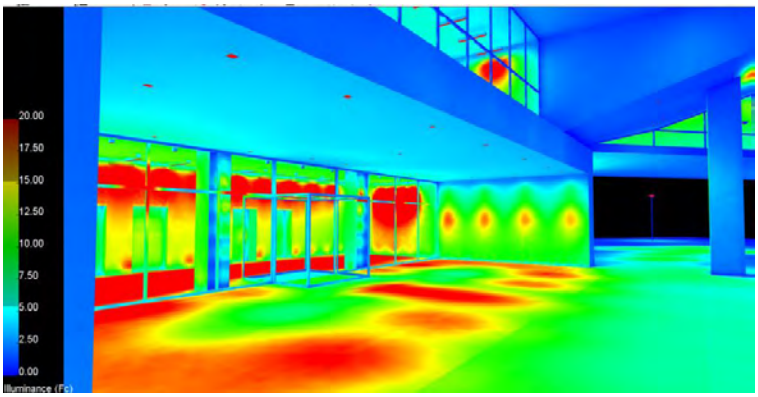


Figure 87: Exterior Plaza Lighting Design - Perspective View of Entrance & Lobby (Color: Illuminance).

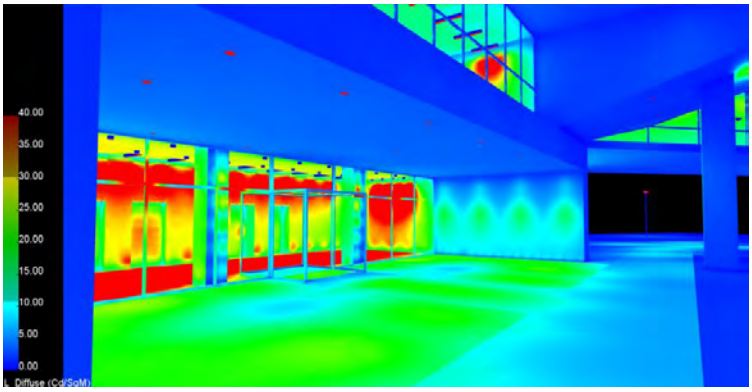


Figure 88: Exterior Plaza Lighting Design - Perspective View of Entrance & Lobby (Color: Illuminance).

Figure 89: Exterior Plaza Lighting Design - Perspective View from South of Bridge.

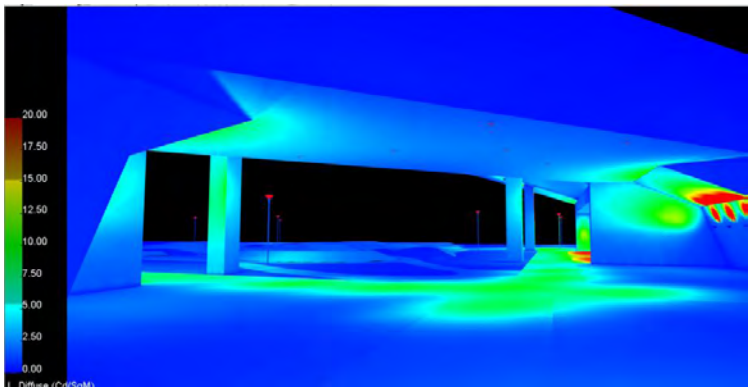


Figure 90: Exterior Plaza Lighting Design - Perspective View from South of Bridge (Color: Illuminance).

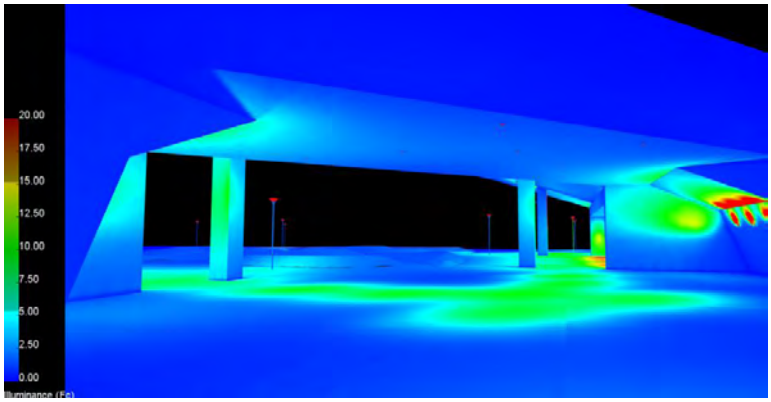
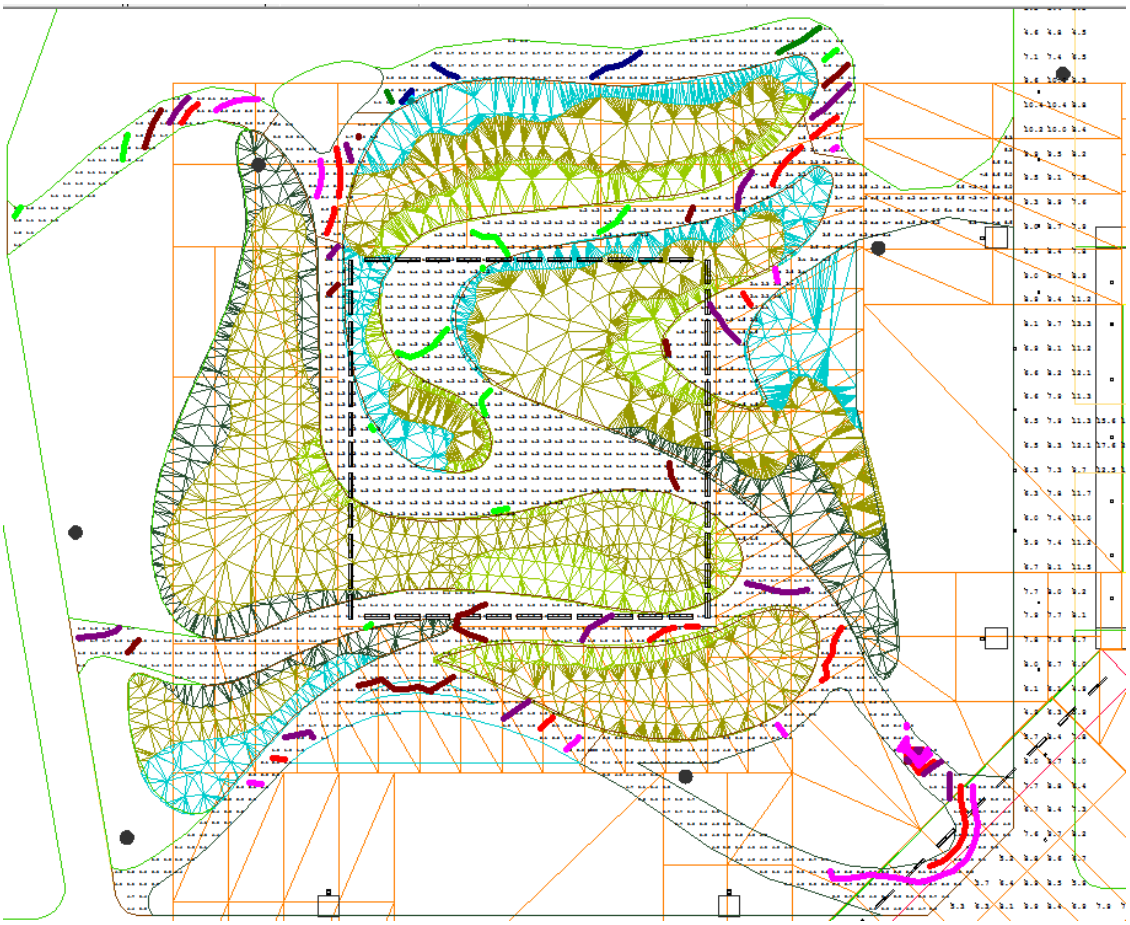


Figure 91: Exterior Plaza Lighting Design - Perspective View from South of Bridge (Color: Illuminance).

Performance Summary

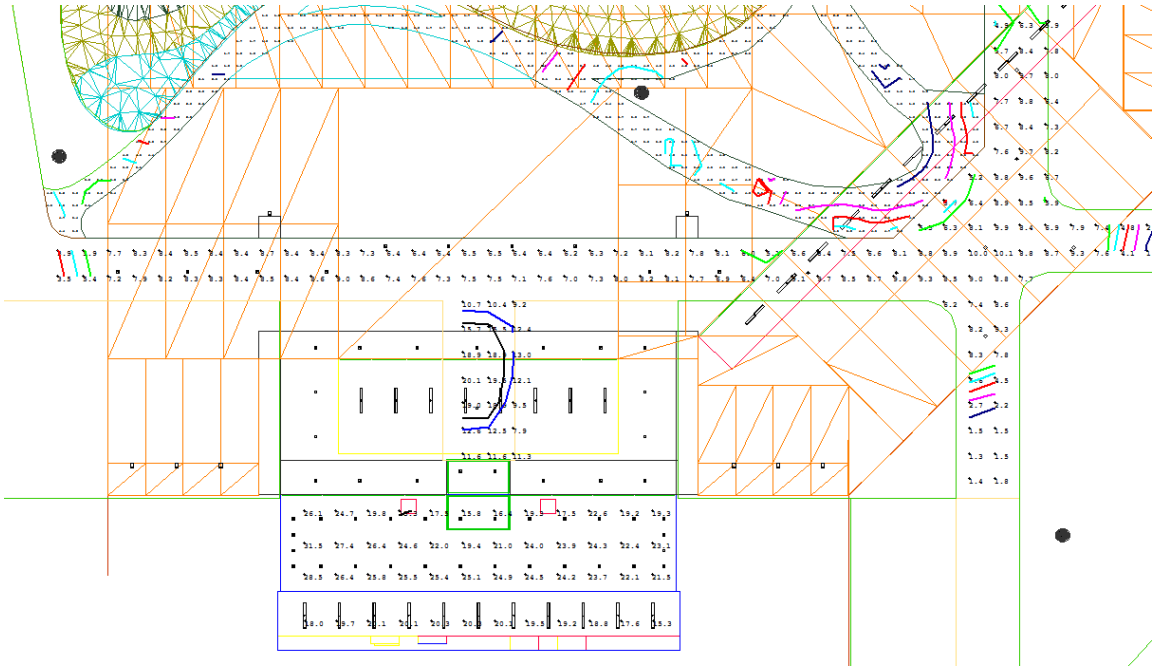
Table 36: Exterior Plaza Illumination Summary.

Exterior Plaza Illumination Summary	Sidewalks	Meandering Path	Entryway
Avg. Illuminance (FC)	9.00	2.12	13.09
Max. Illuminance (FC)	20.90	9.30	20.10
Minimum Illuminance (FC)	3.10	0.60	7.90
Avg/Min	2.90	3.53	1.66
Max/Min	6.74	15.5	2.54
Max/Avg	2.32	4.39	1.53
Coefficient of Variation	0.35	0.92	0.23
Uniform Gradient	2.69	1.17	2.21
Power Density (W/SF)		0.357	



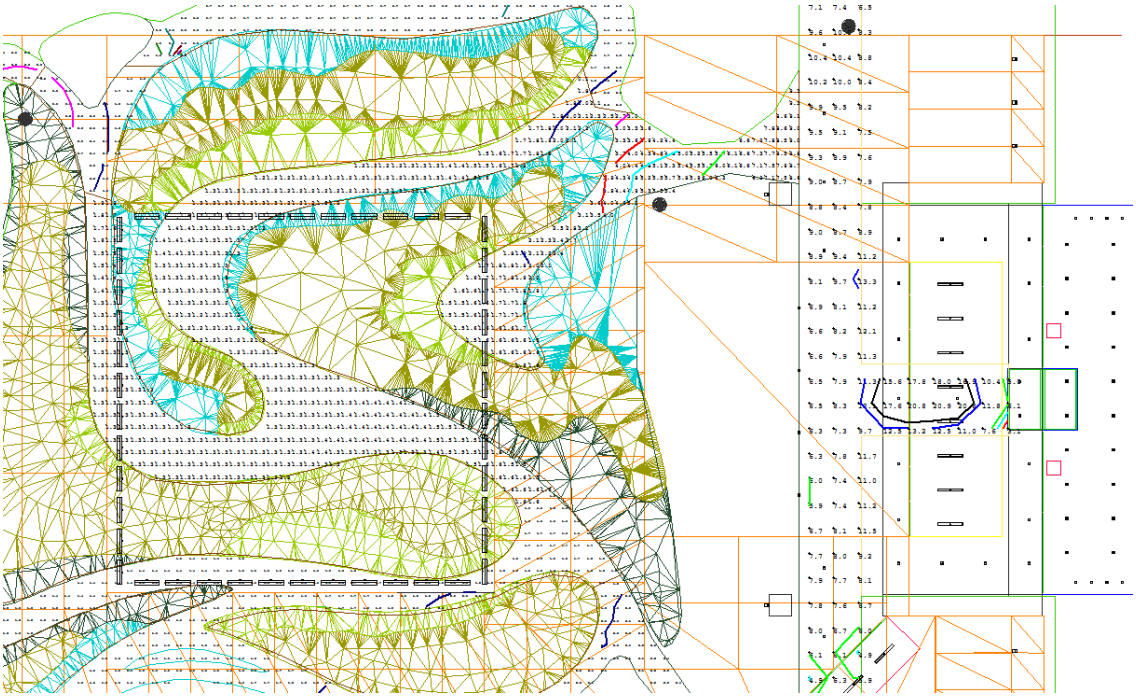
0.1fc - 0.25fc -0.5fc - 0.75fc - 1fc - 1.25fc - 1.5fc - 1.75fc- 2fc - 2.5fc

Figure 92: Meandering Path Illumination Contours.



0.1fc - 0.3fc - 0.6fc - 0.9fc - 1fc - 2fc - 3fc - 4fc - 6fc - 5fc - 12.5fc- 15fc

Figure 93: Life Science Entrance Illumination Contours.



0.1fc - 0.3fc - 0.6fc - 0.9fc - 1fc - 2fc - 3fc - 4fc - 6fc - 5fc - 12.5fc- 15fc

Figure 94: Life Science Entrance Illumination Contours.

Controls

The exterior plaza lighting will be controlled along with other site lighting via two lighting control panels and remote control breakers. There will be a normal power system lighting control panel as well as a normal/emergency lighting control panel feeding all exterior lighting for the Millennium Science Complex. These panels will be located in the basement of the Material Science wing in room N-P052.

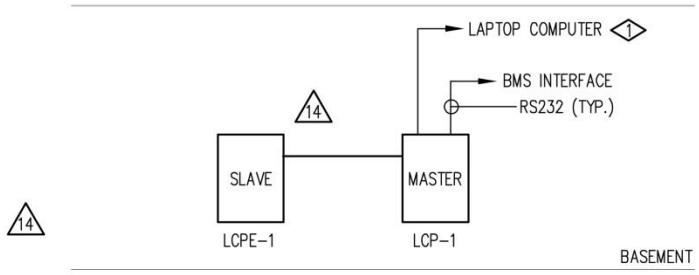
Eaton Cutler Hammer's lighting control panel Pow-R-Command 750 will allow use of up to 3 additional 42-panels, called expansion panels, for a total of 168 remote control breakers. The main panel will control the expansion panels via a subnet communication integrated controller.

The normal distribution system will feed LCP-1, which will use subnet communication systems to control breakers on LCPE-1. The zone control settings will be as follows:

Table 37: Exterior Lighting Control Schedule.

Zone	Time On	LCP-1	LCPE-1
Exterior Pathways	Dusk to Dawn	4,6,29,31,33	
Exterior Stairwells	Dusk to Dawn		2,4,9,11
Plaza Sidewalks	Dusk to Dawn	5,30,32	7
Plaza Entryways	Dusk to Dawn	17,21,24,26	
Cantilever Wash	Dusk to 12PM	11,28	
Oculus Lighting	Dusk to 12PM	14,18,25,27	
Lobby Lighting	24 Hours	1,7,9,13,15,12,35,36	37,43
Loading Dock	Dusk to Dawn		8

The existing system is set up in a similar fashion, and a detailed system description can be found on the following page in Figure 95: Existing Controls for Exterior Lighting.



LIGHTING CONTROL SCHEMATIC DIAGRAM
N.T.S

NOTES:

1 CONTRACTOR TO SUPPLY A NOTEBOOK WITH THE FOLLOWING SPECIFICATIONS:

SYSTEM COMPONENTS:	DELL LATITUDE D420 INTEL® CORE™ DUO PROCESSOR ULV U2400 (1.06GHZ, 533MHZ), GENUINE WINDOWS XP PROFESSIONAL, SP2, WITH MEDIA UP TO 3.0 HOURS BATTERY
CATALOG NUMBER:	4 BLDWGSD

MODULE	DESCRIPTION
LATITUDE D420	INTEL ®CORE™ DUO PROCESSOR ULV U2400 (1.06GHZ, 533MHZ)
OPERATING SYSTEMS	GENUINE WINDOWS XP PROFESSIONAL, SP2, WITH MEDIA
LCD	12.1 INCH WIDE SCREEN WXGA LCD PANEL
MEMORY	1.5GB DDR2-533 SDRAM, (512MB INTEGRATED) 2 DIMMS
INTERNAL KEYBOARD	INTERNAL ENGLISH KEYBOARD
GRAPHICS	INTEL ®INTEGRATED GRAPHICS MEDIA ACCELERATOR 950
HARD DRIVES	60GB HARD DRIVE, 8MM, 4200RPM
FLOPPY DRIVE	NO FLOPPY DRIVE
AC ADAPTER	65W A/C ADAPTER
PRIMARY EXTERNAL OPTICAL DRIVE OPTIONS	D-BAY PLUS 8X DVD+/-RW W/ROXIO™ AND CYBERLINK POWER DVD™
WIRELESS LAN (802.11)	INTEL ®3945 802.11A/G DUAL-BAND MINI CARD
RESOURCE CD	RESOURCE CD AND REFERENCE GUIDE
BATTERIES	4 CELL PRIMARY BATTERY
CARRYING CASES	DELL CORPORATE BACKPACK
WARRANTY & SERVICE	3 YEAR LIMITED WARRANTY PLUS 3 YEAR MAIL-IN SERVICE
FILE SYSTEM	NTFS FILE SYSTEM FOR ALL OPERATING SYSTEMS
ADDITIONAL BATTERIES	ADDITIONAL 9 CELL EXTENDED BATTERY
MISCELLANEOUS	D420 DUAL
PURCHASE INTENT	PURCHASE IS NOT INTENDED FOR RESALE.
OS LABELS	WINDOWS XP BRAND

ACCESSORIES

KENSINGTON POCKETMOUSE PRO USB WIRELESS LASER MOUSE
DELL PART# A0625678
MANUFACTURER PART# 72268
DELL PART# A0625678

Figure 95: Existing Controls for Exterior Lighting.

Building Information Modeling

The definition of B.I.M (Building Information Modeling) as defined by the industry is:

"Building Information Modeling is the process of generating and managing building data during its life cycle."

This is a broad definition that encompasses many of the modeling and design aspects of architectural engineering. As a team of Architectural Engineers, Building Stimulus has come to realize that with a building of this size and stature, the end user is the one who can benefit the most from a detailed B.I.M. model.

Planning with BIM

During pre-construction, the BIM process can enhance coordination amongst all disciplines before construction even begins. 3D models can act as site utilization plans, communicating how the project will change through various phases of construction. Models can produce take-offs providing the most accurate quantities that can be used to develop detailed estimates as well. As pre-construction progresses, owners, as well as sub-contractors, are given a better understanding of the project at hand.

While CPM schedules can show the linear progression of important activities, it fails in helping to visualize the actual construction of the project. Developing an intricate schedule, and linking to accurate 3D models, a 4D model can be created, producing a tool to visualize and communicate the actual construction process to sub-contractors and owners.

Building Stimulus developed a 4D model consisting of the existing steel structure, as well as the architectural precast panels and the glazing. The model was linked to the revised schedule of the proposed double-skin façade. The 4D model was used as a descriptive visualization tool meant to detail the erection process of the architectural precast panels. Below are screenshots of the animation:

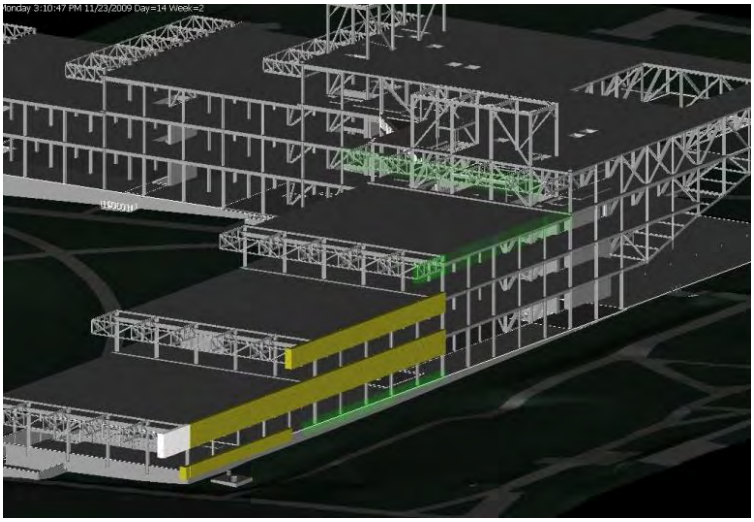


Figure 96: 4D Model of North Façade.

Figure 96 is a screen shot from Building Stimulus' 4D model. The image depicts the installation of precast panels along the North façade. Green regions represent panels in the process of being installed while the yellow represent secured and installed panels.

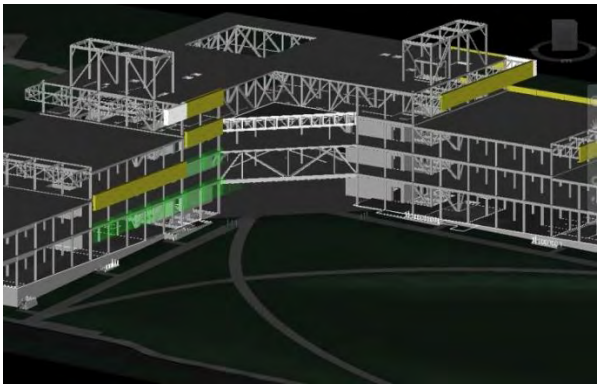


Figure 97: Precast Panel 4D Model.

For buildings such as the Millennium Science Complex, the sequence of an activity, in this case the installation of precast panels, may change locations as the project progresses, as see in Figure 97. 4D models are an optimum tool for expressing the sequence of activities of large projects such as the Millennium Science Complex.

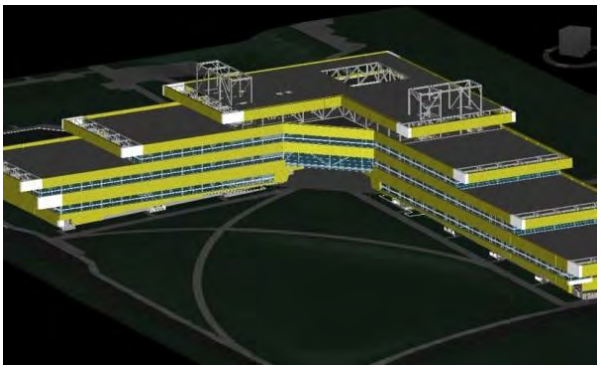


Figure 98: Completed Precast Panel 4D Model.

The use of a double-skin façade significantly altered the sequence of construction for the Millennium Science Complex, yet using the 4D model, the installation of precast panels is easily conveyed

Construction & Coordination

Precise 3D modeling allows MEP trades to hash out conflicts in a conference room rather than in the field. James Faust, Facilities Manager for the Federal Reserve Bank and professor at the Pennsylvania State University once said, “It costs the owner $1 to change an idea on a computer screen, $10 on paper, and $100 in the field.” With this motto in mind, Building Stimulus can help catch construction and planning issues before they become a problem in the field.

Building Stimulus developed detailed 3D models for structural, mechanical, and electrical systems. Using these models, clash detections were run on two week intervals. While clash detections can be a great benefit to a team’s progress, the process is useless without proper communication. At the conclusion of each clash detection, the clashes were separated by types and systems involved. During weekly meetings, team members were informed of current clashes and areas of each model in need of revision. Clash detections benefited Building Stimulus by expediting the development of each 3D model. In doing so, accurate take-offs and measurements could be acquired from the most recent models. Below are instances of frequent clashes encountered by Building Stimulus:

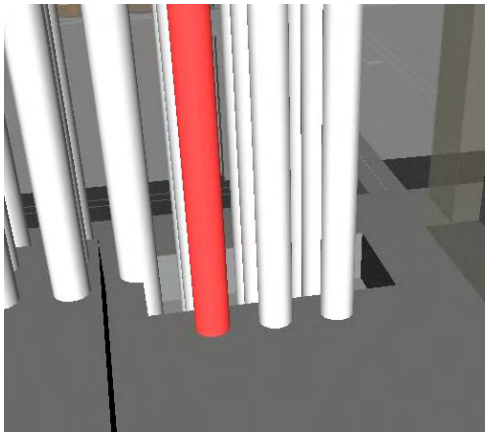


Figure 99: Conduit/Floor Slab Clash.

Figure 99 represents a sample clash encountered by Building Stimulus. As clash detection runs, it transposes the structural 3D model on to the electrical 3D model and alerts you of where they models intersect. Here it is clear that conduit risers are missing the opening in the floor slab that was intended for them to run through. In this case, the electrical designer is notified at team meetings and adjusts the locations of his conduits to meet the needs of the model.

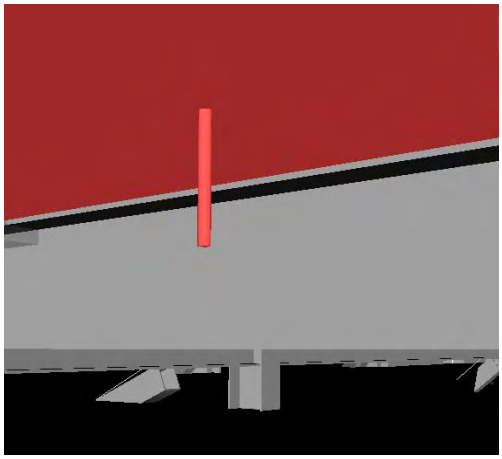


Figure 100: 2nd Floor Light Fixture Clash.

Building Stimulus ran clash detections for the 3rd floor spaces only. Figure 100 is an image of the underside of the 3rd floor slab (in red) on the structural beam. The vertical metal rod (also red) represents the upper connection of a 2nd floor light fixture coming up from below. This clash requires 2nd floor light fixtures to be offset 1’ downwards.

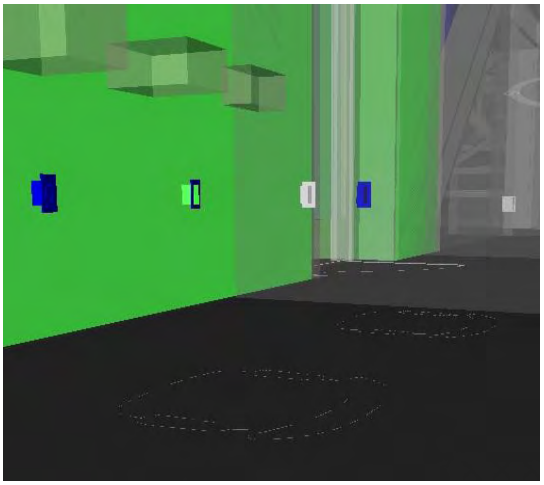


Figure 101: "Allowed" Clash.

While clash detections can help bring model conflicts to light, the process is not perfect. Benign clashes, such as the one in Figure 101, need to be addressed and acknowledged. Figure 101 shows a receptacle in a wall. The model recognizes the receptacle as a 'clash' even though it is in the correct location. The 'clash' is addressed and labeled 'Allowed', hence the green, not red, color. The clash is then removed from the list of unaddressed clashes.

Facilities Management

As the owner pays for a BIM model, there must be a significant cost savings created by the process in order for it to be justified. In addition to improved estimating, scheduling, construction coordination, and the capability of accurate pre-fabrication, the end-user application of facility management has many reoccurring benefits to the owner.

A trained facility management team can use a B.I.M. model as a solid resource for a vast array of equipment information. Each piece of equipment throughout the B.I.M. model has the ability to be tagged with information such as manufacturer, equipment model & equipment number, web-links, replacement parts numbers, user and operation manuals, and countless other parameters. If Penn State's Facility Management team at the Millennium Science Complex wished to, they could require that the building designers and construction team input specific data into the model as per their own requirements.

A small example of building information into a model for facilities management teams has been completed for luminaires affected by lighting design changes in the third floor. Examples of the information put into the BIM model can be found in Appendix H: Lighting Fixture Cutsheets after each of their respective cutsheets. The following section details an example of the process and the information used to compile a BIM Model.

Light Fixture Modeling & Circuiting

Modeling and circuiting lighting fixtures is quite similar to that of circuit and modeling receptacles. There is more use from supplying families and types with more information, for the information can be used to fill a luminaire schedule created from Revit MEP. Each lighting fixture type for lighting redesigns on the third floor were modeled in Revit and given the following parameters:

- Family Name
  - Family Type
    - Electrical
      - Lamp
      - Number of Lamps
      - Wattage Comments
    - Electrical Loads
      - Load Type
      - Apparent Load
    - Photometrics
      - Tilt Angle
      - Photometric Web File (.ies File)
      - Light Loss Factors
      - Initial Intensity
      - Initial Color
    - Identity Data
      - URL (Link to Manufacturer Webpage)
      - Model Number
      - Manufacturer
      - Lighting Fixture Type
      - Description (For Luminaire Schedule)
      - Ballast Manufacturer
      - Ballast Number
      - Keynote
- Electrical Connector
  - Number of Poles
  - Power Factor State
  - Load Classification
  - Voltage
  - Apparent Load Phase 1
  - Apparent Load Phase 2
  - Apparent Load Phase 3
  - Power Factor

Electrical connector properties and family properties for each of the luminaire families used in the Building Stimulus third floor electrical model can be found after the respective cutsheet in Appendix H: Lighting Fixture Cutsheets.

Renovations

As an intensive science research building, Millennium Science Complex will undoubtedly have research labs and environments changed as research needs change. Exchanging fit-outs in labs can be a hassle for the users and owners, as down time means money lost. Providing the owner and facilities management team with a descriptive and accurate existing conditions three-dimensional model can help expedite the speed of both design and construction of future lab fit-out renovations.

BIM Execution Plan

Table 38: BIM Goals Table.

PRIORITY (HIGH/ MED/ LOW)	GOAL DESCRIPTION	POTENTIAL BIM USES
H	Assess Cost Associated with Design Changes – compare money spent/saved vs. quantitative benefit of design change	Cost Estimation, Existing Conditions Modeling
H	Increase Effectiveness of Design – Increase efficiency of structural system, lighting/electrical system, and mechanical system	Design Authoring, Design Reviews, 3D Coordination, Engineering Analysis, Existing Conditions Modeling
H	Interdisciplinary Design Coordination – Effectively implement BIM through open communication and periodical design reviews	Design Reviews, 3D Coordination
M	Increase Effectiveness of Sustainable Goals – Increase thermal and lighting efficiency through implementation of double skin façade	Engineering Analysis, LEED Evaluation, Daylight Integration
M	Improve On-Site Coordination and Efficiency	Site Utilization Planning, 4D Modeling

Table 39: BIM Use Analysis

BIM Use*	Value to Project	Responsible Party	Value to Resp Party	Capability Rating			Proceed with Use
				Resources	Competency	Experience	
Design Authoring	Medium	Sara	Medium	1	3	3	Yes
		Mike	Medium	1	3	3	
		Paul	Medium	1	3	3	
Record Modeling	Medium	Sara	Low	2	2	2	No
		Mike	Low	2	2	2	
		Paul	Low	2	2	2	
Site Utilization Planning	Medium	Jon	High	3	2	1	Yes
Existing Conditions Modeling	High	Jon	Low	2	3	2	Yes
LEED Evaluation	High	Sara	High	2	2	1	Yes
		Mike	High	2	2	1	
		Paul	Low	2	2	1	
		Jon	Medium	2	2	1	
Energy Analysis	High	Sara	High	3	3	2	Yes
Structural Analysis	High	Paul	High	3	3	2	Yes
Cost Estimation	High	Jon	High	3	2	2	Yes
4D Modeling	Medium	Jon	High	3	2	2	Yes
3D Coordination (Design)	High	Sara	Medium	3	2	2	Yes
		Mike	Medium	3	3	3	
		Paul	Medium	3	2	2	
		Jon	High	3	2	2	
Daylight Integration & Lighting Analysis	Medium	Mike	High	3	2	2	Yes
Building Systems Analysis	Medium	Sara	High	2	2	2	No
		Mike	Medium	2	2	2	
		Paul	Low	2	2	2	
Design Reviews	Medium	Sara	High	3	3	3	Yes
		Mike	High	3	3	3	
		Paul	High	3	3	3	
		Jon	High	3	3	3	

Design Authoring

Description: "A process in which 3D software is used to develop a BIM model based on criteria that is important to the translation of the building's design. Two groups of applications at the core of BIM – base design process are design authoring tools and audit and analysis tools.

Authoring tools create models while audit and analysis tools analyze or add to the richness of information in a model. Most of audit and analysis tools can be used for Design Review and Engineering Analysis BIM Uses. Design authoring tools are a first step towards BIM and the key is connecting 3D model with powerful database of properties, quantities, means and methods, costs and schedules." (BIM Project Execution Planning Guide)

Goal: Building Stimulus felt it would be necessary to develop and maintain an updated model from the aspect of all disciplines. Design authoring tools could enhance the use of BIM by allowing each discipline to create and update models, and create collaboration across disciplines. The design authoring of models can enhance each group members overall understanding of the project through the design process.

Outcome: Whiting-Turner, as well as RV Architects, provided Revit Architectural and Structural models that enabled certain disciplines to pursue the design and modeling routes initially planned. However, some models lacked the key information or details that could have created a more effective model. Structural models lacked key connection details, and architectural models were aesthetically accurate, yet occasionally lacked dimensional details on certain assemblies.

Site Utilization Planning

Description: "A process in which a 4D model is used to graphically represent both permanent and temporary facilities on site, with the construction activity schedule. Additional information incorporated into the model can include labor resources, materials and associated deliveries, and equipment location. Because the 3D model components are directly linked to the schedule, site management functions such as visualized planning, short-term re-planning , and resources can be analyzed over different spatial and temporal data." (BIM Project Execution Planning Guide)

Goal: 3D modeling can be very effective in portraying on-site activities at a given point in time. 3D models can be used to develop site utilization plans to show the various phases of the construction process. This model could help focus on changes to General Conditions estimates, as well as on-site coordination.

Outcome: While site utilization plans are a very effective and informative tool to provide owners and sub-contractors, they demand an extensive coordination effort for the entire project. Site utilization plans were provided, yet without the use of 3D software. Building Stimulus found that site utilization revisions using 3D models would have been cumbersome, and time consuming, without providing substantial benefits.

Engineering Analysis

Description: "A process in which intelligent modeling software uses the BIM model to determine the most effective engineering method based on design specifications. Development of this information is the basis for what will be passed on to the owner and/or operator for use in the building's systems with respect to energy analysis. These analysis tools and performance simulations can significantly improve the design of the facility and its energy consumption during its lifecycle in the future."

Energy Analysis

Goal: Energy modeling is an effective design approach to determine a more realistic profile of the building's profile. The purpose of this BIM use was to further develop the existing 3D model to incorporate more accurate power densities for the building.

Outcome: Throughout this project, energy models were developed in Revit MEP and Trane TRACE by exporting .gbXml files from Revit MEP to TRACE. This allowed the energy analysis to be updated to more accurately represent the actual energy consumption. It involved an iterative process that could not be fully realized until towards the end of the design phase to allow all the equipment and energy consumption parameters to be modeled to provide a more accurate energy profile.

Structural Analysis

Goal: Structural analysis is necessary to design the supporting structure of the building for applicable lateral and gravity loading. The goal of this BIM use was to accurately model the redesign structure for use in performing a structural take off, 4D modeling, and clash detection.

Outcome: A 3D analytical model of the structural system of the Millennium Science Complex was created in ETABS for the lateral model and SAP 2000 for the cantilever redesign. The main issue with utilizing BIM and structural analysis is the cross-platform interoperability of analysis software and BIM software such as Revit. Neither ETABS or SAP have a plug-in available for importing models to Revit for integration uses. Thus, in this thesis project a model had to be maintained concurrently in both the analysis software and modeling software. This is obviously not an optimal solution for achieving the best BIM processes.

Daylight Integration & Lighting

Goal: To achieve energy efficient lighting designs by incorporating natural daylight contribution into a room to help achieve desired illuminance levels, increase user comfort and visual appearance of the space.

Outcome: Throughout perimeter public spaces of the Millennium Science Complex, the dimming of electrical lighting has coincided with daylight levels to maintain a constant illuminance levels in public spaces. This has lowered electrical usage throughout the building. In private spaces, luminaire switching allows for occupants create a personalized environment that can maximize their perception of their space. Dynamic shading louvers on the plan-west and plan-south facades help eliminate blinding glare of direct sunlight while allowing ambient sunlight to fill the space. Existing fabric roller shades on the remaining facades proved efficient in minimizing direct glare.

Building Systems Analysis

Description: A process that measures how a building's performance compares to the specified design. This includes an analysis of the mechanical system operational characteristic including the energy use of a building. Other aspects of this analysis could include, but are not limited to, ventilated façade studies, lighting analysis, internal and external CFD airflow, and solar analysis.

Goal: Alternative energy sources, such as wind turbines, were evaluated to determine the applicability for the building's use. Also, a new mechanical system was evaluated for energy savings possibilities.

Outcome: Wind turbines were analyzed by completing an external CFD airflow model of the building and its surrounding structures. The CFD software Phoenics was used. Through the implementation of BIM, .stl files for

the buildings' shapes and sizes were exported from AutoCad 3D files to Phoenics to more accurately simulate the airflow. BIM also enhanced the coordination between the lighting and mechanical systems during the redesign to incorporate luminaire integrated chilled beams. The allowed an enhanced integrated discipline design for the building systems.

Cost Estimation

Description: "A process in which a BIM model can be used to generate an accurate quantity take-off and cost estimate early in the design process and provide cost effects of additions and modifications with potential to save time and money and avoid budget overruns. This process also allows designers to see the cost effects of their changes in a timely manner which can help curb excessive budget overruns due to project modifications." (BIM Project Execution Planning Guide)

Goal: The material take-off process can be a tedious effort. 3D models can provide quick and effect take-offs to be used with cost data, resulting in a hastened estimate process. Cost estimations using 3D software demand accurate and detailed models from all disciplines to obtain the most accurate estimate. The BIM process is greatly enhanced when cost data is incorporated and communicated to all parties involved. Trades and disciplines become aware of the financial state of the design and if any changes must be made to reduce costs.

Outcome: 3D models and computer software greatly expedited the take-off process. Revit Architecture developed and automatically updated and maintained fixture schedules and quantities. Electronic cost databases were not available, so other means of cost research was required.

While some software was extremely beneficial, the lack of accurate models did hinder the take-off process of the structural system. Structural Revit models lacked the required detail to create an accurate take-off of the area of focus so electronic take-offs were performed by other means.

In coordination with the structural designer, the construction manager utilized SAP 2000 software to obtain accurate take-offs and quantities of existing structural systems, as well as the redesigned systems.

4D Modeling

Description: "A process in which a 4D model (3d models with the added dimension of time) is utilized to effectively plan the phased occupancy in a renovation, retrofit, addition, or to show the construction sequence and space requirements on a building site. 4D modeling is a powerful visualization and communications tool that can give a project team much better understanding of project milestones and construction plans." (BIM Project Execution Planning Guide)

Goal: 4D modeling is a very effective tool to illustrate the sequence of construction as well as coordinate construction. Building Stimulus decided early on to use a 4D model in any fashion as long as it was effective and useful. The Construction Management student would determine the extent of its use and what the focus of the model would be.

Outcome: Building Stimulus decided to use the 4D model to illustrate the sequence of panel installation on the Millennium Science Complex. Using Revit models provided, including the panel models and structural model, the 4D animation shows the direction of installation and speed at which construction occurs.

3D Coordination

Description: “A process in which clash detection software is used during the coordination process to determine field conflicts by comparing 3D models of buildings systems. The goal of clash detection is to eliminate the major system conflicts prior to installation.” (BIM Project Execution Planning Guide)

Goal: The focus of select disciplines within Building Stimulus was to develop and maintain an updated 3D model of designed systems. Using these models, the Construction Management discipline would utilize clash detection technology to compare updated designs. Upon detection of clashes, the location and clash type will be distributed amongst relevant team members at weekly meetings for revision.

Outcome: Building Stimulus found the clash detection process to be a very quick and effective method to monitor discrepancies and clashes between models. Beginning in mid-March, clash detections were performed on 2-week intervals and given to relevant disciplines for revision. Electrical and structural models experienced the most clashes, with many instances of conduit running through floor slabs and/or structural beams. Many clashes that were experienced were the result of models recognizing acceptable lighting and electrical fixtures not as compatible building systems, but clashes. These clashes were acknowledged as ‘acceptable’ and discarded.

Integrated Project Delivery

With the assistance of Thornton Tomasetti and faculty of the Architectural Engineering program at Penn State, the Integrated Project Delivery (IPD) process was explored and utilized to complete this year-long senior thesis project. The American Institute of Architects (AIA) defines IPD as a project delivery method that, "leverages early contributions of knowledge and expertise through the utilization of new technologies, allowing all team members to better realize their highest potentials while expanding the value they provide throughout the project lifecycle." To effectively implement IPD the goals of the group were established at the beginning of the project and continually evaluated based on developments by each group member.

The IPD approach relies heavily on excellent communication. Establishing methods of communication between four students on different schedules with varying responsibilities in and out of the project, was of particular importance. In today's culture we are rarely without some form of electronic communication. This poses many advantages in terms of staying in touch and up to date on the latest project developments on an instant basis. However, electronic communication cannot account for all transmission of information between group members. Many of the most influential discussions during this thesis project were achieved at a conference table with a pencil and paper. It was during these roundtable discussions where the ability to draw and effectively communicate spatially truly highlights the purpose of learning the principles of architectural drafting in 2nd and 4th year Architectural Studios.

All of this is not to say technology is a hindrance to effective communication, in fact it is much the opposite. It provides an entirely new dimension to the communication process. Outside the use of BIM a number of different technologies were used to effectively communicate and keep the project moving on schedule, including: Google Calendar, Google Chat, Doodle, and Microsoft Project. The figure below is an example of how Google Calendar was used for reference when the master schedule was not available via Microsoft Project. This technology required that each group member had a Google account, all of whom previously did. This calendar format allowed for group members to view their duties in a color format with the ability to receive reminders on upcoming tasks via text message or email. This format also allowed users to view the project schedule with the rest of their personal calendar to manage their time effectively even when on the go, as this format is viewable on a smartphone.

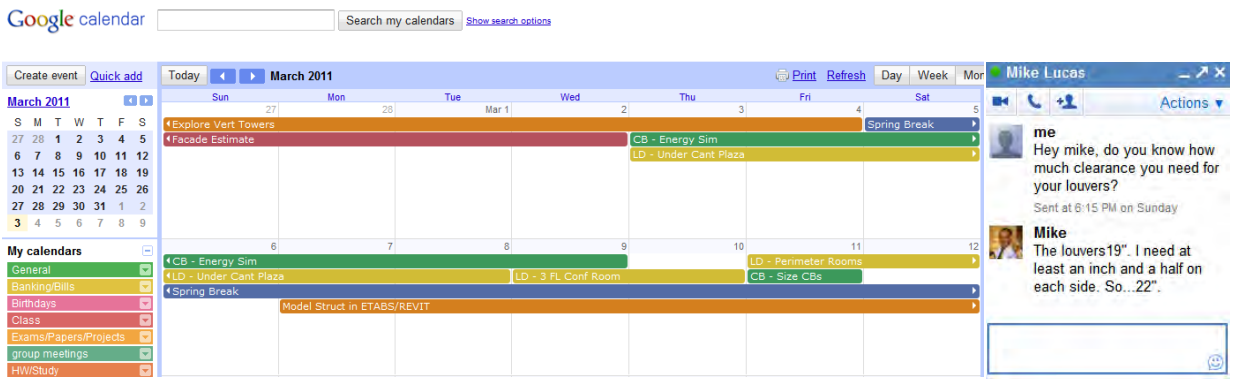


Figure 102: Communication Techniques.

In addition to Google Calendar, Google Chat was also used as a communication tool when group members were working in separate environments. This proved useful when to communicate a small amount of information in a quick an efficient manner.

As stated previously, to work effectively as a team it was necessary to meet at the minimum on a weekly basis in person. Often times the group members were in the thesis lab at the same time and impromptu meetings occurred on a regular basis. However, there were a number of times when trying to plan the next meetings and a common time could not be established. When this situation occurred the group relied on a free online meeting scheduler service called Doodle. As shown in the figure below, Doodle allows the author of the meeting to enter a few available dates and times he/she is available and send an invitation for team members to select when they are available and at what time. This was use periodically throughout the year to schedule meetings when it proved to be difficult in person.

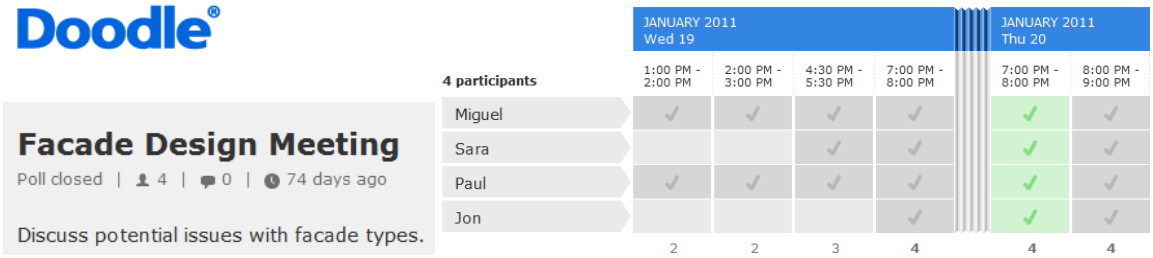


Figure 103: Meeting Time Scheduling Techniques.

Microsoft Project was used to keep track of the master schedule for Building Stimulus. This proved to be a very effective format because each team member was able to view their color coded schedule clearly and easily while being able to view the overall project schedule organized by area of design, ie: façade, cantilever structure, Navisworks update, etc. Another useful tool in Project is the ability to assign a percent complete value to each task. As a group it was agreed that the schedule would be updated at least once per week, by Monday at noon. This allowed for group members to view the progress of certain tasks of other group members and determine whether there was potential for an issue to develop or if progress was on track.

The use of technology certainly aided the process of communication, progress monitoring, and following a schedule. However, technology is a tool that requires motivation and desire for it to be effective. It is easy to delete an email reminder or ignore a meeting invitation but, when a fellow group member asks about the status of task it is much easier to diagnose issues that may be developing and determine the proper method of resolving the problem. Group members of Building Stimulus understood this from the beginning of the project and found effective methods of communication and provided constructive advice to group members experiencing troubles with design or motivation. At team meetings there was always an open line of communication and trust among team members that provided the foundation for each person to feel comfortable taking advice, asking questions, and giving advice. This is essential for highly effective teamwork and producing quality integrated work.

Conclusion

The intent of this thesis report was to explore the redesign of particular systems of the Millennium Science Building utilizing an Integrated Project Delivery Method and Building Information Modeling. Integration and communication among disciplines was key to the success of the project. At the start of the project, overall goals were established and developed using the BIM Execution Plan. Building Stimulus focused the design alternatives to achieve an overall team goal of improving the efficiency and performance of the building while still maintaining the architectural integrity that the architect, Raphael Vinoly, intended for its contribution to the University Park Campus. In order to accomplish this overall goal, three areas of concentration were identified.

The main focus for the design team in order to improve the efficiency of the building's performance involved redesigning the façade of the Millennium Science Complex. This allowed an extensive implementation of integrated project development as this component affected each discipline. A double skin façade was designed to allow for enhanced thermal performance and daylighting control for the perimeter spaces of Millennium Science. After several iterative processes, this design was implemented on two of the building's faces, resulting in an additional cost of $71,686.34, to optimize the cost to performance ratio. The glazing was redesigned to enhance its thermal performance by decreasing the U-value from 0.29 to 0.126, this resulted in a building associated utillity savings $26,909 per year. The current precast panels were redesigned to decrease the panel thickness and in turn cost, and structural load imposed on the building. The panel configuration was also redesigned to accommodate the twenty-four inch air gap necessary for the double skin.

Through the use of BIM processes and Revit MEP, enhanced accuracy in terms of modeling the building's energy performance was also achieved. By modeling the mechanical and electrical components, the original energy model developed in the fall semester was revised to account for accurate plug loads designated in the laboratory spaces to obtain a more realistic energy profile. In order to facilitate the energy performance, lighting designs were created to efficiently meet IESNA design criteria and ASHRAE 90.1 lighting power densities. Lighting designs were also incorporated with the mechanical system through the implementation of chilled beams in the office spaces to reduce energy consumption by 1465 MBTU per year.

The final area of concentration for Building Stimulus lied with the most iconic portion of the building, the large cantilever. At the cantilever is where the two wings of the building, Life Science and Material Science, join to merge the two research facilities. The truss system of the cantilever was modified by introducing an additional column to each truss, decreasing the unsupported length of the cantilever by 22 feet. This resulted in a reduction in deflection at the tip of the cantilever of 0.7 in. The web and chord members were also redesigned to be optimized for strength and deflection, resulting in a savings of 76 tons of steel and $144,645.37 . Underneath the cantilever, a new lighting design for the existing plaza was created to enhance the iconic stature of the cantilever.

Building Stimulus utilized BIM throughout the duration of this thesis project. The use of BIM software, such as Revit and Navisworks, allowed the team to work collaboratively in redesigning the alternative systems purposed by Building Stimulus. Specifically, the 3rd floor was chosen as the area of primary focus for BIM analysis. The time commitment needed to perform BIM on the entire project would have taken away from time needed to focus on the alternative redesigns. This was determined to be an effective method for utilizing BIM, while also having enough time to thoroughly redesign the alternative systems recommended in the proposal. Certain shortcomings influenced the interoperability of the software packages as they relate to BIM, however the overall goals of integrated project delivery were successfully met and achieved.

Individual Thesis Requirements

Lighting Designs

Lighting Design Summary

Five spaces have been focused on for lighting design. Each of these spaces has been design to meet IESNA Design Criteria and ASHRAE 90.1-2007 lighting power densities.

Spaces that have been focused on for electrical lighting design include a third floor conference room (N-308A/B and W-306A/B), the exterior plaza located under the cantilevered structure, a typical student study area that are located throughout the buildings perimeter areas, corridor lighting, and a typical office.

The typical student study area has also included a detailed daylighting study that has been integrated into the Building Stimulus' façade design.

The main entrance of the Millennium Science Complex is located where each of the two wings of the building joins. The cantilevered connection creates a plaza area that houses an entrance to each Material Science and Life Science wings. Under the square opening in the structure above, a pathway exist that sends walkers through a swirling pattern that leads from one entrance to the other. The design of the pathway was intended to be directionless to discourage use. The structure below is a quiet lab area has been deemed extremely vibration sensitive and heavy use will disrupt the research and experiments below.

A conference room on the third floor offers a chance to create a lighting design with multiple scenes for the differing tasks in the space. Since tasks such as meetings and presentations, and conferencingwill take place in this space, different scenes have been designed to accomadate all activities.

The Student Study Areas throughout the complex are located periodically along the perimeter of the science complex. Daylight integration into these spaces was a primary focus of the lighting design in this space, and has been coordinated with other disciplines to ensure the most efficient overall design of the system on all fronts. Electric light in this space has been designed to complement the daylight integration and work in tandem to create a visually uniform and appealing workspace.

Due to the addition of chilled beams, a typical private office has been added to the lighting design list in order to explore the opportunity of integrated luminaires and chilled beam as one fixture.

Conference Room Lighting Design (Multiple Scenes)

Spatial Summary

The third floor has two conference rooms that lie adjacent to the oculus, one in the Material Science wing, and on in the Life Science wing. Both rooms are identical, with a removable partition splitting the room in half. The plans show that furniture layouts (Figure 104: W306A/B Conference Room - Plan View.) have a conference table and office chairs on one half of the room, while office chairs are aligned for presentation audiences on the other half. Two sets of cabinetry are recessed in the wall along the between the two entrances to the space.

The space is 42’ x 18’2” with the cabinetry wall recesses being 3’x1.5” x 12’1.25” each. The total area of the space is 845.65ft^2. Using the ASHRAE 90.1, Table 9.6.1 Lighting Power Density of 1.3W/ft^2 for conference rooms, the total allotment for lighting should not exceed 1099W for the space.

Further research in the design of the space shows that a hard isolation ceiling is located above the 10’ finished ceiling. The hard isolation ceiling is placed at 11’ above the third floor, and was designed to create a sturdy place to mount projection screens. The concrete floor above is an unacceptable mounting point for the projectors due to mechanical equipment being placed directly above the space. The isolation ceiling also provides an acoustic barrier between the space and the penthouse mechanical equipment.

Drawings & Layout

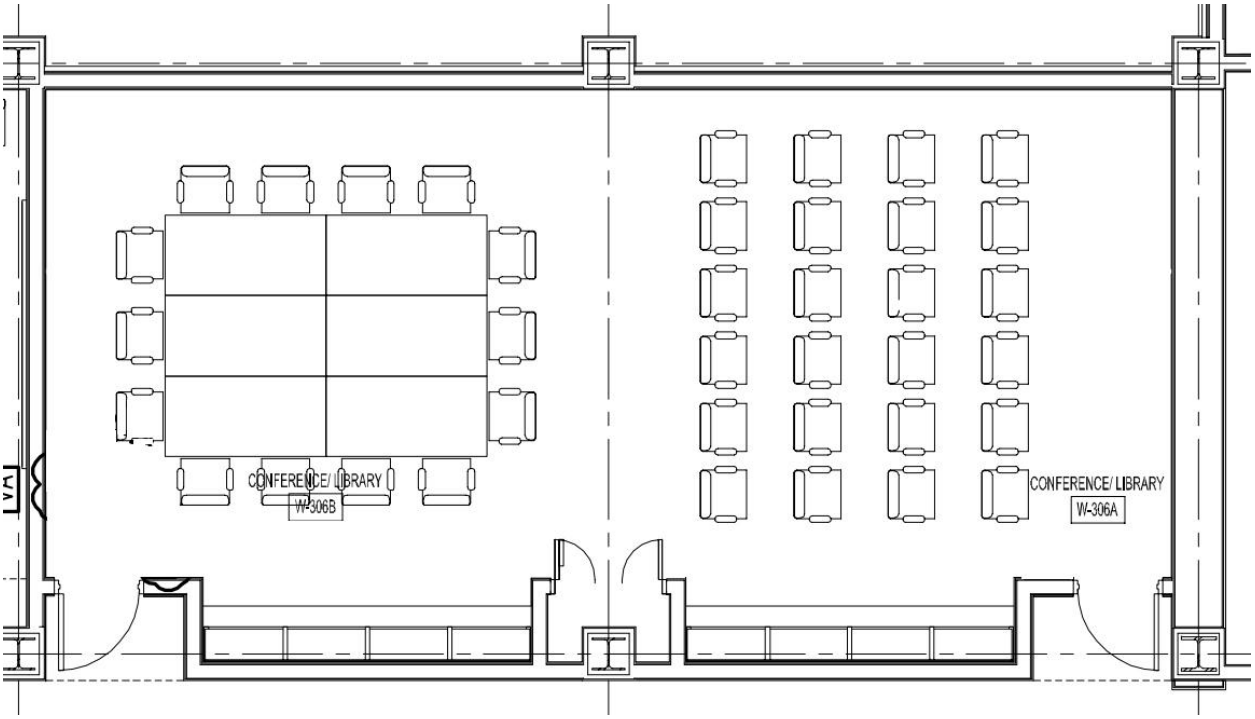


Figure 104: W306A/B Conference Room - Plan View.

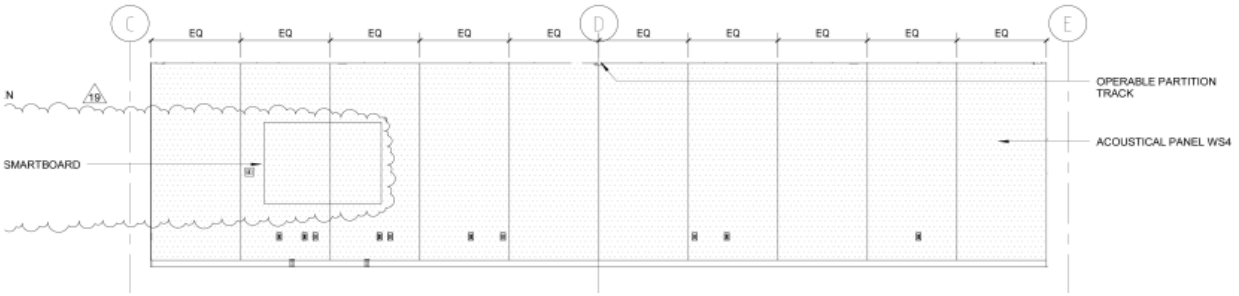


Figure 105: W-306A/B North Elevation.

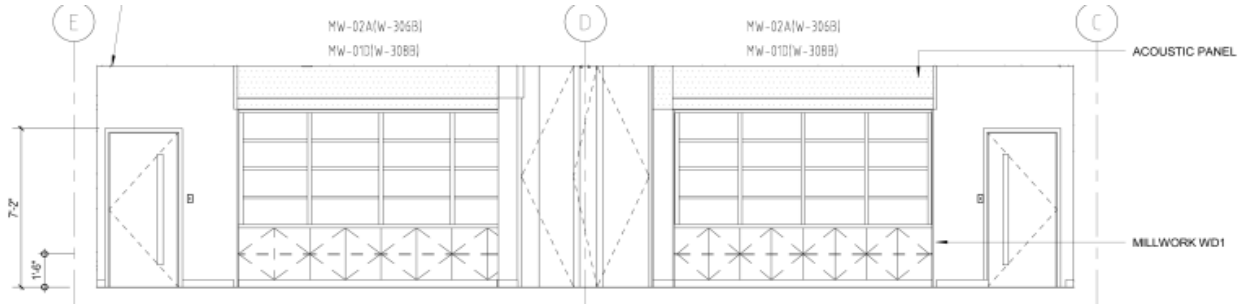


Figure 106: W-306A/B South Elevation.

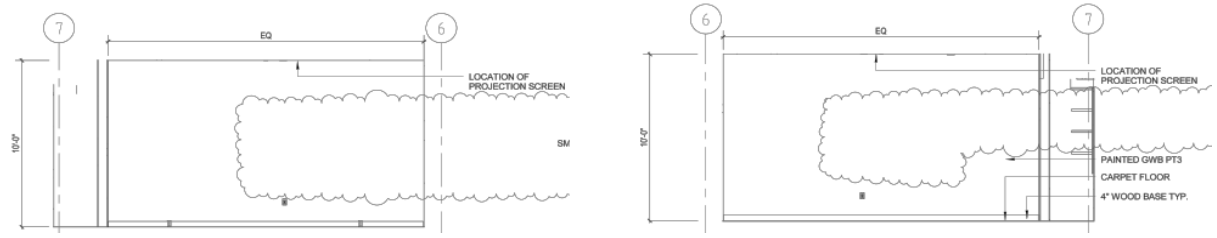


Figure 107: W-306A/B East & West Elevation.

Tasks & Activities

Major uses of this space will include meetings and conferencing. Some video conferencing may also take place as well, but with the lack of video conferencing equipment scheduled to be installed in the spaces, it can be assumed that video conferencing use will be at a minimum as suggested from comments at the December Lutron Presentation.

Materials

Table 40: Conference Room Materials List.

Conference Room Materials		
Surface	Reflectance	Transmittance
Gypsum Ceiling	0.86	
ACT Ceiling	0.78	
Door Glazing		0.5
Door**	0.50	
Door Trim**	0.50	
Floor**	0.13	
Floor Molding**	0.30	
Shelving**	0.50	
Wall	0.76	
Wall Paneling	0.23	
**Values from AGi32 swatches for similar materials		

Design Considerations

The IESNA Handbook suggests several high priority considerations for conference/seminar rooms for meeting tasks and video conferencing. These considerations are as follow:

- Meeting tasks:
  - Considerations (IESNA Handbook)
    - Appearance of Space and Luminaires
    - Direct Glare Avoidance
    - Modeling of Faces
  - Design Suggestions
    - Horizontal 30fc (IESNA Handbook)
    - Vertical 5fc (IESNA Handbook)
    - Power Density 1.2W/SF (ASHRAE 90.1, Table 9.6.1)
- Video Conferencing
  - Considerations (IESNA Handbook)
    - Direct Glare Avoidance
    - Modeling of Faces
    - Source-Task-Eye Geometry
  - Design Suggestions
    - Horizontal 50fc (IESNA Handbook)
    - Vertical 30fc (IESNA Handbook)
    - Power Density 1.2W/SF (ASHRAE 90.1, Table 9.6.1)
- Luminance Ratios (IESNA Handbook)
  - Paper-VDT 3:1/1:3
  - Task-Surroundings 3:1/1:3
  - Task-Remote Surface 10:1/1:10

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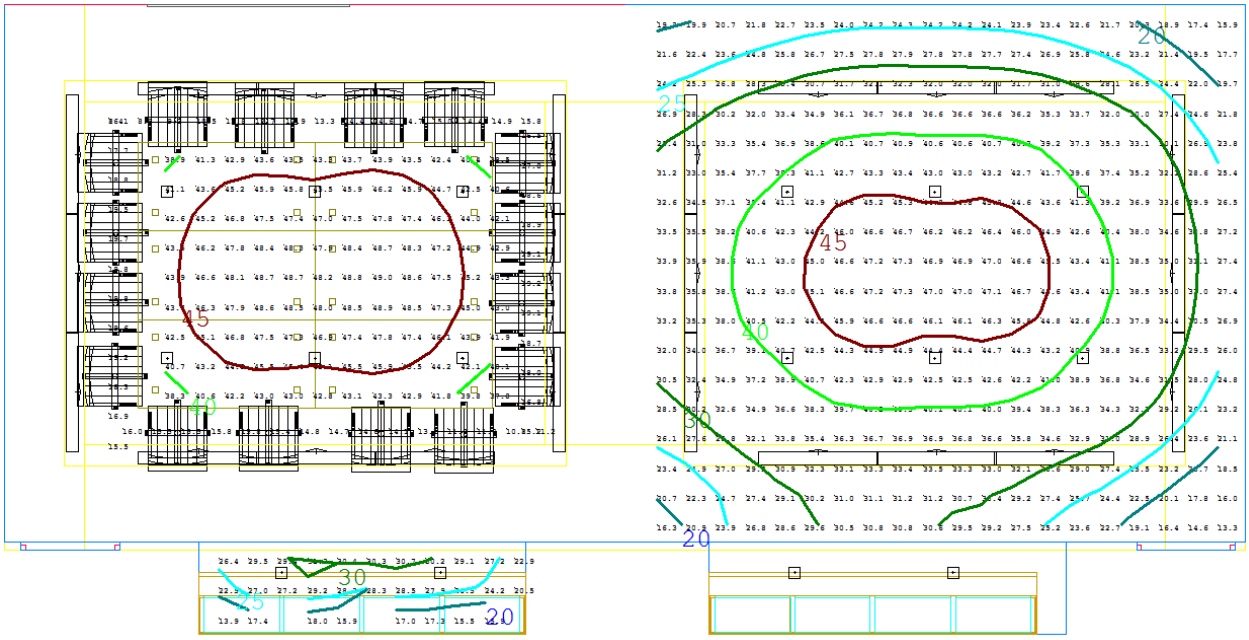
Performance Summary

Scene 1: Video Conferencing

Scene1 is the video conference setting on the Grafik Eye system. This setting will utilize all luminaires in the space, at full power. The desk surface reaches upwards of 49fc in the center, while the perimeter of the desk averages 42.5fc.



20fc -25fc-30fc-40fc -45fc

Figure 108: Conference Room Scene 1 Illuminance Contours.

Table 41: Conference Room Lighting Performance for Scene 1.

Conference Room Illumination Summary	Conference Table (Horz.)	Conference Table (Vert.)	Presentation Space	Cabinet Counter Top
Avg. Illuminance (FC)	45.01	17.03	33.79	25.84
Max. Illuminance (FC)	49.00	21.90	47.30	32.80
Minimum Illuminance (FC)	37.80	11.10	13.30	14.50
Avg/Min	1.19	1.53	2.54	1.78
Max/Min	1.30	1.97	3.56	2.26
Max/Avg	1.09	1.29	1.40	1.27
Coefficient of Variation	0.06	0.15	0.24	0.23
Uniform Gradient	1.06	N/A	1.28	1.80
Power Density (W/SF)	1.2			

*Note: Vertical illuminance does not meet IESNA Design criteria. As per Lutrons comments, the space does not include substantial video conferencing equipment, therefore it can be assumed all video conferencing will be done will mobile video conferencing stations. It has been assumed these mobile stations will include lighting fixtures to meet criteria.

Figure 109: Conference Room Lighting Design - Perspective View of Scene 1.

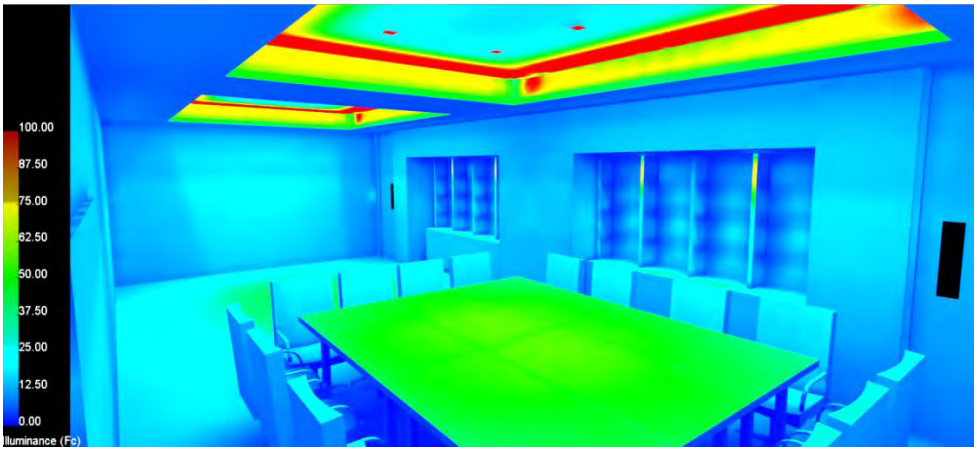


Figure 110: Conference Room Lighting Design - Perspective View (Pseudo Color: Illuminance) of Scene 1.

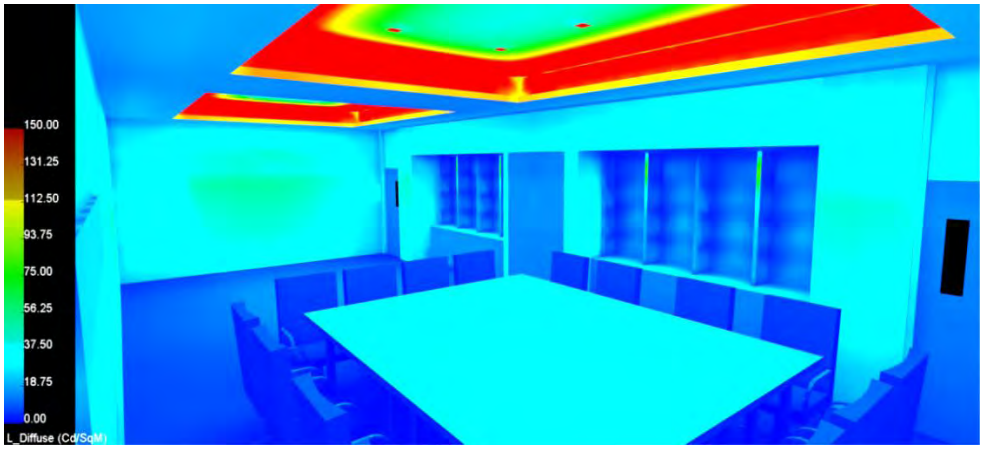


Figure 111: Conference Room Lighting Design - Perspective View (Pseudo Color: Luminance) of Scene 1.

Scene 2: Meetings & Conferences

Scene2 is the meeting and conferencing setting on the Grafik Eye system. This setting will utilize cove luminaires as well as the cabinetry downlighting at full power. The desk surface reaches 31.50fc in the center, while the perimeter of the desk averages 30.30fc.

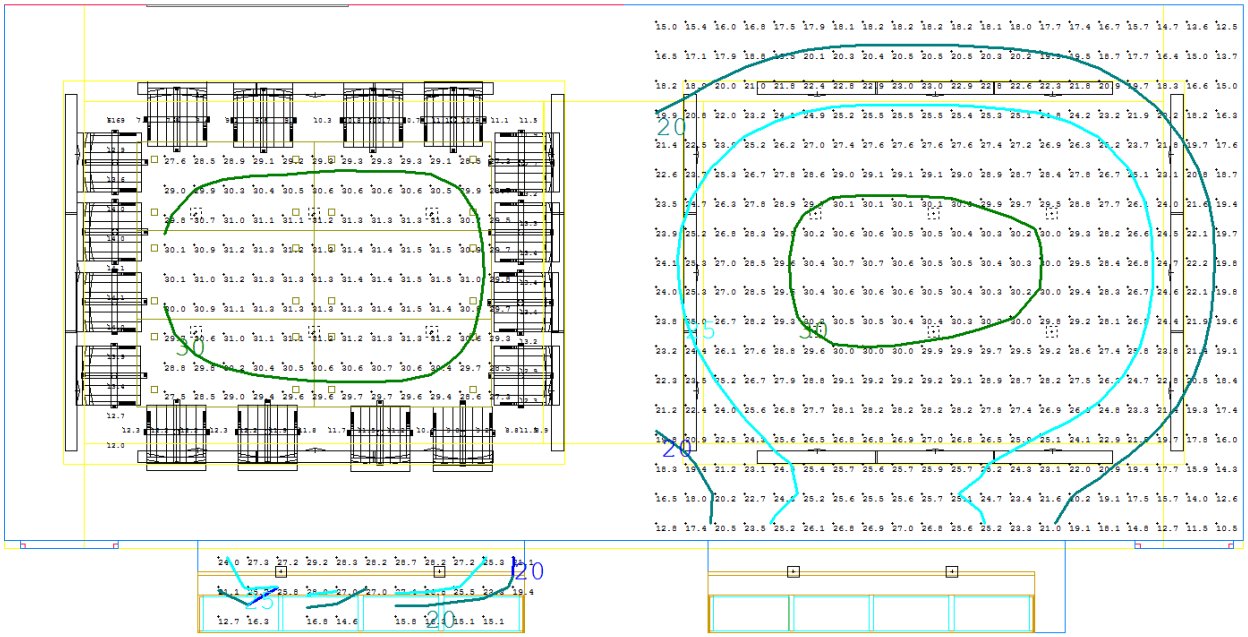


Figure 112: Conference Room Scene 2 Illuminance Contours.

Table 42: Conference Room Lighting Performance for Scene 2.

Conference Room Illumination Summary	Conference Table (Horz.)	Conference Table (Vert.)	Presentation Space	Cabinet Counter Top
Avg. Illuminance (FC)	30.30	12.23	24.22	23.15
Max. Illuminance (FC)	31.50	14.10	30.70	29.20
Minimum Illuminance (FC)	27.30	9.60	10.50	12.70
Avg/Min	1.11	1.27	2.31	1.82
Max/Min	1.15	1.47	2.92	2.30
Max/Avg	1.04	1.15	1.27	1.26
Coefficient of Variation	0.03	0.16	0.19	0.23
Uniform Gradient	1.05	N/A	1.36	1.85
Power Density (W/SF)			1.2	

Figure 113: Conference Room Lighting Design - Perspective View of Scene 2.

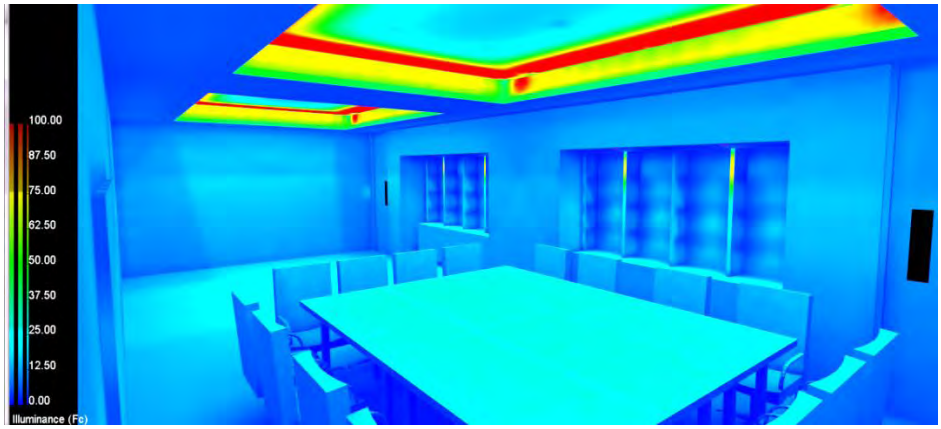


Figure 114: Conference Room Lighting Design - Perspective View (Pseudo Color: Illuminance) of Scene 2.

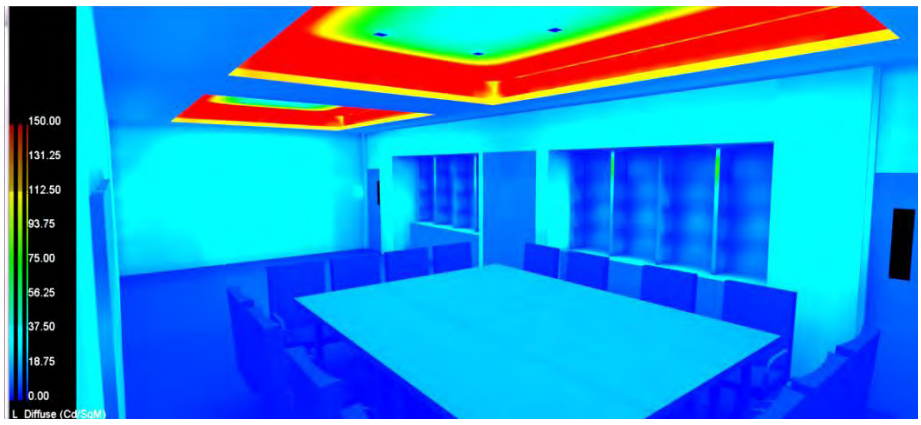
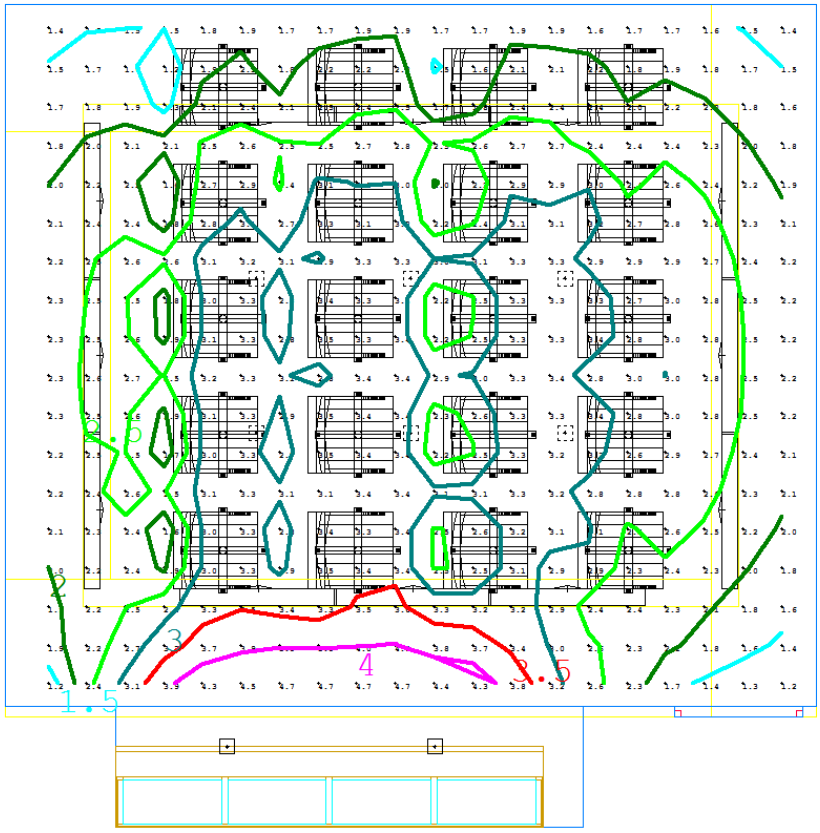


Figure 115: Conference Room Lighting Design - Perspective View (Pseudo Color: Luminance) of Scene 2.

Scene 3: Presentations

Scene3 is the setting for presentation scenes on the Grafik Eye system. This setting utilizes cove luminaires at 10% dimming level while the cabinetry downlighting is at 25% power. The desk surface reaches 31.50fc in the center, while the perimeter of the desk averages 30.30fc.



1.5fc-2.0fc-2.5fc -3.0fc - 3.5fc - 4.0fc

Figure 116: Conference Room Scene 3Illuminance Contours.

Table 43: Conference Room Lighting Performance for Scene 3.

Conference Room Illumination Summary	Presentation Space
Avg. Illuminance (FC)	2.63
Max. Illuminance (FC)	4.70
Minimum Illuminance (FC)	1.20
Avg/Min	2.19
Max/Min	3.92
Max/Avg	1.79
Coefficient of Variation	0.26
Uniform Gradient	2.00
Power Density (W/SF)	1.2

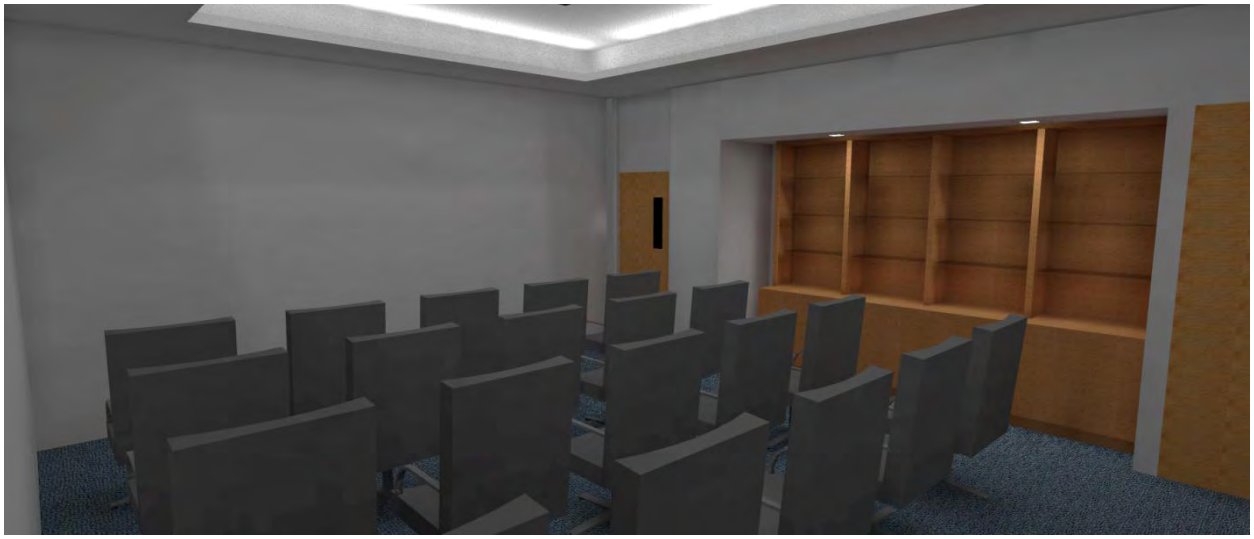


Figure 117: Conference Room Lighting Design - Perspective View of Scene 2.

Figure 118: Conference Room Lighting Design - Perspective View (Color: Illuminance) of Scene 2.

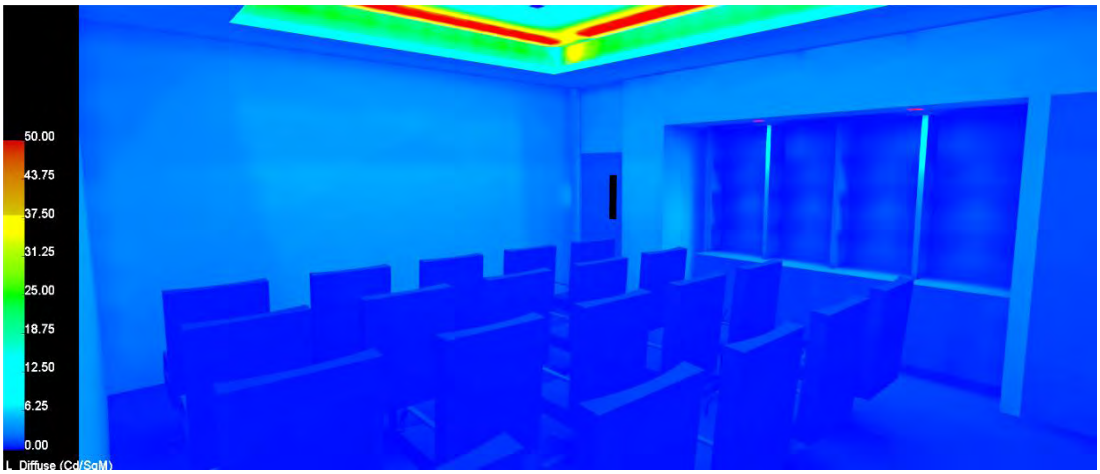


Figure 119: Conference Room Lighting Design - Perspective View (Color: Luminance) of Scene 2.

Controls

The three scenes shown in this design are to be controlled using a lighting control system by Lutron known as the Grafik Eye. Since the room is able to be separated by a foldable partition, each section is to be controlled separately. The Grafik Eye system has been programmed to have four settings known as scenes, and they are as follows:

1. Video Conferencing Scene
2. Meeting Scene
3. Presentation Scene
4. User Defined Scene

Each scene allows users to easily select different lighting settings for the rooms various purposes. Each button on the control system will be engraved with a short text description its respective scene, as well as a small descriptive image. The user defined setting will allow users to program an additional scene as they deem necessary.

The control system divides the lighting fixtures in each space into three zones, which are as follows:

1. Cove Lighting (switching zones a & g)
2. Cove Downlights (switching zones b & f)
3. Cabinetry Downlights (switching zones c & e)

Each space has also be equipped with a passive infrared occupancy sensor. Lutron's LOS-CUS-500-WH has been used, as it is able to cover the 450SF of each space without being falsely turned on by occupants passing by in the corridor. When LOS-CIR-450-WH occupancy sensor is used in conjunction with the Grafik Eye lighting control system, the sensor requires a power pack to be installed. Lutron's PP-230H Power Pack has been used in this design. Wiring diagrams can be found in Appendix G: Lighting Wiring Diagrams, and control diagrams can be found on page 386, in Appendix I: Lighting Control Cutsheets.

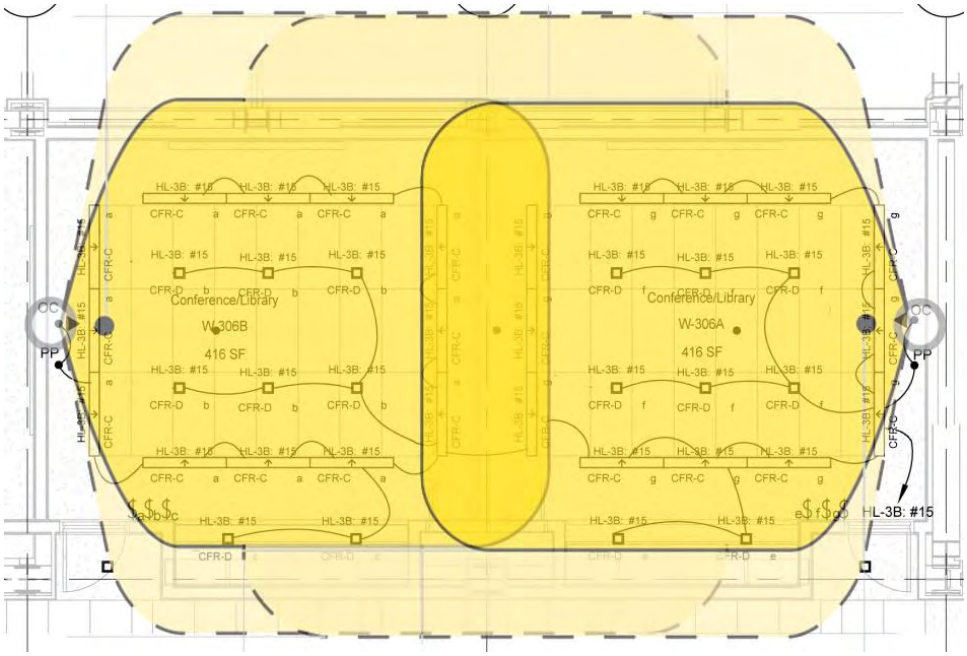
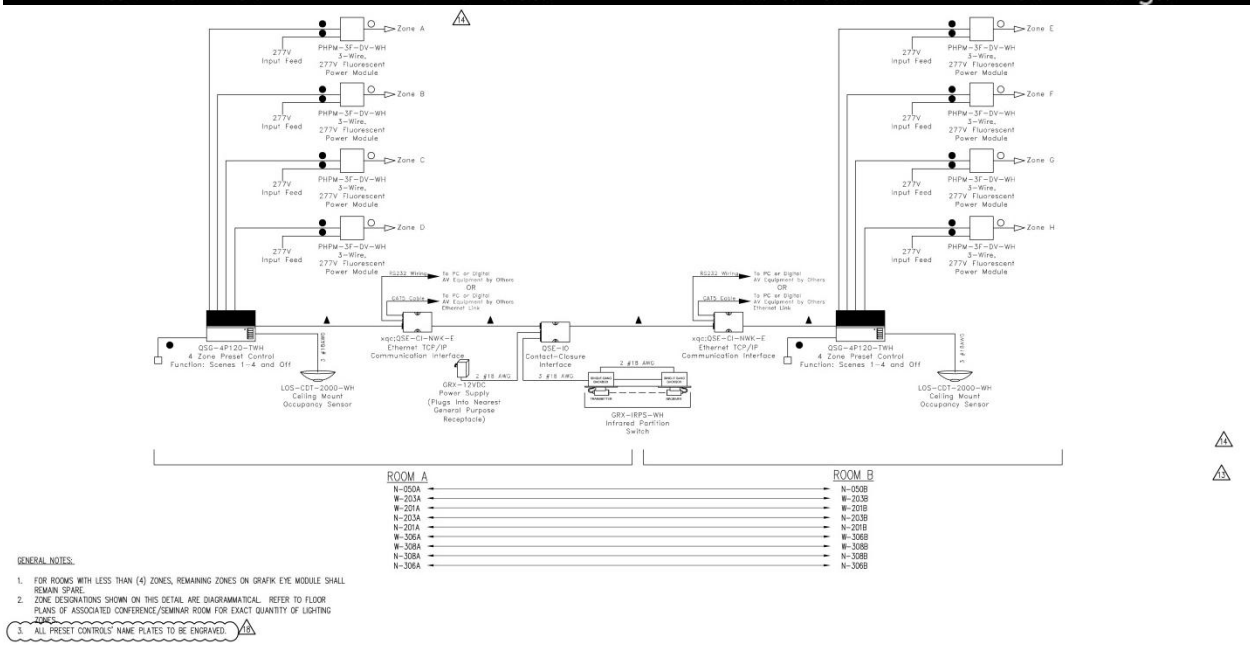


Figure 120: Conference Room Occupancy Coverage Diagram.

Figure 121: Scene 1 - Video Conferencing Grafik Eye Setup (Zone 1 = 100%; Zone 2 = 100%; Zone 3 = 100%.

Figure 122: Scene 2 - Meeting Grafik Eye Setup (Zone 1 = 100%; Zone 2 = Off; Zone 3 = 100%).

Figure 123: Scene 3 - Presentations Grafik Eye Setup (Zone 1 = 10%; Zone 2 = Off; Zone 3 = 25%).



6 / E6.3D

TYPICAL LUTRON GRAFIK EYE WIRING DIAGRAM FOR CONFERENCE ROOMS AND SEMINAR ROOMS
N.T.S.

Figure 124: Existing Conference Room Control Diagram.

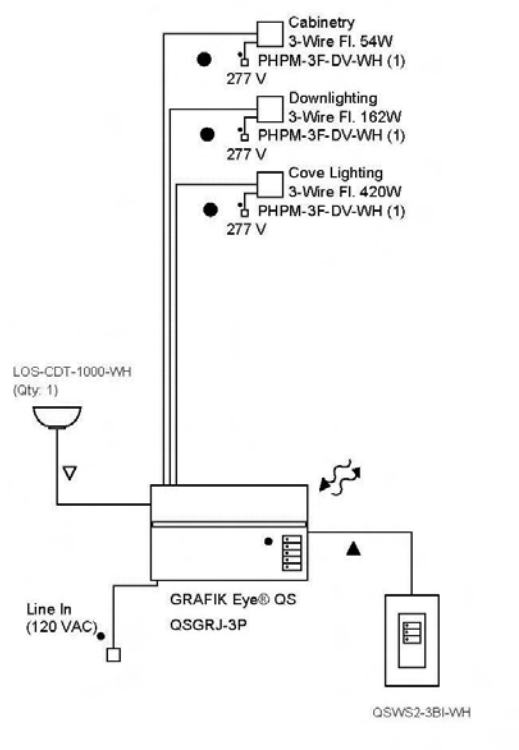


Figure 125: Redesigned Conference Room Control Diagram.

Cove Lighting Installation Detail

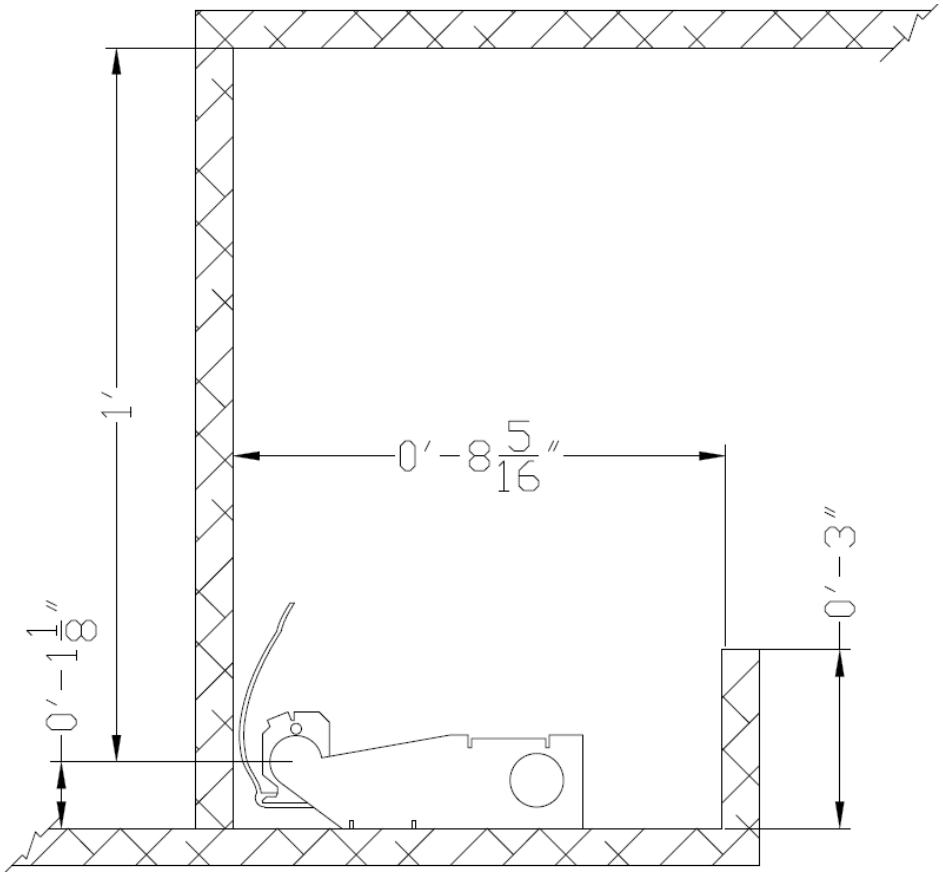


Figure 126: Conference Room Cove Lighting Detail.

Process and Material Take-Off

As the lighting redesign progressed throughout the building, it became critical to maintain an updated drawing and fixture schedule to compare to the original plan. For comparisons, the 3rd floor was chosen to show direct benefits and drawbacks of the lighting design. The original take-offs can be found in Appendix D: Construction Management. Utilizing RS Means 2011 values for interior lighting, the overall costs of the 3rd floor amounted to $30,881.55 with the bulk of the costs resulting from the NF-1 light fixtures (1' x 4' recessed fluorescent downlights) found throughout the corridors and office spaces.

Lighting Costs

At the conclusion of the lighting design, a floor – by – floor cost analysis was performed comparing the costs saved by removing existing lighting, and the costs incurred by installing new fixtures. The full estimates of 1st, 2nd, and 3rd floor lighting changes can be seen in in Appendix D: Construction Management. The table below summarizes costs and savings per building space for each floor.

Table 44: Lighting Cost Summary.

Floor	Corridor Savings	Office Savings	Study Area Savings	Conf. Room Savings	Total Floor Savings
1st	$ 1,200.00	$ 3,927.00	$ -	$ -	$ 5,127.00
2nd	$ 1,330.00	$ 12,219.00	$ 2,400.00	$ -	$ 15,949.00
3rd	$ 1,080.00	$ 13,107.00	$ 1,200.00	$ 2,125.00	$ 17,512.00

Upon completion of the Millennium Science Complex lighting redesign, the switch from fixtures requiring fewer lamps clearly shows significant cost benefits. However, the large savings seen in office spaces can be misleading. As seen in the full estimate in in Appendix D: Construction Management, all NF – 1B fixtures were removed from office spaces and replaced with OFF – D fixtures. However, the cost of OFF-D fixtures was not taken into account in these estimates as the OFF – D fixture is the Integrated Chilled Beam/Lighting assembly and is included in mechanical costs, not lighting costs. While tremendous savings are seen in this table in office spaces, the reality is not so. This issue is further discussed in the Existing Office Costs vs. Proposed Office Costs portion of the Chilled Beam/Lighting Integration sections.

Electrical

SKM Analysis

This electrical depth topic was performed cooperatively between the electrical/lighting students of each IPD/BIM team. Due to time constraints and the repetitive nature of the distribution system, the scope of the depth topic was limited to distribution equipment that serves the third floor of the Millennium Science Complex. Each individual IPD/BIM team also focused their thesis on the third floor of the building for coordination. The intent of this depth topic is to gain experience in using SKM Power Tools for Windows. The equipment that was modeled in SKM can be seen in Table 45 on the following page.

Table 45: SKM Model Equipment Schedule.

SKM Model Equipment Schedule							
	Lvl	Name	Location	*Floorplan*	Voltage	RATING	Series Rating
Switchgear	0	MDS-01A	W-P003	*E2.0B-P*	480/277V	5,000A	100 kAIC
		MDS-01B	W-P003	*E2.0B-P*	480/277V	5,000A	100 kAIC
	0M	MDS-02A	N-P051	*E2.0MD-LP*	480/277V	2,000A	100 kAIC
		MDS-02B	N-P051	*E2.0MD-LP*	480/277V	2,000A	100 kAIC
		EMDS-1	N-P052	*E2.0MD-LP*	480/277V	2,000A	65 kAIC
Switchboards	0M	EDPS-1E1	N-P052	*E2.0MD-LP*	480/277V	800A	65 kAIC
		EDPS-1E2	N-P052	*E2.0MD-LP*	480/277V	800A	65 kAIC
	Level 2	SDP-2B	W-P249	*E2.2B-P*	480/277V	1,000A	65 kAIC
		SDP-2D	N-P258	*E2.2BD-P*	480/277V	1,000A	65 kAIC
		SDP-2D1	N-P238	*E2.2E-P*	480/277V	1,000A	65 kAIC
	Lvl 3	EDPS-3B	W-P338	*E2.3B-P*	208/120V	800A	65 kAIC
		EDPS-3D	N-P347	*E2.3D-P*	208/120V	800A	65 kAIC
	Penthouse	EDPS-M41	N-M401	*E2.4C-P*	480/277V	800A	65 kAIC
		EDPS-M42	N-M401	*E2.4C-P*	480/277V	800A	65 kAIC
		MDP-M41	N-M401	*E2.4C-P*	480/277V	1,000A	65 kAIC
		MDP-M42	N-M401	*E2.4C-P*	480/277V	1,000A	65 kAIC
Panelboards: Level 3	Level 3B	HL-3B	W-P338	*E2.3B-P*	480/277V	200A	14 kAIC Min.
		HMS-3B	W-P338	*E2.3B-P*	480/277V	100A	14 kAIC Min.
		LB-3B1/2	W-Q304	*E4.3B*	208/120V	225A	10 kAIC Min.
		LB-3B3/4	W-321	*E4.3B*	208/120V	225A	10 kAIC Min.
		LB-3B5/6	W-337	*E4.3B*	208/120V	225A	10 kAIC Min.
		LB-3B7	W-Q304	*E4.3B*	208/120V	225A/MLO	10 kAIC Min.
		LBS-3B1/2	W-Q304	*E4.3B*	208/120V	225A	10 kAIC Min.
		LBS-3B3/4	W-321	*E4.3B*	208/120V	225A	10 kAIC Min.
		LR-3B	W-P338	*E2.3B-P*	208/120V	150A	10 kAIC Min.
		LR-3B5/6	W-337	*E4.3B*	208/120V	225A	10 kAIC Min.
		LS-3B	W-P338	*E2.3B-P*	208/120V	100A	10 kAIC Min.
	3C	LB-3C1/2	W-Q302	*E2.3C-P*	208/120V	150A	10 kAIC Min.
		LR-3C1/2	N-Q307	*E2.3C-P*	208/120V	225A	10 kAIC Min.
	Level 3D	HL-3D	N-P347	*E2.3D-P*	480/277V	200A	14 kAIC Min.
		HM-3D	N-P347	*E2.3D-P*	480/277V	100A	14 kAIC Min.
		HMS-3D	N-P347	*E2.3D-P*	480/277V	100A	14 kAIC Min.
		LB-3D1/2	N-361	*E4.3D*	208/120V	175A	10 kAIC Min.
		LB-3D5/6	N-361	*E4.3D*	208/120V	175A	10 kAIC Min.
		LB-3D7/8	N-361	*E4.3D*	208/120V	175A	10 kAIC Min.
		LBS-3D1/2	N-Q304	*E4.3D*	208/120V	225A	10 kAIC Min.
		LBS-3D5/6	N-361	*E4.3D*	208/120V	225A	10 kAIC Min.
		LR-3D1/2	N-P346	*E2.3D-P*	208/120V	225A	10 kAIC Min.
		LR-3D3/4	N-P346	*E2.3D-P*	208/120V	225A	10 kAIC Min.
		LS-3D	N-P347	*E2.3D-P*	208/120V	100A	10 kAIC Min.
	Lvl	Name	Location	*Enl. Plan*	Rating	Poles/Ph/Voltage	Series Rating
Distribution Equipment	Mezzanine	ATS-HS1	N-P052	*E2.0MD-LP*	800 A	4P, 480V	65 kAIC
		ATS-HS2	N-P052	*E2.0MD-LP*	800 A	4P, 480V	65 kAIC
		ATS-HS3	N-P052	*E2.0MD-LP*	800 A	4P, 480V	65 kAIC
		ATS-HS4	N-P052	*E2.0MD-LP*	800 A	4P, 480V	65 kAIC
	Lvl 2	TRN-SDP-2B	W-P249	*E2.2B-P*	300 kVA	480Δ - 208Y/120V	N/A
		TRN-SDP-2D	N-P258	*E2.2D-P*	300 kVA	480Δ - 208Y/120V	N/A
		TRN-SDP-2D1	N-P238	*E2.2E-P*	300 kVA	480Δ - 208Y/120V	N/A
	Level 3	TRE-EDPS-3B	W-P338	*E2.3B-P*	225 kVA	480Δ - 208Y/120V	N/A
		TRE-EDPS-3D	N-P347	*E2.3D-P*	225 kVA	480Δ - 208Y/120V	N/A
		UPS-3D-1/2	N-361	*E4.3D*	50 kVA	N/A	Unknown
		UPS-3D-5/6	N-361	*E4.3D*	50 kVA	N/A	Unknown
	Lvl	Name	Location	Motor Size	Sizing Remarks		Column Not Used
Mech. Equipment	Penthouse	ACF-1	N-M401	100 hp	200 A MCP, 175 A FS		-----
		ACF-2	N-M401	100 hp	200 A MCP, 175 A FS		-----
		ACF-3	N-M401	100 hp	200 A MCP, 175 A FS		-----
		ACF-4	N-M401	100 hp	200 A MCP, 175 A FS		-----
		ACF-5	N-M401	100 hp	200 A MCP, 175 A FS		-----
		ACF-6	N-M401	60 hp	110 A MCP, 100 A FS		-----
		ACF-7	N-M401	60 hp	110 A MCP, 100 A FS		-----
		ACF-8	N-M401	60 hp	110 A MCP, 100 A FS		-----

The Power Tools for Windows analysis software from SKM is an excellent tool for calculating voltage drop, arc flash characteristics, short circuit current, equipment sizing, motor starting, and breaker coordination. Each of the aforementioned analyses is critical to ensure the safety of a distribution system. One goal of engineering design, in any area of study, is to ensure the safety of users and occupants. By knowing arc flash and short circuit characteristics of equipment, each piece of distribution equipment can be safely sized to avoid loss of life during maintenance or fires associated with electrical equipment.

When starting a model in SKM, there are two screens to work from – the component editor and the one-line diagram. The component editor allows the designer to specify exactly the equipment that will be constructed by the contractor. Within the component editor, specific equipment characteristics can be drawn out from the SKM library. The one-line diagram holds the same purpose as a one-line diagram in paper drawings – to orient the viewer with how equipment is fed and ordered throughout the building. Figure 127 below shows the library and component editor overlaid on the one-line diagram for a bus that is used as a main switchgear.

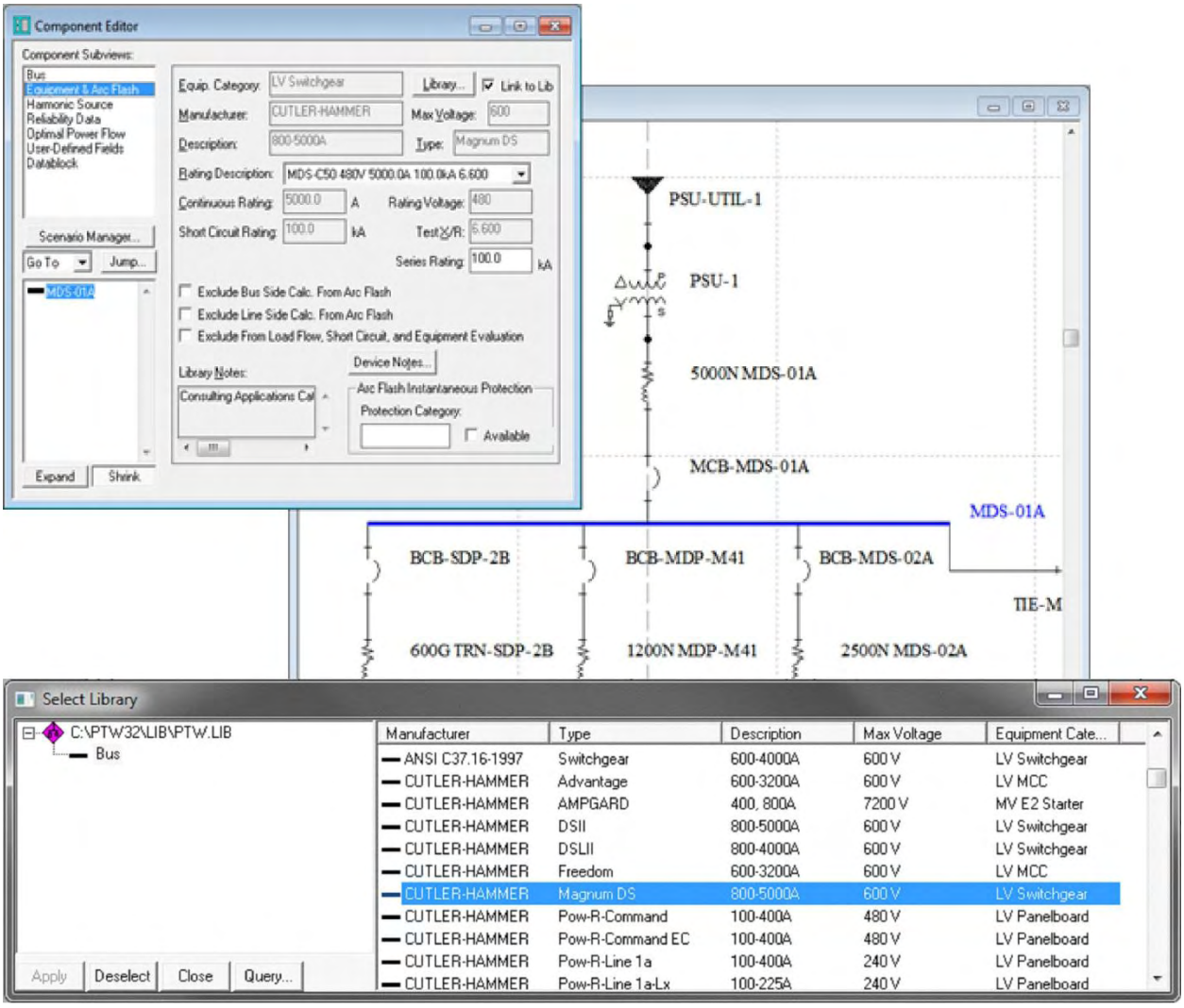


Figure 127: MDS-01A Equipment Inputs.

As the circuits continue, the switchgear feed other distribution panels. Between these two bus types, the engineer can specify wire sizes, insulation, lengths, and ampacity according to the National Electric Code's table 310.16. Many values for wire sizes can be drawn out of SKM in the same fashion as discussed in the previous example. The wire sizing example can be seen in 'Figure 128: Wire Sizing in SKM' below:

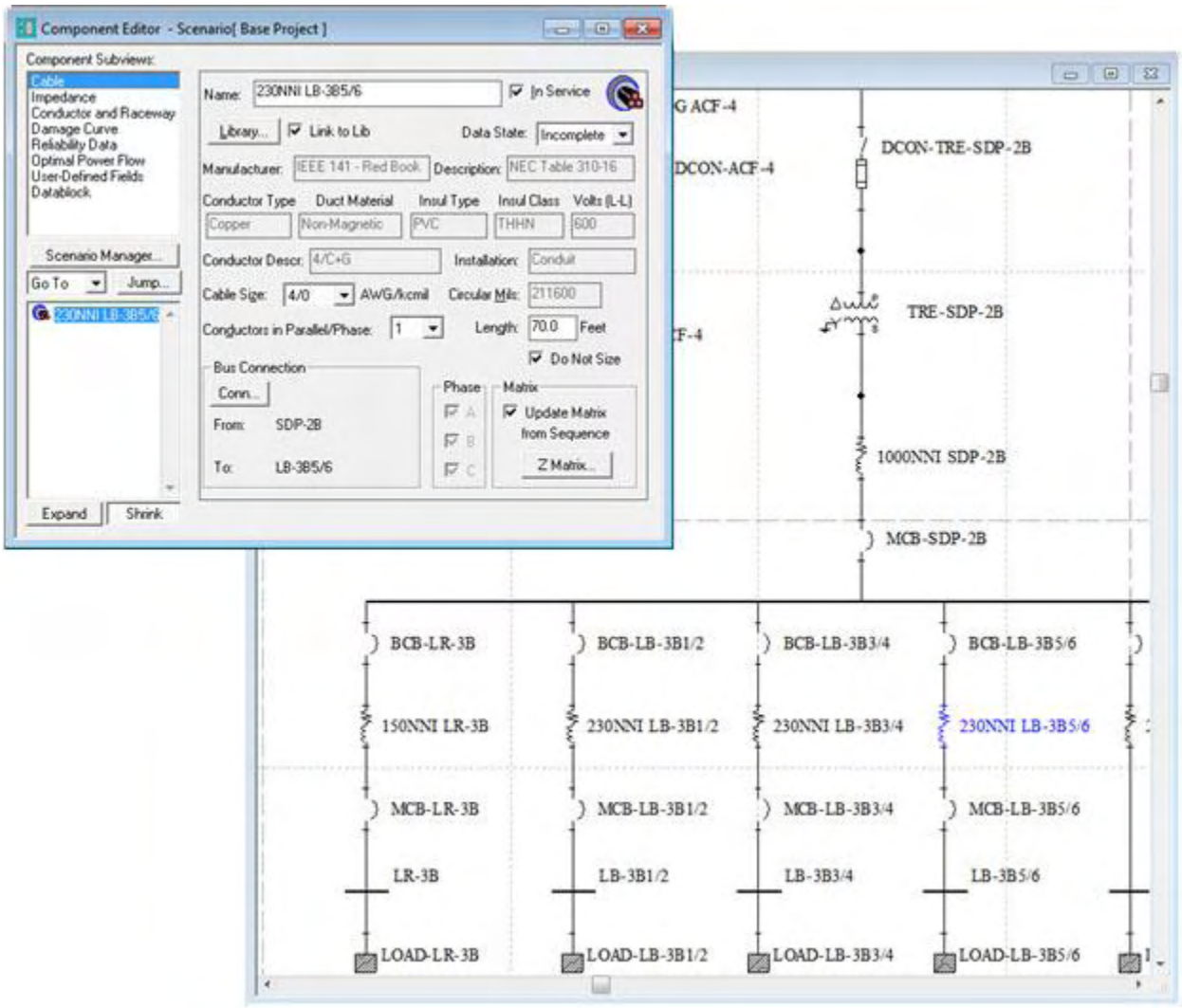


Figure 128: Wire Sizing in SKM.

Panelboards further down the one-line diagram are powered by voltage-reducing transformers from 480V to 208Y/120V. As with the previous examples, it is possible to specify various attributes to these transformers such as primary and secondary voltages, impedance, kVA rating and connection type. There is also a contingent of equipment in the SKM library to assist the designer – see Figure 129below:

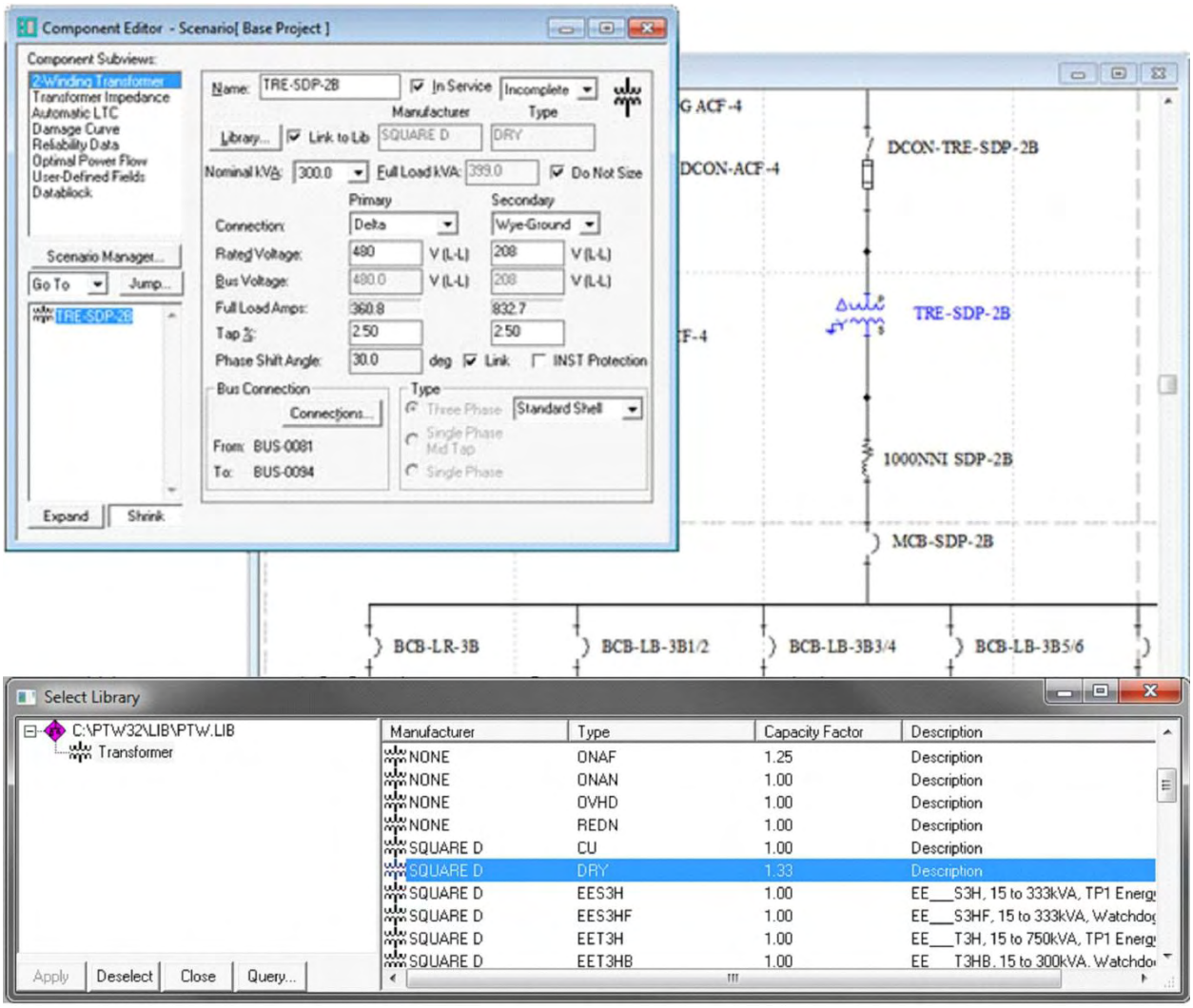


Figure 129: Transformer Inputs in SKM.

The ends of circuits in SKM cannot be left open. Therefore, each circuit must either end at a bus (panelboard, switchboard, switchgear, etc.) or at a load. These loads can be synchronous motors, induction motors (squirrel cage by NEC), or a non-motor panel load. Again, the engineer can specify detailed information about each piece of equipment through the component editor. Figure 130 and Figure 131below illustrate the inclusion of an induction motor load and non-motor panelboard load for the third floor of the Millennium Science Complex.

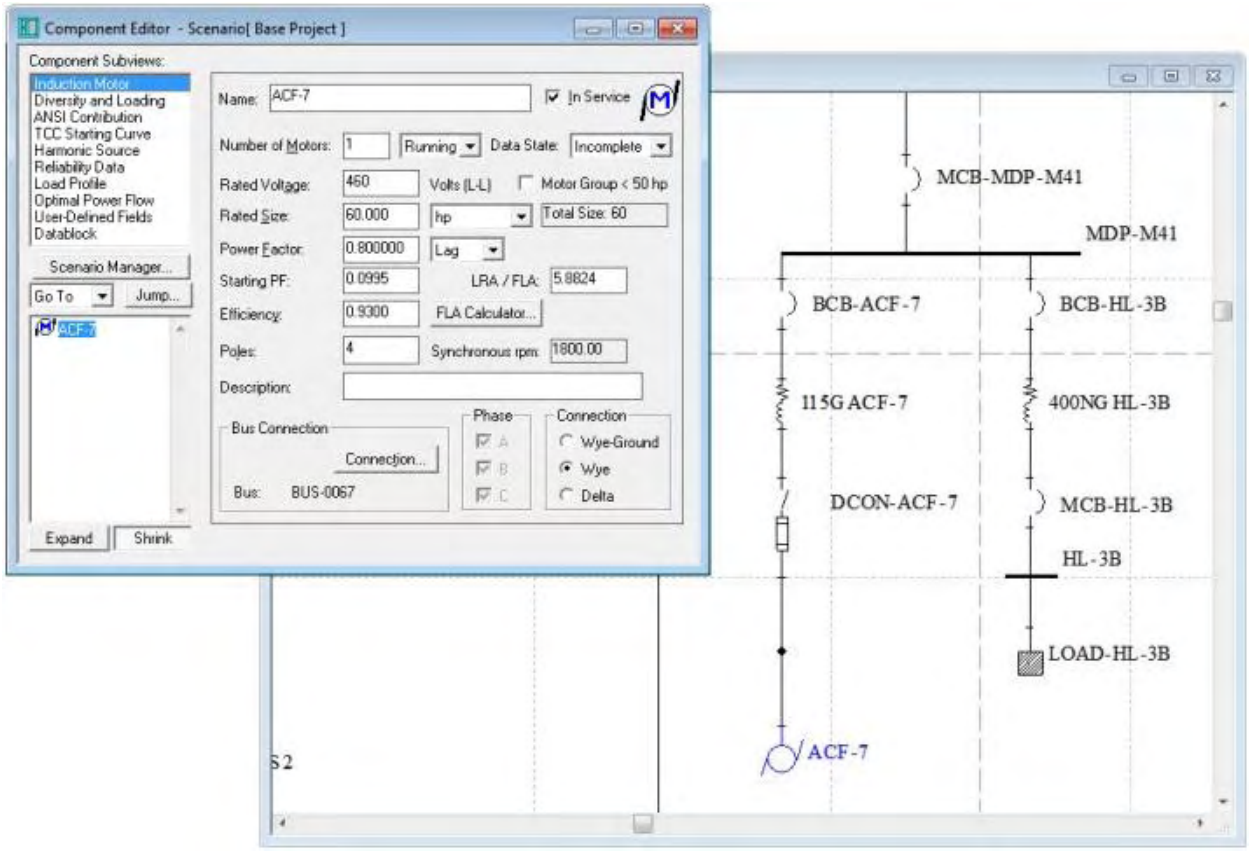


Figure 130: Induction Motor Inputs in SKM.

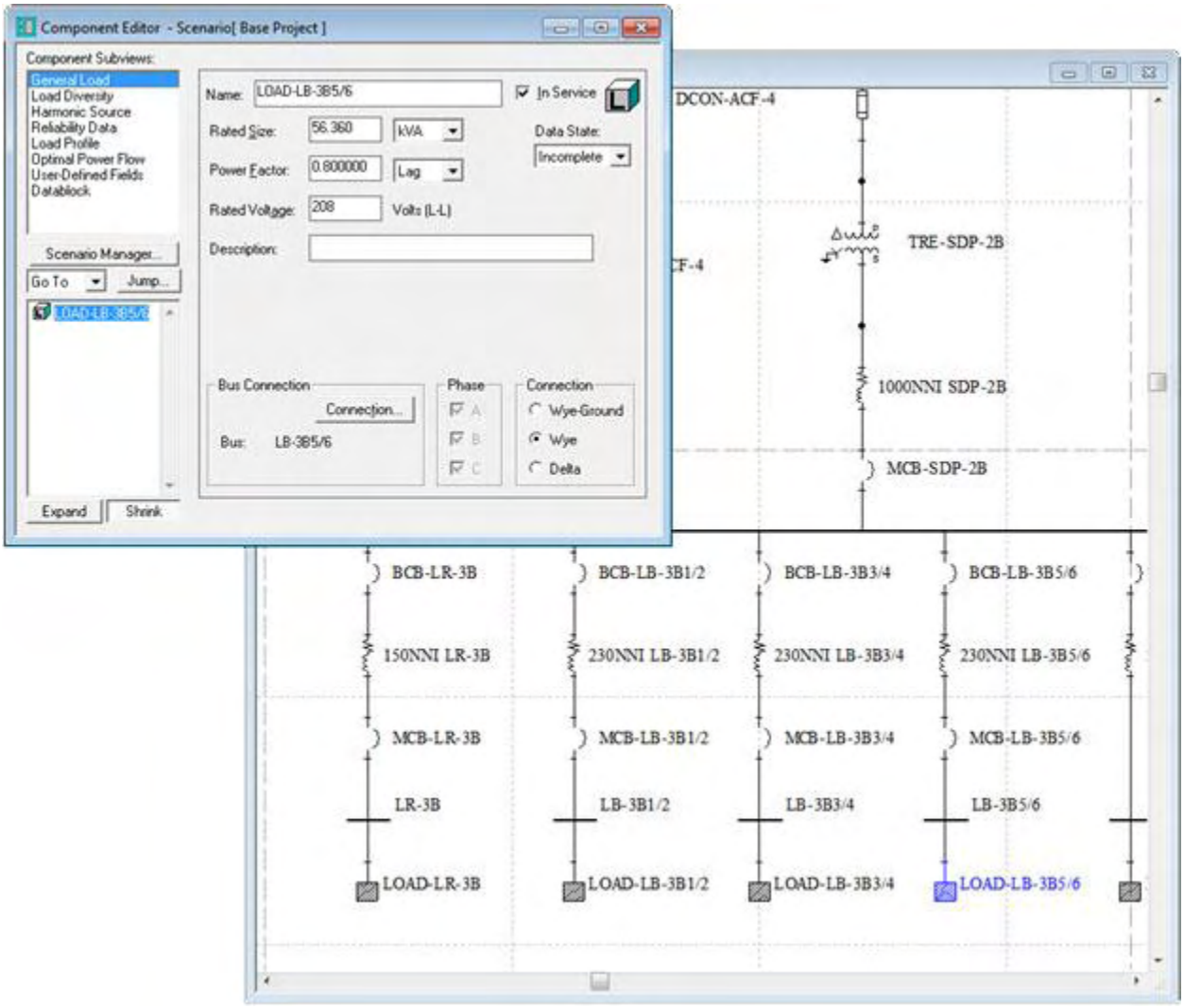


Figure 131: Non-Motor Load Inputs in SKM.

The following figures illustrate the distribution equipment servicing the third floor of the Millennium Science Complex, beginning with the overall one-line diagram:

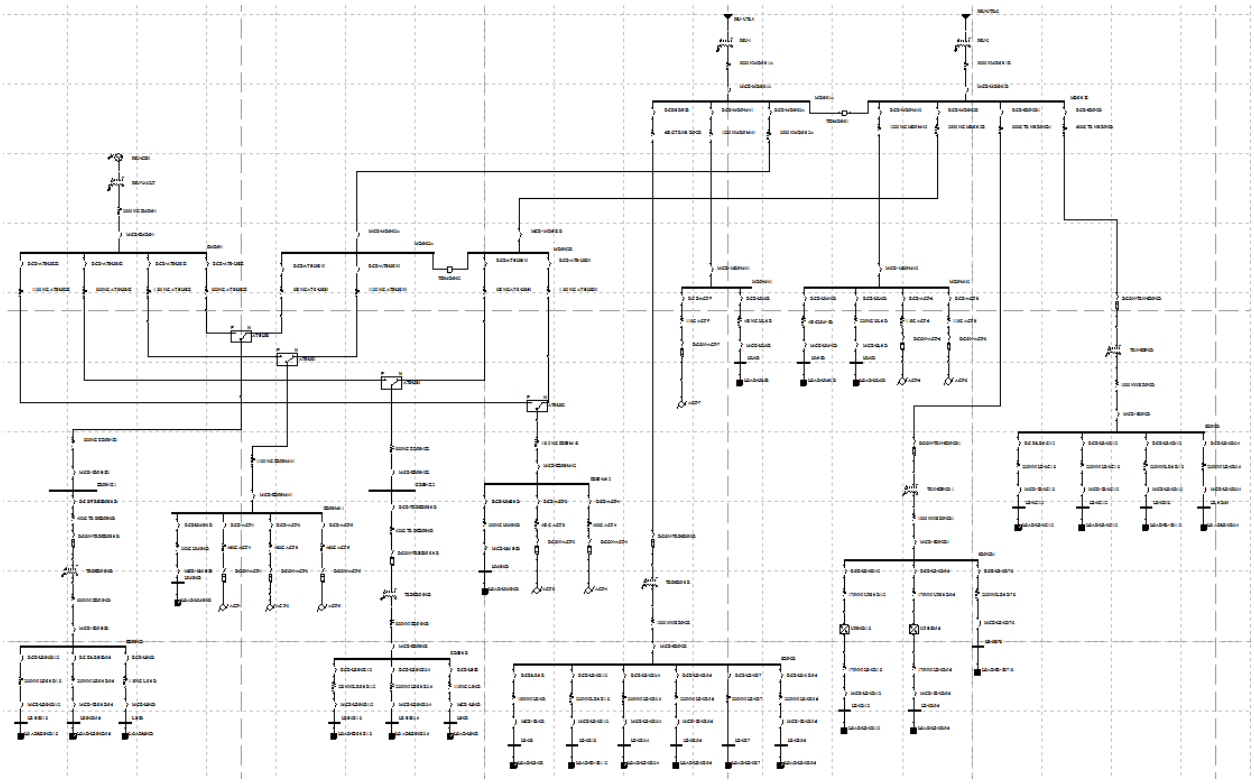


Figure 132: Millennium Science Complex third floor service equipment one-line diagram.

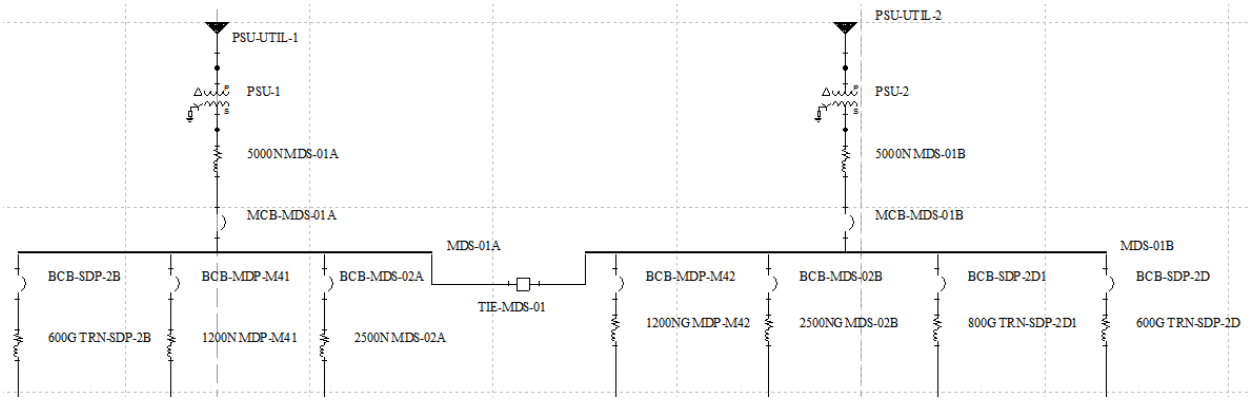


Figure 133: MDS-01A and MDS-01B one-line diagram.

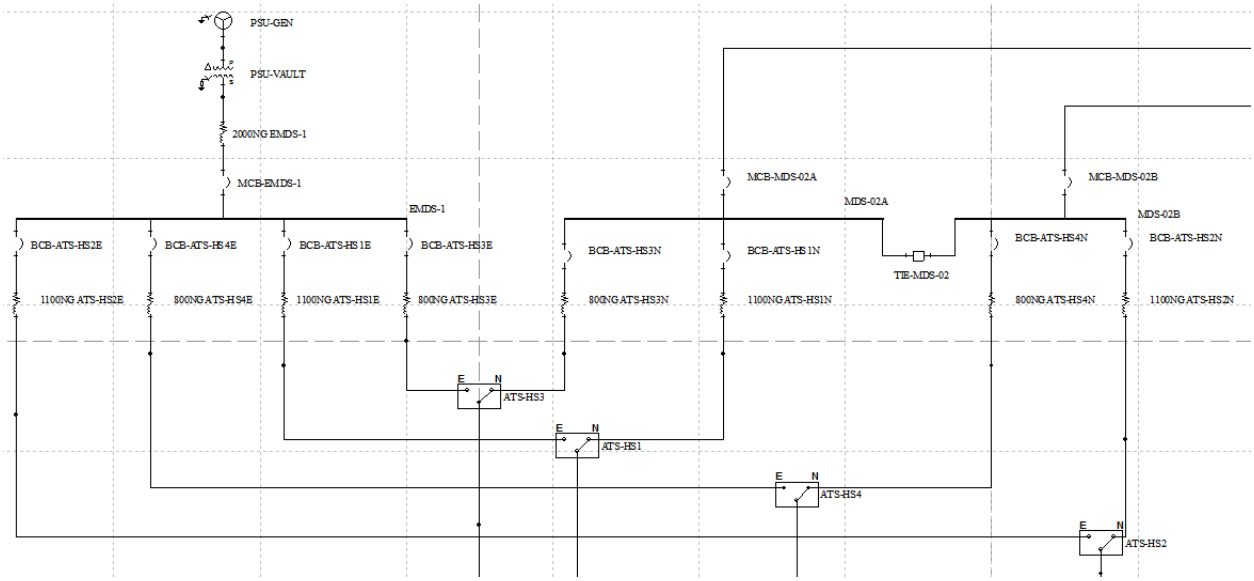


Figure 134: EMDS-1, MDS-02A, MDS-02B, and ATSs one-line diagram.

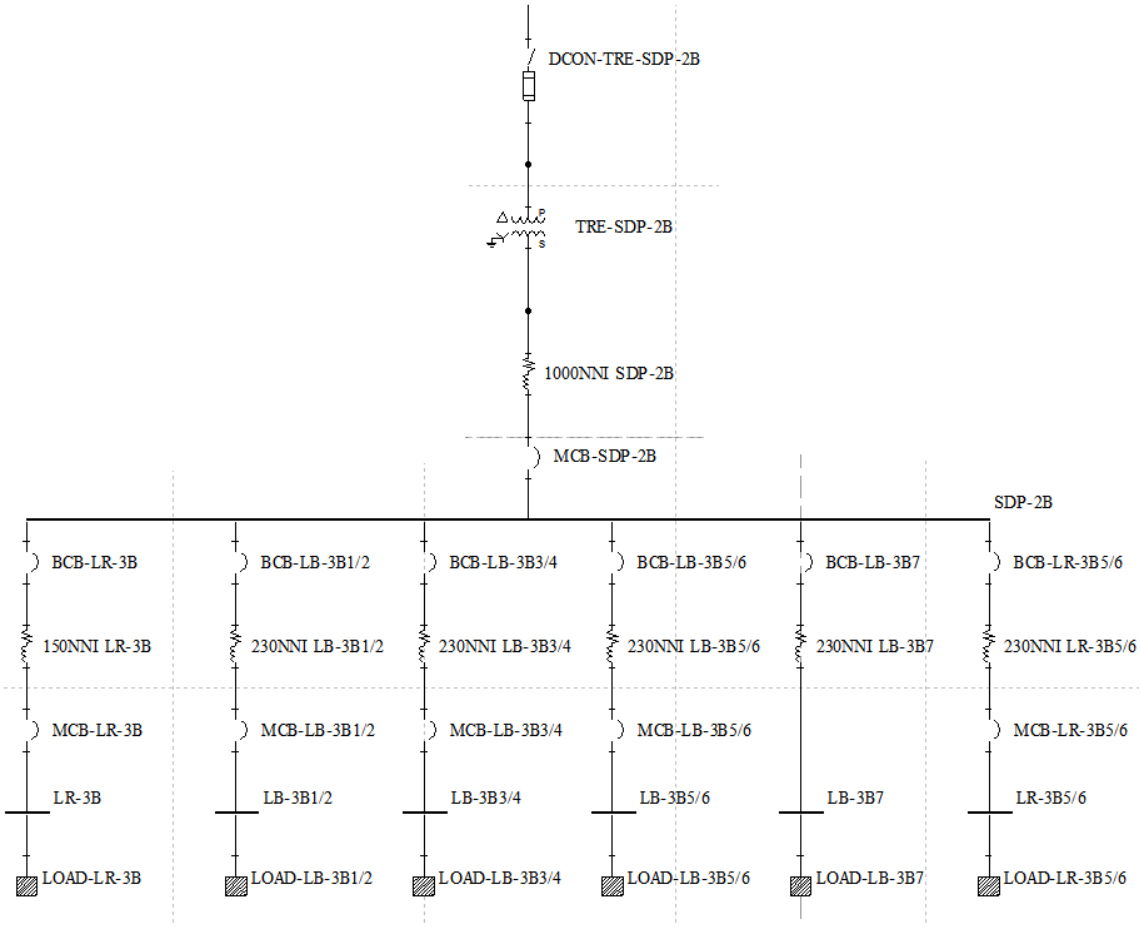


Figure 135: SDP-2B and loads one-line diagram.

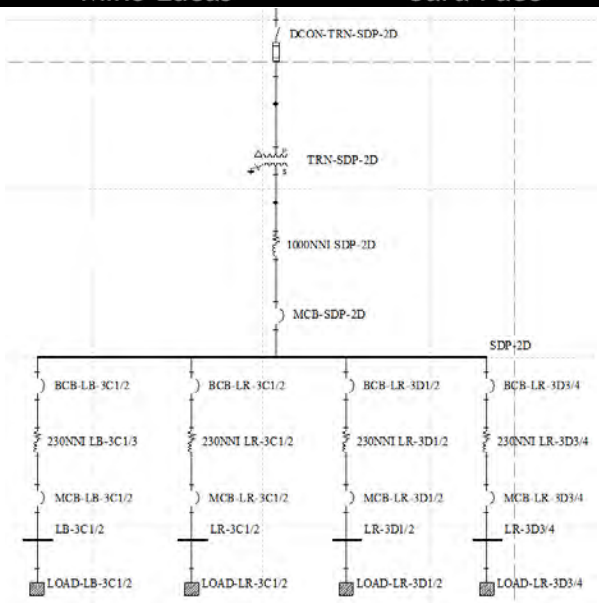


Figure 136: SDP-2D and loads one-line diagram.

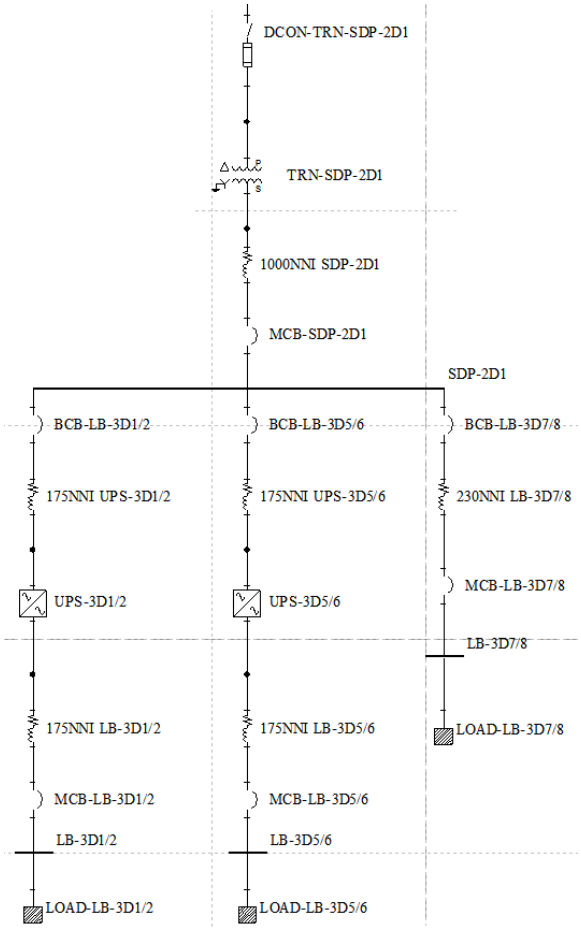


Figure 137: SDP-2D1 and loads one-line diagram.

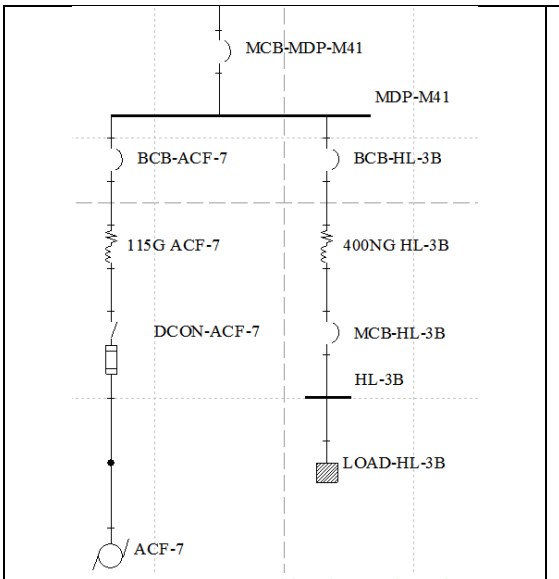


Figure 138: MDP-M41 and loads one-line diagram.

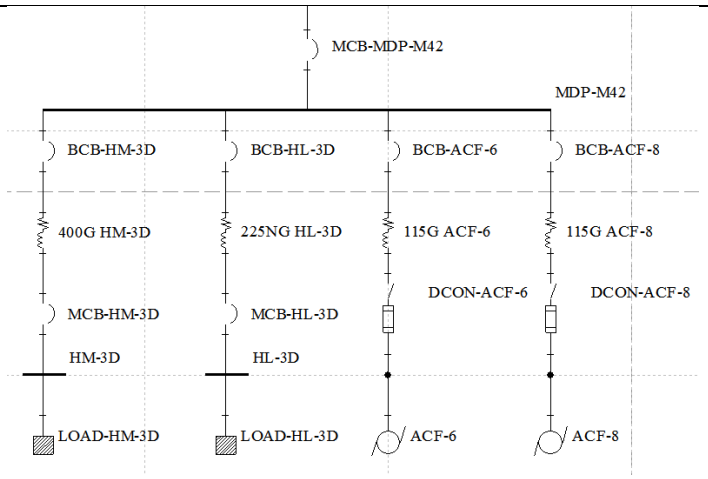


Figure 139: MDP-M42 and loads one-line diagram.

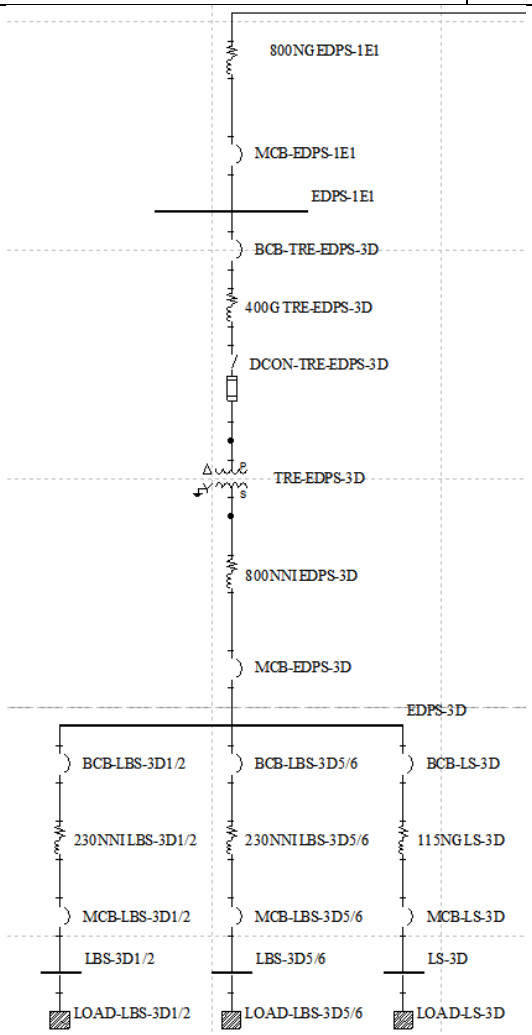


Figure 140: EDPS-1E1 and loads one-line diagram.

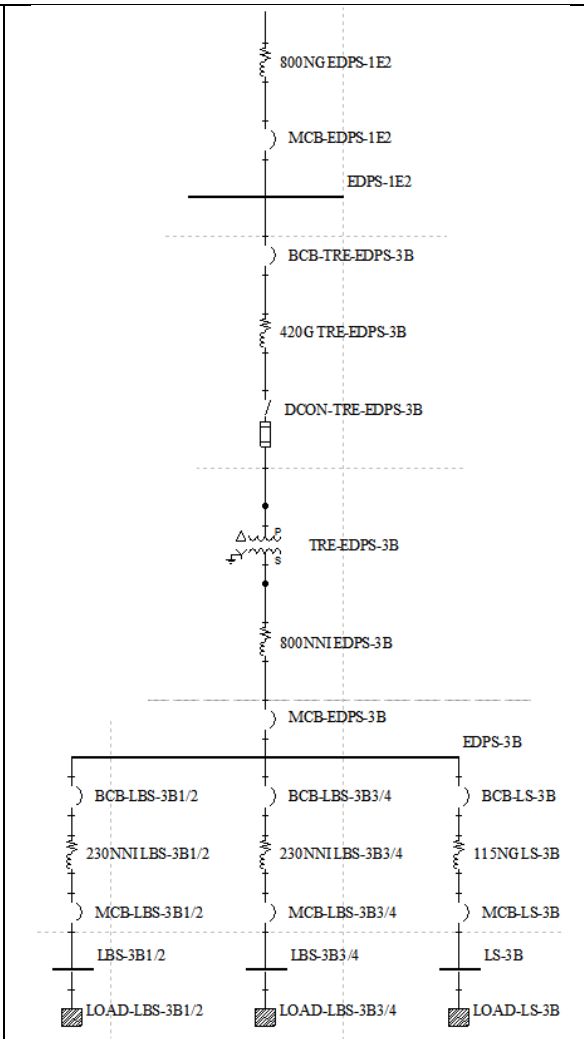


Figure 141: EDPS-3B and loads one-line diagram.

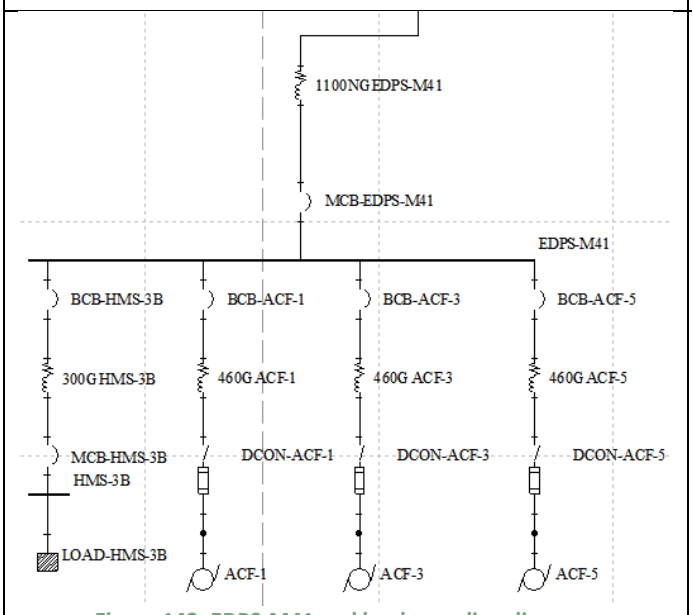


Figure 142: EDPS-M41 and loads one-line diagram.

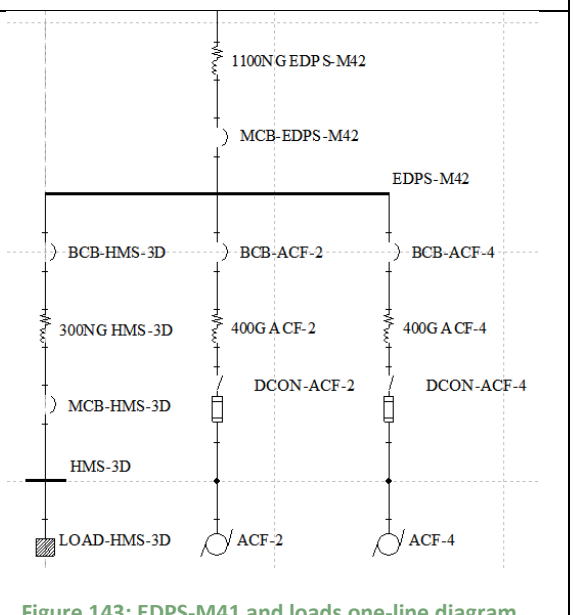


Figure 143: EDPS-M41 and loads one-line diagram.

Once the one-line diagram is finalized and all components will run through the analysis software without fatal errors or warnings, it is possible to run a report on arc flash, short circuit, equipment sizing, etc. Utility available fault current for this depth topic is courtesy of Penn State OPP. The two main utility feeds for the Millennium Science Complex contribute 37,246A (PSU1) and 34,372A (PSU-2). Results from the SKM analysis can be seen in Table 46 below.

Table 46: Transformer Impedance Summary.

Transformer Impedance Summary				
Tag	**Primary Voltage**	**Secondary Voltage**	**%R**	**%X**
PSU-1	12.47kV Delta	480Y/277V	0.4775	5.73
PSU-2	12.47kV Delta	480Y/277V	0.4775	5.73
PSU-VAULT	4160V Delta	480Y/277V	1.05	5.65
TRN-SDP-2D	480V Delta	208Y/120V	2.07	4.00
TRN-SDP-2D1	480V Delta	208Y/120V	2.07	4.00
TRE-SDP-2B	480V Delta	208Y/120V	2.07	4.00
TRE-EDPS-3B	480V Delta	208Y/120V	2.36	3.83
TRE-EDPS-3D	480V Delta	208Y/120V	2.36	3.83

As stated in the introduction to this analysis, knowing arc flash and short circuit characteristics of equipment can help engineers prevent loss of live in worst-case-scenario events. Ideally, each piece of equipment should have an interrupting rating greater than the analysis results in the SKM output. The highlighted values in Table 47 on the following page are pieces of equipment that can be deemed in violation of their interrupting rating or are close to violating their interrupting rating. The higher voltage panelboard (H- prefix) are currently rated for 14,000 AIC. The two HMS panel boards above can now be seen to be unsafe for the event of a short circuit – given the manner in which this system was modeled. Similarly, panelboard LR-3B is close to its maximum interrupting current rating. On panelboard schedules, a *minimum* value for interrupting current is written in. After viewing this results table, designs can be adjusted to account for dangers such as panelboard failures and arc flashes.

Table 47: SKM Short Circuit Report Summary.

Fault Analysis Summary					
Bus Name	Voltage	Available Fault Current			
	L-L	3-Phase	X/R	LINE/GRND	X/R
EDPS-1E1	480	39353.3	3	8391.63	0.2
EDPS-1E2	480	38449.6	2.9	8364.93	0.2
EDPS-3B	208	8147.9	1.6	9238.12	1.6
EDPS-3D	208	9963.3	1.6	10713.51	1.6
EDPS-M41	480	26611.3	2.1	7238.23	0.3
EDPS-M42	480	32169.3	2.4	7817.41	0.3
EMDS-1	480	10039.0	4.9	1621.01	0.1
HL-3B	480	13108.6	1.6	5383.71	0.5
HL-3D	480	11810.3	1.2	4971.80	0.5
HM-3D	480	13304.3	1.6	5406.24	0.5
HMS-3B	480	15707.0	1.4	5858.97	0.4
HMS-3D	480	17537.7	1.4	6259.26	0.4
LB-3B1/2	208	7593.2	1.1	6792.20	1.2
LB-3B3/4	208	7756.9	1.1	6964.21	1.2
LB-3B5/6	208	7756.9	1.1	6964.21	1.2
LB-3B7	208	8104.7	1.2	7334.45	1.2
LB-3C1/2	208	4502.6	0.9	4019.60	1
LB-3D1/2	208	138.7	7.9	134.64	8.1
LB-3D5/6	208	138.7	7.9	134.64	8.1
LB-3D7/8	208	4508.2	0.9	4021.00	1
LBS-3B1/2	208	6467.5	1.2	6633.94	1.2
LBS-3B3/4	208	6467.5	1.2	6633.94	1.2
LBS-3D1/2	208	7560.1	1.2	7361.22	1.2
LBS-3D5/6	208	7560.1	1.2	7361.22	1.2
LR-3B	208	9213.2	1.2	8620.65	1.2
LR-3B5/6	208	7756.9	1.1	6964.21	1.2
LR-3C1/2	208	3773.0	0.8	3288.52	0.9
LR-3D1/2	208	6503.1	1.1	6244.65	1.2
LR-3D3/4	208	6503.1	1.1	6244.65	1.2
LS-3B	208	6746.9	1.1	7098.78	1
LS-3D	208	7936.7	1.1	7928.46	1
MDP-M41	480	18646.1	1.9	6337.24	0.4
MDP-M42	480	19033.2	1.9	6367.69	0.4
MDS-01A	480	57411.7	5.7	9248.60	0.1
MDS-01B	480	57406.8	5.7	9248.52	0.1
MDS-02A	480	44453.2	3.5	8669.88	0.2
MDS-02B	480	44450.1	3.5	8669.80	0.2
SDP-2B	208	10951.5	1.6	10647.34	1.7
SPD-2D	208	8645.7	1.4	9083.76	1.5
SDP-2D1	208	8574.7	1.3	9026.44	1.6

Short Circuit Hand Calculation

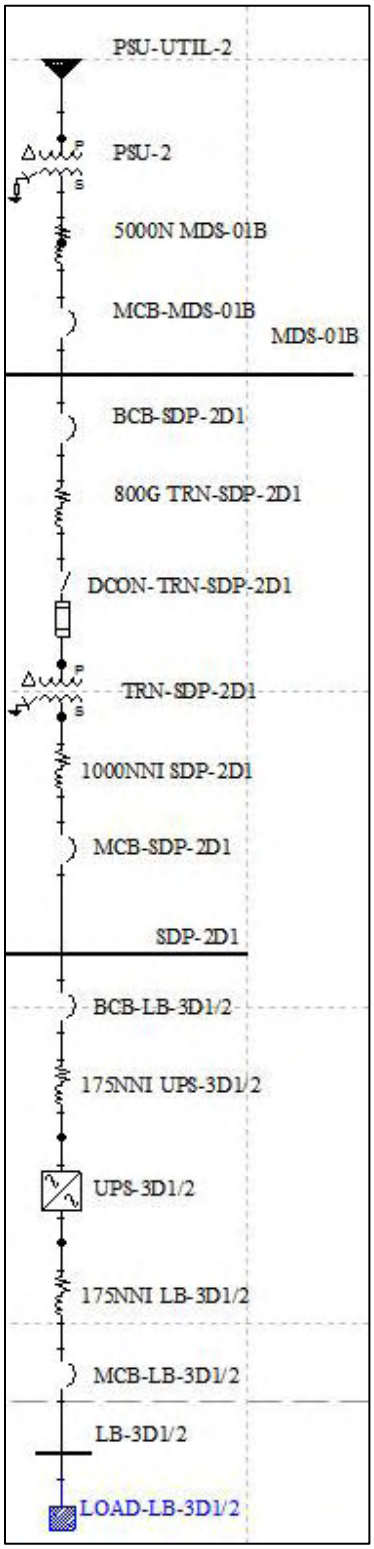


Figure 144: Short Circuit Analysis Path.

A short circuit analysis of the follow sting of electrical components was completed using the per-unit method:

- PSU Utility
- TRN-PSU-2
  - (12) Sets of 750
- MDS-01B
  - (2) Sets of 600
- TRN-SDP-2D1
  - (3) Sets of 400
- SDP-2D1
  - (1) Set of 2/0
- UPS-3D1/2
  - (1) Set of 2/0
- LB-3D1/2

The one-line view of this run can be seen to the left in Figure 144: Short Circuit Analysis Path. The results are found on the following page in Table 48: Short Circuit Analysis Calculation Table.

Table 48: Short Circuit Analysis Calculation Table.

Short Circuit Aalysis (Per Unit Method)															
Equipment Characteristics											Per-Unit Value				
Mark	%X	%R	%Z	kVA	X/1000ft	R/1000ft	Z/1000ft	Length (ft)	No. Sets	3ph Voltage (V)	Mark	X_u	R_u	Z_u	I_{sc}
Utility	0.235			42563.55						12470	Utility	0.2349		0.2349	
															1970.656
TRN-PSU-2	5.730	0.478	5.750	5000						480	PSU-2	0.1146	0.0096	0.1150	
															34371.90
FEEDER MDS-01B (750)					0.0445	0.0216	0.0495	30	12	480	FEEDER MDS-01B	0.0048	0.0023	0.0054	
															33852.67
MDS-01B										480	MDS-01B				
															33852.67
FEEDER TRN-SDP-2D1 (600)					0.0257	0.0463	0.0530	1000	2	480	FEEDER TRN-SDP-2D1	0.5577	1.0048	1.1492	
															7994.798
TRN-SDP-2D1	2.070	4.000	4.504	300						480	TRN-SDP-2D1	0.6900	1.3333	1.5013	
															4001.658
FEEDER SDP-2D1 (400)					0.0490	0.0356	0.0606	154	3	208	FEEDER SDP-2D1	0.5814	0.4224	0.7186	
															7452.76
SDP-2D1											SDP-2D1				
															7452.76
FEEDER UPS-3D1/2 (2/0)					0.0553	0.1020	0.1150	200	1	208	FEEDER UPS-3D1/2	2.5564	4.7152	5.3636	
															3054.251
UPS-3D1/2	0.992	0.012	0.992	50						208	UPS-3D1/2	1.9840	0.0240	1.9841	
															2506.928
FEEDER-LB-3D1/2 (2/0)					0.0553	0.1020	0.1150	10	1	208	FEEDER-LB-3D1/2	0.1278	0.2358	0.2682	
															2447.643
LB-3D1/2											LB-3D1/2				

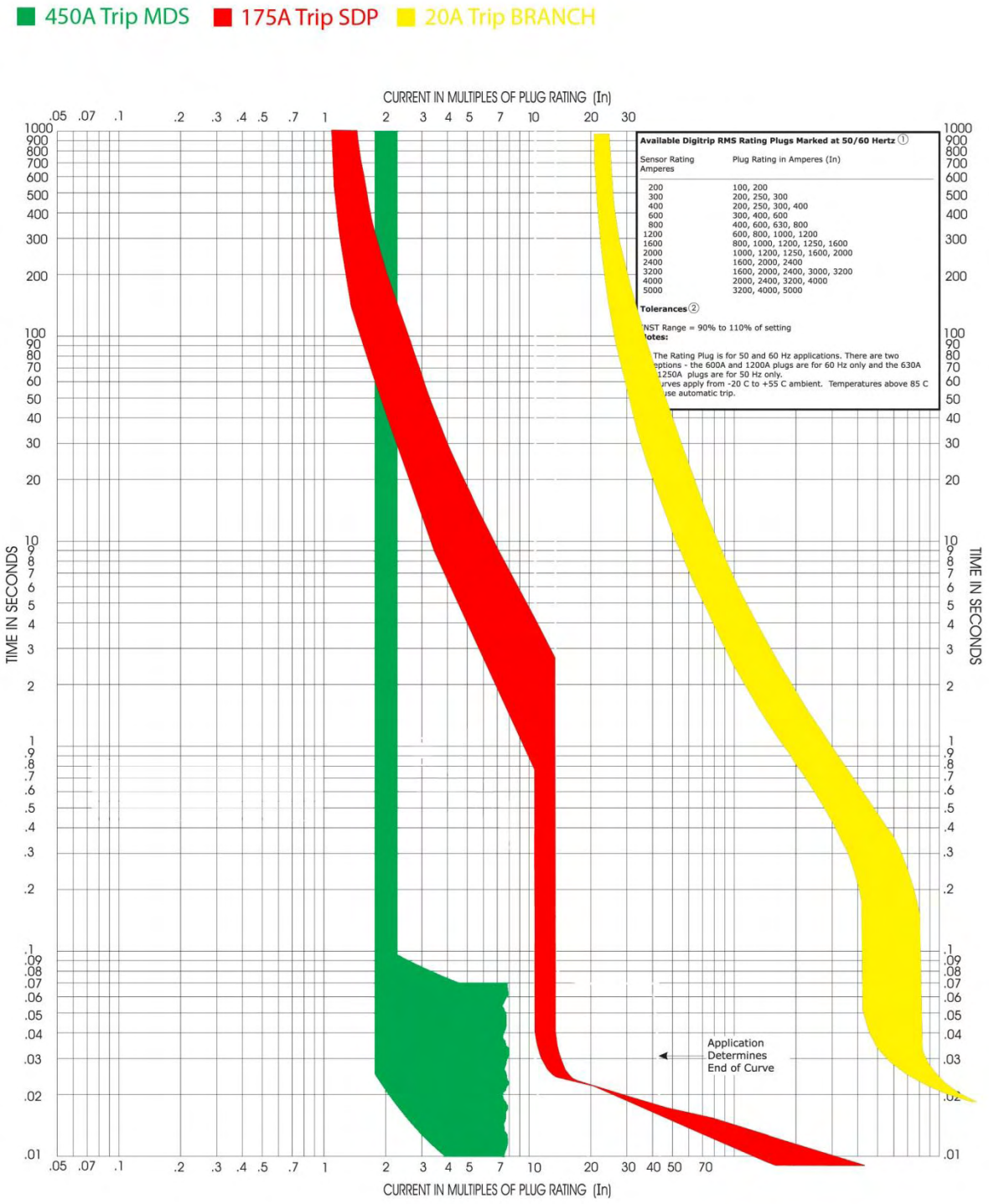


Figure 145: Short Circuit Device Coordination.

Revit MEP Modeling

Summary

The use of an in depth program such as Revit MEP allows for quick integration between disciplines. Specifically, Mechanical and Electrical designers can exchange accurate design loads almost instantaneously. The process of setting up a Revit MEP Model can be intensive up front, yet allow for easy changes to systems and designs closer to the end of the design timeline.

The Millennium Science Complex is an intensive research lab with extensive electrical plug loads and research equipment throughout. The use of ASHRAE suggested electrical design load watts/SF according to the type of room in question would be an underestimation for mechanical equipment sizing. The use of Revit MEP while designing an electrical system can allow the designer to provide each room with an actual connected load and W/SF.

The Building Stimulus took the opportunity to explore the use of Revit MEP as both an electrical design tool and a BIM/IPD design tool. In the following sections the topics of using Revit MEP as an electrical design tool, a building information modeling tool, and an integration tool between disciplines.

Revit MEP as a Lighting Design Tool

Entering Material Properties

Professionals who have used platforms of AutoDesk Revit are usually familiar with the materials editing process, but not to the level of detail that can be fully achieved with the programs. With respect to lighting design, the generic material types in Revit MEP simply are not enough to provide detailed renderings of spaces, which keep lighting design out of BIM. Embedded within the material properties of Revit Architecture are custom materials. In order to appropriately model surfaces such as "painted gypsum wall board with [manufacturer] cool gray paint," the designer should use a custom wall.

When going deeper into the wall construction and materials, the user will notice that there is not much room for customization in the generic Revit material types. For example, the standard gypsum wall board acts like a painted surface (Figure 42). There are pre-loaded properties of finishes in the following combinations of color, finish, and application:

Color	Finish	Application
Customizable	Flat/Matte	Brush
	Eggshell	Roller
	Platinum	Spray
	Pearl	
	Semi-gloss	
	Gloss	

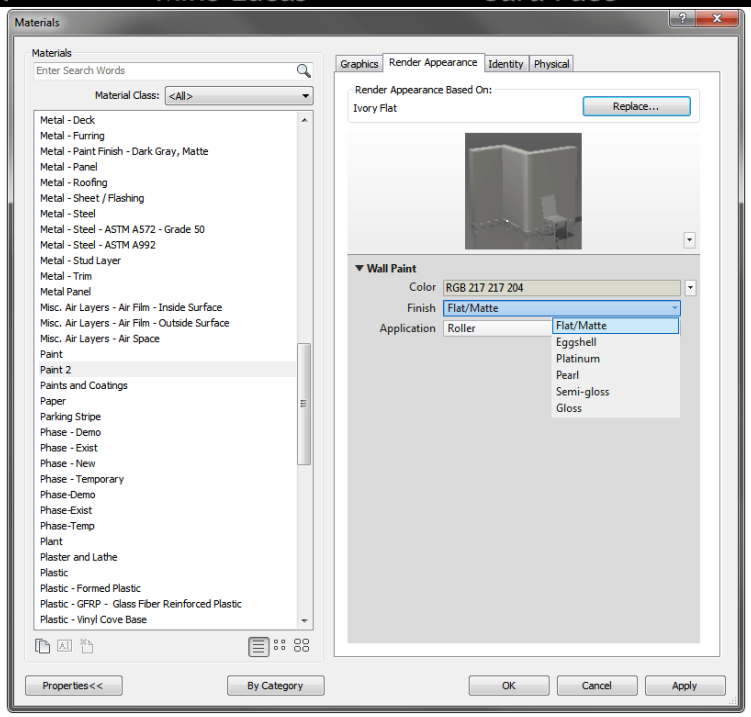


Figure 146: Material Properties - Finishes.

Each of these finishes and applications has properties of reflectance, specularity, roughness, etc. that cannot be accessed by the designer. A good way to make the surface somewhat custom to the design is to begin with a "Generic" material and adjust colors and reflectivity (Figure 43).

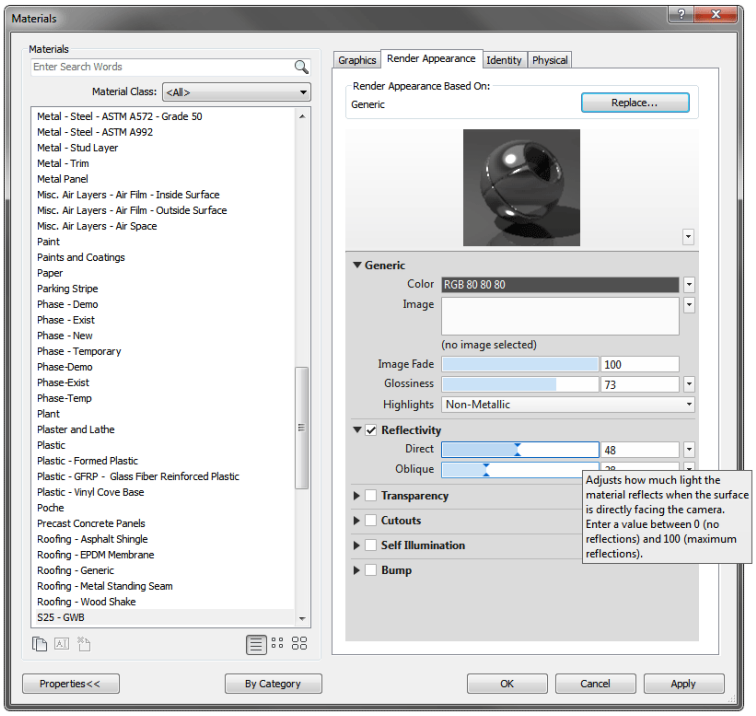


Figure 147: Material Properties – Custom Finishes.

These properties, however, are not exactly the inputs lighting designers wish to be able to control. The direct reflectivity and oblique reflectivity are defined by Revit Architecture as follows:

Direct Reflectivity: Measurement of how much light the material reflects when the surface is directly facing the camera. Enter a value between 0 (no reflections) and 1 (maximum reflections).

Oblique Reflectivity: Measurement of how much light the material reflects when the surface is at an angle to the camera. Enter a value between 0 (no reflections) and 1 (maximum reflections).

This means that designers must perform a calculation to find the relative reflectivity of their surfaces, or guess and hope that their inputs are somewhat accurate. On the positive end, there are materials that do have relative inputs. Glass types allow the designer to input reflectance and number of sheets in the panel. Glass types do not, however, allow for specification of transmittance. Without usable inputs such as reflectance, instead of reflectivity, and transmittance, instead of transparency, lighting design in platforms of Revit is simply too time consuming and not worth the input relative to programs such as AGI32.

Setting Design Criteria

One of the largest challenges of lighting designers is establishing appropriate design criteria for spaces. The discussion up to this section has been design criteria for three spaces in the Millennium Science Complex. With the advent of Building Information Modeling, lighting design has an opportunity to merge into a larger world than lighting software. In its current state, building information modeling lacks in ultimate usefulness of design criteria such as design illuminance and other measurable quantities such as uniformity gradient, coefficient of variance, and luminance ratios. However, this observation is only applicable to Revit MEP 2011 as it is the primary software for IPD/BIM Thesis 2010-2011.

Revit MEP allows for specialized space criteria once a schedule is created. It is possible to add custom parameters, but it is not possible to edit pre-loaded templates (Figure 44). Other information, such as power densities (similar to ASHRAE 90.1) is already embedded into space types. It is possible to add custom parameters through schedules (Figure 45).

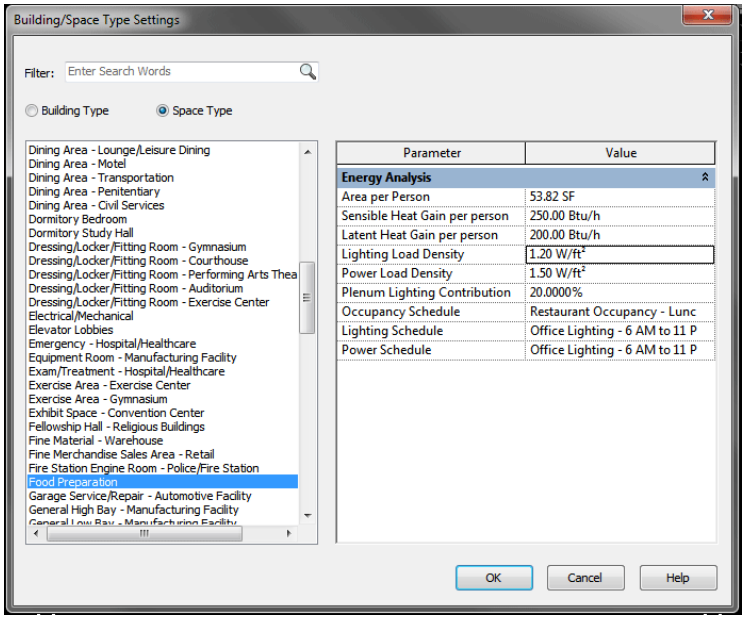


Figure 148: Space Type.

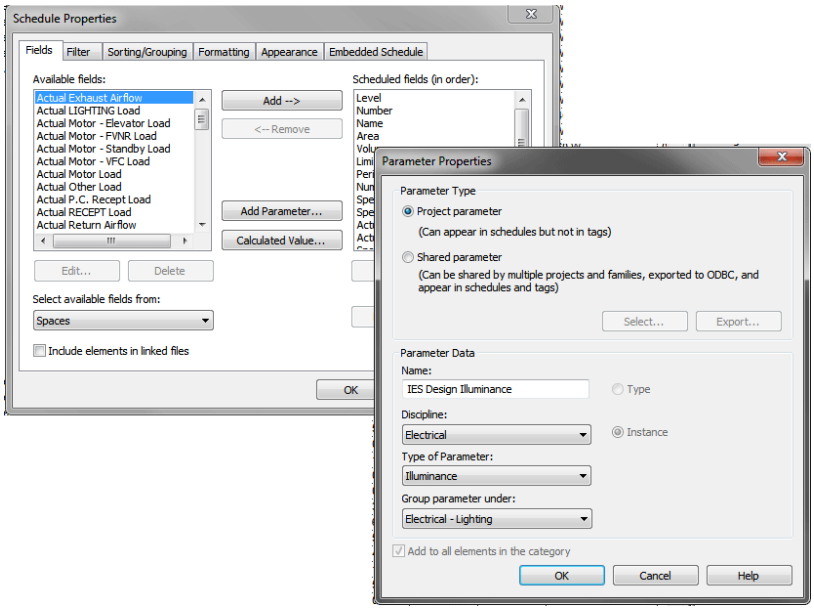


Figure 149: Parameter Properties.

For the inputs above, the parameter "IES Design Illuminance" will appear under the "Electrical – Lighting" properties of the space and be in "Illuminance" parameters (i.e. footcandles). Now that this parameter has been created, each space can be edited to have its IES recommended illumination value within its properties. These new parameters can be drawn out of the BIM model in a schedule, but are arbitrary to space type. Not being associated with a pre-specified space type creates a labor-intensive chore to assign design criteria to spaces.

If IES values and parameters can be associated in the base space types, then it will be possible to have a visual check on initial space design compliance. Discussed in the next section will be how Revit calculates average illuminance values and their comparison to actual hand calculations.

Calculation Process Revit MEP

Embedded in space types as discussed in "Setting Design Criteria" of this document are calculated statistics applicable to lighting design. Parameters for these calculations include:

Variable Inputs
Lighting Calculation Workplane
Ceiling Reflectance
Wall Reflectance
Floor Reflectance

Outputs
Average Estimated Illumination (AEI)
Room Cavity Ratio (RCR)

These inputs are separate from the "reflectivity" parameters discussed in the previous topic. The reflectances in this topic are applied to the space. The space is essentially an imaginary box that fills a room to its extents. The reflectance values apply to the ceiling, walls, and floor of the space box and are not associated with the materials in the room whatsoever. Each reflectance can be thought of as an area average for the entire area it is analogous to in the space.

The room cavity ratio is automatically calculated from the "lighting calculation workplane" and the mounting height of the luminaire. All calculations are used in a basic Lumen Method for the space. This inherently cannot take criteria such as vertical illuminance, actual uniformity, or luminance ratios as discussed in the last topic. Other

inputs are available that affect the calculation such as customizable light loss factors and initial intensity (by efficacy, flux, luminous intensity, or illuminance at a distance). The image from Revit MEP's help site below shows these inputs (Figures 46 and 47). These all are combined into a total light loss factor for the calculation.

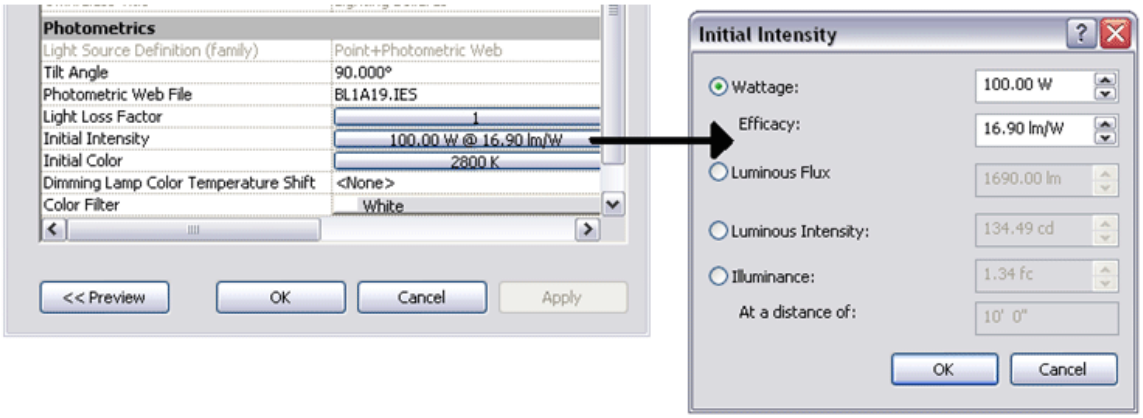


Figure 150: Initial Intensity.

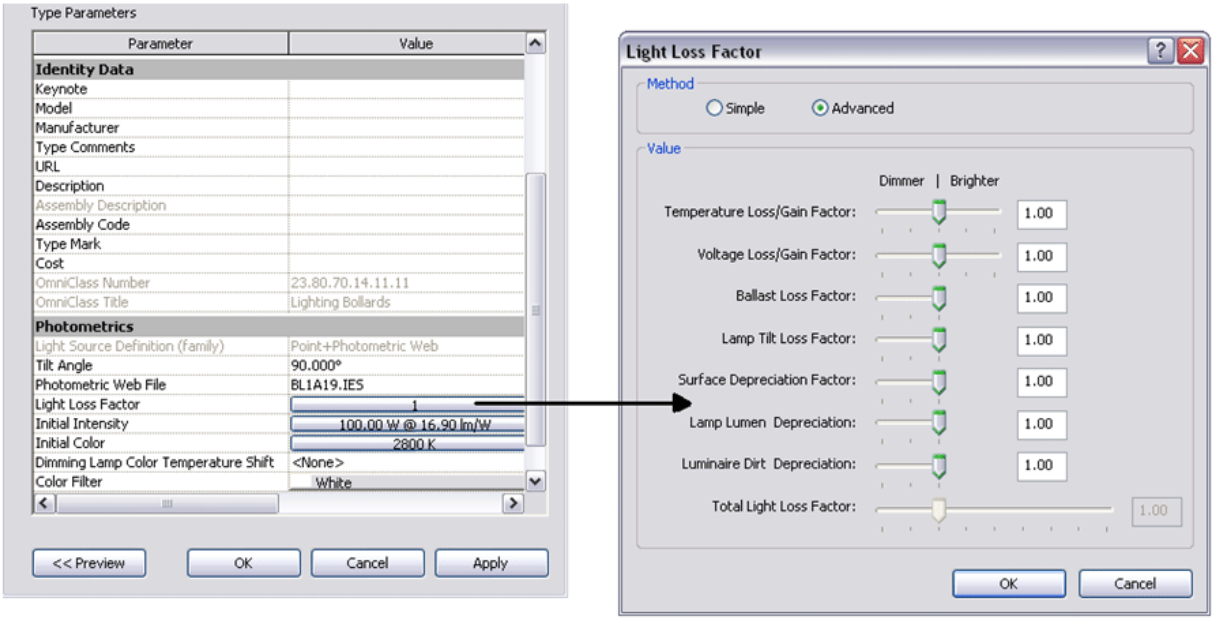


Figure 151: Light Loss Factors.

Revit's calculation process incorporates all of the input factors from each luminaire and adds them individually. Regardless of luminaire position, orientation, and distribution, a simple addition of flux is the only equation used to calculate total illuminance:

$$AEI = \sum_{i=1}^{n} \frac{Lumens\ at\ Workplane_i}{Area}$$

The quantity of lumens at the work plane is a peculiar calculation also. It is a product of the "initial intensity" from the properties seen in the image above, total light loss factors, and the coefficient of utilization of the luminaire. It is unclear in the Revit MEP help page how the coefficient of utilization is actually calculated and used and CU does not appear in an output in the properties box of a space. What the total calculation boils down to is the following:

$$AEI = \sum_{i=1}^{n} \frac{(II * LLF * CU)_i}{Space\ Area}$$

Where: II = Initial Intensity in lumens
LLF = total light loss factors
CU = Coefficient of Utilization

As the equation turns out, room reflectance values should have direct bearing on the average estimated illumination of the space, as should the task plane height. In reality, the user cannot determine how CU and RCR are used in these calculations. In normal lighting calculations, a room cavity ratio, wall reflectance, and ceiling cavity reflectance are used to interpolate on a chart for the luminaire. In the example below (Figure 48), reflectance values are changed from ceiling/wall/floor of 0.8/0.6/0.2 (standard) to other values.

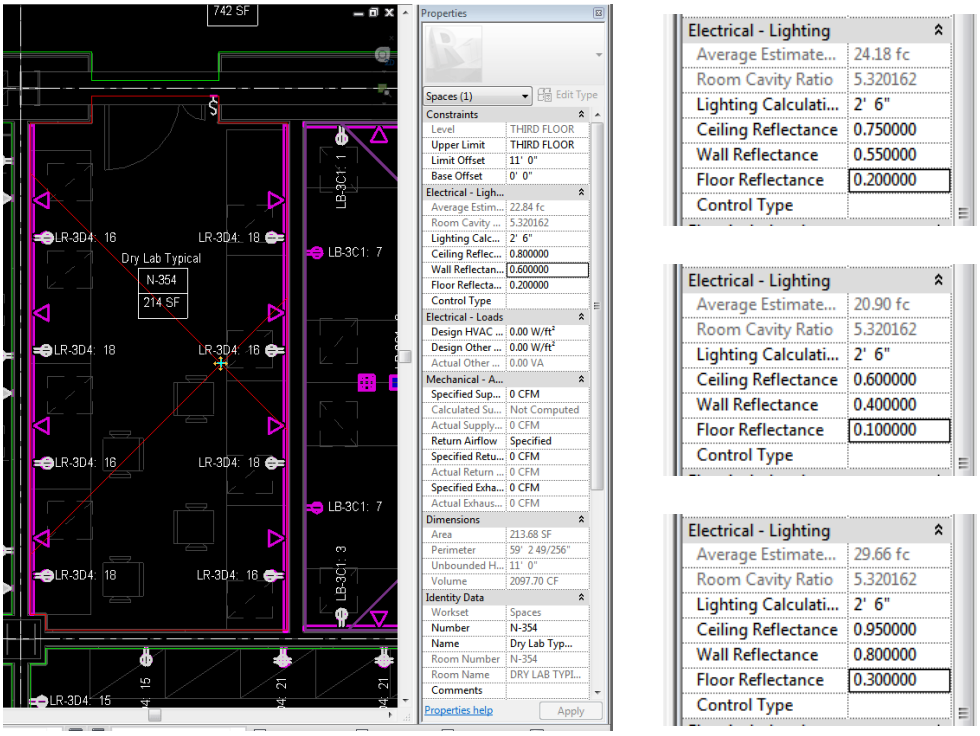


Figure 152: Changing Reflectance Values.

Notice the inconsistent change in the calculated illuminance and RCR relative to the given equation. If this calculation were a true Lumen Method, the equations would depend on CU as in the IESNA Handbook shown here:

$$Illuminance = \frac{(\#\ of\ Luminaires)(\varphi\ per\ Luminaire)(CU)(LLF)}{Workplane\ Area}$$

$$Where:\ \ CU\ \propto\ \ F(\rho_{CC}, \rho_W, RCR)$$

Upon examining luminaires and spaces, it is possible that the "Room Cavity Ratio" report in the properties dialog is actually a product of RCR and CU. Upon further investigation, this is not true. If reflectances are changed in a space, the coefficient of utilization is automatically changed per luminaire, provided that the "Calculate Coefficient of Utilization" box is checked in the luminaire properties. Using flux transfer, a coefficient of utilization can be obtained that is similar to the value calculated in Revit MEP:

$$\begin{bmatrix} -1 & \rho_1 F_{1-2} & \rho_1 F_{1-3} \\ \rho_2 F_{2-1} & -1 & \rho_2 F_{2-3} \\ \rho_3 F_{3-1} & \rho_3 F_{3-2} & (\rho_3 F_{3-3}) - 1 \end{bmatrix} \begin{bmatrix} M_1 \\ M_2 \\ M_3 \end{bmatrix} = \begin{bmatrix} -M_{01} \\ -M_{02} \\ -M_{03} \end{bmatrix}$$

$$CU = \frac{M_{FC} * A_{FC}}{\varphi_{LAMP} * \rho_{FC}}$$

Using the flux balance method, this room has a coefficient of utilization of 0.507 as opposed to a Revit MEP calculated value of 0.518. "Room Cavity Ratio" in Revit MEP is still unclear as to how to achieve this value. For the same room, Revit MEP's output RCR has a value of 5.320. The actual RCR as calculated by the IESNA Handbook has a value of 5.698. When hand-calculated RCR and CU are combined in the Lumen Method equation discussed previously, this room should be calculated to be between 24.80 fc and 30.03 fc depending upon efficiency of the light fixture. Revit MEP calculates the average estimated illumination for this space to be 24.95 fc, which is analogous to an efficiency of 72.7% in the Lumen Method calculation.

In conclusion, Revit MEP's calculation of "average estimated illuminance" can be a good starting point for lighting design, but is not clear enough communicating how these values are calculated. If a more extensive demonstration of how Revit MEP calculates average estimated illuminance can be written into the program, there could be more use for lighting design estimation in Revit.

Electrical Impacts from Lighting Design

Building Stimulus has focused on the third floor for the primary zone for redesign. Because of this, lighting designs of the third floor typical spaces have been extrapolated throughout the third floor for electrical analysis.

Panel HL-3B feeds the normal system lighting in the Life Science wing, while HLE-3B feeds the normal/emergency system lighting in the Life Science wing. Similarly, Panel HL-3D feeds the normal system lighting in the Material Science wing, while HLE-3B feeds the normal/emergency system lighting in the Material Science wing.

There are 23 typical offices as well as two distinguished offices on the 3rd floor of the Material Science wing which are circuited to panel HL-3D.The corridor lighting design will affect 4384SF of circulation space in the Material Science wing, where normal system lighting will be fed from HL-3D and normal/emergency system lighting is fed from HLE-3D. Room N308A/B is a conference room totaling 846SF which is circuited to HL-3D. The Life Science wing also contains three student study areas, two are 780SF and the other is 313SF – all three of which are fed from panel HL-3D.

There are 15 typical offices as well as a single distinguished office on the 3rd floor of the Life Science wing which are circuited panel HL-3B. The corridor lighting design affects 4270SF of circulation space in the Life Science wing, where normal system lighting is fed from HL-3B and normal/emergency system lighting is fed from HLE-3B. The Life Science wing also has a conference room, totaling 846SF which is circuited to HL-3B.

Site and lobby lighting is fed from panels LCP-1 and LCPE-1. LCP-1 feeds the normal lighting system while LCPE-1 feeds the normal/emergency lighting systems. These panels have been adjusted to work with the exterior plaza lighting design.

Table 49: Lighting Design Panel Schedules

Lighting Design Impacted Panelboards							
Panel Tag	Voltage	System	Exterior Plaza	Conference Room	Student Study Area	Corridor	Office
LCP-1	277/480V, 3P, 4W	N	X				
LCPE-1	277/480V, 3P, 4W	N/E	X				
HL-3B	277/480V, 3P, 4W	N		X		X	X
HL-3D	277/480V, 3P, 4W	N		X	X	X	X
HLE-3D	277/480V, 3P, 4W	N/E				X	
HLE-3B	277/480V, 3P, 4W	N/E				X	

Existing Panel Schedules

LCP-1

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: LCP-1	Mounting: Surface:	X	Main Lugs Only:	.	Amp Main CB	.
277/480V, 3 Phase, 4 Wire	Flush:	.	Shunt Trip Main:	.	Amp Bus	225
14,000MIN A.I.C. SYM	In MCC	.	Feed Through:	.	Ground Bus	.
Neutral: 100%	Number of Poles:	42	TVSS:	.	Isolated Ground Bus	.

CKT No.	Load	TRIP (Amp)	KVA/Phase A	KVA/Phase B	KVA/Phase C	CKT No.	CKT No.	KVA/Phase A	KVA/Phase B	KVA/Phase C	TRIP (Amp)	Load	CKT No.
1	Zone 1 LS Lobby Lighting	20	0.42			1	2	0.00			20	Spare	2
3	Spare	20		0.00		3	4		0.24		20	Zone 19 Site Lighting	4
5	Zone 3 Exterior Lighting	20			1.40	5	6			0.24	20	Zone 20 Site Lighting	6
7	Zone 4 LS Lobby Lighting	20	0.31			7	8	0.36			20	Zone 21 Site Lighting	8
9	Zone 5 LS Lobby Lighting	20		0.56		9	10		0.70		20	Zone 22 Site Lighting	10
11	Zone 6 Exterior Lighting	20			1.25	11	12			0.00	20	Spare	12
13	Zone 7 ML Lobby Lighting	20	0.84			13	14	0.38			20	Zone 24 Site Lighting	14
15	Zone 8 ML Lobby Lighting	20		0.56		15	16		0.00		20	Spare	16
17	Zone 9 LS Exterior Lighting	20			1.40	17	18			0.40	20	Zone 26 Site Lighting	18
19	Spare	20	0.00			19	20	0.05			20	Zone 27 Site Lighting	20
21	Zone 11 Exterior Lighting	20		1.25		21	22		0.40		20	Zone 28 Site Lighitng	22
23	Zone 12 ML Lobby Lighting	20			0.31	23	24			0.27	20	Zone 29 Exterior Lighting	24
25	Zone 13 Exterior Lighting	20	0.63			25	26	0.27			20	Zone 30 Exterior Lighting	26
27	Zone 14 Exterior Lighting	20		0.84		27	28		0.23		20	Zone 31 Exterior Lighting	28
29	Zone 15 Site Lighting	20			2.10	29	30			0.20	20	Zone 32 Exterior Lighting	30
31	Zone 16 Site Lighting	20	2.10			31	32	0.23			20	Zone 33 Exterior Lighting	32
33	Zone 17 Site Lighting	20		1.90		33	34		0.27		20	Zone 34 Exterior Lighting	34
35	Zone 35 ML Lobby Lighting	20			0.46	35	36			0.42	20	Zone 36 LS Lobby Lighting	36
37	Spare	20	0.00			37	38	0.00			20	Spare	38
39	Spare	20		0.00		39	40		0.00		20	Spare	40
41	Spare	20			0.00	41	42			0.00	20	Spare	42

Subtotals (kVA):		4.30	5.11	6.92		1.29	1.84	1.53		Subtotals (kVA)
Total Loads:	Phase A:	5.59 kVA				80 %				Demand Factor
	Phase B:	6.95 kVA				16.79 kVA				Demand Load
	Phase C:	8.45 kVA				20.99 kVA				Load x 1.25
Total Connected Load:	20.99 kVA					25.28 A				Demand Amps

*Denotes Programmable Remote Control Breaker

Figure 153: Existing Panel Schedule LCP-1.

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: LCPE-1	Mounting: Surface:	X	Main Lugs Only:	.	Amp Main CB	90
277/480V, 3 Phase, 4 Wire	Flush:	.	Shunt Trip Main:	.	Amp Bus	100
14,000MIN A.I.C. SYM	In MCC	.	Feed Through:	.	Ground Bus	.
Neutral: 100%	Number of Poles:	42	TVSS:	.	Isolated Ground Bus	.

	CKT No.	Load	TRIP (Amp)	KVA/Phase A	KVA/Phase B	KVA/Phase C	CKT No.	CKT No.	KVA/Phase A	KVA/Phase B	KVA/Phase C	TRIP (Amp)	Load	CKT No.	
	1	Spare	20	0.00			1	2	0.22			20	Zone 42 Exterior Lighting	2	*
	3	Spare	20		0.00		3	4		0.23		20	Zone 41 M. Lobby Lighting	4	*
*	5	Zone 37 LS Lobby Lighting	20			0.23	5	6			0.17	20	Zone 43 Exterior Lighting	6	*
*	7	Zone 38 Exterior Lighting	20	0.70			7	8	0.77			20	Loading Dock	8	*
*	9	Zone 39 Exterior Lighting	20		0.70		9	10		0.00		20	Spare	10	
*	11	Zone 40 Exterior Lighting	20			0.70	11	12			0.00	20	Spare	12	
	13	Spare	20	0.00			13	14	0.00			20	Spare	14	
	15	Spare	20		0.00		15	16		0.00		20	Spare	16	
	17	Spare	20			0.00	17	18			0.00	20	Spare	18	
	19	Spare	20	0.00			19	20	0.00			20	Spare	20	
	21	Spare	20		0.00		21	22		0.00		20	Spare	22	
	23	Spare	20			0.00	23	24			0.00	20	Spare	24	
	25	Spare	20	0.00			25	26	0.00			20	Spare	26	
	27	Spare	20		0.00		27	28		0.00		20	Spare	28	
	29	Spare	20			0.00	29	30			0.00	20	Spare	30	
	31	Spare	20	0.00			31	32	0.00			20	Spare	32	
	33	Spare	20		0.00		33	34		0.00		20	Spare	34	
	35	Spare	20			0.00	35	36			0.00	20	Spare	36	
	37	Spare	20	0.00			37	38	0.00			20	Spare	38	
	39	Spare	20		0.00		39	40		0.00		20	Spare	40	
	41	Spare	20			0.00	41	42			0.00	20	Spare	42	

Subtotals (kVA):		0.70	0.70	0.93		0.99	0.23	0.17	Subtotals (kVA)
Total Loads:	Phase A:	1.69 kVA				80 %			Demand Factor
	Phase B:	0.93 kVA				2.98 kVA			Demand Load
	Phase C:	1.10 kVA				3.72 kVA			Load x 1.25
Total Connected Load:	3.72 kVA					4.48 A			Demand Amps

*Denotes Programmable Remote Control Breaker

Figure 154: Existing Panel Schedule LCPE-1.

HL-3B

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: HL-3B	Mounting: Surface:	X	Main Lugs Only:	.	Amp Main CB	200
277/480V, 3 Phase, 4 Wire	Flush:	.	Shunt Trip Main:	.	Amp Bus	225
14,000MIN A.I.C. SYM	In MCC	.	Feed Through:	.	Ground Bus	X
Neutral: 100%	Number of Poles:	42	TVSS:	.	Isolated Ground Bus	.

CKT No.	Load	TRIP (Amp)	KVA/Phase A	KVA/Phase B	KVA/Phase C	CKT No.	CKT No.	KVA/Phase A	KVA/Phase B	KVA/Phase C	TRIP (Amp)	Load	CKT No.
1	Nuerophts-Invitro Lighting	20	2.21			1	2	2.21			20	Nuerophts-Invitro Lighting	2
3	Nuerophts-Invitro Lighting	20		1.83		3	4		1.83		20	Nuerophts-Invitro Lighting	4
5	Optical Imagimg Lighting	20			2.58	5	6			2.40	20	Fumehood, Tissue Culture Lighting	6
7	Fumehood Procedure, Hot Room	20	2.18			7	8	1.72			20	Toilet, Equip Corr. Lighting	8
9	Faculty, Grad Student Lighting	20		2.07		9	10		1.76		20	Faculty GMAD Hudson Lighting	10
11	Elec. Equipment, Post Doc & Light	20			1.74	11	12			1.74	20	BCI Teaching, GMAD, Post Doc Lighting	12
13	Conference Library Lighting	20	1.32			13	14	1.82			20	Office, Staff, Kitchen Lighting	14
15	Conference Library Lighting	20		1.79		15	16		2.27		20	Corridor Lighting	16
17	Terrace Lighting	20			1.00	17	18			1.69	20	Corridor Lighting	18
19	Motorized Shades	20	0.50			19	20	1.93			20	Café/Common Lighting	20
21	Motorized Shades	20		0.50		21	22		1.67		20	Café/Common Lighting	22
23	Motorized Shades	20			0.50	23	24			0.60	20	Track Lighitng	24
25	Spare	20				25	26	2.40			20	Track Lighting	26
27	Spare	20				27	28				20	Spare	28
29	Spare	20				29	30				20	Spare	30
31	Spare	20				31	32				20	Spare	32
33	Spare	20				33	34				20	Spare	34
35	Spare	20				35	36				20	Spare	36
37	Spare	20				37	38				20	Spare	38
39	Spare	20				39	40				20	Spare	40
41	Spare	20				41	42				20	Spare	42

Subtotals (kVA):		6.21	6.19	5.82	
Total Loads:	Phase A:	16.29 kVA			
	Phase B:	13.72 kVA			
	Phase C:	12.25 kVA			
Total Connected Load:		42.26 kVA			

10.08	7.53	6.43		Subtotals (kVA)
90 %				Demand Factor
38.03 kVA				Demand Load
47.54 kVA				Load x 1.25
57.25 A				Demand Amps

Figure 155: Existing Panel Schedule HL-3B.

HL-3D

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: HL-3D	Mounting: Surface:	X	Main Lugs Only:	.	Amp Main CB	200
277/480V, 3 Phase, 4 Wire	Flush:	.	Shunt Trip Main:	.	Amp Bus	225
14,000MIN A.I.C. SYM	In MCC	.	Feed Through:	.	Ground Bus	X
Neutral: 100%	Number of Poles:	42	TVSS:	.	Isolated Ground Bus	.

CKT No.	Load	TRIP (Amp)	KVA/Phase A	KVA/Phase B	KVA/Phase C	CKT No.	CKT No.	KVA/Phase A	KVA/Phase B	KVA/Phase C	TRIP (Amp)	Load	CKT No.
1	Student Lighting	20	0.83			1	2	1.70			20	Staff &Faculty Lighting	2
3	Electroactive Poly Lighting	20		1.60		3	4		1.90		20	Student Lighting	4
5	Organic Elec & Pho Lighting	20			1.60	5	6			1.90	20	Student Lighting	6
7	Dry Lab A&B, Staff Lighting	20	1.41			7	8	2.20			20	Staff Lighting	8
9	Staff Admin, Kitchen Lighitng	20		1.23		9	10		1.32		20	Conference Room Lighting	10
11	Dry Lab, Misc. Comp. Lighting	20			1.28	11	12			1.52	20	Conference Room Lighting	12
13	Corridor Lighting	20	1.60			13	14				20	Spare	14
15	Corridor Lighitng	20		1.54		15	16				20	Spare	16
17	Corridor Lighitng	20			1.68	17	18				20	Spare	18
19	Spare	20				19	20				20	Spare	20
21	Spare	20				21	22				20	Spare	22
23	Spare	20				23	24				20	Spare	24
25	Spare	20				25	26				20	Spare	26
27	Spare	20				27	28				20	Spare	28
29	Spare	20				29	30				20	Spare	30
31	Spare	20				31	32				20	Spare	32
33	Spare	20				33	34				20	Spare	34
35	Spare	20				35	36				20	Spare	36
37	Spare	20				37	38				20	Spare	38
39	Spare	20				39	40				20	Spare	40
41	Spare	20				41	42				20	Spare	42

Subtotals (kVA):		3.84	4.37	4.56		3.90	3.22	3.42	Subtotals (kVA)
Total Loads:	Phase A:	7.74 kVA				80 %			Demand Factor
	Phase B:	7.59 kVA				18.65 kVA			Demand Load
	Phase C:	7.98 kVA				23.31 kVA			Load x 1.25
Total Connected Load:	23.31 kVA					28.07 A			Demand Amps

Figure 156: Existing Panel Schedule HL-3D

HLE-3B

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: HLE-3B	Mounting: Surface:	X	Main Lugs Only:	.	Amp Main CB		100
277/480V, 3 Phase, 4 Wire	Flush:	.	Shunt Trip Main:	.	Amp Bus		100
14,000MIN A.I.C. SYM	In MCC	.	Feed Through:	.	Ground Bus		X
Neutral: 100%	Number of Poles:	42	TVSS:	.	Isolated Ground Bus		.

CKT No.	Load	TRIP (Amp)	KVA/Phase A	KVA/Phase B	KVA/Phase C	CKT No.	CKT No.	KVA/Phase A	KVA/Phase B	KVA/Phase C	TRIP (Amp)	Load	CKT No.
1	Stair W1 Lighting	20	1.02			1	2	2.27			20	Toilet & Corridor Lighting	2
3	Stair W1 Lighting	20		1.45		3	4		0.90		20	Exit Sign	4
5	Stair W2 Lighting	20			0.58	5	6			0.28	20	Warning Light	6
7	Stair W2 Lighting	20	0.29			7	8				20	Spare	8
9	Café/Commons Lighting	20		0.70		9	10				20	Spare	10
11	Spare	20				11	12				20	Spare	12
13	Spare	20				13	14				20	Spare	14
15	Spare	20				15	16				20	Spare	16
17	Spare	20				17	18				20	Spare	18
19	Spare	20				19	20				20	Spare	20
21	Spare	20				21	22				20	Spare	22
23	Spare	20				23	24				20	Spare	24
25	Spare	20				25	26				20	Spare	26
27	Spare	20				27	28				20	Spare	28
29	Spare	20				29	30				20	Spare	30
31	Spare	20				31	32				20	Spare	32
33	Spare	20				33	34				20	Spare	34
35	Spare	20				35	36				20	Spare	36
37	Spare	20				37	38				20	Spare	38
39	Spare	20				39	40				20	Spare	40
41	Spare	20				41	42				20	Spare	42

Subtotals (kVA):		1.31	2.15	0.58		2.27	0.90	0.28		Subtotals (kVA)
Total Loads:	Phase A:	3.58 kVA				60 %				Demand Factor
	Phase B:	3.05 kVA				4.494 kVA				Demand Load
	Phase C:	0.86 kVA				5.618 kVA				Load x 1.25
Total Connected Load:		7.49 kVA				6.765 A				Demand Amps

Figure 157: Existing Panel Schedule HLE-3B.

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: HLE-3D	Mounting: Surface:	X	Main Lugs Only:	.	Amp Main CB	100
277/480V, 3 Phase, 4 Wire	Flush:	.	Shunt Trip Main:	.	Amp Bus	225
14,000MIN A.I.C. SYM	In MCC	.	Feed Through:	.	Ground Bus	X
Neutral: 100%	Number of Poles:	42	TVSS:	.	Isolated Ground Bus	.

CKT No.	Load	TRIP (Amp)	KVA/Phase A	KVA/Phase B	KVA/Phase C	CKT No.	CKT No.	KVA/Phase A	KVA/Phase B	KVA/Phase C	TRIP (Amp)	Load	CKT No.
1	Exit Sign	20	0.10			1	2	1.02			20	Stair N-1 Lighting	2
3	Toilet & Corridor Lighting	20		2.16		3	4		1.46		20	Stair N-1 Lighting	4
5	Organic Elec & Pho, Lab Lighting	20			2.30	5	6				20	Spare	6
7	Spare	20				7	8				20	Spare	8
9	Spare	20				9	10				20	Spare	10
11	Spare	20				11	12				20	Spare	12
13	Spare	20				13	14				20	Spare	14
15	Spare	20				15	16				20	Spare	16
17	Spare	20				17	18				20	Spare	18
19	Spare	20				19	20				20	Spare	20
21	Spare	20				21	22				20	Spare	22
23	Spare	20				23	24				20	Spare	24
25	Spare	20				25	26				20	Spare	26
27	Spare	20				27	28				20	Spare	28
29	Spare	20				29	30				20	Spare	30
31	Spare	20				31	32				20	Spare	32
33	Spare	20				33	34				20	Spare	34
35	Spare	20				35	36				20	Spare	36
37			4.94			37	38				20	Spare	38
39	Panel LE-3D Via XFMR 'TRE-LE-3D'	50		3.80		39	40				20	Spare	40
41					3.80	41	42				20	Spare	42

Subtotals (kVA):		5.04	5.96	6.1		1.02	1.46	0		Subtotals (kVA)
Total Loads:	Phase A:	6.06 kVA				60 %				Demand Factor
	Phase B:	7.42 kVA				11.75 kVA				Demand Load
	Phase C:	6.10 kVA				14.69 kVA				Load x 1.25
Total Connected Load:	19.58 kVA					17.68 A				Demand Amps

Figure 158: Existing Panel Schedule HLE-3D.

Panel Redesigns

The Millennium Science Complex has an electrical system designed for expansion. Over 60% of the circuits throughout the building are spare loads. The calculation from the panelboard worksheets that were provided has been altered to account for the inevitable expansion of the building. The panelboard worksheets have been primarily altered to design feeders and main circuit breakers (if applicable) for the redesigned panels.

Spare capacity has been addressed in a "worst-case scenario" situation. All lighting panels are at 277V, leaving the calculation for 20A spare loads as follows:

- 20A x 0.8 (NEC max loading of current protection device) = 16A Max connected load
- 16A x 0.8 (Good Engineering Practice) = 12.8A Max connected load
- 12.8A * 277V = 3546.6VA
- 3.5kVA will be used as spare loads in panelboard worksheets for sizing MCB's and feeder sizes.

Table 50: Panelboard Redesign Summary.

Panelboard	Original Design Load (A)	Calculated Design Load (kVA)	Calculated DF	Calculated Design Load (A)
LCP-1	25.28	20.65	0.82	25.51
LCPE-1	4.48	3.50	0.80	4.21
HL-3B	57.25	38.19	0.90	51.96
HLE-3B	9.02	6.37	0.91	8.75
HL-3D	28.07	16.65	0.92	23.14
HLE-3D	17.68	18.56	0.84	25.50

LCP-1

PANELBOARD SIZING WORKSHEET

Panel Tag---------->					LCP-1	Panel Location:			N-P052	
Nominal Phase to Neutral Voltage------->					277	Phase:			3	
Nominal Phase to Phase Voltage-------->					480	Wires:			4	
Pos	Ph.	Load Type	Cat.	Location	Load	Units	I. PF	Watts	VA	Remarks
1	A	Zone 1 LS Lobby Lighting	3		0.42	kva	0.80	336	420	
2	A	Spare	9		3.50	kva	0.80	2800	3500	
3	B	Spare	9		3.50	kva	0.80	2800	3500	
4	B	Zone 19 Site Lighting	4		0.94	kva	0.90	850	944	Site Post Lighting
5	C	L.S. Sidewalk Lighting	4	L.S.	0.55	kva	0.90	499	554	
6	C	Zone 20 Site Lighitng	4		1.06	kva	0.90	956	1062	Site Post Lighting
7	A	Zoen 4 LS Lobby Lighting	3		0.31	kva	0.80	248	310	
8	A	Spare	9		3.50	kva	0.80	2800	3500	Removed Circuit
9	B	Zone 5 LS Lobby Lighting	3		0.56	kva	0.80	448	560	
10	B	Spare	9		3.50	kva	0.80	2800	3500	
11	C	L.S. Uplighting	4	L.S.	0.95	kva	0.90	856	951	
12	C	Spare	9		3.50	kva	0.80	2800	3500	
13	A	Zone 7 ML Lobby Lighting	3		0.84	kva	0.80	672	840	
14	A	West Octulous	3		0.71	kva	0.90	643	715	
15	B	Zone 8 ML Lobby Lighitng	3		0.56	kva	0.80	448	560	
16	B	Spare	9		3.50	kva	0.80	2800	3500	
17	C	L.S. Entry Wall Washing	4	L.S.	0.62	kva	0.80	492	616	
18	C	North Octulous	3		0.66	kva	0.80	524	655	
19	A	Spare	9		0.00	kva	0.80	0	0	
20	A	Zone 27 Site Lighting	3		0.05	kva	0.80	40	50	
21	B	L.S. Entry Downlighting	4	L.S.	0.43	kva	0.80	341	427	
22	B	Zone 28 Site Lighting	3		0.40	kva	0.80	320	400	
23	C	Zone 12 ML Lobby Lighting	3		0.31	kva	0.80	248	310	
24	C	M.S. Entry Downlighting	4	M.S.	0.43	kva	0.80	341	427	
25	A	South Octulous	3		0.66	kva	0.80	524	655	
26	A	M.S. Entry Wall Washing	4	M.S.	0.43	kva	0.80	341	427	
27	B	East Octulous	3		0.71	kva	0.80	572	715	
28	B	M.S. Uplighting	4	M.S.	1.06	kva	0.80	845	1057	
29	C	Zone 15 Site Lighting	3		2.10	kva	0.80	1680	2100	
30	C	M.S. Sidewalk	4	M.S.	0.62	kva	0.80	492	616	
31	A	Zone 16 Site Lighting	3		2.10	kva	0.80	1680	2100	
32	A	Bridge Downlighting	3		0.32	kva	0.80	256	320	
33	B	Zone 17 Site Lighting	3		1.90	kva	0.80	1520	1900	
34	B	Spare	9		3.50	kva	0.80	2800	3500	Removed Circuit
35	C	Zone 35 ML Lobby Lighting	3		0.46	kva	0.80	368	460	
36	C	Zone 36 LS Lobby Lighting	3		0.42	kva	0.80	336	420	
37	A	Spare	9		3.50	kva	0.80	2800	3500	
38	A	Spare	9		3.50	kva	0.80	2800	3500	
39	B	Spare	9		3.50	kva	0.80	2800	3500	
40	B	Spare	9		3.50	kva	0.80	2800	3500	
41	C	Spare	9		3.50	kva	0.80	2800	3500	
42	C	Spare	9		3.50	kva	0.80	2800	3500	
PANEL TOTAL								53.3	66.1	Amps= 79.5

PHASE LOADING						kW	kVA	%	Amps
PHASE TOTAL	A					15.9	19.8	31%	71.6
PHASE TOTAL	B					22.1	27.6	43%	99.5
PHASE TOTAL	C					15.2	17.3	27%	62.3

LOAD CATAGORIES			Connected			Demand				Ver. 104
			kW	kVA	DF	kW	kVA	PF		
1	receptacles		0.0	0.0		0.0	0.0			
2	computers		0.0	0.0	0.70	0.0	0.0			
3	fluorescent lighting		10.9	13.5	1.00	10.9	13.5	0.81		
4	Metal Halide lighting		6.0	7.1	1.00	6.0	7.1	0.85		
5	incandescent lighting		0.0	0.0	1.00	0.0	0.0			
6	HVAC fans		0.0	0.0	0.80	0.0	0.0			
7	heating		0.0	0.0	0.70	0.0	0.0			
8	kitchen equipment		0.0	0.0	0.60	0.0	0.0			
9	Spare Load		36.4	45.5	0.60	21.8	27.3	0.80		
Total Demand Loads						38.7	47.9			
Spare Capacity			0%			0.0	0.0			
Total Design Loads						38.7	47.9	0.81	Amps=	57.60

Default Power Factor =	0.80
Default Demand Factor =	100 %

Figure 159: LCP-1 Panelboard Worksheet.

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: LCP-1	Mounting: Surface:	X	Main Lugs Only:	X	Amp Main CB	.
277/480V, 3 Phase, 4 Wire	Flush:	.	Shunt Trip Main:	.	Amp Bus	225
14,000MIN A.I.C. SYM	In MCC	.	Feed Through:	X	Ground Bus	.
Neutral: 100%	Number of Poles:	42	TVSS:	.	Isolated Ground Bus	.

	CKT No.	Load	TRIP (Amp)	KVA/Phase A	KVA/Phase B	KVA/Phase C	CKT No.	CKT No.	KVA/Phase A	KVA/Phase B	KVA/Phase C	TRIP (Amp)	Load	CKT No.	
*	1	Zone 1 LS Lobby Lighting	20	0.42			1	2	0.00			20	Spare	2	
	3	Spare	20		0.00		3	4		1.05		20	Zone 19 Site Lighting	4	*
*	5	L.S. Sidewalk Lighting	20			0.62	5	6			1.18	20	Zone 20 Site Lighting	6	*
*	7	Zone 4 LS Lobby Lighting	20	0.31			7	8	0.00			20	Spare	8	
*	9	Zone 5 LS Lobby Lighting	20		0.56		9	10		0.00		20	Spare	10	
*	11	L.S. Uplighting	20			1.06	11	12			0.00	20	Spare	12	
*	13	Zone 7 ML Lobby Lighting	20	0.84			13	14	0.71			20	West Octulous	14	*
*	15	Zone 8 ML Lobby Lighting	20		0.56		15	16		0.00		20	Spare	16	
*	17	L.S. Entry Wall Washing	20			0.31	17	18			0.66	20	North Octulous	18	*
	19	Spare	20	0.00			19	20	0.05			20	Zone 27 Site Lighting	20	*
*	21	L.S. Entry Downlighting	20		0.43		21	22		0.40		20	Zone 28 Site Lighitng	22	*
*	23	Zone 12 ML Lobby Lighting	20			0.31	23	24			0.43	20	M.S. Entry Downlighting	24	*
*	25	South Octulous	20	0.66			25	26	0.43			20	M.S. Entry Wall Washing	26	*
*	27	East Octulous	20		0.71		27	28		1.06		20	M.S. Uplighting	28	*
*	29	Zone 15 Site Lighting	20			2.10	29	30			0.62	20	M.S. Sidewalk	30	*
*	31	Zone 16 Site Lighting	20	2.10			31	32	0.32			20	Bridge Downlighting	32	*
*	33	Zone 17 Site Lighting	20		1.90		33	34		0.00		20	Spare	34	
*	35	Zone 35 ML Lobby Lighting	20			0.46	35	36			0.42	20	Zone 36 LS Lobby Lighting	36	*
	37	Spare	20	0.00			37	38	0.00			20	Spare	38	
	39	Spare	20		0.00		39	40		0.00		20	Spare	40	
	41	Spare	20			0.00	41	42			0.00	20	Spare	42	

Subtotals (kVA):		4.33	4.16	4.85	1.51	2.51	3.30		Subtotals (kVA)
Total Loads:	Phase A:	5.84 kVA			82.05 %				Demand Factor
	Phase B:	6.67 kVA			16.95 kVA				Demand Load
	Phase C:	8.15 kVA			21.18 kVA				Load x 1.25
Total Connected Load:	20.65 kVA				25.51 A				Demand Amps

*Denotes Programmable Remote Control Breaker

Figure 160: Redesigned Panel LCP-1.

LCP-1		
Tag		LCP-1
Feed From		MDP-1E1
Voltage System		277/480V
Calculated Design Load (kW)		38.72
Calculated Power Factor		0.81
Calculated Design Load (kVA)		47.87
Calculated Design Load (A)		57.60
Feeder Protection Size		75
	Phase	(3) #4
	Neutral	#4
	Ground	#8
Wire Area (Sq. in.)		
	Each Phase	0.0824
	Total - All Phases	0.2472
	Nuetral	0.0824
	Ground	0.0366
	Total - All Wires	0.3662
Minimum Conduit Area (Sq. In.) (Above x 2.5)		0.9155
Conduit Size (NEC Chapter 9, Table 4)		1.25" RMC
Conduit Size (NEC Chapter 9, Table 4)		1.25" RMC
Feeder Length		10
Final Voltage Drop (V)		0.4
Final Voltage Drop (%)		0.1
Feeder Re-sizing		No

Figure 161: LCP-1 Feeder Worksheet.

LCPE-1

PANELBOARD SIZING WORKSHEET

Panel Tag---------->					LCPE-1	Panel Location:			N-P052		
Nominal Phase to Neutral Voltage------->					277	Phase:			3		
Nominal Phase to Phase Voltage-------->					480	Wires:			4		
Pos	Ph.	Load Type	Cat.	Location	Load	Units	I. PF	Watts	VA	Remarks	
1	A	Spare	9		3.50	kva	0.80	2800	3500		
2	A	Zone 42 Exterior Lighting	3		0.22	kva	0.80	176	220		
3	B	Spare	9		3.50	kva	0.80	2800	3500		
4	B	Zone 41 M. Lobby Lighting	3		0.23	kva	0.80	184	230		
5	C	Zone 37 LS Lobby Lighting	3		0.23	kva	0.80	184	230		
6	C	Zone 43 Exterior Lighting	3		0.17	kva	0.80	136	170		
7	A	Sidewalk Downlighting	3		0.48	kva	0.80	384	480		
8	A	Loading Dock	3		0.77	kva	0.80	616	770		
9	B	Zone 39 Exterior Lighting	3		0.70	kva	0.80	560	700		
10	B	Spare	9		3.50	kva	0.80	2800	3500		
11	C	Zone 40 Exterior Lighting	3		0.70	kva	0.80	560	700		
12	C	Spare	9		3.50	kva	0.80	2800	3500		
13	A	Spare	9		3.50	kva	0.80	2800	3500		
14	A	Spare	9		3.50	kva	0.80	2800	3500		
15	B	Spare	9		3.50	kva	0.80	2800	3500		
16	B	Spare	9		3.50	kva	0.80	2800	3500		
17	C	Spare	9		3.50	kva	0.80	2800	3500		
18	C	Spare	9		3.50	kva	0.80	2800	3500		
19	A	Spare	9		3.50	kva	0.80	2800	3500		
20	A	Spare	9		3.50	kva	0.80	2800	3500		
21	B	Spare	9		3.50	kva	0.80	2800	3500		
22	B	Spare	9		3.50	kva	0.80	2800	3500		
23	C	Spare	9		3.50	kva	0.80	2800	3500		
24	C	Spare	9		3.50	kva	0.80	2800	3500		
25	A	Spare	9		3.50	kva	0.80	2800	3500		
26	A	Spare	9		3.50	kva	0.80	2800	3500		
27	B	Spare	9		3.50	kva	0.80	2800	3500		
28	B	Spare	9		3.50	kva	0.80	2800	3500		
29	C	Spare	9		3.50	kva	0.80	2800	3500		
30	C	Spare	9		3.50	kva	0.80	2800	3500		
31	A	Spare	9		3.50	kva	0.80	2800	3500		
32	A	Spare	9		3.50	kva	0.80	2800	3500		
33	B	Spare	9		3.50	kva	0.80	2800	3500		
34	B	Spare	9		3.50	kva	0.80	2800	3500		
35	C	Spare	9		3.50	kva	0.80	2800	3500		
36	C	Spare	9		3.50	kva	0.80	2800	3500		
37	A	Spare	9		3.50	kva	0.80	2800	3500		
38	A	Spare	9		3.50	kva	0.80	2800	3500		
39	B	Spare	9		3.50	kva	0.80	2800	3500		
40	B	Spare	9		3.50	kva	0.80	2800	3500		
41	C	Spare	9		3.50	kva	0.80	2800	3500		
42	C	Spare	9		3.50	kva	0.80	2800	3500		
PANEL TOTAL								98.0	122.5	Amps=	147.4

PHASE LOADING						kW	kVA	%	Amps
PHASE TOTAL	A					32.0	40.0	33%	144.3
PHASE TOTAL	B					34.3	42.9	35%	155.0
PHASE TOTAL	C					31.7	38.2	32%	137.9

LOAD CATAGORIES			Connected			Demand				Ver. 104
			kW	kVA	DF	kW	kVA	PF		
1	receptacles		0.0	0.0		0.0	0.0			
2	computers		0.0	0.0	0.70	0.0	0.0			
3	Metal Halide Lighitng		2.8	3.5	1.00	2.8	3.5	0.80		
4	HID lighting		0.0	0.0	1.00	0.0	0.0			
5	incandescent lighting		0.0	0.0	1.00	0.0	0.0			
6	HVAC fans		0.0	0.0	0.80	0.0	0.0			
7	heating		0.0	0.0	0.70	0.0	0.0			
8	kitchen equipment		0.0	0.0	0.60	0.0	0.0			
9	Spare Load		95.2	119.0	0.60	57.1	71.4	0.80		
Total Demand Loads						59.9	74.9			
Spare Capacity						0.0	0.0			
Total Design Loads						59.9	74.9	0.80	Amps=	90.1

Default Power Factor =	0.80
Default Demand Factor =	100 %

Figure 162: LCPE-1 Panel Worksheet.

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: LCPE-1	Mounting: Surface:	X	Main Lugs Only:	.	Amp Main CB	100
277/480V, 3 Phase, 4 Wire	Flush:	.	Shunt Trip Main:	.	Amp Bus	100
14,000MIN A.I.C. SYM	In MCC	.	Feed Through:	.	Ground Bus	.
Neutral: 100%	Number of Poles:	42	TVSS:	.	Isolated Ground Bus	.

	CKT No.	Load	TRIP (Amp)	KVA/Phase A	KVA/Phase B	KVA/Phase C	CKT No.	CKT No.	KVA/Phase A	KVA/Phase B	KVA/Phase C	TRIP (Amp)	Load	CKT No.	
	1	Spare	20	0.00			1	2	0.22			20	Zone 42 Exterior Lighting	2	*
	3	Spare	20		0.00		3	4		0.23		20	Zone 41 M. Lobby Lighting	4	*
*	5	Zone 37 LS Lobby Lighting	20			0.23	5	6			0.17	20	Zone 43 Exterior Lighting	6	*
*	7	Sidewalk Downlighting	20	0.48			7	8	0.77			20	Loading Dock	8	*
*	9	Zone 39 Exterior Lighting	20		0.70		9	10		0.00		20	Spare	10	
*	11	Zone 40 Exterior Lighting	20			0.70	11	12			0.00	20	Spare	12	
	13	Spare	20	0.00			13	14	0.00			20	Spare	14	
	15	Spare	20		0.00		15	16		0.00		20	Spare	16	
	17	Spare	20			0.00	17	18			0.00	20	Spare	18	
	19	Spare	20	0.00			19	20	0.00			20	Spare	20	
	21	Spare	20		0.00		21	22		0.00		20	Spare	22	
	23	Spare	20			0.00	23	24			0.00	20	Spare	24	
	25	Spare	20	0.00			25	26	0.00			20	Spare	26	
	27	Spare	20		0.00		27	28		0.00		20	Spare	28	
	29	Spare	20			0.00	29	30			0.00	20	Spare	30	
	31	Spare	20	0.00			31	32	0.00			20	Spare	32	
	33	Spare	20		0.00		33	34		0.00		20	Spare	34	
	35	Spare	20			0.00	35	36			0.00	20	Spare	36	
	37	Spare	20	0.00			37	38	0.00			20	Spare	38	
	39	Spare	20		0.00		39	40		0.00		20	Spare	40	
	41	Spare	20			0.00	41	42			0.00	20	Spare	42	

Subtotals (kVA):		0.48	0.70	0.93		0.99	0.23	0.17		Subtotals (kVA)
Total Loads:	Phase A:	1.47 kVA				80.00 %				Demand Factor
	Phase B:	0.93 kVA				2.80 kVA				Demand Load
	Phase C:	1.10 kVA				3.5 kVA				Load x 1.25
Total Connected Load:	3.5 kVA					4.215 A				Demand Amps

*Denotes Programmable Remote Control Breaker

Figure 163: Redesigned LCPE-1 Panel.

LCPE-1		
Tag		LCPE-1
Feed From		HLE-0D
Voltage System		277/480V
Calculated Design Load (kW)		59.92
Calculated Power Factor		0.80
Calculated Design Load (kVA)		74.90
Calculated Design Load (A)		90.13
Feeder Protection Size		100
	Phase	(3) #3
	Neutral	#3
	Ground	#8
Wire Area (Sq. in.)		
	Each Phase	0.0973
	Total - All Phases	0.2919
	Nuetral	0.0973
	Ground	0.0366
	Total - All Wires	0.4258
Minimum Conduit Area (Sq. In.) (Above x 2.5)		1.0645
Conduit Size (NEC Chapter 9, Table 4)		1.25" RMC
Conduit Size (NEC Chapter 9, Table 4)		1.25" RMC
Feeder Length		10
Final Voltage Drop (V)		0.3
Final Voltage Drop (%)		0.1
Feeder Re-sizing		No

Figure 164: LCPE-1 Feeder Worksheet.

PANELBOARD SIZING WORKSHEET

Panel Tag---------->					HL-3B	Panel Location:			W-P338		
Nominal Phase to Neutral Voltage------->					277	Phase:			3		
Nominal Phase to Phase Voltage-------->					480	Wires:			4		
Pos	Ph.	Load Type	Cat.	Location	Load	Units	I. PF	Watts	VA	Remarks	
1	A	Neurophts-Invitro Lighting	3		2.21	kva	0.90	1989	2210		
2	A	Neurophts-Invitro Lighting	3		2.21	kva	0.90	1989	2210		
3	B	Neurophts-Invitro Lighting	3		1.83	kva	0.90	1647	1830		
4	B	Neurophts-Invitro Lighting	3		1.83	kva	0.90	1647	1830		
5	C	Optical Imaging Lighting	3		2.58	kva	0.90	2322	2580		
6	C	Fumehood, Tissue Culture Lighting	3		2.40	kva	0.90	2160	2400		
7	A	Fumehood, Procedure, Hot Room	3		2.18	kva	0.90	1962	2180		
8	A	Toilet, Equip Corr. Lighting	3		1.72	kva	0.90	1548	1720		
9	B	Faculty, Grad Student Lighting	3		0.50	kva	0.90	450	499	Office Redesign	
10	B	Faculty, GMAD Hudson Lighting	3		1.27	kva	0.90	1150	1274	Office Redesign	
11	C	Elec. Equip, Post Doc Lighting	3		1.74	kva	0.90	1566	1740		
12	C	BCI Treaching, GMAD, Post Doc LTG	3		1.74	kva	0.90	1566	1740		
13	A	Conference Library Lighitng	3		1.32	kva	0.90	1188	1320		
14	A	Office, Staff, Kitchen Lighting	3		1.82	kva	0.90	1638	1820		
15	B	Conference Library Lighting	3		1.35	kva	0.95	1278	1352	Conference Room Redesign	
16	B	Corridor Lighting	3		1.37	kva	0.93	1282	1372	Corridor Redesign	
17	C	Terrace Lighting	3		1.00	kva	0.90	900	1000		
18	C	Corridor Lighitng	3		1.02	kva	0.94	950	1015	Corridor Redesign	
19	A	Motorized Shades	3		0.50	kva	0.90	450	500		
20	A	Café/Common Lighitng	3		1.93	kva	0.90	1737	1930		
21	B	Motorized Shades	3		0.50	kva	0.90	450	500		
22	B	Café/Common Lighitng	3		1.67	kva	0.90	1503	1670		
23	C	Motorized Shades	3		0.50	kva	0.90	450	500		
24	C	Track Lighting	3		0.60	kva	0.90	540	600		
25	A	Spare	9		3.50	kva	0.80	2800	3500		
26	A	Track Lighting	3		2.40	kva	0.90	2160	2400		
27	B	Spare	9		3.50	kva	0.80	2800	3500		
28	B	Spare	9		3.50	kva	0.80	2800	3500		
29	C	Spare	9		3.50	kva	0.80	2800	3500		
30	C	Spare	9		3.50	kva	0.80	2800	3500		
31	A	Spare	9		3.50	kva	0.80	2800	3500		
32	A	Spare	9		3.50	kva	0.80	2800	3500		
33	B	Spare	9		3.50	kva	0.80	2800	3500		
34	B	Spare	9		3.50	kva	0.80	2800	3500		
35	C	Spare	9		3.50	kva	0.80	2800	3500		
36	C	Spare	9		3.50	kva	0.80	2800	3500		
37	A	Spare	9		3.50	kva	0.80	2800	3500		
38	A	Spare	9		3.50	kva	0.80	2800	3500		
39	B	Spare	9		3.50	kva	0.80	2800	3500		
40	B	Spare	9		3.50	kva	0.80	2800	3500		
41	C	Spare	9		3.50	kva	0.80	2800	3500		
42	C	Spare	9		3.50	kva	0.80	2800	3500		
PANEL TOTAL								82.1	97.7	Amps=	117.6

PHASE LOADING						kW	kVA	%	Amps
PHASE TOTAL	A					28.7	33.8	35%	122.0
PHASE TOTAL	B					26.2	31.3	33%	113.1
PHASE TOTAL	C					27.3	31.2	32%	112.5

LOAD CATAGORIES			Connected			Demand				Ver. 104
			kW	kVA	DF	kW	kVA	PF		
1	receptacles		0.0	0.0		0.0	0.0			
2	computers		0.0	0.0	0.70	0.0	0.0			
3	fluorescent lighting		34.5	38.2	1.00	34.5	38.2	0.90		
4	HID lighting		0.0	0.0	1.00	0.0	0.0			
5	incandescent lighting		0.0	0.0	1.00	0.0	0.0			
6	HVAC fans		0.0	0.0	0.80	0.0	0.0			
7	heating		0.0	0.0	0.70	0.0	0.0			
8	kitchen equipment		0.0	0.0	0.60	0.0	0.0			
9	Spare Load		47.6	59.5	0.60	28.6	35.7	0.80		
Total Demand Loads						63.1	73.9			
Spare Capacity			0%			0.0	0.0			
Total Design Loads						63.1	73.9	0.85	Amps=	88.9

Default Power Factor =	0.80
Default Demand Factor =	100 %

Figure 165: HL-3B Panelboard Worksheet.

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: HL-3B	Mounting: Surface:	X	Main Lugs Only:	.	Amp Main CB	100
277/480V, 3 Phase, 4 Wire	Flush:	.	Shunt Trip Main:	.	Amp Bus	225
14,000MIN A.I.C. SYM	In MCC	.	Feed Through:	.	Ground Bus	X
Neutral: 100%	Number of Poles:	42	TVSS:	.	Isolated Ground Bus	.

CKT No.	Load	TRIP (Amp)	KVA/Phase A	KVA/Phase B	KVA/Phase C	CKT No.	CKT No.	KVA/Phase A	KVA/Phase B	KVA/Phase C	TRIP (Amp)	Load	CKT No.
1	Nuerophts-Invitro Lighting	20	2.21			1	2	2.21			20	Nuerophts-Invitro Lighting	2
3	Nuerophts-Invitro Lighting	20		1.83		3	4		1.83		20	Nuerophts-Invitro Lighting	4
5	Optical Imagimg Lighting	20			2.58	5	6			2.40	20	Fumehood, Tissue Culture Lighting	6
7	Fumehood Procedure, Hot Room	20	2.18			7	8	1.72			20	Toilet, Equip Corr. Lighting	8
9	Faculty, Grad Student Lighting	20		0.50		9	10		1.27		20	Faculty GMAD Hudson Lighting	10
11	Elec. Equipment, Post Doc & Light	20			1.74	11	12			1.74	20	BCI Teaching, GMAD, Post Doc Lighting	12
13	Conference Library Lighting	20	1.32			13	14	1.82			20	Office, Staff, Kitchen Lighting	14
15	Conference Library Lighting	20		1.35		15	16		1.37		20	Corridor Lighting	16
17	Terrace Lighting	20			1.00	17	18			1.02	20	Corridor Lighting	18
19	Motorized Shades	20	0.50			19	20	1.93			20	Café/Common Lighting	20
21	Motorized Shades	20		0.50		21	22		1.67		20	Café/Common Lighting	22
23	Motorized Shades	20			0.50	23	24			0.60	20	Track Lighitng	24
25	Spare	20				25	26	2.40			20	Track Lighting	26
27	Spare	20				27	28				20	Spare	28
29	Spare	20				29	30				20	Spare	30
31	Spare	20				31	32				20	Spare	32
33	Spare	20				33	34				20	Spare	34
35	Spare	20				35	36				20	Spare	36
37	Spare	20				37	38				20	Spare	38
39	Spare	20				39	40				20	Spare	40
41	Spare	20				41	42				20	Spare	42

Subtotals (kVA):		6.21	4.18	5.82		10.08	6.146	5.755		Subtotals (kVA)
Total Loads:	Phase A:	16.29 kVA				90.39 %				Demand Factor
	Phase B:	10.33 kVA				34.52 kVA				Demand Load
	Phase C:	11.58 kVA				43.15 kVA				Load x 1.25
Total Connected Load:	38.19 kVA					51.96 A				Demand Amps

Figure 166: Redesigned Panel HL-3B.

HL-3B		
Tag		HL-3B
Feed From		MDP-M41
Voltage System		277/480V
Calculated Design Load (kW)		63.08
Calculated Power Factor		0.85
Calculated Design Load (kVA)		73.89
Calculated Design Load (A)		88.92
Feeder Protection Size		100
	Phase	(3) #3
	Neutral	#3
	Ground	#8
Wire Area (Sq. in.)		
	Each Phase	0.0973
	Total - All Phases	0.2919
	Nuetral	0.0973
	Ground	0.0366
	Total - All Wires	0.4258
Minimum Conduit Area (Sq. In.) (Above x 2.5)		1.0645
Conduit Size (NEC Chapter 9, Table 4)		1.25" RMC
Conduit Size (NEC Chapter 9, Table 4)		1.25" RMC
Feeder Length		207 ft
Final Voltage Drop (V)		5.6
Final Voltage Drop (%)		2.0
Feeder Re-sizing		No

Figure 167: HL-3B Feeder Worksheet.

PANELBOARD SIZING WORKSHEET

Panel Tag---------->					HLE-3B	Panel Location:			W-P338	
Nominal Phase to Neutral Voltage------->					277	Phase:			3	
Nominal Phase to Phase Voltage-------->					480	Wires:			4	
Pos	Ph.	Load Type	Cat.	Location	Load	Units	I. PF	Watts	VA	Remarks
1	A	Stair W1 Lighting	3		1.02	kva	0.90	918	1020	
2	A	Toilet & Corridor Lighting	3		1.15	kva	0.97	1114	1150	Corridor Redesign
3	B	Stair W1 Lighting	3		1.45	kva	0.90	1305	1450	
4	B	Exit Sign	3		0.90	kva	0.90	810	900	
5	C	Stair W2 Lighting	3		0.58	kva	0.90	522	580	
6	C	Warning Light	3		0.28	kva	0.90	252	280	
7	A	Stair W2 Lighting	3		0.29	kva	0.90	261	290	
8	A	Spare	9		3.50	kva	0.80	2800	3500	
9	B	Café/Commons Lighting	3		0.70	kva	0.90	630	700	
10	B	Spare	9		3.50	kva	0.80	2800	3500	
11	C	Spare	9		3.50	kva	0.80	2800	3500	
12	C	Spare	9		3.50	kva	0.80	2800	3500	
13	A	Spare	9		3.50	kva	0.80	2800	3500	
14	A	Spare	9		3.50	kva	0.80	2800	3500	
15	B	Spare	9		3.50	kva	0.80	2800	3500	
16	B	Spare	9		3.50	kva	0.80	2800	3500	
17	C	Spare	9		3.50	kva	0.80	2800	3500	
18	C	Spare	9		3.50	kva	0.80	2800	3500	
19	A	Spare	9		3.50	kva	0.80	2800	3500	
20	A	Spare	9		3.50	kva	0.80	2800	3500	
21	B	Spare	9		3.50	kva	0.80	2800	3500	
22	B	Spare	9		3.50	kva	0.80	2800	3500	
23	C	Spare	9		3.50	kva	0.80	2800	3500	
24	C	Spare	9		3.50	kva	0.80	2800	3500	
25	A	Spare	9		3.50	kva	0.80	2800	3500	
26	A	Spare	9		3.50	kva	0.80	2800	3500	
27	B	Spare	9		3.50	kva	0.80	2800	3500	
28	B	Spare	9		3.50	kva	0.80	2800	3500	
29	C	Spare	9		3.50	kva	0.80	2800	3500	
30	C	Spare	9		3.50	kva	0.80	2800	3500	
31	A	Spare	9		3.50	kva	0.80	2800	3500	
32	A	Spare	9		3.50	kva	0.80	2800	3500	
33	B	Spare	9		3.50	kva	0.80	2800	3500	
34	B	Spare	9		3.50	kva	0.80	2800	3500	
35	C	Spare	9		3.50	kva	0.80	2800	3500	
36	C	Spare	9		3.50	kva	0.80	2800	3500	
37	A	Spare	9		3.50	kva	0.80	2800	3500	
38	A	Spare	9		3.50	kva	0.80	2800	3500	
39	B	Spare	9		3.50	kva	0.80	2800	3500	
40	B	Spare	9		3.50	kva	0.80	2800	3500	
41	C	Spare	9		3.50	kva	0.80	2800	3500	
42	C	Spare	9		3.50	kva	0.80	2800	3500	
PANEL TOTAL								101.0	125.4	Amps= 150.9

PHASE LOADING						kW	kVA	%	Amps
PHASE TOTAL	A					33.1	41.0	33%	147.9
PHASE TOTAL	B					33.5	41.6	34%	150.0
PHASE TOTAL	C					34.4	41.5	33%	149.7

LOAD CATAGORIES			Connected			Demand				Ver. 104
			kW	kVA	DF	kW	kVA	PF		
1	receptacles		0.0	0.0		0.0	0.0			
2	computers		0.0	0.0	0.70	0.0	0.0			
3	fluorescent lighting		5.8	6.4	1.00	5.8	6.4	0.91		
4	HID lighting		0.0	0.0	1.00	0.0	0.0			
5	incandescent lighting		0.0	0.0	1.00	0.0	0.0			
6	HVAC fans		0.0	0.0	0.80	0.0	0.0			
7	heating		0.0	0.0	0.70	0.0	0.0			
8	kitchen equipment		0.0	0.0	0.60	0.0	0.0			
9	Spare Load		95.2	119.0	0.80	76.2	95.2	0.80		
Total Demand Loads						82.0	101.6			
Spare Capacity			0%			0.0	0.0			
Total Design Loads						82.0	101.6	0.81	Amps=	122.23

Default Power Factor =	0.80
Default Demand Factor =	100 %

Figure 168: HLE-3B Panelboard Worksheet.

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: HLE-3B	Mounting:	Surface:	X	Main Lugs Only:	.	Amp Main CB	125
277/480V, 3 Phase, 4 Wire		Flush:	.	Shunt Trip Main:	.	Amp Bus	125
14,000MIN A.I.C. SYM		In MCC	.	Feed Through:	.	Ground Bus	X
Neutral: 100%	Number of Poles:		42	TVSS:	.	Isolated Ground Bus	.

CKT No.	Load	TRIP (Amp)	KVA/Phase A	KVA/Phase B	KVA/Phase C	CKT No.	CKT No.	KVA/Phase A	KVA/Phase B	KVA/Phase C	TRIP (Amp)	Load	CKT No.
1	Stair W1 Lighting	20	1.02			1	2	1.15			20	Toilet & Corridor Lighting	2
3	Stair W1 Lighting	20		1.45		3	4		0.90		20	Exit Sign	4
5	Stair W2 Lighting	20			0.58	5	6			0.28	20	Warning Light	6
7	Stair W2 Lighting	20	0.29			7	8				20	Spare	8
9	Café/Commons Lighting	20		0.70		9	10				20	Spare	10
11	Spare	20				11	12				20	Spare	12
13	Spare	20				13	14				20	Spare	14
15	Spare	20				15	16				20	Spare	16
17	Spare	20				17	18				20	Spare	18
19	Spare	20				19	20				20	Spare	20
21	Spare	20				21	22				20	Spare	22
23	Spare	20				23	24				20	Spare	24
25	Spare	20				25	26				20	Spare	26
27	Spare	20				27	28				20	Spare	28
29	Spare	20				29	30				20	Spare	30
31	Spare	20				31	32				20	Spare	32
33	Spare	20				33	34				20	Spare	34
35	Spare	20				35	36				20	Spare	36
37	Spare	20				37	38				20	Spare	38
39	Spare	20				39	40				20	Spare	40
41	Spare	20				41	42				20	Spare	42

Subtotals (kVA):		1.31	2.15	0.58
Total Loads:	Phase A:	2.46 kVA		
	Phase B:	3.05 kVA		
	Phase C:	0.86 kVA		
Total Connected Load:	6.37 kVA			

1.15	0.90	0.28		Subtotals (kVA)
91.24 %				Demand Factor
5.812 kVA				Demand Load
7.265 kVA				Load x 1.25
8.749 A				Demand Amps

Figure 169: Redesigned Panel HLE-3B.

HLE-3B		
Tag		HLE-3B
Feed From		EDP-L0B
Voltage System		277/480V
Calculated Design Load (kW)		81.97
Calculated Power Factor		0.81
Calculated Design Load (kVA)		101.57
Calculated Design Load (A)		122.23
Feeder Protection Size		125
	Phase	(3) 3/0
	Neutral	3/0
	Ground	#4
Wire Area (Sq. in.)		
	Each Phase	0.2223
	Total - All Phases	0.6669
	Nuetral	0.2223
	Ground	0.0366
	Total - All Wires	0.9258
Minimum Conduit Area (Sq. In.) (Above x 2.5)		2.3145
Conduit Size (NEC Chapter 9, Table 4)		2.00" EMT
Conduit Size (NEC Chapter 9, Table 4)		2.00" EMT
Feeder Length		290
Final Voltage Drop (V)		5.5
Final Voltage Drop (%)		2.0
Feeder Re-sizing		Yes

Figure 170: HLE-3B feeder worksheet.

PANELBOARD SIZING WORKSHEET

Panel Tag---------->					HL-3D	Panel Location:		N-P347		
Nominal Phase to Neutral Voltage------->					277	Phase:		3		
Nominal Phase to Phase Voltage-------->					480	Wires:		4		
Pos	Ph.	Load Type	Cat.	Location	Load	Units	l. PF	Watts	VA	Remarks
1	A	Student Lighting	3		0.54	kva	1.00	537	537	Student Redesign
2	A	Staff & Faculty Lighting	3		1.63	kva	0.90	1467	1626	Office Redesign
3	B	Electroactive Poly Lighting	3		1.60	kva	0.90	1440	1600	
4	B	Student Lighting	3		1.18	kva	0.94	1110	1177	Student Redesign
5	C	Organix Elec & Pho Lighting	3		1.60	kva	0.90	1440	1600	
6	C	Student Lighting	3		1.18	kva	0.90	1059	1177	Student Redesign
7	A	Dry Lab A&B, Staff Lighting	3		1.41	kva	0.94	1330	1410	
8	A	Staff Lighting	3		1.66	kva	0.90	1496	1662	Office Redesign
9	B	Staff Admin, Kitchen Lighting	3		1.23	kva	0.90	1107	1230	
10	B	Conference Room Lighting	3		1.35	kva	0.95	1278	1352	Conference Room Redesign
11	C	Dry Lab, Misc. Comp. Lighting	3		1.28	kva	0.90	1152	1280	
12	C	Conference Room Lighitng	3		1.52	kva	0.90	1368	1520	
13	A	Corridor Lighitng	3		0.50	kva	1.00	504	504	Corridor Redesign
14	A	Spare	9		3.50	kva	0.90	3150	3500	
15	B	Corridor Lighitng	3		0.90	kva	0.93	842	904	Corridor Redesign
16	B	Spare	9		3.50	kva	0.90	3150	3500	
17	C	Corridor Lighitng	3		1.14	kva	0.93	1060	1142	Corridor Redesign
18	C	Spare	9		3.50	kva	0.80	2800	3500	
19	A	Spare	9		3.50	kva	0.80	2800	3500	
20	A	Spare	9		3.50	kva	0.80	2800	3500	
21	B	Spare	9		3.50	kva	0.80	2800	3500	
22	B	Spare	9		3.50	kva	0.80	2800	3500	
23	C	Spare	9		3.50	kva	0.80	2800	3500	
24	C	Spare	9		3.50	kva	0.80	2800	3500	
25	A	Spare	9		3.50	kva	0.80	2800	3500	
26	A	Spare	9		3.50	kva	0.80	2800	3500	
27	B	Spare	9		3.50	kva	0.80	2800	3500	
28	B	Spare	9		3.50	kva	0.80	2800	3500	
29	C	Spare	9		3.50	kva	0.80	2800	3500	
30	C	Spare	9		3.50	kva	0.80	2800	3500	
31	A	Spare	9		3.50	kva	0.80	2800	3500	
32	A	Spare	9		3.50	kva	0.80	2800	3500	
33	B	Spare	9		3.50	kva	0.80	2800	3500	
34	B	Spare	9		3.50	kva	0.80	2800	3500	
35	C	Spare	9		3.50	kva	0.80	2800	3500	
36	C	Spare	9		3.50	kva	0.80	2800	3500	
37	A	Spare	9		3.50	kva	0.80	2800	3500	
38	A	Spare	9		3.50	kva	0.80	2800	3500	
39	B	Spare	9		3.50	kva	0.80	2800	3500	
40	B	Spare	9		3.50	kva	0.80	2800	3500	
41	C	Spare	9		3.50	kva	0.80	2800	3500	
42	C	Spare	9		3.50	kva	0.80	2800	3500	
PANEL TOTAL								93.5	113.2	Amps= 136.2

PHASE LOADING						kW	kVA	%	Amps
PHASE TOTAL	A					30.9	37.2	33%	134.4
PHASE TOTAL	B					31.3	37.8	34%	136.3
PHASE TOTAL	C					31.3	36.8	33%	132.9

LOAD CATAGORIES			Connected			Demand				Ver. 104
			kW	kVA	DF	kW	kVA	PF		
1	receptacles		0.0	0.0		0.0	0.0			
2	computers		0.0	0.0	0.70	0.0	0.0			
3	fluorescent lighting		17.2	18.72	1.00	17.2	18.7	0.92		
4	HID lighting		0.0	0.0	1.00	0.0	0.0			
5	incandescent lighting		0.0	0.0	1.00	0.0	0.0			
6	HVAC fans		0.0	0.0	0.80	0.0	0.0			
7	heating		0.0	0.0	0.70	0.0	0.0			
8	kitchen equipment		0.0	0.0	0.60	0.0	0.0			
9	Spare Load		76.3	94.5	0.60	45.8	56.7	0.81		
Total Demand Loads						63.0	75.4			
Spare Capacity			0%			0.0	0.0			
Total Design Loads						63.0	75.4	0.83	Amps=	90.8

Default Power Factor =	0.80
Default Demand Factor =	100 %

Figure 171: HL-3D Panelboard Worksheet.

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: HL-3D	Mounting: Surface:	X	Main Lugs Only:	.	Amp Main CB	100
277/480V, 3 Phase, 4 Wire	Flush:	.	Shunt Trip Main:	.	Amp Bus	225
14,000MIN A.I.C. SYM	In MCC	.	Feed Through:	.	Ground Bus	X
Neutral: 100%	Number of Poles:	42	TVSS:	.	Isolated Ground Bus	.

CKT No.	Load	TRIP (Amp)	KVA/Phase A	KVA/Phase B	KVA/Phase C	CKT No.	CKT No.	KVA/Phase A	KVA/Phase B	KVA/Phase C	TRIP (Amp)	Load	CKT No.
1	Student Lighting	20	0.39			1	2	1.05			20	Staff &Faculty Lighting	2
3	Electroactive Poly Lighting	20		1.60		3	4		0.88		20	Student Lighting	4
5	Organic Elec & Pho Lighting	20			1.60	5	6			0.88	20	Student Lighting	6
7	Dry Lab A&B, Staff Lgihting	20	1.41			7	8	0.91			20	Staff Lighting	8
9	Staff Admin, Kitchen Lighitng	20		1.23		9	10		1.35		20	Conference Room Lighting	10
11	Dry Lab, Misc. Comp. Lighting	20			1.28	11	12			1.52	20	Conference Room Lighting	12
13	Corridor Lighting	20	0.50			13	14				20	Spare	14
15	Corridor Lighitng	20		0.90		15	16				20	Spare	16
17	Corridor Lighitng	20			1.14	17	18				20	Spare	18
19	Spare	20				19	20				20	Spare	20
21	Spare	20				21	22				20	Spare	22
23	Spare	20				23	24				20	Spare	24
25	Spare	20				25	26				20	Spare	26
27	Spare	20				27	28				20	Spare	28
29	Spare	20				29	30				20	Spare	30
31	Spare	20				31	32				20	Spare	32
33	Spare	20				33	34				20	Spare	34
35	Spare	20				35	36				20	Spare	36
37	Spare	20				37	38				20	Spare	38
39	Spare	20				39	40				20	Spare	40
41	Spare	20				41	42				20	Spare	42

Subtotals (kVA):		2.30	3.73	4.02	
Total Loads:	Phase A:	4.27 kVA			
	Phase B:	5.96 kVA			
	Phase C:	6.42 kVA			
Total Connected Load:	16.65 kVA				

1.97	2.23	2.40		Subtotals (kVA)
92.33 %				Demand Factor
15.38 kVA				Demand Load
19.22 kVA				Load x 1.25
23.14 A				Demand Amps

Figure 172: Revised Panel Schedule HL-3D.

HL-3D		
Tag		HL-3D
Feed From		MDP-M42
Voltage System		277/480V
Calculated Design Load (kW)		62.97
Calculated Power Factor		0.83
Calculated Design Load (kVA)		75.42
Calculated Design Load (A)		90.76
Feeder Protection Size		100
	Phase	(3) #3
	Neutral	#3
	Ground	#8
Wire Area (Sq. in.)		
	Each Phase	0.0973
	Total - All Phases	0.2919
	Nuetral	0.0973
	Ground	0.0366
	Total - All Wires	0.4258
Minimum Conduit Area (Sq. In.) (Above x 2.5)		1.0645
Conduit Size (NEC Chapter 9, Table 4)		1.25" RMC
Conduit Size (NEC Chapter 9, Table 4)		1.25" RMC
Feeder Length		207 ft
Final Voltage Drop (V)		5.6
Final Voltage Drop (%)		2.0
Feeder Re-sizing		No

Figure 173: HL-3D Feeder Worksheet.

PANELBOARD SIZING WORKSHEET

Panel Tag---------->					HLE-3D	Panel Location:		N-P347		
Nominal Phase to Neutral Voltage------->					277	Phase:		3		
Nominal Phase to Phase Voltage-------->					480	Wires:		4		
Pos	Ph.	Load Type	Cat.	Location	Load	Units	I. PF	Watts	VA	Remarks
1	A	Exit Sign	3		0.10	kva	0.90	90	100	
2	A	Stair N-1 Lighting	3		1.02	kva	0.90	918	1020	
3	B	Toilet & Corridor Lighting	3		1.10	kva	0.97	1066	1100	Corridor Redesign
4	B	Stair N-1 Lighting	3		1.45	kva	0.90	1305	1450	
5	C	Office Lighting	3		2.30	kva	0.90	2070	2300	*Typo, no offices on this circuit
6	C	Spare	9		3.50	kva	0.80	2800	3500	
7	A	Spare	9		3.50	kva	0.80	2800	3500	
8	A	Spare	9		3.50	kva	0.80	2800	3500	
9	B	Spare	9		3.50	kva	0.80	2800	3500	
10	B	Spare	9		3.50	kva	0.80	2800	3500	
11	C	Spare	9		3.50	kva	0.80	2800	3500	
12	C	Spare	9		3.50	kva	0.80	2800	3500	
13	A	Spare	9		3.50	kva	0.80	2800	3500	
14	A	Spare	9		3.50	kva	0.80	2800	3500	
15	B	Spare	9		3.50	kva	0.80	2800	3500	
16	B	Spare	9		3.50	kva	0.80	2800	3500	
17	C	Spare	9		3.50	kva	0.80	2800	3500	
18	C	Spare	9		3.50	kva	0.80	2800	3500	
19	A	Spare	9		3.50	kva	0.80	2800	3500	
20	A	Spare	9		3.50	kva	0.80	2800	3500	
21	B	Spare	9		3.50	kva	0.80	2800	3500	
22	B	Spare	9		3.50	kva	0.80	2800	3500	
23	C	Spare	9		3.50	kva	0.80	2800	3500	
24	C	Spare	9		3.50	kva	0.80	2800	3500	
25	A	Spare	9		3.50	kva	0.80	2800	3500	
26	A	Spare	9		3.50	kva	0.80	2800	3500	
27	B	Spare	9		3.50	kva	0.80	2800	3500	
28	B	Spare	9		3.50	kva	0.80	2800	3500	
29	C	Spare	9		3.50	kva	0.80	2800	3500	
30	C	Spare	9		3.50	kva	0.80	2800	3500	
31	A	Spare	9		3.50	kva	0.80	2800	3500	
32	A	Spare	9		3.50	kva	0.80	2800	3500	
33	B	Spare	9		3.50	kva	0.80	2800	3500	
34	B	Spare	9		3.50	kva	0.80	2800	3500	
35	C	Spare	9		3.50	kva	0.80	2800	3500	
36	C	Spare	9		3.50	kva	0.80	2800	3500	
37	A	Panel LE-3D	8	3 Pole	4.94	kva	1.00	4940	4940	
38	A	Spare	9		3.50	kva	0.80	2800	3500	
39	B	Panel LE-3D	8	3 Pole	3.80	kva	1.00	3800	3800	
40	B	Spare	9		3.50	kva	0.80	2800	3500	
41	C	Panel LE-3D	8	3 Pole	3.80	kva	1.00	3800	3800	
42	C	Spare	9		3.50	kva	0.80	2800	3500	
PANEL TOTAL								113.2	137.5	Amps= 165.5

PHASE LOADING						kW	kVA	%	Amps
PHASE TOTAL	A					36.7	44.6	33%	160.9
PHASE TOTAL	B					37.0	44.9	33%	161.9
PHASE TOTAL	C					39.5	47.4	35%	171.1

LOAD CATAGORIES			Connected			Demand				Ver. 104
			kW	kVA	DF	kW	kVA	PF		
1	receptacles		0.0	0.0		0.0	0.0			
2	computers		0.0	0.0	0.70	0.0	0.0			
3	fluorescent lighting		5.4	6.0	1.00	5.4	6.0	0.91		
4	HID lighting		0.0	0.0	1.00	0.0	0.0			
5	incandescent lighting		0.0	0.0	1.00	0.0	0.0			
6	HVAC fans		0.0	0.0	0.80	0.0	0.0			
7	heating		0.0	0.0	0.70	0.0	0.0			
8	Distribution Panel		12.5	12.5	1.00	12.5	12.5	0.80		
9	Spare Load		95.2	119.0	0.60	57.1	71.4	0.80		
Total Demand Loads						75.1	89.9			
Spare Capacity			0%			0.0	0.0			
Total Design Loads						75.1	89.9	0.84	Amps=	108.2

Default Power Factor =	0.80
Default Demand Factor =	100 %

Figure 174: Panelboard HLE-3D Worksheet.

BRANCH CIRCUIT PANELBOARD SCHEDULE

Panel Name: HLE-3D	Mounting: Surface:	X	Main Lugs Only:	.	Amp Main CB	125
277/480V, 3 Phase, 4 Wire	Flush:	.	Shunt Trip Main:	.	Amp Bus	225
14,000MIN A.I.C. SYM	In MCC	.	Feed Through:	.	Ground Bus	X
Neutral: 100%	Number of Poles:	42	TVSS:	.	Isolated Ground Bus	.

CKT No.	Load	TRIP (Amp)	KVA/Phase A	KVA/Phase B	KVA/Phase C	CKT No.	CKT No.	KVA/Phase A	KVA/Phase B	KVA/Phase C	TRIP (Amp)	Load	CKT No.
1	Exit Sign	20	0.10			1	2	1.02			20	Stair N-1 Lighting	2
3	Toilet & Corridor Lighting	20		1.14		3	4		1.46		20	Stair N-1 Lighting	4
5	Organic Elec & Pho, Lab Lighting	20			2.30	5	6				20	Spare	6
7	Spare	20				7	8				20	Spare	8
9	Spare	20				9	10				20	Spare	10
11	Spare	20				11	12				20	Spare	12
13	Spare	20				13	14				20	Spare	14
15	Spare	20				15	16				20	Spare	16
17	Spare	20				17	18				20	Spare	18
19	Spare	20				19	20				20	Spare	20
21	Spare	20				21	22				20	Spare	22
23	Spare	20				23	24				20	Spare	24
25	Spare	20				25	26				20	Spare	26
27	Spare	20				27	28				20	Spare	28
29	Spare	20				29	30				20	Spare	30
31	Spare	20				31	32				20	Spare	32
33	Spare	20				33	34				20	Spare	34
35	Spare	20				35	36				20	Spare	36
37			4.94			37	38				20	Spare	38
39	Panel LE-3D Via XFMR 'TRE-LE-3D'	50		3.80		39	40				20	Spare	40
41					3.80	41	42				20	Spare	42

Subtotals (kVA):		5.04	4.94	6.1		1.02	1.46	0		Subtotals (kVA)
Total Loads:	Phase A:	6.06 kVA				91.26 %				Demand Factor
	Phase B:	6.40 kVA				16.94 kVA				Demand Load
	Phase C:	6.10 kVA				21.17 kVA				Load x 1.25
Total Connected Load:	18.56 kVA					25.5 A				Demand Amps

Figure 175: Revised Panel Schedule HLE-3D.

HLE-3D		
Tag		HLE-3D
Feed From		EDP-L0B
Voltage System		277/480V
Calculated Design Load (kW)		75.11
Calculated Power Factor		0.84
Calculated Design Load (kVA)		89.91
Calculated Design Load (A)		108.20
Feeder Protection Size		125
	Phase	(3) 300 MCM
	Neutral	#300 MCM
	Ground	#4
Wire Area (Sq. in.)		
	Each Phase	0.2679
	Total - All Phases	0.8037
	Nuetral	0.2679
	Ground	0.0366
	Total - All Wires	1.1082
Minimum Conduit Area (Sq. In.) (Above x 2.5)		2.7705
Conduit Size (NEC Chapter 9, Table 4)		2" RMC
Conduit Size (NEC Table C.1)		2" RMC
Feeder Length		500
Final Voltage Drop (V)		4.9
Final Voltage Drop (%)		1.8
Feeder Re-sizing		Yes

Figure 176: HLE-3D Feeder Worksheet.

Mechanical

MAE Course Related Study

As part of Building Stimulus' goal to improve the overall efficiency performance of the Millennium Science Complex, sustainability and energy conservation were a large focus throughout the redesign process. The iconic stature of the MSC yields itself to being a beacon for energy and sustainability use in buildings. This is why a decrease in the dependence of fossil fuel consumption and reduced carbon emissions produced by the Millennium Science Complex was sought after during redesign. After investigating several alternative energy sources, rooftop mounted wind turbines were selected to be utilized for the Complex. It is one of the tallest buildings on campus and is capable of acquiring higher wind speeds due to this height.

Several wind turbine manufacturers were investigated for their applicability with respect to aesthetics and performance. Two companies were narrowed down based on the aforementioned criteria. Those companies were AeroVironment and Cascade Renewable Energy. AeroVironment's Architectural Wind offers a building integrated wind turbine that is attached along the roof line of the building. The ingenuity of the design is that the turbine takes advantage of the wind's acceleration that occurs as it passes over the building's parapet. Based on this special design, the company has received 3 utility patents. According to the manufacturer, this accelerated wind can increase the turbine's electrical power generation by more than 50% compared to locations outside of the acceleration zone. Figure 177 illustrates how the Architectural Wind turbine can be applied to a building's rooftop. This turbine requires at least 2.2 m/s wind velocity to start up the turbine and its rated power is 1000 watts at speeds of 11 m/s or higher.

Figure 177: AeroVironment's Architectural Wind.

Figure 178: Cascade Renewable Energy Swift Wind Turbine.

The Swift wind turbine provided by Cascade Renewable Energy is a more traditional design. While this turbine may not be as aesthetically designed as the architectural wind, it is capable of achieving higher power production outputs. Figure 178 illustrates a typical Swift wind turbine building application. It is a horizontal axis turbine that is capable of being mounted to the structure as well. The turbine requires a wind velocity of 3.58 m/s for start-up, which is slightly higher than Architectural Wind. The peak production for this particular turbine is also higher than Architectural Wind, in which it can attain power outputs of over 1.5 kW at peak production and has a similar power output of 1.0 kW at 11 m/s. Cascade's technical specifications for the turbine estimates an annual energy production of approximately 1200 kWh for 5 m/s annual average wind speed and 1900 kWh for 6 m/s annual average wind speed. This power output is based on just one wind turbine's production.

Based on typical meteorological year (TMY) data for State College, as measured from the University Park Airport from 1991 to 2005, the prevailing wind for the site was determined to be 3.6 m/s measured 250^{o} from North (where North is considered to be 360^{o}). This leads to the prevailing wind to be from the westerly direction, which aligns with the apex of the building where the two wings meet: life science and material science. Based on this prevailing wind speed, this site is capable of generating enough velocity to start up both AeroVironment's and Cascade's wind turbines. In order to attain more accurate wind velocity profiles for the Millennium Science Complex, based on flow patterns caused by the structure and surrounding buildings, a computational fluid dynamics (CFD) model was used to determine the profiles. Knowledge from the Master's course, AE 559: Computational Fluid Dynamics was utilized extensively during this analysis to develop the model.

For the analysis, the CFD software, Phoenics, was used to model both the Millennium Science Complex and its surrounding buildings on campus. Developing the physical model for the CFD simulation provided a great opportunity for the inclusion of BIM techniques. Using AutoCad 3D and Revit, the massings for the surrounding buildings and MSC were developed as three dimensional objects, which were then exported as .stl files into

Phoenics. By creating the objects in AutoCad using the existing site plan and utilizing the model developed for MSC in Revit, it saved time during the model development phase. The size and locations were specified in the AutoCad file. Exporting the site and buildings as an .stl allowed attached properties (size and location) to be maintained once it was imported into Phoenics with a domain size of (900, 900, 100). Once the model was setup in Phoenics, the prevailing wind data was included for the boundary conditions, where the reference height was assumed to be 10.0 meters and the ground plane was modeled as a friction boundary. The properties for the simulation were set to be isothermal since the analyzed property of interest is outdoor wind velocity. The turbulence model used during the simulation process was the standard K-ε Chen model. This model was selected based on its reliability and widespread acceptance for the accuracy of the results attained. The numerical scheme set for the simulation was the hybrid scheme.

Several simulations were run to develop the velocity profiles around the Millennium Science Complex. After continuous refinement of the mesh for a grid size of (107, 108, 20), numerical schemes and relaxation factors for the simulation model, the simulation was able to attain a percent mass residual of 0.096%, which is less than 0.1%. This indicates that the solution was able to reach convergence and therefor is can be assumed that the outflow model of the site represents approximate performance of the windflow over the buildings.

Figure 179 and Figure 180 show the Z-plane velocity profiles at heights of 24 m and ground plane, respectively. Based on these profiles, the optimal location for wind turbines for the Millennium Science Complex should be along the buiding's north and west rooflines.

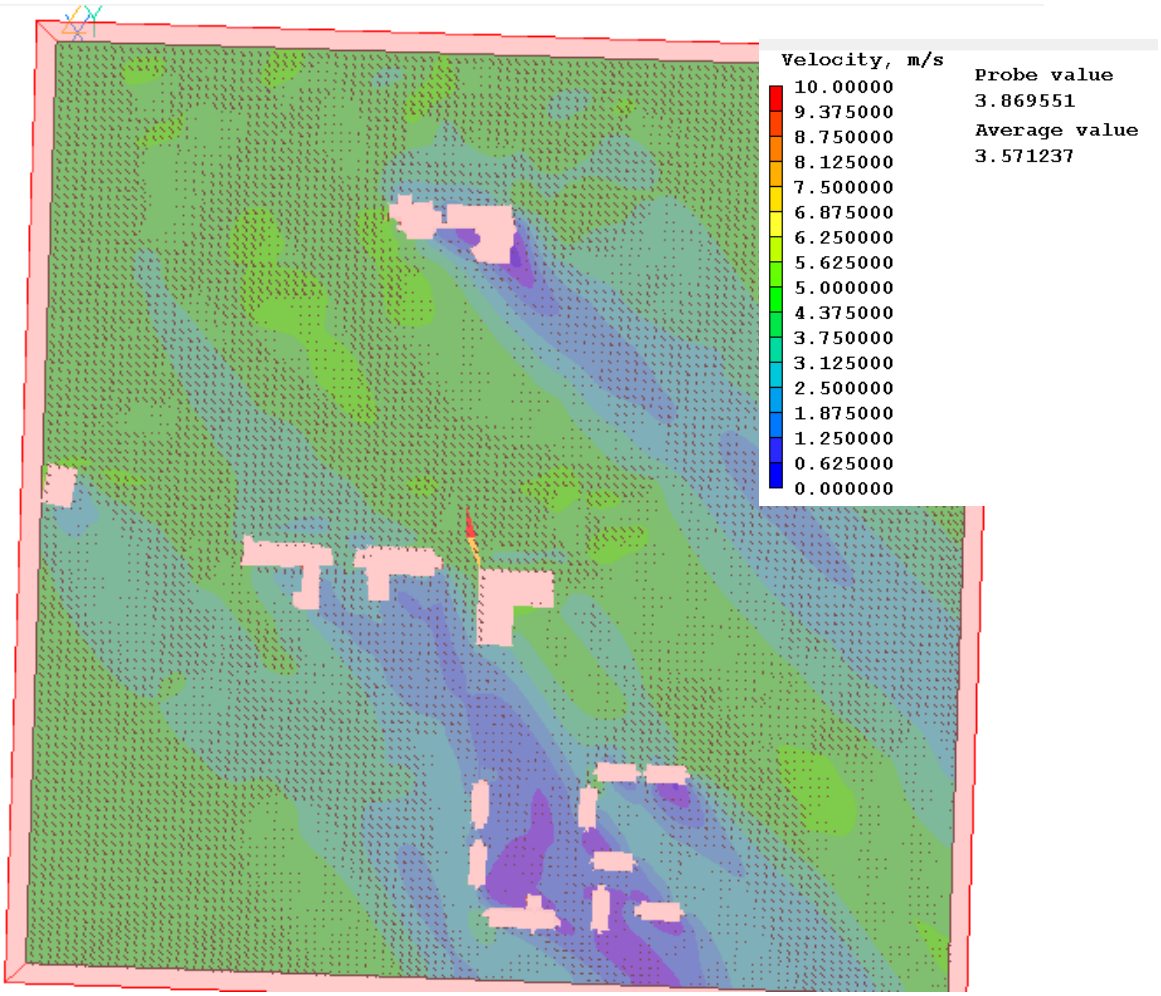


Figure 179: Z-Plane Velocity Profile: Z=24 m, Probe Position: (500, 430, 24)

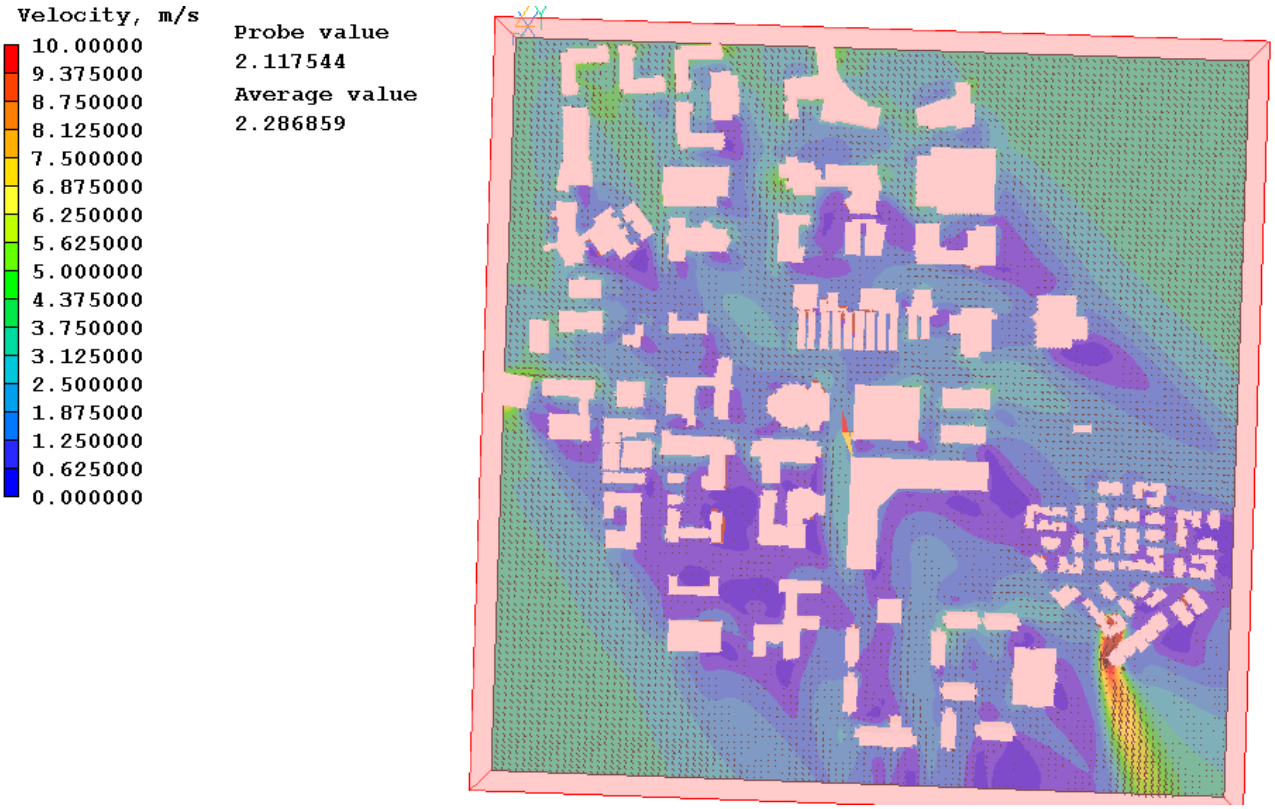


Figure 180: Z-Plane Velocity Profile: ground plane, Probe Position: (500, 430, 0.5)

The Y and X-plane velocity profiles for the wind around the building of interest, Millennium Science Complex, are shown Figure 181 and Figure 182, respectively. They both show higher wind speeds at the top of the building, which indicates that this location would be more appropriate for the location of wind turbines. Based on these profiles, the optimal location for the wind turbines was along the top of the cantilever.

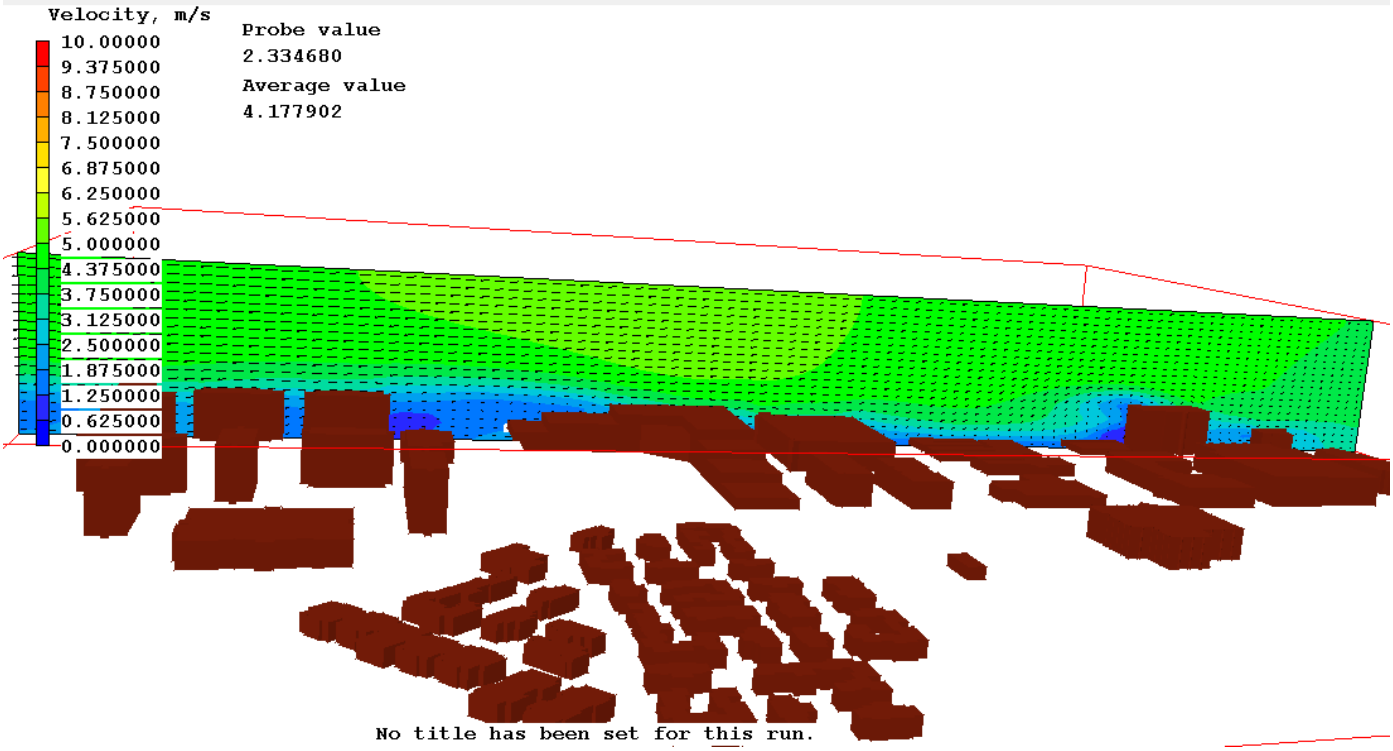


Figure 181: Y-Plane Velocity Profile, Probe Location (500, 430, 10)

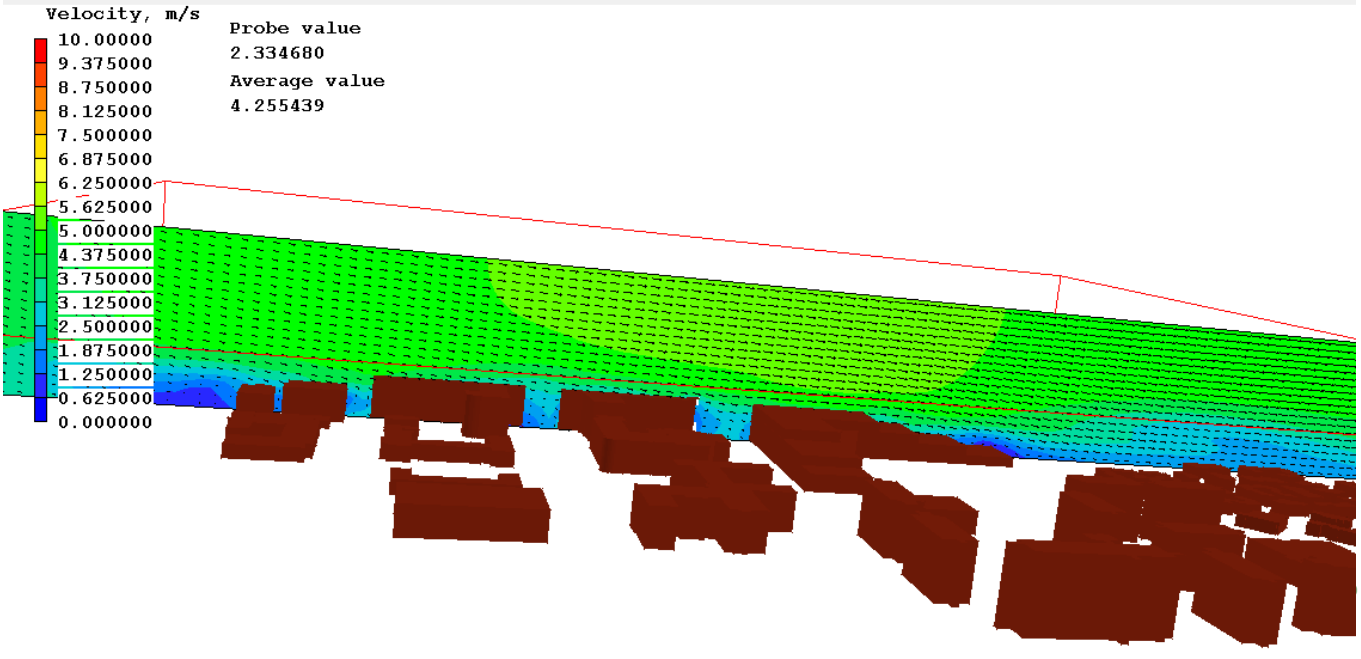


Figure 182: X-Plane Velocity Profile, Probe Location (500, 430, 10)

The additions of wind turbines were then added to the simulation to determine the face velocities. These results can be seen in Appendix C: Energy Analysis. Incorporating the wind turbines to the top of the cantilever impacts the architecture of MSC since they will be noticeable from the ground view by pedestrians and other onlookers. Figure 183 shows how the added Architectural Wind turbines impact the architecture.

Figure 183: AeroVironment Architectural Wind Building Integration.

While these turbines are more aesthetically pleasing as compared to other wind turbines, the addition impacts the feel of linearity that the architect Raphael Vinoly desired in his vision. However, by placing the wind turbines in a prominent location, it adds to MSC's profile as an iconic building on campus as a beacon for energy use and sustainability. This public display helps educate the others about clean energy and how it can be successfully utilized.

Figure 184shows the designed layout for the wind turbines along the roof of the cantilever. As per the spacing requirements for Swift wind turbine, one turbine is allowed to be placed at every column line, which is every 22 feet. This results in 18 turbines to be mounted to the structure. Using the prevailing wind speed of 3.6 m/s, the average maximum velocity that occurs at the Millennium Science Complex is approximately 4.9 m/s, according to the CFD results.

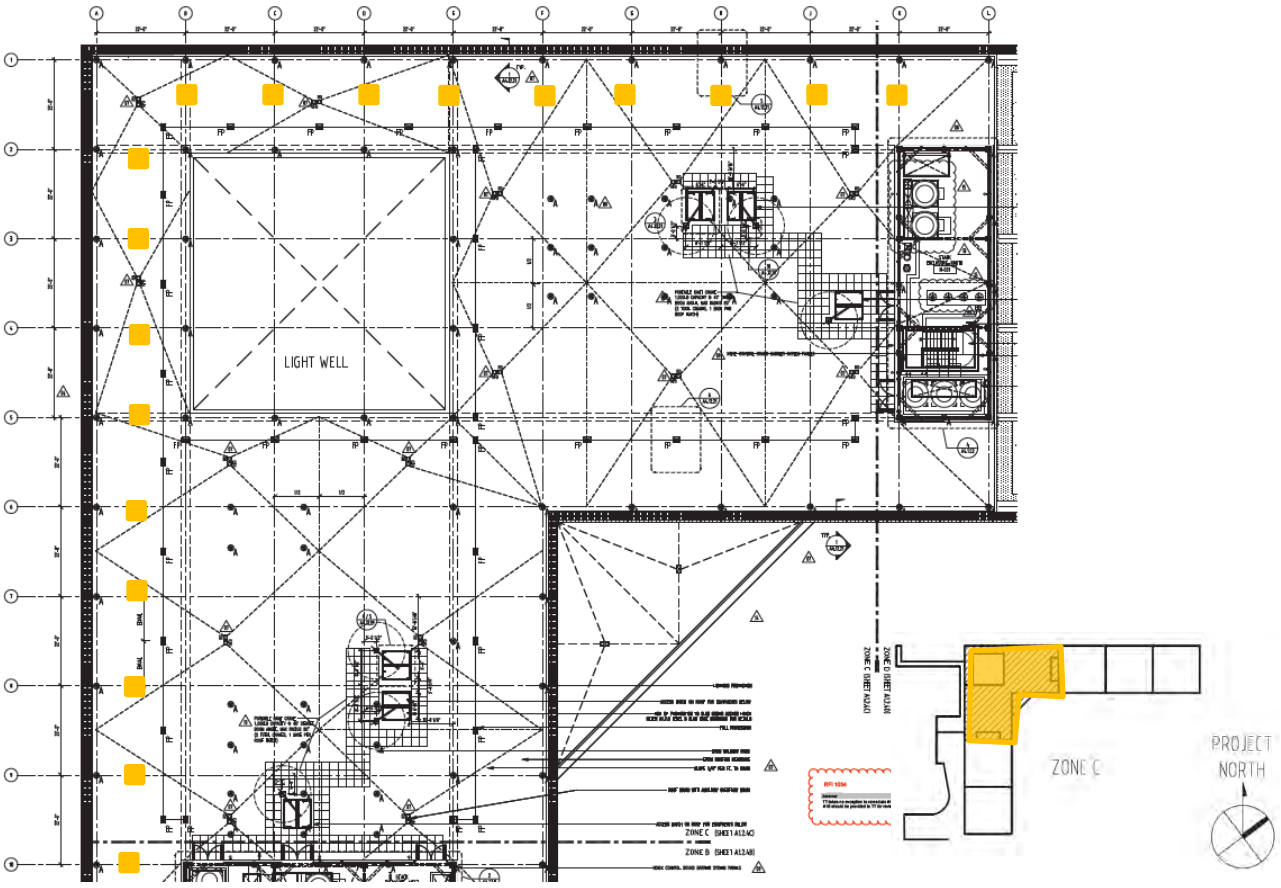


Figure 184: Wind Turbine Location.

According to the manufacturer's data for both the Cascade wind turbines and AeroVironment Architectural Wind, this results in an expected annual energy production power output of approximately 1200 kWh per turbine, which is a total 21,600 kWh for the total rooftop array. These production values are based on Cascade's values for 5.0 m/s average wind speed. This contributes to approximately 3% of the Millennium Science Complex's total energy consumption on the third floor alone, which results in an annual savings of $1,624 based on Penn State's utility data for electricity cost. For a rooftop array of this size, the total initial cost is $153,000 at $8,500 per unit, based on Cascade's data. For a simple payback period, it would require 94 years for return on investment and the lifetime expectancy for the array is only 20 years. Based on the size of the building and the energy consumption, it was determined by Building Stimulus to not be advantageous to the lifecycle cost of the building.

Due to its impact on the architecture and the small energy actually provided by the turbines for the building's energy use, Building Stimulus determined that these qualities outweighed the benefits provided from raising awareness to the campus by putting the wind turbines on a public display. Therefore, the wind turbines were not part of the final recommended design by Building Stimulus for Millennium Science Complex.

Structural

Gravity System Check

The gravity system of the MSC was not the main focus of Building Stimulus' building redesign. However, a sample calculation of the gravity system was performed to check the adequacy of the existing structure. These calculations and a chart of the applicable gravity loads on the structure can be found in Appendix A: Structural Analysis. A sample beam, girder, and column were chosen to be checked at the bay between grid lines 12-13 and B-C, shown in the figure below.

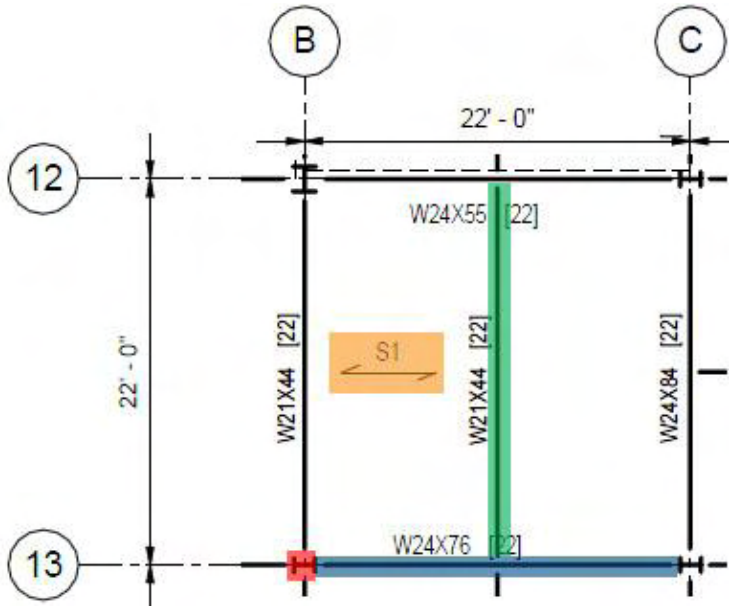


Figure 185: Gravity System Callout.

It was noticed that the beam was upsized from a minimum size of W14x22 to a W21x44 this could possibly be due to the vibration requirements of this sensitive laboratory building. A thorough vibrational analysis would be needed to confirm this claim but as this was not involved in the goals of the group this was not performed. This claim is not without validity however, the increase in beam section results in an increase in I from 199 in^4 to 843 in^4 and an increase in weight of 22 plf. Both of these factors contribute to the vibration reduction of the floor system. Specifically the floor system had to be upsized to limit the max velocity of the floor system with respect to impulse loading due to human activity. Design guidelines were defined as 4000 ui/s for the life science wing for example, these limits are defined by AISC Design Guide 11.

Lateral System Check

The lateral system of the Millennium Science Complex was not the main focus of the structural investigation of this thesis report. However, a lateral analysis was conducted on the existing lateral system and a series of resisting elements were checked for shear capacity. As seen in Figure 186 a lateral system model was generated in ETABS and the applicable lateral loads were applied to determine a controlling load case. Lateral loads for both earthquake and wind were calculated using ASCE7-05, and detailed calculations can be found in Appendix A: .

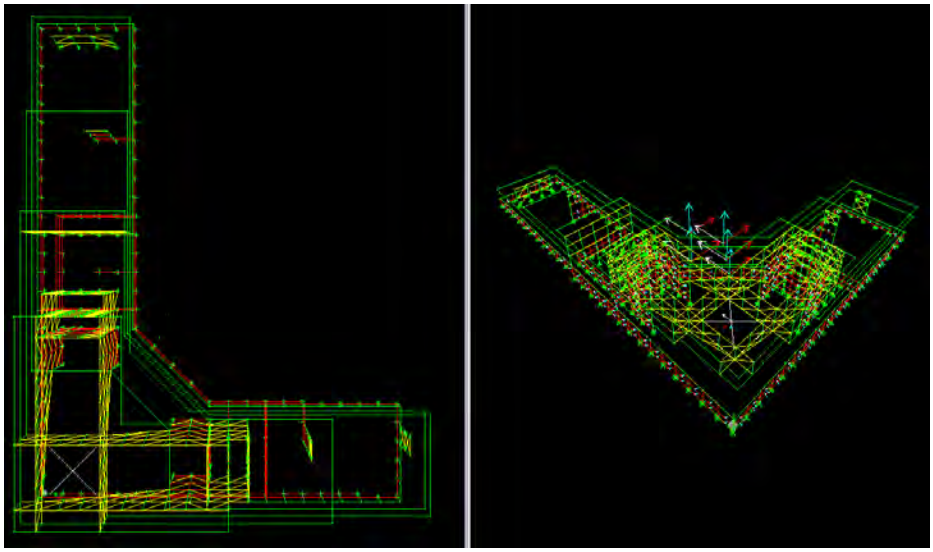


Figure 186: ETABS Lateral Model.

Earthquake loads were applied with a 5% accidental torsion in accordance with section 12.8.4.2. The effect of the amplification factor designated in section 12.8.4.3 was considered because of the presence of a building torsional irregularity of type 1a, however, section 12.8.4.3 indicates that the amplification factor only applies to structures assigned to Seismic Design Category C, D, E, or F. Therefore, because the MSC is under SDC: B, section 12.8.4.3 does not apply. Wind loads were applied using Figure 6-9 of Method 2 – Main Wind Force Resisting System, shown in Figure 187. Based on maximum shear transferred to critical lateral resisting elements the earthquake load was determined to be the critical load case for this structure. Although Pennsylvania is not a particularly earthquake prone region, the large building weight and small overall height of the building both contribute to the earthquake load resulting in the controlling lateral load case. In addition to the lateral load calculations, a series of detailed shear capacity checks can also be found in Appendix A: .

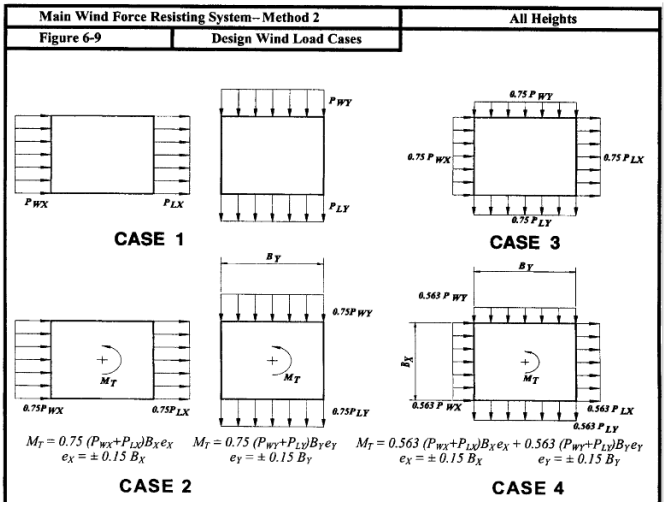


Figure 187: ASCE7-05 Figure 6-9 – MWFRS Wind Load Application.

MAE Course Related Study

To fulfill the MAE requirements of BIM Thesis, material explored in both Computer Modeling of Building Structures and Building Enclosures was used to complete the structural analysis of the Millennium Science Complex. ETABS was used to model the lateral system of the building to perform a lateral system check for the existing structural system. The methods of placing rigid end offsets and modeling a membrane floor system for accurate in and out of plane lengthening in SAP 2000 was carried out for a thorough analysis of the cantilever. Also, methods learned in Building Enclosures were used to size the glazing and mullion system of the redesigned double skin façade.

Acknowledgements

Building Stimulus and its members would like to extend a big "Thank You" to the following individuals and companies for help and input for our Thesis.

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- Members of K.G.B. Maser
- Last but not least, all friends and family

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International Building Code (IBC), 2006 Edition

American Institute of Steel Construction (AISC), Steel Construction Manual, 13th edition, LRFD

American Society of Civil Engineers (ASCE), ASCE7-05, Minimum Design Loads for Buildings and Other Structures

Precast/Prestressed Concrete Institute (PCI), Design Handbook, 6th Edition

RS Means Online Database

Appendix

Appendix A: Structural Analysis

Lateral System Distribution Check

	NS-Load Direction			
Frame	Total	Col	Brace	Wall
A	0	0	0	0
B	395.0119	5.6586	30.3466	359.0067
C	0.0457	0.0457	0	0
D	0.1928	0.1928	0	0
E	352.1036	5.5897	31.4656	315.0483
F	0.132	0.0335	0	0.0985
G	0	0	0	0
H	0.429	0.429	0	0
J	0.48	0.48	0	0
K	687.2726	4.686	6.271	676.3156
L	11.2206	0.031	0	11.1896
M	6.6218	0.2942	0	6.3276
N	0.1065	0.0102	0	0.0963
P	0.0675	0.0675	0	0
Q	0.6474	0.6474	0	0
R	0.5752	0.0027	0	0.5725
S	0	0	0	0
T	0.0023	0.0023	0	0
U	0.0178	0.0178	0	0
V	106.8865	1.8679	0	105.0186
W	0.022	0.022	0	0
X	0.0005	0.0005	0	0
Y	0.0003	0.0003	0	0
Z	0	0	0	0
AA	5.6249	0.5613	5.0637	
BB	0	0	0	0
Radial	0.7654	0.7654	0	0
Total	1568.2263			
Applied	1581			
% diff	0.81			

EW-Load Direction

Frame	Total	Col	Brace	Wall
1	0.4053	0.1355	0	0.2698
2	393.6461	5.2453	13.1252	375.2756
3	0.0374	0.0374	0	0
4	0.2228	0.2228	0	0
5	316.6231	4.9592	28.0517	283.6122
6	4.6241	0.0207	0	4.6034
7	0	0	0	0
8	0.1356	0.1356	0	0
9	0.3765	0.3765	0	0
10	666.1471	4.8363	5.5675	655.7433
11	7.4544	0.4752	6.9792	0
12	3.2325	0.0622	3.1703	0
13	0.0201	0.001	0	0.0191
14	0.0285	0.0285	0	0
15	83.525	2.2138	0	81.3112
16	0.07	0.07	0	0
17	0.00833	0.00833	0	0
18	0.00078	0.00078	0	0
19	0.0012	0.0012	0	0
20	15.7909	0.1521	0	15.6388
21	0	0	0	0
Radial	21.9897			21.9897
Total	1514.34			
Applied	1581			
% diff	4.22			

Torsional Irregularity/Drift Data

Max Displacement		Max Drift	
0.0519	in @ Rf.	0.0103	%
0.0653	in @ Rf.	0.016	%
0.0679	in @ Rf.	0.0171	%

Check of Wall on Frame 2

Check Concrete Wall

Vu =	375	K	lw =	44	ft
Vc =	1603	K	hw =	56	ft
Ø =	0.75		tw =	30	in
ØVc =	1202	**>Vu, OK**			

Check Braces

Vu = 13.13 K

	ØVn	
W14x90	185	K
W14x99	206	K
W14x120	256	K
Total =	647	**> Vu, OK**

Check Columns

Vu = 5.25 K

	ØVn	
W14X550	1450	K
W14X550	1450	K
W14x283	648	K
W14x283	648	K
W14x283	648	K
Total =	4844	**> Vu, OK**

Check of Wall on Frame 15

Check Concrete Wall

Vu =	81	K	lw =	22	ft
Vc =	481	K	hw =	20	ft
Ø =	0.75		tw =	18	in

ØVc = 361 **>Vu, OK**

Check Columns

Vu = 2.21 K

	ØVn	
W14X99	206	K
W14X99	206	K

Total = 412 **> Vu, OK**

Check of Wall on Frame 10

Check Concrete Wall

Vu =	666	K	lw =	66	ft
Vc =	1282	K	hw =	56	ft
Ø =	0.75		tw =	16	in

ØVc = 962 **>Vu,OK**

Check Columns

Vu = 4.84 K

	ØVn	
W14x283	648	K
W14x283	648	K
W14x90	185	K
W14x90	185	K

Total = 1666 **>Vu,OK**

Lateral Loads

Design Seismic Base Shear (ASCE7-05)

V= CsW 12.8-1

W: Effective Weight- 12.7.2

Cs: Seismic Coeff.- 12.8.1.1

$$Cs = \text{Min} \begin{vmatrix} S_{ds}/(R/I) \\ S_{D1}/(T*R/I) \\ S_{D1}*TI/(T^2*R/I) \end{vmatrix} > 0.01$$

In addition, where S1 > 0.6

$Cs > 0.5S_1/(R/I)$ Eq. 12.8-6

Fa,Fv- Table 11.4-1, 11.4-2

Ss, S1- USGS website, using long./lat. of site location

R: Response Mod. Coeff.- Table 12.2-1

I: Importance Factor- 11.5

Occ. Cat.- Table 1-1

$$T = \text{Min} \begin{vmatrix} Cu*Ta \\ Tb \end{vmatrix} \quad S_{ds}= 2/3(S_{MS}) \quad S_{MS}= Fa*Ss \quad S_{D1}= 2/3(S_{M1}) \quad S_{M1}= Fv*S1$$

Cu- Table 12.8-1

Ta- 12.8.2.1

Tb- Fundamental Mode of Vibration from Modal Analysis w/Mass input

Design Seismic Base Shear- MSC Complex, University Park, PA

Latitude: 40.802 Site Class: D

Longitude: -77.86 Occ. Cat: III

Ss = 0.147 g (Site Class B)

S1= 0.049 g (Site Class B)

Fa= 1.6

Fv= 2.4

S_{MS}= 0.2352 g S_{DS}= 0.1568 g

S_{M1}= 0.1176 g S_{D1}= 0.0784 g

Lateral Force Resisting System: Ordinary Steel Concentrically Braced Frames

R=	3.25	
I=	1.25	
SDC:	B	(No Limitations)
Tl=	6	s (Fig. 22-15)

Design Base Shear

Ta=	0.512	s	Cs=	Min	0.0603	=	0.0346
Cu=	1.7				0.0346		
Cu*Ta=	0.871	s			0.2386		

Floor Weights (slabs, beams, columns, façade)

	slabs(K)	columns(K)	beams(K)	braces(K)	façade(K)	W(K)
Level-2	4186.6	472.09	889.46	582.3126	1331	7461.03
Level-3	4670.6	383.12	1011.99	935.0597	1890	8890.80
Mech.	6258.12	280.02	762.95	1024.646	2213	10538.70
Roof	1771.44	147.31	481.01	761.4857	2590	5751.22
					Total	32641.75

V= CS*W

Cs= 0.0346

W= 45663 K

V= **1581** **K**

MWFRS Wind Analysis (ASCE7-05)- MSC Complex

Location:	University Park, PA
Topography:	Campus Setting. Buildings to North, North West, West, and South. Mostly open terrain to East with small obstructions
Bulding Dimensions:	L-Shaped. North Wing outside dimension = 550 ft, West Wing outside dimension = 440 ft. Building Heights (From Pollock Road): 85'-6" ft to Roof level, 66 ft to Mechanical Penthouse, 48 ft to Third Floor, 30 ft to second floor, 10 ft to first floor. Roof Step Backs: Roof steps to: North Wing- Steps Down to Mech. Penthouse level at 220 ft, Third Floor at 330 ft, and Second Floor at 440 ft. - Same on West Wing except the last step down does not exist
Framing:	Primarily Steel Framing- W-Flange columns, beams, and cross-bracing. The floor system is a composite beam and concrete slab on metal deck.
Cladding:	Alternate horizontal strips of precast concrete panels and exterior glazing for each floor of elevation. Assume no debris resistant glazing.
Roof Top:	Primary Roof consists of EPDM Walkway Pads and EODM Fooring Membrane tapered. The lower roofs are all green roofs. All roofs flat.

a) Basic Wind Speed (Fig. 6-1): V = 90mph

b) Exposure: (6.5.2.3) Exposure B: Urban/Suburban, wooded, numerous closely spaced obstructions- single family dwellings and larger.

c)Building Classification: Construction Type IIIB, Occ. Cat: B with special Occ. areas of H-5

d) Velocity Pressure: $q_z = 0.000256 k_z k_{zt} k_d V^2 I$

kz (Table 6-3) =	15	20	39	57	75.75	87	(ft)
	0.575	0.624	0.755	0.842	0.913	0.950	

kzt (Fig. 6-4) =	1	, assume homo-topo
kd (Table 6-4) =	0.85	, buildings
$V^2 = 90^2$ =	8100	
I (Table 6-1) =	1.15	
qz =	**20.27**	*kz **psf** *depends on height

e) Gust Effect Factor: G= 0.85 (Rigid Structure T< 1.0s, refer to Seismic Analysis)

f) Internal Pressure Coefficient: GCpi = +/- 0.18 (assume Enclosed Building)

g) Design Wind Pressures: P = qGCp - qi(Gcpi)

q = qz (windward, depends on height)

q = qh (leeward, taken at height-h)

G = 0.85

qi = qh (windward, leeward, and roofs for enclosed buildings)

GCpi = +/- 0.18

Cp values determined:

h) Wall Cp: (Fig. 6-6 cont'd)

Cpw =	0.8	(windward, with qz)
Cpsw =	-0.07	(side walls, with qh)
Cpl=	-0.5	L/B = 0-1 (Leeward, with qh)
	-0.3	L/B = 2
	-0.2	L/B = > 4

i) Roof Cp: (Fig. 6-6 cont'd)

angle < 10deg., h/L < 0.5

Hor. Dist. From Wind. Edge		Cp (1st)	Cp (2nd)
0-h/2, h/2-h		-0.9	-0.18
h-2h		-0.5	-0.18
> 2h		-0.3	-0.18

j) MWFRS Pressures P = qGCp - qi(Gcpi)

Terrain Exposure Constants

Exposure	α	Zg(ft)	â	b^	α–	b-	c
B	7.00	1200.00	0.14	0.84	0.25	0.45	0.30

l (ft)	Ɛ	Zmin (ft)
320.00	0.33	30.00

Windward Walls

Height	qz	G	Cp	**qzGCp**
z= 15ft	11.65	0.85	0.8	7.92
z= 20ft	12.65	0.85	0.8	8.60
z= 39ft	15.31	0.85	0.8	10.41
z= 57ft	17.06	0.85	0.8	11.60
z= 75.75ft	18.50	0.85	0.8	12.58
z= 87ft	19.25	0.85	0.8	13.09

Leeward Walls

	qh	G	Cp	**qhGCp**
Wind- short side	19.25	0.85	-0.2	-3.27
Wind-Long Side	19.25	0.85	-0.5	-8.18
Side Walls	19.25	0.85	-0.7	-11.45

Roof- First Value

Length	qh	G	Cp	**qzGCp**
0-h	19.25	0.85	-0.9	-14.73
h-2h	19.25	0.85	-0.5	-8.18
>2h	19.25	0.85	-0.3	-4.91

Roof- Second Value

	qh	G	Cp	**qzGCp**
all lengths	19.25	0.85	-0.18	-2.95

Wall Areas

	Windward			Leeward-Long Side		Leeward-Short Side
Height	E/W(SF)	N/S(SF)		E/W(SF)	N/S(SF)	E/W=N/S(SF)
z= 0-15ft	6398	8335		4638	6571	1760
z= 15-20ft	2136	2778		1549	2195	587
z= 20-39ft	8444	10141		6215	7911	2229
z= 39-57ft	7564	7564		5452	5452	2112
z= 57-75.75ft	5753	5753		3553	3553	2200
z= 75.75-87ft	2740	2740		1420	1420	1320

Floor Loads by Area

	Windward		Leeward-Long Side		Leeward-Short Side
Floor Level	E/W(K)	N/S(K)	E/W(K)	N/S(K)	E/W=N/S(SK)
First Floor	52.2	67.9	38.0	53.8	5.8
Second Floor	87.9	105.5	50.8	64.7	7.3
Third Floor	87.7	87.7	44.6	44.6	6.9
Mech. Pent.	72.4	72.4	29.1	29.1	7.2
Roof	35.9	35.9	11.6	11.6	4.3

Final Story Forces y x

	Load		Shear		Moment	
Floor Level	E/W(K)	N/S(K)	E/W(K)	N/S(K)	E/W(K-ft)	N/S(K-ft)
First Floor	153	204	867	968	1534	2040
Second Floor	234	284	713	764	7009	8523
Third Floor	223	223	480	480	10694	10694
Mech. Pent.	174	174	257	257	11473	11473
Roof	83	83	83	83	7087	7087
Totals*(1.6)			**867**	**968**	**37798**	**39817**

Components and Cladding Wall Panels

p = q(GCp) − qh (GCpi) (lb/ft2)

Windward

					Area 4/5		
Floor Level	Wall Area	h	qz	qh	GCp	Gcpi	P(psf)
First Floor	440	20	12.65	19.25	0.638	0.18	11.53
Second Floor	418	39	15.31	19.25	0.651	0.18	13.43
Third Floor	396	57	17.06	19.25	0.665	0.18	14.81
Mech. Pent.	412.5	75.75	18.50	19.25	0.655	0.18	15.58
Roof	214.5	87	19.25	19.25	0.778	0.18	18.45

Leeward

					Area 4	Area 5			
Floor Level	Wall Area	h	qz	qh	GCp	GCp	Gcpi	P4(psf)	P5(psf)
First Floor	440	20	12.65	19.25	-0.725	-1.100	0.18	-17.42	-24.64
Second Floor	418	39	15.31	19.25	-0.734	-1.137	0.18	-17.60	-25.35
Third Floor	396	57	17.06	19.25	-0.743	-1.173	0.18	-17.77	-26.05
Mech. Pent.	412.5	75.75	18.50	19.25	-0.736	-1.146	0.18	-17.64	-25.52
Roof	214.5	87	19.25	19.25	-0.819	-1.476	0.18	-19.23	-31.87

Moment Due to Wind - ASCE7-05

	X Length	Y Length	MTx	MTy
First Floor	5120	6668	117814.6	203993.9
Second Floor	5468	6916	191627.7	294721.3
Third Floor	5596	5596	187014.5	187014.5
Mech. Penthouse	4276	4276	111496.1	111496.1
Roof	2956	2956	36754.47	36754.47

Gravity Systems Check

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GRAVITY SYSTEM - MEMBER SIZE CONFIRMATION (TYP. BEAM)

ASSUME $a = 1"$ $\therefore Y_2 = t - \frac{a}{2} = 5.5"$

$M_u = 258.7^{IK}$ - FROM GRAVITY LOAD SPREADSHEET

TRY W14x22 — TABLE 3-19

$\phi M_n = 266^{IK}$ $\Sigma Q_n = 241 \rightarrow 241/17.2 = 14.0 \rightarrow 28$ studs

$a = \frac{241}{.85(4)(66)} = 1.07$ $Y_2 = 6.25 - \frac{1.07}{2} = 5.715 > 5.5$ ∴ OK

$M_u = 258.7 \leq \phi M_n = 266$ ∴ OK

$V_u = 47.0 \leq \phi V_n = 94.8$ ∴ OK

UNSHORED STRENGTH

W14x22 $\phi_b M_p = 125^{IK}$ - TABLE 3-19

$w_u = 1.4(.05(11) + .022) = 0.801$ K/LF

$w_u = 1.2(.05(11) + .022) + 1.6(0.02(11)) = 1.038$ K/LF

$M_u = \frac{w_u L^2}{8} = \frac{1.038(22)^2}{8} = 62.80^{IK} \leq \phi_b M_p = 125^{IK}$ ∴ OK

DEFLECTION CHECK

$I = 199 \text{ in}^4$

$I_{LB} = 622 \text{ in}^4$ TABLE 3-20

$\Delta_{LL} = \frac{5 w_{LL} L^4}{384 E I_{LB}} = \frac{5(0.15)(11)(22)^4(1728)}{384(29000)(622)} = 0.482 \text{ in} \leq \Delta_{LL} = \frac{L}{360} = 0.73$ ∴ OK

$\Delta_{DL} = \frac{5 w_{DL} L^4}{384 E I} = \frac{5(0.05+0.022)(11)(22)^4(1728)}{384(29000)(199)} = 0.723 \leq \Delta_{DL} = \frac{L}{240} = 1.10$ ∴ OK

W14x22 MIN. BEAM REQUIRED FOR GRAVITY SYSTEM.

W21x44 ← BEAM USED FOR VIB CONTROL.

TYP. GIRDER W24 x 76

assume $a \simeq 1"$ $\therefore Y_2 = +- \frac{a}{2} \Rightarrow 5.5"$

$M_u = 1040.6^{IK}$ - GRAVITY LOAD SPREADSHEET

TRY W24x62 - TABLE 3-19

$\phi M_n = 1050^{IK}$ $\Sigma Q_n = 600 \rightarrow 600/21.2 = 28.3 \rightarrow 58$ studs

$a = \frac{600}{.85(4)(66)} = 2.67$ $Y_2 = 6.25 - \frac{2.67}{2} = 4.92" < 5.5 \therefore NG$

TRY W24 x 68

$\phi M_n = 1080^{IK}$ $\Sigma Q_n = 479 \rightarrow 479/21.2 = 22.6 \rightarrow 46$ studs

$a = \frac{479}{.85(4)(66)} = 2.13 \rightarrow Y_2 = 6.25 - \frac{2.13}{2} = 5.18 < 5.5" \therefore NG$

$\therefore$ USE W24 x 76 $\rightarrow$ CHECKED FOR ADEQUACY IN GIRDER CHECK TABLE

Loading Schedule

Floor Loading Schedule							Confirmed Loads	
Floor	Elevation (ft-in.)	Occupancy	Slab Type	Loads			ASCE7-05 LL	USD - DL
				Slab (PSF)	SDL (PSF)	LL (PSF)		
Level Roof	1245'-6"	Roof	S1	50	25	30	30	48.8
Mechanical Penthouse	1226'-0"	Mechanical	S2	110	25	150		106
Third Floor	1208'-0"	Green Roof	S3	76	120	30		75.8
		Office	S1	50	30	50	50	48.8
		Material Science Labs	S1	50	30	150		48.8
		Life Science Labs	S1	50	30	150		48.8
		Corridors	S1	50	30	Area Served	Area Served	48.8
		Elevator Lobbies	S1	50	30	100	100	48.8
Second Floor	1190'-0"	Green Roof	S3	76	120	30		75.8
		Office	S1	50	30	50	50	48.8
		Material Science Labs	S1	50	30	150		48.8
		Life Science Labs	S1	50	30	100		48.8
		Corridors	S1	50	30	Area Served	Area Served	48.8
		Elevator Lobbies	S1	50	30	100	100	48.8
First Floor	1170'-0"	Plaza Landscape	S2	110	300	100	100	106
		Office	S1	50	30	50	50	48.8
		Material Science Labs	S1	50	30	150		48.8
		Life Science Labs	S1	50	30	100		48.8
		Corridors	S1	50	30	100	100	48.8
		Mechanical Mezzanine	Grating	10	10	150		
		Elevator Lobbies	S1	50	30	100	100	48.8
Basement Mezzanine	1160'-0"	Retail	S1	50	30	50		48.8

Beam Check

Bay 12-13,B-C 3rd Floor							
Member ID		W21x44					
	Shear Studs	22					
Concrete	f'_c	4	ksi				
	Density	115	pcf				
Beam	F_y	50	ksi				
	F_u	65	ksi				
	E	29000	ksi				
	I	843	in^4				
	I_{LB}	1490	in^4				
	spacing	11	ft				
	span	22	ft				
	b_{eff}	66	in				
	t	6.25	in				
	Assumed a	1	in				
	Y_2=t-a/2	5.5					
Loads	Dead Load						
	Slab SW	0.0500	ksf				
	Beam SW	0.0440	klf				
	SDL	0.0300	ksf				
	Total DL	0.1240					
	Live Load						
	floors supporting	1					
	L_o	0.150	ksf				
	K_{LL}	2					
	A_T	242	sf				
	$K_{LL}A_T$	484					
	Reduction Coeff.	Unreducible					
	L	0.150	ksf				
	Construction LL	0.02					
	Check Member Strength						
	w_u=1.2D+1.6L	4.2768	klf				
	$V_u=w_uL/2$	47.0	≤	ϕV_n	217	OK	Table 3-2
	$M_u=w_uL^2/8$	258.7	≤	ϕM_n	522	OK	Table 3-19

Check Shear Studs						
ΣQ_n	162					Table 3-19
Q_n	17.2					Table 3-21
# of Studs = $(\Sigma Q_n/Q_n)*2$	20	≤	# Studs Specified	22	OK	
Check a						
a	0.721925134	≤	assumed a	1	OK	
Check Unshored Strength						
w_u=1.4D	0.832	klf				
w_u=1.2D+1.6L	1.065	klf				
$M_u=w_uL^2/8$	64.4	≤	ϕ_bM_p	358	OK	Table 3-19
Deflection Check						
$\Delta_{LL}=5w_{LL}L^4/384EI_{LB}$	0.201	≤	Δ_{LL}=L/360	0.73	OK	
$\Delta_{CDL}=5w_{CDL}L^4/384EI$	0.223	≤	Δ_{LL}=L/240	1.10	OK	

Girder Check

Bay 12-13,B-C 3rd Floor			
Member ID		W24x76	
	Shear Studs	22	
Concrete	f'_c	4	ksi
	Density	115	pcf
Steel	F_y	50	ksi
	F_u	65	ksi
	E	29000	ksi
Girder	I	2100	in^4
	I_{LB}	3470	in^4
	b_{eff}	66	in
	t	6.25	in
	span	22	ft
	Assumed a	1.25	in
	Y_2=t-a/2	5.5	
Beam	spacing	11	ft
	span	22	ft
Loads	Dead Load		
	Slab SW	0.0500	ksf
	Girder SW	0.0760	klf
	SDL	0.0300	ksf
	Total DL	0.1560	
	Live Load		
	floors supporting	1	
	L_o	0.150	ksf
	K_{LL}	2	
	A_T	484	sf
	$K_{LL}A_T$	968	
	Reduction Coeff.	Unreducible	
	L	0.150	ksf
	Construction LL	0.02	ksf
	Construction DL (on beam)	0.594	klf
	Check Member Strength		

$P_u=w_{uBeam}L_{Beam}$	94.6	k					
$V_u=P_u/2$	47.3	≤	ϕV_n	316	k	OK	Table 3-2
$M_u=P_uL/4$	1040.6	≤	ϕM_n	1050	ft-k	OK	Table 3-19
Check Shear Studs							
ΣQ_n	280				k		Table 3-19
Q_n	21.2				k		Table 3-21
# of Studs = $(\Sigma Q_n/Q_n)*2$	28	>	# Studs Specified	22		No Good	
Check a							
a	1.248	≤	assumed a	1.25	in	OK	
Check Unshored Strength							
$w_u=1.4D$	0.143	klf					
$P_u=$	23.4	k					
$M_u=(w_uL^2/8)+(Pl/4)$	137.5	≤	$\phi_b M_p$	750	ft-k	OK	Table 3-19
Deflection Check							
$\Delta_{LL}=PL^3/48EI_{LB}$	0.360	≤	$\Delta_{LL}=L/360$	0.73	in	OK	
$\Delta_{CDL}=PL^3/48EI$	0.083	≤	$\Delta_{CDL}=L/240$	1.10	in	OK	

Column Check

B-13 Supporting FL3	W14x68	
F_y	50	ksi
L	18	ft
KL_x	18.0	ft
KL_y	18.0	ft
P_u	298.1	k
ϕP_n	512 @ KL=8	k
$P_u = 301.08 \leq \phi P_n = 512$	OK	
Min W14	W14x61	
ϕP_n	457	k

Cantilever Redesign

Existing Strength Calculations

TABLE: Element Forces - EXISTING

Frame	Section	Station	OutputCase	P	V2	V3	M2	M3	L	K	KL	P_r	P_c	P_r/P_c		M2	M3	px10³	bx10³	by10³	Interaction Eqn.	
Text		in	Text	Kip	Kip	Kip	Kip-in	Kip-in	in													
Frame 2.1	W14X99	377.44	Design Loads	-171.566	3.275	-0.031	9.931	-131.806	377.44	0.8	25.16267	-179.51	806.7899	0.222499	H1-a	0.827583	-30.2596	1.2395	1.6	2.85	0.273273009	<1.0 OK
Frame 2.1		0	Design Loads	-179.51	-4.5	-0.031	-1.831	-363.115														
Frame 2.9	W14X193	341.104	Design Loads	-128.765	-7.952	1.468	298.985	-644.097	341.104	0.8	22.7	-141.187	1834.002	0.076983	H1-b	24.91542	-53.6748	1.24	0.709	1.32	0.131869735	<1.0 OK
Frame 2.9		0	Design Loads	-141.187	7.23	1.468	-201.667	-520.955														
Frame 2.14	W14X193	338.742	Design Loads	-1137.76	16.651	-3.284	693.381	-1856.62	338.742	0.8	22.5828	-1149.97	1842.423	0.62416	H1-a	57.78175	-154.719	0.5428	0.709	1.32	0.810127349	<1.0 OK
Frame 2.14		0	Design Loads	-1149.97	1.469	-3.284	-419.04	1212.347														
Frame 2.23	W14X145	355.276	Design Loads	-420.371	6.804	-0.892	116.879	-190.77	355.276	0.8	23.68507	-430.634	1323.433	0.325392	H1-a	-16.6772	16.84717	0.7556	0.989	1.78	0.371738798	<1.0 OK
Frame 2.23		0	Design Loads	-430.634	-4.592	-0.892	-200.126	202.166														
Frame 2.25	W14X145	355.276	Design Loads	-789.607	6.3	-2.606	472.301	-491.139	355.276	0.8	23.7	-799.871	1323.433	0.604391	H1-a	39.35842	-40.9283	0.76	0.989	1.78	0.650109737	<1.0 OK
Frame 2.25		0	Design Loads	-799.871	-5.096	-2.606	-453.467	-277.364														
Frame 2.26	W14X145	355.276	Design Loads	-632.415	7.55	-1.527	357.061	-728.315	355.276	0.8	23.7	-642.678	1323.433	0.485614	H1-a	29.75508	-60.6929	1.30	0.989	1.78	0.898385585	<1.0 OK
Frame 2.26		0	Design Loads	-642.678	-3.847	-1.527	-185.287	-70.501														
Frame 5.1	W14X109	377.44	Design Loads	-132.716	3.796	-0.07	19.937	-185.755	377.44	0.8	25.16267	-141.432	891.7993	0.158592	H1-b	1.661417	-30.2424	1.1213	1.43	2.56	0.132733239	<1.0 OK
Frame 5.1		0	Design Loads	-141.432	-4.735	-0.07	-6.497	-362.909														
Frame 5.13	W14X90	0	Design Loads	-846.997	-3.582	-0.189	-56.775	-20.641	300.719	0.8	20.04793	-846.997	875.411	0.967542	H1-a	-4.73125	-1.72008	1.1423	1.65	3.26	0.985804069	<1.0 OK
Frame 5.13		300.719	Design Loads	-843.164	3.445	-0.189	2.84E-14	4.55E-13														
Frame 5.16	W14X90	0	Design Loads	-137.337	-3.513	0	0	0	338.742	0.8	22.5828	-137.337	805.5964	0.170479	H1-b	0	-2.8E-14	1.2413	1.74	3.26	0.085239336	<1.0 OK
Frame 5.16		338.742	Design Loads	-131.688	3.513	0	0	-3.4E-13														
Frame 5.18	W14X90	338.742	Design Loads	-394.91	3.513	0	0	-3.4E-13	338.742	0.8	22.5828	-400.559	805.5964	0.49722	H1-a	0	-2.8E-14	1.2413	1.74	3.26	0.497220461	<1.0 OK
Frame 5.18		0	Design Loads	-400.559	-3.513	0	0	0														
Frame 5.25	W14X90	0	Design Loads	-260.69	-3.513	0	0	0	355.276	0.8	23.68507	-260.69	774.6098	0.336544	H1-a	0	1.9E-14	1.291	1.74	3.26	0.336543628	<1.0 OK
Frame 5.25		355.276	Design Loads	-254.362	3.513	0	0	2.27E-13														
Frame 5.26	W14X90	355.276	Design Loads	590.951	3.513	0	0	2.27E-13	355.276	0.8	23.68507	590.951	774.6098	0.762902	H1-a	0	1.9E-14	1.03	1.74	3.26	0.60867953	<1.0 OK
Frame 5.26		0	Design Loads	584.623	-3.513	0	0	0														
Frame 5.27	W14X90	0	Design Loads	167.463	-3.513	0	0	0	355.276	0.8	23.68507	173.791	774.6098	0.224359	H1-a	0	1.9E-14	1.03	1.74	3.26	0.17900473	<1.0 OK
Frame 5.27		355.276	Design Loads	173.791	3.513	0	0	2.27E-13														
Frame 5.28	W14X90	0	Design Loads	-67.933	-3.513	0	0	0	355.276	0.8	23.68507	-67.933	774.6098	0.0877	H1-b	0	1.9E-14	1.291	1.74	3.26	0.043849818	<1.0 OK
Frame 5.28		355.276	Design Loads	-61.605	3.513	0	0	2.27E-13														

P_c Calculation

Frame 2.1	W14X99		P	806.7899	Frame 5.1	W14X109		P	891.7993	Frame 5.27	W14X90		P	774.6098
A	29.1				A	32				A	26.5			
K	0.8				K	0.8				K	0.8			
L	377.44				L	377.44				L	355.276			
ry	3.71				ry	3.73				ry	3.7			
E	29000	ksi			E	29000	ksi			E	29000	ksi		
Fy	50	ksi			Fy	50	ksi			Fy	50	ksi		
Kl/r	81.38868	≤	4.71sqrt(E/Fy)	113.4318	Kl/r	80.95228	≤	4.71sqrt(E/Fy)	113.4318	Kl/r	76.81643	≤	4.71sqrt(E/Fy)	113.4318
Fe = pi2E/(kl/r)^2	43.20855	ksi			Fe = pi2E/(kl/r)^2	43.67567	ksi			Fe = pi2E/(kl/r)^2	48.50533	ksi		
Fcr	30.80527	YES	P	806.7899	Fcr	30.96525	YES	P	891.7993	Fcr	32.4784	YES	P	774.6098
Fcr	37.8939	NO	P	992.4413	Fcr	38.30356	NO	P	1103.143	Fcr	42.53918	NO	P	1014.559
Frame 2.9	W14X193		P	1834.002	Frame 5.13	W14X90		P	875.411	Frame 5.28	W14X90		P	774.6098
A	56.8				A	26.5				A	26.5			
K	0.8				K	0.8				K	0.8			
L	341.104				L	300.719				L	355.276			
ry	4.05				ry	3.7				ry	3.7			
E	29000	ksi			E	29000	ksi			E	29000	ksi		
Fy	50	ksi			Fy	50	ksi			Fy	50	ksi		
Kl/r	67.37857	≤	4.71sqrt(E/Fy)	113.4318	Kl/r	65.02032	≤	4.71sqrt(E/Fy)	113.4318	Kl/r	76.81643	≤	4.71sqrt(E/Fy)	113.4318
Fe = pi2E/(kl/r)^2	63.04551	ksi			Fe = pi2E/(kl/r)^2	67.70169	ksi			Fe = pi2E/(kl/r)^2	48.50533	ksi		
Fcr	35.87641	YES	P	1834.002	Fcr	36.70487	YES	P	875.411	Fcr	32.4784	YES	P	774.6098
Fcr	55.29092	NO	P	2826.472	Fcr	59.37438	NO	P	1416.079	Fcr	42.53918	NO	P	1014.559
Frame 2.14	W14X193		P	1842.423	Frame 5.16	W14X90		P	805.5964					
A	56.8				A	26.5								
K	0.8				K	0.8								
L	338.742				L	338.742								
ry	4.05				ry	3.7								
E	29000	ksi			E	29000	ksi							
Fy	50	ksi			Fy	50	ksi							
Kl/r	66.912	≤	4.71sqrt(E/Fy)	113.4318	Kl/r	73.24151	≤	4.71sqrt(E/Fy)	113.4318					
Fe = pi2E/(kl/r)^2	63.92779	ksi			Fe = pi2E/(kl/r)^2	53.35598	ksi							
Fcr	36.04115	YES	P	1842.423	Fcr	33.77763	YES	P	805.5964					
Fcr	56.06468	NO	P	2866.026	Fcr	46.7932	NO	P	1116.018					
Frame 2.23	W14X145		P	1323.433	Frame 5.18	W14X90		P	805.5964					
A	42.7				A	26.5								
K	0.8				K	0.8								
L	355.276				L	338.742								
ry	3.98				ry	3.7								
E	29000	ksi			E	29000	ksi							
Fy	50	ksi			Fy	50	ksi							
Kl/r	71.41226	≤	4.71sqrt(E/Fy)	113.4318	Kl/r	73.24151	≤	4.71sqrt(E/Fy)	113.4318					
Fe = pi2E/(kl/r)^2	56.12446	ksi			Fe = pi2E/(kl/r)^2	53.35598	ksi							
Fcr	34.4375	YES	P	1323.433	Fcr	33.77763	YES	P	805.5964					
Fcr	49.22115	NO	P	1891.569	Fcr	46.7932	NO	P	1116.018					
Frame 2.25	W14X145		P	1323.433	Frame 5.25	W14X90		P	774.6098					
A	42.7				A	26.5								
K	0.8				K	0.8								
L	355.276				L	355.276								
ry	3.98				ry	3.7								
E	29000	ksi			E	29000	ksi							
Fy	50	ksi			Fy	50	ksi							
Kl/r	71.41226	≤	4.71sqrt(E/Fy)	113.4318	Kl/r	76.81643	≤	4.71sqrt(E/Fy)	113.4318					
Fe = pi2E/(kl/r)^2	56.12446	ksi			Fe = pi2E/(kl/r)^2	48.50533	ksi							
Fcr	34.4375	YES	P	1323.433	Fcr	32.4784	YES	P	774.6098					
Fcr	49.22115	NO	P	1891.569	Fcr	42.53918	NO	P	1014.559					
Frame 2.26	W14X145		P	1323.433	Frame 5.26	W14X90		P	774.6098					
A	42.7				A	26.5								
K	0.8				K	0.8								
L	355.276				L	355.276								
ry	3.98				ry	3.7								
E	29000	ksi			E	29000	ksi							
Fy	50	ksi			Fy	50	ksi							
Kl/r	71.41226	≤	4.71sqrt(E/Fy)	113.4318	Kl/r	76.81643	≤	4.71sqrt(E/Fy)	113.4318					
Fe = pi2E/(kl/r)^2	56.12446	ksi			Fe = pi2E/(kl/r)^2	48.50533	ksi							
Fcr	34.4375	YES	P	1323.433	Fcr	32.4784	YES	P	774.6098					
Fcr	49.22115	NO	P	1891.569	Fcr	42.53918	NO	P	1014.559					

Redesign Strength Calculations

TABLE: Element Forces - REDESIGN

Frame	Section	Station	OutputCase	P	V2	V3	M2	M3	L	K	KL	P_r	P_c	P_r/P_c		M,2	M,3	px10^3	b_xx10^3	b_yx10^3	Interaction Eqn.	
Text		in	Text	Kip	Kip	Kip	Kip-in	Kip-in	in							Kip-ft	Kip-ft					
Frame 2.1	W14X90	377.44	Design Loads	-107.691	3.206	0.006006	-0.306	-168.981	377.44	0.8	25.16267	-114.871	732.782	0.15676	H1-1b	0.163417	-23.7634	1.3647	1.79	3.26	0.126832972	<1.0 OK
		0	Design Loads	-114.871	-3.821	0.006006	1.961	-285.161														
Frame 2.8	W14X257	341.104	Design Loads	-1882.07	8.275	4.529	-999.241	-832.527	341.104	0.8	22.74027	-1898.65	2472.317	0.767965	H1-1a	-83.2701	-122.266	0.4045	0.508	0.964	0.910347941	<1.0 OK
Frame 2.8		0	Design Loads	-1898.65	-11.997	4.529	545.488	-1467.19														
Frame 2.14	W14X193	338.742	Design Loads	-1099.33	15.892	-3.255	685.908	-1788.41	338.742	0.8	22.5828	-1111.53	1842.423	0.603298	H1-1a	57.159	-149.034	0.5428	0.709	1.32	0.784413176	<1.0 OK
Frame 2.14		0	Design Loads	-1111.53	0.71	-3.255	-416.785	1023.536														
Frame 2.23	W14X90	355.276	Design Loads	-374.391	-3.245	-0.571	-127.359	77.961	355.276	0.8	23.68507	-374.391	774.6098	0.483328	H1-1a	-10.6133	6.49675	1.291	1.74	3.26	0.529232036	<1.0 OK
Frame 2.23		0	Design Loads	-368.063	3.782	-0.571	75.379	-17.352														
Frame 2.27	W14X159	355.276	Design Loads	-1319.88	6.719	1.189	-136.346	-481.328	355.276	0.8	23.68507	-1331.15	1452.802	0.916266	H1-1a	23.83575	-40.1107	0.6883	0.889	1.62	0.990538459	<1.0 OK
Frame 2.27		0	Design Loads	-1331.15	-5.796	1.189	286.029	-317.328														
Frame 2.28	W14X145	0	Design Loads	-718.966	-5.098	2.547	515.291	-369.61	355.276	0.8	23.68507	-718.966	1323.433	0.543258	H1-1a	42.94092	-48.5573	0.7556	0.989	1.78	0.667716247	<1.0 OK
Frame 2.28		355.276	Design Loads	-708.703	6.298	2.547	-389.671	-582.687														
Frame 2.33	W14X550	0	Design Loads	-3711.06	-14.115	-8.21	-1914.26	-1125.62	269.75	0.8	17.98333	-3711.06	6157.084	0.60273	H1-1a	-159.521	223.4977	0.1624	0.202	0.407	0.712801835	<1.0 OK
Frame 2.33		269.75	Design Loads	-3666.73	-14.115	-8.21	300.308	2681.972														
Frame 2.34	W14X550	312	Design Loads	-3625.3	43.756	-8.778	3038.713	-9020.92	312	0.8	20.8	-3676.57	5815.643	0.632186	H1-1a	253.2261	-751.744	0.172	0.204	0.407	0.888604502	<1.0 OK
Frame 2.34		0	Design Loads	-3676.57	43.756	-8.778	300.026	4631.015														
Frame 5.1	W14X90	0	Design Loads	-81.372	-3.704	-0.047	-4.737	-264.548	377.44	0.8	25.16267	-81.372	732.782	0.111045	H1-1b	1.0945	-22.0457	1.3647	1.6	2.85	0.09871491	<1.0 OK
Frame 5.1		377.44	Design Loads	-74.193	3.323	-0.047	13.134	-192.57														
Frame 5.8	W14X109	0	Design Loads	-570.872	-5.871	0.065	22.318	-547.883	341.104	0.8	22.74027	-570.872	973.6549	0.586319	H1-1a	1.859833	-45.6569	1.0271	1.39	2.56	0.6545293	<1.0 OK
Frame 5.8		341.104	Design Loads	-563.892	2.659	0.065	0	3.41E-13														
Frame 5.13	W14X145	0	Design Loads	-1221.27	-10.147	-0.881	-264.918	-1337.98	300.719	0.8	20.04793	-1221.27	1471.02	0.830222	H1-1a	-22.0765	-111.498	0.6798	0.956	1.78	0.976110568	<1.0 OK
Frame 5.13		300.719	Design Loads	-1215.06	1.249	-0.881	5.68E-14	2.05E-12														
Frame 5.16	W14X120	0	Design Loads	-159.559	-4.718	0	0	0	338.742	0.8	22.5828	-159.559	1082.108	0.147452	H1-1b	0	-5.7E-14	0.9241	0.971	2.32	0.073726023	<1.0 OK
Frame 5.16		338.742	Design Loads	-151.973	4.718	0	0	-6.8E-13														
Frame 5.18	W14X145	338.742	Design Loads	-625.828	5.698	0	0	4.55E-13	338.742	0.8	22.5828	-634.99	1369.065	0.463813	H1-1a	0	3.79E-14	0.7304	0.989	1.78	0.463812982	<1.0 OK
Frame 5.18		0	Design Loads	-634.99	-5.698	0	0	0														
Frame 5.25	W14X120	0	Design Loads	-403.419	-4.718	0	0	-2.3E-13	355.276	0.8	23.68507	-403.419	1041.354	0.387398	H1-1a	0	-1.9E-14	0.9603	1.25	2.32	0.387398488	<1.0 OK
Frame 5.25		355.276	Design Loads	-394.921	4.718	0	0	-2.3E-13														
Frame 5.26	W14X90	0	Design Loads	542.576	-3.513	0	0	0	355.276	0.8	23.68507	548.904	774.6098	0.70862	H1-1a	0	1.9E-14	1.03	0.709	3.26	0.56537112	<1.0 OK
Frame 5.26		355.276	Design Loads	548.904	3.513	0	0	2.27E-13														
Frame 5.27	W14X90	0	Design Loads	141.835	-3.513	0	0	0	355.276	0.8	23.68507	148.164	774.6098	0.191276	H1-1b	0	1.9E-14	1.03	1.74	3.26	0.07630446	<1.0 OK
Frame 5.27		355.276	Design Loads	148.164	3.513	0	0	2.27E-13														
Frame 5.28	W14X120	355.276	Design Loads	-144.27	4.718	0	0	-2.3E-13	355.276	0.8	23.68507	-152.768	1041.354	0.146701	H1-1b	0	-1.9E-14	0.9603	1.25	2.32	0.073350651	<1.0 OK
Frame 5.28		0	Design Loads	-152.768	-4.718	0	0	0														
Frame 5.35	W14X550	269.75	Design Loads	-2914.69	-7.761	8.504	-273.57	1451.941	269.75	0.8	17.98333	-2959.02	6157.084	0.480588	H1-1a	168.3751	120.9951	0.1624	0.791	1.32	0.798550083	<1.0 OK
Frame 5.35		0	Design Loads	-2959.02	-7.761	8.504	2020.501	-641.604														
Frame 5.36	W14X550	312	Design Loads	-2868.84	27.531	9.059	-3099.66	-5910.57	312	0.8	20.8	-2920.11	5815.643	0.502113	H1-1a	-258.305	-492.548	0.172	0.202	0.407	0.70673795	<1.0 OK
Frame 5.36		0	Design Loads	-2920.11	27.531	9.059	-273.296	2679.043														

P_c Calculation

Frame 2.1	W14X90		P	732.782	Frame 5.1	W14X90		P	732.782	Frame 5.28	W14X120		P	1041.354
A	26.5				A	26.5				A	35.3			
K	0.8				K	0.8				K	0.8			
L	377.44				L	377.44				L	355.276			
ry	3.7				ry	3.7				ry	3.74			
E	29000	ksi			E	29000	ksi			E	29000	ksi		
Fy	50	ksi			Fy	50	ksi			Fy	50	ksi		
Kl/r	81.60865	≤	4.71sqrt(E	113.4318	Kl/r	81.60865	≤	4.71sqrt(E	113.4318	Kl/r	75.99487	≤	4.71sqrt(E	113.4318
Fe = pi2E/(kl/	42.97594	ksi			Fe = pi2E/(kl/	42.97594	ksi			Fe = pi2E/(kl	49.55976	ksi		
Fcr	30.72461	YES	P	732.782	Fcr	30.72461	YES	P	732.782	Fcr	32.77791	YES	P	1041.354
Fcr	37.6899	NO	P	898.9041	Fcr	37.6899	NO	P	898.9041	Fcr	43.46391	NO	P	1380.849
Frame 2.8	W14X257		P	2472.317	Frame 5.8	W14X109		P	973.6549	Frame 5.35	W14X550		P	6157.084
A	75.6				A	32				A	162			
K	0.8				K	0.8				K	0.8			
L	341.104				L	341.104				L	269.75			
ry	4.13				ry	3.73				ry	4.49			
E	29000	ksi			E	29000	ksi			E	29000	ksi		
Fy	50	ksi			Fy	50	ksi			Fy	50	ksi		
Kl/r	66.07341	≤	4.71sqrt(E	113.4318	Kl/r	73.15903	≤	4.71sqrt(E	113.4318	Kl/r	48.06236	≤	4.71sqrt(E	113.4318
Fe = pi2E/(kl/	65.5608	ksi			Fe = pi2E/(kl/	53.47636	ksi			Fe = pi2E/(kl	123.9046	ksi		
Fcr	36.33623	YES	P	2472.317	Fcr	33.80746	YES	P	973.6549	Fcr	42.22966	YES	P	6157.084
Fcr	57.49682	NO	P	3912.084	Fcr	46.89876	NO	P	1350.684	Fcr	108.6644	NO	P	15843.26
Frame 2.14	W14X193		P	1842.423	Frame 5.13	W14X145		P	1471.02	Frame 5.36	W14X550		P	5815.643
A	56.8				A	42.7				A	162			
K	0.8				K	0.8				K	0.8			
L	338.742				L	300.719				L	312			
ry	4.05				ry	3.98				ry	4.49			
E	29000	ksi			E	29000	ksi			E	29000	ksi		
Fy	50	ksi			Fy	50	ksi			Fy	50	ksi		
Kl/r	66.912	≤	4.71sqrt(E	113.4318	Kl/r	60.44603	≤	4.71sqrt(E	113.4318	Kl/r	55.5902	≤	4.71sqrt(E	113.4318
Fe = pi2E/(kl/	63.92779	ksi			Fe = pi2E/(kl/	78.33614	ksi			Fe = pi2E/(kl	92.61925	ksi		
Fcr	36.04115	YES	P	1842.423	Fcr	38.2779	YES	P	1471.02	Fcr	39.88781	YES	P	5815.643
Fcr	56.06468	NO	P	2866.026	Fcr	68.7008	NO	P	2640.172	Fcr	81.22708	NO	P	11842.91

Frame 2.23	W14X90		P	774.6098	Frame 5.16	W14X120		P	1082.108
A	26.5				A	35.3			
K	0.8				K	0.8			
L	355.276				L	338.742			
ry	3.7				ry	3.74			
E	29000	ksi			E	29000	ksi		
Fy	50	ksi			Fy	50	ksi		
Kl/r	76.81643	≤	4.71sqrt(E	113.4318	Kl/r	72.45818	≤	4.71sqrt(E	113.4318
Fe = pi2E/(kl/	48.50533	ksi			Fe = pi2E/(kl/	54.51586	ksi		
Fcr	32.4784	YES	P	774.6098	Fcr	34.06068	YES	P	1082.108
Fcr	42.53918	NO	P	1014.559	Fcr	47.81041	NO	P	1518.937
Frame 2.27	W14X159		P	1452.802	Frame 5.18	W14X145		P	1369.065
A	46.7				A	42.7			
K	0.8				K	0.8			
L	355.276				L	338.742			
ry	4				ry	3.98			
E	29000	ksi			E	29000	ksi		
Fy	50	ksi			Fy	50	ksi		
Kl/r	71.0552	≤	4.71sqrt(E	113.4318	Kl/r	68.08884	≤	4.71sqrt(E	113.4318
Fe = pi2E/(kl/	56.68994	ksi			Fe = pi2E/(kl/	61.73704	ksi		
Fcr	34.56583	YES	P	1452.802	Fcr	35.6249	YES	P	1369.065
Fcr	49.71708	NO	P	2089.609	Fcr	54.14339	NO	P	2080.73
Frame 2.28	W14X145		P	1323.433	Frame 5.25	W14X120		P	1041.354
A	42.7				A	35.3			
K	0.8				K	0.8			
L	355.276				L	355.276			
ry	3.98				ry	3.74			
E	29000	ksi			E	29000	ksi		
Fy	50	ksi			Fy	50	ksi		
Kl/r	71.41226	≤	4.71sqrt(E	113.4318	Kl/r	75.99487	≤	4.71sqrt(E	113.4318
Fe = pi2E/(kl/	56.12446	ksi			Fe = pi2E/(kl/	49.55976	ksi		
Fcr	34.4375	YES	P	1323.433	Fcr	32.77791	YES	P	1041.354
Fcr	49.22115	NO	P	1891.569	Fcr	43.46391	NO	P	1380.849
Frame 2.33	W14X550		P	6157.084	Frame 5.26	W14X90		P	774.6098
A	162				A	26.5			
K	0.8				K	0.8			
L	269.75				L	355.276			
ry	4.49				ry	3.7			
E	29000	ksi			E	29000	ksi		
Fy	50	ksi			Fy	50	ksi		
Kl/r	48.06236	≤	4.71sqrt(E	113.4318	Kl/r	76.81643	≤	4.71sqrt(E	113.4318
Fe = pi2E/(kl/	123.9046	ksi			Fe = pi2E/(kl/	48.50533	ksi		
Fcr	42.22966	YES	P	6157.084	Fcr	32.4784	YES	P	774.6098
Fcr	108.6644	NO	P	15843.26	Fcr	42.53918	NO	P	1014.559
Frame 2.34	W14X550		P	5815.643	Frame 5.27	W14X90		P	774.6098
A	162				A	26.5			
K	0.8				K	0.8			
L	312				L	355.276			
ry	4.49				ry	3.7			
E	29000	ksi			E	29000	ksi		
Fy	50	ksi			Fy	50	ksi		
Kl/r	55.5902	≤	4.71sqrt(E	113.4318	Kl/r	76.81643	≤	4.71sqrt(E	113.4318
Fe = pi2E/(kl/	92.61925	ksi			Fe = pi2E/(kl/	48.50533	ksi		
Fcr	39.88781	YES	P	5815.643	Fcr	32.4784	YES	P	774.6098
Fcr	81.22708	NO	P	11842.91	Fcr	42.53918	NO	P	1014.559

Appendix B: Enclosure Analysis

FACADE GLAZING DESIGN 1

4' x 11' → 1220 mm x 3350 mm

LAMINATED ANEALED GLASS LITE

$A = 4.087 m^2$

$AR = \frac{3350}{1220} = 2.75$

Components and Cladding wind press as per ASCE 7-05 : 31.87 psf

→ Try 8mm (5/16 in)

NFL = 1.50 LS = 0 ← E 1300-04 pg 35

LOADING		GTF	TL
SHORT DURATION	-	1.0	1.50(1.0) = 1.50 kPa → 31.33 psf < 31.87 psf ∴ NG X
LONG DURATION	-	0.5	1.50(0.5) = .75 kPa → 15.66 psf

→ Try 10 mm (3/8 in)

NFL = 2.0 LS = 0

LOADING		GTF	TL
SD	-	1.0	2.0(1.0) = 2.0 kPa → 41.77 psf > 31.87 psf ∴ ok ✓
LD	-	0.5	2.0(0.5) = 1.0 kPa → 20.89 psf

FACADE | MULLION DESIGN | 1

TRANSOMS – Mid DESIGN WIND PRESSURE = 32 psf

$w = 32(4) = 128$ plf

$M = \frac{w\ell^2}{8} = \frac{.128\,k/ft(11')^2}{8} = 1.936$ 'k

$V = \frac{w\ell}{2} = \frac{.128(11)}{2} = 0.704\,k = 3.132$ kN

$\Delta = \frac{5w\ell^4}{384EI} = \frac{5(.128)(11)^4(1728)}{384EI} = \frac{42166}{EI}$

T5 ALUMINUM 1 psi = 6.895×10^{-3} N/mm²

allowable stresses

$\sigma_{axial} = 62\ N/mm^2 = 8.99$ ksi

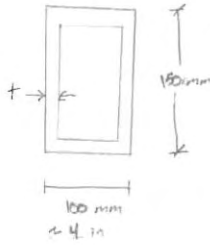
$\sigma_{bending} = 69\ N/mm^2 = 10$ ksi

$\sigma_{shear} = 37\ N/mm^2 = 5.37$ ksi

$\sigma_{bearing} = 117\ N/mm^2 = 16.97$ ksi

$\Delta_{allow} = \frac{span}{180} \le 20$ mm

$= \frac{11(12)}{180} = 0.73$ in $= 18.63$ mm



← Assumed dimensions

BENDING

$\sigma_{bend} = \frac{Mc}{I} = \frac{M}{S} \rightarrow S_{req} = \frac{M}{\sigma_{bend}} = \frac{1.936(12)}{10} = 2.32\ in^3 = 38070\ mm^3$

$38070 \le \frac{\frac{1}{12}(100)(150)^3 - \frac{1}{12}(100-2t)(150-2t)^3}{50}$

$1963500 \le (100-2t)(150-2t)^3 \le 314658000$

try $t = 5$ mm

$246{,}960{,}000 \le 314658000$ ∴ ok ✓

$t_{req} = 5$mm - for bending

FACADE | MULLION DESIGN | 2

SHEAR

$\tau = \frac{3}{2}\frac{V}{A} \rightarrow 37 = \frac{3}{2}\frac{3132}{A_{req}} \rightarrow A_{req} = 127\ mm^2$

$127 \leq (100)(150) - (100-2t)(150-2t)$

$(100-2t)(150-2t) \leq 14873$

try $t = 4\ mm$

$13916 \leq 14873$ ∴ ok & BENDING STILL CONTROLS

DEFLECTION

$\Delta_{ALLOW} = 18.63\ mm$ CHECK @ $t = 5mm$

$$\Delta = \frac{42166(kin^3)(254\ mm/in)^3\left(\frac{1000\ lb/k}{0.22481\ lb/N}\right)}{70000\ N/mm^2\left(\frac{1}{12}(100)(150)^3 - \frac{1}{12}(100-2t)(150-2t)^3\right)}$$

7545000

$= 5.82\ mm < 18.63\ mm$

∴ ok ✓

BEARING

2 - bolts

Shear Force per bolt $\frac{3132}{2} = 1566\ N$

EACH BOLT WILL HAVE 2 BEARING SURFACES

$\sigma_{bearing} = 117\ N/mm^2$

$117 = \frac{1566}{2(5)D} \rightarrow D = 1.34\ mm$ (very low)

→ Use a standard, 12 mm (½) diam. steel bolt

FACADE | MULLION DESIGN | 3

MULLION

$M = \frac{PL}{4} = \frac{3.132(8)(12)(25.4)}{4} = 1909\ kN\,mm$

$V = \frac{P}{2} = \frac{3.132}{2} = 1.57\ kN$

$\Delta = \frac{PL^3}{48EI} = \frac{3.132(8(12)(25.4))^3}{48EI} = \frac{94600911\ kN\,mm^3}{EI}$

$\Delta_{ALLOW} = \frac{8(12)}{180} = 0.53\ in = 13.46\ mm$

BENDING

$S_{req} = \frac{1909(1000)}{69} = 27667\ mm^3 < S_{req\ TRANSOM}$ ∴ OK ✓ DESIGN

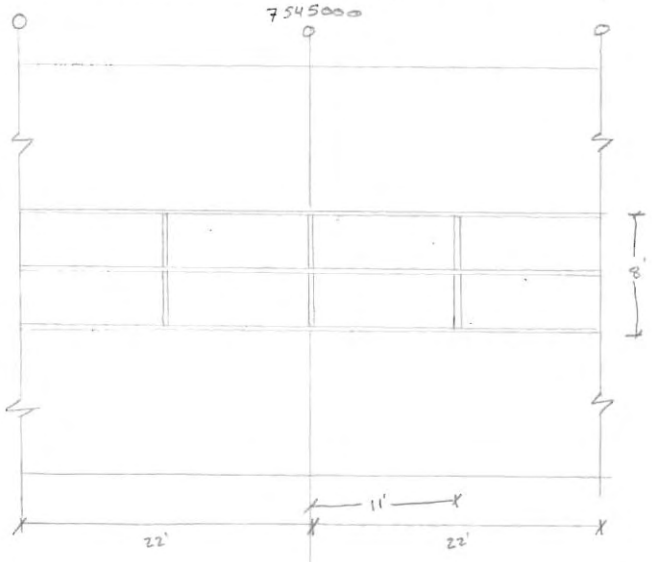
SHEAR

$\tau = \frac{3}{2}\left(\frac{1.57(1000)}{A_{req}}\right) = 37 \rightarrow A_{req} = 63.6\ mm^2 < A_{req\ Transom}$ ∴ OK ✓

DEFLECTION

$\Delta = \frac{94600911\ kN\,mm^3(1000)}{70000\ N/mm^2\left(\frac{1}{12}(100)(150)^3 - \frac{1}{12}(100-24)(150-24)^3\right)} = 1.79 \leq 13.46\ mm$ ∴ OK ✓

7545000



Panel							
fc		5000					
E		4030509					
fr		353.55	FoS =1.5 p363 pci				
Wind				**SW**			
b		12.00		b		12.00	
t		6.00		t		6.00	
wu		32.00	lb/ft	wu		75.00	lb/ft
Mu	wuL2/8	0.77	ftk/ft	Mu	wuL2/8	1.59	ftk/ft
pMn	frI0.9/c	1.91		pMn	frI0.9/c	1.91	

Long Rib Wind							
b		6.00		**A**	1968		
t		18.00		**I**	216		
wu		352.00	lb/ft	**I hung**	665.5		
Mu	wuL2/8	8.52	ftk	**Wp**	13		
pMn	frI0.9/c	8.59	ftk	**V**	150.33ft^3	5.57yd^3	

Long Rib sw	3 (end)			**Long Rib sw**	3 (middle)		
b		8.00		b		16.00	
t		18.00		t		18.00	
wu		512.50	lb/ft	wu		1025.00	lb/ft
Mu	wuL2/8	10.85	ftk	Mu	wuL2/8	21.70	ftk
pMn	frI0.9/c	11.46	ftk	pMn	frI0.9/c	22.91	ftk

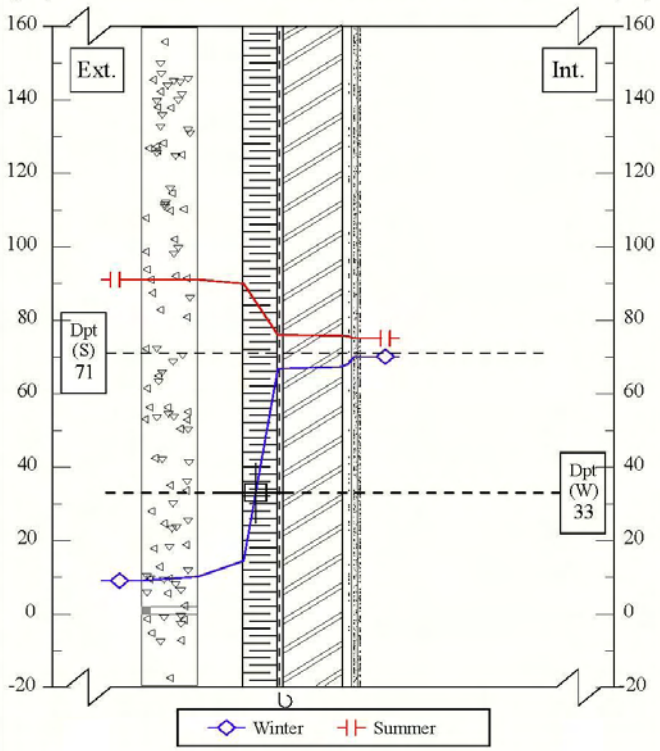
Deflection 3				
delta sw trans	5wl4/384EI	0.012501	L/360	0.366667
delta wind	5wl4/384EI	0.193736	L/360	0.733333
delta sw hung	5wl4/384EI	0.000938	L/360	0.733333

Enclosure R-Value Analysis 4 in cavity

R VALUE ANALYSIS

The Heat, Air and Moisture Building Science Toolbox - V.1B-E/U (12)

WALL SECTION AND TEMPERATURE GRADIENTS



PROJECT

Name	BS Thesis
Number	1
City	Harrisburg, PA
Date	3/31/2011
Analysis by:	Paul Kuehnel
Wall Type	
Option	

CLIMATIC CONDITIONS

	Winter		Summer	
	Int.	Ext.	Int.	Ext.
Temp (°F)	70	9	75	91
RH (%)	25	79	50	50
DPT (°F)	33	4	56	71

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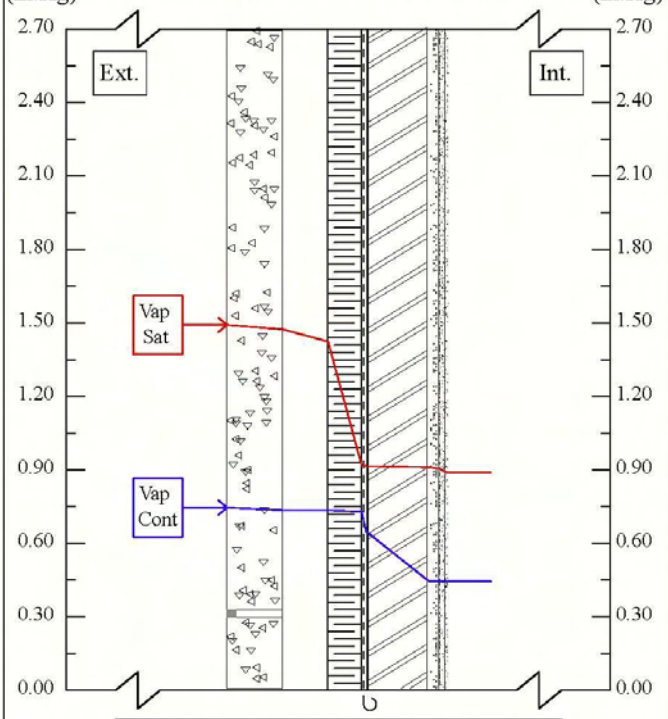
	Generic Material	Manufacturer	Model No.	Thick (in.)	RVal (R)	W.Temp. (°F)	S.Temp. (°F)
1	precast, face seal, 5 in.	No Recor...	Generic...	5.00	0.34	10.1	91.0
2	cavity, 4 in.	No Recor...	Generic...	4.00	0.98	14.4	89.9
3	rigid ins.,(expand.), 3 in.	No Recor...	Generic...	3.00	11.86	66.2	76.0
4	poly film, (4mil)	No Recor...	Generic...	0.00	0.12	66.7	75.9
5	steel stud, 5-1/2 in.	No Recor...	Generic...	5.51	0.12	67.2	75.7
6	air film (ext), 3/4 in.	No Recor...	Generic...	0.75	0.17	68.0	75.5
7	gypsum bd., 1/2 in., (#1)	No Recor...	Generic...	0.50	0.46	70.0	75.0
	Total or (Layer 0)			18.02	14.04	(8.6)	(91.4)

Enclosure Condensation Analysis – 4 in cavity summer

CONDENSATION ANALYSIS

The Heat, Air and Moisture Building Science Toolbox - V.1B-E/U (12)

WALL SECTION AND
VAPOUR PRESSURE GRADIENTS



** NO CONDENSATION **

PROJECT

Name	BS Thesis
Number	1
City	Harrisburg, PA
Date	3/31/2011
Analysis by:	Paul Kuehnel
Wall Type	Option

CLIMATIC CONDITIONS

	Winter		Summer	
	Int.	Ext.	Int.	Ext.
Temp (°F)	—	—	75	91
RH (%)	—	—	50	50
DPT (°F)	—	—	56	71

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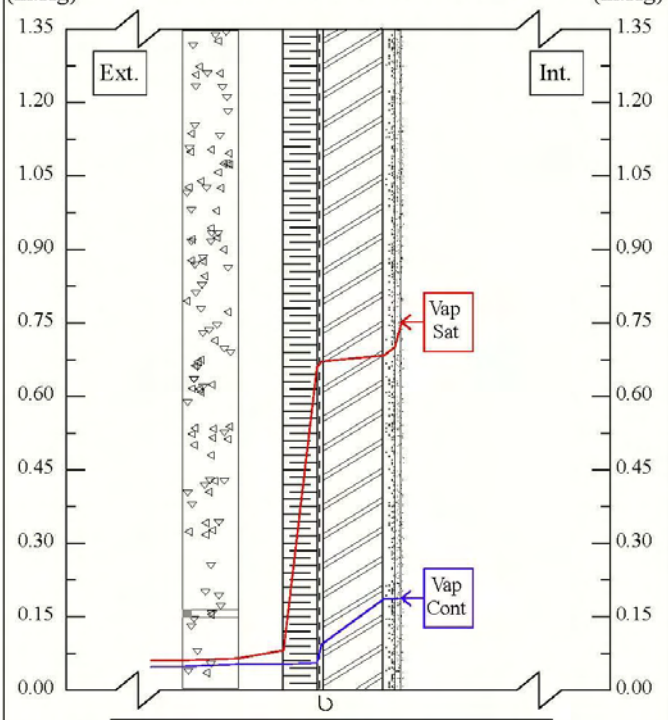
	Material	Manufacturer	Model No.	Rvap (1/M)	Temp (°F)	VapSat (in.Hg)	VapCont (in.Hg)
1	precast, face seal, 5 in.	No Recor...	Generic...	1.506	90.6	1.451	0.724
2	cavity, 4 in.	No Recor...	Generic...	0.033	89.5	1.401	0.724
3	rigid ins.,(expand.), 3 in.	No Recor...	Generic...	0.773	76.0	0.905	0.718
4	poly film, (4mil)	No Recor...	Generic...	11.443	75.9	0.901	0.639
5	steel stud, 5-1/2 in.	No Recor...	Generic...	28.607	75.7	0.897	0.439
6	air film (ext), 3/4 in.	No Recor...	Generic...	0.001	75.5	0.891	0.439
7	gypsum bd., 1/2 in., (#1)	No Recor...	Generic...	0.197	75.0	0.876	0.438
8							
9							
10							
11							
12							
	TOTAL or (Layer 0)			42.735	(91.0)	(1.469)	(0.734)

Enclosure Condensation Analysis – 4 in cavity winter

CONDENSATION ANALYSIS

The Heat, Air and Moisture Building Science Toolbox - V.1B-E/U (12)

WALL SECTION AND
VAPOUR PRESSURE GRADIENTS



** NO CONDENSATION **

PROJECT

Name	BS Thesis
Number	1
City	Harrisburg, PA
Date	3/31/2011
Analysis by:	Paul Kuehnel
Wall Type	
Option	

CLIMATIC CONDITIONS

	Winter		Summer	
	Int.	Ext.	Int.	Ext.
Temp (°F)	70	9	—	—
RH (%)	25	79	—	—
DPT (°F)	33	4	—	—

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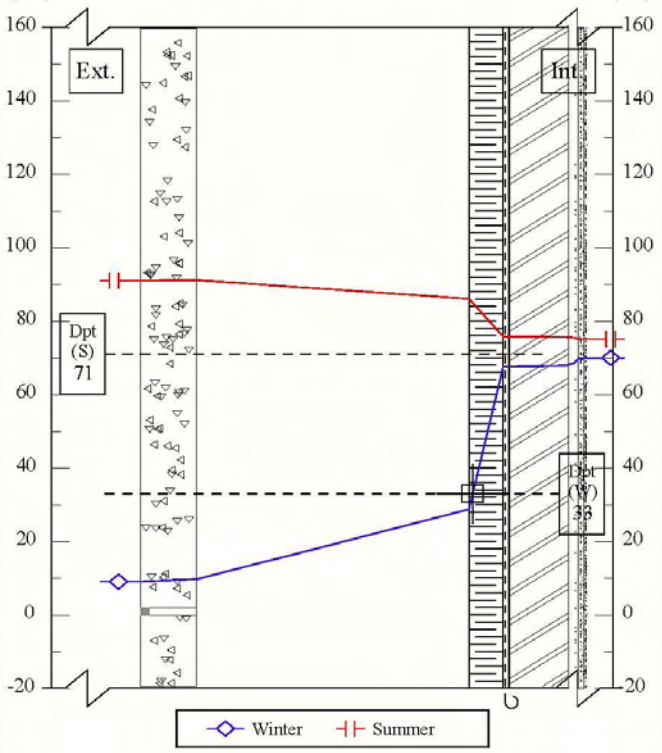
	Material	Manufacturer	Model No.	Rvap (1/M)	Temp (°F)	VapSat (in.Hg)	VapCont (in.Hg)
1	precast, face seal, 5 in.	No Recor...	Generic...	1.506	10.5	0.064	0.052
2	cavity, 4 in.	No Recor...	Generic...	0.033	14.7	0.080	0.052
3	rigid ins.,(expand.), 3 in.	No Recor...	Generic...	0.773	66.2	0.650	0.055
4	poly film, (4mil)	No Recor...	Generic...	11.443	66.7	0.661	0.092
5	steel stud, 5-1/2 in.	No Recor...	Generic...	28.607	67.2	0.673	0.184
6	air film (ext), 3/4 in.	No Recor...	Generic...	0.001	68.0	0.690	0.184
7	gypsum bd., 1/2 in., (#1)	No Recor...	Generic...	0.197	70.0	0.740	0.185
8							
9							
10							
11							
12							
	TOTAL or (Layer 0)			42.735	(9.0)	(0.060)	(0.047)

Enclosure R-Value Analysis – 24 in cavity

R VALUE ANALYSIS

The Heat, Air and Moisture Building Science Toolbox - V.1B-E/U (12)

WALL SECTION AND TEMPERATURE GRADIENTS



PROJECT

Name	BS Thesis
Number	1
City	Harrisburg, PA
Date	3/31/2011
Analysis by:	Paul Kuehnel
Wall Type	
Option	

CLIMATIC CONDITIONS

	Winter		Summer	
	Int.	Ext.	Int.	Ext.
Temp (°F)	70	9	75	91
RH (%)	25	79	50	50
DPT (°F)	33	4	56	71

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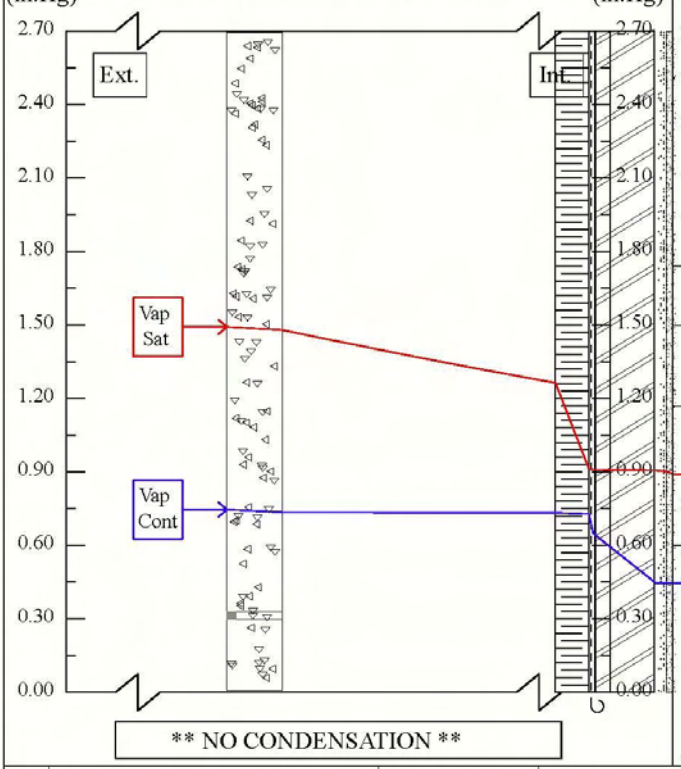
	Generic Material	Manufacturer	Model No.	Thick (in.)	RVal (R)	W.Temp. (°F)	S.Temp. (°F)
1	precast, face seal, 5 in.	No Recor...	Generic...	5.00	0.34	9.7	91.1
2	cavity, 4 in.	No Recor...	Generic...	4.00	0.98	12.9	90.3
3	cavity, 4 in.	No Recor...	Generic...	4.00	0.98	16.0	89.4
4	cavity, 4 in.	No Recor...	Generic...	4.00	0.98	19.2	88.6
5	cavity, 4 in.	No Recor...	Generic...	4.00	0.98	22.4	87.7
6	cavity, 4 in.	No Recor...	Generic...	4.00	0.98	25.6	86.9
7	cavity, 4 in.	No Recor...	Generic...	4.00	0.98	28.8	86.0
8	rigid ins.,(expand.), 3 in.	No Recor...	Generic...	3.00	11.86	67.2	75.8
9	poly film, (4mil)	No Recor...	Generic...	0.00	0.12	67.6	75.7
10	steel stud, 5-1/2 in.	No Recor...	Generic...	5.51	0.12	67.9	75.6
11	air film (ext), 3/4 in.	No Recor...	Generic...	0.75	0.17	68.5	75.4
12	gypsum bd., 1/2 in., (#1)	No Recor...	Generic...	0.50	0.46	70.0	75.0
				38.02	18.95	(8.6)	(91.4)

Enclosure Condensation Analysis – 24 in cavity summer

CONDENSATION ANALYSIS

The Heat, Air and Moisture Building Science Toolbox - V.1B-E/U (12)

WALL SECTION AND
VAPOUR PRESSURE GRADIENTS



** NO CONDENSATION **

PROJECT

Name	BS Thesis
Number	1
City	Harrisburg, PA
Date	3/31/2011
Analysis by:	Paul Kuehnel
Wall Type	Option

CLIMATIC CONDITIONS

	Winter		Summer	
	Int.	Ext.	Int.	Ext.
Temp (°F)	—	—	75	91
RH (%)	—	—	50	50
DPT (°F)	—	—	56	71

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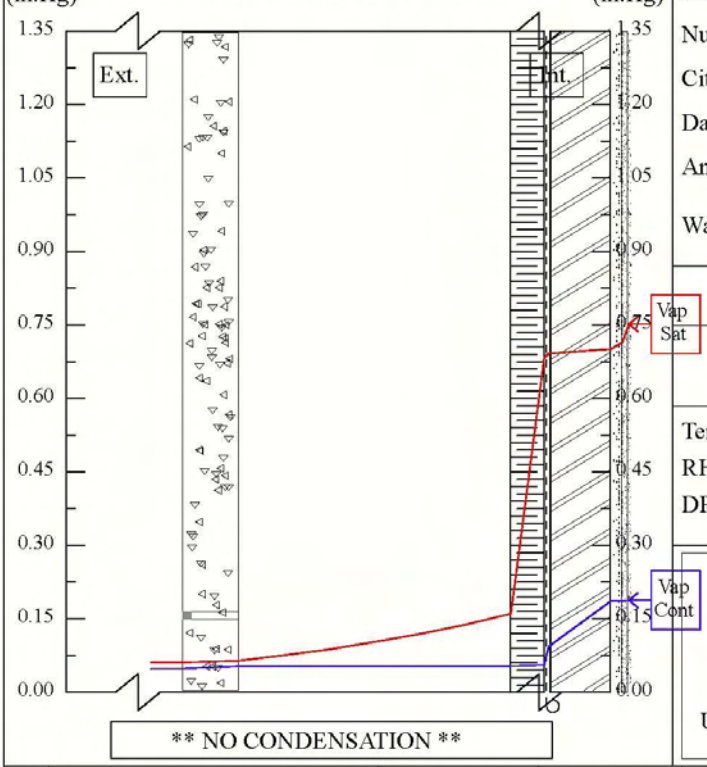
	Material	Manufacturer	Model No.	Rvap (1/M)	Temp (°F)	VapSat (in.Hg)	VapCont (in.Hg)
1	precast, face seal, 5 in.	No Recor...	Generic...	1.506	90.7	1.456	0.724
2	cavity, 4 in.	No Recor...	Generic...	0.033	89.9	1.418	0.724
3	cavity, 4 in.	No Recor...	Generic...	0.033	89.1	1.382	0.723
4	cavity, 4 in.	No Recor...	Generic...	0.033	88.2	1.346	0.723
5	cavity, 4 in.	No Recor...	Generic...	0.033	87.4	1.311	0.723
6	cavity, 4 in.	No Recor...	Generic...	0.033	86.6	1.277	0.723
7	cavity, 4 in.	No Recor...	Generic...	0.033	85.7	1.244	0.722
8	rigid ins.,(expand.), 3 in.	No Recor...	Generic...	0.773	75.7	0.898	0.717
9	poly film, (4mil)	No Recor...	Generic...	11.443	75.6	0.895	0.638
10	steel stud, 5-1/2 in.	No Recor...	Generic...	28.607	75.5	0.892	0.439
11	air film (ext), 3/4 in.	No Recor...	Generic...	0.001	75.4	0.887	0.439
12	gypsum bd., 1/2 in., (#1)	No Recor...	Generic...	0.197	75.0	0.876	0.438
	TOTAL or (Layer 0)			42.900	(91.0)	(1.469)	(0.734)

Enclosure Condensation Analysis – 24 in cavity winter

CONDENSATION ANALYSIS

The Heat, Air and Moisture Building Science Toolbox - V.1B-E/U (12)

WALL SECTION AND
VAPOUR PRESSURE GRADIENTS



** NO CONDENSATION **

PROJECT

Name	BS Thesis
Number	1
City	Harrisburg, PA
Date	3/31/2011
Analysis by:	Paul Kuehnel
Wall Type	Option

CLIMATIC CONDITIONS

	Winter		Summer	
	Int.	Ext.	Int.	Ext.
Temp (°F)	70	9	—	—
RH (%)	25	79	—	—
DPT (°F)	33	4	—	—

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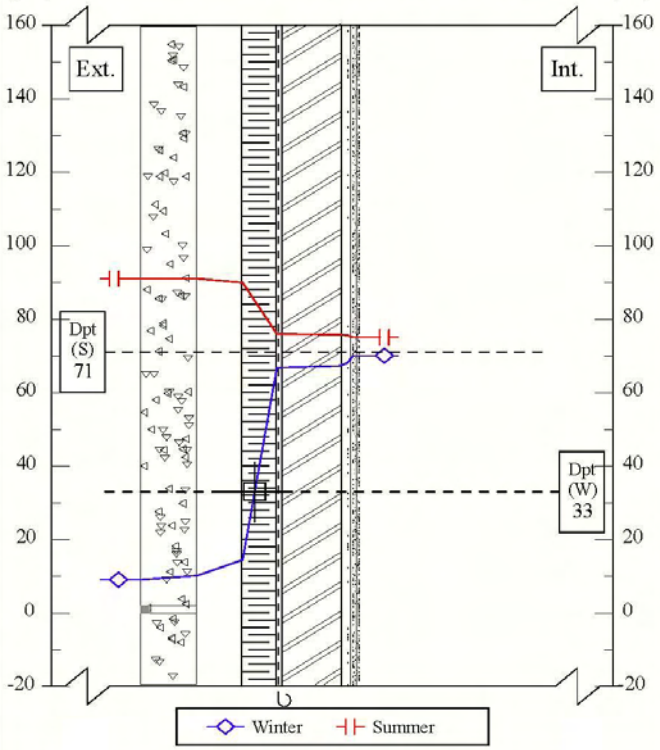
	Material	Manufacturer	Model No.	Rvap (1/M)	Temp (°F)	VapSat (in.Hg)	VapCont (in.Hg)
1	precast, face seal, 5 in.	No Recor...	Generic...	1.506	10.1	0.063	0.052
2	cavity, 4 in.	No Recor...	Generic...	0.033	13.2	0.074	0.052
3	cavity, 4 in.	No Recor...	Generic...	0.033	16.4	0.086	0.052
4	cavity, 4 in.	No Recor...	Generic...	0.033	19.6	0.101	0.052
5	cavity, 4 in.	No Recor...	Generic...	0.033	22.7	0.117	0.053
6	cavity, 4 in.	No Recor...	Generic...	0.033	25.9	0.136	0.053
7	cavity, 4 in.	No Recor...	Generic...	0.033	29.0	0.158	0.053
8	rigid ins.,(expand.), 3 in.	No Recor...	Generic...	0.773	67.2	0.672	0.055
9	poly film, (4mil)	No Recor...	Generic...	11.443	67.6	0.681	0.092
10	steel stud, 5-1/2 in.	No Recor...	Generic...	28.607	68.0	0.690	0.184
11	air film (ext), 3/4 in.	No Recor...	Generic...	0.001	68.5	0.703	0.184
12	gypsum bd., 1/2 in., (#1)	No Recor...	Generic...	0.197	70.0	0.740	0.185
	TOTAL or (Layer 0)			42.900	(9.0)	(0.060)	(0.047)

Enclosure R-Value Analysis – 24 in adjusted

R VALUE ANALYSIS

The Heat, Air and Moisture Building Science Toolbox - V.1B-E/U (12)

WALL SECTION AND TEMPERATURE GRADIENTS



PROJECT

Name	BS Thesis
Number	1
City	Harrisburg, PA
Date	3/31/2011
Analysis by:	Paul Kuehnel
Wall Type	
Option	

CLIMATIC CONDITIONS

	Winter		Summer	
	Int.	Ext.	Int.	Ext.
Temp (°F)	70	9	75	91
RH (%)	25	79	50	50
DPT (°F)	33	4	56	71

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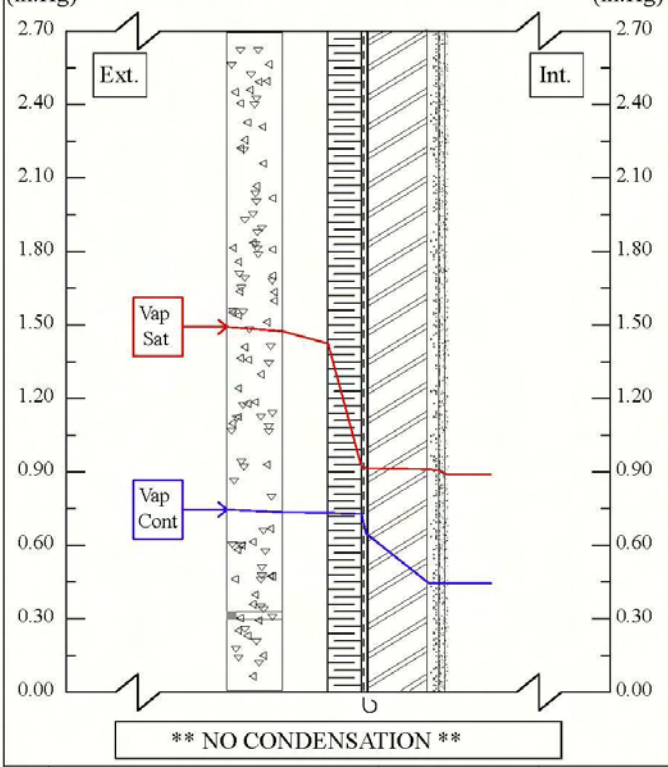
	Generic Material	Manufacturer	Model No.	Thick (in.)	RVal (R)	W.Temp. (°F)	S.Temp. (°F)
1	precast, face seal, 5 in.	No Recor...	Generic...	5.00	0.34	10.1	91.0
2	cavity, 4 in.	No Recor...	Generic...	4.00	0.98	14.4	89.9
3	rigid ins.,(expand.), 3 in.	No Recor...	Generic...	3.00	11.86	66.2	76.0
4	poly film, (4mil)	No Recor...	Generic...	0.00	0.12	66.7	75.9
5	steel stud, 5-1/2 in.	No Recor...	Generic...	5.51	0.12	67.2	75.7
6	air film (ext), 3/4 in.	No Recor...	Generic...	0.75	0.17	68.0	75.5
7	gypsum bd., 1/2 in., (#1)	No Recor...	Generic...	0.50	0.46	70.0	75.0
	Total or (Layer 0)			18.02	14.04	(8.6)	(91.4)

Enclosure Condensation Analysis – 24 in adjusted summer

CONDENSATION ANALYSIS

The Heat, Air and Moisture Building Science Toolbox - V.1B-E/U (12)

WALL SECTION AND
VAPOUR PRESSURE GRADIENTS



** NO CONDENSATION **

PROJECT

Name	BS Thesis
Number	1
City	Harrisburg, PA
Date	3/31/2011
Analysis by:	Paul Kuehnel
Wall Type	
Option	

CLIMATIC CONDITIONS

	Winter		Summer	
	Int.	Ext.	Int.	Ext.
Temp (°F)	—	—	75	91
RH (%)	—	—	50	50
DPT (°F)	—	—	56	71

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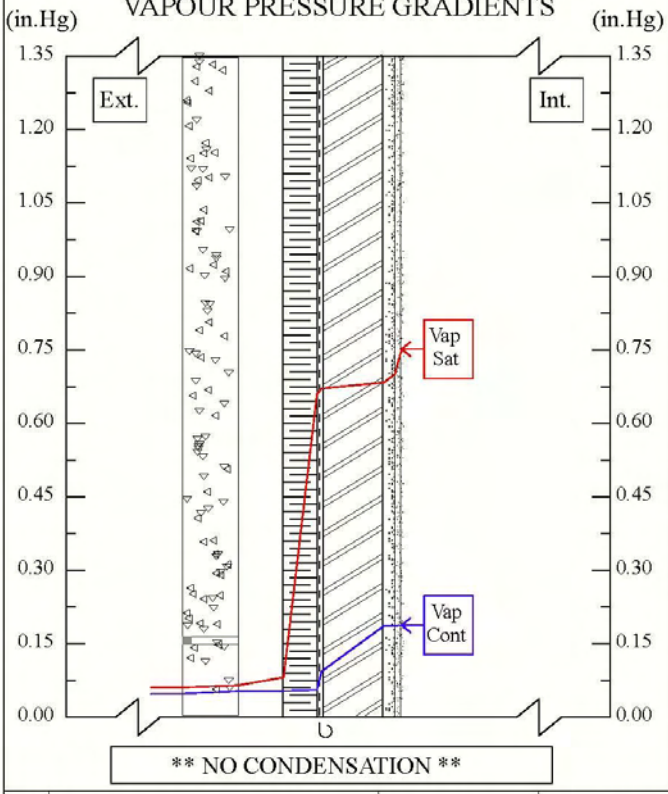
	Material	Manufacturer	Model No.	Rvap (1/M)	Temp (°F)	VapSat (in.Hg)	VapCont (in.Hg)
1	precast, face seal, 5 in.	No Recor...	Generic...	1.506	90.6	1.451	0.724
2	cavity, 4 in.	No Recor...	Generic...	0.197	89.5	1.401	0.722
3	rigid ins.,(expand.), 3 in.	No Recor...	Generic...	0.773	76.0	0.905	0.717
4	poly film, (4mil)	No Recor...	Generic...	11.443	75.9	0.901	0.638
5	steel stud, 5-1/2 in.	No Recor...	Generic...	28.607	75.7	0.897	0.439
6	air film (ext), 3/4 in.	No Recor...	Generic...	0.001	75.5	0.891	0.439
7	gypsum bd., 1/2 in., (#1)	No Recor...	Generic...	0.197	75.0	0.876	0.438
8							
9							
10							
11							
12							
	TOTAL or (Layer 0)			42.901	(91.0)	(1.469)	(0.734)

Enclosure Condensation Analysis – 24 in adjusted winter

CONDENSATION ANALYSIS

The Heat, Air and Moisture Building Science Toolbox - V.1B-E/U (12)

WALL SECTION AND
VAPOUR PRESSURE GRADIENTS



** NO CONDENSATION **

PROJECT

Name	BS Thesis
Number	1
City	Harrisburg, PA
Date	3/31/2011
Analysis by:	Paul Kuehnel
Wall Type	
Option	

CLIMATIC CONDITIONS

	Winter		Summer	
	Int.	Ext.	Int.	Ext.
Temp (°F)	70	9	—	—
RH (%)	25	79	—	—
DPT (°F)	33	4	—	—

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UNIVERSITY PARK, PA, USA, 16802

	Material	Manufacturer	Model No.	Rvap (1/M)	Temp (°F)	VapSat (in.Hg)	VapCont (in.Hg)
1	precast, face seal, 5 in.	No Recor...	Generic...	1.506	10.5	0.064	0.052
2	cavity, 4 in.	No Recor...	Generic...	0.197	14.7	0.080	0.053
3	rigid ins.,(expand.), 3 in.	No Recor...	Generic...	0.773	66.2	0.650	0.055
4	poly film, (4mil)	No Recor...	Generic...	11.443	66.7	0.661	0.092
5	steel stud, 5-1/2 in.	No Recor...	Generic...	28.607	67.2	0.673	0.184
6	air film (ext), 3/4 in.	No Recor...	Generic...	0.001	68.0	0.690	0.184
7	gypsum bd., 1/2 in., (#1)	No Recor...	Generic...	0.197	70.0	0.740	0.185
8							
9							
10							
11							
12							
	TOTAL or (Layer 0)			42.901	(9.0)	(0.060)	(0.047)

Glazing Configuration Thermal and Solar Performance Analysis

Window v6.3.9.0 Glazing System Thermal and Optical Properties 02/22/11 00:06:12

ID : 15
Name : Double Skin 3 with Shading
Tilt : 90.0
Glazings: 4
KEFF : 0.3787
Width : 25.168
Uvalue : 0.12
SHGCc : 0.17
SCc : 0.20
Vtc : 0.22
RHG : 40.66

Layer Data for Glazing System '15 Double Skin 3 with Shading'

ID	Name	D(")	Tsol	1 Rsol	2 Tvis	1 Rvis	2 Tir	1 Emis	2 Keff
Outside									
6046	VE12M.VIR	#0.223	.383	.286	.449	.792	.060	.047	.000	.840	.040	.578
1	Air	6.343										.017
23	Double Skin Shading	0.024	.000	.700	.700	.000	.700	.700	.320	.638	.638	92.4
1	Air	6.343										.626
6046	VE12M.VIR	#0.223	.383	.286	.449	.792	.060	.047	.000	.840	.040	.578
1	Air	0.500										.016
6046	VE12M.VIR	#0.223	.383	.286	.449	.792	.060	.047	.000	.840	.040	.578
Inside												

Environmental Conditions: 1 NFRC 100-2010

	Tout (F)	Tin (F)	WndSpd (mph)	Wnd Dir	Solar (Btu/h-ft2)	Tsky (F)	Esky
Uvalue	-0.4	69.8	12.30	Windward	0.0	-0.4	1.00
Solar	89.6	75.2	6.26	Windward	248.2	89.6	1.00

Temperature Distribution (degrees F)

	Winter		Summer	
	Out	In	Out	In
Lay1	1.3	1.6	120.6	122.8
Lay2	18.2	18.2	167.0	167.0
Lay3	25.6	25.8	161.1	160.7
Lay4	48.7	49.0	123.0	122.3

Window v6.3.9.0 Glazing System Thermal and Optical Properties 02/22/11 00:15:37

ID : 15
Name : Double Skin 3 with Shading
Tilt : 90.0
Glazings: 4
KEFF : 0.3787
Width : 25.168
Uvalue : 0.12
SHGCc : 0.17
SCc : 0.20
Vtc : 0.22
RHG : 40.66

Layer Data for Glazing System '15 Double Skin 3 with Shading'

ID	Name	D(")	Tsol	1 Rsol	2 Tvis	1 Rvis	2 Tir	1 Emis	2 Keff
Outside									
6046	VE12M.VIR	#0.223	.383	.286	.449	.792	.060	.047	.000	.840	.040	.578
	1 Air	6.343										.017
23	Double Skin Sha	0.024	.000	.700	.700	.000	.700	.700	.320	.638	.638	92.4
	ding											
	1 Air	6.343										.626
6046	VE12M.VIR	#0.223	.383	.286	.449	.792	.060	.047	.000	.840	.040	.578
	1 Air	0.500										.016
6046	VE12M.VIR	#0.223	.383	.286	.449	.792	.060	.047	.000	.840	.040	.578
Inside												

Environmental Conditions: 1 NFRC 100-2010

Tout (F)	Tin (F)	WndSpd (mph)	Wnd Dir	Solar (Btu/h-ft2)	Tsky (F)	Esky

```
Uvalue    -0.4  69.8   12.30  Windward     0.0  -0.4  1.00
Solar     89.6  75.2    6.26  Windward   248.2  89.6  1.00


      Temperature Distribution (degrees F)
        Winter          Summer
       Out    In       Out    In
      ----   ----     ----   ----
Lay1   1.3    1.6    120.6 122.8
Lay2  18.2   18.2    167.0 167.0
Lay3  25.6   25.8    161.1 160.7
Lay4  48.7   49.0    123.0 122.3


Window v6.3.9.0 Glazing System Thermal and Optical Properties 02/22/11
00:16:00


ID      : 15
Name    : Double Skin 3 with Shading
Tilt    : 90.0
Glazings: 4
KEFF    : 0.3787
Width   : 25.168
Uvalue  : 0.12
SHGCc   : 0.17
SCc     : 0.20
Vtc     : 0.22
RHG     : 40.66


Layer Data for Glazing System '15 Double Skin 3 with Shading'

ID     Name            D( ") Tsol  1 Rsol 2 Tvis  1 Rvis 2  Tir  1 Emis 2
Keff
------ --------------- ----- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---
-
Outside
  6046 VE12M.VIR      #0.223 .383 .286 .449 .792 .060 .047 .000 .840 .040
.578
       1 Air           6.343
.017
    23 Double Skin Sha 0.024 .000 .700 .700 .000 .700 .700 .320 .638 .638
92.4
       ding
       1 Air           6.343
.626
  6046 VE12M.VIR      #0.223 .383 .286 .449 .792 .060 .047 .000 .840 .040
.578
       1 Air           0.500
.016
  6046 VE12M.VIR      #0.223 .383 .286 .449 .792 .060 .047 .000 .840 .040
.578
Inside
```

Environmental Conditions: 1 NFRC 100-2010

	Tout (F)	Tin (F)	WndSpd (mph)	Wnd Dir	Solar (Btu/h-ft2)	Tsky (F)	Esky
Uvalue	-0.4	69.8	12.30	Windward	0.0	-0.4	1.00
Solar	89.6	75.2	6.26	Windward	248.2	89.6	1.00

Temperature Distribution (degrees F)

	Winter		Summer	
	Out	In	Out	In
Lay1	1.3	1.6	120.6	122.8
Lay2	18.2	18.2	167.0	167.0
Lay3	25.6	25.8	161.1	160.7
Lay4	48.7	49.0	123.0	122.3

Window v6.3.9.0 Glazing System Thermal and Optical Properties 02/22/11 00:07:30

ID : 14
Name : Double Skin 2 with Shading
Tilt : 90.0
Glazings: 4
KEFF : 0.3772
Width : 25.168
Uvalue : 0.12
SHGCc : 0.14
SCc : 0.16
Vtc : 0.19
RHG : 32.49

Layer Data for Glazing System '14 Double Skin 2 with Shading'

ID	Name	D(")	Tsol	1 Rsol	2 Tvis	1 Rvis	2 Tir	1 Emis	2 Keff
Outside									
6261	VNE163.VIR	#0.223	.281	.359	.511	.701	.061	.031	.000	.840	.032	.578
	1 Air	6.343										.017
23	Double Skin Sha ding	0.024	.000	.700	.700	.000	.700	.700	.320	.638	.638	92.4
	1 Air	6.343										.626
6046	VE12M.VIR	#0.223	.383	.286	.449	.792	.060	.047	.000	.840	.040	.578
	1 Air	0.500										.016
6046	VE12M.VIR	#0.223	.383	.286	.449	.792	.060	.047	.000	.840	.040	.578
Inside												

Environmental Conditions: 1 NFRC 100-2010

	Tout (F)	Tin (F)	WndSpd (mph)	Wnd Dir	Solar (Btu/h-ft2)	Tsky (F)	Esky
Uvalue	-0.4	69.8	12.30	Windward	0.0	-0.4	1.00
Solar	89.6	75.2	6.26	Windward	248.2	89.6	1.00

Temperature Distribution (degrees F)

Winter		Summer	
Out	In	Out	In

	----	----	----	----
Lay1	1.3	1.6	120.0	122.0
Lay2	18.3	18.4	151.4	151.4
Lay3	25.7	26.0	145.2	144.9
Lay4	48.7	49.0	114.0	113.5

Window v6.3.9.0 Glazing System Thermal and Optical Properties 02/22/11 00:14:04

ID : 14
Name : Double Skin 2 with Shading
Tilt : 90.0
Glazings: 4
KEFF : 0.3772
Width : 25.168
Uvalue : 0.12
SHGCc : 0.14
SCc : 0.16
Vtc : 0.19
RHG : 32.49

Layer Data for Glazing System '14 Double Skin 2 with Shading'

ID	Name	D(")	Tsol	1	Rsol 2	Tvis	1	Rvis 2	Tir	1	Emis 2	Keff
Outside												
6261	VNE163.VIR	#0.223	.281	.359	.511	.701	.061	.031	.000	.840	.032	.578
	1 Air	6.343										.017
23	Double Skin Sha ding	0.024	.000	.700	.700	.000	.700	.700	.320	.638	.638	92.4
	1 Air	6.343										.626
6046	VE12M.VIR	#0.223	.383	.286	.449	.792	.060	.047	.000	.840	.040	.578
	1 Air	0.500										.016
6046	VE12M.VIR	#0.223	.383	.286	.449	.792	.060	.047	.000	.840	.040	.578
Inside												

Environmental Conditions: 1 NFRC 100-2010

	Tout (F)	Tin (F)	WndSpd (mph)	Wnd Dir	Solar (Btu/h-ft2)	Tsky (F)	Esky
	-----	----	------	--------	------	----	----
Uvalue	-0.4	69.8	12.30	Windward	0.0	-0.4	1.00
Solar	89.6	75.2	6.26	Windward	248.2	89.6	1.00

```
      Temperature Distribution (degrees F)
        Winter          Summer
       Out    In       Out    In
      ----   ----      ----   ----
Lay1   1.3    1.6     120.0 122.0
Lay2  18.3   18.4     151.4 151.4
Lay3  25.7   26.0     145.2 144.9
Lay4  48.7   49.0     114.0 113.5


Window v6.3.9.0 Glazing System Thermal and Optical Properties 02/22/11
00:14:21


ID      : 14
Name    : Double Skin 2 with Shading
Tilt    : 90.0
Glazings: 4
KEFF    : 0.3772
Width   : 25.168
Uvalue  : 0.12
SHGCc   : 0.14
SCc     : 0.16
Vtc     : 0.19
RHG     : 32.49



Layer Data for Glazing System '14 Double Skin 2 with Shading'

ID     Name            D( ") Tsol  1 Rsol 2 Tvis  1 Rvis 2  Tir  1 Emis 2
Keff
------ --------------- ----- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---
-
Outside
  6261 VNE163.VIR     #0.223 .281 .359 .511 .701 .061 .031 .000 .840 .032
.578
       1 Air           6.343
.017
    23 Double Skin Sha 0.024 .000 .700 .700 .000 .700 .700 .320 .638 .638
92.4
       ding
       1 Air           6.343
.626
  6046 VE12M.VIR      #0.223 .383 .286 .449 .792 .060 .047 .000 .840 .040
.578
       1 Air           0.500
.016
  6046 VE12M.VIR      #0.223 .383 .286 .449 .792 .060 .047 .000 .840 .040
.578
Inside


Environmental Conditions: 1 NFRC 100-2010
```

	Tout (F)	Tin (F)	WndSpd (mph)	Wnd Dir	Solar (Btu/h-ft2)	Tsky (F)	Esky
Uvalue	-0.4	69.8	12.30	Windward	0.0	-0.4	1.00
Solar	89.6	75.2	6.26	Windward	248.2	89.6	1.00

Temperature Distribution (degrees F)

	Winter		Summer	
	Out	In	Out	In
Lay1	1.3	1.6	120.0	122.0
Lay2	18.3	18.4	151.4	151.4
Lay3	25.7	26.0	145.2	144.9
Lay4	48.7	49.0	114.0	113.5

Window v6.3.9.0 Glazing System Thermal and Optical Properties 02/22/11 00:08:06

ID : 13
Name : Double Skin 1 with Shading
Tilt : 90.0
Glazings: 4
KEFF : 0.3787
Width : 25.168
Uvalue : 0.12
SHGCc : 0.15
SCc : 0.17
Vtc : 0.18
RHG : 35.32

Layer Data for Glazing System '13 Double Skin 1 with Shading'

ID	Name	D(")	Tsol 1	Rsol 2	Tvis 1	Rvis 2	Tir 1	Emis 2	Keff
Outside									
6071	VE62M.VIR	#0.223	.290	.110	.445	.675	.059	.039	.000	.840	.040	.578
	1 Air	6.343										.017
23	Double Skin Sha ding	0.024	.000	.700	.700	.000	.700	.700	.320	.638	.638	92.4
	1 Air	6.343										.626
6046	VE12M.VIR	#0.223	.383	.286	.449	.792	.060	.047	.000	.840	.040	.578
	1 Air	0.500										.016
6046	VE12M.VIR	#0.223	.383	.286	.449	.792	.060	.047	.000	.840	.040	.578
Inside												

Environmental Conditions: 1 NFRC 100-2010

	Tout (F)	Tin (F)	WndSpd (mph)	Wnd Dir	Solar (Btu/h-ft2)	Tsky (F)	Esky
Uvalue	-0.4	69.8	12.30	Windward	0.0	-0.4	1.00
Solar	89.6	75.2	6.26	Windward	248.2	89.6	1.00

Temperature Distribution (degrees F)

Winter		Summer	
Out	In	Out	In

```
Lay1   1.3   1.6    135.3 138.3
Lay2  18.2  18.2    165.0 165.0
Lay3  25.6  25.8    157.7 157.3
Lay4  48.7  49.0    119.8 119.2


Window v6.3.9.0 Glazing System Thermal and Optical Properties 02/22/11
00:11:20


ID      : 13
Name    : Double Skin 1 with Shading
Tilt    : 90.0
Glazings: 4
KEFF    : 0.3787
Width   : 25.168
Uvalue  : 0.12
SHGCc   : 0.15
SCc     : 0.17
Vtc     : 0.18
RHG     : 35.32



Layer Data for Glazing System '13 Double Skin 1 with Shading'

ID     Name            D( ") Tsol  1 Rsol 2 Tvis  1 Rvis 2  Tir  1 Emis 2
Keff
------ --------------- ----- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---
-
Outside
  6071 VE62M.VIR      #0.223 .290 .110 .445 .675 .059 .039 .000 .840 .040
.578
       1 Air           6.343
.017
    23 Double Skin Sha 0.024 .000 .700 .700 .000 .700 .700 .320 .638 .638
92.4
       ding
       1 Air           6.343
.626
  6046 VE12M.VIR      #0.223 .383 .286 .449 .792 .060 .047 .000 .840 .040
.578
       1 Air           0.500
.016
  6046 VE12M.VIR      #0.223 .383 .286 .449 .792 .060 .047 .000 .840 .040
.578
Inside


Environmental Conditions: 1 NFRC 100-2010

          Tout   Tin  WndSpd   Wnd Dir   Solar  Tsky  Esky
          (F)    (F)   (mph)           (Btu/h-ft2)  (F)
         -----  ----  ------  --------  ------  ----  ----
Uvalue    -0.4  69.8   12.30  Windward     0.0  -0.4  1.00
Solar     89.6  75.2    6.26  Windward   248.2  89.6  1.00
```

```
      Temperature Distribution (degrees F)
        Winter          Summer
       Out    In       Out    In
      ----   ----      ----   ----
Lay1   1.3    1.6     135.3 138.3
Lay2  18.2   18.2     165.0 165.0
Lay3  25.6   25.8     157.7 157.3
Lay4  48.7   49.0     119.8 119.2

Window v6.3.9.0 Glazing System Thermal and Optical Properties 02/22/11
00:12:48


ID      : 13
Name    : Double Skin 1 with Shading
Tilt    : 90.0
Glazings: 4
KEFF    : 0.3787
Width   : 25.168
Uvalue  : 0.12
SHGCc   : 0.15
SCc     : 0.17
Vtc     : 0.18
RHG     : 35.32



Layer Data for Glazing System '13 Double Skin 1 with Shading'

ID     Name            D( ") Tsol  1 Rsol 2 Tvis  1 Rvis 2  Tir  1 Emis 2
Keff
------ --------------- ----- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---
-
Outside
  6071 VE62M.VIR      #0.223 .290 .110 .445 .675 .059 .039 .000 .840 .040
.578
       1 Air           6.343
.017
    23 Double Skin Sha 0.024 .000 .700 .700 .000 .700 .700 .320 .638 .638
92.4
       ding
       1 Air           6.343
.626
  6046 VE12M.VIR      #0.223 .383 .286 .449 .792 .060 .047 .000 .840 .040
.578
       1 Air           0.500
.016
  6046 VE12M.VIR      #0.223 .383 .286 .449 .792 .060 .047 .000 .840 .040
.578
Inside


Environmental Conditions: 1 NFRC 100-2010
```

	Tout (F)	Tin (F)	WndSpd (mph)	Wnd Dir	Solar (Btu/h-ft2)	Tsky (F)	Esky
Uvalue	-0.4	69.8	12.30	Windward	0.0	-0.4	1.00
Solar	89.6	75.2	6.26	Windward	248.2	89.6	1.00

Temperature Distribution (degrees F)

	Winter		Summer	
	Out	In	Out	In
Lay1	1.3	1.6	135.3	138.3
Lay2	18.2	18.2	165.0	165.0
Lay3	25.6	25.8	157.7	157.3
Lay4	48.7	49.0	119.8	119.2

Window v6.3.9.0 Glazing System Thermal and Optical Properties 02/22/11 00:08:51

ID : 12
Name : MSC Original
Tilt : 90.0
Glazings: 2
KEFF : 0.0166
Width : 0.946
Uvalue : 0.22
SHGCc : 0.34
SCc : 0.39
Vtc : 0.63
RHG : 80.31

Layer Data for Glazing System '12 MSC Original'

ID	Name	D(")	Tsol 1	Rsol 2	Tvis 1	Rvis 2	Tir 1	Emis 2	Keff
Outside									
6046	VE12M.VIR	#0.223	.383	.286	.449	.792	.060	.047	.578
1	Air	0.500							.017
6046	VE12M.VIR	#0.223	.383	.286	.449	.792	.060	.047	.578
Inside									

Environmental Conditions: 1 NFRC 100-2010

	Tout (F)	Tin (F)	WndSpd (mph)	Wnd Dir	Solar (Btu/h-ft2)	Tsky (F)	Esky
Uvalue	-0.4	69.8	12.30	Windward	0.0	-0.4	1.00
Solar	89.6	75.2	6.26	Windward	248.2	89.6	1.00

Optical Properties for Glazing System '12 MSC Original'

Angle	0	10	20	30	40	50	60	70	80	90	Hemis
Vtc :	0.630	0.637	0.621	0.602	0.580	0.541	0.459	0.314	0.136	0.000	0.504
Rf :	0.098	0.086	0.082	0.086	0.102	0.127	0.171	0.273	0.511	0.999	0.154
Rb :	0.076	0.064	0.060	0.065	0.081	0.107	0.152	0.259	0.502	0.999	0.135
Tsol :	0.255	0.259	0.252	0.244	0.235	0.220	0.187	0.128	0.056	0.000	0.205
Rf :	0.309	0.301	0.299	0.302	0.311	0.328	0.356	0.428	0.608	0.999	0.345
Rb :	0.472	0.466	0.464	0.466	0.474	0.487	0.510	0.566	0.704	0.999	0.498
Abs1 :	0.341	0.344	0.350	0.354	0.354	0.354	0.360	0.356	0.282	0.001	0.346
Abs2 :	0.095	0.096	0.099	0.100	0.099	0.098	0.097	0.087	0.054	0.000	0.093

```
SHGCc: 0.338 0.342 0.338 0.331 0.322 0.306 0.272 0.207 0.108 0.000 0.287

Tdw-K  :  0.200
Tdw-ISO:  0.414
Tuv    :  0.027




      Temperature Distribution (degrees F)
        Winter         Summer
       Out   In       Out   In
      ----  ----     ----  ----
Lay1   2.6   3.1    112.6 114.0
Lay2  41.4  41.9    114.6 114.3


Window v6.3.9.0 Glazing System Thermal and Optical Properties 02/22/11
00:10:08


ID      : 12
Name    : MSC Original
Tilt    : 90.0
Glazings: 2
KEFF    : 0.0166
Width   : 0.946
Uvalue  : 0.22
SHGCc   : 0.34
SCc     : 0.39
Vtc     : 0.63
RHG     : 80.31



Layer Data for Glazing System '12 MSC Original'

ID     Name            D( ") Tsol  1 Rsol 2 Tvis  1 Rvis 2  Tir  1 Emis 2
Keff
------ --------------- ----- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---
-
Outside
  6046 VE12M.VIR      #0.223 .383 .286 .449 .792 .060 .047 .000 .840 .040
.578
       1 Air           0.500
.017
  6046 VE12M.VIR      #0.223 .383 .286 .449 .792 .060 .047 .000 .840 .040
.578
Inside


Environmental Conditions: 1 NFRC 100-2010

          Tout   Tin  WndSpd   Wnd Dir   Solar  Tsky  Esky
```

	(F)	(F)	(mph)		(Btu/h-ft2)	(F)	
Uvalue	-0.4	69.8	12.30	Windward	0.0	-0.4	1.00
Solar	89.6	75.2	6.26	Windward	248.2	89.6	1.00

Optical Properties for Glazing System '12 MSC Original'

Angle	0	10	20	30	40	50	60	70	80	90	Hemis
Vtc :	0.630	0.637	0.621	0.602	0.580	0.541	0.459	0.314	0.136	0.000	0.504
Rf :	0.098	0.086	0.082	0.086	0.102	0.127	0.171	0.273	0.511	0.999	0.154
Rb :	0.076	0.064	0.060	0.065	0.081	0.107	0.152	0.259	0.502	0.999	0.135
Tsol :	0.255	0.259	0.252	0.244	0.235	0.220	0.187	0.128	0.056	0.000	0.205
Rf :	0.309	0.301	0.299	0.302	0.311	0.328	0.356	0.428	0.608	0.999	0.345
Rb :	0.472	0.466	0.464	0.466	0.474	0.487	0.510	0.566	0.704	0.999	0.498
Abs1 :	0.341	0.344	0.350	0.354	0.354	0.354	0.360	0.356	0.282	0.001	0.346
Abs2 :	0.095	0.096	0.099	0.100	0.099	0.098	0.097	0.087	0.054	0.000	0.093
SHGCc:	0.338	0.342	0.338	0.331	0.322	0.306	0.272	0.207	0.108	0.000	0.287

Tdw-K : 0.200
Tdw-ISO: 0.414
Tuv : 0.027

Temperature Distribution (degrees F)

	Winter		Summer	
	Out	In	Out	In
Lay1	2.6	3.1	112.6	114.0
Lay2	41.4	41.9	114.6	114.3

Window v6.3.9.0 Glazing System Thermal and Optical Properties 02/22/11 00:10:38

ID : 12
Name : MSC Original
Tilt : 90.0
Glazings: 2
KEFF : 0.0166
Width : 0.946
Uvalue : 0.22
SHGCc : 0.34
SCc : 0.39
Vtc : 0.63
RHG : 80.31

Layer Data for Glazing System '12 MSC Original'

ID	Name	D(")	Tsol 1	Rsol 2	Tvis 1	Rvis 2	Tir 1	Emis 2	Keff
Outside									
6046	VE12M.VIR	#0.223	.383	.286	.449	.792	.060	.047	.000	.840	.040	.578
1	Air	0.500										.017
6046	VE12M.VIR	#0.223	.383	.286	.449	.792	.060	.047	.000	.840	.040	.578
Inside												

Environmental Conditions: 1 NFRC 100-2010

	Tout (F)	Tin (F)	WndSpd (mph)	Wnd Dir	Solar (Btu/h-ft2)	Tsky (F)	Esky
Uvalue	-0.4	69.8	12.30	Windward	0.0	-0.4	1.00
Solar	89.6	75.2	6.26	Windward	248.2	89.6	1.00

Optical Properties for Glazing System '12 MSC Original'

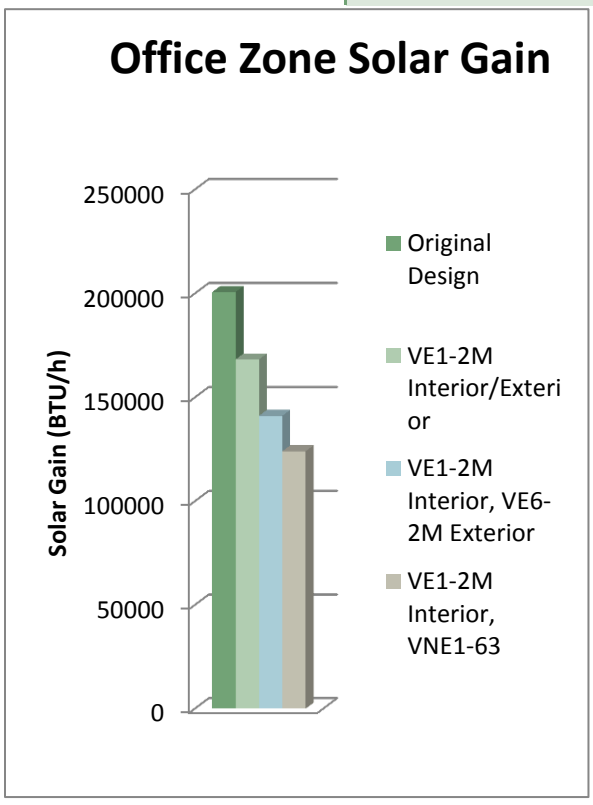
Angle	0	10	20	30	40	50	60	70	80	90	Hemis
Vtc :	0.630	0.637	0.621	0.602	0.580	0.541	0.459	0.314	0.136	0.000	0.504
Rf :	0.098	0.086	0.082	0.086	0.102	0.127	0.171	0.273	0.511	0.999	0.154
Rb :	0.076	0.064	0.060	0.065	0.081	0.107	0.152	0.259	0.502	0.999	0.135
Tsol :	0.255	0.259	0.252	0.244	0.235	0.220	0.187	0.128	0.056	0.000	0.205
Rf :	0.309	0.301	0.299	0.302	0.311	0.328	0.356	0.428	0.608	0.999	0.345
Rb :	0.472	0.466	0.464	0.466	0.474	0.487	0.510	0.566	0.704	0.999	0.498
Abs1 :	0.341	0.344	0.350	0.354	0.354	0.354	0.360	0.356	0.282	0.001	0.346
Abs2 :	0.095	0.096	0.099	0.100	0.099	0.098	0.097	0.087	0.054	0.000	0.093
SHGCc:	0.338	0.342	0.338	0.331	0.322	0.306	0.272	0.207	0.108	0.000	0.287

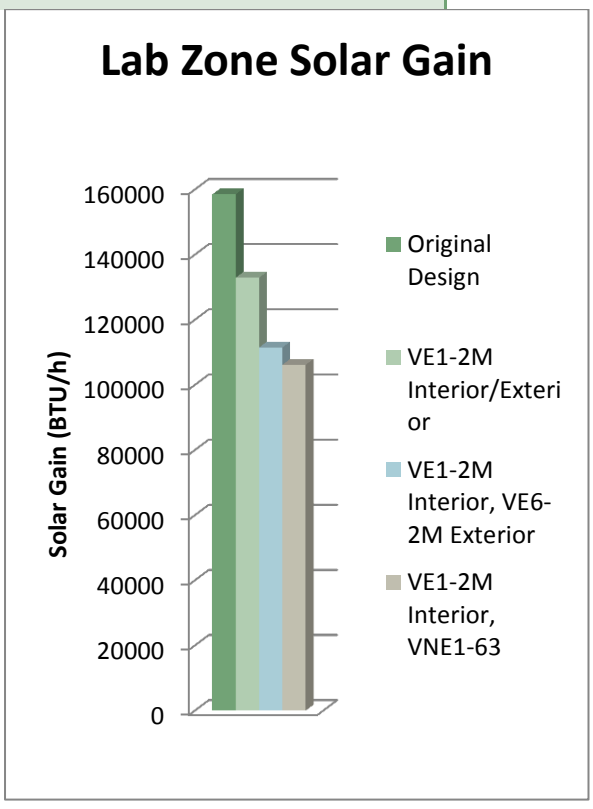
Tdw-K : 0.200
Tdw-ISO: 0.414
Tuv : 0.027

Temperature Distribution (degrees F)

	Winter		Summer	
	Out	In	Out	In
Lay1	2.6	3.1	112.6	114.0
Lay2	41.4	41.9	114.6	114.3

	VE1-2M Both	VE6-2M Ext.	VNE1-63 Ext.	Existing
U-factor (Summer) (BTU/hr ft² F)	0.107	0.106	0.104	0.29
SC	0.326	0.273	0.260	0.388
SHGC	0.283	0.237	0.226	0.338
Solar Transmissibility	0.185	0.150	0.153	0.256
Visible Transmissibility	0.502	0.428	0.444	0.630
Solar Reflectivity, Inside	0.481	0.480	0.481	0.472
Visible Reflectivity, Inside	0.0949	0.0919	0.0886	0.0762
Keff (BTU/hr ft F)	0.3966	0.3966	0.3883	-0.2297
Air Gap Keff (BTU/hr ft F)	0.7874	0.7874	0.1988	-





System Checksums

By ACADEMIC

Lab

Variable Volume Reheat (30% Min Flow Default)

ACADEMIC USE ONLY

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 7 / 17
Outside Air: OADB/WB/HR: 89 / 72 / 92

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	0	0	0	0
Skylite Cond	0	0	0	0
Roof Cond	0	126,864	126,864	15
Glass Solar	175,386	0	175,386	21
Glass/Door Cond	16,456	0	16,456	2
Wall Cond	233	840	1,074	0
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	31,046		31,046	4
Sub Total ==>	223,121	127,704	350,826	43
Internal Loads				
Lights	51,927	13,353	65,280	8
People	121,283	0	121,283	15
Misc	71,546	0	71,546	9
Sub Total ==>	244,756	13,353	258,109	31
Ceiling Load	17,184	-17,184	0	0
Ventilation Load	-231,094	0	-231,094	-28
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	355,844		355,844	43
Exhaust Heat		-26,201	-26,201	-3
Sup. Fan Heat			114,907	14
Ret. Fan Heat		0	0	0
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	609,811	97,672	822,390	100.00

CLG SPACE PEAK

Mo/Hr: 3 / 17
OADB: 54

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	0	0
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	220,940	43
Glass/Door Cond	-20,351	-4
Wall Cond	-219	0
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	-19,163	-4
Sub Total ==>	181,208	35
Internal Loads		
Lights	51,927	10
People	60,641	12
Misc	71,546	14
Sub Total ==>	184,115	36
Ceiling Load	5,631	1
Ventilation Load	-170,982	-33
Adj Air Trans Heat	0	0
Ov/Undr Sizing	315,958	61
Exhaust Heat		
OA Preheat Diff.		
RA Preheat Diff.		
Additional Reheat		
Underflr Sup Ht Pkup		
Supply Air Leakage		
Grand Total ==>	515,930	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 11

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-114,604	4.63
Glass Solar	0	0	0.00
Glass/Door Cond	-62,449	-62,449	2.52
Wall Cond	-720	-3,710	0.15
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-55,694	-55,694	2.25
Sub Total ==>	-118,864	-236,458	9.56
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-14,177	0	0.00
Ventilation Load	-142,485	-142,485	5.76
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-294,412	-294,412	11.90
Exhaust Heat		17,763	-0.72
OA Preheat Diff.		-1,349,940	54.57
RA Preheat Diff.		0	0.00
Additional Reheat		-468,348	18.93
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-569,938	-2,473,880	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	90.0
Ra Plenum	77.5	67.1
Return	77.5	67.1
Ret/OA	77.5	67.1
Fn MtrTD	0.4	0.0
Fn BldTD	1.0	0.0
Fn Frict	2.9	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	24,661	25,881
Terminal	24,661	25,881
Main Fan	24,661	25,881
Sec Fan	0	0
Nom Vent	25,881	25,881
AHU Vent	25,881	25,881
Infil	857	857
MinStop/Rh	25,881	25,881
Return	31,500	32,720
Exhaust	6,839	6,839
Rm Exh	19,899	19,899
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	104.9	100.0
cfm/ft²	1.58	1.66
cfm/ton	130.06	
ft²/ton	82.21	
Btu/hr·ft²	145.97	-158.46
No. People	303	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	68.5	822.4	719.7	24,238	77.5	62.9	63.6	50.7	50.6	55.5
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	121.1	1,452.9	902.6	25,881	87.7	72.1	95.1	56.1	55.3	65.0
Total	189.6	2,275.3								

AREAS

	Gross Total ft²	Glass ft²	Glass (%)
Floor	15,587		
Part	0		
Int Door	0		
ExFlr	0		
Roof	12,965	0	0
Wall	5,490	3,539	64
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-1,120.1	25,881	50.7	90.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	-1,349.9	25,881	20.6	68.0
Total	-2,470.0			

Project Name: Millennium Science Complex
Dataset Name: PSU MSC_DSF.trc

TRACE® 700 v6.2.6.5 calculated at 10:10 PM on 03/27/2011
Alternative - 3 System Checksums Report Page 1 of 2

System Checksums

By ACADEMIC

Office — **Variable Volume Reheat (30% Min Flow Default)**

ACADEMIC USE ONLY

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 7 / 14
Outside Air: OADB/WB/HR: 91 / 74 / 102

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	0	0	0	0
Skylite Cond	0	0	0	0
Roof Cond	0	64,226	64,226	5
Glass Solar	214,769	0	214,769	18
Glass/Door Cond	29,903	0	29,903	3
Wall Cond	893	2,091	2,983	0
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	76,461		76,461	7
Sub Total ==>	322,026	66,317	388,343	33
Internal Loads				
Lights	70,723	17,681	88,404	8
People	192,061	0	192,061	16
Misc	85,848	0	85,848	7
Sub Total ==>	348,632	17,681	366,313	31
Ceiling Load	19,282	-19,282	0	0
Ventilation Load	0	0	315,756	27
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	0		0	0
Exhaust Heat		-30,871	-30,871	-3
Sup. Fan Heat			92,809	8
Ret. Fan Heat		41,006	41,006	3
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	689,940	74,850	1,173,356	100.00

CLG SPACE PEAK

Mo/Hr: 9 / 13
OADB: 81

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	0	0
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	335,720	55
Glass/Door Cond	8,117	1
Wall Cond	253	0
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	12,480	2
Sub Total ==>	356,570	58
Internal Loads		
Lights	70,723	12
People	96,031	16
Misc	85,848	14
Sub Total ==>	252,601	41
Ceiling Load	5,683	1
Ventilation Load	0	0
Adj Air Trans Heat	0	0
Ov/Undr Sizing		
Exhaust Heat	0	0
OA Preheat Diff.		
RA Preheat Diff.		
Additional Reheat		
Underflr Sup Ht Pkup		
Supply Air Leakage		
Grand Total ==>	614,854	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 11

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-99,539	12.18
Glass Solar	0	0	0.00
Glass/Door Cond	-123,845	-123,845	15.16
Wall Cond	-3,143	-10,928	1.34
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-102,409	-102,409	12.53
Sub Total ==>	-229,398	-336,722	41.21
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-39,705	0	0.00
Ventilation Load	0	-330,193	40.42
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-5,511	-5,511	0.67
Exhaust Heat		32,057	-3.92
OA Preheat Diff.		-63,919	7.82
RA Preheat Diff.		-112,718	13.80
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-274,614	-817,005	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	90.0
Ra Plenum	76.1	65.6
Return	77.5	65.6
Ret/OA	80.7	43.4
Fn MtrTD	0.3	0.0
Fn BldTD	0.7	0.0
Fn Frict	2.2	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	29,390	12,470
Terminal	29,390	12,470
Main Fan	29,390	12,470
Sec Fan	0	0
Nom Vent	6,506	5,083
AHU Vent	6,506	5,083
Infil	1,576	1,576
MinStop/Rh	12,470	12,470
Return	30,966	14,047
Exhaust	8,083	6,659
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	22.1	40.8
cfm/ft²	1.03	0.44
cfm/ton	300.57	
ft²/ton	293.12	
Btu/hr·ft²	40.94	-28.51
No. People	384	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	97.8	1,173.4	832.0	26,103	80.7	64.8	67.4	51.8	49.2	48.6
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	97.8	1,173.4								

AREAS

	Gross Total ft²	Glass ft²	Glass (%)
Floor	28,662		
Part	0		
Int Door	0		
ExFlr	0		
Roof	11,570	0	0
Wall	12,852	7,018	55
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-524.9	12,470	51.8	90.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-292.1	6,506	11.0	51.8
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-817.0			

Project Name: Millennium Science Complex
Dataset Name: PSU MSC_DSF.trc

TRACE® 700 v6.2.6.5 calculated at 10:10 PM on 03/27/2011
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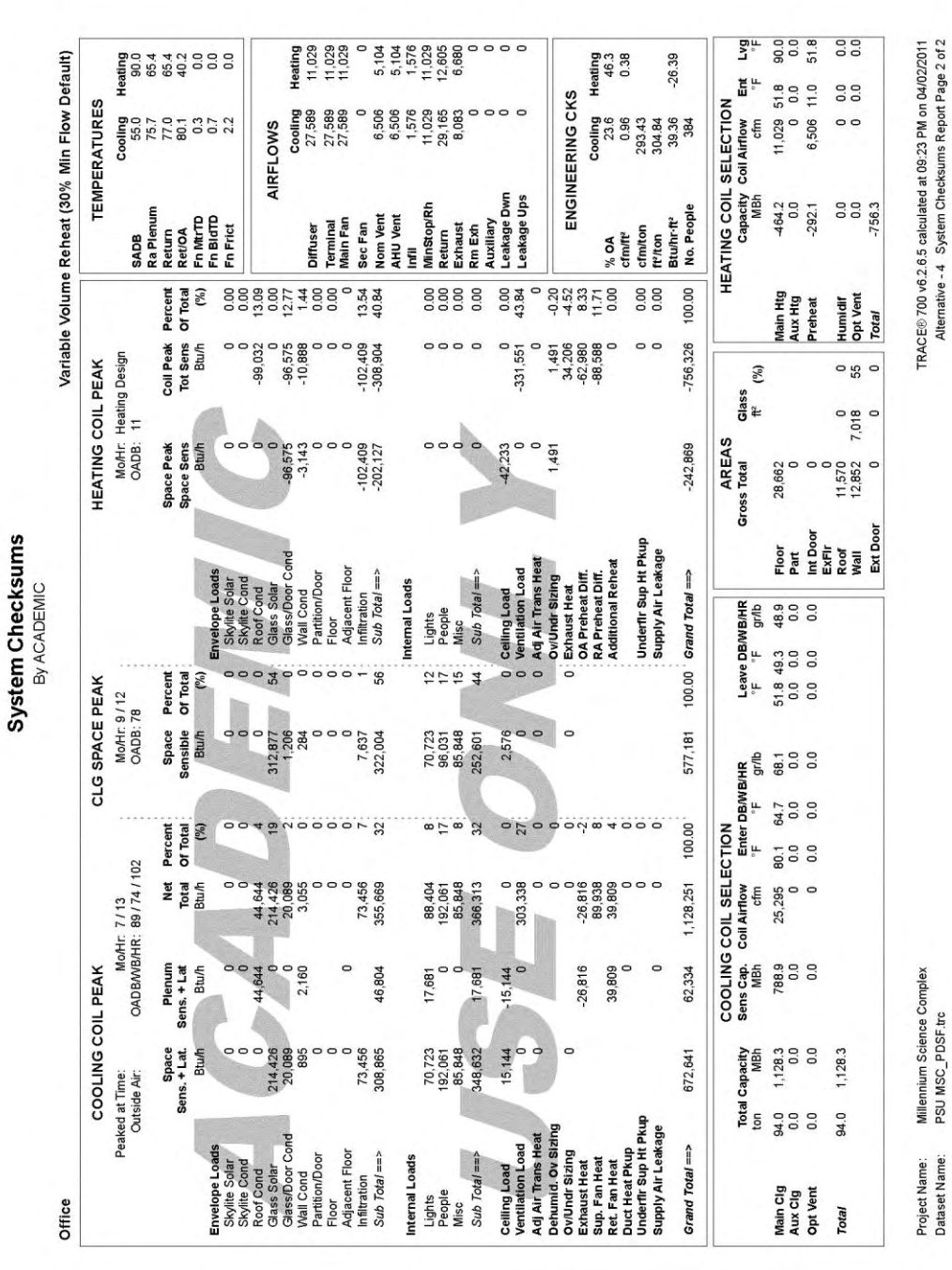
Double Skin Facade



System Checksums
By ACADEMIC

Office — Variable Volume Reheat (30% Min Flow Default)

COOLING COIL PEAK — Peaked at Time: Outside Air: — MoHr: 7 / 13 — OADB/WB/HR: 89 / 74 / 102

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	0	0	0	0
Skylite Cond	0	0	0	0
Roof Cond	0	44,644	44,644	4
Glass Solar	214,426	0	214,426	19
Glass/Door Cond	20,089	0	20,089	2
Wall Cond	895	2,160	3,055	0
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	73,456		73,456	7
Sub Total ==>	308,865	46,804	355,669	32
Internal Loads				
Lights	70,723	17,681	88,404	8
People	192,061	0	192,061	17
Misc	85,848	0	85,848	8
Sub Total ==>	348,632	17,681	366,313	32
Ceiling Load	15,144	-15,144	0	0
Ventilation Load	0	0	303,338	27
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	0	-26,816	-26,816	-2
Exhaust Heat			89,938	8
Sup. Fan Heat		39,809	39,809	4
Ret. Fan Heat		0	0	0
Duct Heat Pkup			0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	672,641	62,334	1,128,251	100.00

CLG SPACE PEAK — MoHr: 9 / 12 — OADB: 78

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	0	0
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	312,877	54
Glass/Door Cond	1,206	0
Wall Cond	284	0
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	7,637	1
Sub Total ==>	322,004	56
Internal Loads		
Lights	70,723	12
People	96,031	17
Misc	85,848	15
Sub Total ==>	252,601	44
Ceiling Load	2,576	0
Ventilation Load	0	0
Adj Air Trans Heat	0	0
Dehumid. Ov Sizing		
Ov/Undr Sizing	0	0
Exhaust Heat		
OA Preheat Diff.		
RA Preheat Diff.		
Additional Reheat		
Underflr Sup Ht Pkup		
Supply Air Leakage		
Grand Total ==>	577,181	100.00

HEATING COIL PEAK — MoHr: Heating Design — OADB: 11

	Space Peak Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-99,032	13.09
Glass Solar	0	0	0.00
Glass/Door Cond	-96,575	-96,575	12.77
Wall Cond	-3,143	-10,888	1.44
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-102,409	-102,409	13.54
Sub Total ==>	-202,127	-308,904	40.84
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-42,233	0	0.00
Ventilation Load	0	-331,551	43.84
Adj Air Trans Heat		0	0
Dehumid. Ov Sizing	1,491	1,491	-0.20
Exhaust Heat		34,206	-4.52
OA Preheat Diff.		-62,980	8.33
RA Preheat Diff.		-88,588	11.71
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-242,869	-756,326	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	90.0
Ra Plenum	75.7	65.4
Return	77.0	65.4
Ret/OA	80.1	40.2
Fn Mfr/TD	0.3	0.0
Fn Bld/TD	0.7	0.0
Fn Frict	2.2	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	27,589	11,029
Terminal	27,589	11,029
Main Fan	27,589	11,029
Sec Fan	0	0
Nom Vent	6,506	5,104
AHU Vent	6,506	5,104
Infil	1,576	1,576
MinStop/Rh	11,029	11,029
Return	29,165	12,605
Exhaust	8,083	6,680
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	23.6	46.3
cfm/ft²	0.96	0.38
cfm/ton	293.43	
ft²/ton	304.84	
Btu/hr-ft²	39.36	-26.39
No. People	384	

AREAS

	Gross Total ft²	Glass ft² (%)
Floor	28,662	
Part	0	
Int Door	0	
Ext/Flr	0	
Roof	11,570	0 0
Wall	12,852	7,018 55
Ext Door	0	0 0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-464.2	11,029	51.8	90.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-292.1	6,506	11.0	51.8
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-756.3			

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB/WB/HR °F	°F	gr/lb	Leave DB/WB/HR °F	°F	gr/lb
Main Clg	94.0	1,128.3	788.9	25,295	80.1	64.7	68.1	51.8	49.3	48.9
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	94.0	1,128.3								

Project Name: Millennium Science Complex
Dataset Name: PSU MSC_PDSF.trc

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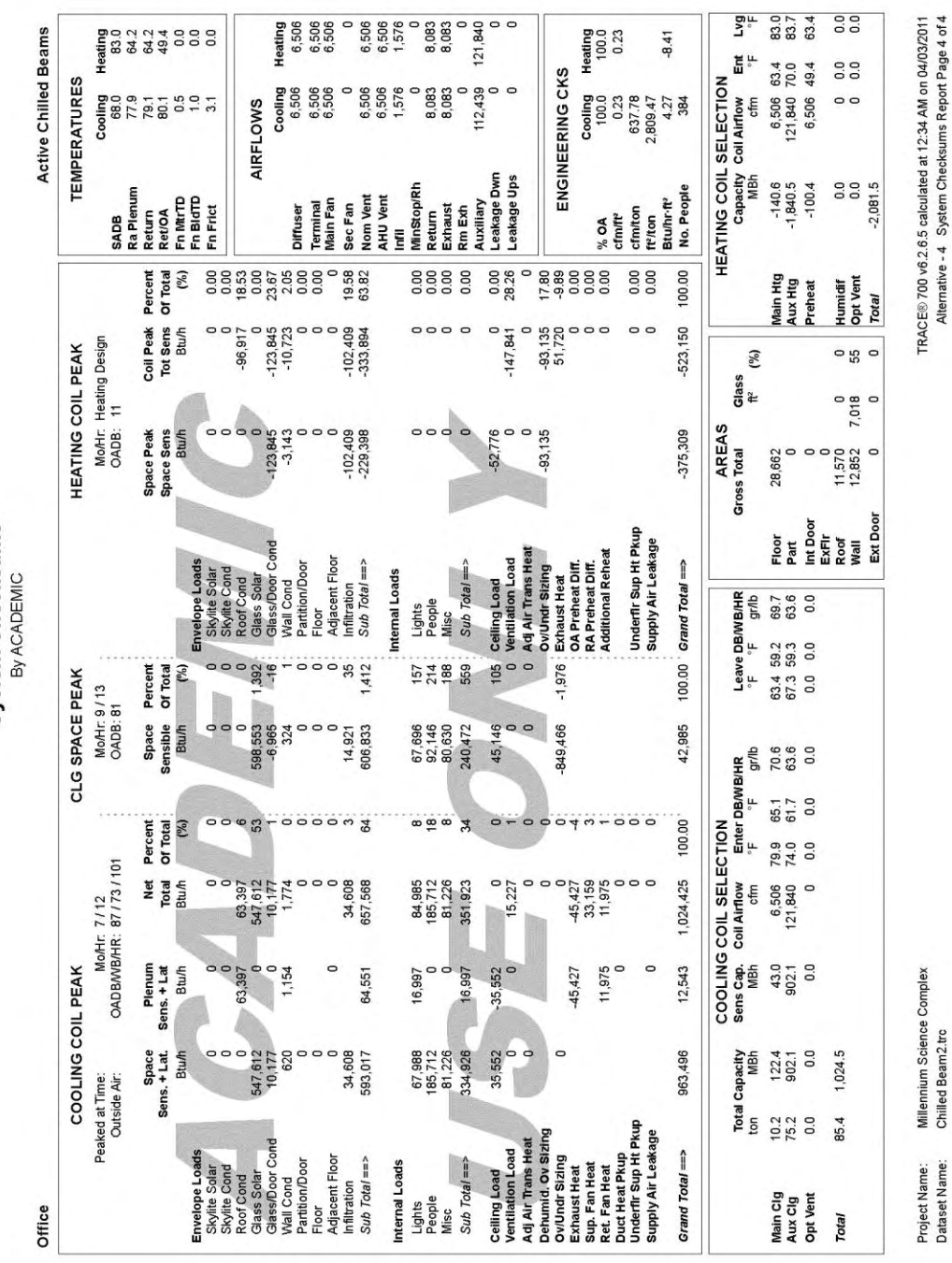
ACADEMIC USE ONLY

Chilled Beams



System Checksums
By ACADEMIC

Active Chilled Beams

Office

COOLING COIL PEAK — Mo/Hr: 7 / 12 — OADB/WB/HR: 87 / 73 / 101 — Peaked at Time: — Outside Air:

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads	0	0	0	0
Skylite Solar	0	0	0	0
Skylite Cond	0	0	63,397	6
Roof Cond	63,397	0	547,612	53
Glass Solar	547,612	0	10,177	1
Glass/Door Cond	10,177	1,154	1,774	0
Wall Cond	620	0	0	0
Partition/Door	0	0	0	0
Floor	0	0	0	0
Adjacent Floor	0	0	34,608	3
Infiltration	34,608	64,551	657,568	64
Sub Total ==>	593,017			
Internal Loads				
Lights	67,988	16,997	84,985	8
People	185,712	0	185,712	18
Misc	81,226	0	81,226	8
Sub Total ==>	334,926	16,997	351,923	34
Ceiling Load	35,552	-35,552	0	0
Ventilation Load	0	0	15,227	1
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	0		0	0
Exhaust Heat		-45,427	-45,427	-4
Sup. Fan Heat			33,159	3
Ret. Fan Heat		11,975	11,975	1
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	963,496	12,543	1,024,425	100.00

CLG SPACE PEAK — Mo/Hr: 9 / 13 — OADB: 81

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads	0	0
Skylite Solar	0	0
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	598,553	1,392
Glass/Door Cond	-6,965	-16
Wall Cond	324	1
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	14,921	35
Sub Total ==>	606,833	1,412
Internal Loads		
Lights	67,696	157
People	92,146	214
Misc	80,630	188
Sub Total ==>	240,472	559
Ceiling Load	45,146	105
Ventilation Load	0	0
Adj Air Trans Heat	0	0
Ov/Undr Sizing	-849,466	-1,976
Exhaust Heat		
OA Preheat Diff.		
RA Preheat Diff.		
Additional Reheat		
Underflr Sup Ht Pkup		
Supply Air Leakage		
Grand Total ==>	42,985	100.00

HEATING COIL PEAK — Mo/Hr: Heating Design — OADB: 11

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads	0	0	0.00
Skylite Solar	0	0	0.00
Skylite Cond	0	-96,917	18.53
Roof Cond	0	0	0.00
Glass Solar	-123,845	-123,845	23.67
Glass/Door Cond	-3,143	-10,723	2.05
Wall Cond	0	0	0.00
Partition/Door	0	0	0.00
Floor	0	0	0
Adjacent Floor	-102,409	-102,409	19.58
Infiltration	-229,398	-333,894	63.82
Sub Total ==>			
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-52,776	-147,841	28.26
Ventilation Load	0	0	0
Adj Air Trans Heat		0	
Ov/Undr Sizing	-93,135	-93,135	17.80
Exhaust Heat		51,720	-9.89
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
Underflr Sup Ht Pkup	0	0	0.00
Supply Air Leakage	0	0	0.00
Grand Total ==>	-375,309	-523,150	100.00

TEMPERATURES

	Cooling	Heating
SADB	68.0	83.0
Ra Plenum	77.9	64.2
Return	79.1	64.2
Ret/OA	80.1	49.4
Fn Mtr TD	0.5	0.0
Fn Bld TD	1.0	0.0
Fn Frict	3.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	6,506	6,506
Terminal	6,506	6,506
Main Fan	6,506	6,506
Sec Fan	0	0
Nom Vent	6,506	6,506
AHU Vent	6,506	6,506
Infil	1,576	1,576
MinStop/Rh	0	0
Return	8,083	8,083
Exhaust	8,083	8,083
Rm Exh	0	0
Auxiliary	112,439	121,840
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	100.0	100.0
cfm/ft²	0.23	0.23
cfm/ton	637.78	
ft²/ton	2,809.47	
Btu/hr-ft²	4.27	-8.41
No. People	384	

AREAS

	Gross Total ft²	Glass ft²	(%)
Floor	28,662		
Part	0		
Int Door	0		
ExFlr	0		
Roof	11,570	0	0
Wall	12,852	7,018	55
Ext Door	0	0	0

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB/WB/HR °F	°F	gr/lb
Main Clg	10.2	122.4	43.0	6,506	79.9	65.1	70.6
Aux Clg	75.2	902.1	902.1	121,840	74.0	61.7	63.6
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0
Total	85.4	1,024.5					

Leave DB/WB/HR: °F 63.4, °F 67.3, °F 0.0; gr/lb 59.2, 59.3, 0.0; 69.7, 63.6, 0.0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-140.6	6,506	63.4	83.0
Aux Htg	-1,840.5	121,840	70.0	83.7
Preheat	-100.4	6,506	49.4	63.4
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-2,081.5			

Project Name: Millennium Science Complex
Dataset Name: Chilled Beam2.trc

TRACE® 700 v6.2.6.5 calculated at 12:34 AM on 04/03/2011
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ACADEMIC USE ONLY

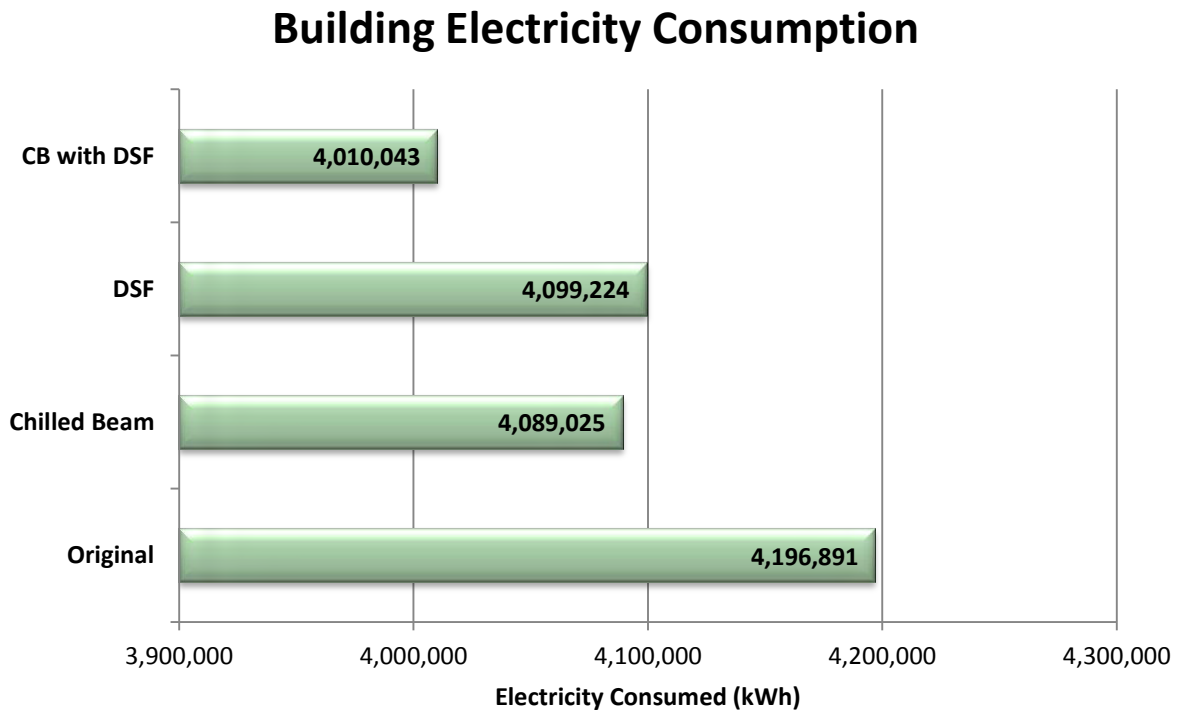
Summarized Redesign Analysis-Base Model

Total Building Energy Consumption for Final Design Parameters.

	Building (MBtu)	Source (MBtu)
Original	46,724	76,243
Chilled Beam	45,638	75,041
Double Skin Facade	42,578	71,410
CB with DSF	41,412	69,797
Total Savings for Combined System	**5,311**	**6,446**

Building HVAC Associated Emissions for Final Design.

	CO_2	SOx	NOx
Original	16,649,602	128,726	25,877
Chilled Beam	16,263,067	125,739	25,275
Double Skin Façade	15,173,621	117,312	23,583
Chilled Beam w/ DSF	14,757,205	114,092	22,933
Total Savings	1,892,397	14,634	2,944



Building Electricity Consumption Comparison for Design Parameters.

Comparison of Yearly Utility Cost for Design Parameters.

	Electricity kWh	Electricity Cost	Purchased Chilled Water (therms)	Purchased CW Cost	Purchased Steam (therms)	Purchased Steam (cost)	Total Cost
Original	4,196,917	$315,480	176,057	$322,184	147,933	$121,305	**$758,969**
Chilled Beam	4,088,983	$307,372	136,773	$250,295	127,910	$104,886	**$662,553**
Double Skin Façade	4,099,207	$308,139	147,163	$269,309	136,609	$112,019	**$689,467**
Chilled Beam w/ DSF	4,010,041	$301,435	132,044	$241,641	123,198	$101,022	**$644,098**
Total Savings	**186,876**	**$14,045**	**44,013**	**$80,543**	**23,735**	**$20,283**	**$114,871**

System Checksums

By ACADEMIC

Lab — **Variable Volume Reheat (30% Min Flow Default)**

ACADEMIC USE ONLY

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 7 / 17
Outside Air: OADB/WB/HR: 89 / 72 / 92

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	0	0	0	0
Skylite Cond	0	0	0	0
Roof Cond	0	131,761	131,761	8
Glass Solar	175,386	0	175,386	10
Glass/Door Cond	16,456	0	16,456	1
Wall Cond	233	963	1,196	0
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	31,046		31,046	2
Sub Total ==>	223,121	132,723	355,844	20
Internal Loads				
Lights	51,257	13,180	64,437	4
People	121,283	0	121,283	7
Misc	1,370,518	0	1,370,518	78
Sub Total ==>	1,543,057	13,180	1,556,238	89
Ceiling Load	5,339	-5,339	0	0
Ventilation Load	-616,192	0	-616,192	-35
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	230,393		230,393	13
Exhaust Heat		-59,478	-59,478	-3
Sup. Fan Heat			281,147	16
Ret. Fan Heat		1	1	0
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	1,385,718	81,087	1,747,952	100.00

CLG SPACE PEAK

Mo/Hr: 12 / 15
OADB: 46

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	0	0
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	224,616	17
Glass/Door Cond	-29,763	-2
Wall Cond	-362	0
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	-26,431	-2
Sub Total ==>	168,060	13
Internal Loads		
Lights	51,257	4
People	60,641	5
Misc	1,370,518	105
Sub Total ==>	1,482,416	114
Ceiling Load	-1,357	0
Ventilation Load	-455,911	-35
Adj Air Trans Heat	0	0
Ov/Undr Sizing	105,925	8
Exhaust Heat		
OA Preheat Diff.		
RA Preheat Diff.		
Additional Reheat		
Underflr Sup Ht Pkup		
Supply Air Leakage		
Grand Total ==>	1,299,132	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 11

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-118,636	2.29
Glass Solar	0	0	0.00
Glass/Door Cond	-62,449	-62,449	1.20
Wall Cond	-720	-3,815	0.07
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-55,694	-55,694	1.07
Sub Total ==>	-118,864	-240,596	4.64
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-4,423	0	0.00
Ventilation Load	-379,927	-379,929	7.33
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-1,016,492	-1,016,492	19.61
Exhaust Heat		42,452	-0.82
OA Preheat Diff.		-2,189,096	42.24
RA Preheat Diff.		0	0.00
Additional Reheat		-1,398,893	26.99
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-1,519,705	-5,182,552	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	90.0
Ra Plenum	75.1	69.1
Return	75.1	69.1
Ret/OA	75.1	69.1
Fn MtrTD	0.4	0.0
Fn BldTD	1.0	0.0
Fn Frict	2.9	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	62,098	69,009
Terminal	62,098	69,009
Main Fan	62,098	69,009
Sec Fan	0	0
Nom Vent	69,009	69,009
AHU Vent	69,009	69,009
Infil	857	857
MinStop/Rh	69,009	69,009
Return	112,065	118,977
Exhaust	49,968	49,968
Rm Exh	19,899	19,899
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	111.1	100.0
cfm/ft²	3.98	4.43
cfm/ton	165.48	
ft²/ton	41.54	
Btu/hr-ft²	288.90	-332.05
No. People	303	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	145.7	1,748.0	1,602.9	59,304	75.1	62.1	63.6	50.7	50.6	55.5
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	229.6	2,755.2	1,914.1	69,009	82.0	68.1	82.3	56.8	55.6	65.0
Total	375.3	4,503.2								

AREAS

	Gross Total ft²	Glass ft²	Glass (%)
Floor	15,587		
Part	0		
Int Door	0		
ExFlr	0		
Roof	12,965	0	0
Wall	5,490	3,539	64
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-2,986.6	69,009	50.7	90.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	-2,189.1	69,009	39.2	68.0
Total	-5,175.7			

Project Name: Millennium Science Complex
Dataset Name: PSU MSC NewPlug LoadsBASE.trc

TRACE® 700 v6.2.6.5 calculated at 12:49 PM on 03/27/2011
Alternative - 4 System Checksums Report Page 1 of 2

System Checksums

By ACADEMIC

Office — **Variable Volume Reheat (30% Min Flow Default)**

ACADEMIC USE ONLY

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 7 / 14
Outside Air: OADB/WB/HR: 91 / 74 / 102

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	0	0	0	0
Skylite Cond	0	0	0	0
Roof Cond	0	65,479	65,479	4
Glass Solar	214,769	0	214,769	13
Glass/Door Cond	29,903	0	29,903	2
Wall Cond	893	2,188	3,081	0
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	78,502		78,502	5
Sub Total ==>	324,066	67,667	391,734	23
Internal Loads				
Lights	74,880	18,720	93,600	6
People	192,061	0	192,061	11
Misc	479,441	0	479,441	28
Sub Total ==>	746,383	18,720	765,103	45
Ceiling Load	13,040	-13,040	0	0
Ventilation Load	0	0	324,239	19
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	0		0	0
Exhaust Heat		-24,753	-24,753	-1
Sup. Fan Heat			159,347	9
Ret. Fan Heat		68,730	68,730	4
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	1,083,489	117,324	1,684,400	100.00

CLG SPACE PEAK

Mo/Hr: 9 / 13
OADB: 81

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	0	0
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	335,720	33
Glass/Door Cond	8,117	1
Wall Cond	253	0
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	12,480	1
Sub Total ==>	356,570	35
Internal Loads		
Lights	74,880	7
People	96,031	9
Misc	479,441	47
Sub Total ==>	650,352	64
Ceiling Load	4,030	0
Ventilation Load	0	0
Adj Air Trans Heat	0	0
Ov/Undr Sizing		
Exhaust Heat		
OA Preheat Diff.		
RA Preheat Diff.		
Additional Reheat		
Underflr Sup Ht Pkup		
Supply Air Leakage		
Grand Total ==>	1,010,952	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 11

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-101,003	9.66
Glass Solar	0	0	0.00
Glass/Door Cond	-123,845	-123,845	11.85
Wall Cond	-3,143	-11,042	1.06
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-102,409	-102,409	9.80
Sub Total ==>	-229,398	-338,300	32.37
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-32,410	0	0.00
Ventilation Load	0	-377,449	36.12
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-132,147	-132,147	12.64
Exhaust Heat		29,026	-2.78
OA Preheat Diff.		-31,263	2.99
RA Preheat Diff.		-194,988	18.66
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-393,955	-1,045,121	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	90.0
Ra Plenum	75.4	66.4
Return	76.8	66.4
Ret/OA	78.8	48.4
Fn MtrTD	0.3	0.0
Fn BldTD	0.7	0.0
Fn Frict	2.2	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	48,326	17,889
Terminal	48,326	17,889
Main Fan	48,326	17,889
Sec Fan	0	0
Nom Vent	6,506	5,810
AHU Vent	6,506	5,810
Infil	1,576	1,576
MinStop/Rh	17,889	17,889
Return	49,903	19,466
Exhaust	8,083	7,387
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	13.5	32.5
cfm/ft²	1.69	0.62
cfm/ton	344.29	
ft²/ton	204.19	
Btu/hr·ft²	58.77	-36.46
No. People	384	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	140.4	1,684.4	1,332.5	44,816	78.8	62.6	60.1	51.8	49.3	48.8
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	140.4	1,684.4								

AREAS

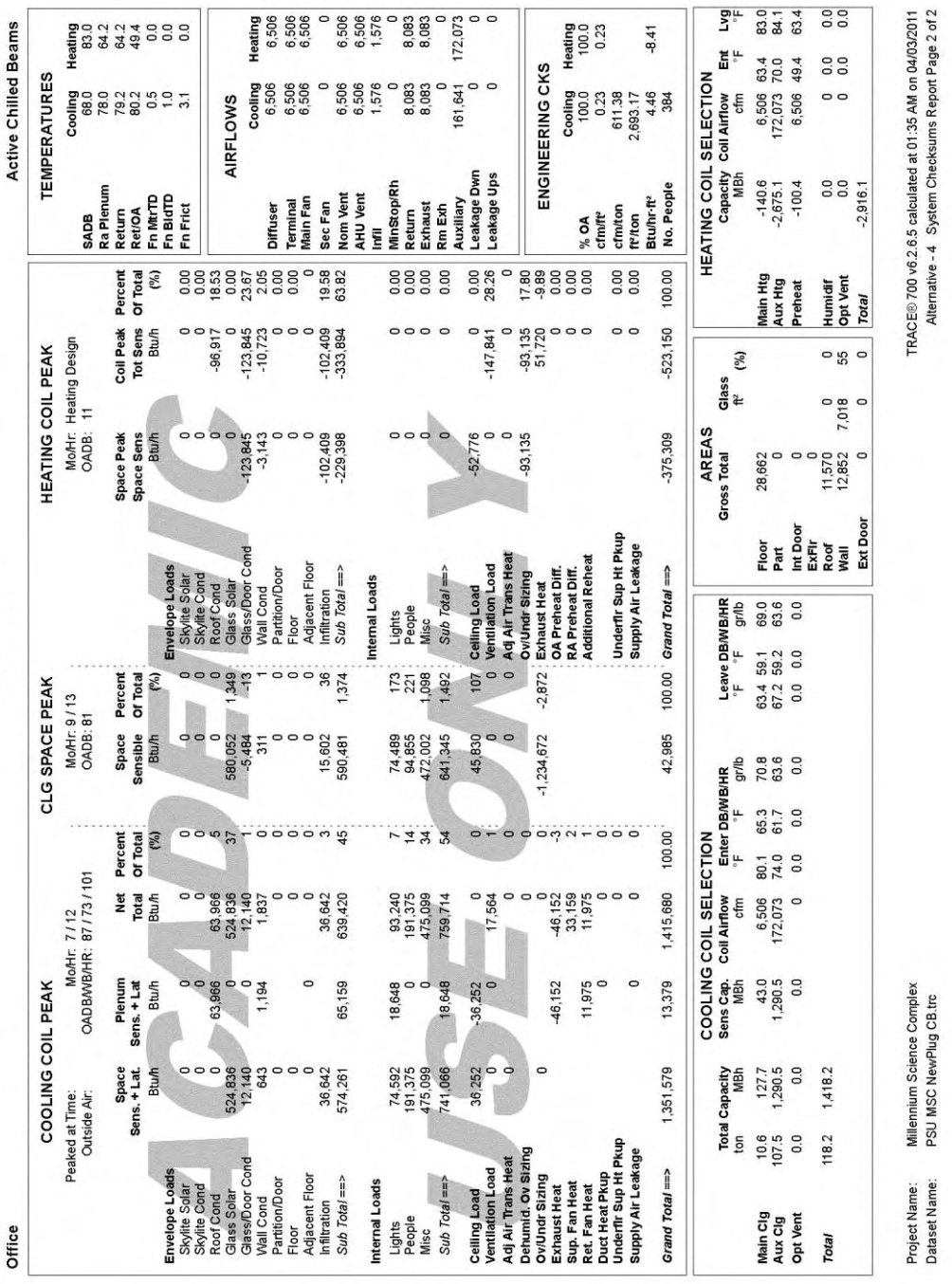
	Gross Total ft²	Glass ft²	Glass (%)
Floor	28,662		
Part	0		
Int Door	0		
ExFlr	0		
Roof	11,570	0	0
Wall	12,852	7,018	55
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-753.0	17,889	51.8	90.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-292.1	6,506	11.0	51.8
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-1,045.1			

Project Name: Millennium Science Complex
Dataset Name: PSU MSC NewPlug LoadsBASE.trc

Revised Plug Loads with Chilled Beams



System Checksums
By ACADEMIC

Office — Active Chilled Beams

COOLING COIL PEAK — Peaked at Time: 7 / 12 — Outside Air: OADB/WB/HR: 87 / 73 / 101

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	0	0	0	0
Skylite Cond	0	0	0	0
Roof Cond	0	63,966	63,966	5
Glass Solar	524,836	0	524,836	37
Glass/Door Cond	12,140	0	12,140	1
Wall Cond	643	1,194	1,837	0
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	36,642		36,642	3
Sub Total ==>	574,261	65,159	639,420	45
Internal Loads				
Lights	74,592	18,648	93,240	7
People	191,375	0	191,375	14
Misc	475,099	0	475,099	34
Sub Total ==>	741,066	18,648	759,714	54
Ceiling Load	36,252	-36,252	0	0
Ventilation Load	0	0	17,564	1
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	0		0	0
Exhaust Heat		-46,152	-46,152	-3
Sup. Fan Heat			33,159	2
Ret. Fan Heat		11,975	11,975	1
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	1,351,579	13,379	1,415,680	100.00

CLG SPACE PEAK — Mo/Hr: 9 / 13 — OADB: 81

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	0	0
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	580,052	1,349
Glass/Door Cond	-5,484	-13
Wall Cond	311	1
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	15,602	36
Sub Total ==>	590,481	1,374
Internal Loads		
Lights	74,489	173
People	94,855	221
Misc	472,002	1,098
Sub Total ==>	641,345	1,492
Ceiling Load	45,830	107
Ventilation Load	0	0
Adj Air Trans Heat	0	0
Ov/Undr Sizing		
Exhaust Heat	-1,234,672	-2,872
OA Preheat Diff.		
RA Preheat Diff.		
Additional Reheat		
Underflr Sup Ht Pkup		
Supply Air Leakage		
Grand Total ==>	42,985	100.00

HEATING COIL PEAK — Mo/Hr: Heating Design — OADB: 11

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-96,917	18.53
Glass Solar	0	0	0.00
Glass/Door Cond	-123,845	-123,845	23.67
Wall Cond	-3,143	-10,723	2.05
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-102,409	-102,409	19.58
Sub Total ==>	-229,398	-333,894	63.82
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-52,776	0	0.00
Ventilation Load	0	-147,841	28.26
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-93,135	-93,135	17.80
Exhaust Heat		51,720	-9.89
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-375,309	-523,150	100.00

TEMPERATURES

	Cooling	Heating
SADB	68.0	83.0
Ra Plenum	78.0	64.2
Return	79.2	64.2
Ret/OA	80.2	49.4
Fn Mtr/TD	0.5	0.0
Fn Bld/TD	1.0	0.0
Fn Frict	3.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	6,506	6,506
Terminal	6,506	6,506
Main Fan	6,506	6,506
Sec Fan	0	0
Nom Vent	6,506	6,506
AHU Vent	6,506	6,506
Infil	1,576	1,576
MinStop/Rh	0	0
Return	8,083	8,083
Exhaust	8,083	8,083
Rm Exh	0	0
Auxiliary	161,641	172,073
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	100.0	100.0
cfm/ft²	0.23	0.23
cfm/ton	611.38	
ft²/ton	2,693.17	
Btu/hr-ft²	4.46	-8.41
No. People	384	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB/WB/HR °F	°F	gr/lb	Leave DB/WB/HR °F	°F	gr/lb
Main Clg	10.6	127.7	43.0	6,506	80.1	65.3	70.8	63.4	59.1	69.0
Aux Clg	107.5	1,290.5	1,290.5	172,073	74.0	61.7	63.6	67.2	59.2	63.6
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	118.2	1,418.2								

AREAS

	Gross Total ft²	Glass ft²	(%)
Floor	28,662		
Part	0		
Int Door	0		
ExFlr	0		
Roof	11,570	0	0
Wall	12,852	7,018	55
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-140.6	6,506	63.4	83.0
Aux Htg	-2,675.1	172,073	70.0	84.1
Preheat	-100.4	6,506	49.4	63.4
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-2,916.1			

Project Name: Millennium Science Complex
Dataset Name: PSU MSC NewPlug CB.trc

TRACE® 700 v6.2.6.5 calculated at 01:35 AM on 04/03/2011
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ACADEMIC USE ONLY

System Checksums

By ACADEMIC

Lab

Variable Volume Reheat (30% Min Flow Default)

ACADEMIC USE ONLY

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 7 / 17
Outside Air: OADB/WB/HR: 89 / 72 / 92

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	0	0	0	0
Skylite Cond	0	0	0	0
Roof Cond	0	131,717	131,717	8
Glass Solar	149,434	0	149,434	9
Glass/Door Cond	13,205	0	13,205	1
Wall Cond	233	962	1,195	0
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	31,046		31,046	2
Sub Total ==>	193,918	132,679	326,597	19
Internal Loads				
Lights	51,257	13,180	64,437	4
People	121,283	0	121,283	7
Misc	1,370,518	0	1,370,518	80
Sub Total ==>	1,543,057	13,180	1,556,238	90
Ceiling Load	5,444	-5,444	0	0
Ventilation Load	-603,910	0	-603,910	-35
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	226,863		226,863	13
Exhaust Heat		-58,981	-58,981	-3
Sup. Fan Heat			276,843	16
Ret. Fan Heat		1	1	0
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	1,365,373	81,435	1,723,650	100.00

CLG SPACE PEAK

Mo/Hr: 12 / 15
OADB: 46

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	0	0
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	205,094	16
Glass/Door Cond	-23,888	-2
Wall Cond	-362	0
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	-26,431	-2
Sub Total ==>	154,412	12
Internal Loads		
Lights	51,257	4
People	60,641	5
Misc	1,370,518	107
Sub Total ==>	1,482,416	116
Ceiling Load	-1,383	0
Ventilation Load	-446,823	-35
Adj Air Trans Heat	0	0
Ov/Undr Sizing	89,025	7
Exhaust Heat		
OA Preheat Diff.		
RA Preheat Diff.		
Additional Reheat		
Underflr Sup Ht Pkup		
Supply Air Leakage		
Grand Total ==>	1,277,648	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 11

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-118,595	2.33
Glass Solar	0	0	0.00
Glass/Door Cond	-50,029	-50,029	0.98
Wall Cond	-720	-3,814	0.07
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-55,694	-55,694	1.09
Sub Total ==>	-106,444	-228,133	4.48
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-4,522	0	0.00
Ventilation Load	-372,353	-372,353	7.32
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-1,006,091	-1,006,091	19.78
Exhaust Heat		42,371	-0.83
OA Preheat Diff.		-2,153,899	42.34
RA Preheat Diff.		0	0.00
Additional Reheat		-1,369,509	26.92
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-1,489,410	-5,087,615	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	90.0
Ra Plenum	75.1	69.1
Return	75.1	69.1
Ret/OA	75.1	69.1
Fn MtrTD	0.4	0.0
Fn BldTD	1.0	0.0
Fn Frict	2.9	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	61,071	67,633
Terminal	61,071	67,633
Main Fan	61,071	67,633
Sec Fan	0	0
Nom Vent	67,633	67,633
AHU Vent	67,633	67,633
Infil	857	857
MinStop/Rh	67,633	67,633
Return	109,663	116,225
Exhaust	48,592	48,592
Rm Exh	19,899	19,899
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	110.7	100.0
cfm/ft²	3.92	4.34
cfm/ton	165.22	
ft²/ton	42.17	
Btu/hr·ft²	284.57	-325.97
No. People	303	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	143.6	1,723.7	1,580.0	58,397	75.1	62.1	63.6	50.7	50.6	55.5
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	226.0	2,712.0	1,881.3	67,633	82.0	68.1	82.4	56.8	55.6	65.0
Total	369.6	4,435.6								

AREAS

	Gross Total ft²	Glass ft²	Glass (%)
Floor	15,587		
Part	0		
Int Door	0		
ExFlr	0		
Roof	12,965	0	0
Wall	5,490	3,539	64
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-2,927.1	67,633	50.7	90.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	-2,153.9	67,633	39.1	68.0
Total	-5,081.0			

Project Name: Millennium Science Complex
Dataset Name: PSU MSC NewPlug_DSF_CB.trc

TRACE® 700 v6.2.6.5 calculated at 01:01 AM on 04/03/2011
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System Checksums

By ACADEMIC

Office — **Active Chilled Beams**

ACADEMIC USE ONLY

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 7 / 12
Outside Air: OADB/WB/HR: 87 / 73 / 101

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	0	0	0	0
Skylite Cond	0	0	0	0
Roof Cond	0	67,287	67,287	5
Glass Solar	431,462	0	431,462	33
Glass/Door Cond	8,663	0	8,663	1
Wall Cond	704	1,309	2,012	0
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	38,580		38,580	3
Sub Total ==>	479,409	68,596	548,005	41
Internal Loads				
Lights	74,592	18,648	93,240	7
People	191,375	0	191,375	14
Misc	475,099	0	475,099	36
Sub Total ==>	741,066	18,648	759,714	57
Ceiling Load	37,026	-37,026	0	0
Ventilation Load	0	0	20,681	2
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	0		0	0
Exhaust Heat		-47,002	-47,002	-4
Sup. Fan Heat			33,159	2
Ret. Fan Heat		11,975	11,975	1
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	1,257,502	15,190	1,326,532	100.00

CLG SPACE PEAK

Mo/Hr: 9 / 12
OADB: 78

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	0	0
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	489,038	1,138
Glass/Door Cond	-7,325	-17
Wall Cond	309	1
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	15,653	36
Sub Total ==>	497,675	1,158
Internal Loads		
Lights	74,489	173
People	94,855	221
Misc	472,002	1,098
Sub Total ==>	641,345	1,492
Ceiling Load	45,716	106
Ventilation Load	0	0
Adj Air Trans Heat	0	0
Ov/Undr Sizing	-1,141,751	-2,656
Exhaust Heat		
Sup. Fan Heat		
Ret. Fan Heat		
Duct Heat Pkup		
Underflr Sup Ht Pkup		
Supply Air Leakage		
Grand Total ==>	42,985	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 11

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-96,917	19.51
Glass Solar	0	0	0.00
Glass/Door Cond	-97,498	-97,498	19.63
Wall Cond	-3,143	-10,723	2.16
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-102,409	-102,409	20.61
Sub Total ==>	-203,050	-307,546	61.91
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-52,776	0	0.00
Ventilation Load	0	-147,841	29.76
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-93,135	-93,135	18.75
Exhaust Heat		51,720	-10.41
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-348,961	-496,802	100.00

TEMPERATURES

	Cooling	Heating
SADB	68.0	83.0
Ra Plenum	78.1	64.2
Return	79.3	64.2
Ret/OA	80.2	49.4
Fn MtrTD	0.5	0.0
Fn BldTD	1.0	0.0
Fn Frict	3.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	6,506	6,506
Terminal	6,506	6,506
Main Fan	6,506	6,506
Sec Fan	0	0
Nom Vent	6,506	6,506
AHU Vent	6,506	6,506
Infil	1,576	1,576
MinStop/Rh	0	0
Return	8,083	8,083
Exhaust	8,083	8,083
Rm Exh	0	0
Auxiliary	149,674	159,673
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	100.0	100.0
cfm/ft²	0.23	0.23
cfm/ton	595.36	
ft²/ton	2,622.61	
Btu/hr·ft²	4.58	-8.41
No. People	384	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	10.9	131.1	43.0	6,506	80.2	65.4	71.3	63.4	59.1	69.0
Aux Clg	99.6	1,195.5	1,195.5	159,673	74.0	61.7	63.6	67.2	59.2	63.6
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	110.6	1,326.7								

AREAS

	Gross Total ft²	Glass ft²	Glass (%)
Floor	28,662		
Part	0		
Int Door	0		
ExFlr	0		
Roof	11,570	0	0
Wall	12,852	7,018	55
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-140.6	6,506	63.4	83.0
Aux Htg	-2,473.8	159,673	70.0	84.1
Preheat	-100.4	6,506	49.4	63.4
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-2,714.8			

Project Name: Millennium Science Complex
Dataset Name: PSU MSC NewPlug_DSF_CB.trc

The Building Stimulus
Millenium Science Complex
University Park, PA
Paul Kuehnel Mike Lucas Sara Pace Jon Brangan
Building Stimulus

Penn State Utility Data

Utility Charge Rates

Some Departments pay the cost of their utility usage to OPP. These are Departments such as Housing and Food Service and Athletics. The following chart shows the billable rates charged as well as our avoidable costs that are used for Energy Savings Projects for FY 09-10:

Utility	Avoided Costs	Billable Rate	Units	Comments
Electricity	$1.09	$1.09	KW	5 sub-stations only, 1st half
	$0.07781	$0.09648	KWH	5 sub-stations only, 1st half
Electricity	$1.09	$1.09	KW	5 sub-stations only, 2nd half
	$0.07517	$0.09481	KWH	5 sub-stations only, 2nd half
Natural Gas	$8.66	$9.83	MCF	Blended Rate
Steam	$9.85	$21.65	1000 pounds	
Water & Wastewater	$3.32	$8.39	1000 gallons	
Chilled Water	$0.22	$0.22	Ton-Hour	Estimated Cost

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ALTOONA BLAIR CO ARPT, PA, USA

WMO#: 725126

Lat: 40.30N Long: 78.32W Elev: 1470 StdP: 13.93 Time Zone: -5.00 (NAE) Period: 82-06 WBAN: 14736

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB	
			99.6%			99%			0.4%		1%			
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD
1	4.7	9.6	-6.4	4.1	7.5	-1.7	5.3	11.9	27.5	29.4	24.9	27.1	8.9	260

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
7	19.3	88.5	72.0	85.7	70.7	83.0	69.6	74.7	83.9	73.2	82.0	71.6	79.8	8.0	280

Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Hours
0.4%			1%			2%			0.4%		1%		2%		8 to 4 &
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	55/69
72.0	125.0	79.6	70.3	118.0	77.7	69.1	112.9	76.2	39.1	83.9	37.6	82.0	36.3	79.9	731

Extreme Annual Design Conditions

Extreme Annual WS			Extreme Max WB	Extreme Annual DB				n-Year Return Period Values of Extreme DB							
				Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
21.9	18.8	17.2	82.4	-2.6	92.5	8.1	3.5	-8.4	95.0	-13.2	97.1	-17.7	99.1	-23.6	101.6

Monthly Climatic Design Conditions

			Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperatures, Degree-Days and Degree-Hours		Tavg	50.4	27.9	30.6	38.1	49.5	58.8	67.5	71.7	70.0	62.6	52.2	42.6	31.9
		Sd		11.40	9.59	10.63	9.41	8.00	6.47	5.14	5.51	7.30	8.33	9.28	10.28
		HDD50	2679	690	546	398	121	15	0	0	0	4	76	259	570
		HDD65	5959	1150	964	837	472	226	50	7	19	130	404	673	1027
		CDD50	2810	4	2	28	105	287	526	672	619	381	143	36	7
		CDD65	617	0	0	2	6	33	126	214	173	56	7	0	0
		CDH74	4899	0	0	16	76	336	1003	1711	1299	417	40	1	0
		CDH80	1333	0	0	2	10	67	260	524	375	94	1	0	0
Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4%	DB		61.1	61.4	75.6	81.4	85.5	89.8	92.3	91.5	87.4	78.5	70.7	64.4
		MCWB		55.9	50.0	59.6	63.6	68.3	72.5	73.0	73.5	69.5	64.5	58.6	56.9
	2%	DB		55.1	53.8	67.5	75.5	81.6	86.0	88.8	87.5	82.4	74.2	65.0	57.8
		MCWB		49.5	45.7	54.8	59.4	65.7	70.6	72.8	71.6	67.8	62.6	55.3	52.0
	5%	DB		48.4	48.6	60.8	70.2	78.0	83.1	85.7	84.0	78.9	70.2	61.1	51.7
		MCWB		43.2	41.9	51.2	57.2	64.0	69.5	71.5	70.4	66.3	60.5	54.1	46.1
	10%	DB		42.5	44.4	54.4	65.1	73.3	80.2	82.4	81.2	75.2	66.2	57.0	45.7
		MCWB		37.8	39.3	46.6	54.0	61.5	68.0	70.4	69.2	65.5	58.5	51.2	40.8
Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures	0.4%	WB		57.3	52.5	61.6	65.7	71.4	76.1	77.4	76.2	73.2	68.2	61.4	58.5
		MCDB		60.2	58.5	72.5	75.9	81.9	84.2	87.2	85.9	81.4	75.3	66.5	64.2
	2%	WB		51.0	46.8	56.5	62.0	68.5	73.4	74.9	74.1	70.7	65.2	58.4	53.5
		MCDB		54.4	52.2	64.8	71.7	77.8	81.7	84.4	83.5	78.0	70.2	63.1	57.6
	5%	WB		43.5	43.1	51.6	59.1	66.1	71.4	73.3	72.5	68.9	62.4	55.4	46.9
		MCDB		47.4	47.8	59.5	68.0	74.7	79.6	82.3	81.0	75.2	68.2	59.3	50.5
	10%	WB		38.0	39.5	47.1	55.9	63.6	69.8	71.8	70.9	67.2	59.5	51.7	41.6
		MCDB		42.3	43.8	53.9	64.0	71.2	77.6	80.0	78.4	72.8	65.4	56.6	45.8
Mean Daily Temperature Range		MDBR		12.9	14.5	16.7	19.5	19.6	19.2	19.3	19.6	19.3	18.3	14.9	13.0
	5% DB	MCDBR		18.8	21.3	25.0	26.0	25.5	22.6	22.8	23.3	24.0	23.7	20.6	19.3
		MCWBR		15.1	15.8	15.9	15.0	12.7	10.9	10.1	10.7	12.0	13.7	14.4	15.1
	5% WB	MCDBR		17.2	18.8	22.5	22.9	21.6	19.6	19.0	19.8	18.1	19.6	17.6	17.9
		MCWBR		14.9	14.9	15.8	14.9	12.3	10.7	9.6	10.3	10.6	12.8	14.8	15.6
Clear Sky Solar Irradiance		taub		0.301	0.324	0.361	0.361	0.415	0.473	0.482	0.486	0.392	0.349	0.318	0.300
		taud		2.397	2.247	2.155	2.248	2.059	1.910	1.913	1.879	2.215	2.330	2.438	2.472
		Ebn,noon		274	281	281	289	274	258	254	248	268	269	265	265
		Edh,noon		29	37	44	43	52	61	60	60	41	34	28	26

CDD*n* Cooling degree-days base n°F, °F-day
CDH*n* Cooling degree-hours base n°F, °F-hour
DB Dry bulb temperature, °F
DP Dew point temperature, °F
Ebn,noon } Clear sky beam normal and diffuse hori-
Edh,noon } zontal irradiances at solar noon, Btu/h/ft2
Elev Elevation, ft
Enth Enthalpy, Btu/lb
HDD*n* Heating degree-days base n°F, °F-day
Hours 8/4 & 55/69 Number of hours between 8 a.m. and 4 p.m with DB between 55 and 69 °F
HR Humidity ratio, grains of moisture per lb of dry air
Lat Latitude, °
Long Longitude, °
MCDB Mean coincident dry bulb temperature, °F
MCDBR Mean coincident dry bulb temp. range, °F
MCDP Mean coincident dew point temperature, °F
MCWB Mean coincident wet bulb temperature, °F
MCWBR Mean coincident wet bulb temp. range, °F
MCWS Mean coincident wind speed, mph
MDBR Mean dry bulb temp. range, °F
PCWD Prevailing coincident wind direction, °, 0 = North, 90 = East
Period Years used to calculate the design conditions
Sd Standard deviation of daily average temperature, °F
StdP Standard pressure at station elevation, psi
taub Clear sky optical depth for beam irradiance
taud Clear sky optical depth for diffuse irradiance
Tavg Average temperature, °F
Time Zone Hours ahead or behind UTC, and time zone code
WB Wet bulb temperature, °F
WBAN Weather Bureau Army Navy number
WMO# World Meteorological Organization number
WS Wind speed, mph

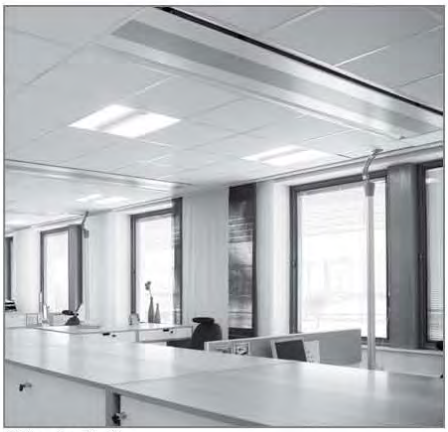
Chilled Beam Manufacturers

AA CHILLED BEAMS

AHC | Active, Adaptable, High-Capacity

KRUEGER
Excellence in Air Distribution

AHC



Office Application

Patient Care Application

Introduction: AHC

Designed with adaptability in mind, the AHC incorporates a manual or motorized VAV valve which allows additional air into the space as needed to handle varying room loads. Additionally, the AHC is capable of higher capacity then its ADC counterpart.

MODEL

AHC - Adaptable / Adjustable Active Chilled Beam

FEATURES

- Combined cooling, heating, and supply air unit for flush installation within a suspended ceiling.
- Well suited for spaces with high cooling loads, low humidity load, and variable ventilation requirements.
- Ideal solution for applications where high-quality environmental conditions, demand-based ventilation, and individual room control are appreciated.
- Individually adjustable velocity conditions with *Krueger by Halton* Velocity Control (HVC).
- Built-in flexibility of operation for partition wall relocations with *Krueger by Halton* Velocity Control.
- Individually adjustable supply airflow rate for changes in space layout using *Krueger by Halton* Air Quality (HAQ) control.
- Demand based control of supply airflow rate for efficient use of energy in constant-pressure ductwork zone applications; when the airflow rate changes have no effect on the coil cooling/heating capacities of the chilled beam.
- Enhanced life cycle performance with optimized low air and water flow rates.

OPTIONS

- Combined cooling and heating coil, or model with electric heating foil.
- Manual or motorized *Krueger by Halton* Air Quality (HAQ).
- Integrated exhaust valve.
- Direct light fittings.
- Adapted to Dampa ceiling installation.
- Flush mounted T5 luminaires integrated with the chilled beam. Luminaires are equipped with high-quality optics suitable for working using computer monitors.

FINISHES

- Standard finish is Polyester Painted White (RAL 9010).
- Custom colors available.

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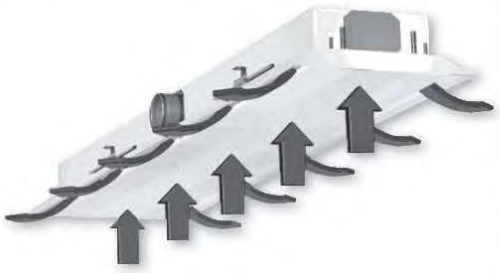
AHC Application & Installation



FUNCTION

The AHC chilled beam is designed to be installed flush with a suspended ceiling. The primary supply air enters the plenum of the active chilled beam. From there it is diffused into the room through nozzles and the diffuser of the HAQ- control. Supply slots located at the bottom of the beam.

The supply air nozzle jets efficiently induce ambient room air. The induced air flows through the heat exchanger, where it is either cooled or heated. The supply air jet is directed horizontally along the ceiling surface.

AIR QUALITY AND TEMPERATURE CONTROLS

The cooling and heating capacities of the chilled beam are controlled by regulating the water flow rate according to the control signal of the room temperature controller.

Air quality control for a room space can be arranged using, e.g., a CO_2 sensor when room air temperature is controlled separately by regulating the water flow rate. Alternatively, a temperature sensor can be used for air quality control, with the airflow rate modulated in the first sequence and, if the temperature exceeds the set point, the water valve starting to open in the second sequence.

In heating mode, it is recommended that the temperature difference between the jet outlet and room air would not be greater than 6°F. The inlet water temperature of the heat exchanger should not be higher than 95°F. Optimal heating performance requires an appropriate primary airflow rate. Thus, the air handling unit shall operate during heating periods to ensure proper heating performance.

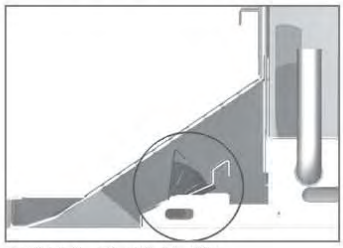
VELOCITY CONTROL IN OCCUPIED ZONE

Krueger by Halton Velocity Control (HVC) is used for adjusting room air velocity conditions either when room layout is changed (e.g., in cases where the partition wall is located near the chilled beam) or when local, individual velocity conditions need to be altered. HVC adjustment has an impact on the induced room air flow through the heat exchanger, and therefore it either increases or decreases both the velocities in the occupied zone and the cooling/heating capacity of the chilled beam.

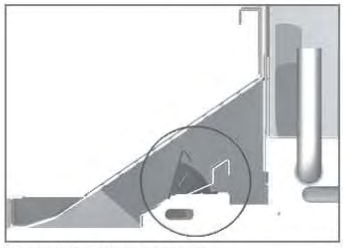
Krueger by Halton Velocity Control uses manual velocity adjustment with three settings:

1 = Throttle Position
2 = Normal Position
3 = Boost Position

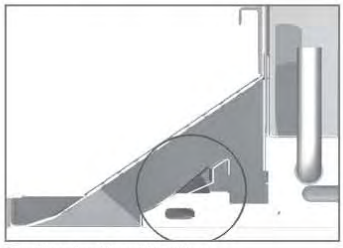
The HVC damper is divided into sections to enable the adjustment of conditions in different parts of the occupied zone. It is recommended to design the chilled beam in the normal position in order to allow both throttle and boost functions during the building's life cycle.



Position 1 = Throttle Position



Position 2 = Normal Position



Position 3 = Boost Position

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AA CHILLED BEAMS

AHC | Active, Adaptable, High-Capacity

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Excellence in Air Distribution

AHC Application & Installation

AIRFLOW RATE CONTROL

The supply airflow of the chilled beam nozzle jets are dependent on effective length and static chamber pressure, which can be adjusted e.g. using separate airflow adjustment damper.

Optional *Krueger by Halton* Air Quality control (HAQ) is used for adjusting and/or controlling the outdoor airflow rate in a room space. The airflow rate is dependent on the opening position of the control damper and the static chamber pressure.

Airflow rate adjustment is needed when the use of the space is changed and there is need to adapt the supply airflows. Airflow rate can be adjusted either manually or automatically, on the basis of demand, with a motorized control damper.

A chilled beam equipped with HAQ manual airflow rate adjustment can be retrofitted to motorized version for demand based ventilation.

It is recommended that chilled beams for demand based airflows should be connected to constant pressure ductwork zone, when

* the HAQ adjustment has no impact on nozzle jet airflow.
* the HAQ adjustment has no impact on either the coil cooling or heating capacities.
* the HAQ airflow control has not significant impact to ductwork pressure conditions and respectively to airflow rates of other chilled beams in the same ductwork zone.

The appearance of different units - with constant, adjustable, or variable airflow - is identical.

The *Krueger by Halton* Air Quality control unit's position and the selection of chilled beam nozzle size allow adjustment of the primary airflow rate in the space. The separate airflow adjustment damper installed in the duct branch is used for balancing the airflow in the ductwork.

When a motorized air quality control (HAQ) unit is used, the maximum and minimum airflow rates are adjusted with the stroke limiters of the damper.

The primary airflow rate of each beam is adjusted using the *Krueger by Halton* Air Quality control unit during the installation and commissioning. There is no need to change or plug nozzles of the chilled beam.

Duct installation of the exhaust valve.

INSTALLATION

The AHC active chilled beam is especially suitable for ceiling mounting running parallel to exterior wall of the room. When selecting of the chilled beam orientation, the location of the supply air and water circuit connections are taken into account.

The chilled beam can be attached directly to the ceiling surface (H1 = 9") or suspended using threaded drop rods (5/16"). Each beam is equipped with movable brackets fixed to both sides of the beam. It is recommended that the brackets be positioned one quarter of the unit length (L/4) away from the end of the beam.

Install the main pipelines of the cooling and heating water circuits above the level of the chilled beam in order to enable venting of the pipework.

The duct connection is at the same end of the chilled beam as the pipe connections. Relocation of the duct connection to either side of the chilled beam can be done easily on-site by using a screw driver.

An optional exhaust valve is installed in the front. Only left and right supply air duct connections are possible. By choosing the exhaust valve option, the active length is total length (L) - 16".

Duct installation of the exhaust valve.

Replacing manual HAQ with a motorized HAQ.

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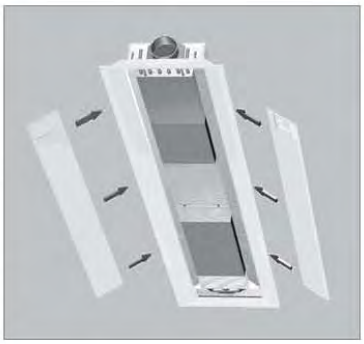
AHC Application & Installation

ELECTRIC HEATING INSTALLATION AND SAFETY INSTRUCTIONS
Final circuit design criteria (the more restrictive must be applied):
The total power of a single final circuit shall not exceed 2000 W.
The total number of chilled beam units in a single final circuit shall not exceed 6 pieces.

Electric Connections
Beams shall be connected to protective earth, PE.
The final circuit shall include a fuse, max. 10 A.
The power supply shall be protected with a ground fault circuit interrupter, 30 mA.

Operation:
The electric heating power supply shall be switched off if there is no air flow through the chilled beam (for example, if the air handling unit is switched off or the fire damper is closed).

Electric Heating Foil
The luminaires within a single chilled beam are interconnected in the factory as standard. The power supply is connected using a plug connector (Enstonet) located at the connection end of the beam. An extra cable with or without plug is delivered upon request. Plug types are standard Schuko, Enstonet and Wieland.



ADJUSTMENT

Cooling
The recommended cooling water mass flow rate is 0.32 - 1.58 gpm, resulting in a temperature rise of 2 - 8°F in the heat exchanger. To avoid condensation, the recommended inlet water temperature of the heat exchanger is 57 - 61°F.

Heating
The recommended heating water mass flow rate is 0.16 - 0.63 gpm, resulting in a temperature drop of 10 - 30°F in the heat exchanger. The maximum temperature of the inlet water for the heat exchanger is 95°F.

Balancing and Control of Water Flow Rates
Balance the water flow rates of the chilled beam with adjustment valves installed on the outlet side of the cooling and heating water loops. The cooling capacity and heating capacity of the chilled beam are controlled by regulating the water mass flow rate. The water mass flow rate can be controlled by using an ON/OFF valve or a two- or three-way proportional valve.

Adjustment of Supply Airflow Rate
Connect a manometer in the measurement tap and measure the static pressure in the chilled beam. The airflow rate is calculated according to the formula below.

Total Air Flow Rate qv
qv = qv1 + qv2

Where
qv = Total Airflow Rate, l/s or m³/h
qv1 = Nozzle Jet Airflow Rate, l/s or m³/h
qv2 = Air Quality Control Diffuser Airflow Rate l/s or m³/h

Nozzle Jet Airflow Rate qv1

$$q_v = k * l_{eff} * \sqrt{\Delta p_m}$$

l_{eff} = Length of the Coil, m
Δpm = Measured Static Chamber Pressure, Pa

k (l/s)	k (m³/h)
1.38	4.97

Air Quality Control Diffuser Airflow Rate qv2

$$q_v = a * k * \sqrt{\Delta p_m}$$

a = HAQ Position
Δpm = Measured Static Chamber Pressure, Pa

k (l/s)	k (m³/h)
0.17	0.61

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AHC Application & Installation

Adjustment of the Airflow Range in Constant Airflow Applications

Define the position of HAQ in millimeters that correspond to airflow rate at the actual chamber pressure level. Adjustment of HAQ is done manually with the help of position scale by adjusting the opening of the unit. It is possible to verify the opening in millimeters on the position scale.

In order to ensure accurate adjustment it is recommended to adjust HAQ-position and in the same time read the targeted chamber pressure using the manometer. It is also possible to remove the HAQ-unit from the frame by opening two knurled-head screws (4) for the adjustment.

Adjustment of the Airflow Range in Variable Airflow Applications

1. Release of the actuator
2. Restriction of the max. opening
3. Restriction of the min. opening

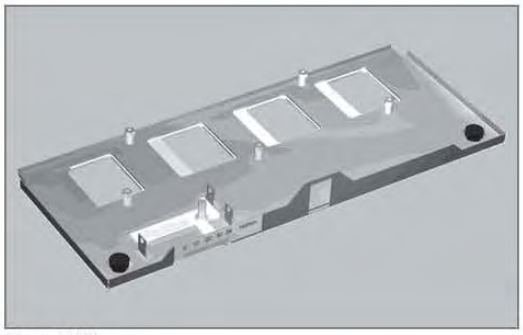
Switch-off the power supply of the actuator. Disengage the actuator gear into manual override position by releasing the knob. Define the maximum and minimum positions, in millimeters that correspond to maximum and minimum airflow rates at the actual chamber pressure level. The maximum and minimum positions are adjusted with two knurled-head screws (2,3). It is possible to verify the opening in millimeters on the position scale.

Switch on the power supply (24 VAC) of the actuator. The actuator calibrates the min. and max. positions automatically according to the set limits. The actuator can be controlled from this point on by using a 0 - 10VDC control signal (0 VDC=min. position, 10 VDC = max. position). It is also possible to remove the HAQ-unit from the frame by opening two knurled-head screws (4) for the adjustment.

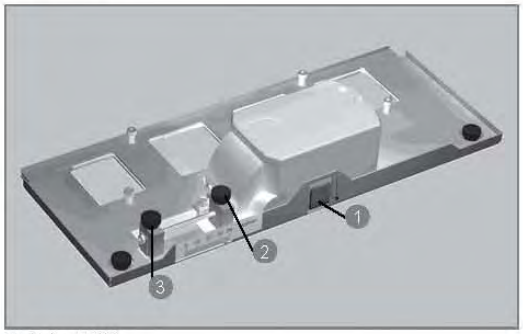
Adjustment of Exhaust Airflow Rate

The valve is adjusted by rotating the central cone. Measure (A) the opening position (in mm) of the central cone. There is a special tool available from Krueger for accurate opening position measurement. Set a pressure probe inside the valve, and measure the differential pressure with a manometer. The airflow rate is calculated using the formula below, using k-factors presented in the table. After the adjustment, lock the central cone with the locking nut.

$$q_v = k * \sqrt{\Delta p_m}$$



Manual HAQ



Motorized HAQ

URH125	
A	k
-15	0, 65
-12	0, 92
-9	1, 22
-6	1, 53
-3	1, 84
0	2, 17
3	2, 52
6	2, 83
9	3, 14
12	3, 46
15	3, 77

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AHC Application & Installation

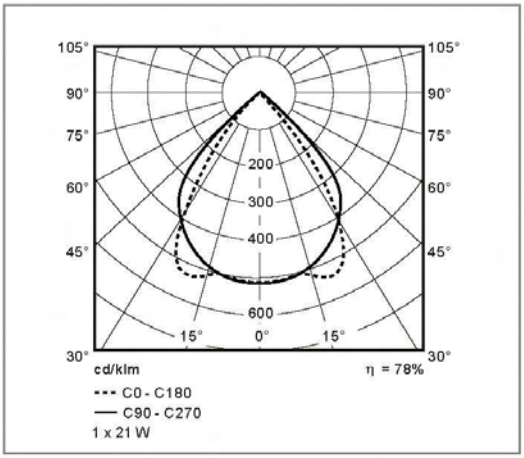
LIGHTING

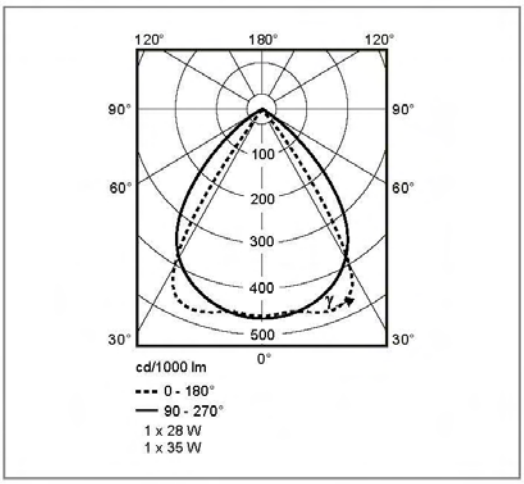
The chilled beams can be optionally equipped with luminaires. The luminaires have fluorescent tubes and optics based on T5 technology providing good lighting conditions for office work performed using computer monitors. The luminaires (21 W, 28 W or 35 W) are integrated into the bottom panel of the beam. The chilled beam can be equipped with up to 2 pieces of direct light fittings, depending on the beam length and luminaire type.

A connecting cable with a plug can be delivered factory-installed upon request. The luminaires are delivered with either a standard or a dimmable electronic ballast.

NOTE: UL listing not available on lighted models.

LIGHTING DISTRIBUTION CURVES





LUMINAIRE PROPERTIES

Lamp T5	W	21	28	35
Lamps / Luminaire	pcs	1	1	1
Light Flux	lm	1900	2600	3300
Light Output Ratio	-	0.74	0.7	0.72
Ballast	-	Electronic	Electronic	Electronic

ALTERNATIVE NUMBERS OF LUMINAIRES IN CHILLED BEAMS

Luminaire Type	W	21	28	35
Luminaire Nominal Length	mm	900	1200	1500
Reflector Length	mm	878	1178	1478
Beam Nominal Length				
One-piece	1200	-	-	-
	1300	-	-	-
	1400	1	-	-
	1500	1	-	-
	1600	1	-	-
	1700	-	1	-
	1720	-	1	-
	1800	-	1	-
	1900	-	1	-
	2000	-	-	1
	2100	-	-	1
	2200	-	-	1
	2300	-	-	1
	2400	-	-	1
Two-piece	2500	-	-	-
	2600	-	-	-
	2700	2	-	-
	2800	2	-	-
	2900	2	-	-
	3000	2	-	-
	3100	2	-	-
	3200	2	-	-
	3300	-	2	-
	3400	-	2	-
	3500	-	2	-
	3600	-	2	-

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AA CHILLED BEAMS

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AHC Service & Maintenance

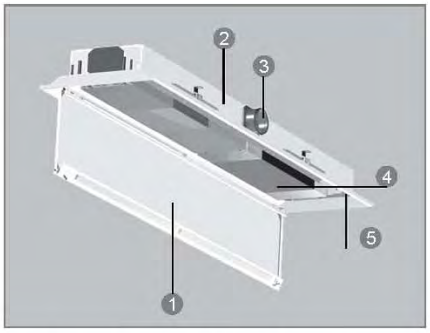
SERVICING

Open the front panel of the supply air plenum, the ductwork, and the heat exchanger. In beams longer than 96", the front panel can be opened in two sections. Clean the supply air plenum and finned coils of the heat exchanger with a vacuum cleaner, taking care not to damage the finned coils. Clean the front panel and, if required, the side plates, using a damp cloth.

The *Krueger by Halton* Air Quality control unit (HAQ) is removable for chamber cleaning. Unscrew the screws for removing the HAQ.

The fluorescent lamp of the luminaire can be changed and the reflector cleaned from below the beam, by removing the luminaire grid.

When opening the front panel, pay attention to the cables of units equipped with integrated light fittings.

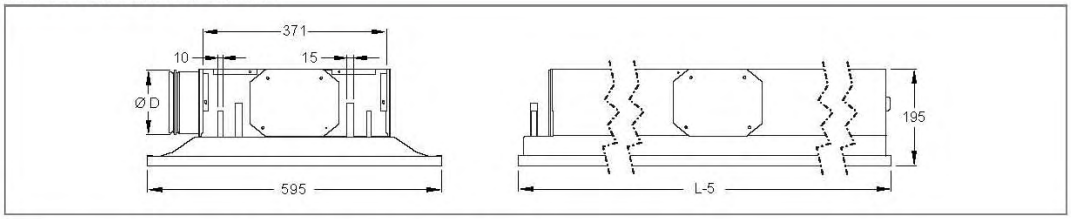


Code	Description
1	Front Panel
2	Side Plate
3	Supply Air Connection

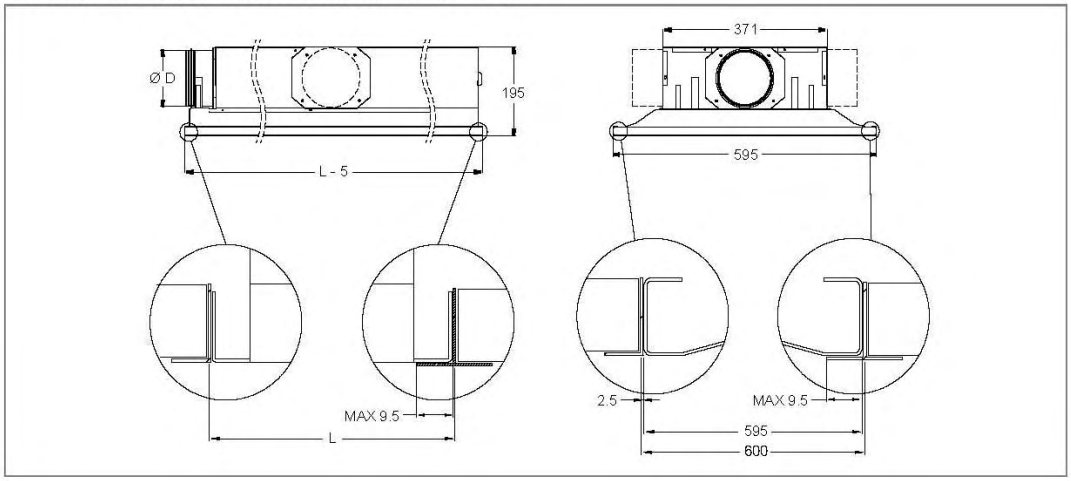
Code	Description
4	Heat Exchanger
5	Access Panel

AHC Dimensional Information

AHC FRONT AND SIDE VIEWS



AHC SUSPENDED CEILING INTEGRATION INSTALLATION



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CHILLED BEAMS AA

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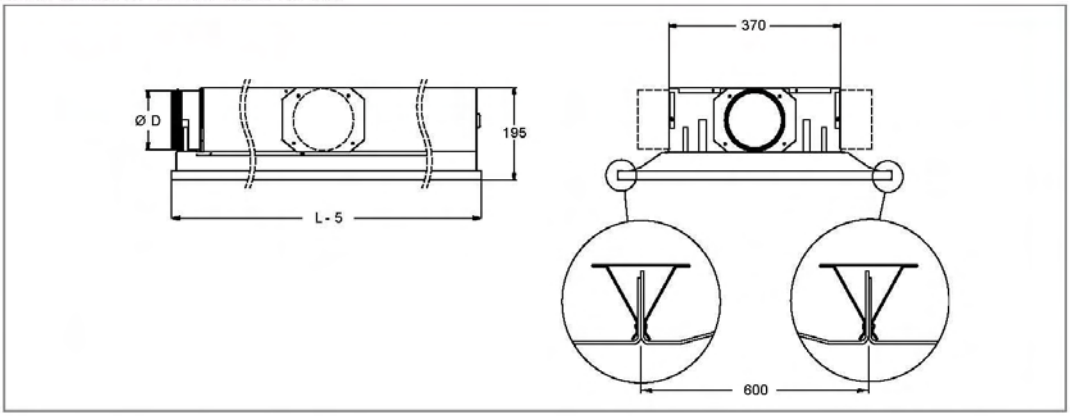
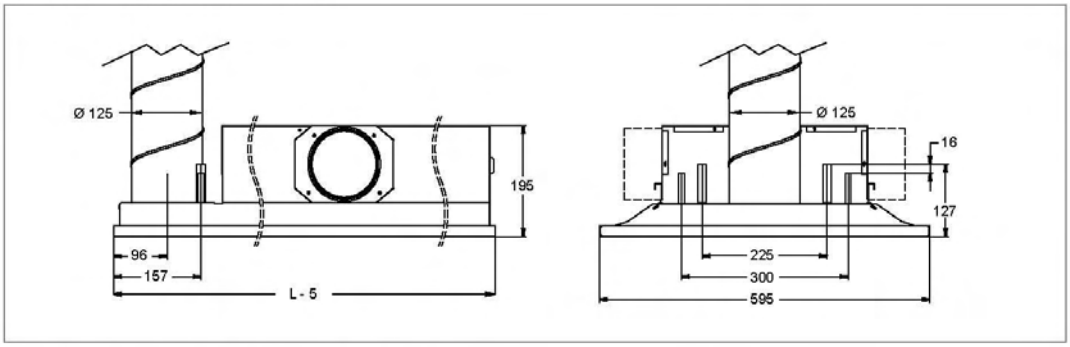
AHC Dimensional Information

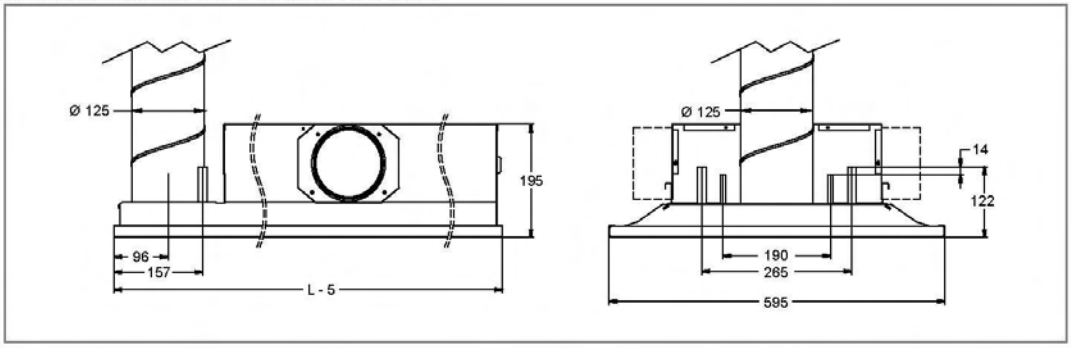
AHC DAMPA CEILING INSTALLATION



AHC INSTALLATION WITH EXHAUST



AHC INSTALLATION WITH EXHAUST AND LIGHT



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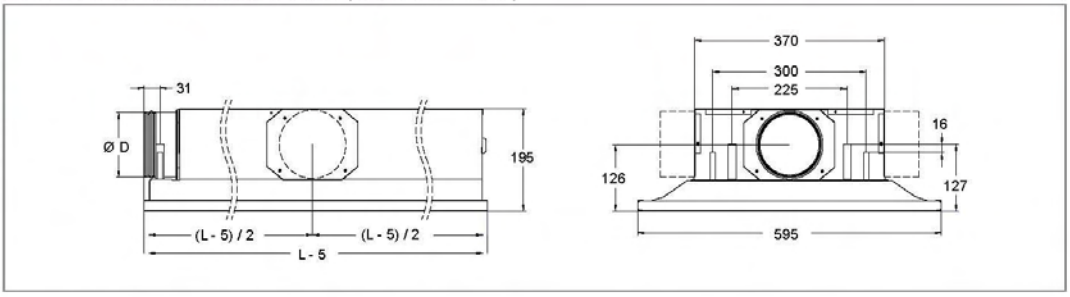
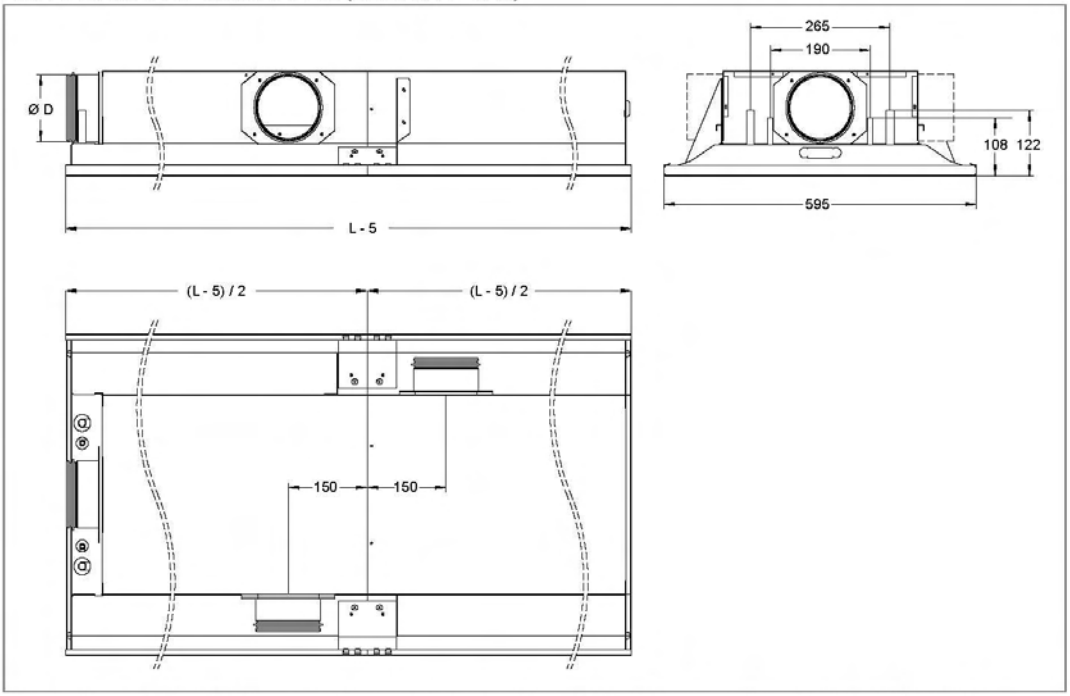
AHC Dimensional Information

AHC PIPE AND DUCT CONNECTIONS (SIZES 1200 - 2400)



AHC PIPE AND DUCT CONNECTIONS (SIZES 2500 - 3600)



NOTE: All dimensions in inches. Cooling/heating water pipe connections are copper 1/2" and 3/8" with wall thickness of 0.04". The maximum chilled/hot water circuit operating pressure is 150 psi. The supply air duct connection is D5 inches. MSM damper removable through access panel. Krueger by Halton Air Quality Control Damper (HAQ) takes 12" of the total beam length, decreasing the effective length.

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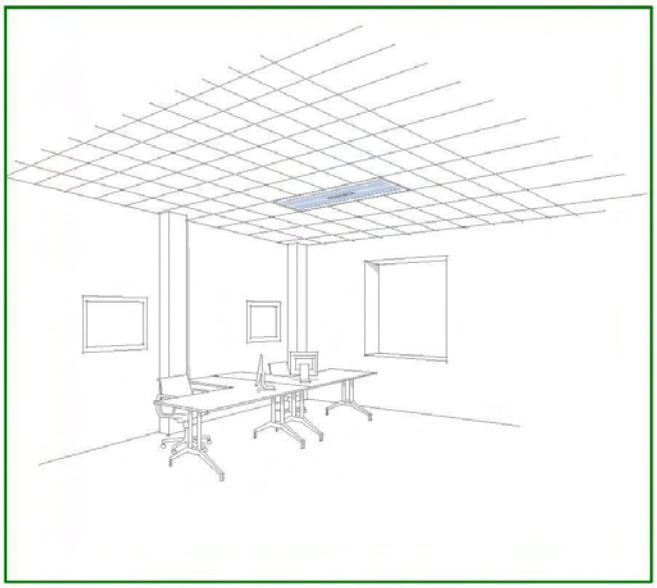
Chilled beam Flexicool® IQID



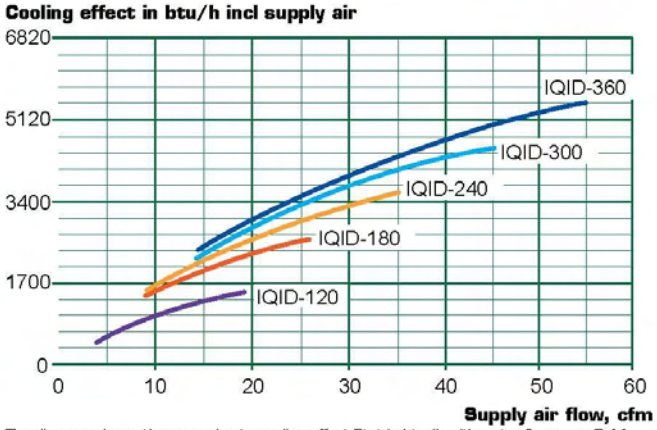
Functions

- FPC
- High air flow
- Controls
- Lighting
- Comfort control
- Heating
- Sprinkler

The chilled beam Flexicool® IQID is an integrated system for ventilation, cooling and heating, fulfilling most needs for indoor climate. The IQID chilled beam is a very flexible chilled beam that is available as a basic model, but can also be equipped with a number of functions to provide a multifunctional chilled beam. The following functions are available for IQID: heat, comfort setting, Flow Pattern Control (FPC air deflector), function for high air flow, control and regulation equipment, lighting and provision for a sprinkler system. These various functions are described in separate parts in the catalogue.
IQID has a covered upper side and is intended for flush-mounting in false ceilings and has dimensions adapted to a false ceiling module of 23.62 inch

Quick Selection

Cooling effect in btu/h incl supply air



The diagram shows the approximate cooling effect Ptot in btu/h with water flow qw = 0.11 cfm, temperature difference between room air and supply air Δt= 46.4 °F, pressure drop 0.28 inWG on the air side and max. sound pressure level LA10 = 30 dB(A).

Product Facts

- IQID chilled beam for flushmounting in false ceilings
- Very flexible - available in a wide range of executions from basic to multifunctional
- Adapted for standard 23.62 inch false ceiling module
- Fastening brackets for rapid and simple installation - lift up - snap in place
- Available with the following functions: heating, comfort control, Flow Pattern Control (FPC air deflector), function for high air flow, control equipment, lighting and provision for a sprinkler system

Product code example

Covered chilled beam
IQID-240-1-1-01, standard.

Specifications are subject of alteration without further notice.

Application and function, material

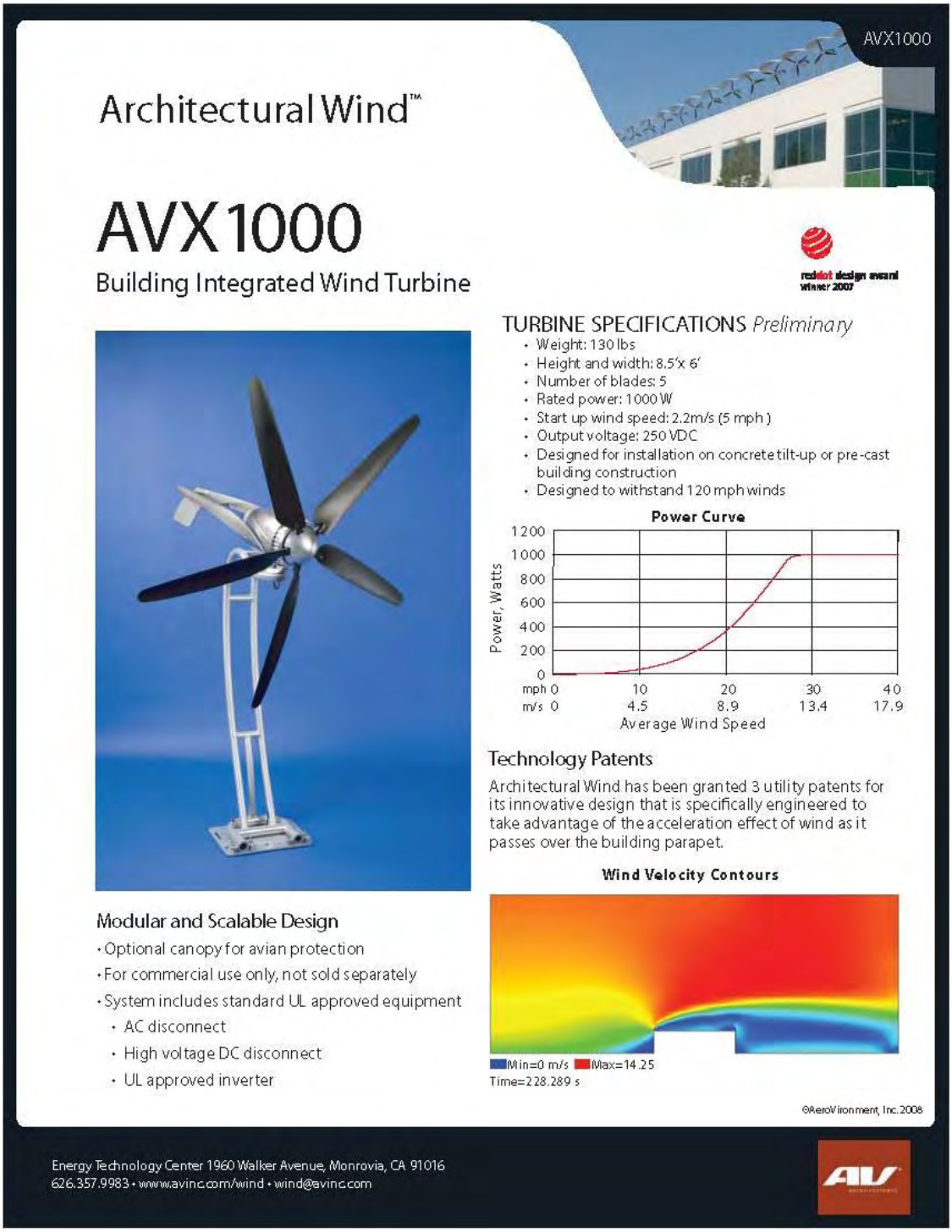
Function

The chilled beam IQID is designed for ceiling mounting, and it is suited for ceiling modules of size 23.62 inch both in length and width, which means that it is flush with the ceiling surface. The IQID chilled beam is a very flexible chilled beam that is available as a basic model, but can also be equipped with a number of functions to provide a multifunctional chilled beam. The following functions are available for IQID: heating, comfort control, Flow Pattern Control (FPC air deflector), function for high air flow, control equipment, lighting and provision for a sprinkler system. The air flow can be adjusted by means of the patented adjusting rails (Comfort control, optional function, read more in separate catalogue section) with which the length of the holes in the supply air duct is changed. This can easily be done with normal adjustments. A regulating damper is normally not required. The adjustable hole lengths allow different air distribution (two-way, one-way and middle positions). The simple adjustment of air distribution and capacity makes it possible to adapt to changing conditions in the future. Before delivery, the hole lengths of standard beams are preset at the longest possible position to provide a starting position for later adjustment (if the beam have comfort control). The beam can be supplied with a coil for heating water, read more in separate catalogue section Heating. The purging nipple is a choice in the product code.

Material

The casing is mainly made of galvanized steel sheet. The frontplate is powder painted in white. The standard colour RAL 9010, which corresponds to NCS 0502-Y, gloss level 30. Coil made of copper pipe with connection, Øout = 0.59 inch, and aluminium fins. Maximum working pressure 6423.12 inWG.

MAE Technical requirement: Wind Turbine Analysis



TECHNICAL SPECIFICATIONS

Type	Upwind, horizontal axis, structure or pole-mountable wind turbine
Power Output	Over 1.5 kW @ peak production 1.0 kW @ 11 m/s (24.6 mph)
Annual Energy Production	Approximately - 1,200 kWh @ 5 m/s (11.2 mph) annual average wind speed 1,900 kWh @ 6 m/s (13.4 mph) annual average wind speed
Electrical Power	240VAC, 60Hz output voltage
Electrical Connection	Grid-tied system
Inverter	7 amp AC, custom designed brushless PMG
Rotor (Blade/Ring) Diameter	7 ft
Braking System	Dynamic & mechanical over-speed protection
Mast for Structure Mount	16 ft, aluminum (to BS1387, ISO65 specifications)
Mounting Brackets	Specifically designed mounting system with damping to reduce vibration
Lateral Loading	600 lbs @ 40.2 m/s (90 mph) 400 RPM maximum in a 20.1 m/s (45 mph) wind
Minimum Clearance Above Roof Line	2 ft above highest peak
Standard Pole Heights	30, 45, & 60 ft
Distance Between Multiple Units	Recommended 25 ft
Unit Weight	Approximately 250 lbs
Cut-In Speed	3.58 m/s (8 mph)
Maximum Designed Wind Speed	64.8 m/s (145 mph)
Product Design Life	20 yrs*
Acoustic Emissions	Less than 35 dB (A) for all wind speeds
EMI (Electromagnetic Emissions)	CE certified, BS EN 6100
Safety, Electrical & Reliability Standards	Certified to - UL 1741 IEEE 1547 & 1547.1 CSA C22.2 NO 107.1-01
Maintenance	Sealed component system, recommended annual visual inspection
Warranty	Parts - 5 yrs**

* "Design Life" is not a guarantee of a specific unit's performance.
** See full warranty for details and limitations

The SWIFT Wind Turbine has been designed to be environmentally sustainable. The product produces more energy in its lifetime than is incorporated in the material and processes used to manufacture it, therefore making the turbine 'harm neutral.'

cascade
RENEWABLE ENERGY

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a division of Cascade Engineering, Inc.
North American Marketer & Manufacturer
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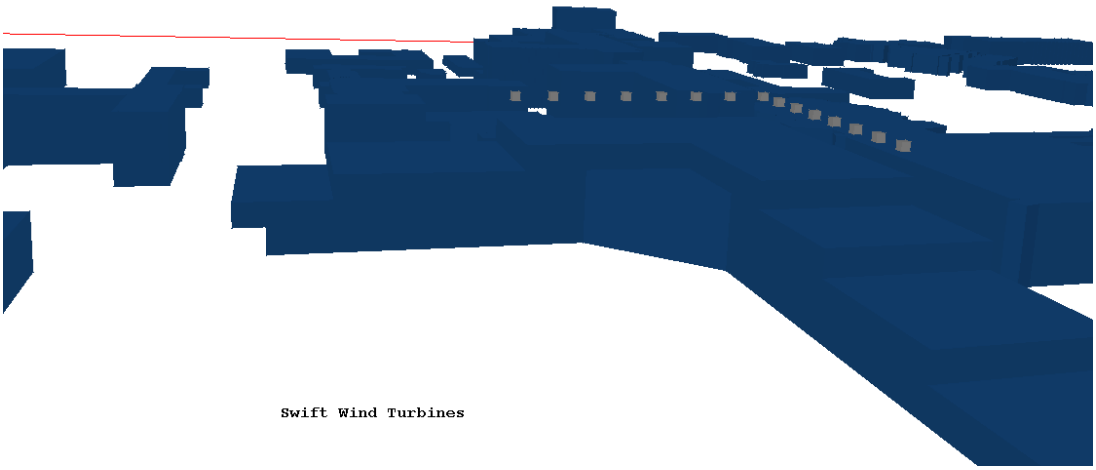
Grand Rapids, MI 49512
P 866.544.5520
F 616.975.4717
info@swiftwindturbine.com
www.swiftwindturbine.com

Using the manufacturer's data for the size of the turbines, the turbines were modeled in the simulation as simple blocks. The table below summarizes the object dimension and sizes in the simulation domain for Cascade's Swift turbines and the image below shows the turbines simulated as blocks. These turbines are required to be mounted 4.9 meters above the roofline for building integration



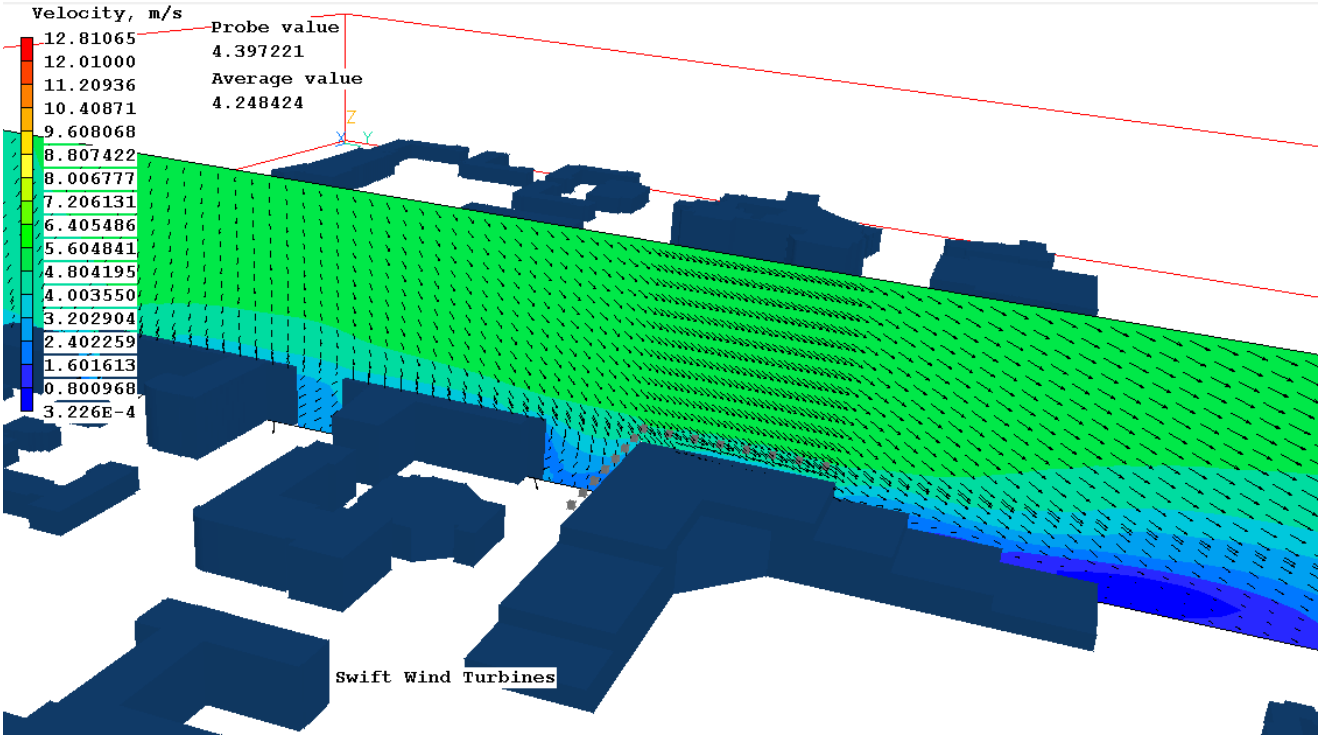
Swift Turbine Addition to Building

Dimensions and Positions of Swift Turbines in Simulation Domain

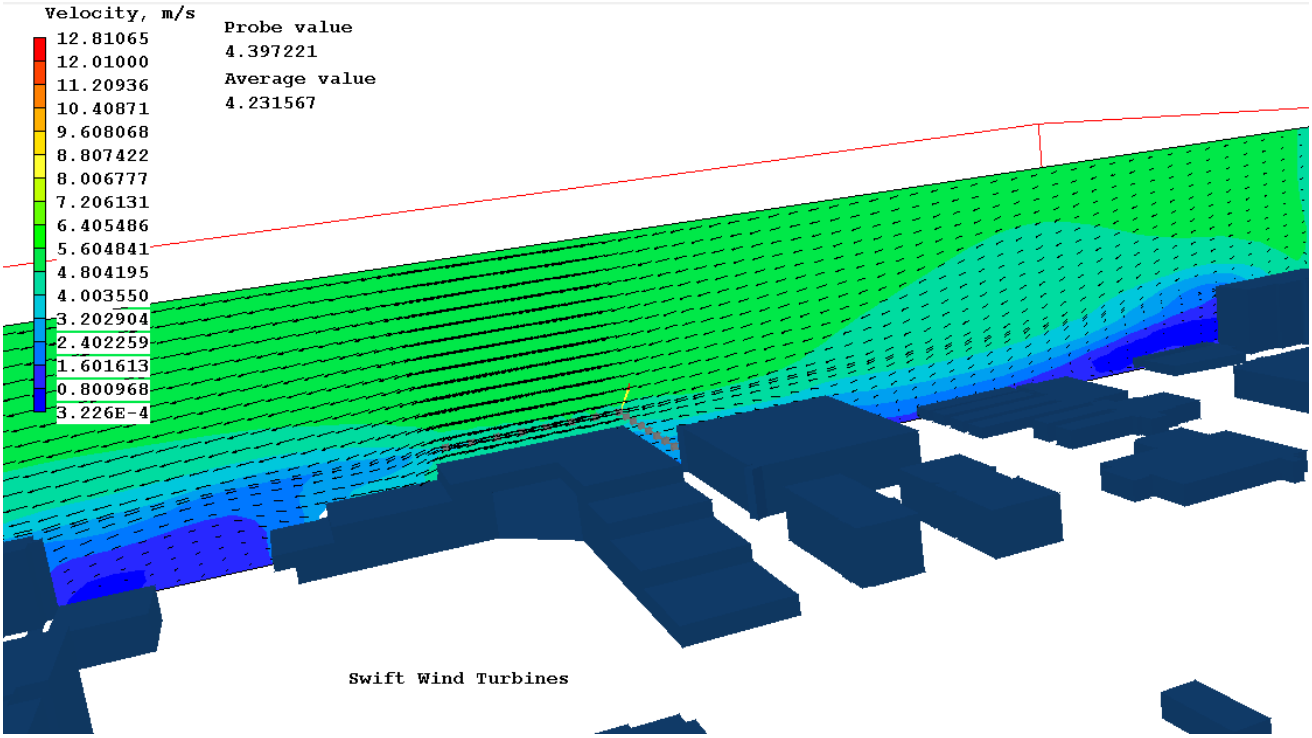
	Size			Location		
	delta x [m]	delta y [m]	delta z [m]	x [m]	y [m]	z [m]
Buildings	850.138	881.4054	36.1442	0.0	0.0	0.0
Turbine1	2.13	2.13	2.13	500.0	430.0	28.9
Turbine2	2.13	2.13	2.13	509.76	430.0	28.9
Turbine3	2.13	2.13	2.13	519.52	430.0	28.9
Turbine4	2.13	2.13	2.13	529.28	430.0	28.9
Turbine5	2.13	2.13	2.13	539.04	430.0	28.9
Turbine6	2.13	2.13	2.13	548.80	430.0	28.9
Turbine7	2.13	2.13	2.13	558.56	430.0	28.9
Turbine8	2.13	2.13	2.13	568.32	430.0	28.9
Turbine9	2.13	2.13	2.13	500.00	439.76	28.9
Turbine10	2.13	2.13	2.13	500.00	449.52	28.9
Turbine11	2.13	2.13	2.13	500.00	459.28	28.9
Turbine12	2.13	2.13	2.13	500.00	469.04	28.9
Turbine13	2.13	2.13	2.13	500.00	478.80	28.9
Turbine14	2.13	2.13	2.13	500.00	488.56	28.9
Turbine15	2.13	2.13	2.13	500.00	498.32	28.9

The addition of the turbines in the simulation domain caused the mesh grid to be altered due to new constraints. This resulted in an increased grid size of X=123, Y=134, and Z=22. Using the same turbulence model and numerical

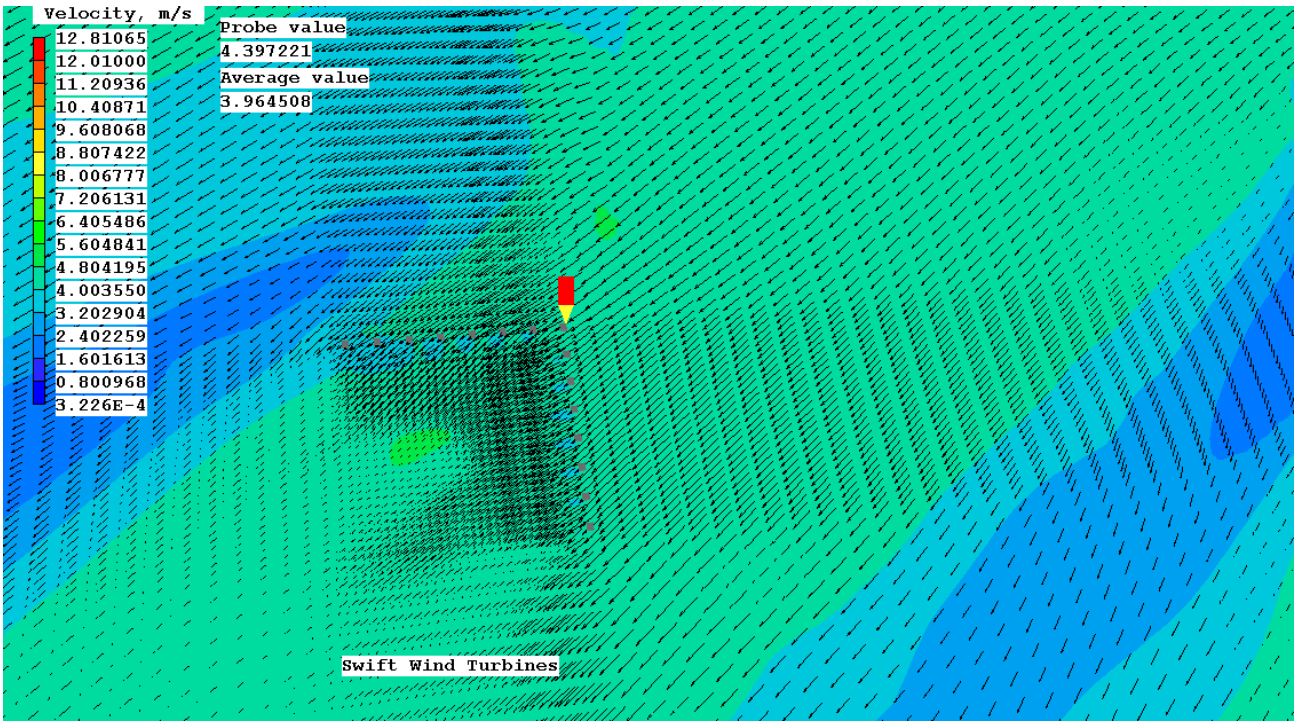
scheme as earlier, the simulation time for 3000 iterations was 4 hours 48 minutes. The mass residual for the simulation was 1.033 x 10^3 kg/s and the total mass inflow was 6.040584x 10^5 kg/s which is 0.166% mass residual. While this is slightly larger than the recommended percent residual of 0.1%, it is still much less than the 1% allowed for this project. Therefore, it can be assumed that the solution was able to reach convergence. The three images below show the X-, Y-, and Z-plane velocity profiles for the resulting turbine additions.



Swift Wind Turbine Addition, X-velocity profile at (500, 430, 30)



Swift Wind Turbine Addition, Y-Velocity Profile at (500, 430, 30)



Swift Wind Turbine Z-Velocity Profile at (500, 430, 30)

Based on these resulting face velocities, the average velocity for each turbine is approximately between 4.4 m/s and 4.9 m/s.

AeroVironment's Architectural Wind turbines were modeled in the simulation domain as well. The table below summarizes the input values for the objects.

Dimensions and Positions of Architectural Wind Turbines in Simulation Domain

	Size			Location		
	delta x [m]	delta y [m]	delta z [m]	x [m]	y [m]	z [m]
Buildings	850.138	881.4054	36.1442	0.0	0.0	0.0
Turbine1	1.83	1.83	2.59	500.0	430.00	240.0
Turbine2	1.83	1.83	2.59	500.0	432.33	28.9
Turbine3	1.83	1.83	2.59	500.0	434.66	28.9
Turbine4	1.83	1.83	2.59	500.0	436.99	28.9
Turbine5	1.83	1.83	2.59	500.0	439.32	28.9
Turbine6	1.83	1.83	2.59	500.0	441.65	28.9
Turbine7	1.83	1.83	2.59	500.0	443.98	28.9
Turbine8	1.83	1.83	2.59	500.0	446.31	28.9
Turbine9	1.83	1.83	2.59	500.0	448.64	28.9
Turbine10	1.83	1.83	2.59	500.0	450.97	28.9
Turbine11	1.83	1.83	2.59	500.0	453.30	28.9
Turbine12	1.83	1.83	2.59	500.0	455.63	28.9
Turbine13	1.83	1.83	2.59	500.0	457.96	28.9
Turbine14	1.83	1.83	2.59	500.0	460.29	28.9
Turbine15	1.83	1.83	2.59	500.0	462.62	28.9
Turbine16	1.83	1.83	2.59	500.0	464.95	28.9
Turbine17	1.83	1.83	2.59	500.0	467.28	28.9
Turbine18	1.83	1.83	2.59	500.0	469.61	28.9
Turbine19	1.83	1.83	2.59	500.0	471.94	28.9
Turbine20	1.83	1.83	2.59	500.0	474.27	28.9
Turbine21	1.83	1.83	2.59	500.0	476.60	28.9
Turbine22	1.83	1.83	2.59	500.0	478.93	28.9
Turbine23	1.83	1.83	2.59	500.0	481.26	28.9
Turbine24	1.83	1.83	2.59	500.0	483.59	28.9
Turbine25	1.83	1.83	2.59	500.0	485.92	28.9
Turbine26	1.83	1.83	2.59	500.0	488.25	28.9
Turbine27	1.83	1.83	2.59	500.0	490.58	28.9
Turbine28	1.83	1.83	2.59	500.0	492.91	28.9
Turbine29	1.83	1.83	2.59	500.0	495.24	28.9
Turbine30	1.83	1.83	2.59	500.0	497.57	28.9
Turbine31	1.83	1.83	2.59	500.0	499.90	28.9
Turbine32	1.83	1.83	2.59	502.33	430.00	28.9

Turbine33	1.83	1.83	2.59	504.66	430.00	28.9
Turbine34	1.83	1.83	2.59	506.99	430.00	28.9
Turbine35	1.83	1.83	2.59	509.32	430.00	28.9
Turbine36	1.83	1.83	2.59	511.65	430.00	28.9
Turbine37	1.83	1.83	2.59	513.98	430.00	28.9
Turbine38	1.83	1.83	2.59	516.31	430.00	28.9
Turbine39	1.83	1.83	2.59	518.64	430.00	28.9
Turbine40	1.83	1.83	2.59	520.97	430.00	28.9
Turbine41	1.83	1.83	2.59	523.30	430.00	28.9
Turbine42	1.83	1.83	2.59	525.63	430.00	28.9
Turbine43	1.83	1.83	2.59	527.96	430.00	28.9
Turbine44	1.83	1.83	2.59	530.29	430.00	28.9
Turbine45	1.83	1.83	2.59	532.62	430.00	28.9
Turbine46	1.83	1.83	2.59	534.95	430.00	28.9
Turbine47	1.83	1.83	2.59	537.28	430.00	28.9
Turbine48	1.83	1.83	2.59	539.61	430.00	28.9
Turbine49	1.83	1.83	2.59	541.94	430.00	28.9
Turbine50	1.83	1.83	2.59	544.27	430.00	28.9
Turbine51	1.83	1.83	2.59	546.60	430.00	28.9
Turbine52	1.83	1.83	2.59	548.93	430.00	28.9
Turbine53	1.83	1.83	2.59	551.26	430.00	28.9
Turbine54	1.83	1.83	2.59	553.59	430.00	28.9
Turbine55	1.83	1.83	2.59	555.92	430.00	28.9
Turbine56	1.83	1.83	2.59	558.25	430.00	28.9
Turbine57	1.83	1.83	2.59	560.58	430.00	28.9
Turbine58	1.83	1.83	2.59	562.91	430.00	28.9
Turbine59	1.83	1.83	2.59	565.24	430.00	28.9
Turbine60	1.83	1.83	2.59	567.57	430.00	28.9
Turbine61	1.83	1.83	2.59	569.90	430.00	28.9

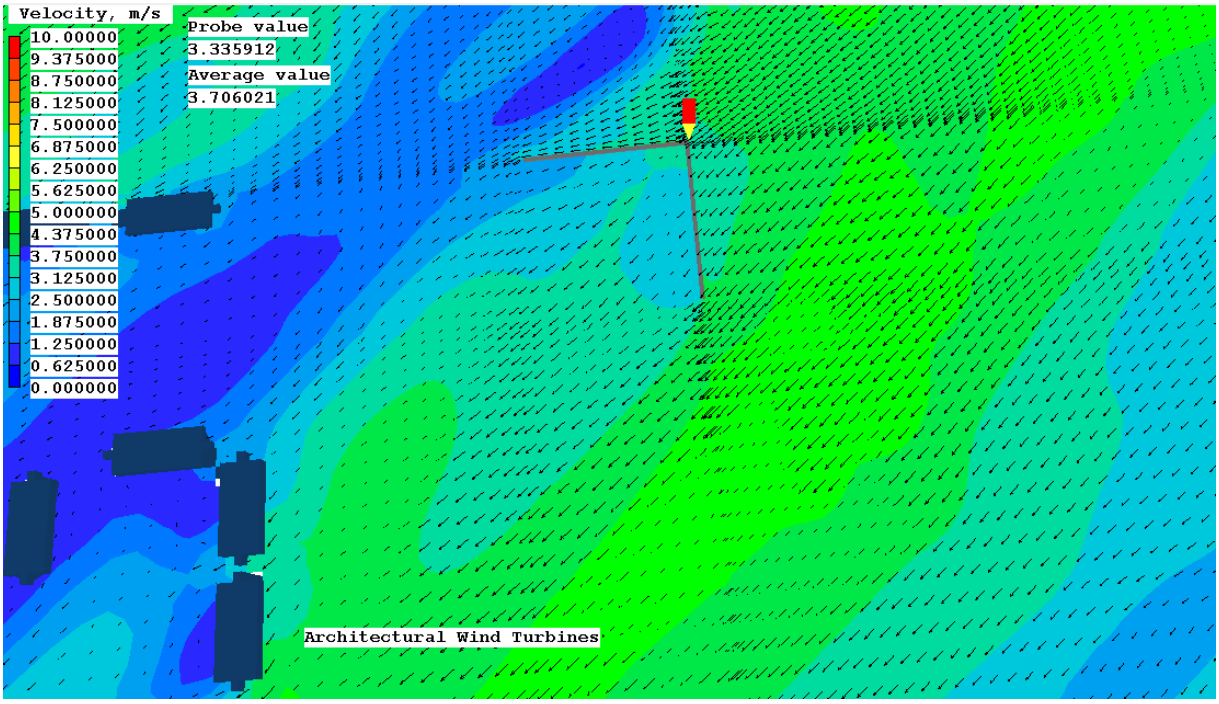
The mesh was also affected by added objects, resulting in a new grid size of X=215, Y=170, and Z=23. Again, using the same turbulence model and numerical scheme (hybrid), the simulation took 4 hours 47 minutes to complete 1000 iterations. The mass residual for the simulation was 5.553×10^5 kg/s and the total mass inflow was 1.526797×10^6 kg/s which is 36.37% mass residual. This mass residual was very high, much larger than the minimum recommendation of 1.0%. Therefore, the solution was not abe to reach convergence and did not provide an accurate representation of the airflow for the added turbines.

Since the objects were so small and the spacing between them was also very small as well, it had negative effects on the simulation. This was very similar to the previous modeling errors that had occurred in the initial setup of the campus model. Therefore, in order to remedy it, the Architectural Wind turbines were revised and simulated as two long strips along the roofline. The following table summarizes the revised turbine modeled blocks.

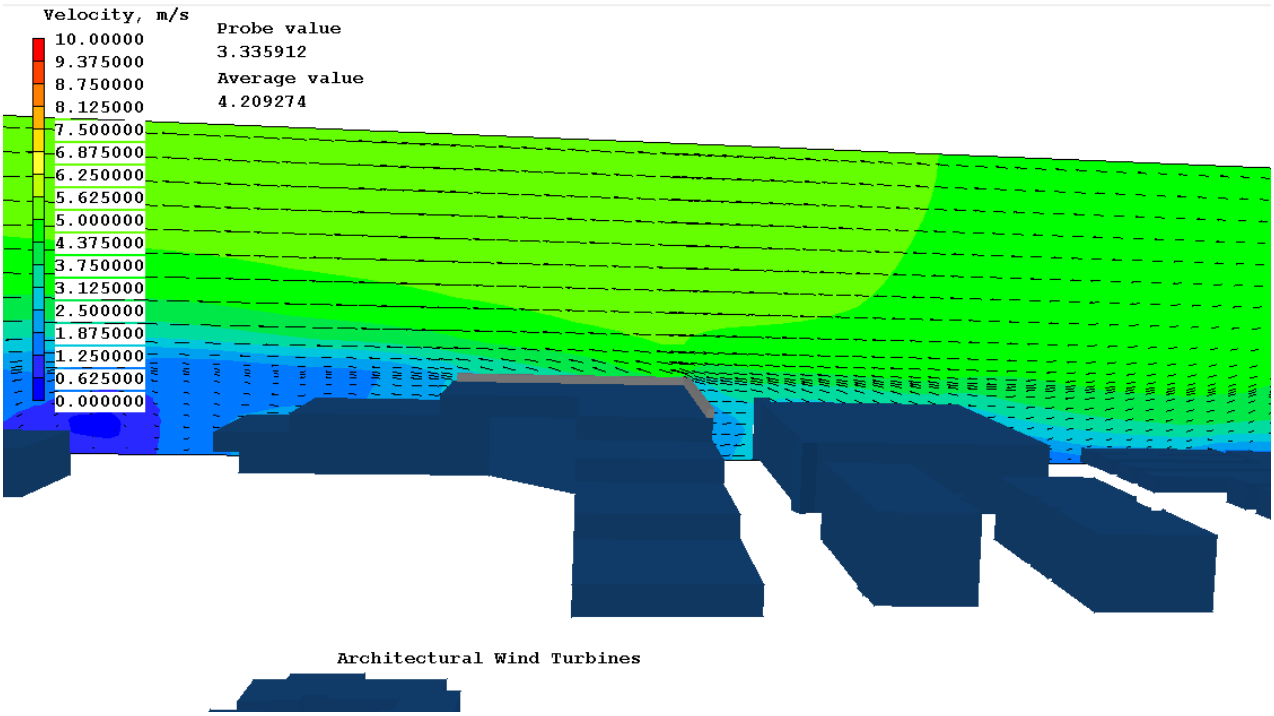
Revised Dimensions and Positions of Architectural Wind Turbines in Simulation Domain

	Size			Location		
	delta x [m]	delta y [m]	delta z [m]	x [m]	y [m]	z [m]
Buildings	850.138	881.4054	36.1442	0.0	0.0	0.0
Turbine1	1.83	7.233	2.59	500.0	430.0	240.0
Turbine2	7.04	1.83	2.59	501.83	430.0	240.0

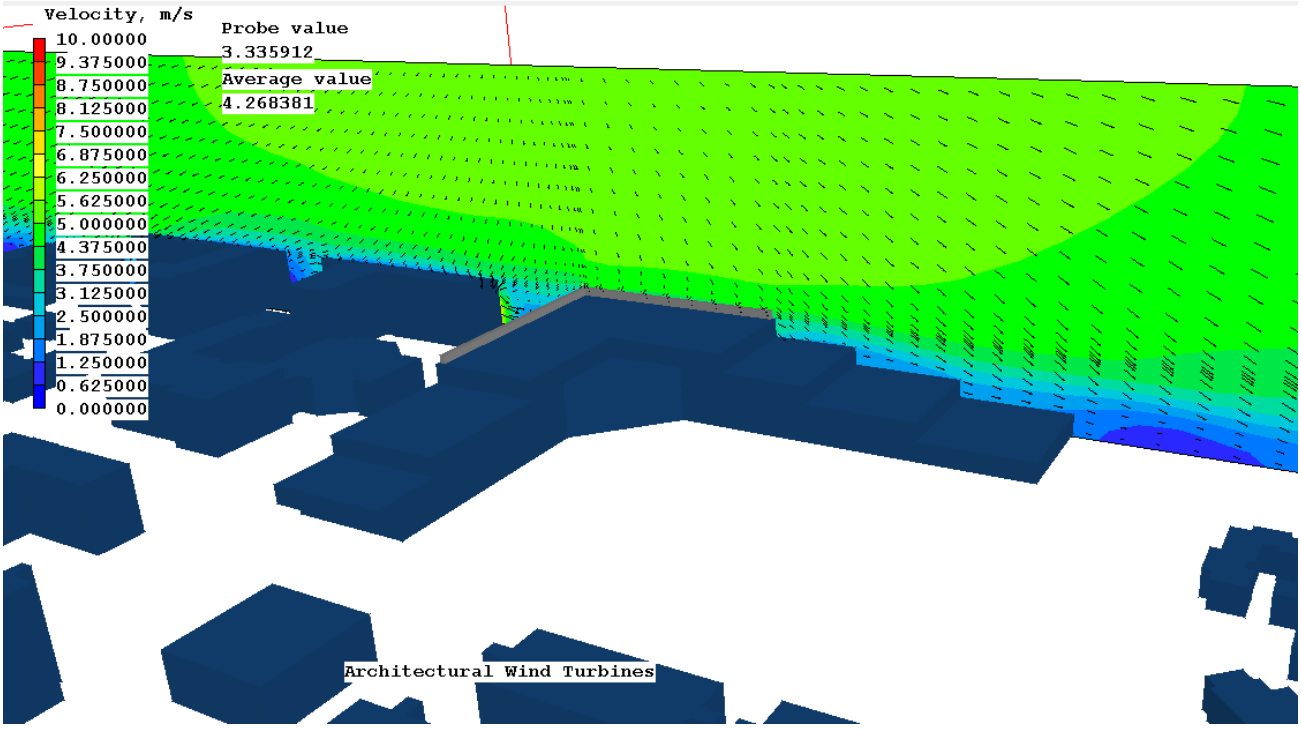
The mesh was revised for a final time to be X=117, Y=111, Z=22. Using the number of iterations set to 5000, it took 5 hours 59 minutes to complete the simulation. This resulted in mass residual of 5197 x 10^2 kg/s and the total mass inflow was 6.039137x 10^5 kg/s, which is 0.086% mass residual. Therefore, the solution was able to reach convergence, indicating that revision proved to be successful. Not only is the percent residual less than 0.1%, but also less than the convergence value for the simulation done without the turbine additions. The below figures illustrate the velocity profiles for each direction around the added wind turbines.



Architectural Wind Turbine (simplified) Z-Velocity Profile (500, 430, 26)



Architectural Wind Turbine (Simplified) Y-Velocity Profile (500, 430, 26)

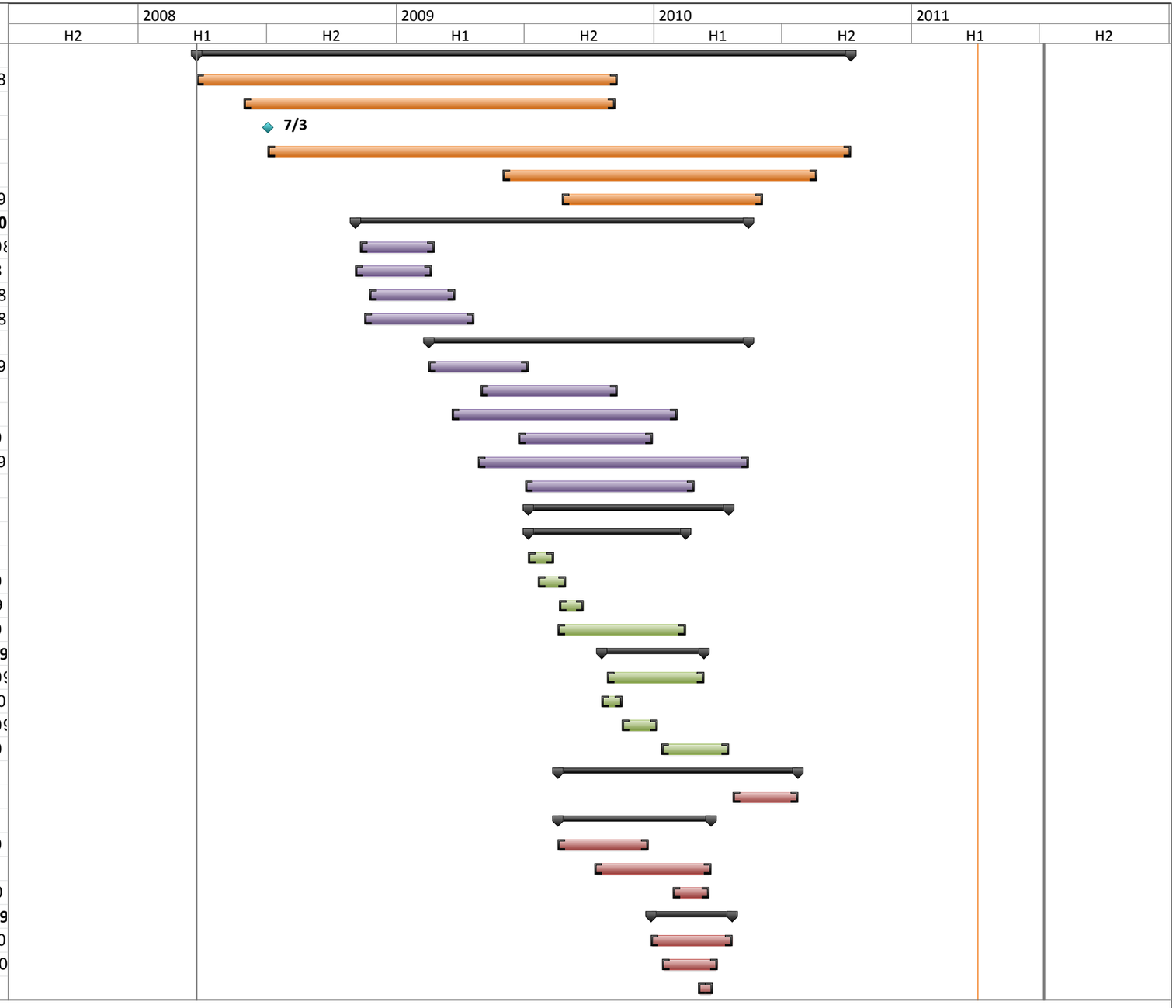


Architectural Wind Turbine (simplified) X-plane Velocity Profile (500, 430, 26)

Appendix D: Construction Management

Existing Schedule and Revised Schedule

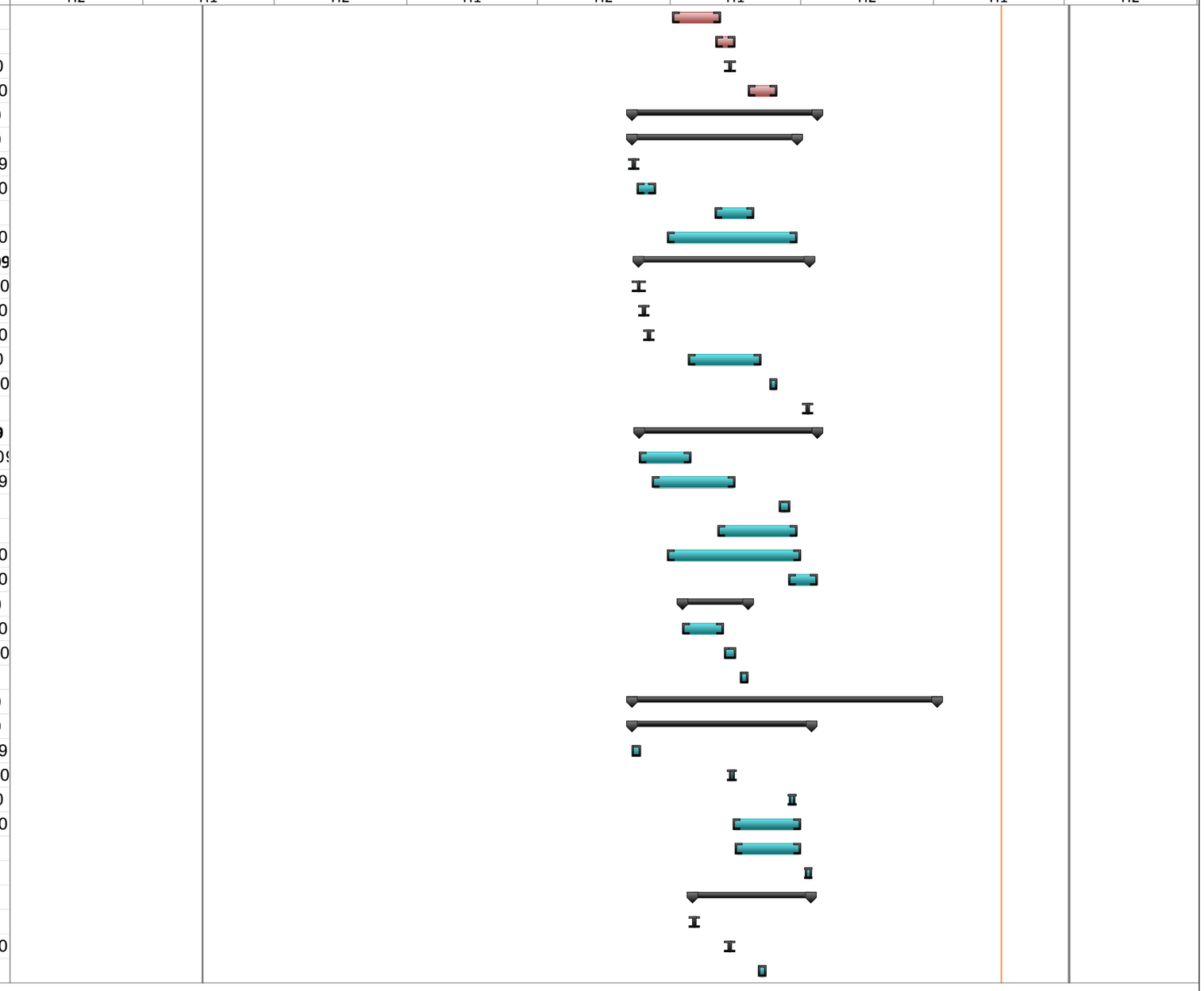
ID	Task Mode	Task Name	Duration	Start
1		**Design/Bid & Award/ Procurement**	**663 days**	**Mon 3/24/08**
2		Design Phase	426 days	Mon 3/24/08
3		Bid/Award	376 days	Fri 5/30/08
4		Notice To Proceed	0 days	Thu 7/3/08
5		Submittal/Fabrication/Procurement	590 days	Thu 7/3/08
6		Material Science Coordination Drawings	319 days	Mon 6/1/09
7		Life Sciences Coordination Drawings	204 days	Mon 8/24/09
8		**Foundation**	**399 days**	**Tue 11/4/0**
9		Material Sciences Excavation and Shoring	75 days	Tue 11/11/08
10		Life Sciences Excavation and Shoring	78 days	Tue 11/4/08
11		Material Sciences Mini-Piles	87 days	Mon 11/24/08
12		Life Sciences Mini Piles	111 days	Mon 11/17/08
13		**Foundation's & Slab - On - Grade**	**325 days**	**Mon 2/16/09**
14		CL BB - Y5	101 days	Mon 2/16/09
15		CL Y5 - S5	137 days	Fri 5/1/09
16		CL J - S5	228 days	Sat 3/21/09
17		CL T - L	136 days	Tue 6/23/09
18		Areaways & Cleanrooms	275 days	Mon 4/27/09
19		CL 13 - 20	171 days	Fri 7/3/09
20		**Superstructure**	**204 days**	**Tue 7/7/09**
21		**Material Sciences**	**159 days**	**Tue 7/7/09**
22		CL BB - W	26 days	Tue 7/7/09
23		CL W - R	29 days	Tue 7/21/09
24		CL R - J	24 days	Thu 8/20/09
25		Shear Wall	130 days	Tue 8/18/09
26		**Life Sciences**	**105 days**	**Mon 10/19/09**
27		Shear Walls	99 days	Tue 10/27/09
28		CL 12 - 16	21 days	Mon 10/19/0
29		CL 16 - 21	36 days	Tue 11/17/09
30		Core/Areaway	69 days	Tue 1/12/10
31		**Concrete Slabs**	**244 days**	**Tue 8/18/09**
32		Tunnel Phase CL A1 - LS	66 days	Fri 4/23/10
33		**Material Sciences**	**155 days**	**Tue 8/18/09**
34		CL BB - R	92 days	Tue 8/18/09
35		CL R - M	117 days	Fri 10/9/09
36		CL M - H	37 days	Thu 1/28/10
37		**Life Sciences**	**83 days**	**Mon 12/28/09**
38		CL 12 - 16	83 days	Mon 12/28/0
39		CL 16 - 21	56 days	Wed 1/13/10
40		CL 12 - 8	14 days	Fri 3/5/10



Project: Existing Schedule Summa
Date: Tue 4/5/11

Task
Split
Milestone
Summary
Project Summary
External Tasks
External Milestone
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Deadline
Progress

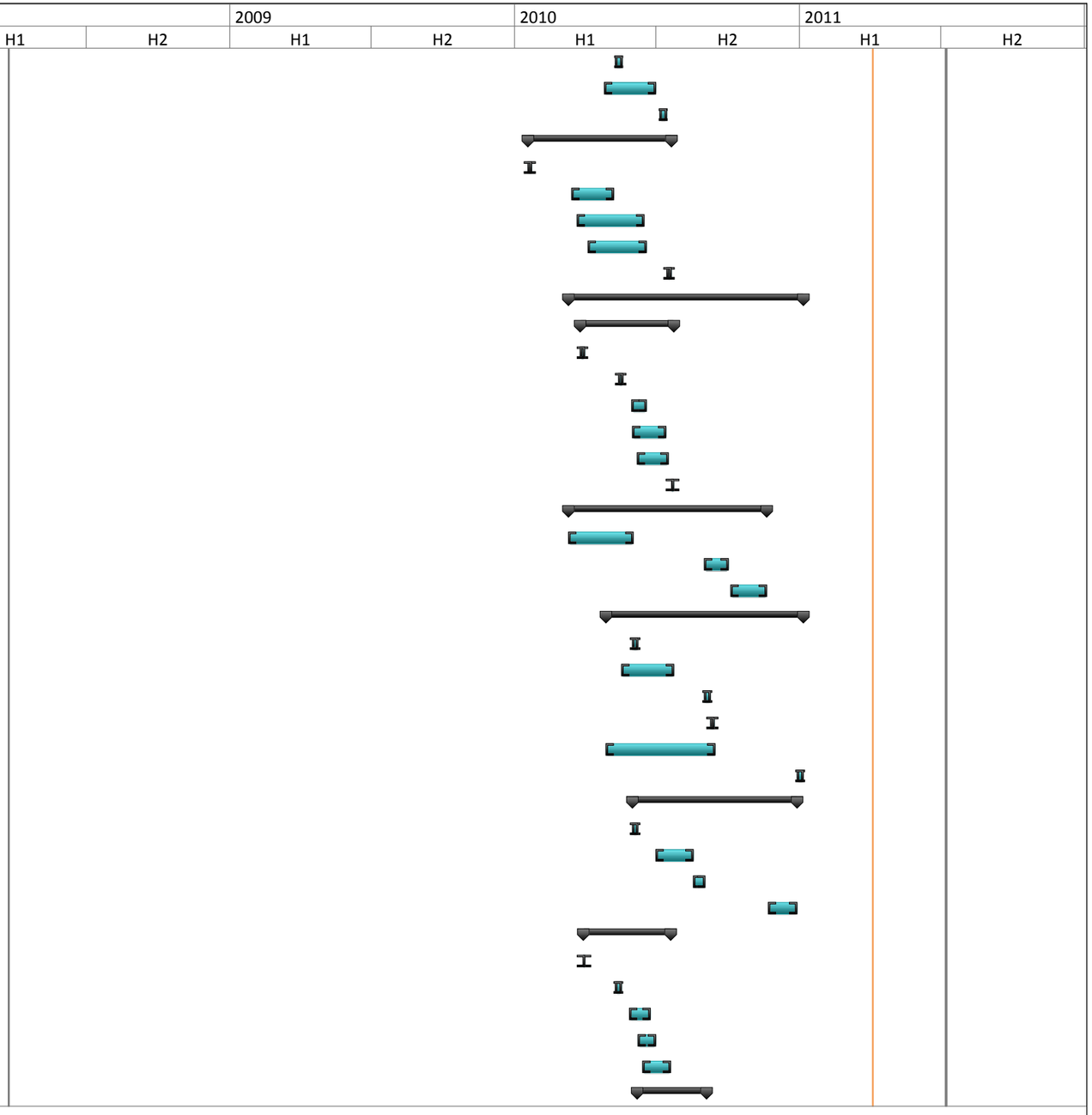
ID	Task Mode	Task Name	Duration	Start
41		Areaway Lv1 & Lv2	49 days	Mon 1/4/10
42		Areaway Lv3	19 days	Fri 3/5/10
43		Areaway Lv4	4 days	Tue 3/23/10
44		Areaway Roof	30 days	Mon 4/19/10
45		**Material Sciences Enclosure**	**185 days**	**Mon 11/9/09**
46		**North Elevation**	**165 days**	**Mon 11/9/09**
47		Precast Attach Steel	5 days	Mon 11/9/09
48		Precast Panels	20 days	Mon 11/16/0
49		Insulation/Air Barrier Precast Panels	38 days	Thu 3/4/10
50		Ribbon Windows	130 days	Mon 12/28/0
51		**East Elevation**	**169 days**	**Wed 11/18/09**
52		Precast Attach Steel	1 day	Wed 11/18/0
53		Precast Panels	5 days	Mon 11/23/0
54		Insulation/Air Barrier Precast Panels	5 days	Mon 11/30/0
55		Ribbon Windows	73 days	Tue 1/26/10
56		PH Louvers	8 days	Wed 5/19/10
57		Sunshade	3 days	Thu 7/8/10
58		**South Elevation**	**177 days**	**Thu 11/19/09**
59		Precast Attach Steel	52 days	Thu 11/19/0
60		Precast Panels	83 days	Mon 12/7/09
61		PH Louvers	11 days	Tue 6/1/10
62		Insulation/Air Barrier Precast Panels	80 days	Mon 3/8/10
63		Ribbon Windows	133 days	Mon 12/28/0
64		Sunshade	30 days	Mon 6/14/10
65		**Roofing**	**65 days**	**Mon 1/18/10**
66		Level 2 Green Roof	41 days	Mon 1/18/10
67		Level 3 Green Roof	12 days	Wed 3/17/10
68		Level 4 Green Roof	8 days	Thu 4/8/10
69		**Life Sciences Enclosure**	**303 days**	**Mon 11/9/09**
70		**East Elevation**	**179 days**	**Mon 11/9/09**
71		Precast Attach Steel	10 days	Mon 11/9/09
72		Precast Panels	5 days	Wed 3/24/10
73		PH Louvers	6 days	Tue 6/15/10
74		Ribbon Windows	68 days	Mon 3/29/10
75		Insulation/Air Barrier Precast Panels	65 days	Thu 4/1/10
76		Sunshade	7 days	Wed 7/7/10
77		**South Elevation**	**118 days**	**Mon 2/1/10**
78		Precast Attach Steel	5 days	Mon 2/1/10
79		Precast Panels	5 days	Mon 3/22/10
80		Insulation/Air Barrier Precast Panels	9 days	Mon 5/3/10



Project: Existing Schedule Summa
Date: Tue 4/5/11

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

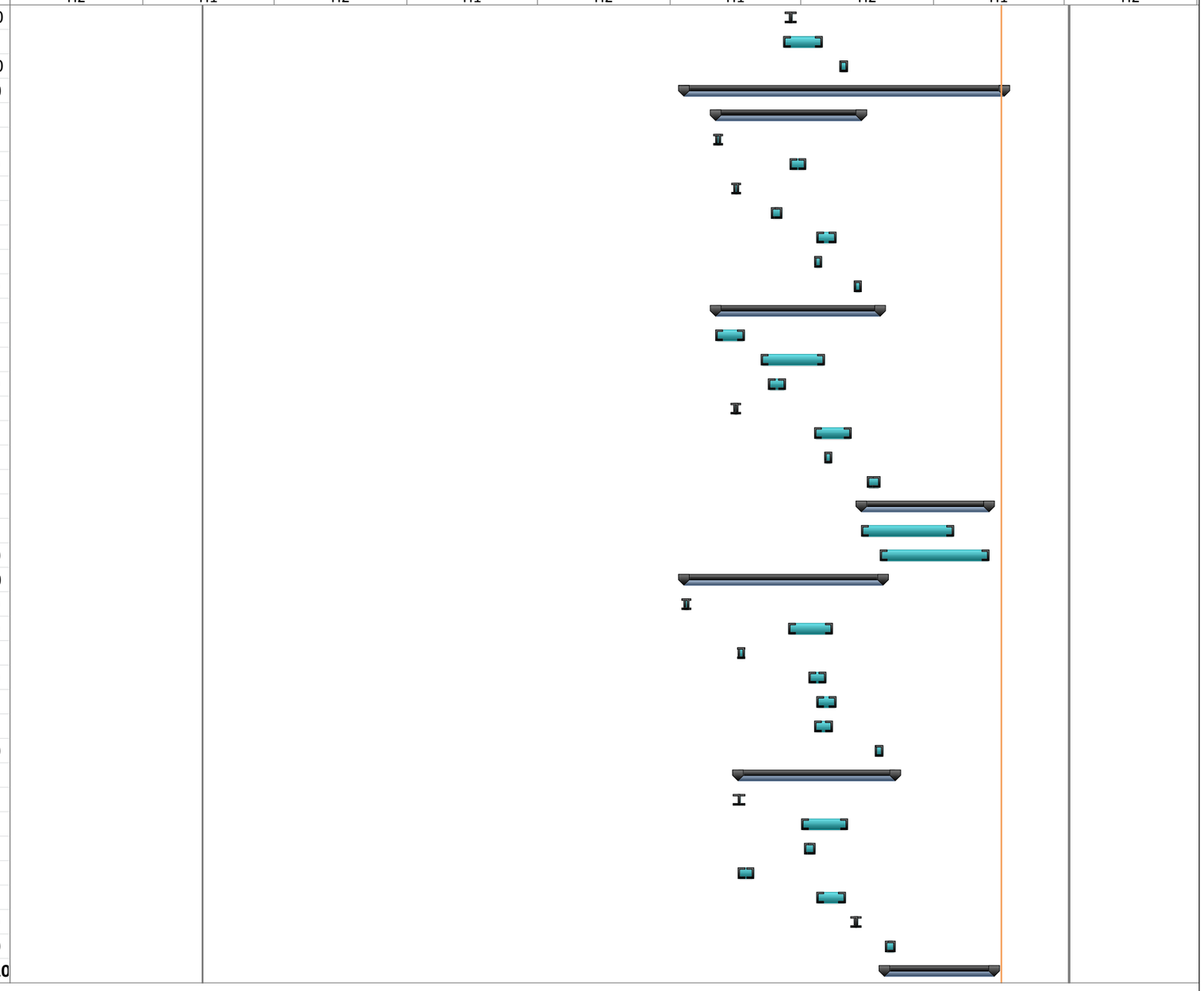
ID	Task Mode	Task Name	Duration	Start
81		PH Louvers	7 days	Mon 5/10/10
82		Ribbon Windows	48 days	Mon 4/26/10
83		Sunshade	7 days	Tue 7/6/10
84		**West Elevation**	**132 days**	**Mon 1/18/10**
85		Precast Attach Steel	5 days	Mon 1/18/10
86		Precast Panels	40 days	Mon 3/15/10
87		Ribbon Windows	62 days	Mon 3/22/10
88		Insulation/Air Barrier Precast Panels	55 days	Mon 4/5/10
89		Sunshade	4 days	Thu 7/15/10
90		**Areaway Enclosure**	**215 days**	**Thu 3/11/10**
91		**North Elevation**	**86 days**	**Fri 3/26/10**
92		Precast Attach Steel	4 days	Fri 3/26/10
93		Precast Panels	4 days	Fri 5/14/10
94		Ribbon Windows	15 days	Mon 5/31/10
95		PH Louvers	31 days	Tue 6/1/10
96		Insulation/Air Barrier Precast Panels	30 days	Mon 6/7/10
97		Sunshade	3 days	Wed 7/21/10
98		**Soffit Exterior**	**182 days**	**Thu 3/11/10**
99		Exterior Miscellaneous Steel Frame	59 days	Thu 3/11/10
100		Exterior Frame/Sheath	23 days	Wed 9/1/10
101		Exterior Metal Panels	34 days	Tue 10/5/10
102		**Areaway Entrance Exterior**	**181 days**	**Wed 4/28/10**
103		Miscellaneous Steel Frame	5 days	Tue 6/1/10
104		2nd Floor Windows	49 days	Tue 5/18/10
105		Exterior Frame/Sheath	6 days	Wed 9/1/10
106		Waterproofing	3 days	Thu 9/9/10
107		Storefront	100 days	Wed 4/28/10
108		Exterior Metal Panels	6 days	Wed 12/29/1
109		**Areaway Lightwell**	**151 days**	**Tue 6/1/10**
110		Exterior Miscellaneous Steel Frame	5 days	Tue 6/1/10
111		Exterior Frame/Sheath	34 days	Thu 7/1/10
112		Waterproofing	11 days	Wed 8/18/10
113		Exterior Metal Panels	27 days	Mon 11/22/1
114		**West Elevation**	**80 days**	**Tue 3/30/10**
115		Precast Attach Steel	2 days	Tue 3/30/10
116		Precast Panels	6 days	Mon 5/10/10
117		Ribbon Windows	19 days	Fri 5/28/10
118		PH Louvers	17 days	Tue 6/8/10
119		Insulation/Air Barrier Precast Panels	26 days	Mon 6/14/10
120		**Areaway Roofing**	**65 days**	**Mon 6/7/10**



Project: Existing Schedule Summa
Date: Tue 4/5/11

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

ID	Task Mode	Task Name	Duration	Start
121		Stair/Core Level 6 Roofing	4 days	Tue 6/15/10
122		PH/Areaway Level 5 Roofing	40 days	Mon 6/7/10
123		PH/Areaway Level 5 Roof Trimout	9 days	Tue 8/24/10
124		**Life Sciences Rough-In & Finishes**	**318 days**	**Wed 1/20/10**
125		**Lv3 Lab Rough-In**	**144 days**	**Fri 3/5/10**
126		Interior Walls	5 days	Fri 3/5/10
127		Perimeter Walls	16 days	Wed 6/16/10
128		Fireproofing	5 days	Tue 3/30/10
129		VAV Installation	11 days	Fri 5/21/10
130		Plumbing Rough-In	19 days	Fri 7/23/10
131		Electrical/Power Rough-In	8 days	Tue 7/20/10
132		Drywall	8 days	Mon 9/13/10
133		**Lv3 Core Rough-In**	**162 days**	**Fri 3/5/10**
134		Interior Walls	28 days	Fri 3/5/10
135		Perimeter Walls	62 days	Fri 5/7/10
136		VAV Installation	18 days	Mon 5/17/10
137		Fireproofing	5 days	Tue 3/30/10
138		Electrical/Power Rough-In	37 days	Tue 7/20/10
139		Plumbing Rough-In	8 days	Tue 8/3/10
140		Drywall	12 days	Fri 10/1/10
141		**Lv3 Finishes**	**127 days**	**Thu 9/23/10**
142		Lab Finishes	92 days	Thu 9/23/10
143		Core Finishes	109 days	Tue 10/19/10
144		**Lv2 Lab Rough-In**	**198 days**	**Wed 1/20/10**
145		Interior Walls	5 days	Wed 1/20/10
146		Perimeter Walls	45 days	Mon 6/14/10
147		Fireproofing	7 days	Mon 4/5/10
148		VAV Installation	18 days	Mon 7/12/10
149		Plumbing Rough-In	19 days	Fri 7/23/10
150		Electrical/Power Rough-In	19 days	Tue 7/20/10
151		Drywall	9 days	Tue 10/12/10
152		**Lv2 Core Rough-In**	**156 days**	**Mon 4/5/10**
153		Interior Walls	3 days	Mon 4/5/10
154		Perimeter Walls	46 days	Fri 7/2/10
155		VAV Installation	11 days	Tue 7/6/10
156		Fireproofing	16 days	Mon 4/5/10
157		Electrical/Power Rough-In	28 days	Fri 7/23/10
158		Core Plumbing Rough-In	5 days	Mon 9/13/10
159		Drywall	10 days	Tue 10/26/10
160		**Lv2 Finishes**	**110 days**	**Mon 10/25/10**



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Project Summary
External Tasks
External Milestone
Inactive Task
Inactive Milestone
Inactive Summary
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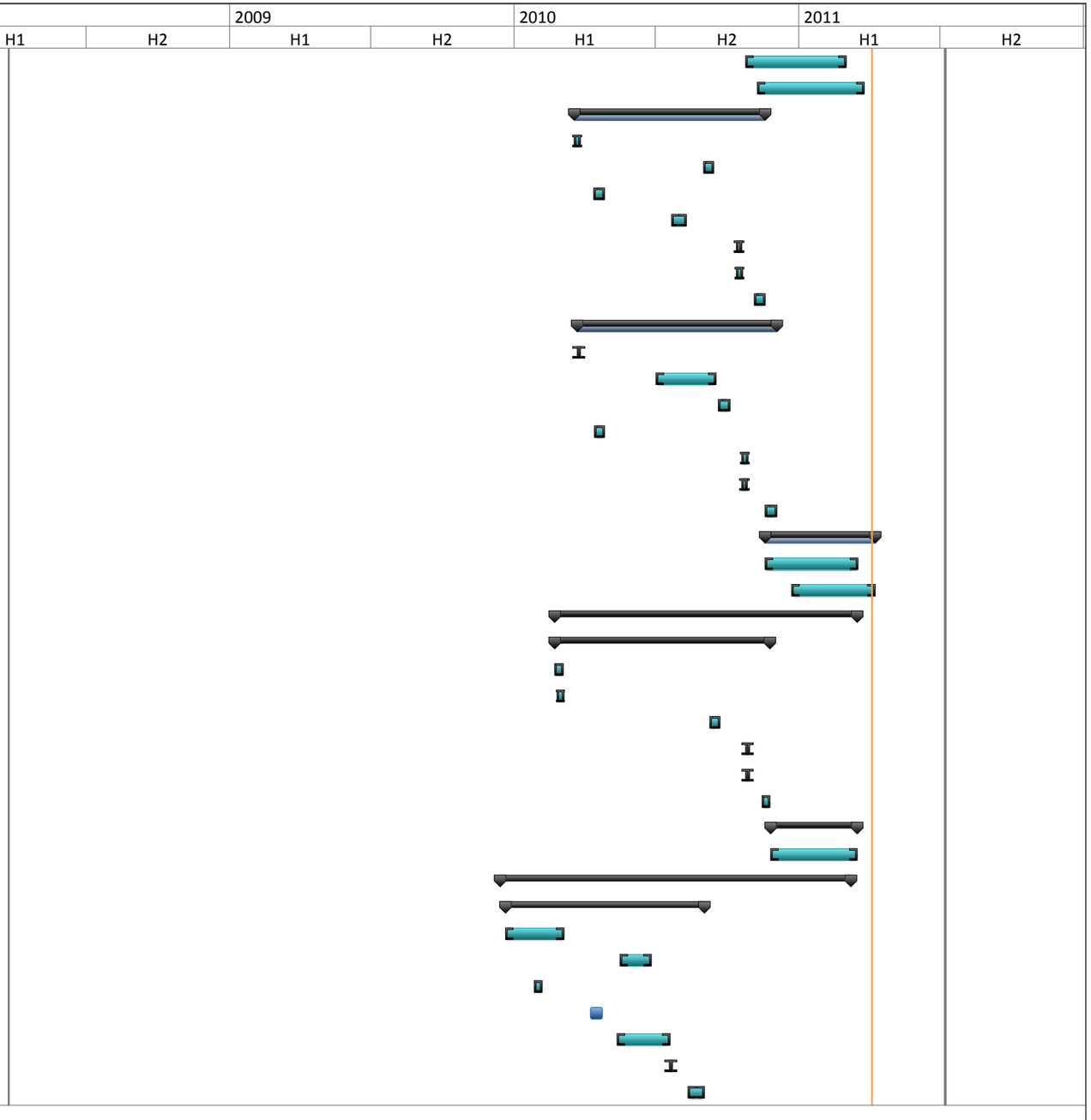
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Deadline
Progress

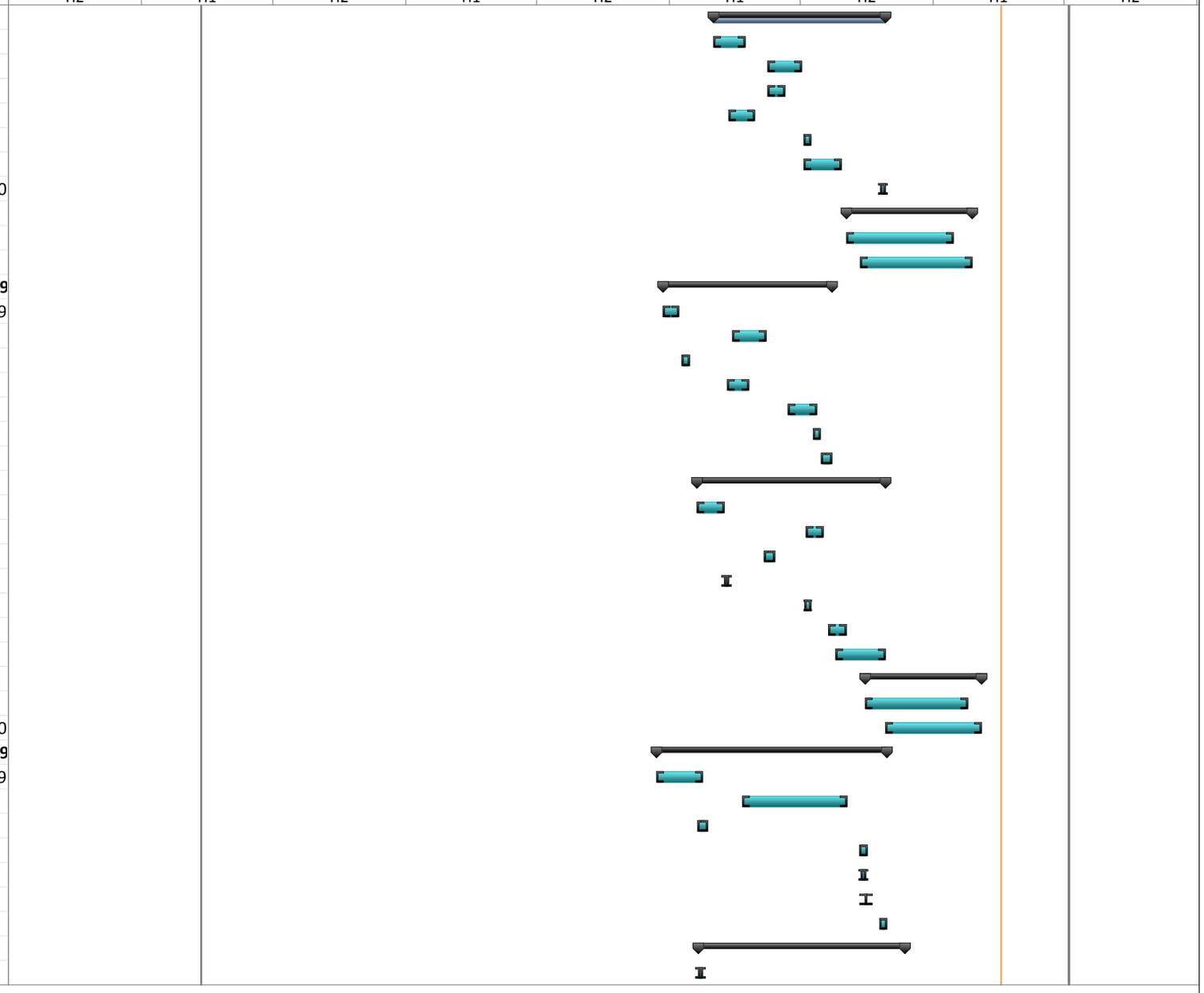
ID	Task Mode	Task Name	Duration	Start
161		Lv2 Labs	93 days	Mon 10/25/10
162		Lv2 Core	99 days	Tue 11/9/10
163		**Lv1 Lab Rough-In**	**175 days**	**Fri 3/19/10**
164		Interior Walls	6 days	Fri 3/19/10
165		Perimeter Walls	9 days	Wed 9/1/10
166		Fireproofing	10 days	Tue 4/13/10
167		VAV Installation	13 days	Thu 7/22/10
168		Plumbing Rough-In	5 days	Wed 10/13/10
169		Electrical/Power Rough-In	6 days	Wed 10/13/10
170		Drywall	10 days	Fri 11/5/10
171		**Lv1 Core Rough-In**	**184 days**	**Tue 3/23/10**
172		Interior Walls	4 days	Tue 3/23/10
173		Perimeter Walls	55 days	Fri 7/2/10
174		VAV Installation	11 days	Mon 9/20/10
175		Fireproofing	9 days	Wed 4/14/10
176		Electrical/Power Rough-In	6 days	Wed 10/20/10
177		Core Plumbing Rough-In	5 days	Wed 10/20/10
178		Drywall	11 days	Fri 11/19/10
179		**Lv1 Finishes**	**101 days**	**Fri 11/19/10**
180		Lv1 Labs	85 days	Fri 11/19/10
181		Lv1 Core	77 days	Thu 12/23/10
182		**Lv0 Areaway Rough-In & Finishes**	**278 days**	**Mon 2/22/10**
183		**Lv0 Rough-In**	**198 days**	**Mon 2/22/10**
184		Fireproofing	9 days	Mon 2/22/10
185		Interior Walls	7 days	Thu 2/25/10
186		VAV Installation	9 days	Thu 9/9/10
187		Electrical/Power Rough-In	5 days	Mon 10/25/10
188		Plumbing Rough-In	5 days	Mon 10/25/10
189		Drywall	8 days	Mon 11/15/10
190		**Lv0 Finishes**	**79 days**	**Fri 11/26/10**
191		Lv0 Finishes	79 days	Fri 11/26/10
192		**Material Sciences Rough-In & Finishes**	**322 days**	**Mon 12/14/09**
193		**Lv3 Lab Rough-In**	**183 days**	**Mon 12/21/09**
194		Interior Walls	55 days	Mon 12/21/09
195		Perimeter Walls	30 days	Mon 5/17/10
196		Fireproofing	8 days	Wed 1/27/10
197		VAV Installation	11.06 days	Thu 4/8/10
198		Plumbing Rough-In	48 days	Thu 5/13/10
199		Electrical/Power Rough-In	4 days	Mon 7/19/10
200		Drywall	15 days	Thu 8/12/10



Project: Existing Schedule Summa
Date: Tue 4/5/11

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

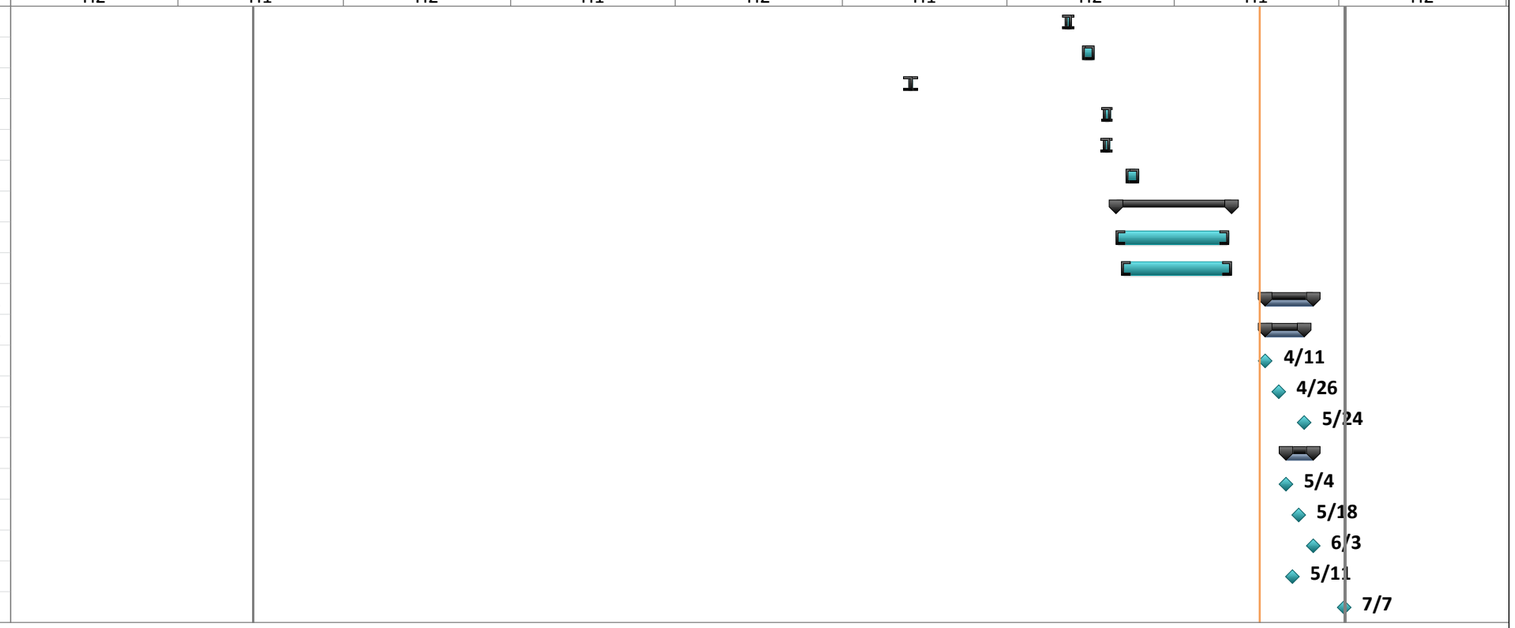
ID	Task Mode	Task Name	Duration	Start
201		**Lv3 Core Rough-In**	**170 days**	**Wed 3/3/10**
202		Interior Walls	32 days	Wed 3/3/10
203		Perimeter Walls	35 days	Mon 5/17/10
204		VAV Installation	18 days	Mon 5/17/10
205		Fireproofing	26 days	Wed 3/24/10
206		Electrical/Power Rough-In	8 days	Tue 7/6/10
207		Plumbing Rough-In	38 days	Tue 7/6/10
208		Drywall	5 days	Wed 10/20/10
209		**Lv3 Finishes**	**124 days**	**Fri 9/3/10**
210		Lab Finishes	106 days	Fri 9/3/10
211		Core Finishes	111 days	Wed 9/22/10
212		**Lv2 Lab Rough-In**	**168 days**	**Wed 12/23/09**
213		Interior Walls	16 days	Wed 12/23/09
214		Perimeter Walls	35 days	Mon 3/29/10
215		Fireproofing	9 days	Mon 1/18/10
216		VAV Installation	22 days	Mon 3/22/10
217		Plumbing Rough-In	30 days	Mon 6/14/10
218		Electrical/Power Rough-In	8 days	Mon 7/19/10
219		Drywall	11 days	Fri 7/30/10
220		**Lv2 Core Rough-In**	**187 days**	**Mon 2/8/10**
221		Interior Walls	28 days	Mon 2/8/10
222		Perimeter Walls	17 days	Fri 7/9/10
223		VAV Installation	11 days	Wed 5/12/10
224		Fireproofing	4 days	Thu 3/18/10
225		Electrical/Power Rough-In	7 days	Wed 7/7/10
226		Core Plumbing Rough-In	19 days	Mon 8/9/10
227		Drywall	49 days	Thu 8/19/10
228		**Lv2 Finishes**	**115 days**	**Wed 9/29/10**
229		Lv2 Labs	102 days	Wed 9/29/10
230		Lv2 Core	95 days	Wed 10/27/10
231		**Lv1 Lab Rough-In**	**229 days**	**Mon 12/14/09**
232		Interior Walls	46 days	Mon 12/14/09
233		Perimeter Walls	105 days	Mon 4/12/10
234		Fireproofing	10 days	Tue 2/9/10
235		VAV Installation	9 days	Tue 9/21/10
236		Plumbing Rough-In	5 days	Thu 9/23/10
237		Electrical/Power Rough-In	2 days	Wed 9/29/10
238		Drywall	8 days	Tue 10/19/10
239		**Lv1 Core Rough-In**	**204 days**	**Wed 2/10/10**
240		Interior Walls	4 days	Wed 2/10/10



Project: Existing Schedule Summa
Date: Tue 4/5/11

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

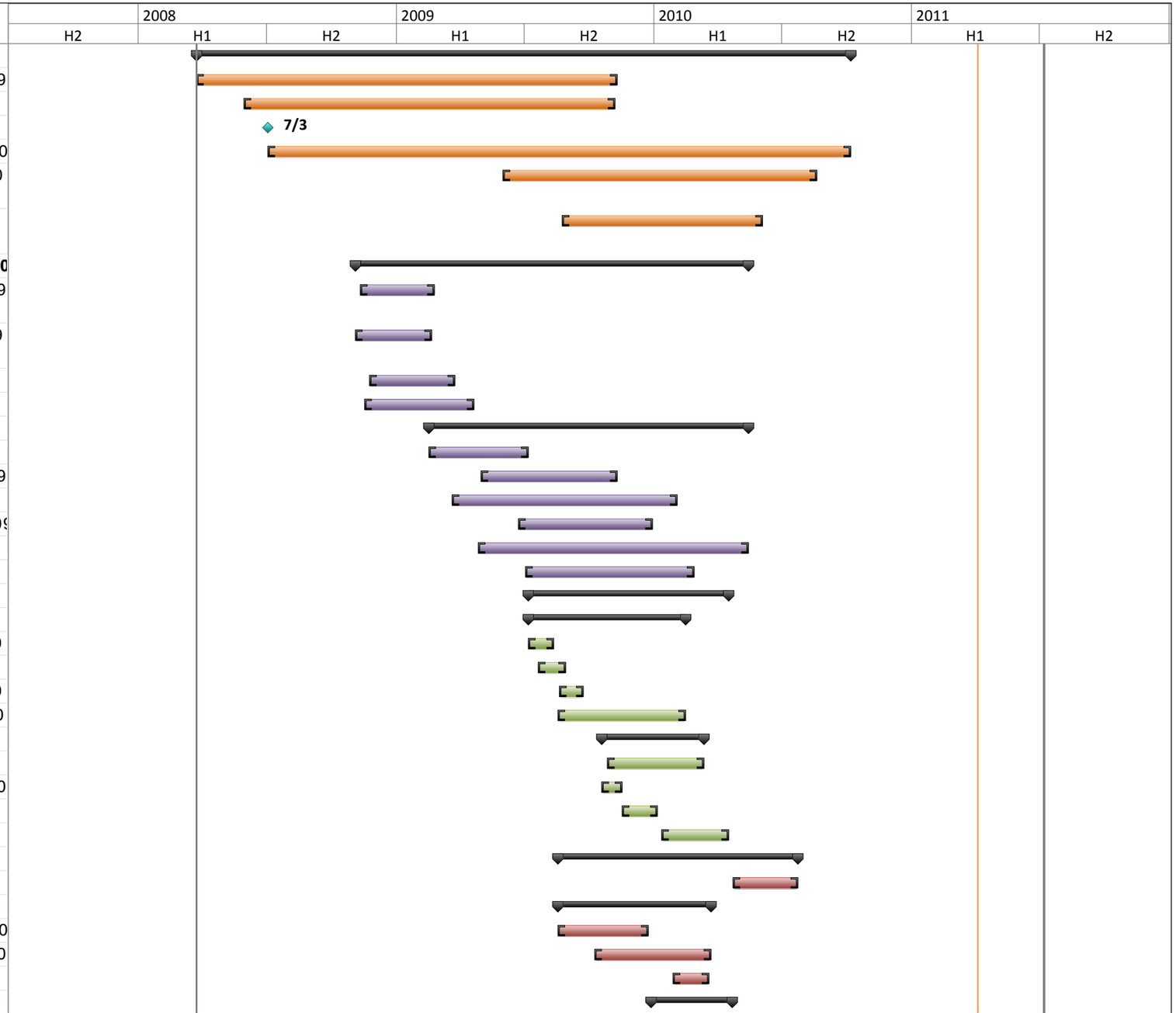
ID	Task Mode	Task Name	Duration	Start
241		Perimeter Walls	5 days	Fri 9/3/10
242		VAV Installation	9 days	Wed 9/22/10
243		Fireproofing	4 days	Mon 3/15/10
244		Electrical/Power Rough-In	6 days	Fri 10/15/10
245		Core Plumbing Rough-In	5 days	Fri 10/15/10
246		Drywall	10 days	Tue 11/9/10
247		**Lv1 Finishes**	**91 days**	**Fri 10/29/10**
248		Lv1 Labs	88 days	Fri 10/29/10
249		Lv1 Core	87 days	Thu 11/4/10
250		**Close-Out**	**39 days**	**Mon 4/11/11**
251		**Material Sciences**	**31 days**	**Mon 4/11/11**
252		Level 3 Close-Out	0 days	Mon 4/11/11
253		Level 2 Close-Out	0 days	Tue 4/26/11
254		Level 1 Close-Out	0 days	Tue 5/24/11
255		**Life Sciences**	**22 days**	**Wed 5/4/11**
256		Level 3 Close-Out	0 days	Wed 5/4/11
257		Level 2 Close-Out	0 days	Wed 5/18/11
258		Level 1 Close-Out	0 days	Fri 6/3/11
259		Level 0 Close-Out	0 days	Wed 5/11/11
260		**Building Turnover**	0 days	Thu 7/7/11



Project: Existing Schedule Summa
Date: Tue 4/5/11

Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Deadline	
Split		External Tasks		Inactive Summary		Manual Summary		Progress	
Milestone		External Milestone		Manual Task		Start-only			
Summary		Inactive Task		Duration-only		Finish-only			

ID	Task Mode	Task Name	Duration	Start	Finish
1		**Design/Bid & Award/ Procurement**	**663 days**	**Mon 3/24/08**	**Wed 10/6/10**
2		Design Phase	426 days	Mon 3/24/08	Mon 11/9/09
3		Bid/Award	376 days	Fri 5/30/08	Fri 11/6/09
4		Notice To Proceed	0 days	Thu 7/3/08	Thu 7/3/08
5		Submittal/Fabrication/Procurement	590 days	Thu 7/3/08	Wed 10/6/10
6		Material Science Coordination Drawings	319 days	Mon 6/1/09	Thu 8/19/10
7		Life Sciences Coordination Drawings	204 days	Mon 8/24/09	Thu 6/3/10
8		**Foundation**	**399 days**	**Tue 11/4/0**	**Fri 5/14/10**
9		Material Sciences Excavation and Shoring	75 days	Tue 11/11/08	Mon 2/23/09
10		Life Sciences Excavation and Shoring	78 days	Tue 11/4/08	Thu 2/19/09
11		Material Sciences Mini-Piles	87 days	Mon 11/24/08	Tue 3/24/09
12		Life Sciences Mini Piles	111 days	Mon 11/17/08	Mon 4/20/09
13		**Foundation's & Slab - On - Grade**	**325 days**	**Mon 2/16/09**	**Fri 5/14/10**
14		CL BB - Y5	101 days	Mon 2/16/09	Mon 7/6/09
15		CL Y5 - S5	137 days	Fri 5/1/09	Mon 11/9/09
16		CL J - S5	228 days	Sat 3/21/09	Tue 2/2/10
17		CL T - L	136 days	Tue 6/23/09	Tue 12/29/09
18		Areaways & Cleanrooms	275 days	Mon 4/27/09	Fri 5/14/10
19		CL 13 - 20	171 days	Fri 7/3/09	Fri 2/26/10
20		**Superstructure**	**204 days**	**Tue 7/7/09**	**Fri 4/16/10**
21		**Material Sciences**	**159 days**	**Tue 7/7/09**	**Sun 2/14/10**
22		CL BB - W	26 days	Tue 7/7/09	Tue 8/11/09
23		CL W - R	29 days	Tue 7/21/09	Fri 8/28/09
24		CL R - J	24 days	Thu 8/20/09	Tue 9/22/09
25		Shear Wall	130 days	Tue 8/18/09	Sun 2/14/10
26		**Life Sciences**	**105 days**	**Mon 10/19/09**	**Fri 3/12/10**
27		Shear Walls	99 days	Tue 10/27/09	Fri 3/12/10
28		CL 12 - 16	21 days	Mon 10/19/0	Mon 11/16/0
29		CL 16 - 21	36 days	Tue 11/17/09	Tue 1/5/10
30		Core/Areaway	69 days	Tue 1/12/10	Fri 4/16/10
31		**Concrete Slabs**	**244 days**	**Tue 8/18/09**	**Fri 7/23/10**
32		Tunnel Phase CL A1 - LS	66 days	Fri 4/23/10	Fri 7/23/10
33		**Material Sciences**	**155 days**	**Tue 8/18/09**	**Mon 3/22/10**
34		CL BB - R	92 days	Tue 8/18/09	Wed 12/23/0
35		CL R - M	117 days	Fri 10/9/09	Mon 3/22/10
36		CL M - H	37 days	Thu 1/28/10	Fri 3/19/10
37		**Life Sciences**	**83 days**	**Mon 12/28/09**	**Wed 4/21/10**



Project: Proposed Schedule Summ
Date: Tue 4/5/11

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

ID	Task Mode	Task Name	Duration	Start	Finish
38		CL 12 - 16	83 days	Mon 12/28/0	Wed 4/21/10
39		CL 16 - 21	56 days	Wed 1/13/10	Wed 3/31/10
40		CL 12 - 8	14 days	Fri 3/5/10	Wed 3/24/10
41		Areaway Lv1 & Lv2	49 days	Mon 1/4/10	Thu 3/11/10
42		Areaway Lv3	19 days	Fri 3/5/10	Wed 3/31/10
43		Areaway Lv4	4 days	Tue 3/23/10	Fri 3/26/10
44		Areaway Roof	30 days	Mon 4/19/10	Fri 5/28/10
45		**Single-Skin Enclosure**	**168 days**	**Mon 11/9/09**	**Wed 6/30/10**
46		**Material Sciences North Elevation**	**165 days**	**Mon 11/9/09**	**Fri 6/25/10**
47		Precast Attach Steel	5 days	Mon 11/9/09	Fri 11/13/09
48		Precast Panels	13 days	Mon 11/16/0	Wed 12/2/09
49		Insulation/Air Barrier Precast Panels	38 days	Thu 3/4/10	Mon 4/26/10
50		Ribbon Windows	130 days	Mon 12/28/0	Fri 6/25/10
51		**Material Sciences East Elevation**	**122 days**	**Wed 11/18/09**	**Thu 5/6/10**
52		Precast Attach Steel	1 day	Wed 11/18/0	Wed 11/18/0
53		Precast Panels	5 days	Mon 11/23/0	Fri 11/27/09
54		Insulation/Air Barrier Precast Panels	5 days	Mon 11/30/09	Fri 12/4/09
55		Ribbon Windows	73 days	Tue 1/26/10	Thu 5/6/10
56		**Life Sciences East Elevation**	**160 days**	**Thu 11/19/09**	**Wed 6/30/10**
57		Precast Attach Steel	10 days	Mon 11/9/09	Fri 11/20/09
58		Precast Panels	9 days	Thu 12/3/09	Tue 12/15/09
59		Insulation/Air Barrier Precast Panels	65 days	Thu 4/1/10	Wed 6/30/10
60		Ribbon Windows	68 days	Mon 3/29/10	Wed 6/30/10
61		**Life Sciences South Elevation**	**160 days**	**Thu 11/19/09**	**Wed 6/30/10**
62		Precast Attach Steel	5 days	Fri 11/20/09	Thu 11/26/09
63		Precast Panels	5 days	Wed 12/16/0	Tue 12/22/09
64		Insulation/Air Barrier Precast Panels	80 days	Mon 3/8/10	Fri 6/25/10
65		Ribbon Windows	48 days	Mon 4/26/10	Wed 6/30/10
66		**Roofing**	**65 days**	**Mon 1/18/10**	**Sun 4/18/10**
67		Level 2 Green Roof	41 days	Mon 1/18/10	Mon 3/15/10
68		Level 3 Green Roof	12 days	Wed 3/17/10	Thu 4/1/10
69		Level 4 Green Roof	8 days	Thu 4/8/10	Sun 4/18/10
70		**Double-Skin Enclosure**	**290 days**	**Thu 11/26/09**	**Wed 1/5/11**
71		**Material Science South Elevation**	**194 days**	**Thu 11/26/09**	**Tue 8/24/10**
72		Precast Attach Steel	5 days	Thu 11/26/09	Wed 12/2/09
73		Precast Panels	13 days	Wed 12/23/0	Fri 1/8/10

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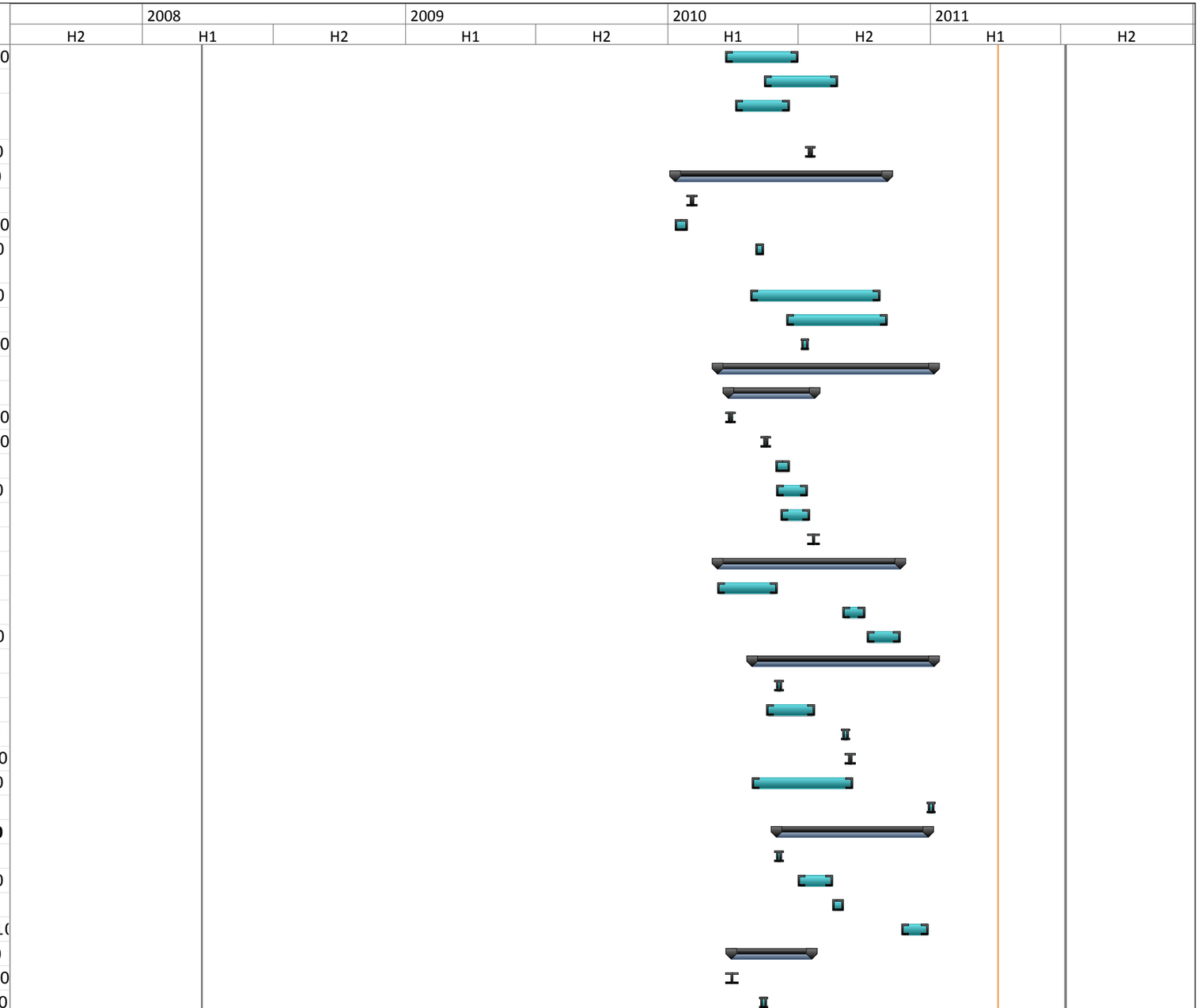
Task
Split
Milestone
Summary
Project Summary
External Tasks
External Milestone
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Deadline
Progress

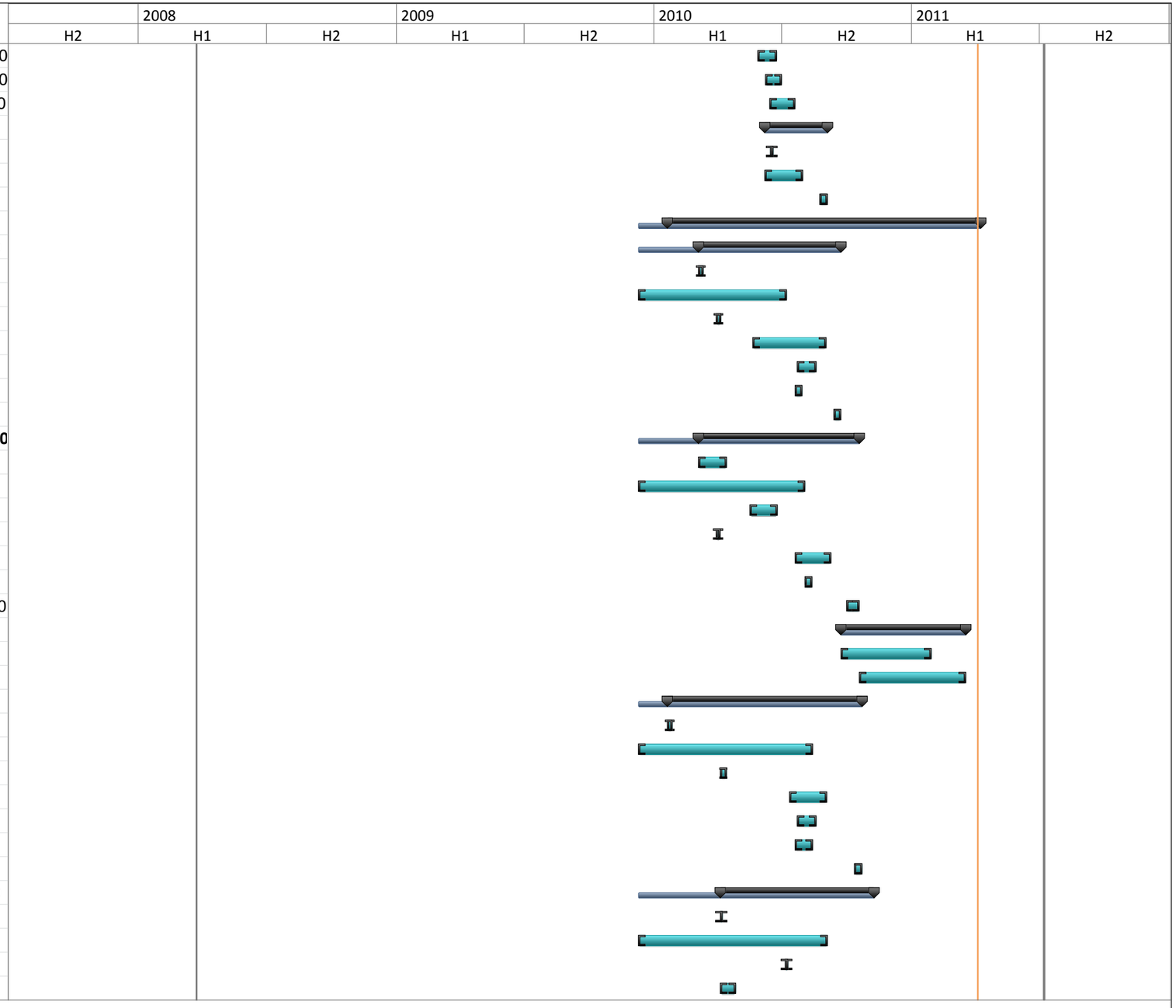
ID	Task Mode	Task Name	Duration	Start	Finish
74		Ribbon Windows	73 days	Mon 3/22/10	Wed 6/30/10
75		Interior Ribbon Windows	73 days	Sat 5/15/10	Tue 8/24/10
76		Insulation/Air Barrier Precast Panels	55 days	Mon 4/5/10	Fri 6/18/10
77		Sunshade	4 days	Thu 7/15/10	Tue 7/20/10
78		**Life Science West Elevation**	**211 days**	**Mon 1/11/10**	**Mon 11/1/10**
79		Precast Attach Steel	5 days	Mon 2/1/10	Fri 2/5/10
80		Precast Panels	13 days	Mon 1/11/10	Wed 1/27/10
81		Insulation/Air Barrier Precast Panels	9 days	Mon 5/3/10	Thu 5/13/10
82		Ribbon Windows	130 days	Mon 4/26/10	Fri 10/22/10
83		Interior Ribbon Windows	100 days	Tue 6/15/10	Mon 11/1/10
84		Sunshade	7 days	Tue 7/6/10	Wed 7/14/10
85		**Areaway Enclosure**	**215 days**	**Thu 3/11/10**	**Wed 1/5/11**
86		**North Elevation**	**86 days**	**Fri 3/26/10**	**Fri 7/23/10**
87		Precast Attach Steel	4 days	Fri 3/26/10	Wed 3/31/10
88		Precast Panels	4 days	Fri 5/14/10	Wed 5/19/10
89		Ribbon Windows	15 days	Mon 5/31/10	Fri 6/18/10
90		PH Louvers	31 days	Tue 6/1/10	Tue 7/13/10
91		Insulation/Air Barrier Precast P	30 days	Mon 6/7/10	Fri 7/16/10
92		Sunshade	3 days	Wed 7/21/10	Fri 7/23/10
93		**Soffit Exterior**	**182 days**	**Thu 3/11/10**	**Fri 11/19/10**
94		Exterior Miscellaneous Steel Fr	59 days	Thu 3/11/10	Tue 6/1/10
95		Exterior Frame/Sheath	23 days	Wed 9/1/10	Fri 10/1/10
96		Exterior Metal Panels	34 days	Tue 10/5/10	Fri 11/19/10
97		**Areaway Entrance Exterior**	**181 days**	**Wed 4/28/10**	**Wed 1/5/11**
98		Miscellaneous Steel Frame	5 days	Tue 6/1/10	Mon 6/7/10
99		2nd Floor Windows	49 days	Tue 5/18/10	Fri 7/23/10
100		Exterior Frame/Sheath	6 days	Wed 9/1/10	Wed 9/8/10
101		Waterproofing	3 days	Thu 9/9/10	Mon 9/13/10
102		Storefront	100 days	Wed 4/28/10	Tue 9/14/10
103		Exterior Metal Panels	6 days	Wed 12/29/1	Wed 1/5/11
104		**Areaway Lightwell**	**151 days**	**Tue 6/1/10**	**Tue 12/28/10**
105		Exterior Miscellaneous Steel Fr	5 days	Tue 6/1/10	Mon 6/7/10
106		Exterior Frame/Sheath	34 days	Thu 7/1/10	Tue 8/17/10
107		Waterproofing	11 days	Wed 8/18/10	Wed 9/1/10
108		Exterior Metal Panels	27 days	Mon 11/22/1	Tue 12/28/1(
109		**West Elevation**	**80 days**	**Tue 3/30/10**	**Mon 7/19/10**
110		Precast Attach Steel	2 days	Tue 3/30/10	Wed 3/31/10
111		Precast Panels	6 days	Mon 5/10/10	Mon 5/17/10



Project: Proposed Schedule Summ
Date: Tue 4/5/11

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

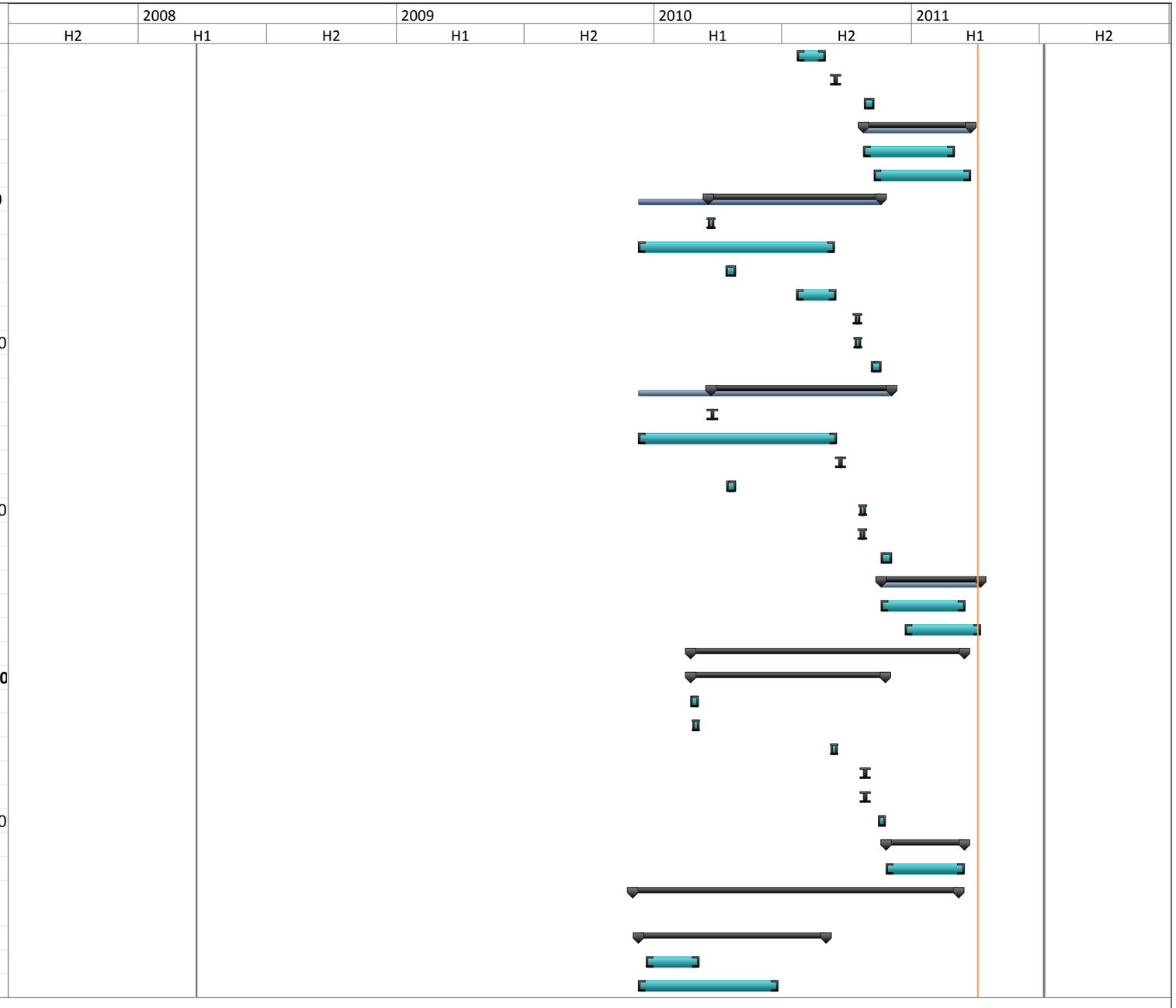
ID	Task Mode	Task Name	Duration	Start	Finish
112		Ribbon Windows	19 days	Fri 5/28/10	Wed 6/23/10
113		PH Louvers	17 days	Tue 6/8/10	Wed 6/30/10
114		Insulation/Air Barrier Precast P	26 days	Mon 6/14/10	Mon 7/19/10
115		**Areaway Roofing**	**65 days**	**Mon 6/7/10**	**Fri 9/3/10**
116		Stair/Core Level 6 Roofing	4 days	Tue 6/15/10	Fri 6/18/10
117		PH/Areaway Level 5 Roofin	40 days	Mon 6/7/10	Fri 7/30/10
118		PH/Areaway Level 5 Roof T	9 days	Tue 8/24/10	Fri 9/3/10
119		**Life Sciences Rough-In & Finishes**	**318 days**	**Wed 1/20/10**	**Fri 4/8/11**
120		**Lv3 Lab Rough-In**	**144 days**	**Fri 3/5/10**	**Wed 9/22/10**
121		Interior Walls	5 days	Fri 3/5/10	Thu 3/11/10
122		Perimeter Walls	150 days	Thu 12/10/09	Wed 7/7/10
123		Fireproofing	5 days	Tue 3/30/10	Mon 4/5/10
124		VAV Installation	74 days	Fri 5/21/10	Wed 9/1/10
125		Plumbing Rough-In	19 days	Fri 7/23/10	Wed 8/18/10
126		Electrical/Power Rough-In	8 days	Tue 7/20/10	Thu 7/29/10
127		Drywall	8 days	Mon 9/13/10	Wed 9/22/10
128		**Lv3 Core Rough-In**	**162 days**	**Fri 3/5/10**	**Mon 10/18/10**
129		Interior Walls	28 days	Fri 3/5/10	Tue 4/13/10
130		Perimeter Walls	168 days	Thu 12/10/09	Mon 8/2/10
131		VAV Installation	29 days	Mon 5/17/10	Thu 6/24/10
132		Fireproofing	5 days	Tue 3/30/10	Sun 4/4/10
133		Electrical/Power Rough-In	37 days	Tue 7/20/10	Wed 9/8/10
134		Plumbing Rough-In	8 days	Tue 8/3/10	Thu 8/12/10
135		Drywall	12 days	Fri 10/1/10	Mon 10/18/10
136		**Lv3 Finishes**	**127 days**	**Thu 9/23/10**	**Fri 3/18/11**
137		Lab Finishes	92 days	Thu 9/23/10	Fri 1/28/11
138		Core Finishes	109 days	Tue 10/19/10	Fri 3/18/11
139		**Lv2 Lab Rough-In**	**198 days**	**Wed 1/20/10**	**Fri 10/22/10**
140		Interior Walls	5 days	Wed 1/20/10	Tue 1/26/10
141		Perimeter Walls	177 days	Thu 12/10/09	Fri 8/13/10
142		Fireproofing	7 days	Mon 4/5/10	Tue 4/13/10
143		VAV Installation	39 days	Mon 7/12/10	Thu 9/2/10
144		Plumbing Rough-In	19 days	Fri 7/23/10	Wed 8/18/10
145		Electrical/Power Rough-In	19 days	Tue 7/20/10	Fri 8/13/10
146		Drywall	9 days	Tue 10/12/10	Fri 10/22/10
147		**Lv2 Core Rough-In**	**156 days**	**Mon 4/5/10**	**Mon 11/8/10**
148		Interior Walls	3 days	Mon 4/5/10	Wed 4/7/10
149		Perimeter Walls	192 days	Thu 12/10/09	Fri 9/3/10
150		VAV Installation	4 days	Tue 7/6/10	Fri 7/9/10
151		Fireproofing	16 days	Mon 4/5/10	Mon 4/26/10



Project: Proposed Schedule Summ
Date: Tue 4/5/11

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

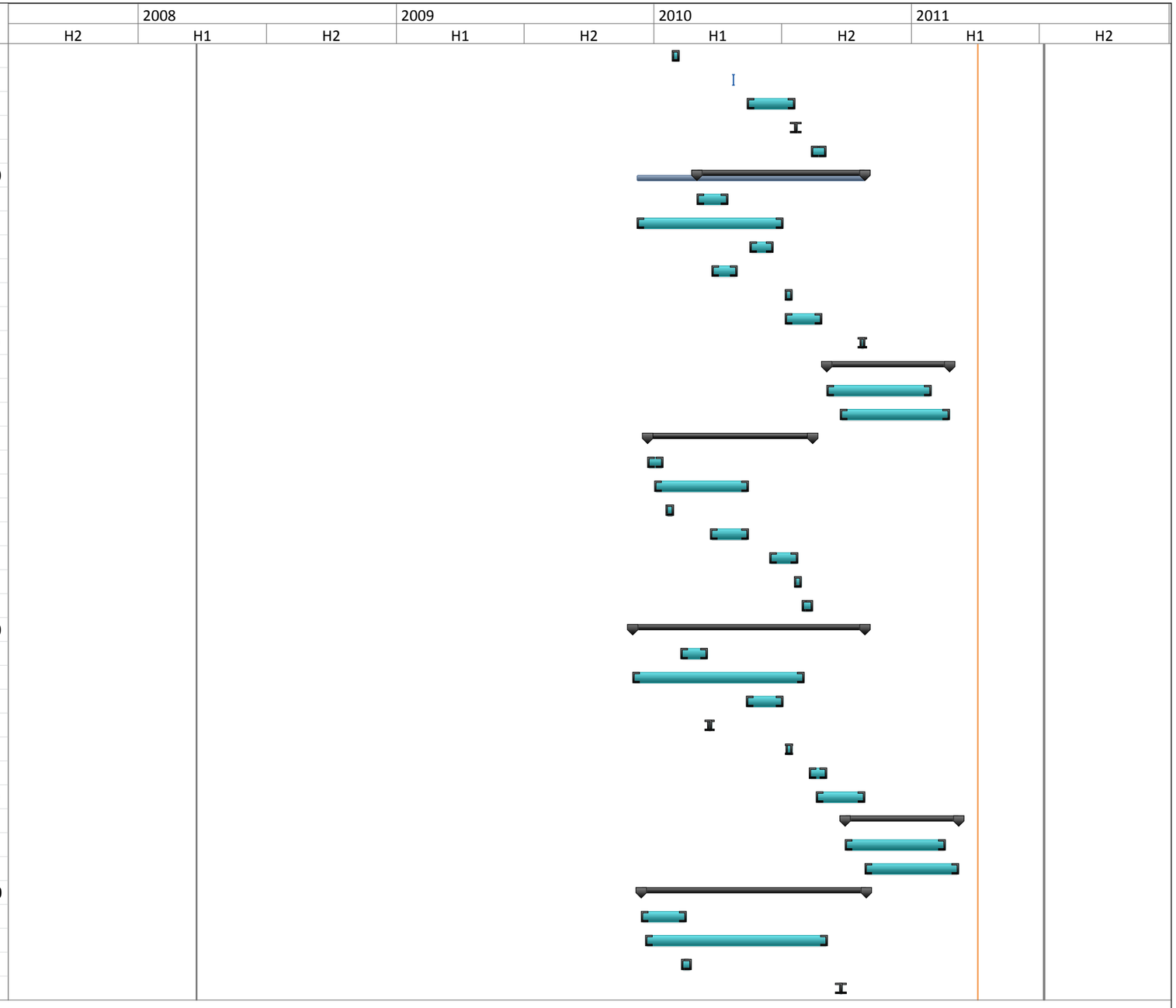
ID	Task Mode	Task Name	Duration	Start	Finish
152		Electrical/Power Rough-In	28 days	Fri 7/23/10	Tue 8/31/10
153		Core Plumbing Rough-In	5 days	Mon 9/13/10	Fri 9/17/10
154		Drywall	10 days	Tue 10/26/10	Mon 11/8/10
155		**Lv2 Finishes**	**110 days**	**Mon 10/25/10**	**Fri 3/25/11**
156		Lv2 Labs	93 days	Mon 10/25/10	Wed 3/2/11
157		Lv2 Core	99 days	Tue 11/9/10	Fri 3/25/11
158		**Lv1 Lab Rough-In**	**175 days**	**Fri 3/19/10**	**Thu 11/18/10**
159		Interior Walls	6 days	Fri 3/19/10	Fri 3/26/10
160		Perimeter Walls	198 days	Thu 12/10/09	Mon 9/13/10
161		Fireproofing	10 days	Tue 4/13/10	Mon 4/26/10
162		VAV Installation	40 days	Thu 7/22/10	Wed 9/15/10
163		Plumbing Rough-In	5 days	Wed 10/13/10	Tue 10/19/10
164		Electrical/Power Rough-In	6 days	Wed 10/13/10	Wed 10/20/10
165		Drywall	10 days	Fri 11/5/10	Thu 11/18/10
166		**Lv1 Core Rough-In**	**184 days**	**Tue 3/23/10**	**Fri 12/3/10**
167		Interior Walls	4 days	Tue 3/23/10	Fri 3/26/10
168		Perimeter Walls	201 days	Thu 12/10/09	Thu 9/16/10
169		VAV Installation	5 days	Mon 9/20/10	Fri 9/24/10
170		Fireproofing	9 days	Wed 4/14/10	Mon 4/26/10
171		Electrical/Power Rough-In	6 days	Wed 10/20/10	Wed 10/27/10
172		Core Plumbing Rough-In	5 days	Wed 10/20/10	Tue 10/26/10
173		Drywall	11 days	Fri 11/19/10	Fri 12/3/10
174		**Lv1 Finishes**	**101 days**	**Fri 11/19/10**	**Fri 4/8/11**
175		Lv1 Labs	85 days	Fri 11/19/10	Thu 3/17/11
176		Lv1 Core	77 days	Thu 12/23/10	Fri 4/8/11
177		**Lv0 Areaway Rough-In & Finishes**	**278 days**	**Mon 2/22/10**	**Wed 3/16/11**
178		**Lv0 Rough-In**	**198 days**	**Mon 2/22/10**	**Wed 11/24/10**
179		Fireproofing	9 days	Mon 2/22/10	Thu 3/4/10
180		Interior Walls	7 days	Thu 2/25/10	Fri 3/5/10
181		VAV Installation	7 days	Thu 9/9/10	Fri 9/17/10
182		Electrical/Power Rough-In	5 days	Mon 10/25/10	Fri 10/29/10
183		Plumbing Rough-In	5 days	Mon 10/25/10	Fri 10/29/10
184		Drywall	8 days	Mon 11/15/10	Wed 11/24/10
185		**Lv0 Finishes**	**79 days**	**Fri 11/26/10**	**Wed 3/16/11**
186		Lv0 Finishes	79 days	Fri 11/26/10	Wed 3/16/11
187		**Material Sciences Rough-In & Finishes**	**330 days**	**Wed 12/2/09**	**Tue 3/8/11**
188		**Lv3 Lab Rough-In**	**190 days**	**Thu 12/10/09**	**Wed 9/1/10**
189		Interior Walls	55 days	Mon 12/21/09	Fri 3/5/10
190		Perimeter Walls	142 days	Thu 12/10/09	Fri 6/25/10



Project: Proposed Schedule Summ
Date: Tue 4/5/11

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

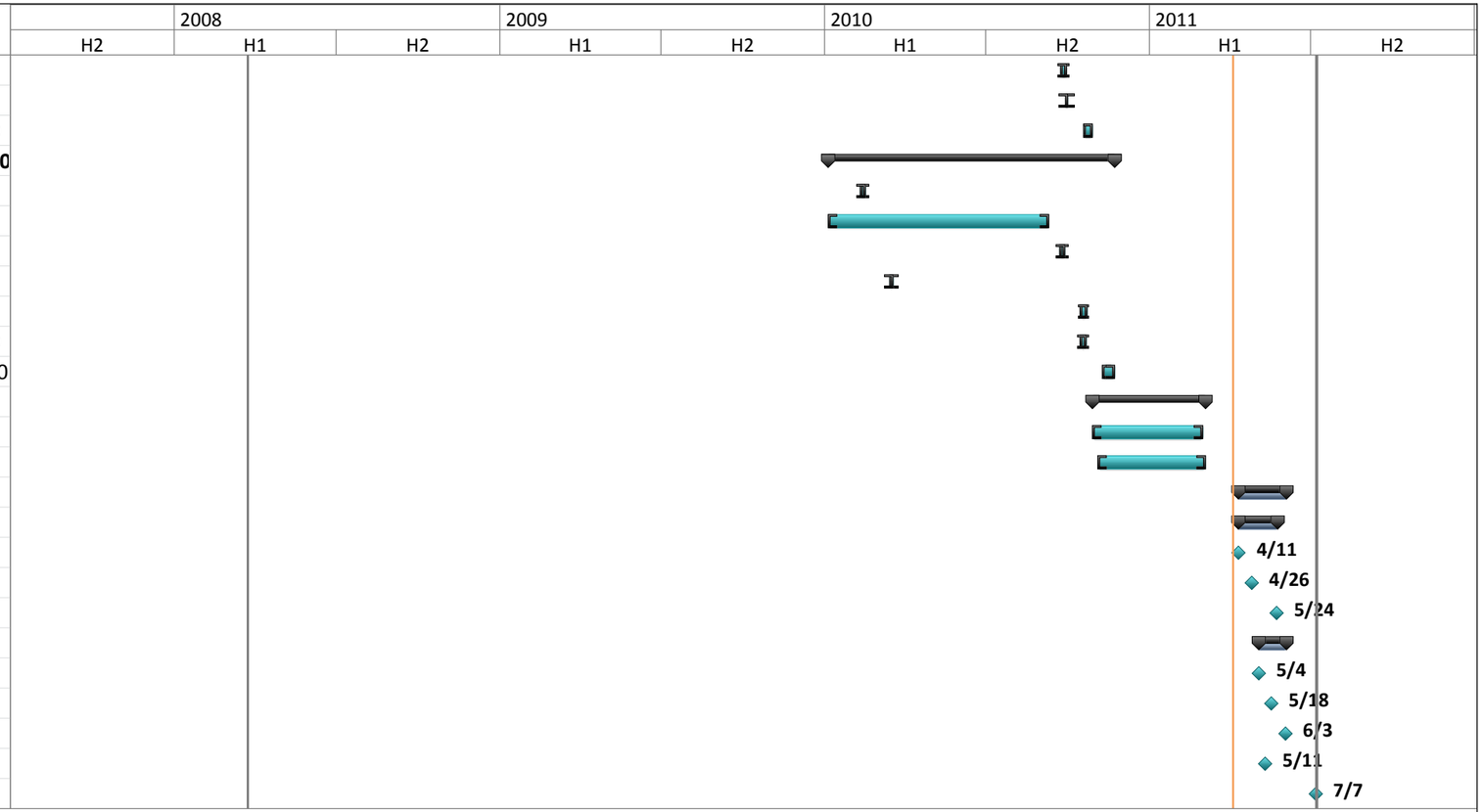
ID	Task Mode	Task Name	Duration	Start	Finish
191		Fireproofing	8 days	Wed 1/27/10	Fri 2/5/10
192		VAV Installation	1 day	Fri 4/23/10	Fri 4/23/10
193		Plumbing Rough-In	48 days	Thu 5/13/10	Mon 7/19/10
194		Electrical/Power Rough-In	4 days	Mon 7/19/10	Thu 7/22/10
195		Drywall	15 days	Thu 8/12/10	Wed 9/1/10
196		**Lv3 Core Rough-In**	**170 days**	**Wed 3/3/10**	**Tue 10/26/10**
197		Interior Walls	32 days	Wed 3/3/10	Thu 4/15/10
198		Perimeter Walls	149 days	Tue 12/8/09	Fri 7/2/10
199		VAV Installation	25 days	Mon 5/17/10	Fri 6/18/10
200		Fireproofing	26 days	Wed 3/24/10	Wed 4/28/10
201		Electrical/Power Rough-In	8 days	Tue 7/6/10	Thu 7/15/10
202		Plumbing Rough-In	38 days	Tue 7/6/10	Thu 8/26/10
203		Drywall	5 days	Wed 10/20/10	Tue 10/26/10
204		**Lv3 Finishes**	**124 days**	**Fri 9/3/10**	**Wed 2/23/11**
205		Lab Finishes	106 days	Fri 9/3/10	Fri 1/28/11
206		Core Finishes	111 days	Wed 9/22/10	Wed 2/23/11
207		**Lv2 Lab Rough-In**	**168 days**	**Wed 12/23/09**	**Fri 8/13/10**
208		Interior Walls	16 days	Wed 12/23/09	Wed 1/13/10
209		Perimeter Walls	96 days	Sat 1/2/10	Fri 5/14/10
210		Fireproofing	9 days	Mon 1/18/10	Thu 1/28/10
211		VAV Installation	40 days	Mon 3/22/10	Fri 5/14/10
212		Plumbing Rough-In	30 days	Mon 6/14/10	Fri 7/23/10
213		Electrical/Power Rough-In	8 days	Mon 7/19/10	Wed 7/28/10
214		Drywall	11 days	Fri 7/30/10	Fri 8/13/10
215		**Lv2 Core Rough-In**	**235 days**	**Wed 12/2/09**	**Tue 10/26/10**
216		Interior Walls	28 days	Mon 2/8/10	Wed 3/17/10
217		Perimeter Walls	174 days	Wed 12/2/09	Sun 8/1/10
218		VAV Installation	38 days	Wed 5/12/10	Fri 7/2/10
219		Fireproofing	4 days	Thu 3/18/10	Tue 3/23/10
220		Electrical/Power Rough-In	7 days	Wed 7/7/10	Thu 7/15/10
221		Core Plumbing Rough-In	19 days	Mon 8/9/10	Thu 9/2/10
222		Drywall	49 days	Thu 8/19/10	Tue 10/26/10
223		**Lv2 Finishes**	**115 days**	**Wed 9/29/10**	**Tue 3/8/11**
224		Lv2 Labs	102 days	Wed 9/29/10	Thu 2/17/11
225		Lv2 Core	95 days	Wed 10/27/10	Tue 3/8/11
226		**Lv1 Lab Rough-In**	**229 days**	**Mon 12/14/09**	**Thu 10/28/10**
227		Interior Walls	46 days	Mon 12/14/09	Mon 2/15/10
228		Perimeter Walls	186 days	Sun 12/20/09	Fri 9/3/10
229		Fireproofing	10 days	Tue 2/9/10	Mon 2/22/10
230		VAV Installation	4 days	Tue 9/21/10	Fri 9/24/10



Project: Proposed Schedule Summ
Date: Tue 4/5/11

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

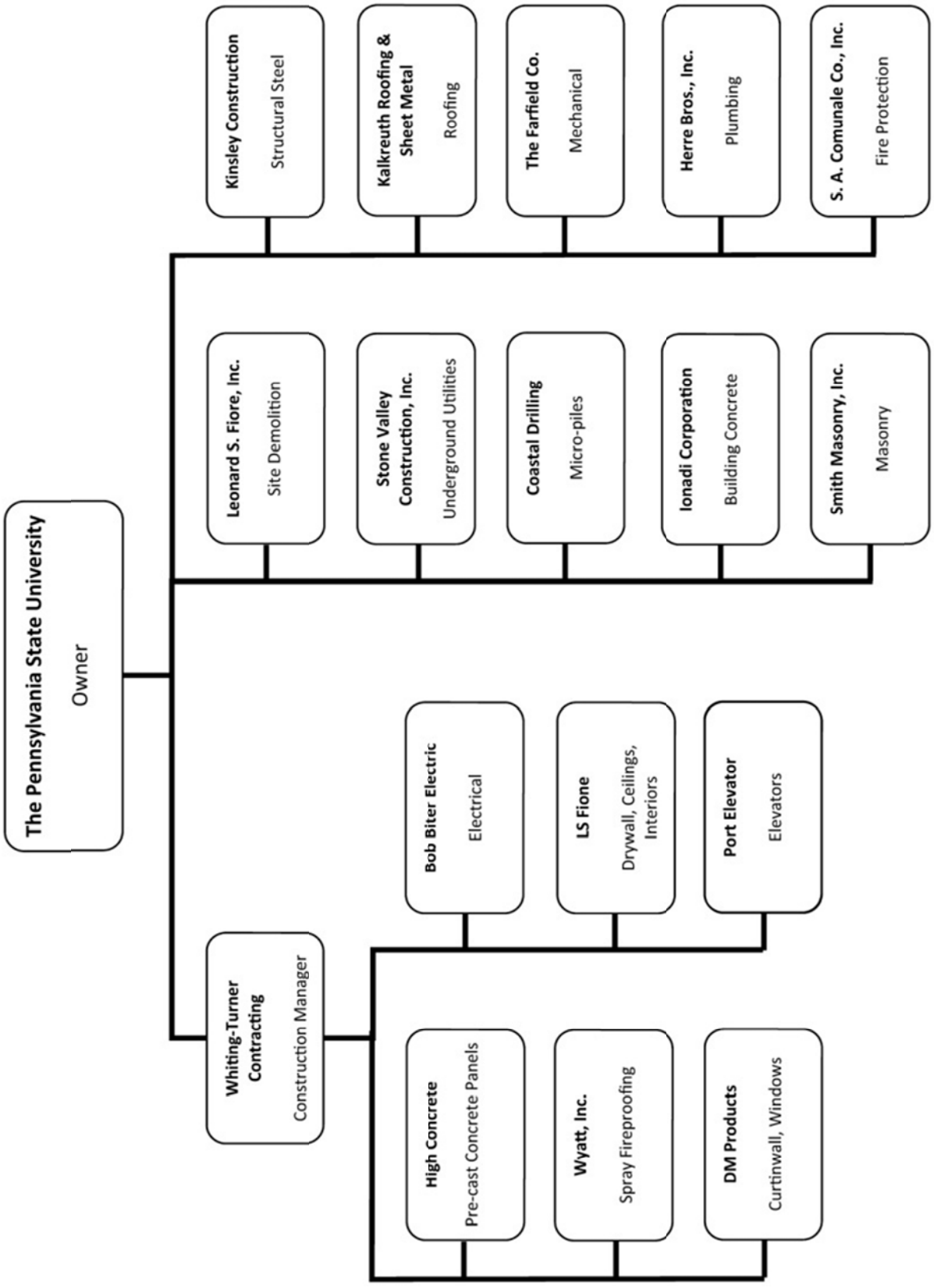
ID	Task Mode	Task Name	Duration	Start	Finish
231		Plumbing Rough-In	5 days	Thu 9/23/10	Wed 9/29/10
232		Electrical/Power Rough-In	2 days	Wed 9/29/10	Thu 9/30/10
233		Drywall	8 days	Tue 10/19/10	Thu 10/28/10
234		**Lv1 Core Rough-In**	**230 days**	**Tue 1/5/10**	**Mon 11/22/10**
235		Interior Walls	4 days	Wed 2/10/10	Mon 2/15/10
236		Perimeter Walls	178 days	Tue 1/5/10	Thu 9/9/10
237		VAV Installation	4 days	Wed 9/22/10	Mon 9/27/10
238		Fireproofing	4 days	Mon 3/15/10	Thu 3/18/10
239		Electrical/Power Rough-In	6 days	Fri 10/15/10	Fri 10/22/10
240		Core Plumbing Rough-In	5 days	Fri 10/15/10	Thu 10/21/10
241		Drywall	10 days	Tue 11/9/10	Mon 11/22/10
242		**Lv1 Finishes**	**91 days**	**Fri 10/29/10**	**Fri 3/4/11**
243		Lv1 Labs	88 days	Fri 10/29/10	Tue 3/1/11
244		Lv1 Core	87 days	Thu 11/4/10	Fri 3/4/11
245		**Close-Out**	**40 days**	**Mon 4/11/11**	**Fri 6/3/11**
246		**Material Sciences**	**32 days**	**Mon 4/11/11**	**Tue 5/24/11**
247		Level 3 Close-Out	0 days	Mon 4/11/11	Mon 4/11/11
248		Level 2 Close-Out	0 days	Tue 4/26/11	Tue 4/26/11
249		Level 1 Close-Out	0 days	Tue 5/24/11	Tue 5/24/11
250		**Life Sciences**	**23 days**	**Wed 5/4/11**	**Fri 6/3/11**
251		Level 3 Close-Out	0 days	Wed 5/4/11	Wed 5/4/11
252		Level 2 Close-Out	0 days	Wed 5/18/11	Wed 5/18/11
253		Level 1 Close-Out	0 days	Fri 6/3/11	Fri 6/3/11
254		Level 0 Close-Out	0 days	Wed 5/11/11	Wed 5/11/11
255		**Building Turnover**	0 days	Thu 7/7/11	Thu 7/7/11



Project: Proposed Schedule Summ
Date: Tue 4/5/11

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline	
Split	External Tasks	Inactive Summary	Manual Summary	Progress	
Milestone	External Milestone	Manual Task	Start-only		
Summary	Inactive Task	Duration-only	Finish-only		

Project Delivery Tree



Existing Façade Estimate

Exterior Enclosure	Unit	Quantity	Unit Cost	Total Cost
Precast Panels				
Precast Panels with Brick Face	SF	91,539.00	60.00	$5,492,340.00
Crane Size Increase	LS	1.00	50,000.00	$50,000.00
On-Site Mock Up	Allow	1.00	100,000.00	$100,000.00
Factory Pointing of Brick Face	SF	107,731.00	2.00	$215,462.00
Precast Column Connections	EA	600.00	250.00	$150,000.00
			Total:	$6,007,802.00
Building Insulation				
Rigid Insulation - 4" Soffit	SF	4,840.00	4.50	$21,780.00
Insulation on back of Precast 3"	SF	107,979.00	6.25	$674,868.75
EIFS	SF	3,020.00	15.00	$45,300.00
			Total:	$741,948.75
Caulking				
Exterior Precast Panels	LF	11,256.00	3.50	$39,396.00
Exterior Metal Panels	LF	8,456.00	3.50	$29,596.00
Exterior Glass and Glazing	LF	20,094.00	3.50	$70,329.00
Exterior Louvers	LF	8,456.00	3.50	$29,596.00
			Total:	$168,917.00
Metal Panels				
Insulated Metal Panels - MP - 2	SF	0.00	22.00	$0.00
Composite Metal Panel Soffits - MP - 1	SF	81,392.00	45.00	$3,662,640.00
MP - 1 Panels @ Trellis	SF	6,086.00	55.00	$334,730.00
Waterproofing at Metal Panels	SF	59,568.00	3.50	$208,488.00
Masonry at Louvers adj. to Green Roof	SF	784.00	15.50	$12,152.00
Masonry at Parapets	SF	3,757.00	15.50	$58,233.50
			Total:	$4,276,243.50
Light Gauge Metal Framing				
Stud Framing at Metal Panels	SF	34,161.00	12.00	$409,932.00
Stud Framing at Metal Panels - Reduced Scope	SF	25,046.00	8.00	$200,368.00
Sub-Framing for Terra Cotta Panel	SF	28,271.00	16.50	$466,471.50
			Total:	$1,076,771.50
Louvers				
Architectural Louvers - Building Façade	SF	4,672.00	50.00	$233,600.00
Architectural Louvers - Green Roof	SF	784.00	12.50	$9,800.00
Mechanical Louvers - OA Intake	SF	2,464.00	50.00	$123,200.00

			Total:	$366,600.00
Windows				
Exterior Windows - Ribbon System	SF	32,194.00	55.00	$1,770,670.00
Metal Sunscreen	LF	3,880.00	150.00	$582,000.00
Curtain Wall	SF	1,708.00	85.00	$145,180.00
Exterior Windows - 2nd Floor Areas	SF	704.00	55.00	$38,720.00
Storefront at Plaza	SF	1,400.00	45.00	$63,000.00
Glass Entrance Doors				
Single	EA	10.00	2,500.00	$25,000.00
Double	EA	6.00	6,000.00	$36,000.00
Motor Operator Premium	EA	4.00	3,500.00	$14,000.00
Remove/Replace Vestibule for Tunnel Tie-in	LS	1.00	45,000.00	$45,000.00
			Total:	$2,719,570.00
Total	$15,357,852.75			

Revised Façade Estimate

Exterior Enclosure	Unit	Quantity	Unit Cost	Total Cost
Precast Panels				
Precast Panels with Brick Face	SF	91,539.00	55.00	$5,034,645.00
Crane Size Increase	LS	1.00	50,000.00	$50,000.00
On-Site Mock Up	Allow	1.00	100,000.00	$100,000.00
Factory Pointing of Brick Face	SF	107,731.00	2.00	$215,462.00
Precast Column Connections	EA	725.00	250.00	$181,250.00
Metal Safety Grates	LF	1,584.50	30.22	$47,883.59
			Total:	$5,629,240.59
Building Insulation				
Rigid Insulation - 4" Soffit	SF	4,840.00	4.50	$21,780.00
Polyethylene Vapor Barrier	SQ	10,797.00	9.34	$100,843.98
Insulation Cavity Wall - 3"	SF	107,979.00	6.25	$674,868.75
EIFS	SF	3,020.00	15.00	$45,300.00
			Total:	$842,792.73

Caulking				
Exterior Precast Panels	LF	11,256.00	3.50	$39,396.00
Exterior Metal Panels	SF	8,456.00	3.50	$29,596.00
Exterior Glass and Glazing	LF	20,094.00	3.50	$70,329.00
Interior Glass and Glazing	LF	10,047.00	3.50	$35,164.50
Exterior Louvers	LF	8,456.00	3.50	$29,596.00
			Total:	$204,081.50
Metal Panels				
Insulated Metal Panels - MP - 2	SF	0.00	22.00	$0.00
Composite Metal Panel Soffits - MP - 1	SF	81,392.00	45.00	$3,662,640.00
MP - 1 Panels @ Trellis	SF	6,086.00	55.00	$334,730.00
Waterproofing at Metal Panels	SF	59,568.00	3.50	$208,488.00
Masonry at Louvers adj. to Green Roof	SF	784.00	15.50	$12,152.00
Masonry at Parapets	SF	3,757.00	15.50	$58,233.50
			Total:	$4,276,243.50
Light Gauge Metal Framing				
Stud Framing at Metal Panels	SF	34,161.00	12.00	$409,932.00
Stud Framing at Metal Panels - Reduced Scope	SF	25,046.00	8.00	$200,368.00
Sub-Framing for Terra Cotta Panel	SF	28,271.00	16.50	$466,471.50
			Total:	$1,076,771.50
Louvers				
Architectural Louvers - Building Façade	SF	0.00	50.00	$0.00
Architectural Louvers - Green Roof	SF	0.00	12.50	$0.00
Mechanical Louvers - OA Intake	SF	2,464.00	50.00	$123,200.00
			Total:	$123,200.00
Windows				
Exterior Windows - Ribbon System	SF	32,194.00	55.00	$1,770,670.00
Interior Windows (Applied to Double Skin)	SF	12,392.00	45.00	$557,640.00
Metal Sunscreen	LF	2,295.50	150.00	$344,325.00
Curtain Wall	SF	1,708.00	85.00	$145,180.00
Solar Shades	LF	1,584.50	150.00	$237,675.00
Exterior Windows - 2nd Floor Areas	SF	704.00	55.00	$38,720.00
Storefront at Plaza	SF	1,400.00	45.00	$63,000.00
Glass Entrance Doors				
Single	EA	10.00	2,500.00	$25,000.00
Double	EA	6.00	6,000.00	$36,000.00
Motor Operator Premium	EA	4.00	3,500.00	$14,000.00

Remove/Replace Vestibule for Tunnel Tie-in	LS	1.00	45,000.00	$45,000.00
			Total:	$3,277,210.00
Total $15,429,539.82				

VAV Take-Off and Estimate

Room Description	Existing VAV CFM	VAV CFM Capac.	Unit	Crew	Daily Output	Labor Hours	Bare Material	Bare Labor	Total
sp-N-302A-Copy	525	600	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-302B-Reception	525	600	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-302-Staff_Admin	525	600	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-305-IT_Staff_Office	220	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-306A-Conference	310	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-306B-Conference	425	600	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-307-Storage	85	200	Ea.	Q9	11.00	1.455	$ 725.00	$ 67.50	$ 792.50
sp-N-308A-Seminar_Room	630	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-308B-Seminar_Room	630	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-309-IT_Staff_Office	220	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-310B-Kitchen	255	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-310-CafeCommons	2930	2000-4000	Ea.	Q9	6.00	2.67	$ 435.00	$ 124.00	$ 559.00
sp-N-310C-Copy	510	600	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-310D-Mail	510	600	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-310E-Copy	510	600	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-314-Storage	85	200	Ea.	Q9	11.00	1.455	$ 725.00	$ 67.50	$ 792.50
sp-N-315-Distinguished_Office	490	600	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-317-Staff_Assistant	660	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-n319-distinquished office	660	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-320-Staff_Assistant	660	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-321-	840	1000	Ea.	Q9	8.00	2.00	$	$	$

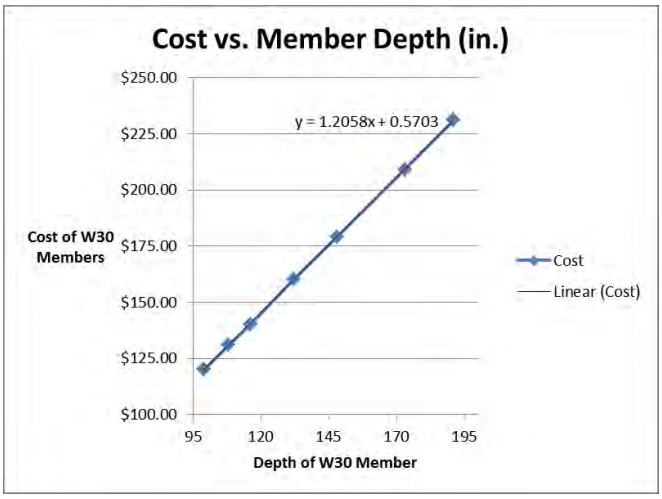
Staff_Assistant							755.00	93.00	848.00
sp-N-322-Faculty	840	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-323-Faculty	840	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-324-Student	840	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-325-Student	840	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-326-Student	840	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-327-Student	840	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-328-Student	840	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-329-Faculty	840	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-330-Faculty	420	600	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-331-Lounge	840	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-332-Faculty	290	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-333-Faculty	580	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-334-Student	580	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-335-Student	580	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-336-Faculty	580	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-337-Faculty	290	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-338-Lounge	630	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-339-Faculty	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-340-Faculty	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-341-Student	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-342-Student	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-343-Student	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-344-Student	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-345-Student	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-346-PHD_Office	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-347-PHD_Office	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-348-Staff_Office	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-349-Staff_Office	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-350-Staff_Office	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00

sp-N-351-Staff_Office	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-352-Staff_Office	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-353-Staff_Office	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-355-Staff_Office	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-356-Staff_Office	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-J346-Janitor_Closet	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-P346-Electrical	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-P347-Electrical	600	800	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-N-Q301-Corridor	350	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-Q302-Corridor	350	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-Q303-Corridor	350	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-Q304-Corridor	350	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-Q305-Corridor	350	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-Q306-Corridor	350	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-Q307-Corridor	350	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-Q308-Corridor	185	200	Ea.	Q9	11.00	1.455	$ 725.00	$ 67.50	$ 792.50
sp-N-Q310-Corridor	350	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-R323-Women	210	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-R324-Unisex_Restroom	210	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-R346-Men	210	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-T347-Telecom	210	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-N-Z301-Stair_N1	350	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-302A-Staf_Office	320	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-302B-Staff_Office	345	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-302C-Reception	345	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-302D-Copy	210	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-302-Staff_Admin	210	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-305-Grad_Student	480	600	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-306A-ConferenceLibrary	265	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50

sp-W-306B-ConferenceLibrary	315	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-307-KitchenBreak	255	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-308A-Conference	310	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-308B-Conference	425	600	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-309-Post_Doc_Office	265	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-311-Faculty_Office	820	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-W-312-Faculty_Office	820	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-W-313-Faculty_Office	820	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-W-315-Faculty_Office	820	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-W-316-Faculty_Office	820	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-W-317-Faculty_Office	820	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-W-318-Hershey_MD	820	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-W-319-Hershey_MD	820	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-W-320-Senior_Post_Doc	840	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-W-338-Senior_Post_Doc	840	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-W-339-Hershey_MD	840	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-W-340-Faculty_Office	840	1000	Ea.	Q9	8.00	2.00	$ 755.00	$ 93.00	$ 848.00
sp-W-341-Faculty_Office	560	600	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-342-Faculty_Office	560	600	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-343-Staff_Assistant	300	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-344-Distinguished_Office	210	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-345-Grad_Student	480	600	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-346-Storage	85	200	Ea.	Q9	11.00	1.455	$ 725.00	$ 67.50	$ 792.50
sp-W-J337-Janitor_Closet	210	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-J338-Janitor_Closet	210	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-P338-Electrical	340	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-Q301-Corridor	350	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-Q302-Corridor	370	600	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-Q303-Corridor	350	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-Q304-Corridor	350	400	Ea.	Q9	10.00	1.60	$	$	$

							735.00	74.50	809.50
sp-W-Q305-Corridor	365	600	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-Q306-Corridor	370	600	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-R321-Women	210	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-R337-Men	210	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-T338-Telecom	210	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-Z301-Stair_W1	350	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
sp-W-Z302-Stair_W2	350	400	Ea.	Q9	10.00	1.60	$ 735.00	$ 74.50	$ 809.50
					Total Hours	206.89		Total	$ 95,585.50
					Total Days	25.86075			

W30 x 90 Plotted Data



W30	Cost
99	120
108	131
116	140
132	160
148	179
173	209
191	231

TABLE: Material List 2 - By Section Property EXISTING															
Section	NumPieces	TotalLength	TotalWeight	Length	Unit	Crew	Daily Output	Labor Hours	Total Hours	Bare Material	Bare Labor	Bare Equipment	Bare Total	Location	Total Cost
Text	Unitless	in	Kip	Ft											
W14X109	17	2176.101	19.532	181.34175	L.F.	E2	720	0.078	14.1446565	204.93	4.8	2.67	212.4	1.029	$ 39,633.98
W14X120	24	755.114	7.497	62.92616667	L.F.	E2	960	0.058	3.64971767	145	2.44	1.63	149.07	1.029	$ 9,652.44
W14X145	39	8974.024	107.609	747.8353333	L.F.	E2	984	0.057	42.626614	247.95	3.51	1.95	253.41	1.029	$ 195,004.71
W14X159	24	2070.244	27.261	172.5203333	L.F.	E2	984	0.057	9.833659	271.89	3.51	1.95	277.35	1.029	$ 49,236.12
W14X176	24	2070.244	30.217	172.5203333	L.F.	E2	912	0.061	10.5237403	300.15	3.78	2.1	306.03	1.029	$ 54,327.49
W14X193	66	14859.651	237.379	1238.30425	L.F.	E2	984	0.057	70.5833423	330.03	3.51	1.95	335.49	1.029	$ 427,486.41
W14X211	238	27550.464	480.472	2295.872	L.F.	E2	984	0.057	130.864704	360.81	3.51	1.95	366.27	1.029	$ 865,295.40
W14X233	11	677.484	13.063	56.457	L.F.	E2	984	0.057	3.218049	398.43	3.51	1.95	403.89	1.029	$ 23,463.69
W14X257	44	3696	78.836	308	L.F.	E2	984	0.057	17.556	439.47	3.51	1.95	444.93	1.029	$ 141,012.55
W14X283	287	23457.779	550.046	1954.814917	L.F.	E2	984	0.057	111.42445	483.93	3.2	1.95	489.39	1.029	$ 984,410.21
W14X311	4	1224.768	31.528	102.064	L.F.	E2	984	0.057	5.817648	531.81	3.51	1.95	537.27	1.029	$ 56,426.17
W14X370	30	3441.853	105.842	286.8210833	L.F.	E2	984	0.057	16.3488018	632.7	3.51	1.95	638.16	1.029	$ 188,345.84
W14X398	76	5434.208	179.812	452.8506667	L.F.	E2	984	0.057	25.812488	680.58	3.51	1.95	686.04	1.029	$ 319,683.21
W14X426	36	1584	56.151	132	L.F.	E2	984	0.057	7.524	728.46	3.51	1.95	733.92	1.029	$ 99,686.89
W14X455	13	1395.779	52.641	116.3149167	L.F.	E2	984	0.057	6.62995025	778.05	3.51	1.95	783.51	1.029	$ 93,776.78
W14X550	96	3982	181.771	331.8333333	L.F.	E2	984	0.057	18.9145	940.5	3.51	1.95	945.96	1.029	$ 323,004.19
W14X61	2	599.06	2.989	49.92166667	L.F.	E2	984	0.057	2.845535	104.31	3.51	1.95	109.77	1.029	$ 5,638.82
W14X90	87	19460.619	143.881	1621.71825	L.F.	E2	740	0.076	123.250587	111	3.58	2.19	116.77	1.029	$ 194,859.71
W14X99	13	754.997	6.176	62.91641667	L.F.	E2	984	0.057	3.58623575	169.29	3.51	1.95	174.75	1.029	$ 11,313.49
W12X120	2	754.88	7.541	62.90666667	L.F.	E2	960	0.058	3.64858667	145	2.44	1.63	149.07	1.029	$ 9,649.44
W30X90	4	1056	7.89	88	L.F.	E2	984	0.057	5.016	109.09	3.58	1.95	114.62	1.029	$ 10,379.07
W14X120		809.25	97.11	67.4375	L.F.	E2	960	0.058	3.911375	145	2.44	1.63	149.07	1.029	$ 10,344.44
W14X61		269.75	16.455	22.47916667											
Total			**1220.8495**	**Tons**				Total Hours	637.73064					**Cost**	$ 4,112,631.06
								Days	79.7163301						

Redesigned Truss Take-Off and Estimate

TABLE: Material List 2 - By Section Property REDESIGNED																		
Section	NumPieces	TotalLength	TotalWeight	Length	Unit	Crew	Daily Output	Labor Hours	Total Hours	Bare Material	Bare Labor	Bare Equipment	Bare Total	Location	Cost	Issue
Text	Unitless	in	Kip	Ft												
W14X109	8	2813.864	25.257	234.4886667	L.F.	E2	720	0.078	18.290116	204.93	4.8	2.67	212.4	1.029	$ 51,249.75	2009
W14X120	47	9974.685	99.03	831.22375	L.F.	E2	960	0.058	48.2109775	145	2.44	1.63	149.07	1.029	$ 127,503.93	2011
W14X145	38	5250.737	62.962	437.5614167	L.F.	E2	984	0.057	24.9410008	247.95	3.51	1.95	253.41	1.029	$ 114,098.03	2009
W14X159	15	2098.588	27.634	174.8823333	L.F.	E2	984	0.057	9.968293	271.89	3.51	1.95	277.35	1.029	$ 49,910.22	2009
W14X176	4	1388.036	20.26	115.6696667	L.F.	E2	912	0.061	7.05584967	300.15	3.78	2.1	306.03	1.029	$ 36,424.94	2011
W14X193	94	9746.747	155.702	812.2289167	L.F.	E2	984	0.057	46.2970483	330.03	3.51	1.95	335.49	1.029	$ 280,397.02	2009
W14X211	266	32106.499	559.928	2675.541583	L.F.	E2	984	0.057	152.50587	360.81	3.51	1.95	366.27	1.029	$ 1,008,389.76	2009
W14X233	22	1359.692	26.218	113.3076667	L.F.	E2	984	0.057	6.458537	398.43	3.51	1.95	403.89	1.029	$ 47,090.98	2009
W14X257	4	1392.76	29.708	116.0633333	L.F.	E2	984	0.057	6.61561	439.47	3.51	1.95	444.93	1.029	$ 53,137.62	2009
W14X283	245	17495.571	410.242	1457.96425	L.F.	E2	984	0.057	83.1039623	483.93	3.2	1.95	489.39	1.029	$ 734,205.00	2009
W14X311	13	1260.856	32.457	105.0713333	L.F.	E2	984	0.057	5.989066	531.81	3.51	1.95	537.27	1.029	$ 58,088.77	2009
W14X370	32	4119.336	126.676	343.278	L.F.	E2	984	0.057	19.566846	632.7	3.51	1.95	638.16	1.029	$ 225,419.21	2009
W14X398	65	4752	157.239	396	L.F.	E2	984	0.057	22.572	680.58	3.51	1.95	686.04	1.029	$ 279,550.32	2009
W14X426	36	1584	56.151	132	L.F.	E2	984	0.057	7.524	728.46	3.51	1.95	733.92	1.029	$ 99,686.89	2009
W14X550	104	6309	287.994	525.75	L.F.	E2	984	0.057	29.96775	940.5	3.51	1.95	945.96	1.029	$ 511,761.29	2009
W14X90	146	24992.459	184.78	2082.704917	L.F.	E2	740	0.076	158.285574	111	3.58	2.19	116.77	1.029	$ 250,250.18	2009
W30X90	4	1056	7.89	88	L.F.	E2	984	0.057	5.016	109.09	3.58	1.95	114.62	1.029	$ 10,379.07	-
W14X342	2	601.438	17.191	50.11983333	L.F.	E2	984	0.057	2.8568305	584.82	3.51	1.95	590.28	1.029	$ 30,442.69	2009
Total			**1143.6595**	**Tons**				**Total Hours**	655.225331						$ 3,967,985.69	
			77.19	**Tons**	Saved!			**Days**	81.9031664							
Savings														Savings	$ 144,645.37	

Original 3rd Floor Lighting Take-Off and Estimate

Type of Luminaire	Quantity	Locations	Description	Lamps	Manufacturer & Series #	RS Means Material Cost	RS Means Labor Cost	Total Cost Per	Total ($)
NF - 1	55	Typical Open Lab Corridor and enclosed Corridors	1 x 4 Ceiling recessed fluorescent downlights	(2) 32W T8 Fluorescent	Ledalite/Voice #9814-D1-CR&ST-T232-S	$ 50.50	$ 64.00	$ 114.50	6,297.50
DC-1A	37	Open Corridors (8' width)	6"x6" square open aperture ceiling recessed fluorescent down lights	42W Triple Tube CFL	Kurt Versen Lighting - #H8643 -SW-WT	$ 65.00	$ 50.50	$ 115.50	4,273.50
NF - 1B	51	Typical Open Lab Corridor and enclosed Corridors	1 x 4 Ceiling recessed fluorescent downlights	(2) 32W T8 Fluorescent	Ledalite/Voice #9814-D1-CR&ST-T232-S	$ 50.50	$ 64.00	$ 114.50	5,839.50
NF-5	6	Ground floor lobby elevator front ceiling	Recessed Linear Fluorescent Slot Lights with lens	(2) T8 Fluorescent Staggered	SELUXM100 Staggered/ M1R1S-2T8-OD	$ 68.50	$ 50.50	$ 119.00	714.00
EL - 5	1	Throughout	Ceiling Concealed retractable emergency lighting fixture. In activating, the lamps rotate out and on	(2) 75W Quartz Halogen/GU-10 Bi-pin	Concealite/Chameleon #F5-REM-75-277VAC	$ 26.50	$ 15.05	$ 41.55	41.55
SDF-6	2	Fire rating treated ceiling in typical elevator lobby	Compact fluorescent down lights with "fire rating ceiling recessed enclosure"	(2)26W CFL	Lightolier/ Lytecaster Housing #1102T with Fire rated enclosure #16FR2X10	$ 110.00	$ 50.50	$ 160.50	321.00
DC-1A	33	Open Corridors (8' width)	6" x 6" square open aperture ceiling recessed fluorescent down lights	42W Triple Tube CFL	Kurt Versen Lighting - #H8643 -SW-WT	$ 59.50	$ 70.50	$ 130.00	4,290.00
DC-1	14	Open Corridors (5' width)	6" x 6" square open aperature ceiling recessed compact fluorescent down lights	32W Triple Tube CFL	Kurt Versen Lighting - #H8643 -SW-WT	$ 65.00	$ 50.50	$ 115.50	1,617.00
NF - 1	53	Typical Open Lab Corridor and enclosed Corridors	1 x 4 Ceiling recessed fluorescent downlights	(2) 32W T8 Fluorescent	Ledalite/Voice #9814-D1-CR&ST-T232-S	$ 50.50	$ 64.00	$ 114.50	6,068.50
NF - 1Bd1	42	Typical opened laboratories in building perimeters	1 x 4 Ceiling recessed fluorescent downlights with 10% dimming ballasts	(3) 32W T8 Fluorescent	Ledalite/Voice #9814-D1-CR&ST-T232-S	$ 152.50	$ 114.00	$ 266.50	11,193.00
NF - 1B	72	Typical Open Lab Corridor and enclosed Corridors	1 x 4 Ceiling recessed fluorescent downlights	(2) 32W T8 Fluorescent	Ledalite/Voice #9814-D1-CR&ST-T232-S	$ 50.50	$ 64.00	$ 114.50	8,244.00
NF-5	6	Ground floor lobby elevator front ceiling	Recessed Linear Fluorescent Slot Lights with lens	(2) T8 Fluorescent Staggered	SELUXM100 Staggered/ M1R1S-2T8-OD	$ 68.50	$ 50.50	$ 119.00	714.00
SDF-6	2	Fire rating treated ceiling in typical elevator lobby	Compact fluorescent down lights with "fire rating ceiling recessed enclosure"	(2)26W CFL	Lightolier/ Lytecaster Housing #1102T with Fire rated enclosure #16FR2X10	$ 110.00	$ 50.50	$ 160.50	321.00
							Total	$	49,934.55

Floor- By- Floor Lighting Savings

3rd Floor Material Sciences											
		Fixture	Quantity Added	Quanitity Removed		RSMeans Mat. Cost	RSMeans Labor Cost	Total Cost Per Unit	Total		
	Corridor										
		NF - 1	0	53		$ 50.50	$ 64.00	$ 114.50	$ (6,068.50)		
		COR-D	53	0		$ 31.50	$ 47.50	$ 79.00	$ 4,187.00		
			53	53						Cost	$(1,881.50)
	Offices										
		NF - 1B	0	72		$ 50.50	$ 64.00	$ 114.50	$ (8,244.00)		
		OFF-D	0	0		$ 1,566.00	$ 47.50	$ 1,613.50	$ -		
			0	72						Cost	$(8,244.00)
	Study Areas										
		NF - 1Bd1	0	30		$ 152.50	$ 114.00	$ 266.50	$ (7,995.00)		
		STD-D	30	0		$ 133.50	$ 100.50	$ 234.00	$ 7,020.00		
			30	30						Cost	$ (975.00)
	Conf. Rooms										
		NF-1Bd1	0	18		$ 152.50	$ 114.00	$ 266.50	$ (4,797.00)		
		DC-4d1	0	12		$ 126.00	$ 103.50	$ 229.50	$ (2,754.00)		
		DC-1	0	4		$ 65.00	$ 50.50	$ 115.50	$ (462.00)		
		CFR-D	14	0		$ 81.50	$ 50.50	$ 132.00	$ 1,848.00		
		CFR-C	24	0		$ 31.50	$ 47.50	$ 79.00	$ 1,896.00		
			38	34						Cost	$(4,269.00)

3rd Floor Life Sciences											
		Fixture	Quantity Added	Quantity Removed		RSMeans Mat. Cost	RSMeans Labor Cost	Total Cost Per Unit	Total		
	Corridor										
		NF - 1	0	55		$ 50.50	$ 64.00	$ 114.50	$ (6,297.50)		
		COR-D	55	0		$ 31.50	$ 47.50	$ 79.00	$ 4,345.00		
			55	55						Cost	$(1,952.50)
	Offices										
		NF - 1B	0	51		$ 50.50	$ 64.00	$ 114.50	$ (5,839.50)		
		OFF-D	0	0		$ 1,566.00	$ 47.50	$ 1,613.50	$ -		
			0	51						Cost	$(5,839.50)
	Study Areas										
		NF - 1Bd1	0	0		$ 152.50	$ 114.00	$ 266.50	$ -		
		STD-D	0	0		$ 133.50	$ 100.50	$ 234.00	$ -		
			0	0						Cost	$ -
	Conf. Rooms										
		NF-1Bd1	0	18		$ 152.50	$ 114.00	$ 266.50	$ (4,797.00)		
		DC-4d1	0	12		$ 126.00	$ 103.50	$ 229.50	$ (2,754.00)		
		DC-1	0	4		$ 65.00	$ 50.50	$ 115.50	$ (462.00)		
		CFR-D	14	0		$ 81.50	$ 50.50	$ 132.00	$ 1,848.00		
		CFR-C	24	0		$ 31.50	$ 47.50	$ 79.00	$ 1,896.00		
			38	34						Cost	$(4,269.00)
						Summary Costs	$ (27,430.50)				

Location											
2nd Floor Material Sciences											
		Fixture	**Quantity Added**	**Quanitity Removed**		**RSMeans M**	**RSMeans Labo**	**Total Cost P**	**Total**		
	Corridor										
		NF - 1	0	61		$ 50.50	$ 64.00	$ 114.50	$ (6,984.50)		
		COR-D	61	0		$ 31.50	$ 47.50	$ 79.00	$ 4,819.00		
			61	61						**Cost**	$(2,165.50)
	Offices										
		NF - 1B	0	78		$ 50.50	$ 64.00	$ 114.50	$ (8,931.00)		
		OFF-D	0	0		$ 1,566.00	$ 47.50	$ 1,613.50	$ -		
			0	78						**Cost**	$(8,931.00)
	Study Areas										
		NF - 1Bd1	0	60		$ 152.50	$ 114.00	$ 266.50	$(15,990.00)		
		STD-D	60	0		$ 133.50	$ 100.50	$ 234.00	$ 14,040.00		
			60	60						Cost	$(1,950.00)
	Conf. Rooms										
		NF-1Bd1	0	0		$ 152.50	$ 114.00	$ 266.50	$ -		
		DC-4d1	0	0		$ 126.00	$ 103.50	$ 229.50	$ -		
		DC-1	0	0		$ 65.00	$ 50.50	$ 115.50	$ -		
		CFR-D	0	0		$ 81.50	$ 50.50	$ 132.00	$ -		
		CFR-C	0	0		$ 31.50	$ 47.50	$ 79.00	$ -		
			0	0						**Cost**	$ -

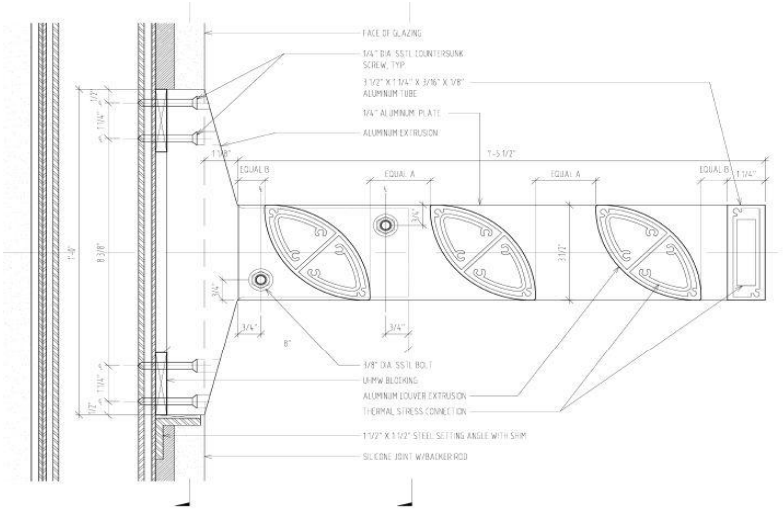
2nd Floor Life Sciences											
		Fixture	**Quantity Added**	**Quantity Removed**		**RSMeans Mat. C**	**RSMeans Labor**	**Total Cost P**	**Total**		
	Corridor										
		NF - 1	0	72		$ 50.50	$ 64.00	$ 114.50	$ (8,244.00)		
		COR-D	72	0		$ 31.50	$ 47.50	$ 79.00	$ 5,688.00		
			72	72						Cost	$(2,556.00)
	Offices										
		NF - 1B	0	33		$ 50.50	$ 64.00	$ 114.50	$ (3,778.50)		
		OFF-D	0	0		$ 1,566.00	$ 47.50	$ 1,613.50	$ -		
			0	33						Cost	$(3,778.50)
	Study Areas										
		NF - 1Bd1	0	0		$ 152.50	$ 114.00	$ 266.50	$ -		
		STD-D	0	0		$ 133.50	$ 100.50	$ 234.00	$ -		
			0	0						Cost	$ -
	Conf. Rooms										
		NF-1Bd1	0	0		$ 152.50	$ 114.00	$ 266.50	$ -		
		DC-4d1	0	0		$ 126.00	$ 103.50	$ 229.50	$ -		
		DC-1	0	0		$ 65.00	$ 50.50	$ 115.50	$ -		
		CFR-D	0	0		$ 81.50	$ 50.50	$ 132.00	$ -		
		CFR-C	0	0		$ 31.50	$ 47.50	$ 79.00	$ -		
			0	0						Cost	$ -
						Summary Costs	$ (19,381.00)				

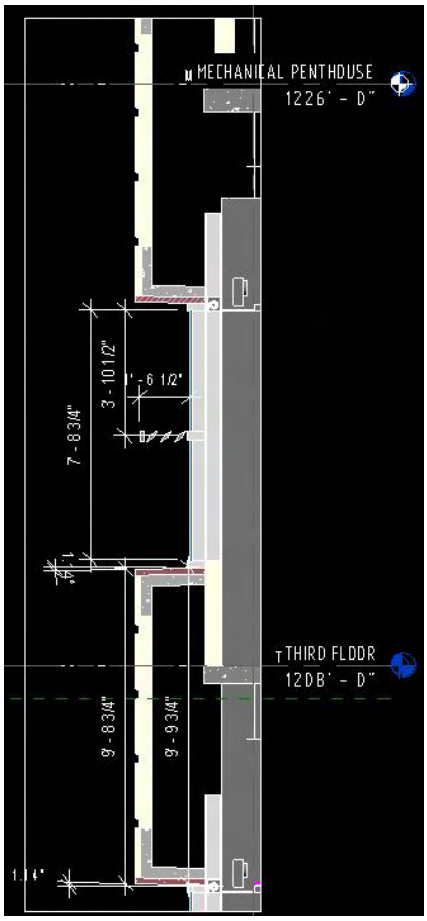
1st Floor Material Sciences											
		Fixture	**Quantity Added**	**Quanitity Removed**		**RSMeans M**	**RSMeans Lal**	**Total Cost P**	**Total**		
	Corridor										
		NF - 1	0	74		$ 50.50	$ 64.00	$ 114.50	$(8,473.00)		
		COR-D	74	0		$ 31.50	$ 47.50	$ 79.00	$ 5,846.00		
			74	74						**Cost**	$(2,627.00)
	Offices										
		NF - 1B	0	33		$ 50.50	$ 64.00	$ 114.50	$(3,778.50)		
		OFF-D	0	0		$1,566.00	$ 47.50	$1,613.50	$ -		
			0	33						**Cost**	$(3,778.50)
	Study Areas										
		NF - 1Bd1	0	0		$ 152.50	$ 114.00	$ 266.50	$ -		
		STD-D	0	0		$ 133.50	$ 100.50	$ 234.00	$ -		
			0	0						Cost	$ -
	Conf. Rooms										
		NF-1Bd1	0	0		$ 152.50	$ 114.00	$ 266.50	$ -		
		DC-4d1	0	0		$ 126.00	$ 103.50	$ 229.50	$ -		
		DC-1	0	0		$ 65.00	$ 50.50	$ 115.50	$ -		
		CFR-D	0	0		$ 81.50	$ 50.50	$ 132.00	$ -		
		CFR-C	0	0		$ 31.50	$ 47.50	$ 79.00	$ -		
			0	0						**Cost**	$ -

1st Floor Life Sciences											
		Fixture	**Quantity Added**	**Quantity Removed**		**RSMeans M**	**RSMeans Lal**	**Total Cost P**	**Total**		
	Corridor										
		NF - 1	0	46		$ 50.50	$ 64.00	$ 114.50	$(5,267.00)		
		COR-D	46	0		$ 31.50	$ 47.50	$ 79.00	$ 3,634.00		
			46	46						Cost	$(1,633.00)
	Offices										
		NF - 1B	0	0		$ 50.50	$ 64.00	$ 114.50	$ -		
		OFF-D	0	0		$1,566.00	$ 47.50	$1,613.50	$ -		
			0	0						Cost	$ -
	Study Areas										
		NF - 1Bd1	0	0		$ 152.50	$ 114.00	$ 266.50	$ -		
		STD-D	0	0		$ 133.50	$ 100.50	$ 234.00	$ -		
			0	0						Cost	$ -
	Conf. Rooms										
		NF-1Bd1	0	0		$ 152.50	$ 114.00	$ 266.50	$ -		
		DC-4d1	0	0		$ 126.00	$ 103.50	$ 229.50	$ -		
		DC-1	0	0		$ 65.00	$ 50.50	$ 115.50	$ -		
		CFR-D	0	0		$ 81.50	$ 50.50	$ 132.00	$ -		
		CFR-C	0	0		$ 31.50	$ 47.50	$ 79.00	$ -		
			0	0						Cost	$ -
						Summary C	$(8,038.50)				

Appendix E: Daylighting Results & Information

Existing Louver Detail





Solar Shade Cutsheets

A Mestek Company
awv
Solar Shading Systems

Solar Shading Systems

Architectural Solutions

All AWV solar shade devices are
licensed products of Colt International Ltd.

COLT

Introduction

Front Page: Berlaymont, Brussels

Over 236,800 sq. ft. of controllable Colt Shadoglass louvers were installed onto the European Commission Headquarters. These act as a high performance secondary facade. The control system was supplied by Colt and adjusts the position of the blades in response to changing climatic conditions and available daylight.

INTRODUCTION

Excessive solar heat gain and solar glare can be a costly and unwanted hindrance for building owners. In addition, owners require designers to reduce heat gain, with solar shading recommended as a preventative measure unless glass areas are minimized.

AWV solar shading systems offer designers the opportunity for distinctive architectural impact, while reducing solar heat gain.

SOLAR RADIATION & LOUVERS

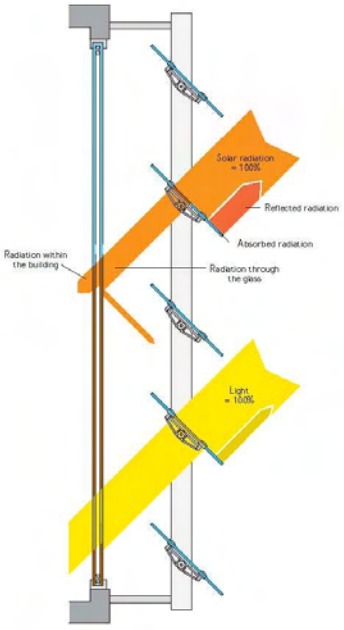
External solar shading is one of the most effective ways to control the internal conditions of a building.

Radiation from the sun is transmitted, absorbed and reflected by the blades. As a result, solar heat gain is prevented from passing into the building, minimizing ventilation requirements and reducing cooling loads. If a controllable system is installed, adjustable blades track the position of the sun, thereby reducing the numbers of days when the building overheats. Equally, in winter the blades may be adjusted in such a way that the building benefits from the heat from the sun, and they can be closed at night reducing heat loss.

Simultaneously, daylight levels are enhanced, and levels of glare are reduced.

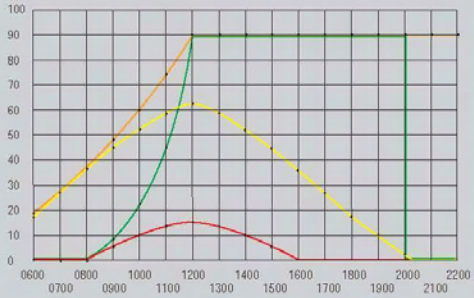
AWV's OFFER

- Calculation of sun angles and heat loads.
- Selection of the most appropriate system from a wide range of options.
- Solar Shading panels are available in various configurations, materials, finishes and coatings to meet the requirements of almost any project.
- Three advanced control options are available, ICS 4-Link for large or medium sized projects, Soltronic for smaller projects, and the innovative Girasol thermohydraulic system, which requires no external energy source.
- All systems are durable and reliable with low maintenance needs.

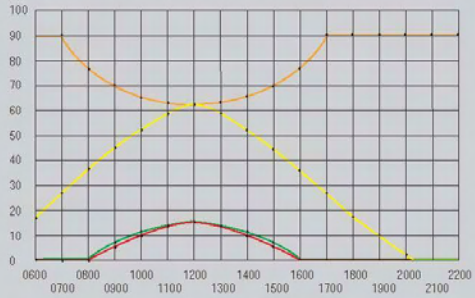


SUN PATH DIAGRAMS

East facade



South facade



GMT Time (h)

Sun altitude in summer
Sun altitude in winter
Blade angle in summer (June)
Blade angle in winter (Dec)

Notes: 1. When blade angles >90° - facade is in the shade. 2. Nomally the angle of the blade follows the VSA (vertical shadow angle). When shading is not required (i.e. when facade is in the shade or when the sky is overcast), the blades may be set for a maximum daylight entry or vision to the outside, or are closed for night security insulation.

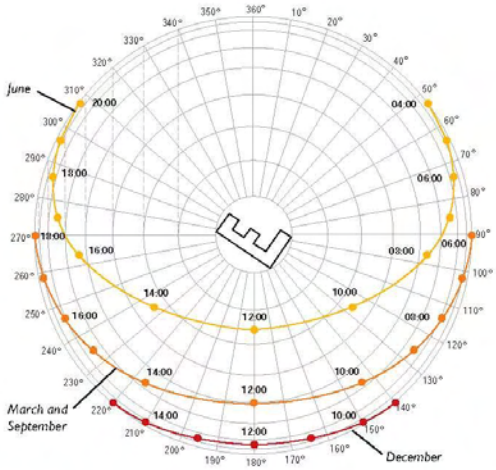
TOTAL CONTROL

Although fixed solar shading performs well on a South facing facade, performance is dramatically reduced on a East or West facing facade which receives a large amount of sunshine during the day.

A controllable shading system can best overcome this problem. Sun tracking blades follow the path of the sun, making sure the solar shading system always optimizes the amount of daylight entry.

On dull or overcast days the blades are controlled in such a way that if clouds pass over the building, the blades will automatically open to maximize daylight entry and then later revert back to their original position.

The Sun path diagram (right) for latitude 52°N shows the position of the sun throughout the day during the months of June, March/September and December.



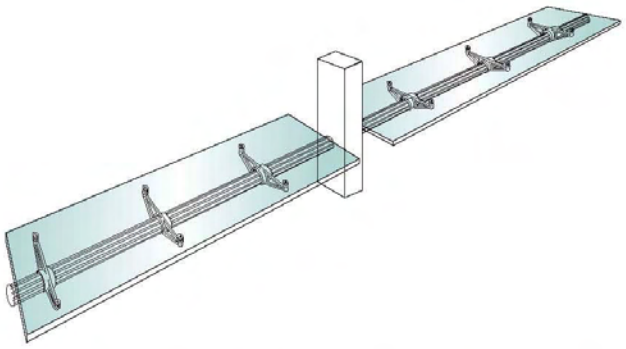
Carrier System 1 (LS1)

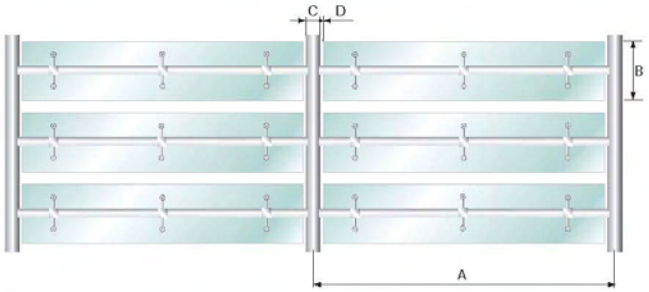
CARRIER SYSTEM 1 (LS1)

Intended for wider spans, Carrier System 1 incorporates a central aluminum torsion tube along the length of the blade, and is ideal for continuous facades, as well as for roofs.

For glass, cross sectional blade widths from 11.75" and up to 23.5" are available.

This carrier system is also suited for use with metal, fabric, wood, terracotta clay and translucent acrylic blades.





Glass Parameters Table

Dimensions	LS1 - 55	LS1 - 65A	LS1 - 65B
A in. (max)	97.50	128.75	128.75
B in.	11.75 - 19.50	13.75 - 21.50	16.50 - 23.50
C in.	2.50	2.50	2.50
D in.	.50	.50	.50
Angle of rotation°	0 - 100	0 - 100	0 - 100
Torsion tube Ø in.	2.00	2.50	2.50

Note: Table to be used as a guide only. Allowable dimensions depend upon the specific requirements of the project.

Shadoglass

Shadoglass describes a fixed or controllable external solar shading system that incorporates glass blades. A Shadoglass shading system can reduce solar heat gain, lower air conditioning running costs, and lessen glare while maximizing the use of natural daylight. The glass blades are available in various colors, surface finishes and coatings to meet specific design requirements. This enables the designer to control the quality of light entering the building. Photovoltaic cells may be integrated into the glass so as to obtain further energy benefits.

Features and benefits

- Available as standard in widths of up to 23.50".
- Available in unsupported spans of up to 6.50 ft., supported spans of up to 13.00 ft. (depending on windloads and other criteria).
- Wide range of colors, surface finishes and coatings.
- All principal support components manufactured from corrosion-resistant extruded aluminum alloy with stainless steel fixings.
- Fixed or controllable.
- May permit the integration of photovoltaic cells.

Controls

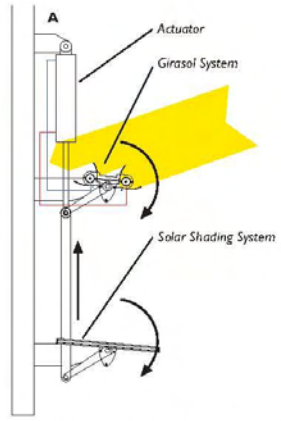
AWV Solar Shading systems may be controlled in three different ways:

- Hand control via lever or crank handle.
- Electrically operated via actuators, which require a controller such as ICS 4-Link, SolTronic or a client BMS.
- Self powered via a thermal hydraulic controller Colt Girasol. This operates autonomously and requires no additional source of power other than the sun.

GIRASOL

Girasol operates solar shading louvers without the need for electrical power or a sophisticated control system.

Absorber tubes, enclosed by mirrors, force a hydraulic cylinder to open or close the blades according to the position of the sun.



Tubes are filled with a special hydraulic fluid and as the sun moves over the building, there will be an imbalance of heat between the two tubes and the blades will open or close as appropriate.

ICS 4-LINK

ICS 4-Link is ideally suited to larger projects with more complex control requirements. It is a generic control system that can operate HVAC, smoke control and solar shading systems.

This product has a wide variety of operating modes, including sun tracking, daylighting optimization and PV illumination. It responds to timers and sensors to ensure that the building 'reacts' appropriately to the sun's position and to the weather.

Remote operation is available via an internal modem interface and a manual override is also possible.

SOLTRONIC

SolTronic is ideally suited for small to medium sized projects. It is a simplified version of ICS 4-Link and can control up to ten actuators in any single zone.

This product responds to external weather conditions, automatically calculating the position of the sun, and adjusts the position of the blades accordingly.

A Mestek Company
awv
Solar Shading Systems

COMMISSIONING

Proper commissioning by experts is essential. We recommend that our specialist staff commission and certify the system.

MAINTENANCE & TESTING

AWV solar shading systems require virtually no maintenance.

All components of any system should be serviced at least once a year and tested monthly.

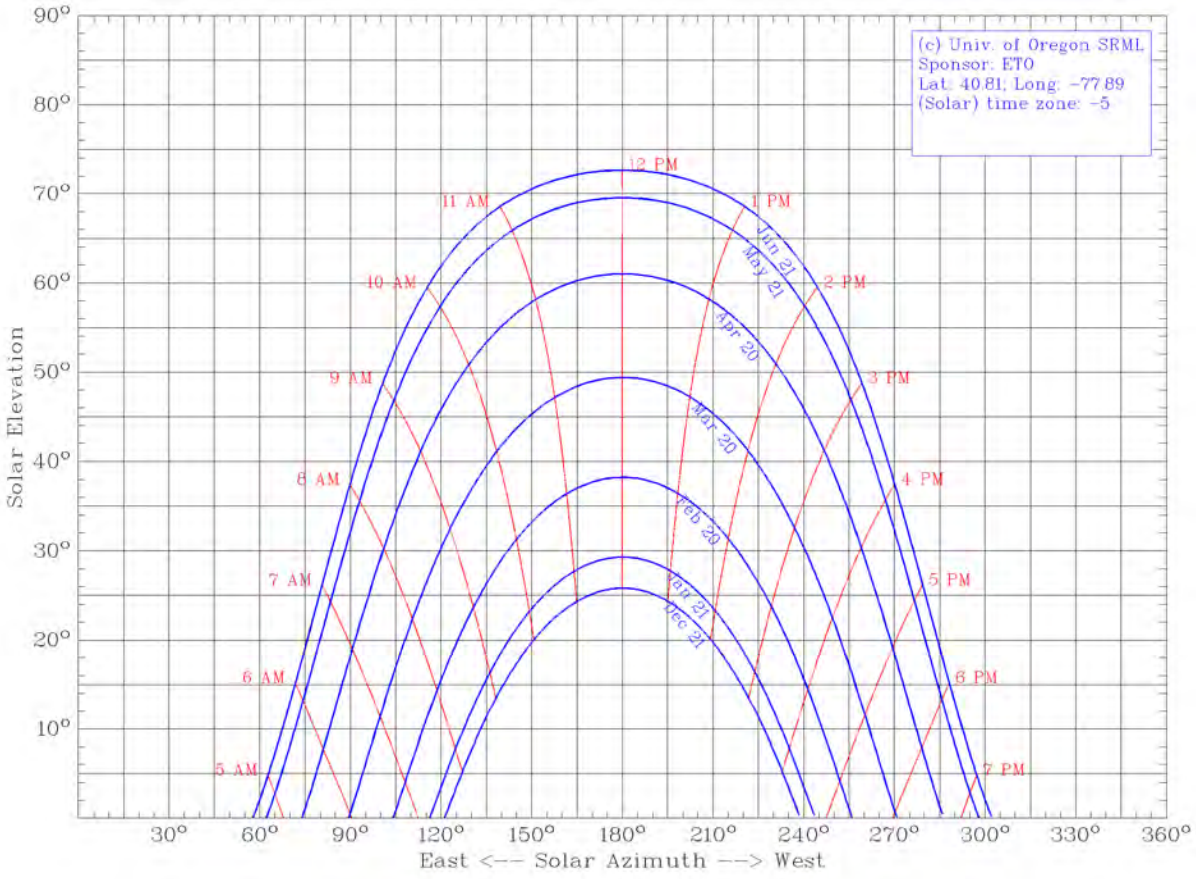
U.S. GREEN BUILDING COUNCIL MEMBER

All AWV solar shade devices are licensed products of Colt International Ltd.

COLT

American Warming and Ventilating
7301 International Drive
Holland, OH 43528
Tel 419.865.5000
Fax 419.865.1375
www.awv.com

Yearly solar Azimuth for University Park, PA



Daylight Integration with Electrical Lighting

Northwest Material Science Façade

Annual Savings kWh:	776.12
System Cost:	0.0
Energy Cost (per kWh):	0.08
Demand Charge (per kWh):	0.0
Peak Demand Time (0-24.0):	0.0
NOTE: All costs must be in the same units.	
Savings Per Year:	62.089600000000004

Daysim EconomicAnalysis for Northwest Material Science Student Study Area.

Energy Tables (KWh)

Controlled Zone | Grand Total

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Base	152.76	132.84	146.12	132.84	152.76	146.12	146.12	152.76	139.48	152.76	146.12	99.63	1700.35
Optimal	103.06	81.83	77.92	55.8	60.56	51.34	50.25	56.15	69.23	86.09	98.78	67.86	858.92
Algorithm	112.71	90.36	81.25	60.73	65.83	52.45	51.88	62.35	72.94	90.46	105.83	77.35	924.22
Savings	40.04	42.47	64.86	72.1	86.92	93.67	94.23	90.4	66.53	62.29	40.28	22.27	776.12

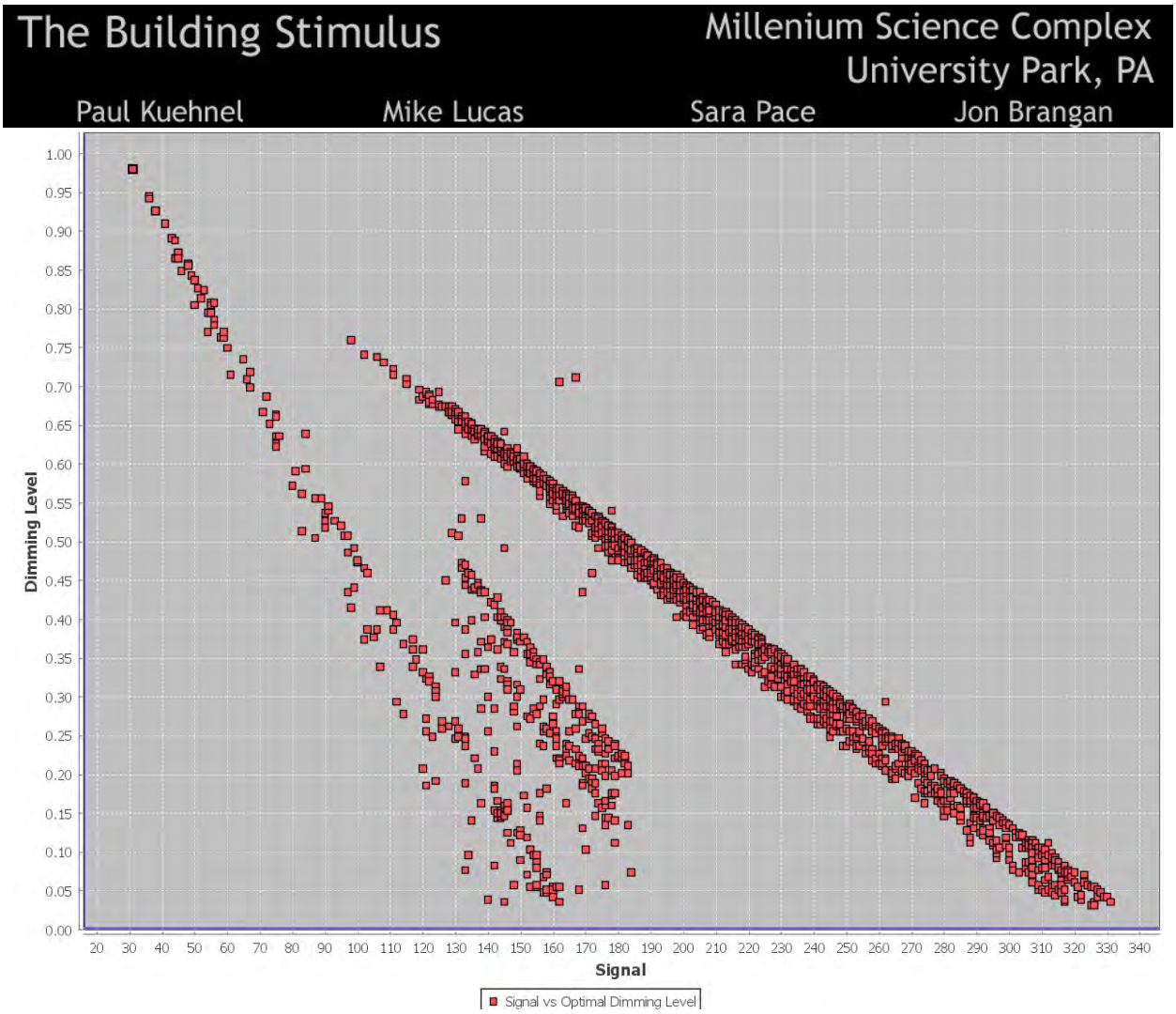
Daysim Controled Zone Energy Table for Northwest Material Science Student Study Area.

Energy Tables (KWh)

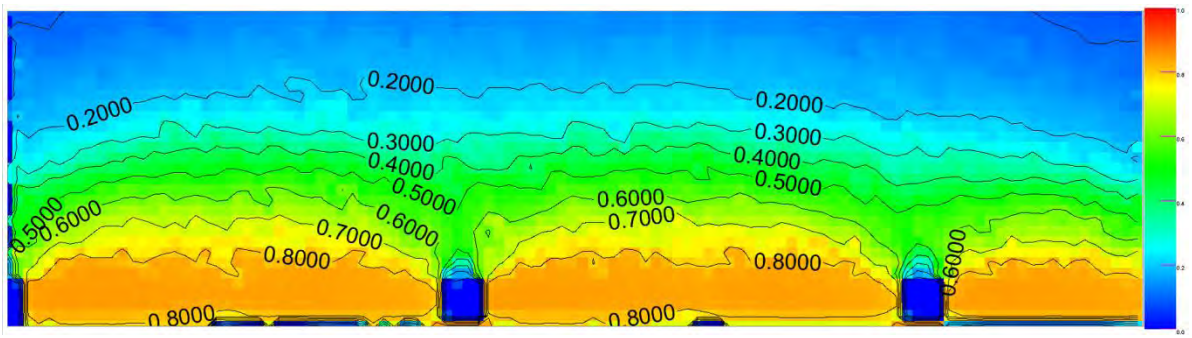
Controlled Zone | Grand Total

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Base	229.71	199.75	219.72	199.75	229.71	219.72	219.72	229.71	209.73	229.71	219.72	149.81	2556.82
Optimal	180.01	148.74	151.52	122.71	137.51	124.94	123.85	133.1	139.49	163.04	172.38	118.04	1715.39
Algorithm	189.66	157.27	154.85	127.65	142.78	126.05	125.49	139.3	143.2	167.41	179.44	127.53	1780.69
Savings	40.04	42.47	64.86	72.1	86.92	93.67	94.23	90.4	66.53	62.29	40.28	22.27	776.12

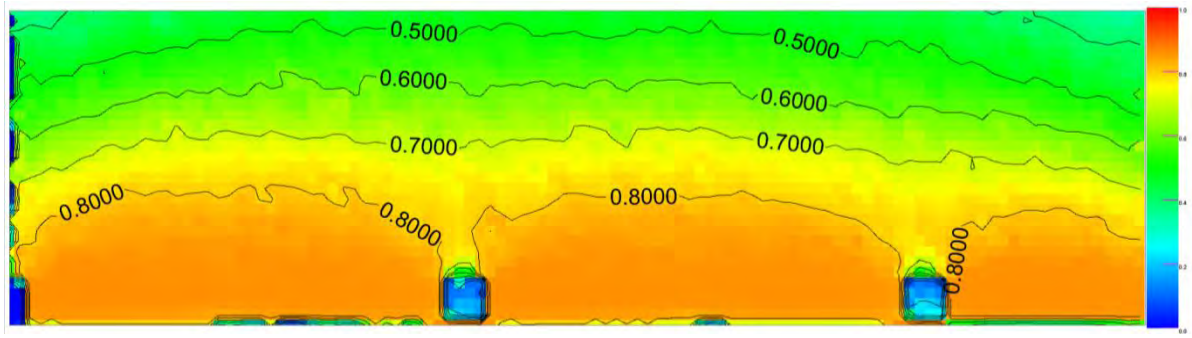
Daysim Controled Zone Energy Table for Northwest Material Science Student Study Area.



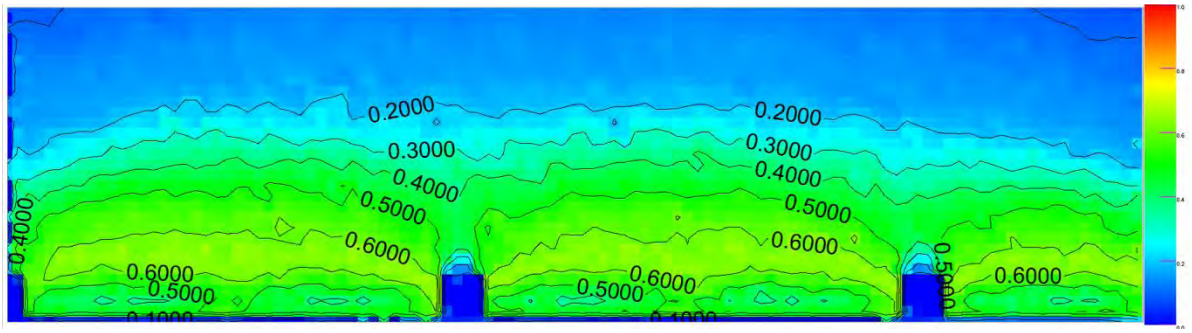
Dimming Level vs. Photosensor Signal for Northwest Facing Material Science Student Study Area.



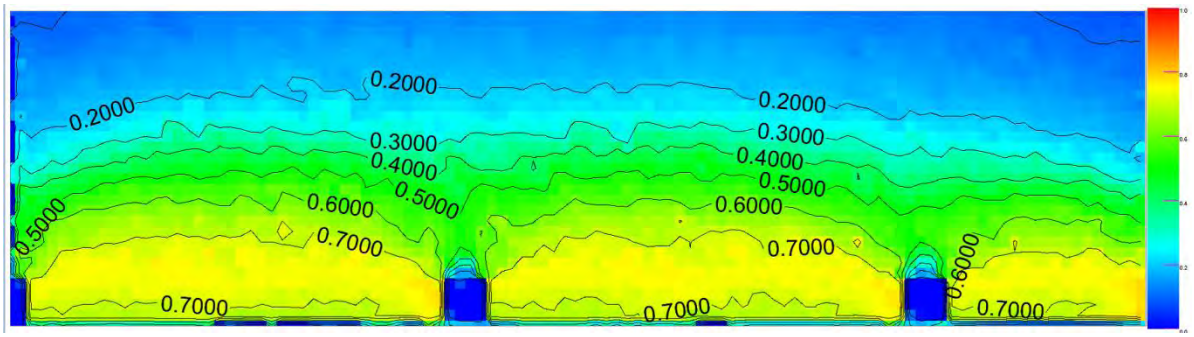
Daylight Autonomy for Northwest Facing Facade (322.8lux).



Continuous Daylight Autonomy for Northwest Facing Material Science Facade (322.8lux).

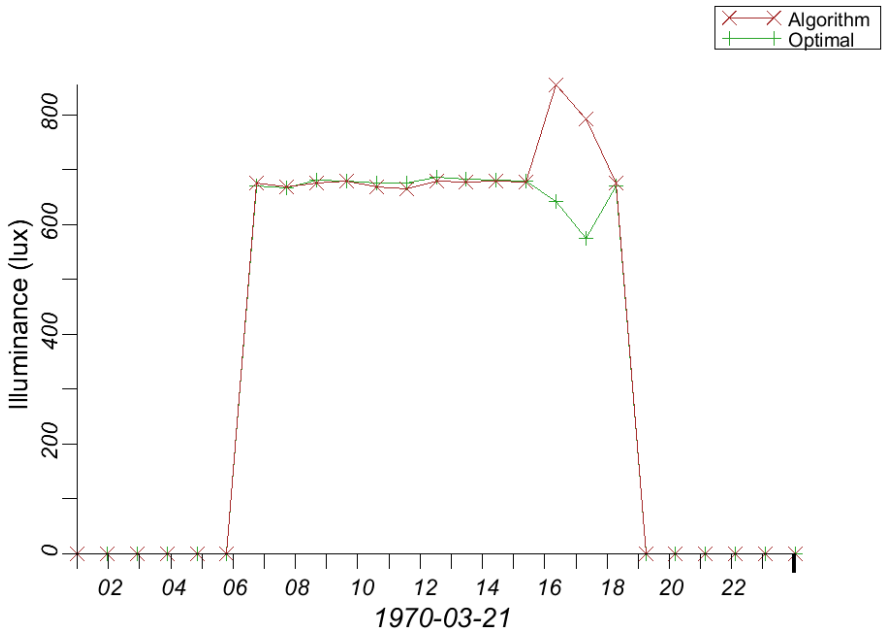


Daylight Illuminance for Northwest Facing Material Science Facade (322.8 to 1000lux).

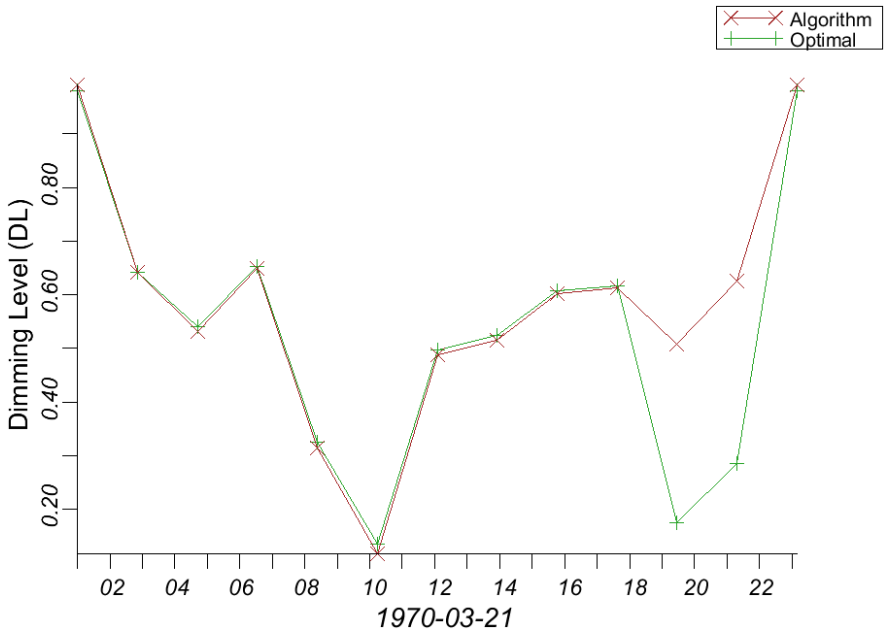


Useful Daylight Illuminance for Northwest Facing Material Science Facade (322.8 to 2000lux).

Fall & Spring Equinox: 7:00AM through 7:00PM

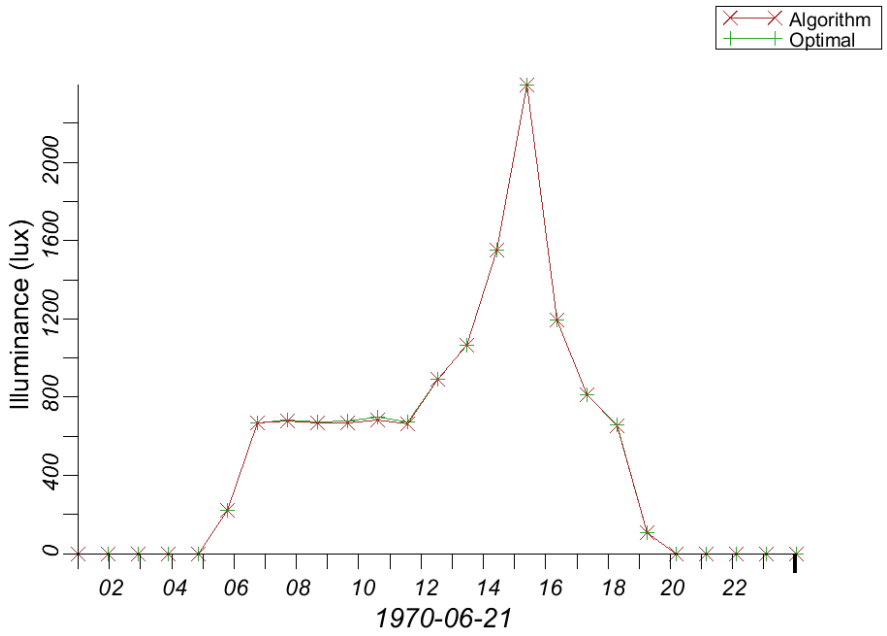


Daysim 'Illuminance Timeplot' for Northwest Material Science Façade (Fall & Spring Equinox).

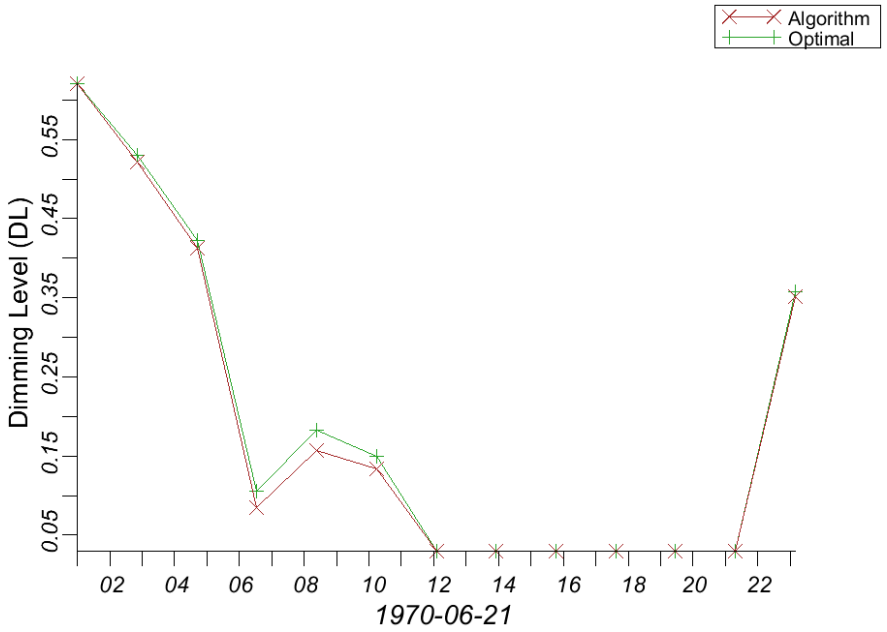


Daysim 'Dimming Timeplot' for Northwest Material Science Façade (Fall & Spring Equinox).

Summer Solstice: 7:00AM through 7:00PM

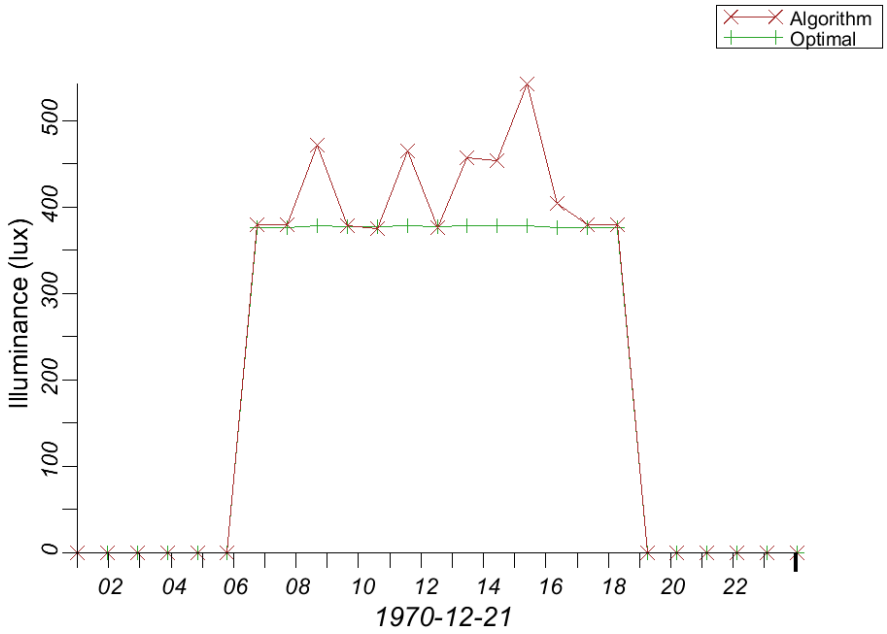


Daysim 'Illuminance Timeplot' Table for Northwest Material Science Façade (Summer Solstice).

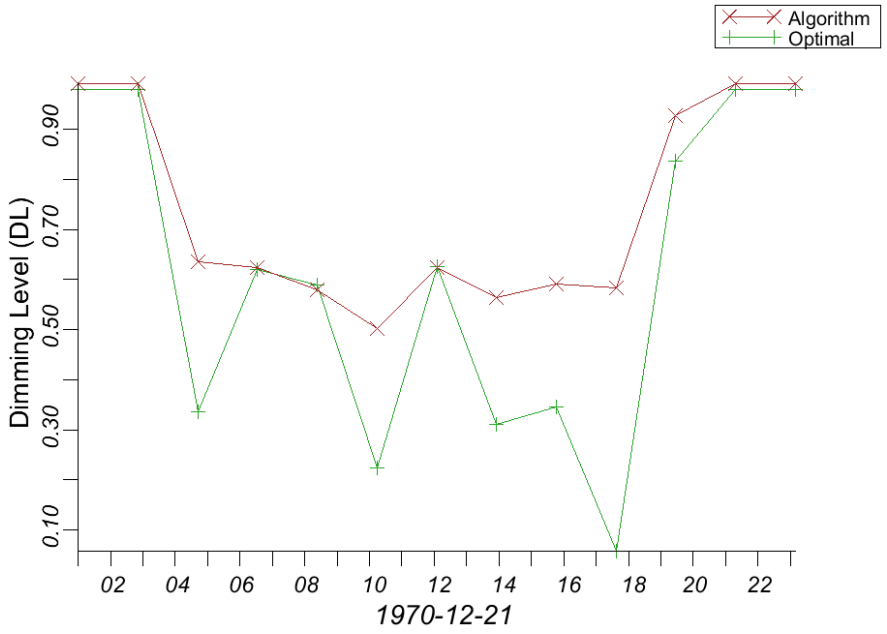


Daysim 'Dimming Timeplot' Table for Northwest Material Science Façade (Summer Solstice).

Winter Solstice: 7:00AM through 7:00PM



Daysim 'Illuminance Timeplot' Table for Northwest Material Science Façade (Winter Solstice).



Daysim 'Dimming Timeplot' Table for Northwest Material Science Façade (Winter Solstice).

Northeast Life Science Façade

Annual Savings kWh: 861.05

System Cost: 0.0

Energy Cost (per kWh): 0.08

Demand Charge (per kWh): 0.0

Peak Demand Time (0-24.0): 0.0

NOTE: All costs must be in the same units.

Savings Per Year: 68.884

Daysim Annual Energy Savings for Northeast Facing Life Science Façade Student Study Area.

Energy Tables (KWh)

Controlled Zone | Grand Total

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Base	152.76	132.84	146.12	132.84	152.76	146.12	146.12	152.76	139.48	152.76	146.12	99.63	1700.35
Optimal	100.52	79.53	70.73	47.01	44.91	33.23	31.1	44.02	60.6	82.85	97.22	66.7	758.46
Algorithm	110.82	88.81	76.38	52.64	52.29	37.32	35.58	50.16	66.23	88.38	105.14	75.49	839.29
Savings	41.94	44.02	69.74	80.19	100.46	108.79	110.53	102.6	73.25	64.38	40.97	24.13	861.05

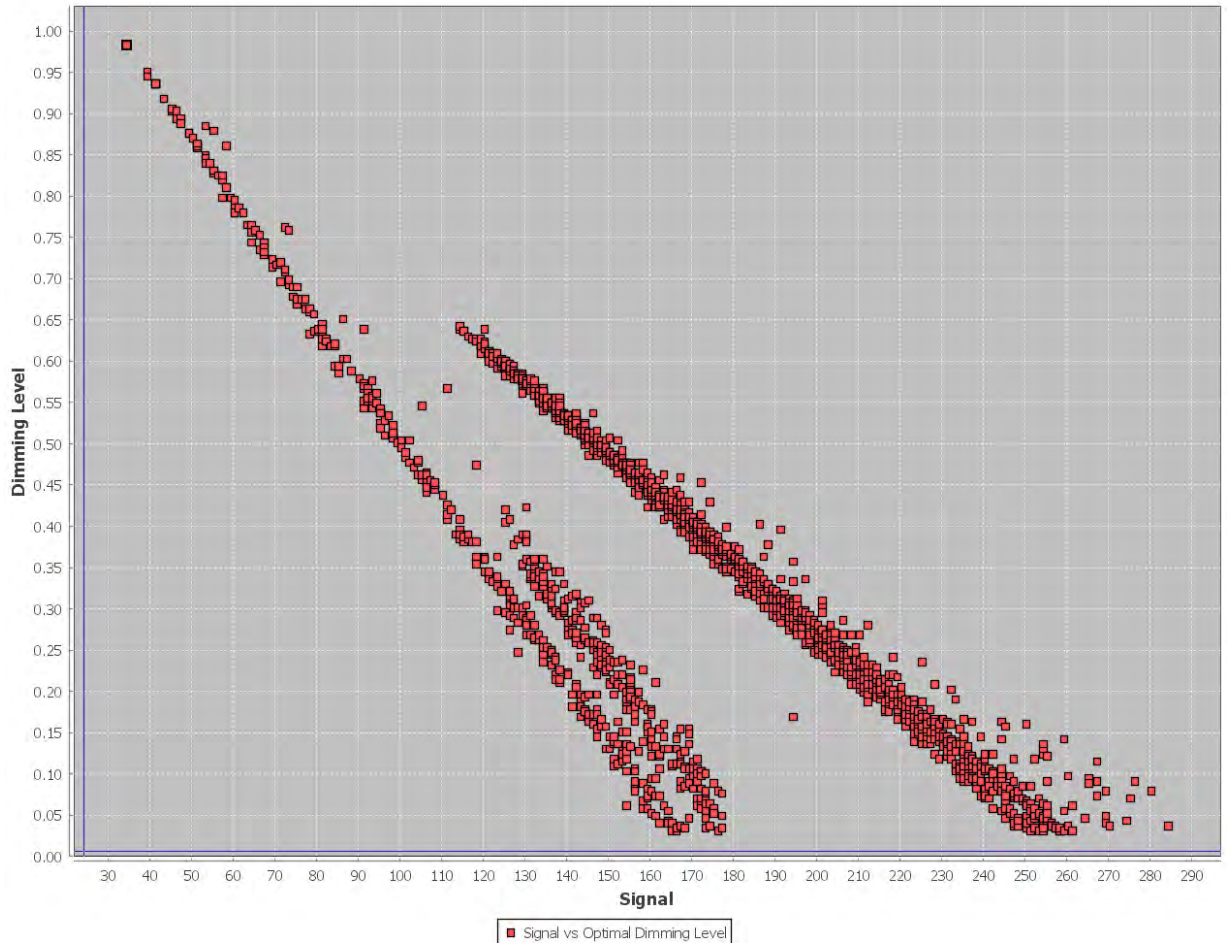
Daysim 'Controlled Zone Energy' Table for Northeast Facing Life Science Façade Student Study Area.

Energy Tables (KWh)

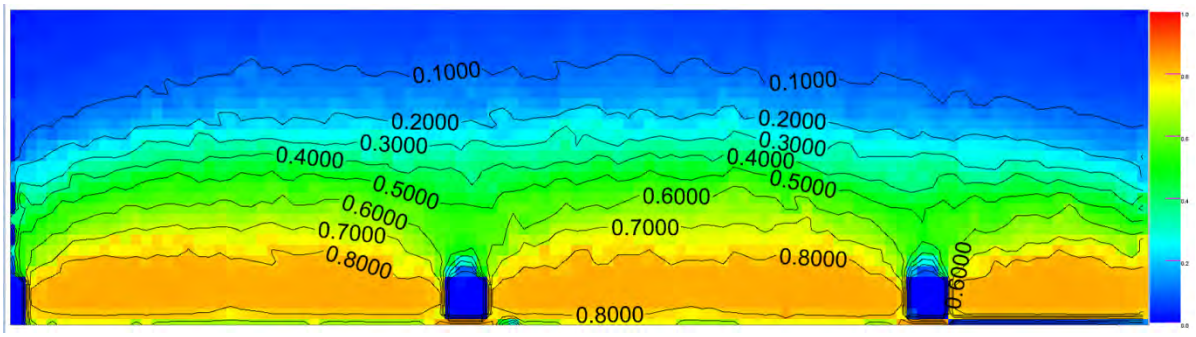
Controlled Zone | Grand Total

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Base	229.71	199.75	219.72	199.75	229.71	219.72	219.72	229.71	209.73	229.71	219.72	149.81	2556.82
Optimal	177.47	146.44	144.33	113.92	121.85	106.83	104.7	120.97	130.86	159.8	170.82	116.88	1614.93
Algorithm	187.77	155.73	149.98	119.55	129.24	110.92	109.18	127.11	136.48	165.32	178.75	125.68	1695.77
Savings	41.94	44.02	69.74	80.19	100.46	108.79	110.53	102.6	73.25	64.38	40.97	24.13	861.05

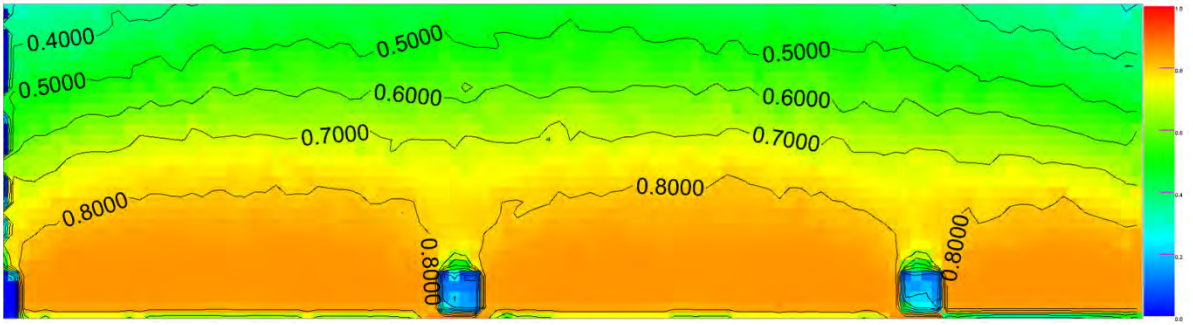
Daysim 'Controlled Zone & Corridor Energy' Table for Northeast Facing Life Science Façade Student Study Area.



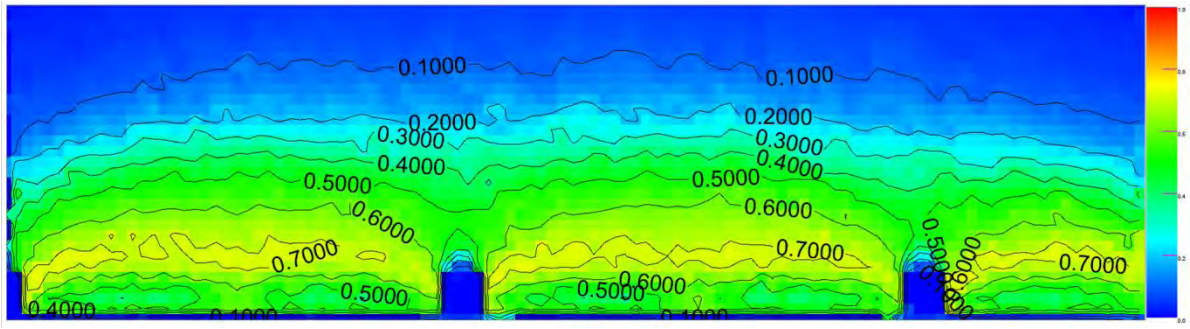
Daysim Photosensor Signal Vs. Dimming Level for Northeast Facing Life Science Student Study Area.



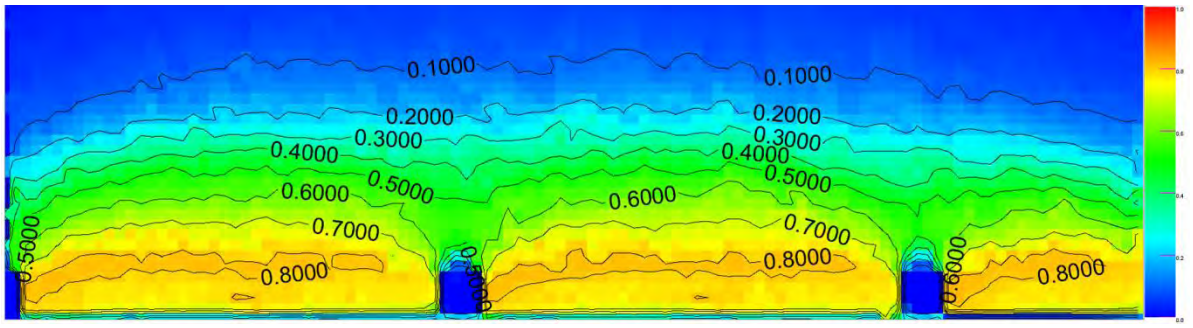
Daylight Autonomy for Northeast Facing Life Science Façade (322.8lux).



Continuous Daylight Autonomy for Northeast Facing Life Science Façade (322.8lux).

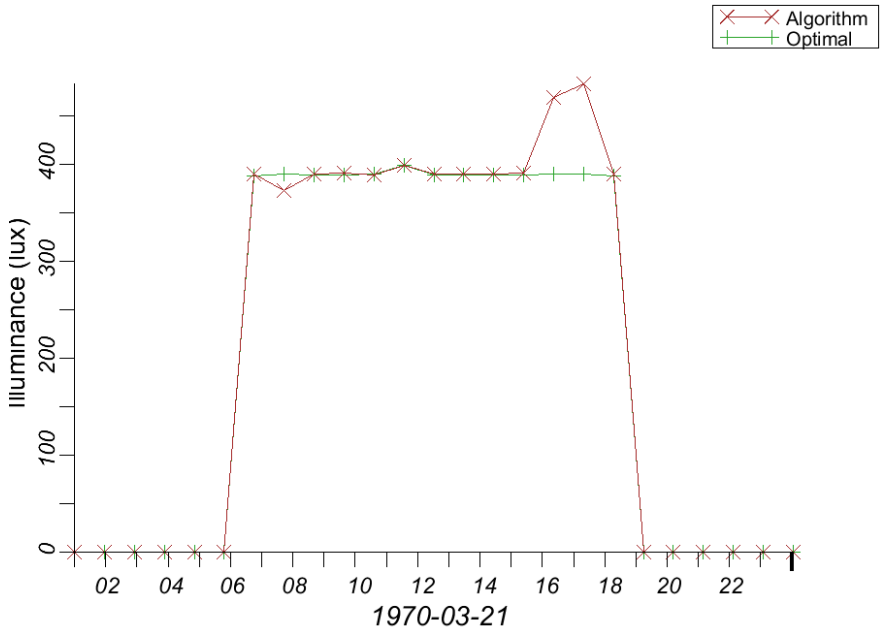


Useful Daylight Illuminance for Northeast Facing Life Science Façade (322.8 to 1000lux).

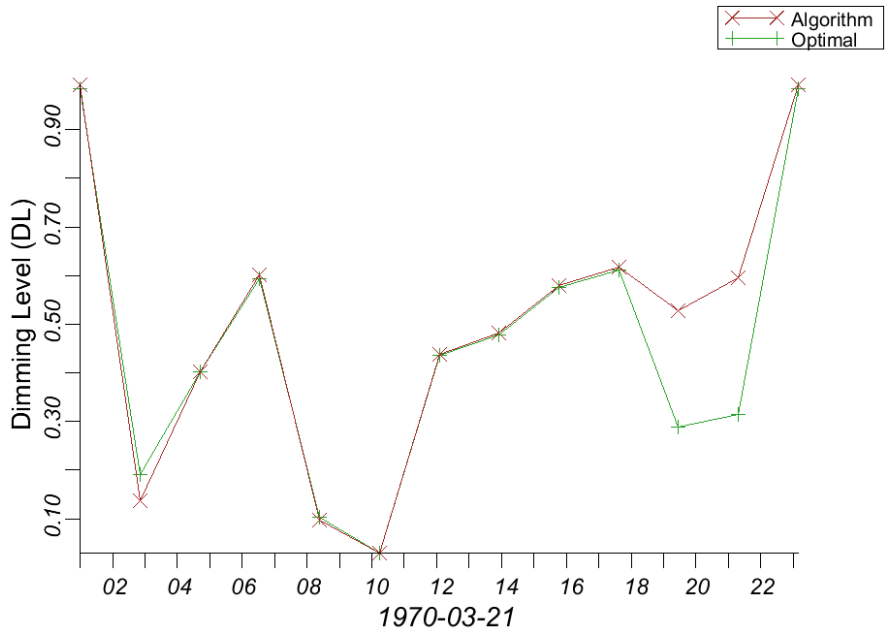


Useful Daylight Illuminance for Northeast Facing Life Science Façade (322.8 to 2000lux).

Fall & Spring Equinox: 7:00AM through 7:00PM

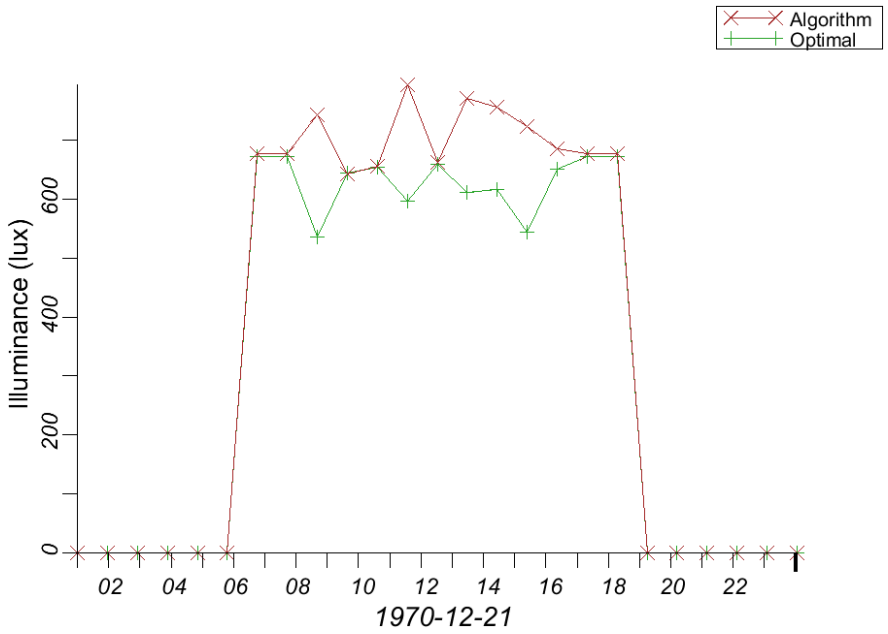


Daysim Illuminance Timeplot for Northeast Life Science Façade (Fall & Spring Equinox).

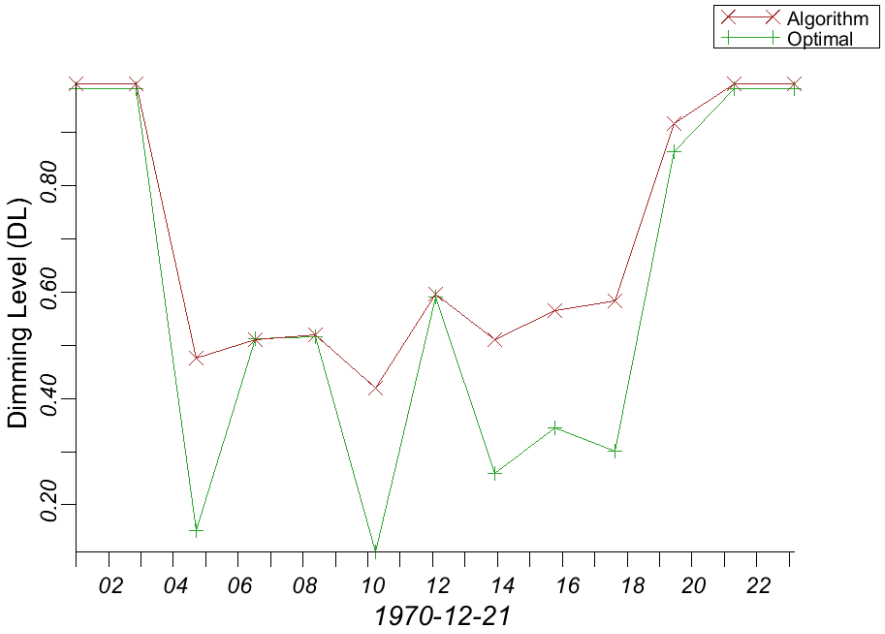


Daysim Dimming Timeplot for Northeast Life Science Façade (Fall & Spring Equinox).

Winter Solstice: 7:00AM through 7:00PM

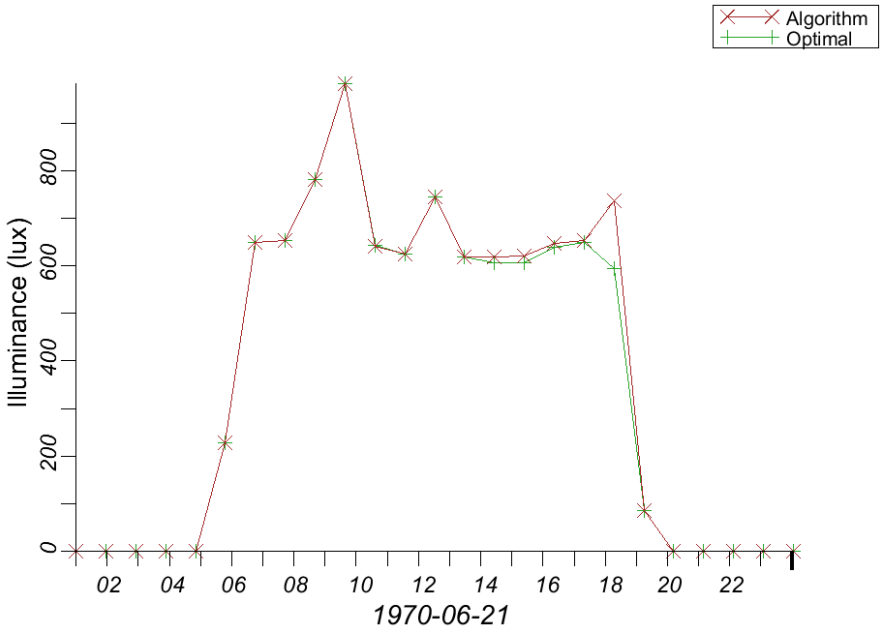


Daysim Illuminance Timeplot for Northeast Life Science Façade (Winter Solstice).

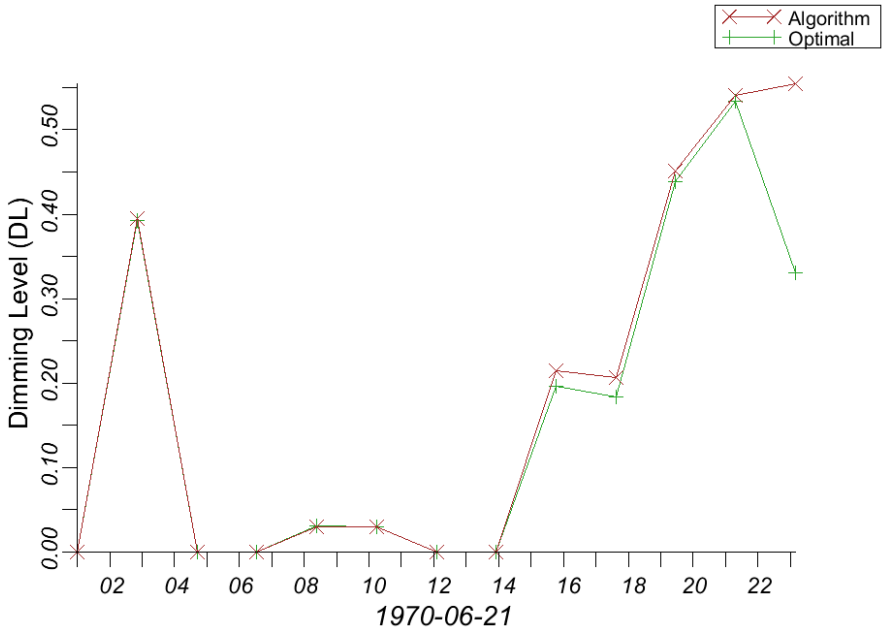


Daysim Dimming Timeplot for Northeast Life Science Façade (Winter Solstice).

Summer Solstice: 7:00AM through 7:00PM



Daysim Illuminance Timeplot for Northeast Life Science Façade (Summer Solstice).



Daysim Illuminance Timeplot for Northeast Life Science Façade (Sumemr Solstice).

Southeast Material Science Façade

Annual Savings kWh: 788.86

System Cost:	0.0
Energy Cost (per kWh):	0.08
Demand Charge (per kWh):	0.0
Peak Demand Time (0-24.0):	0.0

NOTE: All costs must be in the same units.

Savings Per Year: 63.1088

Daysim EconomicAnalysis for Southeast Material Science Student Study Area.

Energy Tables (KWh)

Controlled Zone | Grand Total

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Base	152.76	132.84	146.12	132.84	152.76	146.12	146.12	152.76	139.48	152.76	146.12	99.63	1700.35
Optimal	106.61	90.5	75.85	70.82	82.12	65.45	62.13	73.96	70.84	81.91	91.55	71.74	943.53
Algorithm	106.93	90.77	71.45	68.85	79.58	59.01	55.74	70.06	66.74	78.86	91.09	72.36	911.48
Savings	45.83	42.06	74.67	63.98	73.18	87.11	90.37	82.7	72.74	73.9	55.02	27.26	788.86

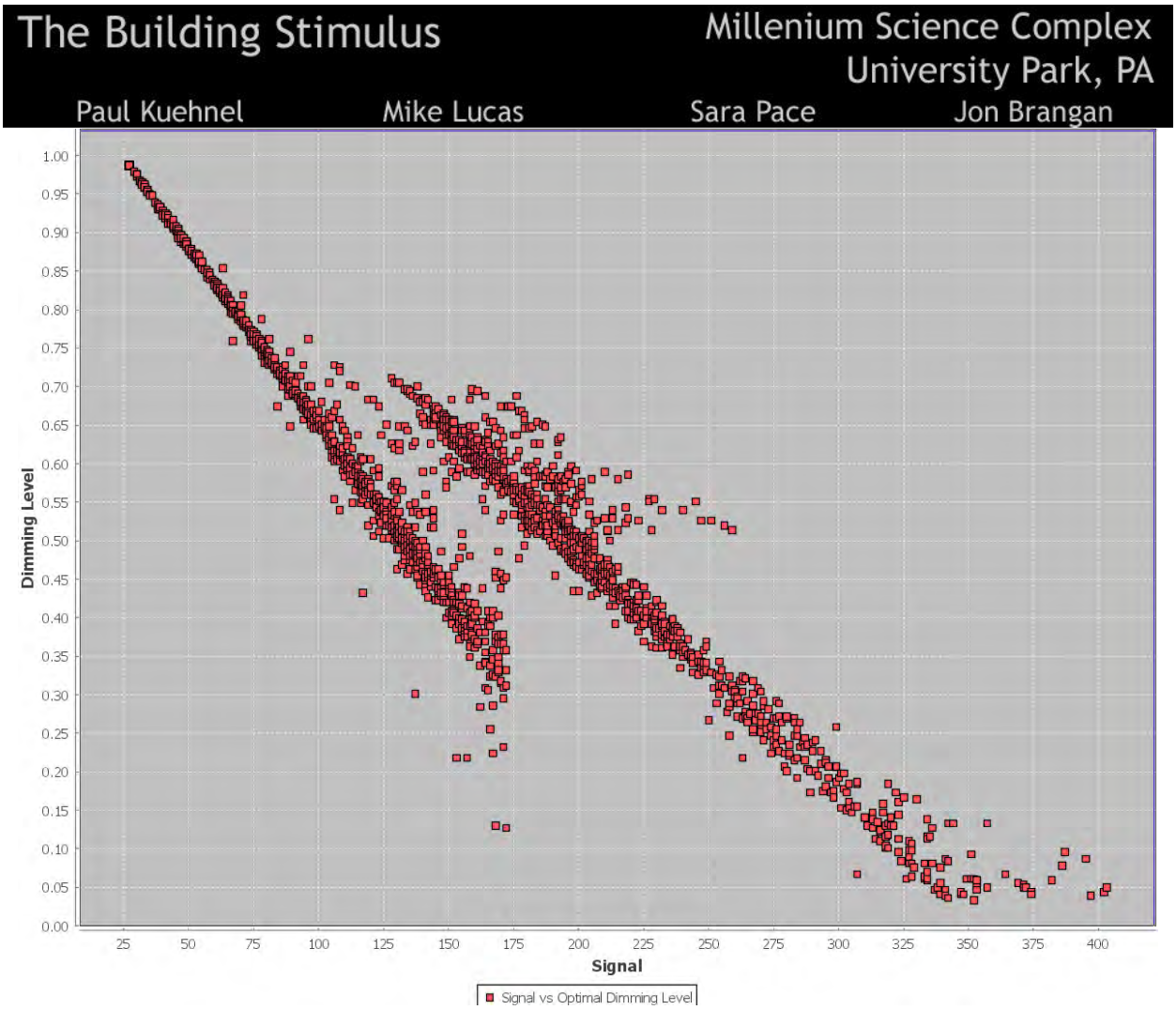
Daysim Controled Zone Energy Table for Southeast Material Science Student Study Area.

Energy Tables (KWh)

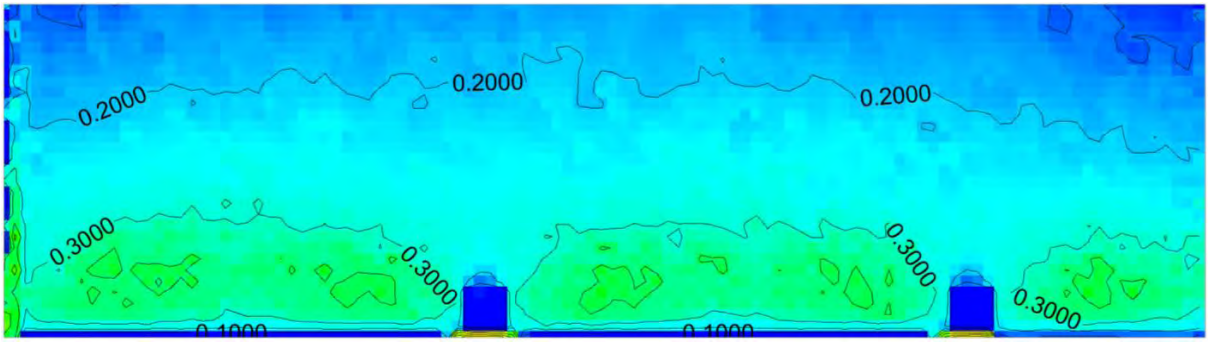
Controlled Zone | Grand Total

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Base	229.71	199.75	219.72	199.75	229.71	219.72	219.72	229.71	209.73	229.71	219.72	149.81	2556.82
Optimal	183.56	157.41	149.45	137.73	159.07	139.05	135.74	150.91	141.1	158.86	165.16	121.92	1800.0
Algorithm	183.88	157.68	145.05	135.77	156.53	132.61	129.34	147.01	136.99	155.8	164.69	122.54	1767.95
Savings	45.83	42.06	74.67	63.98	73.18	87.11	90.37	82.7	72.74	73.9	55.02	27.26	788.86

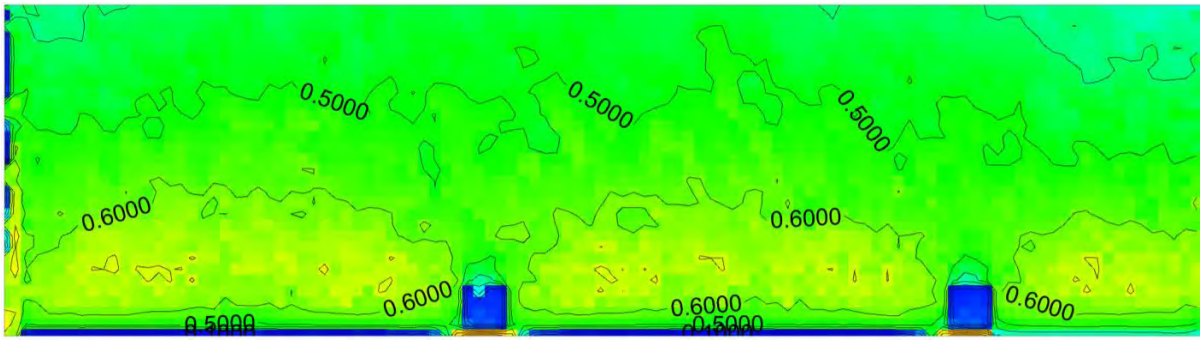
Daysim Controled Zone Energy Table for Southeast Material Science Student Study Area.



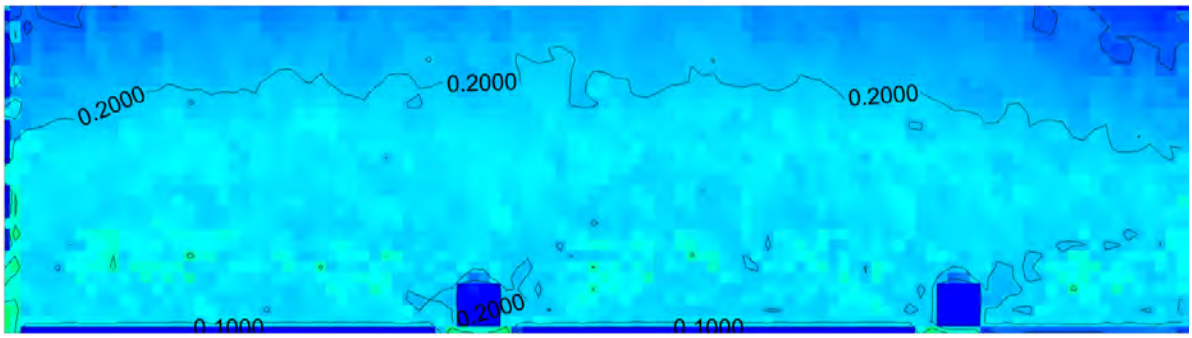
Dimming Level vs. Photosensor Signal for Southeast Facing Material Science Student Study Area.



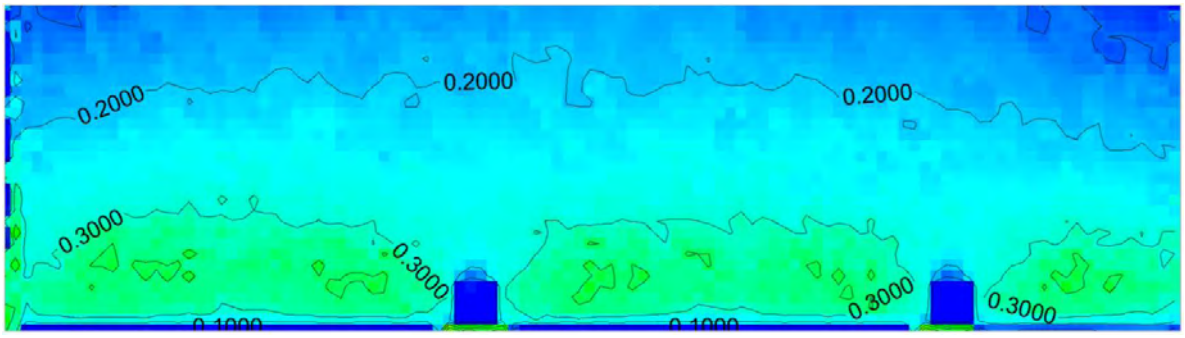
Daylight Autonomy for Southeast Facing Material Science Facade (322.8lux).



Continuous Daylight Autonomy for Southeast Facing Material Science Facade (322.8lux).

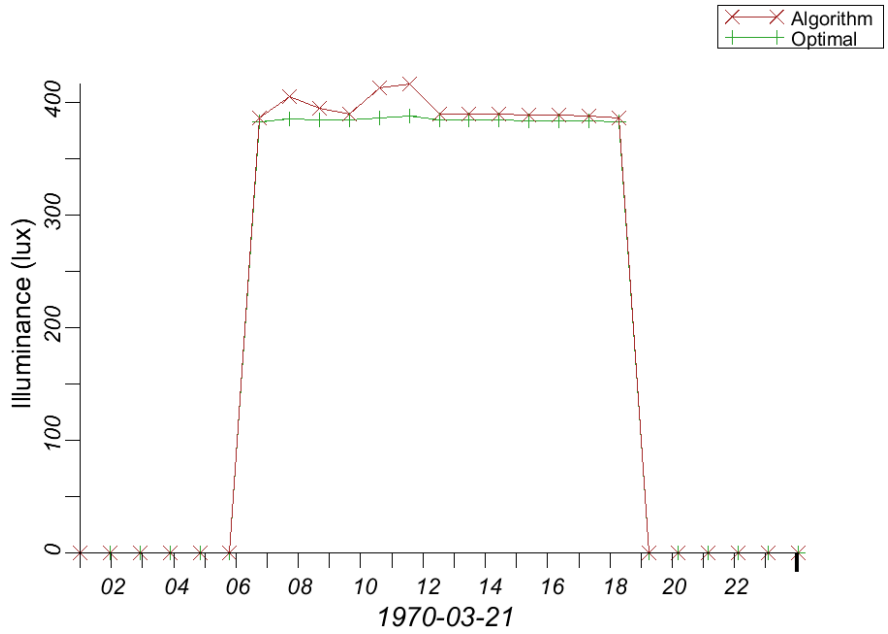


Daylight Illuminance for Southeast Facing Material Science Facade (322.8 to 1000lux).

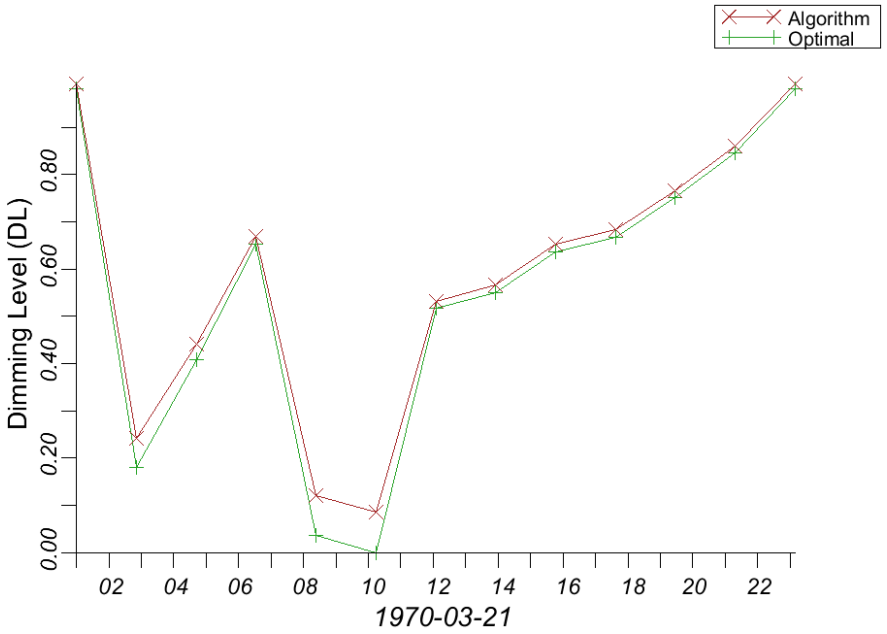


Useful Daylight Illuminance for Southeast Facing Material Science Facade (322.8 to 2000lux).

Fall & Spring Equinox: 7:00AM through 7:00PM

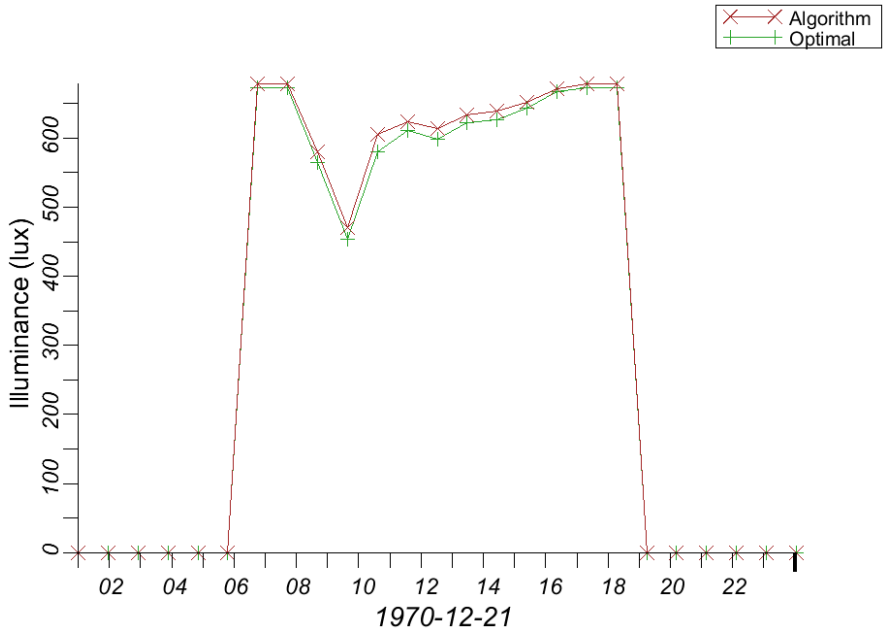


Daysim Illuminance Timeplot for Southeast Material Science Façade (Fall & Spring Equinox).

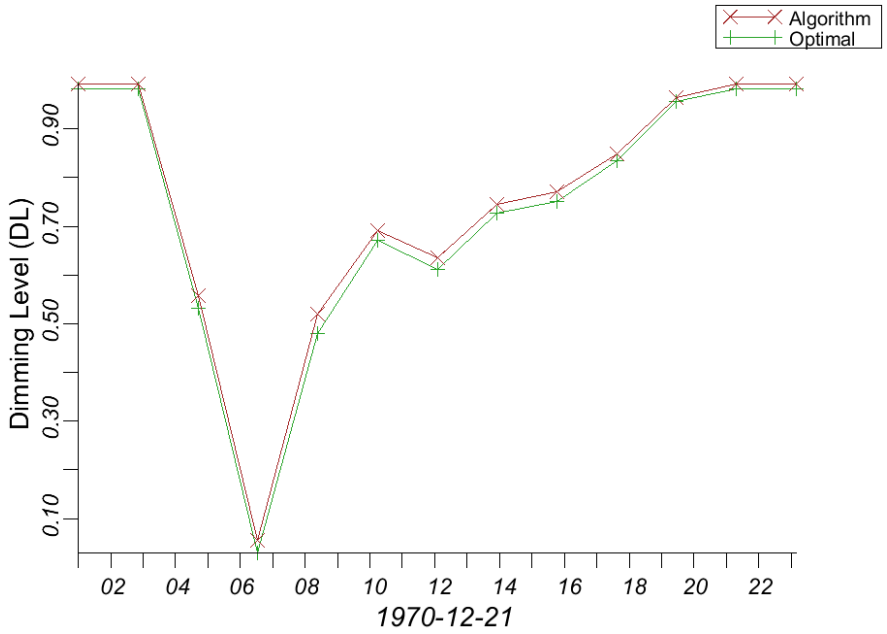


Daysim Dimming Timeplot for Southeast Material Science Façade (Fall & Spring Equinox).

Winter Solstice: 7:00AM through 7:00PM

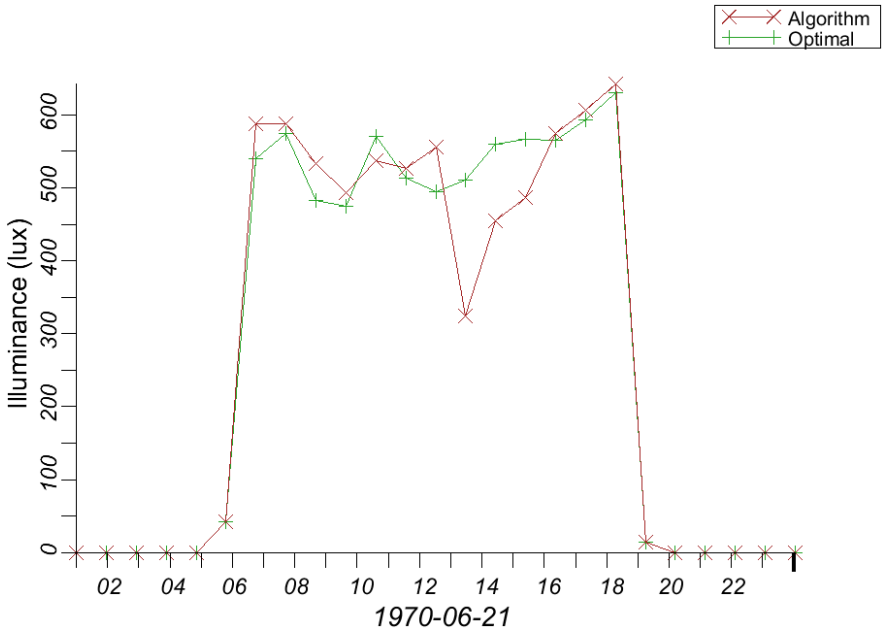


Daysim Illuminance Timeplot for Southeast Material Science Façade (Winter Solstice).

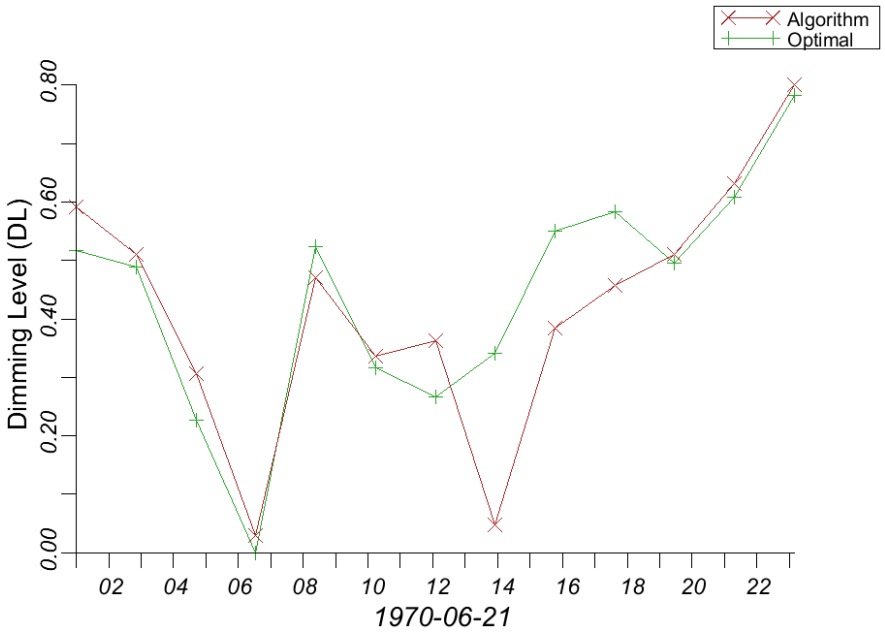


Daysim Dimming Timeplot for Southeast Material Science Façade (Winter Solstice

Summer Solstice: 7:00AM through 7:00PM



Daysim Illuminance Timeplot for Southeast Material Science Façade (Summer Solstice).



Daysim Dimming Timeplot for Southeast Material Science Façade (Summer Solstice).

Southwest Life Science Façade

Annual Savings kWh: 703.35

System Cost: 0.0

Energy Cost (per kWh): 0.08

Demand Charge (per kWh): 0.0

Peak Demand Time (0-24.0): 0.0

NOTE: All costs must be in the same units.

Savings Per Year: 56.268

Daysim Annual Energy Savings for the Southwest Life Science Student Study Area.

Energy Tables (KWh)

Controlled Zone | Grand Total

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Base	152.76	132.84	146.12	132.84	152.76	146.12	146.12	152.76	139.48	152.76	146.12	99.63	1700.35
Optimal	101.74	89.5	73.45	79.16	95.38	76.92	73.47	79.07	71.43	80.89	88.49	72.56	982.12
Algorithm	107.81	95.12	78.33	79.77	93.56	70.01	67.52	76.66	76.21	83.54	92.5	75.9	996.99
Savings	44.94	37.71	67.78	53.06	59.19	76.11	78.59	76.1	63.26	69.22	53.61	23.72	703.35

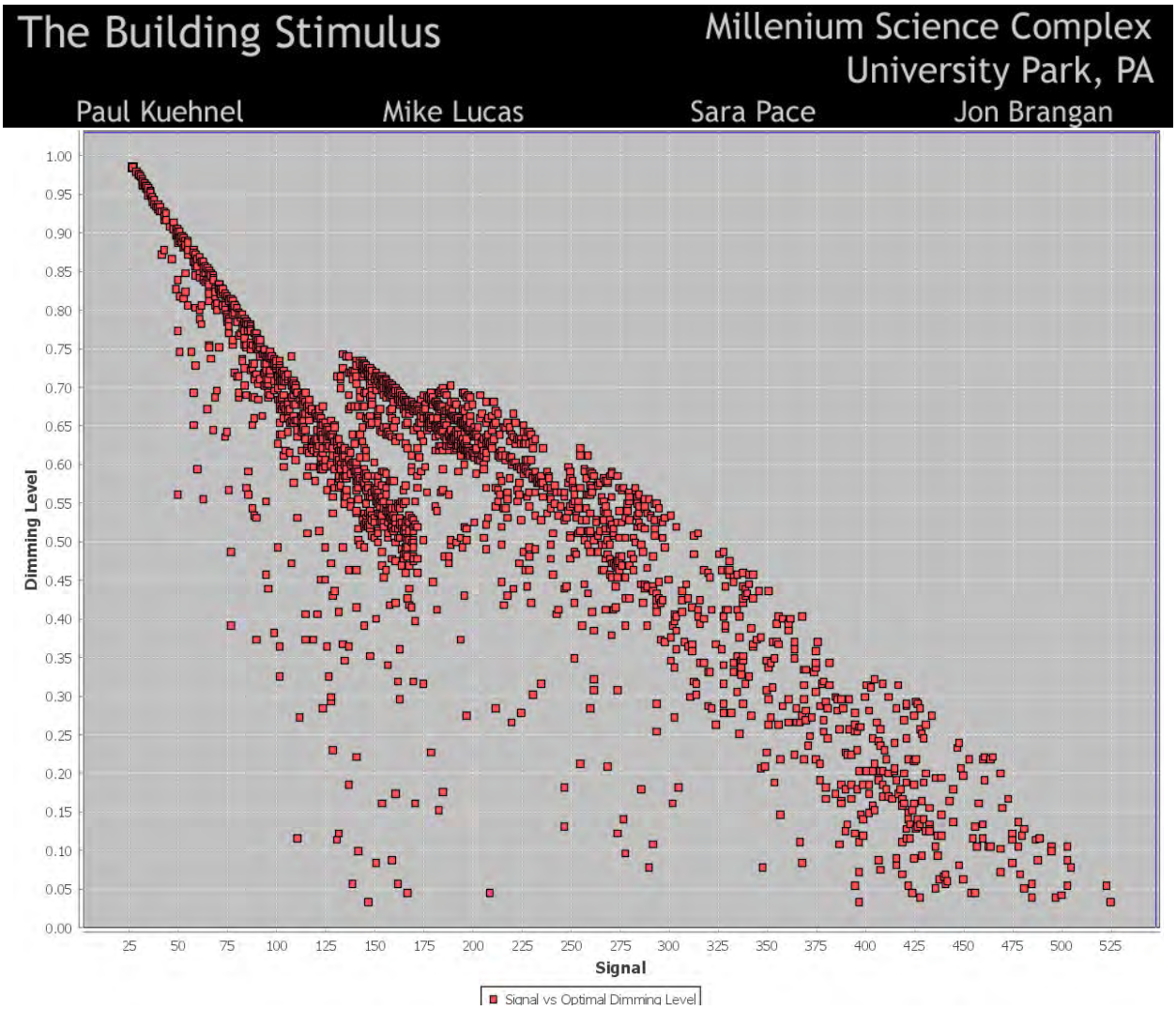
Daysim Controlled Zone Energy Table for the Southwest Life Science Student Study Area.

Energy Tables (KWh)

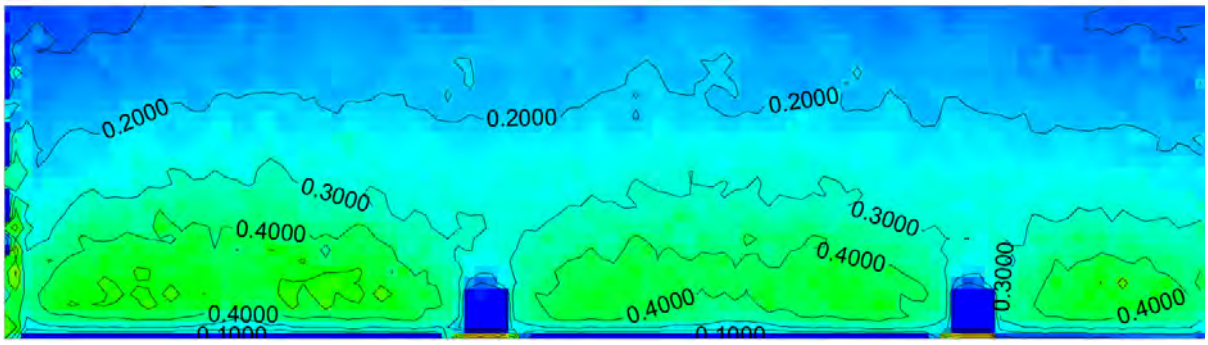
Controlled Zone | Grand Total

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Base	229.71	199.75	219.72	199.75	229.71	219.72	219.72	229.71	209.73	229.71	219.72	149.81	2556.82
Optimal	178.69	156.41	147.05	146.07	172.33	150.52	147.07	156.02	141.69	157.84	162.09	122.75	1838.59
Algorithm	184.76	162.03	151.94	146.68	170.51	143.61	141.12	153.61	146.47	160.49	166.1	126.09	1853.46
Savings	44.94	37.71	67.78	53.06	59.19	76.11	78.59	76.1	63.26	69.22	53.61	23.72	703.35

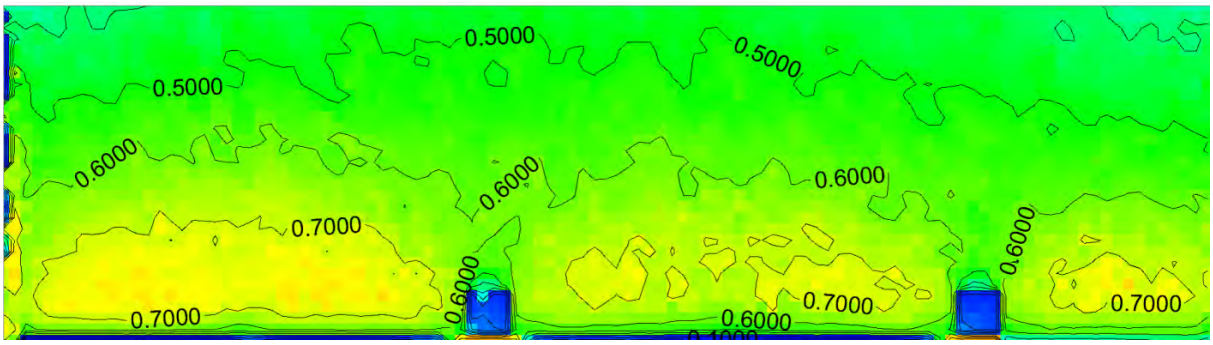
Daysim Controlled Zone & Corridor Energy Table for the Southwest Life Science Student Study Area.



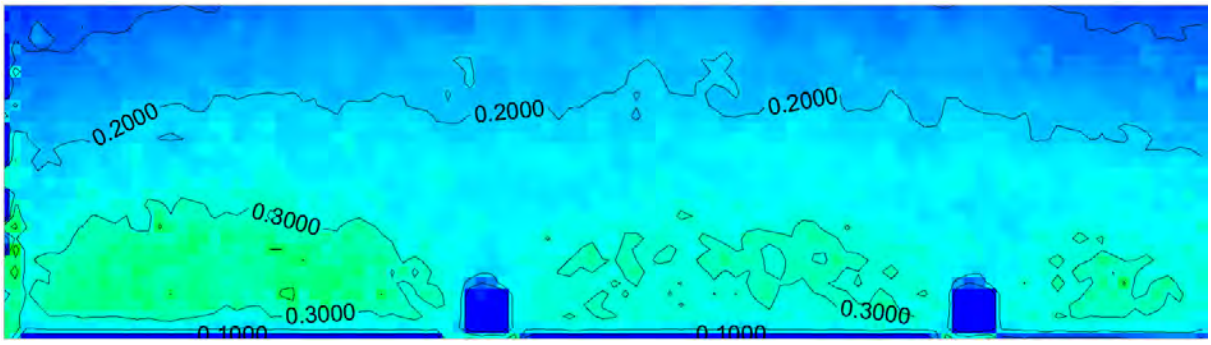
Daysim Photosensor Signal Vs. Dimming Level for the Southwest Life Science Student Study Area.



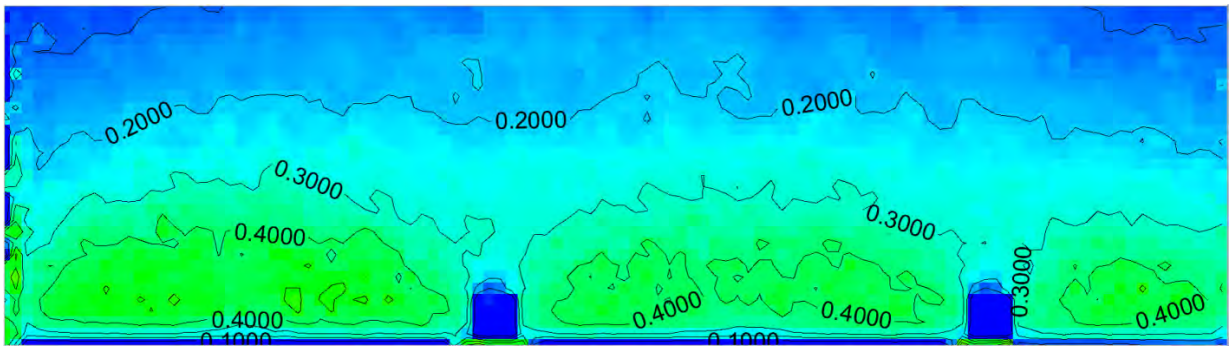
Daylight Autonomy for Southwest Facing Life Science Facade (322.8lux).



Continuous Daylight Autonomy for Southwest Facing Life Science Facade (322.8lux).

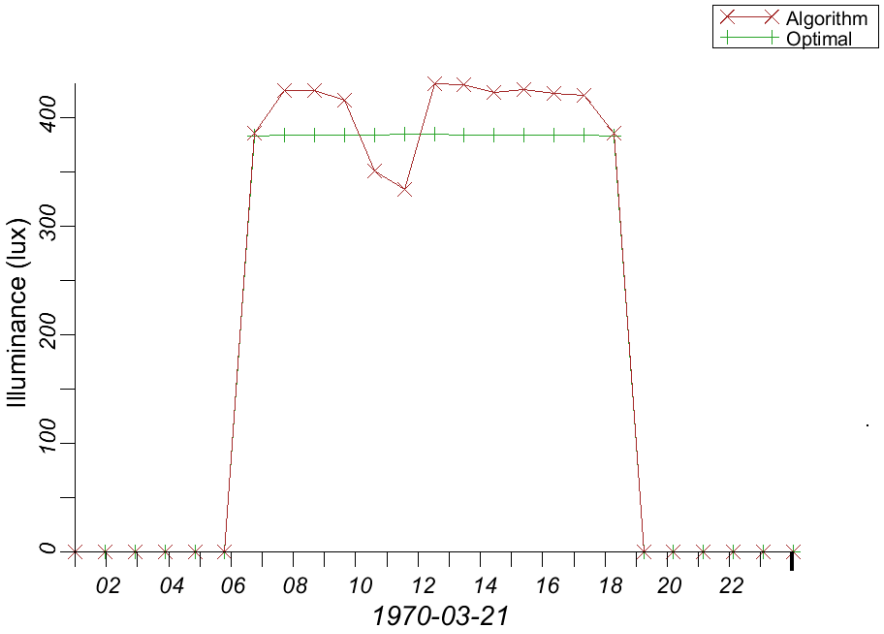


Useful Daylight Illuminance for Southwest Facing Life Science Facade (322.8 to 1000lux).

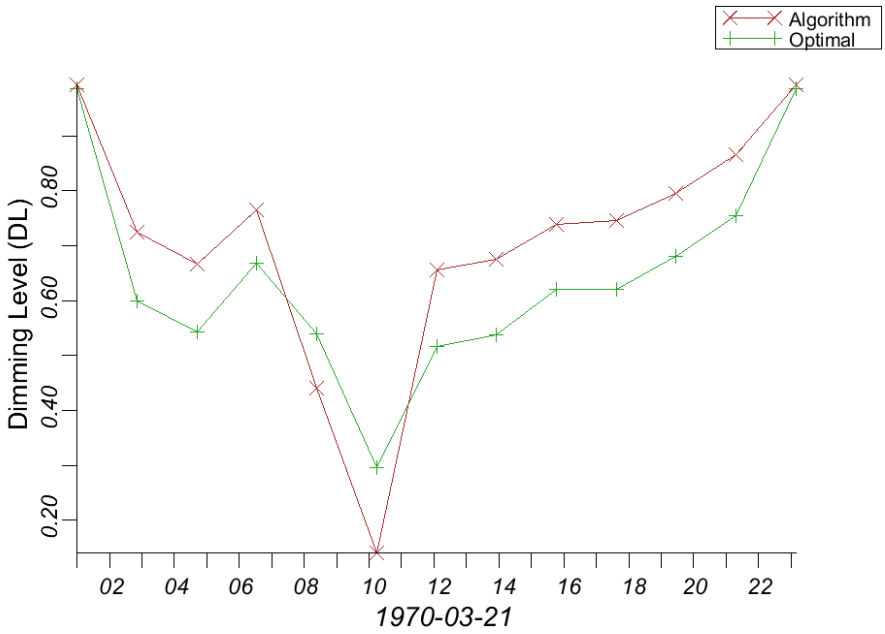


Useful Daylight Illuminance for Southwest Facing Life Science Facade (322.8 to 2000lux).

Fall & Spring Equinox: 7:00AM through 7:00PM

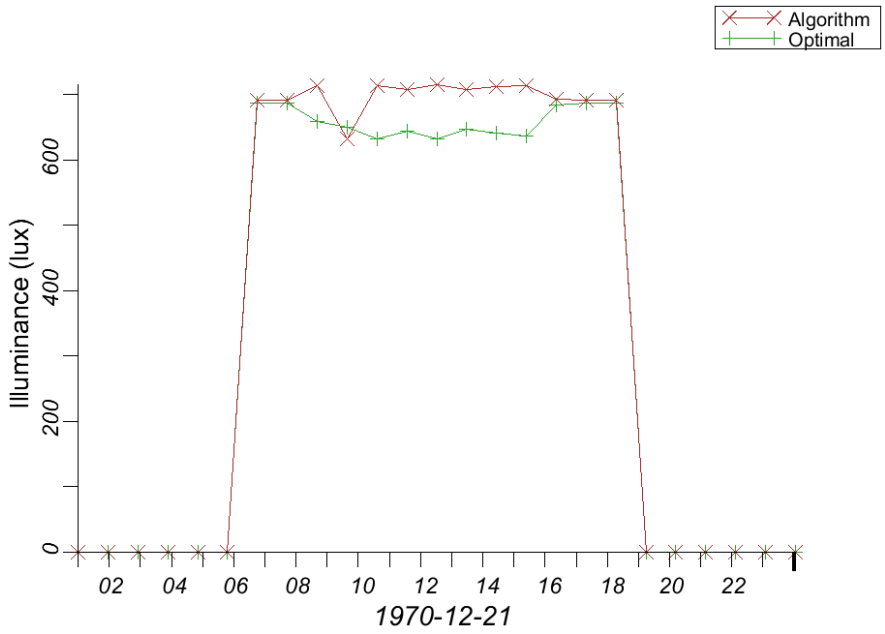


Daysim Illuminance Timeplot for Southwest Life Science Façade (Fall & Spring Equinox).

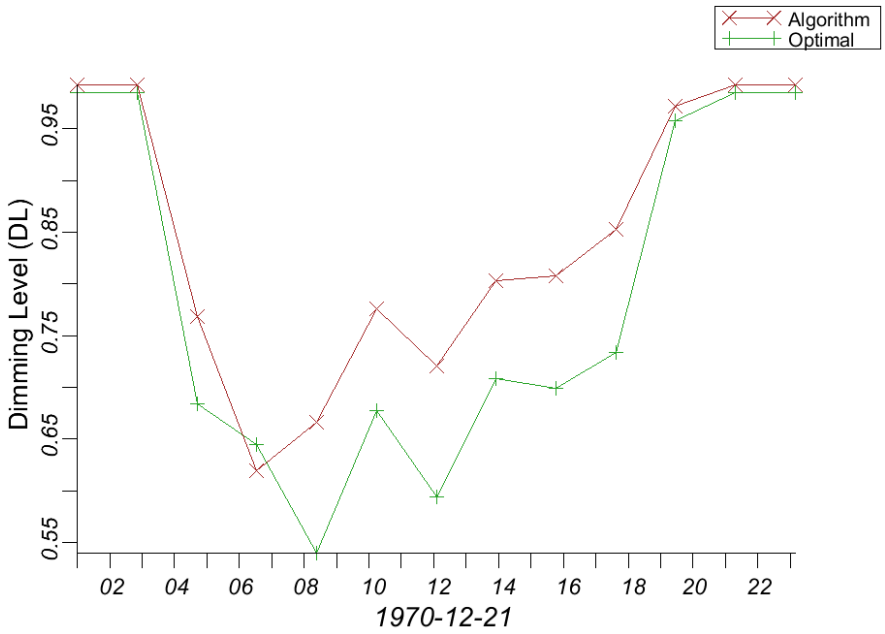


Daysim Dimming Timeplot for Southwest Life Science Façade (Fall & Spring Equinox).

Winter Solstice: 7:00AM through 7:00PM

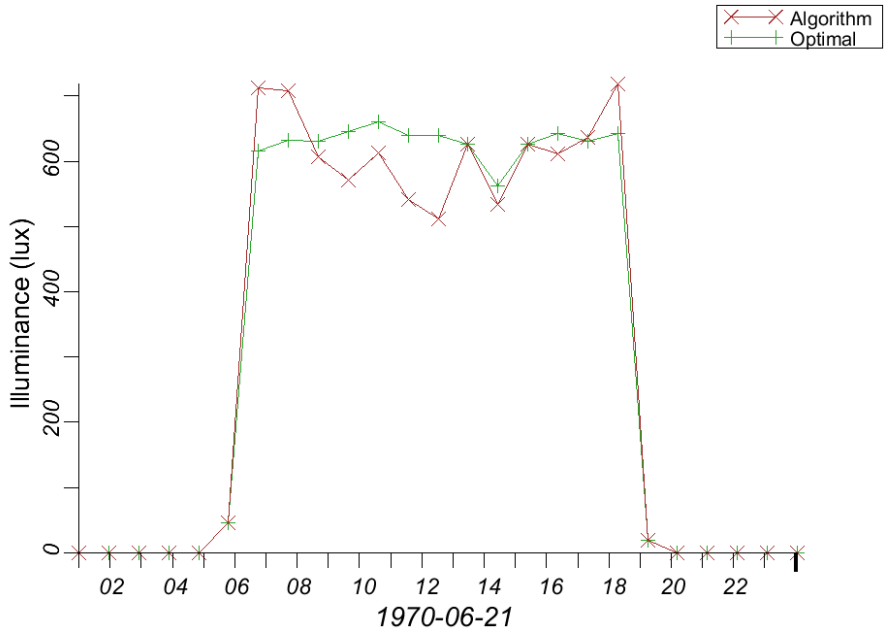


Daysim Illuminance Timeplot for Southwest Life Science Façade (Winter Solstice).

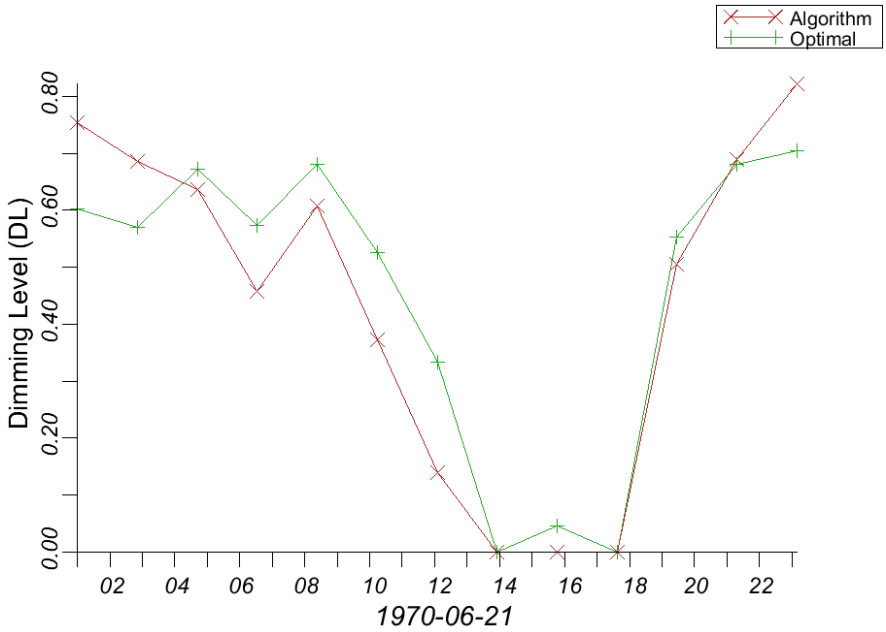


Daysim Dimming Timeplot for Southwest Life Science Façade (Winter Solstice).

Summer Solstice: 7:00AM through 7:00PM



Daysim Illuminance Timeplot for Southwest Life Science Façade (Summer Solstice).



Daysim Dimming Timeplot for Southwest Life Science Façade (Summer Solstice).

Appendix F: Comprehensive Luminaire Schedule

Luminaire Scehdule

Type	Image	Manufacturer	Catalog No.	Description	Location	Ballast	Lamp	VA	Input W	PF	BF	LLF	Voltage
CAN-Ua		Elliptipar	M152-210C-V-06-2-V00	Adjustable wall mounted cooper color finish metal halide uplight.	Cantilever Underside Wash	Phillips: AS205WQUADEE	(1) Philips: CDM210/T9/930/U/E	257.78	232.00	0.900	1.00	0.616	277V
CAN-Ub		Elliptipar	M151-070G-X-06-2-V00	Adjustable wall mounted cooper color finish metal halide uplight.	Cantilever Underside Wash	Phillips: 71A5237P	(1) Philips: CDM70/T6/842	94.44	85.00	0.900	1.00	0.575	277V
CAN-R		Cooper: Iris	P406TAT-MH4CMH 39T6E-E4CMHCB-MB	Recessed medium beamlens downlight with 4"x4" square aperature.	Exterior Plaza Entryways and Sidewalks	Phillips: 71A5037BP	(1) Philips: CDM35/T6/842	53.33	48.00	0.900	1.00	0.741	277V
CAN-W		Cooper: Iris	P406TAT-MH4CMH 39T6E-E4LWW-8H-SF-MTP4MB	Recessed Lens Wall Wash Luminaire with 4"x4" aperature.	Exterior Plaza Lobby Entryways	Phillips: 71A5037BP	(1) Philips: CDM35/T6/842	53.33	48.00	0.900	1.00	0.741	277V
CAN-L		Elliptipar	F164-T128-H-07-2-000	2' cantilevered-pole-mounted flourescent wall washing luminaire. Finish to match metal paneling.	Cantilever Octulous	Phillips - Centium: ICN-2S28	(1) Philips: F28T5/841/ALTO	31.86	31.50	0.989	0.99	0.626	277V
XPO-1		Louis Poulsen	Kipp Model 416 with post 4.5-12 Black	PSU Campus standard pole mounted luminaire. 12' post height/	Exterior Pathways	Phillips: 71A5337BP	(1) Philips: CDM 100W/840 Med ED17P CL ALTP+FB	131.11	118.00	0.900	1.00	0.658	277V
CFR-D		Cooper: Iris	P4-E4DLCBH-26TTT	4.5” x 4.5” recessed medium beam downlight luminaire with square opening.	Conference Rooms	Lutron EcoSystem: EC3DT4MWKU1S	(1) Philips: PL-T CFTR32W/GX24q	27.70	27.00	0.975	0.95	0.739	277V
CFR-C		Elliptipar	F306-T155-S-00-1-000	4’ cove mounted luminaire with asymmetrical ceiling washing distribution. light	Conference Rooms	Lutron EcoSystem: EC5-T832-G-UNV-317L	(1) Philips: F32T8 ADV835 Alto II	37.86	35.23	0.931	1.17	0.988	277V
OFF-D12		Kuegar	Custom	2'x 12' Custom Integrated chilled beam luminaire.	Typical Private Offices	Philips: ICN-2S28-N	(6) Philips: F21T5 835 Alto 40PK	150.00	147.00	0.980	1.02	0.862	277V
OFF-D8		Kuegar	Custom	2'x 8' Custom Integrated chilled beam luminaire.	Typical Private Offices	Philips: ICN-2S28-N	(4) Philips: F21T5 835 Alto 40PK	100.00	98.00	0.980	1.02	0.862	277V
OFF-D4		Kuegar	Custom	2'x 4' Custom Integrated chilled beam luminaire.	Typical Private Offices	Philips: ICN-2S28-N	(2) Philips: F21T5 835 Alto 40PK	50.00	49.00	0.980	1.02	0.862	277V
STD-D		Lightolier	VPS1G12PR132277SO	1’x4’ Recessed Fluorescent, 3” Deep, 12 Cell Parabolic Louvered Lens designed for intensive VDT use.	Student Study Areas	Advance Mark 7: IZT-3S32-SC	(1) Philips: F32T8 ADV835 Alto II	34.16	34.00	0.995	1.00	0.882	277V
COR-D		Lightolier	CFS1GHP132277SO	High Performance Recessed Fluorescent Direct/Indirect 1' x 4' with Perforated Basket.	Corridors	Phillips - Centium: ICN-2P32-SC	(1) Philips: F32T8 ADV835 Alto II	36.01	36.00	1.000	1.05	0.927	277V

Appendix G: Lighting Wiring Diagrams

Third Floor Life Science

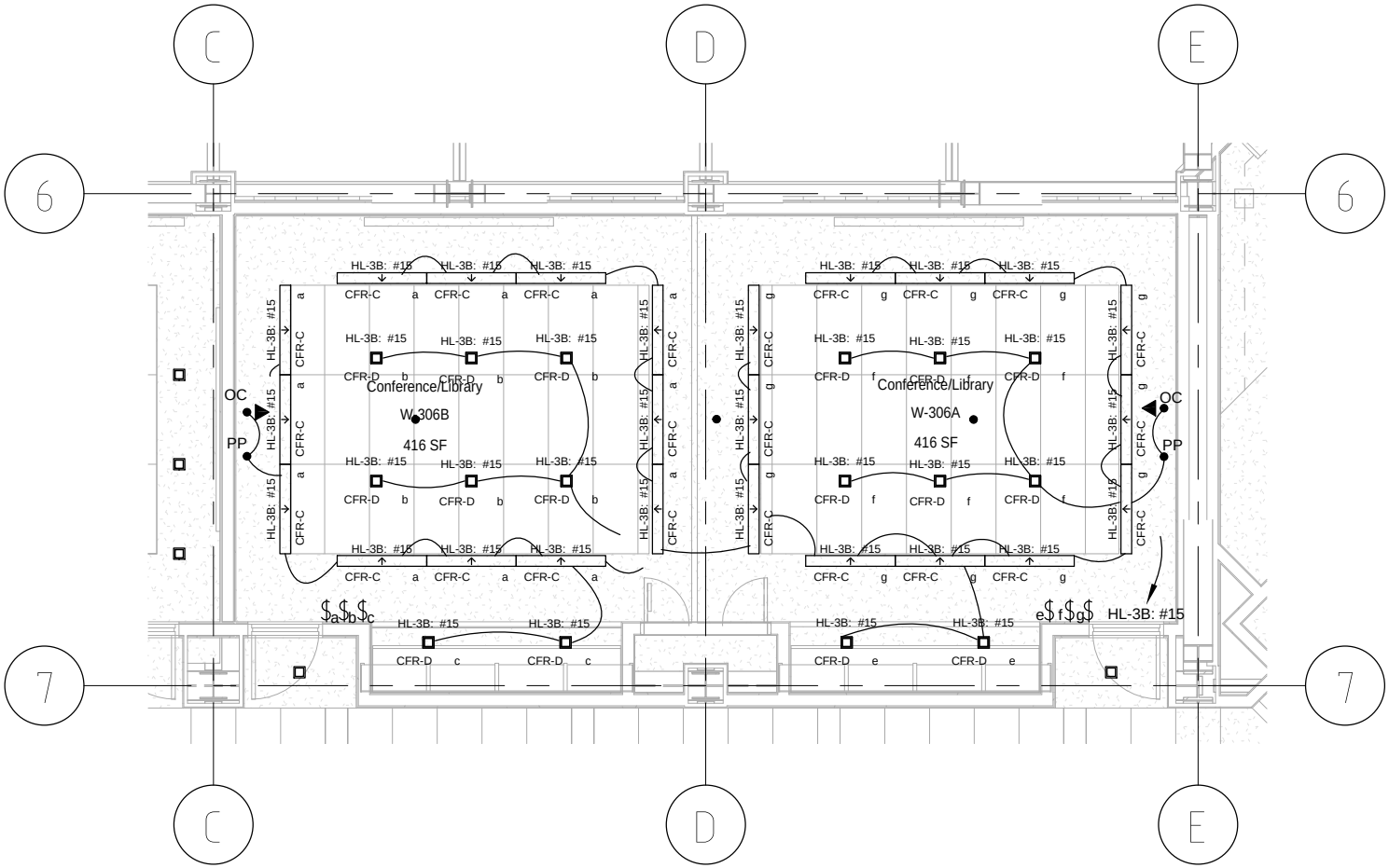
See attached full size drawings (E-2.3BL "Exterior Plaza Lighting") for overall wiring diagrams and lighting layout of corridors, student study areas, offices and areas affected by lighting design in the third floor.

Third Floor Material Science

See attached full size drawings (E-2.3DL "Exterior Plaza Lighting") for overall wiring diagrams and lighting layout of corridors, student study areas, offices and areas affected by lighting design in the third floor.

Exterior Courtyard

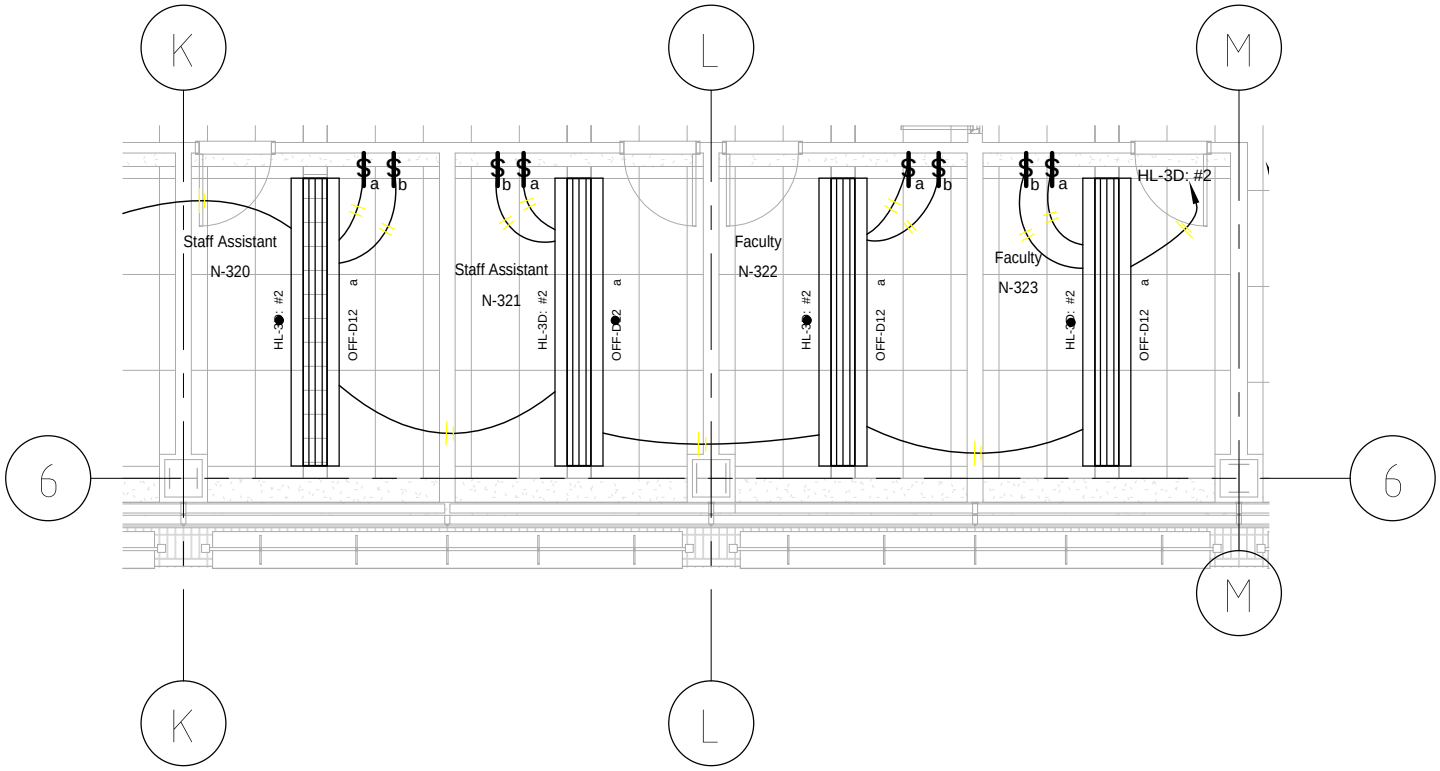
See attached full size drawings (E-6.3 "Exterior Plaza Lighting") for overall wiring diagrams and lighting layout of the Exterior Plaza Area.



The BuildingSTIMULUS
THE GREEN BUILDING SPECIALISTS

04/07/2011
LWM124

E-6.1
Conference Room Lighting Detail



1
E-6.2

Typical Office Lighting Detail

1/8" = 1'-0"

The BuildingSTIMULUS
THE GREEN BUILDING SPECIALISTS

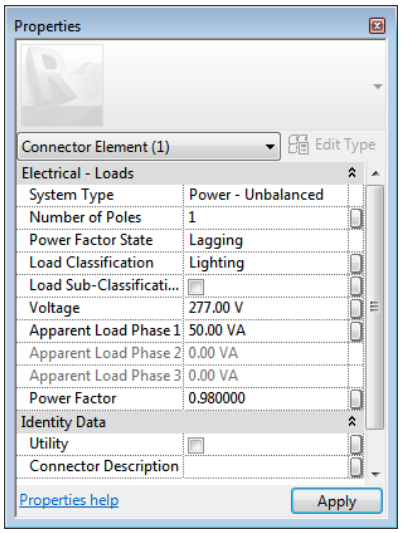
04/07/11
LWM124

E-6.2
Typical Office Lighting Detail

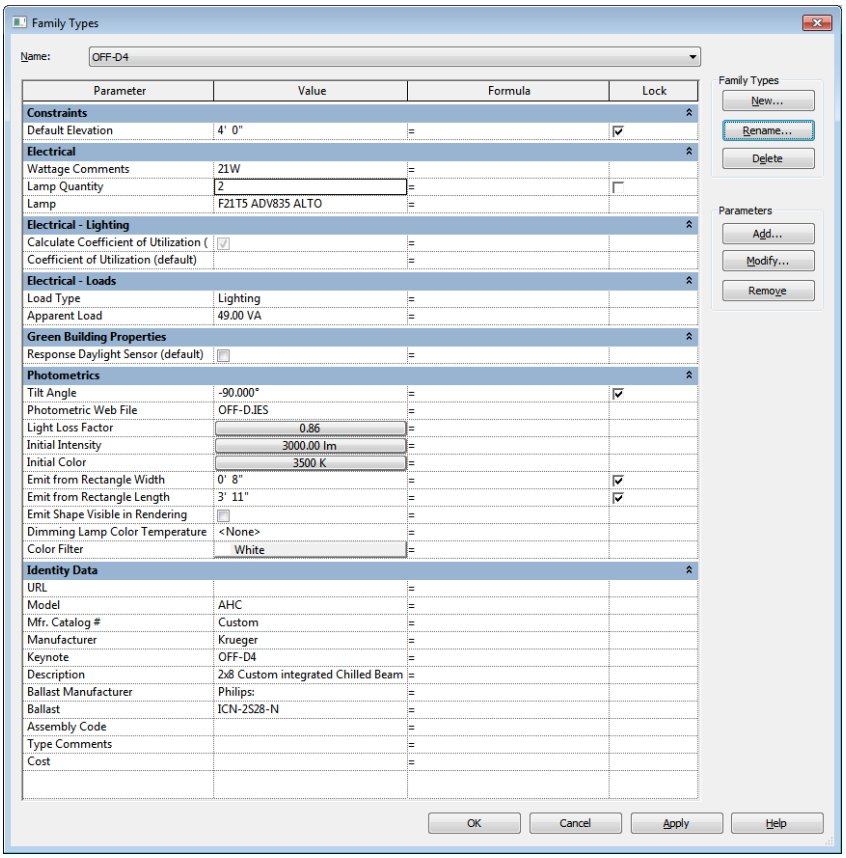
Appendix H: Lighting Fixture Cutsheets

Typical Office: OFF-D4

See Appendix C: Energy Analysis for complete cutsheet information.



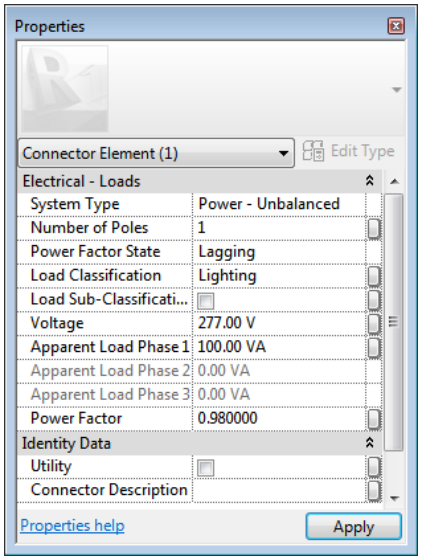
OFF-D4 Revit Electrical Connector Properties.



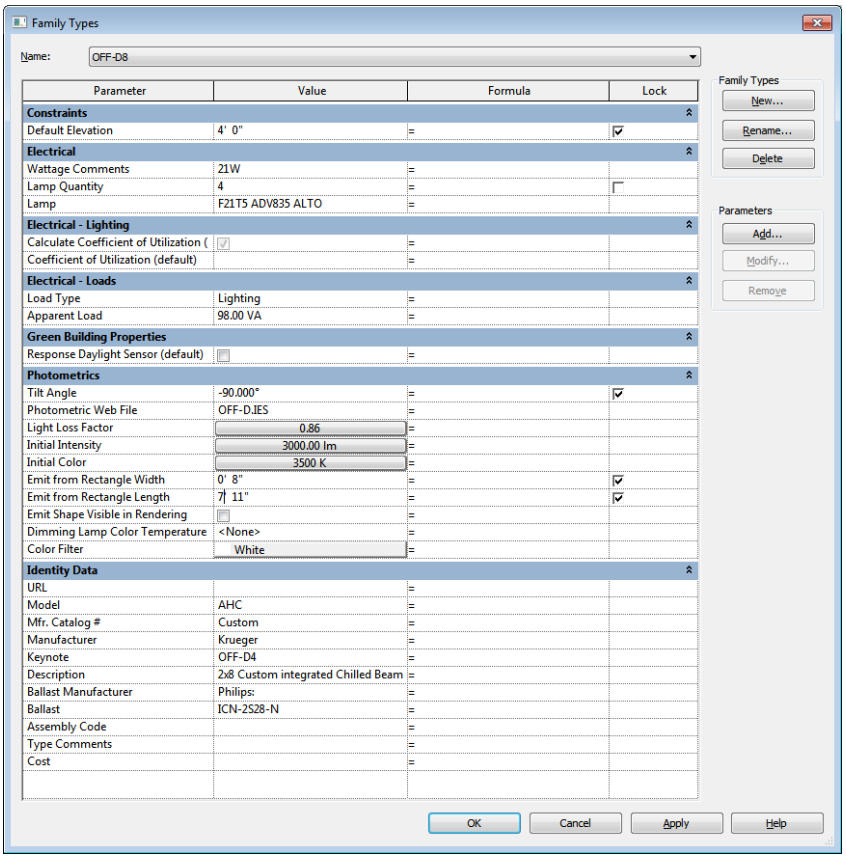
OFF-D4 Revit Family Type Data.

Typical Office: OFF-D8

See Appendix C: Energy Analysis for complete cutsheet information.



OFF-D8 Revit Electrical Connector Properties.



OFF-D8 Revit Family Type Data.

Typical Office: OFF-D12

See Appendix C: Energy Analysis for complete cutsheet information.

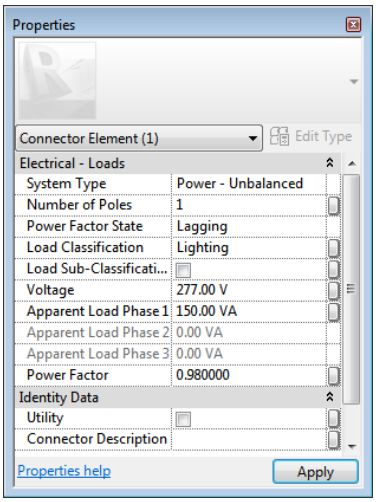
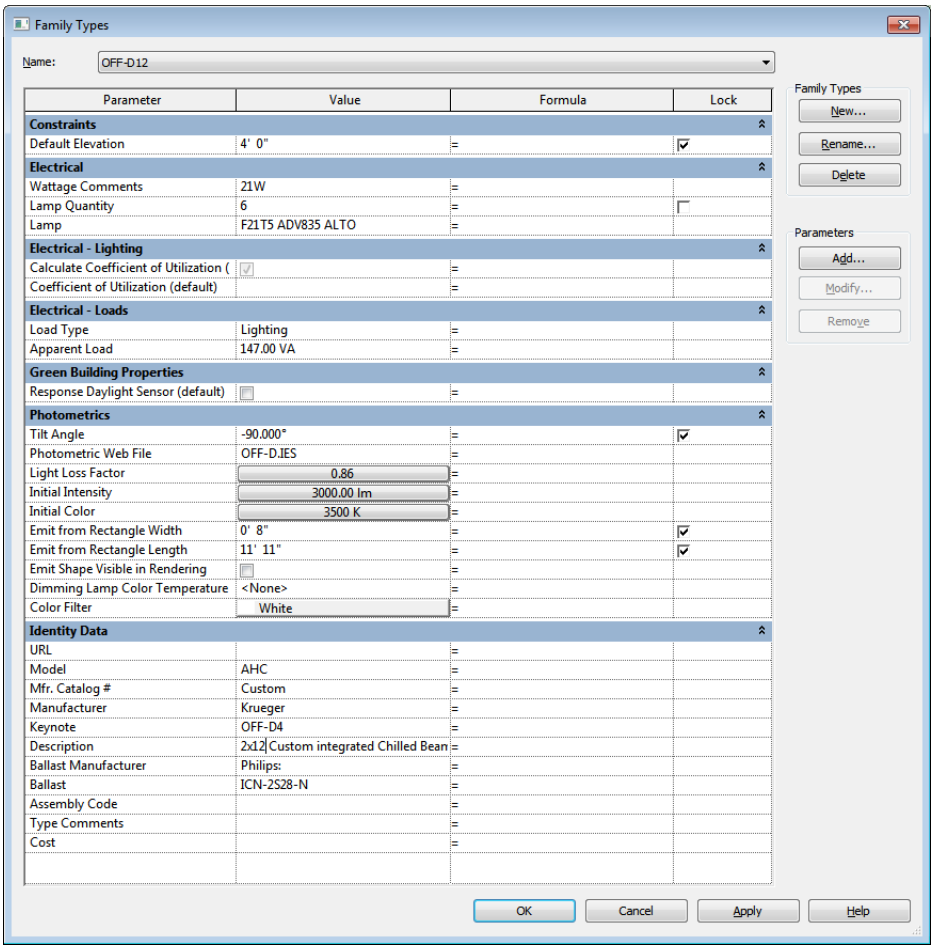


Figure 188: OFF-D12 Revit Electrical Connecter Properties.



OFF-D12 Revit Family Type Data.

Student Study Area: Type STD-D

VP PARABOLIC **VPA1G12PR132**

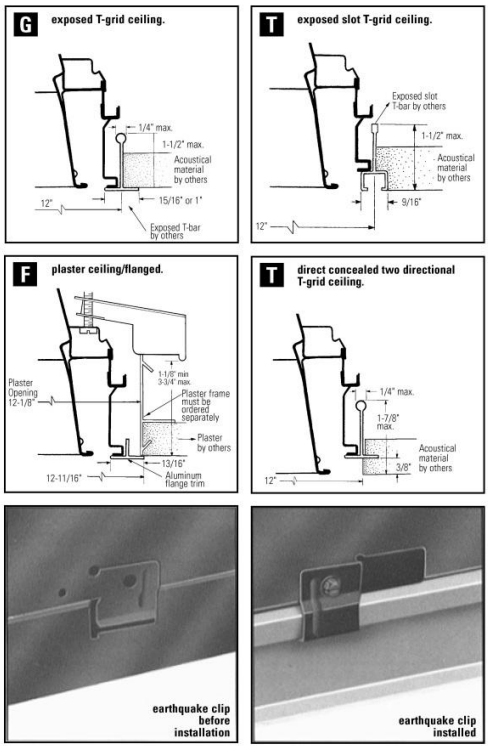
Page 1 of 2

1'x4' RECESSED FLUORESCENT, 3" DEEP, 12 CELL (1 ROW) PARABOLIC LOUVER
STATIC OR AIR SUPPLY/RETURN, IES RP1 FOR INTENSE VDT USE (PREFERRED)

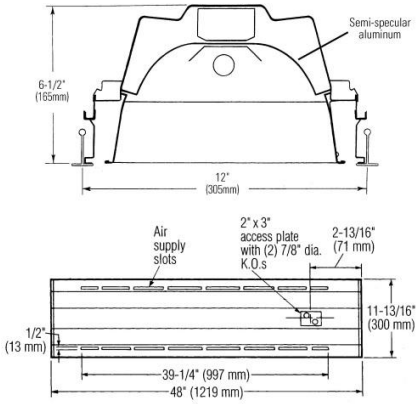
Features

- Meets IES RP1 for lighting VDT areas with intense use.
- 72.0% efficient (T8).
- 1.6 spacing mounting ratio.
- Specular, low iridescence, pre-anodized aluminum louver.
- Vertical grain on louver eliminates reflected lamp image on cross baffle.
- Louver frame with positive light stop.
- Spring loaded latches (self centering).
- Reversible louver hinging.
- Louver has protective dust guard.
- Only 6-5/8" deep body.
- Black housing exterior for cooler ballast operating temperature.
- Turned-in edges for safe handling.
- Built-in earthquake clip (pat. no. 5,072,344).
- UL-Listed twin knockout access plate.
- Air closure strips (optional).
- Construction to meet NYC Code or Chicago Plenum is available.

MOUNTING METHODS



DIMENSIONS



Job Information	**Type:** STD-D
Job Name:	Millennium Science Complex
Cat. No.:	VPS1G12PR132277SO
Lamp(s):	(1) 32W T8
Volts/Ballast:	277V Advance Mark 7: IZT-3S32-SC

Lightolier a Genlyte Thomas Company www.lightolier.com
Technical Information: (978) 657-7600 • Fax (978) 658-0595
631 Airport Road, Fall River, MA 02720 • (508) 679-8131 • Fax (508) 674-4710
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A0902 **SECTION 2/Folio G05-10 REV. A**

LIGHTOLIER®

VP PARABOLIC **VPA1G12PR132**

1'x4' RECESSED FLUORESCENT, 3" DEEP, 12 CELL (1 ROW) PARABOLIC LOUVER STATIC OR AIR SUPPLY/RETURN, IES RP1 FOR INTENSE VDT USE (PREFERRED)

PHOTOMETRY

MODEL NO. VPA1G12PR132120SO

LTL LUMINAIRE TESTING LABORATORY
905 Harrison Street • Allentown, PA 18103 • (610) 770-1044 • Fax (610) 770-8912

LTL NUMBER: 03011 DATE: 6-17-1996
PREPARED FOR: LIGHTOLIER INC.
CATALOG NUMBER: VPA1G12PR132SO
LUMINAIRE: FORMED STEEL HOUSING, FORMED SEMI-SPECULAR ALUMINUM REFLECTOR WITH SPECULAR MYLAR INSERT, SPECULAR ALUMINUM PARABOLIC 12-CELL LOUVER
BALLAST: MOTOROLA M1-RN-T8-LLL-120
LAMPS: ONE PHILIPS F32T8/TL741 RATED AT 2850 LUMENS.
MOUNTING: RECESSED
LUMEN TO CANDELA RATIO USED = 9.18
TOTAL INPUT WATTS = 30.4 AT 120.0 VOLTS
THE 0 DEGREE PLANE IS PARALLEL WITH THE LAMPS.

#03011

CANDELA DISTRIBUTION

	0.0	22.5	45.0	67.5	90.0	FLUX
0	967	967	967	967	967	
5	966	971	974	970	973	93
15	926	948	994	1045	1062	283
25	814	883	1087	1296	1374	505
35	659	838	1171	1279	1245	653
45	478	678	676	416	261	414
55	65	124	108	70	33	93
65	0	0	6	21	13	10
75	0	0	0	1	0	0
85	0	0	0	0	0	0
90	0	0	0	0	0	0

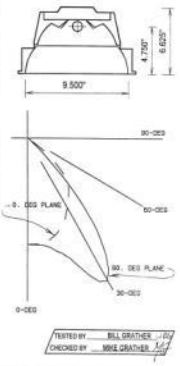
ZONAL LUMEN SUMMARY

ZONE	LUMENS	%LAMP	%FIXT
0- 30	880	30.9	42.9
0- 40	1533	53.8	74.9
0- 60	2040	71.6	99.5
0- 90	2051	72.0	100.0
90-180	0	0.0	0.0
0-180	2051	72.0	100.0

TOTAL LUMINAIRE EFFICIENCY: 72.0%
CIE TYPE: DIRECT
PLANE: 0-DEG 90-DEG
SPACING CRITERIA: 1.1 1.6
SHIELDING ANGLES: 36 40
LUMINOUS LENGTH: 46.250 9.500

LUMINANCE IN CANDELA PER SQUARE METER

ANGLE IN DEG	AVERAGE 0-DEG	AVERAGE 45-DEG	AVERAGE 90-DEG
0	3411.	3411.	3411.
45	2385.	3372.	1302.
55	400.	664.	203.
65	0.	50.	109.
75	0.	0.	0.
85	0.	0.	0.



TESTED BY: BILL GRATHER
CHECKED BY: MIKE GRATHER

THIS REPORT BASED ON LM-41 AND OTHER PERTINENT IES PROCEDURES.

LER = FP - 59.4 IW - 30.4 BF - 0.88
Comparative yearly lighting energy cost per 1000 lumens = $4.04

coefficients of utilization — zonal cavity method

	RF	20			20			20		
	RC	80			50			30		
	RW	70	50	30	50	30	10	50	30	10
room cavity ratio	1	81	79	77	74	73	72	72	71	70
	2	77	73	70	69	67	65	67	65	63
	3	72	67	63	64	61	58	62	59	57
	4	67	61	57	59	55	52	57	54	52
	5	63	56	51	54	50	47	53	49	46
	6	59	52	47	50	46	42	49	45	42
	7	55	47	42	45	41	38	45	41	38
	8	51	43	37	41	37	34	40	36	33
	9	47	38	33	37	33	30	36	32	29
	10	43	35	30	34	29	26	33	29	26

visual comfort probability

	room size		ceiling height					ceiling height			
	W	L	8.5	10.0	13.0	16.0		8.5	10.0	13.0	16.0
luminaries lengthwise	20	20	93	93	92	82	luminaries crosswise	97	96	95	90
	20	30	93	93	92	82		97	96	96	91
	20	40	93	93	92	82		97	96	96	92
	20	60	93	93	92	83		97	96	96	92
	30	20	93	93	93	85		97	96	96	91
	30	30	93	93	93	85		97	96	96	92
	30	40	93	94	92	85		97	96	96	92
	30	60	93	94	93	86		98	96	96	92
	30	80	93	94	93	86		98	96	96	92
	40	20	93	93	93	86		97	96	96	91
	40	30	93	94	92	87		97	96	96	92
	40	40	93	94	93	87		98	96	96	92
	40	60	93	94	93	87		98	96	96	92
	40	80	94	94	93	87		98	96	96	92
	40	100	94	94	93	87		98	96	96	82
	60	30	93	94	93	87		97	96	96	92
	60	40	93	94	93	87		98	96	96	92
	60	60	94	94	93	87		98	96	96	92
	60	80	94	94	93	87		98	96	96	92
	60	100	94	94	93	87		98	96	96	92
	100	40	94	94	93	87		98	96	96	92
	100	60	94	94	93	87		98	96	96	92
	100	80	94	94	93	87		98	96	96	92
	100	100	94	94	93	87		98	96	97	92

ORDERING INFORMATION

Explanation of Catalog Number. Example: VPA1G12PR132120SOGLR

	VP	S	1	G	12	P	R	1	32	277	SO	
BLANK = Standard **N** = NYC Code	**VP:** 3" Deep Pre-anodized Aluminum Louver for intense VDT use	**BODY STYLE:** **A**=Air Handling **S**=Static	**FIXTURE WIDTH**	**CEILING TYPE:** **G**= Grid (lay-in T bar) **F**=Flanged (overlap) Z spline and plaster frame. **T**=Slot grid or two-directional concealed T (see options)	**NUMBER OF CELLS:** 1 row of 12 cells	**LOUVER FINISH:** **P**=Low Iridescence Specular	**REFLECTOR:** **R**=Specular 95% Reflective	**LAMP QUANTITY**	**LAMP/FIXTURE LENGTH:** **32**=T8 **34**=T12 (Nominal 48")	**VOLTAGE:** 120 or 277	**BALLAST TYPE:** 1 Lamp Mag. T12 **LE** <20THD 1 Lamp Elec. T8 LOL Dimming **SO*** **HI*** <10THD **PS** – *Instant Start Standard Other dimming options, consult factory.	**OPTIONS:** Add appropriate suffix to catalog no, ie: (GLR)

OPTIONS & ACCESSORIES

ACCESS PLATE: Top Wiring access plate is shipped with fixture as standard. When access plates are required in advance for wiring convenience, specify separately. Order Catalog Number: **ACP CSP**.
ELECTRICAL WIRING OPTIONS: Consult factory.
FUSING: Internal fast-blow fusing. SUFFIX: **GLR**.
Internal slow-blow fusing. SUFFIX: **GMF**.
RADIO INTERFERENCE FILTER: 120 or 277 volt, 50 or 60 Hz. One per fixture standard. SUFFIX: **RF**.
CONTINUOUS ROW INSTALLATION: For F type fixtures, half-width flanges are required between fixtures. Order Catalog Number: **1FCTRIM** (each joint).
SPLAY TRIM: For T ceiling type only. SUFFIX: **CTZ14 S2 SPLAY TRIM**.
AIR CLOSURE STRIPS: SUFFIX **ACS4** (factory installed).
DRYWALL KIT: Order Catalog Number: **FK91X4**. Request Folio 0A30-10.
CHICAGO PLENUM: SUFFIX: **CP**.

SPECIFICATIONS

PERFORMANCE: In an installation of 1 lamp 32W luminaires in a room cavity ratio of 1, reflectance 80% ceiling, 50% wall, 20% floor, the C.U. shall not be less than .79 with a spacing to mounting ratio of 1.6 perpendicular to the lamps. To meet IES RP-1 preferred for VDT areas the VCP (visual comfort probability) shall not be less than 94 either crosswise or lengthwise, and the maximum average brightness at 55°, 65°, 75° and 85° shall not exceed 664,109, 0, and 0 candelas per square meter respectively in the 0°, 45° and 90° horizontal planes. Candelas at nadir (0°) not to exceed 967.
AIR HANDLING: (VPA only) side air passages for air supply or air return. Optional side closure strips. Air return is also provided through the lamp compartment through fixture body ends.
MATERIALS: Chassis parts are die-formed embossed cold rolled steel. **Housing** is embossed for rigidity with all edges turned-in for safe handling.
LOUVER: Pre-anodized aluminum (Coilzak® or equal).
FINISH: Louver—specular low iridescence pre-anodized reflector sheet.
REFLECTOR: Low-iridescence, semi-specular with low iridescence specular center section. **Chassis exterior**—black baked polyester enamel.
ELECTRICAL: Thermally protected class "P" ballast C.B.M. approved, non PCB. If K.O. is within 3" of ballast, use wire suitable for at least 90°.
LABELS: I.B.E.W./UL and C-UL.

Job Information **Type:** STD-D

Lightolier a Genlyte Thomas Company www.lightolier.com
Technical Information: (978) 657-7600 • Fax (978) 658-0595
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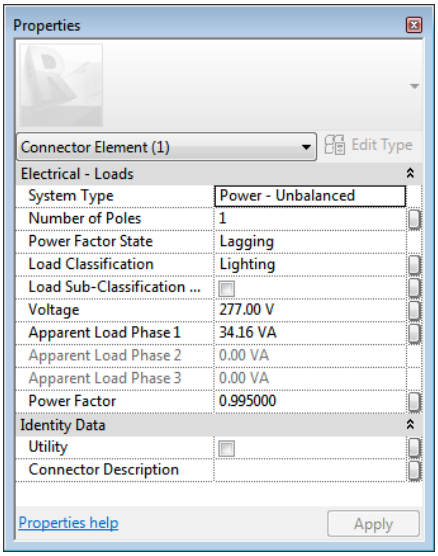
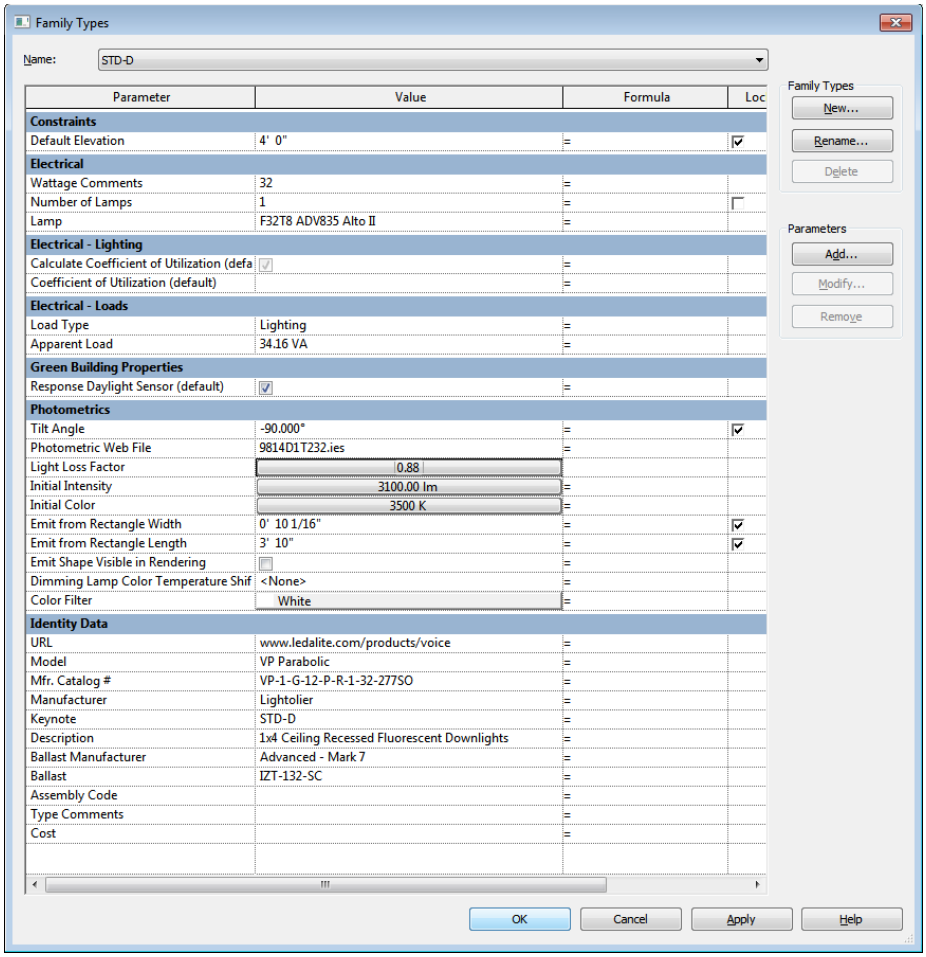
A0902 **SECTION 2/Folio G05-10 REV. A**

LIGHTOLIER®



STD-D Revit Electrical Connector Properties.



STD-D Revit Family Type Data.

Conference Room: Type CFR-D

IRIS®

DESCRIPTION

Energy Star qualified recessed medium beam downlight luminaire with 4 inch square aperture utilizing horizontal 26W DTT or 26/32W TTT compact fluorescent lamp. The electronic compact flourescent ballast meets stringent Energy Star requirements including FCC Title 47 CFR part 18 for consumer equipment. Platform is suitable for direct contact with insulation and 2x8 residential construction. Platform and element combination produces square distribution with excellent light control and low aperture brightness.

Catalog #	P4-E4DLCBH-26TTT	Type: CFR-D
Project	Millennium Science Complex	
Comments	Conference Room Downlight	Date
Prepared by	MWL	2/2/2011

SPECIFICATION FEATURES

Frame
Galvanized steel plaster frame with integral bar hanger receivers. Setscrews provide positive horizontal locking.

Collar
Matte black steel collar adjusts vertically for 1/2" - 1" thick ceilings and can be rotated +/- 7.5° thru the aperture. Integral gun sights facilitate the use of guide strings or laser lines. Shipped with a paint overspray protector installed in the collar.

Housing
Double wall aluminum housing painted matte black for a visually dark interior. Removable hinged top allows for top access. All fasteners are captive.

Optical Element
Mousetrap type springs pull flange tight to ceiling. Light trap eliminates spill light at edge of flange and reflector. Available in self-flanged or metal trim ring versions. May also be installed rimless using optional plastering lathing ring.

Gaskets
Closed cell gaskets achieve restrictive airflow requirements without additional caulking.

Bar Hangers
Captive preinstalled bar hangers adjusts from 8-1/2" to 24" wide; pass thru feature allows shortening without removal. Captive nail penetrates standard and engineered lumber. Mounting flange levels platform with ceiling. Integral clip attaches directly to t-bar.

Primary Reflector
Miro® Erotek segmented upper reflector yields a smooth square beam with medium distribution. Accepts 26W DTT, 26/32W TTT compact fluorescent lamp.

Lower Reflector
Aluminum parabolic shielding prismatoid provides for 55° cutoff and is available in a wide range of semi specular Alzak® finishes. Corrugated Baffle: An optional embossed pattern that extends through the flange adding a subtle design element and reduces aperture brightness.

Junction Box
(7) 1/2" trade size pry outs, (3) integral clamps for non-metallic cable. Rated for (4) #12 thru branch circuits. Wago® type push wire connectors for field connections

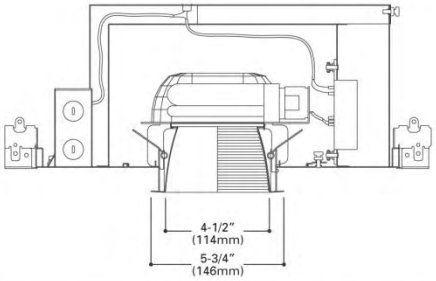
Ballast
Energy Star thermally protected, current controlled rapid start 120VAC input ballast produces full light output and rated lamp life.

Lamp Socket
4 pin Gx24q3/4 base with rotary lock socket ensures positive lamp retention. Lamp socket locks into one of two positions accommodating different lamp lengths.

Lamp
Generic compact fluorescent lamp designations (by others)
- CFTR32W/GX24q 2700K
- CFTR32W/GX24q 3000K
- CFTR26W/GX24q 2700K
- CFTR26W/GX24q 3000K

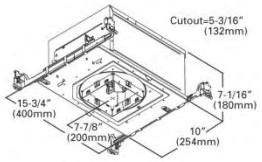
Up to 12,000 hour rated average life. 82 CRI rated lamps provide excellent color and high visual comfort. Color temperature options offer 2700K warm or 3000K medium warm incandescent-like light.

Code Compliance
Thermally protected, IP labeled, Energy Star qualified, cULus listed for protected damp locations and ASTM-E283 AIRTITE(tm). Suitable for direct contact with insulation. Meets EMI/RFI requirements per FCC part 18 consumer limits. Meets State of California Title 24, Wahington State Energy Code, New York State Energy Conservation Construction Code, and International Energy Conservation Code.



P40832ICAT
P4081D26ICAT
P4081D32ICAT
E4DL E4DLCB
26W DTT, 26 or 32W TTT Compact Fluorescent

4 Inch Square Downlight



ENERGY DATA		
Min. Starting Temp -18°C		Sound Rating Class A
EMI/RFI Emissions FCC Part 18 Consumer Limits		
Input Frequency 50/60 Hz		Power Factor > 0.98
THD < 16%		Input Voltage 120V
26W	Input Power	29W
	Input Current	0.24A
32W	Input Power	36W
	Input Current	0.31A
ENERGY DATA - DIMMING		
Min. Starting Temp 10°C		
Sound Rating Inaudible in a 27dBa Ambient		
EMI/RFI Emissions FCC Part 18 Consumer Limits		
Input Frequency 60 Hz		Power Factor > 0.95
Input Voltage 120V		THD < 20%
26W Input Current		0.27A
32W Input Current		0.33A

ORDERING INFORMATION: Complete unit consists of platform and optical element.

Platform
P40832ICAT = 4" Square Aperture Energy Star IC Housing 26/32W
P4081D26ICAT = 4" Square Aperture 26W Lutron TuWire Dimming, Energy Star IC Housing
P4081D32ICAT = 4" Square Aperture 32W Lutron Tuwire Dimming, Energy Star IC Housing

Optical Element
E4DL = 4" Square Aperture Lower Shielding Prismatoid, Open
E4DLCB = 4" Square Aperture Corrugated Lower Shielding Prismatoid, Open

Finish
Alzak® Finishes
H = Clear Haze
WMH = Warm Haze
WHH = Wheat Haze
KH = Cognac Haze
GPH = Graphite Haze
CTH = Cobalt Haze
CCH = Chocolate Haze
BH = Black Haze
Painted Finishes
MW = Matte White
MB = Matte Black

Flange
(Blank) = Metal Trim Ring, Matte White
SF = Self Flanged
SFWF = Self Flanged, Matte White Flange (SFWF not available with corrugated baffle)

Accessories
PLR4x4 = Plaster lathing ring for rimless
RLA4x4 = Rimless adapter for solid ceiling surfaces
EDC4x41 = Extended depth collar for 1" - 1-1/2" thick ceilings
EDC4x42 = Extended depth collar for 1-1/2 - 2" thick ceilings
MTR4MW = Metal trim ring, matte white
MTR4MB = Metal trim ring, matte black
MTR4SN = Metal trim ring, satin nickel
MTR4AC = Metal trim ring, antique copper
MTR4TBZ = Metal trim ring, tuscan bronze

ENERGY STAR

COOPER Lighting
www.cooperlighting.com

Specifications and Dimensions subject to change without notice.
Consult your representative for additional options and finishes.

ADI071553
02/29/2008 4:53:57 PM

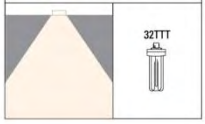
P40832ICAT E4DL E4DLCB

Photometrics

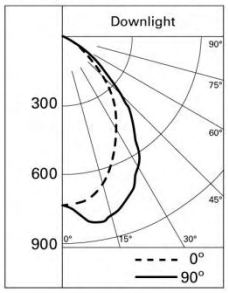
Photometric Results

Spacing Criterion = 1, 1.3
Efficiency = 50.6%

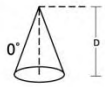
Test No. 254P232
Platform = P4
Element = E4DLH
Lumens = 2400
Lamp = CF32TTT/E/841



Candlepower Distribution



Cone of Light



D	FC	L	W
4'	47	4.0'	4.9'
5'	30	5.0'	6.2'
6'	21	6.1'	7.4'
7'	15	7.1'	8.7'
8'	12	8.1'	9.9'

Candelas

Vertical Angle	CD
90	0
85	2
75	15
65	44
55	113
45	248
35	396
25	525
15	650
5	704
0	711

Zonal Lumens Summary

Zone	Lumens	% Lamp	% Luminaire
0- 30	568	23.7	46.8
0- 40	856	35.7	70.5
0- 60	1162	48.4	95.7
0- 90	1214	50.6	100
90-180	0	0	0
0-180	1214	50.6	100

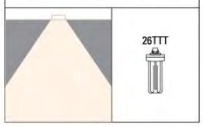
Coefficients of Utilization

Ceiling Wall % RCR	70 50 30 10	70 50 30 10	50 30 10	50 30 10	50 30 10	0
	Zonal cavity method -- floor reflectance = 20%					
0	60 60 60 60	59 59 59 59	56 56 56	54 54 54	52 52 52	51
1	57 55 53 52	55 54 52 51	52 51 50	50 49 48	48 47 47	46
2	53 50 47 45	52 49 47 45	47 45 44	46 44 43	44 43 42	41
3	49 45 42 40	48 45 42 39	43 41 39	42 40 38	41 39 37	37
4	46 41 38 35	45 41 37 35	40 37 35	38 36 34	37 35 34	33
5	43 38 34 31	42 37 34 31	36 33 31	35 33 31	35 32 30	30
6	40 35 31 28	39 34 31 28	33 30 28	33 30 28	32 30 28	27
7	38 32 28 26	37 32 28 26	31 28 26	30 27 25	30 27 25	24
8	35 30 26 24	35 29 26 23	29 26 23	28 25 23	28 25 23	22
9	33 28 24 22	33 27 24 22	27 24 21	26 23 21	26 23 21	20
10	31 26 22 20	31 25 22 20	25 22 20	25 22 20	24 22 20	19

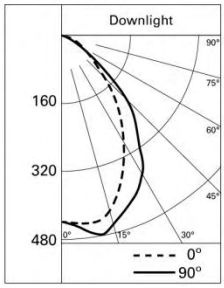
Photometric Results

Spacing Criterion = 1, 1.2
Efficiency = 39.5%

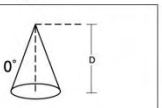
Test No. 254P229
Platform = P4
Element = E4DLH
Lumens = 1800
Lamp = CF26TTT/E/830



Candlepower Distribution



Cone of Light



D	FC	L	W
4'	28	4.0'	4.9'
5'	18	5.0'	6.1'
6'	12	6.0'	7.3'
7'	9	7.0'	8.6'
8'	7	8.0'	9.8'

Candelas

Vertical Angle	CD
90	0
85	1
75	8
65	24
55	61
45	140
35	239
25	338
15	427
5	442
0	438

Zonal Lumens Summary

Zone	Lumens	% Lamp	% Luminaire
0- 30	339	18.8	47.6
0- 40	507	28.2	71.3
0- 60	682	37.9	95.9
0- 90	711	39.5	100
90-180	0	0	0
0-180	711	39.5	100

Coefficients of Utilization

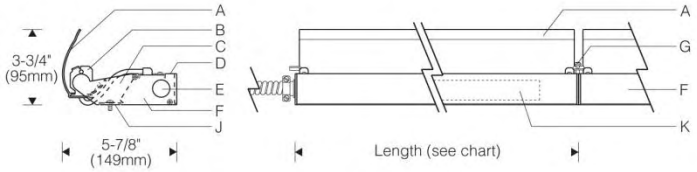
Ceiling Wall % RCR	70 50 30 10	70 50 30 10	50 30 10	50 30 10	50 30 10	0
	Zonal cavity method -- floor reflectance = 20%					
0	47 47 47 47	46 46 46 46	44 44 44	42 42 42	40 40 40	40
1	44 43 42 41	43 42 41 40	40 40 39	39 38 38	38 37 37	36
2	41 39 37 35	41 38 37 35	37 36 34	36 35 33	35 34 33	32
3	39 36 33 31	38 35 33 31	34 32 30	33 31 30	32 31 29	29
4	36 32 30 28	35 32 29 28	31 29 27	30 28 27	29 28 26	26
5	34 30 27 25	33 29 27 25	29 26 24	28 26 24	27 25 24	23
6	32 27 24 22	31 27 24 22	26 24 22	26 24 22	25 23 22	21
7	30 25 22 20	29 25 22 20	24 22 20	24 22 20	23 21 20	19
8	28 23 21 19	27 23 20 19	23 20 18	22 20 18	22 20 18	18
9	26 22 19 17	26 21 19 17	21 19 17	21 18 17	20 18 17	16
10	25 20 18 16	24 20 17 16	20 17 16	19 17 16	19 17 16	15

Lighting the Ceiling — Small concealed, integral

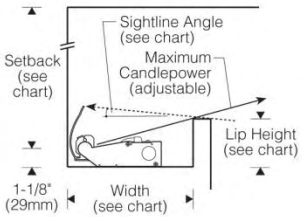
T5 Fluorescent
T8 Fluorescent

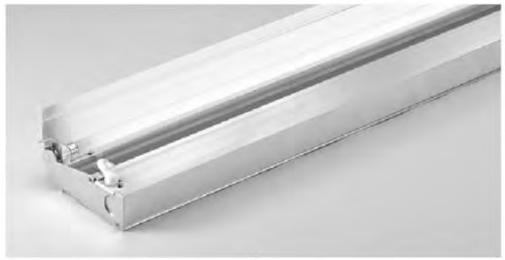
Style 306

Style 306 1:8 Scale



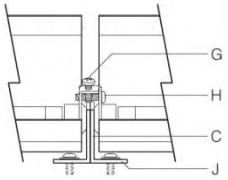
Cove 1:10 Scale





Joint 1:4 Scale

(ballast compartment not shown for clarity)



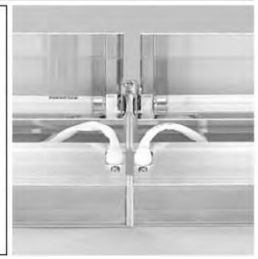
Nominal Lamp Length	Luminaire Length	
	T5	T8
1 x 2'	23-1/16" (586mm)	24-3/4" (628mm)
1 x 3'	34-7/8" (886mm)	36-3/4" (932mm)
1 x 4'	46-11/16" (1186mm)	48-3/4" (1237mm)
1 x 5'	58-1/2" (1486mm)	60-1/2" (1537mm)
2 x 3'	69-1/2" (1765mm)	73-3/16" (1859mm)
2 x 4'	93-1/8" (2365mm)	97-3/16" (2468mm)
2 x 5'	116-5/8" (2963mm)	120-7/8" (3069mm)

Cove Dimensions

(max. candlepower aimed 15° above horiz.)

Sight-line	0° (horiz. cutoff)	5°	10°
Width *(inside)*	10-5/8" (270mm)	8-1/4" (210mm)	6-3/4" (171mm)
Lip *(inside)*	3-3/4" (95mm)	3" (76mm)	2-5/8" (67mm)
Setback *(varies)*	Recommended minimum: 12" T5 and T8, 18" T5HO		

Note: Finish interior of cove matte white for best results.



Specifications

A Specular extruded aluminum reflector
B Stainless steel lamp-holder/support brackets
C Aluminum sidearm with mounting tab
D Extruded aluminum ballast/wireway channel cover
E Conduit entry (one each end, conduit and connector by others)
F Extruded aluminum ballast/wireway compartment
G Rotation locking screw
H Joiner/alignment screw
J Mounting tab (fastener by others)
K Integral electronic ballast

Finish:
Reflector – extruded high purity aluminum with clear anodized specular finish. Sidearms and ballast/wireway compartment – mill finish aluminum. All luminaire hardware – stainless steel.

Mounting:
Lay-in installation requires only one fastener per joint (by others). Sidearms with mounting tabs can be base or wall mounted. Luminaires can be mounted individually or joined together to form a continuous row.

Reflector aiming is adjustable and is fixed in position by rotation locking screws at each sidearm. When mounted in a continuous row, joiner screws lock reflectors together allowing all in the row to be aimed together.

Standard:
UL listed or CSA certified for damp locations (Style 124 painted model with lens recommended for damp locations).

Electrical:
Use 90°C wire for supply connections.

Integral electronic HPF thermally protected class P ballast (with end-of-life protection for T5 lamps). Ballast/wireway compartment includes one conduit entry at each end. Channel cover removes for access to ballast and wiring. Luminaires may be butted end-to-end (connectors by others) for through wiring. Optional #12 AWG prewired modular through wiring with quick connectors.

Master/satellite combination is available (Configuration **3**, see Ordering Information). Master supplied with 2-lamp ballast (wiring, conduit and connectors between master and satellite units by others).

Optional electronic dimming ballast; compatible dimmer switch required (by others). Consult sales representative for compatibility and specifications.

Optional integral emergency battery operates one lamp. Separate unswitched supply is required.

For complete ballast specifications, see Accessories Section.

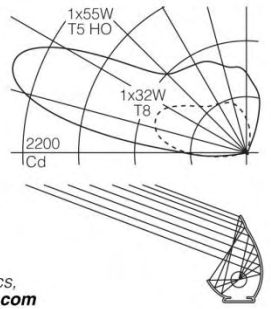
Features

- *Choose T5 for precise optical control or widely utilized T8*
- *Compact and flexible – effective indirect cove lighting for malls, offices, lobbies, conference rooms and corridors*
- *Adjustable – all reflectors in a row join and aim together; rotation locking screws secure position**
- *Integral electronic ballast thru wiring for easy installation*

C 20.0

Performance

Two parabolic reflector sections drive light across the ceiling from one edge. An elliptical section shields the lamp from normal viewing angles and redirects its light to a parabola. Glare is minimized and asymmetry of the beam is maximized resulting in high beam efficiency and superior surface uniformity.



For complete photometrics, visit ***thelightingquotient.com***

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10/10 ***U.S. Patents 5,550,725 and D432,696; EPO 0710796.**

The Building Stimulus
Millenium Science Complex
University Park, PA
Paul Kuehnel Mike Lucas Sara Pace Jon Brangan
Conference Room: Type CFR-C

To Order

Style 306

To form a Catalog Number

F	306	-	A132	-	S	-	00	-	2	-	00	0
1	2		3		4		5		6		7	8

Project: **Millennium Science Complex**

Type: **CFR-C**

1 Source

F = Linear fluorescent

2 Style

306 = Small concealed, **integral** ballast

3 Lamp

Note: To order by overall row length, enter **ROW CODE** in place of Lamp Code below (see Row Charts on page C-20.2 for T8 or C-20.4 for T5). Row Code specifies a row complete with all necessary reflectors and ballasts.

A **1** **32** = **Lamp Code**

Lamp Wattage (see chart below)

Reflector Configuration, specify **1**, **2** or **3** (see chart below)

A = T8 Fluorescent
T = T5 Fluorescent

Example: **A325** = two nominal 3' reflectors, each for use with one 25W T8 lamp; one 2-lamp ballast

C 20.1

Reflector Configuration

1	1 - Lamp Ballast 1-Lamp Reflector
2	2 - Lamp Ballast 2-Lamp Reflector
3	2 - Lamp Ballast 1-Lamp Reflector (Master) 1-Lamp Reflector (Satellite)

Lamp Wattage

Lamp Length (nominal)	*Lamp Wattage (Lamp Number)*		
	T8	*T5*	*T5HO*
2'	**17** (F17T8)	**14** (F14T5)	**24** (F24T5/HO)
3'	**25** (F25T8)	**21** (F21T5)	**39** (F39T5/HO)
4'	**32** (F32T8)	**28** (F28T5)	**55** (F54T5/HO)
5'	**40** (F40T8)	**35** (F35T5)	**80** (F80T5/HO)

For complete lamp and ballast information, see Accessories Section. Standard T5 lamp color is 3000K/80+ CRI. T8 lamps by others.

4 Mounting

S = Sidearms with mounting tabs

5 Finish

00 = Bright anodized reflector with mill finish ballast compartment

6 Voltage/Ballast

Electronic	*Dimming**
1 = 120V	**T** = 120V
2 = 277V	**V** = 277V
3 = 347V (Canada)	

* Consult sales representative for dimming 5' lamps (lamp codes **Ax40**, **Tx35**, **Tx80**) and for Reflector Configuration **3**. Availability for wattages and voltages varies with ballast manufacturer and control type – see **thelightingquotient.com** for additional dimming specifications and limitations.

7 Option (See Accessories Section for specifications)

00 = No options
0E = Integral emergency battery pack with indicator lamp and test button. Operates one lamp. Available in nominal 4', 6' and 8' units only (lamp codes **A132**, **A225**, **A232**, **A332**, **T128**, **T221**, **T228**, **T328**, **T155**, **T239**, **T255** and **T355**).
0K = Prewired modular #12 AWG through wiring with quick connectors
EK = Combination of emergency battery pack and prewired modular through wiring as described above
XX = For modification not listed, include detailed description. Consult factory prior to specification.

8 Destination Requirement

0 = UL listed or CSA certified for U.S.
J = UL listed or CSA certified for Canada

Example

F306 - A240 - S - 00 - 1 - 0E0

Small concealed fluorescent consisting of one nominal 10' luminaire, for use with two 40W T8 lamps. Integral 120V electronic 2-lamp ballast. Sidearm with mounting tabs. Supplied with integral emergency battery pack. UL listed or CSA certified for U.S.

Accessories

Order separately. See Accessories Section for specifications.

AFK000X **0** = Ballast **fuse** kit
0 = U.S.
J = Canada

12/09

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114 Boston Post Road, West Haven, Connecticut 06516, USA
Voice 203.931.4455 • Fax 203.931.4464 • **thelightingquotient.com**

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Lighting the Ceiling — Small concealed, integral — T8 Fluorescent — Style 306

To order by Row Code – T8 lamps

When the Style 306 small concealed fluorescent is run continuously in **straight** coves, **elliptipar** offers the option of specifying and ordering the entire row as one catalog number. Ordering by row eliminates the need to calculate length, type and quantity of reflectors.

Steps to specify Row Code:

1. Determine clear inside length of cove.
2. Round up to nearest foot and find the nominal row length in chart.
3. Determine what lengths/wattages of lamps will be used and select the corresponding lamp combination codes.
   Example: If only 3' and 4' lamps are to be used on the project, specify row codes ending with **A**, **B** and/or **D** only.
4. If for a given nominal row length a preferred lamp combination is not listed, select the next shorter row that is available in the desired lamp combination.
5. Once the nominal row length and lamp combination has been found in the chart, note the actual overall row length (last column).
6. Consider the unlighted length at each end of the row (subtract the overall row length from the clear inside length, and divide the remainder by two). It is generally recommended that the unlighted length at each end be between 6" and 12".
7. Enter the four character Row Code in place of the Lamp Code described on page C-20.1. The remainder of the catalog number is formed as shown on page C-20.1.

Features

- *Time saving – simplifies specification and ordering*
- *One catalog number – includes all necessary reflectors to install row*
- *Assured fit – all you need is the clear inside length of the cove*

3 Row Code

Note: Enter row code in place of Lamp Code described on page C-20.1.

R ___ = **Row Code**

Lamp Combination*
- **A** = All nominal 3' lamps
- **B** = All nominal 4' lamps
- **C** = All nominal 5' lamps
- **D** = Nominal 3' and 4' lamps
- **F** = Nominal 3' and 5' lamps
- **G** = Nominal 4' and 5' lamps

Nominal Row Length in feet, between 3' and 50' **

* Not all lamp combinations are available for each nominal row length (see chart).

** Nominal row lengths over 50' can be formed by combining shorter row lengths (example: a nominal 60' row can be ordered as two nominal 30' rows).

Example

F306 - R16C - S - 00 - 2 - 000

Nominal 16' long row of Style 306 small concealed T8 fluorescent using only nominal 5' (40W) lamps. Row includes one nominal 10' reflector for use with two 5' lamps, one nominal 5' reflector for use with one 5' lamp and integral 277V electronic ballasts. Overall row length is 15' 1-3/8".

Nominal Row Length (feet)	*Lamp Combination*	*Nominal 3' Luminaire (1 x nominal 3' lamp)*	*Nominal 4' Luminaire (1 x nominal 4' lamp)*	*Nominal 5' Luminaire (1 x nominal 5' lamp)*	*Nominal 6' Luminaire (2 x nominal 3' lamps)*	*Nominal 8' Luminaire (2 x nominal 4' lamps)*	*Nominal 10' Luminaire (2 x nominal 5' lamps)*	*Overall Row Length*
04	**A**	1						3' 0-3/4"
05	**B**		1					4' 0-3/4"
06	**C**			1				5 0-1/2"
07	**A**				1			6' 1-3/16"
08	**D**	1	1					7' 1-1/2"
09	**B**					1		8' 1-3/16"
09	**F**	1		1				8' 1-1/4"
10	**A**	1			1			9' 1-15/16"
10	**G**		1	1				9' 1-1/4"
11	**C**						1	10' 0-7/8"
11	**D**		1		1			10' 1-15/16"
12	**D**	1				1		11' 1-15/16"
12	**F**			1	1			11' 1-11/16"
13	**A**				2			12' 2-3/8"
13	**B**		1			1		12' 1-15/16"
14	**D**	1	1		1			13' 2-11/16"
14	**F**	1					1	13' 1-5/8"
14	**G**			1		1		13' 1-11/16"
15	**D**				1	1		14' 2-3/8"
15	**F**	1		1	1			14' 2-7/16"
15	**G**		1				1	14' 1-5/8"
16	**C**			1			1	15' 1-3/8"
16	**D**	1	1			1		15' 2-11/16"
17	**B**					2		16' 2-3/8"
17	**F**				1		1	16' 2-1/16"
18	**D**	1			1	1		17' 3-1/8"
18	**F**			1	2			17' 2-7/8"
18	**G**		1	1		1		17' 2-7/16"
19	**A**				3			18' 3-9/16"
19	**D**		1		1	1		18' 3-1/8"
19	**F**	1		1			1	18' 2-1/8"
19	**G**					1	1	18' 2-1/16"
20	**D**	1				2		19' 3-1/8"
20	**F**	1			1		1	19' 2-13/16"
20	**G**		1	1			1	19' 2-1/8"

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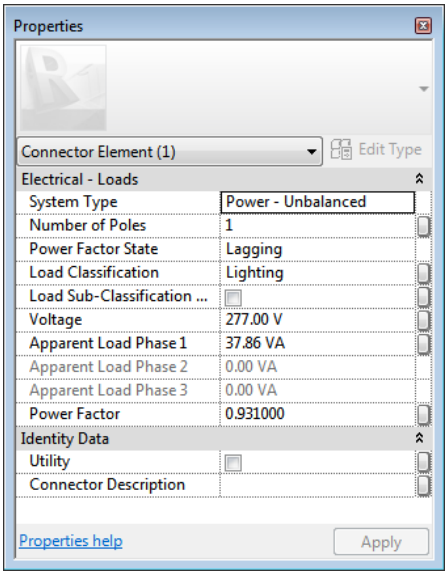
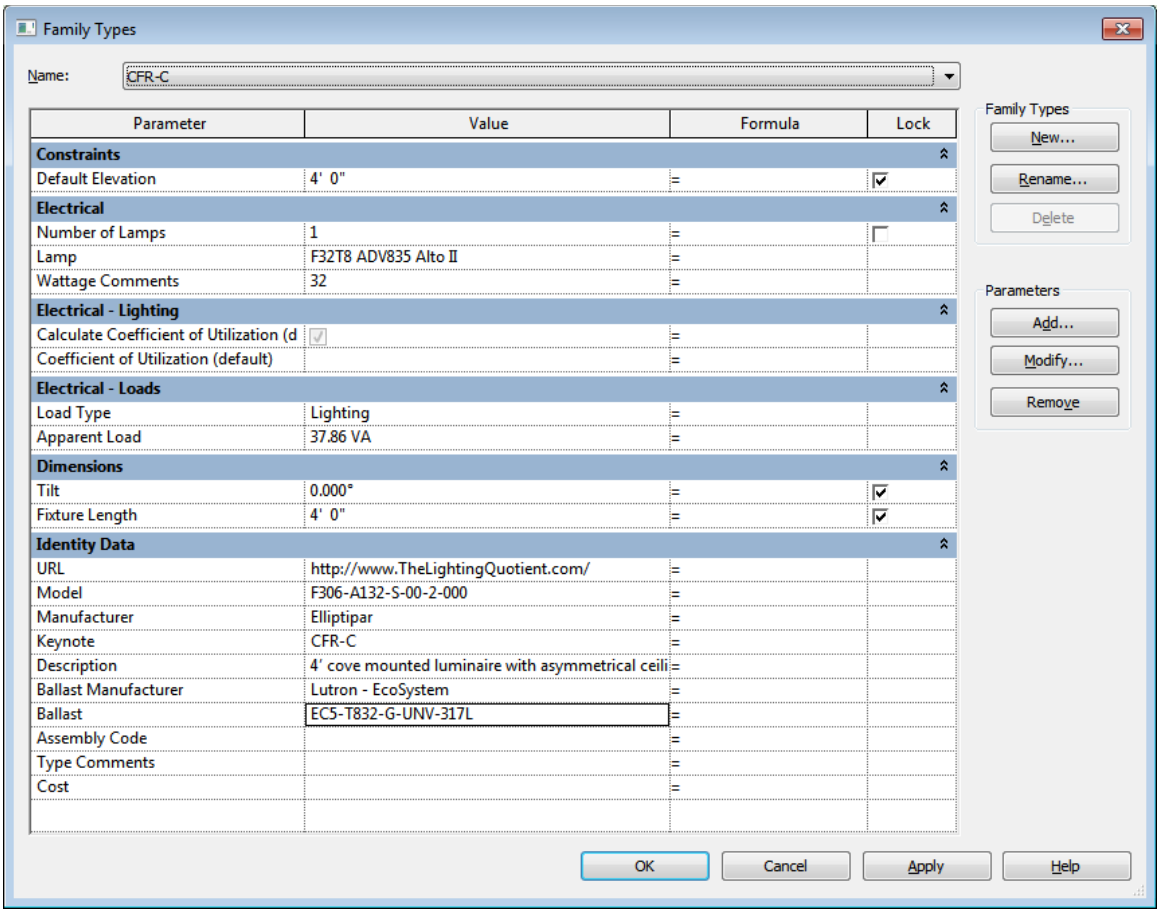


CFR-C Revit Electrical Connector Properties.



Revit CFR-C Family Type Data.

Corridor: COR-D

LIGHTOLIER

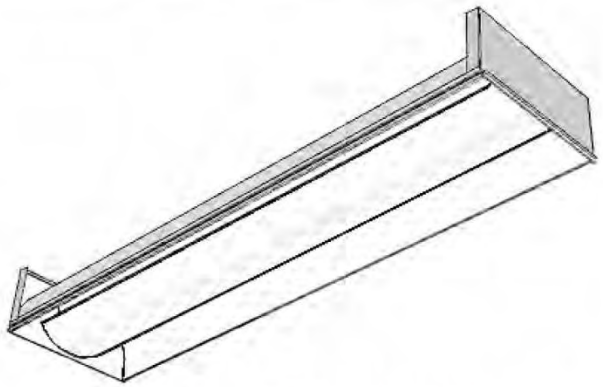
Coffaire HP **CFS1GHP**

Page 1 of 2

High Performance Recessed Fluorescent Direct/Indirect 1' x 4' with Perforated Basket ~ Static 1 or 2 Lamp T8 or T5

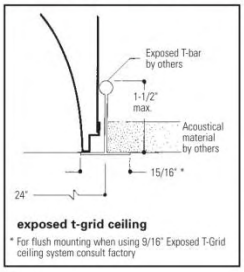
Features

- Direct/indirect lamp shield appearance with soft contoured interior.
- Perforated mesh lamp basket with unique TransOptix lens.
- Body 95% reflective Flat White Powder Coated.
- 95% Internal Mirro reflector.
- 69.1% efficient (2 lamp 32W T8).
- 77.4% efficient (2 lamp 28W T5).
- Only 4-31/32" deep.
- Same fixture fits both G and T ceiling types.
- Fits flush to face of slot grid (T) ceiling.
- Injection molded light stop at basket ends.
- Ballast accessible thru lamp compartment from room side.
- Perforated lamp shield hinges from either side.
- Can be continuous row mounted.
- Wiring access plate standard.
- 2 earthquake clips standard.
- Housing is 20 gauge steel, meets NYC Code requirements.
- Construction to meet Chicago Plenum requirements is available.



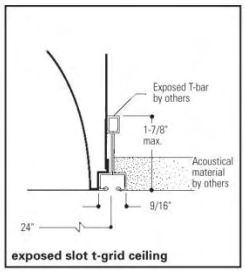
Patent number 6,746,325

Mounting Methods



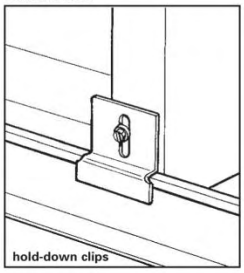
exposed t-grid ceiling

* For flush mounting when using 9/16" Exposed T-Grid ceiling system consult factory

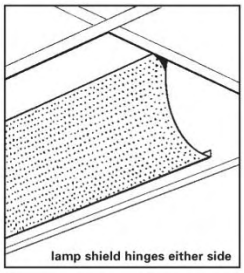


exposed slot t-grid ceiling

Features

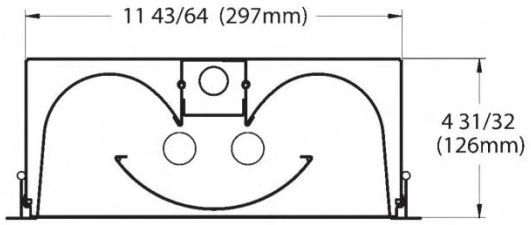


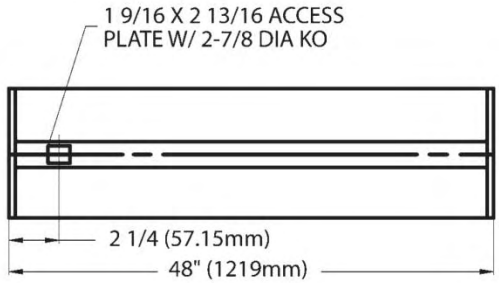
hold-down clips



lamp shield hinges either side

Dimensions





Job Information	**Type:** COR-D
Job Name:	Millennium Science Complex
Cat. No.:	CF-S-1-G-HP-1-32-277-SO
Lamp(s):	(1) F32T8
Volts/Ballast:	277V

For Factory Technical Information: (978) 657-7600 • Fax (978) 658-0595
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Section 5/Folio M15-61

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Coffaire HP **CFS1GHP**

High Performance Recessed Fluorescent Direct/Indirect 1' x 4' with Perforated Basket ~ Static 1 or 2 Lamp T8 or T5

Model No. CFS1GHP232UNVHI

LER = FP - 65.7 IW - 57.4 BF - 0.88
Comparative yearly lighting energy cost per 1000 lumens = $3.65

Report Number: G2009088
Catalog Number: CFS1GHP232UNVHI
Lamps: (2) F32T8/ADV/841/ALTO
Luminaire: Coffaire HP 1'x4' with 95% reflective white reflectors and perforated basket.
Ballast: B232I-UNV-HP-B
Report is based on 3100 Lumens per lamp.
Efficiency: 69.1%

CIE Type-Direct-Indirect

Plane:	0-Deg	90-Deg
Spacing Criteria:	1.2	1.2
Shielding Angles:	90	90
Plane:	0-Deg	90-Deg
Luminous Length:	46.920	10.920

CANDELA DISTRIBUTION

	0.0	45.0	90.0	FLUX
0	1631	1637	1637	
5	1613	1621	1630	154
15	1543	1547	1559	438
25	1419	1417	1428	655
35	1239	1229	1255	776
45	1014	1005	1050	785
55	757	758	792	681
65	491	490	502	486
75	525	236	224	248
85	50	51	51	59
90	0	0	0	

COEFFICIENTS OF UTILIZATION – ZONAL CAVITY METHOD. EFFECTIVE FLOOR CAVITY REFLECTANCE 0.20

RC	80			50			30		
RW	70	50	30	50	30	10	50	30	10
1	72	72	69	68	66	64	65	63	62
2	69	63	59	60	56	53	57	54	52
3	63	56	50	53	48	45	51	47	44
4	58	50	44	47	42	38	45	41	38
5	53	44	38	42	37	33	41	36	33
6	49	40	34	38	33	29	37	32	29
7	46	36	30	35	30	26	34	29	26
8	42	33	27	32	27	23	31	26	23
9	40	30	25	29	24	21	29	24	21
10	37	28	23	27	22	19	26	22	19

ZONAL LUMEN SUMMARY

ZONE	LUMENS	% LAMP	% FIXT
0- 30	1247	20.1	29.1
0- 40	2023	32.6	47.2
0- 60	3490	56.3	81.5
0- 90	4283	69.1	100.0
90-180	0	0.0	0.0
0-180	4283	69.1	100.0

LUMINANCE DATA IN CANDELA/SQ. METER

AVERAGE IN DEG.	AVERAGE 0-DEG.	AVERAGE 45-DEG.	AVERAGE 90-DEG.
45	4337.	4298.	4491.
55	3991.	3996.	4176.
65	3513.	3506.	3592.
75	2944.	2757.	2617.
85	1735.	1770.	1770.

Model No. CFS1GHP228120WA

LER = FP - 67.6 IW - 55.4 BF - 0.93
Comparative yearly lighting energy cost per 1000 lumens = $3.55

Report Number: G2009092
Catalog Number: CFS1GHP228120VWA
Lamps: (2) F28T5/835/ALTO
Luminaire: Coffaire HP 1'x4' with 95% reflective white reflectors and perforated basket.
Ballast: WA Energy Saver System
Report is based on 2600 Lumens per lamp.
Efficiency: 77.4%

CIE Type-Direct-Indirect

Plane:	0-Deg	90-Deg
Spacing Criteria:	1.2	1.2
Shielding Angles:	90	90
Plane:	0-Deg	90-Deg
Luminous Length:	46.920	10.920

CANDELA DISTRIBUTION

	0.0	45.0	90.0	FLUX
0	1530	1530	1530	
5	1516	1530	1530	145
15	1453	1450	1461	411
25	1335	1329	1343	615
35	1167	1157	1184	730
45	956	948	989	740
55	716	714	743	642
65	465	459	462	456
75	235	218	208	231
85	45	50	50	56
90	0	0	0	

COEFFICIENTS OF UTILIZATION – ZONAL CAVITY METHOD. EFFECTIVE FLOOR CAVITY REFLECTANCE 0.20

RC	80			50			30		
RW	70	50	30	50	30	10	50	30	10
1	85	81	78	76	74	71	73	71	69
2	77	71	66	67	63	59	64	61	58
3	70	63	56	59	54	50	57	53	49
4	65	56	49	53	47	43	51	46	42
5	59	50	43	47	41	37	46	41	37
6	55	45	38	43	37	33	41	36	32
7	51	41	34	39	33	29	38	33	29
8	48	37	31	36	30	26	35	30	26
9	44	34	28	33	27	23	32	27	23
10	42	32	25	30	25	21	30	25	21

ZONAL LUMEN SUMMARY

ZONE	LUMENS	% LAMP	% FIXT
0- 30	1170	22.5	29.1
0- 40	1900	36.5	47.2
0- 60	3282	63.1	81.5
0- 90	4026	77.4	100.0
90-180	0	0.0	0.0
0-180	4026	77.4	100.0

LUMINANCE DATA IN CANDELA/SQ. METER

AVERAGE IN DEG.	AVERAGE 0-DEG.	AVERAGE 45-DEG.	AVERAGE 90-DEG.
45	4089.	4054.	4230.
55	3775.	3764.	3917.
65	3327.	3284.	3306.
75	2746.	2547.	2430.
85	1561.	1735.	1735.

Ordering Information

Explanation of Catalog Number. Example: CFS1GHP232UNVHI

CF	S	1	G	HP	1	32	277	SO	
Coffaire HP: Direct/Indirect: Recessed with Perforated Mesh Shield	Body Style: S = Static	Fixture Width	Ceiling Type: Fits both Standard Grid and Slot Grid	High Performance	Lamp Quantity 1 = 1 Lamp 2 = 2 Lamp	Lamp: (By Others) 32 = T8 28 = T5 54 = T5HO (Nominal 24")	Voltage: 120, 277 or UNV=120-277	Ballast Type:	Options: Add appropriate suffix to catalog no., ie: (A)

CN — For Local 3 Manufacturing

For Local 3 Manufacturing, substitute **CN** for **CF**. Example: **CN**H1GHP232UNVHI.

Ballast Type:

	<20THD	<10THD
1 & 2 Lamp Elec. T8	SO*	HI*
1-2 Lamp 28W Elec. T5	–	PI†
1-2 Lamp 28W Elec. T5	–	PG††
1-2 Lamp 54W Elec. T5	–	PG††
Linear T5 Instant Start less than 10THD, 57.5 Input Watts, 0.93 Ballast Factor		WA
LOL Dimming T8	PS	–

*Instant Start Standard
†Instant Start (120V or 277V only)
††Program Rapid Start (**UNV** only)
Other dimming options. Consult factory.

NOTE:
For **T8 UNV**, you must use **HI** Ballast Code.

Options/Accessories

Fusing: Internal fast blow fusing: SUFFIX: **A**.
Internal slow blow fusing: SUFFIX: **C**.
Drywall Kit: Order Catalog Number: **FK91X4**.
Electrical Wiring Options: Consult factory.
Chicago Plenum: SUFFIX: **C**.

Specifications

Performance: In an installation of 2 lamp 32W luminaires in a room cavity ratio of 1, with reflectance 80% ceiling, 50% wall, 20% floor, the C.U. shall not be less than .72. To reduce glare the average brightness at 65° shall not exceed 3592 candelas per square meter. To control veiling reflections, luminaire output in the 30°-90° zone shall not be less than 70.9%.
Materials: Chassis parts are die-formed code gauge steel.
Lamp Shield: 22 gauge steel perforated mesh lamp shield with unique TransOptix lens.
Finish: Chassis exterior – White baked polyester enamel. Rust preventative undercoating. **Cavity** – 95% reflective white baked polyester enamel. **Reflector** – 95% reflective Miro aluminum reflector. **Lamp Shield** – 95% reflective white baked polyester enamel.

Specifications (continued)

Electrical: Thermally protected class "P' ballast C.B.M. approved, non PCB. If K.O. is within 3" of ballast, use wire suitable for at least 90°. UL Listed for damp locations.
Labels: I.B.E.W./UL and ULc Listed.
This product may have a mercury containing lamp. Manage in accord with Disposal Laws. See: www.lamprecycle.org

Job Information **Type:** COR-D

For Factory Technical Information: (978) 657-7600 • Fax (978) 658-0595
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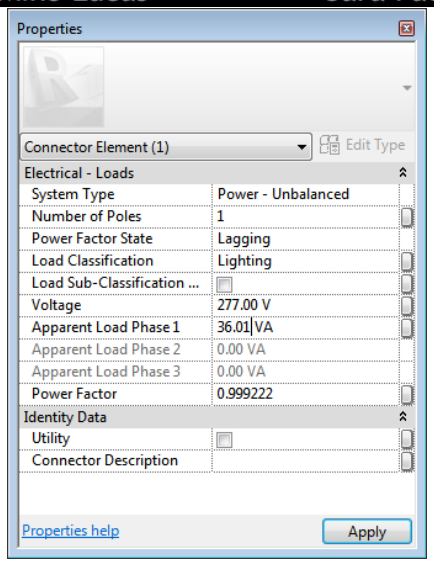
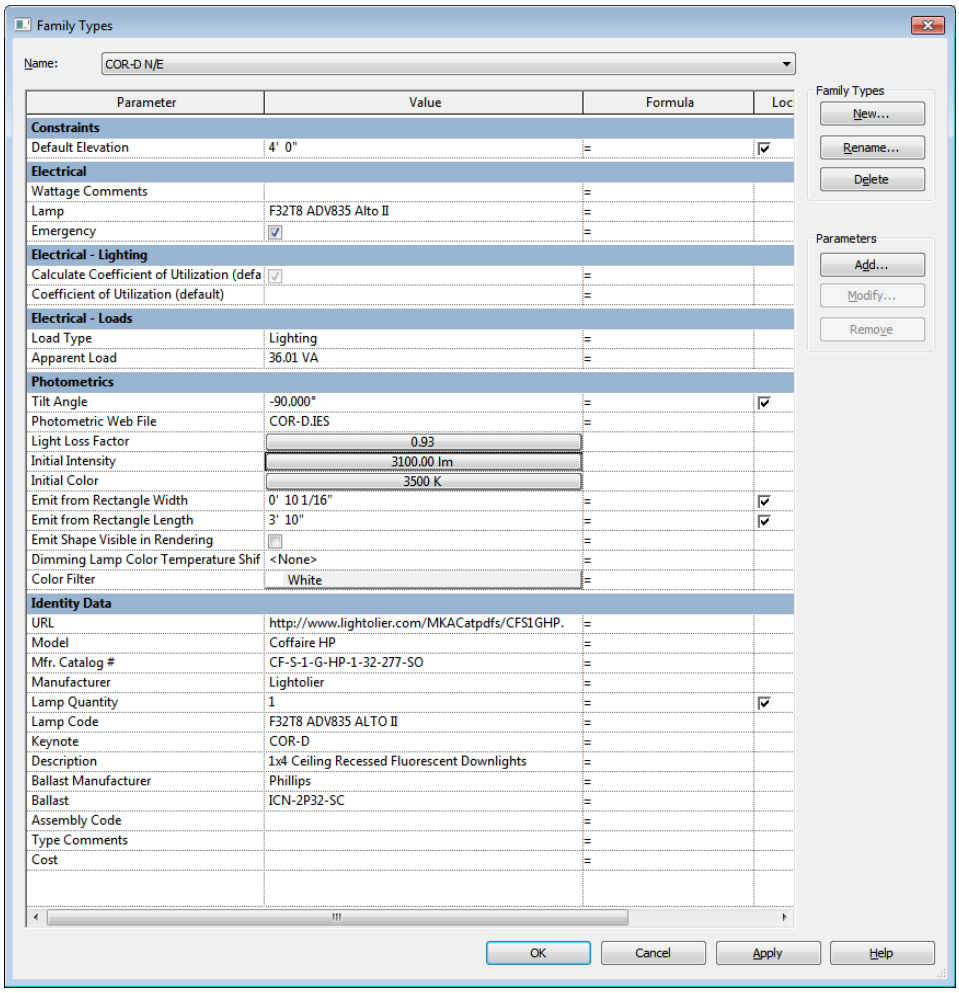


COR-D Revit Electrical Connector Properties.



COR-D Revit Family Type Data.

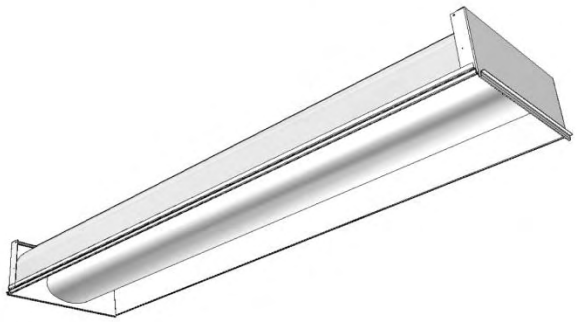
Office: OFF-D

HP90 Recessed Fluorescent **H9S1GLR132 or 232**

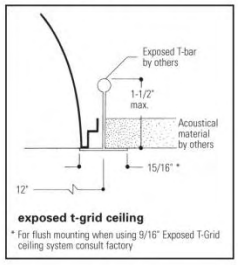
Direct/Indirect – 1' x 4' with Acrylic Linear Prismatic Lens
Static, 1 or 2 Lamp T8

Features

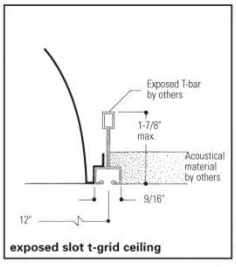
- 78.4% efficient (2 lamp, 32W T8).
- 77.8% efficient (1 lamp, 32W T8).
- Direct/indirect appearance with soft contoured interior.
- Lens encloses lamp compartment.
- Translucent DR acrylic high light transmission linear prismatic lens.
- Tension screws secure ends to body.
- Same fixture fits both G and T ceiling types.
- Fits flush to face of slot grid (T) ceiling types.
- Lamp shield opens from either side.
- 95% reflective specular aluminum reflector.
- Ballast accessible from room side.
- Built-in earthquake clips.
- Can be continuous row mounted.
- Wiring access plate standard.
- Optional DALI ballast iGEN TECHNOLOGY accepts digital dimming controllers, scene controllers and automatic control devices.
- Construction to meet NYC Code or Chicago Plenum available.



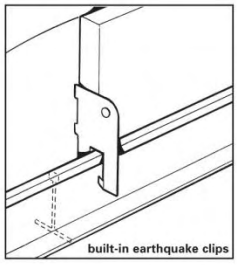
Mounting Methods

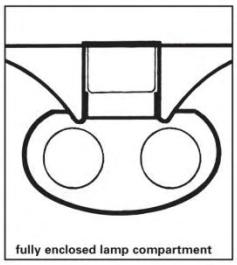


exposed t-grid ceiling
* For flush mounting when using 9/16" Exposed T-Grid ceiling system consult factory

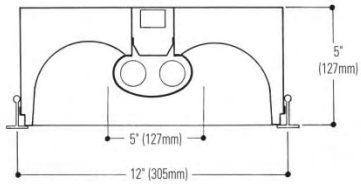


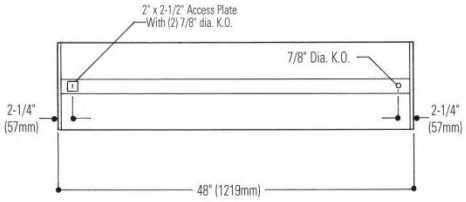
exposed slot t-grid ceiling


built-in earthquake clips


fully enclosed lamp compartment

Dimensions





Job Information	Type: OFF-D
Job Name:	Millennium Science Complex
Cat. No.:	HP-90-S1-GLR-132-277-SO
Lamp(s):	(1) F32T8
Volts/Ballast:	277

For Factory Technical Information: (978) 657-7600 • Fax (978) 658-0595
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HP90 Recessed Fluorescent **H9S1GLR132 or 232**

Direct/Indirect – 1' x 4' with Acrylic Linear Prismatic Lens
Static, 1 or 2 Lamp T8

Model No. H9S1GLR132UNVHI

LER = FP - 72.2 IW - 29.4 BF - 0.88
Comparative yearly lighting energy cost per 1000 lumens = $3.32

Report Number: G2010170
Catalog Number: H9S1GLR132UNVHI
Lamps: (1) F32 T8
Luminaire: HP90 1' x 4' with linear prismatic lens.
Ballast: IOP1S32-SC
Report is based on 3100 Lumens per lamp.
Efficiency: 77.8%
CIE Type-Direct-Indirect

Plane:	0-Deg	90-Deg
Spacing Criteria:	1.2	1.5
Shielding Angles:	90	90
Plane:	0-Deg	90-Deg
Luminous Length:	47.040	11.040

CANDELA DISTRIBUTION

	0.0	45.0	90.0	FLUX
0	749	740	740	
5	731	739	745	70
15	704	728	749	206
25	651	701	746	323
35	573	654	721	409
45	475	589	679	450
55	361	504	563	430
65	240	355	339	320
75	123	167	141	165
85	27	35	35	39
90	0	0	3	

COEFFICIENTS OF UTILIZATION – ZONAL CAVITY METHOD. EFFECTIVE FLOOR CAVITY REFLECTANCE 0.20

RC	80			50			30		
RW	70	50	30	50	30	10	50	30	10
1	85	81	77	76	73	71	73	71	69
2	77	70	65	66	62	58	63	60	57
3	70	61	55	58	52	48	55	51	47
4	64	54	47	51	45	41	49	44	40
5	58	48	41	45	39	35	44	39	35
6	54	43	36	41	35	30	39	34	30
7	50	39	32	37	31	27	36	30	26
8	46	35	29	34	28	24	33	27	24
9	43	32	26	31	26	21	30	25	21
10	40	30	23	29	23	19	28	23	19

ZONAL LUMEN SUMMARY

ZONE	LUMENS	% LAMP	% FIXT
0- 30	600	19.3	24.9
0- 40	1008	32.5	41.8
0- 60	1889	60.9	78.3
0- 90	2413	77.8	100.0
90-180	0	0.0	0.0
0-180	2413	77.8	100.0

LUMINANCE DATA IN CANDELA/SQ. METER

AVERAGE IN DEG.	AVERAGE 0-DEG.	AVERAGE 45-DEG.	AVERAGE 90-DEG.
45	2004.	2485.	2865.
55	1878.	2622.	2929.
65	1694.	2506.	2393.
75	1418.	1925.	1625.
85	924.	1198.	1198.

Model No. H9S1GLR232UNVHI

LER = FP - 72.0 IW - 59.4 BF - 0.88
Comparative yearly lighting energy cost per 1000 lumens = $3.33

Report Number: G2010210
Catalog Number: H9S1GLR232UNVHI
Lamps: (2) F32T8
Luminaire: HP90 1' x 4' with linear prismatic lens.
Ballast: ICN-2P32-SC
Report is based on 3100 Lumens per lamp.
Efficiency: 78.4%
CIE Type-Direct-Indirect

Plane:	0-Deg	90-Deg
Spacing Criteria:	1.2	1.4
Shielding Angles:	90	90
Plane:	0-Deg	90-Deg
Luminous Length:	47.040	11.040

CANDELA DISTRIBUTION

	0.0	45.0	90.0	FLUX
0	1603	1603	1603	
5	1587	1596	1608	152
15	1526	1552	1580	439
25	1408	1463	1519	676
35	1239	1332	1417	834
45	1028	1156	1265	889
55	787	948	1022	824
65	532	659	667	624
75	278	337	309	340
85	64	71	70	82
90	0	0	0	

COEFFICIENTS OF UTILIZATION – ZONAL CAVITY METHOD. EFFECTIVE FLOOR CAVITY REFLECTANCE 0.20

RC	80			50			30		
RW	70	50	30	50	30	10	50	30	10
1	85	81	78	76	74	71	73	71	69
2	77	71	65	66	62	59	64	60	57
3	70	62	55	58	53	49	56	52	48
4	64	55	48	52	46	41	50	45	41
5	59	49	42	46	40	36	45	39	35
6	54	44	37	42	36	31	40	35	31
7	50	40	33	38	32	27	37	31	27
8	47	36	29	34	29	24	34	28	24
9	44	33	27	32	26	22	31	26	22
10	41	30	24	29	24	20	29	23	20

ZONAL LUMEN SUMMARY

ZONE	LUMENS	% LAMP	% FIXT
0- 30	1267	20.4	26.1
0- 40	2101	33.9	43.2
0- 60	3814	61.5	78.5
0- 90	4861	78.4	100.0
90-180	0	0.0	0.0
0-180	4861	78.4	100.0

LUMINANCE DATA IN CANDELA/SQ. METER

AVERAGE IN DEG.	AVERAGE 0-DEG.	AVERAGE 45-DEG.	AVERAGE 90-DEG.
45	4338.	4878.	5338.
55	4094.	4931.	5316.
65	3756.	4652.	4709.
75	3205.	3885.	3562.
85	2191.	2431.	2396.

Ordering Information

Explanation of Catalog Number. Example: H9S1GLR232UNVHI

HP90	S	1	G	L	R	1	32	277	SO	-	
HP90 Direct/Indirect Recessed	**Body Style:** **S** = Static	**Fixture Width**	**Ceiling Type:** Fits both Standard Grid and Slot Grid	Acrylic Lens	**Reflector:** Specular Aluminum	**Lamp Quantity** **1**=1 Lamp **2**=2 Lamp	**Lamp:** (By Others) **32**=T8 32W * (Nominal 48") * 28W T8 available	**Voltage:** 120, 277 or **UNV**=120-277	**Ballast Type:** <10THD		**Options:** Add appropriate suffix to catalog no., ie: (A)

H9	Standard HP90
HY	For NYC Code – I.B.E.W. Manufactured

1 or 2 Lamp Elec. T8	**HI** *
1 or 2 Lamp Elec. T8	**P2** †
LOL Dimming T8	**PS**

*Instant Start Standard
†Program Start
Other dimming options. Consult factory.

NOTE: For **T8 UNV**, you must use **HI** Ballast Code.

Options/Accessories

Fusing: Internal fast blow fusing: SUFFIX: **A**.
Internal slow blow fusing: SUFFIX: **C**.
Drywall Kit: Order Catalog Number: **FK91X4**.
Electrical Wiring Options: Consult factory.
For motion or light sensor: See Folio 0A20-10.

Specifications

Performance: In an installation of 2 lamp 32W luminaires in a room cavity ratio of 1, with reflectance 80% ceiling, 50% wall, 20% floor, the C.U. shall not be less than .81. To reduce glare the average brightness at 65° shall not exceed 4709 candelas per square meter. To control veiling reflections, luminaire output in the 30°-90° zone shall not be less than 73.9%.
Materials: Chassis parts are die-formed code gauge steel.
Lamp Shield: Linear prismatic translucent DR acrylic lens.

Specifications (continued)

Finish: Chassis exterior – baked white polyester enamel.
Cavity – baked white polyester enamel. Rust preventative undercoating. **Reflector** – low iridescence specular aluminum 95% reflectance.
Electrical: Thermally protected class "P" ballast C.B.M. approved, non PCB. If K.O. is within 3" of ballast, use wire suitable for at least 90°.
UL Listed for damp locations.
Labels: I.B.E.W./UL and ULc Listed.
This product may have a mercury containing lamp. Manage in accord with Disposal Laws. See: www.lamprecycle.org

Job Information **Type:** OFF-D

For Factory Technical Information: (978) 657-7600 • Fax (978) 658-0595
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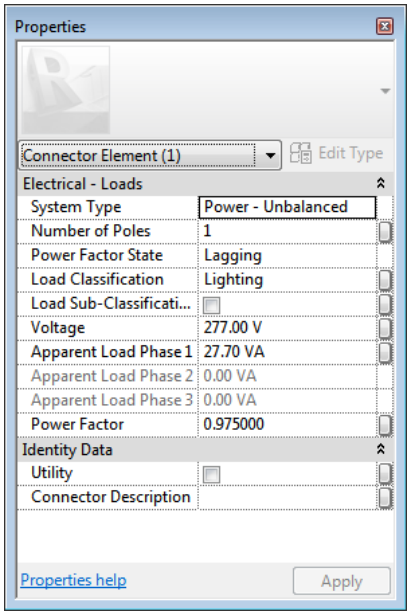


Figure 189: CFR-D Revit Electrical Connector Properties.

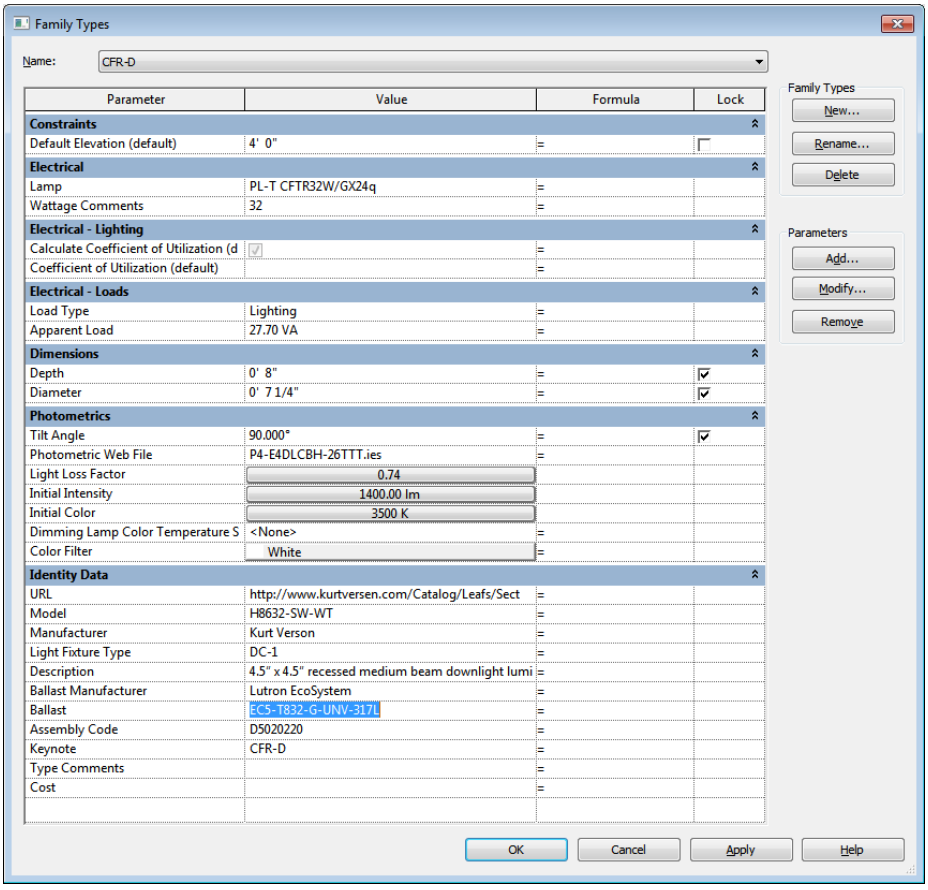


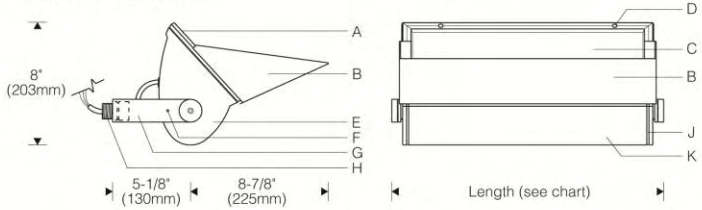
Figure 190: CFR-D Revit Family Type Data.

Uplighting Large outdoor, remote

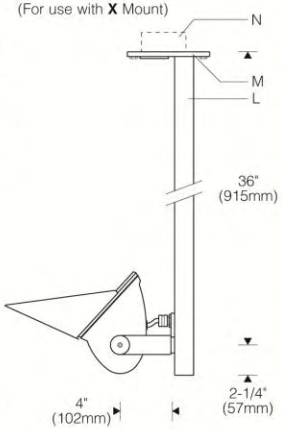
Metal Halide | Tungsten Halogen

Style 152

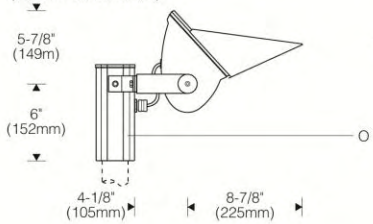
V Mount 1:10 Scale



Cantilever 1:12 Scale
(For use with **X** Mount)



Side-Mount Slipfitter 1:12 Scale
(For use with **X** Mount)



Wattage	*Source*	*Length*
150	MH	12-1/16" (306mm)
300-500	Halogen	
210-400	MH	17-13/16"* (452mm)
900, 1000	Halogen	24-7/8"* (632mm)
2x400	MH	

*Yoke includes (2) 9/32" diameter holes at 12" (305mm) centers for supplemental mounting support (1/4" fasteners by others).

Specifications

- **A** Mitred extruded aluminum door with silicone gasket
- **B** Cutoff visor (included)
- **C** Clear, flat, thermal and impact resistant tempered glass lens
- **D** Tamper-resistant captive door screws
- **E** Die-cast aluminum end plates
- **F** Locking set screw
- **G** Aluminum yoke
- **H** 1/2" NPT nipple
- **J** Aluminum reveal plates (black)
- **K** Specular extruded aluminum reflector
- **L** 1-1/2" x 2" aluminum arm
- **M** Welded aluminum mounting plate with splice access cover
- **N** Recessed outlet box
- **O** Accessory extruded aluminum slipfitter for 2-3/8" O.D. pole or tenon

Finish:
Exterior surfaces – 6 stage pretreatment and electrostatically applied thermoset polyester powder coating for a durable abrasion, fade and corrosion resistant finish. Choice of semi-gloss colors (see ordering information).

Reflector and internal end plates – extruded high purity aluminum with clear anodized specular finish. All hardware and components – non-corrosive stainless steel or aluminum. Door secured with captive tamper-resistant (#10 Torx) screws in stainless steel threaded reflector inserts to prevent seizing. Yoke attaches with recessed hex socket screws.

Mounting:
1/2" NPT nipple (wet location outlet box or fitting by others).

Aluminum cantilever mounting assembly ordered separately; specify **X** mount. Suitable backing structure required.

Accessory slipfitter ordered separately. Top-mount for single unit, or side-mount for one or two (back-to-back) units; specify **X** mount. Fits 2-3/8" O.D. stanchion, pole or tenon (by others).

Standard:
UL listed or CSA certified for wet locations.

Electrical:
Use 90°C wire for supply connections. Leads exit reflector through watertight flush cord entry, silicone coated fiberglass sleeving; 8" exposed beyond nipple (60" leads on **X** mount).

Tungsten halogen – recessed single contact (RSC) lampholders in patented clamping supports for maximum heat dissipation.

Metal halide – Mogul lampholder is pulse rated for use with either horizontal or universal position reduced envelope pulse start lamps. End-of-lamp aligner ensures consistent optical performance, minimizes damage from shock or vibration. Ballast – remote HPF constant wattage autotransformer (CWA) or electronic rated for -20°F/-29°C starting. Weatherproof aluminum enclosure includes three 7/8" dia. entries and one 3/8" liquidtight conduit connector. Optional remote ballast for dry indoor location.

For complete ballast specifications, see Accessories Section.

REV. 8/08

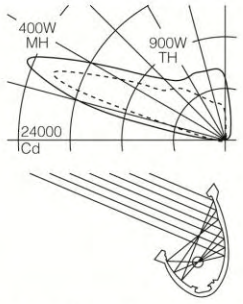
Features

- *Compact yet powerful – up to 1000W halogen, 2x400W metal halide for uplighting large vaults, canopies or arches*
- *Lamp support on mogul base lamps ensures arc tube is in optical center*
- *Built to last – all aluminum and stainless steel components, tempered glass lens, tamper-resistant door screws*

U 7.0

Performance

Two parabolic reflector sections drive light across the overhead plane from one edge. An elliptical section redirects its light to a parabola and shields the lamp. Asymmetry is maximized resulting in high beam efficiency and superior surface uniformity. The fast "runback" minimizes wasted spill light. Wide lateral distribution permits greater spacings.



For complete photometrics, visit www.elliptipar.com

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To Order

Style 152

To form a Catalog Number

M	1	5	2	-	210C	-	V	-	06	-	2	-	V	0	0
1			2		3		4		5		6		7		8

Project: **Millennium Science COmplex**

Type: **CAN-Ua**

1 Source

M = Metal halide
T = Tungsten halogen

2 Style

152 = Large outdoor, **remote** ballast

3 Lamp

Lamp Code	Watt-age	Lamp Number	Volt-ages	Remote Distance
Ceramic Arc Tube Pulse Start Metal Halide (90+ CRI)				
210C	210	CDM210/T9/930/U/E	**2, U**	30' (9m)
315C	315	CDM315/T9/930/U/E	**2, U**	30' (9m)
Ceramic Arc Tube Pulse Start Metal Halide (80+ CRI)*				
150G	150	CDM150/T6/830	**1, 2**	15' (4.5m)
			T, U	5' (1.5m)
250C	250	CMH250/U/830/R	**A, B**	50' (15m)
400C	400	CMH400/U/830/R	**A, B**	50' (15m)
240C	2x400	(2) CMH400/U/830/R	**A, B**	50' (15m)
Quartz Arc Tube Pulse Start Metal Halide (68 CRI)*				
250P	250	MS 250W/H75/ T15/PS/740	**A, B**	50' (15m)
			2, U	16' (4.8m)
320P	320	MS 320W/H75/ T15/S/PS/740	**A, B**	50' (15m)
			2, U	16' (4.8m)
350P	350	MS 350W/H75/ T15/PS/740	**A, B**	50' (15m)
			2, U	16' (4.8m)
Tungsten Halogen				
0300	300	Q300T3	**A**	
0350	350	Q350T3/CL/HIR	**A**	
0500	500	Q500T3	**A**	
0900	900	Q900T3/CL/HIR	**B, G**	
1000	1000	Q1000T3	**A, F, G**	

For complete lamp and ballast information, see Accessories Section.
* Use only clear metal halide horizontal or universal position lamp with compact envelope. Standard lamp colors are 3000K for Ceramic Arc Tube Pulse Start lamps and 4000K for Quartz Arc Tube Pulse Metal Halide lamps.

U 7.1

4 Mounting

V = External yoke with 1/2" NPT nipple (wet location outlet box or fitting by others)
X = External yoke for use with accessory cantilever or slipfitter (order separately)

5 Finish

02 = Semi-gloss white
06 = Dark bronze
07 = Silver
08 = Semi-gloss black
12 = Green
99 = Custom RAL or computer matched color to be specified, consult sales representative.

6 Voltage

Electronic (Metal Halide only):
1 = 120V
2 = 277V
T = 120V dim*
U = 208-277V dim*

Magnetic and Tungsten Halogen:
A = 120V
B = 277V
F = 220V (TH)
G = 240V (TH)

*100-50% dimming, 0-10V compatible controls by others. Consult factory for dimming the 210W lamp.

7 Option (See Accessories Section for specifications)

V0 = Cutoff visor included, no other options
VL = Micro-prismatic tempered glass lens (replaces clear, flat lens, offers smoother light pattern at reduced peak candlepower).
VR = Halogen standby lamp with relay field connected at remote ballast. 100W maximum (lamp included). Not available for 2x400W.
VX = For modification not listed, include detailed description. Consult factory prior to specification.
Note: Cutoff visor included unless specified otherwise.

8 Standard

0 = UL, Underwriters Laboratories
J = CSA, Canadian Standards Association

Example

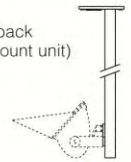
M152 - 0400 - V - 07 - B - V00

Large outdoor model for use with 400 watt ceramic arc tube pulse start metal halide lamp. External yoke with 1/2" NPT nipple. Silver powder coat finish. Remote 277V ballast in weatherproof enclosure. UL. Cutoff visor included.

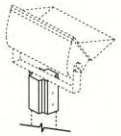
Accessories

Order separately. See Accessories Section for specifications.

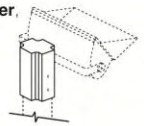
AC [ ] [ ] **36** [ ] = **Cantilever**, 36" (914mm) setback (for use with **X** mount unit)
0 = UL
J = CSA
5 Finish
L = single unit
U = double unit (back to back)



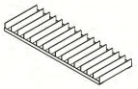
ASF [ ] **T10** = **Top-mount slipfitter**, for 2-3/8" O.D. pole, stanchion or tenon (for use with single **X** mount unit)
5 Finish



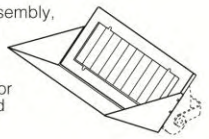
ASF [ ] **S** [ ] **0** = **Side-mount slipfitter**, for 2-3/8" O.D. pole, stanchion or tenon (for use with **X** mount units)
1 = single unit
2 = double unit (back to back)
5 Finish



AE [ ] **V** [ ] **0D0** = External vertical blade **baffle**, black, for lengthwise shielding
2 = 25° shielding
4 = 45°
C = 300W-350W TH; 150W MH (not for use with 500W TH)
D = 210-400W MH
F = 900W, 1000W TH, 2x400W MH



AXF = Wet location **color filter** assembly, interchangeable frame with stripped color glass, visor.
Not suitable for all lamp wattages. Consult factory for complete specifications and ordering information.



AFK000X [0] = Ballast **fuse** kit
0 = UL
J = CSA

REV. 7/09

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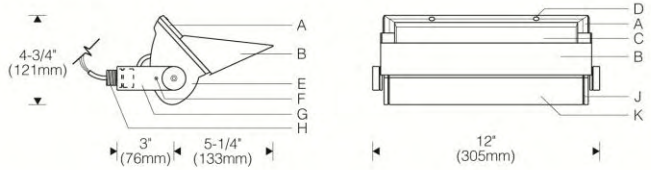
Uplighting Small outdoor, remote

Ceramic Metal Halide | Tungsten Halogen

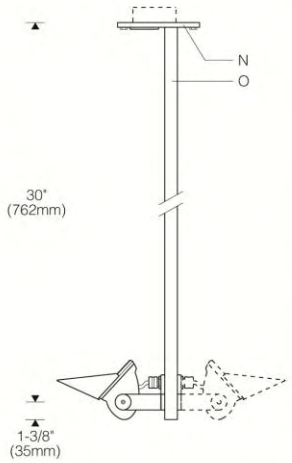
Style 151

V Mount 1:8 Scale



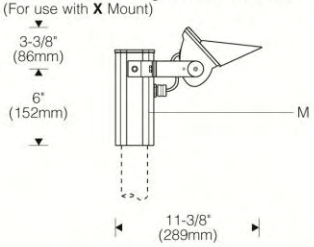
Cantilever 1:12 Scale

(For use with **X** Mount)



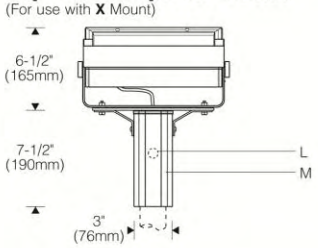
Side-Mount Slipfitter 1:12 Scale

(For use with **X** Mount)



Top-Mount Slipfitter 1:12 Scale

(For use with **X** Mount)



Specifications

- **A** Mitred extruded aluminum door frame with silicone gasket
- **B** Cutoff visor (included)
- **C** Micro-prismatic, thermal and impact resistant tempered glass lens
- **D** Tamper-resistant captive door screws
- **E** Die-cast aluminum end plates
- **F** Locking set screw
- **G** Aluminum yoke
- **H** 1/2" NPT nipple
- **J** Aluminum reveal plates (black)
- **K** Specular extruded aluminum reflector
- **L** 1/2" NPT entry (with plug)
- **M** Accessory extruded aluminum slipfitter for 2-3/8" O.D. pole or tenon
- **N** Welded aluminum mounting plate with splice access cover
- **O** 1" x 1-1/2" aluminum arm

Finish:

Exterior surfaces – 6 stage pretreatment and electrostatically applied thermoset polyester powder coating for a durable abrasion, fade and corrosion resistant finish. Choice of semi-gloss colors (see ordering information).

Reflector – extruded high purity aluminum with clear anodized specular finish. All hardware and components – non-corrosive stainless steel or aluminum. Door secured with captive tamper-resistant (#10 Torx) screws in stainless steel threaded reflector inserts to prevent seizing. Yoke attaches with recessed hex socket screws.

Mounting:

1/2" NPT nipple (wet location outlet box and outlet box cover or fitting by others).

Aluminum cantilever mounting assembly ordered separately; specify **X** mount. Suitable backing structure required.

Accessory slipfitter ordered separately. Top-mount for single unit, or side-mount for one or two (back-to-back) units; specify **X** mount. Fits 2-3/8" O.D. stanchion, pole or tenon (by others).

Electrical:

Use 90°C wire for supply connections. Leads exit reflector through watertight flush cord entry and silicone coated fiberglass sleeving with 8" (.2m) exposed beyond nipple. 60" (1.5m) leads for **X** mount.

Tungsten halogen – recessed single contact (RSC) or DC bayonet lampholders retained with patented clamping supports for maximum heat dissipation.

Metal halide – G12 lampholder for use with single ended lamp. Remote high reactance autotransformer ballast (-20°F/-30°C starting) or electronic ballast (5°F/-15°C starting). Die-cast aluminum weatherproof ballast enclosure includes four 1/2" NPT threaded entries. Electronic ballast provides improved voltage regulation, energy savings and automatic shut-off feature to eliminate end-of-life lamp cycling. Optional remote ballast for dry indoor location.

For complete ballast specifications, see Accessories Section.

Standard:

UL listed or CSA certified for wet locations.

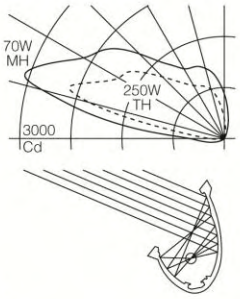
Features

- *Compact size, minimal setbacks and wide spacings – ideal for unobtrusive uplighting of soffits, canopies, vaults*
- *Durable and secure – thermal and impact resistant lens, tamper-resistant fasteners, set screw in yoke locks aiming*
- *Precured silicone gaskets, unique flush cord entry – seal out dirt and moisture, maintain performance*

U 1.0

Performance

Two parabolic reflector sections drive light across the overhead plane from one edge. An elliptical section redirects its light to a parabola and shields the lamp. Asymmetry is maximized resulting in high beam efficiency and superior surface uniformity. The fast "runback" minimizes wasted spill light. Wide lateral distribution permits greater spacings.



For complete photometrics, visit ***thelightingquotient.com***

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10/10

To Order

Style 151

Project: **Millennium Science Complex**

Type: **CAN-Ub**

To form a Catalog Number

M	1	5	1	-	070G	-	X	-	06	-	2	-	V	0	0
1			2		3		4		5		6		7		8

1 Source

M = Metal halide
T = Tungsten halogen

2 Style

151 = Small outdoor, **remote** ballast

3 Lamp

Lamp Code	*Wattage*	*Lamp Number*	*Voltages*	*Remote Distance*
Ceramic Arc Tube Pulse Start Metal Halide (80+ CRI)*				
035G	35	CDM35/T6/830	**1, 2**	15' (4.5m)
			A, B	10' (3m)
070G	70	CDM70/T6/830	**1, 2**	15' (4.5m)
			A, B	20' (6m)
150G	150	CDM150/T6/830	**1, 2**	15' (4.5m)
			A, B	10' (3m)
Tungsten Halogen				
0100	100	Q100DC	**A**	
0150	150	Q150DC	**A**	
0200	200	Q200T3	**A**	
0250	250	Q250DC	**A**	

U 1.1

For complete lamp and ballast information, see Accessories Section.
* Standard lamp color is 3000K/80+ CRI.

4 Mounting

V = External yoke with 1/2" NPT nipple (wet location outlet box and outlet box cover or fitting by others)
X = External yoke for use with accessory cantilever or slipfitter (order separately)

5 Finish

02 = Semi-gloss white
06 = Dark bronze
07 = Silver
08 = Semi-gloss black
12 = Green
99 = Custom RAL or computer matched color to be specified, consult sales representative.

6 Voltage/Ballast

Electronic	*Magnetic*
1 = 120V	**A** = 120V
2 = 277V	**B** = 277V

7 Option (see Accessories Section for specifications)

V0 = Cutoff visor included, no other options
VD = Remote ballast for dry indoor location (not for use with 150W magnetic)
VH = Long distance remote metal halide **magnetic** ballast
35W: 15' minimum up to 50' maximum (4.5m - 15m)
70W: up to 50' maximum (15m)
150W: up to 50' maximum (15m)
VR = Halogen standby lamp with relay field connected at remote ballast. Lamp included (wattage varies).
VX = For modification not listed, include detailed description. Consult factory prior to specification.
Note: Cutoff visor included unless specified otherwise.

8 Destination Requirement

0 = UL listed or CSA certified for U.S.
J = UL listed or CSA certified for Canada

Example

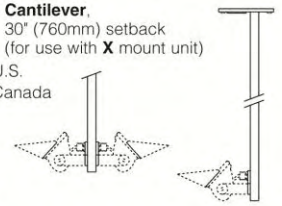
M151 - 150G - X - 06 - 1 - VDJ

Small outdoor model for use with 150 watt metal halide lamp. External yoke for use with accessory cantilever or slipfitter (order separately). Dark bronze powder coat finish. Remote encapsulated 120V electronic ballast suitable for dry indoor location. UL listed or CSA certified for Canada. Cutoff visor included.

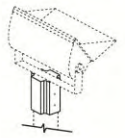
Accessories

Order separately. See Accessories Section for specifications.

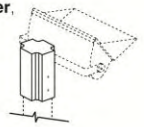
AC [ ] [ ] **30** [ ] = **Cantilever**, 30" (760mm) setback (for use with **X** mount unit)
0 = U.S.
J = Canada
5 Finish
S = single unit
V = double unit (back to back)



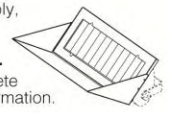
ASF [ ] **T10** = **Top-mount slipfitter**, for 2-3/8" O.D. pole, stanchion or tenon (for use with single **X** mount unit)
5 Finish



ASF [ ] **S** [ ] **0** = **Side-mount slipfitter**, for 2-3/8" O.D. pole, stanchion or tenon (for use with **X** mount units)
1 = single unit
2 = double unit (back to back)
5 Finish



AXF = Wet location **color filter** assembly, interchangeable frame with stripped color glass, visor.
Maximum 200W TH, 70W CMH.
Note: Consult factory for complete specifications and ordering information.



AEBV [ ] **0D0** = External vertical blade **baffle**, black for lengthwise shielding
2 = 25° shielding
4 = 45°

AFK000X [0] = Ballast **fuse** kit
0 = U.S.
J = Canada

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Exterior Plaza: CAN-R

IRIS®

DESCRIPTION

Recessed medium beam lens downlight luminaire with 4 inch square aperture utilizing horizontal T6 G12 ceramic metal halide lamp. Modular platform can be reconfigured from below the ceiling to accept a broad range of lamp modules and optical elements. Platform is suitable for shallow plenum commercial construction. Insulation must be kept 3" from top and sides of housing. Platform + module + element combination produces square distribution with excellent light control and low aperture brightness.

Catalog #	P406TAT-MH4CMH-39T6E-E4CMHCB-MB	Type: CAN-R
Project	Millennium Science Complex	
Comments		Date: 3/9/2011
Prepared by	MWL	

SPECIFICATION FEATURES

Frame
Galvanized steel plaster frame with integral bar hanger receivers. Set-screws provide positive horizontal locking.

Collar
Matte black steel collar adjusts vertically for 1/2" - 1" thick ceilings and can be rotated +/- 7.5° thru the aperture. Integral gun sights facilitate the use of guide strings or laser lines. Shipped with a paint overspray protector installed in the collar.

Lamp Module
Installed or removed thru the aperture or from the top and allows lamp orientation at 0°, 90°, 180° and 270° positions.

Housing
Steel housing painted matte black for a visually dark interior. Removable hinged top allows for top access. All fasteners are captive.

Gaskets
Closed cell gaskets achieve restrictive airflow requirements without additional caulking.

Optical Element
Mousetrap type springs pull flange tight to ceiling. Light trap eliminates spill light at edge of flange and reflector. Available in self-flanged or metal trim ring versions. May also be installed rimless using optional plastering lathing ring.

Bar Hangers
Captive preinstalled bar hangers adjusts from 8-1/2" to 24" wide; pass thru feature allows shortening without removal. Captive nail penetrates standard and engineered lumber. Mounting flange levels platform with ceiling. Integral clip attaches directly to t-bar.

Butterfly Bracket
Provides 3" of vertical adjustment and accept 1/2" EMT, C channel or bar hangers.

Primary Reflector
Miro® segmented upper reflector yields a smooth square beam with medium distribution. Accepts 20W, 39W or 70W T6 G12 ceramic metal halide lamps and will not accept lower CRI type lamps.

Lower Reflector
Aluminum parabolic shielding prismatoid with integral diffuse glass lens provides for 55° cutoff and is available in a wide range of semi specular Alzak® finishes. Corrugated Baffle: An optional embossed pattern that extends through the flange adding a subtle design element and reduces aperture brightness.

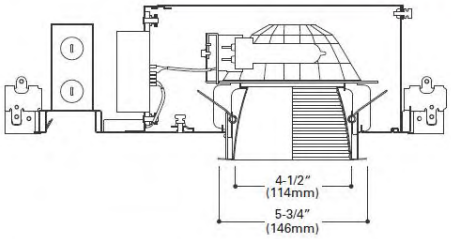
Junction Box
(7) 1/2" trade size pry outs, (3) integral clamps for non-metallic cable. Rated for (8) #12 thru branch circuits. Wago® type push wire connectors for field connections

Ballast
Universal input electronic ballast provides full light output and rated lamp life. Provides noise free operation and starting. Offers excellent line voltage regulation resulting in increased color stability and flicker free operation.

Thermal Protector
Self-resetting thermal protector protects against improper lamping and direct contact with insulation.

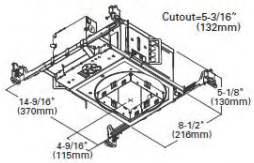
Lamp Socket
Pulse rated ceramic G12 lampholder connects to ballast with electrical quick connects.

Code Compliance
Thermally protected and cULus listed for protected wet locations and ASTM-E283 AIRTITE(tm).



P406TAT
MH4CMH20T6E
MH4CMH39T6E
MH4CMH70T6E
E4CMH
E4CMHCB
20/39/70W T6
Ceramic Metal
Halide

4 Inch Square Lens Downlight



ENERGY DATA		Min. Starting Temp -30°C	
Sound Rating Class A		EMI/RFI Emissions FCC 18C	
Input Frequency 50/60 Hz		Power Factor > 0.99	
Input Voltage 108V - 305V		THD < 10%	
20W	Input Power	24W	Nominal
	Input Current	120V 0.20A	277V 0.09A
39W	Input Power	44W	Nominal
	Input Current	120V 0.37A	277V 0.16A
70W	Input Power	77W	Nominal
	Input Current	120V 0.65A	277V 0.28A

ORDERING INFORMATION: Complete unit consists of platform, lamp module and optical element.

Platform	Lamp Module	Ballast Option	Optical Element	Finish	Flange	Accessories
	MH4CMH					

P406TAT = 4" Square Aperture Non-IC Housing
P406TCP = 4" Square Aperture Non-IC Chicago Plenum Housing

MH4CMH = Horizontal Ceramic Metal Halide, Lamp Module

20T6E = 20W T6 G12 CMH 120-277 UNV
39T6E = 39W T6 G12 CMH 120-277 UNV
70T6E = 70W T6 G12 CMH 120-277 UNV

E4CMH = 4" Square Aperture Lower Shielding Prismatoid, Lens
E4CMHCB = 4" Square Aperture Corrugated Lower Shielding Prismatoid, Lens

Alzak® Finishes
H = Clear Haze
WMH = Warm Haze
WHH = Wheat Haze
KH = Cognac Haze

Painted Finishes
BH = Black Haze
MW = Matte White
MB = Matte Black

[Blank] = Metal Trim Ring, Matte White
SF = Self Flanged
SFWF = Self Flanged, Matte White Flange (SFWF not available with corrugated baffle)

Accessories
PLR4x4 = Plaster lathing ring for rimless
RLA4x4 = Rimless adapter for solid ceiling surfaces
EDC4x41 = Extended depth collar for 1" - 1-1/2" thick ceilings
EDC4x42 = Extended depth collar for 1-1/2 - 2" thick ceilings
L4X4HEX = Matte black hex cell louver
MTR4MW = Metal trim ring, matte white
MTR4MB = Metal trim ring, matte black
MTR4SN = Metal trim ring, satin nickel
MTR4AC = Metal trim ring, antique copper
MTR4TBZ = Metal trim ring, tuscan bronze

COOPER Lighting
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Specifications and Dimensions subject to change without notice.
Consult your representative for additional options and finishes.

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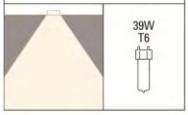
02/27/2008 9:19:54 AM

P406TAT-MH4CMH20T6E-E4CMH

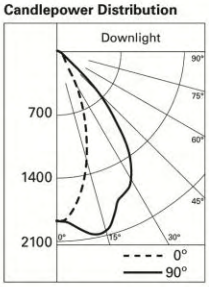
Photometric Results

Spacing Criterion = .6, 1.3
Efficiency = 59.9%

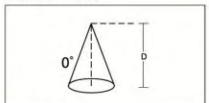
Test No. P11040
Platform = P4
Element = E4CMH
Lumens = 3300
Lamp = CMH39/T6/G12



Candlepower Distribution



Cone of Light



D	FC	L	W
4'	120	2.7'	4.9'
5'	77	3.4'	6.2'
6'	53	4.1'	7.4'
7'	39	4.8'	8.6'
8'	30	5.5'	9.9'

Candelas

Vertical Angle	CD
90	0
85	3
75	15
65	37
55	76
45	127
35	222
25	658
15	1259
5	1778
0	1852

Zonal Lumens Summary

Zone	Lumens	% Lamp	% Luminaire
0- 30	1198	36.3	60.6
0- 40	1623	49.2	82.2
0- 60	1918	58.1	97.1
0- 90	1976	59.9	100
90-180	0	0	0
0-180	1976	59.9	100

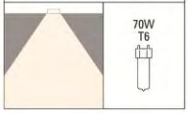
Coefficients of Utilization

Ceiling Wall % RCR	70 50 30 10	70 50 30 10	50 30 10	50 30 10	50 30 10	0
	Zonal cavity method -- floor reflectance = 20%					
0	71 71 71 71	70 70 70 70	67 67 67	64 64 64	61 61 61	60
1	68 66 64 63	66 64 63 62	62 61 60	60 59 58	58 57 56	55
2	64 60 58 55	62 59 57 55	57 55 54	56 54 52	54 53 51	50
3	60 56 52 50	59 55 52 49	53 51 49	52 50 48	50 49 47	46
4	57 52 48 45	55 51 47 45	50 47 44	48 46 44	47 45 43	42
5	53 48 44 41	52 47 44 41	46 43 41	45 42 40	44 42 40	39
6	50 45 41 38	50 44 40 38	43 40 37	42 39 37	41 39 37	36
7	48 42 38 35	47 41 37 35	40 37 35	40 37 34	39 36 34	33
8	45 39 35 32	44 39 35 32	38 35 32	37 34 32	37 34 32	31
9	43 37 33 30	42 36 33 30	36 32 30	35 32 30	35 32 30	29
10	41 34 31 28	40 34 31 28	34 30 28	33 30 28	33 30 28	27

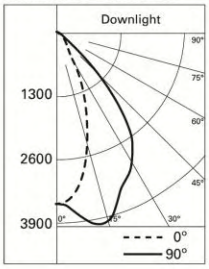
Photometric Results

Spacing Criterion = .7, 1.3
Efficiency = 59.9%

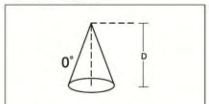
Test No. P11038
Platform = P4
Element = E4CMH
Lumens = 6600
Lamp = CMH39/T6/G12



Candlepower Distribution



Cone of Light



D	FC	L	W
8'	58	5.5'	9.7'
9'	46	6.2'	10.9'
10'	37	6.9'	12.1'
13'	22	9.0'	15.8'
16'	15	11.1'	19.4'

Candelas

Vertical Angle	CD
90	0
85	4
75	28
65	70
55	142
45	239
35	422
25	1231
15	2361
5	3363
0	3470

Zonal Lumens Summary

Zone	Lumens	% Lamp	% Luminaire
0- 30	2331	35.3	60.3
0- 40	3167	48	81.9
0- 60	3753	56.9	97
0- 90	3868	58.6	100
90-180	0	0	0
0-180	3868	58.6	100

Coefficients of Utilization

Ceiling Wall % RCR	70 50 30 10	70 50 30 10	50 30 10	50 30 10	50 30 10	0
	Zonal cavity method -- floor reflectance = 20%					
0	70 70 70 70	68 68 68 68	65 65 65	62 62 62	60 60 60	59
1	66 64 63 61	65 63 61 60	61 59 58	58 57 57	56 56 55	54
2	62 59 56 54	61 58 56 54	56 54 52	54 53 51	53 51 50	49
3	59 54 51 49	57 54 51 48	52 50 47	51 48 47	49 47 46	45
4	55 50 47 44	54 50 46 44	48 46 43	47 45 43	46 44 42	41
5	52 47 43 40	51 46 43 40	45 42 40	44 41 39	43 41 39	38
6	49 44 40 37	48 43 39 37	42 39 36	41 38 36	40 38 36	35
7	47 41 37 34	46 40 37 34	39 36 34	39 36 34	38 35 33	32
8	44 38 34 32	43 38 34 31	37 34 31	36 33 31	36 33 31	30
9	42 36 32 29	41 35 32 29	35 31 29	34 31 29	34 31 29	28
10	40 34 30 27	39 33 30 27	33 30 27	32 29 27	32 29 27	26

IRIS®

DESCRIPTION

Recessed lens wall wash luminaire with 4 inch square aperture utilizing horizontal T6 G12 ceramic metal halide lamp. Modular platform can be reconfigured from below the ceiling to accept a broad range of lamp modules and optical elements. Platform is suitable for shallow plenum commercial construction. Insulation must be kept 3" from top and sides of housing. Platform + module + element combination produces smooth vertical illumination with a minimal downlight component.

Catalog #	P406TAT-MH4CMH-39T6E-E4LWW-BH-SF-MTR 4MB	Type
Project	Millennium Science Complex	CAN-W
Comments		Date
Prepared by	MWL	

SPECIFICATION FEATURES

Frame
Galvanized steel plaster frame with integral bar hanger receivers. Setscrews provide positive horizontal locking.

Collar
Matte black steel collar adjusts vertically for 1/2" - 1" thick ceilings and can be rotated +/- 7.5° thru the aperture. Integral gun sights facilitate the use of guide strings or laser lines. Shipped with a paint overspray protector installed in the collar.

Lamp Module
Installed or removed thru the aperture or from the top and allows lamp orientation at 0°, 90°, 180° and 270° positions.

Housing
Steel housing painted matte black for a visually dark interior. Removable hinged top allows for top access. All fasteners are captive.

Gaskets
Closed cell gaskets achieve restrictive airflow requirements without additional caulking.

Optical Element
Mousetrap type springs pull flange tight to ceiling. Light trap eliminates spill light at edge of flange and reflector. Available in self-flanged or metal trim ring versions. May also be installed rimless using optional plastering lathing ring.

Bar Hangers
Captive preinstalled bar hangers adjusts from 8-1/2" to 24" wide; pass thru feature allows shortening without removal. Captive nail penetrates standard and engineered lumber. Mounting flange levels platform with ceiling. Integral clip attaches directly to t-bar.

Butterfly Bracket
Provides 3" of vertical adjustment and accept 1/2" EMT, C channel or bar hangers.

Primary Reflector
Miro® segmented upper reflector. Accepts 20W, 39W or 70W T6 G12 ceramic metal halide lamps and will not accept lower CRI lamp type.

Lower Reflector
Specular aluminum kicker reflector integral with angle cut parabolic shielding prismatoid and glass spread lens. Provides smooth vertical illumination with a minimal downlight component. Available in a wide range of semi specular Alzak® finishes.

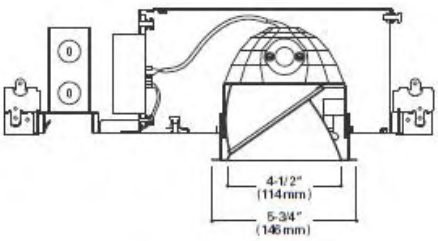
Junction Box
(7) 1/2" trade size pry outs, (3) integral clamps for non-metallic cable. Rated for (8) #12 thru branch circuits. Wago® type push wire connectors for field connections

Ballast
Universal input electronic ballast provides full light output and rated lamp life. Provides noise free operation and starting. Offers excellent line voltage regulation resulting in increased color stability and flicker free operation.

Thermal Protector
Self-resetting thermal protector protects against improper lamping and direct contact with insulation.

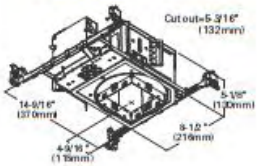
Lamp Socket
Pulse rated ceramic G12 lampholder connects to ballast with electrical quick connects.

Code Compliance
Thermally protected and cULus listed for protected wet locations and ASTM-E283 AIRTITE(tm).



P406TAT
MH4CMH20T6E
MH4CMH39T6E
MH4CMH70T6E
E4LWW
20/39/70W T6
Ceramic Metal
Halide

4 Inch Square Lens Wall Wash



Sound Rating Class A		Min. Starting Temp -30°C	
Input Frequency 50/60 Hz		EMI/RFI Emissions FCC 18C	
Input Voltage 108V - 305V		Power Factor > 0.98	
		THD < 10%	
20W	Input Power	24W	Nominal
	Input Current	120V 0.20A	277V 0.09A
39W	Input Power	44W	Nominal
	Input Current	120V 0.37A	277V 0.16A
70W	Input Power	77W	Nominal
	Input Current	120V 0.65A	277V 0.28A

ORDERING INFORMATION: Complete unit consists of platform, lamp module and optical element.

Platform	Lamp Module	Ballast Option	Optical Element	Finish	Flange	Accessories
	MH4CMH					

Platform
- P406TAT = 4" Square Aperture Non-IC Housing
- P406TCP = 4" Square Aperture Non-IC Chicago Plenum Housing

Lamp Module
- MH4CMH = Horizontal Ceramic Metal Halide, Lamp Module

Ballast Option
- 20T6E = 20W T6 G12 CMH 120-277 UNV
- 39T6E = 39W T6 G12 CMH 120-277 UNV
- 70T6E = 70W T6 G12 CMH 120-277 UNV

Optical Element
- E4LWW = 4" Aperture Lower Shielding Prismatoid, Lens Wall Wash

Finish
Alzak® Finishes
- H = Clear Haze
- WMH = Warm Haze
- WHH = Wheat Haze
- KH = Cognac Haze
- GPH = Graphite Haze
- CTH = Cobalt Haze
- CCH = Chocolate Haze
- BH = Black Haze

Painted Finishes
- MW = Matte White
- MB = Matte Black

Flange
- [Blank] = Metal Trim Ring, Matte White
- SF = Self Flanged
- SFWF = Self Flanged, Matte White Flange

Accessories
- PLR4x4 = Plaster lathing ring for rimless
- RLA4x4 = Rimless adapter for solid ceiling surfaces
- MTR4MW = Metal trim ring, matte white
- MTR4MB = Metal trim ring, matte black
- MTR4SN = Metal trim ring, satin nickel
- MTR4AC = Metal trim ring, antique copper
- MTR4TBZ = Metal trim ring, tuscan bronze

COOPER Lighting
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Specifications and Dimensions subject to change without notice.
Consult your representative for additional options and finishes.

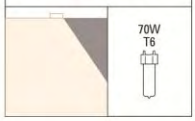
ADI060694
02/27/2008 9:25:00 AM

P406TAT MH4CMH20T6E E4LWW

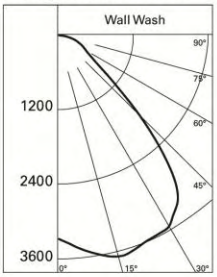
Photometric Results

Efficiency = 51.0%

Test No. P11176
Platform = P406TAT
Element = E4LWWH
Lumens = 6600
Lamp = CMH70/T6/G12



Candlepower Distribution



Candelas

CD Wall	Vertical Angle
0	90
42	85
246	75
428	65
687	55
1901	45
3324	35
3582	25
3676	15
3421	5
3271	0

Zonal Lumens Summary

Zone	Lumens	% Lamp	% Luminaire
0- 30	1854	28.1	55.1
0- 40	2527	38.3	75
0- 60	3177	48.1	94.3
0- 90	3368	51	100
90-180	0	0	0
0-180	3368	51	100

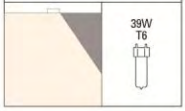
Single Unit Footcandles **Multiple Unit Footcandles**

	3' from wall (distance from fixture along wall)				3' from wall (spacing between fixtures)						4' from wall (spacing between fixtures)					
DD	■	1'	2'	3'	■ — 3' — ■			■ — 4' — ■			■ — 4' — ■			■ — 5' — ■		
1	29	14	5	2	34	18	34	31	11	31	15	7	15	14	5	14
2	40	25	10	4	50	34	50	45	21	45	24	15	24	23	10	23
3	75	44	15	6	88	57	88	81	33	81	32	22	32	29	15	29
4	77	52	20	7	94	72	94	85	42	85	50	32	50	47	21	47
5	53	42	21	9	74	69	74	62	45	62	55	40	55	51	26	51
6	36	31	19	9	57	58	57	46	41	46	47	40	47	42	29	42
7	24	22	16	9	46	47	46	35	35	35	39	37	39	34	28	34
8	18	16	12	8	37	37	37	28	39	28	32	32	32	27	25	27
9	13	12	10	7	30	30	30	23	24	23	27	28	2	22	22	22
10	10	9	8	6	25	25	25	19	20	19	23	23	23	19	19	19

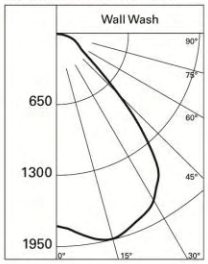
Photometric Results

Efficiency = 51.7%

Test No. P11174
Platform = P406TAT
Element = E4LWWH
Lumens = 3300
Lamp = CMH39/T6/G12



Candlepower Distribution



Candelas

CD Wall	Vertical Angle
0	90
19	85
117	75
196	65
297	55
822	45
1628	35
1859	25
1962	15
1837	5
1779	0

Zonal Lumens Summary

Zone	Lumens	% Lamp	% Luminaire
0- 30	978	29.6	57.4
0- 40	1312	39.7	76.9
0- 60	1615	48.9	94.7
0- 90	1705	51.7	100
90-180	0	0	0
0-180	1705	51.7	100

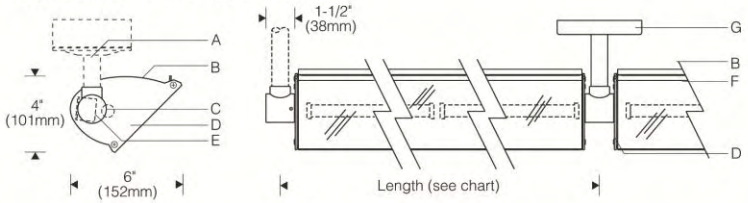
Single Unit Footcandles **Multiple Unit Footcandles**

	2' from wall (distance from fixture along wall)				2' from wall (spacing between fixtures)						3' from wall (spacing between fixtures)					
DD	■	1'	2'	3'	■ — 2' — ■			■ — 3' — ■			■ — 3' — ■			■ — 4' — ■		
1	37	13	4	1	45	29	45	40	14	40	16	9	16	15	5	15
2	73	27	6	2	87	60	87	78	25	78	22	16	22	20	10	20
3	71	37	8	3	90	81	90	78	37	78	39	27	39	36	15	36
4	41	29	10	3	65	65	65	49	39	49	45	36	45	41	20	41
5	24	19	10	4	47	48	47	33	32	33	36	34	36	31	23	31
6	15	13	8	4	35	35	35	24	24	24	29	29	29	23	21	23
7	10	9	6	3	26	27	26	18	18	18	23	24	23	18	18	18
8	7	6	5	3	20	20	20	14	14	14	19	19	19	14	15	14
9	5	5	4	3	16	16	16	11	11	11	16	16	16	12	12	12
10	4	4	3	2	13	13	13	9	9	9	13	13	13	10	10	10

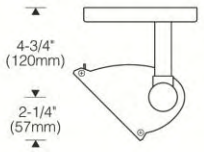
Lighting the Vertical

Medium outdoor, integral — T5 Fluorescent — **Style 164**

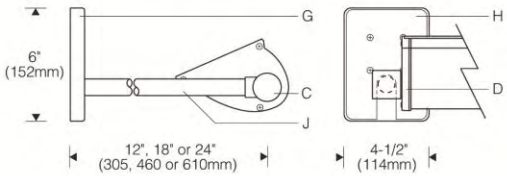
Style F164 1:8 Scale (Lighting downward)



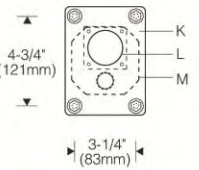
Surface Hanger



Cantilever Hanger (Lighting upward)



Mounting Plate



Lamp Length	*Length (center to center of hubs)*
1 x 2'	25-1/4" (640mm)
1 x 3'	37" (940mm)
1 x 4'	48-3/4" (1240mm)
1 x 5'	60-5/8" (1540mm)
2 x 3'	72" (1830mm)
2 x 4'	96" (2440mm)

Specifications

A 1/2" fittings, rigid conduit supports (by others)
B Specular extruded aluminum reflector
C Aluminum hubs with silicone o-ring gaskets (ordered separately)
D Die-cast aluminum end plates
E Integral electronic ballast / internal wireway
F UV and impact resistant acrylic snap-on lens with silicone gasket
G Cantilever, pendant or surface hangers with hubs (ordered separately)
H Aluminum cover (conceals fasteners)
J Tubular steel arm or stem
K Die-cast aluminum mounting plate (fasteners by others)
L Outlet box access with gasketed cover (electrical feed only)
M Outlet box (by others)

Finish:
Exterior surfaces - 6 stage pretreatment and electrostatically applied thermoset polyester powder coating for a durable abrasion, fade and corrosion resistant finish. Choice of semi-gloss colors (see ordering information).

Reflector - extruded high purity aluminum with clear anodized specular finish. All hardware and components - non corrosive stainless steel or aluminum.

Snap-on lens - composite of impact resistant and UV stabilized acrylic. Silicone gasket for watertight operation when facing upward or downward.

Electrical:
Use 90C° wire for supply connections and through wire.

Electrical feed hanger (optional) mounts over recessed outlet box (by others) with gasketed access cover. Internal wireway allows supply wiring to be fed through mounting hub to adjacent units. Locate electrical feed at end of row.

Integral electronic HPF thermally protected class P ballast rated for 0°F/-18°C starting.

For complete ballast specifications, see Accessories Section.

Mounting:
1-1/2" dia. x 1-1/2" aluminum hubs with 1/2" NPT threaded entry. Reflector aiming is adjustable - locks with set screws.

Specify with hubs only for use with 1/2" rigid conduit or fittings supplied by others.

Optional accessory surface, pendant or cantilever hangers (ordered separately). Hangers include aluminum mounting plate, cover plate and hub with 7/8" O.D. steel arm/stem (1/4-20 fasteners by others). Suitable backing structure required - allow 3 lbs/ft (21.6kg/m) (8' unit = 24 lbs).

Specify end kit or intermediate hubs/hangers.

Standard:
UL listed or CSA certified for wet locations when mounted horizontally. For positions other than horizontal, consult factory.

REV. 6/07 **U.S. Patent 7,213,949**

Features

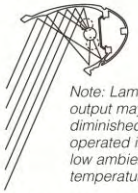
- *Reflector optimized for T5 - precise optical control for lighting facades, walls and signs from minimal setbacks*
- *Snap-on acrylic lens - watertight, facing up or down*
- *Rugged all aluminum, stainless steel construction - polyester powder coat exceeds 1000 hour salt spray test*
- *Versatile - surface, cantilever or pendant mount; thru wiring*

V 2.2

Performance

Two parabolic reflector sections drive light down (or up) the vertical plane from one edge. An elliptical section redirects its light to a parabola and shields the lamp from normal viewing angles. The fast "runback" minimizes glare and spill light. Asymmetry of the beam is maximized resulting in high beam efficiency and superior surface uniformity.

Adjustable - max. Cd shown aimed 25° above nadir.



Note: Lamp light output may be diminished when operated in low ambient temperatures.

For complete photometrics, see www.elliptipar.com.

elliptipar

To Order

Style 164

To form a Catalog Number

F	1	6	4	T128	H	07	2	00	0
1	2			3	4	5	6	7	8

Project: Millennium Science COmplex

Type: CAN-L

1 Source

F = Linear fluorescent

2 Style

164 = Medium outdoor, **integral** ballast

3 Lamp

T1 28 = **T5 Fluorescent Lamp Code**

Lamp Wattage (see chart below)

Lamp Configuration

T1 = Single-lamp cross section, 1-lamp in length
T2 = Single-lamp cross section, 2-lamp in length
D2 = Dual-lamp cross section, 1-lamp in length
D4 = Dual-lamp cross section, 2-lamp in length

Example: **T255** = Nominal 8' (2.4m) housing with (2) 54W T5HO lamps (in length)

V 2.3

Length (nominal)	*T5*		*T5HO **	
	Code	*Lamp(s)*	*Code*	*Lamp(s)*
T5 Fluorescent				
2' (0.6m)	**T114**	1 x F14T5	**T124**	1 x F24T5/HO
	D214	2 x F14T5	**D224**	2 x F24T5/HO
3' (0.9m)	**T121**	1 x F21T5	**T139**	1 x F39T5/HO
	D221	2 x F21T5	**D239**	2 x F39T5/HO
4' (1.2m)	**T128**	1 x F28T5	**T155**	1 x F54T5/HO
	D228	2 x F28T5	**D255**	2 x F54T5/HO
5' (1.5m)	**T135**	1 x F35T5	**T180**	1 x F80T5/HO
	D235	2 x F35T5	**D280**	2 x F80T5/HO
6' (1.8m)	**T221**	2 x F21T5	**T239**	2 x F39T5/HO
	D421	4 x F21T5	**D439**	4 x F39T5/HO
8' (2.4m)	**T228**	2 x F28T5	**T255**	2 x F54T5/HO
	D428	4 x F28T5	**D455**	4 x F54T5/HO

For complete lamp and ballast information, see Accessories Section. Standard T5 lamp color is 3000K / 80+ CRI. T8 lamps by others.

* **NEW** T5HO amalgam lamps are available that produce > 90% of full light output over a broader temperature range than standard lamps - see **www.elliptipar.com** or consult factory for specifications.

4 Mounting

H = For use with mounting hubs (1/2" rigid conduit supports or fittings supplied by others), or

For use with accessory surface, pendant or cantilever hangers.

Note: Order either hubs only or hubs with hangers separately. For reflector positions other than horizontal, consult factory.

5 Finish

02 = Semi-gloss white
06 = Dark bronze
07 = Silver
08 = Semi-gloss black
12 = Green
99 = Custom RAL or computer matched color to be specified, consult sales representative.

6 Voltage/Ballast

Electronic
1 = 120V
2 = 277V
3 = 347V (Canada)*

Dimming
Application is limited due to minimum 50°F (10°C) starting temperature; consult factory.

* Consult sales representative for availability of 347V.

7 Option

00 = No options
V0 = Extruded aluminum cutoff visor (Suggested when additional shielding is desired - see Uplighting page U-2.2 for additional information.)
XX = For modification not listed, include detailed description. Consult factory prior to specification.

8 Standard

0 = UL, Underwriters Laboratories
J = CSA, Canadian Standards Association

Example

F164 - T255 - H - 12 - 1 - 000

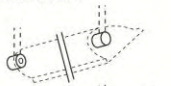
Medium outdoor fluorescent for use with two 54W T5HO lamps in nominal 8 foot reflector. For use with mounting hubs (1/2" rigid conduit supports by others) or accessory hangers. Green powder coat finish. Integral 2-lamp 120V electronic ballast. UL.
(Order end kit and intermediate mounting hubs or hangers separately.)

Hubs Only (order separately)

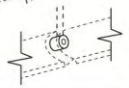
For use with 1/2" rigid conduit or fittings (supplied by others).

Order one hub **end kit** for each individually mounted luminaire or each row. For a continuous row, order one **intermediate** hub for each additional luminaire in the row. Example: a row of five reflectors requires 1 hub end kit and 4 intermediate hubs. **Note: Locate electrical feed at end of row.**

HOD 00 **000** = **End kit** (includes 2 mounting hubs)
5 Finish



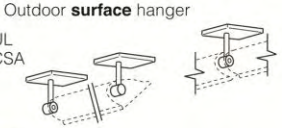
HOC [ ] **000** = **Intermediate** mounting hub
5 Finish



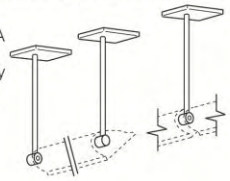
Hubs with Hangers (order separately)

Order one hanger **end kit** for each individually mounted luminaire or each row. For a continuous row, order one **intermediate** hanger for each additional luminaire in the row. Example: two rows of four reflectors requires 2 end kits and 6 intermediate hangers. **Note: Hubs included. End kit includes one electrical feed hanger - locate at end of row.**

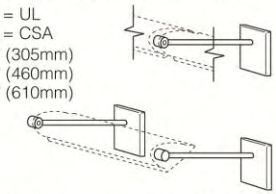
HB [ ] [ ] **00** [ ] = Outdoor **surface** hanger
0 = UL
J = CSA
5 Finish
A = Intermediate
B = End kit



HB [ ] [ ] [ ] [ ] = Outdoor **pendant** hanger
0 = UL
J = CSA
Length, in inches, specify 12, 18, 24, 30 36, 42, or 48
5 Finish
F = Intermediate
G = End kit



HB D 07 2 0 = Outdoor **cantilever** hanger
0 = UL
J = CSA
12 = 12" (305mm)
18 = 18" (460mm)
24 = 24" (610mm)
5 Finish
C = Intermediate
D = End kit



The external shapes of the asymmetric reflectors are trademarks of ***elliptipar****. Certain products illustrated may be covered by applicable patents and patents pending. For a list of patents, see Contents pages. These specifications supersede all prior publications and are subject to change without notice.* © 2007 ***elliptipar****.*

REV. 7/07 **elliptipar**

elliptipar
114 Boston Post Road, West Haven, Connecticut 06516, USA
Voice 203.931.4455 • Fax 203.931.4464 • **www.elliptipar.com**

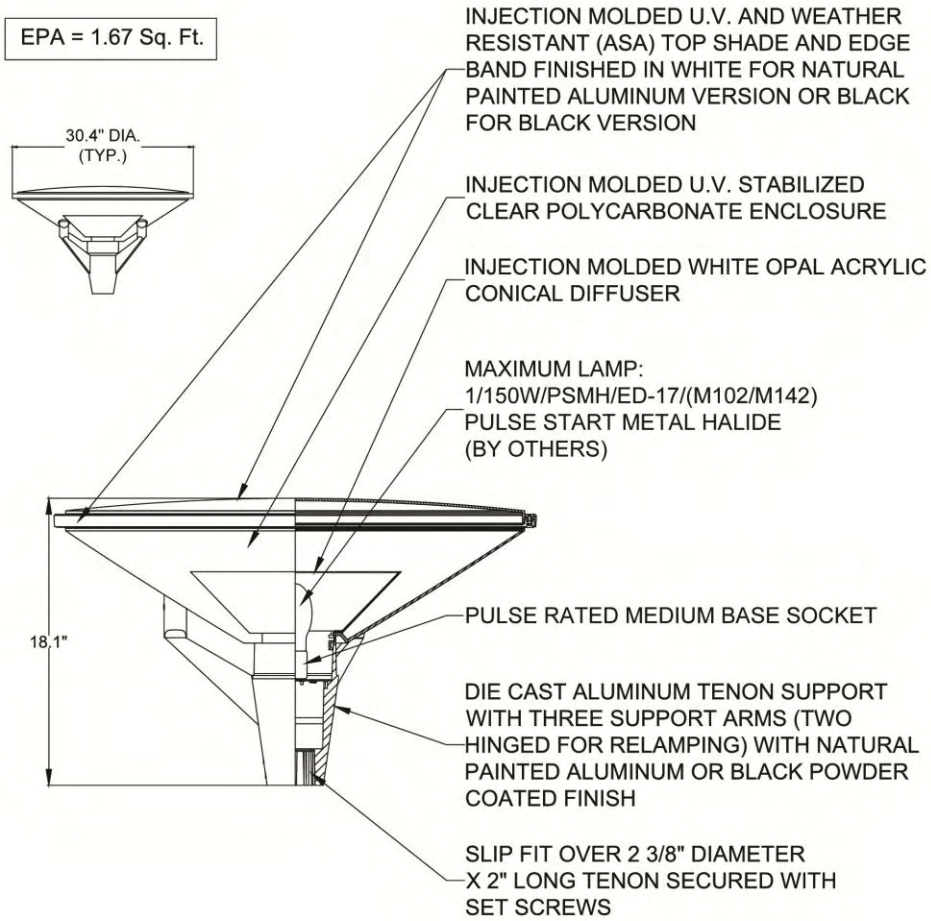
Exterior Plaza: XPO-1

Kipp Post

metal halide

Design: Alfred Homann

Type: XPO-1
Project: Millennium Science Complex
Catalog Number: KIP-1-150-MH-ed17

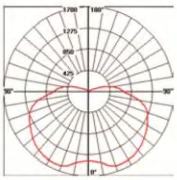


louis poulsen
Louis Poulsen Lighting, Inc., 3260 Meridian Parkway, Fort Lauderdale, FL 33331 Telephone: (954) 349-2525 Fax: (954) 349-2550
www.louispoulsen.com

Kipp Post

post tops/poles & cable hung

metal halide



Photometric Report:	KIP-Conical-175W-HID.IES
Report No.:	LP2750
Poulsen Report No.:	KIP-Conical-175W-HID.IES
Luminaire:	Kipp, Conical
Lamp:	1/175W/MH
Efficiency:	58.7%
Cutoff Classification:	Semi-cutoff
Description:	All data shown are per 15000 lumens. This report can be used for calculation on all versions listed below. Use only actual lumen data when calculating.

Candlepower Distribution

Vertical Angle	Candela
0	1385
5	1413
15	1540
25	1598
35	1576
45	1503
55	1401
65	1307
75	1168
90	697
120	7
150	1
180	1

Zonal Lumen Summary

Zone	Lumens	% Lamp	% Fixture
0-30	1304	8.7	14.8
0-40	2285	15.2	25.9
0-60	4658	31.1	52.9
0-90	7852	52.3	89.1
90-120	947	6.3	10.8
90-130	950	6.3	10.8
90-150	955	6.4	10.8
90-180	956	6.4	10.9
0-180	8808	58.7	100.0

Design
Alfred Homann

Concept
Kipp Post emits symmetrical, downward illumination. The relationship between the slightly curved design of the top shade and the calculated distance to the light source ensures a uniform and wide distribution of light. The design of the internal diffuser ensures an optimal and glare free illumination.

Finish
Natural painted aluminum or black, powder coated.

Material
Diffuser: Injection molded white opal acrylic. Top shade: Black or white, injection molded ASA. Enclosure: Injection molded clear polycarbonate. Frame: Die cast aluminum.

Mounting
Post top: Mounted on dual round aluminum (DRA) or round straight aluminum (RSA) pole.

Weight
Max. 24 lbs.

Label
cUL, Wet location. IBEW.

Product code	Light source	Voltage	Finish	Distribution	Transition to pole
KIP	1/150W/CMH/T-6 G12 1/150W/MH/ED-17 medium 1/85W/QL	120/277V 120V 277V	BLK NAT PAINT ALU	OPAL	T-DRA-5"-3" T-RSA-4.5"

Specification notes:
a. QL variants provided with 120V or 277V HF integral generator and can only be used with RSA-4.5" pole.
b. CMH and MH variants provided with one 120/277V F-can style ballast to be mounted in RSA-4.5" or DRA-5"-3" poles.

Info notes:
I. Black top shade is provided with black finish.
II. White top shade is provided with natural painted aluminum finish.
III. Enclosure is U.V. stabilized polycarbonate.
IV. For pole selection, refer to Pole page.
V. The comparable EU version has the following classification: Ingress Protection Code: IP66.

louis poulsen

Louis Poulsen Lighting, Inc., 3260 Meridian Parkway, Fort Lauderdale, FL 33331 Telephone: (954) 349-2525 Fax: (954) 349-2550

www.louispoulsen.com

Appendix I: Lighting Control Cutsheets

Student Study Area& Conference Room: LOS-CUS

Sensors | LOS-CUS Series | Occupant Sensors

LOS-CUS 1 09.04.08

Ultrasonic Ceiling Mount Sensor

The LOS-CUS Series ceiling-mount ultrasonic sensors can integrate into Lutron systems or function as stand-alone controls using a Lutron power pack. Any movement within the sensor's range causes a shift in the original emitted frequency. The sensor's receiver identifies any change in frequency as motion and either turns the lights on or maintains lights on.

Features

- Intelligent, continually adapting ultrasonic sensor
- Snap-locks to ceiling-mounted cover plate
- Excellent minor motion sensitivity
- Non-Volatile Memory: settings saved in protected memory are not lost during power outages
- 500 to 2000 sq.ft. (46 to 186 m²) coverage when mounted on an 8 - 12 ft. (2.4 to 3.7 m) ceiling
- Affords choice of turning lights off or dimming to a preset level in the unoccupied state when integrated with a Lutron system.

Models Available

Cat. No.	Color	Coverage	Field of View
LOS-CUS-500-WH	White	500 sq.ft. (46 m²)	180°
LOS-CUS-1000-WH	White	1000 sq.ft. (93 m²)	180°
LOS-CUS-2000-WH	White	2000 sq.ft. (186 m²)	360°

Self-Adaptive Feature

Designed to meet the challenges found in a wide variety of spaces, the LOS-CUS Series provides reliable detection with high minor motion detection. The intelligent, continually adapting sensor technology eliminates manual sensitivity and timer adjustments during installation and over the life of the product. The internal microprocessor analyzes the information from the ultrasonic technology and determines the optimum setting to use in order to properly cover the space. Should the room be reconfigured (e.g., new furniture), the software will adapt to continue to provide correct time out for the lights.

LUTRON. SPECIFICATION SUBMITTAL Page 1

Job Name:	Model Numbers:	
Millenium Science Complex	LOS-CUS-1000	
Job Number: Building Stimulus	LOS-CUS-500	

Specifications

Timer Adjustment

- Automatic mode: Continually adapting sensor automatically adjusts settings to the space
- Manual mode: 8 to 30 minutes
- Test mode: 8 seconds

LED Lamp

- Green: ultrasonic motion detected

Housing

- Rugged, high-impact, injection-molded plastic
- Color-coded leads 6 in. (15 cm)

Power

- Operating voltage: 20 - 24 V⎓, PELV (Class 2; USA) low-voltage
- Operating current: 33 mA nominal
- Control output: 20 - 24 V⎓ active high logic control signal with short-circuit protection, open collector when unoccupied
- UL and CUL listed

Operating Environment

- Temperature: 32 to 104 °F (0 to 40 °C)
- Relative humidity: less than 95%, non-condensing
- For indoor use only

Dimensions

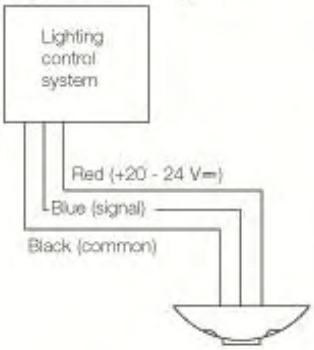
Front View Side View

Job Name:	Model Numbers:	
Millenium Science Complex	LOS-CUS-1000	
Job Number: Building Stimulus	LOS-CUS-500	

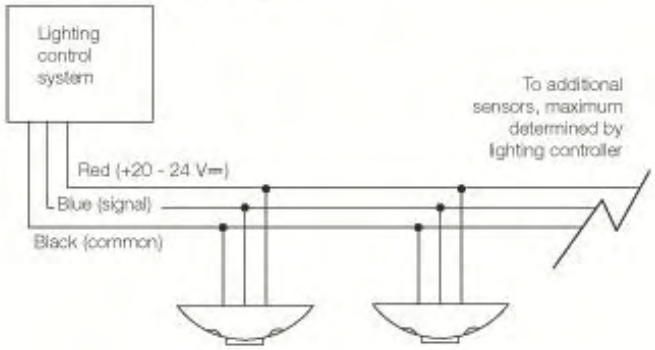
Wiring

Note: Power pack may be required when interfaced to lighting control system; see below.

Single Sensor to System



2 or More Sensors to System



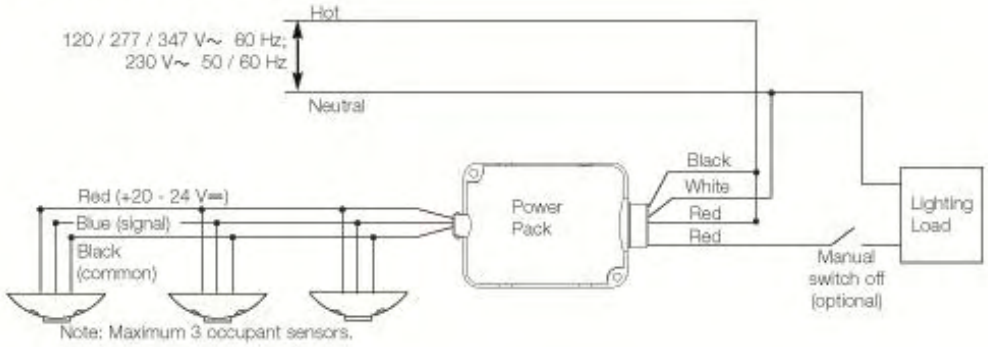
Power Supply Options

Lutron Lighting Control System	Power Pack Required?
Digital microWATT™	No
EcoSystem®	No
GRAFIK 5000 / 6000 / 7000	No, when used with seeTouch® wallstations with occupant sensor connections.
GRAFIK Eye® 3000 / 4000	Yes
HomeWorks®	Yes
LCP128™	No, when used with *seeTouch* wallstations with occupant sensor connections.
microWATT®	No
RadioRA®	Yes
RadioTouch®	No
Softswitch128®	No, when used with *seeTouch* wallstations with occupant sensor connections.

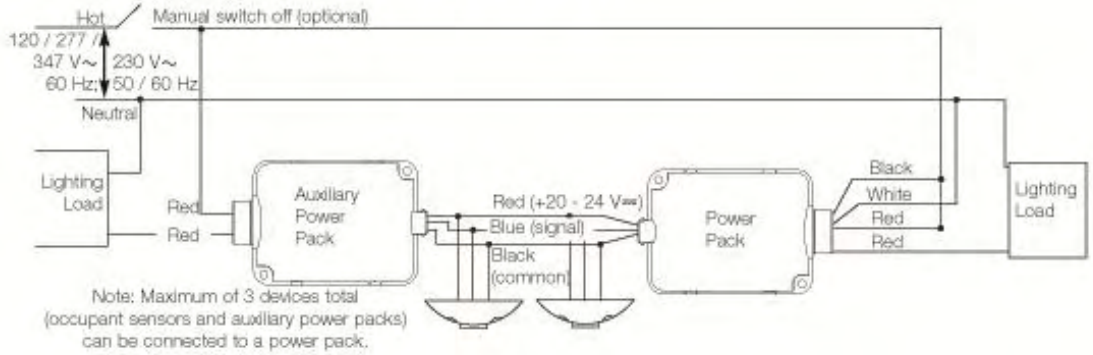
Job Name:	Model Numbers:	
Millenium Science Complex	LOS-CUS-1000	
Job Number: Building Stimulus	LOS-CUS-500	

Wiring: Stand-Alone Control

1 to 3 Sensors with Power Pack



Switching Multiple Loads with Auxiliary Power Packs



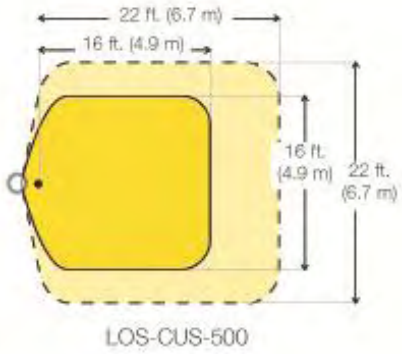
Job Name:	Model Numbers:	
Millenium Science Complex	LOS-CUS-1000	
Job Number: Building Stimulus	LOS-CUS-500	

Installation

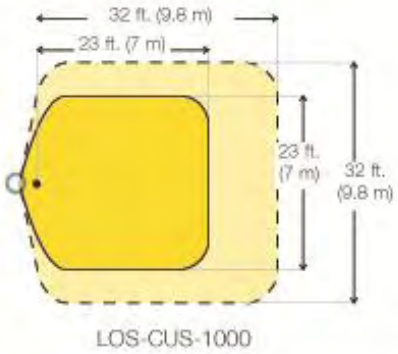
Sensor Placement

- Mount the sensor so the grilles face the open portion of the room and are not facing a nearby wall, window, or other obstructing object.
- Keep the occupant sensor away from air flow from ventilation outlets, windows, fans, etc.
- If installing a 180° occupant sensor (500 and 1000 models), place the sensor on the same wall as the doorway so that traffic in a hallway will not affect the sensor; otherwise, place in center of room.
- Closely follow the diagrams shown concerning major and minor motion coverage. The sensor can detect major motion (such as a person taking a half-step) at a greater distance than it can detect minor motion (such as writing or typing at a desk).
- Decrease total coverage area by 15% for "soft" rooms (for example, heavy draperies or heavy carpeting).

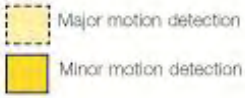
Range Diagrams

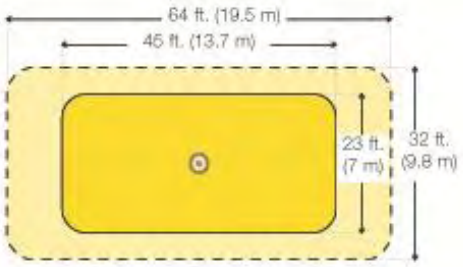


LOS-CUS-500



LOS-CUS-1000



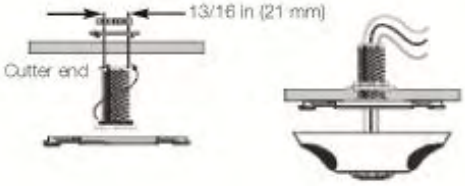


LOS-CUS-2000

Installation

Mounting

Normal Mounting
Twist and lock threaded mounting post onto cover plate. Drill through ceiling tile with assembly, using cutter end of the threaded mounting post. Secure with washer and nut.

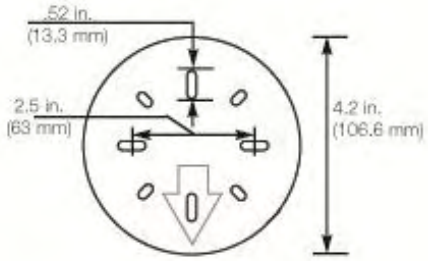


Mounting to Non-Standard Ceiling or Fixture
Mount twist-lock cover plate using mounting screws, nuts, and washers (included). Drill/punch wire routing hole through ceiling tile at center of cover plate.

Wire Lengths

# Sensors	1	2	3	1	2	1
# Aux. PP	0	0	0	1	1	2
22 AWG	750 ft.	375 ft.	250 ft.	375 ft.	250 ft.	250 ft.
0.5 mm²	365 m	180 m	120 m	90 m	120 m	120 m
20 AWG	1200 ft.	600 ft.	400 ft.	600 ft.	400 ft.	400 ft.
0.75 mm²	730 m	365 m	240 m	365 m	240 m	365 m
18 AWG	2400 ft.	1200 ft.	800 ft.	1200 ft.	800 ft.	800 ft.

Mounting Plate Dimensions



Job Name:	Model Numbers:	
Millenium Science Complex	LOS-CUS-1000	
Job Number: Building Stimulus	LOS-CUS-500	

Sensor Adjustments

Override Settings

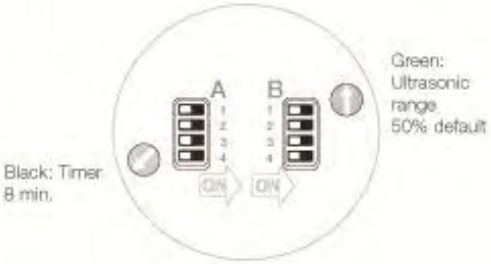
Timer Test Mode

1. Remove the retainer cover.
2. Rotate the black timer adjustment knob to about midway (12 o'clock).
3. Return setting to minimum setting (full CCW).

Note: The timer will remain in the 8-second test mode for 1 hour, then automatically reset to 8 minutes.

4. To manually take the timer out of the 8-second test mode, turn the timer adjustment approximately 1/16" clockwise to make the setting slightly above minimum (just above the 8-minute setting).

Factory Settings



Job Name:	Model Numbers:	
Millenium Science Complex	LOS-CUS-1000	
Job Number: Building Stimulus	LOS-CUS-500	

Student Study Area: LRF2-DCRB-WH

Radio Powr Savr™	LRF2-DCRB-WH	Wireless Daylight Sensor

369-244a 1 02.16.10

Wireless Daylight Sensor

Lutron's wireless daylight sensor is a battery-powered sensor that automatically controls lights via RF communication to compatible dimming or switching devices. This sensor mounts to the ceiling and measures light in the space. The sensor then wirelessly transmits the light level to the associated dimming or switching devices that automatically control the lights to balance light level in the space. The sensor combines both convenience and exceptional energy savings along with ease of installation.

Features

- Lutron's reliable proportional daylight open loop control
- Light range (0–10,000 fc)
- Photopic response matches human eye
- Designed to give a linear response to changes in viewed light level
- Wireless daylight sensor has simple calibration
- One sensor is capable of switching, stepped dimming, and continuous dimming of multiple zones
- Intuitive test mode provides instant system verification
- 10-year battery life
- Multiple ceiling mount methods available for different ceiling materials
- Works seamlessly with Radio Powr Savr™ Occupancy and Vacancy Sensors and Pico™ wireless controls
- Front accessible test buttons make setup easy
- Each sensor can be added to up to 10 compatible RF dimming and switching devices for spaces with multiple zones of lighting
- RoHS compliant
- Capable of override for a maximum of 2 hours

Models Available:

- LRF2-DCRB-WH 434 MHz *Daylight Sensor*

Compatible RF Devices:

- For use with Lutron® products only
- Communicates to the following wireless Lutron systems:
  - Maestro Wireless®
  - GRAFIK Eye® QS Wireless

LUTRON® SPECIFICATION SUBMITTAL Page

Job Name:	Model Numbers:
Job Number:	

Radio Powr Savr™ LRF2-DCRB-WH Wireless Daylight Sensor

369-244a 2 02.16.10

Specifications

Standards

- FCC Approved. Complies with the limits for a Class B digital device, persuant to Part 15 of the FCC Rules.
- IC (RSS-210)
- Meets CA Title 24 requirements

Power / Performance

- Operating voltage: 3 V⎓
- Operating current: 7 µA
- Requires one CR 2450 lithium battery
- 10-year battery life
- Non-volatile memory (settings are stored during power loss)

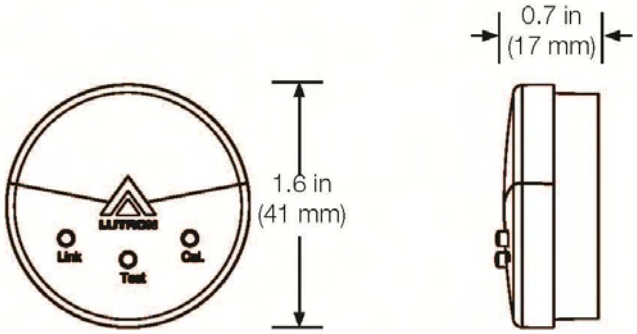
Environment

- Temperature: 32 °F to 104 °F (0 °C to 40 °C)
- For indoor use only

Range

- Local load controls must be located within 60 ft (18 m) line of sight, or 30 ft (9 m) through walls, of a daylight sensor

Dimensions



LUTRON® SPECIFICATION SUBMITTAL Page

Job Name:	Model Numbers:
Job Number:	

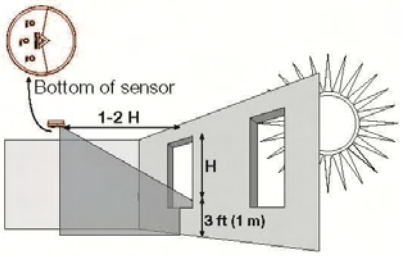
Radio Powr Savr™ LRF2-DCRB-WH Wireless Daylight Sensor

369-244a 3 02.16.10

Mounting

Location for average size areas

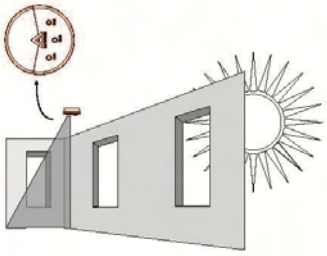
Arrow points towards the area viewed by the sensor (towards windows)



H = Effective Window Height

Location for narrow areas (corridors, private offices)

Arrow points towards the area viewed by the sensor (away from window)



Installation

Determine the Daylight Sensor Mounting Location using the diagrams at left:

- The arrow on the daylight sensor points toward the area viewed by the sensor.
- Place the daylight sensor so its viewing area is centered on the nearest window at a distance from the window of one to two times the effective window height (H).
- The effective window height (H) starts at the window sill or 3 ft (1 m) up from the floor, whichever is higher, and ends at the top of the window.
- Ensure that the view of the daylight sensor is not obstructed.
- Do not position the daylight sensor in the well of a skylight or above indirect lighting fixtures.
- For narrow areas where the daylight sensor cannot be placed 1-2 (H) from windows, place sensor near windows facing into the space.

Daylight Sensor Communication

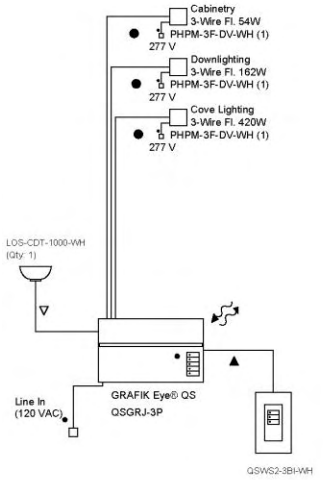
- A sensor can communicate with up to 10 local load devices
- A single local load device or zone can have only one daylight sensor communicate to it

LUTRON® SPECIFICATION SUBMITTAL Page

Job Name:	Model Numbers:
Job Number:	

Conference Room: Lutron Grafik Eye Lighting Control System

GRAFIK Eye® QS	One Line Diagram



Wiring Notes:	● 2 #12 AWG (2.5 mm²)	▼ 2 #18 AWG (1.0 mm²)	■ 277 VAC Input Power	▲ Lutron GRX-CBL-346S or GRX-PCBL-346S
	▽ 3 #18 AWG (1.0 mm²)	□ 120 VAC Input Power	★ Only connect 3 wires (Common, mux, mux)	

Lutron

Project Name: Millennium Science Complex	
Project Number:	**Page:** 1

GRAFIK Eye. QS — Bill of Materials

Description	Model Number	Qty.
GRAFIK Eye® QS Wireless Control Unit	QSGRJ-3P	1
GRAFIK Eye® QS Faceplate Kit	QSGFP-WH-NST	1
Occupancy Sensor, Dual Tech, 1000 sq ft, active high, 20-24 VDC, white	LOS-CDT-1000-WH	1
Power Module	PHPM-3F-DV-WH	3
QS 3-Button Wallstation, insert	QSWS2-3BI-WH	1

Lutron

Project Name: Millennium Science Complex

Project Number: **Page:** 2

GRAFIK Eye® QS

Button Kit Engraving Form

Project Information
Project Name: Millennium Science Complex
Installer Company: _____
Installer Name: _____
Phone: _____

Shipping Information
Name: _____
Company: _____
Address: _____
City: _____ State: _____ Zip: _____
Phone: _____ Fax: _____

	Type:	Model Number:	Engraving Certificate Number:	Button color:
1	Scene Control			white (WH)

Lutron Electronics Co. Inc.
Dept 309 engraving
7200 Suter Road
Coopersburg, PA 18036
www.lutron.com
Phone: 610.282.3800

LUTRON®

Project Name: Millennium Science Complex

Lutron Project #: **P.O.#:**

Lutron Order #: **Page:** 3

GRAFIK Eye. QS Load Schedule

Model Number: QSGRJ-3P

Phase Control Zones

Zone	Name	Load Type	No. Fixtures	Wattage/Fixture	Total Wattage
1	Cove Lighting	3-Wire Fl.	12	35	420
2	Downlighting	3-Wire Fl.	6	27	162
3	Cabinetry	3-Wire Fl.	2	27	54

Lutron

Project Name: Millennium Science Complex

Project Number: **Page:** 4

GRAFIK Eye® QS

Preset Dimming Control

GRAFIK Eye® QS with lid closed.

GRAFIK Eye® QS with lid open.

Actual colors may vary slightly.

Light Zones:	Colors:	
3	**Faceplate:**	white (WH)
Shade Groups:	**Stripe:**	gray (GR)
0	**Buttons:**	white (WH)

Model Number:		
Unit:	QSGRJ-3P	**Quantity:** 1

LUTRON SPECIFICATION SUBMITTAL

Project Name: Millennium Science Complex

Project Number: **Page:** 5

GRAFIK Eye® QS

Full-size Image

Actual colors may vary slightly.

Selected Wall Color

Benjamin Moore Paints	**Affinity Colors:** Fusion www.myaurapaints.com

*Actual color may differ slightly; please refer to paint chips for most accurate representation.

LUTRON

Project Name:	Millennium Science Complex		
Project Number:		**Page:**	6

Conference Room: PP-230H Power Pack

Sensors | PP Series | Power Packs

PP-1 06.09.05

PP Series Power Packs

PP-120H
PP-230H
PP-277H
PP-347H

PP-SH

Power switch packs provide both the 24 V⎓ power supply to operate Lutron sensors as well as the 20 A line voltage relay to control the load in one compact housing. The unit can be placed outside or inside the junction box with a simple twist-on nut. The auxiliary relay model can be used with line voltage power packs to switch additional loads.

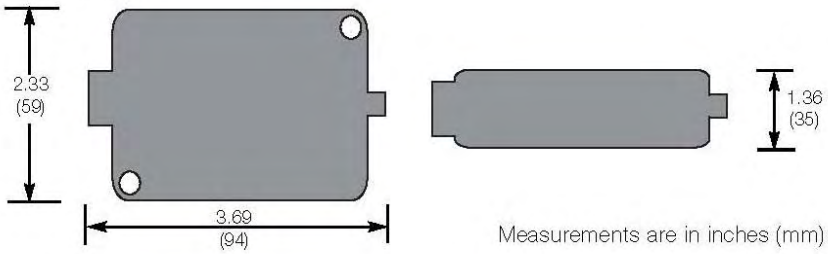
Features

- High-impact UL94 5 VA flammability-rated plastic case construction.
- Relay: Class B (130°C) insulating material; silver alloy contacts.
- 120 V, 277 V, or 347 V∿ transformer: 60 Hz;
  230 V transformer: 50 Hz.
- 24 V= nominal output; 100 mA nominal, full wave rectified and filtered.
- 7" wire leads, 18 AWG input; 7" leads, 16 AWG contacts.
- Relay contact rating:
  --20 A: 120/230/277 V ballast
  --15 A: 347 V ballast
  --15 A: 120 V incandescent
- Complies with requirements for use in a compartment handling conditioned air (plenum).
- Supports up to 3 devices, including occupant sensors and PP-SH units.
- Operating environment: 32°F to 104°F (0°C to 40°C);
  less than 90% relative humidity, non-condensing.
- For indoor use only.

Model Numbers

Catalog Number	Power Input	Control Input	Power Output
PP-120H	120 V∿, 60 Hz	24 V⎓, 5 mA	24 V⎓, 100 mA
PP-230H	230 V∿, 50 & 60 Hz	24 V⎓, 5 mA	24 V⎓, 100 mA
PP-277H	277 V∿, 60 Hz	24 V⎓, 5 mA	24 V⎓, 100 mA
PP-347H	347 V∿, 60 Hz	24 V⎓, 5 mA	24 V⎓, 100 mA
PP-SH	N/A	24 V⎓, 5 mA	N/A

Dimensions



Measurements are in inches (mm)

LUTRON. SPECIFICATION SUBMITTAL Page 1

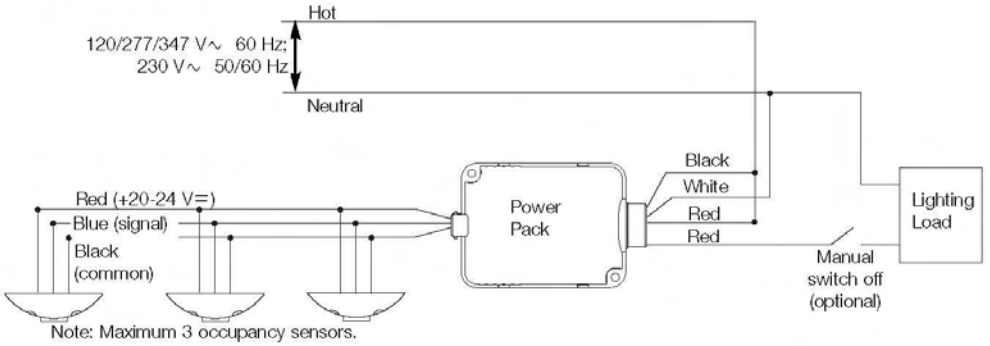
Job Name:	Model Numbers:	
Millennium Science Complex	PP-277H	
Job Number:		

Sensors | PP Series | Power Packs

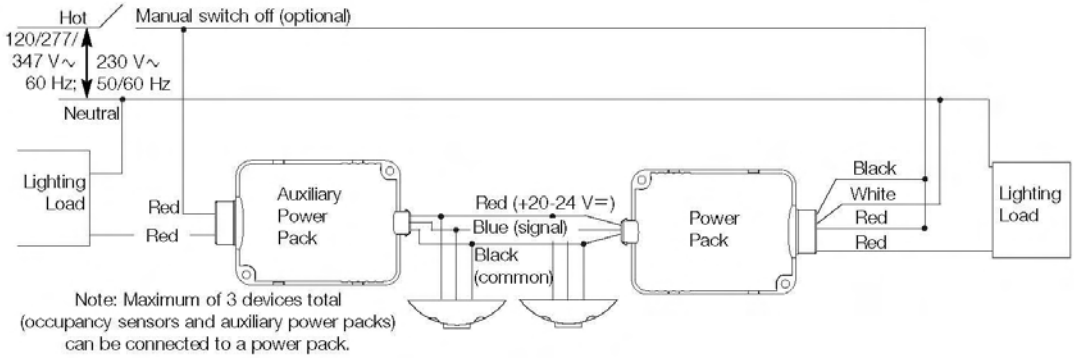
PP-2 06.09.05

Wiring

1 to 3 Sensors with Power Pack



Switching Multiple Loads with Auxiliary Power Packs



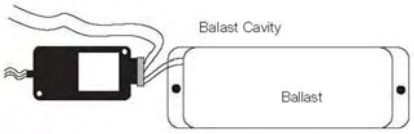
LUTRON. SPECIFICATION SUBMITTAL Page 2

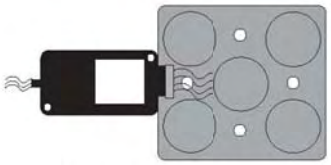
Job Name:	Model Numbers:	
Millennium Science Complex	PP-277H	
Job Number:		

Sensors | PP Series | Power Packs

PP-3 06.09.05

Mounting





Fits inside junction box or standard fluorescent fixture ballast cavity

Mount with 6/32 x 1.25" pan heac screws

Mounts to standard 4" x 4" junction box through knockout with 1/2" EMT threaded nipple.

Note: Always turn power off and lock out during unit installation.
Always instal unit in accordance with applicable national and local electrical codes.

Installation

- Wire according to appropriate Wiring Diagram.
- Warning: Risk of electrical shock from energized equipment.
  Always turn power OFF and lock out during unit installation.
  Always install units in accordance with applicable national and local electrical codes.

LUTRON. SPECIFICATION SUBMITTAL Page 3

Job Name:	Model Numbers:	
Millennium Science Complex	PP-277H	
Job Number:		

Appendix J: Lamp Cutsheets

Philips: F32T8 ADV835 Alto II

Advantage™ T8

F32T8 ADV835 ALTO

Philips Advantage T8 lamps offer high lumen output in an environmentally responsible lamp.

Product data

• Product Data

Product number	139881
Full product name	F32T8 ADV835 ALTO II
Short product name	F32T8 ADV835 ALTO II
Pieces per Sku	1
Skus/Case	25
Bar code on pack	046677139889
Bar code on case	50046677139884
Logistics code(s)	927869783601

• General Characteristics

Base	Medium Bi-Pin [Medium Bi-Pin Fluorescent]
Base Information	Green Base
Bulb	T8
Energy Saving	Energy Saving
Rated Avg Life [12-Hr Prog St]	36000 hr
Rated Avg Life [12-Hr Inst St]	30000 hr
Rated Avg Life [3-Hr Prog St]	30000 hr
Rated Avg Life [3-Hr Inst St]	24000 hr

• Electrical Characteristics

Watts	32 W

• Environmental Characteristics

Mercury (Hg) Content	1.7 mg
Picogram per Lumen Hour	24 p/LuHr

• Light Technical Characteristics

Color Code	Advantage 835 [CCT of 3500K]
Color Rendering Index	85 Ra8
Color Designation	Advantage 835
Color Temperature	3500 K
Initial lumen	3100 Lm
Design Mean Lumens	3000 Lm

• Product Dimensions

Nominal Length [inch]	48

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Philips: F21T5/835/ALTO/40PK

T5 Standard

21W/835 Min Bipin T5 HE ALTO UNP

Philips T5 flourescent Lamps featuring ALTO® Lamp Technology offer increased energy savings and low toxicity in a slim profile

Product data

• Product Data

Product number	230821
Full product name	21W/835 Min Bipin T5 HE ALTO UNP
Short product name	F21T5/835/ALTO 40PK
Pieces per Sku	1
eop_pck_cfg	40
Skus/Case	40
Bar code on pack	46677230821
Bar code on case	2008410030134
Logistics code(s)	927990883522
tpd_ilcos_cd	FDH-21/35/1B-L/P-G5-16
eop_net_weight_pp	78.000 gr

• General Characteristics

System Description	High Efficiency
Base	Miniature Bipin
Base Information	Green [Green Base]
Bulb	T5 [16 mm]
Rated Avg. Life	24000 hr
Life to 10% fail	19000 hr
Preheat EL,3h	
LSF HF Preheat 20000h Rated,3h	85 %
LSF HF Preheat 12000h Rated,3h	95 %
LSF HF Preheat 8000h Rated,3h	97 %
LSF HF Preheat 6000h Rated,3h	98 %
LSF HF Preheat 4000h Rated,3h	98 %
LSF HF Preheat 2000h Rated,3h	99 %
LSF HF Preheat 16000h Rated,3h	94 %

• Electrical Characteristics

Watts	21 W
Lamp Voltage EL 25°C	125 V
Lamp Current EL 25°C	0.170 A
Dimmable	Yes
Lamp Wattage EL 35°C	20.7 W
Lamp Current EL 35°C	0.170 A
Lamp Voltage EL 35°C	123 V
Lamp Wattage EL 25°C, Rated	21.3 W
Lamp Wattage EL 25°C, Nominal	21 W

• Environmental Characteristics

Energy Efficiency Label (EEL)	A
Mercury (Hg) Content	1.4 mg

• Light Technical Characteristics

Color Code	835 [CCT of 3500K]
Color Rendering Index	85 Ra8
Color Designation	White
Color Temperature	3500 K
Chromaticity Coordinate X	409 -

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T5 Standard

Chromaticity Coordinate Y	397 -
Inital Lumens	2100 Lm
Luminance Average EL 25°C	1.5 cd/cm2
Lum Efficacy Rated HF 25°C	90 Lm/W
Lum Efficacy Rated HF 35°C	101 Lm/W
LLMF HF 20000h Rated	88 %
LLMF HF 16000h Rated	90 %
LLMF HF 12000h Rated	91 %
LLMF HF 8000h Rated	93 %
LLMF HF 6000h Rated	94 %
LLMF HF 4000h Rated	95 %
LLMF HF 2000h Rated	96 %

Luminous Flux EL 25°C, Rated	1920 Lm
Luminous Flux EL 25°C, Nominal	1920 Lm
Design Temperature	35 C

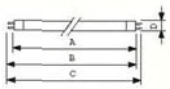
- Product Dimensions

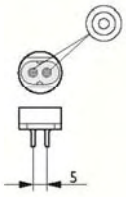
Base Face to Base Face A	849.0 mm
Insertion Length B	853.7 (min), 856.1 (max) mm
Overall Length C	863.2 mm
Diameter D	17 mm

- Measuring Conditions

Calibration Current	0.170 A
HF Generator Rated Voltage	246 V
Resistor	725 ohm

Dimensional drawing



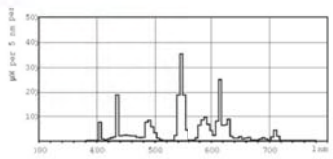


Product	A (Max)	B (Min)	B (Max)	C (Max)	D (Max)
TLS HE F21T5/835 HE Alto	849.0	853.7	856.1	863.2	17

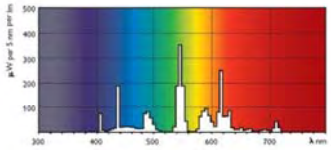
2011, March 18
data subject to change

T5 Standard

Photometric data



Lightcolor/835



Lightcolor /835

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www.philips.com/lighting

2011, March 18
data subject to change

Philips: PL-T CFTR32W/GX24q

PL-T Triple 4-Pin Base Energy Advantage

PL-T XEW 26W/835/4P ALTO 21W

Philips Linear Compact Fluorescent Lamps offer designers, specifiers and end-users new levels of efficiencies and versatility in sizes,configurations and application possibilities. With so many elegant fixtures available to complement their small size, high light output and advanced technology, Philips Energy Advantage lamps are fast becoming the preferred choice when maximum effciency and sleek design solutions are required.

Product data

- Product Data

Product number	407809
Full product name	PL-T XEW 26W/835/4P ALTO 21W
Short product name	PL-T 26W/835/XEW/4P/ALTO 21W
Pieces per Sku	1
Skus/Case	10
Bar code on pack	46677407803
Bar code on case	50046677407808
Logistics code(s)	927905383520
eop_net_weight_pp	64.000 gr

- General Characteristics

Base	GX24q-3
Base Information	4P
Life to 10% fail	10000 hr
Preheat EL,3h	

- Electrical Characteristics

Watts	26 W
Lamp Wattage EL	21 W
Lamp Voltage EL	72 V
Lamp Current EL	0.300 A

- Environmental Characteristics

Mercury (Hg) Content	1.4 mg

- Light Technical Characteristics

Color Code	835 [CCT of 3500K]
Color Rendering Index	82 Ra8
Color Designation	White
Color Temperature	3500 K
Chromaticity Coordinate X	412 -
Chromaticity Coordinate Y	402 -
Initial Lumens	1400 Lm
Luminous Efficacy Lamp EL	66 Lm/W
Lumen Maintenance EL 2000h	92 %
Lumen Maintenance EL 5000h	87 %

- Product Dimensions

Base Face to Base Face A	86.7 mm
Insertion Length B	111.0 mm
Overall Length C	126.7 mm
Diameter D	41.0 mm

PHILIPS
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Philips: F28T5/841/ALTO

Philips T5 Fluorescent Lamps featuring ALTO® Lamp Technology

Ideal for general, decorative and architectural lighting in offices, retail stores, hotels, schools and hospitals

T5 Lamps

† This lamp is better for the environment because of its reduced mercury content. All Philips ALTO® lamps give you end-of-life options which can simplify and reduce your lamp disposal costs depending on your state and local regulations.

* Fluorescent lamps that are TCLP compliant reduce the amount of pollutants released into the environment.

Powerful, environmentally-responsible ultra-slim lamps

Philips T5 Flourescent Lamps featuring ALTO® Lamp Technology offer increased energy savings and low toxicity in a slim profile.

Sustainable lighting solution
- Less mercury combined with energy efficiency and long life reduces the impact on the environment
- Our green end-caps mean you are using ALTO® environmentally-responsible lamps
- Just 1.4mg of mercury

Miniaturization
- Slim profile lamp and ballast

Operated on programmed start electronic ballasts only

Philips T5 warranty period: 36 months

PHILIPS
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Philips T5 Fluorescent Lamps featuring ALTO® Lamp Technology

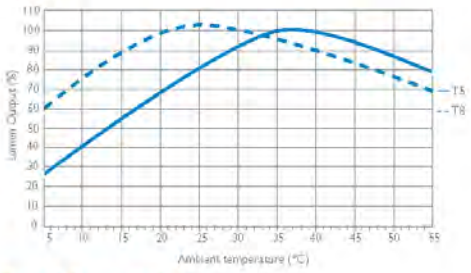
Ordering, Electrical and Technical Data (Subject to change without notice)

Product Number	Ordering Code	Watts	Bulb	Base	Pkg. Qty.	Color Temp (K)	CRI	Nom. Length (In.)	Rated Avg. Life (Hrs.)[1]	Approx. Initial Lumens[2,3]	Design Lumens[4]
23077-1	F14T5/830/ALTO	14	T5	Min. Bipin	40	3000K	85	22	25,000	1350	1275
23079-7	F14T5/835/ALTO	14	T5	Min. Bipin	40	3500K	85	22	25,000	1350	1275
23080-5	F14T5/841/ALTO	14	T5	Min. Bipin	40	4100K	85	22	25,000	1350	1275
23081-3	F21T5/830/ALTO	21	T5	Min. Bipin	40	3000K	85	34	25,000	2100	2000
23082-1	F21T5/835/ALTO	21	T5	Min. Bipin	40	3500K	85	34	25,000	2100	2000
23083-9	F21T5/841/ALTO	21	T5	Min. Bipin	40	4100K	85	34	25,000	2100	2000
23084-7	F28T5/830/ALTO	28	T5	Min. Bipin	40	3000K	85	46	25,000	2900	2750
23085-4	F28T5/835/ALTO	28	T5	Min. Bipin	40	3500K	85	46	25,000	2900	2750
23086-2	F28T5/841/ALTO	28	T5	Min. Bipin	40	4100K	85	46	25,000	2900	2750
23088-8	F35T5/830/ALTO	35	T5	Min. Bipin	40	3000K	85	58	25,000	3650	3450
23091-2	F35T5/835/ALTO	35	T5	Min. Bipin	40	3500K	85	58	25,000	3650	3450
23095-3	F35T5/841/ALTO	35	T5	Min. Bipin	40	4100K	85	58	25,000	3650	3450

1) Average life under specified test conditions with lamps burned off and restarted no more frequently than once every 3 operating hours. Lamp life is appreciably longer if lamps are started less frequently.
2) Approximate initial lumens. The lamp lumen output is based upon lamp performance after 100 hours of operating life, when the output is measured during operation on a reference ballast under standard laboratory conditions.
3) For expected lamp lumen output, commercial ballast manufacturers can advise the appropriate ballast factor for each of their ballasts when they are informed of the designated lamp. The ballast factor is a multiplier applied to the designated lamp lumen output.
4) Design lumens are the approximate lamp lumen output at 40% of the lamp's rated average life. This output is based upon measurements obtained during lamp operation on a reference ballast under standard laboratory conditions.
5) Average life under engineering data with lamps burned off and restarted once every 12 operating hours.

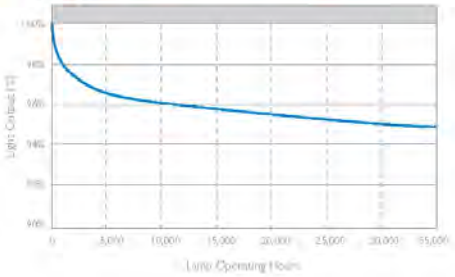
Lumens vs. Ambient Temperature

T5 Lamp



Energy Lumen Maintenance

T5 Lamp



Rated Average Life

T5 Lamp

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P-5123-E
www.philips.com

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P.O. Box 6800
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1-800-555-0050
A Division of Philips Electronics North America Corporation

Philips Lighting
281 Hillmount Road
Markham, Ontario
Canada L6C 2S3
1-800-555-0050
A Division of Philips Electronics Ltd.

Philips: CDM 100W/840 Med ED17P CL ALTP+FB

MasterColor® CDM ED17 Protected

MasterColor CDM 100W/830 Med ED17P CL ALTO+FB

Range of protected, high-efficiency long life ceramic metal halide lamps with a stable color over lifetime and a crisp, sparkling light to be used in open fixtures.

Product data

- Product Data

Product number	233684
Full product name	MasterColor CDM 100W/830 Med ED17P CL ALTO+FB
Short product name	CDM 100W/830 Med ED17P CL ALTO+FB
Pieces per Sku	1
Skus/Case	12
Bar code on pack	046677233686
Bar code on case	50046677233681
Logistics code(s)	928601137601

- General Characteristics

Base	Medium [Single Contact Medium Screw]
Base Information	Brass [Brass Base]
Bulb	ED17P [Protected]
Bulb Material	Hard Glass
Bulb Finish	Clear
Operating Position	Universal [Any or Universal (U)]
Main Application	General Lighting
RatedAvgLife(See Family Notes)	16000 hr

- Electrical Characteristics

Watts	100 W
Lamp Voltage	101 V
Lamp Current	1.1 A
Ignition Time	10 s
Ignition Supply Voltage	235 V
Re-ignition Time [min]	10 min

- Environmental Characteristics

Mercury (Hg) Content	5.8 mg

- Light Technical Characteristics

Color Code	830 [CCT of 3000K]
Color Rendering Index	80 (min), 85 (nom) Ra8
Color Designation	Warm White
Color Temperature	3000 K
Color Temperature technical	2800 (min), 3000 (nom), 3200 (max) K
Chromaticity Coordinate X	.421 (min), .430 (nom), .439 (max) -
Chromaticity Coordinate Y	.386 (min), .392 (nom), .398 (max) -
Initial Lumens	8600 Lm
Luminous Efficacy Lamp	86 Lm/W
Lumen Maintenance 2000h	86 %
Lumen Maintenance 5000h	79 %
Design Mean Lumens	6450 Lm

- UV-related Characteristics

PET (NIOSH)	322 h.klx
Damage Factor D/fc	.201 -

- Product Dimensions

Light Center Length L	3.438 in
Max Overall Length (MOL) - C	5.438 in

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Philips: CDM70/T6/842 and CDM35/T6/842

Philips MasterColor®
Ceramic Metal Halide
4000K Tubular
Single-Ended T6 Lamps

Ideal for retail display lighting, general and indirect lighting, wall washing and fiberoptic systems

CDM/T6	4000K

A compact solution for retail displays

The Philips MasterColor® 4000K Tubular Single-Ended T6 lamp is a compact, energy efficient, ceramic metal halide lamp that provides crisp, sparkling light.

Excellent color
- 84–96 CRI (color rendering index)
- Color stability over life within ± 200K
- Lamp to lamp color consistency over life

Total cost of ownership benefits
- High lamp efficacy (up to 94 LPW)
- Energy-efficient alternative to incandescent/halogen
- Improved lumen maintenance over standard metal halide

Application versatility
- Universal operating position
- Compact lamp dimensions for high beam intensities

FadeBlock™
- Lamps feature integrated UV blocking medium for reduced fading of fabrics and paintings

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Philips MasterColor® Ceramic Metal Halide 4000K Tubular Single-Ended T6 Lamps

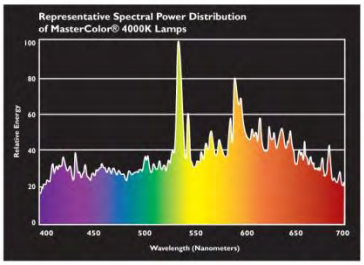
CDM/T6

Ordering Data

Product Number	Ordering Code	Pkg. Qty.	Nom. Watt.	ANSI Ballast Code	Approx. Initial Lumens[1]	Approx. Mean Lumens[2]	CRI
20886-8	CDM35/T6/842	12	39	M130/E	3300	2800	84
28137-8	CDM70/T6/942	12	70	M139/E	6600	4620	92
37369-6	CDM150/T6/942	12	150	M142, M102/E	12,700	8900	96

Electrical and Technical Data

Lamp Operating Volt. (rms)(Nom.)[3] ——— 85 (39W)
88 (70W)
96 (150W)
Initial Lamp Volt. Range (rms)[4] ——— 77-93 (39W)
80-100 (70W)
85-105 (150W)
Lamp Operating
Current (Amps) Nominal (rms) ——— 0.46 (39W)
0.98 (70W)
1.8 (150W)
Lamp Current Crest Factor (Maximum) ——— 1.8
Warm-up to 80% Full Brightness ——— 2 minutes
Restrike Time for Hot Lamps ——— 4–8 minutes
Ballast Open Circuit Voltage ——— 198 RMS Min.
Pulse Peak Volts ——— 3000-4000
Pulse Width @ 90% Peak ——— 2 Micro Sec. Minimum
Pulse Repetition Rate (Minimum)[5] ——— 2 per Half Cycle
Minimum Operating Temp. ——— -30°C (-22°F)



Physical Characteristics

Bulb Size ——— T-6
Bulb Finish ——— Clear
Base ——— G-12 Bi-Pin
Max. Overall Length (MOL) ——— 3 15/16" (39W/70W)
4 1/2" (150W)
Light Center Length (LCL) ——— 2 7/32"
Arc Length ——— 0.2" (5mm)(39W)
0.275" (7mm)(70W)
0.354" (9mm) (150W)
Arc Tube Material ——— Polycrystalline Alumina
Max. Bulb Temp. ——— 500°C (932°F)(39W/70W)
650°C (1202°F) (150W)
Max. Base Temp. ——— 280°C (536°F) (39W/70W)
250°C (482°F)(150W)
Max Bulb to Base Eccentricity ——— 3°
Max. Arc Tube to Base Eccentricity ——— 3°

Operating Characteristics

Rated Average Life, Hours.[6] ——— 6000 (39W)
12,000 (70W/150W)
Correlated Color Temp. (CCT)[2] ——— 4200K
CIE Chromaticity Approx.[2] ——— x-.365, y-.364 (39W)
x-.372 y-.379 (70W)
x-.375 y-.363 (150W)
Efficacy (lpw) ——— 81 (39W)
94 (70W)
85 (150W)

Operating Position

Universal-Enclosed Luminaires Only

Note: Use CDM35T6/842 lamps only on thermally protected electronic ballast.

1) Measured at 100 hrs. life. Approximate lumen values listed are for vertical operation of the lamp.
2) Approximate lumen output at 40% of lamp rated average life.
3) Measured at rated lamp watts on a linear reactor. LPW does not include ballast losses.
4) Measured with the lamp operating at rated watts.
5) Option-Pulse Width @ 90% Peak, 1 micro second minimum with 2 pulses per half cycle.
6) Rated average life is the life obtained, on the average, from large representative groups of lamps in laboratory tests under controlled conditions at 10 or more operating hours per start. It is based on survival of at least 50% of the lamps and allows for individual lamps or groups of lamps to vary considerably from the average.

WARNINGS, CAUTIONS AND OPERATING INSTRUCTIONS for MasterColor® Ceramic Metal Halide Lamps: Single-Ended CDM-T G12, CDM-TC G8.5 (Universal); Double-Ended CDM-TD RX7 (Horizontal ± 45°, Enclosed Fixtures Only)

"WARNING: These lamps can cause serious skin burn and eye inflammation from short wave ultraviolet radiation if outer envelope of the lamp is broken or punctured. Do not use where people will remain for more than a few minutes unless adequate shielding or other safety precautions are used. Certain lamps that will automatically extinguish when the outer envelope is broken or punctured are commercially available." This lamp complies with FDA radiation performance standard 21 CFR subchapter J. (USA:21CFR 1040.30 Canada:SOR/DORS/80-381)

If the outer bulb is broken or punctured, turn off at once and replace the lamp to avoid possible injury from hazardous short wave ultraviolet radiation. Do not scratch the outer bulb or subject it to pressure as this could cause the outer bulb to crack or shatter. A partial vacuum in the outer bulb may cause glass to fly if the envelope is struck.

WARNING: The arc-tube of metal halide lamps are designed to operate under high pressure and at temperatures up to 1000° C and can unexpectedly rupture due to internal or external factors such as a ballast failure or misapplication If the arc-tube ruptures for any reason, the outer bulb may break and pieces of extremely hot glass might be discharged into the surrounding environment. If such a rupture were to happen, **THERE IS A RISK OF PERSONAL INJURY, PROPERTY DAMAGE, BURNS AND FIRE. Certain lamps that will retain all the glass particles should inner arc-tube rupture occur are commercially available from Philips Lighting Company.**

RELAMP FIXTURES AT OR BEFORE THE END OF RATED LIFE. Allowing lamps to operate until they fail is not advised and may increase the possibility of inner arc tube rupture.

This lamp contains an arc tube with a filling gas containing less than 10 nCi of Kr-85 and is distributed by Philips Lighting Company, a division of Philips Electronics North America Corporation, Somerset, New Jersey, 08875.

CAUTION: TO REDUCE THE RISK OF PERSONAL INJURY, PROPERTY DAMAGE, BURNS AND FIRE RESULTING FROM AN ARC-TUBE RUPTURE THE FOLLOWING **LAMP OPERATING INSTRUCTIONS** MUST BE FOLLOWED:

LAMP OPERATING INSTRUCTIONS:

1. RELAMP FIXTURES AT OR BEFORE THE END OF RATED LIFE. Allowing lamps to operate until they fail is not advised and may increase the possibility of inner arc tube rupture.
2. Use only in fully enclosed fixtures capable of withstanding particles of glass having temperatures up to 1000° C. Lens/diffuser material must be heat resistant. Consult fixture manufacturer regarding the suitability of the fixture for this lamp.
3. Do not operate a fixture with a missing or broken lens/diffuser.
4. Operate lamp only within specified limits of operating position.
5. Before lamp installation/replacement, shut power off and allow lamp and fixture to cool to avoid electrical shock and potential burn hazards.
6. Use only auxiliary equipment meeting Philips and/or ANSI standards. Use within voltage limits recommended by ballast manufacturer.
   A. Operate lamp only within specified limits of operation.
   B. For total supply load refer to ballast manufacturers electrical data.
   C. Operate CDM-T (G12 base) lamps only on thermally protected ballasts.
   D. Operate CDM-TC lamps (G8.5 base) only on thermally protected electronic ballasts.
   E. Operate CDM-T (G12 base) 39W/842 lamps only on thermally protected electronic ballasts.
7. Periodically inspect the outer envelope. Replace any lamps that show scratches, cracks or damage.
8. If a lamp bulb support is used, be sure to insulate the support electrically to avoid possible decomposition of the bulb glass.
9. Protect lamp base, socket and wiring against moisture, corrosive atmospheres and excessive heat.
10. Time should be allowed for lamps to stabilize in color when turned on for the first time. This may require several hours of operation, with more than one start. Lamp color is also subject to change under conditions of excess vibration or shock and color appearance may vary between individual lamps.
11. Lamps may require 4 to 8 minutes to re-light if there is a power interruption.
12. Take care in handling and disposing of lamps. If an arc tube is broken, avoid skin contact with any of the contents or fragments.

Specifications are subject to change without notice.
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Philips: CDM210/T9/930/U/E

MasterColor® CDM
Elite MW System

Ideal for architectural facade lighting, illumination of pedestrian areas, indoor retail outlets, warehouses, manufacturing facilities

MasterColor® CDM

The next generation of white light

MasterColor® CDM Elite MW. The medium wattage CDM lighting system that gives superior, long-lasting white light for both indoor and outdoor use.

Light quality
- Excellent color rendering of CRI 90+
- Crisp, white light in 3000K and 4200K
- Stable color performance over entire life
- New socket design provides higher optical efficiency

Philips "Green Flagship Product"
- Low mercury, no lead
- Up to 120 lm/w
- Efficient electronic ballast that uses less energy than magnetic options
- 93% ballast efficacy

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MasterColor® CDM Elite MW

Ordering, Electrical and Technical Data (Subject to change without notice)

Product Number	Lamp Ordering Code	Nom. Watts	ANSI Code	Approx. Initial Lumens[1]	Approx. Mean Lumens[2]	Efficacy (lm/w)	Color Temp. (Kelvin)	CRI	Burn Position	Rated Avg. Life (Hrs.)[3]	Lumen Maint. 20khr (%)
22062-4	CDM Elite MW 210/T9/930/U/E	210	C183/E	24,200	22,100	115	3000	90+	Universal	24,000	80
21831-3	CDM Elite MW 315/T9/930/U/E	315	C182/E	37,800	34,700	120	3000	90+	Universal	30,000	80
22063-2	CDM Elite MW 210/T9/942/U/E	210	C183/E	23,100	20,800	110	4200	90+	Universal	20,000	80
22064-0	CDM Elite MW 315/T9/942/U/E	315	C182/E	36,200	32,600	115	4200	90+	Universal	24,000	80
23806-3	CDM Elite MW 210/T9/930/U/O	210	C183/O	23,100	20,700	110	3000	90+	Universal	20,000	80
23807-1	CDM Elite MW 315/T9/930/U/O	315	C182/O	36,200	32,500	115	3000	90+	Universal	20,000	80
23808-9	CDM Elite MW 210/T9/942/U/O	210	C183/O	22,100	19,900	105	4200	90+	Universal	20,000	80
23809-7	CDM Elite MW 315/T9/942/U/O	315	C182/O	34,700	31,200	110	4200	90+	Universal	20,000	80

All lamps are dimmable to 50% power (0-10V).

Product Number	Ballast Ordering Code	Input Voltage Range	Input Current Max. Operating	Power Factor	Peak Ignition Voltage	Normal Ballast Size Housing (mm)	Case Material	Ballast Weight	Ballast to Lamp Distance (max)[4]
IZTMH210315RLF	Elite MW 210W	200–277V	1.2 @ 208V, 0.9 @ 277V	>0.90	3.5 kV	208 x 124 x 56	Metal case with flying leads	4.3 lb	30 (1nF max load)
IZTMH210315RLF	Elite MW 315W	200–277V	1.8 @ 208V, 1.3 @ 277V	>0.90	3.5 kV	208 x 124 x 56	Metal case with flying leads	4.3 lb	30 (1nF max load)

1) Measured at 100 hours of life in a vertical operating position. Measured at rated lamp watts on electronic ballast. Lumens per watt does not include ballast losses.

2) Approximate lumen output at 40% of lamp rated average life.

3) Rated average life is obtained at 50% survival rate. All MasterColor® CDM Elite MW ceramic metal halide lamps are designed for 30,000 hours. Based on data available at this time, the current rated average life is as published. Contact your sales representative for new updates.

4) 30ft w/ typical 18 gauge 1kV wire recommended.

WARNINGS, CAUTIONS, AND OPERATING INSTRUCTIONS FOR MASTERCOLOR® CDM ELITE MEDIUM WATT CERAMIC METAL HALIDE TUBULAR SINGLE-ENDED LAMPS

WARNING: These lamps can cause serious skin burn and eye inflammation from short wave ultraviolet radiation if outer envelope of the lamp is broken or punctured. Do not use where people will remain for more than a few minutes unless adequate shielding or other safety precautions are used. Certain lamps that will automatically extinguish when the outer envelope is broken or punctured are commercially available." This lamp complies with FDA radiation performance standard 21 CFR subchapter J. (USA: 21 CFR 1040.30 CanadaSOR/DORS/80-381)

If the outer bulb is broken or punctured, turn off at once and replace the lamp to avoid possible injury from hazardous short wave ultraviolet radiation. Do not scratch the outer bulb or subject it to pressure as this could cause the outer bulb to crack or shatter. A partial vacuum in the outer bulb may cause glass to fly if the envelope is struck.

WARNING: The arc-tube of metal halide lamps are designed to operate under high pressure and at temperatures up to 1000° C and can unexpectedly rupture due to internal or external factors such as a ballast failure or misapplication. If the arc-tube ruptures for any reason, the outer bulb may break and pieces of extremely hot glass might be discharged into the surrounding environment. If such a rupture were to happen, THERE IS A RISK OF PERSONAL INJURY, PROPERTY DAMAGE, BURNS AND FIRE.

RELAMP FIXTURES AT OR BEFORE THE END OF RATED LIFE. Allowing lamps to operate until they fail is not advised and may increase the possibility of inner arc tube rupture. This lamp contains an arc tube with a filling gas containing less than 30 nCi of Kr-85 and is distributed by Philips Lighting Company, a division of Philips Electronics North American Corporation.

CAUTION: TO REDUCE THE RISK OF PERSONAL INJURY, PROPERTY DAMAGE, BURNS AND FIRE RESULTING FROM AN ARC-TUBE RUPTURE THE FOLLOWING LAMP OPERATING INSTRUCTIONS MUST BE FOLLOWED:

LAMP OPERATING INSTRUCTIONS:

1. Relamp fixtures at or before the end of rated life. Allowing lamps to operate until they fail is not advised and may increase the possibility of inner arc tube rupture.
2. If the lamp is marked on the base with /E, use only in enclosed fixture capable of withstanding particles of glass having temperatures up to 1000°C. If the lamp is marked on the base with /O, lamp should retain all the glass particles should inner arc tube rupture occur.
3. Before lamp installation/replacement, shut power off and allow lamp and fixture to cool to avoid electrical shock and potential burn hazards.
4. Use only auxiliary equipment meeting Philips and/or ANSI standards. Use within voltage limits recommended by ballast manufacturer:
   A. Operate lamp only within specified limits of operation.
   B. For total supply load refer to ballast manufacturers electrical data.
   C. All Pulse Start lamps require a socket rated to withstand a 4,000 volt pulse
5. Periodically inspect the outer envelope. Replace any lamps that show scratches, cracks or damage.
6. If a lamp bulb support is used, be sure to insulate the support electrically to avoid possible decomposition of the bulb glass.
7. Protect lamp base, socket and wiring against moisture, corrosive atmospheres and excessive heat.
8. Time should be allowed for lamps to stabilize in color when turned on for the first time. This may require several hours of operation, with more than one start. Lamp color is also subject to change under conditions of excess vibration or shock, and color appearance may vary between individual lamps.
9. Lamps may require 10 minutes to re-light if there is a power interruption.
10. Take care in handling and disposing of lamps. If an arc tube is broken, avoid skin contact with any of the contents or fragments.
11. Use this lamp only in fixtures that contain a Pulse Start metal halide ballast and are specifically designed for use with Pulse Start metal halide lamps.

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Appendix K: Ballast Data

Philips: IZT-3S32-SC

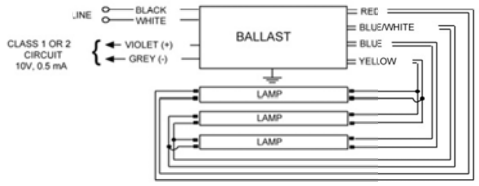
PHILIPS ADVANCE

IZT-3S32-SC@277V	
Brand Name	MARK 7 0-10V
Ballast Type	Electronic Dimming
Starting Method	Programmed Start
Lamp Connection	Series
Input Voltage	120-277
Input Frequency	50/60 HZ
Status	Active

Electrical Specifications

Lamp Type	Num. of Lamps	Rated Lamp Watts	Min. Start Temp (°F/C)	Input Current (Amps)	Input Power (Watts) (min/max)	Ballast Factor (mir/max)	MAX THD %	Power Factor	Lamp Current Crest Factor	B.E.F.
F17T8	3	17	50/10	0.20	16/54	0.03/1.00	10	0.99	1.7	1.85
F25T8	3	25	50/10	0.28	16/76	0.03/1.00	10	0.99	1.7	1.32
* F32T8	3	32	50/10	0.34	18/93	0.03/1.00	10	0.99	1.7	1.08

Wiring Diagram



Diag. 57A

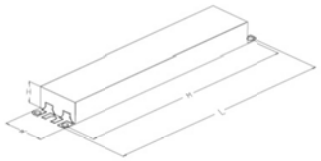
The wiring diagram that appears above is for the lamp type denoted by the asterisk (*)

Standard Lead Length (inches)

	in.	cm.
Black	22	55.9
White	22	55.9
Blue	26	66
Red	46	116.8
Yellow	26	66
Gray	36	91.4
Violet	36	91.4

	in.	cm.
Yellow/Blue		0
Blue/White	46	116.8
Brown		0
Orange		0
Orange/Black		0
Black/White		0
Red/White		0

Enclosure



Enclosure Dimensions

OverAll (L)	Width (W)	Height (H)	Mounting (M)
9.50 "	1.7 "	1.18 "	8.90 "
9 1/2	1 7/10	1 9/50	8 9/10
24.1 cm	4.3 cm	3 cm	22.6 cm

Revised 05/27/2004

Data is based upon tests performed by Philips Lighting Electronics N.A. in a controlled environment and is representative of relative performance. Actual performance can vary depending on operating conditions. Specifications are subject to change without notice. All specifications are nominal unless otherwise noted.

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Customer Support/Technical Service: 800-372-3331 · OEM Support: 866-915-5886

Philips: ICN-2P32-N

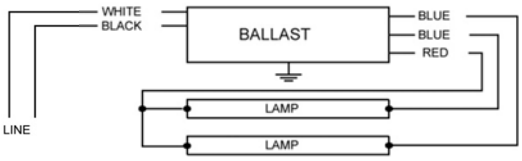
PHILIPS ADVANCE

ICN-2P32-N @ 277V	
Brand Name	CENTIUM
Ballast Type	Electronic
Starting Method	Instant Start
Lamp Connection	Parallel
Input Voltage	120-277
Input Frequency	50/60 HZ
Status	Active

Electrical Specifications

Lamp Type	Num. of Lamps	Rated Lamp Watts	Min. Start Temp (°F/C)	Input Current (Amps)	Input Power (ANSI Watts)	Ballast Factor	MAX THD %	Power Factor	MAX Lamp Current Crest Factor	B.E.F.
* F32T8	1	32	0/-18	0.13	35	1.05	10	0.99	1.6	2.92
F32T8	2	32	0/-18	0.22	55	0.89	10	0.99	1.6	1.59

Wiring Diagram



Diag. 64-A

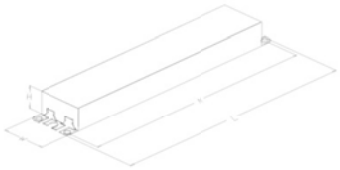
The wiring diagram that appears above is for the lamp type denoted by the asterisk (*)

Standard Lead Length (inches)

	in.	cm.
Black	28	71.1
White	45	114.3
Blue	24	61
Red	24	61
Yellow		0
Gray		0
Violet		0

	in.	cm.
Yellow/Blue		0
Blue/White		0
Brown		0
Orange		0
Orange/Black		0
Black/White		0
Red/White		0

Enclosure



Enclosure Dimensions

OverAll (L)	Width (W)	Height (H)	Mounting (M)
9.5 "	1.3 "	1.0 "	8.9 "
9 1/2	1 3/10	1	8 9/10
24.1 cm	3.3 cm	2.5 cm	22.6 cm

Revised 04/08/2009

Data is based upon tests performed by Philips Lighting Electronics N.A. in a controlled environment and is representative of relative performance. Actual performance can vary depending on operating conditions. Specifications are subject to change without notice. All specifications are nominal unless otherwise noted.

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PHILIPS ADVANCE

ICN-2P32-N @ 277V	
Brand Name	CENTIUM
Ballast Type	Electronic
Starting Method	Instant Start
Lamp Connection	Parallel
Input Voltage	120-277
Input Frequency	50/60 HZ
Status	Active

Electrical Specifications

Notes:

Section I - Physical Characteristics

1.1 Ballast shall be physically interchangeable with standard electromagnetic or standard electronic ballasts, where applicable.

1.2 Ballast shall be provided with integral leads color-coded per ANSI C82.11.

Section II - Performance Requirements

2.1 Ballast shall be _____ (Instant, Rapid or Programmed) Start.

2.2 Ballast shall provide Independent Lamp Operation (ILO) for Instant Start ballasts allowing remaining lamp(s) to maintain full light output when one or more lamps fail.

2.3 Ballast shall contain auto restart circuitry in order to restart lamps without resetting power (except T8/HO and FT5 ballasts).

2.4 Ballast shall operate from 60 Hz input source of 120V, 277V or 347V as applicable with sustained variations of +/- 10% (voltage and frequency). IntelliVolt models shall operate from 50/60 Hz input source of 120V through 277V with sustained variations of +/- 10% (voltage and frequency).

2.5 Ballast shall be high frequency electronic type and operate lamps at a frequency above 42 kHz ("GCN" models between 20 kHz and 30kHz) to avoid interference with infrared devices and eliminate visible flicker.

2.6 Ballast shall have a Power Factor greater than 0.98 for primary lamp.

2.7 Ballast shall have a minimum ballast factor for primary lamp application as follows: 0.75 for Low Watt, 0.85 for Normal Light Output and 1.20 for High Light.

2.8 Ballast shall provide for a Lamp Current Crest Factor of 1.7 or less.

2.9 Ballast input current shall have Total Harmonic Distortion (THD) of less than 20% for Standard models and THD of less than 10% for Centium models when operated at nominal line voltage with primary lamp.

2.10 Ballast shall have a Class A sound rating for all 4-foot lamps and smaller.

2.11 Ballast shall have a minimum starting temperature of _____ [-18C (0F) for standard T8 and Long Twin Tube lamps, 10C (50F) for standard T12 lamps, 0C (32F) for Slimline T8 lamps and "GCN" models, -29C (-20F) for T8/HO lamps,] for primary lamp application. Ballast shall have a minimum starting temperature of 60F (16C) for energy-saving lamps.

2.12 Ballast shall tolerate sustained open circuit and short circuit output conditions.

2.13 ICN models shall have lamp striation reduction feature.

Section III - Regulatory Requirements

3.1 Ballast shall not contain any Polychlorinated Biphenyl (PCB).

3.2 Ballast shall be Underwriters Laboratories (UL) listed, Class P and Type 1 Outdoor; and Canadian Standards Association (CSA) certified where applicable.

3.3 Ballast shall comply with ANSI C62.41 Category A for Transient protection.

3.4 Ballast shall comply with ANSI C82.11 where applicable.

3.5 Ballast shall comply with the requirements of the Federal Communications Commission (FCC) rules and regulations, Title 47 CFR part 18, Non-Consumer (Class A) for EMI/RFI (conducted and radiated).

3.6 Ballast shall comply with NEMA 410 for in-rush current limits.

3.7 ICN models shall meet NEMA Premium/CEE requirements for Super T8 rebates

3.8 Ballast shall meet RoHS Compliance Standards

Section IV - Other

4.1 Ballast shall be manufactured in a factory certified to ISO 9001 Quality System Standards.

4.2 Ballast shall carry a five-year warranty from date of manufacture against defects in material or workmanship, including replacement, for operation at a maximum case temperature of 70C.

4.3 Manufacturer shall have a twenty-year history of producing electronic ballasts for the North American market.

Note: Energy saving T8 lamps (25W, 28W or 30W) may experience lamp striations if operated on ballasts not rated for their use.

Revised 04/08/2009

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Tel: 800-322-2086 · Fax: 888-423-1882 · www.philips.com/advance
Customer Support/Technical Service: 800-372-3331 · OEM Support: 866-915-5886

Philips: ICN-3P32-SC

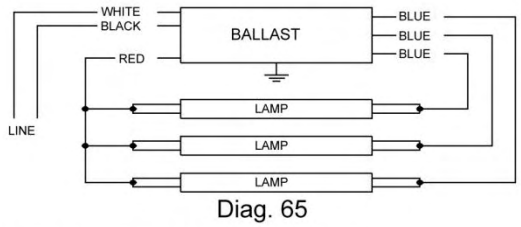
PHILIPS
ADVANCE

ICN-3P32-SC@277V	
Brand Name	CENTIUM
Ballast Type	Electronic
Starting Method	Instant Start
Lamp Connection	Parallel
Input Voltage	120-277
Input Frequency	50/60 HZ
Status	Active

Electrical Specifications

Lamp Type	Num. of Lamps	Rated Lamp Watts	Min. Start Temp (°F/C)	Input Current (Amps)	Input Power (ANSI Watts)	Ballast Factor	MAX THD %	Power Factor	MAX Lamp Current Crest Factor	B.E.F.
F32T8	2	32	0/-18	0.24	65	1.01	10	0.98	1.7	1.55
* F32T8	3	32	0/-18	0.31	84	0.88	10	0.99	1.7	1.05

Wiring Diagram



Diag. 65

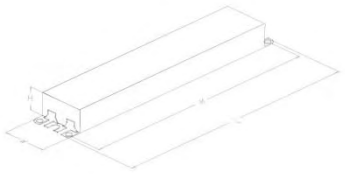
The wiring diagram that appears above is for the lamp type denoted by the asterisk (*)

Standard Lead Length (inches)

	in.	cm.
Black	25.0	
White	25.0	
Blue	31.0	
Red	37.0	
Yellow		
Gray		
Violet		

	in.	cm.
Yellow/Blue		
Blue/White		
Brown		
Orange		
Orange/Black		
Black/White		
Red/White		

Enclosure



Enclosure Dimensions

OverAll (L)	Width (W)	Height (H)	Mounting (M)
9.50 "	1.7 "	1.18 "	8.90 "
9 1/2	1 7/10	1 9/50	8 9/10
24.1 cm	4.3 cm	3 cm	22.6 cm

Revised 04/08/2009

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PHILIPS
ADVANCE

ICN-3P32-SC@277V	
Brand Name	CENTIUM
Ballast Type	Electronic
Starting Method	Instant Start
Lamp Connection	Parallel
Input Voltage	120-277
Input Frequency	50/60 HZ
Status	Active

Electrical Specifications

Notes:

Section I - Physical Characteristics

1.1 Ballast shall be physically interchangeable with standard electromagnetic or standard electronic ballasts, where applicable.

1.2 Ballast shall be provided with integral leads color-coded per ANSI C82.11.

Section II - Performance Requirements

2.1 Ballast shall be _____ (Instant, Rapid or Programmed) Start.

2.2 Ballast shall provide Independent Lamp Operation (ILO) for Instant Start ballasts allowing remaining lamp(s) to maintain full light output when one or more lamps fail.

2.3 Ballast shall contain auto restart circuitry in order to restart lamps without resetting power (except T8/HO and FT5 ballasts).

2.4 Ballast shall operate from 60 Hz input source of 120V, 277V or 347V as applicable with sustained variations of +/- 10% (voltage and frequency). IntelliVolt models shall operate from 50/60 Hz input source of 120V through 277V with sustained variations of +/- 10% (voltage and frequency).

2.5 Ballast shall be high frequency electronic type and operate lamps at a frequency above 42 kHz ("GCN" models between 20 kHz and 30kHz) to avoid interference with infrared devices and eliminate visible flicker.

2.6 Ballast shall have a Power Factor greater than 0.98 for primary lamp.

2.7 Ballast shall have a minimum ballast factor for primary lamp application as follows: 0.75 for Low Watt, 0.85 for Normal Light Output and 1.20 for High Light.

2.8 Ballast shall provide for a Lamp Current Crest Factor of 1.7 or less.

2.9 Ballast input current shall have Total Harmonic Distortion (THD) of less than 20% for Standard models and THD of less than 10% for Centium models when operated at nominal line voltage with primary lamp.

2.10 Ballast shall have a Class A sound rating for all 4-foot lamps and smaller.

2.11 Ballast shall have a minimum starting temperature of _____ [-18C (0F) for standard T8 and Long Twin Tube lamps, 10C (50F) for standard T12 lamps, 0C (32F) for Slimline T8 lamps and "GCN" models, -29C (-20F) for T8/HO lamps,] for primary lamp application. Ballast shall have a minimum starting temperature of 60F (16C) for energy-saving lamps.

2.12 Ballast shall tolerate sustained open circuit and short circuit output conditions.

2.13 ICN models shall have lamp striation reduction feature.

Section III - Regulatory Requirements

3.1 Ballast shall not contain any Polychlorinated Biphenyl (PCB).

3.2 Ballast shall be Underwriters Laboratories (UL) listed, Class P and Type 1 Outdoor; and Canadian Standards Association (CSA) certified where applicable.

3.3 Ballast shall comply with ANSI C62.41 Category A for Transient protection.

3.4 Ballast shall comply with ANSI C82.11 where applicable.

3.5 Ballast shall comply with the requirements of the Federal Communications Commission (FCC) rules and regulations, Title 47 CFR part 18, Non-Consumer (Class A) for EMI/RFI (conducted and radiated).

3.6 Ballast shall comply with NEMA 410 for in-rush current limits.

3.7 ICN models shall meet NEMA Premium/CEE requirements for Super T8 rebates

3.8 Ballast shall meet RoHS Compliance Standards

Section IV - Other

4.1 Ballast shall be manufactured in a factory certified to ISO 9001 Quality System Standards.

4.2 Ballast shall carry a five-year warranty from date of manufacture against defects in material or workmanship, including replacement, for operation at a maximum case temperature of 70C.

4.3 Manufacturer shall have a twenty-year history of producing electronic ballasts for the North American market.

Note: Energy saving T8 lamps (25W, 28W or 30W) may experience lamp striations if operated on ballasts not rated for their use.

Revised 04/08/2009

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Lutron: ICN-2S28-N

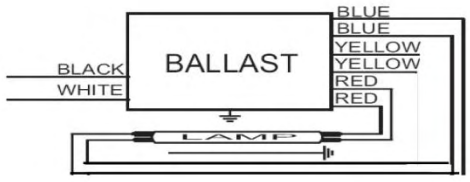
PHILIPS ADVANCE

ICN-2S28-N@277	
Brand Name	CENTIUM T5
Ballast Type	Electronic
Starting Method	Programmed Start
Lamp Connection	Series
Input Voltage	120-277
Input Frequency	50/60 HZ
Status	Active

Electrical Specifications

Lamp Type	Num. of Lamps	Rated Lamp Watts	Min. Start Temp (°F/C)	Input Current (Amps)	Input Power (ANSI Watts)	Ballast Factor	MAX THD %	Power Factor	MAX Lamp Current Crest Factor	B.E.F.
F14T5	1	14	0/-18	0.07	17	1.07	10	0.98	1.7	6.29
F14T5	2	14	0/-18	0.13	33	1.04	10	0.98	1.7	3.15
* F21T5	1	21	0/-18	0.10	25	1.06	10	0.98	1.7	4.24
F21T5	2	21	0/-18	0.17	49	1.02	10	0.98	1.7	2.08
F28T5	1	28	0/-18	0.12	31	1.05	10	0.98	1.7	3.39
F28T5	2	28	0/-18	0.23	61	1.00	10	0.98	1.7	1.64
F28T5/ES (25W)	1	25	32/00	0.11	30	1.00	10	0.98	1.7	3.33
F28T5/ES (25W)	2	25	32/00	0.21	57	1.00	10	0.98	1.7	1.75

Wiring Diagram



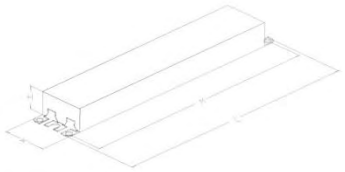
The wiring diagram that appears above is for the lamp type denoted by the asterisk (*)

Standard Lead Length (inches)

	in.	cm.
Black	23	58.4
White	23	58.4
Blue	27	68.6
Red	27	68.6
Yellow	42	106.7
Gray		0
Violet		0

	in.	cm.
Yellow/Blue		0
Blue/White		0
Brown		0
Orange		0
Orange/Black		0
Black/White		0
Red/White		0

Enclosure



Enclosure Dimensions

OverAll (L)	Width (W)	Height (H)	Mounting (M)
9.5 "	1.3 "	1.0 "	8.9 "
9 1/2	1 3/10	1	8 9/10
24.1 cm	3.3 cm	2.5 cm	22.6 cm

Revised 09/07/2010

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PHILIPS ADVANCE

ICN-2S28-N@277	
Brand Name	CENTIUM T5
Ballast Type	Electronic
Starting Method	Programmed Start
Lamp Connection	Series
Input Voltage	120-277
Input Frequency	50/60 HZ
Status	Active

Electrical Specifications

Notes:

Section I - Physical Characteristics

1.1 Ballast shall be physically interchangeable with standard electromagnetic or standard electronic ballasts, where applicable.

1.2 Ballast shall be provided with integral leads or poke-in wire trap connectors color-coded per ANSI C82.11.

Section II - Performance Requirements

2.1 Ballast shall be Programmed Start.

2.2 Ballast shall contain auto restart circuitry in order to restart lamps without resetting power.

2.3 Ballast shall operate from 50/60 Hz input source of _____ (120V through 277V or 347V through 480V) with sustained variations of +/- 10% (voltage and frequency).

2.4 Ballast shall be high frequency electronic type and operate lamps at a frequency above 42 kHz to avoid interference with infrared devices and eliminate visible flicker.

2.5 Ballast shall have a Power Factor greater than 0.98 for primary lamp.

2.6 Ballast shall have a minimum ballast factor of 1.00 for primary lamp application.

2.7 Ballast shall provide for a Lamp Current Crest Factor of 1.7 or less.

2.8 Ballast input current shall have Total Harmonic Distortion (THD) of less than 20% for Standard models and THD of less than 10% for Centium models when operated at nominal line voltage with primary lamp.

2.9 Ballast shall have a Class A sound rating.

2.10 Ballast shall have a minimum starting temperature of _____ {-18C (0F) or -28C (-20F)} for primary lamp. Consult lamp manufacturer for temperature versus light output characteristics.

2.11 Ballast shall provide Lamp EOL Protection Circuit.

2.12 Ballast shall tolerate sustained open circuit and short circuit output conditions.

2.13 Four-lamp ballast shall have (semi-independent or independent) lamp operation.

Section III - Regulatory Requirements

3.1 Ballast shall not contain any Polychlorinated Biphenyl (PCB).

3.2 Ballast shall be Underwriters Laboratories (UL) listed, Class P and Type 1 Outdoor; and Canadian Standards Association (CSA) certified where applicable.

3.3 Ballast shall comply with ANSI C62.41 Category A for Transient protection.

3.4 Ballast shall comply with ANSI C82.11 where applicable.

3.5 Ballast shall comply with the requirements of the Federal Communications Commission (FCC) rules and regulations, Title 47 CFR part 18, Non-Consumer (Class A) for EMI/RFI (conducted and radiated).

3.6 Ballast shall comply with UL Type CC rating.

3.7 Ballast shall comply with NEMA 410 for in-rush current limits.

Section IV - Other

4.1 Ballast shall be manufactured in a factory certified to ISO 9001 Quality System Standards.

4.2 Ballast shall carry a five-year warranty from date of manufacture against defects in material or workmanship, including replacement, for operation at a maximum case temperature of 70C. Ballasts with a "90C" designation in their catalog number shall also carry a three-year warranty at a maximum case temperature of 90C.

4.3 Manufacturer shall have a twenty-year history of producing electronic ballasts for the North American market.

Revised 09/07/2010

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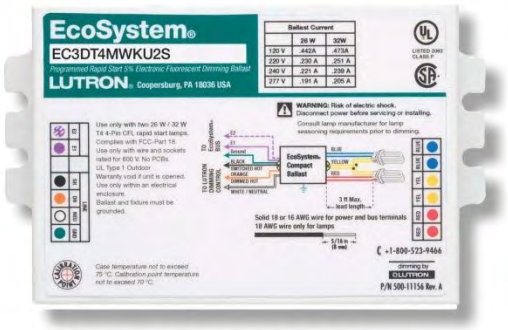
Lutron: EC5-T832-G-UNV-317L

EcoSystem® Compact Fluorescent Ballasts Digital Dimming Ballasts

369-339 B 10.20.10 1

EcoSystem Digital Ballasts

EcoSystem compact ballasts provide high-performance dimming for any compact fluorescent application, including within an *EcoSystem* Lighting Control System. *EcoSystem* compact ballasts offer 100% to 5% dimming, providing both energy savings and lighting flexibility.



EcoSystem ballast case type K

Features

- Continuous, flicker-free dimming from 100% to 5%
- Compatible with *EcoSystem* Digital Bus control, GRAFIK Eye® QS Control Unit, and Quantum® software, allowing for integration into an existing/planned *EcoSystem* Lighting Control System.
- Supports standard 3-wire line-voltage phase control technology.
- Programmed rapid start design ensures full-rated lamp life while dimming and cycling.
- Lamps turn on to any dimmed level without flashing to full brightness.
- Low harmonic distortion throughout the entire dimming range.
- Frequency of operation ensures that ballast does not interfere with infrared devices.
- Inrush current limiting circuitry eliminates circuit breaker tripping, switch arcing, and relay failure.
- Ultra-quiet operation.
- Protected from miswires of any input power to control lead, or from lamp leads to each other and/or ground.
- End-of-lamp-life protection circuitry ensures safe operation throughout entire lamp life
- Nonvolatile memory restores all ballast settings after power failure
- 100% performance tested at factory.
- 5-year limited warranty with *Lutron* field service commissioning (3-year standard warranty) from date of purchase. For additional Warranty information, please visit http://www.lutron.com/ResourceLibrary/warranty/Limited%20Comm.pdf

LUTRON® SPECIFICATION SUBMITTAL Page 1

Job Name:	Model Numbers:	
Millennium Science Complex	EC3DT4MWKU1S	
Job Number: Building Stimulus		

Specifications

Standards

- UL Listed (evaluated to the requirements of UL935)
- UL Type 1 Outdoor for damp locations
- CSA Certified (evaluated to the requirements of C22.2 No. 74)
- Class P thermally protected
- Meets ANSI C82.11 High Frequency Ballast Standard
- Meets FCC Part 18 Non-Consumer requirements for EMI/RFI emissions
- Meets ANSI C62.41 Category A surge protection standards up to and including 4 kV
- Manufacturing facilities employ ESD reduction practices that comply with the requirements of ANSI/ESD S20.20
- Lutron Quality Systems registered to ISO 9001.2000

Performance

- Operating Voltage: 120, 220/240, 277 V~ at 50 or 60 Hz
- Grounding: ballast and fixture must be grounded for proper dimming
- Dimming Range: 100% to 5% measured relative light output
- Lamp Starting: programmed rapid start
- Lamp Current Crest Factor: less than 1.7
- Light Output Variation: Constant ±2% light output for line voltage variations of ±10%
- Lamp Life: Average lamp life meets or exceeds specified lamp ratings
- Power Factor: 0.95 minimum
- Total Harmonic Distortion (THD): Less than 10%
- Inaudible in a 27 dBA ambient
- Maximum Inrush Current: 3 A per ballast at 277 V~, 7A per ballast at 120 V~
- Standby power: Less than 1 W

Environment

- Minimum lamp starting temperature: 50 °F (10 °C)
- Relative humidity: less than 90% non-condensing
- Sound Rating: inaudible in a 27 dB ambient
- Maximum ballast case temperature: 167 °F (75 °C)

Ballast Wiring & Mounting

- Ballast is grounded by the specified terminal or by a mounting screw to the fixture
- Terminal blocks on the ballast accept the following wire gauges:
  Power Wiring and *EcoSystem* Bus:
  one 16 AWG (1.31 mm^2) or 18 AWG (0.82 mm^2) solid per terminal
  Lamp Wiring:
  one 16 AWG (1.31 mm^2) or 18 AWG (0.82 mm^2) solid per terminal
- Only one wire per terminal
- Ballast mounts using two mounting tabs or studs within a fluorescent fixture
- Wiring from the ballast to lamp sockets shall not exceed 3 ft (.91 m) for T4 compact lamps
- Ballast does not have sensor terminals

Lamp Seasoning

Refer to lamp manufacturer for lamp seasoning requirements prior to dimming

Job Name:	Model Numbers:	
Millennium Science Complex	EC3DT4MWKU1S	
Job Number: Building Stimulus		

EcoSystem Compact Fluorescent Ballast Models

Lamp Type	Lamp Watts	No. of Lamps	Model	Case Size	Input Voltage (VAC)	Input Current (A)	Input Power (W)	Ballast Factor (BF)	System Lumens (lm)	System Efficacy (lm/W)	Ballast Efficacy Factor	Relative Efficacy (RSE)
T4 4-Pin Quad-Tube or Triple-Tube	18 W	1	EC3DT418KU1S (Studded) EC3DT418KU1 (Non-studded)	K	120	0.18	21.3	0.95	1140	53.5	4.46	0.80
				K	220	0.10	21.1	0.95	1140	54.0	4.50	0.81
				K	240	0.09	21.4	0.95	1140	53.3	4.44	0.80
				K	277	0.08	20.8	0.95	1140	54.8	4.57	0.82
		2	EC3DT418KU2S (Studded) EC3DT418KU2 (Non-studded)	K	120	0.34	41.1	0.95	2280	55.5	2.31	0.83
				K	220	0.18	39.6	0.95	2280	57.6	2.40	0.86
				K	240	0.17	39.4	0.95	2280	57.9	2.41	0.87
				K	277	0.15	39.9	0.95	2280	57.1	2.38	0.86
	26 W	1	EC3DT4MWKU1S (Studded) EC3DT4MWKU1 (Non-studded)	K	120	0.22	26.4	0.95	1710	64.8	3.60	0.94
				K	220	0.12	26.8	0.95	1710	63.9	3.55	0.92
				K	240	0.11	26.9	0.95	1710	63.7	3.54	0.92
				K	277	0.10	27.0	0.95	1710	63.4	3.52	0.92
		2	EC3DT4MWKU2S (Studded) EC3DT4MWKU2 (Non-studded)	K	120	0.43	51.6	0.95	3420	66.3	1.84	0.96
				K	220	0.23	49.9	0.95	3420	68.5	1.90	0.99
				K	240	0.21	50.6	0.95	3420	67.5	1.88	0.98
				K	277	0.19	51.4	0.95	3420	66.6	1.85	0.96
T4 4-Pin Triple-Tube	32 W	1	EC3DT4MWKU1S (Studded) EC3DT4MWKU1 (Non-studded)	K	120	0.29	34.8	0.95	2280	65.5	2.73	0.87
				K	220	0.15	33.0	0.95	2280	69.1	2.88	0.92
				K	240	0.14	33.6	0.95	2280	67.9	2.83	0.90
				K	277	0.12	33.2	0.95	2280	68.6	2.86	0.91
		2	EC3DT4MWKU2S (Studded) EC3DT4MWKU2 (Non-studded)	K	120	0.55	66.0	0.95	4560	69.1	1.44	0.92
				K	220	0.29	64.5	0.95	4560	70.7	1.47	0.94
				K	240	0.26	63.0	0.95	4560	72.3	1.51	0.96
				K	277	0.24	65.5	0.95	4560	69.7	1.45	0.93
	42 W	1	EC3DT442KU1S (Studded) EC3DT442KU1 (Non-studded)	K	120	0.36	43.2	0.95	3040	70.4	2.20	0.92
				K	220	0.20	42.9	0.95	3040	70.8	2.21	0.93
				K	240	0.18	42.7	0.95	3040	71.2	2.23	0.93
				K	277	0.15	42.6	0.95	3040	71.3	2.23	0.94
		2	EC3DT442KU2S (Studded) EC3DT442KU2 (Non-studded)	K	120	0.73	87.6	0.95	6080	69.4	1.08	0.91
				K	220	0.39	85.9	0.95	6080	70.8	1.11	0.93
				K	240	0.35	85.1	0.95	6080	71.5	1.12	0.94
				K	277	0.31	85.4	0.95	6080	71.2	1.11	0.93

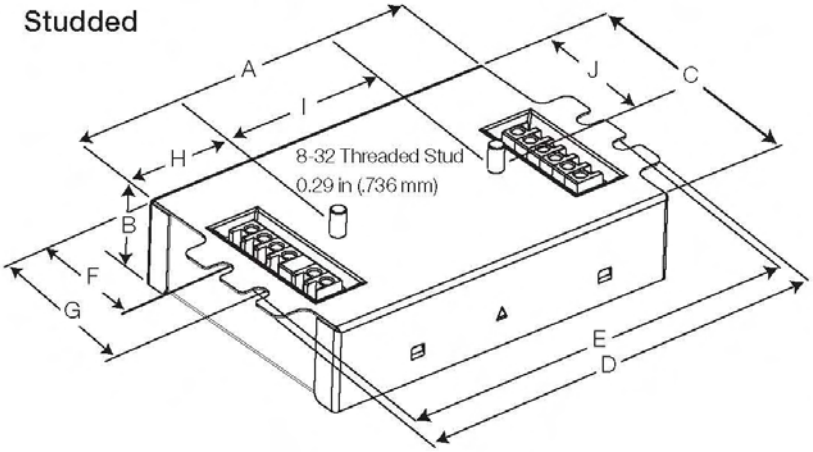
NOTE: The "S" at the end of the ballast model number indicates a studded option. Remove the "S" for a non-studded ballast.

LUTRON® SPECIFICATION SUBMITTAL Page 3

Job Name:	Model Numbers:	
Millennium Science Complex	EC3DT4MWKU1S	
Job Number: Building Stimulus		

EcoSystem Compact Fluorescent Ballast Case Dimensions

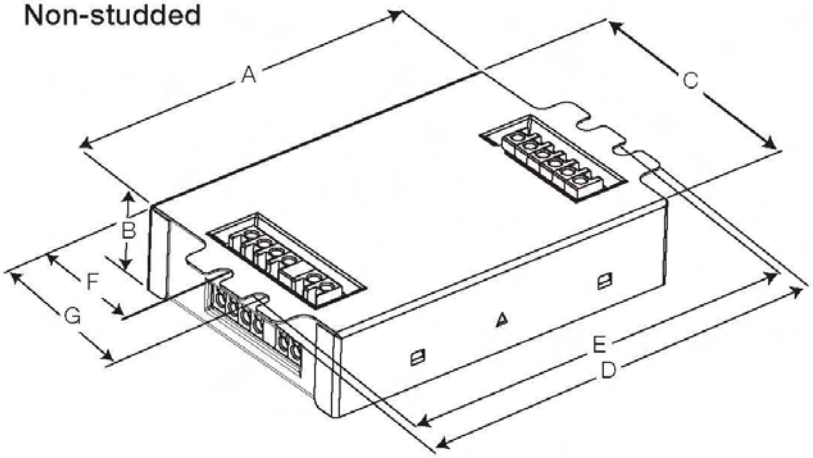
Studded



A	4.20 in (107 mm)
B	1.00 in (25 mm)
C	3.00 in (76 mm)
D	4.90 in (124 mm)
E	4.60 in (117 mm) (mounting centers)
F	1.42 in (36 mm)
G	1.99 in (51 mm)
H	1.09 in (28 mm)
I	2.00 in (51 mm)
J	1.60 in (41 mm)

NOTE: Studded version does not have side connectors.

Non-studded



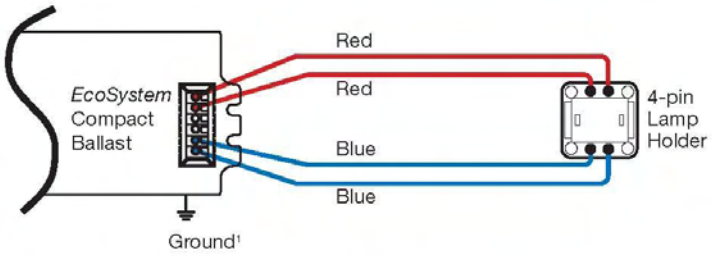
A	4.20 in (107 mm)
B	1.00 in (25 mm)
C	3.00 in (76 mm)
D	4.90 in (124 mm)
E	4.60 in (117 mm) (mounting centers)
F	1.42 in (36 mm)
G	1.99 in (51 mm)

LUTRON® SPECIFICATION SUBMITTAL Page 4

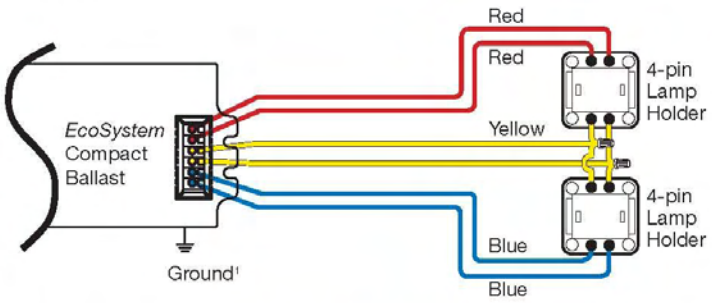
Job Name:	Model Numbers:	
Millennium Science Complex	EC3DT4MWKU1S	
Job Number: Building Stimulus		

Lamp Wiring Diagrams

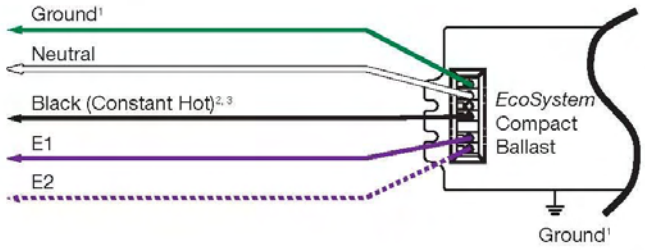
One Compact Fluorescent Lamp



Two Compact Fluorescent Lamps



EcoSystem Power Wiring Diagrams



[1] Ballast is grounded via the case or terminal.
[2] Wire colors shown are for *Lutron* controls and ballasts only. Dimming control wires may not match ballast wire colors.
[3] The Constant Hot must not be wired to a switching device.

Note: For T4 compact lamps, maximum lamp-to-ballast wire length is 3 ft (.91 m) to guarantee proper performance.

Job Name:	Model Numbers:	
Millennium Science Complex	EC3DT4MWKU1S	
Job Number: Building Stimulus		

369-339 B 10.20.10 6

EcoSystem Bus Wiring Diagrams

EcoSystem Bus Overview

- The *EcoSystem* Bus wiring (E1 and E2) connects the digital ballasts together to form a lighting control system
- Each *EcoSystem* Bus supports up to 64 digital ballasts, 32 occupant sensors, 8 daylight sensors, and 64 wallstations or IR receivers
- Sensors do not directly connect to *EcoSystem* compact ballasts
- E1 and E2 (*EcoSystem* bus wires) are polarity insensitive and can be wired in any topology
- An *EcoSystem* Bus Supply provides power for the *EcoSystem* Bus and supports system programming
- All *EcoSystem* Bus programming is completed by using the *EcoSystem* Programmer, GRAFIK Eye® QS Control Unit with *EcoSystem* Lighting Control System, or Quantum™ Software

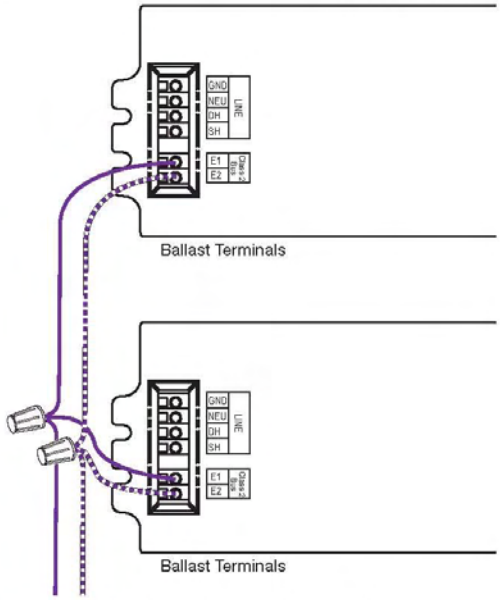
EcoSystem Bus Wiring

- *EcoSystem* Ballast Bus terminals only accept one 16 AWG (1.31 mm^2) or 18 AWG (0.82 mm^2) solid wire
- Make sure that the supply breaker to the Digital Ballast and *EcoSystem* Bus Supply is OFF when wiring
- Connect the two conductors to the two Digital Ballast terminals E1 and E2 as shown
- Using two different colors for E1 and E2 will reduce confusion when wiring several ballasts together
- The *EcoSystem* Bus may be wired Class 1 or Class 2. Consult applicable electrical codes for proper wiring practices

Notes

- The *EcoSystem* Bus Supply does not have to be located at the end of the Digital Loop
- E1 and E2 wires are not polarity sensitive
- *EcoSystem* Bus length is limited by the wire gauge used for E1 and E2 as follows:

Wire Gauge	Bus Length (max)
12 AWG (3.31 mm^2)	2200 ft (670 m)
14 AWG (2.08 mm^2)	1400 ft (427 m)
16 AWG (1.31 mm^2)	900 ft (274 m)



To the *EcoSystem* Bus Supply & up to 64 total ballasts

LUTRON® SPECIFICATION SUBMITTAL Page 6

Job Name:	Model Numbers:	
Millennium Science Complex	EC3DT4MWKU1S	
Job Number: Building Stimulus		

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EcoSystem Ballast Wiring: Line Voltage Dimmers

EcoSystem Ballasts and 3-wire dimmers

- Lutron® 3-wire dimmers only control the ballasts they are wired to; *EcoSystem* ballasts do not support grouping of 3-wire control input.

3-Wire Control Wiring

- Make sure that the supply breaker to the Digital Ballast is OFF when wiring.
- Wire as shown

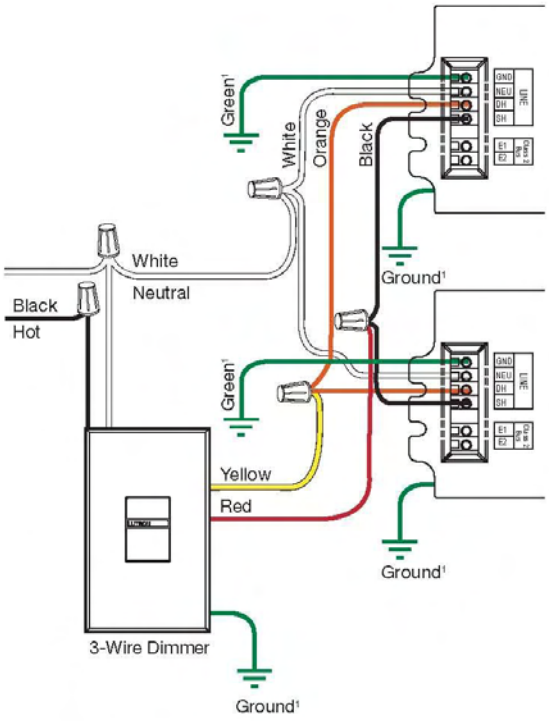
Line input	Connects to
Hot	Dimmer Black Wire
Neutral	Dimmer White Wire

Dimmer wire	Connects to
Yellow	Ballast Orange (DH)
Red	Ballast Black (SH)
White	Ballast White (NEU)
Green	Earth Ground (GND)

- *EcoSystem* ballast line voltage and 3-wire input terminals only accept one 16 AWG (1.31 mm^2) or 18 AWG (0.82 mm^2) solid wire.

Emergency and 3-wire

- *EcoSystem* ballasts controlled by a wallbox dimmer should not be used for emergency/egress lighting unless an external emergency ballast is used in the fixture. See Lutron App. Note #50.
- *EcoSystem* ballasts may be used for emergency/egress lighting when controlled by a *Lutron* dimming panel (GP); where the panel is a dedicated emergency panel.



¹ Ballast is grounded via the case or terminal

Notice

3-Wire control turns off digital ballasts when the control is in the off position.

LUTRON® SPECIFICATION SUBMITTAL Page 7

Job Name:	Model Numbers:	
Millennium Science Complex	EC3DT4MWKU1S	
Job Number: Building Stimulus		

ELECTRICIANS AND CONTRACTORS

Ballast/Socket Leads

Lead lengths from ballast to socket must not exceed 3 ft (.91 m) for T4 linear lamps.

Lamp Sockets

Lamp sockets as per IEC 60400 are required to ensure positive lamp-pin to socket contact. T4 compact sockets must be the 4-pin type, and must be used with 4-pin compact lamps.

Ballast Operating Temperature

Ballast case temperature must not exceed 167 °F (75 °C) at any point on ballast. Calibration point temperature must not exceed 158 °F (70 °C).

Wiring and Grounding

Ballast and lighting fixture must be effectively grounded. Ballasts must be installed per national and local electrical codes.

FACILITIES MANAGERS

PERFORMANCE

Lamp Seasoning Requirements

Some fluorescent lamp manufacturers recommend that new fluorescent lamps be operated at full output ("seasoned") before they can be dimmed to render lamp impurities inert, ensuring proper dimming performance and average rated lamp life. Please contact your lamp manufacturer for seasoning requirements.

SERVICE

Replacement Parts

Use replacement parts with exact *Lutron* model numbers. Consult Lutron if you have any questions.

Further Information

For further information, please visit us at www.lutron.com/ballasts or contact our 24-hour Technical Support Center at 1-800-523-9466.

LUTRON® SPECIFICATION SUBMITTAL Page 8

Job Name:	Model Numbers:	
Millennium Science Complex	EC3DT4MWKU1S	
Job Number: Building Stimulus		

Lutron: EC5-T832-G-UNV-317L

EcoSystem® Five Control Input Digital Dimming Ballasts

EcoSystem Multiple Control Input Ballasts

Digital electronic dimming ballasts maximize the benefits of a lighting management system. *EcoSystem* Ballasts offer 100% to 10% dimming; ideal for use where saving energy, increasing flexibility, and maximizing productivity are the goals of the lighting design.

EcoSystem case type G

EcoSystem case type J

Features

- Continuous, flicker-free dimming from 100% to 10%
- Provides power for and responds to one occupancy sensor, one photo sensor, and one personal control input (infrared receiver or wallstation)
- Communicates status and sensor inputs over the *EcoSystem* Bus
- Programmed rapid start design ensures full rated lamp life while dimming and cycling
- Lamps turn on to any dimmed level without flashing to full brightness
- Low harmonic distortion throughout the entire dimming range
- Frequency of operation ensures that ballast does not interfere with infrared devices
- End-of-lamp-life protection circuitry ensures safe operation throughout entire lamp life
- Ultra-quiet operation
- Nonvolatile memory restores all ballast settings after power failure
- Ballasts maintain consistent light output for linear lamp lengths (i.e. 4 ft., 3 ft., 2 ft. have same relative output)
- Protected from miswires of any input power to control lead, or from lamp leads to each other and/or ground
- 100% performance tested at factory

LUTRON® SPECIFICATION SUBMITTAL Page 1

Job Name:	Model Numbers:	
Millennium Science Complex	EC5 T832 G UNV 317L	
Job Number: Buildign Stimulus		

Specifications

Standards

- California Energy Commission (CEC) Listed
- UL Listed (evaluated to the requirements of UL935)
- CSA certified (evaluated to the requirements of C22.2 No. 74)
- Some models are NOM Listed
- Class P thermally protected
- Meets ANSI C82.11 High Frequency Ballast Standard
- Meets FCC Part 18 Non-Consumer requirements for EMI/RFI emissions
- Meets ANSI C62.41 Category A surge protection standards up to and including 4 kV
- Manufacturing facilities employ ESD reduction practices that comply with the requirements of ANSI/ESD S20.20
- Lutron Quality Systems registered to ISO 9001.2000

Performance

- Operating Voltage: 120, 220/240, 277 V~ at 50 or 60 Hz
- Grounding: ballast and fixture must be grounded for proper dimming
- Dimming Range: 100% to 10% measured relative light output
- Lamp Starting: programmed rapid start
- Lamp Current Crest Factor: less than 1.7
- Light Output Variation: Constant ±2% light output for line voltage variations of ±10%
- Lamp Life: Average lamp life meets or exceeds specified lamp ratings
- Power Factor: 0.95 minimum
- Total Harmonic Distortion (THD): Less than 20%
- Inaudible in a 27 dBA ambient
- Maximum Inrush Current: 3 A per ballast at 277 V~, 7A per ballast at 120 V~
- Class 2 Output: +20 V⎓, 50mA maximum (one daylight sensor, one keypad and one occupancy sensor can be connected)

Environment

- Minimum lamp starting temperature: 50 °F (10 °C)
- Relative humidity: less than 90% non-condensing
- Sound Rating: inaudible in a 27 dB ambient
- Maximum ballast case temperature: 75 °C (167 °F)

Ballast Wiring & Mounting

- Ballast is grounded by a mounting screw to the fixture
- Terminal blocks on the ballast accept the following wire gauges:
  Power Wiring, Lamp Wiring, and *EcoSystem* Bus:
  only one #18 AWG solid per terminal
  Class 2 Sensors:
  only one #22 AWG solid per terminal
- Only one wire per terminal
- Class 2 sensor wiring must be separated from all power and Class 1 wiring, consult all applicable local and national codes
- Ballast mounts using two screws (or sheet metal feature and one screw) within a fluorescent fixture
- Wiring from the ballast to lamp sockets shall not exceed 7 ft. for T8, T5, and T5HO lamps
- Wiring from the ballast to lamps sockets shall not exceed 3 ft. for T5 Twin Tube lamps

Lamp Seasoning

Refer to lamp manufacturer for lamp seasoning requirements prior to dimming

LUTRON® SPECIFICATION SUBMITTAL Page 2

Job Name:	Model Numbers:	
Millennium Science Complex	EC5 T832 G UNV 317L	
Job Number: Buildign Stimulus		

EcoSystem Ballasts for linear and U bend T8 Lamps

Lamp	No. of Lamps	Model	Case Size	Input Voltage (VAC)	Input Current (A)	Input Power (W)	Ballast Factor (BF)	System Lumens (lm)	System Efficacy (lm/W)	Ballast Efficacy Factor	Relative Efficacy (RSE)
F32T8 (48 in)	1	EC5 T832 J UNV 1	J	277 240 120	0.11 0.13 0.26	31.6 31.0 31.3	0.85 0.85 0.85	2550 2550 2550	81 82 81	2.69 2.74 2.72	0.86 0.87 0.87
	2	EC5 T832 G UNV 2L	G	277 240 120	0.22 0.25 0.49	59.6 57.6 58.8	0.85 0.85 0.85	5100 5100 5100	86 89 87	1.43 1.48 1.45	0.91 0.94 0.93
		EC5 T832 J UNV 2	J	277 240 120	0.21 0.25 0.49	57.4 59.0 59.1	0.85 0.85 0.85	5100 5100 5100	89 86 86	1.48 1.44 1.44	0.95 0.92 0.92
	3	EC5 T832 G UNV 3L	G	277 240 120	0.31 0.36 0.72	86.5 84.0 85.9	0.85 0.85 0.85	7650 7650 7650	88 89 89	0.98 1.01 0.99	0.94 0.97 0.95
		EC5 T832 G UNV 317L	G	277 240 120	0.41 0.47 0.95	105.7 106.5 106.8	1.17 1.17 1.17	10,530 10,530 10,530	100 99 99	1.11 1.10 1.10	1.06 1.05 1.05
F25T8 (36 in)	1	EC5 T825 J UNV 1	J	277 240 120	0.10 0.11 0.23	27.6 27.0 26.9	0.85 0.85 0.85	1828 1828 1828	66 68 68	3.08 3.15 3.16	0.77 0.79 0.79
	2	EC5 T825 J UNV 2	J	277 240 120	0.18 0.20 0.41	48.9 49.0 49.0	0.85 0.85 0.85	3665 3665 3665	75 75 75	1.74 1.73 1.73	0.87 0.87 0.87
F17T8 (24 in)	1	EC5 T817 J UNV 1	J	277 240 120	0.08 0.08 0.17	20.6 20.0 20.1	0.85 0.85 0.85	1190 1190 1190	68 60 70	4.13 4.25 4.23	0.70 0.72 0.72
	2	EC5 T817 J UNV 2	J	277 240 120	0.13 0.15 0.31	36.2 37.0 37.0	0.85 0.85 0.85	2380 2380 2380	66 64 64	2.35 2.30 2.30	0.80 0.78 0.78

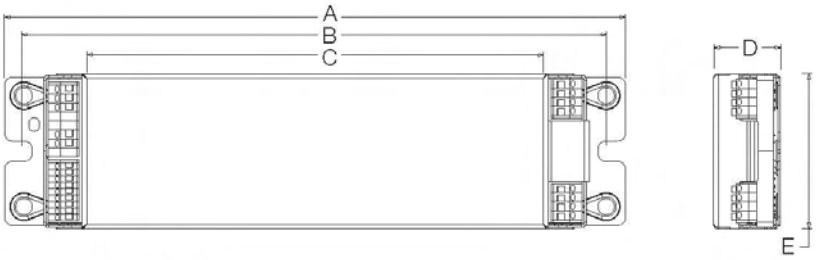
EcoSystem Ballasts for linear and U bend T8 Lamps: Reduced Wattage

Lamp	No. of Lamps	Model	Case Size	Input Voltage (VAC)	Input Current (A)	Input Power (W)	Ballast Factor (BF)	System Lumens (lm)	System Efficacy (lm/W)	Ballast Efficacy Factor	Relative Efficacy (RSE)
F32T8 (48 in)	1	EC5 T8RW J UNV 1 30 W	J	277 240 120	0.11 0.12 0.24	28.9 28.7 29.2	0.85 0.85 0.85	2350 2350 2350	81 82 80	2.94 2.96 2.91	0.88 0.89 0.87
		EC5 T8RW J UNV 1 28 W		277 240 120	0.10 0.11 0.22	26.3 26.2 26.5	0.85 0.85 0.85	2202 2202 2202	84 84 83	3.23 3.24 3.21	0.90 0.91 0.90
		EC5 T8RW J UNV 1 25 W		277 240 120	0.09 0.10 0.21	24.8 24.5 24.9	0.85 0.85 0.85	2061 2061 2061	83 84 83	3.43 3.47 3.41	0.86 0.87 0.85
	2	EC5 T8RW J UNV 2 30 W	J	277 240 120	0.19 0.22 0.44	52.5 52.5 53.4	0.85 0.85 0.85	4701 4701 4701	90 90 88	1.62 1.62 1.59	0.97 0.97 0.96
		EC5 T8RW J UNV 2 28 W		277 240 120	0.18 0.20 0.42	48.9 48.6 50.0	0.85 0.85 0.85	4403 4403 4403	90 91 88	1.74 1.75 1.70	0.97 0.98 0.95
		EC5 T8RW J UNV 2 25 W		277 240 120	0.17 0.19 0.38	46.6 45.9 46.5	0.85 0.85 0.85	4123 4123 4123	88 90 89	1.82 1.85 1.83	0.91 0.93 0.91
	3	EC5 T8RW G UNV 3L 30 W	G	277 240 120	0.28 0.32 0.65	76.3 76.3 78.1	0.85 0.85 0.85	7051 7051 7051	92 92 90	1.11 1.11 1.09	1.00 1.00 0.98
		EC5 T8RW G UNV 3L 28 W		277 240 120	0.26 0.30 0.60	71.1 70.4 71.6	0.85 0.85 0.85	6605 6605 6605	93 94 92	1.20 1.21 1.19	1.00 1.01 1.00
		EC5 T8RW G UNV 3L 25 W		277 240 120	0.25 0.28 0.58	67.9 67.4 69.0	0.85 0.85 0.85	6184 6184 6184	91 92 90	1.25 1.26 1.23	0.94 0.95 0.92

Reduced wattage lamps may exhibit light to moderate striations (moving bands of bright and dark spots) across the lamp at certain dimming levels. While striations do not harm the lamp or ballast, it can be distracting in fixtures where the lamp is directly visible.

EcoSystem Ballast Case Dimensions

G Case



G Case Dimensions

A = 9.5 in (241 mm)

B = 8.9 in (226 mm)

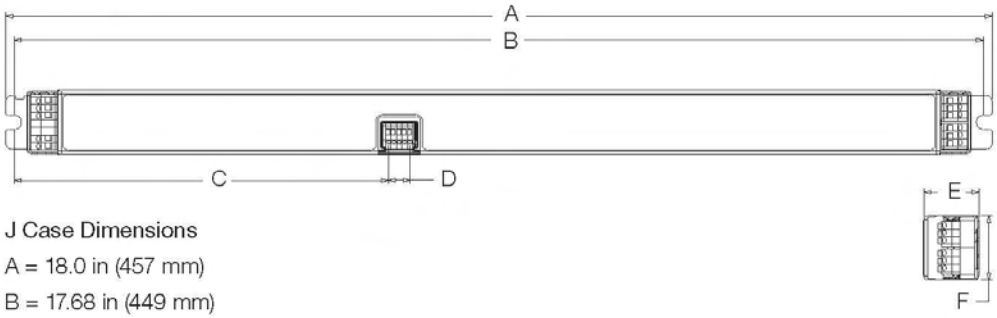
C = 7.1 in (180 mm)

D = 1.0 in (25 mm)

E = 2.38 in (60 mm)

G case ballasts ship with 36 in. leads for lamp connections and 18 in. leads for Hot, Neutral, E1 and E2 connections

J Case



J Case Dimensions

A = 18.0 in (457 mm)

B = 17.68 in (449 mm)

C = 6.82 in (173 mm)

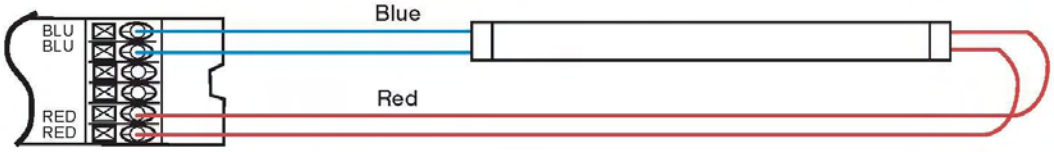
D = .394 in (10 mm)

E = 1.0 in (25 mm)

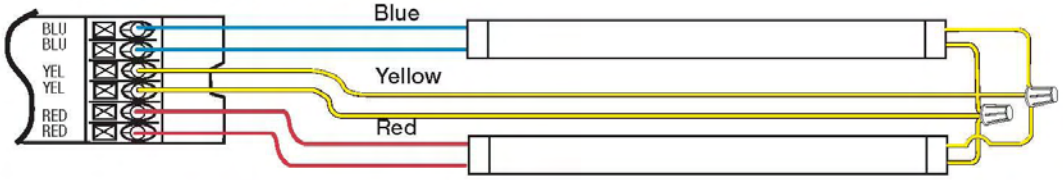
F = 1.18 in (30 mm)

EcoSystem Ballast Wiring Diagrams - T8, T5, T5 HO

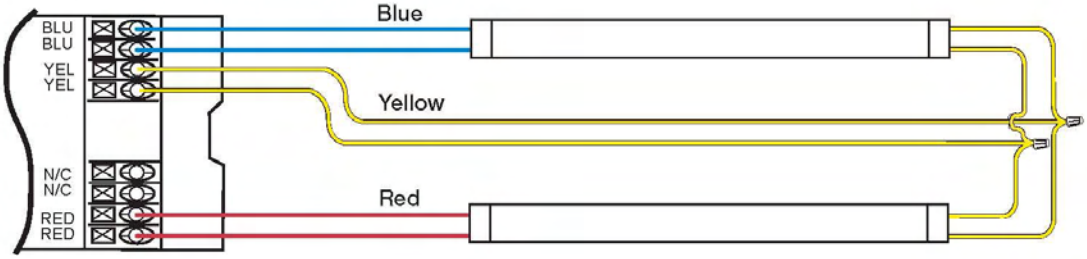
Wiring to One Lamp (J case shown)



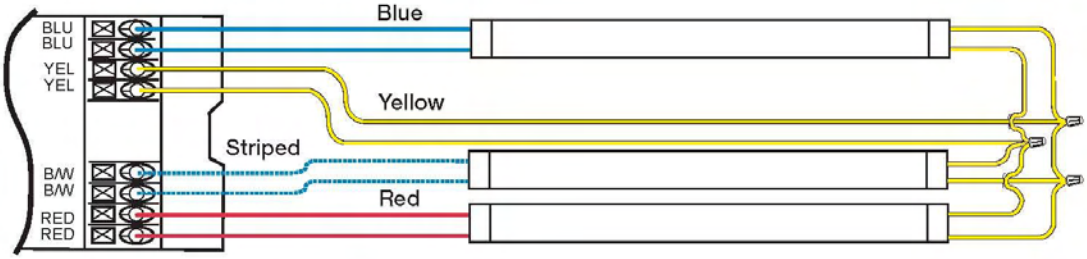
Wiring to Two Lamps (J case shown)



Wiring to Two Lamps (G case shown)



Wiring to Three Lamps (G case shown)



NOTICE

- Maximum ballast to lamp socket lead length is 7 feet (2 m)
- Wire colors shown are labeled on the ballast, but may vary depending upon fixture construction

LUTRON® SPECIFICATION SUBMITTAL Page 6

Job Name:	Model Numbers:	
Millennium Science Complex	EC5 T832 G UNV 317L	
Job Number: Buildign Stimulus		

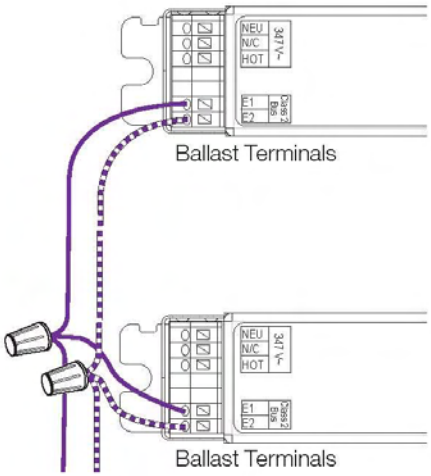
EcoSystem Ballast Wiring: *EcoSystem* Bus

EcoSystem Bus Overview

- The *EcoSystem* Bus wiring (E1 and E2) connects the digital ballasts together to form a lighting control system
- Each *EcoSystem* Bus supports up to 64 digital ballasts, 32 occupant sensors, 8 daylight sensors, and 64 wallstations or IR receivers
- E1 and E2 (*EcoSystem* bus wires) are polarity insensitive and can be wired in any topology
- An *EcoSystem* Bus Supply provides power for the *EcoSystem* Bus and supports system programming
- All *EcoSystem* Bus programming is completed by using the *EcoSystem* Programmer

EcoSystem Bus Wiring

- Ballast *EcoSystem* Bus terminals only accept one #18 AWG solid wire
- Make sure that the supply breaker to the Digital Ballast and *EcoSystem* Bus Supply is OFF when wiring
- Connect the two conductors to the two Digital Ballast terminals E1 and E2 as shown
- Using two different colors for E1 and E2 will reduce confusion when wiring several ballasts together
- The *EcoSystem* bus may be wired Class 1 or Class 2. Consult applicable electrical codes for proper wiring practices



To the *EcoSystem* Bus Supply & up to 64 total ballasts

Notes

- The *EcoSystem* Bus Supply does not have to be located at the end of the Digital Loop
- E1 and E2 wires are not polarity sensitive
- *EcoSystem* Bus length is limited by the wire gauge used for E1 and E2 as follows:

Wire Gauge	Bus Length (max)
12 AWG	2200 ft (670 m)
14 AWG	1400 ft (427 m)
16 AWG	900 ft (274 m)

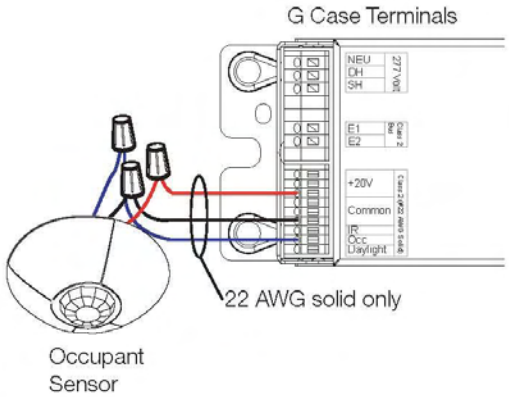
EcoSystem Ballast Wiring: Occupancy Sensor

Wiring to a Lutron Occupant Sensor (LOS-XX)

- Sensor wiring summary:

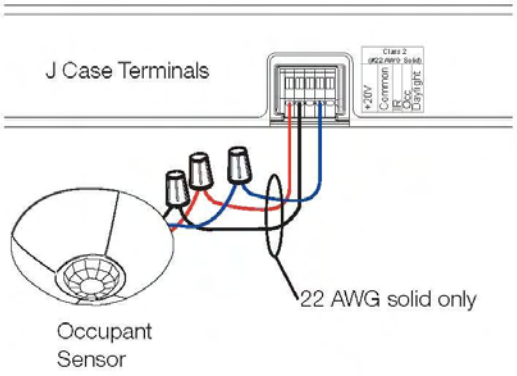
Sensor Wire	Ballast Terminal	Terminal Color
Red	+20 V⎓	Red
Black	Common	Black
Blue	Occ	Blue

- Make sure that the supply breaker to the Digital Ballast is OFF when wiring
- Connect the three conductors to the three ballast terminals as shown
- Occupant sensor must be placed within 50 feet (15 m) of the ballast
- Ballast Class 2 terminals only accept one 22 AWG solid wire



Notes

- Only applies to ballasts with an integral sensor connection
- Occupant sensors from other manufacturers may be used with *EcoSystem* ballasts if the sensor meets the following criteria:
  Vin = +20 V⎓, current draw less than 35 mA
- If other manufacturer's occupant sensors are used terminal colors and sensor wire colors may not match
- All sensor and wallstation wiring is Class 2. Follow all applicable national and local codes for proper circuit separation and protection.



Attention Electricians and Fixture Manufacturers

Ballast/Socket Leads

Lead lengths from ballast to socket must not exceed 7 feet (2 m) for linear lamps (T5, T5HO, T8). Lead lengths must not exceed 3 feet (1 m) for T5 twin tube lamps.

Lamp Sockets

Lamp sockets as per IEC 60400 are required to ensure positive lamp-pin to socket contact.

Mounting for T5 and T5HO Lamps

Mount lamps 3/8 in. ± 1/8 in. away from the grounded metal surface.

Mounting for T8 & T5 Twin Tube Lamps

Mount lamps 1/2 in. ± 1/4 in. away from the grounded metal surface.

Having a lamp too close to the grounded metal will reduce lamp life. Having a fluorescent lamp too far away from the grounded metal will make the lamp flicker or not turn on at all.

Lamp Seasoning Requirements

Consult lamp manufacturer's recommendations on lamp seasoning prior to dimming.

Further Information

For further information please visit www.lutron.com/ecosystem or contact our 24-hour Technical Support Center at 1-800-523-9466

LUTRON® SPECIFICATION SUBMITTAL Page 9

Job Name:	Model Numbers:	
Millennium Science Complex	EC5 T832 G UNV 317L	
Job Number: Buildign Stimulus		

Philips: ICN-4S54-90C2LS

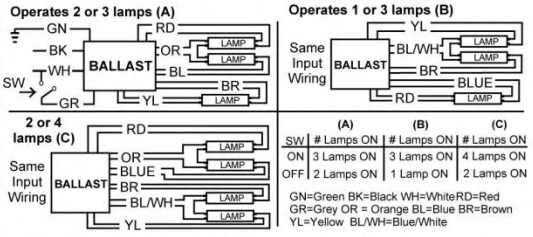
PHILIPS
ADVANCE

ICN4S5490C2LS@277	
Brand Name	CENTIUM T5
Ballast Type	Electronic
Starting Method	Programmed Start
Lamp Connection	Series/Parallel
Input Voltage	277
Input Frequency	50/60 HZ
Status	Active

Electrical Specifications

Lamp Type	Num. of Lamps	Rated Lamp Watts	Min. Start Temp (°F/C)	Input Current (Amps)	Input Power (ANSI Watts)	Ballast Factor	MAX THD %	Power Factor	MAX Lamp Current Crest Factor	B.E.F.
F54T5/HO	1	54	-20/-29	0.24	62	0.99	30	0.90	1.7	1.60
* F54T5/HO	2	54	-20/-29	0.43	117	0.99	10	0.98	1.7	0.85
F54T5/HO	3	54	-20/-29	0.66	179	1.00	10	0.98	1.7	0.56
F54T5/HO	4	54	-20/-29	0.86	234	1.00	10	0.98	1.7	0.43

Wiring Diagram



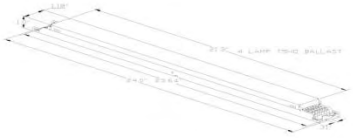
The wiring diagram that appears above is for the lamp type denoted by the asterisk (*)

Standard Lead Length (inches)

	in.	cm.
Black	0	0
White	0	0
Blue	0	0
Red	0	0
Yellow	0	0
Gray	0	0
Violet	0	0

	in.	cm.
Yellow/Blue	0	0
Blue/White	0	0
Brown	0	0
Orange	0	0
Orange/Black	0	0
Black/White	0	0
Red/White	0	0

Enclosure



Enclosure Dimensions

OverAll (L)	Width (W)	Height (H)	Mounting (M)
24 "	1.18 "	1 "	23.64 "
24	1 9/50	1	23 16/25
61 cm	3 cm	2.5 cm	60 cm

Revised 09/10/2010

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Customer Support/Technical Service: 800-372-3331 · OEM Support: 866-915-5886

PHILIPS ADVANCE

ICN4S5490C2LS@277	
Brand Name	CENTIUM T5
Ballast Type	Electronic
Starting Method	Programmed Start
Lamp Connection	Series/Parallel
Input Voltage	277
Input Frequency	50/60 HZ
Status	Active

Electrical Specifications

Notes:

Section I - Physical Characteristics

1.1 Ballast shall be physically interchangeable with standard electromagnetic or standard electronic ballasts, where applicable.

1.2 Ballast shall be provided with integral leads or poke-in wire trap connectors color-coded per ANSI C82.11.

Section II - Performance Requirements

2.1 Ballast shall be Programmed Start.

2.2 Ballast shall contain auto restart circuitry in order to restart lamps without resetting power.

2.3 Ballast shall operate from 50/60 Hz input source of _____ (120V through 277V or 347V through 480V) with sustained variations of +/- 10% (voltage and frequency).

2.4 Ballast shall be high frequency electronic type and operate lamps at a frequency above 42 kHz to avoid interference with infrared devices and eliminate visible flicker.

2.5 Ballast shall have a Power Factor greater than 0.98 for primary lamp.

2.6 Ballast shall have a minimum ballast factor of 1.00 for primary lamp application.

2.7 Ballast shall provide for a Lamp Current Crest Factor of 1.7 or less.

2.8 Ballast input current shall have Total Harmonic Distortion (THD) of less than 20% for Standard models and THD of less than 10% for Centium models when operated at nominal line voltage with primary lamp.

2.9 Ballast shall have a Class A sound rating.

2.10 Ballast shall have a minimum starting temperature of _____ {-18C (0F) or -28C (-20F)} for primary lamp. Consult lamp manufacturer for temperature versus light output characteristics.

2.11 Ballast shall provide Lamp EOL Protection Circuit.

2.12 Ballast shall tolerate sustained open circuit and short circuit output conditions.

2.13 Four-lamp ballast shall have (semi-independent or independent) lamp operation.

Section III - Regulatory Requirements

3.1 Ballast shall not contain any Polychlorinated Biphenyl (PCB).

3.2 Ballast shall be Underwriters Laboratories (UL) listed, Class P and Type 1 Outdoor; and Canadian Standards Association (CSA) certified where applicable.

3.3 Ballast shall comply with ANSI C62.41 Category A for Transient protection.

3.4 Ballast shall comply with ANSI C82.11 where applicable.

3.5 Ballast shall comply with the requirements of the Federal Communications Commission (FCC) rules and regulations, Title 47 CFR part 18, Non-Consumer (Class A) for EMI/RFI (conducted and radiated).

3.6 Ballast shall comply with UL Type CC rating.

3.7 Ballast shall comply with NEMA 410 for in-rush current limits.

Section IV - Other

4.1 Ballast shall be manufactured in a factory certified to ISO 9001 Quality System Standards.

4.2 Ballast shall carry a five-year warranty from date of manufacture against defects in material or workmanship, including replacement, for operation at a maximum case temperature of 70C. Ballasts with a "90C" designation in their catalog number shall also carry a three-year warranty at a maximum case temperature of 90C.

4.3 Manufacturer shall have a twenty-year history of producing electronic ballasts for the North American market.

Revised 09/10/2010

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Philips: M98/M143

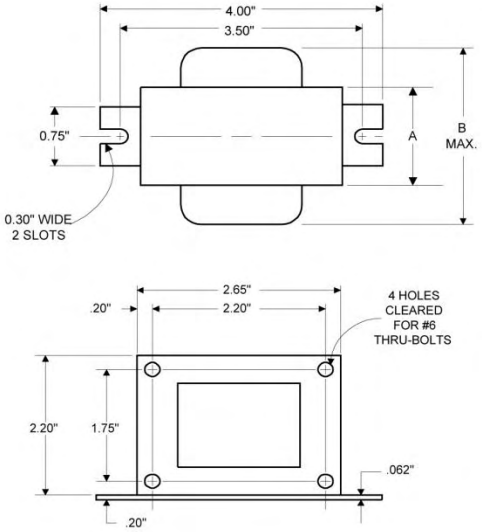
PHILIPS ADVANCE

Metal Halide Lamp Ballast

Catalog Number 71A5237P
For 70W M98/M143
60 Hz R-HPF
Status: Active

DIMENSIONS AND DATA

2 5/8 X 2 3/16 CORE



INPUT VOLTS		277				
CIRCUIT TYPE	R-HPF					
POWER FACTOR (min)	90%					
REGULATION						
Line Volts	±5%					
Lamp Watts	±10%					
LINE CURRENT (Amps)						
Operating		0.32				
Open Circuit		0.80				
Starting		0.50				
UL TEMPERATURE RATINGS						
Insulation Class	H(180°C)					
Coil Temperature Code	1029	A				
MIN. AMBIENT STARTING TEMP.	-20°F or -30°C					
NOM. OPEN CIRCUIT VOLTAGE	277					
INPUT VOLTAGE AT LAMP DROPOUT		190				
INPUT WATTS	85					
RECOMMENDED FUSE (Amps)		2				
CORE and COIL						
Dimension (A)	1.55					
Dimension (B)	2.70					
Weight (lbs.)	2.9					
Lead Lengths	12"					
CAPACITOR REQUIREMENT						
Microfarads	8.0					
Volts (min.)	280					
Fault Current Withstand (amps)						
60 Hz TEST PROCEDURES (Refer to Philips Lighting Electronics N.A. TEST Procedure for HID Ballasts - Form 127						
High Potential Test (Volts)						
1 minute	2000					
2 seconds	2500					
Open Circuit Voltage Test (Volts)	260-290					
Short-Circuit Current Test (Amps)						
Secondary Current	0.85-1.25					
Input Current		0.20-0.45	-	-	-	-

Capacitor: 7C080L30RA

Capacitance: 8
Dia/Oval Dim: 1.25
Height: 2.75
Temp Rating: 105°C

Ignitor: LI533-H4

Ballast to Lamp Distance (BTL) = 2 feet
Temp Rating: 105°C

Wiring Diagram:

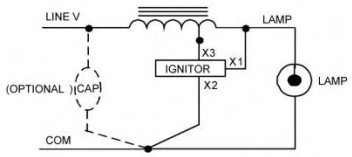


Fig. G

U.L. RECOGNIZED

Typical Ordering Information

(please call Philips Lighting Electronics N.A. for suffix availability)

Order Suffix	Description

Data is based upon tests performed by Philips Lighting Electronics N.A. in a controlled environment and is representitive of relative performance. Actual performance can vary depending on operating conditions. Specifications are subject to change without notice.

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Revised: 07/31/09

Philips: M90/M140

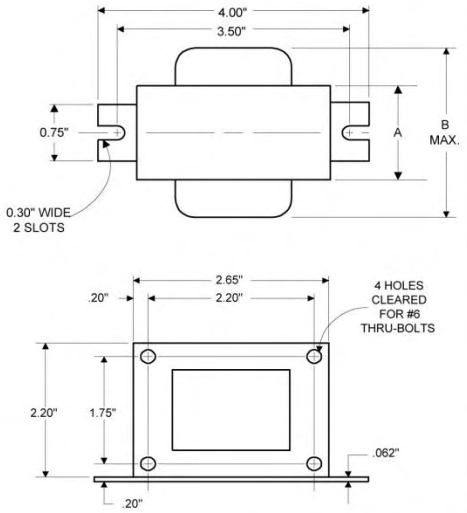
PHILIPS ADVANCE

Metal Halide Lamp Ballast

Catalog Number 71A5337P
For 100W M90/M140
60 Hz R-HPF
Status: Active

DIMENSIONS AND DATA

2 5/8 X 2 3/16 CORE



INPUT VOLTS		277				
CIRCUIT TYPE	R-HPF					
POWER FACTOR (min)	90%					
REGULATION						
Line Volts	±5%					
Lamp Watts	±10%					
LINE CURRENT (Amps)						
Operating		0.45				
Open Circuit		1.05				
Starting		0.70				
UL TEMPERATURE RATINGS						
Insulation Class	H(180°C)					
Coil Temperature Code	1029	A				
MIN. AMBIENT STARTING TEMP.	-20°F or -30°C					
NOM. OPEN CIRCUIT VOLTAGE	277					
INPUT VOLTAGE AT LAMP DROPOUT		190				
INPUT WATTS	118					
RECOMMENDED FUSE (Amps)		3				
CORE and COIL						
Dimension (A)	1.65					
Dimension (B)	2.75					
Weight (lbs.)	3.2					
Lead Lengths	12"					
CAPACITOR REQUIREMENT						
Microfarads	10.0					
Volts (min.)	280					
Fault Current Withstand (amps)						
60 Hz TEST PROCEDURES (Refer to Philips Lighting Electronics N.A. TEST Procedure for HID Ballasts - Form 127						
High Potential Test (Volts)						
1 minute	2000					
2 seconds	2500					
Open Circuit Voltage Test (Volts)	260-290					
Short-Circuit Current Test (Amps)						
Secondary Current	1.05-1.55					
Input Current		0.25-0.35	-	-	-	-

Capacitor: 7C100M30RA

Capacitance: 10
Dia/Oval Dim: 1.65
Height: 2.75
Temp Rating: 105°C

Ignitor: LI533-H4

Ballast to Lamp Distance (BTL) = 2 feet
Temp Rating: 105°C

Wiring Diagram:

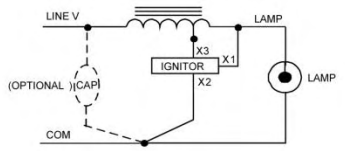


Fig. G

U.L. RECOGNIZED

Typical Ordering Information

(please call Philips Lighting Electronics N.A. for suffix availability)

Order Suffix	Description

Data is based upon tests performed by Philips Lighting Electronics N.A. in a controlled environment and is representitive of relative performance. Actual performance can vary depending on operating conditions. Specifications are subject to change without notice.

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Revised: 07/31/09

Philips: AS205WQUADEE

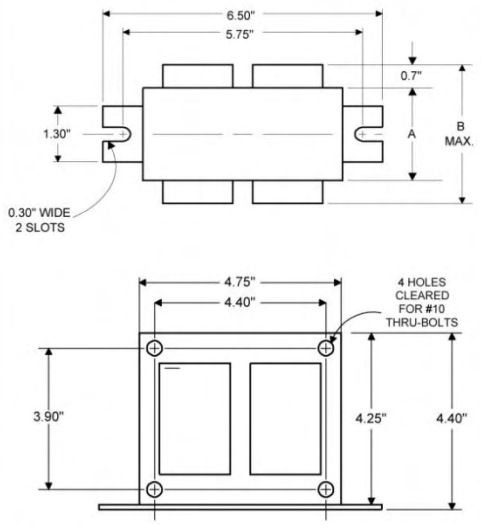
PHILIPS ADVANCE

Metal Halide Lamp Ballast

Catalog Number AS205WQUADEE
For 205W C184 ALLSTART
60 Hz SUPER-CWA
Status: Active

DIMENSIONS AND DATA

4 1/4 X 4 3/4 CORE - 2 COIL UNIT



INPUT VOLTS		120	208	240	277	
CIRCUIT TYPE	SUPER-CWA					
POWER FACTOR (min)	95%					
REGULATION						
Line Volts	±10%					
Lamp Watts	±10%					
LINE CURRENT (Amps)						
Operating		2.00	1.13	1.00	0.86	
Open Circuit		1.78	0.96	0.90	0.76	
Starting		1.55	0.89	0.78	0.77	
UL TEMPERATURE RATINGS						
Insulation Class	H(180°C)					
Coil Temperature Code	1029	A	A	A	A	
MIN. AMBIENT STARTING TEMP.	-20°F or -30°C					
NOM. OPEN CIRCUIT VOLTAGE	280					
INPUT VOLTAGE AT LAMP DROPOUT		60	104	120	139	
INPUT WATTS	232					
RECOMMENDED FUSE (Amps)		5	3	3	2	
CORE and COIL						
Dimension (A)	1.71					
Dimension (B)	3.68					
Weight (lbs.)	11.8					
Lead Lengths	12"					
CAPACITOR REQUIREMENT						
Microfarads	16.0					
Volts (min.)	400					
Fault Current Withstand (amps)						
60 Hz TEST PROCEDURES (Refer to Philips Lighting Electronics N.A. TEST Procedure for HID Ballasts - Form 127						
High Potential Test (Volts)						
1 minute	2000					
2 seconds	2500					
Open Circuit Voltage Test (Volts)	254-308					
Short-Circuit Current Test (Amps)						
Secondary Current	2.26-2.76					
Input Current		1.15-1.73	0.67-1.00	0.57-0.86	0.50-0.75	-

Capacitor: 7C160P40

Capacitance: 16
Dia/Oval Dim: 1.75
Height: 3.75
Temp Rating: 105°C

Wiring Diagram:

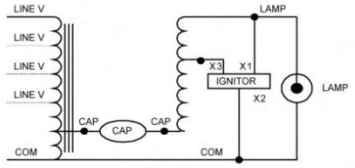


Fig. M

U.L. RECOGNIZED

Ignitor: LI533-H4

Ballast to Lamp Distance (BTL) = 2 feet
Temp Rating: 105°C

Typical Ordering Information

(please call Philips Lighting Electronics N.A. for suffix availability)

Order Suffix	Description
EE	EISA COMPLIANT - 88% EFFICIENT BALLAST

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Revised: 09/16/10

Appendix L: Panelboard Cutsheets

Eaton Cutler-Hammer: Pow-R-Line 1a

EATON | Cutler-Hammer

June 2006
Sheet 0821

Panelboards
Pow-R-Line 1a 22.1-1

General Description — Pow-R-Line 1a

22

Pow-R-Line 1a

Pow-R-Line 1a

General Description

Panelboard Ratings

Voltage:
- 240 Vac maximum.

Main Lugs:
- 100 – 400 amperes.

Main Breakers:
- 100 – 400 amperes.

Branch Breakers:
- 15 – 100 amperes (Bolt-on or plug-on chassis).

Short Circuit Current Ratings (Symmetrical)
- 240 Vac: 10 kA and 22 kA fully rated.
- 240 Vac: 22 – 200 kA series rated.

Service
- 3-phase, 4-wire 208Y/120 V and 240/120 V Delta.
- Single-phase, 3-wire 120/240 V.
- Single-phase, 2-wire 120 V.
- 3-phase, 3-wire 208 and 240 V.

Suitable for service entrance applications when specified.

Mains

For available mains, refer to **Table 22.1-1**.

Main breakers, 100 amperes, Types BAB and QBH are horizontally mounted, same as branch breakers. All other main breakers are vertically mounted.

Branch Circuits

For available branch devices, refer to **Table 22.1-2**.

Main Lugs Only

The short circuit rating of the MLO assembled panelboard will be fully rated based upon the lowest rated branch device or may be series rated with an approved upstream device.

Main lugs only ampere ratings: 100, 225 and 400.

Main Circuit Breakers

The short circuit rating shown is that of the main breaker only. The short circuit rating of the assembled panelboard is the rating of the lowest fully rated main or branch device or the rating of an approved series rated combination

Table 22.1-1. Main Circuit Breakers

Breaker Frame Amperes	Breaker Type	Interrupting Rating (kA Symmetrical) at 240 V
100	BAB	10
100	QBHW	22
100	EHD	18
150	FDB	18
225	FD	65
225	HFD	100
225	FDC	200
225	EDB	22
225	EDS	42
225	ED	65
225	EDH	100
225	EDC	200
250	JD	65
250	HJD	100
250	JDC	200
400	DK	65
400	KD	65
400	HKD	100
400	KDC	200

Table 22.1-2. Branch Circuit Breakers

Breaker Type	Ampere Rating	Number of Poles	Interrupting Rating (kA Symmetrical)		
			120 V	120/240 V	240 V
BAB, HQP	15 – 70	1	10	—	—
BAB, HQP	15 – 100	2	—	10	—
BAB, HQP	15 – 100	2, 3	—	—	10
BAB-D ①, HQP-D ①	15 – 60	1, 2	10	10	—
BAB-C ②, HQP-B ②	15 – 30	1, 2	10	10	—
BABRP ③	15 – 30	1, 2	10	10	—
BABRSP ③	15 – 30	1, 2	10	10	—
QBGF, QBGFEP,	15 – 50 ④	1, 2	10	10	—
QPGF, QPGFEP	15 – 50 ④	1, 2	10	10	—
QBAF ⑤, QBAG ⑥	15 – 20	1, 2	10	10	—
QBHW	15 – 70	1	22	—	—
QBHW	15 – 100	2	—	22	—
QBHW	15 – 100	2, 3	—	—	22
QBHGF, QBGFEP	15 – 30	1, 2	22	22	—
QPHGF, QPHGFEP	15 – 30	1, 2	22	22	—
QBHAF ④, QBHAG ⑤	15 – 20	1, 2	22	22	—

① HID (High Intensity Discharge) rated breaker.
② Switching Neutral breaker. 1-pole device requires 2-pole space, 2-pole device requires 3-pole space.
③ Solenoid operated breaker.
④ 50 ampere is 2-pole only.
⑤ Arc fault breaker.
⑥ Arc fault breaker with GFCI.

Series Rated Combinations

Refer to series rating tables beginning on **Page 22.0-11** for the approved series rated combinations available for the branch circuit breakers listed in **Table 22.1-2**.

CA08104001E For more information visit: **www.EatonElectrical.com**

22.1-2 Panelboards Pow-R-Line 1a

Pow-R-Line 1a Specifications

Bussing

100 – 400 amperes: Tin-plated aluminum is standard, copper is available as an option.

Boxes

Boxes are made from code-gauge galvanized steel.

Blank ends are supplied as standard, knockouts are available upon request.

EZ Trim

Trims are made from code-gauge steel and painted ANSI 61 gray.

All panelboards have door-in-door as standard with multi-point catch and lock, and concealed mounting hardware.

Modifications

Table 22.1-3. Sub-Feed Lugs (Main Lugs Only)

Amperes	Panel Height Addition
100	0 Inches (0 mm)
225	0 Inches (0 mm)

Table 22.1-4. Through-Feed Lugs

Amperes	Information
100	See **Table 22.1-6**
225	See **Table 22.1-6**
400	See **Table 22.1-6**

Table 22.1-5. Sub-Feed Breakers (One Per Panel)

Ampere Rating	Breaker Type	Interrupting Rating (kA Symmetrical) at 240 V
150	FDB	18
225	FD	65
225	HFD	100
225	FDC	200
225	EDB	22
225	EDS	42
225	ED	65
225	EDH	100
225	EDC	200
250	JD	65
250	HJD	100
250	JDC	200
400	DK	65
400	KD	65
400	HKD	100
400	KDC	200

Shunt Trips

Shunt trips are available on breakers. BAB, HQP, QBHW and QPHW require one additional pole space for shunt trip, i.e., 1-pole is 2-pole size, 2-pole is 3-pole size and 3-pole is 4-pole size.

Ground Bar

Standard bolted in box. Aluminum is standard. Copper is available as an option.

Enclosures

Types 1, 12, 3R, 4 and 4X.

TVSS

Integrated onto panelboard chassis. For complete product description and available ratings, refer to **Section 36**.

Box Sizing and Selection

Box size for all Type 1 panelboards are available from **Table 22.1-6**.

Instructions

1. Select the rating and type of mains required.
2. Count total number of branch circuit poles (including spaces) required in the panelboard. Do not count main breaker poles. Convert 2- or 3-pole branch breakers to single-poles, i.e., 3-pole breaker, count as three poles.

Note: For horizontal mounted mains (BAB Type), use main lug table, include space in branch section for mains.

3. Using correct table, type of mains and ampere rating per Step 1, find total number of poles.

Note: Where total number of poles (Step 2) fall between number in table, use the next higher number.

4. Read box size across columns to the right.

Top and Bottom Gutters (minimum)

5-1/2 inches (139.7 mm).

Side Gutters

20-inch (508.0 mm) wide box: 6-1/2 inches (165.1 mm).

Table 22.1-6. Type 1 Panelboards — Dimensions in Inches (mm)

Ampere Rating of Mains	Main Breaker Type Mounting Position		Maximum Number of Branch Circuits Including Provisions	Box Dimensions ①② Height	Width	Depth
100 Amperes						
100 A ③ Main Lugs or Main Breaker	EHD, FDB, FD, HFD, FDC Vertical		18	36 (914.4)	20 (508.0)	5.75 (146.1)
			30	48 (1219.2)	20 (508.0)	5.75 (146.1)
			42	48 (1219.2)	20 (508.0)	5.75 (146.1)
			48	60 (1524.0)	20 (508.0)	5.75 (146.1)
100 A ③ Main Lugs or Main Breaker with 100 A Through-Feed Lugs or Sub-Feed Breaker	EHD, FDB, FD, HFD, FDC Vertical		18	48 (1219.2)	20 (508.0)	5.75 (146.1)
			30	48 (1219.2)	20 (508.0)	5.75 (146.1)
			42	60 (1524.0)	20 (508.0)	5.75 (146.1)
			48	60 (1524.0)	20 (508.0)	5.75 (146.1)
225 Amperes						
225 A ④ Main Lugs or Main Breaker	EDB, EDS, ED, EDH, EDC, FD, HFD, FDC Vertical		18	36 (914.4)	20 (508.0)	5.75 (146.1)
			30	48 (1219.2)	20 (508.0)	5.75 (146.1)
			42	48 (1219.2)	20 (508.0)	5.75 (146.1)
			48	60 (1524.0)	20 (508.0)	5.75 (146.1)
225 A ④ Main Lugs or Main Breaker with 225 A or 100 A Sub-Feed Lugs or Breaker	EHD, FDB, FD, HFD, FDC, EDB, EDS, ED, EDH, EDC Vertical		18	48 (1219.2)	20 (508.0)	5.75 (146.1)
			30	48 (1219.2)	20 (508.0)	5.75 (146.1)
			42	60 (1524.0)	20 (508.0)	5.75 (146.1)
			48	60 (1524.0)	20 (508.0)	5.75 (146.1)
400 Amperes						
400 A Main Lugs or Main Breaker	DK, KD, HKD, KDC Vertical		18	60 (1524.0)	20 (508.0)	5.75 (146.1)
			30	60 (1524.0)	20 (508.0)	5.75 (146.1)
			42	72 (1828.8)	20 (508.0)	5.75 (146.1)
			48	72 (1828.8)	20 (508.0)	5.75 (146.1)
400 A Main Lugs or Main Breaker with 225 A or 100 A Sub-Feed Lugs or Breaker	DK, KD, HKD, KDC Vertical	Mains	18	60 (1524.0)	20 (508.0)	5.75 (146.1)
			30	72 (1828.8)	20 (508.0)	5.75 (146.1)
			42	72 (1828.8)	20 (508.0)	5.75 (146.1)
			48	90 (2286.0)	20 (508.0)	5.75 (146.1)
	EHD, FDB, FD, HFD, FDC, EDB, EDS, ED, EDH, EDC Vertical	Sub-Feed Breakers				

① Smaller panelboard box sizes are available if required. Contact Eaton for application information.
② Add 8 inches (203.2 mm) for TVSS.
③ For horizontal mounted mains (BAB Type), use main lug table, include space in branch section for mains.
④ JD, HJD, JDC is same space requirement as 400 ampere DK, HKD, KDC.

Eaton Cutler-Hammer: Pow-R-Line 2a

EATON | Cutler-Hammer

June 2006
Sheet 0823

Panelboards
Pow-R-Line 2a 22.2-1

General Description — Pow-R-Line 2a

22

Pow-R-Line 2a

Pow-R-Line 2a

General Description

Panelboard Ratings

Voltage:
- 240 Vac maximum.
- 480Y/277 Vac maximum.

Note: PRL2a panelboards are suitable for use on 3-phase, 3-wire applications when derived from a 3-phase, 4-wire 480Y/277 Vac service where the neutral is not brought to the panelboard. For 3-phase, 3-wire 480 Vac Delta services use a PRL3a panelboard.

- 250 Vdc maximum.

Main Lugs:
- 100 – 400 amperes.

Main Breakers:
- 100 – 400 amperes.

Branch Breakers:
- 15 – 100 amperes (bolt-on).

Short Circuit Current Ratings (Symmetrical)
- 240 Vac: 65 kA fully rated.
- 240 Vac: 100 – 200 kA series rated.
- 480Y/277 Vac: 14 kA fully rated.
- 480Y/277 Vac: 22 – 150 kA series rated.
- 250 Vdc: 10 kA and 14 kA fully rated.

Service
- 3-phase, 4-wire 208Y/120 V and 240/120 V Delta and 480Y/277 V.
- Single-phase, 3-wire 120/240 V.
- Single-phase, 2-wire 120 V.
- 3-phase, 3-wire 208 and 240 V.
- 2-wire 125 Vdc.
- 2-wire 250 Vdc.

Suitable for service entrance applications when specified.

Mains

For available mains, refer to **Table 22.2-1**.

The GHB main breaker is horizontally mounted, same as branch breakers. All other main breakers are vertically mounted.

Branch Circuits

For available branch devices, refer to **Table 22.2-2**.

Main Lugs Only

The short circuit rating of the MLO assembled panelboard will be fully rated based upon the lowest rated branch device or may be series rated with an approved upstream device.

Main lugs only ampere ratings: 100, 225 and 400.

Main Circuit Breakers

The short circuit rating shown is that of the main breaker only. The short circuit rating of the assembled panelboard is the rating of the lowest fully rated main or branch device or the rating of an approved series rated combination.

Table 22.2-1. Main Circuit Breakers

Breaker Frame (Amperes)	Breaker Type	Interrupting Rating (kA Symmetrical)		
		240 V	480Y/277 V	125/250 Vdc
100	GHB①	65	14	14
100	EHD	18	14	10
150	FDB	18	14	10
225	FD	65	35	10
225	HFD	100	65	22
225	FDC	200	100	22
225	ED	65	—	—
250	EDH	100	—	—
250	EDC	200	—	—
250	JD	65	35	10
250	HJD	100	65	22
250	JDC	200	100	22
400	DK	65	—	10
400	KD	65	35	10
400	HKD	100	65	22
400	KDC	200	100	22

① At 480 V, use on 480Y/277 V systems only.

Table 22.2-2. Branch Circuit Breakers

Breaker Type	Ampere Rating	Number of Poles	Interrupting Rating (kA Symmetrical)				
			120 V	240 V	277 V	480Y/277 V	125/250 Vdc
GHB①	15 – 100	1	65	—	14	—	14
GHB①	15 – 100	2, 3	—	65	—	14	14
GHQ	15 – 20	1	65	—	14	—	—
HGHB	15 – 30	1	65	—	25	—	—
GHQRSP②②	15 – 20	1, 2	65	65	14	14	—
GHBS②	15 – 30	1, 2	65	65	14	14	—
GHBGFEP	15 – 60	1	—	—	14	—	—

① At 480 V, use on 480Y/277 Vac systems only.
② Solenoid operated breaker.

Series Rated Combinations

Refer to series rating tables beginning on **Page 22.0-11** for the approved series rated combinations available for the branch circuit breakers listed in **Table 22.2-2**.

22.2-2 Panelboards Pow-R-Line 2a

EATON | Cutler-Hammer

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Technical Data — Pow-R-Line 2a

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Technical Data

Bussing

100 – 400 amperes: Tin-plated aluminum is standard, copper is available as an option.

Boxes

Boxes are made from code-gauge galvanized steel.

Blank ends are supplied as standard, knockouts are available upon request.

EZ Trim

Trims are made from code-gauge steel and painted ANSI 61 gray.

All panelboards have door-in-door as standard with multi-point catch and lock, and concealed mounting hardware.

Modifications

Table 22.2-3. Sub-Feed Lugs (Main Lugs Only)

Amperes	Panel Height Addition
100 225	0 Inches (0 mm) 0 Inches (0 mm)

Table 22.2-4. Through-Feed Lugs

Amperes	Information
100 225 400	See **Table 22.2-6** See **Table 22.2-6** See **Table 22.2-6**

Table 22.2-5. Sub-Feed Breakers (One Per Panel)

Ampere Rating	Breaker Type	Interrupting Rating (kA Symmetrical)	
		240 V	480Y/277 V
150	FDB	18	14
225 225 225	FD HFD FDC	65 100 200	35 65 100
225 225 225	ED EDH EDC	65 100 200	— — —
250 250 250	JD HJD JDC	65 100 200	35 65 100
400 400 400	KD HKD KDC	65 100 200	35 65 100

Shunt Trips

Shunt trips are available on breakers. GHB breakers with shunt trips require 3-pole frame.

Ground Bar

Standard bolted in box. Aluminum is standard. Copper is available as an option.

Enclosures

Types 1, 12, 3R, 4/4X.

TVSS

Integrated onto panelboard chassis. For complete product description and available ratings, refer to **Section 36**.

Box Sizing and Selection

Box size for all Type 1 panelboards are available from **Table 22.2-6**.

Instructions

1. Using description on the required panelboard, select the rating and type of mains required.
2. Count total number of branch circuit poles (including spaces) required in the panelboard. Do not count main breaker poles. Convert 2- or 3-pole branch breakers to single-poles. i.e., 3-pole breaker, count as three poles.

Note: For horizontal mounted mains (GHB Type), use main lug table, include space in branch section for mains.

3. Using correct table, type of mains and ampere rating per Step 1, find total number of poles.

Note: Where total number of poles (Step 2) fall between number in table, use the next higher number.

4. Read box size across columns to the right.

Top and Bottom Gutters (minimum)

5-1/2 inches (139.7 mm).

Side Gutters

20-inch (508.0 mm) wide box: 5-1/2 inches (139.7 mm).

Table 22.2-6. Type 1 Panelboards — Dimensions in Inches (mm)

Ampere Rating of Mains	Main Breaker Type Mounting Position		Maximum Number of Branch Circuits Including Provisions	Box Dimensions ①② Height	Width	Depth
100 A Panelboards						
100 A ③ Main Lugs or Main Breaker	EHD, FDB, FD, HFD, FDC Vertical		18 30 42 48	36 (914.4) 48 (1219.2) 48 (1219.2) 60 (1524.0)	20 (508.0) 20 (508.0) 20 (508.0) 20 (508.0)	5.75 (146.1) 5.75 (146.1) 5.75 (146.1) 5.75 (146.1)
100 A ③ Main Lugs or Main Breaker with 100 A Through-Feed Lugs or Sub-Feed Breaker	EHD, FDB, FD, HFD, FDC Vertical		18 30 42 48	48 (1219.2) 48 (1219.2) 60 (1524.0) 60 (1524.0)	20 (508.0) 20 (508.0) 20 (508.0) 20 (508.0)	5.75 (146.1) 5.75 (146.1) 5.75 (146.1) 5.75 (146.1)
225 A Panelboards						
225 A ④ Main Lugs or Main Breaker	ED, EDH, EDC, FD, HFD, FDC Vertical		18 30 42 48	36 (914.4) 48 (1219.2) 48 (1219.2) 60 (1524.0)	20 (508.0) 20 (508.0) 20 (508.0) 20 (508.0)	5.75 (146.1) 5.75 (146.1) 5.75 (146.1) 5.75 (146.1)
225 A ④ Main Lugs or Main Breaker with 225 A or 100 A Through-Feed Lugs or Sub-Feed Breaker	EHD, FDB, FD, HFD, FDC, ED, EDH, EDC Vertical		18 30 42 48	48 (1219.2) 48 (1219.2) 60 (1524.0) 60 (1524.0)	20 (508.0) 20 (508.0) 20 (508.0) 20 (508.0)	5.75 (146.1) 5.75 (146.1) 5.75 (146.1) 5.75 (146.1)
400 A Panelboards						
400 A Main Lugs or Main Breaker	DK, KD, HKD, KDC Vertical		18 30 42 48	60 (1524.0) 60 (1524.0) 72 (1828.8) 72 (1828.8)	20 (508.0) 20 (508.0) 20 (508.0) 20 (508.0)	5.75 (146.1) 5.75 (146.1) 5.75 (146.1) 5.75 (146.1)
400 A Main Lugs or Main Breaker with 225 A or 100 A Through-Feed Lugs or Sub-Feed Breaker	DK, KD, HKD, KDC Vertical	Main	18 30 42 48	60 (1524.0) 72 (1828.8) 72 (1828.8) 90 (2286.0)	20 (508.0) 20 (508.0) 20 (508.0) 20 (508.0)	5.75 (146.1) 5.75 (146.1) 5.75 (146.1) 5.75 (146.1)
	EHD, FDB, FD, HFD, FDC, ED, EDH, EDC Vertical	Sub-Feed Breaker				

① Smaller panelboard box sizes are available if required. Contact Eaton for application information.
② Add 8 inches (203.2 mm) for TVSS.
③ For horizontal mounted mains (GHB Type), use main lug table, include space in branch section for mains.
④ JD, HJD, JDC is same space requirement as 400 ampere DK, HKD, KDC.

Eaton Cutler-Hammer: Pow-R-Line 4

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Panelboards
Pow-R-Line 4 22.4-1

General Description — Pow-R-Line 4

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Pow-R-Line 4

PRL4B Circuit Breaker Panelboard

PRL4F Fusible Panelboard

General Description

Panelboard Ratings

Voltage:
- 240 V, 480 V or 600 Vac maximum.
- 250 Vdc maximum.

Main Lugs:
- 250 – 1200 amperes.

Main Breakers:
- 250 – 1200 amperes.

Main Switches:
- 200 – 1200 amperes.

Branches (Bolt-on):
- Breakers 15 – 1200 amperes.
- Fusible switches 30 – 1200 amperes.

Short Circuit Current Ratings (Symmetrical)
- 240 Vac: 10 – 200 kA fully rated.
- 240 Vac: 22 – 200 kA series rated.
- 480 Vac: 14 – 200 kA fully rated.
- 480 Vac: 22 – 150 kA series rated.
- 250 Vdc: 10 – 22 kA fully rated.

Service
- 3-phase, 4-wire 208Y/120 V, 240/120 V Delta and 480Y/277 V.
- Single-phase, 3-wire 120/240 V.
- Single-phase, 2-wire 120 V.
- 3-phase, 3-wire 120, 240, 480 and 600 V.
- 2-wire 125 Vdc.
- 2-wire 250 Vdc.

Suitable for service entrance applications when specified.

Bussing

250 – 1200 amperes tin-plated aluminum is standard, copper is available as an option. Density rated bus is also available as an option.

Main Lugs Only

The short circuit rating of the MLO assembled panelboard will be fully rated based upon the lowest rated branch device or may be series rated with an approved upstream device.

Main lugs only ampere ratings: 250, 400, 600, 800 and 1200.

Main Circuit Breakers

The short circuit rating shown is that of the main breaker only. The short circuit rating of the assembled panelboard is the rating of the lowest fully rated main or branch device, or the rating of an approved series rated combination.

Table 22.4-1. Main Circuit Breakers — Type PRL4B

Breaker Frame Amperes	Breaker Type	Interrupting Rating (kA Symmetrical) 240 V	480 V	600 V	250 Vdc
250	JD	65	35	18	10
250	HJD	100	65	25	22
250	JDC	200	100	35	22
250	LCL	200	200	—	—
400	DK	65	—	—	10
400	KD ①	65	35	25	10
400	CKD ①②	65	35	25	10
400	HKD ①	100	65	35	22
400	CHKD ①②	100	65	35	22
400	KDC ①	200	100	65	22
400	LCL ①	200	200	—	—
400	LA-P	200	200	200	③
600	LGE	65	35	18	22
600	LGH	100	65	35	22
600	LD ①	65	35	25	22
600	CLD ①②	65	35	25	22
600	HLD ①	100	65	35	25
600	CHLD ①②	100	65	35	25
600	LDC ①	200	100	50	25
600	CLDC ②	200	100	50	25
800	MDL ①	65	50	25	22
800	CMDL ①②	65	50	25	22
800	HMDL ①	100	65	35	25
800	CHMDL ①②	100	65	35	25
800	ND ①	65	50	25	—
800	CND ①②	65	50	25	—
800	HND ①	100	65	35	—
800	CHND ①②	100	65	35	—
800	NDC ①	200	100	65	—
800	CNDC ①②	200	100	65	—
800	NB-P	200	200	200	③
1200	ND ①	65	50	25	—
1200	CND ①②	65	50	25	—
1200	HND ①	100	65	35	—
1200	CHND ①②	100	65	35	—
1200	NDC ①	200	100	65	—
1200	CNDC ②	200	100	65	—

① Available with integral ground fault protection.
② 100% rated circuit breaker.
③ 100,000 AIC based on NEMA test procedure.

Main Fusible Switches

The short circuit rating shown is that of the main switch only. The short circuit rating of the assembled panelboards is the rating of the lowest fully rated main or branch device or the rating of an approved series rated combination. (Fuses are not included.)

400 and 600 ampere switches with shunt trip will be rated 100 kA.

Note: Circuit breaker panelboards are designated PRL4B. Fusible Switch panelboards are designated PRL4F.

Table 22.4-2. Main Fusible Switches

Switch Rating Amperes	Fuse Class	Interrupting Rating (kA Symmetrical) 240 V	600 V	250 Vdc
Switches Rated 240 Vac, 250 Vdc				
200	R, T	200	—	10
400	R, T	200	—	10
600	R, T	200	—	—
800	L	200	—	—
1200	L	200	—	—
Switches Rated 600 Vac				
200	R, J, T	200	200	—
400	R, J, T	200	200	—
600	R, J, T	200	200	—
800	L	200	200	—
1200	L	200	200	—

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For more information visit: www.EatonElectrical.com

Table 22.4-3. Branch Circuit Breakers

Breaker Type	Ampere Rating	Number of Poles	Interrupting Rating (kA Symmetrical)						
			120 V	120/240 V	240 V	480 V	600 V	125 Vdc	250 Vdc
BAB	15 – 70	1	10	—	—	—	—	—	—
BAB	15 – 100	2	—	10	—	—	—	—	—
BAB	15 – 100	2, 3	—	—	10	—	—	—	—
QBGF, QBGFEP	15 – 50 ①	1, 2	10	10	—	—	—	—	—
QBHW	15 – 70	1	22	—	—	—	—	—	—
QBHW	15 – 100	2	—	22	—	—	—	—	—
QBHW	15 – 100	2, 3	—	—	22	—	—	—	—
QBHGF, QBHGFEP	15 – 30	1, 2	22	22	—	—	—	—	—
GHB ②③	15 – 100	1	—	—	65	14	—	14	—
GHB ③	15 – 100	2, 3	—	—	65	14	—	—	14
GHQ ②③	15 – 20	1	—	—	65	14	—	—	—
HGHB ②③	15 – 30	1	—	—	65	25	—	—	—
GHBGFEP	15 – 60	1	—	—	65	—	—	—	—
EHD	15 – 100	1	—	—	14	14	—	10	—
EHD	15 – 100	2, 3	—	—	18	14	—	—	10
FDB	15 – 150	2, 3	—	—	18	14	14	—	10
FD ②	15 – 100	1	—	—	65	35	—	10	—
FD	15 – 225	2, 3	—	—	65	35	18	—	10
HFD ②	15 – 100	1	—	—	65	65	—	10	—
HFD	15 – 225	2, 3	—	—	100	65	25	—	22
FDC	15 – 225	2, 3	—	—	200	100	35	—	22
FB-P	15 – 100	2, 3	—	—	200	200	200	—	④
EDB	100 – 225	2, 3	—	—	22	—	—	10	—
EDS	100 – 225	2, 3	—	—	42	—	—	10	—
ED	100 – 225	2, 3	—	—	65	—	—	10	—
EDH	100 – 225	2, 3	—	—	100	—	—	10	—
EDC	100 – 225	2, 3	—	—	200	—	—	10	—
JD	70 – 250	2, 3	—	—	65	35	18	—	10
HJD	70 – 250	2, 3	—	—	100	65	25	—	22
JDC	70 – 250	2, 3	—	—	200	100	35	—	22
LCL	125 – 250	2, 3	—	—	200	200	—	—	—
DK	250 – 400	2, 3	—	—	65	—	—	—	10
KD	100 – 400	2, 3	—	—	65	35	25	—	10
CKD ⑤	100 – 400	3	—	—	100	65	35	—	22
HKD	100 – 400	2, 3	—	—	100	65	35	—	22
CHKD ⑤	100 – 400	3	—	—	100	65	35	—	22
KDC	100 – 400	2, 3	—	—	200	100	65	—	22
LCL	200 – 400	2, 3	—	—	200	200	—	—	—
LA-P	125 – 400	2, 3	—	—	200	200	200	—	④
LGE	250 – 600	3	—	—	65	35	18	—	22
LGH	250 – 600	3	—	—	100	65	35	—	22
LD	300 – 600	2, 3	—	—	65	35	25	—	22
CLD ⑤	300 – 600	3	—	—	65	35	25	—	22
HLD	300 – 600	2, 3	—	—	100	65	35	—	25
CHLD ⑤	300 – 600	3	—	—	100	65	35	—	25
LDC	300 – 600	2, 3	—	—	200	100	50	—	25
CLDC ⑤	300 – 600	3	—	—	200	100	50	—	25
MDL	300 – 800	2, 3	—	—	65	50	25	—	22
CMDL ⑤	300 – 800	3	—	—	65	50	25	—	22
HMDL	300 – 800	2, 3	—	—	100	65	35	—	25
CHMDL	300 – 800	3	—	—	100	65	35	—	25
ND	400 – 800	2, 3	—	—	65	35	25	—	—
CND ⑤	400 – 800	3	—	—	65	35	25	—	—
HND	400 – 800	2, 3	—	—	100	65	35	—	—
CHND ⑤	400 – 800	3	—	—	100	65	35	—	—
NDC	400 – 800	2, 3	—	—	200	100	65	—	—
CNDC ⑤	400 – 800	3	—	—	200	100	65	—	—
NB-P	400 – 800	2, 3	—	—	200	200	200	—	—
ND	600 – 1200	2, 3	—	—	65	35	25	—	—
CND ⑤	600 – 1200	3	—	—	65	35	25	—	—
HND	600 – 1200	2, 3	—	—	100	65	35	—	—
CHND ⑤	600 – 1200	3	—	—	100	65	35	—	—
NDC	600 – 1200	2, 3	—	—	200	100	65	—	—
CNDC ⑤	600 – 1200	3	—	—	200	100	65	—	—

① 50 amperes is 2-pole only.
② 1-pole breaker rated 277 Vac.
③ At 480 V, use on 480Y/277 Vac system only.
④ 100,000 AIC based on NEMA test procedure.
⑤ 100% rated breaker. Requires copper bus. K- and N-Frame breakers require density rated copper bus. Not available in Type 12, 4 and 4X enclosures.

Table 22.4-4. Branch Fusible Switches (Fuses are not included)

Switch Rating Amperes	Mounting	Fuse Class	Interrupting Rating (kA Symmetrical)		
			240 V	600 V	250 Vdc
Switches Rated 240 Vac, 250 Vdc					
30/30	Twin	R	200	—	10
60/60	Twin	R	200	—	10
100/100	Twin	R	200	—	10
200/200	Twin	R, T	200	—	10
100	Single	R	200	—	10
200	Single	R, T	200	—	10
400	Single	R, T	200	—	10
600	Single	R, T	200	—	—
800	Single	L	200	—	—
1200	Single	L	200	—	—
Switches Rated 600 Vac					
30/30	Twin	R, J	200	200	—
60/60	Twin	R, J	200	200	—
100/100	Twin	R, J	200	200	—
200/200	Twin	J, T	200	200	—
100	Single	R, J	200	200	—
200	Single	R, J, T	200	200	—
400	Single	R, J, T	200	200	—
600	Single	R, J, T	200	200	—
800	Single	L	200	200	—
1200	Single	L	200	200	—

Note: Twin branch switches of different ampere ratings are available, i.e., 30/60, 30/100, 60/100.

Circuit Breaker Trip Units

Circuit breakers will have thermal-magnetic trip units with the following exceptions:

- 100% rated breakers and all N frame breakers have Digitrip RMS 310 solid state trip units as standard.
- K, L and M frame 3-pole circuit breakers are optionally available with the Digitrip RMS 310 solid state trip unit.
- The trip function options for the Digitrip RMS 310 include LS and LSI. Main circuit breakers can also include the LSG and LSIG integral ground fault trip functions.
- Digitrip OPTIM trip units are not available in panelboard construction.

Series Rated Combinations

Refer to the series rating tables beginning on **Page 22.0-11** for the approved series rated combinations available for the branch circuit breakers listed in **Table 22.4-3**.

Modifications

Enclosures

Types 12, 3R, 4/4X.

Ground Bar

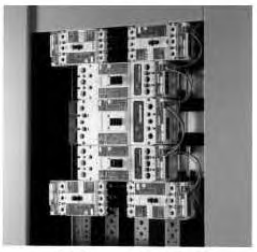
Standard bolted in box with (3) #6 – 300 kcmil terminals. Aluminum is standard. Copper is available as an option.

Trims

Door-in-door trim is available as an option for Type 1 enclosures.

IQ Energy Sentinel™

A UL listed compact, microprocessor-based, breaker mounted device designed to monitor power and energy readings (kW, kWh and kW demand). Device mounts directly to the load side of an F-, J- or K-Frame feeder breaker without requiring additional panel height.



IQ Energy Sentinel

Eaton's Cutler-Hammer IQ Energy Sentinel is shipped with the panel interior and includes instructions for customer installation.

All that is necessary to complete an IQ Energy Sentinel installation is to feed the load conductors through it; connect a neutral wire; and run the shielded twisted pair wire for communications. The IQ Energy Sentinel has a nonvolatile memory, is powered by the circuit breaker, and can be applied on 3-phase, 4-wire or single-phase, 3-wire systems.

Power and energy information from IQ Energy Sentinels can be communicated to a personal computer, a panel-mounted Breaker Interface Module (BIM II), building management or distributed control systems.

IQ Energy Sentinel

Note: The application of the IQ Energy Sentinel in panelboards is limited to PRL4B feeders. Minimum box width of 36 inches (914.4 mm). Single mounting only for all J- and K-Frame breakers equipped with IQ Energy Sentinels.

For enhanced metering data, the IQ Power Sentinel is available. See **Section 3**.

Transient Voltage Surge Suppression

Integrated onto panelboard chassis. For complete product description and available ratings, refer to **Section 36**.

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Main Lug (MLO), Main Breaker, Neutral, Through-Feed (TFL) and Sub-Feed Lug (SFL) "X" Space Requirements

(For compression lugs, or other configurations not shown, refer to Eaton.)

● = Blank means no bus under cover to meet NEC cable bending space.

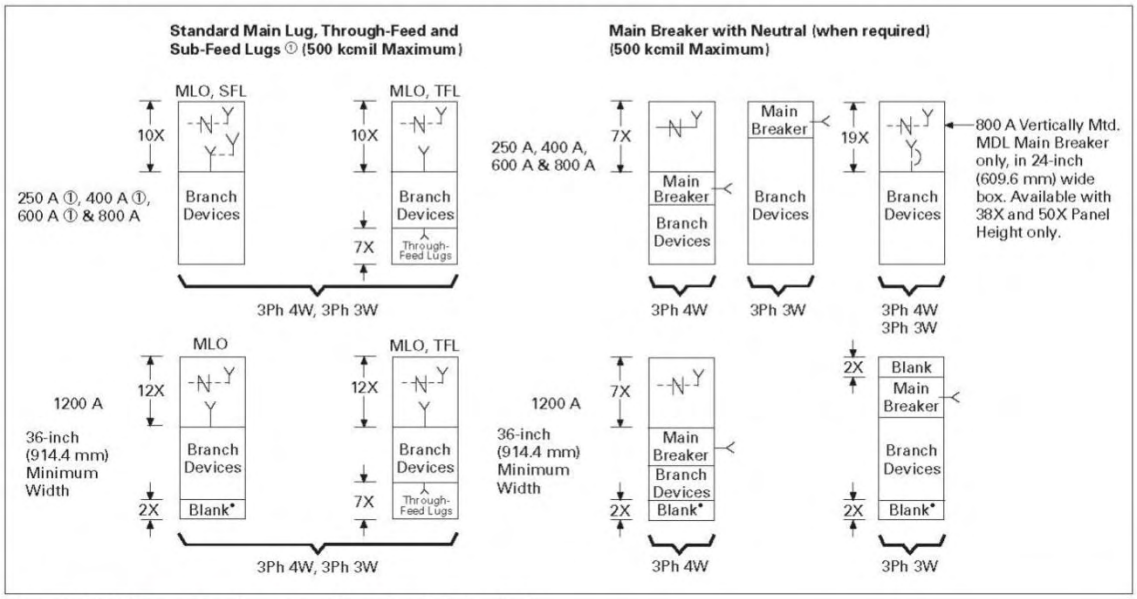

Figure 22.4-1. "X" Space Requirements — Dimensions in Inches (mm)

① Sub-Feed Lugs are available 250 – 600 amperes. For 600 ampere use 1200 ampere "X" space.

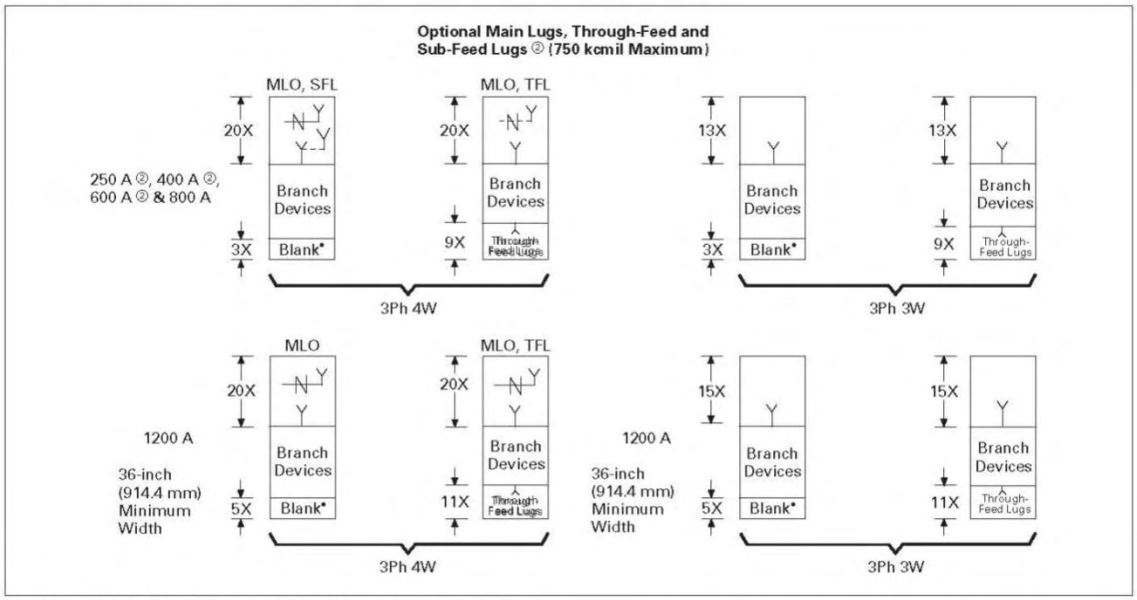

Figure 22.4-2. "X" Space Requirements — Dimensions in Inches (mm)

② Sub-Feed Lugs are available 250 – 600 amperes. For 600 ampere use 1200 ampere "X" space.

Breaker (PRL4B) Type Distribution Panelboards 600 Vac, 250 Vdc

Panel Layout and Dimensions

To determine the dimensions of a given panelboard enclosure, make a layout sketch by fitting together the main branch and lug modules according to the appropriate tables in the layout guide. Assign "X" units to each module as shown and obtain a total "X" number.

The height of the enclosure is related to the total "X" units in the layout as shown in **Figure 22.4-3**. Three standard box heights are available to accommodate any and all layout arrangements. "X" unit totals that do not exactly match those in **Table 22.4-5** must be rounded off to the next higher standard (26X, 38X, 50X).

When a calculated "X" total for a panel exceeds 50X, the panel must be split into two or more separate sections with "X" space for through-feed lugs figured in for all but one section. If a neutral is required, a separate neutral bar and appropriate "X" space must be included in each section.

Layout Example

1 – PRL4B panelboard, 480Y/277 V, 3-Phase, 4-Wire, 65 kA, 800 amperes, main lug, consisting of:

12 – 20 A/1-Pole HFD

2 – 250 A/3-Pole HJD

1 – 400 A/3-Pole HKD

20 A/1P	20 A/1P	1X
20 A/1P	20 A/1P	1X
20 A/1P	20 A/1P	1X
20 A/1P	20 A/1P	1X
20 A/1P	20 A/1P	1X
20 A/1P	20 A/1P	1X
250 A/3P		3X
250 A/3P		3X
400 A/3P		4X
Main Lugs 800 A		10X
Neutral		
TOTAL =		**26X**

Note: For TVSS Unit add 10X.

1. From layout guide, total "X" height of panel = 26X, (which is a design standard and no rounding off is necessary).
2. From **Table 22.4-5**, enclosure height for 26X panel = 57 inches (1447.8 mm).
3. Width = 24 inches (609.6 mm) — directly from layout guide.
4. Total enclosure depth = 11.30 inches (287.0 mm) — standard for all PRL4 panelboards.

Panel Layout and Dimensions — Pow-R-Line 4B

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Table 22.4-5. Standard Panel and Box — Dimensions in Inches (mm)

Panel Height	Box Height	Box Width	Box ① Depth
26X	57 (1447.8)	24 (609.6) ②	10.4 (264.2)
38X	73.5 (1866.9)	24 (609.6) ②	10.4 (264.2)
50X	90 (2286.0)	24 (609.6) ②	10.4 (264.2)
38X	73.5 (1866.9)	36 (914.4)	10.4 (264.2)
50X	90 (2286.0)	36 (914.4)	10.4 (264.2)
38X	73.5 (1866.9)	44 (1117.6)	10.4 (264.2)
50X	90 (2286.0)	44 (1117.6)	10.4 (264.2)

① Box depth is 10.40 inches (264.2 mm), cover adds .90 inches (22.9 mm) for overall enclosure depth of 11.30 inches (287.0 mm).
② 800 amperes maximum bus size in 24 inches (609.6 mm) wide box.

Note: Flush trims available on PRL4B panels with Door-in-Door enclosure only.

Top and Bottom Gutters (minimum)
10.62 inches (269.9 mm)

Side Gutters (minimum)
- 24-inch (609.6 mm) Wide Box: 5 inches (127.0 mm)
- 36-inch (914.4 mm) Wide Box: 6 inches (152.4 mm)
- 44-inch (1117.6 mm) Wide Box: 8 inches (203.2 mm)

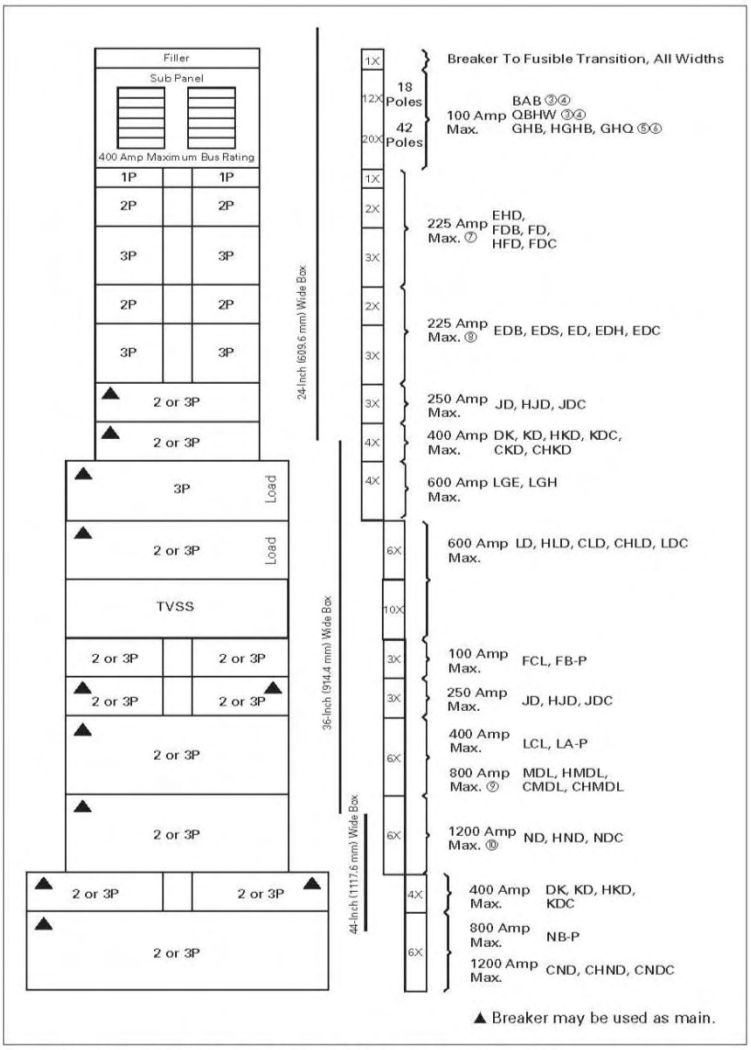


Figure 22.4-3. Layout for Branch and Horizontally Mounted Main Devices

③ BAB and QBHW breakers with shunt trips require one additional pole space, i.e., 1-pole is 2-pole size, 2-pole is 3-pole size, and 3-pole is 4-pole size.
④ If panel contains only BAB or QBHW branch breakers, use a PRL1a panelboard.
⑤ GHB, HGHB or GHQ breakers cannot be mixed on same subchassis as BAB, QBHW.
⑥ If panel contains only GHB, HGHB or GHQ branch breakers, use a PRL2a panelboard.
⑦ When only one single-pole breaker of the group is required on either side of chassis, the single-pole breaker space required changes from 1X to 2X.
⑧ Minimum 36-inch (914.4 mm) wide box is required if optional #6 – 300 kcmil lug is required.
⑨ MDL main breaker in 24-inch (609.6 mm) wide box, refer to **Page 22.4-1**.
⑩ Optional 750 kcmil terminal requires 44-inch (1117.6 mm) wide box.

Note: See **Page 22.4-4** for MLO or Neutral and Vertically Mounted Mains space requirements.

Main Lug (MLO), Main Switch, Neutral Through-Feed Lug (TFL) and Sub-Feed Lug (SFL) "X" Space Requirements

22

(For other configurations refer to Eaton.)

● = Blank means no bus under cover to meet NEC cable bending space.

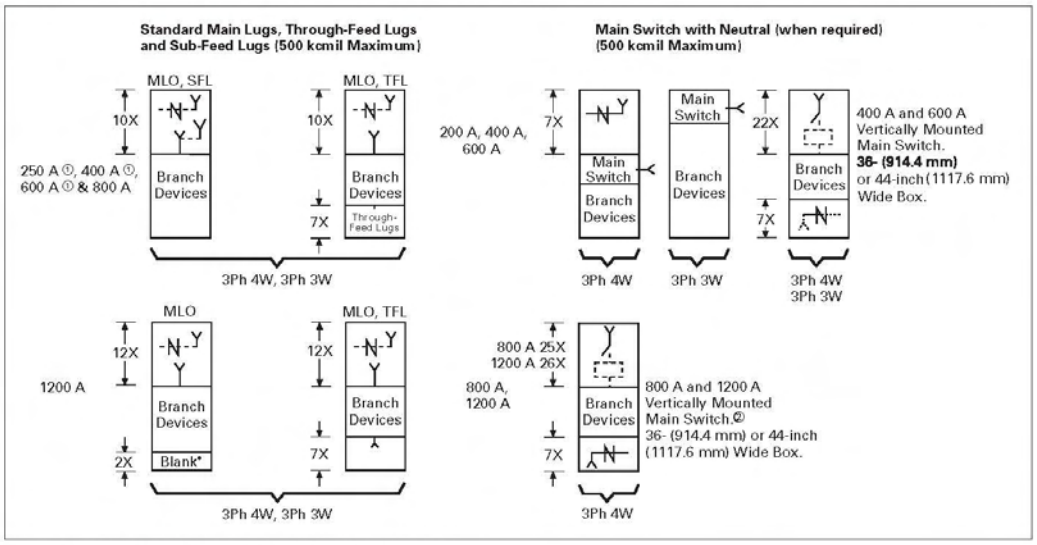


Figure 22.4-4. "X" Space Requirements — Dimensions in Inches (mm)

① Sub-feed lugs are available 250 – 600 amperes, for 600 ampere use 1200 ampere "X" space.

② 800 and 1200 ampere mains available only in vertical mounting.

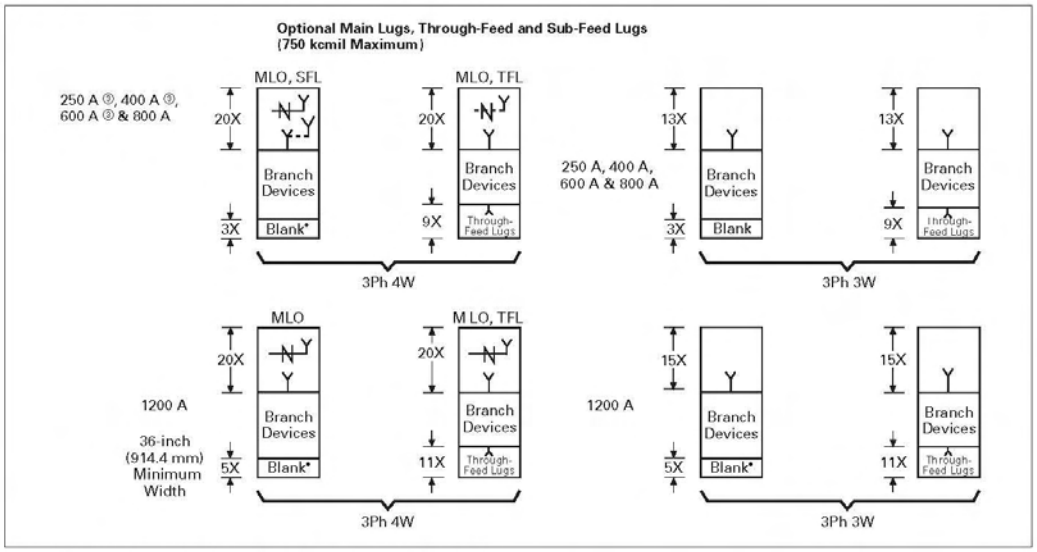


Figure 22.4-5. "X" Space Requirements — Dimensions in Inches (mm)

③ Sub-feed lugs are available 250 – 600 amperes, for 600 ampere use 1200 ampere "X" space.

22

Fusible (PRL4F) Type Distribution Panelboards 600 Vac, 250 Vdc

Panel Layout and Dimensions

To determine the dimensions of a given panelboard enclosure, make a layout sketch by fitting together the main branch and lug modules according to the appropriate tables in the layout guide. Assign "X" units to each module as shown and obtain a total "X" number.

The height of the enclosure is related to the total "X" units in the layout as shown in **Figure 22.4-6**. Three standard box heights are available to accommodate any and all layout arrangements. "X" unit totals that do not exactly match those in **Table 22.4-6** must be rounded off to the next higher standard (38X, 50X).

When a calculated "X" total for a panel exceeds 50X, the panel must be split into two or more separate sections with "X" space for through-feed lugs figured in for all but one section. If a neutral is required, a separate neutral bar and appropriate "X" space must be included in each section.

Layout Example

1 – PRL4F, 3-Phase, 4-Wire, 208Y/120 V complete with 400 A main switch and the following branches:

1 – 200 A/3-Pole

2 – 100 A/3-Pole

2 – 30 A/3-Pole

Panel to have short-circuit rating of 100,000 amperes symmetrical.

400 A Neutral		7X
30 A/3P	30 A/3P	4X
100 A/3P	100 A/3P	4X
200 A/3P		6X
400 A 3-Pole Main Switch (Vertically Mounted)		22X
	Total =	43X

Note: In the above example, if a horizontally mounted 400 A main switch was used, the enclosure size would be:
73.50 inches H x 44.00 inches W x 11.30 inches D (1866.9 mm H x 1117.6 mm W x 287.0 mm D).

1. From layout guide, "X" height of panel = 43X.
2. Rounded off to next higher standard = 50X.
3. From **Table 22.4-6**, enclosure height for 50X panel = 90 inches (2286.0 mm).
4. Width = 36 inches (914.4 mm) since no switch in the assembly requires a 44-inch (1117.6 mm) wide enclosure.
5. Total enclosure depth = 11.30 inches (287.0 mm) — standard for all PRL4 panelboards.

Cabinet Specifications

Boxes: Code-gauge commercial galvanized sheet steel (no knockouts).

Panel Layout and Dimensions — Pow-R-Line 4F

Table 22.4-6. Standard Panel and Box — Dimensions in Inches (mm)

Panel Height	Box Height	Box Width	Box ① Depth
38X	73.5 (1866.9)	36 (914.4)	10.40 (264.2)
50X	90 (2286.0)	36 (914.4)	10.40 (264.2)
38X	73.5 (1866.9)	44 (1117.6)	10.40 (264.2)
50X	90 (2286.0)	44 (1117.6)	10.40 (264.2)

① Box depth is 10.40 inches (264.2 mm), cover adds .90 inches (22.9 mm) for overall enclosure depth of 11.30 inches (287.0 mm).

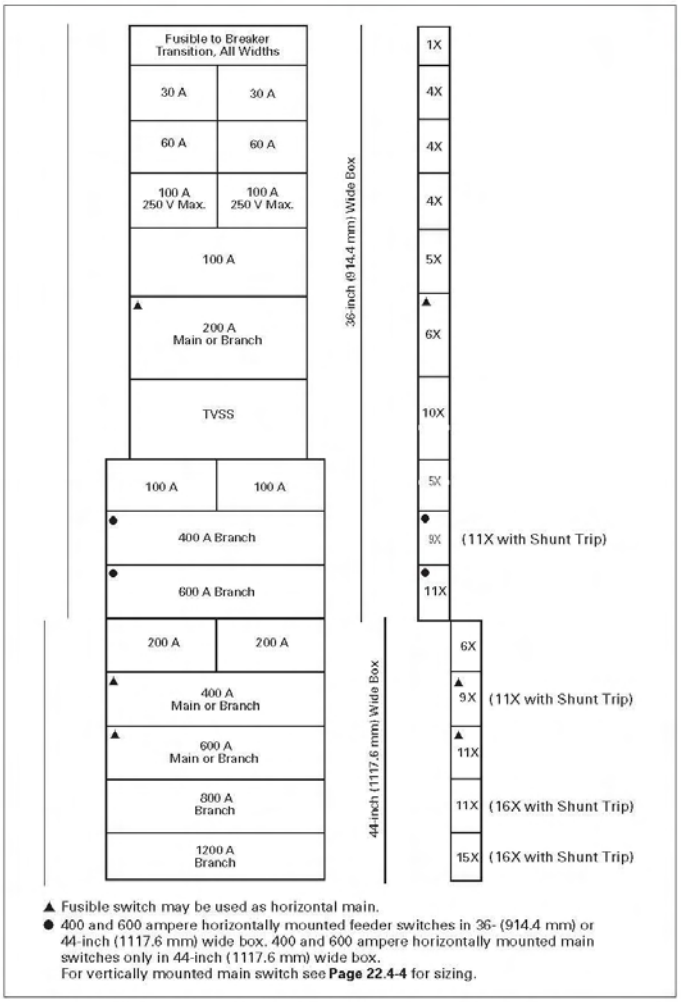
Note: Flush trims are available on PRL4F panels with door-in-door enclosure only.

Top and Bottom Gutters (minimum)

- 10.625 inches (269.9 mm)

Side Gutters (minimum)

- 36-inch (914.4) wide box:
  - 200 A maximum — 8 inches (203.2 mm)
  - 400 – 1200 A maximum — 6 inches (152.4 mm)
- 44-inch (1117.6 mm) wide box:
  - 200 A maximum — 10 inches (254.0 mm)
  - 400 – 1200 A maximum — 8 inches (203.2 mm)



▲ Fusible switch may be used as horizontal main.
● 400 and 600 ampere horizontally mounted feeder switches in 36- (914.4 mm) or 44-inch (1117.6 mm) wide box. 400 and 600 ampere horizontally mounted main switches only in 44-inch (1117.6 mm) wide box.
For vertically mounted main switch see **Page 22.4-4** for sizing.

Figure 22.4-6. Branch and Horizontally Mounted Main Fusible Switch Layout — Dimensions in Inches (mm)

Note: See **Page 22.4-7** for MLO or Neutral and Vertically Mounted Main Space Requirements.

Eaton Cutler-Hammer: Pow-R-Command 750

EATON | Cutler-Hammer

January 2008
Sheet 0921

Lighting Control System Pow-R-Command
Pow-R-Command 750 23.3-1

General Description

23

Pow-R-Command 750

Pow-R-Command 750 Panel

General Description

Eaton's Cutler-Hammer Pow-R-Command 750 is a microprocessor-based programmable lighting control system. The Pow-R-Command 750 can be used as a stand-alone panel, or the user has the option to connect up to three expansion panels to the 750 creating its own stand-alone subnetwork.

Components

- Intelligent power switching equipment.
- LCD programming display and keypad.
- Integration components.

Intelligent Power Switching Equipment

Pow-R-Command 750 Panelboards

Pow-R-Command 750 Panelboards are offered from 100 through 225 amperes in main lug and main breaker configurations. Available voltages are 120/240, 208Y/120 and 480Y/277, single-phase and 3-phase. The panelboard utilizes both branch mounted standard breakers through 100 amperes, and controllable thermal-magnetic breakers which are controlled by the Pow-R-Command 750 System Controller. The Pow-R-Command 750 controllers provide the ability to directly operate up to eight breaker control buses. Such a capability allows a single controller to directly operate up to 168 GHQRSP and BABRSP controllable circuit breakers, with individual control and status feedback of each controllable breaker.

The System Controller also includes load override, holiday scheduling, one-shot or event schedules, off warning to tenants by blinking lights, memory loss protection, power failure/brownout protection, hardware diagnostics, a real-time clock and 16 dry contact switch inputs.

The Pow-R-Command 750 Panelboard is listed UL 67 for panelboards and UL 916 for energy management equipment.

CA08104001E

For more information visit: **www.eaton.com**

23.3-2 Lighting Control System Pow-R-Command Pow-R-Command 750

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January 2008
Sheet 0922

Operational Description — System Configurations

23

Pow-R-Command 750

PRC750 LCD Display

Pow-R-Command 750 Panel

Pow-R-Command Expansion Panel

System Description

The Pow-R-Command 750 system is the premier stand-alone solution to automated lighting control. It provides automated switching of up to 168 branch circuit breakers.

Stand-Alone Subnetwork

Connect up to three expansion panels to the Pow-R-Command 750 giving you the ability to individually control 168 total smart breakers with a single Pow-R-Command 750 panel.

LCD Display and Keypad

The Pow-R-Command 750 LCD display and keypad provides local programming, override, and diagnostic functions.

Memory Loss Protection

Time schedules, time-of-day clock, day/date, and system configuration parameters are protected from memory loss if there is a power failure. The memory loss protection is rated for 10 years.

Power Failure/Brownout Recovery

When system input power drops below normal, the system will not lose its programmed information. Upon return of normal power, breaker positions scheduled during the power failure period are immediately updated. No operator interaction is required.

Astronomical Real-Time Clock

Time-of-day, day/date, automatic leap year and daylight savings time adjustments are provided as standard.

Time Scheduling

The Pow-R-Command 750 supports 50 time schedules as control functions. Any of the 50 local time schedules in a Pow-R-Command 750 controller can be set to control smart breakers in its own panel or the expansion panels connected to it.

Holiday Scheduling

The Pow-R-Command 750 supports 30 local holiday definitions. Like normal time schedules, these definitions can be set to control breakers in its own panel or the expansion panels connected to it.

Input to Output Switch Matrix

The Pow-R-Command 750 offers 16 input switches and other lighting controls. With the Input to Output Switch Matrix feature, an input control terminated on the 750 controller can have discrete control of any breaker(s) in its own panel as well as any expansion panel connected to it.

Message/Alarms

The system will maintain an alarm log. The log will record where the alarm occurred, alarm reason, date and time of the alarm. The log is maintained in non-volatile memory. The alarm log can store up to 300 alarms.

Daylighitng Optimization

Daylighting optimization is available using a combination of inputs on the Pow-R-Command 750 controller or a Switch Override Controller and dimming cable.

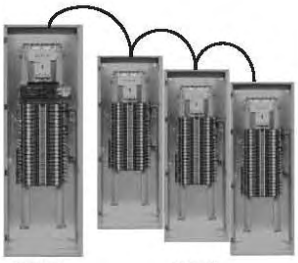
System Configurations

System Architecture

Designed primarily for stand-alone applications, the Pow-R-Command 750 is perfect for smaller lighting control solutions for your building. Each Pow-R-Command 750 Integrated Panelboard can support up to three additional expansion panels (EP).

How to Apply These Products — PRC750 Integrated Controller

Subnet Communication



PRC750 PRCEP

One PRC750 can control up to three additional 42-circuit Pow-R-Command expansion panels (PRCEP) for a total of 160 remote controllable breakers.

Figure 23.3-1. System Architecture

Technical Data

Panelboard Ratings

- Voltage:
  - 240 Vac
  - 480Y/277 Vac
- Main lugs:
  - 100 through 225 amperes
- Main breakers:
  - 100 through 225 amperes
- Branches:
  - 15 through 100 amperes
  - Controllable from 15 through 30 amperes

Interrupting Capacity (Symmetrical)

- 240 Vac: 65 kA maximum fully rated.
- 240 Vac: 100 kA maximum series rated.
- 480Y/277 Vac.

Service

- 3-phase, 4-wire 208Y/120 V, 480Y/277 Vac and 240/120 V Delta.
- Single-phase, 3-wire, 120/240 V.

Mains

For available mains, refer to **Table 23.3-1**.

Branch Circuits

For available branch circuit devices, refer to **Table 23.3-2**.

Main Lugs Only

The short circuit rating of the MLO assembled panelboard will be fully rated based upon the lowest rated branch device or may be series rated with an approved upstream device.

- Main lugs only ampere ratings: 100 and 225.

Main Circuit Breakers

The short circuit rating shown is that of the main breaker only. The short circuit rating of the assembled panelboard is the rating of the lowest fully rated main or branch device or the rating of an approved series rating combination.

Table 23.3-1. Main Circuit Breakers

Breaker Type	Frame Ampere Rating	Interrupting Rating (kA Symmetrical)	
		240 V	480Y/277 V
EHD	100	18	14
FDB	150	18	14
FD	225	65	35
HFD	225	100	65
FDC	225	200	100
ED	225	65	—
EDH	225	100	—
EDC	225	200	—
JD	250	65	35
HJD	250	100	65
JDC	250	200	100

Branch Circuit Breakers

The type GHQRSP and BABRSP are the controllable circuit breakers. Controllable breakers are available in 1- and 2-pole styles, from 15 through 30 amperes. Non-controlled circuit breakers can be located within the panelboard chassis.

Table 23.3-2. Branch Circuit Breakers

Breaker Type	Ampere Rating	Number of Poles	Interrupting Rating (kA Symmetrical)				
			120 V	120/240 V	240 V	277 V	480 V
BAB	15 – 70	1	10	—	—	—	—
BAB	15 – 100	2	—	10	—	—	—
BAB	15 – 100	2, 3	—	—	10	—	—
BAB-D ①	15 – 60	1, 2	10	10	—	—	—
BAB-C ②	15 – 30	1, 2	10	10	—	—	—
BABRSP ③	15 – 30	1, 2	10	10	—	—	—
GHQRSP ③	15 – 20	1, 2	—	—	65	14	14
QBGF ④, QBGFEP ⑤	15 – 50 ⑥	1, 2	10	10	—	—	—

① HID (High Intensity Discharge) rated breaker.
② Switching neutral breaker. 1-pole device requires 2-pole space; 2-pole device requires 3-pole space.
③ Controllable breaker.
④ GFCI for 5 mA personnel protection.
⑤ GFP for 30 mA equipment protection.
⑥ 50 ampere devices are available as 2-pole only.

Series Ratings

Eaton has tested the GHQRSP and BABRSP controllable circuit breakers for Series Rated Combinations up to 200 kAIC with breakers or fuses. For a complete listing of available series ratings, see **Section 22** (Panelboards) Series Ratings **Tables 22.0-6** through **22.0-16**.

Appendix M: Lutron Presentation Comments (12.07.2010)

General:

- Tell story of building architecture influence on lighting.
- Orientation of spaces in building and site.
- Think interior design with material colors.
- Perhaps take a look at a lab space for lighting design.
- Provide more Data (i.e. – proof that daylight will deviate cost and some energy).
- Use tools (AGi32 & Radiance) to provide story of daylight harvesting.

Louvers &Daylighting:

- Investigate study of louvers and daylighting into space more before bashing louvers.
- Be sure to investigate solutions that are feasible for all facades.
- If façade design is to change, include exterior view of building to display new design from what a pedestrian would see.

Student Study Area:

- If uplighting were used, the corridor may not need lighting.
- Reinforce design for these spaces.
- High cabinets could be used for highlighting corridor wall.
- Balancing of space environment between exterior wall/glazing and corridor wall.
- Energy Savings: Control task lighting when no one is in the space.
- Night-Time control is important.
- Exterior view during evenings is important.

Conference Room:

- Provide source of research.
- Linear fixture is not viable solution for Video Conferencing.
- Don't wash a wall behind the user in the V.C. Situation.
- Make sure lighting and colors don't compete with necessary lighting for vertical illumination.
- Determine video camera location to design lighting appropriately.
- Look into materials and colors.
- Video conferencing equipment not present; assume use of a mobile station.

Cantilever Plaza:

- Unique features? Intent? Night-Time memorability?
- "Oculus" (i.e. – Void) is interesting in the space.
- They do not believe that the meandering path was designed to discourage use.
    - It's like being drawn to the "Naughty Garden."
- By highlighting the Oculus, there is an opportunity to use ambient for light the plaza; creating a moon-like glow.
- Uplighting the cantilever would be wise.

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